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ORIGINAL PAPER

Deeper Than Expected: The Finding of a Remarkable Ancient Harbour at *Gadir/Gades* and an Exceptional Sedimentary Archive (Cádiz, Southern Spain)

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Abstract

Geoarchaeological cores were retrieved in the centre of the old "Bahía-Caleta" palaeochannel located between the *Erytheia* and *Cotinusa* islands in the former Cádiz archipelago, in present-day southern Spain. The unprecedented coring depth ($\sim$ 35–50 m) allowed us to identify the bottom of a Phoenician–Punic and Roman harbour. Located at 20–40 m b.s.l. in the sedimentary sequence, silty sand deposits reveal a deep semi-protected shelter with abundant ceramic and archaeobotanical findings. Based on these new results, the palaeotopography of the islands of Cádiz is reinterpreted, demonstrating the presence of a harbour accessible from the west and possibly from the east until (at least) the Roman period. This major discovery opens meaningful perspectives for archaeological, geomorphological and palaeoenvironmental research.

Keywords Geoarchaeology · Paleogeography · Phoenician-Roman city · Classical Archaeology · *Gadir/Gades* · Ancient Harbours

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Gadir/Gades and the Current Hypothesis of a Connected Archipelago in the Phoenician–Punic and Roman Periods

Gadir/Gades, one of the most important cities of the Atlantic–Mediterranean area between the beginning of the Phoenician colonization and Roman periods, is located in a changing coastal environment (Fig. 1a, b). Geological and geomorphological studies demonstrate how Holocene sea-level change and coastal dynamics modified the palaeotopography of the ancient islands of the Cádiz archipelago. At least three islands existed in the past but have now evolved into a single spit due to coastal sedimentation (from Gavala y Laborde 1959 to Gracia et al. 2005).

A pioneering study in the 1970s identified a palaeochannel across the urban area of Cádiz mainly based on topographical data measured throughout the city. It was suggested that it once separated the *Cotinusa* and *Erytheia* islands, the so-called "Bahía-Caleta" or "Ponce" channel (Figs. 1c and 2a) in honour of its discoverer (Ponce Cordones 1985). The existence of this ancient natural channel, considered to be a former downstream palaeochannel of the Guadalete River in geological times, has been accepted since this study was undertaken. Several authors roughly mapped the limits of the palaeochannel and suggested different geological or geomorphological scenarios for its filling (Corzo 1980: 14; Ramírez Delgado 1982: 72–83, 241, plan 1; Muñoz Vicente 1995–1996). Some of these authors argued that it would have been silted up by urban waste and the remains of port activity, which would have progressively slowed down water flow and clogged the channel (Ramírez Delgado 1982: 82).

Later geoarchaeological work carried out by a Spanish–German team focused on the determination of the coastline location and the palaeotopographical reconstruction of the Cádiz islands (Fig. 2b, Arteaga et al. 2001, 2004; Arteaga and Roos 2002; Arteaga and Schulz 2008). Palaeotopographical maps highlighting the historical evolution of the Cádiz archipelago were proposed for four different periods (Neolithic, Phoenician, Roman and medieval). Importantly, this scenario suggests an incipient central connection between the two islands already from *circa* 1100/1000 BC onwards (Fig. 2c). This silting up process continued in later periods, eventually leading to a full land junction between *Cotinusa* and *Erytheia* islands. This assumption was central for a new paradigm; this temporal evolution of the silting up process between both the Cádiz islands was later systematically reproduced accordingly (Botto 2014 for the Phoenician period; Bernal-Casasola and Lara Medina 2012 and Lara Medina 2019 for the Roman period).

In this sense, a proposal for the delineation of the "Bahía-Caleta" channel was recently made based on the distribution of the documented archaeological evidence (Lara Medina 2016). This study updates the map of Ponce and Ramírez (Ramírez Delgado 1982; Ponce Cordones 1985). It has been estimated that the channel had a maximum width of *circa* 400 m at its eastern end and a minimum width of 100/150 m (possibly coinciding with the area of Puerto Chico). Likewise, the author suggests that the sides of the channel would follow the contour lines of 5/6 m such as presented in Fig. 3a (Lara Medina 2018: 418). A medium slope connected the channel banks to the small island to the north (*Erytheia*), and the larger one to the south (*Cotinusa*), where the Imperial Roman city was located (Lara Medina 2019: 35).

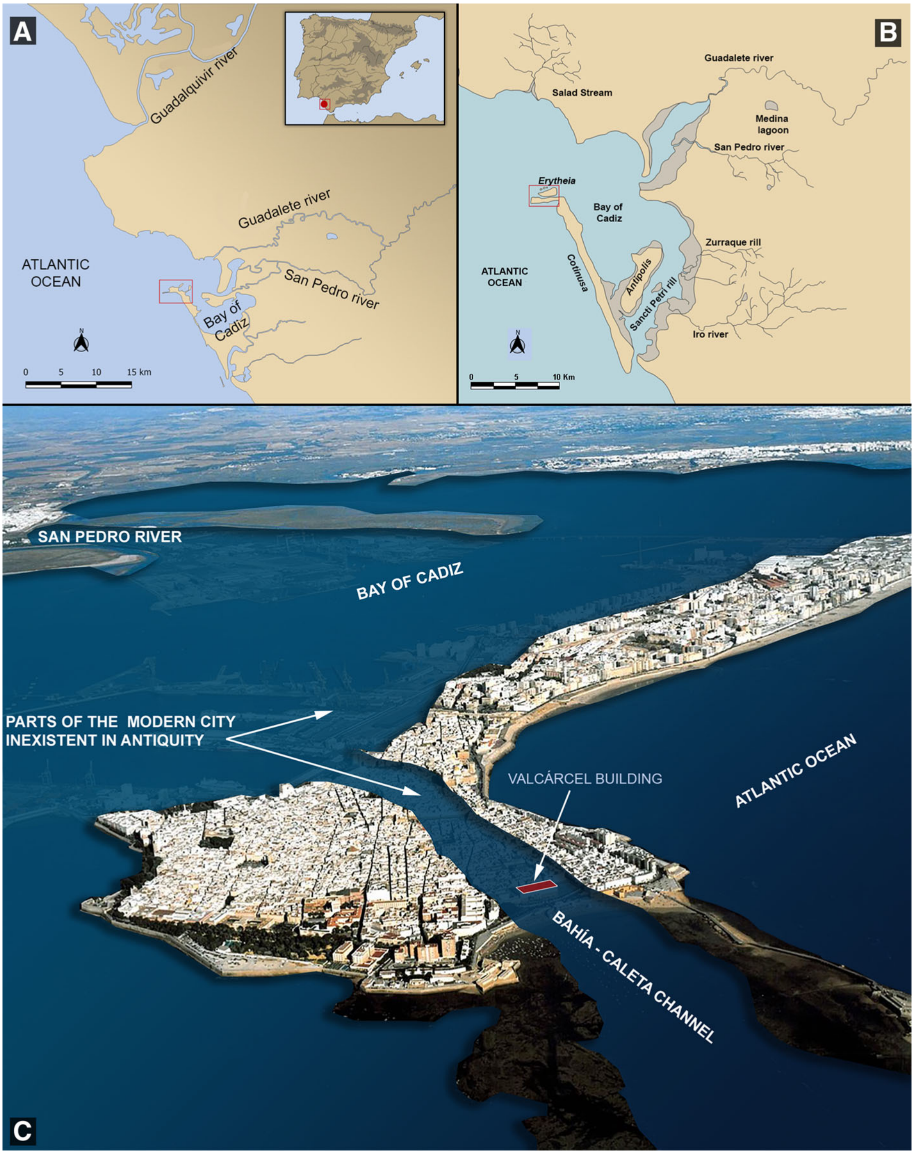

Fig. 1 Location of Cádiz in southern Spain, on the Strait of Gibraltar and along the Atlantic coast of Andalusia (**a**); a proposed reconstruction of the palaeotopography of the Bay of Cádiz during the Phoenician period (**b**); an aerial view of the Bay of Cádiz with the locations of the Valcárcel Building and the "Bahía-Caleta" channel (**c**)

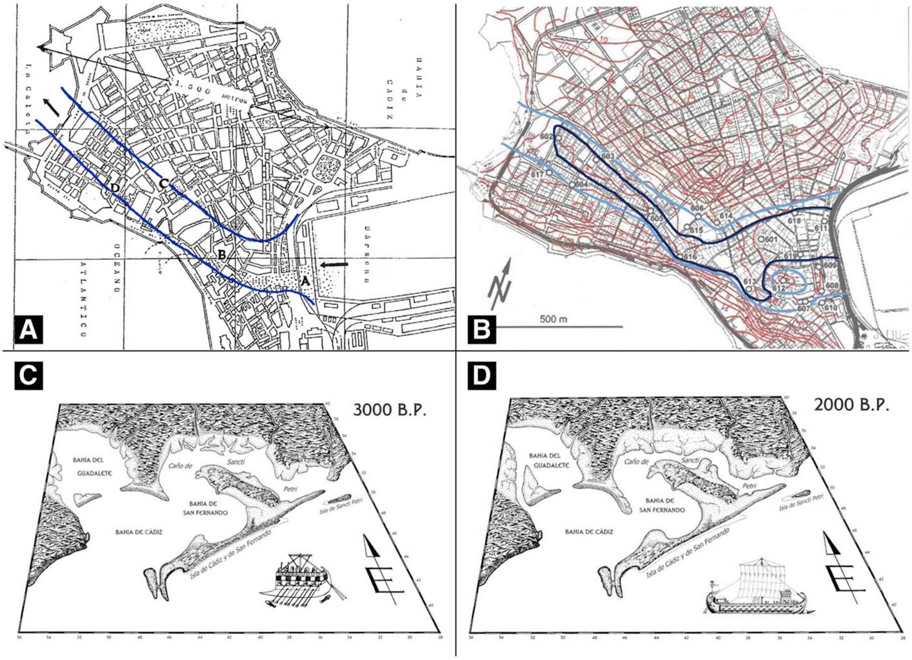

Fig. 2 Hypothesis of the "Bahía-Caleta" channel according to Ponce Cordones (**a**—1985: 114, Fig. 1); according to Arteaga, including the geoarchaeological corings from 2001 in the historic centre of Cádiz (**b**—Arteaga et al. 2001: 412, Fig. 2); and a schematic proposal of the silting process of the islands during the Phoenician (**c**) and Roman periods (**d**), according to a Spanish–German team (Chic et al. 2004: 7, 74)

Urban Archaeology and Inconsistencies Between the Archaeological Record and the Palaeotopographical Paradigm

Similar to the sedimentary filling of the "Bahía-Caleta" channel, unanswered questions or inconsistencies against the framework of an early inter-island sedimentation in the area occupied by the ancient Phoenician *Gadir*/Roman *Gades* remained:

- References to the city in the plural form *Gádira* in Greco-Roman sources (Strabo, *Geo.*, III, 5, 3–4, Pliny, *N.H.* IV, 120), from which the preservation of its insular character can be inferred;
- Regular mention of the "palaeochannel" in existence during Antiquity with Pliny, Solinus and Isidore assessing its width to 100 steps, 700 feet and 120 steps, respectively (see Corzo 1980:7);
- Absence of port structures in the La Caleta beach area (Fig. 3a), and difficulties in matching the coastline associated with the suggested palaeochannel with the spatial extension of some archaeological findings (Bernal-Casasola 2012);
- The absence of buildings or other man-made Phoenician, Punic, Roman or Late Antique structures in the inner perimeter defined by the palaeochannel was previously explained by recent urbanization phases that would have progressively covered and/or damaged previous structures. However, the recent and detailed analysis of more than 70

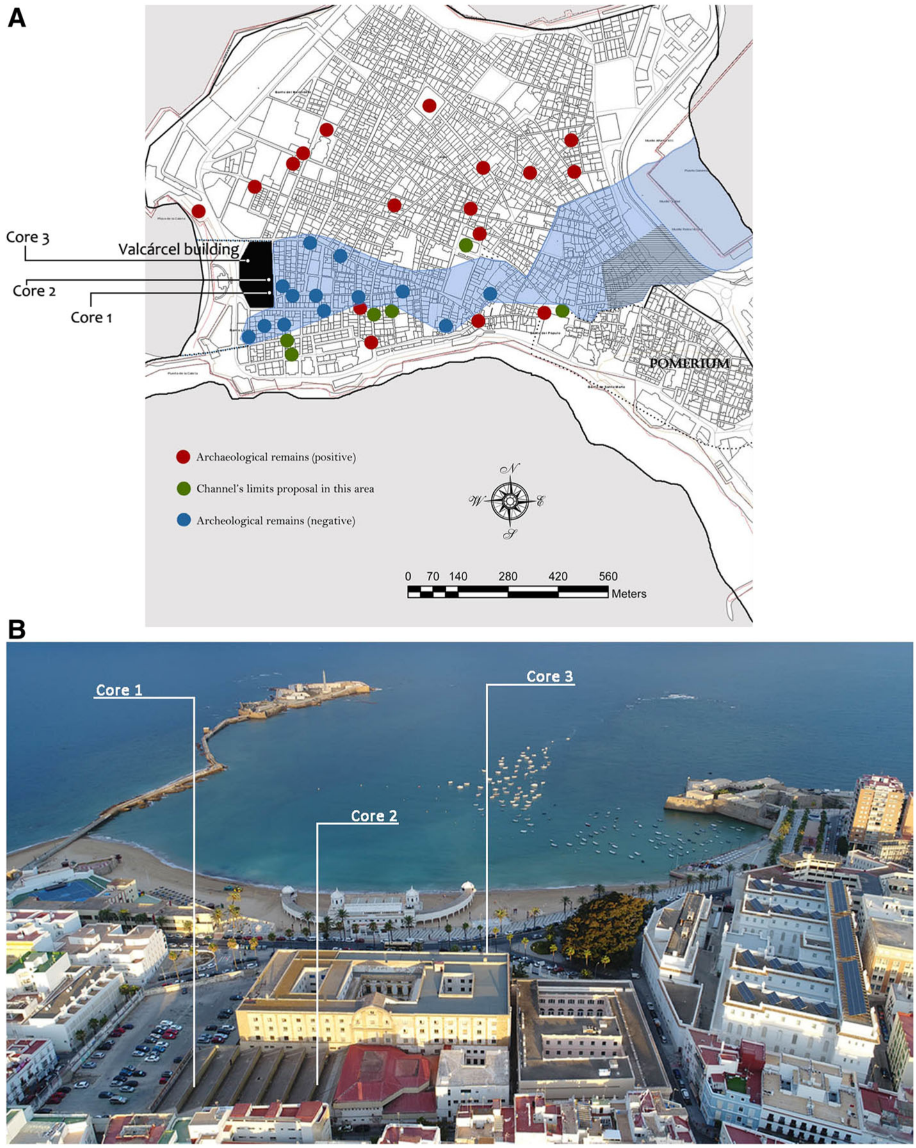

Fig. 3 **a** Hypothesis proposed for the extent of the "Bahía-Caleta" channel (in blue) based on archaeological excavations revealing no archaeological remains from the Phoenician to the Roman periods (Lara Medina 2018: 418). **b** Aerial photograph of the maritime environment of Cádiz showing the western end of the "Bahía-Caleta" channel, the Valcárcel Building and the location of the three geoarchaeological cores (Color figure online)

rescue archaeological excavations in the city centre of Cádiz definitely points to a long timespan without archaeological remains from Antiquity (Lara Medina 2018: 418; Lara Medina 2019: 35; cfr. Fig. 3a).

A Unique Opportunity to Re-evaluate the Problem of the "Bahía-Caleta" Channel: Archaeology and Geoarchaeology Joined in an Interdisciplinary Methodology in the Valcárcel Building

Since the Valcárcel Building is located atop the central zone of the "Bahía-Caleta" channel (Figs. 1c and 3b), its rehabilitation by the University of Cádiz in 2018 presented a unique opportunity to gain new insights into the aforementioned pending questions. Field investigations included both archaeological trenches and geoarchaeological corings (Lara Medina et al. 2019).

The fieldwork was conducted through a series of mechanical archaeological trenches excavated within the Valcárcel Building. The excavated areas covered more than one hectare and encompassed ground floors and basements of the building. Ten well-distributed archaeological trenches reliably record the urban evolution of the study area (Fig. 4a).

Fig. 4 Location map of the ten archaeological trenches and the three geoarchaeological corings carried out in the Valcárcel Building (**a**), and section view of the Valcárcel Building façade with the three corings and the location depth of the bedrock—Core 3 (**b**)

The trenches were excavated down to a maximum depth of 7 m below the ground surface. Stratigraphies were recorded for each trench and artefacts were collected for identification. According to the identified structure and the recovered artefacts, the oldest documented strata dates from the eighteenth century.

Additionally, three geotechnical cores were drilled to reach greater depths. They were performed using a rotational drilling machine with continuous core extraction (8.6 cm of diameter) using a JR-503 hydraulic test-drive probe mounted on a truck (Fig. 5a). The collected cores were transferred to the Laboratory of Archeology and Prehistory of the University of Cádiz located only a few hundred metres away from the Valcárcel Building. Description of the stratigraphy was performed there along with the careful collection of the main observed artefacts and biofacts. Their exact depth was documented. Finally, we characterized and identified the material using a binocular microscope. Carefully selected materials were sent to specialized geochronological laboratories to perform both radiocarbon (Beta Analytic) and thermoluminescence dating (Dating and Radiochemistry Laboratory of the Universidad Autónoma of Madrid).

The main outcomes obtained in the first part of the rescue archaeological activity are summarized as follows:

- in the first upper 3–4 m of the stratigraphic sequence, the excavated structures date from the modern-contemporary period—eighteenth–twentieth centuries AD; activities in this area were horticultural, according to the archival documentation, or related to the Valcárcel Building facilities.
- occurrence of sand layers at 4 m depth below the current floor of the building is interpreted as beach deposits coinciding with the modern sea-level elevation.
- complete absence of Phoenician–Punic or Roman structures throughout the surveyed area.

As for the second part of the fieldwork and based on geotechnical reports from nearby sites and previous historical-archaeological investigations (Arteaga et al. 2001), a coring depth of 15–20 m was expected before reaching bedrock. However, the first core (Core 1) situated in the central area of the palaeochannel revealed a particularly thick sedimentary sequence (down to a depth of 31.5 m), much deeper than the cores retrieved by Arteaga et al. 2001 (i.e. the deepest of their 19 corings reached a thickness of 8.5 m). Importantly, despite the fact that the sedimentary succession contained abundant archaeological remains, the drilling machine was not able to capture the whole geoarchaeological sequence. Consequently, two supplementary deeper cores were drilled to obtain a cross-section through the northern half of the "Bahía-Caleta" channel, and Cores 2 and 3 are located inside and outside the extension of the historical building, respectively (Fig. 4a, b). While Core 3 reached the bedrock at a depth of 50 m, the 45 m-thick Core 2 was particularly rich in archaeological findings (Fig. 5b) and did not reach the bedrock. The latter is thoroughly described in the next section.

Results from the Deep Geoarchaeological Drilling Exemplified by Core 2

Here, we present a preliminary chronostratigraphy of the second core (complete name: Val-18/Core 2), which is representative of the general sedimentary sequence in the palaeochannel. It is divided into six main units (Fig. 6); their depths are indicated below both the topographical surface and sea level (i.e. s.l.; *in italics*).

Fig. 5 Photographs showing the execution process of the geoarchaeological drillings—Core 3 (**a**); with a detail of the archaeological findings in Core 2 at depths between 24 and 42 m below the surface (**b**)

Unit A From − 45 to − 36 m (*41.2 to 32.2 m b.s.l.*), the deposits are composed of dark grey sandy silt. Scarce pebbles (up to 5 cm in B-axis) are observed at different depths. A higher concentration of pebbles is noticed around − 40 m (*36.2 m b.s.l.*). This unit dates to the beginning of the first millennium BC to the middle of the first millennium BC

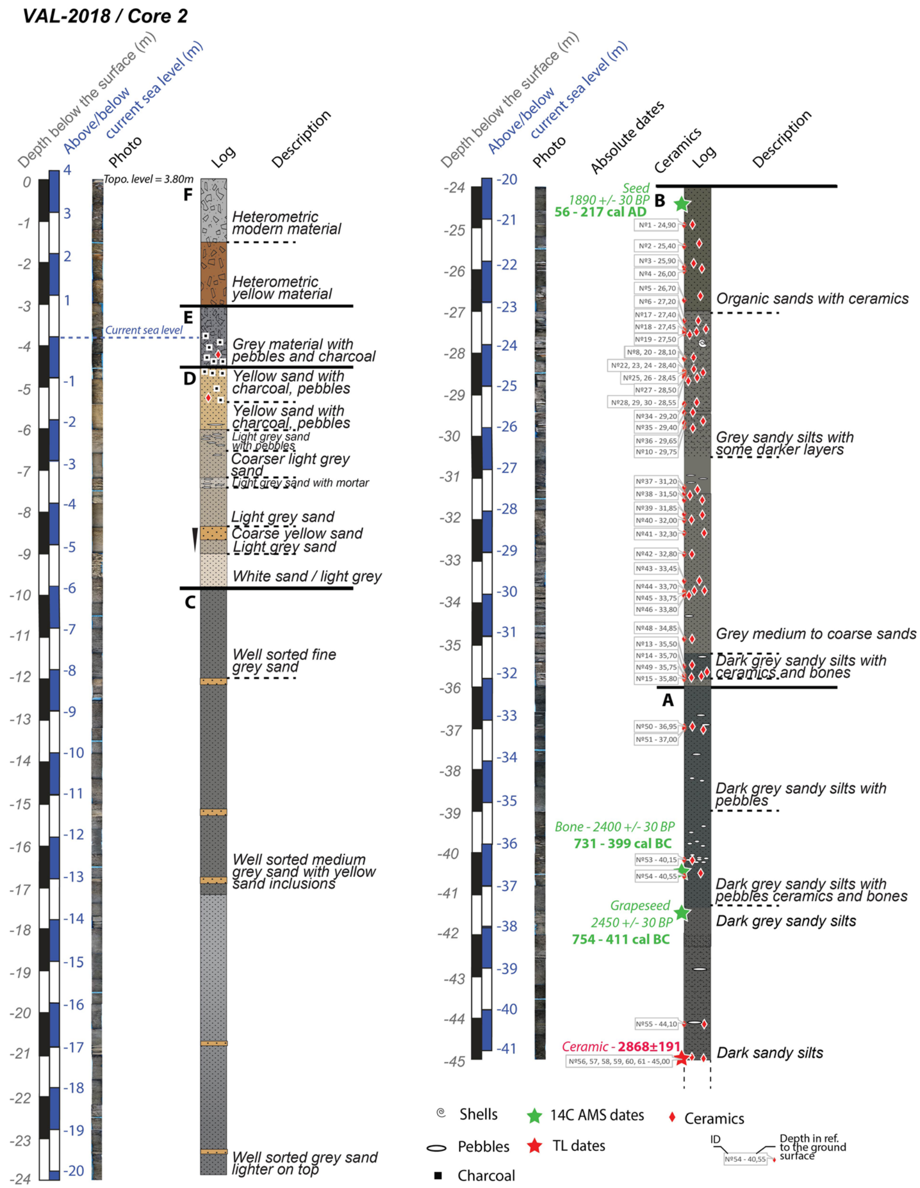

Fig. 6 Stratigraphy of Core 2, indicating the sedimentary units (A to F), the material dated by ^{14}C and thermoluminescence, and depths below the surface of current sea level

(2868 ± 191 BP by thermoluminescence at − 45 m on a ceramic artefact (nb 57), and two radiocarbon dates: 754–411 BC—2450 ± 30 BP—and 731–399 BC—2400 ± 30 BP—at − 41.57 m and − 40.85 m).

Unit B From − 36 to − 24 m (*32.2 to 20.2 m b.s.l.*), the unit encompasses different types of deposits from sandy silt to coarse sand, with light grey to darker organic layers. The deposits are also enriched in abundant ceramics. Some very clear silty clay layers were noticed at − 24.36–24.43 m, − 24.96–25.03 m, − 25.12–25.18 m, − 25.40–25.50 m, − 25.60–25.68 m, − 25.70–25.95 m. The top of this unit (− 24.28 m) was dated to first–third centuries AD based on one ^{14}C age (AD 56–217, 1890 ± 30 BP).

Unit C From − 24 to − 9.85 m (*20.2 to 6.05 m b.s.l.*), the unit is composed of lighter grey sandy deposits, generally very well sorted. From − 24 to − 17 m (*20.20 to 13.20 m b.s.l.*), a change in colour from darker grey sand at the bottom to lighter grey sand towards the top of this sub-unit is noticed. Three fine layers of yellow sand are observed at depths comprised between − 17 and − 9.85 m.

Unit D From − 9.85 to − 4.50 m (*6.05 to 0.7 m b.s.l.*), the deposits are composed of well sorted sand to coarse sand, locally including small pebbles. The colour changes into light grey to yellow–beige. Charcoal was observed at the top of this unit together with some ceramics.

Unit E From − 4.50 to − 3 m (*0.7 m b.s.l. to 0.80 m a.s.l.*), the unit represents a transitional layer between the sandy Unit D and the heterometric material of Unit F. This unit includes grey sediments with pebbles and charcoals.

Unit F From − 3 m to 0 (*3.80 m a.s.l.*), the top unit is composed of heterometric material from anthropic origin. A detailed description of the archaeological layers is available in Lara Medina et al. 2019.

This core represents an exceptionally thick stratigraphical record for the Late Holocene, with at least − 41.2 m of sedimentation below the current sea level for the last 3000 years (Fig. 6). Particularly striking is the sedimentation rate recorded between *41.2 m b.s.l.* and *20.2 m b.s.l.* (ranging from 1.6 to 2.8 cm/year for 20 m according to the preliminary dating results). Two elements have yet to be distinguished: the palaeochannel/palaeogorge itself passing through the city of Cádiz and the sedimentary filling of this channel during the Late Holocene. The depth of the palaeochannel is very surprising: it is at least − 41.2 m below the current sea level, and the substratum was reached at *circa 45 m b.s.l.* in Core 3. However, this pre-Holocene, deeply incised palaeogorge did not display fluvial deposits at its bottom, reached in Core 3. As for its origin, it can be possibly related to a palaeocourse of the (1) Rio de San Pedro, (2) Rio Guadalete or (3) Rio Guadalquivir (discussions in Gracia et al. 2000, 2005). While tectonics could also have played a role in the formation of this palaeogorge, further research is required to unravel its exact origin. During the quick sea-level rise following the Last Glacial Maximum occurring worldwide between the Late Pleistocene/Early Holocene (Lambeck et al. 2014; García-Artola et al. 2018), it would have been submerged by marine waters offering a deep accommodation space for sediment deposition during the Holocene.

Even more surprising is the filling of this palaeochannel/palaeogorge. A quick sedimentation occurred during the Late Holocene and particularly during the first millennium BC/early first millennium AD. The ongoing palaeoenvironmental and geoarchaeological study will try to understand this change in sedimentation. Several hypotheses at different spatial scales will be considered and tested: (1) local factors (e.g. change in the palaeogorge topography modifying the characteristics of the sediment trap—jetty, mole, etc., urban waste); (2) regional factors (e.g. modification of the coastal sediment cells of the Bay of Cádiz, tsunamis, progradation of the Rio de San Pedro, and land use changes in the watershed); or (3) global factors (e.g. palaeoclimatic changes, flood, and storm activity).

During the sampling, about 100 artefacts and biofacts were retrieved along the ~ 45 m-thick sedimentary sequence; a subset of 61 objects was selected owing to their greater size and/or their representativeness (Fig. 7). Apart from the findings of the upper five superficial metres dated of the eighteenth–twentieth centuries, all artefacts/biofacts were found at depths ranging between − 24.9 and − 45 m. Whereas they have a sub-continuous distribution in the whole Unit B (− 36 to − 24 m), their presence is more sporadic at depths greater than − 36 m (Fig. 6). Ceramics (83.6%) strongly dominate the repartition, followed by archaeobotanical remains and stone artefacts (5% each) as well as shell and bone remains (3.3% each).

Considering ceramics, almost all recovered fragments display a characteristic change in colour paste resulting from anaerobic burial. In some instances, they also present resinous coatings inside or attached marine organisms. They demonstrate only little evidence of erosion while those exhibiting rounded surface originate from the lowest part of the sedimentary sequence between − 32 and − 45 m. Some of them were broken up during the extraction process. A majority (62.7%) of the 51 sherds, all of them not handmade but wheel thrown, are common pottery; responding to diverse productions, both of oxidizing and reduction—more abundant—firing fabrics (Fig. 8), and mainly of cooking or storage pots. Some clearly are protohistoric orientalizing grey ceramics (nbs 57 and 58), characteristic of the eighth to sixth centuries BC in the Iberian Peninsula (Vallejo Sánchez 2005). Importantly, this observation is confirmed by absolute dating: the thermoluminescence-dated sherd 57 provides an age of 2868 ± 191 BP (1σ), strongly pointing to the Phoenician Archaic period at the very base of the sequence (− 45 m). The second group consists of transport amphorae, with 18 finds (35.3%) distributed throughout the sequence. Undetermined North African productions, both Roman and possibly pre-Roman, are identified while the provenance of most other pieces remains unknown. We highlight a singular finding: the lower part of a moulded terracotta (unfortunately broken during the drilling in its upper part), whose right foot is preserved as well as parts of the folds of the clothing, and possibly representing a long tunic of a standing figure (nb 15). This type of frequent female terracotta figurines is known in the Cádiz area since the fourth or third centuries BC such as in the sanctuary of La Algaida (Corzo 2010). They are widely distributed from this time on until the first–second centuries AD, for example in *Augusta Emerita* (Gijón 2004: 289, no. 225). In our case, it seems a serial production finished with a knife that we tend to attribute to the Roman Republican or Early Imperial period (this will be later investigated via numerical dating of the host sedimentary layer). The archaeological context of this find at the bottom of the ancient harbour of Cádiz may represent one of the well-known votive offerings used by sailors.

As for the biofacts, the abundance and variety of finds (e.g. shells, bone remains, ichthyological, Fig. 9a, or archaeobotanical items) are important; only a selection is presented herein. Four plant fossils were recorded and identified through a binocular microscope and by comparing them with the specimens from the seed reference collection located at the University of Las Palmas. Since all analysed materials were conserved in water, they exhibit an excellent state of preservation. Furthermore, we identify two remains pertaining to *Pinus pinea* (stone pine). The first one is a pine cone fragment and, though scale fragmentation, still clearly displays the protruding epiphysis together with the six edges characteristic of the bracts of *Pinus pinea* (Fig. 9b). The second one is a fragment of the seed coat or the cover of a pine nut of pinion (only half of this cover is preserved), whose function is to protect the seed (Fig. 9e). Though somewhat damaged, a specimen of

Vitis vinifera (grape seed), clearly showing the characteristics of the species (Fig. 9c), was identified at a depth of − 41–42 m. Importantly, the radiocarbon date yields an age of 754–411 cal BC, thereby strongly pointing to the Phoenician period (Fig. 6). A single olive or wild olive seed (*Olea europaea*), with approximate dimensions of 8 × 5 mm (Fig. 9d), cannot be distinguished as either cultivated or wild olive. Altogether, the common finding of these three species is significant as they correspond to plants of high economic value that have been exploited for their fruits or seeds for human consumption since at least the Phoenician period (Pérez-Jordà et al. 2017). We have not yet documented the seeds or the remains of the wild plants that naturally grew in the survey area. Consequently, it can only

SELECTION OF FINDS FROM CORE-2					
Nº	**Depth (m)**	**Material**	**Dimensions (cm)**	**Description**	**Chronology**
				First sampling	
1	24,9	Pottery	6,8x4,7 x0,9	Possible African amphora with white slip outside (undetermined chronology). Few marine organisms are observed outside. The interior displays brown resin. The fragment was probably partially broken during the drilling of the core. Characteristics of the paste: Heterogeneous fabric, interior brown and grayish exterior.	1^{st}-3^{rd} c. AD
3	25,9	Pottery	6,6x5,4x0,9	Possible African amphora. Marine organisms are recorded inside and outside the pottery. Pitch was noticed inside.	
5	26,7	Pottery	8,3x6x1	Possible African amphora. Marine organisms are observed outside.	
7	27,8	Shell	7,2 x 3,3	Murex (*Bolinus brandaris*)	
8	28,1	Pottery	5,1x 3,5x1,1	Common ware. The paste demonstrates a sandwich fabric with golden mica inclusions. The internal part was resin-coated with perhaps palaeocontent patches.	
10	29,75	Pottery	7,3x3,4x1,4	Amphora sherd, undetermined production	
11	31,35	Pottery	5,7x4,1x0,9	Common grey ware with white inclusions	
15	35,8	Pottery	3,9x3,8x0,7	Fragment of a lower part (flattened) of a moulded terracotta figurine. The right foot is seen with footwear and it can be observed the lower part of the folds of the garment. The paste is a brown fabric, with gray exterior appearance due to oxidation. Several internal fingerings (one even superimposed) were noticed resulting from the push of the clay into the mould.	TPQ 4^{th}-3^{rd} c. BC
				Second sampling	
16	24,10	Vegetal	1,8x1,9x0,6	Bract of stone pine	1^{st}-3^{rd} c. AD
18	27,45	Pottery	6,4x4,1x1,2	Undetermined amphora sherd. It demonstrates a grey fabric and an outer grey surface. The paste includes silver mica and white inclusions. Pitch was observed inside	
22	28,40	Pottery	4,9x2,6x1	Common ware. It displays a grey fabric (also outside) with white and silver inclusions.	
31	28,90	Wood	4,3x2,6x0,5	Burnt undetermined fragment	
32	28,95	Shell	6,6x4,2	Murex (*Hexaplex Trunculus*)	
33	29,00	Bone	3,8x1,9x0,6	Ichthyofauna (large fish jaw), possibly a meagre (*Argyrosomus regius*) or similar from the *Sciaenidae* family (taxonomy thanks to Dr. M. C-Soriguer Escofet, UCA)	
36	29,65	Pottery	3,6x2,9x1,1	Common ware. It demonstrates grey fabric with white and black inclusions. Some areas of the inner surface show orange colour	
38	31,50	Pottery	2,8x2,7x0,4	Common table pottery. It displays a greyish paste with whitish surface where the marks of the wheel thrown are visible. It has some temper of small dimensions of black colour and a large one of the same colour. It is possibly the lower part of an open form.	
41	32,30	Pottery	5x3,8x0,9	Amphora of undetermined production. It demonstrates greyish paste with whitish temper. Resin remains are observed inside. Mechanical extraction marks are observed.	
43	33,45	Pottery	5,3x3,8x0,9	Possible African amphora sherd (partially eroded). It displays orange sandwich fabric inside, with greyish outer surface. It contains white inclusions.	
47	33,95	Wood	4,3x1,9x0,4	Undetermined fragment.	
50	36,95	Pottery	2,8x1,7x0,8	Common pottery (possible jar rim). It demonstrates greyish-orange paste with small and medium black and white colour inclusions. In one of its sides we can see the start of a possible jar pouring spout.	
54	40,55	Pottery	3,4x1,8x0,7	Oxidizing common pottery (partially eroded). A sandwich fabric is observed displaying grey-colour inside the shape and orange-colour outside. Some whitish and black small inclusions are noticed.	
57	45,00	Pottery	5,1x3,1x0,5	Two fragments of grey ware bowl, with rounded rim inside. The paste includes golden mica in very small inclusions.	8^{th}-6^{th} c. BC
58	45,00	Pottery	2,6x2,1x0,9	Common ware rim of a pot. The paste is of grey fabric with small and medium-sized black and white temper, as well as silver mica.	
61	45,00	Pottery	3,5x3,4x0,7	Common pottery, grey fabric, with an exterior greenish finish. The paste demonstrates bright inclusions of whitish and black colour.	

Fig. 7 Table with the selection of fragments of artefacts and biofacts of Core 2 (indicating the sample number, the depth of finding, the raw material, the dimensions and general details)

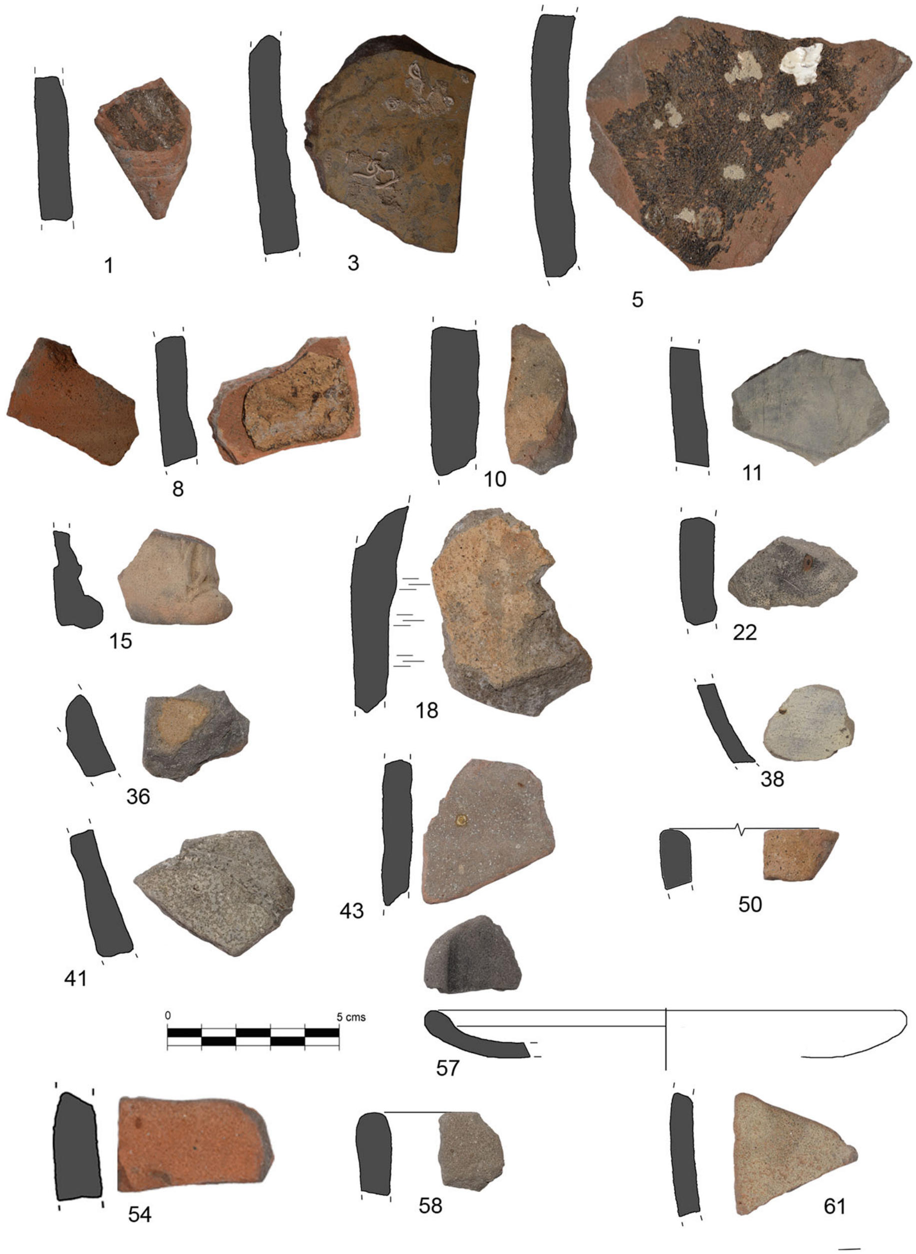

Fig. 8 Illustration of a selection of the main ceramic elements of Core 2

be suggested that the studied samples may correspond to remains of vegetal food consumed in the past and preserved in the sedimentary sequence.

Likewise, some wood remains have been identified, which have been xylologically analysed, based on their botanical identification by observing diagnostic anatomical elements among the different species, genera and families. The observation of the samples

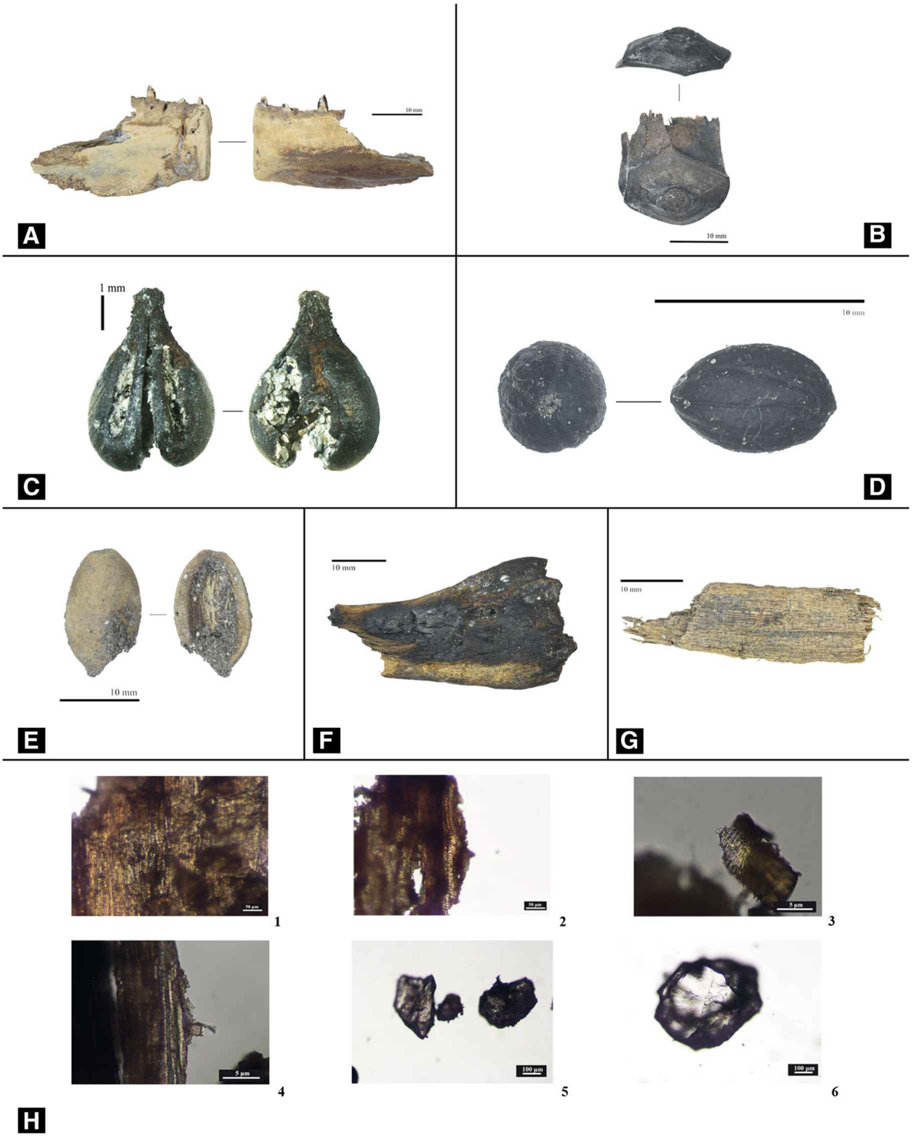

Fig. 9 Ichthyological remain (**a**—33), carpological remains (**b**—16 pine cone scale; **c**—grape seed, − 24.40 m, M-2, ^{14}C dating; **d**—olive/wild olive seed, − 26.73 m, M-3; **e**—pinion, − 33.75 m, M-7) and wood (**f**—31; **g**—47), with details of the xylological remains (**h**—photographs in the transmitted light microscope; 1, × 200, anatomical alterations in nb 31; 2, × 200, spiral thickenings in vessels in nb 31; 3, × 400, spiral thickenings in vessels in nb 31; 4, × 400, fungal mycelia in nb 47; 5, 6, × 100, crystals in the anatomical elements in nb 47) of Core 2

was carried out using a Nikon Eclipse 50iPOL transmitted light optical microscope. Cuttings of each anatomical plane presented by the wood (transverse plane, longitudinal tangential and radial longitudinal) have been made with the help of a razor blade. These anatomical sections have been mounted on a slide for microscopic observation. The two fragments of analyzed wood (Fig. 9f, g) present macroscopic evidence of exposure to a very humid environment. Fungal mycelia were observed on their external and internal parts (Fig. 9h, 4). These two fragments are also very altered by their quick post-depositional drying (Fig. 9h, 1). Due to seawater, the mineral salts obstructed the different anatomical elements of the wood fragments (vessels, fibres, parenchyma cells, etc.), creating concretions on their external and internal surfaces (Fig. 9h, 5, 6). Consequently, it was difficult to identify them with a great resolution. However, the preparation of sheets for the analysis of the tangential longitudinal plane and the radial longitudinal plane confirms they are angiosperms. In this case, due to the poor preservation of the wood samples diagnostic criteria such as the width of rays could not be observed. Although a more accurate identification is not possible, the microscopic analysis has allowed the observation of diagnostic anatomical elements such as spiral thickenings in the vessels and alternate pits of small size (Fig. 9h, 2, 3). Even so, this anatomical element is common among many genera (e.g. *Arbutus*, *Ballota*, *Rosmarinus*, some species of *Prunus*, *Ulmus*, *Celtis*, among others).

All these artefacts and biofacts, together with the preliminary but very promising chronological framework based on a combination of dating methods (ceramic chrono-typology, radiocarbon and thermoluminescence), highlight the remarkable anthropic activity in the harbour of *Gadir/Gades* between Protohistory and the Early Roman period. The first results presented in this contribution will potentially serve as a future robust basis for interdisciplinary studies.

Conclusions and Perspectives: A Very Deep Harbour, A Remarkably Thick Sedimentary Archive and Two Unconnected Islands

The results of this archaeological and geoarchaeological study below the Valcárcel Building in Cádiz are of great relevance for the knowledge of the palaeotopography of the former archipelago of Cádiz (Fig. 10).

For the first time, it has been possible to discover evidence supporting the existence of a harbour at the "Bahía-Caleta" channel in Cádiz. This harbour can be considered as a semi-protected shelter taking into account the silty sand deposits trapped in the palaeochannel. The access of this harbour was at least 200 m wide to the west, and the available water depth is without equal in such an urbanized context, representing no constraint at all for any ship draught (at over 20 m deep). The remarkable depth of the pre-Roman and Roman harbour, largely exceeding the draughts of the biggest ships sailing in Antiquity, could have been a problem for anchoring. Alternative methods could have been used for securing the ships/boats, such as mooring, docking, and beaching. The palaeochannel was still more than 20 m deep in the first–third centuries AD revealing that the difficulties for anchoring still existed during that period.

Additionally, the filling of this deep harbour, especially between *20 and 40 m b.s.l.* in VAL-18-Core 2, represents a sedimentary archive of great importance for tracing the early developments of Cádiz from its origin to the early first millennium AD. The abundance of artefacts and biofacts reveals that this palaeochannel was an exceptional trap recording the history of Cádiz. More than a hundred archaeological fragments were identified using only a single drill with a narrow head diameter, revealing an exceptional density of archaeological material in the sediments. The stratigraphy of the three geoarchaeological sedimentary cores (including Core 2 in Fig. 6) is similar: (i) modern-contemporary anthropic structures in the upper metres (*0–4 m a.s.l.*); (ii) a long sedimentation with almost no

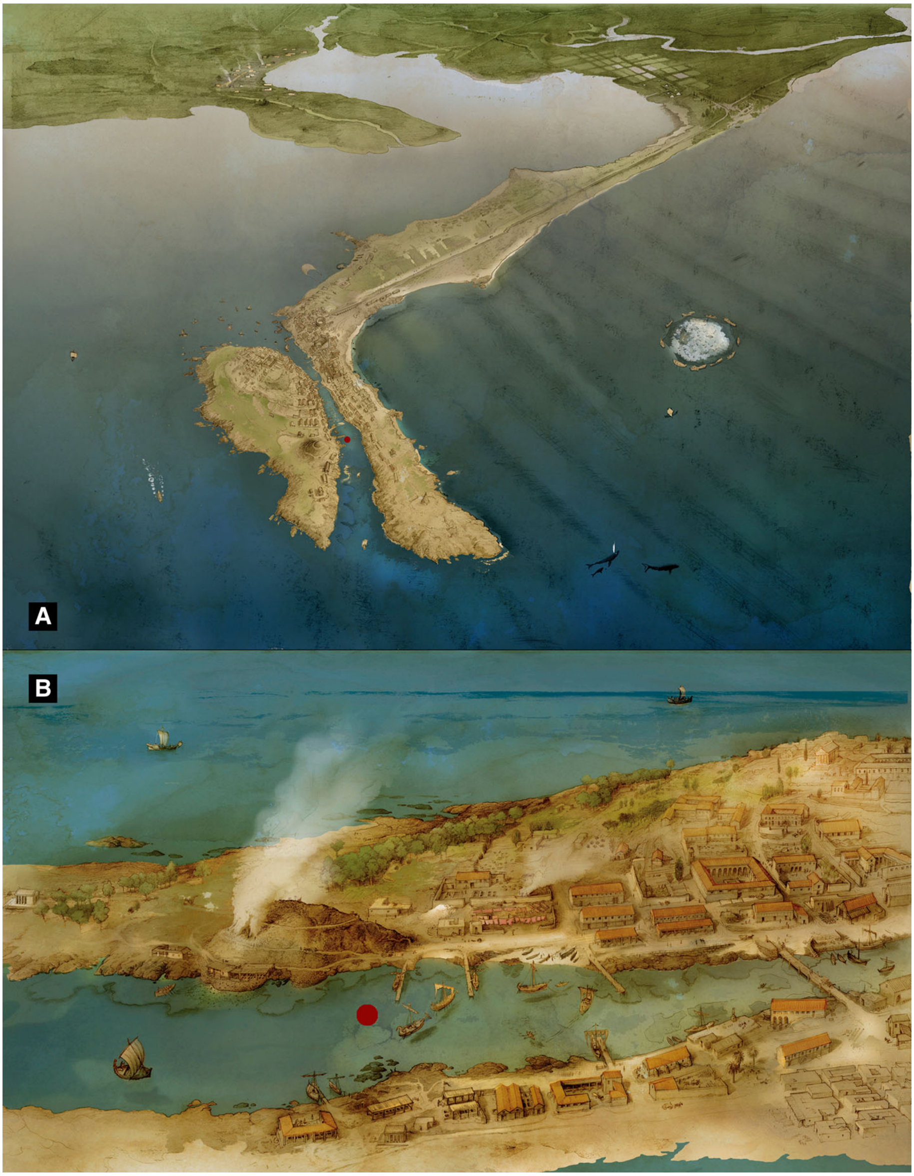

Fig. 10 Reconstruction of the Gaditan islands in the Early Roman period, with the open palaeochannel based on the investigations in the Valcárcel Building (illustration A. Álvarez Marsal, in consultation with D. Bernal-Casasola)

anthropic material (*0–20 m b.s.l.*), interpreted as sedimentation of the palaeochannel with low impact from the city, occurring during the Late Roman and/or medieval periods (dated after AD 56–217—*Terminus Post Quem*); and (iii) a sequence of strong human impact in the sedimentation and a high concentration of anthropic markers (*20 m to more than 41 m b.s.l.*), during the period in which the channel was active and used as a harbour for maritime and commercial activities. The combination of dates using typological dating based on ceramics, ^{14}C dating and thermoluminescence allowed us to attest that the main period of sedimentation occurred between the Archaic Phoenician colonization and the Early Roman Imperial periods.

This important discovery was possible using two methodological strategies put into practice and interrelated: the archaeological excavations conducted in the central zone of the channel, and the drilling of deep geotechnical cores—a strategy that has been very effective in Cádiz and that should continue in the future.

The second point of interest is related to the remarkable depth of this palaeochannel, or palaeogorge. The geological *substratum* was not reached at *40 m b.s.l.* in Core 2, but it stands at *45 m b.s.l.* in Core 3. Its formation is due to natural and geological factors, and not anthropic means. We do not know of the existence of detailed geophysical studies carried out to determine the maximum depth of the channel (Llave et al. 1999), but these will have to be developed in light of these new findings. It will also be necessary to re-evaluate the geological genesis of the palaeochannel, traditionally considered to be incised by a palaeochannel of the Guadalete River (Gracia et al. 2000). This interpretation was discussed precisely because of the shallow depth attributed to this palaeochannel in previous studies (discussion in Arteaga and Roos 2002: 27). The new discovery in the Valcárcel Building area solves this problem; however, it sheds light on others, such as the absence of fluvial deposits—at the bottom of Core 3, at *47 m b.s.l.* Holocene marine deposits are directly deposited over the biocalcarenite (*substratum*). This new evidence demonstrates how the interest of the Valcárcel Building's findings not only connect with historical-archaeological research, but also with the geological research conducted in the Bay of Cádiz.

A detailed geoarchaeological study is in progress on the three extracted stratigraphic columns, in order to obtain a high-resolution chronology of the deposits and to reconstruct palaeogeomorphological modifications (coastal mobility), but also climatic changes and extreme events (storms, tsunamis, etc.). A wide range of analyses will be performed including sediment grain size, organic content, the identification of the depositional context using macro- and microfauna, as well as palaeopollution, palynology and mineralogy. The combination of all these analyses will provide a new set of data for reconstructing the palaeodynamics of the channel, the origin of the sedimentation taking into account human and natural factors affecting this coastal landscape. These studies will be conducted by specialists from the Universities of Strasbourg and Cádiz fundamentally, along with the collaboration of other colleagues and institutions.

We should be cautious, similarly to every research conducted in Human and Experimental Sciences; nevertheless, it seems that these investigations initiate a paradigm shift in relation to the palaeotopography of the old archipelago of Cádiz.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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