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The Palaeo-Environmental Contexts of Three Possible Phoenician Anchorages in Portugal

Shelley Wachsmann

Institute of Nautical Archaeology, Texas A&M University, PO Drawer HG, College Station, TX, 77841–5137, USA, swachsmann@tamu.edu

Richard K. Dunn

Department of Geology and Environmental Science, 158 Harmon Drive, Norwich University, Northfield, VT 05663, USA, rdunn@norwich.edu

John R. Hale

College of Arts and Sciences, University of Louisville, Louisville, KY 40292, USA, jrhale@louisville.edu

Robert L. Hohlfelder

Department of History, Box 234, University of Colorado, Boulder, CO 80309–0234, USA, hohlfeld@spot.colorado.edu

Lawrence B. Conyers

Department of Anthropology, University of Denver, 132 Sturm Hall, Denver, CO 80208, USA, lconyers@du.edu

Eileen G. Ernenwein

Center for Advanced Spatial Technologies, University of Arkansas, Fayetteville, AR 72701, USA, eernenw@cast.uark.edu

Payson Sheets

Anthropology Building, 350 Hale, University of Colorado, Boulder, CO 80309–0233, USA, payson.sheets@colorado.edu

Maria Luisa Pienheiro Blot

Centro Nacional de Arqueologia Náutica e Subaquática, Avenida da India–136, Lisbon 136–1350, Portugal, mariablot.cnans@ipa.min-culture.pt

Filipe Castro

Institute of Nautical Archaeology, Texas A&M University, PO Drawer HG, College Station, TX, 77841–5137, USA, fvcastro@tamu.edu

Dan Davis

Institute of Classical Archaeology, University of Texas at Austin, MCC Building 3925 West Braker Lane, Austin, TX 78759, USA, dandavis@mail.utexas.edu

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The 2002 Joint Expedition of the Institute of Nautical Archaeology and the Centro Nacional de Arqueologia Náutica e Subaquática examined Phoenician maritime involvement in Portugal, combining archaeological, geological and geophysical surveys of former coastal sites—Santa Olaia, Abul and Castro Marim—where previous excavations have uncovered Phoenician remains. Significant geomorphic evolution of bay-head delta and estuarine settings masks the fact that Phoenician sites were situated at the head of marine embayments or on estuary margins, had easy access to the sea, and immediate access to at least one natural anchorage. All sites exhibited topographical criteria familiar from Phoenician trading-stations and merchant outposts in the Mediterranean.

Key words: bay-head delta, estuary, harbours, paleogeography, Phoenicians, Portugal.

In their homeland, the Phoenicians favoured locating their harbours in the lee of an island, as at Tyre, or in the lee of a coastal promontory with extra protection from an offshore bedrock ridge, as at Sidon (Carmona Gonzalez, 2003; Marriner *et al.*, 2005; Marriner *et al.*, 2006a; Marriner *et al.*, 2006b; Marriner and Morhange, 2007: 152–3, 156 fig. 17; Carmona and Ruiz, 2008). Expanding westwards across the Mediterranean, the Phoenicians continued to favour sites with specific natural features which supplied protected anchorages for their ships. Their settlements in Spain, for example, were located in three types of settings: on islands (Gadir/Cadiz), inside estuaries (Castillo de Doña Blanca) or, most frequently, on elevations at the mouths of rivers (Cerro del Prado, Cerro del Villar, Málaga, Toscanos, Morro de Mezquitilla, Chorreras, Almuñécar and Adra) (Aubet, 2001: 257–90, 305–46).[1]

Phoenicians, apparently from the Guadalaquivir enclaves, eventually created additional colonies and trading stations along the Atlantic coasts of Africa and Europe. Ancient authors report the establishment of numerous Phoenician settlements on the Atlantic coast of Morocco, but archaeologically-documented sites remain rare (López Pardo, 1996: 251–64; Neville, 2007: 43 fig. 1.20 and n.170, 44 n.178).[2] In later times the Carthaginians also attempted the colonization of the African Atlantic coast (Oikonomides, 1977; López Pardo, 1991; Markoe, 2000: 189; Aubet, 2001: 192; López Pardo and Suárez Padilla, 2002: 116). Notwithstanding literary claims to north Atlantic voyaging by the Phoenicians, their northernmost archaeologically documented *settlement* is located in Portugal.[3] Generally, the sites which have revealed abundant Phoenician remains are located, as is Castillo de Doña Blanca, on the estuaries or alluvial plains of major rivers, which include from north to south the Mondego, Tagus (Tejo), Sado and Guadiana (Fig. 1) (Arruda, 2000; Aubet Semmler, 2002: 104, 105 fig. 2; Neville, 2007: 35–42).

Understanding these sites is complicated by dramatic geological changes that significantly altered Portugal's landscape in the Holocene Epoch (last 10,000 years). During the peak of the last glacial period, *c.*18,000 BP, global sea-level was about 120 m below present sea-level (Lambeck, 1995: 1027 fig. 3b). At that time, Portugal's river-valleys extended across the now-submerged continental shelf. As the glacial ice-caps melted, sea-level initially rose rapidly and approached present level *c.*6000 BP both globally and in the Mediterranean basin (Lambeck 1995: 1026–34). Various studies in south-western Iberia reveal local relative sea-level approaching present sea-level *c.*6500–5000 BP (Goy *et al.*, 1996: 776–9, figs 2–3, and additional bibliography there; Granja and De Groot, 1996: 162; Dabrio *et al.*, 2000: 388 fig. 4, 389 fig. 5, 397; Dias *et al.*, 2000: 178 fig. 1, 181). The early-mid Holocene rapid sea-level rise flooded or drowned river-valleys, producing large marine embayments that were estuarine in character and extended many kilometres inland. These marine embayments were at maximum expansion from *c.*6500 BP until the last two to three millennia, when sedimentary filling began significantly to decrease their width and length. Sediment was deposited in three ways: in bay-head deltas that advanced down the valleys, creating alluvial plains in up-valley localities; in sub-tidal and tidal settings as estuaries began to fill with tidal flats and tidal marshes; and in shallow lagoons coupled to the growth of sand-spits and barriers which restricted marine inflow (Goy *et al.*, 1996: 776–9,

Figure 1. Map of Portugal showing the locations of Santa Olaia, Abul and Castro Marim. (D. Davis)

figs 2–3; Morales, 1997: 142–5, fig. 14; Dabrio *et al.*, 1999: 273–9, figs 6 and 10, 292; Psuty and Moreira, 2000: 134–7; Boski *et al.*, 2002: 117–21; Martin Ruiz, 2004: 21–4, figs 4–7; Boski *et al.*, 2008: 235 fig. 2). At present, the riverine valleys of Portugal are at various stages of filling, and most still have large estuaries at their lower reaches.

These natural processes have been accelerated by human activity contributing further to the changing landscape of Portugal's river-valleys (see for example Dinis *et al.*, 2006: 45 table 1). Intense deforestation, particularly during and after the medieval period, eroded soils and increased sediment supply to valleys. The introduction of rice cultivation resulted in major landscape transformations as river-valleys were artificially altered and levelled to create a suitable landscape for this form of agriculture.

Salt production has a long tradition in Portugal and its economic value is well documented throughout the country's history (Rau, 1984: 39–46). It is fair to assume that its roots extend far beyond the written record. A temperate climate, with long rainless summers, and flat estuaries made the production of salt through solar evaporation attractive to coastal populations. It is difficult to determine the economic impact of salt production on the formation of the landscape on a case-by-case analysis, but it is fair to assume that salt production has influenced the stability of large areas of many river estuaries because it requires the careful maintenance of large areas of flat ponds, artificially filled and drained of salt water. Records show that during the Middle Ages, there were three main traditions along the Portuguese coast. Between Aveiro and Figueira da Foz (the area of Santa Olaia), salt-ponds were of the type used in north-west France, where the salt is dried directly over the clay or silt on the bottom of the ponds. In the region around Lisbon down to Alcácer do Sal (the region of Abul), salt workers cultivated a thin cover of algae (*Microcleus corium*) to isolate the salt from the silty bottoms of the ponds. This method was also used in the Algarve (the area of Castro Marim), but not consistently. Over time rice-paddies replaced many salt-ponds, particularly those located more inland. All these changes, natural and human, reshaped the geography and geomorphology of the river-valleys to a remarkable degree. Estuaries and marine embayments have largely filled and converted to riverine systems, while rivers have significantly narrowed until, in some places today, they have become little more than narrow canals.

The Phoenicians arrived in Portugal at a time of geological transition when the wide estuaries of the mid-Holocene were undergoing the expansion of tidal flats and marshes, and the overall estuary systems were retreating down valleys towards the sea as extensive shoaling occurred and as bay-head deltas began to advance down valleys (Dabrio *et al.*, 1999: 273 fig. 6, 277 fig. 10, 279; Psuty and Moreira, 2000: 136 fig. 12; Lario *et al.*, 2002; Boski *et al.*, 2008). Sites once located on islands or on peninsulas jutting into or along marine embayments today sit landlocked, surrounded by alluvial plain, rice paddies, saltpans or, in some cases, even buried beneath modern cities (Blot, 2003).

We may assume that the Phoenicians would have sought or created safe and efficient havens for their ships wherever trading activities took them. We are familiar with Phoenician harbours at Mediterranean sites (Frost, 1963: 63–114; Frost, 1995; Marriner *et al.*, 2005; Marriner *et al.*, 2006a; Marriner *et al.*, 2006b; Marriner and Morhange, 2007). But virtually nothing is known about their solutions for mooring in estuarine settings. Furthermore, the Phoenicians had to deal with tides along the Atlantic coast—a phenomenon virtually unknown in the Mediterranean, where tidal variations are generally less than 0.5 m.

The geographical situation raises several archaeological questions. How did the Phoenicians select, and possibly enhance, their mooring sites adjacent to Portuguese sites? Where did they situate anchorages in relation to the settlements themselves? At the outset, we postulated that the locations under consideration had been accessible by ship in Phoenician times and would have required some form of mooring facilities.

Archaeological work at Portuguese terrestrial sites has revealed rich evidence of Phoenician involvement. To put this into perspective, it is worth noting that the excavator of Almaraz, Luís Barros, reports finding over a million Phoenician sherds at this settlement alone (pers. comm.; see also Barros *et al.*, 1993; Barros, 1998; Arruda, 2000: 102–11; Aubet, 2001: 296–7). Despite its distance from the familiar Mediterranean Sea, clearly Portugal was no backwater to the Phoenicians (Arruda, 2000; Neville, 2007: 35–6, 42).

Placing coastal archaeological sites in their proper palaeo-environmental context requires reconstructing the sedimentary and geomorphic evolution of their dynamic coastal systems. Numerous sites of various ages, including specifically Phoenician sites, have been investigated across the Mediterranean and beyond.[4] In the late 1990s, a French and Portuguese archaeological team working at the Phoenician site of Abul on the Rio Sado carried out a geological study of the narrow coastal plain around the site, which is now surrounded by rice paddies (Guy *et al.*, 2000). They concluded that at the time of Phoenician settlement it did not lie on a hill set back from a muddy riverbank, as it does today, but instead formed the end of a promontory projecting into the estuary, surrounded on the north, west and south by sheltered embayments of tidal waters. Some of the presumed locations of anchorages adjacent to other such sites—such as those at Almaraz, at Lisbon's Sé site and at Alcácer do Sal—are today densely built-up, making fieldwork there virtually impossible, unless carried out during urban renewal (Almaraz, see above; the Sé (Amaro, 1993; Cardoso, 1996; Arruda, 2000: 113–30); Alcácer do Sal (Arruda, 2000: 64–86)).

In 2001 members of our team met many of the Portuguese archaeologists excavating sites producing Phoenician or Punic material, thanks to the efforts of Director Francisco Alves, Maria Luisa Blot and their colleagues at the Centro Nacional de Arquelogia Náutica e Subaquatica (CNANS)—the Portuguese governmental organization responsible for maritime archaeology. In 2002, our interdisciplinary team, led by Shelley Wachsmann, surveyed the surroundings of Abul and two other Portuguese settlements with Phoenician material—Santa Olaia on the Rio Mondego, and Castro Marim near the mouth of the Rio Guadiana (Fig. 1). We wished to examine the hypothesis that the regions immediately surrounding these sites, all three of which remain *relatively* unburdened by modern construction, may represent a rich, and so far untapped, source of information regarding their ancient maritime activity (Arruda *et al.*, 2007: 462). We designed a methodology to address the geomorphological and sedimentary environmental changes as well as to study how the Phoenicians exploited local conditions to meet maritime requirements.

During the ensuing field survey, the team conducted geological and remote-sensing studies employing coring, ground-penetrating radar (GPR) and electro-magnetism. Our results enabled us to map the original position of the ancient shorelines, including embayments, and thus to tentatively locate likely Phoenician anchorages/moorings.

Methods

Geology and geophysics

Our team decided upon a field methodology which could be used to explore and map buried coastlines and potential anchorages in the areas presumed to be former marine embayments or estuarine margins. The first goal was to test the assumption that open-water conditions had existed, and if so, when, as well as to identify potential sites for survey. We assumed these would be buried in or near former sandy or silty shorelines, bounded on the landward side by terrestrial sediments or bedrock and on the seaward side by shallow marine or estuarine sand and mud. We used geological cores to test for former open-water conditions while employing geological and geophysical approaches to identify subsurface targets. The methods were refined and modified for the various environmental conditions that we encountered. For the most part we worked in wetlands, tidal flats, rice paddies and unpaved urban settings.

Geologist Richard Dunn collected hand-powered Eijkelkamp brand push-auger cores of the sediments near the sites in an effort to understand the degree and nature of geomorphological change in the landscape, and the chronology of that change. Geological coring provides the stratigraphy and relative chronology of sedimentary environmental changes. To determine the absolute chronology of these changes, organic materials recovered from the geological cores underwent radiocarbon analysis (see Appendix). Dunn examined and described all cores in the field. Data recorded included grain size, Munsell® colour, moisture content, fossil material, charcoal abundance, ceramic abundance and type (if identifiable), and unit thicknesses. Representative sediment samples were removed and analyzed in the laboratory for grain-size distribution, plant remains, as well as macro- and microfossil content. Samples saved for later radiocarbon analyses were sealed in aluminium foil and kept refrigerated to inhibit bacterial growth. Data obtained from coring was combined in cross-section illustrations of the subsurface to demonstrate the vertical and lateral variation in sedimentary deposits. Radiocarbon dates provide chronological control on vertical change and enable us to reconstruct the sedimentation history in the areas studied. Deeply-buried archaeological remains such as those along Portugal's rivers typically have little or no surface expression, and are only discovered by chance or through random digging or probing. Geophysical methods, however, have been successfully employed to map buried landscapes using electronic tools to 'see' into the ground. The most common geophysical methods employed in archaeological settings are magnetometry, electrical resistivity, ground-penetrating radar (GPR) and electromagnetic induction (EM) (Gaffney and Gater, 2003; Conyers, 2004).

While GPR could be used in relatively-dry urban settings, such as at Castro Marim, re-creating the sedimentary palaeo-environments of Portugal's estuaries through the use of shallow geophysical techniques generally presented significant difficulties. Our targeted ancient shorelines, often at depths of greater than 2 m below present surfaces, consist almost entirely of subtle variations in sediment type and content such as changes from sandy and shell-rich mud, to mud that has little sand in it. The slight changes within these sediments are too deeply buried for traditional magnetic methods, which can at most map changes to a few metres depth. Also, the slightly brackish water-saturated medium is too electrically conductive for GPR because radar energy attenuates in the water-column and in the saturated mud close to the surface. Therefore, for wet environments such as Santa Olaia and Abul, EM was the only method we considered, as electromagnetic fields can be transmitted in wet mud and might penetrate deep enough to detect the target features.

Lawrence Conyers and Eileen Ernenwein selected the highly-mobile EM-38, manufactured by Geonics Ltd, which can be used effectively in rice paddies. This device does not require direct contact with the water or sediment surface, as is necessary for electrical-resistivity data collection. The EM induction method operates by inducing an electromagnetic field into the ground, which generates a secondary electromagnetic field when it encounters electrically-conductive materials. Minor changes in the chemical and physical profiles of the underlying sediments affect the secondary EM field differently, and these changes are both measured and mapped spatially within a grid. In electrically-conductive sediments, such as those encountered at the Portuguese sites, the induced field is spread out over a broad area, propagating the electromagnetic energy from 1–3.5 m into the ground. Measurements of subsurface changes were taken about every 10 cm along transects of 30 m or longer, within grids consisting of up to 50 transects spaced 1 m apart. The EM readings were digitized and stored on a small hand–held computer that also saved each reading's location within the grid.

Our first attempts at EM data collection in Portugal necessitated wading across flooded rice fields, moving the EM instrument just above the water surface, and collecting individual readings every metre next to a nylon measuring tape. For each successive transect the tape was repositioned and data collection proceeded at a slow and laborious pace. To facilitate these measurements, our team developed an innovative survey method in which we pulled the EM system and the digitizing computer across the rice paddies inside an inflatable kayak. This moved easily over the growing rice stalks, greatly improving data-collection efficiency while reducing crop damage.

We programmed the data-logger to collect data every 0.4 seconds during each passage across the field, with location control-marks manually placed at the beginning, the centre and the end of each line. Each transect was processed individually by stretching or squeezing all readings between the marks so that they were evenly distributed between known surface locations. Density of data-collection from each line was a function of the kayak's speed: an even spatial distribution of data required that the team members pulling the rope move the vessel at a steady pace. This method was efficient and allowed for the rapid completion of the survey-lines with a larger collection of data-points per transect.

Conyers and Ernenwein generated visual maps of the distribution of the differences in sediment conductivity by plotting the readings, interpolating between them and displaying them spatially. Changes in the underlying bedrock and sediment resulted in dramatic ranges in conductivity measurements within the test grids. Surface sediments consist of estuarine organic-rich sand and mud along with fill imported to level the ground during the creation of the rice fields. The results of many years of mechanized planting and harvesting have almost completely homogenized these fill sediments, and therefore they contribute almost nothing to the variation in the conductivity readings. Changes in conductivity recorded by the EM device, therefore, are apparently almost entirely the result of the spatial distribution of changes in the underlying bedrock and ancient estuarine sediments. Simply put, the conductivity maps effectively illustrate the geological variations that occur between 2–3.5 m in depth, reflecting conditions that existed prior to the complete silting-up of the estuaries and later rice cultivation.

Aerial photography

In preparation for the project, we considered the possibility that aerial photography might be useful provided the depth of geological layers was only moderate. If plant roots in the rice paddies that surrounded Santa Olaia and Abul reached below the plough zone and into sediments that were reasonably undisturbed by modern development, the vegetative contrast might indicate the presence of buried relevant archaeological features. With this in mind, we acquired all available sets of aerial photographs of the sites.[5]

During the spring and summer of 2002, Payson Sheets examined 9 × 9 inch (*c*.23 × 23 cm) sets of overlapping contact prints of the sites with a Fairchild stereo air-photo viewer to determine which of them to enlarge. We then ordered enlargements based on proximity to the sites. All the enlargements were to a scale of 1:3400, with the exception of one of Castro Marim at 1:8000. The aerial photographs were used to map and interpret the geomorphology, but ultimately the depth of sedimentation proved too great for aerial photography to be used to identify buried targets.

Palaeo-geographic reconstruction

Geological cores, sometimes complemented by geophysical investigation, provide a record of sedimentary environmental evolution. This evolution is a function of estuary and coastal dynamics which are in part controlled by relative sea-level change, which includes the combination of global sea-level change, local tectonics, and local sediment supply. Because we know the general history of marine embayment evolution that corresponds to decelerating sea-level rise and sediment infilling, from Portuguese as well as world-wide examples, and we have modern analogues of coastal-alluvial settings from which we can examine the distribution of sedimentary environments, we can reconstruct the evolution of any coastal system if we have subsurface data (coring and geophysics), geomorphological data and chronological control. The sea-level record provides a general age-versus-depth framework within which we must work. Geochronometric techniques, as well as archaeological remains, provide chronological control.

We base the palaeo-geographic maps presented here on our analysis of sedimentary environmental evolution coupled with radiocarbon dating. The maps show the geomorphology or landscapes of a given time, and although they may not be exact in their location of all features, they represent the best geographic distribution based on the geological, geophysical, archaeological and chronological data available, and on the application of modern analogues. Our radiocarbon samples consist of shell, wood or plant remains and were analyzed using the Accelerator Mass Spectrometer (AMS) radiocarbon technique. The two-sigma standard deviation is on the order of a few decades for all samples, which are discussed in calibrated years (Appendix).

Figure 2. Rocha's discoveries of Phoenician pottery and other cultural materials at Santa Olaia in 1902 were the first evidence of Phoenician penetration into Portugal. (from Rocha, 1908: pl. 30)

The sites

Santa Olaia

Located on the Rio Mondego east of Figueira da Foz, Santa Olaia was the first Portuguese site to reveal Phoenician remains (Fig. 2) (Rocha, 1908; Pereira, 1993; Pereira, 1996; Pereira, 1997; Pereira *et al.*, 1998; Arruda, 2000: 227–40; Aubet, 2001: 297; Neville, 2007: 41–2). Summarizing Phoenician involvement at the site, its excavator sees exploratory contacts beginning in the 9th century, the construction of a trading-post towards the end of the 8th century or the beginning of the 7th century, with a heyday in the 7th–6th centuries (Pereira, 1996: 63; Pereira, 1997: 231; Neville, 2007: 42). Although later Punic remains have been reported further north along the Iberian Atlantic coast (da Silva, 1995: 71–3; da Silva, 2000: 95–9; González-Ruibal, 2004; González-Ruibal, 2006; Neville, 2007: 42), after a century of research Santa Olaia remains the northernmost coherent Phoenician settlement along the Atlantic seaboard at which Phoenician artefacts have actually been recorded (Neville, 2007: 41–2). The limits of Phoenician north-Atlantic expansion may have resulted from a lack of appropriate local trading partners. González-Ruibal (2004: 292) notes:

> To put it simply, the Mediterranean sailors might not have been able to find indigenous polities able to engage in profitable and lasting relationships, which would make founding factories in the Galician or north Portuguese coast worthwhile. The Baiões-Santa Luzia aristocracies had probably collapsed shortly before their arrival, and those once-wealthy and powerful communities were being superseded in their power by groups inhabiting the lower Mondego basin, precisely where the Phoenician settlement of Santa Olalla [Santa Olaia] was founded.

The site sprawls down the northern side of a small ridge, which separates the Rio Mondego valley from a large nameless alluvial plain to the north (Fig. 3). Roads in the area of Santa Olaia tend to take advantage of the limestone bedrock's stability in an area where alluvial fill predominates: thus, although located in a rural environment today, Santa Olaia is a transportation hub for local roads and the national highway, all of which largely cover the site's northern side and make geoarchaeological work there problematic.

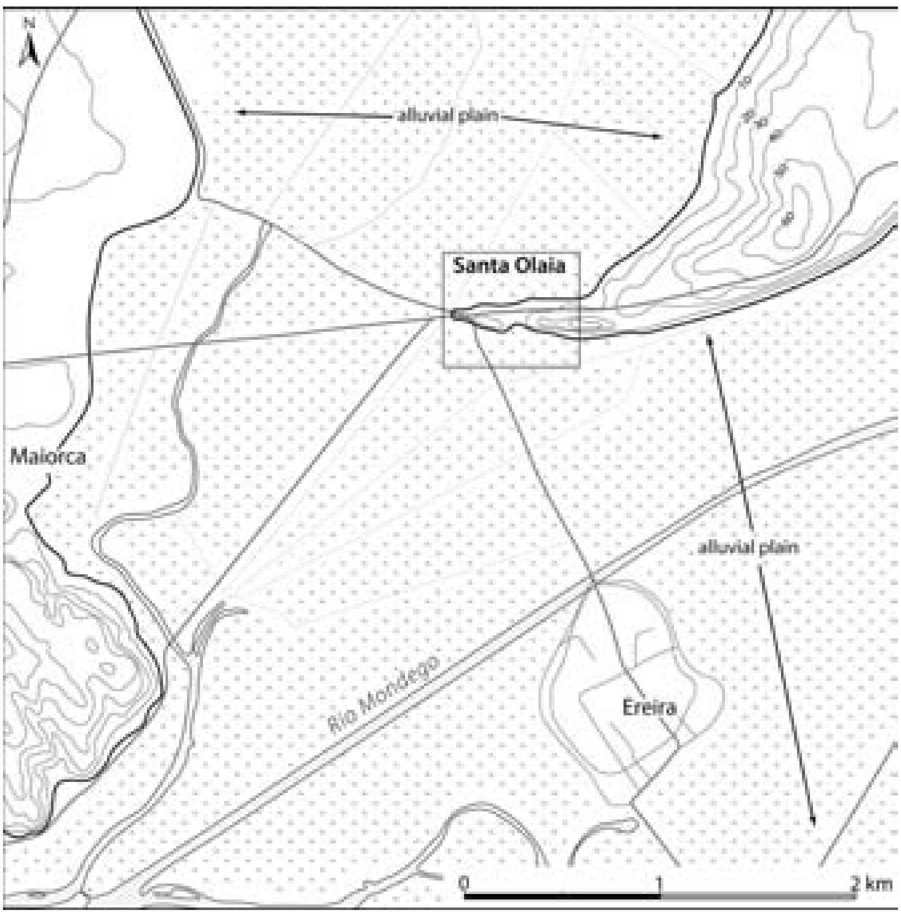


Figure 3. Map of the environs of Santa Olaia. Today Santa Olaia is located nearly 20 km from the open sea. All alluvial plain areas are now under rice cultivation. (D. Davis)

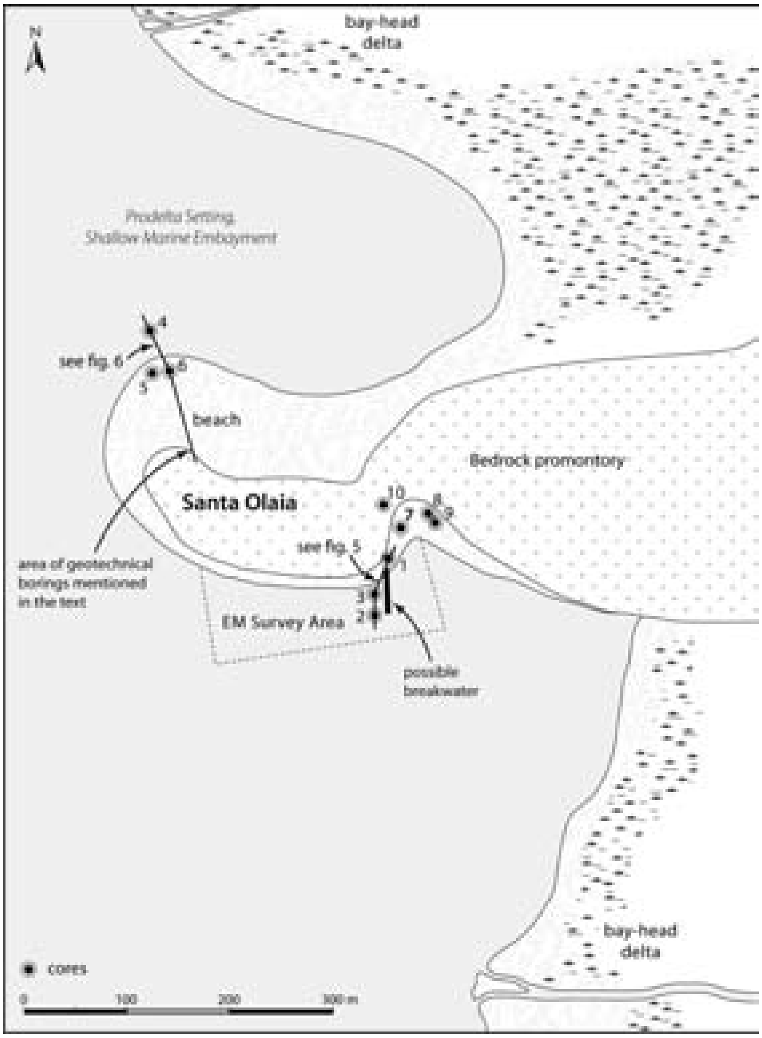


Figure 4. Locations of cores taken at Santa Olaia showing the resultant paleogeography of Santa Olaia at 2600 BP. Geological cross-sections, shown as lines through cores, to the south and north of the site are presented in Figs 5 and 6 respectively. Deltas are migrating down-valley but have yet to reach the Santa Olaia bedrock promontory. Water depths around the site were of the order of 1–3 m and a wide sandy beach existed on the north side of the site. The delta fronts would have been low-lying sand and mud areas, possibly with extensive wetlands. (data: R. Dunn; artwork: D. Davis)

The degree of landscape change here is dramatic. Today Santa Olaia is almost entirely surrounded by rice paddies. The Rio Mondego is so constrained here that it is little more than an irrigation canal. Given the regional sea-level history, albeit poorly defined in this area, and our understanding of the natural process of Holocene Epoch estuarine evolution, we postulated that in the Phoenician era Santa Olaia was accessible by ship from the sea via a wide estuary.

Cores taken in the fields surrounding the site revealed that both the Rio Mondego valley and the northern tributary valley consisted of shallow, open-water conditions at least as early as 4800 BP (Fig. 4). Sediments in the base of the cores here consisted of shelly coarse sand with abundant sub-tidal open-water molluscan fauna which were often preserved in life position, indicating a local fauna buried *in situ* rather than having been transported there by currents (Figs 4–6).

Deep geotechnical borings taken in the middle and north parts of the excavated site revealed a thick sequence of deltaic sandy mud that must have been deposited right to the edge of a steep north slope of the bedrock ridge (Mota & Co., nd). We can approximate the Phoenician levels in our cores because they are bracketed by

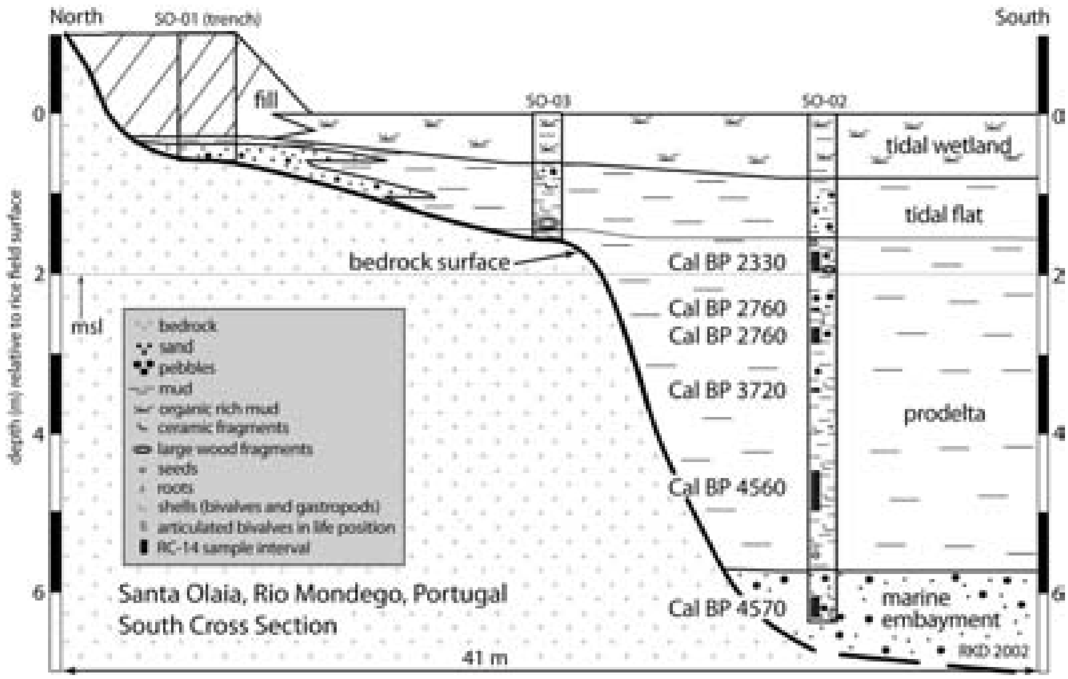


Figure 5. Geological cross-section based on Santa Olaia cores SO-2, SO-3 and backhoe trench SO-1. 'MSL' here represents *approximate* mean sea-level. (data: R. Dunn; artwork: D. Davis)

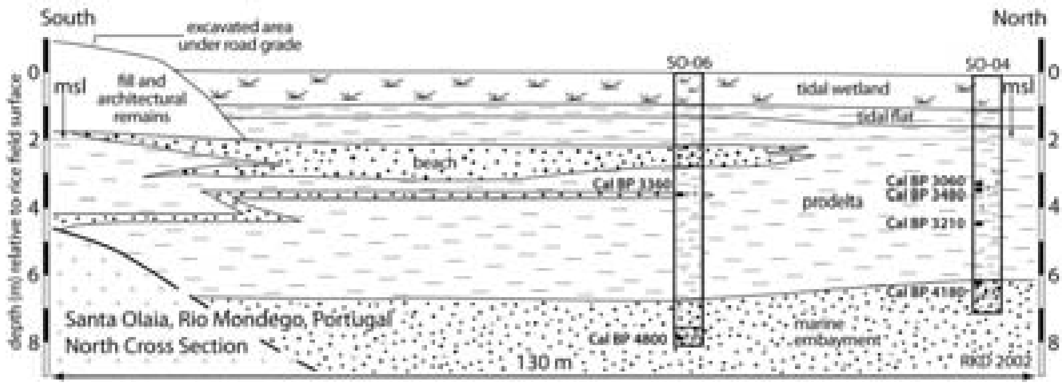


Figure 6. Geological cross-section based on Santa Olaia cores SO-4 and SO-6. 'MSL' here represents *approximate* mean sea-level. For legend see Fig. 5. (data: R. Dunn; artwork: D. Davis)

radiocarbon-dated levels and would be at approximately 2–3 m depth (see especially Fig. 5: Core SO-02). From the core data and radiocarbon ages we conclude that the shallow-water environment existed prior to Phoenician involvement at the site.

These deposits indicate that in the vicinity of mid-Holocene Santa Olaia, the lower Mondego was a wide estuary which extended beyond the site, that currents deposited clean sands, and circulation with marine waters was strong. These conditions prevailed until *c.*4200 BP, when the region began to be dominated by the deposition of brown, slightly-sandy mica-rich silt that is often laminated and contains abundant fine-grained organic matter, charcoal, seeds and bedding concentrations of shell hash, as well as articulated bivalves (Fig. 6, see radiocarbon date from Core SO-04). We interpret this sediment to represent deposits of a prodelta setting, where sedimentation occurred in the distal, submerged portion of the delta system. The presence of charcoal, seeds and mica in particular reveal that much sediment derived from land. These deposits are representative of bay-head deltas advancing down the valleys. For the next two millennia the sub-tidal deposition of this sandy silt continued as the bay-head delta system moved down the valley and toward Santa Olaia.

By the Phoenician era, large deltas had advanced down the two valleys, largely filling areas up-river of the Santa Olaia bedrock ridge and creating shallow-water conditions (~1–2 m) along the coastal zone of the site. Thus, the ridge on which Santa Olaia sits would have been ideally located at the head of an extensive marine embayment almost certainly with a wide fetch for sailing. Our palaeo-geographical reconstruction reveals that the Phoenicians would have had open-water access ~20 km up the Rio Mondego estuary at least as far as Santa Olaia, which would have given them access deep into the Portuguese hinterland. There are no mineral sources near the site, but there are large tin deposits up-river (Map, 1960): Santa Olaia would have served as an ideal processing and transhipment centre from metal-ore-bearing locations further inland along the Rio Mondego (Edmondson, 1987: 34 fig. 3.5, 242–3; Pereira, 1997: 218). Cargo—primarily consisting of mineral resources—could have been refined and loaded at Santa Olaia onto Phoenician vessels for transhipment to other settlements along the Iberian Peninsula or into the Mediterranean world.

Pereira initiated excavations on the northern side of Santa Olaia due to the construction of the national highway (IP3) from Figueira da Foz to Coimbra. The work revealed an industrial installation complete with a variety of furnaces aligned on terraces and protected by a wall (Pereira, 1993: 289–95; Pereira, 1997: 215–19, fig. 100). Correia (1995: 241 n.2; see also Neville, 2007: 41) identifies a mole here and, because of this, considers Santa Olaia a port. Our cores beyond this area encountered gravelly sand at Phoenician levels, suggesting a wide and sandy beach existed there at that time where ships could have been beached safely when tides and winds permitted (Fig. 6: Core SO-06 at a depth of 2–3 m).

At the site's south-eastern side we excavated a backhoe trench. Here, beneath some modern fill and a thin layer of tidal-flat mud, we located the ancient estuary shoreline comprising medium-coarse sand. Cores in the field on this side of the site reveal the same stratigraphic sequence and, therefore, geological history, as on the north side (Fig. 5). Our EM survey on the south-eastern side of the site, within the adjacent rice field, revealed a feature of low conductivity projecting southward that provided a signature opposite to one derived from the clay-rich mud buried in the shallow subsurface (Fig. 7). Shallow cores

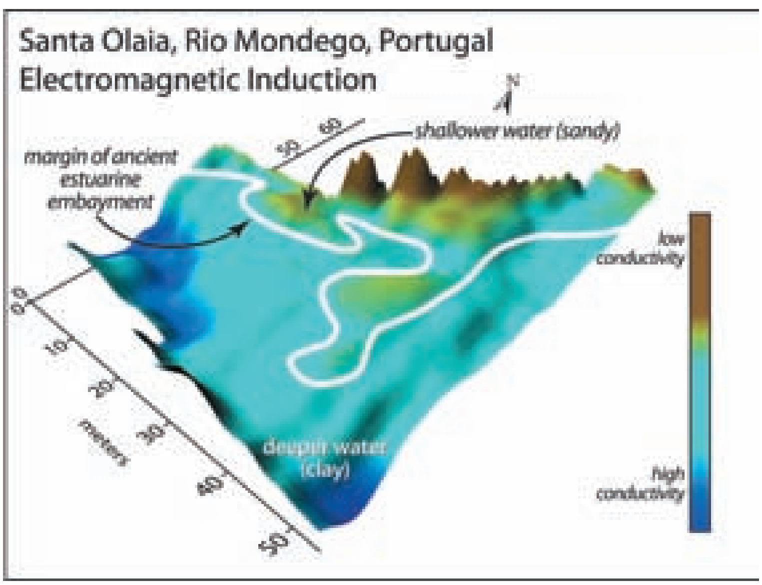


Figure 7. Santa Olaia. EM visual map of sediment conductivity showing a north and south-trending feature of low conductivity in the rice fields south-east of the site. (data: L. Conyers and E. Ernenwein; artwork: D. Davis)

encountered sand and rock fragments which covered the anomaly's surface. Although this may be interpreted as a small bedrock spur, in fact the trend of the anomaly is perpendicular to the trend of the bedrock. For this reason, we tentatively suggest that this may be a stone man-made breakwater or similar feature. The EM survey also confirmed that the shoreline of the palaeo-estuary, consisting of low-conductivity sediment (sands), extended along the bedrock ridge, thus corroborating data from the backhoe trench and cores SO 07–09.

We also conducted coring and trenching around the small bedrock hill of Ereira, located south of Santa Olaia in the middle of the alluvial plain (Fig. 3). We excavated three backhoe trenches on the north side of Ereira near the contact between the hill and the modern alluvial plain and in each we encountered Jurassic black shale within 1.5–3 m of the surface. Above the shale were various sand and gravelly-sand deposits which probably represent the shoreline along a tidal river before the rivers were artificially canalized. The shallow nature of the bedrock, and the close proximity of the modern Mondego channel, suggest that river migration may have removed any Phoenician-era deposits on the immediate northern side of the Ereira hill. A core approximately 50 m north-east of Ereira and two cores from the fields on the south side of Ereira, approximately 70 m from the hill itself, recovered sediments and stratigraphy very similar to that in the cores at Santa Olaia. The basal material was characterized by sand, which may have been open-estuarine sand like that seen near Santa Olaia. A radiocarbon sample from wood in this sand, at about 4 m depth, gave a corrected age of 4430 BP, revealing that it is of the same age as the shelly sand from the bottom of the Santa Olaia cores. Therefore, in the mid-Holocene, ~6000–4200 BP (sample Rd-Er03, Appendix), fairly open-water conditions existed across the width of the Mondego valley and some considerable distance up-valley from Santa Olaia and Ereira. Brown, laminated organic-rich slightly-sandy silt with abundant charcoal and mica above the basal sand at Ereira represents the progradation of a bay-head delta in the area. This is the same delta that approached the south side of Santa Olaia: the timing of delta progradation down the wide Mondego valley, and its tributary valley, is corroborated by the Ereira data and is coincident with similar bay-head delta advance of estuaries along the south-western Iberian coast (Dabrio *et al.*, 1999: 273 fig. 6, 277 fig. 10; Dabrio *et al.*, 2000: 394–5 figs 6–7).

The deltaic sediments in all of the cores are overlain by olive-grey mud and organic-rich mud of tidal-river, tidal-flat and marsh origin, with a 2330 BP date at the level of this shift in sedimentary environments (Figs 4–5, uppermost units with date in SO-02). This shift by approximately 2300 BP—somewhat after the 7th–6th century BC Phoenician heyday at Santa Olaia—reveals that in the Santa Olaia and Ereira area the wide estuary was largely filled by the prograding deltas, and shallow tidal and riverine conditions prevailed. In other words, the deltas had migrated down the valleys of the Rio Mondego and its northern tributary and coalesced once they passed west of the Santa Olaia bedrock peninsula. Deltaic wetlands, tidal creeks and shallow tidal basins now surrounded Santa Olaia and Ereira. The main river may have been nearby, but we do not have the data to establish the position of the primary channel(s) at that time.

Continued sediment deposition across the width of the valley would eventually build up the surface to the point that tidal influence became restricted to channels and an alluvial plain developed. Studies in the region reveal that it is very likely that the lower Rio Mondego estuary remained much more extensive than today and may have largely filled with inter-tidal and alluvial sediment only in the last half millennium (Dinis *et al.*, 2006). The narrow neck of the Santa Olaia peninsula would have provided two protected moorings, on the north and south sides, but the environmental change at *c.*2300 BP would have left the site virtually inaccessible by ship. Whether the site was ultimately abandoned as a result of the delta bypass remains unclear, as we do not have good chronological control regarding its advance in later times.

The excavated archaeological site is located on a low bedrock surface on the north-western side of the Santa Olaia promontory. The anchorage or loading-point to the north side of the site seems to have been immediately offshore from the excavated factory area, and possibly slightly to its east, where the narrowest point of the promontory is found. On the south-western end of the promontory the bedrock forms a cliff at the foot of which are rice paddies which almost certainly overlie beach sand, as we found on its north-eastern and south-eastern sides. Most probably an anchorage on the south side would have been in the area where the ridge is at its

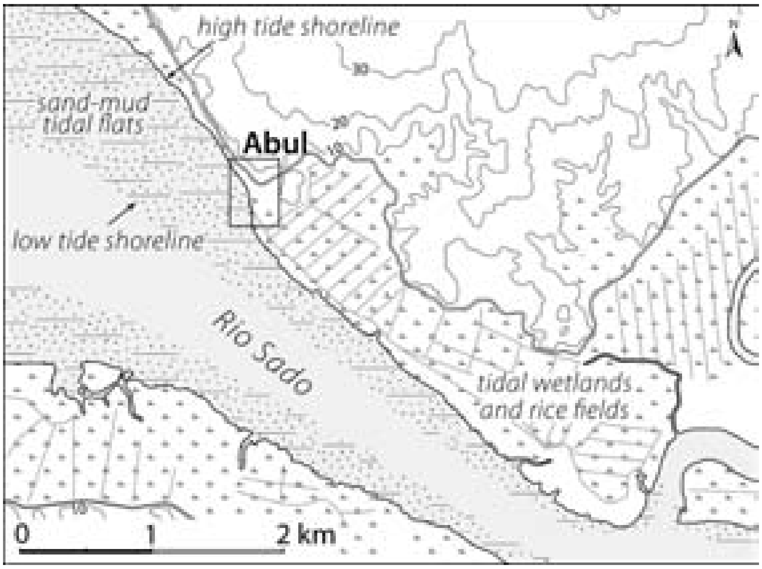


Figure 8. Map of the environs of Abul in the Rio Sado estuary. (D. Davis)

narrowest, which coincides with the location of the hypothesized man-made structure that we identified in the EM survey (Fig. 7).

At the narrowest point of the peninsula, east of the excavated site, there is a low north-south break in the bedrock which may have separated the peninsula from the main ridge. The vegetative overgrowth at the south end, however, made investigation of this area all but impossible, while the construction of the national highway has obliterated the north end of the break, if it existed there (Fig. 3). We attempted to core in the break to test if this had been open in antiquity, but our results were inconclusive. We recovered modern fill overlying coarse broken rock with silt below (Fig. 4: Core SO-10). We also placed three cores at the edge of the field on the south end of the break and found well-rounded fine-to-medium-grained sand of beach origin in all three, below an organic-rich mud of wetland origin (Cores SO-7–9). This suggests that the beach was continuous across the break. At 2 m below the surface, in the sand, we recovered weathered ceramic fragments of indefinable age and several large angular fragments of *Ostrea sp.* (oyster) and although the depth suggests that these materials could be quite old, their age is unknown. Our data are inconclusive regarding the origin and age of the break, it may represent a historic cut through the bedrock to channel water from fields north of the bedrock promontory to fields on the south side, with road construction or lack of use leading to filling and loss of this connection.

Abul

Phoenician Abul A consists of a square building located atop a topographic rise, surrounded today on the north and south by rice paddies, to the west by tidal flats and to the east by a sandstone bedrock spur (Fig. 8) (Mayet and Tavares da Silva, 1993; Mayet and Tavares da Silva, 1996; Mayet *et al.*, 1997; Arruda, 2000: 86–91; Mayet and Tavares da Silva, 2000; Aubet, 2001: 297; Neville, 2007: 39–41). The structure was active from the first half of the 7th to the early 6th centuries BC (Neville, 2007: 39). At present, Abul remains the only uniquely Phoenician site in Portugal, with no later levels covering the Phoenician remains. During the Roman period, however, an amphora factory was constructed on tidal-flat or marsh sediment and fill at the southern base of the hill: it consists of five kilns and other outbuildings (Mayet *et al.*, 1996: 51–63).

Abul's location in the region of several other indigenous sites containing Phoenician materials—Setubal and Alcácer do Sal—along with its structure and its small size, raise the possibility that Abul might have served as a sanctuary for the surrounding area and, in this respect, bears comparison with the Spanish Iron Age cult site of Cancho Roana (Arruda, 2000: 91; Mayet and Tavares da Silva, 2000: 161–3; Celestino and López-Ruiz, 2002; Celestino and López-Ruiz, 2003).

Excavations at Abul revealed that the Phoenician structure underwent two distinct phases. During both periods the building's entrances

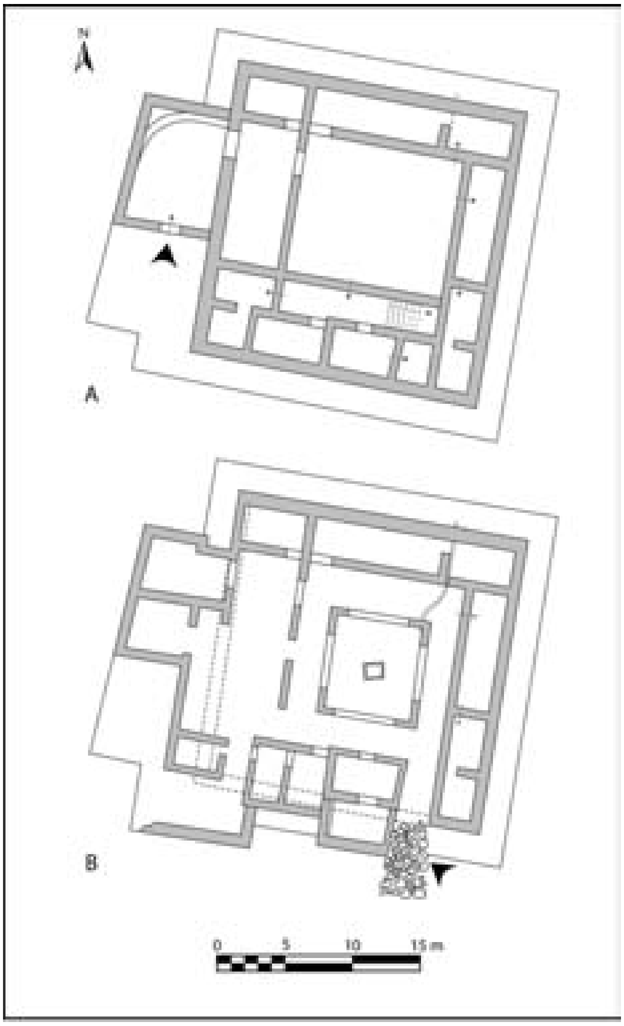


Figure 9. Plans of Abul A. A) First phase. Note the entrance through a room (arrow) on the structure's west side. B) Second phase. Note the stone floor/landing (arrow) at the structure's south-east corner. (after Mayet and Tavares da Silva, 2000: 134 fig. 59, 143 fig. 60)

faced west or south (Fig. 9). The evidence in the second phase is particularly striking: at that time, the structure opened at its south-east side onto a floor paved with large field-stones, 6.5 m long, 2.5 m wide at its northern end and 3.5 m at its southern end (Fig. 9: B (arrow); Figs 10–11: A) (Mayet and Tavares da Silva, 1993: 135 fig. 5; Mayet and Tavares da Silva, 2000: 131–53).

Abul would have been a small bedrock peninsula attached to land on its eastern side throughout antiquity, as confirmed by the site's excavators and our own coring (Guy *et al.*, 2000). Thus the site's entrances would clearly have opened onto the Sado estuary in Phoenician times (Mayet and Tavares da Silva, 2000: 170). As the second-phase floor would have faced open water, the floor makes little sense as an egress to the building unless it served as the landing for a now-missing wooden quay which followed its orientation. The hypothesized quay may have been connected to the paved floor over a layer of red clay uncovered during the excavation (Mayet and Tavares da Silva, 2000: 147, pl. 20). One of the floor's paving stones is of particular interest in this maritime context. It is a 'blind' stone anchor: that is, its apex hawser-hole was left uncompleted (Fig. 11: A (arrow), B). The anchor is 58 cm high and 40 cm wide. We were unable to determine its thickness or weight. The stone is conglomeratic sandstone not local to Abul, but perhaps obtained from the nearby region of Setubal. A second stone may be a damaged anchor, broken at the hawser hole.

Radiocarbon dating by Psuty and Moreira (2000: 136 fig. 12) of basal transgressive peat deposits of the Sado estuary indicates that the average rate of sea-level rise in the estuary basin has been about 1.58 mm/yr during the last 6500 ^{14}C years, with a faster rate before 2600 ^{14}C years BP, and slower after that time, and with local relative sea-level in the lower Sado estuary at about 1 m below present 2600 ^{14}C years BP. At the time of Phoenician occupation, the lower Sado estuary underwent a transition from largely open-water sub-tidal deposition and a narrow fringing marsh to horizontal expansion of inter-tidal deposition and widening salt-marsh.

The elevation of the high-tide terrace at Abul is 20 cm below the present rice field surface, which is at +2 m relative to local mean sea-level (MSL) and equivalent to the high marsh surface elevation used as a datum for the sea-level plot constructed by Psuty and Moreira (2000). A core taken on the high-tide terrace provided a single radiocarbon sample from shell material with a calibrated age of 6270 BP (5850 ^{14}C years BP) (Figs 12–13: Core Abul 19). Although this age is old given its depth, when compared to the sea-level plot of Psuty and Moreira, the core data suggest that open estuarine conditions existed near Abul in the mid Holocene and throughout the time of relatively rapid sea-level rise, with the shoreline at or near the site (Figs 12–13). If the sea-level was about 1 m lower than present in the Phoenician era, as Psuty and Moreira suggest, then the Phoenician level of deposition in Abul core 19 is at a depth of 1–3 m, and the sediments in the core reveal that this was a time of transition from shallow sub-tidal to inter-tidal

Figure 10. Abul, the second-phase Phoenician stone floor or landing (arrow), with the Roman-period amphora kilns visible at a lower level on either side of it. (S. Wachsmann)

deposition, much like Psuty and Moreira (2000) envisage for the entire lower estuary. Our sediment cores in the rice fields adjacent to the site also contain estuarine mud as well as tidal-flat or beach sand at the Phoenician level (Fig. 14). This reveals that in Phoenician times estuarine sediments were being deposited next to the site and the area immediately surrounding Abul was a shallow-water environment with a shoreline about 75 m landward of its present position on the north-western side and 150 m landward on the south-eastern side and less so even into the Roman period (Fig. 12).

In summary, in Phoenician times Abul lay on the margin of a wide estuary, and would have been the terminus of a peninsula surrounded by shallow water, 1–2 m deep and subject to tidal variation, and the coastline adjacent to the site would have consisted of local wetlands, tidal flats and sandy beaches. Abul's location would have afforded an excellent mooring on the south side, and possibly a less-protected one on the north side.

Electromagnetic induction surveys in the neighbouring rice fields verified the extent of subsurface estuarine and tidal-flat mud. Coring and geophysical surveys also revealed that, in the area of the hypothesized southern anchorage, the bottom topography slopes gently south towards what would have been the open bay. The core taken at the modern shoreline revealed a thick section of estuary or bay fill, and suggests that very shallow sub-tidal to inter-tidal conditions prevailed immediately offshore from Abul during Phoenician times (Fig. 13: Core 19). As noted, Psuty and Moreira (2000: 136) suggest that the Sado estuary underwent rapid horizontal expansion of tidal flats and salt-marsh beginning *c*.2600 ^{14}C years BP. Our cores also reveal that by the Roman period, when the base of the rise of Abul served as a kiln site for amphoras manufactured to transport salt fish and *garum*, much of Abul's former open-water area had become extremely shallow tidal flats and tidal wetlands. In the area of the buildings associated with the kilns, our cores encountered artificial fill over tidal-flat deposits (Fig. 14). Interestingly, the Romans used artificial fill derived from the local sandstone in order to build out across the muddy

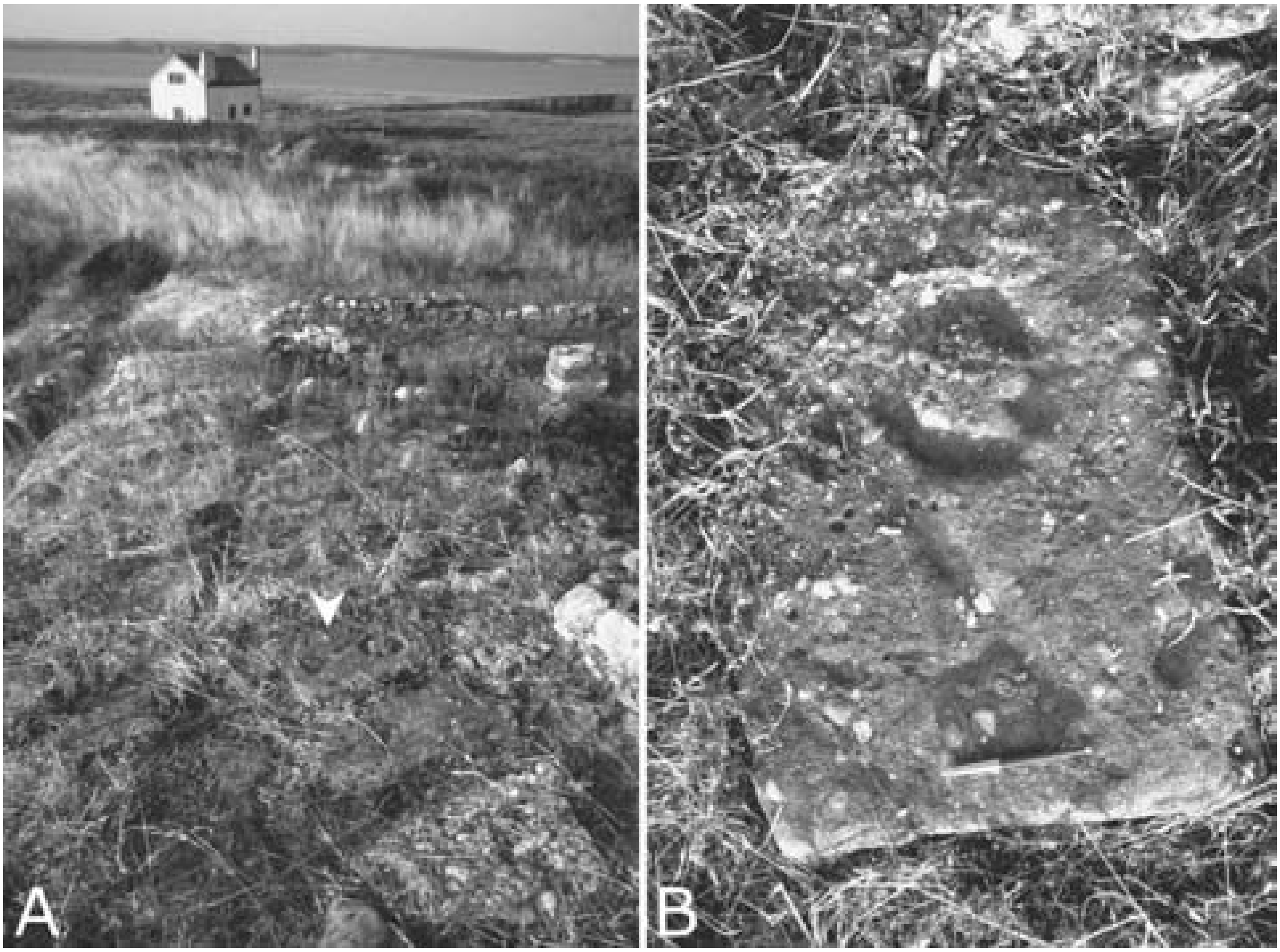


Figure 11. (A) Abul, view looking south following the line of the second-phase stone floor or landing. Note the blind anchor (arrow) embedded in it and the modern wooden quay in the distance. (B) The blind anchor. (S. Wachsmann)

areas and to connect the shoreline with the amphora workshop. Apparently the location of Abul remained important, despite the fact that tidal flats largely encompassed the site. Presumably clay from the tidal flats was a primary source for the making of amphoras (Mayet *et al.*, 1996: 121–65).

Our EM mapping at Abul enabled us to extend the outline of the edge of the estuary beyond the core data. Lower conductivity measurements indicating areas of sand represent the shoreline or beaches on the edge of the ancient embayment (Fig. 15), whereas areas representing deeper water contained mostly clay-rich mud and, therefore, had higher conductivity. A modern rice-field berm appears as a linear feature of low conductivity in the figure because it is composed of coarser-grained fill that was not water saturated. In our reconstruction of the palaeo-coastline of Abul, it is evident that ample locations could have existed for mooring or beaching ships with minimal or no modifications (Fig. 12). Wooden piers built in continuation of the structure's entrances would have provided inexpensive, yet efficient, installations to combat the tidal variations of the Rio Sado by affording docking opportunities regardless of water-level.

Castro Marim

The Iron Age site of Castro Marim, ancient Baesuris, from which Phoenician material has been recovered, is located within the medieval castle, surrounded today by the modern settlement (Arruda, 1996; Arruda, 1997; Arruda, 2000: 36–53, Arruda *et al.*, 2007). Despite Castro Marim having the most urban-developed landscape in which the team worked, open areas remained available for examination. Castro Marim was

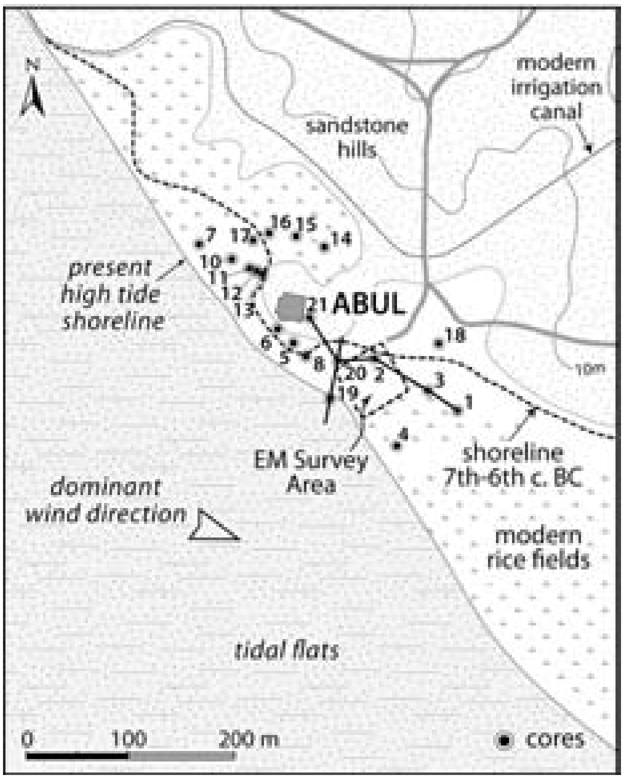


Figure 12. Locations of cores and EM survey taken at Abul showing the resultant paleogeography of the site in the 7th–6th centuries BC. Geological cross-sections, shown as lines through cores, which are perpendicular and parallel to the shore, are presented in Figs 13 and 14 respectively. (data: R. Dunn; artwork: D. Davis)

apparently an indigenous Tartessian settlement, but it was clearly in contact with Phoenician traders beginning in the latter half of the 7th century BC (Arruda, 2000: 52). The site sits atop a small north-projecting promontory at the eastern end of a bedrock ridge that is surrounded to the north, east and south by saltpans, tidal flats, tidal wetlands and low-lying areas of artificial fill. It is in the valley of the Rio Guadiana, a long and wide tidal river which marks the border between southern Portugal and Spain. Phoenician interest in Castro Marim presumably resulted from the mineral resources located farther north along the Rio Guadiana (Map, 1960; Edmondson, 1987: 32 fig. 3.3: 20–29, 212–14; Custódio, 1996a; Custódio, 1996b; Rego, 1996).

The archaeological site of Castro Marim is located over 5 km upstream from the present mouth of the Rio Guadiana and today is separated from the river by about 2 km of tidal flats and tidal wetlands interspersed with saltpans (Fig. 16). The topography and the geological record of Guadiana estuary evolution indicate that the estuary was probably of maximum width following rapid marine transgression and subsequent deceleration of sea-level rise at 6500–5000 BP (Morales, 1997; Boski *et al.*, 2002; Lobo *et al.*, 2003: 982–3 and table 1; Boski *et al.*, 2008). Although sedimentary filling must have been occurring in parts of the lower estuary, we suspected that in Phoenician times the bedrock ridge formed a peninsula that extended into a large marine embayment and that suitable anchorages might have been located in the areas to the north-west and the south-east of the bedrock ridge. Cores in the unpaved area near Castro Marim's municipal parking lot, west of the Iron Age site, revealed at least 10 m of sedimentary fill (Figs 17–18).

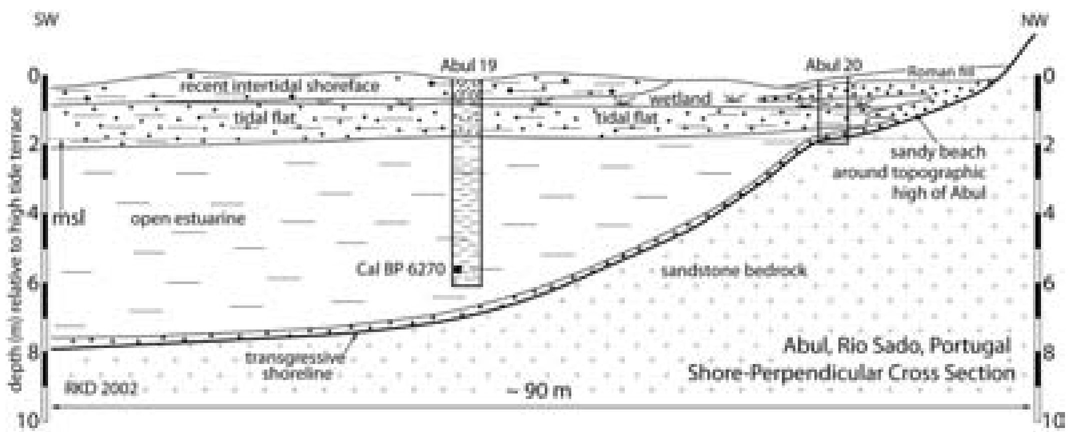


Figure 13. Geological cross-section based on cores Abul 19–20. 'MSL' here represents *approximate* mean sea-level. For legend see Fig. 5. (data: R. Dunn; artwork: D. Davis)

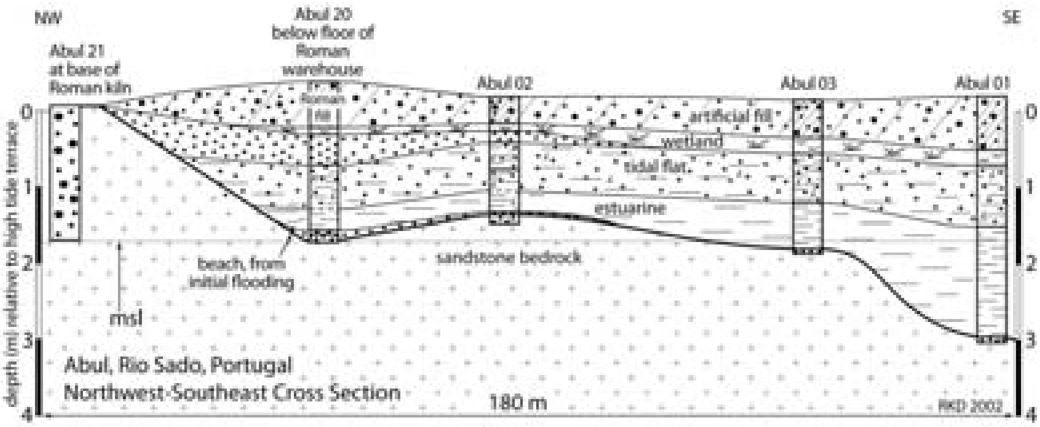


Figure 14. Geological cross-section based on cores Abul 01–03, 20–21. 'MSL' here represents *approximate* mean sea-level. For legend see Fig. 5. (data: R. Dunn; artwork: D. Davis)

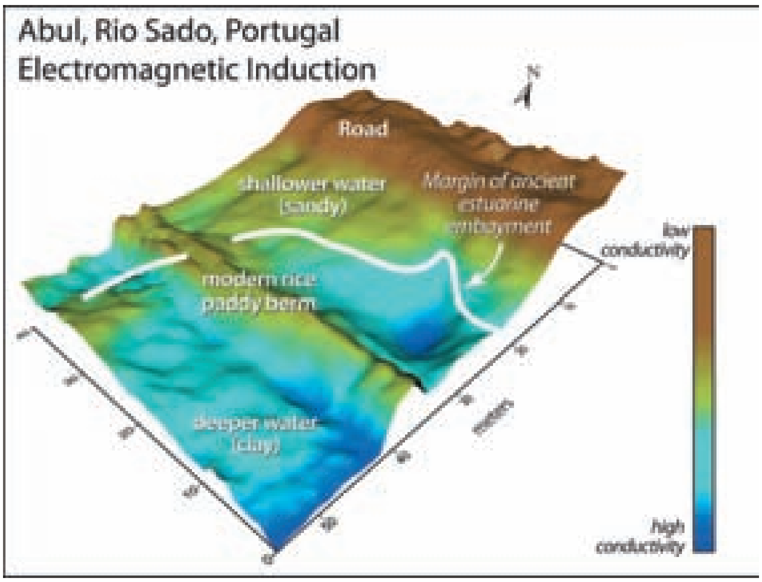


Figure 15. EM visual map of sediment conductivity in a rice field south of Abul. The estuary margin is defined by the transition from high-conductivity mud to low-conductivity sand, presumably marking the palaeo-shoreline. Location of the survey grid is shown on Fig. 12. (data: L. Conyers and E. Ernenwein; artwork: D. Davis)

The material from the cores consisted primarily of several metres of loose mud containing restricted marine fauna, indicative of quiet open water, overlain by stiff mud with decayed organics. Other cores from the lower Guadiana have been interpreted as representing several thousand years of inter-tidal and salt-marsh deposition (Morales, 1997; Boski *et al.*, 2002; Boski *et al.*, 2008), but these cores come from areas near the Guadiana River or near the large sand-spit complex south of Castro Marim, where sediment-supply and sedimentation-rates are relatively high. Our cores from Castro Marim consist primarily of thick homogeneous mud sections that are nearly devoid of plant remains. We interpret this as representing deposition under estuarine conditions near the mouth of a tidal river on the north side of the Castro Marim ridge.

A calibrated ^{14}C age of *c.*7800 BP, derived from shell material recovered from the base of core CM 02, corresponds well with the projected age using Boski *et al.* (2008: 241 fig. 6) age vs. depth graph, and our radiocarbon and lithologic data demonstrate that shallow-water estuarine conditions

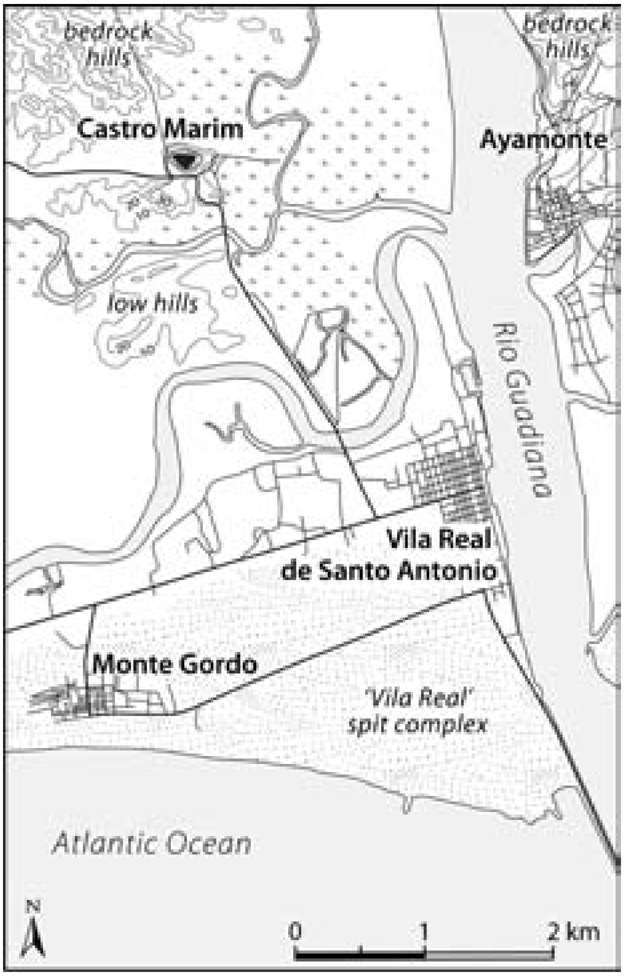


Figure 16. Map of the modern environs of Castro Marim and the Rio Guadiana estuary. (D. Davis)

predominated in the area west of Castro Marim for several millennia (Figs 17–18). To determine the depth in the core that represents deposition during the Phoenician period we used the sedimentation rate from Boski and colleagues to place the Phoenician level at an approximate depth of 5 m in core CM 02. This indicates that the Phoenician period is represented in the core by estuarine mud and, therefore, in Phoenician times this area almost certainly consisted of a muddy-bottom shallow estuarine setting, possibly at the mouth of a tidal river with local tidal flats and, based upon modern analogues, a sandy shoreline. This suggests the availability of naturally-protected moorings when the Phoenicians first began using the site.

Reconstructions of the palaeo-geographies of other estuaries along the coast of the Gulf of Cadiz indicate that several large embayments would have presented themselves to Phoenician ships sailing west from the Straights of Gibraltar (Dabrio *et al.*, 1999: 273 fig. 6, 277 fig. 10; Dabrio *et al.*, 2000: 394–5 figs 6–7). Our local palaeo-geographic reconstruction can be placed into the context of the evolution of the lower Guadiana as a whole (Morales, 1997; Boski *et al.*, 2002; Boski *et al.*, 2008) to show that it is likely that as Phoenician vessels approached the Rio Guadiana, they would have sailed into a large, wide bay with a prominent peninsula that projected into the bay from the west (Figs 17 and 19).

The Iron Age site is located on the small north-projecting promontory at the terminus of the Castro Marim ridge, and in the lee of this promontory our coring revealed that in the Phoenician period there existed water deep enough to accommodate their ships. This, along with a naturally-protected roadstead, would have made Castro Marim an excellent anchorage for Phoenician seafaring merchants. We collected GPR data along a line that extends from bedrock exposed in the town, west of the Iron Age site, to the north and through the area of coring. The geological cores coupled with the GPR results revealed a now-buried shallow bedrock platform with an abrupt deepening to the north (Figs 17–18). This bedrock platform is probably a Pleistocene or early mid-Holocene wave-cut terrace. We suggest it would have served as an excellent waterfront for ships.

Stiff, organic-rich mud in the upper parts of Castro Marim cores reveal that at some point after Phoenician times, tidal flats and local salt-marshes developed which produced shoaling in this area. A core from a similarly-restricted estuary-margin environment reveals that salt-marshes began to develop in some parts of the lower estuary as early as *c.*3500 BP (Boski *et al.*, 2008: 235 fig. 2). However, the presence of a small tidal river near Castro Marim may have inhibited salt-marsh development until much later. Our core lithology appears to compare favourably with cores from the western estuary margin in which organic-rich mud of tidal-flat and wetland origin represents only a thin cap on thick estuarine mud (Morales, 1997: 145 fig. 14). As our cores did not contain material in the upper part of the sediment section for radiocarbon analysis, and as Morales does not have chronological control in his cores, we are unable to date this event. However, the thin nature of these tidal-flat and salt-marsh deposits in our cores suggests quite recent filling of the former open area.

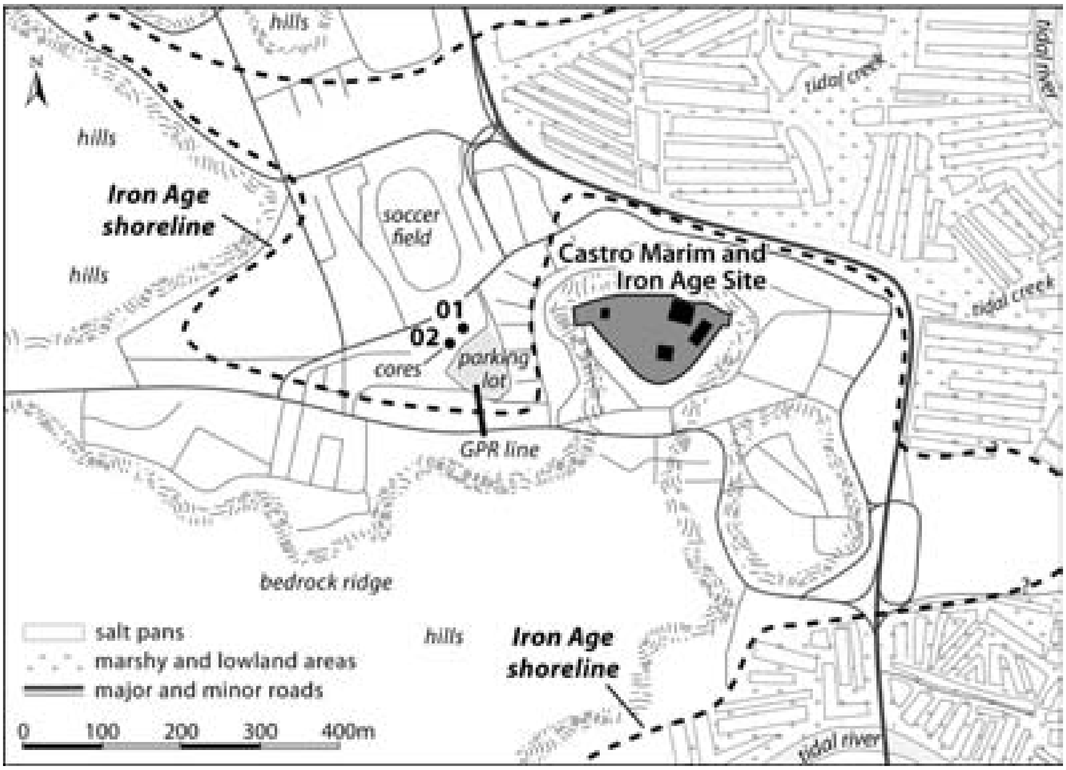


Figure 17. Modern map of the region of Castro Marim showing the locations of the cores and GPR line west of the castle, and the reconstructed Iron Age shoreline. (data: R. Dunn; artwork: D. Davis)

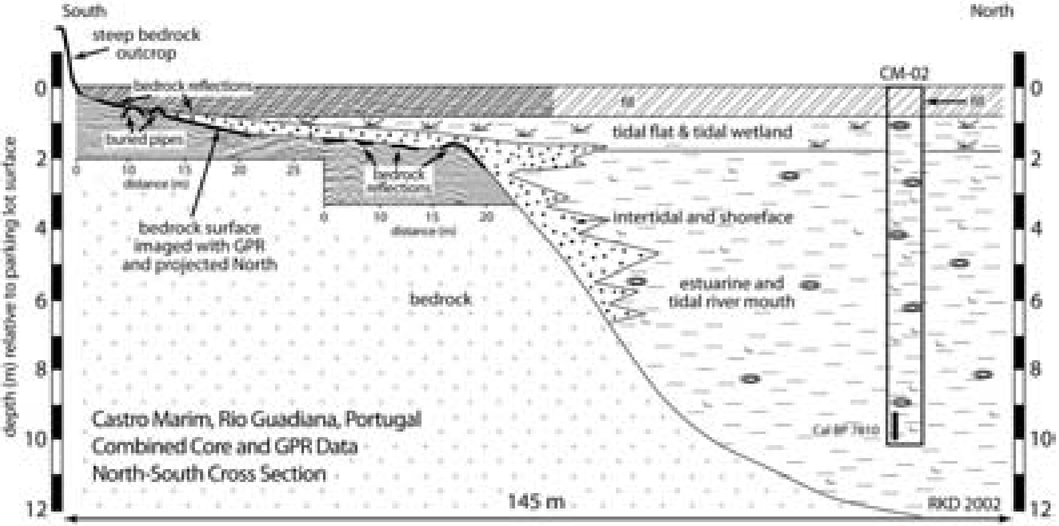


Figure 18. Castro Marim. North-south geological cross-section combining core CM 02 and GPR lines 02 & 002. For legend see Fig. 5. (data: R. Dunn and L. Conyers; section: R. Dunn; artwork: D. Davis)

This conclusion finds support in drawings and maps of Castro Marim and its surroundings dating from the early-16th to the 19th centuries. Two remarkably-detailed drawings by Duarte de Armas dating to *c.*1508–10 show Castro Marim situated on the open coast with tidal rivers on either side of the peninsula (de Armas, 1997: 15; Arruda, 2000: 36). In his view drawn from the north de Armas includes two ships sailing in the open sea, which nearly abuts the citadel (Fig. 20).

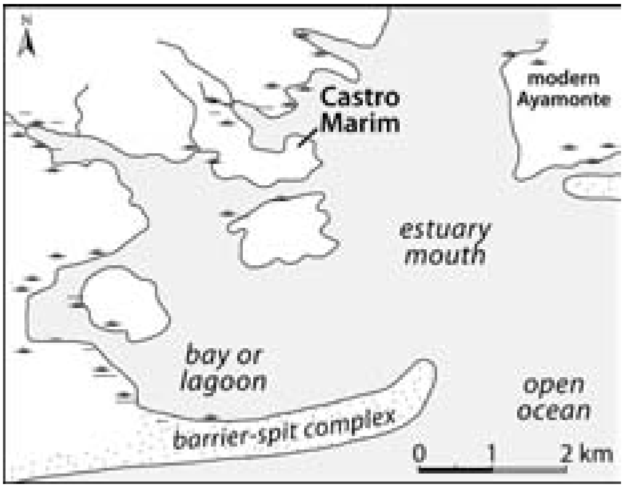


Figure 19. Tentative reconstruction of the region of Castro Marim and the Rio Guadiana estuary during the time of Phoenician contact (modified from Morales, 1997). (data: R. Dunn; artwork: D. Davis)

A caption above the Guadiana estuary duly identifies it at the far left (Table 1: 2). The barrier-spit complex is visible beneath the ships, separated from land by a coastal lagoon or tidal river. On it are five rough mounds which may represent either sand-dunes or heaps of brine salt. Today, this remains an area of saltpans and salt production. A watercourse and possible mill appear at the lower left, with water flowing to the bottom of the drawing. In a second image de Armas shows Castro Marim from the south (Fig. 21) (Table 2). The rivers on either side of Castro Marim are documented in these views, as well as in the Texeira maps, discussed below.

Maps from as late as the early-17th century clearly show Castro Marim located on a coastal headland next to a wide Guadiana estuary to the east and with a bay or lagoon behind what is probably a sandy barrier-spit complex to the south (Fig. 22). The most detailed of these maps—actually a bird's-eye view—from 1634, shows the wide mouth of the Guadiana and a sandy barrier backed by a coastal lagoon on the south side of Castro Marim (Fig. 23). What appears to be a wave-cut coastal cliff along the southern foot of the Castro Marim ridge suggests that open water existed to the foot of the Castro Marim slope. Ships therefore had direct access from the sea to both Castro Marim and Ayamonte even in the 17th century. The Texeira

Figure 20. Duarte de Armas's drawing of Castro Marim as seen from the north (1508–10). See Table 1 for translations of the scene's captions. (from de Armas, 1997, with permission)

Table 1. *Captions in de Armas's drawing of Castro Marim as seen from the north (Fig. 20)*

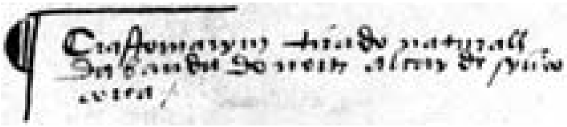
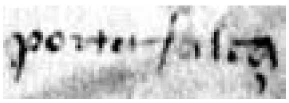
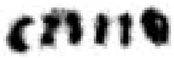
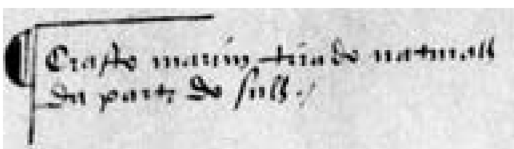
No.	Caption	Portuguese	English
1		Crastomarym tirado naturall da banda do norte alcayde Simão corea	Castro Marim natural view from the north side, *alcaide* (military leader) *Simão Correia* personal name
2		Entrada da foz de Odiana	Odiana (Guadiana) River mouth
3		Arenylha	[toponym]
4		Castello	Castle
5		Porta falça	False door
6		Villa	Village
7		Ermo	isolated

Table 2. *Captions in de Armas's drawing of Castro Marim as seen from the south (Fig. 21)*

No.	Image	Portuguese	English
1		Castromarim tirado naturall da parte do sull	Castro Marim natural view from the south side
2		Esteyro	River branch

maps show a small rocky island directly south of Castro Marim, between the mainland coast and the sandy barrier. Today this 'island' is a low hill surrounded by tidal wetlands and saltpans (Fig. 16).

Based on our geological work and an analysis of maps and illustrations it appears that from the Phoenician era to the middle of the 19th century the area around Castro Marim remained relatively open and easily accessible via open sailing from the sea. A series of maps from 1579 to the late 1880s shows the steady seaward growth of the Vila Real sandy-spit complex, the narrowing of the estuary, and the concomitant isolation of Castro Marim from the sea and estuary (Alvero Seco, 2000: 136–7 [1579]; Texeira *et al.*, 2002 [1634]; Faden, 1797; Cary, 1801; Hall, 1829; *SDUK*, 1831; da Veiga, 1883). Recent addition of artificial fill permitted Castro Marim to expand

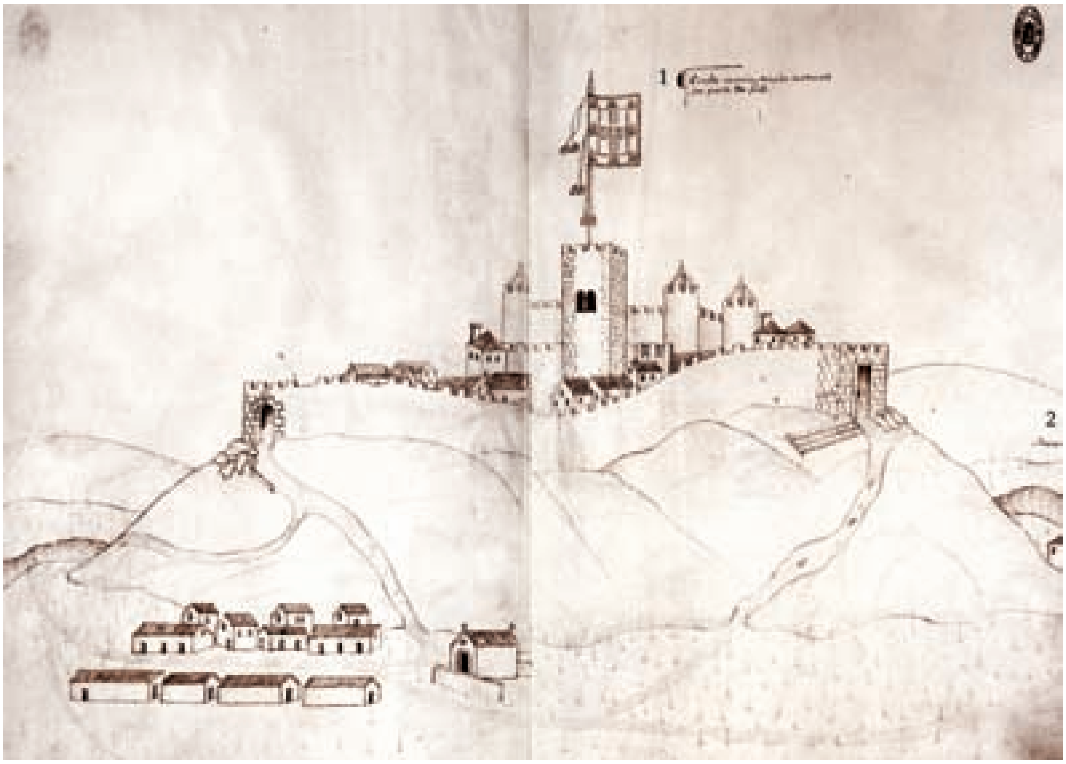


Figure 21. Duarte de Armas's drawing of Castro Marim as seen from the south (1508–10). See Table 2 for translations of the scene's captions. (from de Armas, 1997, with permission)

and create a modern parking area and soccer field. Townspeople we interviewed recalled tidal flats and a sandy beach in the area of the parking lot within the last few decades.

Although we did not core to the south or south-east of Castro Marim, GPR investigation in this area revealed that it is unlikely that the flank of the bedrock ridge could have provided an advantageous anchorage. The maps indicate that the marine shoreline ran at, or near, the south and south-eastern sides of the Castro Marim bedrock ridge in the 16th to 17th centuries, with some protection afforded by the sandy barrier-spit which eventually became the large Vila Real spit-complex. It seems likely, therefore, that in Phoenician times this side of Castro Marim was directly connected to the sea, possibly with some shelter provided by sandy barrier islands or shoals.

Conclusions

As the Phoenicians expanded into the western Mediterranean, they sailed with a rich tradition of working with nature to provide secure anchorages for their ships in the simplest and most expedient manner. When they voyaged beyond the Pillars of Heracles and coasted along the section of the Iberian Peninsula that is now Portugal, they found superb geographical features in the form of broad estuaries ideal for their maritime-based commercial purposes. They had little need to employ, or improve on, their accumulated harbour technology in a region so fortuitously endowed with waterways which penetrated the Iberian heartland.

Nature offered model settings to Phoenician seafarers at Santa Olaia, Abul and Castro Marim. At the time of the Phoenician activity, all three locations afforded elevated peninsulas jutting into, or at the mouth of, extensive estuaries. Each of the sites would have offered good moorings and shelter. Our survey at Santa Olaia identified a low-conductivity anomaly as probably comprising stone. It trends perpendicular to the bedrock and had been exposed at, or near, the ancient shoreline before it had been buried by the silt and mud that choked the estuary. This stone spur on the site's south-eastern side could have been either artificial, or natural but enhanced in some

Figure 22. A) The south-eastern coast of Portugal (Algarve) as depicted on a regional map in Texeira's *Atlas del Rey Planeta*, (1634). B) Detail of the Castro Marim region (see rectangle in A, above). (from Texeira *et al.*, 2002, with permission)

way to serve as a second anchorage, but we found no conclusive evidence for such a man-made augmentation. If such a structure existed, the presence of a stone or rubble quay would mark an exception to the types of maritime installations that seem to be the model elsewhere in Portugal, unless it was a base of a wooden quay, as we postulate for the stone platform at Abul.

Figure 23. Bird's-eye view of Castro Marim and the Rio Guadiana estuary, facing north. *Atlas del Rey Planeta* (1634). (from Texeira *et al.*, 2002, with permission)

Sandy beaches, or bedrock platforms, probably with a sand veneer, may have been sufficient to use as docking facilities in some cases. In others, timber quays built far enough from the shoreline to accommodate the full range of tides would have provided access for trading activities regardless of the water-level of the estuary. Such quays were easy to build, repair or expand, and were conveniently expendable if new sources of minerals or changing local conditions required shifting the location of entrepôts. Decelerating sea-level rise and subsequent filling of the marine embayments by estuarine and deltaic sediments has taken place since *c.*6500–5000 BP. With human land-use also contributing to landscape evolution, changes in Phoenician times would have been swift. We are unable to confirm whether this rapid geomorphic transformation led to abandonment of the sites that we studied.

The combination of geological coring and geophysical survey, coupled with ^{14}C dating, has proven to be a useful method for attempting to reconstruct the amount, nature and general timing

Figure 24. Modern derelicts pepper the banks of Portuguese rivers. A number of abandoned vessels cluster on the shore near Troia (Rio Sado). (S. Wachsmann)

of geomorphological changes at the sites studied. Each of the three sites can now be viewed in the context of its coast-to-offshore palaeo-environment. Our cores identified the sediments and supplied a palaeo-environmental interpretation, while the geophysics enabled us to expand that knowledge across space. We developed data-collection techniques which allowed us to float the geophysical instruments across flooded rice-fields with minimum disturbances to the growing crops, while collecting a dense grid of measurements. Ideally, any future expeditions could collect EM data in rice-growing areas like Santa Olaia and Abul more quickly and efficiently during the spring, when the rice-fields are normally drained and therefore dry. The EM tools could then be walked across the fields quickly, and much larger areas could be mapped. In Portugal we found this combined geological-geophysical survey method rapidly provided valuable subsurface data. This enabled us to create maps of the buried marine, coastal, and alluvial environments while still in the field, and suggests that this might be an inexpensive and non-invasive method of choice in other areas of the world with similar attributes.

Finally, what of the ocean-going ships used by the Phoenicians during their voyages to Portugal? Throughout modern Portugal, derelict vessels may be seen protruding from riverbanks, often near quays (Figs 24–5). Of interest in this regard, towards the end of our work at Santa Olaia, the regional archaeologist, Flávio Imperial, brought to our attention Roman-period amphoras and other artefacts, discovered in the early 1990s under 3–4 m of sediment during the preparations for the IP3 Figueira da Foz to Coimbra highway. These artefacts presumably derive from a buried shipwreck of Roman date. No record had been kept of the exact find-spot of the artefacts, precluding us from relocating the site. We raise the consideration that other worn-out and abandoned hulls might be entombed in the estuarine and deltaic sediments of Portuguese river-valleys, perhaps including some of the vessels employed by the Phoenicians on their Atlantic voyages, which would rank among the most important watercraft in the history of seafaring.[6]

Perhaps the settings most likely to contain preserved wooden-planked hulls are those identified as probable moorings on opposite sides of narrow bedrock promontories. This holds particularly true for small embayments, such as the north and south sides of Santa Olaia, and the north-west side of Castro Marim just below the parking lot. The north and south sides of Abul fulfil this requirement, but the sediments below the rice-paddy level have undergone significant geochemical change as a product of past saltpan production, and later rice cultivation. This would argue against the preservation of wooden hulls if

Figure 25. Vessels often sink, or are abandoned adjacent to wooden quays as, for example, those seen here, at A) Almoral (Rio Tagus) and, (B) these two hulls (arrows) at Villa Real de Santo Antonio (Rio Guadiana). (S. Wachsmann)

such had been deposited there in antiquity. The area to the southwest of Abul, however, between the site and the modern low-tide shoreline, contains a thicker sedimentary section that has not undergone significant geochemical alterations: this area has the highest potential for preserving organic remains and contains the area immediately offshore from the large paved floor or landing which appears to have served as a waterfront access at Abul. In general, we believe that the preservation potential for the survival of wooden hulls in the environments of these locations is moderate to high, as the muds tend to retard geochemical alteration and we regularly encountered wood fragments in our cores. We suggest that in addition to the possibility of ancient hulls buried in the sediment in the anchorage west of the Iron Age site of Castro Marim, hulls might very well exist within the sand of the Vila Real barrier-spit complex and in the organic-rich sandy mud of the back-barrier lagoon or estuary that existed south of Castro

Marim (Figs 16–17). This area remains unexplored and may hold surprises for future investigators. The ancient waterfronts of some modern cities, such as Lisbon and Almaraz, should also be considered in this regard, when urban renewal permits examination (Blot, 2003).

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Notes

1. The bibliography on Phoenician/Punic settlement in Spain is voluminous. See, for example, Carpenter 1958: 49–51; Moscati 1968: 230–42; Aubet Semmler, 1988; Blázquez, 1992; Aubet, 1995: 51–9; Torres, 1995: 36–57, 73–95; Blázquez *et al.*, 1999; González Prats, 1999; Markoe, 2000: 182–6; Aubet, 2001: 257–91; Cunliffe, 2001: 265–75; Bierling and Gitin, 2002; González-Ruibal, 2004; Martín Ruiz, 2004; González-Ruibal, 2006; Neville, 2007.
2. Lixus on the Loukkos River today lies ~4 km from the sea (López Pardo, 1996: 254–6, 259 fig. 3, 275, 283; Lopez Pardo, 2000; Markoe, 2000: 187–8; Aubet, 2001: 156, 161–3, 174,191–2, 297, 300–01, 304, 330; López Pardo and Suárez Padilla, 2002: 120; López Pardo and Cabrero, 2005; Neville, 2007: 44–5, 84, 86, 99, 104, 108, 116, 130). Mogador, possibly ancient Cerne, is at present the southernmost Phoenician enclave on the Moroccan coast confirmed by archaeology (López Pardo, 1991: 62–63; López Pardo, 1996: 260, 262, 263 fig. 5, 276; Markoe, 2000: 188; Aubet, 2001: 191, 301–04, 313–14, 343–4; López Pardo and Suárez Padilla, 2002: 116, 120 n.8; Neville, 2007: 46, 86 n.31, 99 n.127, 166, 108 n.18). This site is located on a small island in a bay opposite a minor river.
3. Various definitions exist for the terms *Phoenician, Punic, Phoenicio-Punic* or *Orientalizing:* regarding the lack of standardization in these terms, see Aubet, 2001: 1, 12–13; Prag, 2006. On literary and other claims regarding Phoenician seafaring, see Aristotle, *Minor Works, On Marvellous Things Heard* 84; Diodorus Siculus 5: 19–20; Strabo 3:5:11; Avienus (Murphy, 1977) 8–9 lines 114–19, 53; Carpenter, 1958: 51–2; Carpenter, 1966: 199–214; Gordon, 1971; Moscati, 1988; Bikai and Bikai, 1990; Casson, 1990; Wachsmann, 1990: 77–8, 80; Casson, 1991: 65–6, 74–5; Cunliffe, 2001: 261–310; Roller, 2006: 22–50.
4. Analysis of coastal evolution is a powerful tool employed at a number of Mediterranean and African Atlantic sites, which include Alexandria (Stanley and Bernasconi, 2006; Stanley *et al.*, 2007); Ephesus (Kraft *et al.*, 2000, Kraft *et al.*, 2007); Troy (Kraft *et al.*, 1980; Kraft *et al.*, 2003); Thermopylae and the Gulf of Malia (Kraft *et al.*, 1987); Lechaion, the harbour of Corinth (Stiros *et al.*, 1996); and Nikopolis on the Ambracian Gulf (Jing and Rapp, 2003). Similar work at Phoenician sites includes reconstructions at Tyre and Sidon (Carmona Gonzalez, 2003; Marriner *et al.*, 2005; Marriner *et al.*, 2006a; Marriner *et al.*, 2006b; Marriner and Morhange, 2007: 152; Carmona and Ruiz, 2008); Kition Bamboula (Morhange *et al.*, 2000); Lixus (Carmona Gonzalez, 2003: 23–8); the Odiel and Tinto estuaries (Dabrio *et al.*, 1999; Dabrio *et al.*, 2000); Cerro del Villar on the Guadalhorce estuary (summarized in Carmona Gonzalez, 2003: 19–23; Neville, 2007); Cadiz and other sites in Spanish Andalusia (as discussed in Aubet, 2001: 262–73; Martin Ruiz, 2004: 21–4; Neville, 2007: 88–90, 107–08); and sites in Portugal (synthesized in Neville, 2007: 35–42).
5. The dates and scales of the aerial photographs were as follows: Santa Olaia: A) 1958: 1:26,000; B) 1965: 1:15,000; C) 1980: 1:30,000; D) 1983: 1:15,000. Abul: A) 1958: 1:26,000; B) 1949: 1:7500. Castro Marim: A) 1958: 1:26,000; B) 1972: 1:8000; C) 1978: 1:30,000.
6. Mediterranean Phoenician wrecks have been found off the Spanish coast at Mazarrón (La Playa de la Isla) and at Bajo de la Campana, and in deep water off the Egyptian coast—Mazarrón (Roldán Bernal *et al.*, 1994; Negueruela *et al.*, 1995; Aizpurua and Méndez, 1996; Negueruela *et al.*, 2000; Neville, 2007: 32, 121 n.132); Bajo de la Campana (Mas, 1985; Roldán Bernal *et al.*, 1991; Roldán Bernal *et al.*, 1995; Aubet, 2001, 341; Neville, 2007: 31–2, 46; Polzer, 2007); Egyptian Coast (Ballard *et al.*, 2002; Stager, 2003). At present the earliest nautical artefacts found in Portuguese waters date to the Roman period (Alves *et al.*, 1989). The following wrecks have been found in Portugal: two log boats found in the Rio Lima, 3rd century BC (Belo, 2003); Corpo Santo, late-14th/early-15th centuries (Alves *et al.*, 2001); Aveiro A, mid-15th century (Alves and Reith, 2001); Arade 1, late-15th century (Alves, 1999; Castro, 2006); Cais do Sodré, 16th century (Alves *et al.*, 2001); *Nossa Senhora dos Mártires*, 1606 (Alves *et al.*, 1998; Castro, 2003); Ponta do Altar B, early-17th century (Alves, 1992); *Océan*, 1759 (Alves, 1984; Alves, 1989); *San Pedro de Alcantara*, 1786 (Blot and Pinheiro Blot, 1991; Blot, 1998); shipwrecks in the Azores include Angra B, 16th century (Crisman and Jordan, 1999a); Angra C and D, 17th century (Garcia *et al.*, 1999; Monteiro, 1999); Angra A, 18th century (Crisman and Jordan, 1999b).

Appendix: Radiocarbon test results

Table 3. *Results are presented for the radiocarbon analysis of 19 samples from the sites in the study. Beta Analytic Inc analyzed the samples and all radiocarbon ages have been calibrated using Intcal98 from Stuiver et al. (1998). The 2 Sigma Standard Deviation has a 95% confidence level*

Sample Data and Calibrated Age	Depth (m) below surface	14C age (BP)	13c/12c Ratio (o/oo)	Conventional 14C age (BP)
Rd-Abul19 (Beta–174226): Shell, 2 Sigma Calibration: Cal BC 4370–4240 (Cal BP 6320–6190)	5.4–5.6	5450 +/– 40	–0.5	5850 +/– 40
Rd-Asl04a∞ (Beta–174227+): Shell, 2 Sigma Calibration: Cal BC 2470–2270 (Cal BP 4420–4220) and Cal BC 2260–2220 (Cal BP 4210–4170)	2.95–3.05	3650 +/– 40	–10.4	3890 +/– 40
Rd-Asl04b∞ (Beta–174228+): Organic Sediment 2 Sigma Calibration: Cal BC 1060–880 (Cal BP 3000–2840)	3.15	2820 +/– 40	–25.0	2820 +/– 40
Rd-Asl04c∞ (Beta–174229+): Shell, 2 Sigma Calibration: Cal BC 1400–1140 (Cal BP 3350–3090)	2.50	2790 +/– 40	–10.4	3030 +/– 40
Rd-Cm02* (Beta–174230): Shell, 2 Sigma Calibration: Cal BC 5960–5780 (Cal BP 7910–7730)	9.5–10.0	6980 +/– 40	–1.8	7360 +/– 40
Rd-So02b† (Beta–174231+): Wood, 2 Sigma Calibration: Cal BC 400–350 (Cal BP 2350–2300) and Cal BC 300–220 (Cal BP 2250–2170)	1.75–2.0	2280 +/– 40	–24.5	2290 +/– 40
Rd-So02dy (Beta–174232+): Wood, 2 Sigma Calibration: Cal BC 880–780 (Cal BP 2840–2730)	2.45	2700 +/– 50	–28.8	2640 +/– 50
Rd-So02e (Beta–174233+): Wood, 2 Sigma Calibration: Cal BC 840–790 (Cal BP 2790–2740)	2.7–2.9	2670 +/– 40	–26.9	2640 +/– 40
Rd-So02f (Beta–174234+): Shell, 2 Sigma Calibration: Cal BC 1940–1650 (Cal BP 3900–3600)	3.5	3160 +/– 60	–5.5	3480 +/– 60
Rd-So02h (Beta–174235+): Shell, 2 Sigma Calibration: Cal BC 2880–2470 (Cal BP 4830–4420)	4.5–5.0	3760 +/– 70	–4.7	4090 +/– 70
Rd-So02ix (Beta–174236): Shell, 2 Sigma Calibration: Cal BC 2760–2540 (Cal BP 4710–4490)	6.10–6.25	4060 +/– 40	–2.4	4430 +/– 40
Rd-So02iy (Beta–174237): Shell, 2 Sigma Calibration: Cal BC 2460–2260 (Cal BP 4410–4210)	6.25–6.40	3800 +/– 40	+0.4	4220 +/– 40
Rd-So04a (Beta–174238): Shell, 2 Sigma Calibration: Cal BC 1220–990 (Cal BP 3170–2940)	3.7	2870 +/– 40	–2.6	3240 +/– 40
Rd-So04b (Beta–174239+): Shell, 2 Sigma Calibration: Cal BC 1650–1450 (Cal BP 3600–3400)	3.9–4.0	2920 +/– 40	–3.3	3280 +/– 40
Rd-So04c (Beta–174240): Shell, 2 Sigma Calibration: Cal BC 1400–1090 (Cal BP 3350–3040)	4.75–4.85	2970 +/– 60	–1.7	3350 +/– 60
Rd-So04d (Beta–174241): Shell, 2 Sigma Calibration: Cal BC 2340–2130 (Cal BP 4300–4080)	6.2–6.3	3730 +/– 40	–0.9	4130 +/– 40
Rd-So06a (Beta–174242): Shell, 2 Sigma Calibration: Cal BC 1490–1320 (Cal BP 3440–3270)	4.3	3090 +/– 40	–1.0	3480 +/– 40
Rd-So06b (Beta–174243): Shell, 2 Sigma Calibration: Cal BC 2900–2660 (Cal BP 4840–4610)	8.0	4140 +/– 50	0.0	4550 +/– 50
Rd-Er03 (Beta–174244+): Wood, 2 Sigma Calibration: Cal BC 2850–2820 (Cal BP 4800–4770) and Cal BC 2680–2280 (Cal BP 4630–4230)	3.9	4030 +/– 80	–28.3	3980 +/– 80

∞ These three results come from a backhoe trench at the Rio Sado site of Alcácer do Sal but no detailed investigation was carried out. Further information is available upon request.
* Cm = Castro Marim
† So = Santa Olaia
\+ = Local reservoir correction applied

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