

Paleo-geography of the Gulf of Cadiz in SW Iberia during the second millennium BCE¹

—by Antonio Rodríguez-Ramírez² and Juan J. R. Villarías-Robles³

ABSTRACT

A remarkable feature of the geomorphological processes at work on the coasts of the Gulf of Cadiz in SW Iberia is the estuarine mouths of a number of large-flowing rivers: Guadiana, Piedras, Tinto-Odiel, Guadalete and Guadalquivir. These mouths exhibit sandy barriers and marshlands. Over the most recent millennia these five estuaries have been conditioned by fluvial-marine dynamics, climate change, neo-tectonics and anthropogenic activity. The systems of sandy littoral barriers and marshlands built up during phases of progradation and aggradation, which were interrupted at intervals in the course of the Holocene by erosional phases of “Extreme wave events” or EWEs (storm surges or tsunamis) and subsidence. A multidisciplinary study from a number of cores drilled in the Guadalquivir paleo-estuary has made it possible to identify evidence of as many as three EWEs in the area in the 2nd millennium BCE: A (~2000 cal yr BCE), B (~1550 cal yr BCE) and C (~1150 cal yr BCE). Evidence of these three events has been recognized elsewhere along the Iberian coasts of the Gulf. The three events caused significant geographical changes, which may have affected human settlements established in the area during the Neolithic and Copper Age periods, as well as during the subsequent Middle Bronze Age. They may have affected, for instance, the site where the city of Cadiz now stands. In the Middle Bronze Age, which EWE C probably terminated, the present-day peninsula of Cadiz was divided into at least three islands, one of them being “Erytheia,” mentioned by Greek geographer and ethnologist Strabo of Amasia around AD 1 in connection with the legend of Geryon or Geryones, king of Tartessus. This legend is intertwined with that of Bronze Age Greek hero Heracles. A large temple dedicated to this character (the *Herakleion*) on one of the islands, arguably Erytheia, made Cadiz famous in Antiquity. Strabo also mentions a settlement by the name of “Port of Menestheus” as well as an oracle by the name of “Oracle of Menestheus” upon the shores of the Gulf of Cadiz. In all likelihood, this “Menestheus” was the same as the Athenian leader Menestheus who fought in the Trojan War, according to Homer in *The Iliad*.

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<https://wettransfer.com/downloads/32f94c42589722ed2c00ec3637879add20171005100537/3fce65bf96d5338e34abf1d0208e2c6f20171005100538/cb19db>; accessed in October, 2017.

²Universidad de Huelva, Departamento de Geodinámica y Paleontología, Facultad de Ciencias Experimentales, Campus de El Carmen, Avenida de las Fuerzas Armadas S/N, 21071 Huelva, Spain. E-mail address: arodri@uhu.es.

³CSIC, Instituto de Lengua, Literatura y Antropología del Centro de Ciencias Humanas y Sociales (ILLA-CCHS), Calle Albasanz 26-28, 28037 Madrid, Spain & Department of Anthropology, The University of Chicago, 1126 East 59th Street, 60637 Chicago, IL. USA. E-mail address: juanjose.villarías@cchs.csic.es.

We would like to start by thanking professors Papamarinopoulos and Paipetis for allowing us to present in this magnificent, though appropriate, scenario such as Olympia the results thus far of the Hinojos Project in Spain with respect to the geomorphological evolution of the coasts of Southwestern Iberia in the 2nd millennium BCE. These results are relevant to any discussion regarding contact and knowledge of that area by Greeks of the Bronze Age, as echoed in the writings of later authors such as Homer, Hesiod, Stesichorus of Himera, Strabo of Amasia and, perhaps, even Plato, the philosopher.

1. The Wickboldt-Kühne Hypothesis

The Hinojos Project started in 2005. It began as a small project with an aim that was simple and straightforward: testing on the ground the basic tenet of a hypothesis that had been published, in somewhat different versions, in 2003 and 2004 by the German scholars Werner Wickboldt and Rainer W. Kühne (Wöstmann 2003a, 2003b; Kühne 2004). These researchers had analysed images of the IRS satellite of the lower Guadalquivir River basin, in Southwestern Spain, where they were able to identify a number of large geometric outlines that appeared to be the marks of man-made structures—specifically, elements of a large archaeological site from Antiquity and perhaps even earlier: from Prehistory. This site could be that of the celebrated, but elusive, pre-Roman city of Tartessus, or that of the political and religious core of Atlantis as described by Plato in his dialogues *Timaeus* and *Critias*; or perhaps both—provided that both names, “Tartessus” and “Atlantis,” belonged in different, yet parallel traditions about the same place. The outlines identified by Wickboldt and Kühne showed at least two rectangles within two circles (see Fig. 1). These features stood in the Marsh of Hinojos within the Guadalquivir paleo-estuary; hence the name of our project: “Hinojos Project.”



Fig. 1: BBC News Announcing R. W. Kühne's Paper "A Location for Atlantis?" (2004). Illustration Altered.

The Wickboldt-Kühne hypothesis soon reached the popular media as well as academic circles; therefrom, it circulated widely all over the world. This quick, worldwide diffusion of the hypothesis was due in large part to the internet, but also in large part to its scientific significance. In order to grasp this significance, we must first comprehend the geomorphological and archaeological contexts that the hypothesis touched on.

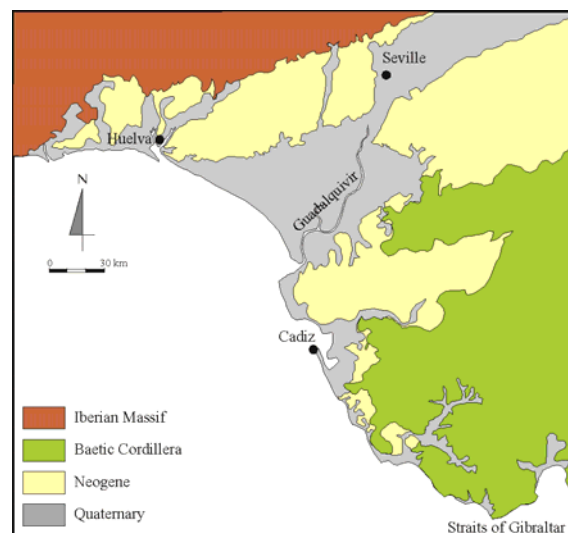


Fig. 2: Geology of Present-day South-west Iberia.

2. Geomorphological features of the Gulf of Cadiz and South-west Iberia

The Marsh of Hinojos is one among many freshwater marshes that today extend over most of the Guadalquivir paleo-estuary, which is the largest geomorphological feature of the Iberian side of the Gulf of Cadiz (see Fig. 2). Much of this paleo-estuary makes up Doñana National Park, a well-known UNESCO MAB Biosphere Reserve. The remaining area comprehends the Guadalquivir River itself, other rivers that converge into the marshland (such as the Guadiamar River) and two spitbars or sandy coastal barriers—known as “Doñana” and “Algaida”—that separate the marshland from the Atlantic Ocean. Such two spitbars are largely covered by active dunes. The marshes flood in the rainy season, from October through to May.

Other large-flowing rivers in Southwestern Iberia that empty into the Atlantic Ocean are Guadiana, Piedras, Tinto-Odiel and Guadalete. Like the estuary of the Guadalquivir River, the estuaries of these other rivers and their hinterlands include spitbars and marshlands, which are the end product of a complex process of land formation that started some 5,000 years ago, following the highest stand of the Ocean after the last Ice Age (Zazo *et al.* 2008). Energized by the intertwined dynamics of the rivers as well as that of the Ocean, such complex process is still active. While the rivers have been filling the estuaries with sediments of clay and silt, the Ocean has been impinging upon and sand-filling the shores by drift currents, wave movement and the tidal flux.

The littoral barriers and the marshlands built up during phases of progradation and aggradation, interrupted at intervals by erosional phases of “Extreme wave events” or EWEs (i. e., storm surges or tsunamis) as well as subsidence of the ground (Rodríguez-Ramírez *et al.* 2014). Progradation develops in periods of slightly low-stand or stability of the marine level, which result in the formation of coastal barriers and extensive tidal plains. By contrast, aggradation takes place in periods of high-stand marine levels and result in vertical accumulations of sediment along the coasts.

Storm surges are one of the effects of the climate fluctuation pattern known as “The North Atlantic Oscillation” (which has a periodicity of about 6 years) and of the cycles of sunspot irradiance (of some 11 years each). Tsunamis result from sudden, violent movements in the crust of the earth along the Azores-Gibraltar Fault or along shorter faults connected with it. The Azores-Gibraltar Fault, running from east to west, marks the westernmost boundary between the tectonic plates of Europe and Africa.

On the middle and the upper continental slope of the Gulf of Cadiz, mud volcanoes and mud diapirs are common structures. Following main NE–SW and NW–SE alignments, they are found at a depth of 350 to 2000 m in the eastern domain of the Gulf (Medialdea *et al.* 2009). The major tectonic structures—thrust faults, extensional faults, strike-slip faults and diapirs—have provided escape pathways for over-pressured material and fluids or have favored upward fluid movement along a sedimentary column to eventually generate the build-up of a mud volcano. The main difference between a mud volcano and a mud diapir is that while the former is characterized by actively extruding material, the latter is the product of a massive movement (Milkov 2000). Other types of structures in the Gulf related to fluid escapes, besides mud volcanoes, are mud-carbonate mounds, pockmarks and slides.

3. An area peopled since at least the Neolithic Period

The effects on the landscape of human activity must be considered as well. Archaeological evidence suggests that the coasts and hinterlands of the Gulf have been settled by human communities since at least the Neolithic period, which started in the area in the 6th millennium BCE, if not earlier (Morales *et al.* 2014; Barich 2014). In the 1920s, Anglo-French archaeologist George E. Bonsor and German linguist Adolf Schulten conducted excavations at the site of Cerro Del Trigo—near the present-day mouth of the Guadalquivir River, where Roman remains had been unearthed—while attempting to find and dig out evidence of the city of Tartessus (Bonsor 1922, 1928; Schulten 1924). The research team included geologist O. Jessen and cartographer A. Lammerer. Like scholars before him, and like Wickboldt and Kühne after him, Schulten—though apparently not Bonsor—believed that the lost city of Tartessus was the same as the political and religious nucleus of Atlantis which Plato described.

Both names, “Tartessus” and “Atlantis,” may indeed refer to the same place or area in different, yet contemporary oral and literary traditions in Antiquity. The city of Tartessus was the capital of a kingdom in south-west Iberia, also called “Tartessus,” that, according to Herodotus, traded regularly with Ionian Greece in the 7th and 6th century BCE, mostly through the city-state of Phocaea. These trade relations soon combined with a political and military alliance between the two powers in the western Mediterranean that rivalled the alliance there between Phoenicians, Carthaginians and Etruscans. The liaison

between the realm of Tartessus and the maritime empire of Phocaea became so close—Herodotus would point out—that the king of Tartessus, Arganthonios, offered the city of Phocaea financial and humanitarian assistance with which to stave off the attack of the Persian Empire.

An erstwhile king of Tartessus, Geryon or Geryones, stands prominently in Greek mythology—particularly as recorded in Hesiod’s *Theogony*—in connection with the story of the labours of demigod Heracles. In the best known version of this story (Graves 1960: 69-70; 1996: 451-462), King Geryon is portrayed as a mighty, super-human figure who ruled in the far west of the known world. His large body was equipped with three trunks and three heads above the waist; furthermore, he had with him a vicious two-headed watchdog, Orthrus. King Geryon owned a large herd of red cattle which Eurystheus, then paramount king of Greece, wanted Heracles to steal for him. Eurystheus had been prompted to this commission by the goddess Hera. Heracles deferred to Eurystheus’s authority and set out for the western end of the Mediterranean Sea. There he opened a sea channel to take the king of Tartessus by surprise—today’s Gibraltar Straights—and landed on an island called “Erýtheia,” where he confronted Geryon. Heracles killed him and his watchdog, stole the herd of cattle and returned to Greece by marching across the Pyrenees and along the northern Mediterranean coast.

As a younger man, Heracles had participated in Jason’s nautical expedition to the land of Colchis—at the farthest end of the Black Sea—to retrieve from King Aeëtes the golden ram’s fleece that had belonged to Prince Phrixus of Boeotia. In the Orphic version of the story of this eventful voyage (West 1983: 37; Anonymous 1987) the participants, known as Argonauts, return home by sailing along the coasts of northern and then west Europe, stopping at the mouths of the river Tartessus on their way to the Gibraltar Straits and ultimately the Mediterranean Sea (Anonymous 1987: 164). Authors such as E. D. Phillips (1966) and K. Kalachanis *et al.* (2016) have argued that this homeward itinerary may have followed a trade route that had been opened in Mycenaean times.⁴

King Geryon, according to 7th-century poet Stesichorus of Himera—as quoted by geographer cum ethnologist Strabo of Amasia (*Geographiká* Bk. III, Ch. 2, Par. 11; 1966: 45)—, had been born in a cave “near the streams” (*pará pagás*) of the river Tartessus and “roughly opposite” (*schedòn antipéras*) the island called “Erýtheia,” where he would

⁴We are indebted to Professor Papamarinopoulos for calling our attention to the relevance of the *Argonautica Orphica* for the early history of the realm of Tartessus.

eventually meet Heracles and die. In Homeric Greek, the plural noun *pagai* meant “streams” as well as “springs” (Liddell & Scott 1968: 1399); moreover, the reference to an island in the quotation calls rather for the first meaning than for the second. Strabo, quoting Pherecydes of Athens (who lived in the 5th century BCE), also wrote (*Geographiká* Bk. III, Ch. 5, Pars. 3-4; 1966: 84-86) that “Erýtheia” was the long island—some 100 stadia or 18 km long—that at Strabo’s time housed the core (*didýme*) of the multi-sited city community (*polis*) of Cadiz, to which he referred, appropriately, as “Ta Gádeira,” literally “The Cadizes” (see Fig. 3).

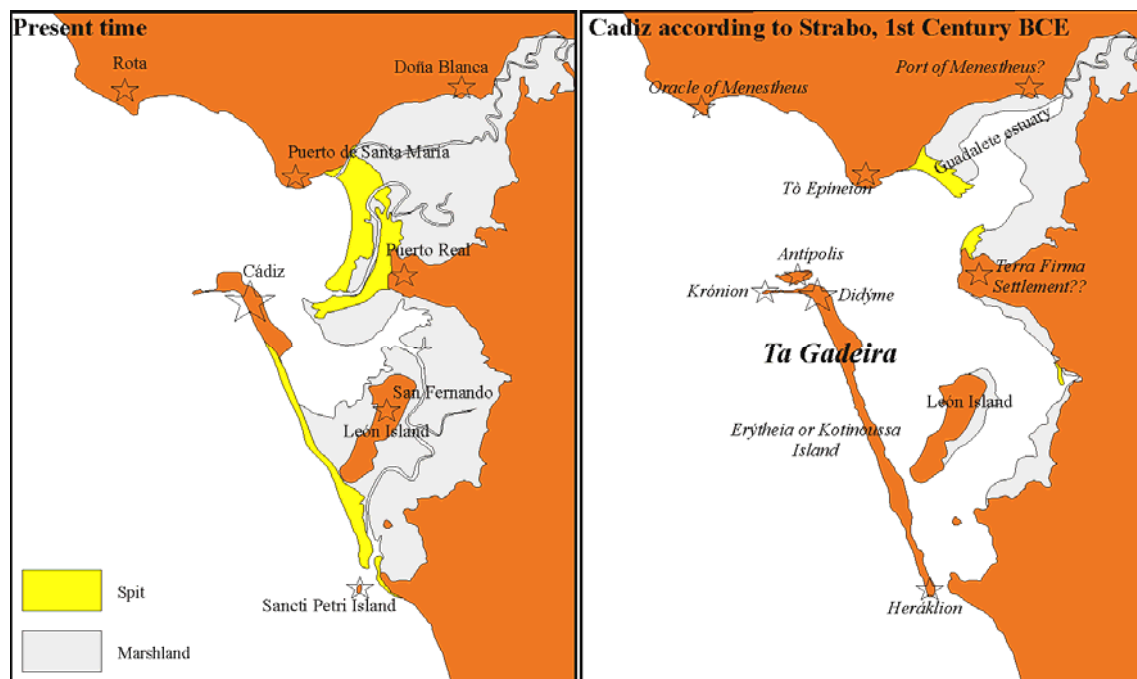


Fig. 3: The islands and bay of Cadiz and their vicinity in present time and according to Strabo of Amasia. Geomorphological data partially referred to in Alonso *et al.* (2015) and Dabrio *et al.* (2000)

Close by the city community, at the north-western end of Erýtheia, stood a temple for the worship of Cronus: “The Krónion.” Greek mythology represents this character (Roman Saturn) as the king of the Titans, who had ruled mankind during its golden age, before the time of the Gods (Graves 1996: 43). North of Erýtheia was a smaller island, where “the antí-polis” of the core of the city community stood. A third island lay between Erýtheia and the mainland, in the Bay of Cadiz: the present-day island of Leon.

There were settlers from the city somewhere on the mainland as well. In addition, a few decades before Strabo’s time a new port, “Tò Epíneion,” had been built on the other

side of the Bay, in all likelihood where Puerto de Santa María now stands. Timaeus of Tauromenium, who wrote in the 3rd century BCE, referred to the 100-stadium island as “Kotinoussa” because of the many olive trees that one could see on it (in Schulten 1925: 95). Strabo also mentions (*Geographiká* Bk. III, Ch. 1, Par. 9; 1966: 29), regarding the Guadalete paleo-estuary, one “Port of Menestheus,” so called after the leader of the Athenians in the Trojan War as told by Homer (1987: 77)—arguably a former port of the city. Elsewhere on the littoral of the Bay sat one “Oracle of Menestheus”: Strabo’s narrative suggests it was at or near the present-day town of Rota, where apparently Roman and pre-Roman remains of a temple or a shrine turned up in the 17th and again in the 19th century (De San Cecilio 1669: 497-504; Sociedad Geográfica de Madrid 1878). According to Flavius Philostratus the Athenian, who wrote in the 3rd century AD, Menestheus was the object of a cult among the citizens of Cadiz (in Grosse 1959: 320-327).

The Heracles of Greek mythology is commonly associated with a character in Near Eastern mythology known as “Melkarth,” who was the object of an agricultural cycle-related cult in the Phoenician city-state of Tyre from the 10th century BCE onwards. Near Eastern mythology represents him as a former divine king of this city-state who had been responsible for daring commercial expeditions and colonization in the Mediterranean Sea (García y Bellido 1963: 72-74). Strabo suggests (*Geographiká* Bk 1, Ch. 3, Par. 2; 1945: 210-212) that the city of Cadiz was founded a few years after the end of the Trojan War by Tyrian explorers who were searching the far west of the known world for the trail of Heracles’s—i. e., Melkarth’s—exploits. The element in King Geryon’s story of Heracles’s opening up the Gibraltar Straights for his labour of stealing the cattle of the king of Tartessus may be interpreted as meaning that Melkarth was thought to have been the first among Easterners in the Mediterranean Basin to open the sea route for trading with Tartessus, or the first to set the terms to the Tartessian authorities for such trading, or both. Upon reaching the long island of Cadiz—Strabo also wrote (*Geographiká* Bk 3, Ch. 3, Par. 5; 1966: 86)—, the Tyrian explorers founded the city of Cadiz at its farthest end while erecting a temple for Heracles, known as “Herákleon,” at the nearest end.

The Book of Kings, in the Old Testament of the Bible (I Kings 10, 21-22; The New Jerusalem Bible 1994: 448) makes reference to a faraway country across the Mediterranean Sea called “Tarshish,” to which the joint trade fleets of King Solomon of Israel and King Hiram of Tyre would sail out in search of “gold and silver, ivory, apes and baboons.” Many a scholar—including Schulten and many others before him—has pointed out that

this “Tarshish” was nothing but the Old Hebrew name for the land, river, kingdom and city that Herodotus, Strabo, and other ancient Greeks called “Tartessus.”

Plato, who wrote in the 4th century BCE, mentioned no kingdom or city of Tartessus, let alone the land of Tarshish. The reference to Atlantis—Plato wrote—came originally from Solon of Athens, who had lived in the first half of the 6th century BCE. Solon heard the Atlantis story to the priests of Sais, then the city capital of Egypt, on the occasion of a visit that he paid there.

Schulten and Bonsor were quite familiar with most of these and other pieces of information from Antiquity about Tartessus, Tarshish and Atlantis. Nevertheless, they failed in their archaeological pursuit at the site of Cerro del Trigo. They found no city there below the remains of the Roman settlement—only sand and the water table. Elsewhere in the paleo-estuary, however, at a number of separate locations, they run into isolated artefacts—especially ground axes—from the Neolithic period and the Copper Age in south-west Iberia, which together compound the time span of a long cultural development in the paleo-estuary that ended c. 2000 BCE. In addition, the geologist in the team, Otto Jessen, drew a map of the geomorphological composition of south-west Spain which suggested that the paleo-estuary had taken thousands of years to turn into the landscape of marshes, relict river channels, small lagoons, levees and spitbars that he saw. From the Tartessian to the Roman period, much of the paleo-estuary had become a large coastal lagoon. Jessen also noticed that many graves in the Roman necropolis at the Cerro del Trigo site were flooded with sea water, which he took to mean that the paleo-estuary was subsiding since or had subsided at one time after the graves had been dug.

Shortly after Bonsor & Schulten’s project, Spanish classical scholar Juan Fernández Amador de los Ríos (1925) argued for an alternative place within the paleo-estuary for the remains of the city of Tartessus and the center of Atlantis: the alluvial island of Tarfia, a few kilometers upstream from Cerro del Trigo. This hypothesis, however, was never tested, as it ran counter to the implications of Jessen’s geomorphological report: namely that Tarfia, like any other alluvial island near the mouth of the Guadalquivir River, could not be old enough to have housed a city in pre-Roman times, not to mention in prehistoric times. These implications were later reinforced by the conclusions of Spanish geologist and mining engineer Juan Gavala y Laborde, who from the 1920s to the 1950s did extensive research on the geomorphological evolution of the Spanish Southwest during the Holocene. Gavala wrote (1927, 1936) that the slow, gradual process of sedimentation in

and filling of the Guadalquivir and other paleo-estuaries in the Gulf of Cadiz made it very unlikely that any of these environments could have carried a significant human settlement before the Middle Ages, when this process reached the point at which such an occupation could have started.

In assuming Jessen's and Gavala's uniformitarian reconstruction of the formation of the landscape in the lower Guadalquivir river basin, subsequent archaeological projects in the area were carried out on the banks of or in sub-areas outside the paleo-estuary rather than in sub-areas of fluvial or marine influence inside it.



Fig. 4: Archaeological Areas and Sites in South-west Spain with deposits from Pre-Roman Times.

These projects (Cf. Collantes de Terán 1969; Cerdán Márquez *et al.* 1975; Escacena & Belén 1991; Campos *et al.* 1995; Campos & Gómez-Toscano 1997; Costa-Caramé *et al.* 2010) brought to light abundant evidence of the rich cultural development that took place in south-west Spain during the Neolithic Period and the Copper Age. Near the north-western bank of the paleo-estuary, this effort included excavating the settlement site of San Bartolomé de Almonte, where archaeologists discovered a clear discontinuity between a Copper Age occupation and a Late Bronze Age occupation; i. e., a hiatus of close to one thousand years by most estimates—from the early 2nd to the early 1st millennium BCE—, largely based on inferences from style variations of structures or artefacts across sites rather than on direct radiocarbon determinations from organic remains collected at these sites

(Ruiz-Mata 1981; Ruiz-Mata & Fernández-Jurado 1986; García-Sanz & Fernández-Jurado 1999).

South and west of the Marsh of Hinojos, a survey project led by J. M. Campos yielded a widespread dispersion of surface findings: flaked and polished stone tools dating to Palaeolithic and Neolithic times, pottery shards from the Neolithic period and the Copper Age, and construction materials and pottery sherds from the Roman period, the Middle Ages and the 16th to the 18th centuries AD. Closer to the Marsh, planting and canal digging projects turned out two ground axes from the Neolithic period and the Copper Age, very similar to the axes found at other locations in the paleo-estuary by Schulten and Bonsor in the 1920s. Only a handful of these dispersed findings can be ascribed with any assurance to the long span between the Copper Age and the Roman period (Campos *et al.* 1992; Campos *et al.* 1993; Campos & Gómez Toscano 2001: 189-194).

At Lebrija and nearby sites on the eastern and south-eastern sectors of the paleo-estuary, such as the Marsh of Rajaldabas, archaeologists identified two hiatuses: the first, between the Copper Age and the Middle Bronze Age (i. e., from the early to the middle 2nd millennium BCE) and the second, between the Middle Bronze Age and the final phase of the Late Bronze Age (i. e., from c. 1200 to c. 900 BCE) (Menanteau 1981: 115-117 and Figs. 70 & 92; Tejera-Gaspar 1985; Caro-Bellido *et al.* 1987). Comparable discontinuities were encountered at other sites in the lower and middle Guadalquivir river basin and its vicinity.

The long hiatus registered at San Bartolomé resembles the interruption encountered for the same time span at Mesas de Asta (near Xeres), Castillo de Doña Blanca (in the Guadalete paleo-estuary) and El Carambolo (west of Seville). Lebrija's two-hiatus anomaly turned up as well at El Berrueco (Medina Sidonia, in the province of Cadiz), Carmona, Acinipo (near Ronda) and Montoro (in the middle Guadalquivir river basin) (Escacena & Belén 1991: 40).

In present-day Cádiz, geophysical exploration of the ground revealed evidence of an erstwhile natural outlet of the Bay through the northern half of today's peninsula (Bendala-Galán 2000: 109-110; Cerpa-Niño 2015: 82). This discovery substantiated Strabo's description of the old city community of *Tá Gáadeira* as sprawling across the long island of Erýtheia and a smaller island north of it.

Shards of Mycenaean pottery from the 13th or early 12th century BCE were found at Montoro (Martín de la Cruz 1984-1985: 213; Bendala-Galán 2000: 65). The presence in the middle Guadalquivir river basin of this foreign pottery is the only clear archaeological evidence thus far that substantiates some form of cultural contact between southern Iberia and the East Mediterranean Sea in the second half of the 2nd millennium BCE.

Following the second hiatus, the final phase of the Late Bronze Age in southwest Iberia, which began in the 9th century BCE, as well as the subsequent Early Iron Age—both periods being the archaeological correlates of the historical kingdom of Tartessus—are exceedingly well represented, in terms of both number of sites and cultural deposits recognized in them.

4. The Hinojos Project

The significance of Wickboldt's and Kühne's hypothesis in 2003 and 2004 lay primarily with vindicating the old search for the city of Tartessus inside the Guadalquivir paleo-estuary; it lay secondarily with bringing back to life in scientific circles the notion that the story of Atlantis may have a basis in historical fact. In 2006, Kühne would also recall the old argument—by F. Kluge and W. Leaf—that a different version of the story of Atlantis can be identified in Homer's *The Odyssey*; specifically, in the information about the Phaeacians of the remote, “at the world's edge” land of Scheria (Homer 1980: 55-153). Kühne, however, considered it more likely that Plato backdated to late Mycenaean times the information about Tartessus that he had learned in Sicily.

The Wickboldt-Kühne hypothesis, in any case, like Fernández Amador de los Ríos's hypothesis, run against the Jessen-Gavala model of the evolution of the Guadalquivir paleo-estuary during the Holocene.

As remarked earlier, the Hinojos Project was originally designed to simply establish whether or not there were archaeological remains in the Marsh of Hinojos, as Wickboldt and Kühne contended, and if there were, to answer the question of how old could they be? Though thus easily conceived of, the Hinojos Project had to be interdisciplinary, however—as it had to address issues of multifarious aspects. Carrying it out required at least a biologist (José Antonio López-Sáez), two geologists (Antonio Rodríguez-Ramírez and José-Noel Pérez-Asensio), two archaeologists (Sebastián Celestino-Pérez and Enrique

Cerrillo-Cuenca), an historian and aircraft pilot (Ángel León) and an historian and cultural anthropologist (Juan J. R. Villarías-Robles). From the standpoint of geological research, the Project was part of a larger scientific context that focuses on the rapid geomorphic dynamics at work along the coasts of South-west Iberia in the Holocene (see, for instance, Menanteau 1981; Vanney & Menanteau 1985-1989; Zazo *et al.* 1994; Lario 1996; Goy *et al.* 1996; Rodríguez-Ramírez *et al.* 1996). This interest had arisen in the 1970s and concerned the Jessen-Gavala model to the extent that it predates the C-14 revolution and, more importantly, Plate Tectonics Theory. In 1998, one of us, Antonio Rodríguez-Ramírez, in a study that included the first geomorphological mapping of Doñana specifically, published sedimentary and geomorphic evidence of at least two high-energy, ocean-born erosive EWEs that had significantly altered the Guadalquivir paleo-estuary in prehistoric as well as historical times. Each of these events resulted in the rupture of the coastal barriers and, subsequently, in the formation inside the paleo-estuary of sets of long sandy and shelly ridges (known as “cheniers”) that the Jessen-Gavala model could not account for. The first prehistoric event took place around 2000 BCE.

In testing the material implications of the Wickboldt-Kühne hypothesis, we began by checking the satellite images that the two German scholars had examined with images from other satellites. We then compared these images with aerial photographs from different series of photographs and different years; we wanted to know if the apparently man-made features on the ground that Wickboldt and Kühne had identified could also be seen in such independent satellite images and aerial photographs. Some of them, as it turned out, could be seen; while others could not. In the process, we identified features that Wickboldt and Kühne had missed. We then conducted extensive surface surveys of the area where the features are. In addition, we took samples of the soil, after drill-coring it at three locations down to a depth of 12 m, and run different types of lab analysis of the sedimentation: mineralogical, litho-stratigraphic and paleontological. Furthermore, we searched those samples for pollen content and radiocarbon dating.

The analyses confirmed the importance of the role played by neo-tectonics in the rapid geomorphological transformations occurred in the Guadalquivir paleo-estuary during the Holocene—an historical fact that neither Jessen nor Gavala knew about, but one that researchers after Gavala suspected, yet failed to explore. In effect, the paleo-estuary is criss-crossed by a number of SW-NE-oriented fault alignments that cut other fault alignments following E-W and NW-SE directions. The most conspicuous of the SW-NE

alignments is the Torre Carbonero-Marilópez Fault (TCMF), which divides the paleo-estuary in about half (Rodríguez-Ramírez *et al.* 2014).

We corroborated the high-energy event of c. 2000 BCE that Antonio had identified in the 1990s. Evidence of this EWE has also been recognized on the littoral of Barbate, some 50 km south-west of the city of Cadiz (Koster and Reicherter 2014). In addition, we discovered evidence of a second EWE in prehistorical times, having occurred about one thousand years later than the first: c. 1150 BCE (Rodríguez-Ramírez *et al.* 2014). Evidence of this second event has also been identified in the Guadalete estuary (Lario *et al.* 1995, Dabrio *et al.* 1999, Luque *et al.* 2001), as well as in the Tinto-Odiel estuary (Morales *et al.* 2008).

The radiocarbon dates that we obtained from organic material in the soil revealed that the geometric features on the ground, man-made though most certainly are, cannot be old enough as to date back to Tartessian or earlier times: the organic material of that age is too deep (several meters down) below the ground surface for archaeological remains of the same age to leave marks up on the surface that can be detected in satellite images or aerial photographs.

Paradoxically, however, the period that followed the marine transgression of c. 2000 BCE produced alluvial soils that left types of pollen and other by-products of human activity somewhere in the paleo-estuary, specifically cereal agriculture and pastoralism. So did the alluvial soils of the period following the second event, c. 1150 BCE. Such biological evidence suggests that during long time spans in the 2nd and 1st millennium BCE much of the paleo-estuary was above sea level—as it is at present—and could have sustained a human community of some form, the material remains of which lie buried in the ground and are, therefore, hidden from view.

On the basis of these first results, we then proceeded to explore the surface and analyse the sedimentation at additional locations in the Marsh of Hinojos and elsewhere in the paleo-estuary. The new results to be arrived at we wanted to compare with the results of colleagues in other sectors of the paleo-estuary, in other paleo-estuaries in the Gulf of Cadiz and in the present-day municipality of Cadiz and its neighbouring districts. Our aim was no longer testing the Wickboldt-Kühne hypothesis, but reconstructing the geomorphological transformations and cultural moments on the Iberian side of the coasts of the Gulf in the course of the Middle and Late Holocene. For this reconstruction we

would take into account the neo-tectonics active in the Gulf as a factor, in addition to factors already considered in the received literature, such as climate change or the dialectic between marine and fluvial dynamics.

We had the Marsh of Hinojos and elsewhere in the paleo-estuary drilled-cored at additional points, to depths ranging from 1.5 to 12 to 18 m., depending on the geomorphological context of the points. As we did for the cores extracted in the first phase of the Project, we analysed the sedimentation in these additional cores and obtained samples from them that could yield C-14 dates for the deposits found in each core. Thereafter, we correlated the deposits by their lithic, mineralogical and paleontological composition as well as by the C-14 dates obtained for them. Finally, we compared the results with those of other projects of other colleagues in the same study area (see Fig. 5).

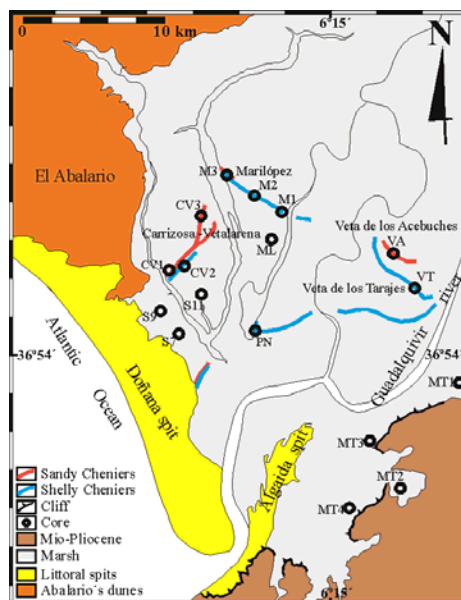


Fig. 5: Location of core-drilling points in the Guadalquivir paleo-estuary (Rodríguez-Ramírez *et al.* 2015).

We thus discovered that south of the Torre Carbonero-Mary López Fault, the paleo-estuary experienced a marked subsidence from about 2000 BCE (the date of the first prehistorical EWE) to the first centuries of the Christian era (Rodríguez-Ramírez *et al.* 2014). The subsidence proceeded through a series of sedimentary sequences of retrogradation and aggradation within a context of relative sea-level rise. The EWE of c. 1150 BCE compounded this sinking development. From the first centuries of the Christian era up to the present, the subsidence has remained relatively dormant, with progradation of the littoral systems and infilling of the marshland progressing within a

context of sea-level stability (Rodríguez-Ramírez *et al.* 2014). In addition, we found evidence of a prehistorical EWE in between, c. 1550 BCE, apparently of lesser magnitude than the other two (Rodríguez-Ramírez *et al.* 2015). This event can be correlated with an earthquake that has been suggested for south-west Portugal c. 1600 BCE (Vizcaíno *et al.* 2006).

Table 1 shows the main characteristics of the evidence of the three EWEs that we have identified for the 2nd millennium BCE. Figure 6 represents the geomorphological effects of these three events in the Guadalquivir paleo-estuary. Following the marine transgression of each of the three events, the regular low-energy dynamics of the Ocean and the rivers resumed. Within a few centuries of the third event, progradation of the Doñana coastal barrier all but isolated the erstwhile wide estuary of the Guadalquivir from the Ocean, generating a coastal lagoon as a result.

	S7	S11	MT3 and MT4	MT2 and MT1
Event C	<p>Muddy matrix Alien lithoclasts Massive layer and erosive base Mixture of disarticulated valves, shell fragments and whole bivalves (estuarine) Moderate transport of benthic foraminifera and hyaline foraminifera High d/p ratio High diversity of species from different environments (mostly estuarine)</p> <p>Paleogeography: marginal area of a confined estuary behind a littoral barrier (Doñana Spit)</p>	<p>Silty sandy matrix Alien lithoclasts Fining-upwardly sequence and erosive base Mudpebbles Upper part of the succession shows bioturbation Mixture of disarticulated valves, shell fragments and whole bivalves (estuarine) Transported benthic foraminifera and porcelanaceous foraminifera High diversity of species from different environments (mostly estuarine)</p> <p>Paleogeography: central basin of a confined estuary behind a littoral barrier (Doñana Spit)</p>	<p>Sandy and sand-silty matrix Alien and large lithoclasts Massive layer and erosive base Mixture of disarticulated valves and shell fragments of marine environments Transported benthic foraminifera and relatively high P/B ratio High diversity of species dominated by estuarine forms</p> <p>Paleogeography: area of estuary exposed to marine dynamics by inlet channel</p>	<p>Mud-sandy matrix Mud pebbles Scarce lithoclasts Archaeological remains Upper part of the succession shows bioturbation Low percentages of transported benthic foraminifera and P/B ratio dominated by estuarine forms. Mixture of estuarine and terrestrial (Gastropoda) species</p> <p>Paleogeography: area away from the coast and confined</p>
Event B	<p>Silty sandy Fining-upwardly successions Gradual contact whole shells (2 valves) and disarticulated valves Moderate transport of benthic foraminifera and hyaline foraminifera High P/B ratio and d/p ratio Moderated diversity of species, dominated by estuarine forms</p> <p>Paleogeography: lower-energy extreme wave event in a semiconfined estuary behind a littoral barrier (Doñana Spit)</p>	<p>Sandy silty matrix erosive base Decreasing grain-size sequences whole shells (2 valves) and disarticulated valves Transported benthic foraminifera and porcelanaceous foraminifera Moderated diversity of species of different environment</p> <p>Paleogeography: lower-energy extreme wave event in a semiconfined estuary behind a littoral barrier (Doñana Spit)</p>	No data	No data
Event A	<p>Heterometric sandy matrix Gravel and alien lithoclasts Massive layer and very erosive base Mixture of disarticulated valves, shell fragments and whole bivalves. Transported benthic foraminifera and porcelanaceous foraminifera High diversity of species dominated by open marine forms</p> <p>Paleogeography: breaking of littoral barrier by overwash and washover fan by large extreme wave event</p>	<p>Heterometric sandy and sandy silt matrix Lesser ratio of gravel and alien lithoclasts Wood Moderate fining-upward sequence and erosive base Moderate bioturbation Mixture of disarticulated valves, shell fragments and whole bivalves Transported benthic foraminifera and porcelanaceous foraminifera High diversity of species (mixture of marine and estuarine)</p> <p>Paleogeography: central basin of an open estuary</p>	No data	No data

Table 1: Characteristics of the evidence of EWEs A, B and C in the Guadalquivir paleo-estuary in the 2nd millennium BCE (Rodríguez-Ramírez *et al.* 2015)

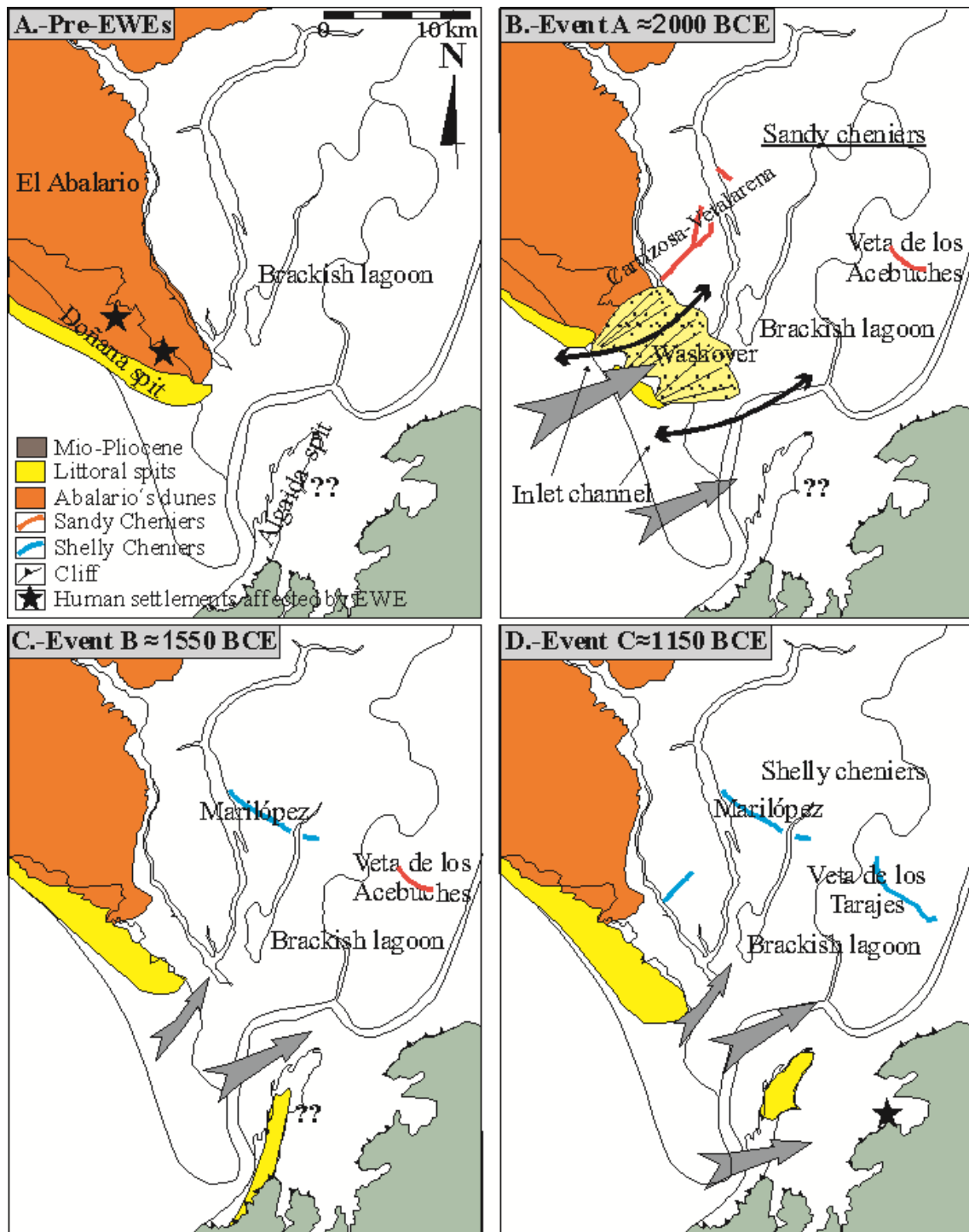


Fig. 6: Geomorphological effects of EWEs A, B and C in the Guadalquivir paleo-estuary in the 2nd millennium BCE (Rodríguez-Ramírez *et al.* 2015).

The first event—to which we refer as “Event A,” c. 2000 BCE—impinged far and wide on the paleo-estuary. It included the generation of a wash-over fan that caused strong erosion in the then forming Doñana sandy barrier as well as in the aeolian systems of El Abalarío, to the north-west. These significant paleo-geographic changes must have severely

affected human settlements established in the sub-areas around the paleo-estuary in the Neolithic period and the Copper Age, resulting in the wide dispersion of artefacts from these periods that have been found in the marshland since the 1920s and in the hiatuses identified at San Bartolomé de Almonte and Lebrija that mark the end of the Neolithic and Copper Age occupation. The magnitude of the event may have been strongly conditioned by the intense subsidence of much of the ground of the paleo-estuary at the same time (Rodríguez-Ramírez *et al.* 2014).

The second event—“Event B,” c. 1550 BCE—looks like it had lesser paleogeographic effects in the paleo-estuary, possibly because the epicentre may have been in south-west Portugal rather than in the Gulf of Cadiz.

The third event—“Event C,” c. 1150 BCE—may have had the same magnitude as Event A, as it also covered an extensive geographic area and cataclysmically affected the Middle Bronze Age settlement of Marsh of Rajaldabas, near the present-day mouth of the Guadalquivir River. This third event may explain, too, the second hiatus at Lebrija and other sites of the Spanish South-west. The marine transgression severely eroded the Doñana spitbar and turned the Algaida spitbar into an island.

The record of this third event in the paleo-estuary might be correlated with that of an event recognized in the Tinto-Odiel and Guadalete estuaries. The cultural effect overall in south-west Iberia may have been the end of the Middle Bronze Age in the region, like the overall cultural effect of Event A may have been the end of the Neolithic-Copper Age Tradition there. The Middle Bronze Age in South-west Iberia was the period of possible trade or other form of contact with Mycenaean Greece and other cultural formations in the eastern Mediterranean, as the finds of Mycenaean pottery in the Guadalquivir River basin suggest. These finds appear to lend some credence to the old stories of Geryon and Heracles, the Titans and the Gods, Odysseus and Menestheus...

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