Palaeoecology and Holocene environmental change from a saline lake in South-West Spain: protohistorical and prehistorical vegetation in Cádiz Bay

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Abstract

Pollen and non-pollen palynomorph analysis of the archaeological site of Pocito Chico (El Puerto de Santa María, Cádiz, SW Spain) has been conducted. The site is located in the saline lake of El Gallo. Chronology extends from Chalcolithic time to the XV century AD. The vegetation dynamics from the pollen diagrams can be correlated with the anthropization of the landscape as well as with the evolution of the paleocoast and the saltmarshes. © 2002 Published by Elsevier Science Ltd.

1. Introduction

This research project was initiated as part of a multi-proxy investigation into Holocene environmental change in Cádiz Bay, SW Spain. The strength of this approach lies in combining the archaeological and lake sediment records to provide an integrated environmental reconstruction encompassing as many different lines of evidence as possible. Now, the pollen analysis of the archaeological deposit of Pocito Chico, located in the saline lake of El Gallo (Fig. 1), has been made.

The course of bog development of the saline lake is analysed by means of investigations of pollen, spores, algae, fungal remains, cyanobacteria and some unknown microfossils. The analysis was expected to provide information about both regional and local vegetation development, but the picture presented by the microfossils is mainly local. Salinity and trophic degree is discussed. The vegetation shows traces of human influence, including cereal culture and anthropization of the environment.

2. Study area

The geographic area of study lies within the Natural Park of the Bay of Cádiz, including the Natural Reserve of the endorheic complex of El Puerto de Santa María, which constitutes a zone of exceptional natural, cultural and landscape value (Fig 1). Its geologic history is relatively recent, having defined its landscape in the last millennia. During the glacial Pleistocene periods, the torrent of the Guadalete River, together with lower sea level, formed gravel deposits on the Pliocene plinth of the Bay (Mayoral Alfaro, 1989; Zazo et al., 1996). The Guadalete River then ended at an ample estuary that extended from the present El Puerto de Santa María to Sancti Petri, with the islands of Cádiz and San Fernando in its interior. After freezing, the hydraulic regime changed, depositing in succession sands, silts, and clays at sea level (Goy and Zazo, 1989; Rodríguez Vidal, 1989).

The contact between the river and the sea allowed the creation of sandy barriers closing the estuary and as well increased the sedimentary deposit inside the bay, thus allowing formation of the thousands of hectares of the present salt marsh (Zazo, 1989; Zazo et al., 1996). Finally, the action of the wind deposited sandy sediments towards the interior, giving rise to numerous coastal dunes. It is indeed from the Flandrian transgression when a relatively fast process of coastal regularisation has taken place, caused by the reduction of sea level, by the action of one active littoral drift, and by the sediment contribution from the fluvial channels (Ojeda Zujar, 1989; Lario, 1996). Towards 5000 BP, the abrupt fall of the marine level, almost reaching the present level, favoured the gradation of the coastline. Under a general...
south-easterly drift, extensive coastal spits developed (Zazo, 1989; Lario, 1996). The landscape formed in this way, and that at the moment remains acceptably conserved, is quite level. However, it reunites a series of varied interrelated ecosystems, including beaches, dunes, plains, and salt marshes. It is indeed the contact between the zone of sea and river which makes the Bay of Cádiz a singular, fragile, natural space and of enormous ecological importance, not only for Andalusia and Spain, but even at the European level, due to its importance for migrating and breeding aquatic birds.

The generalisation of aeolian dynamics, from the Subboreal episode, is recognised in numerous points of the Cádiz coastal landscape, with important episodes of aeolian mantles and dune fields that sealed and hid archaeological establishments of latest Neolithic to Chalcolithic ages (Borja, 1992). In the Cádiz area between Rota and El Puerto de Santa María, at sites such as Cantarranas and Las Viñas (Ruiz Gil and Ruiz Mata, 1999), deforestation must be related to anthropic farming impacting the forest, as indicated by the proliferation of “silos” of cereal storage and in the evolution of the lithic technology towards elements specialised in the handling of wood and cereal, between the Final Neolithic and the Bronze Age (Borja and Ramos, 1993; Valverde, 1993; Ruiz Mata et al., 1996; Ruiz Gil and Ruiz Mata, 1999).

3. Biogeography and vegetation

From a biogeographical point of view, the Atlantic region of Andalucia, in which the province of Cádiz is included, constitutes an original assemblage. The “Gaditano-Onubo-Algarviense” chorologic province (Ceballos and Martín Bolaños, 1930; Asensi Marfil and Díez Garretas, 1987; Rivas Martínez, 1987, 1988), is marked by an abundance of endemic species, particularly in the area of the Gibraltar Strait, resulting from its border position between Europe and Africa (Bejarano Palma, 1997).

The vegetation series corresponding to the studied area are those of the cork oak grove on coastal sandy grounds (Oleo-Querceto suberis S.) in its “gaditana” facies, on sandstone with Calicotome villosa in the neighbourhoods of San Fernando and all the southern region of El Puerto de Santa María. Towards the interior, the corresponding series has Tamo commun-Oleo sylvestris S. or the “gaditano-onubense” facies of the cork oak grove on sandy grounds with Halimium halimifolium to the north of the zone of study. The inner territories belong to the series of dry–subhumid–humid “bético” and “algarviense” oak forest (Smilacis mauritianicae–Querceto rotundifolii S.) (Peinado Lorca and Rivas Martínez, 1987; Rivas Martínez, 1987). The bay between Cádiz, El Puerto de Santa María and San Fernando corresponds, however, to the geomacroseries of salt marsh, coastal salt mines, dunes, and sandy grounds. The riparian zones of the Guadalete River correspond to the riparian geomacroseries, now occupied by zones of irrigated land. Nevertheless, the human performance, as well as the natural dynamics of the zone, have relegated the original vegetation to areas which Bejarano Palma (1997) defines as the “smaller relieves”, that is to say, to not proper coastal zones, so the vegetation assemblages are usually reduced to small habitats where the soils are more evolved.

Nevertheless, the most representative landscape in all the area of study is the salt marsh, since it occupies extensive surfaces and it has constituted a source of economic resources for settlers since antiquity (Bejarano Palma, 1990, 1997). In the case of the salt marshes of the Bay of Cádiz, also known as the Salt marshes of the Guadalete, its origin is the result of the neotectonics that caused the collapse of certain sectors. The combination of this process with the changes of sea level during the Quaternary gave rise to deposition of mud and clays, little evolved into entisols. In itself, the potential vegetation of the salt marshes corresponds to several associations with a disposition in parallel bands with respect to the coastline—as a rule—according to different gradients: Spartinetum densiflorae, Halimione portulacoidis–Sarcocornietum alpini, Inulo crithmoidis–Limnetium furulacei, Cistancho-Suaedetum verae, amongst others (Asensi Marfil and Díez Garretas, 1987). In some points of the surroundings of El Puerto de Santa María, it is possible to detect sandy ground generated by the action of the wind, as happens in the dune systems of Doñana (Huelva). These zones have a particular vegetation formed by Juniperus sp. (Rhamno-Juniperetum macrorcarpe and Rhamno-Juniperetum lyciae) (Asensi Marfil and Díez Garretas, 1987).
The presence of coastal lagoons is another peculiarity of the area, specifically in the zone of the Integral Reserve of the endorheic complex of El Puerto de Santa Maria. These lagoons, of small size, have an origin related to the coastal barrier existence that, closing old drainage routes, created endorheic zones (Recio Espejo, 1989). The potential vegetation of these lagoons are the *Junco-Eleocharidetum palustris* and *Juncetum rugoso-effusi* associations, with *Erico ciliaris-Ulicetum minoris* (Bejarano Palma, 1990, 1997). The lagoons had to occupy almost all the small and medium depressions of the countryside, although as a rule all are seasonal and disappear when temperature increases (Ruiz Mata et al., 1996). Some, like the lagoons of Los Milagros or El Gallo, have undergone an historical process of progressive drying of anthropic origin that has accentuated the natural process. This zone of the Cádiz countryside is modelled by smooth elevations composed of Miocene lagoons that form small plains surrounded by low hills. Due to the lack of slopes, and to the impermeable sequences of the lagoons that rest on a marly gypsiferous plinth, the lagoons have high salt contents, and all are brackish (Ruiz Mata et al., 1996).

The Lagoon of El Gallo, where the deposit of Pocito Chico is based, is one of greatest in extent of the province of Cádiz, and the greater one of the endorheic complex of El Puerto de Santa Maria (Fig. 1). It is located in the region of the coastal countryside (36°41′50″ N, 2°34′50″ W), spilling its waters to the Bay of Cádiz through the Salado stream. This strategic zone between Guadalete and Guadalquivir rivers does not occupy more than 15 km², and is composed of a small depression to lagoon surrounded by low hills. After more than 20 years when the lagoon had “disappeared”, because of the infrastructure development of the zone (ditches, channels of drainage, cultures), it reappeared again in 1996. This has caused the city council as well the local ecological movement to initiate the proceedings necessary to grant suitable protection to this enclave of enormous ecological and historical value. The zoological wealth, especially birds, together with the type of vegetation that it has, indicates that the lagoon of El Gallo is a place with an important source of resources. Rationally exploited, as in previous times, it would become one of the main suppliers of foods and raw materials. The hunting and raising of birds, egg gathering, and the use of rushes and castanets for the town, would be some of the practices and habitual products for the inhabitants of recent Prehistory in the lagoon (Ruiz Mata et al., 1996).

4. Archaeological context

Archaeological investigations in the Bay of Cádiz have shown an occupation of the coastal countryside extending from Sanlúcar de Barrameda, Rota, to El Puerto de Santa María, from at least the IV millennium BC, in a Neolithic–Chalcolithic transition phase and during the Chalcolithic phase, in which there was an important population increase (Ruiz Mata et al., 1996). In this scope of countryside, one of the most interesting archaeological zones is the lagoon of El Gallo. Around the lagoon was based an assembly of towns of different times, from Chalcolithic to modern (XVI–XV AD), that offer a sequence of great interest to analyse a model of population and its historical process (Ruiz Mata et al., 1996). Among them, the towns of Bulé, Arroyo Chaparral, Campín Bajo, Cortijo de los Santos Reyes, Venta Alta, Grañina, and Pocito Chico stand out. In addition, diverse farmhouses of medieval time surround the lagoon area. From the town of Cantarranas, located in the old “portuense” western coastline, dated between 3200 and 2900 BC (Giles et al., 1993–1994; Ruiz Gil and Ruiz Mata, 1999), are towns of the IV millennium BC. The town is based on a hill, about 40 m above sea level, occupying about 10,000 m², with nuclei of rooms (bottoms of cabins) and excavated clay structures in marls (Valverde, 1993).

Out of the towns surrounding the lagoon of El Gallo, one of most important is that of Pocito Chico (Ruiz Mata et al., 1996). This is located on the south slope of the Hill of Grañina. During the different periods from initial occupation, the population has moved towards the lagoon, so that the levels pertaining to modern Andalusi time are near it, whereas those of Copper and Bronze Ages are at greater elevations and, therefore, are farther away from the present edge of the lagoon. Through a trench, a horizontal stratigraphy can be located, possibly related to oscillations of the level of the water, which at prehistoric times had to be higher. Medieval constructions in the lowest level denote a recession of the lagoon water. It is evident that the towns of the lagoon of El Gallo form an isolated assembly, with their own personality, and possibly with economic activities related to El Gallo. The natural resources were the cause of the population, which explains the concentration surrounding the lagoon. The model’s focal point is the lagoon, to which the establishments owe their existence.

5. Methods

A total of 47 palynological samples were taken from the Pocito Chico archaeological site in Structure number 2. Four archaeological levels have been described (Ruiz Mata et al., 1996): Chalcolithic, Bronze Age, Iron Age and Medieval Period.

The chemical method used for the extraction of pollen and spores, as well as non-pollen palynomorphs, with some modifications, is described by Girard and Renault-
PC-I has been divided into two subzones: 5800 years ago (cal. BP), becoming stabilised 4500–4200 that in the south of the Iberian Peninsula was reached related to the maximum of the Flandrian transgression, in human impact. The low percentages of pollen taxa microclimatic conditions in the area, as well as a decline favoured by the topographical isolation and peculiar days form hedgerows, that appear to have been representation of pollen from the conditions, in the oak (Triletes, are possibly indicating forested and humid both Pteridophyte spores, Filicales monoletes and ing of the studied area. High percentages (ca. 9%) of the existence of both cultures in the surround-
Cerealia (>5%) show significant values, indicating low amounts of trees and shrubs (Malvaceae (ca. 13%) and Cardueae (ca. 15%), with very low amounts of trees and shrubs (<10%). The main arboreal taxa are Pinus pinea type and Quercus suber type. Among the herbs, Leguminosae (ca. 10%) and Cerealia (>5%) show significant values, indicating possibly the existence of both cultures in the surrounding of the studied area. High percentages (ca. 9%) of both Pteridophyte spores, Filicales monoletes and triletes, are possibly indicating forested and humid conditions, in the oak (Q. suber) forests. The low representation of pollen from the Q. suber-type place it in relict arboreal communities, patches of which nowadays form hedgerows, that appear to have been favoured by the topographical isolation and peculiar microclimatic conditions in the area, as well as a decline in human impact. The low percentages of pollen taxa indicating salt marsh conditions (Chenopodiaceae) are related to the maximum of the Flandrian transgression, that in the south of the Iberian Peninsula was reached 5800 years ago (cal. BP), becoming stabilised 4500–4200 years ago (Lario, 1996), which would locate the regional Chalcolithic period (IV millennium BC).

According non-pollen palynomorphs, the biozone PC-I have been divided into two subzones:

- **Subzone PC-Ia**, characterised by high percentages of Glomus cf. fasciculatum (type 207), Pseudoschizaea circula, Chaetomium sp. (type 7A), and the types 7B, 16A, 55A, 92, 116 and 124. The first two are related to erosive phenomena (Van Geel et al., 1989; Pantaleón Cano et al., 1996). The ascospores of Chaetomium sp. (type 7A) are abundant in zones of strong accumulation of burned or deadwood as in anthropized sediments (López Sáez et al., 1998). Type 7B is related to the presence in the site of some Ericaceae taxa (Van Geel, 1978). Type 55A is probably an ascospore from a sordariaceous species (Van Geel et al., 1980–1981). Among sordariaceae there are many coprolites species, but some of them can also occur on decaying wood, on culms and on other herbaceous stems and leaves. The occurrence of Type 55A could be also correlated with the levels for which we assume mesotrophic conditions, and the site from this phase was dry enough to be accessible to relatively large mammals. The occurrence of Type 55A is conceivably attributable to the presence of dung as a substrate and its curve may be indicative of frequent foraging visit of herbivores in the site. Type 16A (ascospores) seems to prefer mesotrophic conditions that are usually coincident with relatively dry phases (Van Geel, 1978; Van Geel et al., 1980–1981). Type 116 (Cymatiosphaera) is an acritarch microfossil described by Pals et al. (1980), who report that Type 116 belongs to the indicators of marine influences. This type shows a preference to relatively wet conditions (Bakker and Van Smeerdijk, 1982). The presence of Type 124 is related to the abundance of some Filicales spores (Pals et al., 1980). Type 92 corresponds to fungal spores although at the moment its palaeoecological value is not known, its presence in that subzone can then be related to erosive phenomena or of manifest dryness.

- **Subzone PC-Ib**, characterised by the fall or disappearance of some of the previously mentioned non-pollen palynomorphs: Chaetomium sp., Type 7B, Type 16A, Type 92, Type 116, and Type 124. Some of them (P. circula, Type 55A, Glomus cf. fasciculatum) are present in low percentages, indicating small erosive phenomena as well as some grazing activities. Type 90 is now present, related to local ombrothrophic conditions (Van Geel, 1978; Van Geel et al., 1980–1981).

6. Pollen and non-pollen palynomorph analysis

The diagrams (Figs. 2 and 3) have been divided into five pollen-assemblages zones (PC-I, PC-II, PC-III, PC-IV and PC-V) according the archaeological context, and also into subzones using the constrained incremental sum of squares (Coniss) approach incorporated in Tilia 1.12 and Tilia Graph 1.18 and 1.12 programs (Grimm, 1992).

6.1. PC-I: Chalcolithic period

This basal zone is characterised by a very high representation of nitrophilous taxa, especially Cichorieae (ca. 75% maximum), Aster type (ca. 10%), Malvaceae (ca. 13%) and Cardueae (ca. 15%), with very low amounts of trees and shrubs (<10%). The main arboreal taxa are Pinus pinea type and Quercus suber type. Among the herbs, Leguminosae (ca. 10%) and Cerealia (>5%) show significant values, indicating possibly the existence of both cultures in the surrounding of the studied area. High percentages (ca. 9%) of both Pteridophyte spores, Filicales monoletes and triletes, are possibly indicating forested and humid conditions, in the oak (Q. suber) forests. The low representation of pollen from the Q. suber-type place it in relict arboreal communities, patches of which nowadays form hedgerows, that appear to have been favoured by the topographical isolation and peculiar microclimatic conditions in the area, as well as a decline in human impact. The low percentages of pollen taxa indicating salt marsh conditions (Chenopodiaceae) are related to the maximum of the Flandrian transgression, that in the south of the Iberian Peninsula was reached 5800 years ago (cal. BP), becoming stabilised 4500–4200 years ago (Lario, 1996), which would locate the regional Chalcolithic period (IV millennium BC).

According non-pollen palynomorphs, the biozone PC-I have been divided into two subzones:

- **Subzone PC-Ia**, characterised by high percentages of Glomus cf. fasciculatum (type 207), Pseudoschizaea
Fig. 2. Pocito Chico pollen diagram with most representative taxa: trees, shrubs, and herbs.
available now to the colonisation of the surroundings by species of the riparian forest, as well as of other herbaceous taxa such as Cyperaceae, Lemna minor t. and Nymphaea alba t. In any case, the regression of the sea would expose previously submerged zones rich in salts on the surface, allowing the installation of halophilous elements of Chenopodiaceae/Amaranthus, whose presence becomes continuous in the diagram, reaching almost 15%. A higher representation during this phase of some tree taxa (Juniperus t., P. pinea t., Quercus Ilex–coccifera t. and Q. suber t.) could be based on two main possibilities. Lesser anthropization on the surroundings could allow a greater development of the forest vegetation. Alternatively, the climate could have evolved towards conditions of greater environmental dryness. Both possibilities are reflected clearly in a much greater profusion of the cereal cultures that reach, in this part of the diagram, their maximums, and with a remarkable diminution of the percentage of Leguminosae, and therefore of the irrigated land cultures. Generally, the installation of cereal cultures is detected in the pollen diagrams in the driest phases, as at the Subboreal–Subatlantic transition, which implies a greater temperature and therefore manifest dryness (López García and López Sáez, 1994). This greater extension of the cereal cultures can be authenticated by remarkable climatic variations, mainly by greater environmental dryness. A good representation of this type of vegetation is observed in the parallel maxima of Cerealia and Chenopodiaceae/Amaranthus and some halophilous Gramineae. The Chenopodiaceae mark the development of halophilous vegetation in the territory at this time, possibly suggesting greater environmental dryness and consequent salt concentration in the soils.

During this phase some small erosive phenomena are detected by the presence of P. circula and Glomus cf. fasciculatum, mainly in the subzone PC-IIa. Fire events are well represented by the presence of some charcoal fungi: Chaetomium sp. and possibly Coniochaeta xylariiispora (Type 6). Type 16A is indicative of relatively dry phases (Van Geel, 1978; Van Geel et al., 1980–1981). The abundance of Type 55A is again indicative of grazing activities (mainly into subzone PC-IIa), also implying the appearance of some other indicators.
including *Plantago lanceolata* t. and *P. major/media* t. (Behre, 1981; Galop, 1998). Some marine influences are well defined by the presence of Type 116.

### 6.3. PC-III: Final Bronze Age–Iron Age transition

During the Final Bronze Age, the lagoon of El Gallo was located between two important nuclei of population: the salt marshes of the Guadalquivir with the tartesic town of Mesas de Asta; and the Guadalete River, in whose right margin was initially located the pre-Phoenician town of Las Cumbres, and later the site of Castillo de Doña Blanca (Ruiz Mata et al., 1996). This high density of the prehistoric population, as much surrounding the salt marshes as along the Bay of Cádiz, has its faithful reflection in the pollen diagrams as indicated by a new increase of the anthropization of the surroundings of the Pocito Chico site, implying a substantial increase in nitrophilous taxa: Cichorioideae (maximum of 60%), Cardueae (20%, PC-IIIc) and Boraginaceae (PC-IIIa). The transition, between the end of the Bronze Age and the beginnings of the Iron Age, suggests greater development of the riparian forest, mainly of the alder grove, against a manifest deforestation of *Ulmus* forests. Unlike the previous phase, during this zone PC-IIIa significant reduction of the percentage of Cerealia takes place. The colonisation of the territory by nitrophilous formations reaches new maximums here. As in the previous period, the evolution followed by the cereal cultures can be explained according to the dynamics between the more saline and the fresher coastal marshes. The diminution of the percentage of Cerealia parallels that of Chenopodiaceae/*Amaranthus*, and on the other hand, also relates to the significant increase of those pollen types indicative of the fresher coastal marsh, such as *Asphodelus albus* t., *Cannabis/Humulus* or Cyperaceae.

Some erosive phenomena as well as fire events are detected from non-pollen palynomorphs, characterised by the presence of *P. circula, C. xylariispora* (PC-IIIc), *Chaetomium* sp. (maximum in PC-IIIb) and *Glomus cf. fasciculatum*. Types 8A and 8B, possibly some *Myrothryum* sp. (Van Geel, 1978), are related to some macroscopic remains of *Eriophorum vaginatum* or other marshy taxa. A very well-defined grazing phase is detected in the subzone PC-IIIb by a maximum of Type 55A. Type 74 is present but it is always rather rare in the Pocito Chico section. The subzone PC-IIIc is well characterised by maxima of some types: *Coniochaeta cf. ligniaria* (type 172), Type 173, Type 190, Type 420 and mainly Type 203 (which reaches a maximum in excess of 100% of the pollen sum). Type 173 is positively correlated with some type of *Carex* vegetation (Van Geel et al., 1989). Type 203 (ascospores) indicates terrestrial conditions at the sampling site during subzone PC-IIIc (Van Geel et al., 1989). *Coniochaeta cf. ligniaria* (fungi spores) could be correlated with fire events, because this microfossil is usually present in sediments with a high concentration of charcoal (López Sáez et al., 1998), parallel to the curves of *Chaetomium* sp. and *C. xylariispora*. These types of fire phenomena during the subzone PC-IIIc can be put in relation to cattle activities as well as with phenomena of burns and deforestation to obtain a greater territory for the cattle. Type 190 corresponds to ellipsoid cocoons, possibly cocoons of *Herpobdellidae* or *Tubificidae*, aquatic carnivorous annelids (Van Geel et al., 1982–1983). The fungal spores of Type 420 were probably produced by a representative of the Sordariaceae; they are found together with a maximum of Type 55A, indicating grazing activities during this chronological moment, possibly below euphotic to mesotrophic conditions (Van Geel et al., 1982–1983).

### 6.4. PC-IV: Andalusí period (Middle Age)

The Andalusí period (XIII–XIV centuries AD) includes the largest levels of anthropization of the pollen diagram (Fig. 2). Cichorioideae reaches its maximum values (ca. 80%) in subzone PC-IVa. Also beginning here is the increase of *Aster* t., continued in the later cultural phase. Cardueae is diminished here with respect to biozone PC-III. These facts, as a whole, would denote an anthropization which was hard enough on the surroundings, implying the operation of the territory under diverse economic and social parameters, without resulting in its abandonment. The percentages of cereal in this period are quite low (<1%), which would indicate that it was not necessarily important in the local culture. In fact, the high percentages of nitrophilous taxa would allow us to suggest that the territory of the lagoon of El Gallo during the Andalusí occupation would be occupied fundamentally by anthropic pastures dominated by Cichorioideae, *Aster* t., *Labiatae, Boraginaceae, Dipsacus fullonum* t., and *Malvaceae*, with cereal relegated to a merely testimonial presence or present only regionally. In any case, during the Andalusí period a new maximum for *Plantago lanceolata* t. is observed (subzone PC-IVb), a typical companion of cereal cultures (Behre, 1981; Galop, 1998), which indirectly would allow us to continue maintaining the hypothesis of the local culture of the cereal, although over much lesser extent than during the Final Bronze Age–Iron Age transition, and much less still than in the Chalcolithic–Bronze Age transition.

During the subzone PC-IVa, the first appearance of Type 2 (*Gelasinospora cf. reticulatispora*) is indicated, as well as a small maximum for *Rivularia* t. (Type 170), indicating relatively dry and oligotrophic conditions (Van Geel et al., 1989). This possibly suggests greater dryness, as also indicated by the appearance of *Ephedra dystachia* t. for the first time, possibly corresponding to
the Low-Medieval Warm Episode (1000–1300 AD) (Ruiz Zapata, 1999). In fact, the Andalusí occupation is the first time when a greater development of the typical vegetation of the salty salt marsh takes place (Chenopodiaceae/Amaranthus), due to a greater concentration of salt in the soil.

6.5. PC-V: XV–XVI centuries AD

During this phase, cereal is completely absent, even though P. lanceolata t. returns to show a new maximum, accompanying a slight increase of the anthropic taxa in subphase PC-Vb. The pollen data do not allow us, during this period, to affirm the culture of the cereal. Trees and shrubs are similar to the previous phases PC-III and PC-IV, except for Fraxinus which shows an increase in the subphases PC-IVb and PC-Va. The percentage of anthropic taxa, mainly the Cichorioideae and Cardueae, diminish sensibly with respect to the Andalusí period. Together, the data suggest a hypothesis of much reduced anthropic pressure, mainly in the surroundings of riparian forests. However, the absence of cork oak and, therefore, its total deforestation cannot be affirmed for the Q. ilex or Q. coccifera forests, although these are represented minimally during subphase PC-Va. The complete absence of Quercus forests during subphase PC-Vb could be related to the Little Ice Age (XVI–XVII centuries AD) (Ruiz Zapata, 1999). A significant increase of the Mediterranean pines is not observed, suggesting the non-existence of anthropic reforestation for the centuries treated in this period, even though this pollen type continues to be minimally present, indicating its natural occurrence. Its location was limited to coastal dunes, and thus in spite of its great dispersion, this type of pine grove is not greatly represented in the pollen diagram. Among the non-pollen microfossils, we have not detected any indication of grazing activities or fire events.

7. Conclusions

The landscape that is described from the paleoecological record does not differ in broad strokes from the present one. However, guidelines of evolution of the vegetation can be recognised that are contemporary with different cultural periods.

Thus, during the Chalcolithic period the first passage takes place towards the cultivation of cereal, under conditions of extensive anthropization of the surroundings, with an ample development of nitrophilous formations and some grazing activities. Diaz del Olmo (1989) has proposed that the cork oak (Q. suber) was more suitable than the arboreal species for the precostal zones of vertisols during these periods. If this were so, the surroundings of the lagoon of El Gallo would show a landscape very near to that proposed by Ruiz Mata et al. (1996). The assemblage of non-pollen palynomorphs informs us that the Chalcolithic period was a initial dry and mesotrophic phase (PC-Ia), with high marine influences remaining on the site and very important erosive phenomena possibly related to fire events or to the evolution of the Flandrian transgression (Gracia et al., 1999).

The Chalcolithic–Bronze Age transition is characterised by the greater representation of Cerealia, mainly during the phases of greater dryness and extension of the saline salt marsh. The dynamic relationship of the saline and fresher coastal marsh is observed. The beginning of regressive marine phases would explain this dynamic, as well as the progression of the riparian forest. We can confirm the natural presence of native pine groves during this period, possibly of P. pinea on coastal dunes. Erosive phenomena and fire events at this level could be explained according to agriculture activity as well as sea-level evolution. Grazing activities have been also reported for this cultural transition.

The Final Bronze Age–Iron Age transition supposes a greater development of the typical vegetation of the fresher coastal marsh (mainly Cyperaceae) and a reduction of cereal culture, although these remain, next to a new recolonization of the territory by ample nitrophilous formations of anthropic origin, whose high percentage indicate a remarkable increase of the human population in the region. This evolution of the sea level, following a regression process, is still the cause of some erosive phenomena as well as a greater extent of terrestrial areas. At the end of this phase (PC-IIc) a high degree of cattle activities have been detected, that could be put in relation with both burning and deforestation phenomena to obtain a greater territory for the cattle.

The Andalusí period supposes a high anthropization of the surroundings of the lagoon of El Gallo, with a great development of nitrophilous pastures. The extent of cereal cultivation is not very clear, at least locally, during this phase of greater dryness that would possibly correspond to the Low-Medieval Warm Episode.

During the last part of the diagram (centuries XV and XVI AD.) the environmental anthropization diminishes sensibly with respect to the Andalusí occupation, including the development of riparian forests (mainly of Fraxinus) and the disappearance of the cork oak grove. In addition, native pine groves are regelated to specific habitats. During this phase, the culture of cereal has not been detected.

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