Journal of Archaeological Science: Reports 12 (2017) 755–769

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: www.elsevier.com/locate/jasrep

Reconstructing past landscapes of the eastern plain of Corsica (NW Mediterranean) during the last 6000 years based on molluscan, sedimentological and palynological analyses

Andrés Currás [a],*, Matthieu Ghilardi [a], Kewin Peche-Quilichini [b], Nathalie Fagel [c], Matteo Vacchi [a], Doriane Delanghe [a], Philippe Dussouillez [a], Claude Vella [a], Jean Michel Bontempi [d], Jean-Claude Ottaviani [d]

[a] *Aix-Marseille Université, CEREGE CNRS-IRD UMR34. Aix en Provence, France*
[b] *Department of Archaeology of the Mediterranean Societies. UMR 5140, University of Montpellier, France*
[c] *University of Liège, Belgium*
[d] *Conseil Général de la Haute-Corse (CG2B). Museum of Aleria, Corsica, France*

ARTICLE INFO

Article history:
Received 5 February 2016
Received in revised form 29 August 2016
Accepted 28 September 2016
Available online 11 October 2016

Keywords:
Pollen analysis
NPP
XRD
Geochemistry
Malacology
Corsica
Terrina
Chalcolithic
Palaeoenvironment
Cultural landscapes
Land-use
Lagoon

ABSTRACT

The Aleria Del Sale lagoon in Eastern Corsica provides an excellent location for palaeoenvironmental research in order to better understand the palaeogeography of the island's coastline and to disentangle the role of human and natural factors in landscape evolution. A borehole drilled to a depth of 5.30 m was located a short distance from one of the most relevant archaeological sites on the island. Environmental reconstruction methodologies included mollusc identification, sedimentological and palynological analyses combined with robust chronological control provided by 8 radiocarbon dated samples allowing the reconstruction of the coastal lagoon and the surrounding vegetation history over the last 6 millennia. The Aleria Del Sale lagoon was formed around 3500 cal BCE, when sand bars linked to the deltaic progradation of the Tavignano River enclosed shallow marine waters. Pollen data reveals the existence of a semi-open landscape at this time in which human activity was widespread. The open lagoon shifted into a confined lagoonal system around 2200 cal BCE and this change in the feature was coeval with a notable decrease in human disturbance of the area and the end of the Chalcolithic Terrina occupation. The following period saw shrub and woodland regeneration and the brackish environment continued until the 19th century CE. Human activity did not have a significant impact on the vegetation until the Genoan Period. The evolution of the vegetation history and the diverse human activity across the Eastern Plain during the Bronze Age until the Genoan Period is furthermore explored in this paper. The uppermost layers of the lithostratigraphic sequence reflect the transformation of local conditions in response to recent (20th century) drainage operations.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

In recent decades, work addressing past relationships between humans and the environment have flourished across the Mediterranean (Beffa et al., 2016; Di Rita and Melis, 2013; Calò et al., 2012; Tinner et al., 2016; Mercuri et al., 2012). This is not surprising considering that the region provides a long-term history of human occupation which renders past analogues for present-day issues often linked to Global Change, such as the repercussions of climate variability on human adaptability, ecological risk and resource management (Anderson et al., 2007; Dearing, 2006). Moreover, the study of past socio-environmental interactions has also become of great interest from the archaeological viewpoint, as it has significantly contributed to improve our knowledge on the development of socio-environmental interactions and the cultural landscapes linked to them, as formerly proposed by Berglund (1991).

Despite being the fourth largest island in the Mediterranean, the evolution of the socio-environmental interactions in Corsica (see Fig. 1A) and the development of past cultural landscapes are issues that have not been directly addressed. In contrast, other perspectives have often been adopted. Among them, the reconstruction of vegetation communities since the Late Glacial on the basis of the analysis of fossil pollen (Reille, 1975, 1977, 1984, 1990, 1992b; Reille et al., 1999) and charcoal remains (Carcaillet et al., 1997) should be highlighted. These pioneer works successfully addressed the history of vegetation dynamics across the island with particular regard to the relationships established between plant communities. However, this research is partially constrained by the fact that chronological control was often insufficient to establish refined correlations between vegetation change, climate and human activity.

---

* Corresponding author.
E-mail address: andrescurras@gmail.com (A. Currás).

http://dx.doi.org/10.1016/j.jasrep.2016.09.016
2352-409X/© 2016 Elsevier Ltd. All rights reserved.

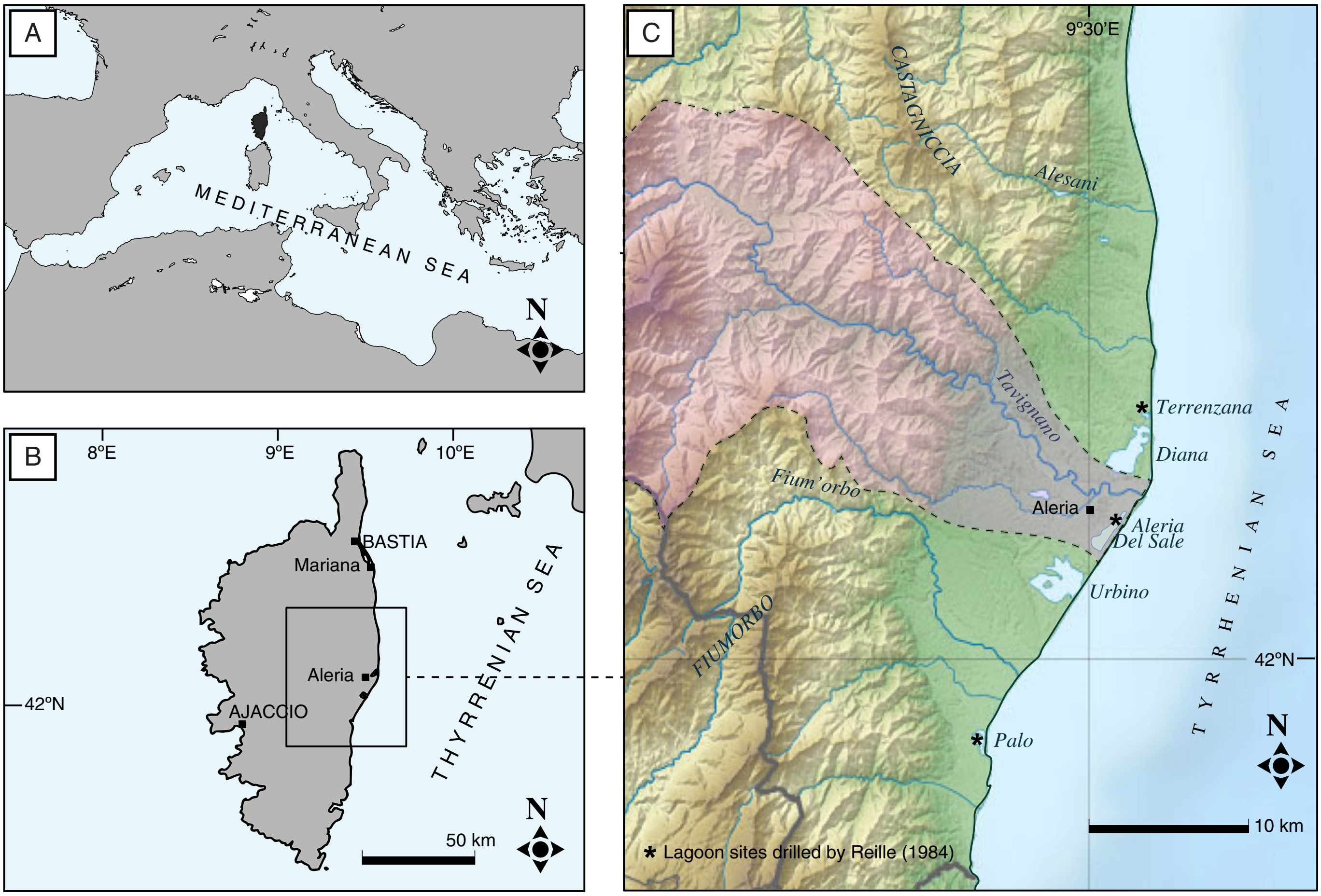

Fig. 1. Map of Corsica and location of the Eastern Corsican Plain. Picture A shows the location of Corsica (in dark gray) in the western Mediterranean. Pictures B and C show the main cities and geographical features of Corsica and the Eastern Plain, including the approximate drainage basin of the Tavignano River (in pink).

For instance, the Eastern Plain of Corsica (Fig. 1B and C) was extensively studied by Reille (1984) on the basis of sedimentary sequences from several coastal lagoons (Aleria Del Sale, Terrenzana and Palo, Fig. 1C). The results of this research demonstrated the dominance of *Erica arborea* maquis and mesic vegetation of deciduous *Quercus* and *Taxus* during the Mid Holocene, prior to the later spread of holm oak since 3700 ± 190 BCE uncal (4492 ± 441 cal BCE, 2σ). Reille argued that the development of holm oak and subsequent sclerophyllous vegetation was linked to the onset of drier mediterranean-like climatic conditions (Reille, 1992b). However, he also suggested that the spread of human activity during the Neolithic period in Corsica (approximately 6000–3000 BCE) might have contributed to this vegetation change, particularly on the Eastern Plain, through the clearance of the deciduous trees (Reille, 1990, 1992b; Reille et al., 1999).

By taking into account Reille's hypothesis, this paper aims to provide new and more refined insights into the past socio-environmental relationships which occurred across the Eastern Plain of Corsica, a particularly interesting area of the island considering both its 6 millennia of human occupation (Camps, 1988) and the presence of diverse coastal lagoons containing palaeoenvironmental archives (Reille, 1984). Issues such as the degree and timing of the vegetation shift during the Neolithic and Chalcolithic periods are investigated. The evolution of the landscape during the subsequently chronologically-defined cultural periods are also addressed. As part of these investigations, special attention is paid to the local palaeogeography of the Aleria Del Sale wetland and its development as a coastal lagoon and evidence for associated human impact. In order to elucidate these palaeoenvironmental topics, multi-proxy sedimentary analyses of the Aleria Del Sale lagoon have been conducted. The evolution of the lagoon is addressed on the basis of mineralogy (including X-Ray Diffraction, Organic Matter content, Loss-of-Ignition), grain size distribution, geochemistry and mollusc identification, while pollen and non-pollen-palynomorphs are used to reconstruct the past vegetation changes. Under this framework, supplementary research regarding the evolution of the shoreline and past sea-level changes has been conducted, the results described in Vacchi et al. (2016a). As outlined above, addressing any links between environmental change and human activity is strictly dependent on the development of sound chronological frameworks. Consequently, priority has been given to reconstruct a reliable age-depth model on the basis of AMS radiocarbon dates.

2. Geographical setting

2.1. The Eastern Plain and Aleria Del Sale Lagoon

The Eastern Plain (so-called Aleria Plain) is a lowland area with occasional low hills located on the east-central part of Corsica (Fig. 1B and C). The Plain is bounded by the Alesani River to the north, the Castagniccia and Fium'orbo mountain ranges to the west, the Solenzara River to the south and the Tyrrhenian Sea to the east (Fig. 1C). It extends about 45 km from north to south and 10 km from west to east with the altudinal range from sea-level to 90 m asl from west to east. The total area is about 320 km^2 (Fig. 1B). In the inner part of the plain, several rivers drain westwards to the sea. Among them, the Tavignano River (ca. 90 km long with a 800 km^2 catchment area) is the longest one in Corsica after Golo River (Vella et al., 2016) and forms a delta north of the Aleria Del Sale lagoon. The sedimentary substrate of the plain consists of

Cenozoic marine sediments, Miocene sandy clays and Quaternary alluvial sediments (Conchon, 1989, 1999).

Several coastal swamps, salt-marshes and lagoons are today separated from the open sea by sandy spits occurring parallel to the coastline. Among them, Aleria Del Sale and Terrenzana originated as former estuarine environments that were enclosed by progradation of deltaic sand barriers and subsequent infilling of inner depressions (Conchon, 1999). The Aleria Del Sale lagoon (circa 3 km long by 1 km wide) is located between three bedrock hills, the mouth of the Tavingano River and a coastal sandy barrier (Fig. 2). Infilling is promoted by rainfall and by the increase of the water-table linked both to the Tavignano River and to the Mio-Pliocene substrate (Lorenzoni et al., 1995). Aleria Del Sale is currently characterized by a swampy environment with the water table no deeper than 1 m during the wet season. The salinization of the lagoon is primarily related to the inundation of seawater through the littoral barrier and is controlled by the seasonal droughts during the spring and the summer. This phenomenon explains the lagoon's toponym, which means “salty” in the Corsican language.

The oldest reference to the lagoon dates back to the 17th century CE, when the Genoan authorities planned to transfer water from the Tavignano River to the lagoon in order to prevent the locals from exploiting precipitated salt deposits during the dry season, to enable irrigated agriculture around the margins and to promote fishing (Salone, 1988; Salone and Amalberti, 1992). In the late 19th century anti-malaria measures were implemented across the Eastern Plain of Corsica, involving the drainage of wetlands and their replacement by cultivated fields. In Aleria Del Sale (Dubray and Roux, 1984) a ditch was built to sever the connection with the sea through the sand barrier. Several channels were dug so that the water inside the lagoon could be drained to the Tavignano River and to the small Ziglione lagoon southwards (Fig. 2). Aleria Del Sale was partially drained between 1915 and 1935, resulting in a major transformation of the hydrological environment.

2.2. Vegetation

The Eastern Plain of Corsica is situated in the thermo-mediterranean biogeographical zone, below 100 m asl. Historically, the influence of the upper meso-mediterranean maquis shrub, which can attain forest-like character (Reille et al., 1999), was widespread across the island near the coast. Nowadays the Eastern Plain is an intensively human-managed area where vineyards, olive groves, citrus trees plantations and kiwi fruit-fields produce a bocage landscape. However, small patches of *Erica arborea*, *Arbutus unedo*, *Quercus ilex* and *Quercus suber* are still visible, providing evidence of the formerly extensive maquis and forest community. Sclerophyllous vegetation such as *Pistacia lentiscus*, *Juniperus phoenicea*, *Phillyrea latilifolia*, *Viburnum tinus*, *Myrtus communis*, *Olea europaea* and *Rosmarinus officinalis* are furthermore common within the shrub communities of the Eastern Plain (Gamisans, 1999).

The saline environment of Aleria Del Sale has allowed the spread of halophilous plants such as *Sarcocornia fruticosa*, *Arthrocnemum macrostachyum*, *Halimione portucaloides*, *Suaeda maritima* and *Hordeum marinum* (Gamisans, 1999; Lorenzoni et al., 1995). In areas of higher moisture availability, *Phragmites australis*, *Scirpus maritimus* and *Juncus subulatus* can be found. On the margins of lakes, trees and shrub vegetation comprising *Fraxinus angustifolia*, *Prunus spinosa* and *Tamarix*

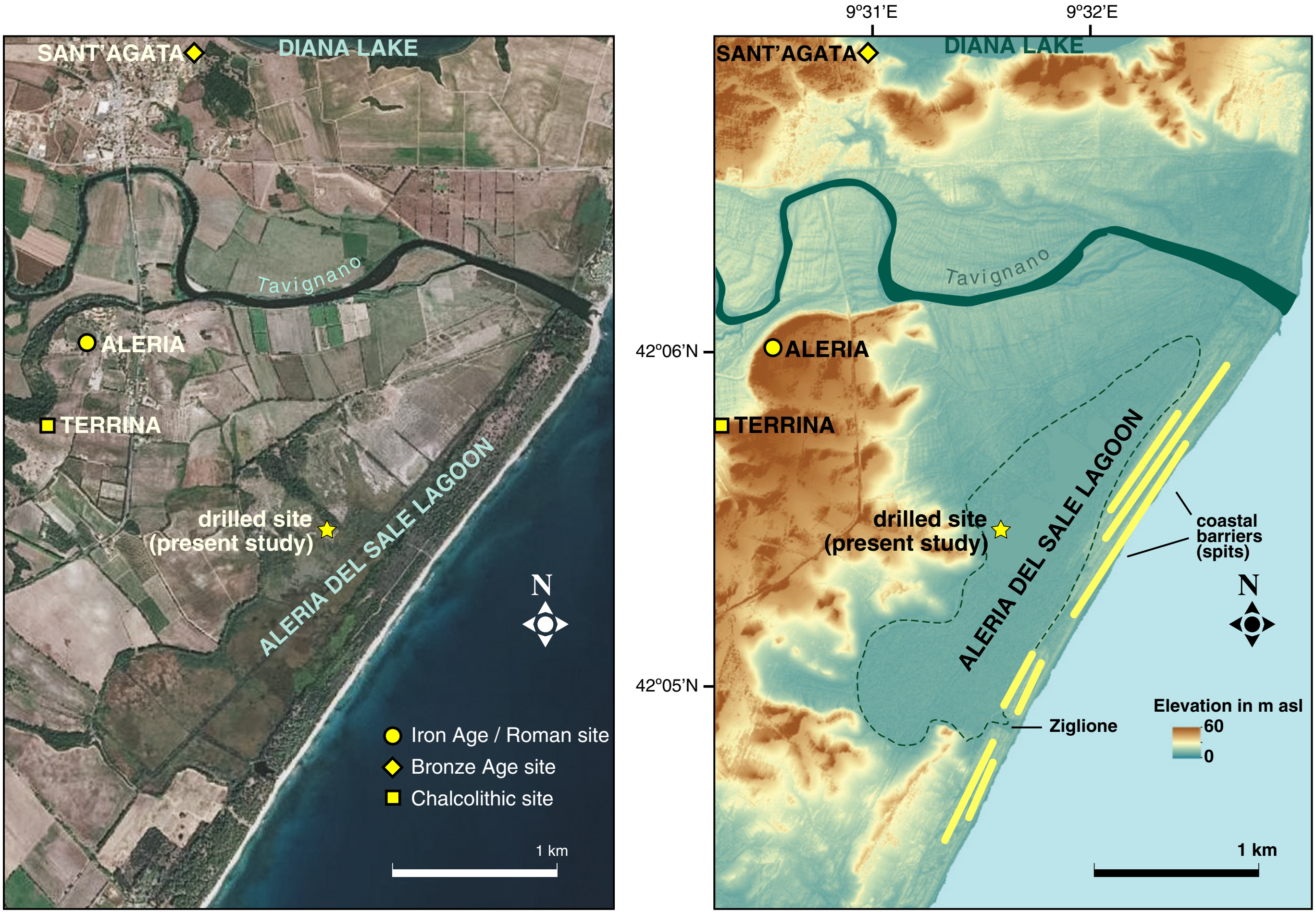

Fig. 2. Aleria Del Sale lagoon, drilling site and location of the main archaeological sites in the Eastern Plain of Corsica. Picture 1 shows the elevation data derived from LIDAR survey. Picture 2 shows a satellite photograph of the area (notice the drainage channels in the lagoon).

africana are found. *Paspalum*, *Plantago major* and *Trifolium fragiferum* are the main grassland communities of the Aleria Del Sale area.

3. Human occupation from Neolithic to modern times

During the 3rd millennium BCE the Terrinian Culture (Late Neolithic–Chalcolithic period) spread across the Eastern Plain of Corsica. Terrina, the partially-excavated eponymous archaeological site (Fig. 2), is believed to have played a prominent role as a central site for the control of the surrounding territory on the Eastern Plain (Camps, 1979, 1988). The dwelling was likely occupied for >1000 years (Pearce, 2013) and has supplied some of the earliest evidence of copper metallurgy in the western Mediterranean (Camps, 1979, 1988).

The human occupation of the Eastern Plain during the 2nd millennium BCE (Bronze Age period) is documented near the coastal lagoons of Palo, Urbino and Diana (Peche-Quilichini and Vidal, forthcoming) by the archaeological sites of Mignataghja, Pinia, Mar'e Stagnu and Sant'Agata (Roth and Congés, 1976). Archaeological evidence becomes more scarce during the late Bronze and Iron Age (early 1st millennium BCE), a trend which seems general for the northern half of the island (Peche-Quilichini, 2012).

The Etruscan village of Alalia developed as the main human settlement of the Eastern Plain from the 6th century BCE. The same city, called Aleria by the Romans, became a strategic point from which the colonization of the whole island was carried out (Jehasse, 1998).

The city of Aleria, together with the northern village of Mariana, located further north (Fig. 1B), played an important role in the spread of Christianity during late Antiquity. The historical evolution of the area in the Early Middle Ages was characterized by political and economic instability, according to Pergola (2001). After the 11th century CE the Eastern Plain and the whole island came under Pisan and Genoan rule. During the Modern Period there is reference to both the human exploitation of salt and molluscs from the coastal lagoons as well as documentary evidence for the high frequency of malaria on the coast (Jaujou, 1954).

4. Materials and methods

In September 2014 fieldwork to recover sediments was undertaken at the Aleria Del Sale lagoon (42°5′35.01″N 9°31′28.17″). A borehole was drilled to a maximum depth of 530 cm below the surface, using a vibracorer. Individual core sections were refrigerated before being split for lithological description and sampled for radiocarbon dating. Sampling for multi-proxy analyses were performed every 5-cm along the core.

4.1. Radiocarbon dating

The chronostratigraphy of the cores was determined by 8 AMS radiocarbon dates derived from *in situ* lagoonal shells (*Cerastoderma glaucum*), charcoal and plant remains. These analyses were performed at the Poznan Laboratory for Radiocarbon (Poland). Lagoonal samples were corrected for the marine reservoir effect ($\Delta R = 46$, error $\Delta R = 40$; Siani et al., 2000), although it must be emphasized that the real (palaeo) reservoir effect —still unknown— varies widely in different marine environments, such as lagoons, coastal swamps and littoral zones (Siani et al., 2000). ^{14}C ages were subsequently calibrated using the Calib 7.1.0 Software (Stuiver and Reimer, 1993) in conjunction with the Marine 13 and IntCal 13 calibration curves (Reimer et al., 2013).

4.2. Loss-on-ignition and grain-size analyses

The loss-on-ignition (LOI) measurements were based on the method of Heiri et al. (2001) and were performed at the University of Liège (Belgium). Sediment samples of 1 g ± 10 mg were taken at 10-cm intervals throughout the core. After drying at 105 °C to constant weight, the samples were heated to 550 °C for 4 h to estimate the organic content. A second heating phase, to 950 °C for a further 2 h, was undertaken to assess the proportion of carbonates. The formula used to calculate the equivalent $CaCO_3$ content is: $CaCO_3\% = 2.27 \times CO_2\%$, where 2.27 (50/22) is the molecular conversion factor.

Grain-size determinations were conducted at CEREGE. Samples were collected at 5-cm intervals. Many samples were fine grained with a general grain size <2 mm. Organic matter was removed prior to analysis (Buurman et al., 1996; Fullen et al., 1996; Scott-Jackson and Walkington, 2005; Wang et al., 2006), and the samples were dispersed using 0.3% sodium hexametaphosphate. The grain-size distribution was measured using a Beckman Coulter LS 13320 laser granulometer with a range of 0.04 to 2000 μm, in 132 fractions. The calculation model (software version 5.01) uses the Fraunhöfer and Mie theory. For the calculation model, water was used as the medium (RI = 1.33 at 20 °C), a refractive index in the range of that of kaolinite for the solid phase (RI = 1.56), and absorption coefficients of 0.15 for the 780-nm laser wavelength and 0.2 for the polarized wavelengths (Buurman et al., 1996). Samples containing fine particles were diluted, measuring between 8 and 12% of obscuration and between 45 and 70% PIDS (Polarization Intensity Differential Scattering) obscuration.

4.3. Mollusc identification

All sediment samples were wet-sieved through a 0.3 mm wire mesh screen and air dried at room temperature. The residue was examined under a binocular microscope and all identifiable shells and characteristic fragments were collected and curated in separate plastic tubes. Identified molluscan shells were subsequently assigned to assemblages according to the Péres and Picard (1964) and Péres (1982) classification system. The different depositional environments found along the core were determined by comparing the mollusc assemblages with the grain size and geochemical analyses. A further description of the different facies and the palaeoenvironment reconstruction is provided by Vacchi et al. (2016a).

4.4. Mineralogical analysis

The mineralogical composition of the sediment was analysed using X-ray diffraction (XRD) of a non-oriented powder. For each sample an aliquot of a few grams of total sediment was used. The sediment was dried at 40 °C and then ground by hand using an agate mortar. The powder was sieved at 150 μm and placed at the back of the sample holder. This protocol was proposed by Moore and Reynolds (1997) in order to limit any preferential orientation of the minerals. The apparatus used was a Bruker D8-Advance Eco 1 Kw diffractometer equipped with a ceramic X-ray tube (Copper Kα radiance, $\lambda = 1.5418$ Å, V = 40 KV, I = 25 mA) with Lynxeye Xe energy dispersive detector in the laboratory of Argiles, Géochimie et Environments sédimentaire (AGEs) at the University of Liège (Belgium). The diffraction pattern is recorded for diffraction angles between 2 and 30° 2 θ. The step size was 0.02° and the time per step was 0.25 s. The primary optic is motorized in order to illuminate a fixed sample length whatever the angular position (16 mm). Each mineral is identified by its diffraction pattern in the bulk powder XRD diagram. Semi-quantitative estimation of each mineral is based on the height intensity of a diagnostic peak (d in Å) multiplied by a correction factor (CF) according to the method proposed by Cook et al. (1975) and Boski et al. (1998). In order to apply the published correction factors, each XRD spectrum was first corrected by simulating a fixed aperture of the slot using the Eva software. The corrected intensities of all identified minerals are summed and the relative percentage of each mineral was calculated with respect to an amount reduced to 100%. A trace mineral is present if recorded at a concentration of ≤3%. The error is ~5–10% or more for minerals with a low abundance (<20%).

4.5. Geochemical analysis

The Pb radiogenic composition and the content of selected trace elements were measured by MC-ICP-MS and ICP-MS of the carbonate-free <63 μm fraction of the sediment. The analytical protocol followed Weis et al. (2006). For each analysis, around 100 mg of bulk sediment were ignited in an oven for 6 h at 550 °C to remove all organic matter by combustion. After calcination, sediment dissolution was carried out in a class-100 clean laboratory at ULg. The samples were dissolved on a hot-plate (125 °C) in 4 ml of HF (40%, 23 N) and 1 ml of HNO_3 (65%, 14 N). For trace elements, the solution was evaporated to dryness and the residue was re-dissolved in 2 ml of HNO_3 (0.05 N). The analysis was performed at the Royal Museum for Central Africa in Tervuren (Belgium). Measurements of international geostandards allowed precision estimates better than 5% at the 2σ level. Pretreatment for Pb isotope analysis involved evaporating the solution to dryness and re-dissolving the residue in 2 ml of HCl (6 N). All acids were of analytical reagent grade, further purified by sub-boiling distillation in PTFE vials. After evaporation, the samples were dissolved in 500 ml HBr 0.8 N and loaded on a HCl-preconditioned column with AG1-×8 (200–400 mesh) exchanging resin. Most cations were first eluted by 4 ml of HBr 0.8 N. Subsequently Pb was eluted using 2 additional ml of HCl 6 N. The Pb-enriched solution was evaporated and kept in a Teflon vial until measurement. The Pb isotope composition was determined in static wet (Pb) mode on a Multi Collector-Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS) Nu plasma at ULB in Brussels. Mass fractionation for Pb was corrected using Tl as an internal standard. The instrumental drift was controlled by standard bracketing using NBS981 standard data (Galer and Abouchami, 1998). Repeated standard measurements (for NBS981: $^{208}Pb/^{204}Pb$ 36.7130 ± 0.0032, $^{207}Pb/^{204}Pb$ 15.4958 ± 0.0012, $^{206}Pb/^{204}Pb$ 16.9390 ± 0.0012, $n = 41$) are consistent with the recommended values ($^{208}Pb/^{204}Pb$ 36.7219 ± 44, $^{207}Pb/^{204}Pb$ 15.4963 ± 16, $^{206}Pb/^{204}Pb$ 16.9405 ± 15) and are in agreement with the laboratory long term values ($^{208}Pb/^{204}Pb$ 36.709 ± 0.021, $^{207}Pb/^{204}Pb$ 15.4951 ± 0.0066, $^{206}Pb/^{204}Pb$ 16.9392 ± 0.0006, $n = 350$; $^{143}Nd/^{144}Nd = 0.511946$, $n = 750$).

4.6. Pollen and non-pollen palynomorphs

Pollen samples were analysed at the CEREGE laboratory and treated following standard preparation procedures, including treatment with HCl, sieving at 200 μm, treatment with HF, KOH and acetolysis, and mounting in glycerin jelly (Fægri and Iversen, 1989). At least 350 terrestrial pollen grains were counted and identified at ×400 magnification with reference to published illustrations and morphological keys (Reille, 1992a, 1998a, 1998b). Non-pollen-palynomorphs (NPPs) were also identified during pollen counts. The determination of Cerealia pollen followed Beug (2004).

Pollen and NPPs taxa were plotted against calibrated age using the dates provided by the age-depth model. Pollen percentages were calculated as percentages of total land pollen, excluding aquatic plants, spores, undetermined pollen and local taxa such as Cyperaceae. NPPs percentages were calculated with reference to total land pollen (Blackford et al., 2006). Palynological indicators of human activity were defined from published literature (Behre, 1981, 1986; Bottema and Woldring, 1990), and mainly include Cichorioideae, Asteroideae, *Plantago lanceolata*-type, *Polygonum aviculare*-type, *Centaurea*, *Trifolium* and *Rumex*. Coprophilous fungal spores such as *Sporormiella*, *Sordaria*, *Tripterospora* and *Podospora* are considered as indicators of grazing activity (Ahmed and Cain, 1972; Blackford and Innes, 2006; van Geel and Aptroot, 2006; Ejarque et al., 2009; Mazier et al., 2009; Cugny et al., 2010). Pollen zone boundaries were defined using Constrained Incremental Sum of Squares cluster analysis implemented by CONISS (Grimm, 1987). Calculation of pollen concentration, expressed in number of grains per gram, has been included to refine the interpretation of percentage variability.

5. Results

5.1. General stratigraphy and chronology

The results of the radiocarbon dating are shown in Table 1. A smoothing spline age-depth model (Fig. 4) was constructed by using R software and the Clam package (Blaauw, 2010). Eight radiocarbon dates and one hypothetical date at the upper part of the sequence were used to construct the age-depth model. The hypothetical date is based on the documentary evidence regarding the drainage of the lagoon (Lorenzoni et al., 1995; Jaujou, 1954; Dubray and Roux, 1984), a process that occurred in an undetermined moment between the late 19th and the mid-20th century CE. These drainage works have been correlated with the sand layer identified in unit D (see below). In order to obtain a reference date, we have made an assumption and considered a sample at 60 cm depth as a marker of 1900 CE to construct the age-depth model. Subsequently, we have associated the samples located above 35 cm depth with the later 20th century CE.

Based on the mollusc identifications and the sedimentological and geochemical analyses, 5 main units (Fig. 3) were identified and are described as follows:

Unit M (525–410 cm, until 3500 cal BCE) consists of homogeneous medium to coarse gray sands. The modal index values range from 600 to 1000 μm while the mean grain-size fluctuates between 500 and 600 μm. The fine fraction (<63.4 μm) is poorly represented, comprising 15–30% of the total. Macro and micro fauna are rare and only occur in the upper part of the unit. Shell fragments, mainly consisting of large pieces of reworked *Cerastoderma glaucum* and, in minor terms, of *Bittium recticulatum* were identified along this unit. Unit M is characteristic of a marine environment with high energy of deposition.

Unit L (410–180 cm, 3500 cal BCE–2200 cal BCE) consists of very fine particles, the modal index and mean grain-size of which exhibit similarly low values, ranging from 10 to 20 μm and interpreted as clay/clayey silts. Based on the mollusc assemblages and the organic matter content, 3 sub-units can be distinguished:

> sub-unit L1 (410–350 cm) is mainly characterized by a high organic matter content, generally between 5 and 6%. The mollusc assemblage shows a major presence of the lagoonal shell *C. glaucum* and sparse evidence of broken *B. reticulatum* shell.
>
> sub-unit L2 (350–300 cm) consists of stiff clays in which the organic matter content increases from the bottom (1%) to the top (6.5%). Small (< 5 mm) intact Hydrobia acuta occur, together with *C. glaucum* lagoonal shells.
>
> sub-unit L3 (300–180 cm) is composed of organic clays, with the organic matter content generally constant at around 5%. Large intact lagoonal shells of *C. glaucum* occur together with sparse *H. acuta* as well as with plant remains and charcoal fragments.

Unit CL (180–65 cm, 2200 cal BCE–1800 cal CE) consists of white to gray clays with the organic matter content decreasing from the bottom (7%) to the top (3.5%). Evidence of oxidation in the form of orange to brown mottles is present throughout. The mollusc assemblage indicates the almost exclusive presence of juvenile *C. glaucum* shells. It is noteworthy that they were deposited in distinct beds, two of which are located at depths of 130 and 140 cm. Sparse evidence of *Loripes lacteus* was also noted in this unit.

Unit D (35–65 cm, circa 1800–1950 CE) consists of homogeneous yellow, medium-to-coarse sands (modal index ~600 μm and mean grain size between 400 and 500 μm). Small iron particles (1–2 mm long) were present within this unit.

Unit S (35–0 cm, 1950–present day) consists of white to light gray clays with numerous traces of oxidation. No identifiable mollusc remains were found.

5.2. Mineralogy

The mineralogy of the sediment core (Fig. 3) consists of clays (27 ± 7%), micas (26 ± 6%), quartz (15 ± 6%), feldspars (K-feldspars and plagioclase 8 ± 5%) and chlorite (7 ± 1%). In addition pyroxene,

Table 1
Radiocarbon dates for Aleria Del Sale.

Lab ID	Depth	m asl	Material	Radiocarbon BP	Cal 2σ	Mean cal BP
Poz-71368	92	−0.56	*Cerastoderma glaucum*	1315 ± 30	1034–1249 CE	808 ± 108
Poz-65452	130	−0.94	*Cerastoderma glaucum*	2810 ± 30	716–396 BCE	2506 ± 160
Poz-65838	168	−1.32	Charcoal	3720 ± 35	2206–2022 BCE	4064 ± 92
Poz-65450	206	−1.7	*Cerastoderma glaucum*	4165 ± 30	2399–2060 BCE	4180 ± 170
Poz-65451	210	−1.74	*Cerastoderma glaucum*	4175 ± 30	2426–2095 BCE	4210 ± 166
Poz-65840	280	−2.44	Plant remains	4065 ± 35	2852–2487 BCE	4620 ± 183
Poz-65453	363	−3.27	*Cerastoderma glaucum*	4935 ± 35	3380–3048 BCE	5164 ± 166
Poz-74770	455	−4.19	*Cerastoderma glaucum*	5260 ± 35	3741–3508 BCE	5575 ± 117

amphibole, serpentine and talc are ubiquitous but present in trace amounts (≤3%). Gypsum and calcite are also present in trace amounts and exhibit a distinctive distribution: gypsum is present (≥1%) only in the lower part of the core (below 180 cm), while in contrast calcite is more common (≥1%) in the upper part.

The mineralogical assemblages (Fig. 1) are dominated by detrital minerals, mainly reflecting an inheritance from the geological substrate. According to the geological map, Aleria Del Sale belongs to the structural unit of the oriental plain composed of Quaternary alluvial sediments (mainly sand). The sedimentary minerals include quartz, micas, feldspars, chlorite and clays. In addition serpentine, talc and partly chlorite indicate a metamorphic origin, supplied by erosion of the Blue Schists cropping out at the northern and western border of the Quaternary sequence. In contrast, calcite and gypsum have different origins. Calcite has a biological derivation since it is composed of mollusc shells, whilst gypsum is an evaporite mineral, formed by direct precipitation from a sulfate-saturated solution.

Six mineralogical units (MU), labelled MU1 to MU6 (upwards) were identified (Fig. 1):

> Unit MU1 (420–410 cm) is characterized by the highest values of feldspar and quartz, reaching 55% and 41%, respectively. Neither gypsum nor calcite was observed. The unit exclusively comprised detrital continental minerals derived from the geological substratum.
>
> Unit MU2 (410–265 cm) is characterized by a fall in the content of both feldspar and quartz. This change is counterbalanced by an increase, by at least a factor of two, of both clay and mica.
>
> In Unit MU3 (265–180 cm) the abundance of clay reached its maximum (45%).
>
> Unit MU4 (180–120 cm) records the disappearance of gypsum and a decrease in the abundance of clay. This is counterbalanced by small increases in mica and quartz. The unit is also characterized by the ubiquitous occurrence of calcite.
>
> In Unit MU5 (120–65 cm) clays are present in greater abundance than in the adjacent units, with a mean of 30% compared with values of 25% in Unit MU3 and 20% in MU6.
>
> Unit MU6 (65–0 cm) is characterized by a sharp change in the mineralogical assemblage. There is a high abundance of quartz (up to 33%) and feldspar (up to 34%) and a lower abundance of clay (down to 15%). Clay abundance slightly increases (26%) in the last studied sample (20 cm). Calcite remains present in units MU4 to MU6 but it is less abundant in MU6 (≤1%).

5.3. Geochemistry

Twelve samples and one duplicate were analysed (Fig. 5). Geochemical analyses were focused on the core interval from 60 to 120 cm, in order to try to detect evidence of any anthropogenic environmental contamination during the last two millennia. One sample from 300 cm was analysed in order to characterize the pre-historical background signature (i.e., older than 3000 BCE). The trace element content, and in particular the measured trace metals (Pb, V, Cr, Co, Ni, Cu, Zn), do not vary

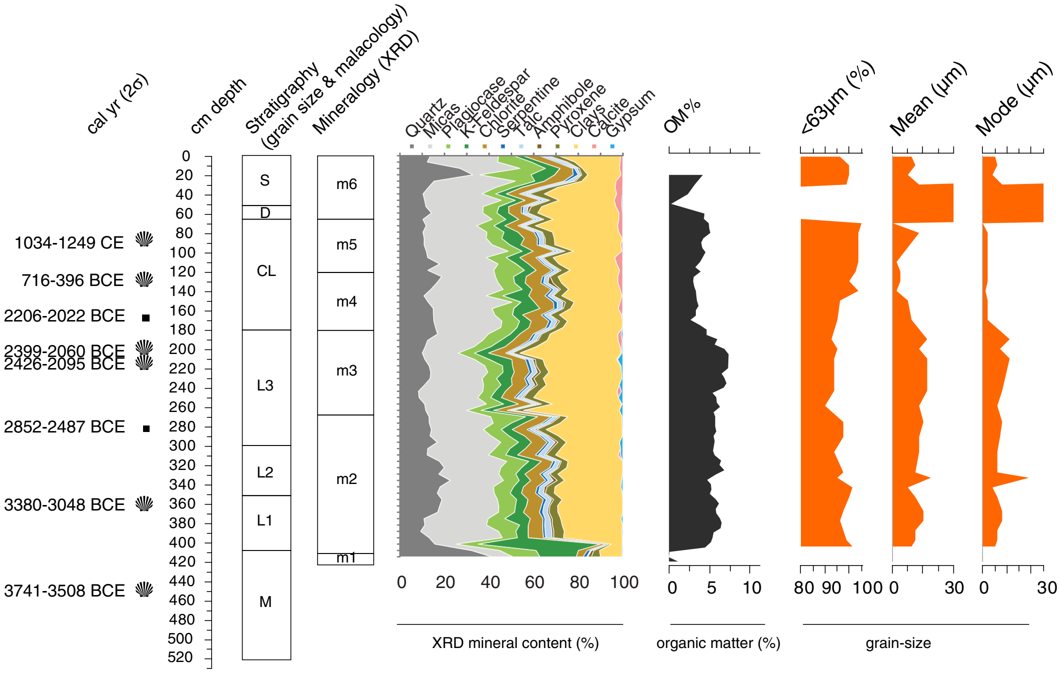

Fig. 3. Lithological units, radiocarbon dates, granulometry, XRD mineralogy and organic matter content for the studied sedimentary core from Aleria Del Sale.

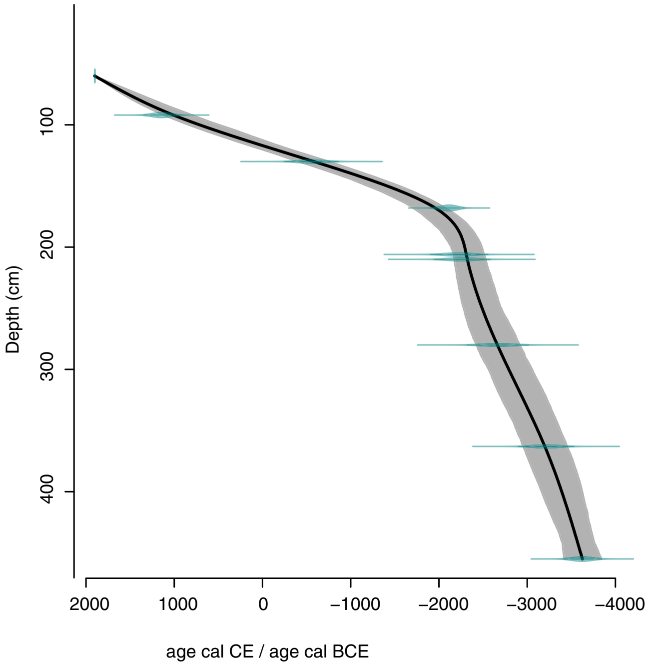

Fig. 4. Age-depth model (smooth spline) for the studied sedimentary core from Aleria Del Sale developed with clam 2.2 software (Blaaw, 2010). Blue lines represent radiocarbon dates. Gray areas include 2σ confidence range of calibrated dates.

significantly in the studied core section. For example, Pb ranges from 17 to 32 ppm within the range of background continental crust values (10–40 ppm, UCC; McLennan, 2001). The ratios between trace metal content and lithogenic elements, such as Sc, Th or Zr, reveal an absence of any significant enrichment in any trace metal (e.g., $0.28 < Pb/Sc < 0.63$; $1.6 < Pb/Th < 2.6$; $0.28 < Pb/Zr < 0.63$).

The isotopic ratios exhibit a narrow range of variation: $18.847 < {}^{206}Pb/{}^{204}Pb < 18.945$; $15.686 < {}^{207}Pb/{}^{204}Pb < 15, 691$; $38.972 < {}^{208}Pb/{}^{204}Pb < 39.012$ (Table 2). All of the Pb isotopic ratios (${}^{206}Pb/{}^{204}Pb$, ${}^{207}Pb/{}^{204}Pb$ and ${}^{208}Pb/{}^{204}Pb$) exhibit similar trends versus depth: the Pb ratios tend to decrease upwards (see enclosed diagram in Fig. 5). The isotopic data are plotted in a biplot ${}^{206}Pb/{}^{207}Pb$ - ${}^{208}Pb/{}^{206}$ diagram (Fig. 5). All of the samples define a linear trend ($r^2 > 0.99$). In general, the isotopic ratios exhibit a trend from high isotopic ratios (~1.2075) in the deeper samples towards lower isotopic ratios in the lower samples (~1.2015).

5.4. Pollen and NPPs

The sedimentary sequence from Aleria Del Sale provided a reliable pollen record (Fig. 6) except for the intervals from 35 to 65 cm depth (Unit D) and 395–525 cm depth (Unit M), where no palynomorphs were preserved. In some cases, the low preservation of the pollen grains restricted the degree of taxonomical determination and hence interpretation of vegetation in this part of the island. For instance, it was not possible to attain a more precise determination of *Pinus* pollen. The identification of *Quercus* pollen was also constrained by the poor preservation of grains and as a result, a more precise classification of oak pollen types was not completely possible for all samples. For reference, a *Quercus ilex* type has been plotted against the total *Quercus* pollen,

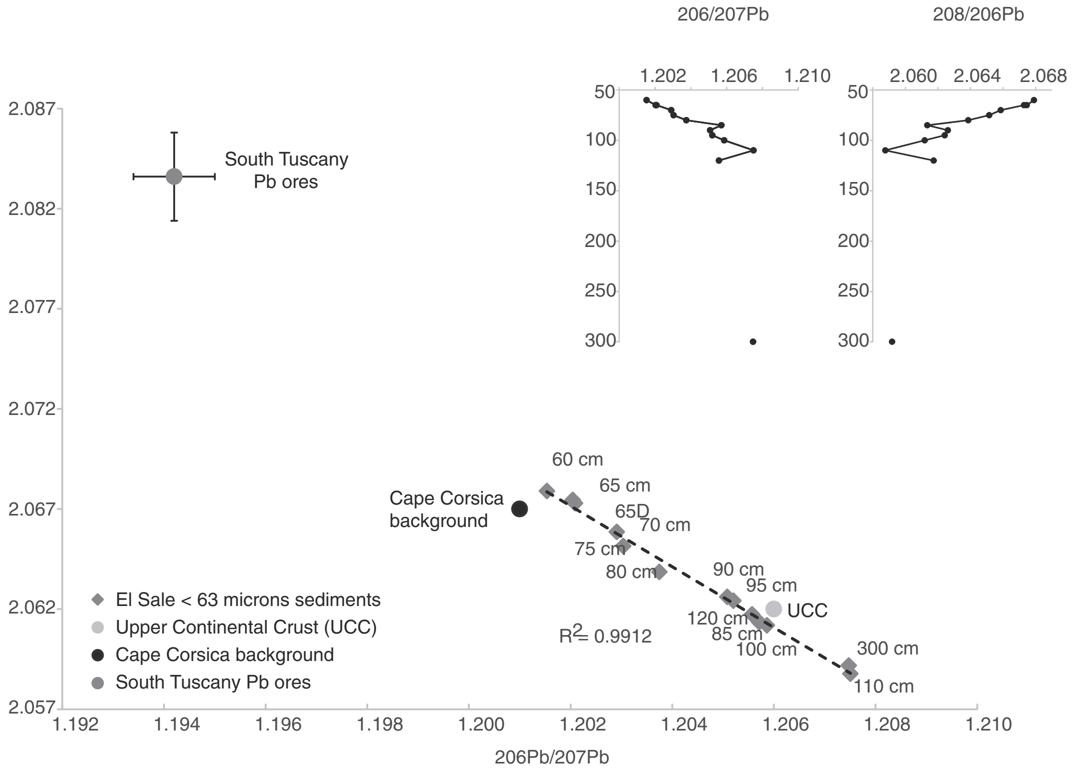

Fig. 5. Biplot ${}^{207}Pb/{}^{206}Pb$ versus ${}^{208}Pb/{}^{206}Pb$ measured on fine <63 mm calcite-free sedimentary fraction of Aleria Del Sale core by MC-ICP-MS. All samples define a linear trend ($r^2 > 0.99$). The representative signatures of two potential sources of sediments are plotted for comparison. The signature of the material delivered by erosion of the sedimentary Eastern Plain of Corsica may be represented by the Upper Continental Crust composition (UCC, data from McLennan, 2001). The signature of material delivered from erosion of the metamorphic Blue Schists has been defined as the mean bulk signature of the lower section of sedimentary cores retrieved in several sites from Cape Corsica (see Fagel et al., same issue). Miocene Pb ores from southern Spain (data from Stos et al., 1995) are plotted as a potential additional anthropogenic source. The two enclosed diagrams report the profile of the Pb isotopic ratios, ${}^{207}Pb/{}^{206}Pb$ and ${}^{208}Pb/{}^{206}Pb$, versus core depth. Note the general upwards evolution of the Pb isotope ratios.

Table 2
Pb isotope and trace element data of El Sale core measured on fine <63 μm calcite-free sedimentary fraction by MC-ICP-MS and ICP-MS, respectively. Underlined values correspond to duplicate (D).

Sample	Pb isotopic composition ^{208}Pb/^{204}Pb	2se	^{207}Pb/^{204}Pb	2se	^{20e}Pb/^{204}Pb	2se	^{207}Pb/^{206}Pb	2se	$^{20£}$Pb/^{20} $^{£}$Pb	2se	Elementary content (ppm) Sc	V	Co	Ni	Cu	Zn	Rb	Sr	Zr	Ba	La	Nd	Pb	Th
60	38.9719	0.0037	15.6858	0.0013	18.8475	0.0012	0.83227	0.00001	2.06790	0.00003	15	134	28	191	53	120	91	87	50	369	44	37	23	12
65	38.9856	0.0016	15.6874	0.0006	18.8570	0.0006	0.83192	0.00001	2.06746	0.00004	12	133	25	158	51	119	81	113	55	393	39	34	17	10
65D	38.9826	0.0017	15.6867	0.0007	18.8568	0.0006	0.83189	0.00001	2.06729	0.00005														
70	38.9884	0.0022	15.6891	0.0008	18.8728	0.0009	0.83132	0.00001	2.06586	0.00004	16	134	24	159	53	123	123	105	51	413	39	32	20	12
75	38.9727	0.0018	15.6867	0.0006	18.8719	0.0007	0.83123	0.00001	2.06515	0.00003	12	141	26	167	60	128	80	108	55	401	36	30	21	10
80	38.9720	0.0019	15.6875	0.0007	18.8836	0.0008	0.83074	0.00001	2.06386	0.00005	14	137	25	155	55	130	107	110	49	402	37	31	26	11
85	38.9980	0.0015	15.6907	0.0005	18.9184	0.0006	0.82939	0.00001	2.06135	0.00003	13	130	24	150	46	124	79	89	64	389	35	29	18	10
90	38.9920	0.0015	15.6873	0.0006	18.9043	0.0006	0.82982	0.00001	2.06261	0.00003	19	127	22	145	40	119	197	92	53	429	40	33	19	15
95	38.9989	0.0021	15.6899	0.0008	18.9095	0.0009	0.82974	0.00001	2.06242	0.00004	14	132	22	146	41	126	104	98	50	415	38	32	22	12
100	38.9965	0.0020	15.6896	0.0008	18.9194	0.0009	0.82928	0.00001	2.06119	0.00003	14	158	25	163	55	130	106	73	52	422	38	33	32	13
110	39.0011	0.0016	15.6884	0.0006	18.9437	0.0007	0.82815	0.00001	2.05877	0.00003	12	142	21	145	44	123	111	73	49	438	38	33	28	13
120	38.9955	0.0019	15.6888	0.0007	18.9139	0.0008	0.82948	0.00001	2.06174	0.00003	15	157	32	163	62	129	104	78	66	384	40	36	32	12
300	39.0115	0.0020	15.6899	0.0007	18.9450	0.0008	0.82817	0.0000	2.05919	0.00004	12	126	29	168	49	125	92	95	51	329	36	32	24	12
Mean	38.9898		15.6883		18.8957		0.83026		2.06345		14	138	25	159	51	125	106	93	54	399	38	33	23	12
Ecartype	0.012		0.0015		0.0329		0.00139		0.00308		2.0	10	3.1	13	7.1	4.1	32	14	5.7	29	2.4	2.3	5.1	1.4
Minimum	38.9719		15.6858		18.8475		0.82815		2.05877		11.8	126	21	145	40	119	79	73	49	329	35	29	17	9.7
Maximum	39.0115		15.6907		18.9450		0.83227		2.06790		18.8	158	32	191	62	130	197	113	66	438	44	37	32	15

which includes both the deciduous type and the undifferentiated *Quercus*.

Pollen zone S4 (395–225 cm) (ca. 3500–2200 cal BCE) is characterized by moderate levels of tree pollen. *Quercus* is the dominant arboreal taxon with percentages around 15% and increasing to 20%. Other tree taxa include *Alnus* (20%), *Pinus* (15 to 20%), *Fagus*, *Corylus* and *Betula*. Among the shrubs, *Erica arborea* attains percentages of around 10%. Other shrub taxa, such as *Juniperus*, *Cistus*, *Viburnum*, *Tamarix* and *Vitis* (probably the wild riparian species), are also present. *Tamarix* exhibits a noticeable peak at around 220 cm depth. Thermo-mediterranean taxa such as *Olea*, *Pistacia*, *Fraxinus* and *Phillyrea* are also recorded, with percentages of around 1%. Among the herbs, Chenopodiaceae (20%) dominates, Poaceae attains values around 10% and Cichoriaideae and Asteroideae are represented below 3%. Brassicaceae, Apiaceae and the ruderal *Plantago lanceolata* type are continuously recorded. Other apophyte taxa such as *Rumex* and *Trifolium* are also recorded. In addition, there is a slight presence of Cerealia pollen within this sub-zone. The hygrophilous Cyperaceae is well recorded (5%), while the aquatic *Typha-Sparganium*-type does not exceed 3%. Several coprophilous fungal spores (*Sordaria*, *Triperospora*, *Podospora* and *Sporormiella*) occur through this pollen zone.

Pollen zone S3 (215–152.5 cm) (ca. 2200–1500 cal BCE) records an abrupt increase in *Quercus*, now attaining values of 25%. Both *Pinus* and *Alnus* temporarily decline at 200 cm depth, but subsequently recover to previous values. Whilst *Erica arborea* remains unchanged, other shrubs such as *Pistacia*, *Phillyrea* or *Vitis* disappear from this zone. A declining trend is exhibited by Chenopodiaceae, Poaceae (reduced to 3%) and Cyperaceae. The principal herb taxa do not exhibit significant variations, except for Brassicaceae, which increases to up to 2%. With the exception of *Rumex* and *Plantago lanceolata*-type, no further human-related taxa are recorded along this pollen zone. This is also valid for coprophilous NPPs.

Pollen zone S2 (150–65 cm) (ca. 1500 cal BCE–1800 cal CE) is the longest zone of the sequence and is characterized by a complex evolution of the main arboreal taxa. *Quercus* gradually increases to 36% between 150 and 125 cm depth but declines sharply and temporary to 18% at 115 cm depth, coincident with a *Pinus* peak of 14%. *Erica arborea* (20%) dominates among the shrub taxa. A minor representation of other shrubs such as *Cistus*, Rosaceae, *Juniperus*, *Vitis*, *Viburnum*, *Phillyrea* and *Olea* is observed throughout the zone, except between 130 and 110 cm depth, where only *Juniperus* is represented. Chenopodiaceae is now less well-represented than previously. Some changes are visible around 100 cm depth, when *Erica arborea* declines abruptly and Asteroideae and Poaceae (10%) increase. Both *Alnus* and *Olea* become more frequent. Fern spores are also recorded. *Castanea* pollen is recorded as a minor taxa along this zone. Cichorioideae is well-represented at around 7% and illustrates an increasing trend. Asteroideae exhibits a slightly lower representation than previously. Cerealia exhibits a minor presence around 150, 135 and 100 cm depth. Apophytic taxa are unequally recorded, with the exception of the continuously recorded *Plantago lanceolata*-type, but generally becomes more frequent around 80 cm depth. Coprohilous fungal spores are absent.

Pollen zone S1 (35–0 cm) (ca. 1950–2014 cal CE) is markedly dominated by Chenopodiaceae, with values around 70% and with occasional peaks of up to 86%. *Pinus*, *Alnus*, *Quercus* and *Castanea* are all represented around 3%. *Erica arborea* attains a 10% peak. Minor evidence of *Vitis*, *Cistus*, *Juniperus* and *Fraxinus* are reported. *Olea*, Poaceae, Cichorioideae and Asteroideae attain percentages of around 5%, with a peak in Cichorioideae of 30% at 20 cm depth. Human-related taxa are represented by *Rumex*, *Centaurea* and *Plantago lanceolata*-type. There is no evidence for NPPs in this pollen zone.

6. Discussion

6.1. Palaeogeographic reconstruction of the Aleria Del Sale lagoon.

The chronostratigraphic sequence obtained for the core drilled in the western-most part of the Aleria Del Sale allows us to reconstruct the palaeogeography of the area for the last 6000 years (Fig. 7).

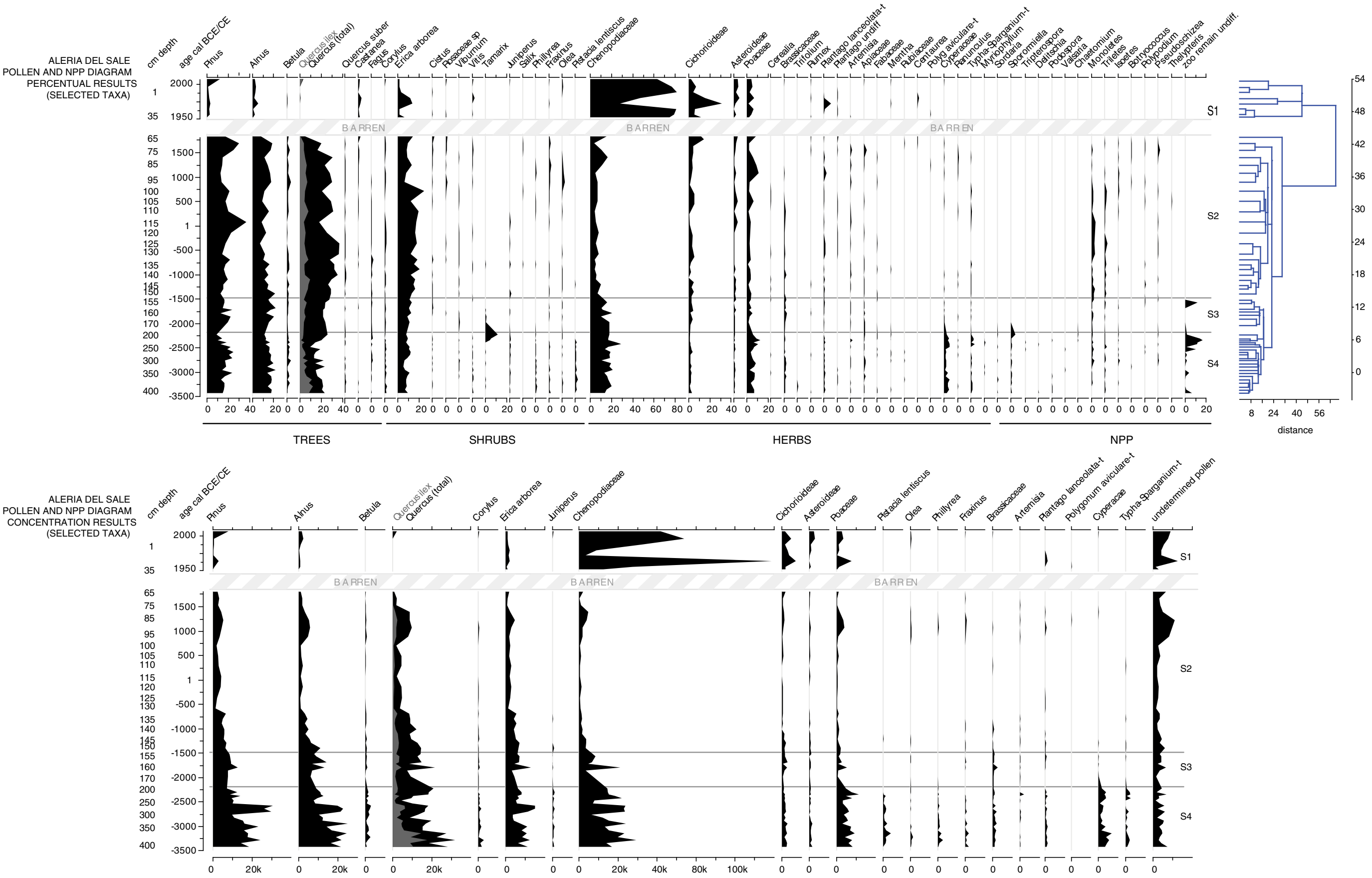

Fig. 6. Pollen and NPP diagrams for the studied sedimentary core from Aleria Del Sale. Values are expressed in percentages of total land pollen (upper diagram) and concentration (bottom diagram) of grains per gram. Pollen analyst: Andrés Currás.

The modern Aleria Del Sale lagoon was an open-marine environment prior to 3500 cal BCE (Late Neolithic period), as indicated by the presence of coarse gray sands mixed with the remains of marine and lagoonal shells (mainly *Bittium reticulatum* and *Cerastoderma glaucum*). The presence of broken and unpaired bivalve remains of *C. glaucum* should not be considered as evidence of deposition *in situ*, since they are likely to be reworked by the sea under high-energy conditions (Vacchi et al., 2016a). This implies that the coastline was located some 800 m inland from its modern position (Fig. 2, Fig. 7). Between 3500 cal BCE and 2200 cal BCE, (which approximately coincides with the Chalcolithic period in Corsica), faunal assemblages (presence of paired valves of *C. glaucum*, *Hydrobia acuta* and scattered fragments of *B. reticulatum*) and sedimentary data (transition to dark clays) indicate a major palaeoenvironnmental change. A lagoonal environment, with intermittent connection with the sea, prevailed during this period (Fig. 7). The presence of gypsum within the clay reinforces the idea of haline water exchanges with the adjacent sea. A peak of gypsum precipitation is however attested to from 2600 to 2200 cal BCE, indicating a probable major phase of evaporation. Simple speculation about the origin of this evaporate phase can be made according to our data. It may be perhaps linked to the seasonal changes reported in the western-central Mediterranean during the Middle Holocene (Magny et al., 2013) that led to temporarily more arid conditions. An alternative explanation is related to the very local geomorphological changes that may have triggered a temporary enclosure of the lagoon. In fact, the modern delta morphodynamics are characterized by a dominant north-south longshore current (Balounin et al., 2013). Thus, the isolation of the body-water can be related to the deltaic progradation of the Tavignano River mouth, which most likely formed a series of coastal sand barriers southwards (Fig. 7) triggering the isolation of lagoonal bodies behind these sandy bars. A higher freshwater influx supplied by the Tavignano River could explain this limnological shift. In addition, a slight increase of the carbonate content reported in samples between 300 and 350 cm depth (circa 3000–2750 cal BCE) may indicate calcium deposition by the Tavignano River, or the possible partial enclosure of the lagoon (secondary origin formation). This geomorphological process has often been described in the Mediterranean (Maselli and Trincardi, 2013) and is primarily related to the negligible rising sea level rates of the last 4000 years which resulted in the major progradation of the north-western Mediterranean coastal plains (Anthony et al., 2014; Vacchi et al., 2016b) .

Several changes are reported after 2200 cal BCE. The grain-size distribution of the sediments evidence lower accumulation rates and a freshwater influx probably caused by the local sedimentary source (the Tavignano River). This progressive fluvial influence —in spite of previous sea connection— is also suggested by the occurrence of oxidation evidence in the sediments (i.e. mottling, etc.). The diversity of mollusc species decreases and now is mainly dominated by small remains of *Cerastoderma glaucum* bicalves (mostly juveniles) and, in minor terms, of *Loripes lacteus* accumulated in distinct beds. Moreover, salinity decreases, as reflected by the lower gypsum content, whilst calcite concentration is higher. This body of evidence indicates that the previous open lagoon turned into a confined water-body with limited connections to the open sea. This geomorphological change occurred at the beginning of the Bronze Age period (i.e. after 2200 cal BCE) and is most likely due to the parallel accretion of external sand bars into the sea enclosing the lagoon due to the distribution of alluvial sediments from the Tavignano River, a process that was enhanced by the silting up of the water body as a result of the stabilization of the rate of sea-level rise (Vacchi et al., 2016b).

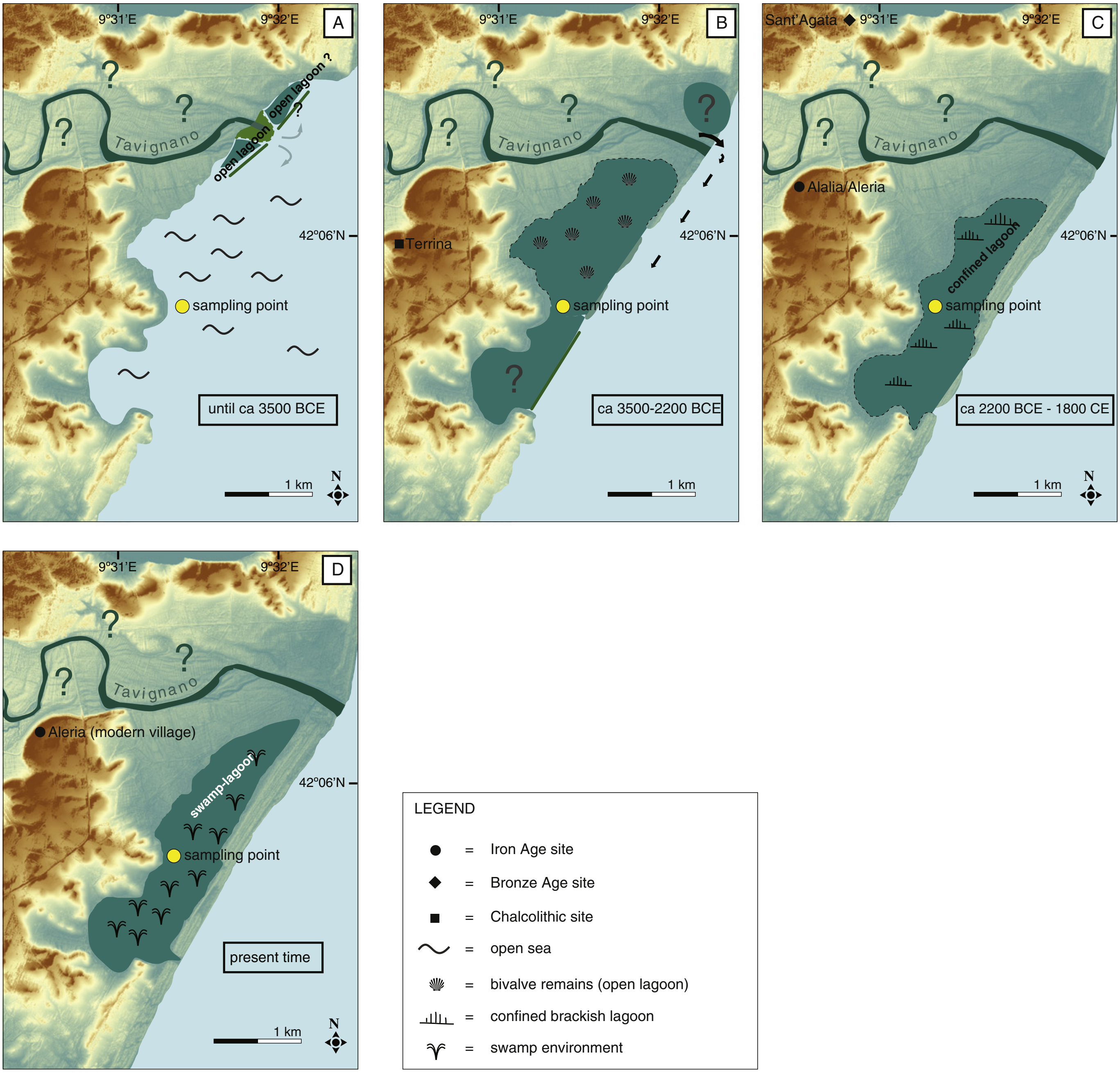

Fig. 7. Reconstruction of Aleria Del Sale palaeogeography. Picture A shows a marine environment prior to the development of the lagoon. Picture B illustrates the first enclosure of the water body as an open lagoon with intermittent connection to the sea. Black arrows indicate the formation of the coastal spits under the sea morphodynamics. Picture C shows the development of a confined lagoon since 2200 cal BCE. Picture D features the current status of the lagoon after modern drainage. The evolution of the Tavignano River bed during the last 6000 year period has not been addressed in this work. In this reconstruction its present-day position has only been used as a point of reference.

The existence of this confined lagoon is recorded at least until the Modern Period. Later on, and as a consequence of the drainage operations occurred in the 19th and 20th centuries CE (Dubray and Roux, 1984), the lagoon shifted to its current swampy status.

6.2. The geochemical signal of human activities 2000 years ago

No evidence of environmental contamination is reported in the measured trace element analyses (Table 2). Moreover, the ratio between trace metal content and any measured lithogenic elements such as Sc, Th or Zr does not indicate any significant enrichment in any trace metal (e.g., $0.28 < Pb/Sc < 0.63$; $1.6 < Pb/Th < 2.6$; $0.28 < Pb/Zr < 0.63$). The binary diagram ^{206}Pb/^{207}Pb–^{208}Pb/^{206} (Fig. 2) may be helpful in detecting any environmental contamination. In this diagram, the linear distribution of the Pb isotope composition of the Aleria Del Sale sediments suggests a mixing between two end-members. According to the geological map, we identify two potential natural end-members: the Quaternary sediments of the Eastern Plain of Corsica and the metamorphic Blue Schists (bedrock). The Upper Continental Crust (UCC, data from McLennan, 2001) may be a good indicator of sediment derived from erosion of the Corsican Eastern Plain. In order to determine a geochemical signature for the weathering products delivered from the Blue Schists we used the mean bulk geochemical composition of the lower section of sediment cores retrieved from several sites around Cape Corsica (see Fagel et al., 2016). Most of the Aleria Del Sale samples plot between those two end-members. However, the Pb ratios are slightly shifted to higher values with regard to the linear trend defined by the deepest sample from this sedimentary core (300 cm, i.e. the pre-anthropogenic background) and the Cape Corsica end-member. The stratigraphic distribution suggests some contribution from a third, probably anthropogenic, end-member. Among human activities, Pb mining during the Roman period may have affected the sedimentary Pb signature. For example, the mean signature of the Miocene Pb ores from Southern Spain (Cartagena, Mazarrón y Almagrera, data from Stos-Gale et al., 1995) may be a potential candidate for explaining the Pb isotopic shift (see Fagel et al., this issue).

6.3. Vegetation history and land-use during the Chalcolithic

The local environmental conditions that allowed the preservation of pollen and NPPs at Aleria Del Sale were established after 3500 cal BCE, when an open lagoon developed and sedimentation of clays occurred. Prior to that time, open marine conditions were too energetic and dynamic to enable any pollen or other microfossil record to be preserved and therefore we cannot discuss the vegetation history of the region prior to the currently described dataset.

The size of this early lagoon remains difficult to estimate and hence it is problematic to identify the extent of the pollen source area, according to Jacobson and Bradshaw (1981). Nevertheless, considering the size attained by the lagoon during the Modern Period (3 km by 1 km), assumptions can be made to presume that the surface of the body-water could have been large enough (Prentice, 1988), at least some hundreds of meters along each axis, to infer that the regional pollen record dominates the assemblage described from Aleria Del Sale. This implies that the vegetation history contained in the sedimentary sequence is that of the whole Eastern Plain of Corsica and probably includes part of the vegetation that grew in the eastern mountains, between the Fium'orbo and Castagniccia ranges (Fig. 1c). In addition, fluvial pollen supply into the lagoon by the Tavignano River could have played a role, as demonstrated by the sedimentological analyses. As a result, pollen reworked within the Tavignano River basin (812 km^2, see Fig. 1c), including high altitude environments (above 1000 m asl) in the centre of the island, could have been transported into the lagoon. This hypothesis has been previously suggested by Reille (1984).

The pollen record indicates that from 3500 to 2300 cal BCE the Eastern Plain of Corsica was a semi-open landscape with the main vegetation consisting of oak forest together with *Erica arborea* maquis. The presence of other Mediterranean sclerophyllous shrubs, such as *Pistacia lentiscus*, *Phillyrea* and *Olea* is furthermore attested. The presence of holm oak at this moment is consistent with previous palaeobotanical works (Reille, 1984, 1992b) and corroborates that in this area of Corsica the spread of sclerophyllous vegetation at the expense of previous deciduous forest had already occurred by circa 3500 cal BCE. Pollen from *Pinus* at this time may reflect the spread of *Pinus nigra* ssp. *laricio* communities occupying higher areas into the eastern mountains, usually above 1000 m als. However, it is also feasible that some of this pollen has been supplied by *Pinus pinaster* species, which can also grow at lower altitude across the Eastern Plain (Gamisans, 1999). In any case, the prevalence of pine woods in the Plain should have been moderate and the occurrence of pine pollen is more likely to be explained by long-distance transport from high altitude areas located inland, where pine woods were more abundant. *Alnus* pollen featuring on the diagram was likely produced by *Alnus glutinosa* species, a mesic tree that probably formed riparian communities with wild *Vitis* shrubs along the margins of the Tavignano River.

The occurrence of Poacea pollen indicates the spread of herb communities in the area and suggests that, in spite of a dense oak and maquis vegetation, some patches of open land existed at that time. The evidence of human activity is demonstrated by Cerealia pollen. However, its minor occurrence does not allow us to determine the real extent of arable land or whether these agricultural practices were local. Other nitrophilous and ruderal taxa, such as *Trifolium*, *Rumex* and *Plantago lanceolata*-type, indicate human disturbance of the soil in the area. The presence of herbivorous animals is suggested in the pollen record by the frequencies of *Delitschia*, *Sporormiella*, *Sordaria*, *Podospora* and *Tripterospora* coprophilous fungal spores. This diverse array of evidence suggests that the Eastern Plain of Corsica was very likely managed by humans at this time. Indeed, the archaeological site of Terrina, located <2 km away from the sampling site, represents a very significant example of human occupation in the Eastern Plain during the 4th millennium BCE (Camps, 1988). This archaeological site was recently dated between 3250 and 2400 cal BCE (Pearce, 2013), an interval which accords well with the anthropogenic indicators recorded in the sedimentary record of Aleria Del Sale. This body of evidence leads us to suggest that human activity at Terrina, including cultivation and pastoralism, could have played a substantial role in maintaining the semi-open landscape of the Eastern Plain of Corsica at that time.

The presence of Cyperaceae and Chenopodiaceae pollen records the local spread of salt-tolerant vegetation such as *Scirpus maritimus*, *Sarcocornia* or *Suaeda* around the margins of the lagoon, perhaps including the sandy bars that were initially enclosing the water-body (Fig. 7). The occurrence of this vegetation corroborates the influence of the sea on the environment at this time.

6.4. Forest recovery during the Bronze Age

Diverse vegetation changes are recorded in the Eastern Plain after 2300 cal BCE. Firstly, local vegetation of Chenopodiaceae and Cyperaceae vegetation retreated, which suggests a shift towards increasing continental conditions. A reduction of the sea water influence, as indicated by the sedimentological data, probably inhibited the development of this halophile vegetation. In addition, possible shifts of the sand bars associated to deltaic progradation could have displaced these communities and subsequently they became less well-represented in the pollen record. In any case, it must be noticed that Cyperaceae and Chenopodiaceae retreat was not synchronous, with the latter occurring with some delay, providing evidence that both plant communities could have had unequal responses to the palaeogeographical changes in the lagoon.

Secondly, a sharp increase in oak and reduction in herbs indicate a forest recovery between approximately 2500 and 2250 cal BCE. This vegetation shift is also supported by pollen concentration data (Fig. 6). The lack of anthropogenic indicators such as Cerealia pollen and coprophilous fungal spores suggest that at this time human activities were absent. Interestingly, the archaeological record indicates that the Terrina site had already been abandoned after 2400 cal BCE (Pearce, 2013), which is in accordance with the decline of the human footprint in the pollen record. Considering this evidence, it is feasible to think that the vegetation shift was favoured by the decline of human activities in the Plain and that oak forest developed once human pressures on the landscape disappeared.

Data shows that the maquis of *Erica arborea* recovered moderately after 2500 cal BCE. However, these shrub communities did not expand as rapidly as oak trees, but show an approximate 500 year time-lag. The latter could provide evidence that in the Eastern Plain of Corsica *Erica* maquis and *Quercus* did not share exactly the same space and that oak was probably spreading through the thick and rich alluvial soils of the Eastern Plain, closer to the lagoon and to the Terrina site. In contrast, *Erica arborea* could have been more abundant across the inner hills to the west where the soils are less well-developed (Reille, 1992b). Under this vegetation distribution, the recovery of the oak woods could have had a more prominent impact on the pollen record than that of *Erica arborea*, as long as human-induced clearances did not reach the maquis in the same way as it did the *Quercus*. Another explanation for this diverse behaviour is that after the spread of *Quercus ilex* within the previous maquis (Reille, 1984, 1992b), *Erica arborea* never recovered to its former extent.

It is important to remark that since around 2200 cal BCE three changes have operated simultaneously: 1) the Terrina dwelling was abandoned. 2) a dense oak forest spread through the previously semi-open Eastern Plain. 3) the connection of the Aleria Del Sale lagoon with the sea was interrupted and it became a confined lagoon. The emergence of these major cultural, landscape and palaeogeographic transformations highlights the significance of the Middle and Late-Holocene transition (2200 cal BCE) in Eastern Corsica regarding the natural conditions and human adaptation strategies and impel us to consider to which extent these changes were mutually dependent (Mercuri and Sadori, 2014; Roberts et al., 2011). In addition, it must be noticed that these changes are contemporary with several cultural and environmental changes identified across multiple sites in the western and central Mediterranean region (Sadori et al., 2011; Beffa et al., 2016), which have been associated with the mid-Holocene climate changes that took place between 2500 and 2000 cal BCE (Magny et al., 2012, 2013). As explained above, we see a close chronological fit between the onset of the Terrina culture and the development of the lagoon around 3500 cal BCE. They both co-existed during a 1300 yr period and they respectively disappeared and shifted into a different environment around 2200/2400 cal BCE. That said, we believe that the data presented in this paper does not allow us to explain the demise of the Chalcolithic culture in Eastern Corsica as the direct and unequivocal result of local environmental and palaeogeographical changes. In spite of this, we emphasize that the links observed between the settlement and the lagoon are close enough to suggest that both elements could have worked as a system-like whole until the changes occurred circa 2200 cal BCE.

The evolution of the landscape of the Eastern Plain from 2100 cal BCE onwards follows a complex trend. The development of oak forest and maquis was constant and stable until 500 cal BCE. During this 1500 year period the spread of forest vegetation was coeval with signs of human activity, as recorded between 1500 and 700 cal BCE by cereal pollen and other anthropogenic indicators such as Cichorioideae, Asteroideae, *Rumex* and *Plantago lanceolata*-type. Conversely, there is no palynological evidence of grazing activity. It is possible that even though the Aleria Plain was no longer an open landscape, some human activity persisted during the Bronze Age. Indeed, the abundance of archaeological artefacts dating from 2200 to 1800 cal BCE in the Aleria region (central Eastern Plain) provides evidence that humans were present in the territory (Tramoni, 2001), although no archaeological site dated to that timeframe has been reported so far. On the contrary, archaeological sites become more frequent after 1800 cal BCE in the Eastern Plain (Peche-Quilichini and Vidal, forthcoming) and it is feasible that the occurrence of anthropogenic taxa is the footprint of this Bronze Age population.

6.5. A new phase of human influence on vegetation in the 6th century BCE

After ca. 700 cal BCE, the increase of ruderal taxa such as Cichorioideae, *Plantago lanceolata*-type and Ceralia pollen indicate that a new phase of human activity occurred in the area. This anthropogenic presence, which seems to recede after 200 cal BCE, may have been linked to the Phoecaean and Etruscan colonization of Aleria and the surrounding territory in the 6th century BCE (Camps, 1988). Nevertheless, human activity did not have a major impact on the forest development of the Eastern Plain, since oak woodland was widespread at that time and grass communities show no evidence of changes. The presence of *Pseudoschizaea* spores at this time could suggest the existence of erosive processes (Pantaleón-Cano et al., 1996) across the Plain, though these algae have also been frequently linked to dryer periods (Scott, 1992; Carrión, 2002). Indeed, the pollen diagram suggests that mesic riparian *Alnus* retreated slightly at this time. This trend is also corroborated by the pollen concentration data and supports the hypothesis of a less humid period in eastern Corsica circa 500 cal BCE. Even though no further evidence of drought have been inferred from the pollen data, it must be noted that in the central Mediterranean region some authors propose the existence of a drier period during the second half of the 1st millennium cal BCE (Magny et al., 2007).

After 500 cal BCE a temporary retreat of the oak forest occurred, while pinewoods expanded. The concentration pollen data corroborates this vegetation shift, which likely suggests that pine forest in the region could have temporary replaced the oak forest inland. The decrease of *Quercus* is coeval with the Roman occupation of the Eastern Plain and subsequent development of Aleria as the main city of the island. In addition, the spread of light-demanding and disturbed-soil tolerant Asteroideae is recorded at this time and may be linked to the land-management. However, further indicators of human impact are absent and therefore it is difficult to explain the degree of land use at that time. Additional palaeoenvironmental and archaeological research is necessary to reach a better understanding of the landscape evolution of eastern Corsica during the Roman period.

One major issue discussed by local archaeologists is the potential existence of a harbour during Roman times (Michel and Pasqualaggi, 2014). Pollen data does not supply consistent evidence of human activity around the lake during the Roman period. Moreover, the lagoon shows little connection to the sea at that time and it is unlikely that Aleria Del Sale could be considered as a suitable coastal environment to host a harbour. More probably, the palaeo-Tavignano River could have been used by boats to reach the ancient city of Aleria.

A slight decline in *Quercus* and the increase in Poaceae, Cichorioideae and Asteroideae indicate the opening of the oak forest since the 3rd century cal CE. After the 5th century cal CE this trend became more pronounced, as evidenced by the sharp decline in *Erica* maquis and the spread of grasslands. Between the 10th and 12th centuries cal CE a less forested landscape characterized the area. Later on, shrub vegetation comprising *Cistus*, *Rosaceae*, *Phillyrea*, and heliophilous taxa such as Apiaceae developed, likely a response to the enduring process of forest clearance. Ruderal and human-related vegetation such as *Plantago lanceolata* become more abundant, suggesting that human activity was associated with this landscape transformation.

Olea also increased at this moment. Being difficult to differentiate between the wild and cultivated species on the basis of pollen morphology, the coeval coincidence of forest clearance and further ruderal taxa lead us to infer that the expansion of this tree was the product of human activity. This interpretation agrees with the general expansion of olive trees in the western and central Mediterranean since the Roman Period and the Middle Ages (Sadori, 2007). According to the age-depth model, these landscape changes took place between the 10th and 12th centuries cal CE, which means that most likely they were linked to the onset of the Genoan period in Corsica (from the 13th century CE onwards). During the Late Middle Ages the oak forest was continuously cleared, grasslands were expanded and human-related vegetation such as *Rumex*, *Plantago lanceolata*, *Polygonum aviculare* and *Centaurea* provide evidence for a significant spread of human activity in the Eastern Plain.

The drainage works carried out in the El Sale Lagoon during the late 1800s and early 1900s interrupted sedimentation. The pollen record of the 20th century, now strongly dominated by Chenopodiaceae vegetation, is significantly different from that prior to the Industrial Period and can be explained by the onset of very different limnological conditions in the lagoon following drainage activities. As a result, local halophile vegetation colonised the soils developed on land previously submerged beneath the water-body.

7. Conclusions

For the first time in Corsica, multi-proxy research using pollen and sedimentological data has been combined with a robust age-depth model in order to provide a reliable palaeoenvironmental reconstruction of vegetation history, land-use and palaeogeographic change across the Eastern Plain of Corsica during the last 6000 years (Fig. 7, Fig. 8).

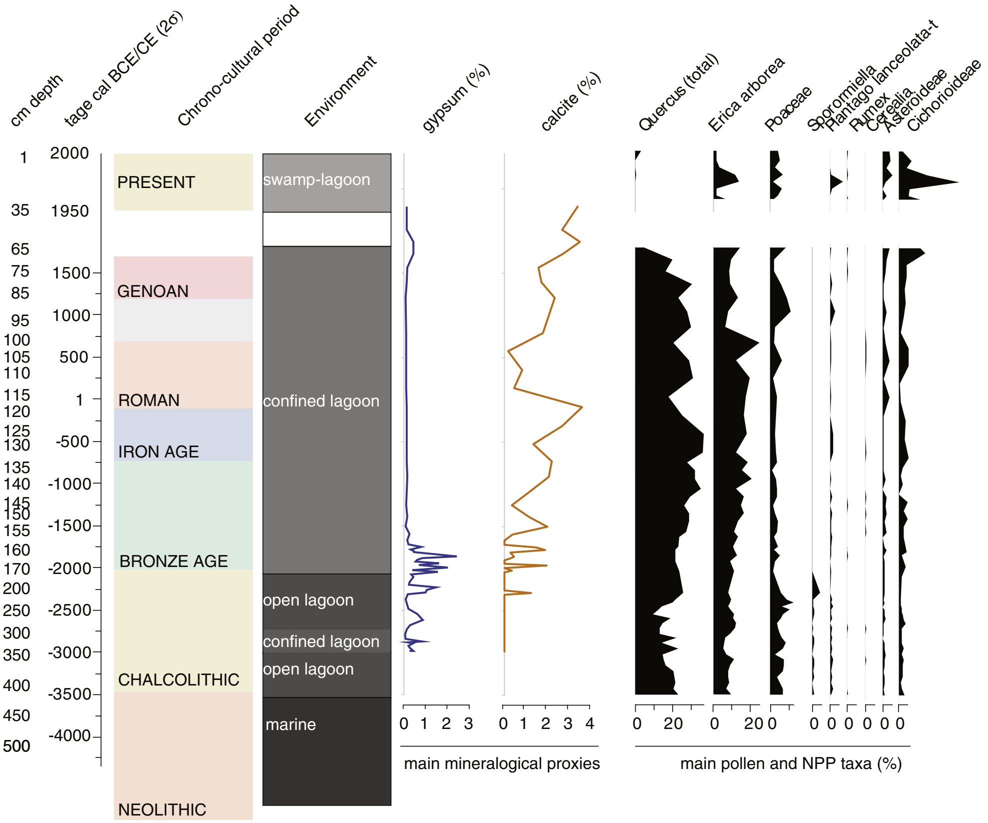

Fig. 8. Synthesis of the main proxies plotted against depth (cm), the chrono-stratigraphy and the main cultural periods, illustrating evidence of major environmental changes that have occurred in Aleria Del Sale during the last 6000 years.

The record from the Aleria Del Sale lagoon dates back to 3500 cal BCE when the progradation of the delta of the Tavignano River triggered the formation of sand bars and the enclosure of the water body behind. By this time the Eastern Plain of Corsica was a semi-open landscape in which cultivation, pastoral activity and probably forest clearances were carried out by the Chalcolithic Terrina population. Around 2200 cal BCE human impact seemed to temporarily decline and oak forest recovered on the Plain. By that same time, further accretion of the sand bars and the stabilization of sea-level rise interrupted the connection of the Aleria Del Sale lagoon to the open sea and the semi-open feature became a confined lagoonal system.

During the Bronze Age period (1800–700 cal BCE) some human activity occurred within a forested landscape. Land-use increased later on, particularly during the Phoecaean and Etruscan occupation (6th to 3rd centuries BCE). Nevertheless, the vegetation history does not provide evidence of a major impact through the Roman period. During the Genoan period, in the late Middle Ages, oak forests and *Erica* maquis declined noticeably as a result of landscape clearances and the expansion of the land-use.

The synchronicity of changes that occurred circa 2200 cal BCE in the Eastern Plain of Corsica enables for speculation that the cultural and environmental transformations could be somehow linked to each other. What was the true mechanism of this connection? On the basis of the present state of investigations no conclusions or simple answers can be drawn to these issues, which underlines the necessity to provide comparable and independent data not only on the evolution of the environmental conditions during the mid-Holocene, but also on the still partially known archaeological context of the island. The results presented in this paper should open up new perspectives, particularly on the Chalcolithic period, that future research should explore in order to test the strength of our hypotheses and to include the Corsican scenario in the context of the Mediterranean Holocene palaeoenvironmental discussions.

Acknowledgements

This article is a contribution of the multi-disciplinary research programme Programme Collectif de Recherche *Géoarchéologie des basses vallées fluviales: la nécessaire prise en compte de l'évolution paysagère au cours de l'Holocène* (*Programme Collectif de Recherche*, 2013-2015) directed by Matthieu Ghilardi (CEREGE) and funded by the French Ministry of Culture and Communication (Direction Régionale des Affaires Culturelles de Corse, Ajaccio) focused on the reconstruction of the relationship between landscape evolution and the human occupation of the lower river valleys of Corsica. We are grateful to Franck Leandri, Director of Archaeology in Corsica for constant support. Le conservatoire du Littoral (Corsica) and it director Michel Muracciole delivered the authorizations for drilling and helped during fieldwork. Financial support was also provided by the MISTRALS/PALEOMEX National Research Programme from CNRS (INEE-INSU) and directed for the Archeomed workshop by Laurent Carozza and Laurent Lespez. Labex OT-Med (Aix-Marseille University). This work is also a contribution to the Fernand Braudel International Fellowship Program and the Labex OT-Med (n° ANR-11-LABEX-0061) funded by the French Government "Investissements d'Avenir" program of the French National Research Agency (ANR) through the A*MIDEX project (n° ANR-11-IDEX-0001-02). The authors would like to thank the assistance provided by Nathalie Anne Marini and colleagues and by Joseph Ghilardi during the fieldwork. Luc Beaufort kindly allowed us to use the CEREGE laboratory. Yoann Poher also contributed with valuable scientific observations. We also thank two annonymous reviewers for their useful remarks on the manuscript. Special thanks may be given to the Editor Andy Howard for polishing the English.

References

Ahmed, S.E., Cain, R.F., 1972. Revision of the genera *Sporormia* and *Sporormiella*. Can. J. Bot. 50, 419–477.

Anderson, D.G., Maasch, K.A., Sandweiss, D.H., Mayewski, P.A., 2007. Climate change and culture: exploring Holocene transitions. In: Anderson, D.G., Maasch, K.A., Sandweiss, D.H. (Eds.), Climate Change and Cultural Dynamics: A Global Perspective on Mid-Holocene Transitions. Elsevier, pp. 1–23.

Anthony, E.J., Marriner, N., Morhange, C., 2014. Human influence and the changing geomorphology of Mediterranean deltas and coasts over the last 6000 years: from progradation to destruction. From progradation to destruction phase? Earth-Sci. Rev. 139, 336–361.

Balounin, Y., Stépanian, A., Belon, R., Bezert, P., Calendini, S., Bellini, G., 2013. The Corsican coastal monitoring network. In: Cipriani, L.E. (Ed.), Coastal Erosion Monitoring - A Network of Regional Observatories. Nuova Grafica Fiorentina, pp. 57–77.

Beffa, G., Pedrotta, T., Colombaroli, D., Henne, P.D., van Leeuwen, J.F.N., Süsstrunk, P., Kaltenrieder, P., Adolf, C., Vogel, H., Pasta, S., Anselmetti, F.S., Gobet, E., Tinner, W., 2016. Vegetation and fire history of coastal north-eastern Sardinia (Italy) under changing Holocene climates and land use. Veg. Hist. Archaeobotany 25 (3), 271–289.

Behre, K.-E., 1981. The interpretation of anthropogenic indicators in pollen diagrams. Pollen Spores 23, 225–245.

Behre, K.-E., 1986. Anthropogenic indicators in pollen diagrams. J. Hist. Geogr. 14 (2), 226–227.

Berglund, B.E., 1991. The Cultural Landscape During 6000 Years in Southern Sweden (Ecological Bulletin 41). Blackwell, Oxford.

Beug, H.-J., 2004. Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete. Pfeil, München.

Blaauw, M., 2010. Methods and code for ‘classical’ age-modelling of radiocarbon sequences. Quat. Geochronol. 5, 512–518.

Blackford, J.J., Innes, J.B., 2006. Linking current environments and processes to fungal spore assemblages: surface NPM data from woodland environments. Rev. Palaeobot. Palynol. 141, 179–187.

Blackford, J.J., Innes, J.B., Hatton, J.J., Caseldine, C.J., 2006. Mid-Holocene environmental change at Black Ridge Brook, Dartmoor, SW England: a new appraisal based on fungal spore analysis. Rev. Palaeobot. Palynol. 141, 189–201.

Boski, T., Pessoa, J., Pedro, P., Thorez, J., Dias, J.M.A., Hall, I.R., 1998. Factors governing abundance of hydrolysable amino acids in the sediments from the NW European Continental margin (47–50°N). Prog. Oceanogr. 42, 145–164.

Bottema, S., Woldring, H., 1990. Anthropogenic indicators in the pollen record of the Eastern Mediterranean. In: Bottema, S., Entjes-Nieborg, G., van Zeist, W. (Eds.), Man's role in the Shaping of the Eastern Mediterranean Landscape. A.A. Balkema, Rotterdam, pp. 231–264.

Buurman, P., Pape, T., Muggler, C.C., 1996. Laser grain-size determination in soil genetic studies: practical problems. Soil Sci. 162 (3), 211–218.

Calò, C., Henne, P.D., Curry, B., Magny, M., Vescovi, E., La Mantia, T., Pasta, S., Vannière, B., Tinner, W., 2012. Spatio-temporal patterns of Holocene environmental change in southern Sicily. Palaeogeogr. Palaeoclimatol. Palaeoecol. 323-325, 110–122.

Camps, G., 1979. La Préhistoire dans la région d'Aleria. Archeologia Corsa. 4, 5–21.

Camps, G., 1988. Préhistoire d'une île. Les origines de la Corse. Les Hespérides, Errance, Paris.

Carcaillet, C., Barakat, H.N., Panaïotis, C., Loisel, R., 1997. Fire and late-Holocene expansion of *Quercus ilex* and *Pinus pinaster* on Corsica. J. Veg. Sci. 8, 85–94.

Carrión, J.S., 2002. Patterns and processes of late quaternary environmental change in a montane region of southwestern Europe. Quat. Sci. Rev. 21, 2047–2066.

Conchon, O., 1989. Dynamique et chronologie du détritisme quaternaire en Corse, domaine méditerranéen montagnard et littoral. Bulletin de l'Association Française pour l'Etude du Quaternaire 4, 201–211.

Conchon, O., 1999. Le littoral de Corse (France) au Quaternaire. Quaternaire 10, 95–105.

Cook, H.E., Johnson, P.D., Matti, J.C., Zemmels, I., 1975. Methods of sample preparation and X-ray diffraction analysis in X-ray mineralogy laboratory. In: Kaneps, A.G., et al. (Eds.), Init. Repts DSDP XXVIII. Print. Office, Washington DC, pp. 997–1007.

Cugny, C., Mazier, F., Galop, D., 2010. Modern and fossil non-pollen palynomorphs from the Basque mountains (western Pyrenees, France): the use of coprophilous fungi to reconstruct pastoral activity. Veg. Hist. Archaeobotany 19 (5–6), 391–408.

Dearing, J.A., 2006. Climate-human-environment interactions: resolving our past. Clim. Past 2, 187–203.

Di Rita, F., Melis, R., 2013. The cultural landscape near the ancient city of Tharros (central West Sardinia): vegetation changes and human impact. J. Archaeol. Sci. 40, 4271–4282.

Dubray, D., Roux, D., 1984. Propositions d'aménagements des zones humides de la réserve de chasse de Casabianda (Haute-Corse). Office National de la Chasse, Service technique, Région Corse, document interne. n. 14 p. 43 (17 annexes).

Ejarque, A., Julià, R., Riera, S., Palet, J.M., Orengo, H.A., Miras, Y., Gascón, C., 2009. Tracing the history of highland human management in the eastern Pre-Pyrenees: an interdisciplinary palaeoenvironmental study at the Pradell fen. Spain. The Holocene. 19, 1241–1255.

Fægri, K., Iversen, J., 1989. In: Faegri, K., Kaland, P.E., Krzywinski, K. (Eds.), Textbook of Pollen Analysis, 4th ed The Blackburn Press, New Jersey.

Fagel, N., Fontaine, N., Plauger, E., Otten, J., Lechenault, M., Ghilardi, M., Goiran, J-P., Mattielli, N. (this issue) Record of Human Activities in the Pb Isotopes Signature of Coastal Sediments From the Roman Archaeological Site of Cala Francese, Cape Corsica (France).

Fagel, N., Fontaine, F., Pleuger, É, Lechenault, M., Lepoint, G., Goiran, J.P., 2016. Reconstitution des paléoenvironnements et des activités humaines à partir de l'étude de sédiments prélevés dans le Cap Corse (Corse, France). Géoarchéologie des îles de Méditerranée. CNRS Éditions, pp. 311–332.

Fullen, M.A., Zheng, Y., Brandsma, R.T., 1996. Comparison of soil and sediment properties of a loamy sand soil. Soil Technol. 10, 35–45.

Galer, S.J.G., Abouchami, W., 1998. Practical application of lead triple spiking for correction of instrumental mass discrimination. 8th Goldschmidt Conf. Mineral. Mag. 62A, 491–492.

Gamisans, J., 1999. La végétation de la Corse (Ed. Édisud).

Grimm, E., 1987. CONISS: a Fortan 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares. Comput. Geosci. 13, 13–35.

Heiri, O., Lotter, A.F., Lemcke, G., 2001. Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. J. Paleolimnol. 25, 101–110.

Jacobson, G.L., Bradshaw, R.H.W., 1981. The selection of sites for paleovegetational studies. Quat. Res. 16, 80–96.

Jaujou, C.M.J., 1954. La lutte antipaludique en Corse. Bull. Org. mond. Santé. 2, 635–677.

Jehasse, O., 1998. Les suburbia d'Aleria et la romanisation de la Corse au second siècle de l'Empire. Bulletin Analytique d'Histoire Romaine. 237, 70–75.

Lorenzoni, C., Muracciole, M., Paradis, G., 1995. Étude de la végétation du Marais del Sale (Est de la Corse, France). Modifications depuis la fin du 19e siècle. Colloques Phytosociologiques, XXIV. pp. 707–726.

Magny, M., Combourieu-Nebout, N., de Beaulieu, J.L., Bout-Roumazeilles, V., Colombaroli, D., Desprat, S., Francke, A., Joannin, D., Ortu, E., Peyron, O., Revel, M., Sadori, L., Siani, G., Sicre, M.A., Sanmartin, S., Simonneau, A., Tinner, W., Vannière, B., Wagner, B., Zanchetta, G., Anselmetti, F., Brugiapaglia, E., Chapron, E., Debret, M., Didier, J., Essallami, L., Galop, D., Gilli, A., Haas, J.N., Kallel, N., Millet, L., Stock, A., Turon, J.L., Wirth, S., 2013. North-south palaohydrological contrasts in the central Mediterranean during the Holocene: tentative synthesis and working hypothesis. Clim. Past 9, 2043–2071.

Magny, M., de Beaulieu, J.-L., Drescher-Schneider, R., Vannière, B., Walter-Simonnet, A.-V., Miras, Y., Millet, L., Bossuet, G., Peyron, O., Brugiapaglia, E., Leroux, A., 2007. Holocene climate changes in the central Mediterranean as recorded by lake-level fluctuations at Lake Accesa (Tuscany, Italy). Quat. Sci. Rev. 26 (13–14), 1736–1758.

Magny, M., Peyron, O., Sadori, L., Ortu, E., Zanchetta, G., Vannière, B., Tinner, W., 2012. Contrasting patterns of precipitation seasonality during the Holocene in the south- and north-central Mediterranean. J. Quat. Sci. 27 (3), 290–296.

Maselli, V., Trincardi, F., 2013. Man made deltas. Sci. Rep. 3.

Mazier, F., Galop, D., Gaillard, M.J., Rendu, C., Cugny, C., Legaz, A., Peyron, O., Buttler, A., 2009. Multidisciplinary approach to reconstructing local pastoral activities – an example from the Pyrenean Mountains (Pays Basque). The Holocene 19 (2), 171–188.

McLennan, S.M., 2001. Relationships between the trace element composition of sedimentary rocks and upper continental crust. Geochem. Geophys. Geosyst. 2 (4). http://dx.doi.org/10.1029/2000GC000109.

Mercuri, A.M., Sadori, L., 2014. Mediterranean culture and climatic change: past patterns and future trends. In: Goffredo, S., Dubinsky, Z. (Eds.), The Mediterranean Sea: Its History and Present Challenges. Springer, Dordrecht, pp. 507–527.

Mercuri, A.M., Bandini Mazzanti, M., Torr, P., Vigliotti, L., Bosi, G., Florenzano, A., Olmi, L., Massamba N'siala, I., 2012. A marine/terrestrial integration for mid-late Holocene vegetation history and the development of the cultural landscape in the Po valley as a result of human impact and climate change. Veg. Hist. Archaeobotany http://dx.doi.org/10.1007/s00334-012-0352-4.

Michel, F., Pasqualaggi, D., 2014. La Corse. 2 A-2B. Carte Archéologique de la Gaule. Paris.

Moore, D.M., Reynolds Jr., R.C., 1997. X-Ray Diffraction and the Identification and Analysis of Clay Minerals. Oxford Univ. Press, Oxford New York.

Pantaleón-Cano, J., Pérez-Obiol, R., Yll, E.I., Roure, J.M., 1996. Significado de Pseudoschizaea en secuencias sedimentarias de la vertiente mediterránea de la península Ibérica e islas Baleares. In: Ruiz Zapata, B. (Ed.), Estudios Palinológicos. Universidad de Alcalá, Alcalá de Henares, pp. 101–105.

Pearce, M., 2013. The absolute chronology of site IV at Terrina (Aléria, Haute-Corse) and early metallurgy on Corsica and Sardinia. Accordia Research Papers. 12, 41–55.

Peche-Quilichini, K., 2012. Le Bronze final et le premier âge du Fer de la Corse: chronologie, production céramique et espaces culturels. Acta Archaeologica 83, 203–223.

Peche-Quilichini K., Vidal L. (forthcoming): Le Bronze ancien 2 dans l'est de la Corse. Apport de l'analyse préliminaire du site de Pinia (Ghisonaccia, Haute-Corse), in: Perrin, T., Sénépart, T., Thirault, E. et Cauliez, J. (dir.) De la tombe au territoire. Actualités de la recherche, Actes des XIes Rencontres Méridionales de Préhistoire Récente (Montpellier, Septembre 2014).

Péres, J.-M., 1982. Major benthic assemblages. In: Kinne, O. (Ed.), Marine Ecology 5. Wiley, Chichester, pp. 373–522 (Part 1).

Péres, J.-M., Picard, J., 1964. Nouveau manuel de bionomie benthique de la mer Méditerranée. Rec. Trav. Station Marine Endoume vol. 31. Marseille.

Pergola, P. (dir.) 2001, Corsica Christiana, 2000 Ans de Christianisme, Catalogue de l'exposition du musée de la Corse à Corte, Ajaccio.

Prentice, I.C., 1988. Records of vegetation in time and space: the principles of pollen analysis. In: Huntley, B., Webb, T. (Eds.), Vegetation History. Handbook of Vegetation Science. Kluwer, Dordrecht, pp. 17–42.

Reille, M., 1975. Contribution pollenanalytique à l'histoire tardiglaciaire et holocène de la végétation de la montagne corse. Thèse des sciences Aix-Marseille III.

Reille, M., 1977. Quelques aspects de l'activité humaine en Corse durant le Subatlantique et ses conséquences sur la végétation. Supplément Bull. AFEQ. 47, 329–352.

Reille, M., 1984. Origine de la végétation actuelle de la Corse sud-orientale; analyse pollinique de cinq marais côtiers. Pollen Spores 1, 43–60 (vol. XXVI).

Reille, M., 1990. Leçons de Palynologie et d'Analyse pollnique. Éditions du CNRS, Paris.

Reille, M., 1992a. Pollen et spores d'Europe et d'Afrique du nord. Laboratoire de Botanique historique et Palynologie, Université d'Aix-Marseille III, Marseille.

Reille, M., 1992b. New pollen-analytical researches in Corsica: the problem of *Quercus ilex* L. and *Erica arborea* L., the origin of *Pinus halepensis* Miller forests. New Phytol. 122, 359–378.

Reille, M., 1998a. Pollen et spores d'Europe et d'Afrique du nord. Supplément 2. Marseille: Laboratoire de Botanique historique et Palynologie, Université d'Aix-Marseille III.

Reille, M., 1998b. Pollen Diagram of the Canniccia Pond (Unpublished report) French Ministry of Culture Direction des affaires culturelles de Corse, Ajaccio.

Reille, M.J., Gamisans, V., Andrieu-Ponel, V., De Balieu, J.-L., 1999. The Holocene at Lac de Creno, Corsica, France: a key site for the whole island. New Phytol. 141, 291–307.

Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., Buck, C.E., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kaiser, K.F., Kromer, B., Manning, S.W., Niu, M., Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C.S.M., Van Der Plicht, J., 2013. IntCal13 and MARINE13 radiocarbon age calibration curves 0–50,000 years cal. BP. Radiocarbon 55 (4), 1869–1887.

Roberts, N., Brayshaw, D., Kuzucuğolu, C., Pérez, R., Sadori, L., 2011. The mid-Holocene climatic transition in the Mediterranean: causes and consequences. The Holocene 21 (1), 3–13.

Roth, A., Congés, G., 1976. Un dépotoir protohistorique près de l'étang de Diane. Archeologia Corsa. 1, 97–112.

Sadori, L. 2007. Southern Europe, in Encyclopedia of Quaternary Science (ed. A.E. Editor-in-Chief: Scott), Elsevier. Oxford. pp, 2763–2773.

Sadori, L., Jahns, S., Peyron, O., 2011. Mid-Holocene vegetation history of the central Mediterranean. The Holocene 21 (1), 117–129.

Salone, A.M., 1988. Tentative de bonification de la plaine d'Aléria au XVIIe siècle par l'assèchement de l'étang Del Sale (ARSEC).

Salone, A.M., Amalberti, F., 1992. La Corse, mages et cartographie. Traduit de l'italien par A.M. Graziani, Ed. A. Piazzola, Ajaccio.

Scott, L., 1992. Environmental implications and origin of micrsocopic Pseudoschizaea. Thiegart and Franz Ex. Potonie emend. In sediments. J. Biogeogr. 19, 349–354.

Scott-Jackson, J.E., Walkington, H., 2005. Methodological issues raised by laser particle size analysis of deposits mapped as clay-with-flints from the Palaeolithic site of Dickett's field, Yarnhams farm, Hampshire, UK. J. Archaeol. Sci. 32, 969–980.

Siani, G., Paterne, M., Arnold, M., Bard, E., Métivier, B., Tisnerat, N., Bassinot, F., 2000. Radiocarbon reservoir ages in the Mediterranean Sea and Black Sea. Radiocarbon 42, 271–280.

Stos-Gale, Z., Gale, N.H., Houghton, J., Speakman, R., 1995. Lead isotope data from the Isotrace Laboratory, Oxford: Archaeometry data base 1, ores from the Western Mediterranean. Archaeometry 37, 407–415.

Stuiver, M., Reimer, P.J., 1993. Extended 14C database and revised CALIB radiocarbon calibration program. Radiocarbon 35, 215–230.

Tinner, W., Vescovi, E., van Leeuwen, J.F.N., Colombaroli, D., Henne, P.D., Kaltenrieder, P., Morales-Molino, C., Beffa, G., Gnaegi, B., van der Knaap, W.O., La Mantia, T., Pasta, S., 2016. Holocene vegetation and fire history of the mountains of Northern Sicily (Italy). Veg. Hist. Archaeobotany http://dx.doi.org/10.1007/s00334-016-0569-8.

Tramoni, P., 2001. Le Néolithique de la Plaine Orientale: données nouvelles sur les premiers résultats des prospections systématiques (communes d'Aleria et de Ghisonaccia, Haute-Corse). L'Aventure des savoirs de 1900 à 2000. Quels acquis pour la Corse?, Actes des Xe Rencontres Interdisciplinaires du musée de l'Alta Rocca, Piazzola, Ajaccio, pp. 11–23.

Vacchi, M., Ghilardi, M., Spada, G., Currás, A., 2016a. New Insights on the Mid to Late-Holocene Relative Sea-Level Changes in Corsica (NW Mediterranean).

Vacchi, M., Marriner, N., Morhange, C., Spada, G., Fontana, A., Rovere, A., 2016b. Multiproxy assessment of Holocene relative sea-level changes in the western Mediterranean: sea-level variability and improvements in the definition of the isostatic signal. Earth Sci. Rev. 155, 172–197.

Van Geel, B., Aptroot, A., 2006. Fossil ascomycetes in Quaternary deposits. Nova Hedwigia 82 (3–4), 313–329.

Vella, C., Costa, K., Istria, D., Dussouillez, P., Ghilardi, M., Fleury, J., Delanghe, D., Demory, F., Cibecchini, F., Moreau, J., Jouët, G., 2016. Evolution du fleuve Golo autour des sites antique et médiéval de Mariana (Corse, France). In: Ghilardi, M. (Ed.) La géoarchéologie des îles de Méditerranée, Actes du colloque GEOMEDISLANDS (30 juin-2 juillet 2015, Cargèse). CNRS éditions, pp. 229–244.

Wang, S., Jin, X., Bu, Q., Zhou, X., Wu, F., 2006. Effects of particle size, organic matter and ionic strength on the phosphate sorption in different trophic lake sediments. J. Hazard. Mater. 128, 95–105.

Weis, D., Kieffer, B., Maerschalk, C., Barling, J., de Jong, J., Williams, G.A., Hanano, D., Pretorius, W., Mattielli, N., Scoates, J.S., Goolaerts, A., Friedman, R.M., Mahoney, J.B., 2006. High-precision isotopic characterization of USGS reference materials by TIMS and MC-ICP-MS. Geochem. Geophys. Geosyst. 7, 30.