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NOTES

HOLOCENE LANDSCAPE EVOLUTION AT THE GARIGLIANO RIVER MOUTH

Ferrari K.[1*], Dall'Aglio P.L.[1], Bellotti P.[2], Davoli L.[2], Di Bella L.[2],
Esu D.[2], Torri P.[3], Bandini Mazzanti M.[3]

[1]*Dipartimento di Storia, Culture, Civiltà – Università di Bologna*
[2]*Dipartimento di Scienza della Terra – Università di Roma*
[3]*Laboratorio di Palinologia e Paleobotanica- Dipartimento di Scienze della Vita – Univ. di Modena e Reggio Emilia*
[*]*Corresponding author: Tel: +393393029444; e-mail: kferrari81@gmail.com*

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Abstract – The Garigliano Plain (between Latium and Campania) is characterized by the presence of wetlands behind the most recent beach ridge. Although modern cartography displays small lakes and the Greek and Latin authors describe a marshy environment close to the river mouth, it is not easy to define the nature of these wetlands and the relationship between the environment and the human presence. This research aims to reconstruct the evolution of the coastal landscape with a multidisciplinary approach that combines the typical analysis from archaeology, topography, geomorphology and palynology. In this paper we have focused on pollen analyses, that reveal an environment characterized by wetland vegetation. In the whole pollen diagram the anthropogenic indicators are very low so the cultivated fields appear to be far from the studied area.

Keywords: geoarchaeology, landscape evolution, Minturnae, palynology, sedimentology, delta plain, wetland

Introduction

Geographical and geological context

The Garigliano Delta Plain is located between Latium and Campania within a graben generated by anti-Apennine faults. During Tyrrhenian time, the coastal zone was characterized by beach ridges bordering a wide bay. The Garigliano River locally eroded the ancient beach ridge during the subsequent glacial phase. After the last glacial maximum, the sea level rose approaching the present sea level about 6 ka BP and new beach-dune ridges developed westward of the older ones. During the last 6 ka, a wetland developed in the area between the recent and ancient beach-dune ridges. The remains of *Minturnae* (a Roman colony) are on the ancient dune ridges, at the inner margin of the low area on the right-hand side of the River Garigliano, which built up a lightly cuspidated wave-dominated delta after the postglacial.
Two systems of beach ridges with a NW-SE trend, referring to the Euthyrrenian (inner system) and to Holocene (outer system), border a depressed area separated by the Garigliano channel. In this depression the area to the north of the Garigliano is narrower than in the south. Some traces of palaeo-channels indicate an old River Garigliano mouth located in the southern area. Historical maps show that these depressions were partially submerged until the 18 th century (on the maps we can observe the presence of coastal lakes – Cardi, 2006) and today they are kept dry by land reclamation infrastructures (channels or water pumps).

Historical context

The coastal plain was not inhabited till the Bronze Age. From the Middle Bronze Age to the Iron Age a small village was on the summit of Monte d'Argento, a rocky promontory 2 km north of the Garigliano mouth (Alessandri, 2007). The archaeological survey revealed the occurrence of some more

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settlements in the surroundings of the wetland (probably Late Bronze Age – see Fig.1).
From the Bronze Age until Roman colonization, the coast was probably unpopulated. We can't find any site with sure Iron Age pottery, save a sanctuary near the shoreline. At least since the 7th century BC the river mouth was used as landing place and place of worship (Fig.1). The goddess venerated (Marica) was associated with water and marshes. This sanctuary was also used as an emporium. In this way the mouth of the river became a place of trade and cultural exchange, a function that continued also in Roman time (Mingazzini, 1938; Bellini, 2007).

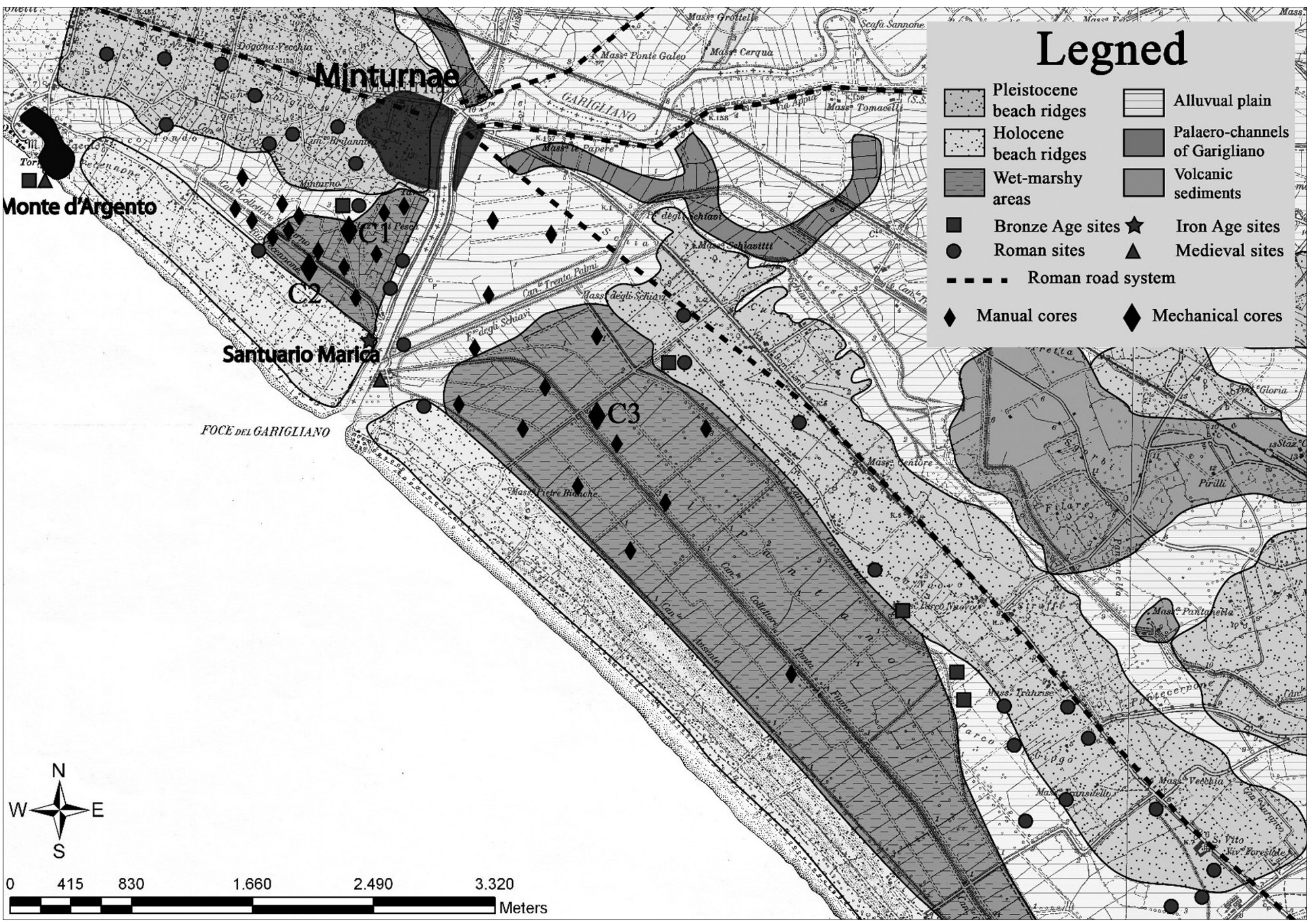

Fig. 1 - Planimetric view of Garigliano river mouth area (from Ferrari et al., 2012).

The Roman conquest started in the last quarter of the 4th century BC and changed the general organization of the territory. In 314 BC Romans destroyed the most important cities of the Aurunci (the population previously living in the area) and subsequently reorganized the territory with the construction of the Via Appia (312 BC), the founding of new colonies (Sessa Aurunca in 313, Sinuessa and Minturnae in 296) and the division and distribution of lands (Guidobaldi & Pesando, 1989).
The colony of *Minturnae*, situated on the Euthyrrenian beach-dune ridge where the Appia Way crossed the Garigliano River, became a very important trade center due to its fluvial harbour and landing place near the river mouth close to the sanctuary of Marica, which were implemented during the 1th century AD.
The archaeological survey found several settlements of the Republican and Imperial periods both on the Euthyrrenian beach-ridge and in the inner fluvial plain (Guidobaldi & Pesando, 1989). Even though the plain was intensively cultivated, the area behind the Holocene beach ridges was still characterized by lakes and marshes, which are described by various Latin and Greek authors. They depict an unpopulated wetland where vegetation, mud and water mixed up (Fig. 1).

From the 3rd century AD, the settlement pattern based on farms and *villae* began to decline. In about the second half of th 6th century AD *Minturnae* itself was probably abandoned and the population moved to the nearby hills where the modern Minturno is situated (Arthur, 1989). The Garigliano River mouth was still used as landing place between 881 and 915 AD, when a colony of Saracens settled close to the ancient city of *Minturnae*. After the battle expelling the Saracens, the coast remained almost unpopulated and the area behind the Holocene beach ridges was occupied by small lakes and marshes, as we can gather from the toponyms of *Pantano di Traetto* and *Pantano di Sessa*. Only last century all this area was reclaimed definitively.

Furthermore, Garigliano plain has some peculiarities that make it an interesting case for study as there is a detailed description of the environment in Roman texts. For this reason it was possible to integrate traditional methodologies of the palaeoenvironmental analysis with historical information to verify the reliability of all the different types of data.

Materials and methods

For this palaeoenvironmental study, we adopted a multidisciplinary approach. After the analysis of ancient maps and aerial photographs, we drew up a geomorphological map whereby we drilled a series of geological cores. We divided our geological survey into three steps: firstly we used a manual auger to acquire general information about the thickness and nature of the sediments; secondly we obtained 3 cores (C1,C2,C3) with a mechanical auger (up to 4.5/6 m in depth) to obtain continuous cores with preserved sedimentary structures; the last step was based on an extensive survey using the manual auger to collect as many details as possible concerning the different extension and thickness of the layers previously found. More than 30 cores on both the north and south side of the river were obtained (Fig. 1). The samples collected with the mechanical auger were subjected to further analyses: grain-size analysis

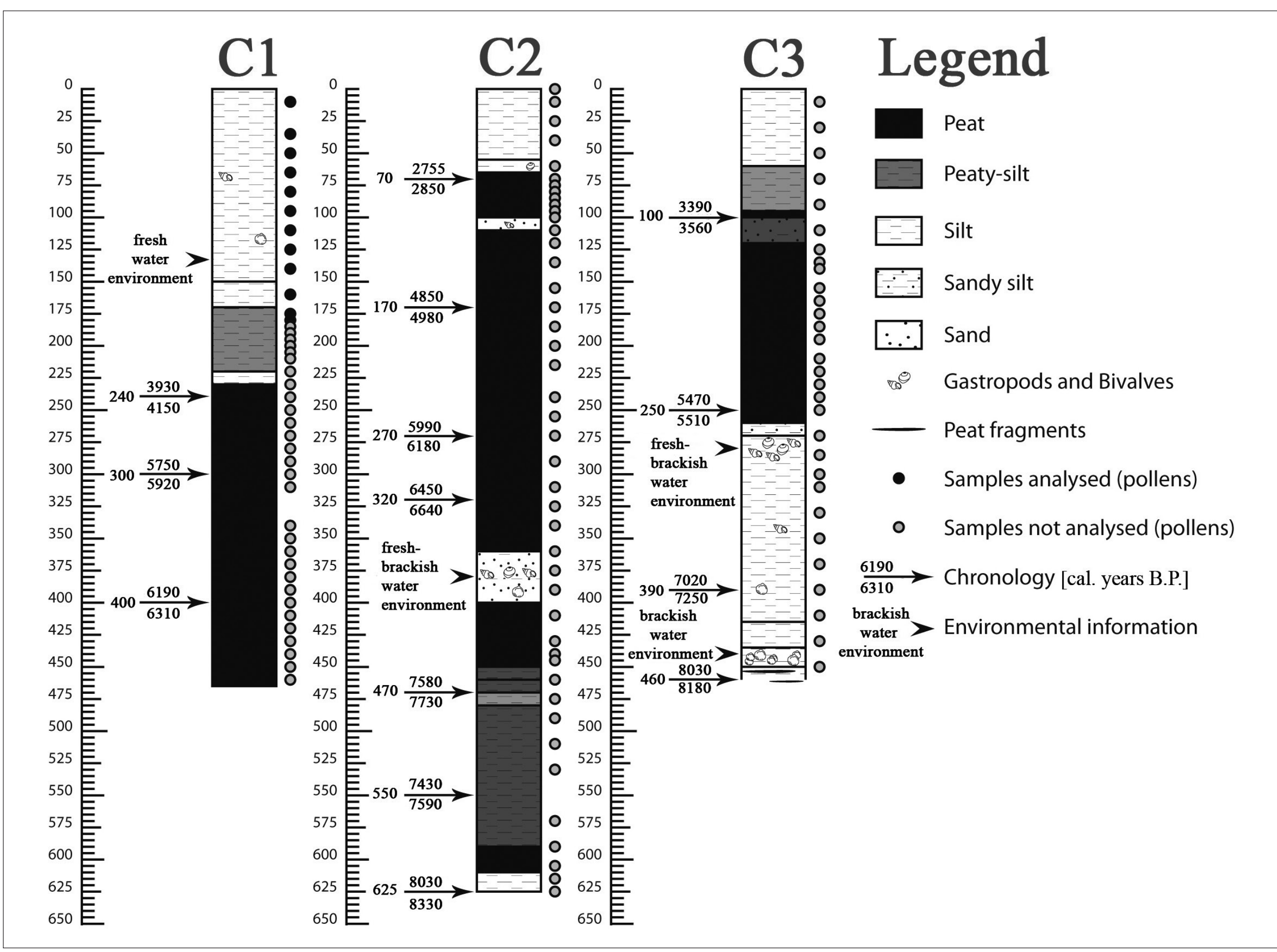

Fig. 2 - Stratigraphy of the three mechanical cores (modified from Ferrari et al., 2012).

by means of mechanical sieving and laser diffractometry for > and < 62μ fractions, respectively; ^{14}C datings, $^{13}C/^{12}C$ and C/N ratios, measured on specimens of the cored sediments selected; pollen analysis.

For pollen analysis 12 samples from the upper part of C1 core (from 10 to 180 cm in depth, Fig. 2) were studied. Sub-samples of 1-2 g were treated using tetra-Na-pyrophosphate, HCl 10%, acetolysis separation with Na-metatungstate hydrate, HF 40% and ethanol (van der Kaars et al., 2001; Florenzano et al., 2012). *Lycopodium* tablets were added to calculate pollen concentration (expressed as pollen grains per gram = p/g). Residues were mounted in glycerol on permanent slides. Identification was made at 1000× magnification with the help of keys, atlases (Moore et al., 1991; Reille, 1992; Reille, 1995; Reille, 1998) and the reference pollen collection of the laboratory of Palynology and Palaeobotany of Modena. On average, 400 pollen grains per sample were identified and results were expressed as percentages of total pollen. NPPs were identified using descriptions and photographs from NPP literature (Grenfell, 1995; van Geel et al., 2003; van Geel & Aptroot, 2006; Miola et al., 2006; Carrion & Navarro, 2002; Komárec & Jankovska, 2001).

Pollen samples reveal a high floristic richness. Totally, 160 taxa have been identified (146 taxa of pollen and spores; 14 types of NNPs). The highest number of terrestrial pollen taxa per sample was 62 and the lowest 46.

The total pollen concentrations range from 17.500 to 1.400.000 p/g (average 222.800 p/g) and the pollen preservation is good/very good.

The results of pollen analysis are presented as a pollen percentage diagram of selected taxa (Fig. 3), including the most important ecological groups. These are composed as follows: riparian trees include *Alnus, Populus* and *Salix*; hygrophytes include *Cyperaceae*, *Thalictrum*, *Typha latifolia* type; freshwater aquatics include *Butomus*, *Lemna*, *Myriophyllum alterniflorum* type, *Myriophyllum verticillatum* type, *Myriophyllum spicatum* type, *Nymphea alba* type, *Potamogeton*, *Sparganium erectum* type; evergreen trees and shrubs include *Quercus* cf. *ilex*, *Myrtus*, *Olea* and *Phillyrea*. The results of preliminary work concerning 12 samples are presented here. This study will be completed with the pollen analysis of further samples from C1, C2, and C3 cores on which several ^{14}C datings were carried out (Ferrari et al., 2012).

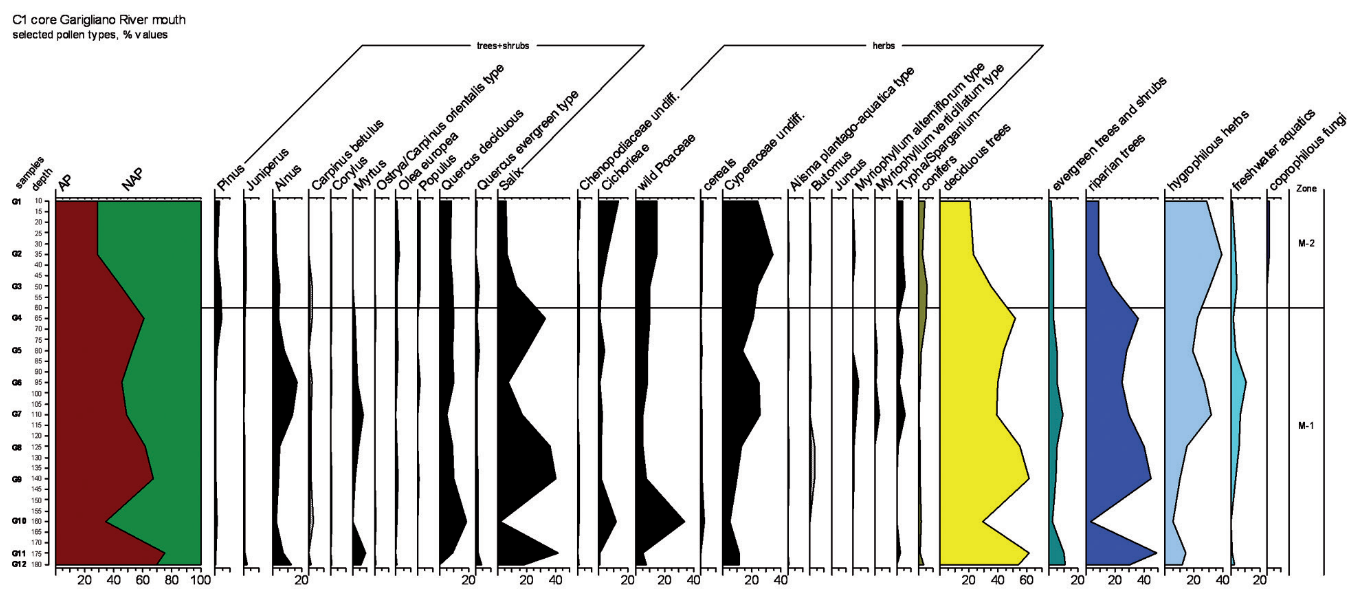

Fig. 3 - Pollen percentage diagram of selected taxa from C1 core.

Results

Sediment lithology

The stratigraphic succession was recorded by two cores in the northern palaeo lagoon and one in the southern one (Fig. 1-2). The sedimentary sequence in the northern palaeo lagoon is characterized by a peaty bottom member 5 m thick (from 6,10 m to 1,65 m in depth). In this member remains of woody plants were found and, locally interbedded, silty-sandy levels with rare fragments of *Cerastoderma glaucum* and *Bithynia tentaculata.* In one of these levels ostracods (*Cypreides torosa*) and euryaline foraminifera (*Ammonia tepida, Elphidium granosum e Ammonia parkinsoniana*) were found. ^{14}C datings in peat show an age range between 8 and 3 ka BP. The bottom member changes upwards (about 1,65 m deep) into a brown silty member with rare remains of freshwater gastropods (*Bithynia tentaculata, Planorbis planorbis e Stagnicola palustris*). The samples analyzed for C1 show the following chronology: 4 m deep 6190÷6310 BP; 3 m deep 5750÷5920 BP; 2,4 m deep 3930-4150 BP; 1,65 m deep 2990÷3170 BP. The sedimentary sequence indicates the occurrence of a marsh since 8 ka BP. The southern palaeo lagoon sedimentary sequence has a two metres thick basal silty member with rare peaty intercalations. In the lower part some levels with *Cerastoderma* sp. and *Loripes* sp. fragments, are interbedded. In the upper part fragments of *Cerastoderma* are mixed with *Bithynia tentaculata,* and *Stagnicola palustris.* The age ranges from 8 to 5.5 ka BP. The basal member is followed upwards (about 2,55 m deep) by a peaty member, 1.5 m thick, deposited between 5.5 and 3.5 ka BP. Finally, the upper member (about 1 m deep) consists of one meter of silt, slightly peaty at the base. The samples analyzed for C3 show the following chronology: 4,6 m deep 8030÷8180 BP; 3,9 m deep 7020÷7250 BP; 2,5 m deep 5470÷5510 BP; 1 m deep 3390÷3560 BP. The sedimentary sequence indicates the occurrence of a bay/estuary evolving into a marsh at about 5.5 ka BP.

Pollen data

In the pollen sequence from C1 core two zones, numbered from the base upwards, have been identified.

Zone M-1 (180 -60 cm)

This zone starts at 60 cm above a sample dated to 4150-3939 BP (240 cm in depth) and includes a sample dated 2990÷3170 BP (165 cm in depth). In this zone arboreal pollen types are dominant (ca. 57 %), and the most important arboreal component is represented by riparian trees (32 %). It is characterized at the bottom by AP values around 70%. The most important arboreal components are *Salix*, *Quercus* deciduous, *Alnus glutinosa* type, and appreciable values of *Myrtus.* Among non-pollen palynomorphs there are algal remains of Botryococcaceae, Zygnemataceae, *Mougeotia*, and *Coleochete*, an epiphytic alga (Poulíčková et al., 2006). At 160 cm AP percentages drop abruptly from 70 to 35 %: riparian trees and freshwater aquatics decrease. This process parallels a temporary expansion of herbs, namely Poaceae 34%. Above this phase AP percentages show a considerable increase, mainly related to an expansion of *Salix* (40%), and the reappearance of the acquatics.

Between 125 and 65cm arboreal pollen values (AP) range from 45,7 to 61,3% (54 %, on average). The following taxa are dominant: *Salix* (7-36%), *Quercus* deciduous (5-10%), *Alnus glutinosa* type (3-16%), and *Myrtus* (1,5 -8%). At 95 cm *Myriophyllum alterniflorum* type (3,8%) shows a peak. *Myriophyllum alterniflorum* D.C. is a light demanding species that grows in water with low mineral content. It is currently used as a biomarker for its sensitivity to “minerals” in solution (Chatenet et al., 2006). Immediately above and below this level, *Myriophyllum verticillatum* type is also present, which is less sensitive in mineral content than the previous one (Pignatti 1982; Chappuis et al., 2011). Furthermore *M. verticillatum* extends into waters having higher calcium contents than appear to be tolerate by *M. alterniflorum* (Hutchinson, 1970).

Zone M-2 (60 -10 cm)

A decline in AP characterizes this interval. Arboreal pollen reaches the lowest value in the sequence (28%), and this is mainly related to a decline in riparian trees, while *Quercus* deciduous together with other taxa of oak-dominated woodland remain essentially unaffected. A decline of *Myrtus* percentage is also observable. An increase in hygrophilous herbs is recorded, especially for Cyperaceae. Among the herbs Cichorieae and wild Poaceae increase, as also increase cereals.

Discussion

The pollen sequence from C1 core reveals an environment in which the wetland vegetation is almost always dominant. At the bottom of the part of the sequence examined (at the peat level, corresponding to the Late Bronze Age), the studied area is covered by rich riparian trees, mostly represented by *Salix* and *Alnus glutinosa* type, which show a moderate resistance to soil salinity (Funk, 2004; Kuzovkina & Quigley, 2004). The herbaceous vegetation is mostly composed by Cyperaceae and wild Poaceae, probably representing local elements of marshy environments. A remarkable amount of fragments of freshwater alga *Coleochaete* and of plant tissues and the recovery of *Rivularia* suggest that there was an eutrophic freshwater basin (Di Rita et al., 2010). However, the area is a mosaic of environments including dryland with groups of *Myrtus*, which probably is part of the dunal vegetation together with *Olea, Juniperus* and *Phillyrea* (Stanisci et al., 2004; Tattini et al., 2006).

Myrtus is an evergreen shrub of the Mediterranean thermophilous maquis (Migliore et al., 2012). It is a self-compatible insect-pollinated shrub (Gonzales-Varo et al., 2009), which usually lives in small-medium groups (Agrimonti et al., 2007), so the recovery of its pollen suggests a rather local presence.

The disappearance of aquatic plant and drop in riparian trees together with the passage from peat to silt, suggest that the area is drying up and grassland is becoming established, while deciduous woods increase. The prevalence of Poaceae and Cichorieae suggest consolidation of grassland that could be grazed (Mercuri et al., 2010). Also the disappearance of *Myrtus* may be related to pastureland use: this taxon is greatly appreciated by sheep and goats (Atzei, 2003).
Above this phase there is a remarkable expansion of riparian trees, mostly represented by *Salix* and *Alnus* and the freshwater aquatics reappear. Plutarch depicts a very similar environment. In 88 BC, during the First Roman Civil War, the Consul Marius fled from the army of his rival Sulla through the territory of *Minturnae*. He crossed the marshes close to the shrine of Marica, and was able to hide in an area rich in vegetation, with shallow water and mud. The area was unpopulated, save for a fisherman's hut (Plut. *Mar.* 37-40).
The presence of *Myriophyllum alterniflorum* with a peak at 95 cm in depth indicates a basin with limpid and oligotrophic water (Chatenet et al., 2006) . We can suppose that this phase corresponds to the Imperial period (approximately I century AD), when Romans reinforced the river banks (structures along the river banks are signaled by Ruegg, 1995 pp. 32-33, 132; Arata, 1993 p. 159 n. 4, p. 160 nn. 5, 11-12; Andreani, 2003 p. 202 sito n. 5) and developed the sanctuary of Marica with new structures (Mingazzini, 1938; Andreani, 2003). In fact, by this actions, they could probably prevent the water of the Garigliano, rich in calcium carbonate, from overflowing into the basin. Moreover this period was also warm and dry. In this context *Myrtus* reappears. At this time the area is covered by oak-dominated woodland, made up of diverse trees (e.g. *Corylus*, *Ulmus*, *Ostrya*/*Carpinus orientalis*, *Carpinus betulus*), by evergreen communities, probably more abundant along the coastal belt, and by riparian trees and freshwater aquatics related to the presence of marshlands.
In the upper part of the sequence, corresponding to the modern age, the increase of Cichorieae and wild Poaceae with the good presence of coprophilous fungal spores, give proof of grazing (Mazier et al., 2009; Mercuri et al., 2010; Torri et al., 2012), which could probably be involved in the progressive reduction of *Myrtus*. The riparian trees decrease, while the high value of Cyperaceae and the presence of freshwater aquatics suggest the persistence of ephemeral freshwater marshland.
In the whole pollen diagram the anthropogenic markers are very low and include *Juglans*, *Morus*, *Vitis* and *Olea* (though in this contest might be wild *Olea*). The cultivated fields appear to be far from the studied area, as documented by the very low value of cereals, whose presence is more constant in the upper part of the sequence. The palaeovegetational record from C1 core documents the landscape trasformation from Late Bronze Age to sub recent.

Conclusions

All the data collected allow us to reconstruct the evolution of the environment close to the river mouth. At about 8-6 ka BP the river delta plain was affected by the presence of a bay/estuary in the southern area while further north a marsh developed. At the end of the postglacial sea level rise (about 6 ka BP) the fluvial sediments were sufficient for more continuous development of the beach ridge, so also the southern area was isolated and the brackish environment changed into a fresh-water marsh.
Both marshes remained practically isolated, from the sea and the river, until about 3 ka BP. The first human settlements near the coast date back to the Late Bronze Age, when the environment was characterized by a freshwater eutrophic basin. The settlements were located on the drained terrain of the Eutyrrhenian dunes and bordered these two basins, probably to take advantage of their natural resources.
Both stratigraphy and pollen analysis show a significant environmental change at the end of the Bronze Age. About 3 ka BP river overflows altered the environmental features of the marshes. During the Iron Age the only archaeological site is the sanctuary of Marica that was associated to the marshy waters and was a landing and trading place.
Roman colonization did not change the nature of the wetland behind the Holocene beach ridges. The stratigraphy shows a sequence of silty-sandy levels and pollen analysis confirms the presence of vegetation typical of a lake with shallow freshwater.
After the Roman period the Garigliano started to overflow into the basin again and gradually filled the lake. The wetlands behind the Holocene beach ridge dunes became increasingly marshy, even though they dried out at times and were utilized for pasture. This process probably took place over a length of time. The northern basin was called *Pantano di Traetto* and the southern one *Pantano di Sessa*. They were still shown on modern maps and were completely reclaimed only in the 20^{th} century.

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