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Title

Human-environment interactions along the Tyrrhenian coasts of southern Italy from the Neolithic to the Early Medieval Age. A geoarchaeological approach.

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Abbreviations

a.s.l. – above sea level

EBA – Early Bronze Age

EMP – Early Medieval Period

EN – Early Neolithic

HP – Hellenistic Period

e.g. – for example

FBA – Final Bronze Age

Fig. – Figure

GP – Greek Period

IA – Iron Age

i.e. – intra alias

LA – Late Ancient

LMP – Late Medieval Period

LN – Late Neolithic

MA – Modern Age

MBA – Middle Bronze Age

MD – Middle Neolithic

Pl. – Plate

RBA – Recent Bronze Age

RP – Roman Period

Tab. – Table

ABSTRACT

Several environmental/climatic and cultural changes have affected central Mediterranean and particularly Italian peninsula during the Holocene. Therefore, the vegetation changes recorded in pollen sequences, especially in the late Holocene, can be partly linked to climate and environmental changes and partly to human impact. Distinguishing these drivers of ecosystem changes is still a challenge.

In this work, the environmental changes that have occurred in the last 8000 years along the southern Tyrrhenian side of Italy have been analyzed using a multidisciplinary approach consisting in pollen analysis, paleoclimate reconstruction on pollen proxy and archeological analysis in well-defined chronological frameworks.

In particular pollen analysis, considered the most appropriate method for reconstructing past landscapes, was carried out on five sediment cores collected along the Italian Tyrrhenian coast, in Campania and Calabria. Two marine cores were selected (Gulf of Salerno and the Gulf of Sant'Eufemia) in order to acquire a regional reference of vegetation changes, identified through pollen analysis, while three continental drilling cores (Sarno/San Vito sinkhole, Cellole/Mondragone, Lacco/Poro Plateau) have provided local vegetation reconstructions.

The pollen data from the two marine cores were used for quantitative climate reconstructions (MAT). In both cores, the reconstructed climatic parameters show an aridification trend beginning in the late Holocene. This trend is also observed in pollen spectra, especially in the progressive decrease in *Abies* that tends to almost completely disappear in modern times. In addition, the climatic curves also show some cold/wet and cold/arid phases comparable with the global events also recognized in other Mediterranean sequences. Among the most important are the 8.2 ka BP event (Gulf of Salerno), the 4.2 ka BP event (mainly in Sant'Eufemia) and the 2.8 ka BP event (Gulfs of Salerno and Sant'Eufemia).

Correlation between the new pollen results and published data have allowed us to better understand the phenomenon of vegetation change at a regional scale. All pollen data collected in the study area show a marked process of wide human deforestation since the Late Ancient Period (3rd cent. AD), while the local resource exploitation seems to occur in different modalities and time around the analyzed continental sites. Moreover, pollen data collected on the coastal plains sees a progressive disappearance of the floodplain forest since the Roman period.

Concerning human land use, fires and cereal crops appear since the Neolithic period, while the first *Vitis* domestication is dated to the Bronze Age. Other tree crops (*Olea*, *Juglans*, *Castanea*) seem well defined only since the Greek-Roman period, even if the start of these crops did not occur in all territories at the same time.

INTRODUCTION

The interaction between human and the environment and, in particular, the adaptation of human to environmental and climate change, is an interesting issue if addressed through a multidisciplinary study. Indeed, it is important that various branches act to understand the dynamics underlying the relationship between "Man and Earth".

Several environmental/climatic and cultural changes have affected central Mediterranean and particularly Italian peninsula during the Holocene (e.g. Giraudi et al., 2011). Therefore, the vegetation changes recorded in pollen sequences, especially in the late Holocene, can be partly linked to climate and environmental changes and partly to human impact (Mercuri et al., 2010b and references therein). Distinguishing these drivers of ecosystem changes is still a challenge.

The primary objective of my research project is to identify the human environmental changes of the last 8.000 years through pollen analysis carried out on continental and marine successions collected along the Tyrrhenian side of southern Italy, and to find the signs of the anthropic impact on this territory with a systematic study (geographical and archeological) of microregional contexts.

I focused my study on this territory where there is a paucity of data to reconstruct the paleolandscape and the human/environment interaction, hoping to provide interesting information about the times and ways in which each population has interacted with the environment, adapting to it or modifying it.

Palynology is widely recognised to be one of the most appropriate method for reconstructing past landscapes, assessing climate changes and related vegetation changes. To achieve these aims, palynology was supported by other methods closely related to pollen analysis such as a careful definition of anthropogenic indicators and microanthracology. In fact, a quantitative analysis of microcharcoals in pollen slides can help to understand the regime of fires in the past.

Environmental changes are also climate driven (e.g. Magny et al., 2013), therefore quantitative reconstruction of climate parameters (Peyron et al., 2017) has been tested here in a frame of strong climate variability and strong human impact (4.2 ka event; e.g. Kaniewski et al., 2018; Bini et al., 2019). Certainly, the multiplication of pollen sequences will allow to evidence the climate variability.

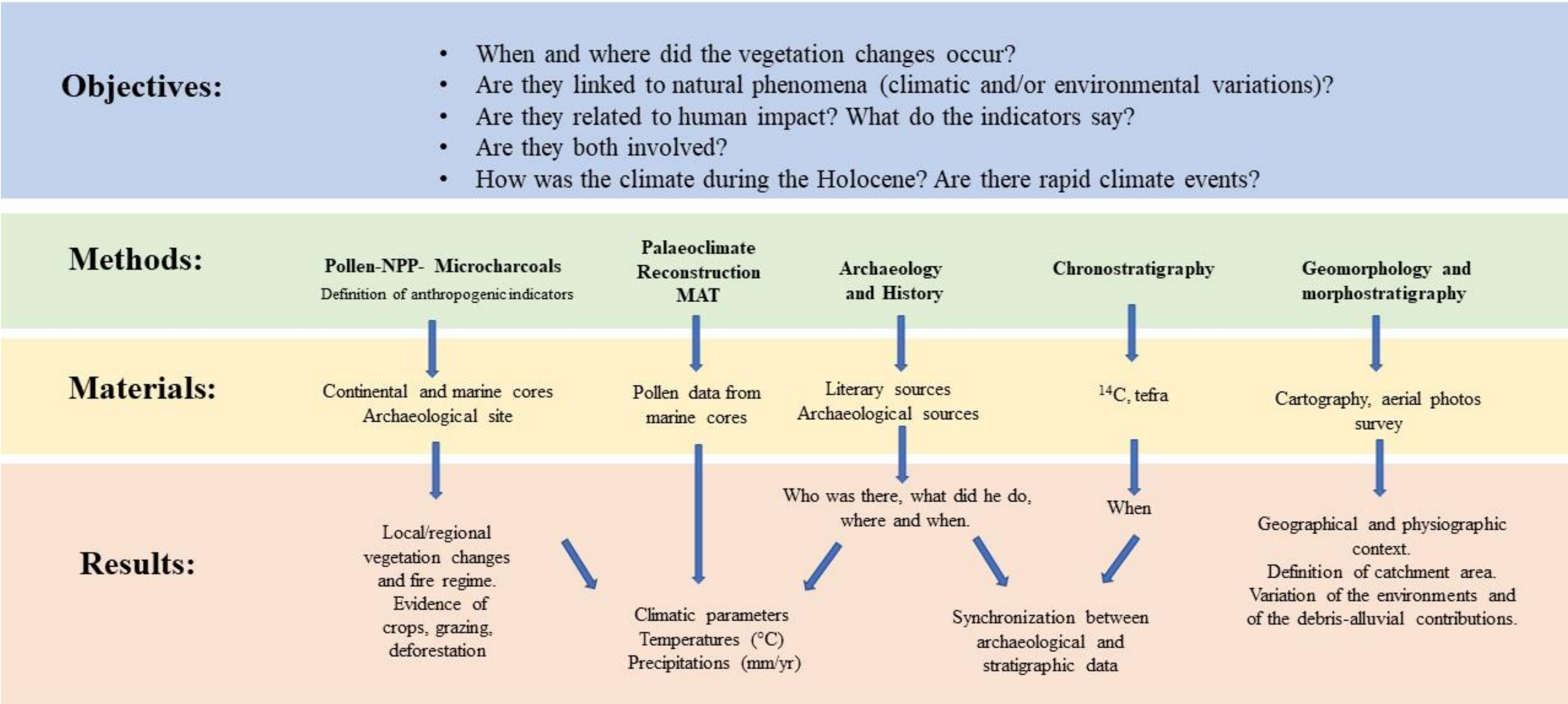
A changing climate may lead to changing societal strategies (e.g. Cremashi et al., 2016, Gogou et al., 2016; Izdebski et al., 2016; Mazzini et al., 2016) where different societies respond in different ways to the same specific climate change (Weiberg et al., 2016). Other studies demonstrate how the same society seems resilient to climate change at one point in time but not at another (Sadori et al., 2016). The Mediterranean region is richly endowed with information on human and environmental history, which makes it suitable for exploring interactions between climate, environment and humans over a variety of time scales (Holmgren et al., 2016).

Southern Italy is particularly interesting for this type of research, considering the continuous anthropic presence in almost all geographical contexts. In fact, the peculiar environmental, climatic, geological and geomorphological conditions of south Italy have made it, since Prehistory, suitable for population, especially for the richness and variety of natural resources available. At this regard, the discovery of many archaeological sites in southern Italy confirm the predilection of these regions by various communities that have alternated, adapting their lifestyle to the surrounding environment and having a strong impact on the relevant territory.

In fact, the high human presence provided various changes in vegetation assemblages, but this topic is still debate (Harris, 2013 and references therein), mainly concerning the "intensity" and the "globaly" of vegetation changes in Mediterranean area. After all, wooded resources have always been the economic basis of the past populations but is not almost clear the real value of this exploitation. At this regard many authors talking about human deforestation in the past but according to Harris (2013) it is necessary to achive a clearer definition of deforestation or define various typology of deforestations withouth generalization.

In this work I have tried to clarify, through comparison of new and published pollen data, the timing and modalities of human deforestation processes by discerning those at regional scale from the local ones.

The following scheme shows the conceptual map of the project and the methods adopted to achieve the main objectives:



Objectives:
When and where did the vegetation changes occur?
Are they linked to natural phenomena (climatic and/or environmental variations)?
Are they related to human impact? What do the indicators say?
Are they both involved?
How was the climate during the Holocene? Are there rapid climate events?
Methods:
Pollen-NPP- Microcharcoals
Definition of anthropogenic indicators
Palaeoclimate Reconstruction MAT
Archaeology and History
Chronostratigraphy
Geomorphology and morphostratigraphy
Materials:
Continental and marine cores
Archaeological site
Pollen data from marine cores
Literary sources
Archaeological sources
14C, tefra
Cartography, aerial photos survey
Results:
Local/regional vegetation changes and fire regime. Evidence of crops, grazing, deforestation
Climatic parameters
Temperatures (°C)
Precipitations (mm/yr)
Who was there, what did he do, where and when.
When
Synchronization between archaeological and stratigraphic data
Geographical and physiographic context.
Definition of catchment area.
Variation of the environments and of the debris-alluvial contributions.

1. STATUS QUESTIONIS

1.1. Previous pollen data from the Tyrrhenian side of southern Italy

In this chapter, I present all pollen data used for comparison with my results (Tab. 1; Fig. 1). Considering the local value of the results obtained, which concern territorial contexts with different geological, geomorphological, environmental and cultural characteristics, it was necessary to use all available pollen data to obtain a complete paleoenvironmental reconstruction.

In particular, I have created four groups with regard to different use of the data in this work and mainly for their different value (Tab. 1; Fig. 1):

- Pollen data located in the same source area of my pollen data (yellow).
- Pollen data coming from the same coastal transect or in internal areas, but located in other catchment areas, to do a synchronic correlation of different environments (green).
- Local pollen data coming from archaeological contexts, to do a correlation between regional results and local results obtained for a precise chronological range (blue).
- Pollen data for palaeoclimatic reconstruction. This latter group also includes data from far away contexts, because in Italy there are few Holocene palaeoclimatic reconstructions based on pollen sequences and it is necessary to consider other regions. Certainly, the choice of these sequences do not include Alpine or in general northern Italian contexts, because there are largely different climatic conditions between South and North Italy (pink).

ID	Comune	Location	Material	References
1	Alessandria del Carretto (CS)	Lake Forano	Continental core (LF)	Sevink et al., 2019
2	Alessandria del Carretto (CS)	Fontana Manca	Continental core (FM)	Sevink et al., 2019
3	Ascea (SA)	Velia	Continental cores (S4 -S36)	unpublished
4	Avella, San Paolo Belsito, Schiava, Visciano, Palma Campania (NA)	Campanian Plain	Archaeological excavation	Vivent and Albore Livadie, 2001
5	Capaccio (SA)	Sele Plain	Continental cores (L1 - L2-L3)	Amato et al., 2013
6	Enna	Lake Pergusa	Continental cores (PRG 1-2; PEW 2)	Peyron et al., 2013 ; Sadori et al., 2013
7	Fagnano Castello (CS)	Lake Trifoglietti	Continental core (S2/Trifo.09)	Joannin et al., 2012 ; de Beaulieu et al., 2017; Peyron et al., 2013

8	Formia (LT)	Vindicio Plain	Continental core (S)	Aiello et al., 2007
9	Gaeta (LT)	Gulf of Gaeta	Marine core (SW104 C5)	Di Rita et al., 2018a
10	Giugliano (NA)	Lake Patria	Continental core (G1b)	Di Rita et al., 2018b
11	Lamezia (CZ)	Lamezia Plain	Continental core (SL1)	Ruello et al., 2018 Russo Ermolli et al., 2018
12	Lamezia (CZ)	S. Eufemia Gulf	Marine core (4a)	unpublished
13	Lamezia (CZ)	S. Eufemia Gulf	Marine core (6bis)	Bernasconi et al., 2010
14	Massa Marittima (GR)	Lake Accesa	Continental cores (AC3, 4, 5, 6, 7)	Drescher-Schneider et al., 2007 ; Magny et al., 2007; 2009, 2013 Peyron et al, 2011; 2013
15	Minturno (LT)	Garigliano Plain	Continental cores (C1 - C2 - C3)	Ferrari et al., 2013a, b; Bellotti et al., 2016
16	Napoli	*Neapolis* harbor	Archaeological excavation	Russo Ermolli et al., 2014
17	Nola (NA)	Croce del Papa	Archaeological excavation	Albore Livadie and Vecchio, 2005
18	Olevano sul Tusciano (SA)	Nardantuono Cave	Archaeological excavation	D'Auria et al., 2019 a, b
19	Poggiomarino (SA)	Longola	Archaeological excavation, continental cores	Di Maio et al., 2011
20	Pompei (NA)	Sarno bath	Continental cores (S5 - S6)	Vignola et al., 2019
21	Pompei (NA)	Pompeii	Archaeological site	Ciarallo et al., 1993; Ciarallo, 2004; Grüger, 2002; Jashemski and Meyer, 1979-1993; 2002; Jashemski and Meyer, 2002
22	Pompei (NA)	Pompeii - Casa dei Casti Amanti	Archaeological site	Mariotti Lippi, 1993
23	Pompei (NA)	Pompeii - Casa delle Nozze di Ercole ed Ebe	Archaeological site	Mariotti Lippi, 2000; Mariotti Lippi and Bellini, 2006.
24	Pontecagnano (SA)	*Picentia*	Archaeological excavation, continental cores	Amato et al., 2009; Russo Ermolli et al., 2011
25	Pozzuoli (NA)	Lake Averno	Continental core	Grüger and Thulin, 1998
26	Reggio Calabria	Canolo Nuovo	Continental core	Schneider, 1985
27	Salerno	S. Leonardo	Continental cores (AR1-AR2)	unpublished
28	Santa Maria del Cedro (RC)	Laos Plain	Archaeological excavation	Amato et al., 2012
29	Torre Annunziata (NA)	Oplontis	Soil samples	Russo Ermolli and Messager, 2014; Russo Ermolli et al., 2017; Barone Lumaga et al., in press; Dimbleby, 2002
30	Tropea	Palazzo Vescovile	Archaeological excavation	Caramiello and Zeme, 1994

Tab. 1 – List of sites delivering pollen data (mainly from southern Tyrrhenian coast of Italy)

Fig. 1 - Location of sites listed in Tab. 1

1.2. **Holocene climate variability in the Mediterranean area**

Quaternary climate is characterized by the alternation of cold (glacial) and warm (interglacial) phases. These glacial/interglacial cycles were characterized, at the level of vegetation, by the rapid alternation of steppe/forest phases. The Holocene is the last interglacial period, the uppermost chronostratigraphic unit of the Quaternary and covers the last 11.700 years. The term "holocènes", which means "entirely recent", was first used by Paul Gervais (1867–69, p. 32) to refer to the warm episode that began at the end of the Lateglacial period, after the Younger Dryas (YD) event. The Holocene has been generally considered to be a period of global climate stability, characterized by warm climate conditions interrupted by rapid climate events such as the 8.2 ka (Magny et al., 2003) or 4.2 ka BP (Bini et al., 2019). The Holocene Climate Optimum or HTM (Holocene Thermal Maximum) is dated to between 9 and 4 cal ka BP (Berger, 1990; Orombelli e Ravazzi, 1996; Orombelli, 1997; Cremaschi 2000; Antonioli et al., 2000; Mackay et al., 2005) and a second warm period, the so-called "Medieval Climate Anomaly/MCA", dates to between AD 900-1350 (Graham et al., 2011). However, in some parts of Mediterranean Europe, the United States and South America it seems that temperatures during the aformentioned warm periods were not very different from present temperatures (Antonioli et al., 2000). The MCA period was characterized by an increase of zonal Indo-Pacific SST gradient with resulting changes in Northern Hemisphere tropical and extra-tropical circulation patterns and hydroclimate regimes (Graham et al., 2011).

Colder episodes were recorded as abrupt climatic shifts (Fig. 2). These episodes appear to have occurred with a cyclicity of approximately 2800–2000 and 1500 yrs (Bond et al., 1997, 2001; Mayewski et al., 2004, Di Rita et al., 2018b) but the timing and the duration of these episodes is still an open question in the Mediterrean area. In the North Atlantic region, Holocene climate events seem to be correlated in time, based on comparison between glacier fluctuations (Denton and Karlen, 1973), ice cores (O'Brien et al., 1995) and marine sediment records (Bond et al., 1997). Some authors use the term 'rapid climate change (RCC)' for these abrupt climatic events because, from a human civilization perspective, they may be considered rapid since they last for just decades or centuries. In addition, these events are not always synchronous across time and space (Mayewski et al., 2004).

Recently, Walker at al., (2018) proposed to divide the Holocene into three stages/ages whose boundaries were based on the most widely recognized climate shifts : 1. The Early Holocene or Greenlandian stage/age, 2. The Middle Holocene or Northgrippian stage/age and 3. The

Late Holocene or Meghalayan stage/age. Their corresponding subseries/subepochs are supported by a Global Boundary Stratotype Section and Point (GSSP) (Walker at al., 2018).

- Early Holocene (11.700 - 8200 cal yr BP): Early Holocene climate probably has more in common with the Lateglacial period than with more recent historical times. In particular, cold events occurred during this period are dated at 11.1, 10.3 and 9.4 cal ka BP (Bond et al., 1997). Mayewski et al. (2004) identify an important event in the interval 9000-8000, between the Early and Middle Holocene corresponding to the 8.2 cal ka BP (Bond et al., 1997, Magny et al., 2003) which is the major event of the whole Holocene.

  The 8.2 ka event appears in the NGRIP1 record. With regard to the European expression of this event, the signal of short-term change is weak in southern Italy. A hydrological partition in Central Europe is suggested with southern Europe marked by dry climate and northern latitudes (ca. 43°–50° N) marked by wet conditions (Magny et al., 2013; Peyron et al., 2013). Similarly, the 8.2 ka event does not seem to show either cold or dry conditions in the southern Aegean Sea relative to more northern sites, although a drop in precipitation is recorded (Triantaphyllou et al., 2009)
- Middle Holocene (8200 – 4200 cal yr BP): climate patterns during this period are complex. As suggested by the synthesis of Magny et al. (2013), contrasting patterns of palaeohydrological changes have been evidenced in the central Mediterranean throughout the Holocene, both on millennial and centennial scales. In terms of precipitation changes, the central Mediterranean during the middle part of the Holocene was characterised by humid winters and dry summers north of ca. 40 N, and humid winters and summers south of ca. 40 N (Peyron et al., 2013, 2017).
- Late Holocene (4200 – until present day): three Bond events occurred in this period (Bond et al., 1997): 4.2 ka (Bond event 3); 2.8 ka (Bond event 2); 1.4 ka (Bond event 1). Moreover, another recent event corresponds to the so called “Little Ice Age/LIA” (800 – 350 cal yr BP) and represents a more variable response in humidity at low latitudes compared to other Holocene events (Bradley and Jones, 1993; Mayewski et al., 2004).

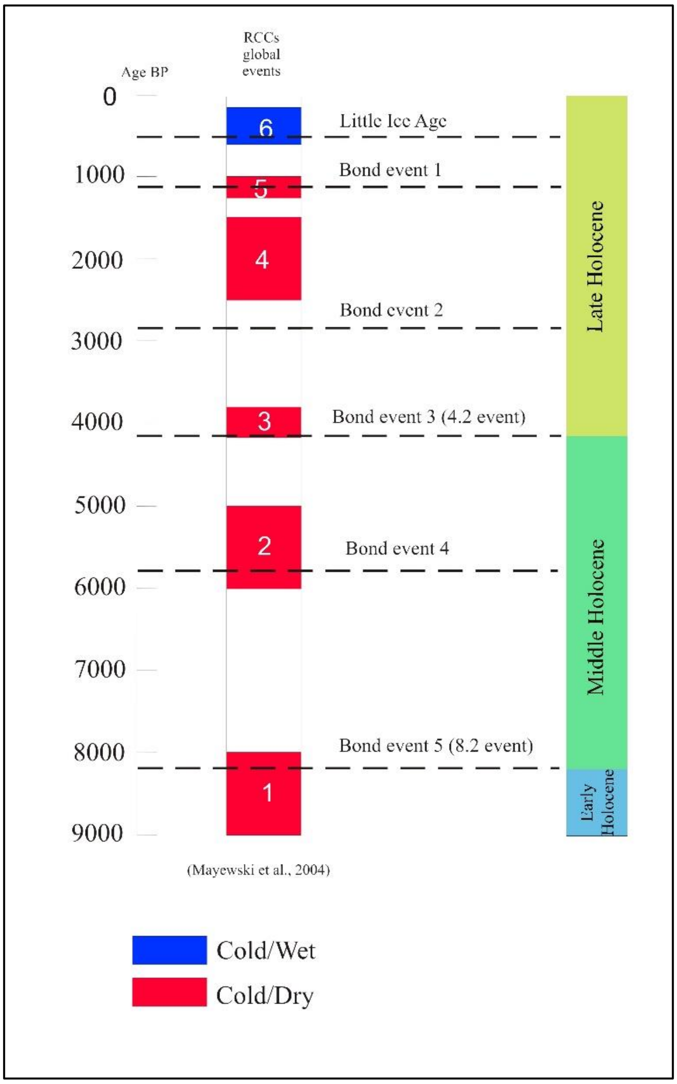


Fig. 2 - Chronological position of Bond global events and RCCs global events. Dashed lines indicate chronological position of related Bond event

The 4.2 cal ka BP event is the most important dry event of the Late Holocene and is characterized by an abrupt reduction in precipitation as the glacier advanced in northern high latitude regions, as well as increases in both sea-surface temperatures (SSTs) and sea-ice cover in the lower Antarctica (Walker et al., 2018). This event is recorded in proxy records across seven continents, from North America and Europe, through West Asia to China; and from Africa, Andean-Patagonian South America, Antarctica and the central North Pacific (Mayewski et al., 2004; Walker et al., 2018). At this time, archaeological data register social crisis and societal collapses in various parts of the world (Walker et al., 2018). In the literature, it is widely postulated that at the base of the North Atlantic “1500-year” climate cycle there is, maybe, a solar forcing mechanism (Denton and Karlen, 1973; O’Brien et al., 1995; Mayewski et al., 1997; Bond et al., 2001). According to Bond et al. (2001), it is possible that surface hydrographic changes may have affected production of North Atlantic

Deep Water, providing an additional mechanism for amplifying the solar signals and transmitting them globally.

Mayewski et al. (2004) believe that this forcing mechanism cannot be accepted for the intervals 9000-8000 and 4200-3800. The 9000–8000 cal yr BP interval occurs when the Northern Hemisphere was still significantly more glaciated than today, so it may be interpreted as a partial return toward glacial conditions following an orbitally driven delay in Northern Hemisphere deglaciation. Moreover, this interval occurred concomitantly with a significant increase in volcanic aerosol production, when bipolar ice sheet dynamics still had significant potential for affecting global climates (Mayewski et al., 2004).

Whereas, the forcing mechanisms behind the 1200-1000 RCC could be linked to the southward migration of the Inter-Tropical Convergence Zone (Mayewski et al., 2004), explaining the low latitude aridity associated with this RCC (Hodell et al., 2001), and/or cooling of North Atlantic surface waters (Bond et al., 1997). It is also possible that tropical deep waters in the Pacific cooled enough to spark the modern El Niño Southern Oscillation (ENSO) regime (Gomez et al., 2004), inhibiting and weakening the Asian monsoon which resulted in widespread drier conditions (Fisher et al., 2008; Fisher, 2011).

The Mediterranean basin is a peculiar climatic area because it is located at the transition between the middle latitudes submitted to the North Atlantic Oscillation (NAO) and the tropical zone. Its particular location could be the reason for the diversity of climatic responses and the chronological asynchronicity of the various global climate events (Jalut et al., 2009). In support of this hypothesis, Bini et al. (2019) show that in the Mediterranean basin between 4.3 and 3.8 ka (4.2 event), climatic and environmental changes occurred alongside changes in the hydrological regime toward more arid conditions. However, at a local scale the evidence is confounded. The authors explore the possibility that this event is regionally articulated with different local climatic expressions, which also relate to different seasonal conditions. Additional data highlight a tripartite climatic oscillation for the 4.2 ka event (Magny et al., 2009; Zanchetta et al., 2016) with the following succession: wet phase (4300-4100 cal yr BP); dry phase (4100-3950 cal yr BP); wet phase (3950-3850 cal yr BP). Di Rita et al. (2019) show that at Italian sites located between 43 and 45° N, the 4.2 ka event has no significant impact on vegetation (Fig. 3). However, at some sites located between 36 and 39° N, the 4.2 ka event causes a dramatic decline in forest cover. Additionally, a marked opening of the forest is noted at several sites located between 39 and 43° N (excluding Sardinia and Corsica). With these data it is possible to hypothesise that human activity, especially intense in southern Italy, may have been favored from the natural opening of vegetation.

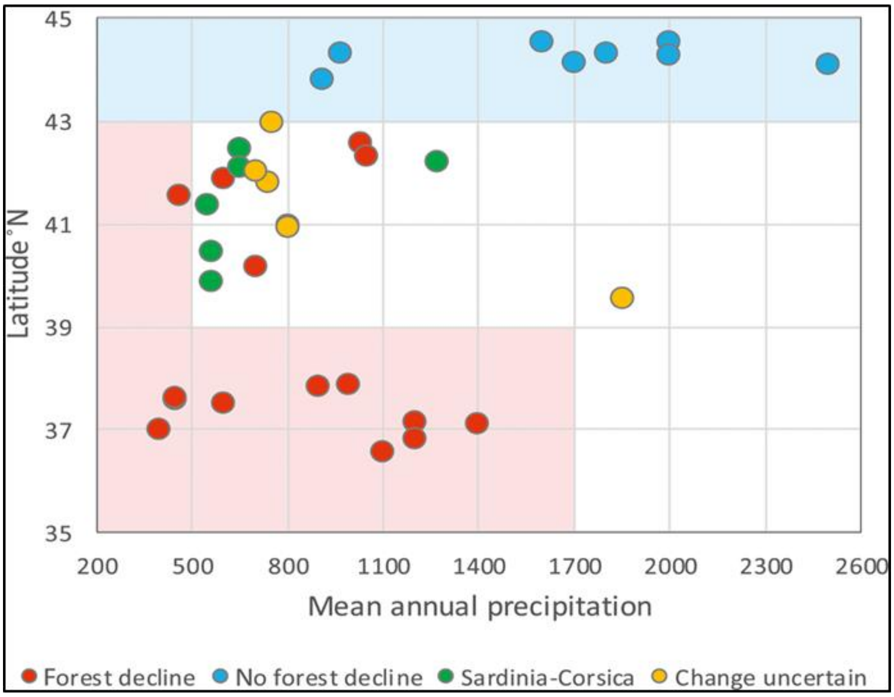


Fig. 3 – Latitude of pollen records from the central Mediterranean plotted against the respective mean annual precipitation for the 4.2 ka event (Di Rita et al., 2019).

Pollen and lake-level records highlight that throughout the Holocene there is a climatic partition between northern and southern Italy (Magny et al., 2013; Peyron et al., 2013). Northern sites such as Lake Ledro and Lake Accesa are characterized by warm/dry conditions. Conversely, southern sites like Lake Trifoglietti and Lake Pergusa are characterized by cool/wet conditions, which become reversed during the Late Holocene.

Climate reconstructions from lake and cave isotope records suggest another division in the history of Holocene Mediterranean climate. These data indicate that in the eastern Mediterranean, an increase in winter precipitation occurred during the Early Holocene followed by an oscillatory decline after ~6 ka BP. In the western Mediterranean, maximum increases in precipitation occurred during the Middle Holocene (around 6–3 ka BP). The Balkans, southern Italy and Tunisia represent presumably the division area of these two climate domains. Therefore, it appears that the climate change occurred in the eastern Mediterranean before it did in the western Mediterranean, although pollen data show that the impact of regional-scale climate changes was superimposed on local conditions with differing levels of sensitivity (Roberts et al., 2011). Concomitant with these climatic changes, complex societies have developed in the Mediterranean basin since the Neolithic

(Roberts et al., 2011) and the pressure on the landscape became more significant since the Roman period. Nevertheless, the major synchronous changes could not have resulted from anthropogenic activity alone, although human activity on these landscapes likely induced the formation of the so-called anthropogenic plant communities in equilibrium with the new climatic conditions (Jalut et al., 2009).

The causes of Holocene climate changes are still much debated, and a multi-proxy approach is necessary to address the issue. It is vitally important to analyse what Michael McCormick (2013) calls "human proxy data" to find a good "consilience" with other scientific proxy data in order to improve our understanding of the relationship between human impact on vegetation and climate change. From this perspective, the scheme with the different chronological expansions of various human culture in the Mediterranean basin proposed by Roberts (2011) represents a good synthesis of the archaeological data, despite the fact that a more comprehensive understanding of each regional situation is needed.

Despite the different responses of climate change in various regions, it is generally possible to distinguish three periods for the Holocene of the circum-Mediterranean area:

- Humid phase (11.500-7000 cal yr BP): during the "Holocene Climate Optimum" it is possible to identify particular markers in the paleoclimatic evolution, which translate into both environmental and cultural changes (Arie et al., 2003). In the Apennines and in the Alps, this period is marked by the diffusion of Mesolithic hunter-gatherer groups into areas made accessible by deglaciation (Antonioli et al., 2000). Then, the so-called "Neolithic revolution" (Childe, 1936), one of the most important cultural and economic change in human history, occurred. This long period started in the eastern part of Mediterranean basin 10.000 years ago and developed in the western part since 7500–7000 years ago. The Neolithic revolution is characterized by the propagation of stable communities dedicated to cultivation and breeding of domesticated livestock. Isotopic speleothem records from Corchia and Soreq caves identified the wettest period between about 8000 and 7000 ka (Zanchetta et al., 2013, 2014). During this period, the highest rate of Neolithic settlement expansion occurred in the western/central Mediterranean (Turney and Brown, 2007). This is also the period of sapropel S1 deposition in the Eastern Mediterranean and Ionian Sea (Zanchetta et al. 2013).

  Jalut et al. (2009) indicate wet conditions in circum-Mediterranean during this period and Mediterranean conditions in SE Spain and Sicily. Moreover, in the Near East, palynological, archaeobotanical and lake isotopic evidence suggest summer aridity in the Early Holocene until 8000 cal yr BP (e.g. van Zeist and Bottema, 1991; Wick et al., 2003). In the context of these contrasting signals, it is possible to think that there were no humidity conditions everywhere in a period corresponding to the weakening of monsoon activity (Peyron et al., 2011).

- Transition phase (7000-5500 cal yr BP): Neolithic communities mostly populate the plains while mountainous areas, with the exception of major routeways (e.g. Val d'Adige), are considered marginal and are rarely occupied. Generally, Neolithic sites are associated with deep soils, indicative of morphodynamic stability and the presence of a dense plant cover (Antonioli et al., 2000).
- Arid phase (5500 cal yr BP - present): concurrent with climatic deteriorations associated with Bond events, important palaeoenvironmental and cultural changes are documented. Archaeologically, the phase corresponding to 5500 – 3300 BP is very important. At the end of this chronological range, the Similaun culture appears in the Po Valley. Associated with this culture there is a phase of generalized soil erosion and slope degradation. However, in the same period there is a considerable economic change, marked by the development of pastoralism and transhumance, as well as the occupation of mountainous areas (Antonioli et al., 2000). This change in settlement preference occurs at different times and in different ways in Europe and is implemented through processes of deforestation that become more consistent during the Bronze Age.

  During the period corresponding to Bond event 1 (1.4 ka), environmental degradation is noted. In fact, many archaeological and literary sources confirm a period of dramatic instability during the Late Antique period, such as the floods of Modena in northern Italy (Antonioli et al., 2000), the floods of Velia (Russo Ermolli et al., 2013) and the significant coastline progradation of Neapolis (Russo Ermolli et al., 2013; 2014) in South Italy. These phenomena could be linked to the synergic action of a worsening climate (Antonioli et al., 2000) and to the collapse of territorial management following the end of the Western Roman Empire (Antonioli et al., 2000; Russo Ermolli et al., 2014).

  At the beginning of the Early Medieval period, an intense deforestation occurs alongside the intensification of agricultural practices in monastic communities. Contemporary developments in Europe also see the movement of settlements to higher and defensible elevations, a phenomenon referred to as "incastellamento". According to Mensing et al. (2016), in central Italy, increased average temperatures probably allowed high elevation settlements to persist during the MCA (Graham et al., 2011), even if social trends played a significant role in the conversion of uplands into an agro-pastoral landscape. In the same work, authors debate about the LIA that, in this area, manifested with cool temperatures and increased precipitation at the beginning of AD 1400. This, combined with the halving of population as a result of the plague, caused the abandonment of high elevation settlements and persistent flooding of the valleys. During the coldest and wettest period (AD 1601), new hydrologic technology allowed the community to drain the wetlands and mitigate the impacts of climate change until AD 1750, when the basin was steadily reclaimed and converted to agriculture.

1.3. “Deforestation or not deforestation, that is the question”

The concept of deforestation is not easy to explain. Hughes (2011) defines deforestation as the “anthropogenic disturbance of the local forest ecosystem”. Normally, the term is associated with an ecological crisis and the factors that induce this process are various.

The most evident factor is population growth, but it is necessary to know how much wood the pre-modern populations needed per capita (in each period) in order to understand the "intensity" and "universality" of the phenomenon of deforestation.

Deforestation has always been the subject of intense debate among scholars who have focused on the intensity of economic activity in ancient times. The debate is still open and therefore this chapter will only try to explain the problem in its broad historical and disciplinary context.

Harris (2013) reflects on the problem using a multidisciplinary approach with regard to the Greek-Roman Mediterranean context, even if, according to Sallares (2007), it is impossible to generalize the phenomenon, due to the fact that human impact varies from area to area, and Mediterranean countries generally cannot be described either as a ruined or as an unchanged landscape.

When dealing with the problem of vegetation cover, the data require an interpretation that goes beyond the concept of “full/empty” (sensu Vanni, 2013-2014); i.e., where there is a dense human occupation (the full), one can derive the distribution of the forest cover (the empty). This scheme is in fact misleading, because the management of forests and the use of spaces cannot necessarily be inferred from the absence of a significant settlement density (see chapter 3.3).

The PhD work of Vanni (2013-2014) is a good summary concerning the exploitation of wooded resources and the different aspects to the question. Primarily, it is necessary to distinguish various forms of wood resource exploitation:

- *Timber use.* It is important to remember that timber was used in the past for various purposes such as house and ship construction, metallurgic technologies, heating, domestic small tools construction etc. In fact, even if the archaeological guide fossil is pottery, found abundantly in archaeological deposits, timber is certainly the most important material used in the past, due to its easy accessibility.
- *The use of wild plants and fruit as human and animal food.* Often this aspect is obscured from the “research” of plant crops, even while it is very important to understand the mode of wild nature exploitation. We should remember that even when wild resources were unimportant in total quantity, they may have been

necessary for many purposes such as snack foods, tools, and ornaments such as antlers, furs, feathers (Albarella, 1997), gums and glues, flavorings, salt, dyes, lithic raw materials, building materials and firewood (Delano Smith, 1983). Especially in wetlands, particularly rich in resources, ethnographic studies have shown that products derived from the plant world make up almost 90% of the material culture of primitive peoples (Aranguren and Revedin, 2008). After all, people familiar with their landscape have always used plants as building materials, fibers for weaving, food and medication. In this regard, we should recall the Italian Paleolithic settlement (c. 28.000 BC) located in Bilancino/Tuscany in which the inhabitants once processed marsh plants such as *Typha* to make a primitive flour (Aranguren and Revedin, 2008; Aranguren and Perazzi, 2013). The Bilancino discovery provides new evidence of an innovation that anticipated by over 20.000 years the so-called Neolithic Revolution. Another recent work carried out by Robb and Van Hove (2003) using the GIS method in Calabria (South Italy) hypothesizes that the Neolithic land use of this area cannot be reduced to the economic needs of agriculture, but must have involved both the use of wild resources and considerable cultural and social choice.

- *Forest destruction to open up the landscape for agricultural purposes and grazing*. Since the prehistoric period humans have preferred to live in open areas, probably the result of deforestation (Accorsi et al., 1983) through felling, sometimes using the "slash and burn" technique; i.e. cutting trees and setting fire to the cleared areas and then hoeing the soil to enrich it with the ash of combustion. This technique is attested to in the Eneolithic S. Pancrazio site in North Italy (Cremaschi, 2009). Deforestation also had the important function of providing large open areas to be exploited for the meadows/pastures, for example, Neolithic and Eneolithic settlements intended for the rearing of animals such as goats, cattle and pigs (Gobbo, 2010). These economic changes pushed the communities towards sedentarization, demographic increase and, therefore, towards the birth of real settlements (Pessina and Tinè, 2008).
- *The change from wild to cultivated tree species.* Not all plants were cultivated in the same period. Each species has its domestication history and these histories are different in every territory. Concerning South Italy, of great interest is the history of the grapevine and its first domesticated form beginning in the Bronze Age in its natural environment (floodplain forest), as well as successive crops during the Greek-Roman period (Russo Ermolli et al., 2011). Certainly, the discussion regarding crops and wild species changes with respect to the context, but some summary work was

carried out in an effort to understand this phenomenon. For example, an interesting work by Mercuri et al. (2013) talks of the progressive development of *Olea*, *Juglans* and *Castanea* (OJC) cultivation in Roman Italy. Also of importance is the debate concerning olive crops. Some scholars suggest the domestication of this plant since the Bronze Age in South Italy, but the discussion is still open because palaeobotanical remains that attest its cultivation are not easily interpretable.

Certainly, this topic is very complicated and is sure to be linked to the demographic pressure (Harris, 2013) that began mainly from the Bronze Age onwards, which brought as consequence the need to cultivate larger areas. Agricultural techniques became more advanced, with the adoption of the plough and the resulting increased speed of working the land. In this regard, in South Italy, the Palma Campania settlements (Albore Livadie, 1981a) that developed during the Early Bronze Age, are interesting. This culture is closely linked to the Vesuvian Pomici di Avellino eruption (1935/1880 BC – Passariello et al., 2009), that has dramatically destroyed, yet also preserved, many of the sites of this culture. At the time of the eruption, Campania was densely inhabited by communities of farmers and pastoralists (Albore Livadie, 2007 and references therein). Some of these settlements were of considerable extent, such as Gricignano (6 ha) with agrarian features (banks, gullies, one cart track) that show a remarkable regularity, hinting at patterned landscape exploitation (Saccoccio et al., 2013).

Moreover, the advent of metallurgy was the most important cultural change that determined the increase of wood exploitation (Harris, 2013). In fact, the core drilling carried out during the 1990s in Greenland showed a large amount of heavy metals, mainly lead and copper, resulting from metallurgical activity, which indirectly suggests a high degree of air pollution resulting from coal combustion (Hong et al., 1994, 1996).

Without doubt the demographic pressure reached its apex during the Greek and even more significantly in the Roman period. The exploitation of wooded resources in this time became quite consistent in response not only to the local population but also to a new economic form based on the export of resources, as testified by archaeological finds and literary sources.

Also in this case, it is not correct to generalize a very complex phenomenon which has affected the various Mediterranean countries at different times. In fact, we know that the export of raw materials and also precious objects was a common practice in the

Mediterranean basin as early as the Neolithic Age[1] and even more since the Bronze Age[2]. Nevertheless, it is important to underline that the “export phenomenon” was associated above all with the demographic increase, one of the causes of the Greek colonization and above all the first “global market” (sensu Geraghty, 2007) of the Roman Empire.

Concerning human impact on the landscape in the Greek and Roman periods, scholars are divided: Meiggs (1982) was cautious regarding the dramatic decline in forests at the end of the Roman Empire, and Harris (2013) notes that the hypothesis of Greek-Roman deforestation is not well-founded. Contrary to this, Thirgood (1981) and Hughes (1994) are in favor of massive deforestation during antiquity. Blondel and Aronson (1999) share these conclusions yet are more critical of the irreversibility of the phenomenon. Grove and Rackham (2001) believe that large deforestation occurred during the Medieval and Modern Ages, focusing on the relationship between the intensive exploitation of wooded resources and the consequent process of soil erosion along with the management practices of these resources.

The study of literary sources can sometimes help us to understand the landscape framework of determinate areas, though a robust interpretation is very important, as are archaeological finds. In this perspective the careful use of literary sources is important such as suggest by Harris (2013).

Another important aspect are climatic changes. In fact, the fluctuation of forest cover also depends on natural events. A changing climate may lead to changing societal strategies (e.g., Cremashi et al., 2016, Gogou et al., 2016; Izdebski et al., 2016; Mazzini et al., 2016) where different societies respond in different ways to the same specific climate change (Weiberg et al., 2016). Other studies demonstrate how the same society seems resilient to climate change at one point in time but not at others (Sadori et al., 2016).

Therefore, in this perspective, attempting to distinguish climate from human impact on vegetation (human deforestation or not) is very difficult without a multidisciplinary approach. In this work we will try to give a small contribution to the topic.

According to Harris (2013) it is necessary to first obtain a clearer definition of deforestation, or define various typologies of deforestation without generalization, hopefully through a multidisciplinary approach.

[1] The routes for the supply of obsidian in Neolithic period are known (i.e. Tinè and Vanzetti, 2014).

[2] It is important to remember in this regard the tin supply and the exports of precious goods, widely attested in the Mediterranean basin. One of the best-known examples is certainly the wreck of Uluburun (Pulak, 2008 and references therein).

2. MATERIALS

The materials studied in this work are listed in the the table below (Tab. 2) and their location is indicated in Fig. 4. Thier detailed description is presented in chapter 5.

ID	Region	Comune	Location	Material	Coordinates
CL1	Campania	Cellole (CE)	Coastal plain	Continental core CL1	40°17'81''E 45°59'712''N
C106	Campania	Salerno (SA)	Gulf of Salerno	Marine core C106	14°42'24''E 40°28'52''N
B24	Campania	Sarno (NA)	Fossa S. Vito	Continental core	40°48'9.97"N 14°38'31.27"E
MDC	Campania	Pollena Trocchia (NA)	Masseria De Carolis/Roman villa with bath	Archaeological site	40°52'0.10"N 14°22'33.88"E
MSK12-C4	Calabria	Lamezia Terme (CS)	Gulf of Sant'Eufemia	Marine core MSK 12 C4	38°46.6090'N 16°10.0070'E
L1	Calabria	Spilinga (VV)	Lacco	Continental core L1	38°36'51.55"N 15°58'9.96"E

Tab. 2 – List of sites analysed inn this work

Fig. 4 – Location of studied sites as listed in Tab. 2

3. METHODOLOGY

The following chapter describes the main methods applied in this work. The complexity of a geoarchaeological project has needed a multidisciplinary approach, thereby it is necessary to choose the best methods to obtain a large amount of statistically valid data.

In this case, the main method adopted is pollen analysis. Palynology is widely considered one of the best methods to reconstruct ancient landscapes and climatic variation.

However, considering the large anthropic pressure occurring in southern Italy since the Neolithic, it is necessary to understand if the vegetation and climate changes recognized in pollen spestra are due to natural or anthropic factors. Therby an accurate knowledge of archaeological data is essential.

Archaeology is a topic belonging to the human sciences but, in recent decades, it has been used for the understanding of complex phenomena that affect not only man and his material culture but also its relationship with the territory and its influence on the landscape transformation through the natural resources exploitation.

Then, for the evaluation of climatic changes occurring in the Holocene, a quantitative palaeoclimate reconstruction was made on the continuous record of the studied marine cores through MAT (Modern Analogue Technique).

3.1. **Palynology**

Palynology is the study of palynomorphs, a general term for microscopic entities such as pollen, spores, diatom cysts, etc. The term "palynology" was first coined in 1955 by Hyde and Williams. It is a combination of the Greek verb παλύνω - I strew or sprinkle, παλύνειν - to strew or sprinkle, the Greek noun παλη - dust, fine meal (very close to the Latin word pollen), and the Greek noun λογος - word, speech (Halbritter et al., 2018). A dominating object of the palynomorph spectrum is the pollen grain. The detailed study of pollen grains originated in the XVI cent. AD, facilitated by the invention of the first microscopes (Wodehouse, 1965). Throughout the 20th cent., a number of subdisciplines have developed within the field, each involving the study of modern and/or subfossil pollen. These subdisciplines include: melissopalynology, aeropalynology, allergology, pollination, harvest forecasts, palaeobotany, palaeoclimatology, palinostratigraphy and most importantly, palaeopalynology (Halbritter et al., 2018).

Palaeopalynology was established at the end of the XIX cent. AD, when P. Reinsch (1884) published the first photomicrographs of fossil pollen and spores from Russian coals. For many decades, palaeopalynology has been a very important discipline for the archaeological sciences and for the reconstruction of palaeolandscapes. Indeed, the combined application of palaeopalynology with other palaeobotanical studies, such as carpology and anthracology, has provided important information on past vegetation change, human land use over time and human exploitation of natural resources.

Pollen is a mass of microspores which represents an extra generation in seed plants. Each pollen grain is a small body which is formed in the male structures of seed-bearing plants. During transportation, through either anemophil or entomophil means, pollen grains are seperated from the parent plant, which results in the transfer of male genetic material to the female structures, where fertilization occurs (Hesse et al. 2008; Encyclopaedia Britannica). During pollen dispersion, post-meiotic products may remain as dyads or tetrades. Alternatively, they may completely disintegrate to form monads.

Pollen grains of different taxa have particular morphological charcteristics; grain sizes vary from less than 10 μm to about 200 μm and the measurement of grains is often important for the recognition of taxa which resembling each other, but which differ in size.

The wall of the pollen (Fig. 5), the sporoderm, is formed by two layers, an internal layer (intine) and an external layer (exine). The intine is composed of cellulose and pectic. It is perishable and is usually absent from fossil pollen. The exine is made up of sporopollenin, an acetolysis and decay-resistant biopolymer, which rates among the most resistive in the organic world. Sporopollenin can withstand strong acids and high temperatures, in fact, the acidity of the substrata favours grain conservation because low pH values inhibit the development of microorganisms which may corrode the grains. However, sporopollenin can be corroded by strong oxidizers.

The exine is divided into two layers: endexine (inner) and ektexine (outer). The ektexine consists of a basal foot layer, an infratectum and a tectum. The endexine is a mainly unstructured, single layer. In light microscopy, the most commonly used terms for the outer structured layer is sexine and for the inner unstructured layer is nexine (Hesse et al., 2008). So, when we talk about granules in the fossil state, we refer to the exine of pollens and spores.

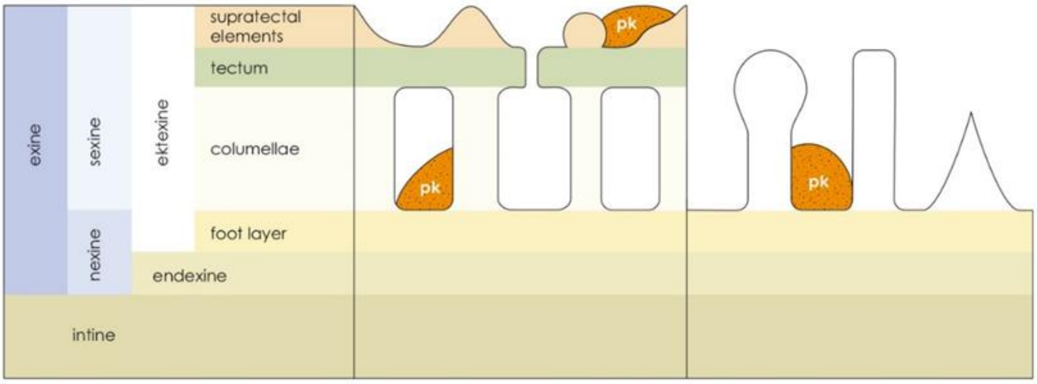


Fig. 5 – Pollen wall stratification (Hesse et al., 2008)

Pollen has openings (apertures) on the wall that function as a germination site (Fig. 6). The openings are present both on the angiosperms and on the gymnosperms but in the latter are different, as often there is a leptome. The pollen polarity determines the type of opening. There are different types of openings, the most important aperture types are colpi and pores (Punt et al., 2007; Hesse et al., 2008). The number of openings is indicated by the prefixes di- or tri-, sometimes are utilized also tetra-, penta - and hexa-, even if usually in the pollen granules with more than three openings at the equator, the openings are called stephanoaperture (**stephanoporate**, **stephanocolpate**, **stephanocolporate**). Colpi and colpori (colpi and pori) may be present simultaneously in some taxa; this condition is called **heteroaperturate** (Hesse et al., 2008). The openings are normally covered by a layer of hexina which may be smooth or ornamented. In addition, there are pollen grains without openings that are called **inaperturate** (ex.: *Populus*).

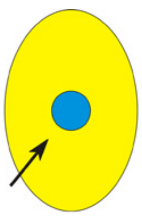
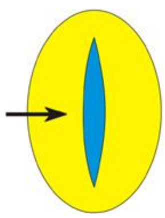
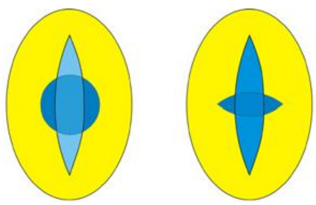
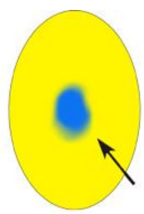
Porus or pore: circular opening.	**Colpus:** elongated opening.	**Colporus:** presence of both the pore and the hit.	**Poroid:** circular or elliptical opening with indistinct margins
			

Fig. 6 - Schematic drawings of the pollen openings (modified after Punt et al., 2007)

Another important element of distinction of pollen grains concerns the features of the surface, the so-called **ornamentation or sculpturing**. Among taxa, ornamentation is extremely variable. The most common ornamentation types include (Fig.7):

- **Areolate:** Pollen grains surface is composed of circular or polygonal areas separated by grooves which form a negative reticulum. Examples: *Apama*-Aristolochiaceae, *Phyllanthus*-Euphorbiaceae (Erdtman, 1947).
- **Clavate:** A club-shaped element of the sexine/ectexine that is higher than 1 μm, with diameter smaller than height and thicker at the apex than the base. See also: baculum, columella, gemma, pilum (Iversen and Troels-Smith, 1950).
- **Echinate:** Describing pollen and spores with an ornamentation comprising spines longer than 1 μm (Wodehouse, 1928). Erdtman (1952) used the term spinose, but in his usage, spines were defined as longer than 3 μm and smaller features as spinules.
- **Foveolate:** A feature of ornamentation consisting of more or less rounded depressions more than 1 μm in diameter. The distance between foveolae is greater than their breadth (Erdtman, 1952).
- **Granulate:** (sensu Erdtman, 1952) A very small and rounded element of the sexine/ectexine that is less than 1 μm in all directions. It's possible to use either the adjective granulate or scabrate.
- **Perforate:** Indicate the presence of holes (less than 1 μm in diameter) generally situated in the tectum (Iversen and Troels-Smith, 1950).
- **Psilate:** Describing a pollen or spore with a smooth surface (Wodehouse, 1928).
- **Reticulate:** A network-like pattern consisting of lumina or other spaces wider than 1 μm bordered by elements (muri) narrower than the lumina (Praglowski and Punt, 1973).
- **Rugulate:** Describing a type of ornamentation consisting of elongated sexine elements more than 1 μm long, arranged in an irregular pattern that is intermediate between striate and reticulate; ex.: *Ulmus*-Ulmaceae (Iversen and Troels-Smith, 1950). Some use the term **vermiculate** for surfaces of pollen grains with rugulae.
- **Striate**: Striae are grooves between elongated sculpturing elements (Fægri and Iversen, 1950) and Striate are generally parallel elements separated by grooves (Iversen and Troels-Smith, 1950).
- **Verrucate:** A wart-like sexine element, more than 1 μm wide, that is broader than it is high and is not constricted at the base; ex: *Plantago*-Plantaginaceae (Iversen and Troels-Smith, 1950).

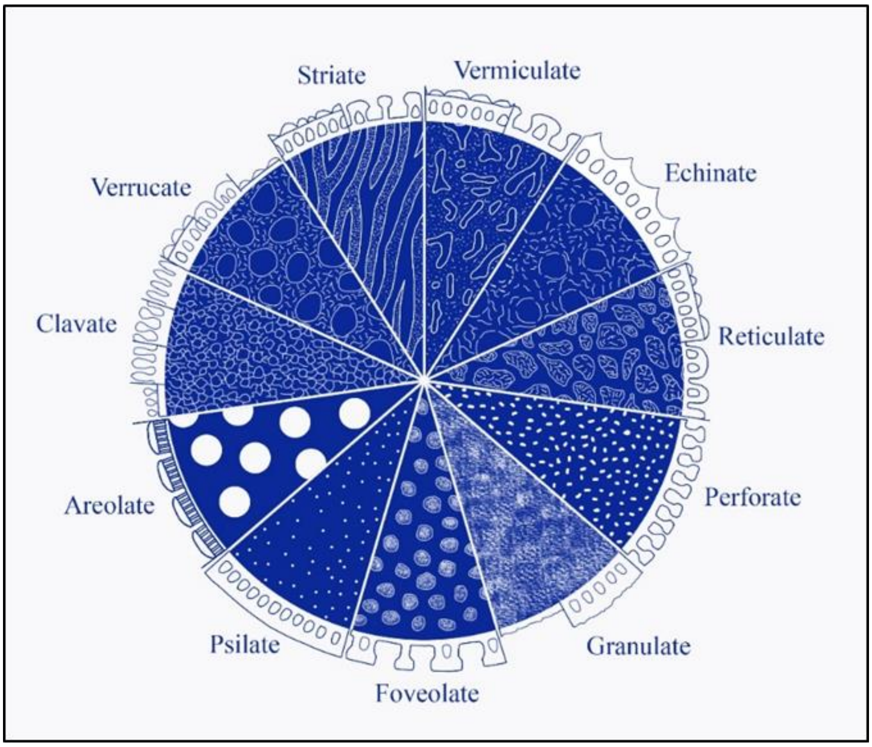


Fig. 7 - Various types of pollen surface ornamentation

The extraction of fossil pollen grains can be conducted on fine sediments from anaerobic (absence of oxygen) environments, both continental (lake sediments, marshes, peat) and marine (pelites in general). Additionally, pollen data recovered from archaeological excavations are very important for the reconstruction of the landscape in the immediate vicinity of the site. Unfortunately, pollen is rarely preserved in archaeological layers because soils are usually rebuilt by past anthropogenic activity. Nevertheless, some particular contexts can provide satisfactory results. Therefore, the most suitable archaeological layers for collecting pollen grains are, for example, the filling of drainage channels, well, cisterns and, in general, humid environments where in the past there was the presence of water[3].
Lake sediments are particularly useful for pollen analysis both for their nature (clay, silt, varve, peat) and for their deposition environment (closer to the pollen production environment). Moreover, the higher sedimentation rates of continental environments (about 0.5-1 mm/year) compared to marine environments (about 0.1-0.3 mm/year), allow to take representative samples of short intervals of time and therefore to obtain high resolution paleoclimatic and palaeoenvironmental reconstructions (Russo Ermolli, 2013).

[3] Think of the marshy areas of the Po Valley, where the Bronze Age Terramare excavations have provided interesting pollen data helping paleopalinology to find an excellent breeding ground in Italy (Bertolani Marchetti et al., 1989; Mercuri et al., 2015).

3.1.1. Sample collection and treatment

Sequences for pollen analysis can be recovered either through coring or in archaeological excavations, but it is important that samples collected from those sequences are well positioned stratigraphically and that they are not contaminated during the collection process. For this reason, it is necessary that the samples are compact so that slices of soil with uncontaminated organic matter trapped inside can be taken. Once taken, samples can be processed in laboratory to extract organic matter of size ranging between 11 μm and 200 μm (indicative size range of pollen grains).

In this study, all samples were cleaned externally and oven dried at 60 °C for approximately one day, although drying time varied depending on the humidity rate of individual samples. After drying, samples were crushed in a mortar and weighed. The quantity of sample treated varied but when possible, quantities between 5 and 10 g were used. One or more tablets containing *Lycopodium* spores were added to each sample prior to chemical treatment; these spores act as markers and allow the total number of pollen grains (concentration) present in each sample to be calculated. Samples were then subjected to a series of chemical and physical treatments. First, hydrochloric acid (HCl) 20% was added to eliminate the carbonates; during this process, there is a phenomenon of effervescence and the complete dissolution of the carbonates will be completed when the effervescence ends. Then, hydrofluoric acid (HF) 50% was added to each sample to eliminate silicates. For all samples, the acid was left to act at least for three days. Afterwards, a further treatment of hot HCl 10% was carried out to remove the insoluble fluorides formed during HF attack. Samples were heated for 10 minutes either on a plate at 60°-70° or in a water bath at a temperature of 90°C then rinsed with water and centrifuged to remove acid residues. To further concentrate the pollen grains, samples were subjected to a series of filters with strainers and an ultrasonic machine. Finally, the process of separation through a heavy liquid was carried out in order to eliminate the remaining minerals. For the latter treatment, Zinc Chloride ($ZnCl_2$) at density of 1.6 was used for some samples, while for other samples LST Heavy Liquid at density 1.8 was used, following a change in laboratory protocol.

In some samples, further treatment was necessary to remove excess organic matter, i.e. Acetolysis. This treatment consisted of processing the samples first with glacial acetic acid to dehydrate the sample, and then with a solution of acetic anhydride and sulphuric acid in a ratio of 9 to 1. The solution was poured into the test tubes containing the samples, then heated in a water bath for three minutes. After the chemical-physical treatments, the samples were taken with a medium, in this case glycerine, which allows the rotation of the pollen even after mounting the slides. The slides were mounted by placing a minimum amount of sample covered with a thin sheet of glass (the cover-object) glued to the slide with Hystolaque glue.

3.1.2. Quantitative analysis, pollen diagrams and zoning

Quantitative analysis was conducted for each sample. Pollen identification and counting were carried out under a light microscope at 400X, 500X and 1000X magnification, with the support of pollen atlases (Reille, 1992, 1995; Beug, 2015) and reference pollen material located at the DiSTAR of University Federico II di Napoli. Where possible, 300+ pollen grains were counted per sample but for marine core samples, where pollen concentration is usually poorer, between 100-150 pollen grains were counted. All pollen grains identified in each sample were noted on worksheets and then reported on an Excel file. The Excel files obtained for each core were imported on the software GpalWin to make the pollen diagrams. Each diagram (shown in the following chapters) presents taxa percent variation (X axis) plotted against age or depth (Y axis). The percentages of each taxon have been calculated on the sum of arboreal pollen (AP) and non-arboreal pollen (NAP), whereas spores, microcharcoals, indeterminate grains and dinoflagellates (EX) are excluded. In marine cores microcharcoals perccentage is calculate on the sum of AP, NAP and EX considering their over-representation.

In some cases, the taxa that constitute the local vegetation are not included in the pollen sum, as they are overrepresented. Indeed, the grains of these mostly aquatic/marsh plants (ex.: Cyperaceae) are deposited in higher quantities than those of the other species, given the closeness to the core site. Furthermore, marine cores are often rich in *Pinus* pollen grains due to its morphology that makes it easily transportable by wind over long distances; for this reason, this taxon is sometimes excluded from the AP sum so as not to mask possible changes in vegetation. Contrary to commonly used procedures, *Pinus* was not excluded from the marine cores because its quantity, not particularly abundant, cannot influence the rate of other APs.

The various taxa have been organized by listing AP first according to their ecological affinities (Mediterranean forest, deciduous forest, floodplain forest, montane forest). *Pinus* is not included in any forest group due to its generic rank of determination, which prevents from giving it a definite place in the landscape. Then, herbaceous taxa (NAP) have been listed, followed by marsh and acquatic plants and finally all elements of EX group.

Constrained Cluster Analysis (CCA) was conducted to facilitate diagram zonation with homogeneous and well-separated subsets (clusters) between available data, which was

marked with MATLAB through codes written by Valentino Di Donato (Federico II University).
Clustering techniques are based on measures related to the similarity of elements. In many approaches this similarity (or dissimilarity) is formulated in terms of distance in a multidimensional space. Clustering algorithms group the elements on the basis of their mutual distance, and therefore whether or not they belong to a set depends on how far the element under consideration is from the set itself. The hierarchical cluster groups the data on different scales represented by a dendrogram. Dendrogram representation for the hierarchical clustering of each core of this work has been set at the extreme right of the diagrams. The horizontal axis of the dendrograms represents the distance or dissimilarity between clusters, the vertical axis represents the objects and clusters.

3.1.3. Pollen dispersal and representation of local/regional vegetation

Pollen grains are deposited with sediments through waterborne (90%) and airborne (10%) transport (Brown et al., 2007). Pollen transport and subsequent deposition may vary in accordance with numerous factors. The transport of pollen to the atmosphere changes with respect to intrinsic palynomorphs properties that remain unchanged over time: pollen size, weight, morphology, and the pollination ecology of the plants producing the pollen. Other factors, such as atmospheric conditions, are instead highly changeable and affect pollen release and dispersal (Faegri and Iversen, 1989; Sugita et al., 1999; Ranta et al. 2008). In a limited situation, in a marine environment, we usually only find pollen types that are preferential to wind transportation due to their shape (eg: *Pinus*).
Despite the significant role of air in pollen dispersion, it is widely accepted that most of the pollen and spores entering medium-sized and larger lakes, as near-shore marine sediments, are fluvially transported from river catchments. In addition to the intrinsic properties of the pollen in question, the waterborne transportation of pollen mainly depends on the size, topography, catchment vegetation and the lake surface area. The majority of fluvial input in temperate basins occur during flood events (Brown, et al. 2007 and references therein). Indeed, spatial resolution of pollen data and the reconstruction of past environments are always correlated to the pollen source area. These assumptions are generally based on basin size and on the study of possible changes of it during the period of sediment accumulation (Calcote, 1995; Bunting et al., 2004). If the catchment is very large, pollen derived from local, extra-local and regional sources will appear in the basin. Contrarily, if the catchment

is small, only pollen derived from local and perhaps extra-local pollen will enter the basin and local vegetation will be over-represented in the spectra.

Sugita's simulation shows that the correlation between pollen load and distance-weighted plant abundance will increase as the vegetation sampling radius increase, approaching at a distance called "relevant" pollen source distance, beyond which you may have little information (Sugita, 1994). Pollen data are, therefore, best compared with distance-weighted plant abundance, rather than with plant abundance itself (Calcote, 1995).

Sofiev et al. (2013) use terms from Seinfeld and Pandis (2006) on spatial and temporal scales of variability of the atmospheric constituents to describe four different scale of pollen dispersion:

- Micro-scale: connected with pollen release at a few metres from the plants.
- Local scale: the pollen dispersion happens within the nearest kilometres from the source.
- Regional scale: this scale covers the processes responsible for the pollen dispersion at distances of up to a hundred kilometres.
- Synoptic, continental and global scale: long-range transport which includes processes of up to 1.000–2000 km, up to 5.000 km, and over 5.000 km, respectively.

Therefore, from the perspective of palaeocological interpretation of fossil pollen data, we can attribute the micro-scale pollen record as coming from close to study sites. At local scales, it is possible to associate pollen data collected from smaller lake, marsh and wetland sites as coming from within surrounding forests (Calcote 1995; Bunting et al., 2004). Instead, in the perspective of a regional-scale, we can insert data obtained by near-shore marine cores and in the last bigger scale we can insert pollen collected in marine cores at a long distance from the coast and in oceanic cores.

In this study, I have analyzed contexts belonging to the first three scales (micro, local, regional), that cover all the territory object of my research. The choice to collected data from archaeological excavations, continental cores and near-shore marine cores, is linked to the need to have a complete vision of vegetation in different focus levels. The correlation among all these data allows us to have a local and regional view of vegetation changes. Indeed, a purpose of this project is to interpret the local data from the continental cores whithin a wider image of vegetation changes coming from marine cores.

Data obtained from the few archaeological contexts analyzed have been correlated to published data to understand, specially, subsistence economy and land use of past populations.

To interpret paleocological pollen data it is very important to remind that all pollen coming from the different vegetation belts are mixed together in the same sample (Fig. 8), so the understanding of which was the vegetation setting from pollen spectra has to rely on comparison with modern vegetation.
This could cause misinterpretation especially when dealing with very ancient vegetation records in which we can still find exotic taxa, no more present in our study area, and we can only imagine which was their role in the vegetation associations and their position in the landscape.
But this problem is reduced in recent records, namely the Holocene, when it is supposed that vegetation had already acquired its modern pattern. But even in the Holocene we have to pay attention to some taxa, which could have changed their position in the landscape, due to climate changes or to man influence.
Respect to this last problem it is very important to understand the kind of deposit, not in the sense of granulometry or environment, but in the sense of if it is natural or man influenced. This aspect is also very important to consider for interpretation because normally the deposits influenced by man can have problems of reworking, presence of hiatuses and so on.

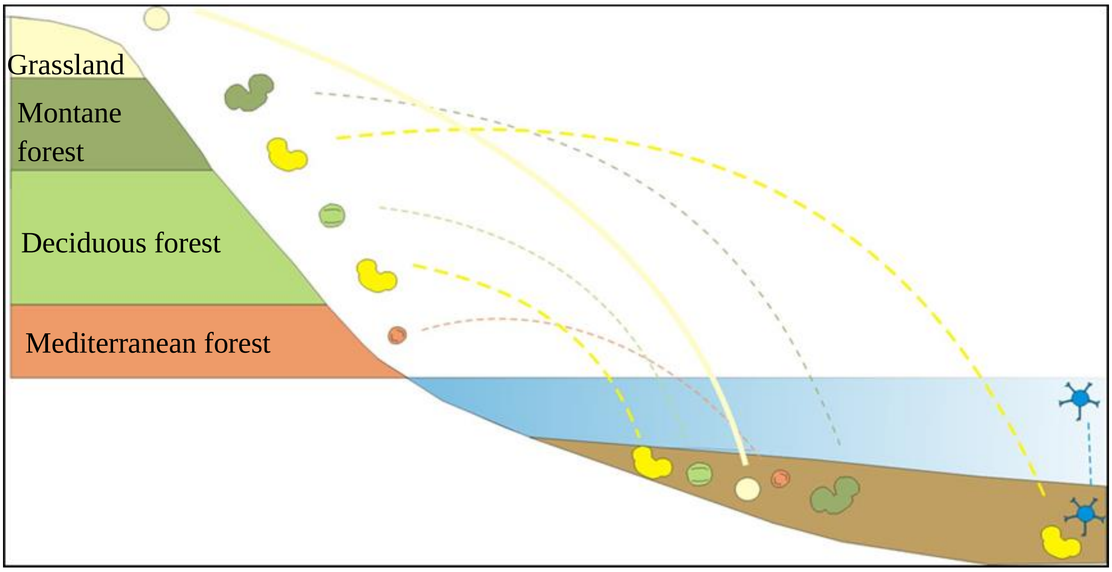


Fig. 8 - Dispersal of wind transported pollen grains from different vegetation belts (after Russo Ermolli, 2013)

3.1.4. Anthropogenic indicators

Since the Neolithic period, human activity has frequently had a discernible effect on natural vegetation, and these effects are often recognized in fossil pollen data. The approach to the problem has varied greatly with respect to the different kinds of human land use and use of natural resources available at the time. Therefore, the understanding of vegetation changes during the Holocene needs a multidisciplinary approach with the exploitation of paleobotanical data and archaeological knowledge of the analyzed territory. Concerning pollen analysis, some elements and individual taxa are accepted by the scientific community as anthropogenic indicators (Behre, 1981; Brun, 2011 and references therein).

Certainly, these indicators must be interpreted with caution and their anthropic value is very difficult to understand, so it is necessary to consider several factors:

1. Source pollen area;
2. Percentage of taxa or groups of taxa (among anthropogenic indicators);
3. Presence or absence of human settlements through a census of the archaeological sites in the territory analyzed.

With the data obtained from this research, it was possible to cluster the most important anthropogenic indicators into four groups based on their effect on the territory (fire events, cultivation, grazing, ruderal taxa). Certainly, the co-presence of more elements among the followings can provide a more reliable view of the anthropic impact and land use.

3.1.4.1. Fire events: the support of microanthracology

Since the Neolithic, the controlled use of fire has brought about major changes to the fire regimes of the planet. In many cases, anthropogenic practices such as slash and burn or logging have altered the planet's ecosystems. Fire regimes depend not only on climatic factors. They also reflect the cultural background of how people managed ecosystems and fire (Conedera et al., 2009). Particularly in fossil pollen samples, it is difficult to identify the stages of anthropogenic deforestation. However, through a combination of data it is possible to develop hypotheses and distinguish natural from anthropogenic fires.

A suitable method is to associate the percentage of forest cover (AP%) with the percentage of microcharcoals. The correspondence of microcharcoal peaks with a lowering of the forest cover can sometimes be interpreted as the consequence of anthropogenic fires. Fevre et al. (2008) assume that a percentage above 70-80% is considered to represent a forested environment, whereas values below 40-50% indicate open environments; intermediate percentages are indicative of a patchy landscape with forested areas and open spaces.

Since the work of Iversen (1941), analyses of fossil micro-charcoal from terrestrial and lacustrine sediments have been widely used and represent a very robust approach for reconstructing fire histories over time and a good indicator of anthropic fires (e.g. Patterson et al., 1987; Carcaillet et al., 2001; Asselin and Payette, 2005).

The charcoal can fragment in fine particles, and these can be lofted to great heights and transported over long distances. These particles may be so fine that they are often only visible microscopically and may be observed in palynological preparations.

Micro-charcoal particles on pollen slides can be analyzed in two main ways; by counting each single particle, or by estimating the total charcoal area in μm^2 by varying numbers of size classes (Lebreton et al., 2018). In any case, in our pollen preparations, only micro-charcoal fragments between 11 and 200 µm (the size range of filters) can be counted, thus excluding the largest particles. Regarding micro-charcoal morphology, only particles with sharp edges that appear black, completely opaque and angular must be considered (Tinner and Hu, 2003; Conedera et al., 2009).

In this work the method of counting has been used but, when charcoal particles are abundant, a minimum counting value has been established; so, according to Finsinger and Tinner (2005), a count of 200/300 items is sufficient to produce a charcoal-concentration estimate with less than ±5% error.

Particles with a size <10 µm, which represent the background noise of macro-regional fires, have been excluded (Sadori et al., 2004), and only micro-charcoals >20 µm have been considered.

A further element to consider for supporting a fire hypothesis are the trilete spores, whose increase could be indicative of fern regeneration on thin soils in deforested areas (Mensing et al., 2015). This method can be a valid alternative to the well recognized method of organizing micro-charcoal particles into size classes to identify the closeness or remoteness of a fire event. In fact, the increase in trilete spores in concomitance with a microcharcoal peak, whatever the size class, can be indicative of a more or less local fire, due to the fact that spores cannot be wind transported far away.

Despite the great value of these anthropogenic indicators, they must be interpreted in the right way. Indeed, even if there is a reduction in AP percentages, not directly associated with fire events, the anthropogenic component must never be excluded. Moreover, we know that, in addition to the practice of fire to open the landscape for agricultural purposes, especially since the Roman period, there has been an intensive exploitation of forest resources for recovering building material (Russo Ermolli et al., 2018). This means that forests were not burned but that the reduction in AP could be linked also to the mere felling of the trees. The above indicates that fire data should be used with care, also referring to the historical knowledge of the area that is engaging.

3.1.4.2. Cultivation

Crops are a clear sign of human impact. However, it is worth stressing that many edible plants that are native to the Mediterranean region are also found in pollen records that predate the Holocene period. With this consideration, it is very important to only infer the presence of crops when a thorough analysis of the percentages has been conducted. This approach cannot be applied to plant crops from all species, for example the olive, whose wild ancestor, the oleaster, is a natural element of the Mediterranean vegetation and can be found, even in large amounts, in association with other sclerophyllous elements, mainly *Quercus ilex*, suggesting a natural expansion under favourable environmental conditions (Kaniewski et al., 2009; Russo Ermolli et al., 2018).

Another important taxon used to infer cultivation is *Vitis* (Fig. 9). Exploitation in its natural environment (floodplain forest) started during the Bronze Age, then it was completely domesticated by Etruscan and Greek people (Forni and Marcone, 2002; Di Pasquale, 2010; Di Pasquale and Russo Ermolli, 2010a, b; Marvelli et al., 2013; Russo Ermolli et al., 2018). Thereby, in pollen spectra from this period we can see a gradual increase in *Vitis* percentages (up to 35% close to vineyards) coincident with the reduction of the other floodplain elements (Russo Ermolli et al., 2011; Russo Ermolli, 2017).

Also *Juglans* (Fig. 9) and *Castanea*, both native to southern Italy, are very important in pollen spectra, even if their percentages are often very low even in presence of near crops (Grüger et al., 2002; Di Pasquale et al., 2010; Russo Ermolli et al., 2011, 2018; Mercuri et al., 2013; Russo Ermolli, 2017).

Regarding horticultural evidence, high percentages of Brassicaceae (Fig. 9) have been found in different places of South Italy during Roman times, such as in the ancient harbor of Naples (Russo Ermolli et al., 2014), in the Villa di Poppea at Oplontis (Russo Ermolli and Messager, 2013), at Pompeii (Vignola et al., 2019) and off the Calabria coast, where it was chronologically constrained to the last 2000 yr (Bernasconi et al., 2010). The Brassicaceae family, which comprises cabbage, broccoli and radish, was a rather common crop in Roman times (Bostock and Riley, 1855; Zohary and Hopf, 1994) and one of the main plant food sources for the Romans (Bostock and Riley, 1855; Jashemski et al., 2002).

In the case of cereal pollen, even when values are low, anthropogenic land use can be inferred because the pollen of domesticated varieties is generally much larger than pollen of wild grasses. The criteria cited by many authors (Beug, 1961; 2004; Faegri and Iversen, 1975; Dickson, 1988) for distinguishing wild grasses from Cerealia type include pollen grains size, exine ornamentation and the size and appearances of pores. However, exine sculpture is a

good criterion of differentiation although in many cases, the exine of fossil cereal pollen is damaged. According to Joly et al. (2007), pollen grains ≥ 45 μm big with an annulus of 10 μm delimited by a protuberance with a distinct outer have been recognized as Cereal type (Fig. 9). The large pollen size and the general low pollen production of cereals make the recovery of their pollen very sporadic even when the coring site is situated near the fields where cereals were growing (Tweddle et al., 2005; Mercuri et al., 2006; 2010a,b).
The Fabaceae family must also be included among the cultivated plant types. Unfortunately, grains of pollen associated with the classic cultivated species, well known since Prehistory (e.g. *Vicia faba*, *Pisum*, etc.), were not found in the samples analysed.

3.1.4.3. <u>Grazing</u>

In recent years, the anthropogenic value of fungal remains has been realised, and often fungal spore analysis is conducted alongside pollen grains when examining anthropogenic activity. Coprophilous fungal spores (Fig. 9) are considered as reliable indicators of pastoral activity because they are uniquely adapted to herbivore dung. They are deposited with dung, and they grow and reproduce there. It is a continuous cycle, where the fungal spores are dispersed from the dung and subsequently consumed by the herbivores. They then pass through the intestines of the herbivore and are again deposited with the dung heap (Bell, 2005; López-Sáez and López-Merino, 2007; Florenzano, 2019). Many studies on coprophilous fungal spores agree that the most reliable indicators of pasture are *Sporormiella* and *Sordaria* types (López-Sáez and López-Merino, 2007; Mazier et al., 2009; Cugny et al., 2010; Ejarque, 2011), unidentified Sordariaceous ascospores (Cugny et al., 2010) followed by other spores such as *Podospora*, *Delitschia* (Mazier et al., 2009; Cugny et al., 2010), *Cercophora* (López-Sáez and López-Merino, 2007; Mazier et al., 2009; Cugny et al., 2010) and Coniochaetaceae (Cugny et al., 2010; Ejarque, 2011). In this work, the coprophilous fungi were counted in each sample and included in a single group. It was not necessary to divide the group by species because their ecological and anthropic value was considered in the same way.
According to Mazier (2007), it is possible to identify a group of taxa called Local Pastoral Pollen Indicators (LPPI) which includes the Cichoriodeae subfamily, (see also Mercuri et al., 2010a; Florenzano et al., 2015; Florenzano, 2019), the Asteroideae subfamily, *Cirsium*-type, *Galium*-type, Ranunculaceae family, *Stellaria*-type and *Potentilla*-type. Another important pastoral indicator is *Trifolium* type of the Fabaceae family (Behre, 1981). *Trifolium* lives in wide varieties of habitats from mountains to forest clearings and meadows. Sometimes the high quantities of this taxon may represent the presence of livestock dung or

the presence of fodder storage nearby (Dietre et al., 2012; Miras et al., 2018)[4]. In addition, the recent work of Miras et al. (2018) proves that *Trifolium* was milled to create animal fodder. Mercuri et al. (2013) has recorded high *Trifolium* pollen values at some archaeological sites in South Italy (Basilicata region) that date to the Hellenistic, Roman and Medieval periods. These data demonstrate that *Trifolium* was likely part of the (cultivated) fodder given to the domestic animals, grown around the settlement.

3.1.4.4. Ruderal taxa

There are some native herb (Fig. 9) taxa that do not directly reflect a specific land use but a background of human activities, so they are usually considered as ruderal habitat indicators or, using the term sensu Mazier (2007), Regional Human Activities Pollen Indicators (RHAPI). Their presence in the sequences analyzed as part of this work are very small but it could be possible that their overall percentages may indicate anthropic impact. Included in this group are cropland weed pollen (YiYin and HaiTing, 2008), such as *Rumex*, *Plantago lanceolata*, *Plantago major-media* (Behre, 1981; Mazier, 2007; Brun, 2011; Mercuri et al., 2013), Urticaceae (Behre, 1981; Brun, 2011; Mercuri et al., 2013), as well as *Theligonum*, Lamiaceae, Apiaceae and Brassicaceae (YiYin and HaiTing, 2008) and also *Artemisia* and Amaranthaceae (Mazier et al., 2007).

[4] Analysis of modern dung samples from pastureland demonstrates high concentrations of *Trifolium* pollen (*pratense*-type and *repens*-type) in association with other herbs such as Poaceae, *Plantago* (*lanceolata* type and *major/media* type) and CFS (Dietre et al., 2012).

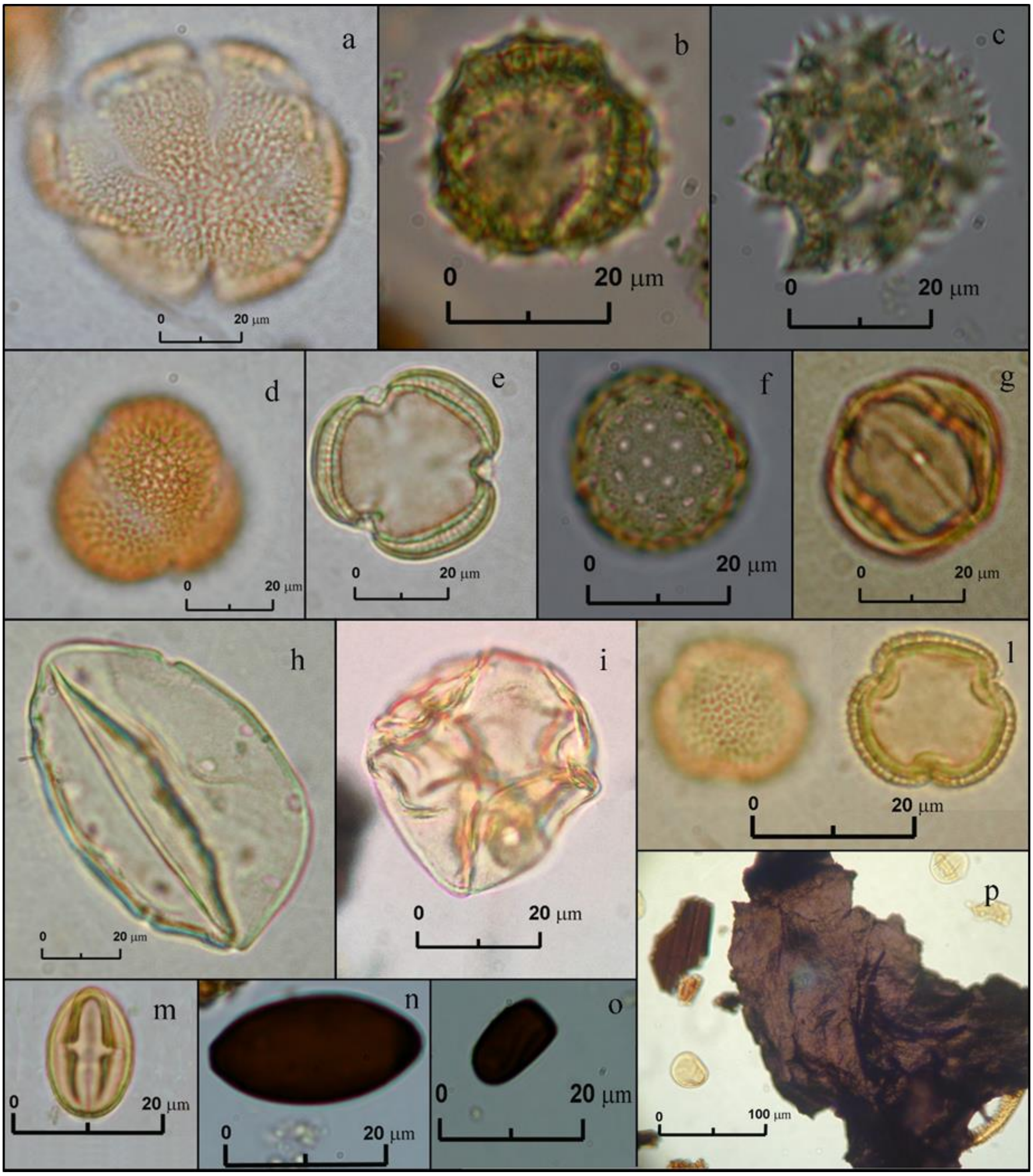


Fig. 9 – Some anthropogenic indicators: (a)Lamiaceae, (b) Asteroideae, (c) Cichorioideae, (d) Brassicaceae, (e) *Artemisia*, (f) Amaranthaceae, (g) *Vitis vinifera*, (h) *Juglans*, (i) Cereals, (l) *Olea* (m) *Castanea*, (n) Sordariaceae, (o) *Sporomiella*, (p) microcharcoal.

3.2. **Quantitative reconstruction of climatic parameters – MAT**

The most standard methods used in climate reconstruction and based on different ecological concepts are as follows:

- Assemblages approaches : Modern Analogue Technique MAT (Guiot, 1990);
- Transfer functions: Weighted averaging WA (Ter Braak and Van Dam, 1989); Partial Least Squares regression PLS (Wold et al., 1984); Weighted Averaging Partial Least Squares WAPLS (Braak and Juggins, 1993); Non-Metric Multidimensional Scaling/Generalized Additive Model NMDS/GAM (Goring et al., 2009).

All transfer functions require a calibration between environmental variables and modern pollen assemblages (Birks et al., 2010). In contrast to the transfer functions, the MAT does not require a real statistical calibration. This method has been choosen here in order to understand if the vegetation changes occurring in the analyzed pollen assemblages were linked to human or natural factor, identifying possible climatic events (chapter 1.2). Moreover, this method performs well in the reconstruction of Holocene climate in the mediterranean area (e.g. Davis et al., 2003; Pross et al., 2009; Peyron et al., 2011, 2017; Mauri et al., 2015).

MAT method performs a climate reconstruction taking a modern pollen dataset (taxa abundances) and an associated (bio) climate variable (temperature, precipitation…), and generating a model of closest modern analogues (called the best analogues), using the calculation of a distance between modern and fossil samples (Juggins, 2019).

Here, some taxa, identified during pollen analysis, but not included in modern dataset were excluded. Morever, taxa likely to represent local environmental conditions (aquatic taxa, spores, etc.) were removed from the fossil pollen data set. Then, the sample counts were standardised to percentages, based on the sum of all remaining taxa.

Our paleoclimate reconstruction is based on 6 best analogues. A minimum "analogue" threshold is established beforehand using a Monte Carlo method. Paleoclimate reconstructions based on the MAT were performed using the Rioja package in R (Juggins, 2016).

For all the results presented here, we used a modern pollen data set that contains more than 3500 modern spectra (lacustrine top-cores, moss polsters and terrestrial samples) with 2000 samples from the Mediterranean region (Peyron et al., 2017). The size of the data set used should be sufficient to cover most of the climate parameters expected to have occurred at the analyzed sites.

Following Prentice et al., (1996), the climatic and bioclimatic variables reconstructed here from the Italian fossil pollen records are:

- AET/PET: the ratio of actual over potential evapotranspiration;
- MTCO: mean temperature of the coldest month;
- MTWA: mean temperature of the warmest month;
- TANN: mean annual temperature;
- PANN: mean annual precipitation;
- SUMMERPR: mean summer precipitation.

The results obtained with MAT are correlated with available climate reconstructions in the same region or in the Mediterranean area (see Tab. 1).

Once identified the most important climatic events, it will be possible to check if these correspond to known climate events. If there is no correspondence and if anthropic taxa are evidenced in the pollen samples, we can conclude that the vegetation changes are more linked to human thanh to climate. An independent climate proy such as for example, molecular biomarkers is needed to confirm or not this hypothesis (Martin et al., in press).

3.3. Archaeology

The archaeological research in the present work was carried out in various ways:

- *Archaeological setting*. A summary of the settlement framework in various study areas (see chapter 4) was carried out in order to understand the times and the modalities of human attendance in each territory. Considering the vast study area and the long period considered, it was decided not to carry out a census of individual archaeological evidence but rather to try and understand the dynamics of the settlement phenomenon. This approach is somewhat difficult to apply, especially for the pre-protohistoric period, such that at times it is only possible to include a list of archaeological evidence (see chapters 4.1.2. and 4.2.2). Conversely, when possible, and mainly for the historical period, of which there is much archeological and literary information, a summary of the archaeological evidence was preferred, discussing the minor and major territorial influences of various Greek and Roman towns located in each territory (see for example Greek, Roman and Medieval evidence of the Sele Plain). In fact, it was thought that for this type of research it was more important to underline the "qualitative" rather than the "quantitative" data. In fact, even if the discovery of a great quantity of archaeological sites provides us with a better global vision of territorial attendance, sometimes also the interpretation of the quality of the discovery is necessary. This because the identification of many sites in an area is not necessarily linked to a greater exploitation of natural resources. In fact, it is more important to have a clear idea of the political and economic value of each settlement found in the study area. For the Sant' Eufemia Plain the census conducted during a research project (PRIN 2011-2013) was used, which saw the collaboration of the Department of Humanistic Studies (DiSU), the Department of Earth Sciences, Environment and Resources (DiSTAR) of the Federico II University of Naples, and the University of Salzburg. In fact, on the basis of this project, many detailed standards have been created in an effort to understand the settlement phenomenon in this territory over a long period (Neolithic - Medieval Age).
- *Palaeobotanical remains.* The occurrence of palaeobotanical remains (charcoal, wood, seeds) in archaeological excavations represents a very important datum when it is possible to identify which plants were used in the past for various purposes. Certainly, these data can help us understand the human preference for some species rather than others, also concerning the more or less large availability of some plants. Moreover, it is possible to hypothesize the occurrence of crops of the same species

both because of their high percentages in archaeological contexts and, sometimes, through genetic analysis. In this regard, it is hoped that more data on this matter will be available in the future.

When present, palaeobotanical remains were used to corroborate or clarify the pollen results obtained in this work. In particular, these data were used for comparisons in the discussion of pollen results from the same area and the same chronological period. It is in fact believed that the exploitation of natural resources has to be discussed by not making wide-ranging chronological and areal comparisons.

- *Chronological framework*. The identification of various cultures that developed in the study area was performed in order to delineate precise archaeological phases and their chronology in which to place pollen results. This aspect is elaborated more precisely in chapter 3.4.3.

3.4. Chronostratigraphy

The large quantity of archaeological data for Mediterranean contexts allows scholars to synchronize all sites through stratigrafic and typological method in order to create a relative archaeological sequence. Obviously, the placement of the various archaeological phases in a precise time range is done through ^{14}C dating. Often, the geological work carried out on cores does not require a large amount of chronological data in order to obtain satisfactory age models. However, when studying Holocene sequences and in particular, when an integrated analysis of geological, paleobotanical and archaeological data is required, it is necessary to associate chronologically samples taken from different corings to certain historical periods. This is necessary because the typological analysis method used in archaeology allows to have a very detailed chronological sequence that sometimes (especially for historical periods) marks the fourth of cent. or even generations. Thereby, it is necessary to build very precise chronological models through many absolute datings.
In this study, tephrostratigraphy and AMS ^{14}C dating were used to construct robust chronological frameworks for each studied sequence[5].

3.4.1. Radiocarbon dating

Radiocarbon (^{14}C) dating is currently the main method of absolute dating used to date organic matter. This method is widely used in many different fields including hydrology, oceanography, geology, palaeoclimatology and archaeology. Carbon is a chemical element present in all organic matter in the form of three isotopes: two stable (^{12}C and ^{13}C) and one radioactive (^{14}C). The latter is transformed by beta decay into nitrogen (^{14}N), with an average half-life of 5.730 years (Libby, 1960; 1961). The disappearance of this isotope is blocked by the continuous production of ^{14}C in the upper layers of the troposphere and stratosphere. A balance between production and decay is then struck, which keeps the concentration of ^{14}C in the atmosphere constant. All living organisms continuously exchange carbon with the atmosphere through different processes. So, as long as an organism is alive, the ratio between its concentration of ^{14}C and that of the other two carbon isotopes remains constant and equal to that found in the atmosphere. After an organism dies, these processes cease and the organism no longer exchanges carbon with the outside, causing the process of ^{14}C decay to begin. The principle of radiocarbon dating is to count the ^{14}C isotopes contained within the sample to be dated in order to establish the age when the organic material in the sample died.

[5] The absolute dates are not carried out directly by the writer in this work but by external laboratories or by other researchers. So, only a few theoretical principles of the method are explained.

In recent years, Accelerator Mass Spectrometry (AMS) ^{14}C dating has allowed ever increasingly small amounts of organic matter to be reliably dated. AMS was first performed in 1977 (General Ionex Corporation) and differs from the decay counting methods in that the amount of ^{14}C in the sample is measured directly, rather than by waiting for the individual radioactive decay events to occur. This makes the technique 1,000 to 10,000 times more sensitive than decay counting.

In this work, AMS ^{14}C dating was performed on bulk sediments and pieces of charcoals taken at various depth along each core, in order to provide chronological control for each studied sedimentary sequence. No dates in the study were obtained using shell or other calcareous material to avoid potential reservoir effects. Both marine and freshwater organisms often derive from aquatic environments that have ^{14}C reservoirs, where ^{14}C levels are lower than atmospheric ^{14}C levels. If a dated sample derives from a context where a reservoir effect occurs, then the measured age of the samples may be younger or older than expected (Philippsen, 2013). As a result, all the dates in this study were obtained from terrestrially derived material such as sediment bulk, charcoal or short-lived plant macrofossils.

The ^{14}C ages used in this work have been determined by different Laboratories. All dates have been calibrated with the Calibration Program CALIB REV7.1.0 (Stuiver et al., 2007). The results are summarised in Tab. 3 below:

Laboratory	**Location**	**Sample core**
CIRCE (Center for Isotopic Research on Culturale and Environmental heritage) – Università degli Studi della Campania Luigi Vanvitelli	Caserta (IT)	C106; CL1; B24
Centro di Datazione e Diagnostica (CEDAD) - Università del Salento	Brindisi (IT)	CL1
REM laboratory	Mannheim (DE)	L1

Tab 3. – List of laboratories where C14 dating have been performed

3.4.2. Tephrochronology

Tephrochronology is a stratigraphic method that can be used for linking, dating and synchronizing geological, palaeoenvironmental, or archaeological sequences or events. The application of tephrochronology always requires tephrostratigraphy, which is the study of tephra l, their distribution, their stratigraphic relationships, and their relative and numerical ages. Explosive volcanic eruptions typically produce large amounts of volcanic ash (tephra/ τέφρα) that is transported, sometimes over huge distances, and later deposited in sedimentary environments generating excellent chronological markers. The term tephra is applicable to all grain sizes (ash < 2 mm diameter; lapilli of 2 - 64 mm; blocks or bombs > 64 mm).

To determine the eruption events linked to a particular tephra deposit, it is necessary to analyse their spatial position (stratigraphy) and to conduct mineralogical and geochemical analyses. The association of each tephra to a well-dated single eruption event allows stratigraphic correlations to be made between geological sequences and archaeological sites where the same tephra has been found (Sulpizio et al., 2008; Lowe et al., 2011). Some of the cores analyzed come from Campania, a region globally known for its volcanic districts (Phlegrean Fields, Ischia, Somma-Vesuvius). The recognition of the tephra identified in the Campania cores allowed us to build high-resolution chronological models.

The large amount of Holocene eruptions that have affected the Campania region has made it necessary to summarise the eruptive history of the volcanic districts mentioned above and to discuss the chronologies for the main eruptions.

- Phlegrean Fields: This volcanic activity is connected to the distensive tectonic that resulted in the formation of the Campanian Plain. The precise date for the beginning of volcanism in the Phlaegraean area remains unknown but sequences of lava and pyroclasts of about 2 million years have been encountered, through drilling, between Villa Literno and Parete while, in some outcrops the oldest volcanic products date from c. 60.000 years. The first notable eruption is the Campanian Ignimbrite which occurred c. 39.000 years ago (39.28 ± 0.11 $^{40}Ar/^{39}Ar$ ka; De Vivo et al., 2001). The products of this eruption have buried much of Campania. In addition, a caldera was formed, sinking a vast area that includes the Phlegrean Fields, part of the city and bay of Naples, and a part of the Pozzuoli bay. After the eruption of the Campanian Ignimbrite, various eruptive centres within its caldera have generated mainly explosive activity, such as Solchiaro eruption (about 23 ka BP - Paterne et al., 1986; de Alteriis et al., 2010; Wulf et al., 2004). Another important event was the Neapolitan Yellow Tuff eruption which occurred c. 15.000 years ago (14.9 ± 0.4 $^{40}Ar/^{39}Ar$ ka; Deino et al., 2004). This eruption caused the formation of a caldera that determined the sinking of an area that includes part of the Phlegraean Fields and the bay of Pozzuoli. This eruption is followed by intense volcanic activity which alternated between dormant periods that can be divided into three phases (Di Vito et al., 1999). During the first phase (c. 12000 and 9500 years ago) around 34 eruptions occurred, with a frequency of 70 years. The most important plinian eruption of this phase is the Pomici Principali eruption (10.3 ka – Arienzo et al., 2010). In the second phase (8600 and 8200 years ago) 6 explosive eruptions happened, with a frequency of 65 years. In the third phase (4800 and 3800 years ago) 16 explosive eruptions and 4 effusive eruptions occurred with a frequency of about 50 years. One of the best dated eruption of this last phase is the Agnano Monte Spina, which occurred at c. 4.100 years BP (Alessio et al., 1971; Rosi et al., 1983; Di Girolamo et al., 1984; Rosi and Santacroce, 1984; Rosi and Sbrana, 1987; de Vita et al., 1999). The last erupion of Mount Nuovo occurred in 1538 AD after a quiescence of about 3000 years (Di Vito et al., 1987).

- Ischia: Ischia island represents the top portion of a volcanic apparatus about 900 m high from the bottom of the sea. It covers an area of about 46 km^2 and reaches a maximum height of 787 m above sea level at Mount Epomeo, located in the central part of the island. The volcanic activity is connected with the tectonic that characterized the evolution of the Tyrrhenian margin of the Apennine chain between the Pliocene and the Quaternary. The precise date for the beginning of volcanic activity on the island is not precisely known. In fact, the oldest dated rocks, which are not the oldest outcrop, have an estimated age of 150 ka (Gillot et al., 1982; Vezzoli, 1988; Orsi et al., 1996, 2003) and belong to a partly eroded volcanic complex. The products of the activity following the formation of this complex date to between c. 150 and 74 ka (Gillot et al., 1982; Vezzoli, 1988). The following period of volcanic activity was characterized by numerous explosive eruptions of variable energy, separated over time by periods of quiescence and culminating with the eruption of the Tufo Verde of Mount Epomeo (55 ka BP; Vezzoli, 1988).
  The last 55 ka of activity on the island have been divided into three phases (Poli et al., 1989; Vezzoli, 1988; Civetta et al., 1991; Civetta et al., 2016). The first phase is dated between 55–33 ka BP, and at the end of this period the Piroclastiti of Citara occurred. The second phase is dated to between c. 30–18 ka BP. This phase is characterized by the important eruption of the Grotta di Terra (28.000 years ago). The last phase is dated to between c. 10 ka– 1302 AD. In the last 5 ka, activity has been discontinuous (Orsi et al.1991, 1996; de Vita et al., 2006). The latest eruption occurred in 1302 AD in the northeast of the island (the Arso lava; Vezzoli, 1988).
- Somma-Vesuvius: The volcanic activity in the area of Somma-Vesuvius dates back to at least 400.000 years ago but the history of the Somma-Vesuvius began c. 25.000

years ago and is characterized by plinian and subplinian eruptions and intercalates from various effusive and low energy explosives eruptions. The Somma-Vesuvius is a composite volcano, or stratovolcano, consisting of the remains of an ancient building, Mount Somma, which was partly destroyed during violent plinian eruptions, as well as the younger Mount Vesuvius, which grew inside (Cioni et al., 1999). The evolution of the volcanic apparatus occurs until c. 19.000 years ago on the eruptive deposits of the Campanian Ignimbrite. In the following Table the most important plinian and subplinian eruptions are listed (Cioni et al., 2008; Di Vito et al., 2013).

Name	**Age**	**References**
Pomici di Base	18,300±180 BP (a) (22,030±175 cal)	Bertagnini et al., 1998; Santacroce et al., 2008 and referenses therein
Greenish Pumice	16,020±130 BP (a) (19,265±105 cal)	Cioni et al., 2003
Pomici Verdoline	16000 / 19000 years ago	Cioni et al., 2003
Pomici di Mercato	8010±35 BP (a) (8890±90 cal)	Cioni et al., 1999; Aulinas et al., 2008; Mele et al., 2011
Pomici di Avellino	3960±60 (a) (4365±40 cal)	Rolandi et al., 1993; Cioni et al., 1999; Mastrolorenzo et al., 2006; Di Vito et al., 2009; Passariello et al, 2009
Protohistoric eruptions (AP1 – AP2 – AP3 – AP4 – AP5 - AP6)	between Pomici di Avellino eruption and Pompeii eruption	Andronico and Cioni, 2002
Pompeii eruption	AD 79	Lirer et al., 1973; Sigurdsson et al., 1985; Barberi et al., 1989; Cioni et al., 1999; Gurioli et al., 2002
Pollena eruption	AD 472	Rosi and Santacroce, 1983; Sulplizio et al., 2005
AS1	AD 512	Cioni et al., 2008
1631 eruption	1631	Rosi et al., 1993
1906 eruption	1906	Bertagnini et al., 1991; Arrighi et al., 2002
1944 eruption	1944	Scandone et al., 1986; Marinelli et al., 1999

Tab. 4 – Main eruptions of Somma-Vesuvius

3.4.3. Archeostratigraphy (culture of Campania and Calabria)

Due to the wide chronological range in which the materials analyzed in this work fall, a chronological table of the various archaeological phases attested in Campania and Calabria from the Neolithic (6200 BP) to the Early Medieval (725 BC) has been created. This chronological table is essential for the integrated use of palaeoenvironmental and archaeological data.

With regard to pre-protohistoric periods (Neolithic-Iron Age), several synthesis works have been developed in the last decades in order to create a chronological frame, based on the "typological method", among the sites which show similar cultural features. Some of the most important studies for the territory object of this work are here mentioned.

The periodization based on the reading of archaeological stratigraphies carried out by Luigi Bernabò Brea is considered one of the most inclusive work (1961) for the Italian Neolithic (6100-3700 BC). This author examined the chronology for both North (Arene Candide in Liguria) and South (Lipari) Italy. Three main phases are identified in this work: Lower Neolithic (from 6100 to 4800 BC); Middle Neolithic (from 4800 to 4300 BC); Upper Neolithic (from 4300 to 3700 BC). Nonetheless, these chronological phases are only indicative and often problematic mainly because cultural facies are scarcely represented. By contrast, the chronology for Campania and Calabria is more accurate due to the multifaceted archaeological cultural aspects attested.

Significant works on the chronocultural articulation of Eneolithic in southern Tyrrhenian Italy were performed a few years ago (Pacciarelli, 2011; Pacciarelli and Talamo, 2011).

The Bronze Age is a very long period (c. 12 centuries) in which several cultural changes took place in Europe and it is defined by a very precise chronology. It was in this period that the Campania and Calabria regions were affected by various settlement choices related to different political, social and economic needs that allow distinguishing the different stages of the Bronze Age.

Even though it is very difficult to understand the transition phases among each period, various works have been tried to define them with new radiocarbon dates in the last ten years. In particular, the last phase of the Early Bronze Age in Campania was characterized by the Pomici di Avellino eruption (see chapter 3.4.2., Passariello et al., 2009) and on the basis of new radiocarbon dating (Pacciarelli et al., 2015; Di Lorenzo et al., 2018) seems to arrive until the 1700 BC. Despite the fact that various chronological works on the Italian Bronze Age (Pacciarelli, 2005; Jung, 2013, 2017; Guidi, 2018) and Iron Age (Guidi, 2018) have been recently carried out, the work by Pacciarelli (2001), which precisely describes all the Bronze and Iron Age phases as well as all the cultures that have developed in the Campania and Calabria regions, still remains mainstream. The chronology of the Late Bronze Age can be summarized through the well dated Aegean pottery which is abundant in the Italian settlements of this period.

With the passage from protohistory to history, delineating a chronology is facilitated by the presence of both archaeological and literary sources or more generally written documents (epigraphs, coins, etc.). With this regard, the Italian historical phase began with the advent of writing in the 8th cent. BC, which coincides with the foundation of the Greek colony of Cuma during the Magna Graecia and Sicily "colonization" process (Boardman, 1994; Mertens, 2006 and references therein). This phenomenon certainly represents a moment of break with the past from the artistic, cultural, political and economic point of view. What is more, various written and archaeological sources that tell us about the foundation of the first Latin republican colonies until the precise period of the Imperial period are available for the Roman period.

As for the Late Antique period, the chronology of this transitional phase is debated. Many historians believe that the beginning of the Late Antique may coincide with the last stages of the Roman Empire. Riegel, for example, believed that deep formal artistic differences can be identified in the 4th cent. AD with the Constantine Empire (AD 306-337), whereas Bianchi Bandinelli identified a break in the early tetrarchic age (AD 284-305) (Enciclopedia Treccani, 2001). The development of historical and archaeological research has led to a regional delineation of the social, cultural and economic characteristics of this period and in particular Savino (2005), speaking of the concept of “deconstruction” of the Roman Empire, believes that this latter happened in different times and ways within the Empire. The author therefore proposes a precise chronological limit for Campania (which might as well be used for Calabria), starting the Late Antique with the Diocletian "provincialisation". As for the end of the period, the author believes that the end of the Western Roman Empire marked the disintegration of the Mediterranean political unity but did not constituted a break of the southern Italy economy (Constantinian reform) which ended with the end of Gregory Magno pontificate.

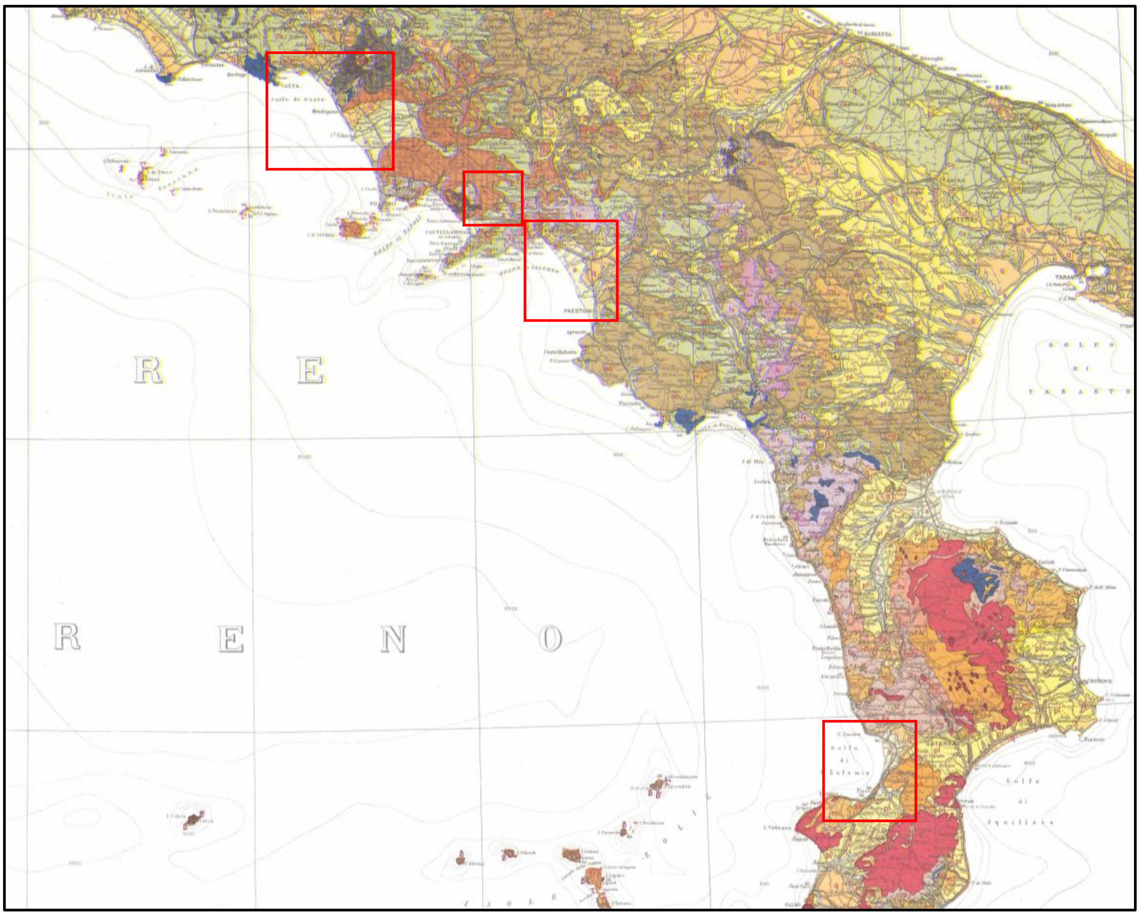
Period	**Chronology**	**Campania Culture**	**Calabria Culture (Tropea Promontory)**
Early/Lower Neolithic	6200 – 4800 BC	Impressed Ceramics	
Middle Neolithic	4800 – 4300 BC	Tricrome Ceramics	Stentinello
		Serra d’Alto	
Final/Upper Neolithic	4300 – 3700 BC	Diana	
Early Eneolithic	3650-3500 BC	Ausino Cave, S. Maria dei Bossi	Margi a Curti
	3500-3300 BC	Taurasi	Focullo
Middle Eneolithic	3300-3050 BC	Gaudo 1	Passo Murato
	3050-2800 BC	Gaudo 2	Gallo Colarizzi
Late Eneolithic	2800-2600 BC	Laterza	
	2600-2350 BC	Laterza/Campaniforme	San Fili
Late Eneolithic - Early Bronze Age	2350-2150 BC	Late Laterza/Cetina	F. Zungri
Early Bronze Age	2150-1850 BC	Palma Campania	Punta di Zambrone (Area D)
Early Bronze Age - Middle Bronze Age 1	1850-1700 BC	Protoappenine	Cessaniti
Middle Bronze Age 2	1700-1400 BC	Protoappennine	Rodi-Tindari
Middle Bronze Age 3	1400-1325/1300 BC	Appennine	Thapsos
			Appennine
Recent Bronze Age – Late Bronze Age	1325/1300-1140/1120 BC	Subappennine	
Final Bronze Age – Late Bronze Age	1140/1120-950/925 BC	Protovillanoviano	
Iron Age 1	950/925-850/825 BC	Fosskulture Villanovian culture/Etruscans	Torre Galli
			Nicotera
Iron Age 2	850/825-730/725 BC		Canale Ianchina
	VIII-VII cen. BC	Orientalizzante	
	VII-VI cen. BC	Archaic period	
Greek Age	VI-V cen. BC	Classical period	
Ellenistic Age	IV-III cen BC	Samnite population	Ausoni population
Roman Age	IV-I cen BC	Republican period	

	III cen. BC - AD 476	27 BC-AD 476	Imperial period
		AD 284-604	Late Ancient
Early Medieval Age	AD 570-774		Lombard reign
	AD 774-1000		Byzantine dominion
	AD 1000-1220		Norman reign

Tab. 5 – Chronology of archaeological cultures

4. STUDY AREAS

In the following pages, a description of the geological and geomorphological setting (Fig. 10) of the regions investigated will be presented. In addition, it was considered necessary to include a historical summary, with support from the arheological data known to date, relating to human population and changes in settlement choices over time, from the Neolithic to the Medieval period.



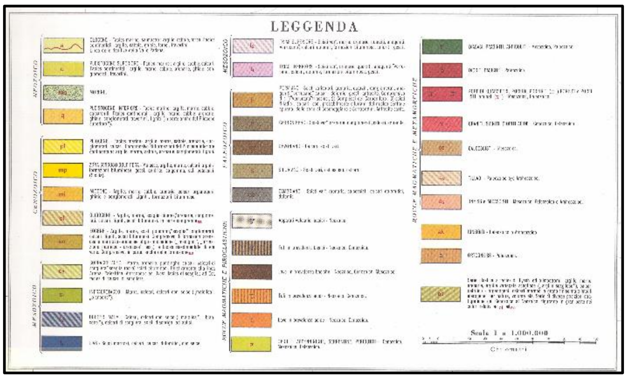


Fig. 10 - Geological map of southern Italy with location of studied areas

4.1. Campania

La Campania, per la sua fecondità detta Felice, fu con maggior lode chiamata Felice & Amena. Era l'amenità propria della riviera del suo mare: la fecondità de' suoi campi fra terra.

Camillo Pellegrino

"Apparato alle antichità di Capua overo Discorsi della Campania Felice" - 1651

Fig. 11 - View of Capri island from Vesuvius

4.1.1. Geological and geomorphological setting

4.1.1.1. Campanian Plain

The Southern Apennine is a north/east-oriented orogenic belt, which developed from Miocene to Quaternary times as a result of interaction between the Adriatic promontory of the African plate and the Sardinia-Corsica block of the European plate. Starting from the late Tortonian, the extension that led to the opening of the Tyrrhenian backarc basin occurred, and since Early Pleistocene times, it caused the formation of large peri-Tyrrhenian basins (Santangelo et al., 2017):

- Garigliano Plain – Gulf of Gaeta;
- Campanian Plain;
- Sele Plain – Gulf of Salerno;
- Policastro Gulf.

The largest southern Apennines peri-Tyrrhenian basin, namely the Campanian Plain has a very flat topography (altitude between 35 and 50 m a.s.l.). It is divided by fault zones into two sub-basins, Volturno Plain and Naples Gulf and is characterized by a huge Quaternary sedimentary record more than two thousand meters thick (Santangelo et al, 2010; 2017).

The plain (Fig. 12) includes, in the central area, the volcanic districts of Phlegrean Fields and Somma-Vesuvius that separate the plain of Volturno from that of Sarno and, in the northern area, the extinct volcano of Roccamonfina. The coastal area of the Campanian Plain has several mountainous areas such as the Massico (North), the mountains of Sorrento, the Amalfi Coast and those of Cilento (South). In addition, the plain is crossed by three major rivers, the Garigliano, the Volturno and the Sarno.

The late Quaternary evolution of the Campanian Plain is closely linked to the eruptive activity of its volcanic districts whose oldest traces have been recorded at Ischia (Gillot et al., 1982) and the Phlegrean Fields (Rosi and Sbrana, 1987) in the first part of the Late Pleistocene, and at Somma-Vesuvius in the later part of the Late Pleistocene (Brocchini et al. 2001).

The geological and geomorphological evolution of the Campanian Plain has been extensively analyzed on the basis of boreholes drilled in the plain both in its northern (Romano et al., 1994) and southern sector (Bellucci, 1994; 1998).

The Campanian Plain was above sea level during the Pliocene (Brancaccio et al., 1991; Cinque et al., 1993). The plain was formed in the Lower Pleistocene, when the area was affected by subsidence, associated with strike-slip tectonics and tension gashes (Cinque et al., 1993). During the Late Pleistocene, the subsidence was associated to the onset of volcanic activity at Ischia and Phlegrean Fields, whose eruptive deposits were intercalated to marine deposits (Santangelo et al., 2010; 2017).

In the second part of the Late Pleistocene, the whole plain emerged due to the subsidence rate reduction and the contemporary last glacial regression (Santangelo et al., 2010). At about 39 ka the extremely violent explosive Campanian Ignimbrite eruption occurred and uniformly covered the entire Campanian Plain with a pyroclastic flow deposit, tens of meters thick (Santangelo et al., 2010).

During the Holocene, in concomitance with the peak of the post-glacial transgression, lagoon and swamp systems formed up to 2 km inland from the present coastline (Barra et al., 1996).

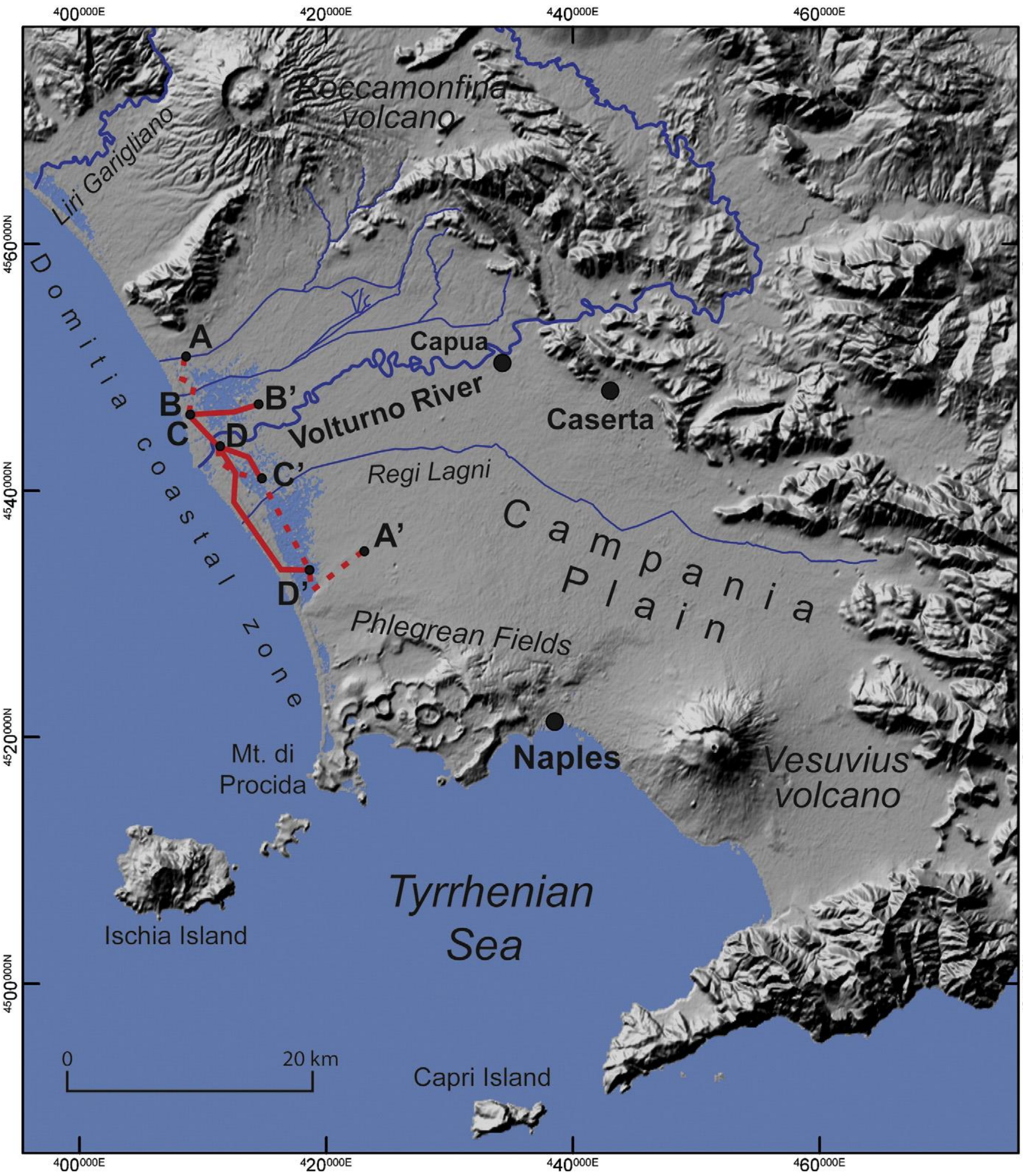


Fig. 12 – Campania Plain (after Amorosi et al., 2012)

4.1.1.1.1. Garigliano Plain

The Garigliano coastal plain is separated from the southern Volturno Plain by the carbonate ridge of Monte Massico. To the NW it is bordered by the limestone massifs of the eastern Aurunci Mountains, to the N by the Suio Mountains and the Roccamonfina district to the NE.

This plain, together with the Volturno Plain, is a graben characterized by an evolution strongly conditioned by the activity of the extensional tectonics linked to the opening of the Tyrrhenian Sea during the Pliocene (Bartole, 1984; Aiello et al., 2018). Over that time span, the graben was filled with marine Pliocene and marine-transitional Pleistocene sediments (Bellotti et al., 2016 and references therein).

Since the Lower Pleistocene, a series of faults were activated conditioning the birth and evolution of the Roccamonfina district, active between 600 and 50 ka (Radicati di Brozolo et al, 1988) whose deposits fill most of the plain.

The late Pleistocene–Holocene evolution of the graben depended from the interaction between late glacio-eustatic cycle (125.000–6000 yr BP), solid river discharges, tephra from the Phlegrean Fields and Vesuvius and the final, smooth tectonic phases (Brancaccio et al.,1991; Di Vito et al., 1999; Bellotti et al., 2016).

The meandering route of the Garigliano River is placed on a flat morphology, with a very gentle slope. The river is the main drainage of the hydrographic network consisting of a series of small streams, almost all from the heights of Roccamonfina.

In the flat area of the Garigliano Plain, there are several orders of river terraces in an altimetric range of 25 m, the most recent of which is set on the oldest pyroclastic deposits (Abate et al., 1998). Those of intermediate age are engraved in the alluvial deposits mixed with pyroclastic elements washed away from the western slope of the Roccamonfina. Parallel to the coast there are Holocene and Tyrrhenian dunes, interrupted by the reincisions made by the Garigliano River and by some streams currently channelled (Brancaccio et al., 1990; Abate et al., 1998)

The Holocene evolution of the plain is summarized by Bellotti et al. (2016) in 4 evolutionary phases:

- Phase 1 (8200-7500 yr BP): presence of a wetland without marine influence partially emerged in the northern part covered by hygrophilous forests, while in the southern part develops a narrow lagoon.

- Phase 2 (7500-5500 yr BP): to the north a depression forms that hosts a freshwater swamp, to the south the presence of the lagoon continues, which passes to freshwater and brackish environments surrounded by mixed forests.
- Phase 3 (5500-3000 yr BP): initially a wave-dominated peak delta develops, due to the transformation of the lagoon barrier system into a coastal plain. The brackish environments progressively disappear and the Garigliano river creeps between two twin marshes, favouring the human settlement also in the plain. After 4000 years BP the swamps are replaced by coastal ponds.
- Phase 4 (3000 yr BP until today): since this last phase the human impact on the territory increases due to the development of agriculture (Bellotti et al., 2016). Near the mouth, during the Iron Age, the sanctuary of Marica was built and in the third cent. BC, the Roman colony of Minturnae was built on a drained area of the Eutyrrhenian dune overlooking the northern pond. The sea, only 1 km away, could be reached through the river, or, alternatively, from the banks of the ponds. Towards the sea, the ponds were bordered by a plain hundreds of meters wide. Based on the sea level in Roman times, about -0.5/-0.8 m, the maximum estimated depth was respectively 1.5 and 2.5 m for the northern and southern ponds. It is interesting to note that historical sources do not mention the use of these ponds as harbors assuming the presence of a river harbor located in a canal. The lack of maintenance of the drainage system in the Middle Ages has resulted in a rapid sedimentation of solid material into the ponds, with consequent phases of partial drying. The ponds were never completely filled, and the areas now need to be kept dry by constant drainage. Based on historical maps and the similarity with other deltas on the Tyrrhenian coast, it is likely that the origin of the most recent delta peak, although created during the Roman period, mainly developed during the XV to XIX centuries.

4.1.1.1.2. Sarno Plain

The Sarno Plain (~15 km long and ~9 km wide) is bounded by carbonate ridges towards NE and SE and exhibit evidence of tectonic features, such as NW-SE, E-W and NE-SW trending fault scarps and triangular facets (Cinque et al., 2000). At the base of the fault scarps, a piedmont area is present, consisting of two generations of coalescent alluvial fans, chronologically constrained to the Upper Pleistocene – Holocene time span (Cinque et al., 1987).

During the Lower and Middle Pleistocene, the Sarno Plain was affected by a strong tectonic subsidence and was filled by a sequence of marine and transitional deposits several hundreds of metres thick resting on the buried Meso-Cenozoic carbonate bedrock (Cinque et al., 1987; Aprile and Toccaceli, 2002; Santo et al., 2019a). Volcanic products from the Somma-Vesuvius and the Phlegrean Fields also accumulated in the last 100 ka (Santangelo et al., 2017 and references therein), as the Campanian Ignimbrite, which represents a most important chronostratigraphic marker.

During the late Upper Pleistocene (39–18 ka), the Sarno Plain was located above sea level whereas during the Holocene, sea level progressively rose, and the coast line moved eastward (Cinque, 1991). The intense volcanic sedimentary input coming from the Vesuvius activity during the late Holocene caused the seaward progradation of the coastline up to the present position (Santangelo et al., 2017 and references therein).

4.1.1.2. Sele Plain

The Sele Plain (Fig. 13) was formed by the aggradation of a Plio-Quaternary tectonic depression located along the western Tyrrhenian margin of the southern Apennine chain and it is delimitated by Monti Lattari and Monti Picentini (N) and by reliefs from Monti Alburni and Cilento (SE). The innermost portion of the plain is characterized by hills, up to 400 m high, formed by uplifted alluvial fans, representing the Early Pleistocene portion of the infill (Amato et al., 2013).

Although the beginning of the collapse is not well defined[6], most authors agree on the assumption that the present morphostructural setting is due to Quaternary extensional tectonics (Santangelo et al., 2017).

A phase of strong tectonic accentuation is testified by the deposition of the extensive epiclastic successions of “Conglomerati di Eboli” (since 1.5 million years ago until Middle Pleistocene) forming many of the hills that interpose between the Sele Plain and the Picentini Mountains in the area between Salerno and Eboli.

Close to the present coastline, a younger coastal sector occurs, representing the evolution of a barrier-lagoon system. After a subaerial exposition during the last glacial, a trangressive trend occurred during the rapid sea level rise of the early-middle Holocene. In the late

[6] Brancaccio et al. (1987) think that the collapse occurred in the Upper Miocene; Sacchi et al. (1994) resume the same dating but assign to the Quaternary only the last 990 m of the sequence analyzed in the off-shore well Mina 1.

Holocene, the coastline gradually reached its modern position due to progradation (Aucelli et al., 2012; Amato et al., 2013).

The plain is interpreted as a semi-graben, WSW-ENE oriented (Sacchi et al., 1994), whose current morphology is the effect of Quaternary extensive tectonics that generated normal faults and reactivated tracts of pre-existing NW-SE faults (Caiazzo et al., 2000). This tectonics is attributable to a Pleistocene deformation event, recognized at regional scale (Caiazzo et al., 2006).

The Vesuvius eruption of AD 79 was the most impressive late Holocene event (Lirer et al., 1973) whose tephra settled in the plain providing a well recognizable stratigraphic marker within the shelf and the upper slope sediments (Aucelli et al., 2012).

Near the Graeco-Roman archaeological area of Poseidonia-Paestum, lobate and terraced morphologies of the Paestum Travertine outcrop are known. They are generated by highly charged calcium carbonate waters coming from the springs located at the base of Mount Soprano. Paestum travertine benches were recently discovered (I.S.P.R.A., 2009) in the near shore zone in front of the Paestum area, at a depth of about 10 m below the sea level and at about 0.8 km from the present coastline (Amato et al., 2013).

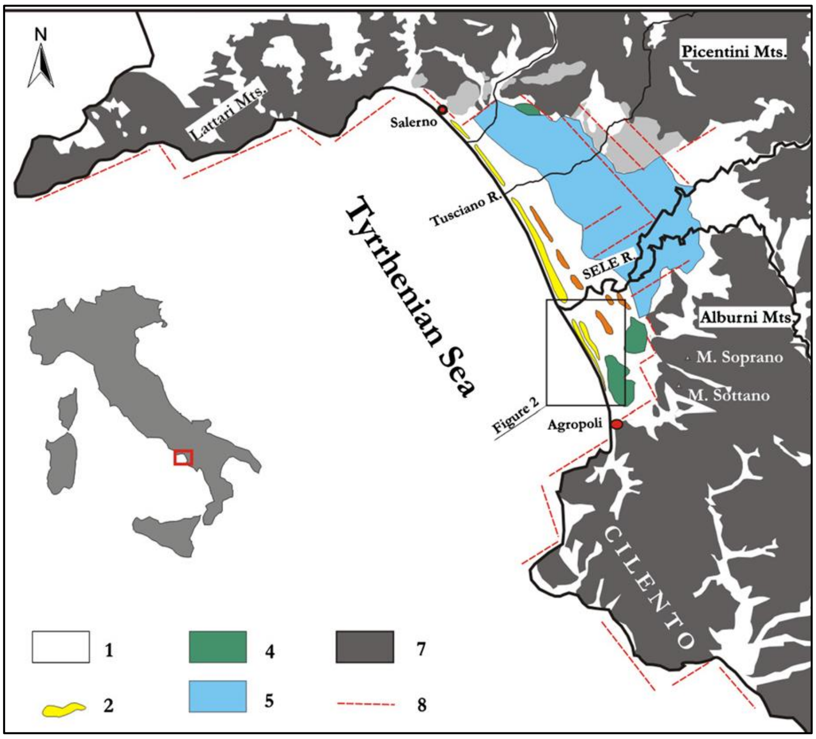


Fig. 13 - Geological sketch of the Sele Plain. 1) Late Quaternary alluvial and coastal deposits; 2) Holocene dune ridges; 3) Late Pleistocene (MIS 5) dune ridges; 4) Middle Pleistocene/Holocene travertine deposits; 5) Middle Pleistocene BattipagliaePersano complex; 6) Early Pleistocene Eboli Conglomerates; 7) Meso-Cenozoic deposits; 8) Main faults (after Amato et al., 2013)

4.1.2. Archaeological setting

This chapter presents the archaeological evidence from the Neolithic to the Middle Ages of each territory in which pollen analysis were carried out (Sele Plain, Garigliano Plain, San Vito Sinkhole).

4.1.2.1. Garigliano Plain

Along the edges of ancient coastal ponds (Bagni Solfurei, Starza, San Pietro, Incaldana), lithics from the Neolithic period were found at some sites, though the complete assemblage indicates that there was no farming in the area. However, the evidence does suggest that fishing, shellfish gathering and the hunting of small game, especially avifauna, was practiced locally. The same scenario is observed at other coastal pond sites in the area, including southern Latium (Aiello et al., 2018).

With regard to the Eneolithic period, an important site with much of the pottery attributed to Gaudo facies and a spindle whorl found in Bagni Solfurei (Fig. 14) confirm the presence of stable settlement also near the shore of a small coastal lake, as the sites recently excavated in Maccarese also show. In addition, evidence of blades (Gaudo culture) and arrow cusps from Arivito and a beautiful flint dagger with opaque retouching from Impiso Bridge (probably attributable to funerary equipment) were found (Aiello et al., 2018).

Between the advanced stage of the Early Bronze Age and the beginning of the Middle Bronze Age, there was a process of selection and concentration of settlements on the slopes of the reliefs of Sant' Eufemia and Arivito (Fig. 14). Perhaps with the introduction of animal-drawn ploughs the soils located inland became farmable. During the Bronze Age a metallurgical production developed, as testified by the discovery in Carinola of a storage place with hundreds of bronze axes (only one remained). At the Middle Bronze Age and the Recent Bronze Age, the Arivito and Francolise sites, this latter located near the left bank of Savuto River, dates back respectively. The greater importance of sheep farming, seasonal short-range transhumance, and the new defensive requirements of the proto-historic communities, seem to have led communities to occupy Mount Petrino in the Late Bronze Age (Aiello et al., 2018). A village dating back at least to the Late Bronze Age was set atop the rocky promontory of Monte d'Argento, and several others were founded on the Eutyrrhenian strand plain bordering the Holocene marshes landward (Alessandri, 2007; Ferrari et al., 2012, 2013; Bellotti et al., 2016). The exploitation of wetlands probably was linked to fishing or for harvesting aquatic plants (Angle and Belardelli, 2007).

During the Iron Age, the coast was probably uninhabited, apart from the area near the mouth of the river. Despite the few archaeological finds of this period, various stable settlements have been identified, such as the very important "Villaggio dei Ciclamini" (Crimaco et al., 2007) on Mount Petrino (Fig. 14), occupied since the 9th cent. BC. These remains are connected to the huts found in the area of Sinuessa and near the Mondragone cemetery and connote a scattered occupation of the territory. The discoveries on the Massico slopes testify the presence of permanent settlements with a social articulation and a developed economy, especially in metals processing[7] (Sirano, 2008).

Moreover, on a Holocene beach ridge between the shoreline and the marshes, there was a place of worship dedicated to the goddess Marica (a chthonian divinity with power and control over water and marshes), which was in use since at least the 7th cent. BC (Andreani, 2003). It was an emporic shrine that mediated the inland and Mediterranean trade (Mingazzini, 1938; Bellini, 2002; 2007).

Historical sources indicate that during the Iron Age the area was occupied by Aurunci people located between the Liri (Garigliano), the Volturno, and the Trebulani mountains, and their largest cities were named Ausona, Vescia, Minturnae, Suessae and Sinope.

The most important settlements of the Aurunci were atop the carbonate terraces in the hinterland (Ferrari et al., 2014). The Etruscans also controlled the coastal areas of the Gulf of Gaeta, and at the mouth of the Volturno River, in the territory occupied by the Opici settlement, they built the town of *Volturnum* that became an important trade point on the road to Capua (Di Rita et al., 2018a).

Literary sources identify this territory as attended by a mosaic of “peoples”: Samnites, Aurunci, and Sidicini known mainly due to facts related to wars with the people of Lazio, and more recently against Rome. In particular, the history of the Aurunci/Ausones and the Osci/Opici is very articulate, referring their development since the Protohistory period (Sirano, 2008).

Archaeologically, some sites certified from the end of the 8th to the beginning of the 7th cent. BC show various cultural characteristics of the populations living there, as well as some of the cultural transformations of this period (Sirano, 2008)[8].

The discoveries of attendance increase for the period between the 7th and 6th cent. BC. To reflect on this period, it is necessary to also mention sites located in a more inland area (with

[7]Of interest is the discovery of an axe deposit at Ventaroli (Sirano, 2008).

[8] Following is a list of the most important discoveries for this period. The information on the sites is taken from Sirano (2008). For a more in-depth analysis it was considered necessary to insert also the Bibliographic references of those who published the individual sites: Alife (Tagliamonte, 2004), necropolis and settlement near Ponte Ronaco in Sessa Aurunca, masseria Cicoli and loc. Lenze in Mondragone (Talamo, 1987), huts and older cabinets of Cales (Gasperetti et al., 1999), cabinets of loc. Torricelle in Teano (Albore Livadie, 1981; Sirano, 2007).

respect to the present study area) so as to understand the settlement phenomenon of the "Valley Liri Culture" (sensu Johannowsky, 2000 and references therein)[9].
In particular, during the 7th cent. BC, the Marica shrine (Fig. 14) at the mouth of the Garigliano continued to be frequented and its monumentalization is dated during 6th cent. BC, when also the Panetelle shrine (Fig. 14) was built (Talamo, 1987).[10]
A debate is still ongoing regarding the continuity of many of these settlements up until the Roman conquest. In the Garigliano Plain, some cities continued during the Archaic and Classic periods, such as that of *Teanum* (Fig. 14), founded by the Aurunci (De Caro, 2012). In the area around Sessa Aurunca, little archaeological evidence has been found, though it is possible to hypothesize settlement continuity up until the Roman period. During the 4th cent. BC, *Teanum* was occupied by the Sidicini, establishing a stable urban form. Despite the quantity of archaeological data that have emerged in the territory, qualitatively it seems that at least in the 5th cent. BC the "Valley Liri Culture" was superimposed on different political, communitarian and linguistic contexts (Sirano, 2008).
The Roman conquest began in the last quarter of the 4th cent. BC and changed the general organization of the territory, extending its dominion to all northern Campania with a complicated system of alliances, foedera and colonies (Ferrari et al, 2013).
The Roman reorganization occurred in around three centuries, with the construction of a road network (Arthur, 1991) centred on the Via Appia (312 BC); the deduction of colonies (Fig. 14) such as Sessa Aurunca (313 BC), *Minturnae* and *Sinuessa* (296 BC), Cales (334 BC), as well as the more recent ones of Volturno and *Liternum* (194 BC); and the centuriation of the territory and the development of a settlement pattern based on farms and villas many of which are archaeologically attested. Because of the alliance with the Samnites during the Second Samnite War, the Auruncan towns and villages (oppida) were destroyed by the Romans in 314 BC. *Minturnae*, *Liternum* and *Volturnum* were not only maritime colonies but also had the function of controlling the river traffic; in fact, they were located,

[9] The "Valley Liri Culture" also developed beyond the areas of present day northern Campania. The guiding fossils of this culture are the so-called red bucchero and the so-called "bombard ollae" in brown impasto (Sirano, 2008). All information is taken from Sirano (2008), though it may be preferable to insert other references for each site.
[10]Following is a list with the most important archaeological discoveries for this period taken mainly by Sirano (2008) and other authors: necropolis of Cales (Passaro a Ciaccia, 2000; Passaro, 2004), necropolis and traces of settlement in Presenzano (Johannowsky 2000, 16-19; Sirano 2005a), necropolises on the Monte Maggiore slopes in Rocchetta and Croce territory (Caiazza, 1986), in Val d'Assano, Terragnano and Pugliano in the Teano territory (Johannowsky, 1963), in Treglia/Trebula (Caiazza, 1986), in localities of Croci and Pantano in Pietramelara (Caiazza, 1986), sporadic material from necropolises in the Contrada di Baia and Latina localities (Cera, 2004), discoveries of the Cubulteria necropolis (Cera, 2004), sanctuaries in the localities of Loreto and Masseria Soppegna (Ruffo, 2010).

respectively, along the Liris/Garigliano, Clanis, and Volturno rivers (Arthur, 1991). The colony of *Minturnae*, situated on the Euthyrrenian beach-dune ridge where the Appia way crossed the Garigliano River, became a very important trading centre (Guidobaldi and Pesando, 1989; Ferrari et al., 2013; Bellotti et al, 2016). *Minturnae* had two river ports, one of which located on the right bank of the river close to the Marica sanctuary as testified by literary (Plutarch) and archaeological sources (Ruegg, 1995; Bellini, 2007; Ferrari et al., 2013; Gregori and Nonnis, 2013; Bellini and Trigona, 2014).

During the Republican period, *Liternum* was residence to Scipio Africanus, who died there in 183 BC. During Imperial times, its inland area was exploited for olive, grape and cereal cultivation (Camodeca, 2010).

Literary sources such as Plutarch (Life of Marius, 37–39) and others[11], describe the *Minturnae* landscape in 1st cent. BC constituted by wetlands with shallow water basins and muddy soils that were rich in marsh vegetation, *Salix* and *Quercus* dominating the arboreal plants (Ferrari et al., 2013a).

The aims of Rome were to sanitize the coastal lands and extend its agricultural capacities. Organized drainage and irrigation of parts of the Garigliano, Savone and Volturno floodplains during the late Republic and early Empire seems proven from archaeological evidence that dates a number of banks and ditches to the classical period. Of interest is also the presence of colmatage deposits formed by the restatement of sediments in marshy areas through transportation by a series of canals which, unfortunately, have not yet been dated. In general, the tales of Plutharc's marsh-dwellers, together with the discovery of a coin hoard, dating to the 3rd cent. BC, at the locality of Costera, suggest that land improvement schemes along the coast went in progress with colonization (Arthur, 1991)[12].

With the advent of the Roman Empire, the development of the precedent towns in this area continued, and the largest number of properties attested under the early and mid-Empire was perhaps under senatorial control (Arthur, 1991).

Other drainage works along the coast are dated to the Empire period, such as the construction of Fossa Neronis (a canal extending along the stretch of coast from south of Sinuessa to the Phlegrean Fields) and the via Domitiana in AD 95 (Arthur, 1991).

From the 3rd cent. AD a period of crisis began and the farms and villas system declined. In AD 455, the town of *Liternum* was destroyed by Vandals (Di Rita et al., 2018a), and around

[11] Appian, De Bello Civili, 1, 7, 61–62; Cicero, Pro Sestio, 22, 50; Ad Quirites 8, 20; In Pisonem, 19, 43.

[12] Sevink date the network in classical period on the basis of the abundant evidence for Roman interest in the area and, indeed, part of it seems to pre-date the centuriation systems (Arthur, 1991).

the second half of the 6th cent. AD, *Minturnae* was very likely abandoned, the population moving to the nearby hills where present day Minturno is situated (Arthur, 1989; Ferrari et al., 2013; Bellotti et al., 2016).

Starting in the 6th cent. AD, the region was progressively occupied by Lombards. As in many realities of the Early Middle period, many Roman structures were reused for different purposes or else completely abandoned. There are many structures built with spolia material, such as the church of San Paride ad Fontem (11th cent. AD) and the former church of San Benedetto. Many other structures that serve as evidence (including churches and convents) are part of the medieval heritage of the city (De Caro, 2012).

For the Early Middle Ages, archaeological sources testify to the continuity of life, albeit with a move to the heights for the village of Arivito at the foot of Mount Petrino (Mondragone), caused by an increase in population and agricultural exploitation of the foothills. The famous thermal baths, near the ancient village of Aquae Sinuessanae continued in use up to the 10th cent. AD, with the testimony of the Lombard princess Aloara, wife of Pandolfo I Capodiferro (Crimaco and Sogliani, 2009).

The Roman acropolis of *Teanum*, was occupied by a Lombard Castellum, which under Arechi II was transformed into a fortress (Gasparetti and Balasco, 1996).

Sessa Aurunca remained active, leaving the ancient public places out of its path until it became Gastaldato in AD 879 under Landaone I, who built the first fort on the site of the arx (Cilento, 1966)[13].

The most important touristic site is the Rocca Montis Draconis, located on top of Mount Petrino. The first visit to the site can be dated from the 8th to the 10th cent. AD, a period in which the area was affected by various interventions of Lombard dukes and gastalds; following the Norman conquest it underwent several changes until the progressive abandonment of the area in the 16th cent. AD (Crimaco and Sogliani, 2009 and references therein).

In Minturnae, from the 4th cent. AD onwards, there was a gradual contraction of the township. During the 9th cent. AD the mouth of the Garigliano River was still used as a landing place until a colony of Saracens settled close to the ancient town of Minturnae (Ferrari et al., 2013; Bellotti et al., 2016). A great battle occurred in AD 915 not far from the Garigliano River between troops of a Christian League of Byzantines, Neapolans, Gaetans, Capuani and Amalfitani that defeated the Muslim guerrillas (Di Branco, 2019). After the

[13] The first document in which is mentioned the Lombard castrum of Sessa Aurunca (castrum Suessae) dates back to 963 AD (Cilento, 1966).

expulsion of the Saracens the coast remained almost unpopulated, and the area behind the Holocene beach ridges was characterized by small lakes and marshes[14] (Ferrari et al., 2013; Bellotti et al., 2016).

Subsequently, during the 11th cent. AD the region was occupied by the Normans and the expansion of Benedictine monasticism in Campania began (Di Rita et al., 2018a).

In the Garigliano Plain, a large marsh south of the mouth of the Volturno River was controlled by the Benedictine Monastery of San Lorenzo d'Aversa. This monastery, through a dense network of rural outbuildings, granges and farms, controlled vast areas of the Campanian Plain as far as the sea, favoring its reclamation and agricultural exploitation[15]. Moreover, thanks to numerous bequests and donations of land, civil and ecclesiastical goods, and royal and papal privileges, it acquired significant political and economic control in southern Italy and became a driving force behind the Benedictine community (Faenza et al., 2009).

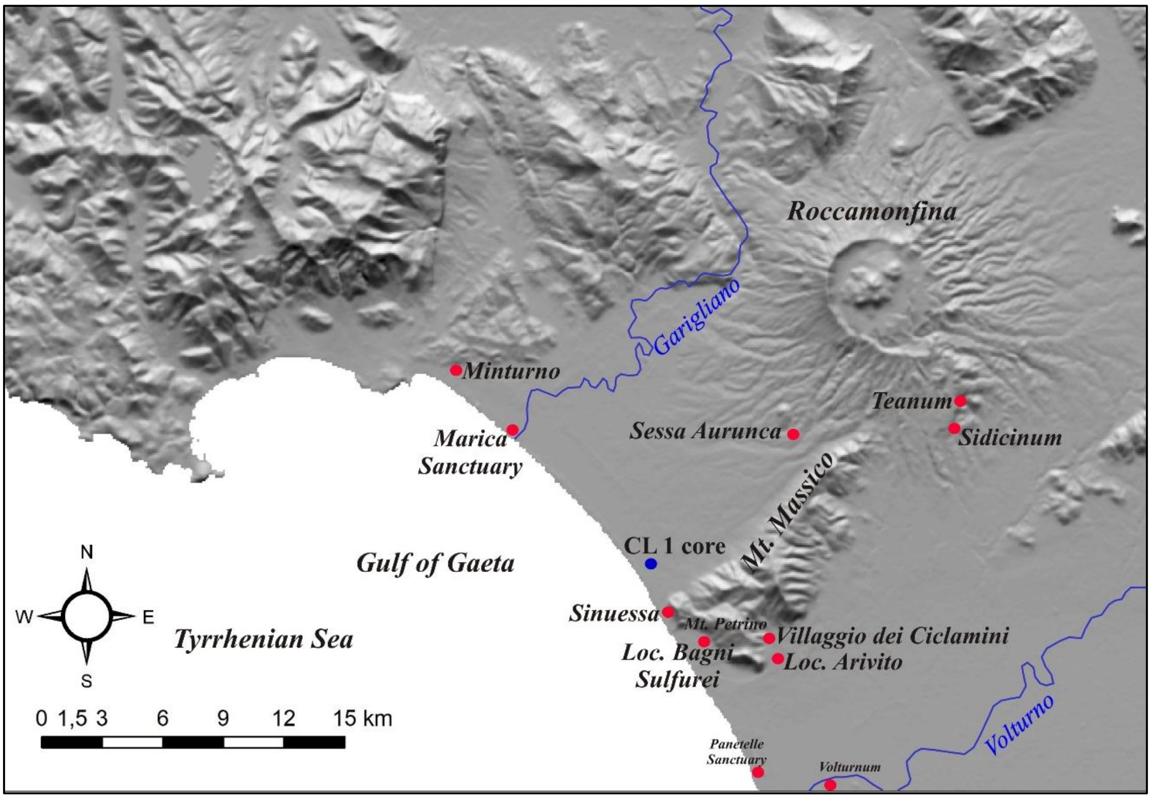


Fig. 14 – Location of CL1 core and the main sites cited in the chapter 4.1.2.1.

[14] The pond/marsh condition in this period is testified to by the toponyms Pantano di Traetto and Pantano di Sessa (Pantano = Italian for marsh or pond) (Ferrari et al., 2013; Bellotti et al., 2016).

[15]Since 1070 Riccardo and Giordano acknowledged the right of the Monastery to own boats (lintres) and paratorie in the lake of Patria; in 1091 Riccardo II granted to the abbey of San Lorenzo iuxta Aversam the port and the mouth of Patria and all the stretch of coast from Castello Maris to Cuma, with the exclusive right to fish in the stretch of sea between Patria, Ischia and Cuma (Faenza et al., 2009).

4.1.2.2. Sarno Plain

The territory of the upper Sarno valley has been populated since the Neolithic. In the Foce Sarno locality, materials dated to the second half of the IV millennium have been found. Archaeologically these materials are attributed to the Middle Neolithic (facies of Capri and Ripoli and facies of Serra d'Alto) and the Final Neolithic (facies Diana-Bellavista).

The territory of the upper Sarno valley it is likely that was occupied during the Eneolithic period. This is attested by some fragments of pottery with hawksbill (embricata?) decoration (Marzocchella, 1994). Moreover, the discovery of finds in polished stone during the archaeological excavations at the site of Longola, Poggiomarino (Fig. 15), suggests a widespread presence in the area (Albore Livadie, 2011).

Traces of Early Bronze Age habitation huts, animal shelters and foodstuffs have been found during the excavation of Longola settlement (Poggiomarino). The life of this settlement was stopped by the Pomici di Avellino eruption, that partly buried the village, as testified by the discovery of ash and pumice related to this plinian eruption (Marzocchella, 1986; 1994; Marzocchella et al., 1999).

Pre-protohistoric sporadic fragments have also been recovered on the slopes of the Saretto hill (Marzocchella et al., 1999) and sporadic materials have been chronologically placed in the Middle Bronze Age 3 (Appennine facies) found near the Palazzo fount and in San Giovanni locality (Marzocchella, 1986; 1994). Middle, Recent and Final Bronze Age material was also found at Longola.

The archaeological importance of the territory is certainly linked to the extensive finds from Iron Age (9th-8th cent. BC) and Orientalizing period (7th cent. BC) necropolis (Fig. 15). The most important necropolis are located in San Marzano (Rota, 1994; d'Agostino, 2010-2011; Longo, 2010a), San Valentino di Torio (Rota, 1994; Longo, 2010b) and Striano (d'Ambrosio, 1988a; 1988b; 1990; 1999; 2003; 2005; Rota 1994). Contacts with the Greek colonies of Cuma and Pithecusa (8th cent. BC) are testified by the presence of rich funerary objects and imported materials (Rota, 1994).

Testimonies of inhabited areas from the Iron Age are present in Poggiomarino, whose stratigraphy goes from the Middle Bronze Age 3 to the 6th cent. BC without interruption. Longola di Poggiomarino site and other finds located along the Sarno avulsion band, refute the recent hypothesis (de Spagnolis, 2001) that places the villages on the slopes of the nearby Sarnesi mountains, showing a preference for morphologies close to waterways or meanders of the river abandoned by the main current (Albore Livadie and Cicirelli, 2003).

During the 6th cent. BC the documentation of the necropolises developed in this area during the Iron Age and Orientalizing period stopped probably due to an abandonment of the small agricultural villages in favour of new urban entities such as Nola, Nocera and Pompeii (Longo, 2010c). After two centuries of presumed abandonment, it seems that the area was resettled. Samnite tombs of the 4th cent. BC, found in Nocera, S. Valentino Torio and Sarno (loc. Villa Venere, loc. Garitta del Capitano, loc. Episcopio, loc. San Lorenzo, Via San Vito), document the resettlement of the countryside and the development of agricultural economy (Rota 1994; Albore Livadie 2011). In the foothills of Sarno, Samnite tombs have been found with very rich outfits and the most recent tombs are placed chronologically between the end of the 3rd and the beginning of the 2nd cent. BC (Rota, 1994).

In the Foce locality (Fig. 15), a small Hellenistic-Roman theatre was found. The theatre was built in the second half of the 2nd BC and modified in Roman times. A large amount of votive clay material, likely related to an extra-urban sanctuary, and dated between the end of the 4th and 2nd cent. BC, was also found in the area. The exact location of the sanctuary has not yet been accertained, but it was probably behind the theatre, as evidenced in other sites. The theatre was damaged by the earthquake of AD 62, after which the area was completely abandoned, as evidenced by other discoveries (De Spagnolis, 1994). There are faint traces of occupation of the site after AD 79 and the terminus post quem for a human presence is suggested by the late ancient eruption of AD 472 that covered the area (De Spagnolis, 1994).

For the Roman period, the archaeological discoveries are abundant in the town of Sarno (De Spagnolis, 1994; Longo, 2010c). The most significant evidence is related to traces of the Serino aqueduct, built in the Julio-Claudian period (1st cent. BC - 1st cent. AD) and which carried water from the Pelosi springs to the Serino up to Puteoli and Misenum. The remains of this famous aqueduct have been found in different parts of the city (via Bricigliano, loc. S. Giovanni, loc. S. Matteo, loc. Foce, loc. Mura d'Arce) and are located on the same axis of the Popilia road (De Spagnolis, 1994). Even the remains of this road axis that connected the Nola and Nocerino countryside are scattered throughout the Sarno territory, allowing for a reconstruction of the course of the road (De Spagnolis, 1994). Some rustic villas (near the Hellenistic theatre, loc. Piscina, loc. Cappella di Paterno, via Calcare, close the modern hospital) are scattered in the Sarno territory but despite the numerous discoveries, it is not possible to prove that a vicus had developed in the territory, although the discovery of a road axis, connecting Pompeii to the Via Popilia in Sarno, highlights the importance of this territory and may attest to the existence of a vicus which connected to the center of Urbula, as attested by literary sources (De Spagnolis, 1994).

The archaeological data for the medieval period is incomplete but written records exist for this period. Following the barbarian raids, local populations took refuge on the hill-slopes of Sarno, where the first settlement of "Terravecchia" was built. With the advent of the Lombards and the establishment of the Benevento Duchy, Sarno became the seat of gastaldato. The top of the hill was fortified, thus starting the history of the castle, whose importance grew between the Norman-Swabian and Aragonese period and subsequently waned during the viceregal period (Cordella, 1994).

Imprecisely dated Lombard tombs (loc. Episcopio), as well as early medieval tombs of local character with Lombard elements (loc. Villa Venere-San Vito) were found in the last centuries. The location of some tombs near a large main road suggests that during the Early Medieval Ages, small settlement groups reused and adapted previous structures and provided routine maintenance of public works (Iannelli, 1994). Other tombs were located near the S. Vito church, whose toponym occurs in 1049 as location of properties and plots of land. Maybe it was already a pole of aggregation for the rural population from the 8th cent. AD. In 1053 an important landed property was still extended in this locality, which is intensely cultivated with sharecropping and possible wine production. This area was cultivated with vineyards, orchards, seeds with shrubby vines, associated with fruit trees and with the ability to cultivate, between rows, various seeds (heat, legumes, etc.). In the loc. Villa Venere (Fig. 15) climbed the olive trees (Iannelli, 1994). The Church of San Vito is located on the southern edge of a sinkhole (San Vito sinkhole). The structure incorporates a Roman column of spolia inside, so it is possible that the church was built on the remains of an ancient Roman temple. Within the same sinkhole, the remains of the early medieval church of Santa Apollonia were discovered. This church contained frescoes dating from the V to IX centuries (Guarino and Nisio, 2009b).

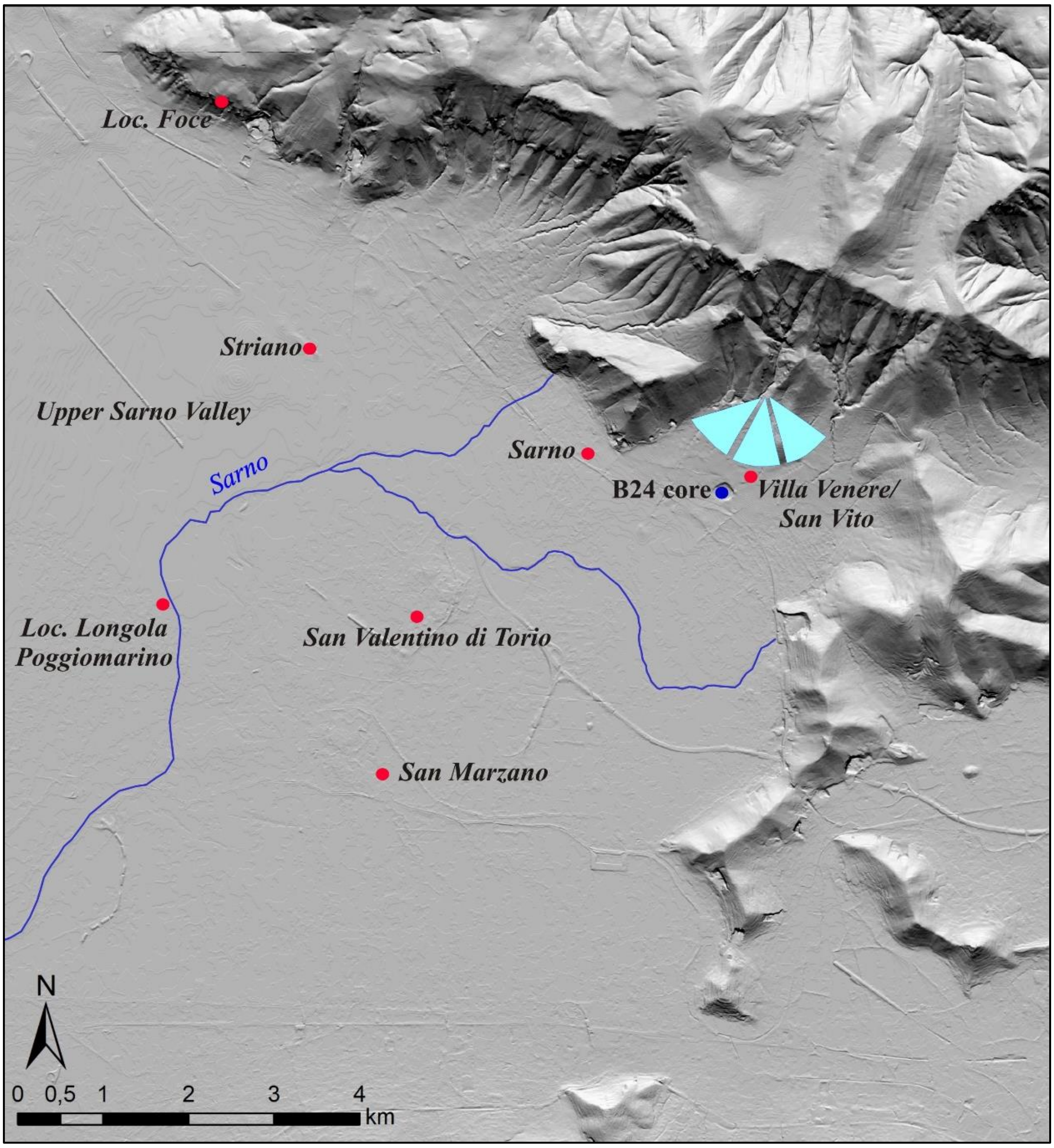


Fig 15 - Location of B24 core and of the main sites cited in chapter 4.1.2.2. To be noted the position of the San Vito Sinkhole at the footslope of the Sarno Mts, within the alluvial talus that contributed to fill the depression.

4.1.2.3. Sele Plain

The first Neolithic evidence in the Sele Plain dates to the Middle Neolithic and has been found in both coastal and inland contexts. In the Salerno area, especially in the foothills, several sites from this period have been found (Di Maio and Scala, 2011). These include the sites of Guarne (Middle and Final Neolithic), San Leonardo, Fuorni (Final Neolithic-Eneolithic initial), and Lamia /Scavata (Final Neolithic). These sites are located on river or marine terraces. Signs of occupation for this period also come from Monte Vetrano (Cinquantaquattro, 2009) and from the Nardantuono cave of Olevano sul Tusciano (Piciocchi, 1973; 1988; Mitrano, 2008). In Pontecagnano (Fig. 16), Neolithic attendance is attested near the airport and Sant'Antonio a Picenzia (Final Neolithic). A settlement dating to the Final Neolithic and the beginning of the Eneolithic was also discovered to the south of the Tusciano, in Castelluccia di Battipaglia (Cinquantaquattro, 2009; Scarano, 2011). In the Paestum area, Neolithic materials, associated with both the Serra d'Alto and Diana cultures, were discovered during the excavations of the ancient city (Temple of Ceres, northern part of the walls, east of the altar of the Basilica, east of the hypogeic sacellum). During the excavations, several obsidian blades that reveal clear contact with the Aeolian islands were discovered. Other discoveries are in Gromola, not far from the Hera Argiva Sanctuary (Bailo Modesti, 2008; Aurino, 2014).

With respect to the Neolithic period, the evidence of anthropic presence during the Eneolithic period is more conspicuous. A district of Paestum called Gaudo (Fig. 16) gave its name to one of the most famous Eneolithic cultures in the Italian peninsula (Brinson, 1945; Sestieri, 1946; Sestieri 1946-1948; Aurino, 2014), known for the most part thanks to the rich necropolises of the period. In the Sele Plain, necropolises of the Gaudo culture have been found in Spina-Gaudo (1 km north of Paestum), in Fratte and Fondo Sabbato in Salerno, in Pontecagnano along the river Picentino (Di Maio and Scala, 2011), and in Madonna della Catena in Eboli (Cinquantaquattro, 2009), while traces of the same period have been found in Boscariello (Salerno); fragments of the same culture were also found to the east of the Basilica and in the locality of Acqua che Suona (south of the ancient city of Paestum). To the west of the Cerere Temple in Paestum (ancient city) a necropolis was investigated by Voza, which instead presents materials similar to the more recent Laterza culture (Bailo Modesti, 2008; Aurino, 2013). Other discoveries generically attributable to the Eneolithic always come from the area of Salerno, close to the hills of Giovi and Piano Montena and from the area of Pontecagnano airport (Bailo Modesti and Salerno, 1998). An important settlement dating back to a moment of transition between the Final Eneolithic and the beginning of the Bronze Age is located in Oliva Torricella on the final stretch of the Fuorni river. The site has yielded among the various materials also some associated with the Balkan culture Cetina (Arcuri et al., 2016). The site of Oliva Torricella, together with others mentioned above and found in the Gulf of Salerno were affected, according to recent investigations, by a tsunami whose epiclastic and volcanoclastic deposits covered the site to a depth of over 60 cm. This phenomenon is dated in a more recent period than the most important eruptive events of the Phlegrean Fields and Ischia, dating to about 300 years before the Vesuvian eruption of the Pomici di Avellino. Therefore, if the trigger had been of volcanic in origin, it must be looked for outside the Campania area (Di Maio and Scala, 2011).

The evidence relating to the Early Bronze Age in the Sele Plain is very limited and difficult to interpret. At the well-known site of Oliva Torricella a number of tombs dating back to this period have been uncovered (Di Maio and Scala, 2011) and four bronze axes with raised margins were found from at the ancient city of Paestum (Fig. 16), typologically framed within the same period (Bailo Modesti, 2008). Some areas seem to be continuously frequented from the Eneolithic to the Late Bronze Age, such as those of Montevetrano (Cinquantaquattro, 2009) and Castelluccia di Battipaglia located north of the plain (Di Maio et al., 2003; Scarano, 2011). The unpublished open site of Ponte Barizzo can be associated to either the Palma Campania or the Protappennine cultures. In Piano Molito (Trentinara), an Apennines (Middle Bronze 3) fortified village was found at the top of a terrace at a height of 490 m a.s.l. during an archaeological mission led by Ross Holloway in 1975 (Albore Livadie et al., 2003; Bailo Modesti, 2008).

In Serroni di Battipaglia, a survey has shown that the area was frequented during the Middle Bronze Age. These findings, together with others from all over the hilly belt that follows the middle course of the river Tusciano up to Monte Raione, where the famous Middle Bronze Age settlement of Nardantuono cave (Olevano sul Tusciano) is located (Piciocchi, 1973; 1988; Mitrano, 2008)[16], suggest an occupation/frequency of the territory probably suited to pastoral and transhumance activities. Another important cave attendance during the Middle Bronze Age is the Ausino Cave of Castelcivita (Mieli, 1991-1992; Pellegrini and Piperno, 2005).

Various findings dated to the Middle Bronze age come from the ancient city of Paestum (BM1-2-3), from the Stromiello property (BM 1-2), from Santa Venera (near the banks of the Salso river), and from Capodifiume (BM3) (Bailo Modesti, 2008).

The settlement framework of the Middle Bronze Age of the Sele Plain is very complex to summarize, especially working within our geographical limit of coastal plain and foothills, which excludes entire inland areas such as the well-known site of Buccino, and the caves of Vallo di Diano widely frequented during the Middle Bronze Age. These numerous inland sites are sometimes connected to the coastal area; therefore to explain the settlement process of the coastal plain and the foothills, in general we can say that the sites are distributed along

[16] In December 2015, as part of the project "Restauro e Valorizzazione del complesso monastico Santuariale di San Michele Arcangelo di Olevano sul Tusciano" (POR Campania ERDF 2007-20163 - Operational Objective 1.9 - CIG: 60424378BF - CUP: D73J14000080000) three archaeological trenches were dug in the Nardantuono Cave to investigate the levels of pre-protohistoric attendance. The excavation materials are being studied by a research group that includes the writer Dr. Ilaria Matarese of Mibact and Dr. Alessia D'Auria, under the scientific direction of Prof. Marco Pacciarelli of the University of Naples Federico II and Dr. Antonio Salerno of Mibact.

river valleys and streams, which connect the hinterland to the coastal plain, as well as on the hills that dominate the points of entry of waterways into the plain, which seems to be linked to strategic needs of territorial control (Cinquantaquattro, 2009).

In the Late Bronze Age, the occupation becomes more consistent also in the northern area of the coastal plain. Recent Bronze Age settlements have been found in the Sant'Antonio locality of Pontecagnano (Aurino, 2010) and, as already mentioned with regard to Castelluccia di Battipaglia, both sites have returned Mycenaean ceramics. Very similar to that of Pontecagnano for settlement methods, structures and materials, is the settlement located in nearby Eboli on the hill of Montedoro, bounded by the Elmice River and a tributary of the Tiranna river. In Eboli (Fig. 16), the Recent Bronze Age is also attested in the Turmine locality, a wide plateau bounded by the hills of Madonna della Catena and Madonna del Castello (Aurino, 2010).

Other important evidence of the Late Bronze Age emerged from the Paestum area, on the Madonna del Granato (Bailo Modesti, 2008), close to the mouth of the Sele (near the Sanctuary of Hera Argiva), and in the localities of S. Cecilia and Volta del Forno (Bailo Modesti, 2008; Cinquataquattro, 2009). The occupation of these areas is evidently linked to control of a crossing-point over the Sele River and of the coastal road system. This itinerary, parallel to the coastline, followed the top of the fossil dune of Gromola and, fording the Sele, touched the locality of San Marco and headed towards Agropoli: at both sites there is evidence for the Final Bronze Age. In particular, the settlement of Agropoli must be linked to the first real protected natural landing place south of the Sele Plain (Cinquantaquattro, 2009).

In the Sele Plain the most important sites of the Iron Age are certainly those of Pagliarone and Pontecagnano. In particular, this last Villanovan settlement managed to establish a wide system of relations, favoring the allocation of indigenous groups at the nerve centers of its territory, of which it ensured control (Bailo Modesti, 2008; Cinquantaquattro, 2009). In fact, the area between Pontecagnano and Paestum will be occupied by a series of sites, essentially consisting of necropolises and arranged along the so-called "paleoduna di Gromola", beyond which an environment dominated by lake basins and marshes harbouring disease made the settlement unsuitable (Aurino, 2010). Some of these (Casella, Arenosola, Gaudo) will be part of a coherent system, consisting of what Bailo Modesti and Gobbi (2010) called "the tribes of the dunes and the sea" and which seem to be established not before the third quarter of the 8th cent. BC. Montevetrano also continued to be frequented (Scala, 2011), while, beyond the Sele, only the settlement of Capodifiume is known, which has yielded tombs from the I Iron Age that represent an attempt to extend the Villanovan communities to the south of the river, along a route that led to the Vallo di Diano (Cinquantaquattro, 2009).

The expansion and consolidation process of Pontecagnano occurred at two different times. The first period corresponds to the advanced phase of the II Iron Age and the second is dated to the Orientalizing period when Pontecagnano, favoring the stabilization of Irpinian communities along the valley of the Picentine, guaranteed the control of resources in the hilly mountain hinterland. Moreover, Pontecagnano comes to exercise forms of control even beyond the Sele[17] (Cinquantaquattro, 2009).

In the southernmost area of the Sele Plain, between the 11th and 10th cent. BC, a settlement was built on the Agropoli promontory, near the castle; it is the remains of a village located in a strategic position. A settlement dating from the same time was found a few kilometres north, in S. Maro, consisting of hearths and dungeons thought to be a place of storage and processing of food (Bailo Modesti, 2008).

During the Orientalizing period, Pontecagnano began a time of great political and economic vitality, as evidenced by the rich, princely tombs (Iannelli, 2011). The city exercises its control over all the harbours of the gulf by establishing wide-ranging relations (Bailo Modesti, 2008).

In the future territory of the city of Paestum, the Orientalizing period is attested by several discoveries probably linked to Pontecagnano (Cinquantaquattro, 2009). Bailo Modesti (2008) believes that, although weak, the orientalizing evidence in the Paestum area suggests exploitation as a necropolis for this territory.

Concerning Greek and Roman periods I have decided to describe in a concise way the evolution (political, economic and cultural) of what I believe to be the most important aggregating poles of the plain in these periods, from the foundation of the first urban centres. This choice is linked to methodological reasons set out in chapter 3.3.

The oldest historical settlement at Salerno (7th cent. BC) is located in Fratte, in the southern part of the Irno river valley. The settlement is located in control position respect to a natural path that connected the Sele Plain to the area of Sarno and Volturno dominated by Capua. Systematic investigations have allowed the identification of various necropolises as production areas probably annexed to the Fratte settlement (Pontrandolfo et al., 2011).

Certainly, one of the most important historical events in the Sele Plain is the foundation of Poseidonia in the 6th cent. BC by the Sybarites after the defeat of Sybaris by Crotone in 510 BC (Mertens, 2006). The construction of the Heraion at the mouth of the Sele River (Fig.

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[17] Paestum, Gaudo, Santa Venera, the Templata and Rovine di Palma localities (Cinquantaquattro, 2009).

16), about 11 km north of Paestum, dates back to the same period (Greco, 2003 and references therein)[18].

With regard to the geological-geomorphological context, the city of Poseidonia stands on a travertine bank, while as far as the coastal area, facing the city, geological surveys have confirmed the presence of marshes and dune ridges, the most important of which is that of Gromola. These ridges crossed the entire Sele Plain (Amato et al., 2013) and certainly represented the main crossing routes of the territory. Another river that laps the city is the Capodifiume stream (Longo, 1999). The Poseidonia plain is particularly important also for a series of extra-urban shrines that at the time of their foundation gained great importance[19].

Other archaeological finds come from Linora (c. 3 km south of Poseidonia), in which traces of a settlement with a necropolis and a shrine have been found. It is an autonomous settlement with respect to the city of Poseidonia, the initial phase of which dates back to the mid-6th cent. BC (Avagliano 1992).

A reorganization of the city of Pontecagnano and of the periurban area is dated between the 6th and 5th cent. BC, with the construction of a road system and rural planning (Amato, 2009 and references therein).

With regard to the Fratte settlement, its emporic origin was strengthened with the foundation of Poseidonia, becoming a connecting centre between Poseidonia and Capua (Pontrandolfo et al., 2011).

Recent archaeological discoveries suggest a Samnite occupation in the 4th cent. BC of the Fratte settlement, which was abandoned around the middle of the 3rd cent. BC (Pontrandolfo et al., 2011). Even the Etruscan-Samnite center of Pontecagnano seems to have been abandoned in part within the first decades of the 3rd cent. BC, while the second half of the 3rd cent. BC dates back to the definition of a new urban layout to relate to the *Picentia* known from the sources (Giglio, 2005 and references therein; Amato et al., 2009)[20].

[18] North of the Sele River, when the foundation of Poseidonia occurred, there were the Etruscans of Pontecagnano and many scholars believe that the construction of the Heraion, right on the border with the Etruscan world, was an act of strength by the Greeks to claim their supremacy (oral communication of prof.ssa Greco G.).

[19] In addition to the Heraion at the mouth of the Sele, there are, in this period, the rural shrines of Getsemani, St. Nicholas in Albanella and that in Acqua or Fontana che Bolle, the shrine at Fonte of Roccadaspide, the shrine in Basi di Colonne (near Porta Marina), probably dedicated to Demeter, as well as a shrine near the mouth of Capodifiume, close to the "Camping Apollo", probably dedicated to Aphrodite, in addition to the sanctuaries built near the city walls (Longo, 1999).

[20] Literary sources (Strabo and Abies the Elder) report on foundation of *Picentia*. In particular, Strabo reports that the Romans deported the Picentine tribe from Piceno and established it in this territory by founding the city of *Picentia*. On the position of the ancient *Picentia*, recent discoveries by the Oriental University of Naples in property Tuono at Pontecagnano, have placed the ancient city in today's Pontecagnano (Giglio, 2005).

Poseidonia will be occupied by the Lucanians in 420 BC (Guidobaldi, 1994; Longo, 1999; Mertens, 2006). During the Lucanian occupation, some suburban shrines continue to be frequented, as well as that of the suburban Heraion[21]. Moreover, various notable painted tombs of the Lucanian period have been identified in the territory (Guidobaldi, 1994; Longo, 1999).

With the Romanization of the territory Poseidonia became a latin colony in 273 BC with the name of *Paestum* (Guidobaldi, 1994; Longo, 1999; Mertens, 2006), while north of the Sele the latin colony of *Salernum* was founded in 194 BC (Pontrandolfo et al., 2011).

The founding of *Salernum* lead to a territorial reorganization and the progressive reduction of the town of *Picentia*, probably because of its fluctuating relations with Rome during the Hannibalic Wars. Many agricultural settlements dated between the 1st cent. BC and 2nd cent. AD are located in the northern part of the Irno Valley and their installation seems to fit into a centurial organization as also seen along the eastern coast of Salerno (Pontrandolfo et al., 2011). The inhabitants of *Picentia* (Fig. 16) were dispersed and sent to live in villages even though a settlement nucleus appears to survive in the classical part of the city along the Via Popilia[22] (Giglio, 2005; Pontrandolfo et al., 2011).

From the settlement framework presented here[23], a territorial organization formed by a series of small towns (*vici*) located within a vast territory controlled administratively by *Salernum* emerges (Giglio, 2005).

Another important Roman settlement in the Sele Plain is *Eburnum*, whose status and date of foundation are unclear [24] (Giglio, 2005).

The Poseidonia plain has yielded various intra-mural and extra-mural archaeological evidence of the Roman Age (republican and imperial) [25] even if it is difficult to outline a framework of the territorial structure.

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[21]Sanctuaries in the localities of Fonte (cult of Hera), in St. Nicholas in Albanella, in Porta Marina and in Santa Venera. the shrine at Capodifiume is dated in the 4th cent. BC and at the end of the same cent. the necropolis of Andriuolo and a near loc. Spinazzo (Guidobaldi, 1994; Longo, 1999).

[22] Recent stratigraphic studies have confirmed the survival of this settlement nucleus even after the eruption of Pompeii in 79 AD (Giglio, 2005; Pontrandolfo et al., 2011).

[23] The bibliography on the subject is vast and the reader is referred to a well-structured work carried out by Giglio (2005) for a summary of the individual pieces of archaeological evidence.

[24] Beloch believes that *Eburnum* was a colony deduced by the Gracchi; certainly in the middle of the Imperial Age it was a town hall ruled by duoviri (Giglio, 2005).

[25] For example, there are some extramural discoveries such as two imperial villas, one of which is located in the locality of Andriulo, to the north of the city walls. Roman structures have been found in the Chiusa del Cerro locality (5 km north of *Paestum*) and Capodifiume. Moreover, close to Vallone del Bagno a house dating from the middle Republican Period connected to agricultural exploitation was found. Imperial discoveries were found in The Chiorbo locality, on the left shoreline of Capodifiume (Santangelo, 2012).

The rural Picentine territory went in crisis after the 4th cent. AD, showing a change in the socio-political structure before the end of the Roman Empire (Amato et al., 2009 and references therein).

Concerning the territory around Paestum, the deconstruction processes of the Roman landowner system are difficult to define and the archaeological traces are too few to outline the pattern of the population in the Late Ancient period. However, it seems that this territory during the 4th cent. AD still had some economic vitality, especially in the production and export of raw materials[26] (Santangelo, 2012).

The Early Middle Age of the Sele Plain, as described above for the Graeco-Roman period, is very complex and is supported by a very rich corpus of literary and archaeological sources. Nevertheless, the present discussion will proceed with a summary of the settlement forms of the plain as in the previous period.

Salerno (Fig. 16) was involved in the Greek-Gothic War (AD 535-553) and finally came under the rule of the Byzantines, before the conquest by the Lombards of Benevento (c. middle of 7th cent. AD). The silence of sources on this event has led to the belief that the city at this time had become secondary, there being also many gaps in the events of the city throughout the first period of Lombard rule (Aceto, 1999).

A rebirth of the city occurred in AD 774, when the Lombard king Arechi II made Salerno (reduced to a small fishing village) his residence, attracting Lombard nobles to the renovated city. This new situation led to a strong interest on the part of the new Lombard lords of Salerno regarding the fertile land that fell within the administrative district of the city between Cava and Sele (Di Muro, 2012).

Written documentation and recent archaeological research attest to the progressive growth of these lands until the second half of the 9th cent. AD, thanks to the advancing colonization and production related to the mountains. The territorial produce was exported through international routes, by Amalfi markets, towards the East as well as the Maghreb. During the 10th cent. AD, after a brief crisis period linked to the Saracen incursions, an agrarian renewal took place in the territory between Salerno and the Sele. In fact, entire families of settlers, with advantageous contracts, cleared the *latifundia* of the great secular and ecclesiastical owners of Salerno and began the construction of a new agricultural landscape. At the same time, a network of castles was built, and between the 10th and 11th cent. AD

[26] From a Cassiodoro letter of 508-511 we learn that Theodorico ordered the owners of the Lucanian ships to transport goods and other products to Gallia in order to alleviate the hunger caused by a famine (Santangelo, 2012).

the districts of Giffoni, Olevano and Eboli were formed and consolidated, breaking up the ancient administrative unit of Salerno (Di Muro, 2005). The 11th cent. AD also saw the rebirth of Eboli after seven centuries of silence.

With the Norman conquest[27] Salerno fell definitively and Gisulfo II, the last Lombard prince, took the road to exile. At the sunset of the Lombard domination the territory was made up of rich villages and flourishing countryside, with the presence of a center, that of Salerno, dedicated to international trade.

The elements that stand out in this landscape, built with great effort, cutting down forests and fighting against a lush natural environment, are the churches, which appear in the documentation almost as indispensable components for the colonization activities carried out in the area, serving as attractive nuclei for the inhabitants of the *curtes* and *tenimenta*.

At the sunset of the Swabian domination, castles, fortified villages, open villages, monasteries, and rural sanctuaries coexist on the plain and on the surrounding hills. The rural churches became more and more the aggregation points par excellence of the settlement on the plain; the hamlets became almost open villages, sometimes connected to a castle, while the "winning" villages are defined in forms structured in an increasingly complex way.

As for the territory of *Paestum*, the deconstruction process already underway from the end of the Roman Empire continued, and the city was either progressively abandoned or repurposed. The evidence of attendance in this area during the Middle Ages is much but scattered. It will suffice to recall only the birth of the Caputaquis settlement (frequented from the Roman Age to the 15th cent. AD), which appears for the first time in a written source of AD 993. A few years later, the place is known as the Caputaquis Castle. Subsequently, it developed as an urban center, with the growth of an extramural suburb in the 11th cent. AD (Santangelo, 2012).

[27] All the information regarding the Norman-Swabian period in the Sele Plain is taken from Di Muro, 2005.

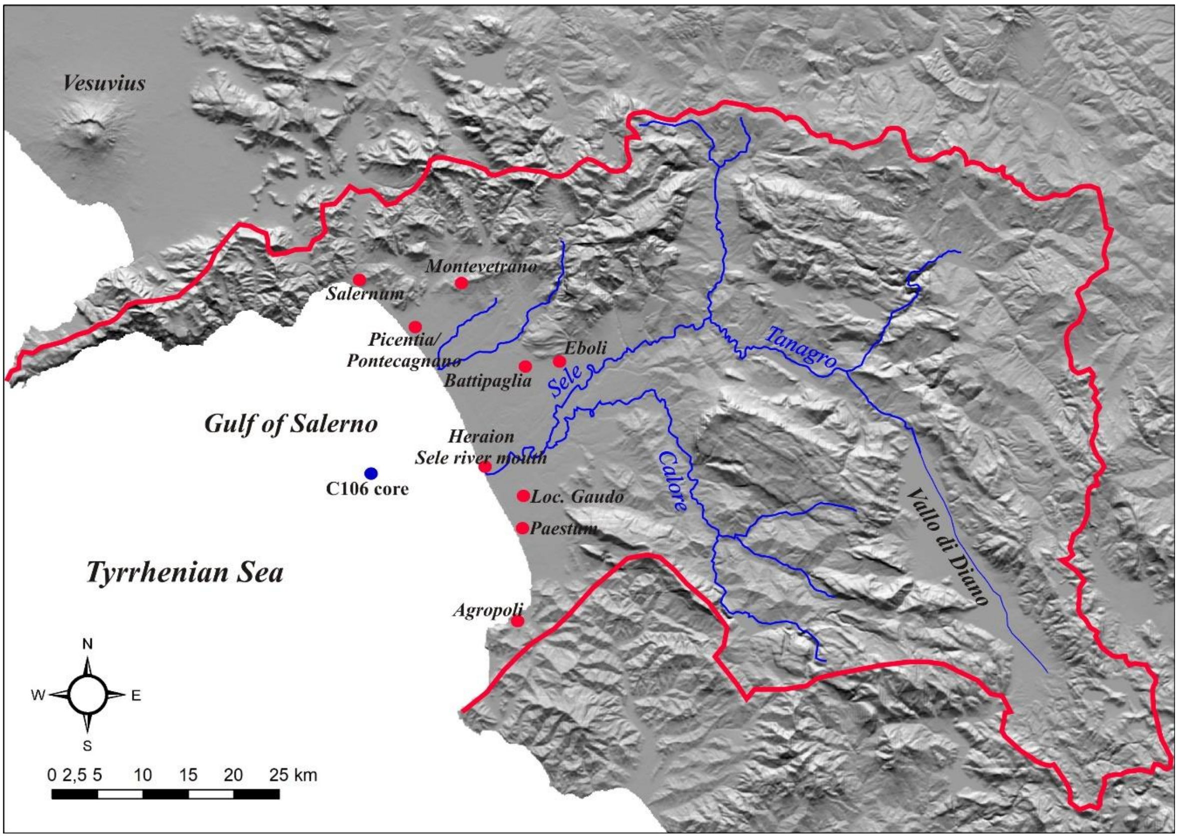

Fig. 16 - Location of C106 core and of the main sites cited in chapter 4.1.2.3. The red line indicates the watershed of the Sele River catchment

4.2. Calabria

Dio diede alla Sila il pino, all'Aspromonte l'ulivo, a Reggio il bergamotto, allo Stretto il pescespada, a Scilla le sirene, a Chianalea le palafitte, a Bagnara i pergolati, a Palmi il fico, alla Pietrosa la rondine marina, a Gioia l'olio, a Cirò il vino, a Rosarno l'arancio, a Nicotera il fico d'India, a Pizzo il tonno, a Vibo il fiore, a Tiriolo le belle donne, al Mesima la quercia, al Busento la tomba del re barbaro, all'Amendolea le cicale, al Crati l'acqua lunga, allo scoglio il lichene, alla roccia l'oleastro, alle montagne il canto del pastore errante da uno stazzo all'altro, al greppo la ginestra, alle piane la vigna, alle spiagge la solitudine, all'onda il riflesso del sole.

Leonida Rèpaci

"Calabria grande e amara" – 1964

Fig. 17 – Punta di Zambrone bay

4.2.1. *Geological and geomorphological setting*

The Tyrrhenian coastal profile of Calabria is characterized by structural highs and troughs, generated by the intense extensional tectonics that affected the Calabrian Arc since the Pliocene (Westaway 1993; Tortorici et al. 1995; Monaco et al. 1996). The uplifted structures are made up of granitic and metamorphic rocks, unconformably covered by Miocene terrigenous, evaporitic and carbonate sediments.

Among such highs, the Capo Vaticano peninsula, also known as Tropea promontory, represents the southern edge of the Sant'Eufemia Plain (Fig. 18), a complex tectonic depression filled by a thick Plio-Quaternary sequence of marine to continental deposits. The promontory is typified by flights of Middle to Late Pleistocene marine terraces (Tortorici et al., 2002; Filocamo et al., 2009), spread at different elevations and separated by structural scarps. The development of such a step-like morphology is the result of the above-mentioned uplifting trend coupled with the sea level variations driven by the Quaternary climatic cyclicity. Seven orders of wave-cut surfaces and/or thin-depositional platforms were recognized by Tortorici et al. (2002) and correlated to the last seven eustatic high-stands, occurred from 330 to 60 ka. The extension of the different terraces depends on the duration of the relative sea level high stand, the erodibility of the substratum and its previous morphology. Due to the lithologic homogeneity of the Capo Vaticano promontory, the original morphology of the substratum has been considered the factor that mostly controls the width of a single marine platform (Tortorici et al., 2002). In fact, the widest surfaces are carved on flat or slightly inclined coastal plains, such as those of Capo Vaticano and Briatico areas, whereas along steeper coastal stretches, the surfaces become narrower, disappearing along the fault scarps. In this case, the paleo-sea level stands are only represented by notch alignments, which are generally obliterated by erosional processes. In particular, the topmost and oldest surface (Terrace I) is made up of an eroded surface extending from Mt. Poro to Vibo Valentia, from 420 up to 711m a.s.l. It was correlated to MIS 9.3 (330 ka) thanks to the TL dating of coarse marine sands (285±40 ka in Bianca et al., 2011) collected near S. Costantino. Terrace IV was related to MIS 5.5 (Tyrrhenian stage) thanks to paleontological data (Barrier et al., 1988) and dating of marine sands (128±13 in Balescu et al., 1997). The lowermost and youngest terrace (Terrace VII), spanning from 25 to 75 m a.s.l., was ascribed to MIS 3.3 (60 ka) on the basis of the TL age of cross-laminated coastal sands (66±5 ka in Bianca et al., 2011).

The Sant'Eufemia Plain is located between Capo Sùvero and Capo Vaticano and is elongated for ca. 20 km. The Plain and the adjacent Gulf are part of the geological and geomorphological context of the Catanzaro graben, a tectonic depression generated by transversal fault systems (Romano et al., 2017). The Catanzaro graben is filled by a Neogene-Quaternary sedimentary succession that overlies the igneous-metamorphic basement, which is widely outcropping in the Serre and the Sila massif (Brutto et al., 2014). The northern foothills of the Sant'Eufemia Plain consist in Late Pleistocene-Holocene conglomerate and sand deposits related to different generations of alluvial fans (Romano et al., 2017; Ruello et al., 2017; Russo Ermolli et al., 2018), while at the southern foothills, dissected Late Pleistocene marine terraces (Tortorici et al., 2002) extend between 50 and 10m a.s.l. The Piana di Curinga terrace, located at c. 30 m a.s.l., is cap by wind-blown sands of fossil beach dunes and bordered by the remains of an ancient sea cliff (Russo Ermolli et al., 2018). The continuity of the terrace is interrupted at north by the Holocene entrenched alluvial fan of Acconia, generated at the outer section of the Turrina stream (Romano et al., 2017; Russo Ermolli et al., 2018).

The Amato River alluvial-coastal plain (about 5 km wide) represents the final segment of a wide fluvial network whose watershed reaches in the highest extremity of Sila Piccola reliefs. The present beach, fed by the Amato River sediment supply, is c. 100 m wide and extends for c. 20 km. In the northern part of the beach there are two small coastal lakes while at the southern part there are beach dune systems that extend up to 2 km away from the coast (Romano et al., 2017; Russo Ermolli et al., 2018).

A recent work (Ruello et al., 2017) on the Sant'Eufemia Plain middle-Holocene sequence demonstrated the presence of wet environments during the progradational trend which followed the early Holocene ingressive phase. In particular, four evolution phases were identified during the Holocene:

- 8300 - 6900 yr. cal BP: eustasy largely prevailed on the tectonic uplift, causing coastline ingression and aggradation;
- 6900 - 2800 yr. cal BP: coastline progradation and aggradation were driven by high detrital inputs and slowdown of sea level rise, during a phase characterized by a general weak subsidence;
- 2800 - 1400 yr. cal BP: higher rates of subsidence favored the establishment of marsh and flooded alluvial plain environments in the back-barrier domain.
- After 1400 yr. cal BP: a substantial stability characterized the Sant'Eufemia Plain.

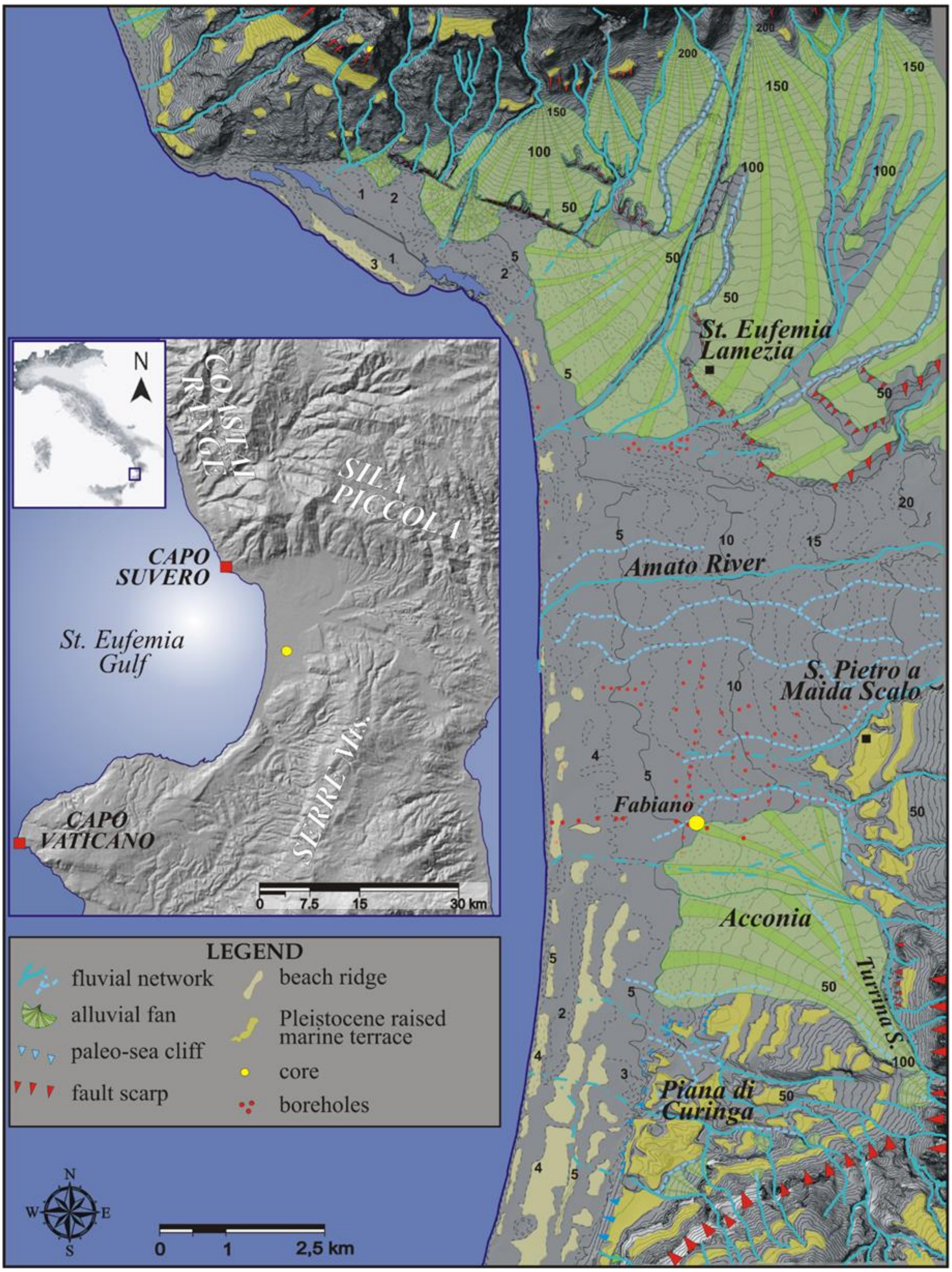

Fig. 18 - Geographical position and geomorphological sketch of the Sant'Eufemia Plain, with location of the core SL1 (after Russo Ermolli et al., 2018)

4.2.2. *Archaeological setting*

In this chapter are exposed the archaeological evidence of Gulf of Sant'Eufemia from the Neolithic to the Medieval Ages (Fig.19).

Most of the information in this chapter are taken from a recent article (Russo Ermolli et al., 2018) on the geoarchaeological surveys conducted in the Lamezia Plain during a PRIN (2011-2013) which saw the collaboration of the Department of Humanistic Studies (DiSU), the Department of Earth Sciences, Environment and Resources of the University Federico II of Naples and the University of Salzburg.

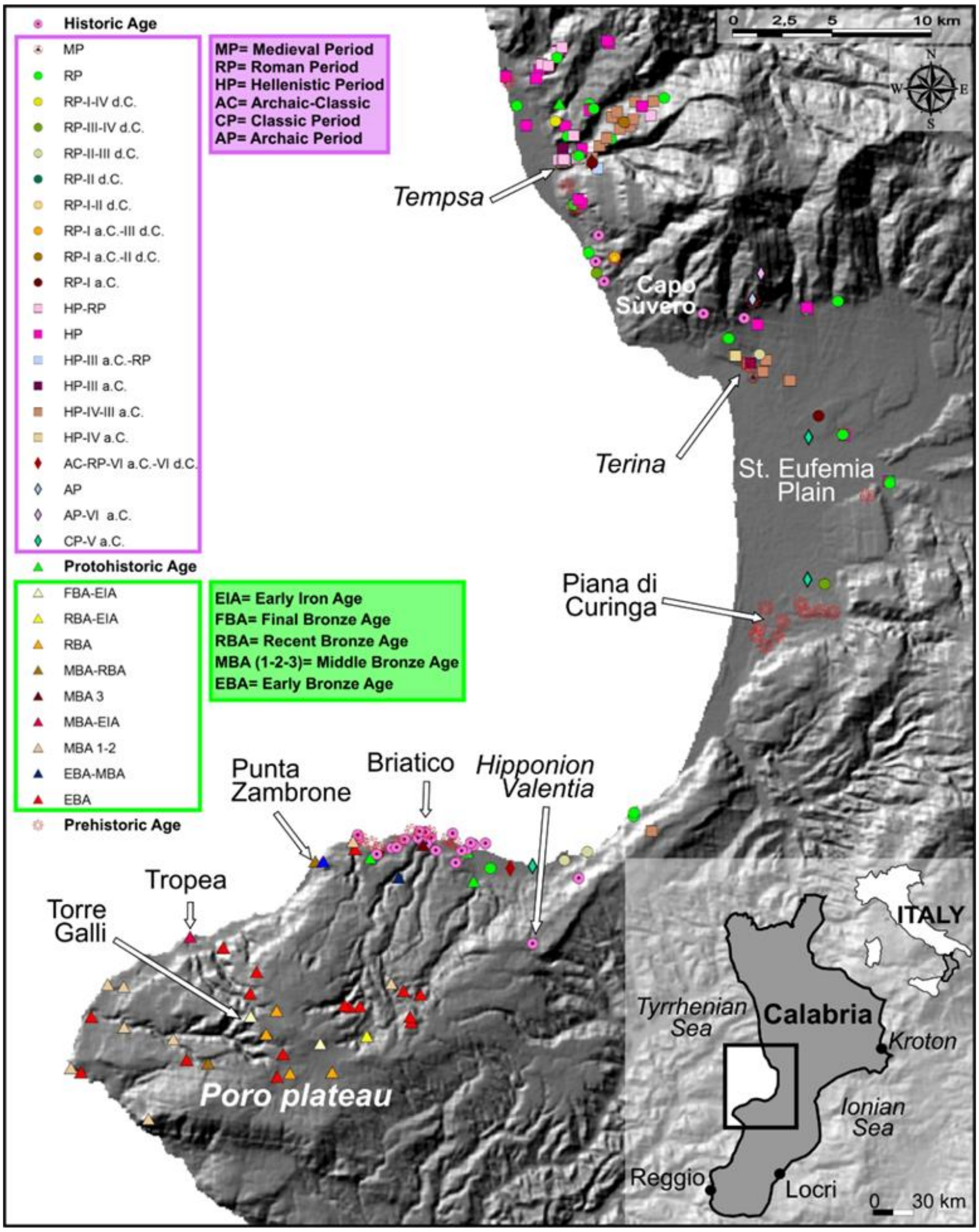

Fig 19 - Distribution of archaeological settlements and sporadic materials and their chronology in central Tyrrhenian Calabria. The most important sites cited in chapter 4.2.2 are indicated (after Russo Ermolli et al., 2018)

Calabria was an important peninsular joint for the trade of Lipari obsidian as testified by the relevance of this matter in the Tyrrhenian Neolithic sites and along the river isthmic pathways, like the Lao River (Ammerman et al., 1978; Tinè and Vanzetti, 2014). In different cave sites of Cosentino, during the first half of the 5th millennium BC, the diffusion of Serra d'Alto facies occurred while the rest of Calabria, during the Early and Middle Neolithic was connected to the Sicily of Stentinello facies. Until the 1960's, there were few reports of Stentinellio pottery in the peninsula because the area of distribution was limited to the islands (Ammermann et al., 1976). Finally, during the last centuries of the 5th millennium BC, in the recent Neolithic, the region assimilated the Diana facies attested in a large part of the peninsula and Sicily (Tinè and Vanzetti, 2014).

With regard to Sant'Eufemia Plain, many Neolithic pottery of Stentiniello Culture and Diana Culture are scattered on the flat surface of the marine terraces between 20 and 40m a.s.l. and also up to about 100m a.s.l. (Ammerman and Bonardi, 1985; Russo Ermolli et al., 2018). Besides the ceramics, abundant Neolithic lithic industry in chert and Lipari obsidian was found. The Neolithic occupation, therefore, lasted for a very long period of almost two millennia. An important area of development of the Stentiniello Culture were the Acconia sand dunes investigated with several excavation campaigns since 1974. In the Acconia area, precisely on the Piana di Curinga (Fig. 19), Ammermann identified an important Stentiniello site (Ammerman et al., 1978, 1988). Here, 48 structures were found, mainly small timber trellis building (Ammerman, 1987a; b). It is not yet clear if these structures should be considered as components of a village that formed in one time or as individual areas of farm occupied at different times in the history of the settlement (Ammerman and Bonardi, 1985).

With regard to the Poro Plateau, the first phase of systematic settlement of this area is dated to the Late Neolithic (Diana facies) when the first traces of ploughing are attested with certainty in Italy (e.g. Giampaola and Stanislao, 2007).

In Calabria, the distribution of sites seems to be homogeneous during the Eneolithic period. Certainly, the most important sites were located inside caves, in northern Calabria (e.g. Grotta della Madonna di Praia a Mare, Grotta Cardini, Grotta S. Michele di Saracena, Grotta S. Angelo III, Grotta Pavolella) and southern Calabria (Grotta S. Sebastiano) (Pacciarelli, 2011).

With regard to the Thyrrenian coast, the human presence in the Piana di Curinga area certainly continued as suggested by the recovery of post-Neolithic pottery (Ammerman et al., 1978). Unfortunately, we do not have more information on these later finds, but a date between the Eneolithic and the Early Bronze Age may be assumed (Russo Ermolli et al., 2018). Whereas, we have more information about many open-air sites located on the Poro Plateau of the Tropea Promontory (e.g. Gallo di Briatico), on the Ionian coast (Cariati, Corazzo, Olivotto Borda, Casa Colosimo, Gerace) and in the inland (Acri, Dipignano) (Pacciarelli 2011).

At the Middle Eneolithic (Gallo-Colarizzi facies), various sites on the Poro Plateau (Fig. 19) are dated as testified by the archeological finds of Passo Murato. Here, in a depressed area regularly subject to water pooling, an important deposit dated to the first phase of Middle Eneolithic was identified in a light grey clay layer located under a peat deposit (Lo Torto et al., 2011).

In general, during the Late Eneolithic (advanced stage of Laterza facies - appearance of San Fili) and Final Eneolithic (Zungri facies) various sites on the Poro plateau were present, while there seems to be an almost total absence of sites on the hills (Pacciarelli, 2001; Di Lorenzo et al., in progress).

With regard to the Early Bronze Age, during the excavation campaign (2011-2013) of Punta di Zambrone site (area D), a new aspect was identified for the first phase of this period, dated to the XXI cent. BC, but, up to now, no sites of this culture were found on the Poro Plateau (Pacciarelli et al., 2015; Pacciarelli, 2017).

During the late phases of the Early Bronze Age (Cessaniti facies), there was a capillary occupation of the Tropea Promontory (Poro Plateau, hilly areas, coastal area) mainly on the hilly belt, suggesting the development of a new economy mainly based on livestock farming (Pacciarelli, 2001). In addition to the birth of major centers on defended plains, such as Cessaniti Cave and Briatico Vecchio (which will last until the Middle Bronze Age 3), the different geomorphological location of the other sites suggests an agricultural vocation for the Poro Plateau (Pacciarelli, 2001; Pacciarelli, 2017) and the development of maritime activity for the site of Grotticella, Capo Vaticano (Pacciarelli, 2001) and Punta di Zambrone (Pacciarelli, 2017).

In addition, during the recent excavations (2012-2013) carried out at the noted Iron Age I site of Torre Galli, a trench dated to the late phase of Early Bronze Age (Cessaniti facies) was found (Pacciarelli, 2017; Pacciarelli et al., 2017). Despite the preliminary data, it is possible to assume, in Torre Galli (Fig. 19), the presence of embryonic central place and/or a refuge place during periods of tension for small settlements recognized on the Poro Plateau (Pacciarelli, 2017).

During the Middle Bronze Age 1 and 2, various hilltop sites arose with the development of a territorial hierarchy and the formation of emerging classes as represented by the well-known burial of Gallo di Briatico. Therefore, between the Early Bronze Age and the first phases of the Middle Bronze Age, a network of major settlements began to form, located on plateaus normally extending from 5 to 15 ha, only exceptionally up to 20 ha. These settlements tended to become the centre of territorial districts in which there were also smaller centers, sometimes of limited duration. These major centers continue to occupy the same plains for several centuries, generally until the Final Bronze Age and often beyond (Pacciarelli, 2004).

In the Gallo di Briatico site, the presence of a Minoan seal in the funerary outfit indicates the preliminary relations of the territory with the Aegean (Pacciarelli, 2001).

During the Middle Bronze Age 3 many of these sites were abandoned with the exception of Tropea (Fig. 19), Briatico Vecchio (Fig. 19), Gallo di Briatico, Pirara and Punta di Zambrone (Pacciarelli, 2017; Russo Ermolli et al., 2018).

During the transition between the Middle Bronze Age 3 and the Recent Bronze Age, on the Tropea Promontory and in general in the rest of southern Calabria, the Thapsos-Milazzese villages were located in very well-defended places such as plateau with steep slopes, indicating a period of politic tension and danger. Almost all settlements were abandoned, and numerous new settlements of the Subapennine facies were implanted both on coastal and inland defended positions, as well as on the open landscape of the Poro Plateau (Pacciarelli, 2001; Jung et al., 2015). Concerning all these new Recent Bronze Age sites, Punta di Zambrone (Fig. 19) certainly represents the most important center of the Tropea Promontory due to the contacts with Aegean communities, although it is not yet possible to define its political value (Pacciarelli, 2017).

Also the territory of Crotone, with many sites along the coast, was very active in maritime exchange between the Middle and the Recent Bronze Age. A different trend seems to be registered in the Sibaritide, where there was a decrease of coastal sites during the Recent and Final Bronze Age and an increase of the hilly internal sites. It is possible to hypotysize the predilection of internal areas for a greater interest in pasture or in the cultivation of fruit trees (Bettelli et al., 2004).

Excavations carried out over the last twenty years in the Sibaritide have demonstrated the high complexity of the Middle and Late Bronze Age communities of Ionian Calabria. The most famous site is certainly the Final Bronze Age site of Broglio di Trebisacce with its large houses, some warehouses of dolia and a forge for the production of metal artefacts (Peroni and Vanzetti, 1998).

In the Final Bronze Age, due to a process of settlement contraction, only Tropea and Mesiano Vecchio survived in the Tropea Promontory. On the Poro Plateau, ceramic fragments of this period were found at the so called Crista di Zungri. A few archaeological data referable to the Final Bronze Age also come from Torre Galli (Pacciarelli, 2001; Pacciarelli, 2017).

In recent years, intensive research has provided information on the first Iron Age Calabria settlements, otherwise known only for necropolises. In this period, the sites are mainly distributed both on the northern (Broglio di Trebisacce, Cirò, Crotone, Strongoli, ecc) and southern Ionian coast (Gerace, Ianchina, S. Onofrio) whereas not much information is available for the Tyrrhenian coast. The earliest archaeological discoveries on the Poro Plateau concern important Iron Age settlements, among which the well-known Torre Galli center (Cardosa, 2004; Pacciarelli, 2004; Russo Ermolli et al., 2018).

The villages of the first Iron Age are configured as economic, social and political autonomous units, able to provide for their own livelihood through the agricultural exploitation of the land located near the villages. Moreover, it is possible to hypothesize the particular attention to the defence of the territory and an evolved form of military organization, as testified by the extreme richness of the grave goods of Torre Galli and Torre Mordillo (Pacciarelli, 2004).

The necropolis of Torre Galli, excavated in 1922-1923 (Orsi, 1926) was referred to a settlement of several hundred of inhabitants (perhaps 400-600) that affected a small part of the plateau (20 ha), only occupied between the VII and VI centuries BC (Pacciarelli, 2004). Regarding the location of the site, despite the limitation from a tactical point of view, it is possible to hypothesize in the site of Torre Galli a strategic center founded around the 950-900 BC for territorial control (Pacciarelli, 2017). In fact, the site is placed in the central part of the promontory, in direct contact with the Poro Plateau fertile soils, and in a high position where is possible to see the surrounded territory and also the southern Tyrrhenian Sea (Pacciarelli 2017; Pacciarelli et al., 2017).

Recent archeological excavations (2012-2013), carried out in a settlement, highlighted a set of structures, mainly relative to a road, flanked on one side by a thick stone wall reinforced internally with wooden poles, and two defensive ditches, bordering the settlement area along its less naturally defended side. The first structure was dated between the Late Copper Age and the beginning of the Middle Bronze Age, the other to the Early Iron Age (Matarese, 2017; Pacciarelli et al., 2017).

In the VIII cent. BC, the decline of Torre Galli does not correspond to the development of other important centers (Pacciarelli, 2001, 2004, 2017; Cardosa, 2004; Matarese, 2017; Pacciarelli et al., 2017).

With the arrival of the Greeks in Calabria and in general in the Italian peninsula, the indigenous populations of the Iron Age (Enotri) remained subjugated by the competition between the Etruscans and Greeks on the dominion over the central Mediterranean, they failed to develop into large proto-city. The villages were abandoned, falling for five centuries under the political and cultural rule of the Greeks (Tinè and Vanzetti, 2014).

The foundation of the Greek colonies in Calabria is part of the wider phenomenon of Greek colonization of the West. A brief summary of the major Calabrian colonies is necessary to understand the economic importance of this territory for the Greeks.

Among the first Greek colonies, we remember those of Crotone and Sibari on the Ionian coast. These cities were both founded by the Achaeans at the end of the 8th cent. BC; in 510 BC Kroton destroyed Sibari and here the pan-Hellenic city of Thuri was founded[28]. According to the sources, the Chalcidese foundation of Rhegion (Reggio) took place in the 8th cent. BC, by the Chalcidans assisted by the inhabitants of the Sicilian colony of Zankle (Messina). Locri Epizephiri, on the Ionian coast, was founded by the Locrids of Greece in the 7th cent. BC (Mertens, 2006).

The Lamezia Plain was only later reached by the Greeks of the Ionian coast and especially by the Krotonians, for which the plain would represent the opening to new political and commercial frontiers (Spadea, 1990). Hipponion foundation is dated to the end of the 7th cent. BC by the inhabitants of Locri, searching for a Tyrrhenian landing place. The city was located in a strong defensive position, nearby an extensive flat area suitable for agriculture and in proximity to the sea; its harbor was located at the northern edge of Capo Vaticano promontory (Lena, 1989; Russo Ermolli et al., 2018).

Also Medma was founded in the 6th cent. BC by the inhabitants of Locri. With the foundation of Hipponion (Fig. 19) and Medma, the exploitation of the fertile Poro Plateau intensified and small coastal towns developed, such as Nicotera and Tropea, of which Diodoro Siculo (XXI 8) spoke.

[28] Before its destruction, Sybaris acquired an important political role and contrasted the increase power of the Spartan colony of Taranto, supporting the foundation of Metaponto colony (second half of 7th cent. BC) by the Achaeans (Mertens, 2006). Metaponto, Sybaris and Kroton in the 6th cent. BC destroyed the colony of Siris, located in Lucania, not far away from Metaponto and at the same place the Heraclea colony was founded by Taranto that was conquested by romans during the 3rd cent. BC (Mertens, 2006; Verger and Pace, 2017).

The problem of early Greek settlements in the Sant'Eufemia Plain has often been debated, especially regarding the precise location of Terina, a sub-colony of Kroton. The most recent studies agree in locating the Greek town in the area of Sant'Eufemia Vetere (Spadea, 1990, 2008; 2009). The Terina (Fig. 19) foundation is generally dated between the end of the 6th and first decades of the 5th cent. BC but there are not many archaeological evidence for this period. Neverthless, from literature and numismatic sources it possible to assume an intense development of this city during the 5th cent. BC, such as to influence the denomination of the whole gulf, called "Terinaios" (Russo Ermolli et al., 2018).

In the last years, in the Sant'Eufemia Plain area, several interesting discoveries of Classical and Hellenistic age (5th-3rd cent. BC) have been done, such as contrada Elemosina, contrada Terravecchia, contrada Bosco Ametello, contrada Celsito, contrada Acquafredda, locality Iardini di Renda and Moscarello. Furthermore, between 4th and 2nd cent. BC, the countryside around this urban center has widely been occupied by farms located mostly on terraces facing the sea, like Balsano and Zuppello farms (Spadea, 1990).

In particular, the arrival of indigenous Brettii people (middle 4th cent. BC) corresponds to the born of the urban area at Iardini di Renda characterized by buildings aligned along a regular road system (Spadea, 2008; Russo Ermolli et al., 2018). During this period, significant cultural and economic changes affected not only Terina, but also Hipponion (Vibo Valentia) to the south, and Nocera Terinese (Pian della Tirena) to the north (Russo Ermolli et al., 2018).

In the 3rd cent. BC, a decline period started with the Terina abandonment after the Second Punic War (Spadea, 2009). At this stage, the area is characterized by an intensely articulated system of farms and small scattered rural settlements, such as those of Lamezia (Palazzo, San Sidero and Zuppello) and Maida (Mancuso and Taliano Grasso, 1999).

Diffuse findings of Hellenistic Age impose us a brief reflection about Calabrian settlement models of this period. In the whole region, a series of fortified settlements with different functions are found. In particular, those on the Tyrrhenian seaboard delimit urban complexes located in favourable positions and developed on archaic indigenous settlements in control of more or less extensive areas occupied with a scattered type mode (Lombardo, 1989; Mollo, 2002; Russo Ermolli et al., 2018).

Nocera Terinese, north of Capo Sùvero, is a settlement of this type (Cicala, 2009, 2017; Russo Ermolli et al., 2018). Territorial studies have allowed to distinguish: real cities, structured centers, structured centers but urbanistically unorganized and ultimately other small settlements like scattered villages, farms concentrations functioning as aggregation point and individual farms, isolated but depending on a major center. In the hilly area behind the Lamezia Plain it worthes mentioning Crichi and Tiriolo sites, born on the enotrian ruins of Iron Age; they are placed along the road active in the Hellenistic age, and even in earlier times, including the isthmus between the rivers Lamato and Corace (Lombardo 1989; Mollo, 2002).

The gradual Romanization of the area can be dated at the beginning of the 3rd cent. BC and at the beginning of the 2nd cent. BC a change in the agrarian landscape organization happned with the foundation of the colonies of Valentia (Greek Hipponion) in the 192 BC and Tempsa (Nocera Terinese?) on the Tyrrhenian seaboard, and of Copiae and Kroton (Sangineto, 2013).

The distruction of Terina leaved all the Sant'Eufemia Plain without a major center, so the agrarian and territorial dynamics of the plain was linked to the Valentia expansion (Russo Ermolli et al., 2018).

When the deduction of Valentia colony and the construction of Via Annia Popilia occurred, there was a large increase of large villas (1st and 2nd cent. AD) on the Poro Plateau and on the coastal plain. Some of these villas showed an interesting overlap with pre-existing farms, as attested at Lamezia (S. Sidero and Zuppello), marking a different kind of agricultural production and distribution (Sangineto, 1994, 2013). This region offered great economic benefits from agriculture, thanks to its favorable position. In fact, the Isthmus S. Eufemia-Squillace was very important for commercial activities and, in general, for any type of interaction between Ionian and Tyrrhenian coasts. Furthermore, the shortest path and low isthmus of Calabria, frequently cited by ancient sources (Aristotele, Strabone, Plinio), faces a pass of only 260 m a.s.l (Givigliano, 1978).

The Valentia harbor became a strategic base for Caesar legionaries and an obligatory stopover on shipping routes to Sicily (Cucarzi et al., 1995).

The villas system gradually declines from the 2nd cent. AD but shows a significant recovery between the 3rd and 4th cent. AD. Properties tend to expand, absorbing smaller structures in large latifundia, with a transition, according to the archaeological literature, from specialized crops to extensively monocultures (Sangineto, 1994; Russo Ermolli et al., 2018). For this period very important is the Acconia villa with baths, dated to the 3rd-4th cent. AD (Mancuso and Taliano Grasso, 1999).

At the end of the 6th cent. AD, when the Roman unity broke up, Calabria was divided into two parts: the central-southern part subject to Byzantium and the other to the Lombards dependent on the Duchy of Spoleto.

Between the Late Antique and the Early Middle Ages, there was an increase in the ruralisation of the territory with the birth of the Pontifical Masses of Sila, Nicotera and Tropea. The papal influence has certainly guaranteed a privileged development of this territory, in fact these two centers (Tropea and Nicotera) also became important port centers eclipsing progressively the ancient Roman port of Valentia (Sogliani, 2012).

The Lombard dominion did not directly concern the Lametino but had a negative influence on the exploitation of its mountain landscape. In fact, timber from the Massa Silana and the mountains Mancuso and Reventino, by concession of the Lombard rulers, was used by the Pope for the Patrimonium Sancti Petri[29].

In the Byzantine period, rural villages (Xorìa) spread, revolving around fortified sites (Kastra) such as Piano della Tirena, in the countryside of Nocera Terinese. Here, according to Paolo Orsi, a small settlement surrounded by walls would have arisen, probably until the 10th cent. AD. A similar fortified settlement, surrounded by walls, then used and strengthened in Norman and Swabian times, would have been built on Mount Tiriolo to control the Lametino-Catanzarese isthmus (La Serra, 2014).

To this occupation model of the territory, attested in the areas immediately north and south of the Poro Plateau (Petrace and Angitola valleys), are associated the rock settlements, particularly widespread in the south, and that on the Poro, have found wide space and continuous use in time until sub contemporary times, such as in the town of Zungri[30] (Di Muro, 2011).

With regard to the christianization of the territory, few and not systematic are the archaeological discoveries in the territory (Palaechristian cemeteries between Ricardi and Tropea).

At the beginning of the 8th cent. AD the interference of Constantinopoli begins with a measure of Leone III Isaurus that obliges the transfer of ecclesiastical property of southern Italy to the imperial tax and the subordination of churches to the Patriarchate of Constantinopoli (Sogliani, 2012). With the spread of Greek orthodoxy through eastern monasticism, there was the birth of important Italo-Greek monastic centers (S. Angelo di Tropea, the monastery of Moladi in Rombiolo and that of Briatico). Moreover, with the Byzantine domination this territory assumed military and defensive characteristics, which,

[29] Gregorio Magno (Registrum Epistularum) in 599 AD wrote about the trade of timber from Valentia to Rome for the construction of San Pietro (Sogliani, 2012).

[30] The farmhouse of the Sbariati di Zungri was mentioned for the first time in the Rationes decimarum of 1310. The village is located on the Poro Plateau and the archaeological evidence testifies to the presence of an agricultural community (Di Muro, 2011).

after the brief interlude of the Arab Emirate of Tropea, increased with the advent of the Normans in the second half of the 11th cent. AD[31].

Around the monastery named after S. Eufemia[32], arose the inhabited pseudonym as it happened in many other places in Calabria.

The medieval settlement of Vibo Valentia is attested from the 10th cent. AD, but the history of the diocese in the 11th cent. AD was ended, with the transfer of the Episcopal seat in Mileto, following the choice of the new Norman invaders to use this city as the residential seat of the comitology power (Sogliani, 2012). In fact, during this period numerous monastic properties were confiscated in favor of the Abbey of the Trinity of Miletus. (http://www.lameziastorica.it/nicastro-sambiase.html#).

With the Swabian dominion of Frederico II (second quarter of 13th cent. AD), Vibo Valentia increased in importance and began to regain all the potential of urban center that had in the past. The Swabian emperor built an imposing castle in masonry, took care of providing land to work to the inhabitants, and appointed a new guardian of the port to control the safety and efficiency. The city, now called Monteleone, will continue to grow even in the Angevin age (Sogliani, 2012).

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[31] Goffredo Malaterra, biographer of the Norman king Ruggero, in his chronicle until the end of the 12th cent. AD, referring to the civitates and very strong castra of Calabria, reports the now Latinized names of castella, castra (Ayellum and Marturanum in the Savuto valley, Catanzarium, Mayda, Skillacium and Neocastrum in the Islamic area), urbes (Cusentia, Geracium, Regium, Russanum), casalia. Castrum designates the fortified village, castellum the light fortress founded from scratch during a siege or a fortified building intended to house a commander or a feudatory. In the brebion (i.e. register, catalogue, inventory of goods) of the metropolitan area of Reggio, dated to the middle of the 11th cent. AD, the monasteries of S. Eufemia, S. Costantino and Santi Quaranta are also listed in the Nicastro area.

[32]Saint Eufemia was a virgin and martyr of Chalcedon (Bithynia), killed on 16 September of the year 303 during the Christians persecution carried out by the Diocletian emperor (285-312 AD).

4.3. Flora and vegetation

Flora represents the complex of plant species, spontaneous or made wild that live in a given territory. The floristic list within a territory is organised using a systematic list, arranged by genera, families, orders and classes. Each species is analysed with qualitative methods to describe it as completely as possible.

As far as Italy is concerned, there are many floristic lists dating back to the last cent., including: Flora Napolitana by M. Tenore (1811-38); Flora italica by A. Bertoloni (1833-54); Flora italiana by F. Parlatore (begun in 1848 and left incomplete); Flora analitica d'Italia (2 vol, 1896-1908 and 1 vol. of Iconographia florae italicae, 1906, with over 4400 figures) by A. Fiori, and those of G. Zangheri (Flora italica, 2 vol., 1976) and S. Pignatti (Flora d'Italia, 3 vol., 1982). Moreover, the study of a territory's vegetation, takes place through an integrated qualitative and quantitative analysis. The floristic lists of a territory are therefore enriched with the quantity of each species present in the investigation area (Pignatti, 1995). Through this type of analysis, it is possible to observe that certain aspects of vegetation are regularly repeated in certain geographical areas, thus defining the types of vegetation (Pignatti, 1995).

Various types of vegetation can be divided into various hierarchical levels linked to the association concept. This concept was developed at the beginning of the last cent. by the Swiss botanist Braun Blanquest, the father of phytosociology. Through phytosociology it is possible to use plant communities as indicators of the environment. Therefore, the plant association represents a more or less stable grouping in balance with the environment, in which the possible presence of exclusive elements reveals a determinate ecology.

The Mediterranean basin is one of the main centers of biodiversity on Earth. This region contains the 10% of the world's top plants in an area that represents only 1.6% of the earth's surface (Médail and Quézel, 1997). It is characterized by a heterogeneous landscape, and the evolution of plant biodiversity has been strongly influenced by geological history, climate change and the impact of human activities (Romano, 2013). The current distribution of vegetation in the Mediterranean regions tends to be arranged according to altitudinal (as we will see below) and latitudinal bands in relation to temperature and precipitation gradients, but vegetation distribution may also depend on other factors including (Magri, 2012):

- Location of the so-called glacial refuge areas[33].

[33] Refuge areas are those areas in which the forest vegetation has been able to persist during the driest phases of the last Ice Age and from which it has radiated into the post-glacial period (Magri, 2012).

- Orography: some particular orographic situations can be very favourable for some plant species, so much so as to buffer their responses to climatic stress, and thus obliterate the climatic signal in the observation of fossil data.
- Human populations: human presence has led to many changes in the plant landscape, through deforestation, cultivation, pastoralism and fires, which contribute to complicate the distribution of species and their response to natural factors.
- Hydrography: the distribution of water resources in the different Mediterranean regions determines a great variability in the composition and density of forest vegetation and especially in the responses of vegetation to climate change[34].

Paleobotanical reconstructions show strong regional differences in the distribution of vegetation and different responses to Holocene climatic variations (see chapter 1.2.).

Ozenda, 1975		**Giacomini, 1958**		**Pignatti, 1979**		**La Valva et al., 1985**	**Ozenda, 1975**	
Haute Provence		Lucanian Appennine		Campania		Campania	Great Moroccan Atlas	
Altimedite-rranean	upper	Top level		Mediterranean of high mountain		High altitude pasture	Altimedite-rranean	upper
	lower							lower
1700 m		2000 m		1800 m		1800 m	2600 m	
Oro-mediterranean (Mediterranean Mountain-2002)		Mountain level	upper Mountain lower	upper	Atlantique	Beechwood	Oro-mediterranean	
				lower				
900 m			1800 m	1000 m		1000 m	1800 m	
Super-mediterranean			Sub-mediterranean	Sub-mountain	Samnite	Mixed forest	Super-mediterranean	
				Sub-mediterranean				
300 m		1000 m		500 m		500 m	1200 m	
Meso-mediterranean (Mediomediterranean – 2002)		Basal level	Mediterranean	Medite-rranean	Medite-rranean	Mediterranean vegetation	Meso-mediterranean	
				coastline			Thermo-mediterranean	

Tab. 6 - Altitudinal distribution of vegetation belts according to different authors

Despite the great regional variability of the vegetational responses to climatic variations, it is possible to recognize various trends involving a large part of the Mediterranean basin. For example, during the Holocene, there has been a general transformation in forest vegetation

[34] In some regions with abundant water availability, no significant vegetation changes occurred, except since Protohistory, probably due to human impact (e.g., Drescher-Schneider et al., 2007; Magri, 2012). On the contrary, in areas where there have been limiting climatic conditions for forest plants, there have been substantial changes in the composition and structure of the Holocene vegetation (Carrión et al., 2007).

where deciduous forest has been replaced by evergreen forests. In addition, over the last thousands of years deforestation has been widespread (Magri, 2012).

The academic debate on forest transformation is still ongoing and sees two opposing fronts. Some believe that the increase in sclerophyll vegetation can be considered an anthropic impact effect, through, for example, the continuous practices of fire (Pons and Quézel, 1998). Others argue that natural causes or the progressive climate Mediterraneanisation (Jalut et al, 2000)[35] caused these changes. Even in the Italian peninsula, where climatic gradients are less regular, a marked increase in evergreen elements is recorded in several pollen sequences during the last thousands of years (cf. Jahns, 1993; Di Rita and Magri, 2009; Magri, 2012).

Of all the contries in the Mediterannean, Italy has the richest flora with 5,599 species (Pignatti, 1982), classifiable as native (i.e. spontaneous and introduced by man but unincreased). To these can be added at least another 500 which have been commonly cultivated or represent sub-spontaneous species (Romano, 2013). The high diversity of the Italian plant landscape is due to its geographical position and its geology and morphology, and to considerable differences in types of microclimate. In Italy climax[36] forest prevails, i.e. the environmental conditions are such that, in the absence of human intervention, forest development is in balance with the environment and is also able to maintain itself. In the mountain ranges at altitudes above 1800-2000 m, there is a change in vegetation. Here herbaceous flora dominates in high altitude prairies (Pedrotti, 1995). More specifically, the southern Italian Tyrrhenian side can be divided into two climate zones with different types of vegetation, i.e. the internal area of the Apennine mountains and the coastal strip. The coast covers a very large territory where, despite the differences in latitude, there is relative homogeneity in the characteristics of the landscape (Pedrotti, 1995)[37].

The altimetric distribution of plant associations has been the topic of important works carried out in the last cent. (Tab. 6), at a number of places including Campania of La Valva (1985), Pignatti (1979), the southern Apennines (Giacomini, 1958) and more generally, on the mountains of the Mediterranean (Ozenda, 1975).

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[35] This interpretation is supported by climatic proxies independent of paleovegetational proxies (e.g. lake levels: Roberts et al., 2008), which recognize in the Mediterranean basin a first part of the Holocene characterized by conditions of general climate humidity and a second part that tends to be arid.

[36] Final stage of vegetation development in a given environment and which remains stable unless environmental factors change (La Valva, 1985).

[37] Throughout this area, the climate is always maritime and Mediterranean type with annual rainfall between 500 and 700 mm, but from north to south there is a certain increase in average temperatures in the period of summer dryness that also affects the vegetation (Pignatti, 1995).

Altimetric data, which is in most cases valid for the area of our interest, can also be used a subdivision of physiognomic type:

- Mediterranean forest
- Deciduous forest
- Floodplain forest
- High Mountain forest
- Coniferous forest
- Herbaceous and aquatic/marsh species

4.3.1. *Mediterranean Forest*

The Mediterranean or evergreen forest is usually found at low altitudes (0-500 m, sensu LaValva, 1985) and is characterized by the holm oak forest (*Quecus ilicis*), at least for the wettest parts of the Mediterranean basin and the Italian coasts. In Italy, holm oak is found in deciduous oak wood formations as a subordinate plant. It is also found in rocky habitats and in Calabria it is currently found up to an altitude of 1100 m (Pignatti, 1982).

The holm oak forest is an evergreen forest characterised by tall trees (*Quercus ilex, Phyllirea latifolia, Arbutus undeo*) and poor understory floral diversity. This is because the very dense evergreen foliage keeps the understory environment in constant darkness. Consequently, the scarcity of light only allows shade tolerant species to grow and thrive.

The vegetation of the "Lecceta" (Holm oak) may become richer in floral diversity following episodes of natural or anthropogenic disturbance. For example, where natural or anthropogenic fires occur, the effected evergreen forest may be replaced by pyrofilious vegetation types (Pignatti, 1995). Additionally, near settlements and in environments where organic matter has accumulated, soils may be rich in nitrates. These nitrate rich soils can, in turn, encourage the development of nitrophilous herbs, such as *Urtica*, *Atriplex*, Chenopodiaceae, *Silene*, *Crepis*, *Taxacum*, etc. (Pignatti, 1995).

A further degradation of the holm oak forest by fire and/or grazing leads to the garrigue, a low scrub with a rich flora, composed of small shrub species (cysts, heather, rosemary) alternating with short grasslands, often with an area of a few square meters (Pignatti, 1995). The food plants of the evergreen forest are very few (olive, strawberry tree), unlike the flora of the garrigue which has many species (grasses, legumes, aromatic plants, etc.).

The Mediterranean forest can be divided into (Quézel and Médail, 2003):

- Thermophilic forest, extremely diversified from the structural point of view, formed for example by European *Olea*, *Ceratonia siliqua*, *Pistacia lentiscus*, etc.. it should be noted that the wild olive is a shrubby tree that can grow in various types of vegetation (formations) in the series of climatic and vegetational zones differentiated by altitude and consequently temperature. It is therefore rare in the upper Mesomediterranean zone (above 500 m).

- Oak sempervirent which has a considerable ecological breadth and is composed essentially of *Quercus ilex*, *Quercus suber* (western Mediterranean) and *Quercus coccifera* subsp. *calliprinos* (eastern Mediterranean).
- Laurifoliae forest (*Laurus*, *Ilex*) very marginal in the Mediterranean region and found in wet and per-humid bioclimates.
- Sclerophyllous forest, with common characteristics to the evergreen forest, so it was therefore decided to include it as its subgroup. The expansion of this forest is lagged to the joint action of climate and man. The characteristic species of this forest are *Q. ilex* sensu lato and *Q. suber* (mainly Western Mediterranean), and *Q. coccifera* subsp. *calliprinos* (Eastern Mediterranean). This forest generally develops at the mesomediterranean level, infiltrating the thermomediterranean when the ecological conditions are favourable.

4.3.2. ***Deciduous forest***

Deciduous or caducifolious forest is well represented in the Mediterranean region and is mainly found in the most irrigated areas and at medium altitudes (500-1000 m sensu La Valva, 1985). It can be divided into:

- Deciduous Mediterranean forest, which is mostly represented by the genus *Quercus*[38] and *Pistacia atlantica* (southern Mediterranean and Near East).
- Sub-Mediterranean deciduous forest located on the northern side of the basin, characterised in particular by *Quercus pubescens*, *Q. frainetto*, *Q. trojana*, *Q. petrea*, *Ostrya carpinifolia*, *Carpinus orientalis* and *Fraxinus ornus*, while beech may also appear locally[39].

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[38] *Q. fagina* sensu lato in North Africa and the Iberian Peninsula; *Q. infectoria* sensu lato, but also *Q. cerris* subsp. *pseudi-cerris*, *Q. ithaburensis* in the eastern Mediterranean and southern Italy (Quézel and Médail, 2003).

[39] A particular case is the formation of deciduous trees in the summer drought period, located on the sub-desert margins of the sub-Mediterranean region, with in particular various types of *Acacia*.

4.3.3. *Floodplain forest*

Floodplain forests occupy the lower areas of a river catchments. Their boundaries correspond with the areas periodically disturbed by river flooding, so their natural history is closely linked to the dynamic physical processes that take place in their adjacent river channels. The early successional species of many floodplain forests are members of the Salicaceae family, including the *Populus* and *Salix* genera. These species are well adapted to live in the highly physically disturbed environment of a floodplain (Hughes et al., 2012).

This type of forest, currently disappeared from our territory following the reclamations made by the Bourbons and the progressive anthropization, which was present above all in the coastal alluvial plains and was the natural habitat of different species, such as the alder (*Alnus*), hazel (*Corylus avellana*), hornbeam (*Carpinus*, *Ostrya*), elm (*Ulmus*), various deciduous oak species, walnut (*Juglans*) and *Vitis*. The latter two species were first used by human and then domesticated (Russo Ermolli, 2018 and references therein). With regard to *Vitis*, the only European species is *Vitis vinifera*, which includes two different subspecies, the domestic vine and the wild vine. Nowadays, the disappearance of all the alluvial plains where the vine developed naturally, has led to the constant regression of the wild vine throughout Europe. Even in Italy today, wild vine can be found almost exclusively in gorge environments ranging from central Italy to Sicily (Di Pasquale and Russo Ermolli, 2010). Considering the heterogeneity of lowland forests and their continuous diachronic evolution, establishing a precise vegetational association is complex. A recent study has shown that temperatures are also the basis of different plant associations (Douda et al., 2016)[40]. However, the division carried out by the European Commission (2007), that divided the European alluvial forest habitats in five groups, is reported here:

- Alluvial forests (Boreal, Alpine and temperate Europe): The dominant trees include *Alnus glutinosa*, *A. incana* (in sub-montane and montane situations), *Fraxinus excelsior*, *Populus nigra*, *Salix alba*, *S. fragilis*, *Betula pubescens* and *Ulmus glabra*. The herbaceous layer is often dominated by tall herbs such as *Filipendula ulmaria*,

[40] A recent work (Douda et al., 2016) demonstred that climate is one of the most important factors correlated with species composition patterns of European floodplain forests and alder carrs. Nemoral communities included in the alliance *Alnion incanae* occurred mainly at 7 °C temperature; the Mediterranean floodplain forests of the alliances *Osmundo-Alnion, Populion albae* and *Platanion orientalis* were characterized by a mean annual temperature higher than 11 °C; while boreal and mountain communities dominated by *Alnus incana* (i.e. the *Alnetum incanae and Pruno-Alnetum incanae*) occurred at mean annual temperature of 3.2 °C).

Angelica sylvestris, Rumex sanguineus, Cirsium oleraceum and *Carex* species, with *Cardamine* species being also important.

- Riparian mixed forests (temperate Europe): *Quercus robur*, *Ulmus laevis* and *U. minor, Fraxinus excelsior* or *F. angustifolia* along the great rivers.
- White willow & white poplar galleries (Mediterranean Europe): Riparian forests of the Mediterranean zone dominated by tall willows (*Salix alba, S. fragilis*) and poplars (*Populus alba, P. caspica, P. euphratica*). Nowadays it is present in France, Greece, Italy, Portugal, Spain.
- Riparian formations on intermittent water courses (Mediterranean Europe): Relict alder galleries (thermo- and meso-Mediterranean zones) with *Alnus glutinosa, A. cordata, Betula* sp., *Fraxinus angustifolia, Osmunda regalis*. Nowadays it is present in France, Italy, Spain, Portugal.
- Plane and sweet-gum woods (Mediterranean Europe): Riparian forests and woods dominated by *Platanus orientalis* and *Liquidambar orientalis*; presence of *Salix alba, Alnus glutinosa, Celtis australis, Populus alba, Fraxinus ornus, Cercis siliquastrum*. Nowadays it is present in Greece and Sicily.

4.3.4. *High Mountain forest*

In this study area, the high mountain arboreal vegetation loses its heterogeneity and is represented exclusively by beech forests. In particular, *Fagus sylvatica* L., which is currently the only species found in Italy. In the southern Apennines it is present between 1000 and 1700 m (Pignatti, 1982; La Valva, 1985). On the southern Apennines, La Valva (1985) distinguishes two types of beech woods based on altitude: a lower one, from a limit varying between 800 and 1000 m, fades from 1500 m into the upper one and stops where the beech woods give way to the summit prairies.

Beech, in some cases sporadic, is associated with silver fir (*Abies alba*). In fact, in the southern Apennines, silver fir plays a dominant role in some forest formations. However, silver fir dominated forests are often relictual, of limited size and very localised. Previously, in some Apennine silver fir populations, a distinct variety has been identified which differs both ecologically and morphologically from the Alpine variety. This distinct Apennine variety has recently been recognized as a separate subspecies: *Abies alba* subsp. apennina (Brullo et al. 2001). In southern Italy, silver fir forests are currently present in Calabria.

Some authors argue that southern Italy, and in particular Calabria, represents an isolated area of silver fir (Larsen, 1986; 1989; Bergmann et al., 1990; Konnert and Bergmann, 1995).

Specifically, Konnert and Bergmann (1995) and Terhürne-Berson et al. (2004) assume that southern Italy sheltered distinct gene pools which differed from those identified in central French or northern Italian populations. This Glacial refuge area might have allowed the spread of autochthonous *Abies* population.

Research shows that the South of Italy represents the extreme southern distribution limit for many species with a wide European diffusion, such as *Fagus sylvatica* L., *Quercus petraea* and *Abies alba*. It is believed that during the Lateglacial the southern regions became "refuge areas", from which these species have then spread again in the rest of Europe (Romano, 2013). Some palaeobotanical findings (pollen and macroremains) identify South Italy as the refuge for *Abies alba* and suggest that it is from here that this species spread across Europe after the Lateglacial period (Terhürne-Berson et al., 2004). However, the debate is still open. Regarding *Fagus sylvatica* L. there are conflicting opinions in the scientific community. Magri (1998) debates the theory of large scale migrational trends from southern and central Italy, because the presence of beech during the earliest Lateglacial at Cànolo Nuovo (Schneider, 1985), Lago Grande di Monticchio (Watts et al., 1996a, b; Allen et al., 2000; de Beaulieu et al., 2017) and Lagaccione (Magri, 1998) indicates that its populations may have survived during the last glacial period at different locations in the peninsula. Moreover, *Fagus* may have spread earlier on the foothills of the Alps than on the northern Apennines.

4.3.5. *Coniferous forest*

Different coniferous species are present in different altimetric bands. The various altimetric bands and the coniferous vegetation in each band is discussed below (sensu Quézel and Médail, 2003):

- Lower zone: where the dominant is the *Pinus halepensis* currently present throughout Italy[41] (Pignatti, 1982), and *Pinus brutia* present in Calabria (Pignatti, 1982). Other local species of some importance are *Pinus pinaster*, *Pinus pinea* or *Cupressus sempervirens*.
- Middle zone: where there are the previous types with the development of *Pinus nigra* (currently also present in Campania) in its many local variants and *Pinus sylvestris* (northern Mediterranean);
- High mountain area: composed essentially of juniper trees such as *Juniperus thurifera* and mainly *Juniperus excelsa* (only in the mountains of the Atlas, Taurus

[41] Western and central Mediterranean and Israel (Quézel and Médail, 2003).

and Lebanon). The high mountain areas also include the fir tree referred to in the previous paragraph.

4.3.6. *Herbaceous and aquatic/marsh taxa*

In the hilly areas (Mediterranean strip), currently subject to agricultural practices, the native tree species are greatly reduced. These hills are dominated by grasslands where grasses, asteraceae and annual legumes prevail. In the so-called Samnite belt (sensu La Valva, 1985), natural herbaceous formations are more frequent because these altimetric zones are less affected by agricultural practices. These herbaceous formations are populations that can be classified in the order of Brometalia because currently there is the constant presence of *Bromus erectus*, a grass with a very wide distribution. In the herbaceous layers of beech woods, *Galium odoratum*, *Sanicula europea*, *Cyclamen hederifolium*, *Ranunculus lanuginousus* subsp. *umbrosus* (La Valva, 1985) dominate.

Marshy and lacustrine aquatic vegetation is composed predominantly of Cyperaceae, *Typha* and *Myriophyllum* whose distribution is limited to the shores of lakes and lagoons. These plants can therefore be found in more or less stable environments such as large lakes, but also in environments that are not very stable and in continuous evolution, such as on the banks of small marshes and lagoons. Their constant presence in pollen sequences is linked to the nature of the matter analysed, which essentially comes from this type of environment, as we shall see below.

5. CASE STUDIES FROM CAMPANIA

5.1. Gulf of Salerno

5.1.1. *"C 106": core stratigraphy*

The C106 gravity core (14°42'24''E-40°28'52''N), 6.17m long, was collected 20.5 km away from the mouth of the Sele River and 4.5 km from the shelf break at 292 m depth. The preliminary results of the core analysis were published in Buccheri et al. (2002) where samples were collected for sedimentological (grain size and total calcium carbonate content), chemical (oxygen and carbon isotope, radiometric dating) and palaeontological (calcareous nannoplankton, planktonic foraminifera, pteropods and pollen) analyses. More detailed palynological analysis were carried out by Russo Ermolli and Di Pasquale (2002) whereas the first palaeoclimate reconstruction through MAT method on foraminifera and pollen data was published by Di Donato et al. (2008). Recent analysis carried out by prof. Petrosino have shown the presence of 11 tephra layers (unpublished data).

Previous investigations of the C106 core show significant changes linked to the main climatic fluctuations of the last 32 ka. In particular, C106 registers a sequence of environmental changes spanning from the Last Glacial period to the Present. The core succession was divided, from the bottom, into 9 units (Fig. 20) alternating between fine sediments and fallout deposits linked to Somma-Vesuvius and Phlegrean Fields eruptions (Buccheri et al., 2002):

- Unit 1: Grey sorted sandy-silt with shell fragments and fine sand lenses.
- Unit 2: Grey subronded pumice and ash. The lower boundary is an erosional contact.
- Unit 3: Grey moderately sorted silt and silty-clay with rounded pumices and shell fragments. The lower boundary is a sharp horizontal contact.
- Unit 4: Grey interbedded poorly sorted sandy-silt, poorly sorted silty-clay and moderately sorted silt, rich in shell fragments.
- Unit 5: Grey poorly sorted sandy-silt with shell fragments. Lower and upper boundaries are erosional contacts.
- Unit 6: Grey very poorly sorted sandy-silt grading to moderately sorted silt at the top, rich in shell fragments and black matter lens and pumices at the bottom.

- Unit 7: Black-grey moderately sorted silt at the bottom grading to very poorly sorted sandy-silt at c. 140 cm and moderately sorted silt at the top. The lower and upper boundaries are erosional contacts.
- Unit 8: Subronded light grey pumices at the bottom (110-88,5 cm), subronded grey pumices (88,5 – 61 cm) and black ash with light grey pumices at the top (61 – 55,5 cm). This is the deposit of Pompeii eruption (79 AD).
- Unit 9: Grey very poorly sorted sandy-silt at the bottom and poorly sorted silt at the top. Silt is mainly constitued by volcanic ash and sand by rounded millimetric pumices. The lower boundary is a sharp horizontal contact.

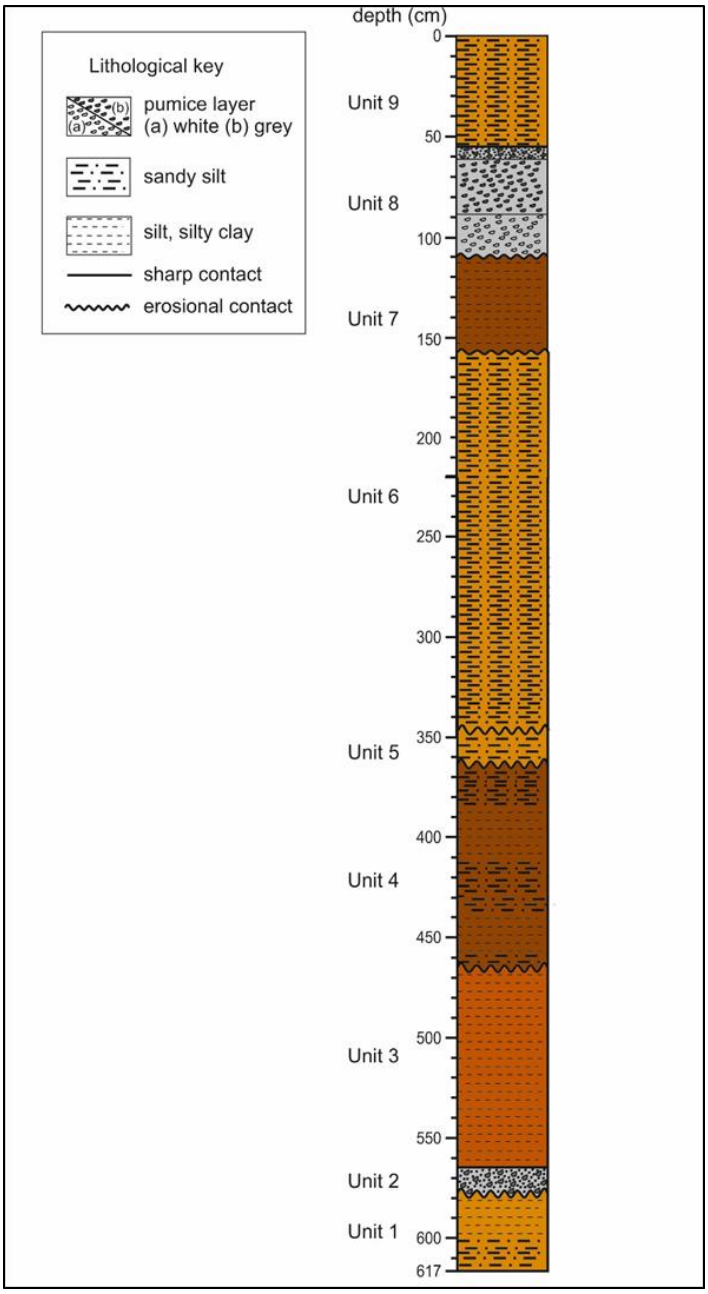

Fig.20 - C106 core log (Petrosino et al., 2019).

5.1.2. *Pollen diagram*

Pollen analysis was undertaken on 98 silty samples collected each 2 cm along the upper part of the core (0-250 cm), which chronologically corresponds to the Holocene period (Units 6-7-8-9). This study allowed obtaining a very high resolution record for the lat 8.000 years with respect to the one provided by Russo Ermolli and Di Pasquale (2002) where sampling pace for the Holocene was 10 cm. All analyzed samples resulted rich in pollen grains. Pollen sums range from 100 to 532 grains; 88 taxa were recognized; concentration values range from 430 to 3100 grains/gram of sediment. Two main compositional pollen zones were identified in the detailed diagram on the basis of CCA (Pl. 1):

- Zone 1 (250 cm -126 cm): This zone is represented by 63 samples. In these layers, tree assemblage is mainly represented by dec. *Quercus*, *Quercus ilex*, *Abies* and *Pinus*. *Quercus ilex* is present in lower values in the deepest 20 cm (6%) but increases progressively up until 166 cm (15% with some peaks until c. 25%). Then there is a light decrease until 134 cm, with a low peak at 152 cm, then another increase until the end of the zone. Percentages for other mediterranean trees (*Olea*, *Phyllirea*, *Ligustrum*, *Pistacia*, *Cistus*, *Ziziphus*, *Neurada*) are very low (c. 1-2%). Ericaceae are abundant, particularly in the deepest part of the zone (between c. 250 and 240 cm). Regarding deciduous forest, dec. *Quercus* is the most representative taxa in Zone 1. Between 246 and 236 cm there is a slight reduction in percentages (the curve value goes down to c. 20%). However, an overall percentage increase is noted for the remainder of the zone (between c. 30% and 48%). *Carpinus* is also well represented. Fluctuating percentages are noted in the deepest part of the zone with slight peaks occuring at 246, 240, 230, 200 and 172 cm of depth. Increased percentages are noted between 156 and 136 cm of depth followed by a percentage decrease in the upper part of the zone. *Ostrya* which is commonly associated with the deciduous forest (although sometimes some species may also be part of the floodplain forest) is well represented between 250-226 cm. All other deciduous taxa are present throughout Zone 1 in low values.

  Concerning floodplain forest taxa, *Alnus* is represented by low percentages. Other floodplain forest taxa are present although values for these species are negligible (less of 1%).

  Pinus percentages are very high throughout Zone 1 but a slight progressive decrease is noted in the upper layers. Mountain forest is well represented by *Abies* and *Fagus*, while *Betula* is present in low values (less of 1%) in only a few samples. *Abies* shows a significant presence (20%) between 250 and 242 cm although percentages show a slight decrease throughout the rest of the zone. In this zone, it seems that the *Abies* curve has a similar trend to the *Pinus* curve. Contrarily *Fagus* values increase in the upper part of the zone.

Throughout Zone 1, arboreal pollen (AP) generally dominates with percentages ranging between 65% and 90%. However, at 288, 260 and 230 cm, AP percentages temporarily fall below 65%. Moreover, an omogeneous depression of the AP curve is noted midzone, highlighted by a negative peak at 180 cm.

Regarding herbaceous taxa, Cichoroideae family dominates the assemblages with values averaging c. 15 % and a peak (30%) at 232 cm. Asteroideae, Poaceae and Amaranthaceae are also present with fluctuating values until 10%. Scrofulariaceae are present, mostly in the bottom layers of Zone 1. Steppe taxa such as *Artemisia* and *Ephedra* are present throughout the zone but only in low percentages. Other herbs are present throughout Zone 1 in consistantly low amounts. Most interestingly, Cereal type pollen grains were recorded in six samples.

Marsh taxa are dominated by Cyperaceae, showing fluctuating values in all the zone never above 10%, while other marsh/acquatic plants are poorly represented. Monolete and Trilete spores are present overall the zone and seem to have the same trend with a progressive increase in the bottom part of the diagram (250-228 cm) and a progressive decrease until the end of the zone. Certainly, Trilete spores have higher values with respect to Monolete spores. Dinoflagellates are abundant mainly in the bottom part of the diagram (250-228 cm) with a peak of 40% at 236 cm, then register two progressive decreases with lower values achieved at 190 and 150 cm.

Coprophilous fungal spores are abundant all along the zone. Microcharcoals are present in high percentages in almost all the zone and show two peaks at 242 and 228 cm depth (over 90%) and a progressive decrease in the upper part of the zone (even if they are representaed always with high percetages).

- Zone 2 (124 cm – 0 cm): This zone is represented by 35 samples. The first elements of Mediterranean forest show significant variations. Initially, *Quercus ilex* percentages decrease progressively then stabilize in the upper part of the diagram at c. 10%. Contrarily, *Olea* percentages increase steadily from 28 cm reaching values of c. 10% in the top sample. In Zone 2, Ericaceae percentages are similar to those in Zone 1 and for Mediterranean taxa there was no significant changes from the previous zone.

Dec. *Quercus* exhibits an increase between 124 – 46 cm and a rapid decrease, reaching values of c. 20%, at the top of the core. *Carpinus* percentages show a steady decrease throughout the zone and ultimately disappears from the record in the uppermost sample, as does *Ostrya*. Other deciduous forest taxa are poorly represented. Regarding floodplain forest taxa, values are broadly the same as in the first zone. A temporary minor increase in *Juglans* is noted in the upper part of the zone. This rise corresponds with a minor increase in *Olea* values at 28 cm. However, *Juglans* disappears fom the record at 4 cm as *Olea* values increase significantly. *Pinus* percentages remain relatively stable thoughout Zone 2. *Abies* percentages fall steadily throughout the zone reaching c. 1% in the upper sample. *Fagus* percentages are lower than in the previous zone although this taxon retains a steady presence c. 5% across most of Zone 2 but only a few grains were recorded in the uppermost samples. Generally, total AP percentages show a rapid decrease between 26 cm and the top of the C106. Additionally, interesting AP fluctuations were noted below 26 cm. For example, at 42 cm AP values fall to c. 65%. Despite rapid changes in forest cover throughout Zone 2, AP curve values never fall below 50%.

There are no significant changes in herbaceous and marsh/water taxa from the previous zone. However, Asteroideae spp. and *Artemisia* show a steady increase from 30 cm to the top of the core. Monolete and coprophilous fungi spores values are consistent across Zone 2. Trilete spores register a peak at 28 cm and reach former values in the upper part of the core.

At the beginning of the Zone 2 there is a rapid decrease in microcharcoal values with values falling to c. 12% at 122 cm. However, from 38 cm upward an initial progressive increase in microcharcoal values occurs followed by significant increase toward the top of C106, with values reaching 90%.

Mediterranean forest	*Quercus ilex*, *Olea*, *Forsytia*, *Phillyrea*, *Ligustrum*, *Pistacia*, *Cistus*, *Ziziphus*, *Coriaria mirtifolia*, Ericaceae, *Tamarix*, *Neurada*	
Deciduous forest	deciduous *Quercus* spp, *Carpinus*, *Ostrya*, *Tilia*, *Acer*, *Ulmus*, *Ilex aquifolium*, *Fraxinus ornus*, *Hedera*, *Sambucus*, *Castanea*	
Floodplain forest	*Alnus*, *Corylus*, *Juglans*, *Populus*, *Fraxinus*, *Salix*, *Vitis*	
Pinus	*Pinus* spp	
Montane forest	*Abies*, *Fagus*, *Betula*	
Herbs	Poaceae, Amaranthaceae, *Centaurea*, Caryophyllaceae, *Paronychia*, Dipsacaceae, *Matthiola*, Scrofulariaceae, *Armeria*, Iridaceae, *Asphodelus*, *Limonium*, Convolvulaceae, *Convolvulus*, *Helianthemum*, *Polygonum*, *Calligonum*, *Geranium*, *Rhamnus*, Rosaceae, *Sanguisorba*, *Peplis portula*, *Hypecoum*, *Ribes*, *Saxifraga*, Plumbaginaceae, *Acanthus*, *Viburnum*, *Linum*, *Rhus*, Boraginaceae, *Ephedra*, Liliaceae	
Anthropogenic herbs	Cereals	Cultivation
	Rumex, *Plantago*, Urticaceae, Lamiaceae, Apiaceae, Brassicaceae, *Mercurialis*, *Artemisia*	Ruderal taxa
	Cichorioideae, Asteroideae, Ranunculaceae, Fabaceae	Grazing
Coprophilous fungi	mainly Coniochaetaceae/Xylariaceae – sp. HdV – 172 (Cugny, 2011)	
Marsh/Water plants	Cyperaceae, *Typha*, *Myriophyllum*	

Tab. 7 - Composition of taxa groups as plotted in the pollen diagram

5.1.3. *Chronological model*

The chronological model for the C106 core was built by means monotonic splines (Fritsch and Carlson, 1980). In the Tab. 8 has been show the 3 dates obtained with ^{14}C in the analyzed core interval (0-250 cm) and 11 tephra layers recognized. As shown in Fig. 21, the higher values of apparent sedimentation rates are recorded in concomitance to tephra deposition.

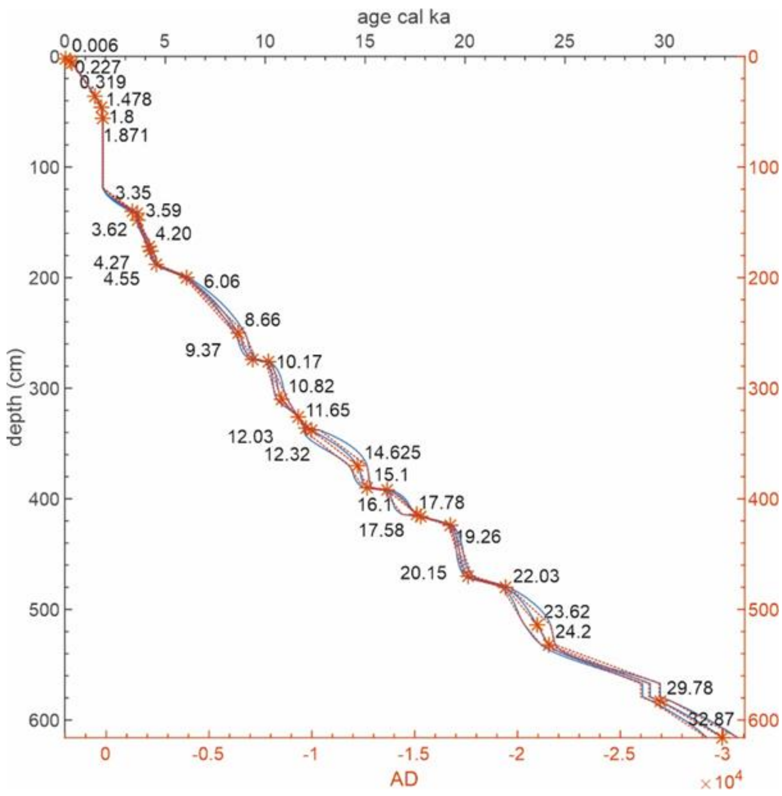

Fig. 21 - Age model for core C106 (Petrosino et al., 2019)

Event	cm	^{14}C	2sigma	Middle value	+2sigma
1944	2	0	0.006	0.006	0.006
1723	4	0	0.227	0.227	0.227
1631	6	0	0.319	0.319	0.319
472 AD	36	0	1.478	1.478	1.478
150 AD	46	0	1.8	1.8	1.8
79 AD	56	1.871	1.871	1.871	1.871
^{14}C	140	3.47	3.232	3.351	3.447
AP3	142	0	3.538	3.588	3.638
AP2	148	0	3.56	3.62	3.68
Astroni	172	0	4.098	4.197	4.297
Averno 2	176	0	4.153	4.269	4.386
Agnano montespina	188	0	4.482	4.553	4.625
^{14}C	200	5.66	5.944	6.064	6.175
^{14}C	250	8.16	8.458	8.656	8.96

Tab. 8 - Age of the recognized tephra layers and of the 14C dated samples - ages in cal ka BP (Petrosino et al., 2019

5.1.4. *Palaeoclimate reconstruction*

Paleoclimate reconstruction was performed using MAT on the C 106 core pollen data (Fig. 22). During the the Middle Holocene (8600 to c. 4500 BP), climate was characterized by relatively stable conditions whereas during the Late Holocene (c. 4500 BP – present) a new phase seems to occurr with a progressive slight increase of temperatures until the present-day. Therby, the climate signal for the Late Holocene is more complex and characterized by several fluctuations.

Between 8500 to 8300 cal BP a cold/wet phase is visible with a strong temperature decrease and high precipitation (TANN: 9°, PANN: 800 mm/yr). Then a warm phase with an increase of temperature and a slight decrease in PANN in noted. This phase reaches its apex at c. 7900 BP. A slight decrease in temperature is then recorded followed by two warm events, one at 6500 BP, which does not correspond to a substantial change in precipitation, and another at 6000 BP (TANN: c. 14°C; PANN: 600 mm/yr). The PANN curve also registers a rapid decrease at c. 7200 BP, but this decrease does not correspond with other significant changes. Starting from 6000 BP, a progressive decrease in temperature occurred which stabilises between 5600 and 5000 BP, while PANN seems to increase gradually until c. 4550 BP.

Later, a transition phase occurred with a warm/dry phase at c. 4100-4050 BP that divides two different climatic trends, a warm/wet phase from 4300 until 4.100 BP and a cold/wet phase from 4050 until 3700 BP. These changes appear clearer in SUMMERPR and MTCO curves.

Afterwards, an aridification process occurred until 2200 BP, well shown by a rapid decrease in SUMMERPR value (two negative peaks of c. 60 mm/yr at 2800 and 2200 BP), even if another cold/wet event occurred at 2600 BP that interrupted temporaly the aridification trend. Afterwards there is another transitional phase, marked by a cold event at 2000 BP followed by a cold/arid event at c. 1870 BP (in corrispondence of the AD 79 Pompeii eruption).

Then climate curves fluctuate but appear to register an aridification trend which lasts from c. 1100 BP until today. In this trend is possible to identify four cold/wet phases. These occur at c. 1600 BP, c. 1250 BP, between 900 and 700 BP, c. 550 BP and in the upper sample. Each of these cold-wet phases are characterised by an increase in SUMMERPR but the last phase also shows an increase in PANN.

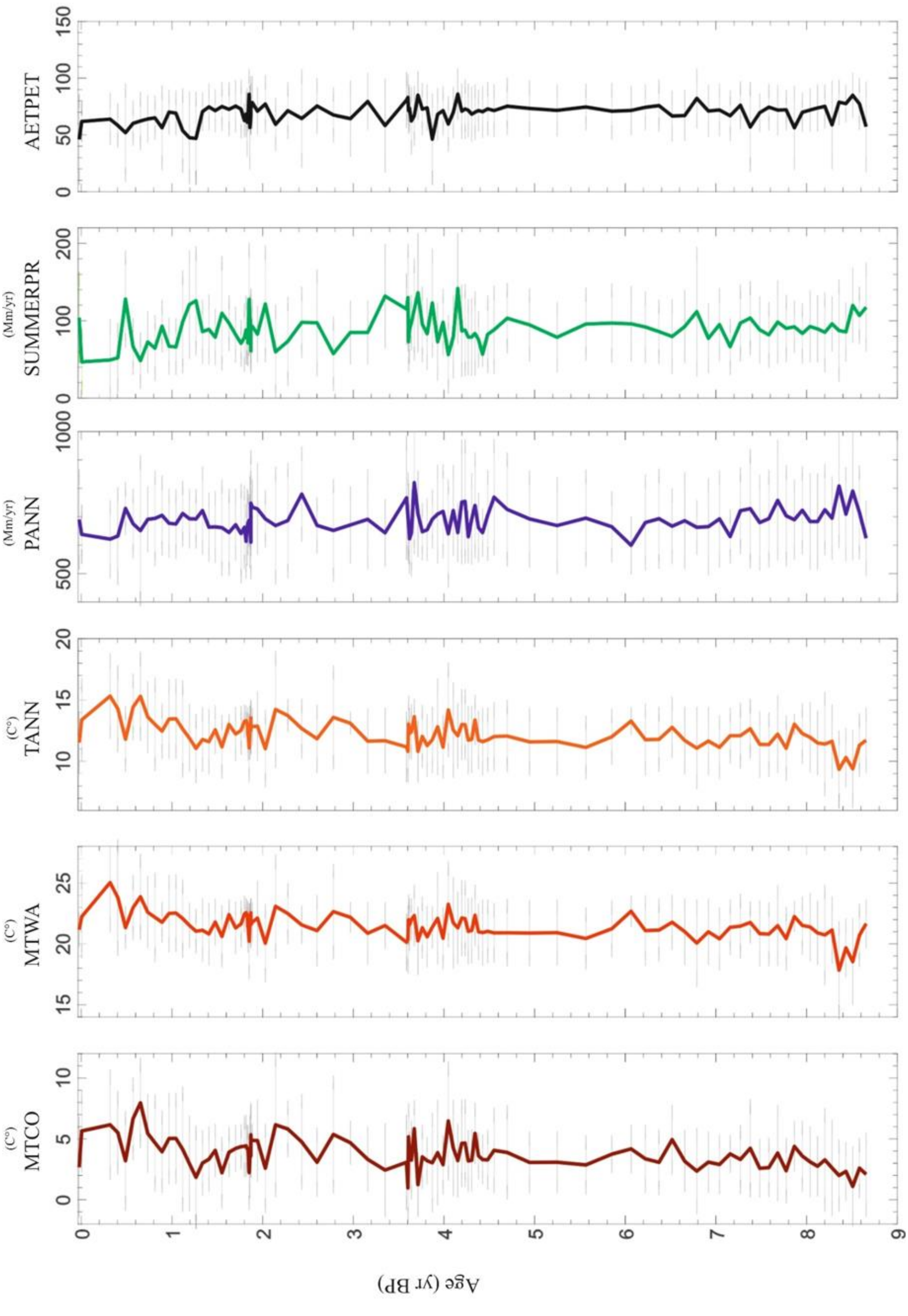

Fig. 22 – Pollen based climate reconstructions for C106 core

5.1.5. Discussion

A synthetic diagram (Fig. 23) based on the chronological model (see chapter 5.1.3.) and corresponding archaeological phases (left side of the diagram) has been constructed with the aim of better visualize the main vegetation changes of the last 8600 yrs. Most taxa are grouped into ecological associations, although some taxa with interesting trends are flanked outside their ecological groups.

Between 8600 BP and the beginning of Middle Neolithic, when the Campanian Plain was not occupied by humans, pollen data show that the forest cover had developed locally and extralocally, and that there was a humid climate.

Interesting is the lower AP percentage recorded between 8500 and 8300 BP, marked by the development of *Abies* and *Q. ilex* and the decrease of dec. *Quercus*. The climate curves for this period register a cold/wet event that, considering the absence of humans, may be linked to the 8.2 ka climatic event (even if there is a slight chronological difference due to chonological uncertainties). At 7900 BP, pollen diagram indicates a period of aridity marked by a general decrease in AP. Another arid period is noted in the pollen diagram at c. 7350 BP.

The occurrence of cereal pollen in very low percentages in a period where no human presence is recorded in the Sele Plain (testified by the lack of archaeological discoveries) is interesting. As mentioned in chapter 4.1.2.3. the Early Neolithic, characterized by the cultural aspects of Impressed Ceramics, is well attested in Campania but its distribution does not cover the whole region. Almost all evidence relating to this period is concentrated in central-northern inner Campania (Talamo and De Lorenzo, 2008; Talamo, 2013). Therefore, the presence of cereal pollen opens up interesting hypothesis on the possible presence of some form of human occupation in the Sele Plain during the Early Neolithic.

During the Early and Middle Eneolithic, a slight decrease in AP percentage is recorded. Even though this decrease is quite slight, the fact that there were many contemporary settlements associated with the Gaudo Culture (Middle Eneolithic) in the Sele Plain makes it conceivable to think that it was the result of human activity.

During the Late Eneolithic, forest cover continued to decrease even if the development of Laterza culture settlements are not very clear in the Sele Plain at the moment.

Between the end of Eneolithic and the Middle Bronze Age, AP percentages fluctuate with an unclear trend.

It is very important to highlight that in the time range between c. 4500 and c. 3500 BP, the occurrence of various tephra layers in the core (Tab. 7) have increased the apparent sedimentation rates. This resulted graphically in a sample crushing, so that some fluctuations, that with a depth scale would not seem significant, with the age scale appear intensified. Nevertheless, various cultural and environmental changes have been attested in this period and it is important to underline these events. Di Maio and Scala (2011) testify to the fact that a Tsunami arrived on the Salerno coast at least 300 years before the Pomici di Avellino eruption (during the transition phase between LE and EBA). In the same period climate curves (see chapter 5.1.4.) show fluctuations probably linked to the 4.2 BP Megadrought event.

Important sites, such as Oliva Torricella (Salerno) and Castelluccia (Battipaglia), testify to the occupation and settlement of the Sele Plain (see chapter 4.1.2.3.) during the Eneolithic and Early Bronze Age. In particular, the Early Bronze Age is characterized by the development of the Palma Campania Culture. Both archaeological and palaeobotanical evidence indicate that the Campania region was subject to intensive agricultural exploitation in this period. This is highlighted by archaeological traces of ploughing at various Campanian Plain sites (Saccoccio et al., 2013)[42] and by palaeobotanical remains, both pollen (Avella, San Paolo Belsito, Schiava, Visciano, Palma Campania – Albore Livadie, 1999; Vivent and Albore Livadie, 2001) and seeds (Nola – Croce del Papa - Costantini et al., 2002, 2007) attesting to extensive cultivation, mainly of cereals (*Triticum monococcum*, *Triticum dicoccum*, *Hordeum vulgare*)[43]. In the Salerno diagram, cereals occur along this period, supporting the above-mentioned evidence.

In the climate curves, the period around 4000 yr cal BP appears climatically complex: a warm/dry event is evidenced at c. 4100-4050 BP. This period separates a warm/wet phase (c. 4300-4100 BP) and a cold/wet phase (c. 4050-3700 BP). This precise tripartition of the 4.2 ka event is also recorded in other climate curves from the Mediterranean (Kaniewski et al., 2018; Bini et al., 2019). However, the 4.2 ka event is faintly recorded in the C106 core pollen record through a slight forest cover decrease associated with a slight development of steppe taxa at 4300 BP. After all, recent works (Magny et al., 2009; Zanchetta et al, 2013;

[42] The most important sites with ploughs traces are Gricignano - U.S. Navy support site, Afragola - T.A.V. V/17, Acerra - Spiniello, Ottaviano - Raggi, Palma Campania – Tirone or Valle, San Paolo Belsito - Montesano. In Gricignano territory an uninterrupted ploughed surface and field system of 60 ha is described, preserved directly below the Pomici di Avellino eruption. The agrarian features (banks, gullies, one cart track) show a remarkable regularity, hinting at patterned landscape exploitation (Saccoccio et al., 2013).

[43] Of these three species, seeds have been found and the imprints of the ears in the volcanic ash of the Pomici di Avellino eruption in the Croce del Papa – Nola village (Costantini et al., 2002).

Bini et al., 2019) debate about the confused expression of this event (1.2.). Di Rita et al. (2019) analyzed the AP curves of some Italian sites and shows that at certain latitudes (43°-39°) the 4.2 ka event did not lead to a decline in forest cover everywhere. For example, reduced forest cover is noted at Gulf of Gaeta, Lago Patria and Lake Trifoglietti, while at Lingua d'Oca-Interporto and Lake Accesa there was no substantial change. At Salerno, located at about 40° of latitude, the 4.2 ka event is not very clear, as suggested by Di Rita et al. (2019) for sites located at this latitude. Between the Eneolithic and the Bronze Ages, intense volcanic activity in Campania (both of the Somma - Vesuvius and the Phlegraean Fields) may have resulted in rapid environmental and climatic regressions alterating also the forest development.

During the Middle and the Recent Bronze Age, reduced AP values are noted but the confused nature of archeological findings from the Sele Plain for this period does not shed light on potential interpretations. Thereby, the presence of cereals in both the Middle and the Recent Bronze Age could indicate that cultivation practices continued in this area. Certainly, in other Campanian territories cultivation is attested for these periods. At the Middle Bronze Age settlement of Tufariello di Buccino, located in the Salerno inland, palaebotanical macroremains include *Triticum* sp. (Lacroix Phippen, 1975). Moreover, new pollen and carpological data from Nardantuono cave (Middle Bronze Age) suggests that agricultural products may have been stored in the cave (D'Auria et al., 2019 a, b)[44]. Even if very preliminary, this datum could confirm a link between the many cave sites and the coastal area. In fact, various Middle Bronze Age finds in the Sele Plain are distributed along valleys and streams connecting the hinterland with the coastal plain (Cinquantaquattro, 2009).

Between 3200 and 2200 BP, climate curves suggest an arid trend which is driven by reduction in deciduous forest and a slight development of *Q. ilex*, which reaches its apex at c. 2600 BP (beginning of 7th cent. BC). To the same period, the Greek colonization process and the foundation of Poseidonia city are dated, so the results of the paleoclimate reconstruction ust be taken with caution. Unfortunately microcharcoals, not showing a very clear trend, cannot help in this discussion although it is possible that intensive exploitation of woodland resources was taking place for the construction of the new city and the development of all economic processes linked to it. Palaeoclimate curves register a cold/wet event at 2600 BP. Independent climate estimates could help to confirm it, for example based on the use of molecular proxies such as BrGDGTs (Martin et al., in press). However, this

[44] Pollen data was carried out by the writer and the carpological analysis by Alessia D'Auria, PhD student at Agrarian Departement of Federico II University.

event is also attested at Lake Accesa where lake levels increases at c. 2800-2600 BP (Magny et al., 2007). At that level, the Salerno pollen diagram indicates an increase of sclerophyll vegetation (*Q. ilex*) which may be linked to a climate mediterranisation (Jalut et al., 2000) or to the impact of anthropogenic activity (Pons and Quézel, 1998). In my point of view, these changes are difficult to understand for the Salerno results because they occurred in concomitance to the Poseidonia foundation and the reorganization of the Pontecagnano city with a new rural planning, which dates to between the 6th and 5th cent. BC. Probably vegetation assemblage was more influenced by this new cultural event which probably masked the concurrent climatic event.

Even though the agricultural economic system of the Greek colonizators of Poseidonia is currenty not fully understood, it is conceivable to think that the territory was planned out to improve cultivation in the Sele Plain. Furthermore, archaelogical excavations of Heraion, at the Sele River mouth, indicate that drainage works were conducted in the Sele marshes through construction of channels and consolidated plans with the waste from sanctuary structures (Greco, 2003). Also Strabo talked about problems of swamping in the area around Paestum and geomorphological surveys confirm the occurrence of marsh conditions until the Classic period (2.5 ka BP), although during the Greek-Roman times (until 1.6 ka cal BP) some marshy depressions were reclaimed for agricultural purposes (Amato et al., 2013). The reduction of marshy areas is also testified by the reduction of floodplain tree taxa in the Salerno pollen diagram for the same period.

Therefore, it is possible to assume that reclamation works in the Sele coastal area date back to the Poseidonia foundation and may have been conducted for agricultural purposes. It may also be the case that the exploitation of forest resources (especially dec. *Quercus*) affected the floodplain trees, that likely surrounded the travertine bank where the ancient city grew. On the other hand, many species of *Quercus* can also grow in floodplain forests. In fact, in this area, *Quercus* has been found in association with *Alnus*, *Ostrya* and *Carpinus* in some pollen samples dating back to the Neolithic period (Amato et al., 2013). This type of vegetation association is today limited to high humidity environments linked to microclimatic conditions, as well as alluvial environments in Italy (Pedrotti and Gafta, 1996) and in temperate regions of central Europe (Polunin and Walters, 1987).

In the Roman period, an agrarian division system affected the Paestum north plain (about 3,000 hectares divided by strigas) between the 4th cent. BC and 79 AD (Gasparri, 1994). Moreover, around the 3rd cent. BC (Roman period), pollen data from the archaeological excavation of *Picentia*, suggest the beginning of *Juglans* cultivation (Amato et al., 2009;

Russo Ermolli et al., 2011). The *Picentia* pollen samples do not have a precise chronology but comparison with the Salerno results could help to date this event. In fact, from the Salerno diagram it is possible to see an increase in *Juglans* percentages between the 1st cent. BC and 1st cent. AD, up until the Pompei eruption (79 AD). This increase appears to be associated with a slight increase of *Olea,* the appearence of *Castanea* and the sporadic presence of cereals. *Olea* and *Juglans* seem then to disappear until the Late Ancient period when they both begin to increase again. *Olea*, *Juglans* and *Castanea* pollen have been observed since Pleistocene times in pollen diagrams. Their presence does not strictly mean that the survival of these trees was linked to crops but according to Mercuri et al. (2013) the presence of these taxa (OJC curve) in pollen diagrams indicates human activity, especially when their curves rise fairly suddenly in combination with consistent archaeological evidence. Therefore, in the Sele Plain, the appearance of two important Roman colonies (*Paestum*, *Salernum*) and the subsequent agrarian reorganisation suggests that the *Olea*, *Juglans* and *Castanea* curves may likely represent cultivation in this territory during the Roman period (1st cent. BC)[45]. Additionally, in the *Neapolis* harbor pollen diagram (Russo Ermolli et al., 2014) the cultivation of walnut is attested from the 1st BC to the 5th AD. In the Gulf of Gaeta (Di Rita et al., 2018a) and Lago d'Averno (Grüger and Thulin, 1998), walnut cultivation is attested since the 1st cent. AD. *Juglans* was also widely used in Campania since Roman times for both timber and food (Allevato et al., 2010; Russo Ermolli et al., 2014).

The temporary stop of walnut and olive increase after the Pompeii eruption (79 AD) could be linked to this catastrophic event which led to strong environment changes and probably to a reorganization of agricultural practices. A new development of tree crops could be dated at the end of the Roman Empire in Salerno. Unfortunately, the archaeological evidence from the Late Ancient period is limited and not well interpreted. However, we know that the rural picentine territory experienced a crisis after the 4th cent. AD (Amato et al., 2009 and references therein). In the territory around Paestum, despite difficulties with defining the Late Ancient population patterns, it seems that during the 4th cent. AD the production and export of raw materials continued (Santangelo, 2012) suggesting the retained of some economic vitality at that time.

Between the Roman period and the Late Ancient, the pollen diagram shows a fluctuating increase of deciduous forest whose causes are difficult to be determined. After this period,

[45] Chestnut pollen is often under-represented in pollen spectra, both in natural and archaeological contexts (Mercuri et al., 2013).

at the beginning of the Early Medieval period, a rapid decrease in forest cover is attested, testifying to deforestation process carried out by local population. Various but disarticulate archaeological data for the Early Medieval period, particularly the work of Di Muro (2005), could be used to improve our understanding on the development of Early Medieveal agricultural practices, mainly in the Norman-Swabian period. In particular, the author tries to reconstruct cultivation practices for this period through various literary sources. What emerges is a multi-crops landscape in the Battipaglia plain until Lombard period with vineyards, cereals, various fruit trees, chestnut, figs and olive with a progressive increase of olive cultivation in the Eboli territory until the 12th cent. AD. This interest in olive crops increased in the 13th cent. AD, as testified by a series of interesting contracts through which the Abbey of Cava and the Monastery of Montevergine directed the planting of olive groves in the Ebolitan hills. These data seem to confirm the progressive increase of Olea attested in the Salerno diagram precisely in this period and until the modern age.

Another interesting aspect of the Salerno diagram concerns the progressive decrease in *Abies* which also occurs in others italian contexts. *Abies alba* dominated the montane forest assemblages of southern Apennines all along the Middle Pleistocene (Russo Ermolli et al., 2014) and was gradually replaced by *Fagus* in response to the general climate aridification of late Quaternary. In the Salerno record, *Abies* is rather abundant up to about 8.000 BP when it decreases and stabilizes around 5% until the Roman age, during which it nearly disappers. In fact, during this period fir timber was widely used for shipbuilding (*Neapolis* shipwrecks; Allevato et al., 2010) and fornitures (*Herculaneum*). Later, it seems to slightly recover during the Late Ancient before disappearing almost completely since the Middle Age.

The Microcharcoal value along all the sequence does not seem to suggest antropogenic fire regimes, maybe because in marine cores microparticles arrive far away from the pollen source area, in a similar way to *Pinus* pollen grains.

Concerning the Coprophilous fungal spores, their overall relative abundance all along the core suggests that they do not have an anthropogenic value.

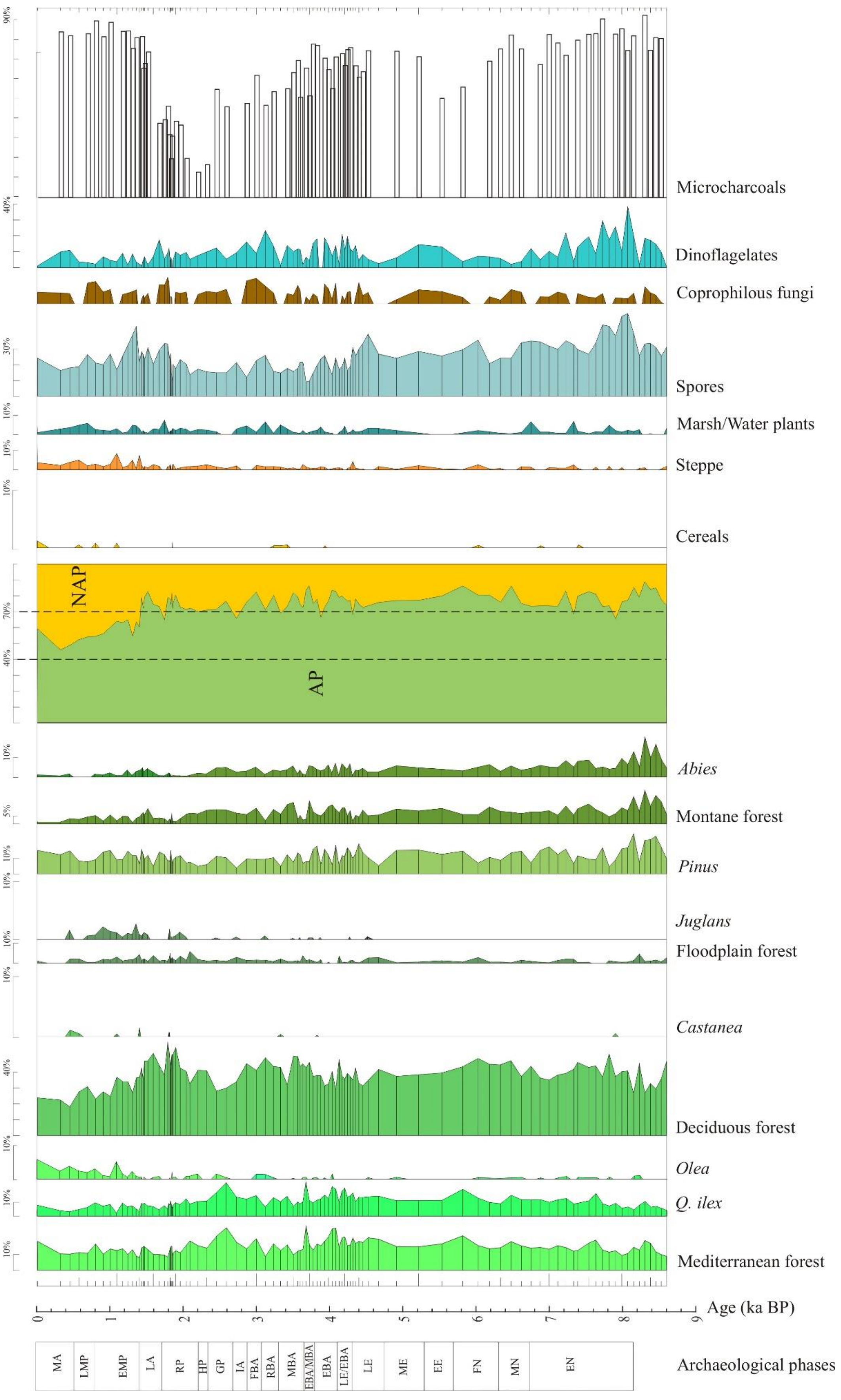

Fig 23 – Synthetic pollen diagram of C106 core plotted against age.

5.2. Sarno Plain

5.2.1. *The San Vito sinkhole: "B24" core stratigraphy*

The term sinkhole[46] is used to indicate a collapse of the topographic surface and the result of this collapse is a sub-circular closed depression. Sinkholes can be induced by either natural causes or human activities. The former usually derive from karst processes in calcareous and evaporite rocks (Waltham et al., 2005; Gutiérrez et al., 2008, 2014; Santo et al., 2011, 2017, 2019b), or may also occur in non-karst terrains such as alluvial sediments (Nisio et al., 2007; Del Prete et al., 2010; Amato et al., 2018; Pazzi et al., 2018)

Fossa San Vito sinkhole (Fig. 24) is located at the foot of the carbonate slopes that bound the Sarno Plain towards NE. It is a sub-circular closed depression (200 m diameter and an area of about 35,000 m^2) and has an asymmetric longitudinal profile, with inner scarp height that increases towards NNW (maximum height ~25m) and decreases towards S-SW (maximum height ~15 m) (Santo et al., 2019a). The Fossa San Vito sinkhole is filled by a sequence of alluvial fan deposits, that cover deposits of the Campanian Ignimbrite eruption occurred at 39 ka (De Vivo et al., 2001; Rolandi et al., 2003).

The origin of this sinkhole is still debated. Del Prete et al. (2008) and Guarino and Nisio (2009a) excluded a possible role played by either mining or volcanic activity. The same authors believed that the collapse occurred suddenly during Medieval or Roman age because they identified an extinct lake within the sink, along whose banks a small Medieval church was built with the ruins of roman structures.

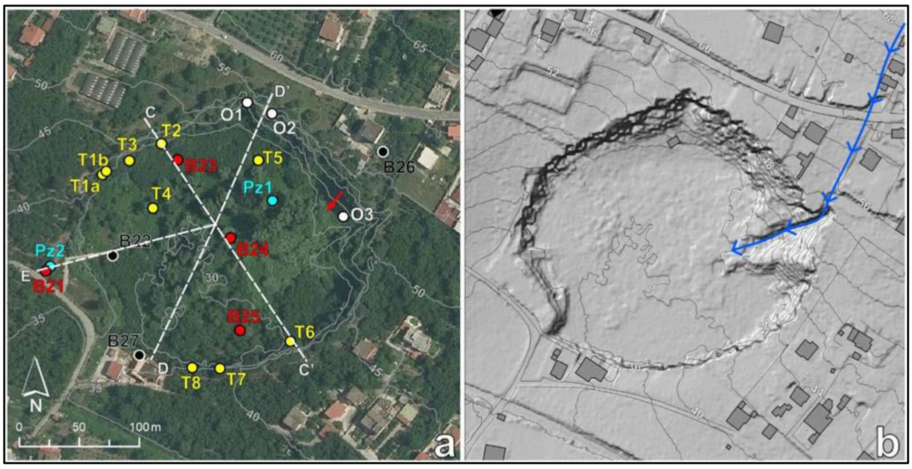

Fig. 24 - a) Fossa San Vito sinkhole. Red and black circles indicate boreholes. Red arrow indicates location of the Romanesque church. (b) 1 m DTM of the Fossa San Vito sinkhole. The blue line indicates the creek feeding the sinkhole (after Santo et al., 2019a)

[46] A regional scale analysis of collapse sinkholes distribution in the Apennines demonstrated that they are concentrate in several zones that show peculiar geological, structural and hydrogeological conditions (Del Prete et al., 2010; Santo et al., 2011). Furthermore, waters may have an important role in sinkhole formation and in some cases, as testified by historical data collected all over the region, the collapse of the topographic surface may be triggered by seismic shaking.

The results obtained by the analysis carried out on five deep cores (B21 – B22 – B23 – B24 – B25) coming from the sinkhole were recently published (Santo et al., 2019a). The composite stratigraphy of these boreholes is as follows:

- A_1: pre Campanian Ignibrite alluvial and pyroclastic deposits (B21 – B22 – B24);
- C_1: Campanian Ignimbrite (B21 – B22 –B24);
- A_2: post Campanian Ignimbrite alluvial and pyroclastic deposits (B 23);
- P_1: pre-sinkhole pyroclastic deposits (B21 – B22 – B24);
- Lac: lacustrine deposits (B22 – B24 – B25);
- P_2: post sinkhole pyroclastic falls (B22 – B23 – B24 – B25);
- R: anthropogenic deposits (B21 – B22 – B23 – B24 – B25).

In addition, the authors distinguish various stages of the possible evolution of the sinkhole:

- A: represents the paleogeography before the collapse, at about 5500 years BP;
- B: moment of the collapse;
- C: formation of the lake. The presence of several tree trunks found at the base of the lacustrine sequence inside the sinkhole suggest that the collapse occurred suddenly;
- D: progressive filling of the lake occurred from 5483 cal years BP[47] until present as testified by the small medieval church located inside the sinkhole (Guarino and Nisio, 2009b). The apparent sedimentation rate of about 6 mm/yr is quite anomalous due to the small size of the sinkhole and the high sedimentary input derived by the contemporary volcanic activity of the Vesuvius, by the degradation of the sinkhole sides and by alluvial inputs from the carbonate slopes.

The core B24 (Fig. 25), object of this work, is located at the center of the San Vito sinkhole. It is 80 m deep and the stratigraphy is formed from the base by (Santo et al., 2019a):

- Alternate alluvial fan gravels and pyroclastic layers, with inter bedded palaeosoils (A1);
- Campanian Ignimbrite in a tuff facies at about 18 m a.s.l.;
- 10 m of chaotic materials consisting of clays and gravels and containing abundant wood from tree trunks;
- Thin layered lacustrine silts and clays, about 25 m thick (Lac);
- At the top of the borehole, several meters of reworked materials and pyroclastic fall deposits are recognized.

[47] The radiocarbon date was carried out on a sample collected at 40m depth (−17m a.s.l.) from borehole B24. It provides the approximate age immediately after the collapse.

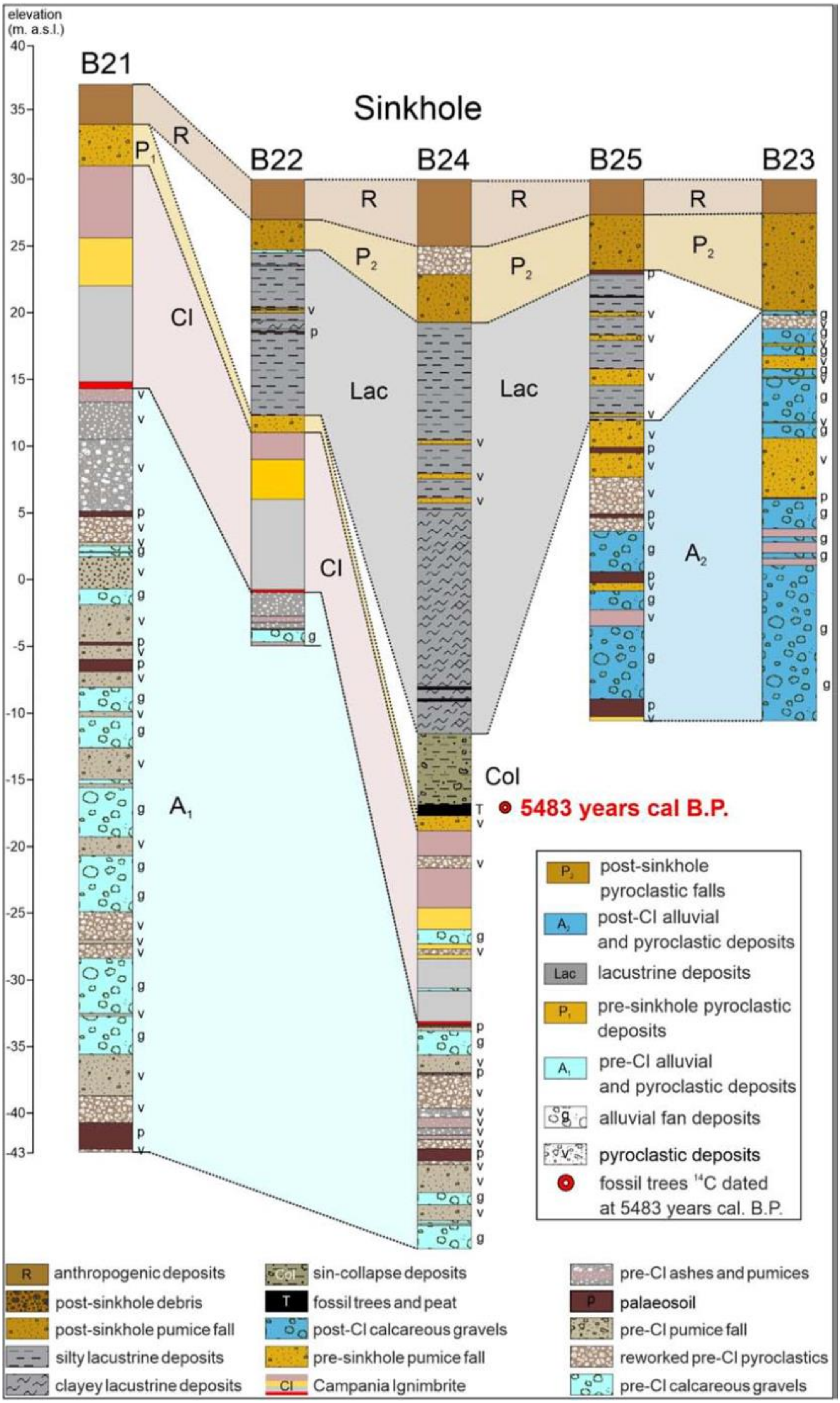

Fig. 25 - Stratigraphic log of the boreholes studed by Santo et al. (2019a)

5.2.2. *Pollen diagram*

Pollen analyses were undertaken on 19 silty samples collected from the B24 core between 10.80 and 43.80 m depth. All analyzed samples resulted rich in pollen grains except sample 21.43 m, which was therefore excluded from the diagram. Pollen sums range from 100 to 1200 grains; 66 taxa were identified; concentration values range from 4300 to 181.000 grains/gram of sediment. Two main compositional pollen zones were identified in the detailed diagram on the basis of CCA (Pl. 2):

- Zone 1 (43.80– 19.35 m): This zone is represented by 12 samples. Tree assemblage is dominated by *Q. ilex*, dec. *Quercus* and *Carpinus*. In particular, *Q. ilex* presents highest percentages in the bottom part of the diagram (42.35 m) at around 50%, then starts to decrease until the end of the zone. Other Mediterranean taxa are poorly represented in this zone. Dec. *Quercus* in the deepest sample has high value (c. 45%) and then starts to decrease until 3692 cm depth after which it rises again reaching the highest percetage of all the diagram (around 55%). It is interesting to note that the trend of the *Carpinus* curve is in opposition to the dec. *Quercus*: when one decreases the other increases. Concerning other deciduous forest elements, those well represented include *Hedera,* which increases in the interval between 33.20 – 31.70 m (10%), and *Ostrya*, present over all zone with stable value, even if a rapid increase is seen at 29.50 m toghether with *Carpinus*.

  Floodplain forest taxa do not show high percentages, and with regard to mountain forest elements, only *Fagus* is well represented in this zone with values that reach 10%.

  In general, the AP curves present high values along all zone (90% - 98%) identifying a closed landscape. The herb assemblages are very low; only the Poaceae family increases at 33.20 m. Only three pollen grains of cereals were counted at 40.21, 36.40 and 34.80 m. Marsh elements are constantly present but in low percentages (less of 1%), with only *Myriophyllum* peaking at 19.35 m. All spores have low values, with only coprophilous fungal spores achieving a rapid increase between 36.40 and 34.80 m. Microcharcoals are not very abundant and it is possible to identify a peak only at 36.40 m (20%).
- Zone 2 (18.25– 10.80 m): This zone is represented by 6 samples. *Q. ilex* decreases progressively and reappears only in the upper part of the zone in corrispondence to the increase of *Olea*. Other Mediterranean elements have low values. Deciduous

forest assemblages are persistently dominated by dec. *Quercus* which first decreases in the middle part of the zone and then increases again in the upper sample (more than 50%). *Carpinus* with respect to Zone 1 almost disappears while *Ulmus* increases in the middle part of the zone. Of interest is a peak for *Castanea* in the deepest sample of the zone (18.25 m) that reaches around 8%, after which it disappears and reappears in the uppermost samples of the diagram. Floodplain forest elements increase progressively in this zone and the assemblage is dominated by *Alnus* (15% at 16.12 m). Also of interest is the light increase of *Corylus* (12.40 m), *Juglans* and *Vitis* (12.95 m). In particular, *Vitis* is present constantly along all the sequence and reaches highest value in this zone (around 8%). *Pinus* is well represented in the first sample of the zone, then decreases progressively such as also *Fagus*, which is always present yet with percentages lower than Zone 1. In general, it is possible to identify a general decrease in forest cover, in particular between 16.12 -12.95 m, with the lower percentage of all the sequence (55%) and a progressive increase in the upper part of the pollen sequence. Contrary to this it is possible to identify a progressive increase of herb assembalges, dominated by Poaceae (peak at around 20%), Cichorioideae (peak 10%), Asteroideae and Caryophyllaceae (peak 6%). Also cereals are persistently present in lower values such as are other herbs. *Artemisia* is almost totally absent along the entire sequence, even if it seems to be present in higher percentages in the upper part of the zone. Marsh elements are dominated by Cyperaceae even if their value is very low. Concerning spores, it is very interesting to note the rapid and significant increase of trilete spores (70% at 16.12 m) and coprophilous fungal spores (35% at 1240 cm), such as also microcharcoals that reach the highest value of all the sequence at 12.95 and 11.90 m (46% - 50%).

Mediterranean forest	*Quercus ilex*, *Olea*, *Ligustrum*, *Phillyrea*, *Pistacia*, *Ziziphus*, *Coriaria mirtifolia*, Ericaceae, *Neurada*	
Deciduous forest	*Quercus*, *Carpinus*, *Ostrya*, *Tilia*, *Acer*, *Ulmus*, *Ilex aquifolium*, *Fraxinus ornus*, *Hedera*, *Castanea*	
Floodplain forest	*Alnus*, *Corylus*, *Juglans*, *Populus*, *Salix*, *Vitis*	
Pinus	*Pinus* spp	
Montane forest	*Abies*, *Fagus*, *Betula*	
Herbs	Poaceae, Amaranthaceae, Caryophyllaceae, *Paronychia*, Dipsacaceae, Scrofulariaceae, *Asphodelus*, *Helianthemum*, *Polygonum*, *Hypecoum*, *Theligonum*, *Calligonum*, *Ephedra*, Liliaceae, Amaryllidaceae, Rosaceae, *Symphytum*, *Sanguisorba*, *Humulus*, *Cannabis*, *Erodium*	
Anthropogenic herbs	Cereals	Cultivation
	Rumex, *Plantago*, *Urtica*, Lamiaceae, Apiaceae, Brassicaceae, *Mercurialis*, *Artemisia*	Ruderal taxa
	Cichorioideae, Asteroideae, Ranunculaceae, Fabaceae	Grazing
Coprophilous fungi	Various sp.	
Marsh/Water plants	Cyperaceae, *Typha*, *Myriophyllum*	

Tab. 9 - Composition of taxa groups as plotted in the pollen diagram

5.2.3. *Chronology*

Fossil trees were found at the bottom of the lacustrine deposits of borehole B24, which corresponds to the beginning of the lacustrine filling of the collapsed surface (Tab. 10). To provide chronological constraints regarding the timing of the collapse, ^{14}C analysis of one of the fossil trees was carried out. The sample in question was collected at 40 m depth and provided an age of 5483 yr cal BP (Santo et al., 2019). Another ^{14}C analysis (Tab. 10) was carried out at 11,60 m of depth that provided an age of 556 yr cal BP (1394 AD). Various tephra layers from Vesusius and Phlegrean Fields were identified in borehole B24 and their study, which is in progress (Prof. Paola Petrosino), will help in clarifying the chronology of the sequence.

Considering the nature of the sinkhole deposit, rich in reworked material, it is impossible to create a convincing chronological model and therefore the absolute datings (^{14}C) were used as reference points to try to reconstruct the history of the landscape that developed around the sinkhole during a period between Early Eneolithic until the Late Middle Ages.

Depth (m)	Radiocarbon age yr BP	cal yr BP 2 sigma	Median probability cal yr BP	cal yr BC /AD 2 sigma	Median probability cal yr BC/AD
11,60	550±32	640-516	578	1310-1434 AD	1372 AD
45,00	4730±26	5583-5505	5544	3633-3555 BC	3594 BC

Tab. 10 - Age of the14C dated samples

5.2.4. *Discussion*

A synthetic diagram (Fig. 26) with plant groups has been created, from which some taxa relevant to the discussion have been extracted.

In the bottom part of the core (Zone 1) the high forest cover suggests the presence of a closed environment. The development of Mediterranean forest in correspondence with the decrease of dec. *Quercus* at 42.35 m depth could be linked to a first exploitation of the territory also testified by the presence of cereals (crops) and coprophilous fungi (grazing). The time of this exploitation is uncertain, but archeological finds, despite being few, indicate that stable settlements occurred in the Early Bronze Age (see chapter 4.1.2.2.). Certainly, without the availability of reliable chronology for this core drilling, it is difficult to formulate any hypotheses though it is necessary to remember the 4.2 ka climatic event as another possible cause of the development of the Mediterranean forest.

Between 36.40 and 34.80 m a slight decrease in forest cover associated with large amounts of coprophilous fungi (grazing) and cereals (crops) could be indicative of the first period of large exploitation of the territory surrounding the San Vito sinkhole. A known extensive occupation of the territory took place in the Iron and Samnite-Roman Ages, but here again, the lack of precise chronology prevents any correlation.

Various Iron Age – Orientalizing sites not far away from the Sarno sinkhole have been found, mainly necropolis[48] and one inhabited area in Longola of Poggiomarino. Palaeobotanical analyses (seed and pollen) at Poggiomarino Iron Age settlement attest cereal cultivation (Celant, 2011; Delle Donne, 2011; Di Maio et al., 2011)[49] such as evidenced in the Sarno diagram.

Concerning possible crops taxa, the continuous presence of *Vitis* along all the sequence with percentage always above 2% is very interesting, suggesting the cultivation of this plant according to Russo Ermolli et al. (2018). The wild variety of *Vitis*, a natural element of the floodplain forest undergrowth, was certainly present since the beginning of the Holocene in the wetlands of the alluvial-coastal plains of southern Italy. Starting from the Bronze Age, *Vitis* was exploited in its natural environment before being completely domesticated by Etruscan and Greek people (Russo Ermolli et al., 2018 and references therein) such as testified in pollen data coming from the Pontecagnano site (Russo Ermolli et al., 2011). Not

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[48] San Marzano necropolis (Rota, 1994; d'Agostino, 2010-2011; Longo, 2010a), San Valentino di Torio necropolis (Rota, 1994; Longo, 2010b) and Striano necropolis (d'Ambrosio, 1988a; 1988b; 1990; 1991; 1999; 2003; 2005; Rota 1994).

[49] In Poggiomarino seed of *Triticum monococcum*, *Triticum dicoccum* and *Hordeum vulgare* were found (Celant, 2011; Delle Donne, 2011), as well as pollen of *Triticum* and *Hordeum* groups (Di Maio et al., 2011)

far away from San Vito sinkhole, an interesting find in Longola Iron Age settlement concerning the cultivation of this element is witnessed by the discovery of a large amount of *Vitis* seeds (Cicirelli et al, 2008; Celant, 2011, Delle Donne, 2011), as well as evidence relating to vine cultivation and pressing of grapes for wine production (Cicirelli et al., 2008). New data from Grotta di Pertosa (Vallo di Diano) attest the presence of large amounts of *Vitis vinifera* seeds in Middle/Late Bronze Age levels (Breglia, 2019).

Another interesting association is the concomitant increase of *Vitis* with *Ulmus* in the upper part of the core. Recent works by Passigli (2018) on the Pontine plain in the Middle Ages testify that viticulture was carried out with the support of elms, suggesting that the Sarnese people also carried out this cultivation practice. Besides, traces of the vine cultivation near the sinkhole of San Vito in the Middle Ages comes from some written sources which speak of a large extended property close to the S. Vito church in 1053, intensely cultivated with vineyards, orchards and seeds, with possible wine production (Iannelli, 1994; Guarino and Nisio, 2009).

Concerning *Juglans* and *Castanea*, the cultivation of these taxa is attested since Roman period in Campania. The *Neapolis* harbor pollen diagram (Russo Ermolli et al., 2014) suggests the cultivation of walnut since the 1st cent.. BC, while in the Gulf of Gaeta (Di Rita et al., 2018a) and in Lago d’Averno (Grüger and Thulin, 1998) walnut cultivation is attested since the 1st cent. AD. *Juglans* was also widely used in Campania since Roman times for both timber and food (Allevato et al., 2010; Russo Ermolli et al., 2014). The bed chronologies of Sarno pollen sequence do not indicate with certainty a period for the beginning of these cultivations, but they were already developed during the Middle Ages.

The association of *Juglans*, *Castanea* and *Olea* (OJC curve), according to Mercuri et al. (2013), can be indicative of crops in pollen diagrams when their curves rise fairly suddenly and in combination with consistent archaeological evidence. In the Sarno diagram the high percentages of forest cover in concomitance with a *Castanea* increase does not lead one to think of its cultivation, such as *Olea* which increase rapidly in the last upper sample, but in concomitance with the *Q. ilex* increase. These data suggest more a natural development of sclerophilous species rather than a form of cultivation, also because in the same period there is a general increase in forest cover that could indicate an abandonment of the area.

Moreover, written sources talk about the presence of olive trees in the Late Middle Age in the loc. Villa Venere, near the San Vito sinkhole (Iannelli, 1994) [50], but do not mention a cultivation form.

In the same upper sample, it is possible to see a rapid increase of *Humulus*. This is very strange because *Humulus* crops are not attested in Italy before 1800, and the sample is very close to the dated sample (1394 AD) meaning that the nature of its development is not clear.

Before the supposed cultivation of *Juglans* and *Vitis*, there was a phase of high human impact as testified by the large amount of microcharcoals and trilete spores, indicative of human fires, the development of cereals crops and the increase of coprophilous fungi and of some anthropogenic herbs indicative of grazing (mainly Cichorioideae, Asteroideae). This occurred in concomitance with a rapid decrease of forest cover (55%) that identifies an open-patchy landscape.

From the environmental point of view, in the synthetic diagram it is possible to note the San Vito pond evolution, with its progressive closure after the barren volcanic interval. In fact, at 1935 cm depth, marsh/water plants (mainly *Myriophyllum*) increase their pollen amounts, indicating the approaching of the shores to the pollen site: the marsh is contracting. From that moment we witness the increase in floodplain taxa (mainly *Alnus*), at 1612 cm depth, in concurrence with the decrease in marsh/water taxa. These results likely indicate a further contraction and final closure of the marsh, which led to the rapid development of an alder forest on the wet soils.

In conclusion it is possible to say that during the prehistoric, protohistoric period there are a few signs of high human impact on the landscape. The landscape was characterized by dense forest cover with only rare cases of tree decrease and some traces of cultivation and grazing that indicate the possible presence of stable settlements in the territory.

In Zone 2, a first large form of territory exploitation with a general decrease of forest cover and the development of cereal crops occurred. After this period, perhaps between the Early and Late Middle Ages alongside the cultivation of cereals, tree crops (*Vitis*, *Juglans*) have also been carried out. Subsequently, in the upper part of the sequence (from 12.40 m) a general increase of forest cover seems to suggest an abandonment of the area during the last part of the Middle Age.

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[50] Iannelli, 1994 talks about written sources of Medieval period and cite G. Mongelli (Regesto Montevergine, IV, n.2917, a. 1316) concerning loc. Villa Venera landscape.

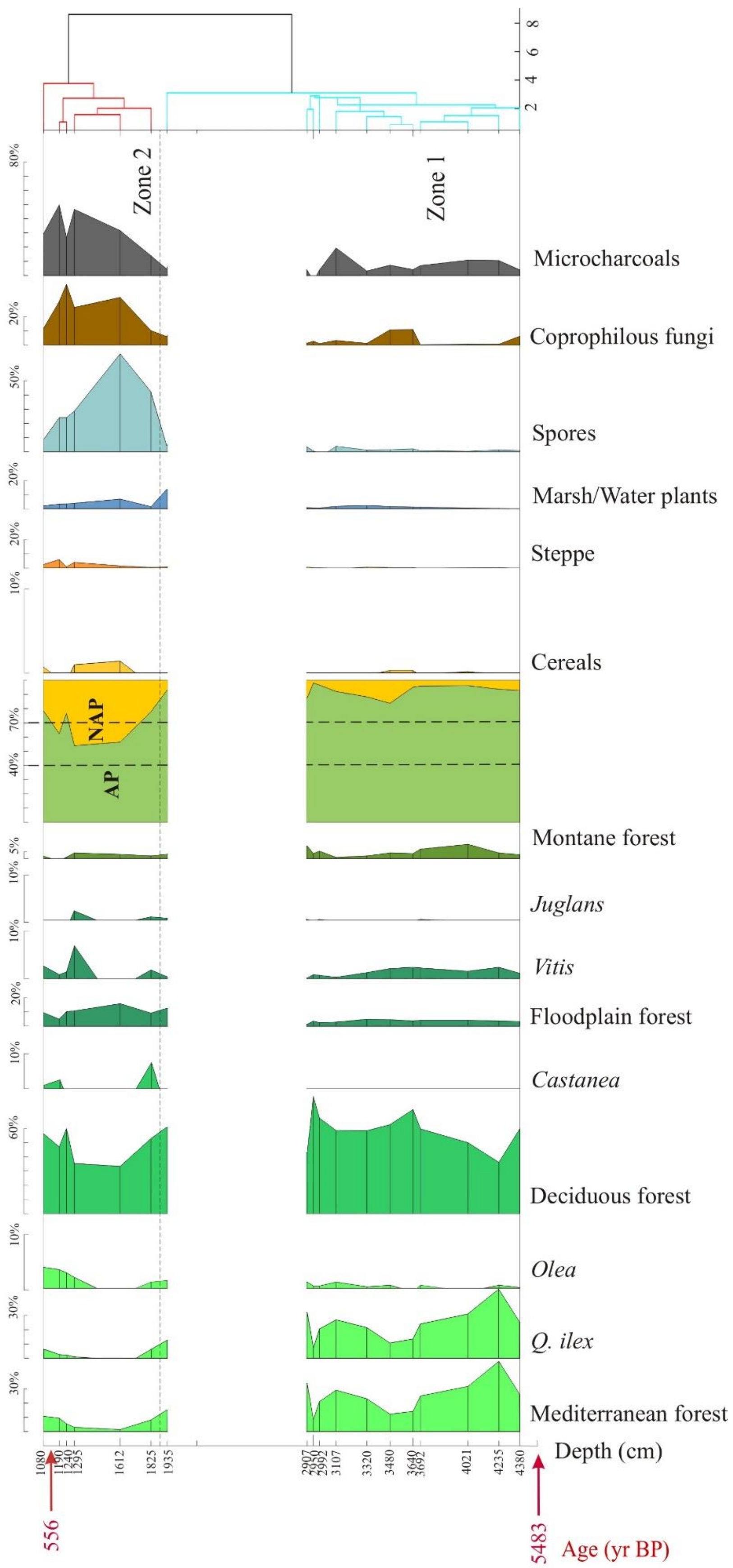

Fig. 26 – Synthetic pollen diagram of B24 core with taxa percentages plotted against depth.

5.3. **Roman Villa with bath of Masseria De Carolis (Pollena Trocchia)**

5.3.1. ***Archaeological knoledge***

The Roman villa (Fig. 27) which contains the baths of Masseria De Carolis (Pollena Trocchia) was built after the Pompeian eruption of AD 79. During the 5th cent. AD, the whole structure was almost completely covered by the products of the so-called Pollena eruption (AD 472) which ended the villa life. The villa was then reused as a rubbish dump as well as an infant cemetery, and mainly was interested by large spoliation.

At the far north-west of the villa a vats system and one of the cisterns was found. These features were recently excavated and a sample for pollen analysis was collected. Almost all the filling of this cistern is made up by the products of the vesuvian eruption of AD 472 which is archeologically sterile. However, interesting palaeobotanical traces have been found, like leaves and branch imprints, anthracological and carpological remains. Analysis of these remains is ongoing. The bottom layers of the cistern consist of silty-clay material rich in animal bones, possible waste meal and pottery. This pottery chronologically constrains the deposit to the end 5th cent., immediately before the eruption.

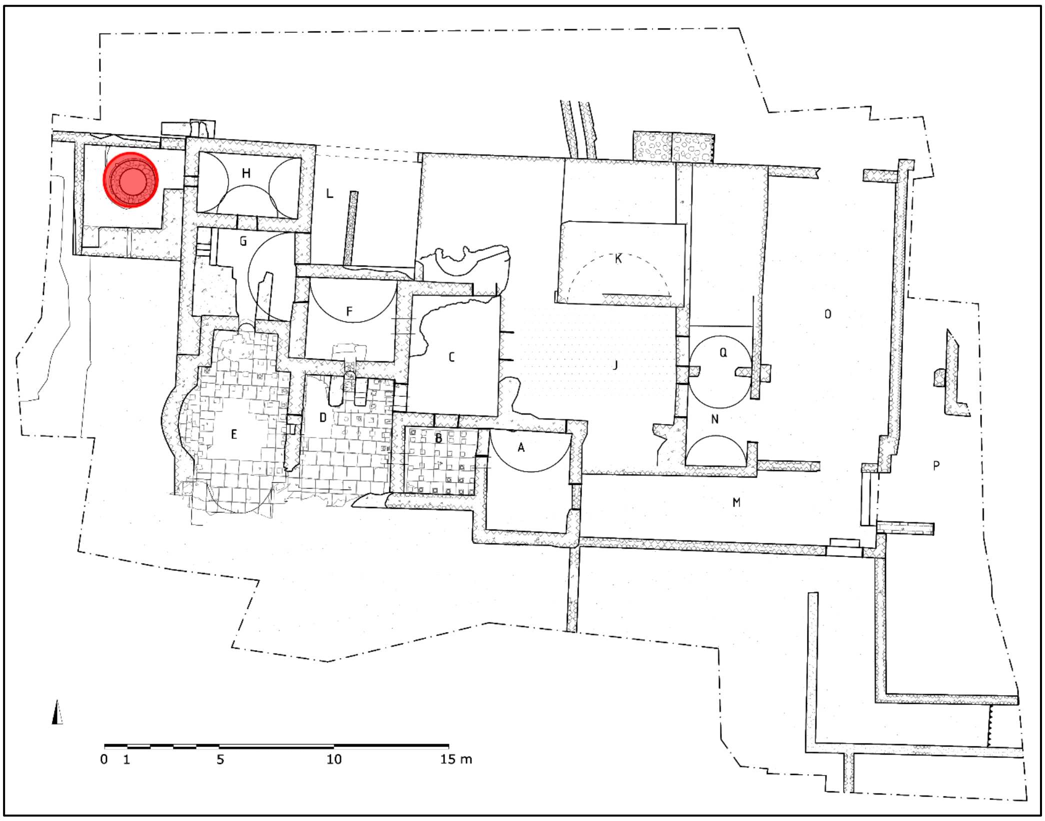

Fig. 27- Plan of the Roman villa with baths in Pollena Trocchia: in red the position of cistern (after De Simone and Martucci, 2016).

Fig. 28 – The cistern's access.

5.3.2. *Pollen spectrum of cistern sediments*

Pollen analysis has been conducted on a sample taken from the silt-clay layer of cistern (Fig. 28, at 20 cm from the base of the cistern). Approximately 150 pollen grains were counted and 27 taxa were recognized. The obtained spectrum (Fig. 29) shows the percentage of identified taxa. Trees are listed on the left (*Quercus*, *Salix, Pinus*, *Quercus ilex,* and *Pistacia*) with values reaching 29%. Moving right, herbs (*Artemisia*, Asteroideae, Poaceae, Scrofulariaceae, Caryophyllaceae, *Paronychia*, Ranunculaceae, *Scabiosa*, *Mercurialis*), aquatic plants (Cyperaceae and Liliaceae, etc.), NPPs (Non-Pollen Palynomorphs) and monolete spores (including *Polypodium*) are listed. Anthropogenic indicators (*Olea*, Brassicaceae, Cichorioideae, CFS, trilete spores and microcharcoals) are listed at the extreme right.

5.3.3. *Discussion*

The sampled layer belongs to the last phase of *villa* life, immediately before the AD 472 eruption. In this last period, the villa had lost its original function and had been reused for other purposes, including funerary rites. At that time, maintenance of the cistern ceased. As a result, sediments from the surrounding area and deliberately deposited waste (pottery and bones) filled the cistern. It is likely that these processes caused the interruption of the water supply from the aqueduct. Therefore, it is likely that the pollen signal observed in the sample from the cistern reflects the local vegetation around the villa at the time of abandonment.

Regarding taxa, *Olea* values of 2.5% may indicate the presence of olive trees in the area around the villa. The presence of *Olea* is also confirmed by the anthracological remains analyzed so far in the site (Allevato et al., 2012; De Simone et al., 2013). These findings are similar to other data from southern Italy, where evidence of olive cultivation is recorded from the Late Ancient (Russo Ermolli et al. 2018), so in the same period of the analysed context. The presence of Brassicaceae is also significant, even if the percentages are not very high; the presence of this family could be indicative of a use of the villa for horticulture. In support of this hypothesis, data obtained from recent archaeological excavations have confirmed the presence of ploughing near the structure. Moreover, clear signs of Brassicaceae cultivation were recorded at Neapolis from the 1st cent. BC to the 5th cent AD (Russo Ermolli et al., 2014).

Even more interesting for the reconstruction of the last phases of use of the villa is the consistent presence of Cichorioideae and Coprophilous fungi, indicative of open environments probably used as pasture. This important association in pollen spectrum could be used to hypothesize that this villa, like other similar structures during the Late Antique period, were abandoned and used sometimes as shelters for livestock and grazing[51]. Archaeologically, no traces of animal shelters have been found inside and around the structure, but this does not exclude the possibility that the villa has been used for grazing.

Another interesting element is the wealth of microcharcoals in association with trilete spores, a clear sign of anthropogenic presence. In this case, there are many hypotheses about the origin of microcharcoals coming from the villa. The following three hypotheses seem rather convincing:

- The cistern is located near the praefurnium (environment “g”) used to warm the thermal water (De Simone et al. 2012), so microcharcoals could be linked to this activity in the oldest phases of the villa[52].
- Microcharcoals could be obtained from calcination activities of architectural remains of the structure subject to processes of plundering[53].
- Maybe several fires have affected the structure in the abandonment phase as a result of the collapse of roofs and other wooden structures.

[51] See the animal shelters founded in the nearby Villa di Augusto of Somma Vesuviana.

[52] Despite the defunctionalisation of this environment in the chronological phase, the closeness of the cistern to this environment is to be noted.

[53] No lime furnaces have been found near the structure, but the clear signs of plundering on the walls of the entire building confirm the presence of recycling activities of building material. That said, it is not unlikely that the furnaces for the calcination of the stones may have been present in the same site of the plundering, as frequently happens in contemporary sites (Savi Scarponi, 2013).

While there are three hypotheses regarding the cause of fire at the villa, with the current state of research it is impossible to confirm with any degree of certainty which hypothesis is correct.

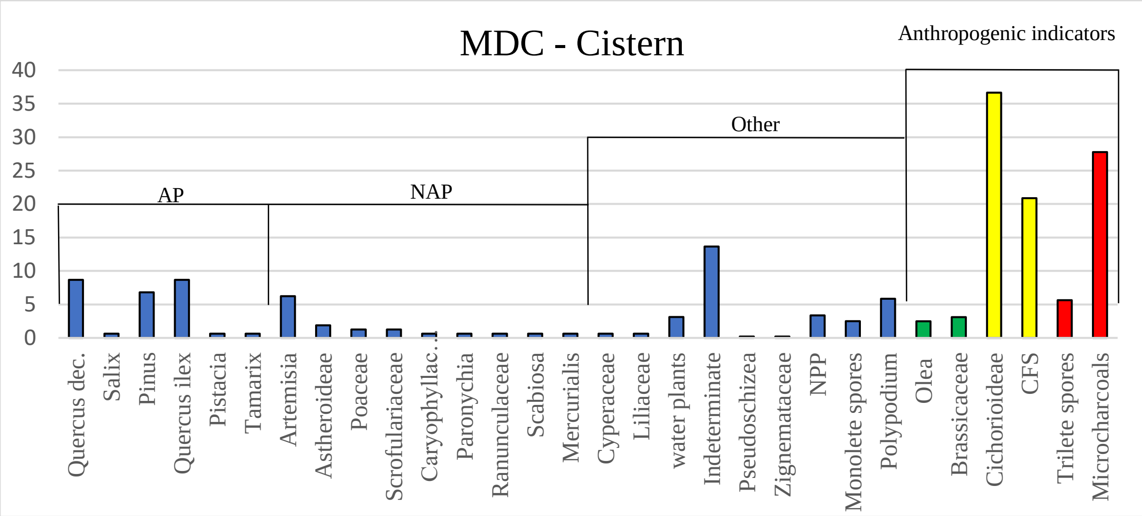

Fig. 29 – Pollen spectrum of the sample coming from the cistern (yellow: taxa indicative of pasture; green: taxa probably cultivate; red: fire indicators)

5.4. Mondragone

5.4.1. *"CL1" core stratigraphy*

In 2016, a 16 m deep core drilling was carried out at Cellole/Mondragone, at an altitude of 1 m a.s.l. (mouthpiece).

The core was sampled and analysed (diatoms, radiolarians, porifera/spicules, echinoderms/radioli, molluscs, bryozoans and serpulids, benthic foraminifera and ostracoda) for palaeoenvironmental reconstruction. It has been possible to distinguish three units (Fig. 30 - Corrado, 2019):

- Unit 1 (marine)
  - -15.00/-12.20 m a.s.l.: marine sands of upper infralittoral environment followed by sands attributed to a beach/dune environment. From -14.00 to -13.50 m a.s.l. there is the presence of rounded greyish centimetric pumices in a greenish grey cynerite matrix. From -15.00 to -12.20 m a.s.l. there are grains of a polygenic nature.
  - 12.20/-8,55 m a.s.l..: fossil remains, mainly sponges and molluscs fragments, indicate an environment between the upper infralittoral and the transitional. Between -12.20 and -11 m a.s.l. there is medium-fine sand, while from -11 to -8.55 m a.s.l. there is sandy-silt.
- Unit 2 (continental-volcanic)
  - -8,55/-4,20 m a.s.l.: volcanic sandy-silt deposit with pumices and minerals which changes to dark-coloured silty-sands with a strong volcanoclastic component.
- Unit 3 (transitional/continental)
  - -4.20/-3.07 m a.s.l.: all analyses indicate a palaeoenvironment variable between the upper infralittoral and transitional, under the influence of continental waters underlined by the occurrence of reworked freshwater taxa. From -4.20 to -4 m a.s.l. the material is composed by blackish grey peaty clay, rich in organic matter. Between -4 and -3.7 m a.s.l., there are clayey-silt with thin silty-sand layers. From -3.7 and -3.07 m a.s.l. there are greenish brown silty and plastic clays with decomposed organic matter.
  - -3.07/-1.10 m a.s.l.: the sediments include almost exclusively silica spicules, presumably belonging to freshwater taxa.

- -1.10/ 1 m a.s.l.: soil samples contain non-indigenous siliceous fossils, interpreted as soils with sandy-silt and volcanoclastic material reshaped by agricultural activities.

Two main tefra layers (CLC, CLD), interposed in the core, were sampled for tefrostratigraphic analysis. Glasses of the CLC layer (-9 m a.s.l.) are of alkali-trachytic composition and were related to the Campanian Ignimbrite eruption, dated at about 39.000 years ago. The deepest tefra layer, CLD (-13.6 m a.s.l.), is made up of well-preserved fragments of pumices and has a phonolithic glass composition. Its dating is in progress and will allow attributing this event to a known eruption.

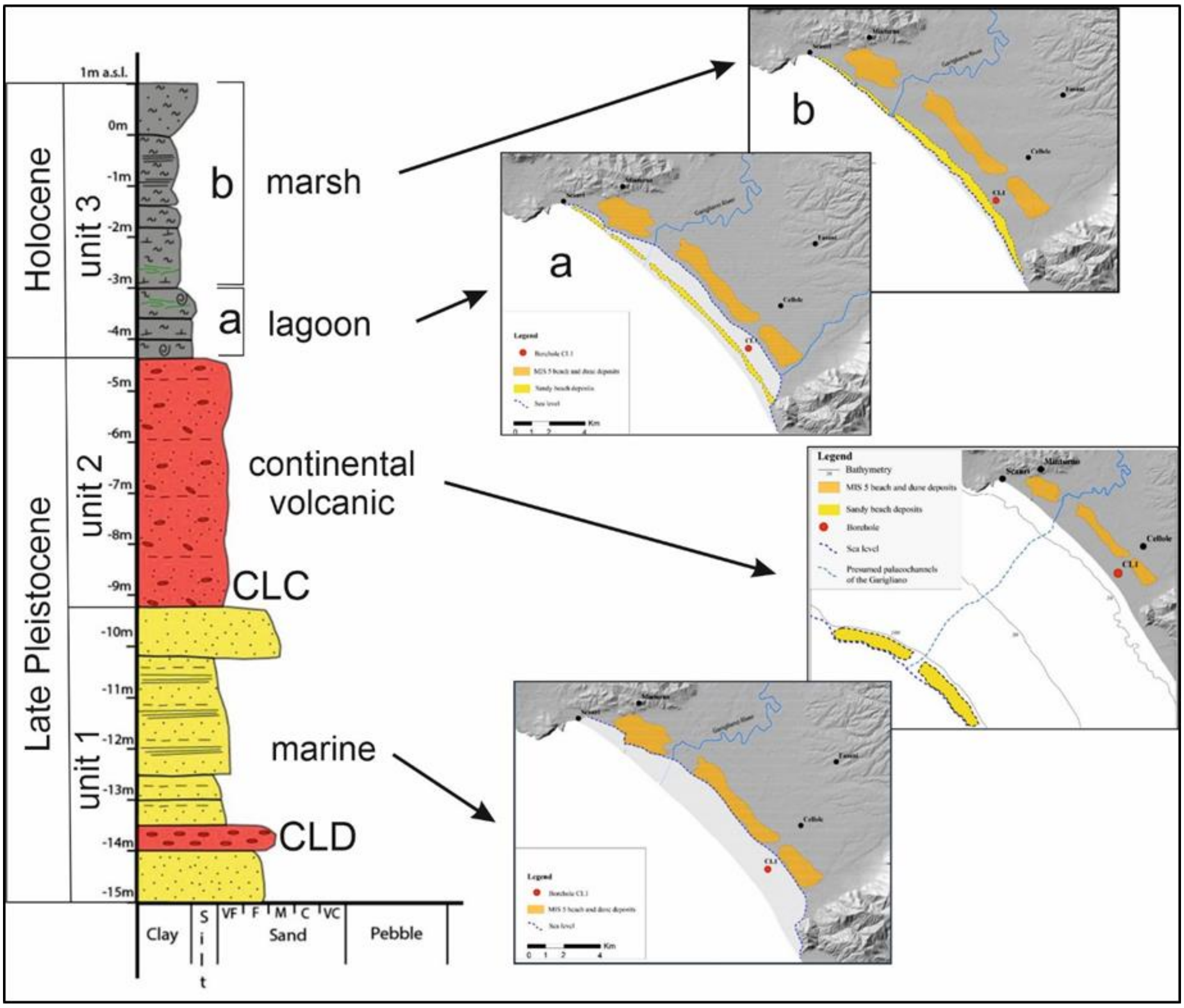

Fig. 30 - Cellole core (CL1) log and corresponding paleogeographical reconstruction (modified after Corrado, 2019).

5.4.2 Pollen diagram

Pollen analysis was undertaken on 29 silty samples collected from the CL1 core down to a depth of 530 cm. Samples resulted quite rich in pollen, only 5 samples were barren. Pollen sums range from 100 to 454 grains; 66 taxa were identified; concentration values range from 6400 to 58.000 grains/gram of sediment. Three main compositional pollen zones were identified in the detailed diagram on the basis of CCA (Pl. 3):

- Zone 1 (500 - 410 cm): This zone is represented by 10 samples. In these layers, tree taxa are essentially represented by dec. *Quercus* and *Quercus ilex*. In particular, *Quercus ilex* presents stable values (c. 15%) all along the zone with an increase between 450 – 440 cm (30%). The percentages of other Mediterranean taxa are very low (c. 1-2%), only the Ericaceae family reaches c. 8% at 420 cm depth.

  With regard to the deciduous forest, dec. *Quercus* have stable percentages all over the zone (30%) with an increase in the bottom part of the diagram at 490 cm (c. 48%). *Carpinus* has stable percentages (8%) from the lower sample until 460 cm, after it decreases (450 cm) swiftly and then increases (c. 13%) in the upper part of the zone (440-410 cm), when also *Ulmus* and *Hedera* (430 cm) increase their percetages (c. 8%). *Ostrya* is present in low percentage (3%) in the bottom part of the zone (500-440 cm), then it seems to almost disappear. All other deciduous elements present low values all over the zone. Concerning the floodplain forest, *Alnus* is constantly present with c. 7%, *Corylus* is well represented at 420 cm (12%), while other floodplain elements have very few values. *Pinus* percentages are very low but show a swift increase at 420 cm (c. 11%). Mountain forest is well represented by *Fagus* that shows fluctuating percentages (around 7%), while *Abies* shows low percentages all over the zone with a light increase at 420 cm (5%). In general, the forest cover (AP) is very abundant with values between c. 85% and 90%.

  Concerning the herbs, the Amaranthaceae family is constantly present with fluctuating values that reach apexes at 500 and 460 cm (c. 11%). Other herbs are poorly represented (1-2%).

  Marsh taxa are mainly represented by the Cyperaceae, of which only a few are present throughout the zone, even if they show a swift increase (11%) between 440 and 430 cm. Monolete and Trilete spores are present all over the zone, with fluctuating values, with higher percentage of the first with respect to the second. Coprophilous fungal spores have low values (1%) while Dinoflagellates seem to have higher values in the lower sample and a progressive decrease until to disappear in the upper sample of the zone.

High percentages of microcharcoals are present in almost all the zone, increasing progressively with two rapid curve inflections at 490 and 440 cm.

- Zone 2 (400 – 280 cm): This zone is represented by 9 samples. *Quercus ilex* decreases progressively until to disappear at 290 cm and then appears again at 280 cm depth. In the upper part of the zone, in correspondence with the *Q. ilex* decrease, a light increase in the Ericaceae family seems to occurr (even if in low percentages). Other Mediterranean taxa are almost absent all along the zone.

  The same trend of *Q. ilex* curve seems evident also for dec. *Quercus*, even if the latter has higher percentages (between 15-20%) all along the zone. *Carpinus* has lower values with respect to Zone 1 (1-3%), while *Ulmus*, that disappears in the bottom part of the zone, appears sporadically and with low percentages starting from the middle part of the zone. Other deciduous forest taxa show low percentages and are not representative of this assemblage.

  Concerning the Floodplain forest, an assemblage change occurred with the almost disappearence of all taxa and the dominance of *Alnus* that increases rapidly until 300 cm (65%) with a successive slight decrease.

  Pinus percentages are very low (less of 1%), even if it seems to achieve a slight increase from 290 cm. *Fagus* percentage starts to decrease with respect to Zone 1 while *Abies* completely disappears. In general, AP trend is the same of Zone 1, with high percentages.

  Concerning herbs, they are very few in this zone and do not show a dominant taxon with respect to others.

  In the marsh assemblage, a change occurs with respect to Zone 1. In fact, a *Myriophyllum* peak appears at 400 cm (10%), while Cyperaceae family increases progressively from 340 cm followed by *Typha* that is well represented from 300 cm depth. Both taxa reach progressively c. 10%.

  Monolete spores seem to show a slight decrease with respect to Zone 1, while Coprophilous fungal spores increase very rapidly in the middle part of the zone (340 – 320 cm) reaching 20% at 330 cm depth. Microcharcoals achieve high values only in the lower sample of the zone (400 cm) after then, a rapid decrease is recorded until reaching the lowest values of the diagram (2-3%).

- Zone 3 (270 – 220 cm): This zone is represented by 5 samples. Here *Q. ilex* continues its progressive decrease while Ericaceae dominate the Mediterranean taxa, reaching the highest value of the diagram (c. 16%) at 260 cm. Dec. *Quercus* increases in the upper sample, *Carpinus* is present only in one sample (240 cm) with low percentages (less of 1%), while *Ulmus* shows fluctuating values (between 1% and 8%) all along the zone. Other deciduous taxa are very poorly represented.

  Concerning Floodplain forest elements, *Alnus* starts a progressive decrease reaching low values in the upper sample (c. 7%), while other floodplain forest taxa are always few but seem to appear almost all in the upper sample. *Pinus* progressively increases reaching 15% in the upper sample, while Mountain elements are not very well represented in this zone.

  In general, a light decrease of AP percentages is achieved in the middle part of the zone with the lowest value of the diagram reached at 250 (c. 68%).

  On the contrary, the herbs, mainly Poaceae and Asteroideae, increase progressively. Moreover, peaks of Apiaceae (250 cm) and Brassicaceae (240 cm) are recorded. Interesting the appearence of a few cereals for the first time in the diagram at 260 and 270 cm depth. With regard to marsh taxa, a very rapid increase of Cyperaceae and *Typha* is recorded in the middle part of the zone reaching the highest percentages of the diagram respectively at 240 cm (85%) and 250 cm (75%). Also *Polygonum* achives a peak (c. 20%) at 250 cm.

  Trilete spores are well represented with respect to Zone 2, with fluctuating values (between 5% and 25%) while Monolete spores are very few. Microcharcoals reach two apexes at 260 cm (80%) and 240 cm (90%) intercalated from a rapid decrease at 250 cm (35%).

Mediterranean forest	*Quercus ilex*, *Olea*, *Ligustrum*, *Phillyrea*, *Pistacia*, *Ziziphus*, *Coriaria*, Ericaceae, *Cistus*, *Myrthus*	
Deciduous forest	*Quercus*, *Carpinus*, *Ostrya*, *Tilia*, *Ulmus*, *Fraxinus ornus*, *Hedera*, *Castanea*	
Floodplain forest	*Alnus*, *Corylus*, *Juglans*, *Populus*, *Salix*, *Vitis*, *Fraxinus*	
Pinus	*Pinus* spp	
Montane forest	*Abies*, *Fagus*	
Herbs	Poaceae, Amaranthaceae, Caryophyllaceae, *Paronychia*, Scrofulariaceae, *Asphodelus*, *Hypecoum*, *Theligonum*, *Ephedra*, Liliaceae, Amaryllidaceae, Rosaceae, *Symphytum*, *Geranium*, *Ribes*	
Anthropogenic herbs	Cereals	Cultivation
	Rumex, *Plantago*, Urticacea, Lamiaceae, Apiaceae, Brassicaceae, *Mercurialis*, *Artemisia*	Ruderal taxa
	Cichorioideae, Asteroideae, Ranunculaceae, Fabaceae	Grazing
Coprophilous fungi	Various sp.	
Marsh/Water plants	Cyperaceae, *Typha*, *Myriophyllum*, *Potamogeton*, *Polygonum*	

Tab. 11 - Composition of taxa groups as plotted in the pollen diagram

5.4.3 *Chronological model*

In order to chronologically constrain the analyzed core interval, three radiocarbon dating (^{14}C) were performed on bulk samples at -1.50 m a.s.l. (250 cm), -2.6 m a.s.l. (360 cm) and -4.3 m a.s.l. (530 cm). The dating results are shown in the table below (Tab. 12):

Depth (m a.s.l.)	Radiocarbon age yr BP	cal yr BP 2 sigma	Median probability cal yr BP	cal yr BC 2 sigma	Median probability cal yr BC
-1,50	2503±40	2456-2742	2587	753-507	638
-2,60	4419±45	4865-5074	5010	3125-2916	3061
-4,30	6802±45	7575-7704	7641	5755-5626	5692

Tab. 12 - Age of the14C dated samples

On the basis of these radiocarbon dates a chronological model has been constructed that constrains this part of the core to a period between the Early Neolithic and the beginning of the Roman Empire.

5.4.4 *Discussion*

A synthetic diagram (Fig. 31) with plant groups has been created, from which some taxa relevant to the discussion have been extracted.

During the Neolithic period, a dense forest cover (AP% around 90%, with only a slight decrease at c. 6600 BP) occupied the coastal plain where an open lagoon was established, at least up to the Final Neolithic, as testified by the presence of Dinoflagellates. No signs of anthropic impact are found in this period, even if the large amount of microcharcoals, seen between the Middle Neolithic and Early Eneolithic associated with coprophilous fungi, suggest human exploitation of the territory. After all, the stable value of the forest cover suggests that wooded resources are being affected by fire in areas far from the coastal region that will remain more or less untouched. Archaeological finds in the Garigliano Plain attest an attendance of the area during the Neolithic period, perhaps without stable settlements (Aiello et al., 2018), such as testified by the CL1 data in which it is clear that Neolithic populations did not decimate the wooded resources around the lagoon, probably exploiting it only through fishing, shell fishing, and the hunting of small game, especially avifauna as suggested by Aiello et al. (2018).

At 5600 (Early Eneolithic), an environmental change is recorded in the sequence. In fact, the lagoon closure, marked by a peak of marsh/water plants takes place in concomitance to the formation of a floodplain forest (mainly *Alnus*). This suggests the transition to a continental environment with the formation of a coastal lake surrounded by wet soils where the alder forest developed. The only stable settlement of the Eneolithic Period is that of Bagni Sulfurei, dated to the Middle Eneolithic. Throughout the entire Bronze Age there was a process of selection and concentration of settlements on the slopes of the reliefs of Sant'Eufemia, Arivito, Mount Petrino (Aiello et al., 2018) and Mount d'Argento. Moreover other sites were founded on the Eutyrrhenian strand plain bordering the Holocene marshes landward (Alessandri, 2007; Ferrari et al., 2012, 2013; Bellotti et al., 2016).

Unfortunately, the high percentages of floodplain taxa mask the inland landscape not showing signs of human impact, even if a peak of coprophilous fungal spores between the Eneolithic period and the Bronze Age could be interpreted as indicating grazing practice. According to Angle and Belardelli (2007), it is possible that the exploitation of wetlands continued for fishing or for harvesting aquatic plants also in this period.

From the Late Bronze Age till the Greek Period, another environmental change occurred with a drastic fall in alder forest and a rapid increase of marsh/water plants, suggesting the progressive closure of the lake, the approaches of its shores to the site of the core and the development of marsh condition. Moreover, at the same time a decrease of AP percentages (the lower value of 65% is reached in the Greek Period) associated with a large amount of microcharcoals and an increase of herbs could indicate an open human landscape. In this regard, the presence of cereals between the Late Bronze and Iron Age is very interesting, such as testified also by pollen analysis carried out in the Gulf of Gaeta (Di Rita et al., 2018a) and Minturno (core C1+C3, Bellotti et al., 2012, 2016) in which cereals[54] were identified. This datum suggests the presence of agricultural practice in the territory, principally not far away from the coastal plain during the Bronze Age.

It is very interesting to see a rapid rise of the Ericaceae family between 3100 and 2800 BP in concomitance with a decrease in *Q. ilex* that could suggest the occurrence of an arid phase during the first important attendance of the territory. An arid phase seems also to have occurred in the Gulf of Gaeta at about 2600 BP. The unperfected chronological correspondence with this core evidence is probably linked to the environmental conditions of the CL1 core, which renders the apparent sedimentation rates more fluctuating, preventing us from constructing an extremely precise chronological model.

The last sample of CL1 seems to show that the final closure of the marsh occurred in the Roman Period, with the decrease of marsh plants and herbs and the development of the oak forest, such as attested in the Gulf of Gaeta (Di Rita et al., 2018a) and Minturno (C2 - Bellotti et al., 2016). It is interesting to recall that literary sources, such as Plutarch (Life of Marius, 37–39), describes the *Minturnae* (about 10 km north of the CL1 core) landscape in the 1st cent. BC as being constituted by wetlands, with shallow water basins and muddy soils rich in marsh vegetation and trees such as *Salix* and *Quercus* (Ferrari et al., 2013a). In addition, archaeological finds suggest that land improvement along the coast had already started during the Roman colonization, followed by the construction of the via Domitiana in AD 95 as well as an important coast drainage work (Fossa Neronis) dated to the first Empire period (Arthur, 1991). These data seem to suggest that the natural closure of the coastal lake may have been favored by the drainage works put in place since that time.

[54] In Minturno (C1+C3) the *Havena*/*Triticum* and *Hordeum* groups were identified (Bellotti et al., 2016).

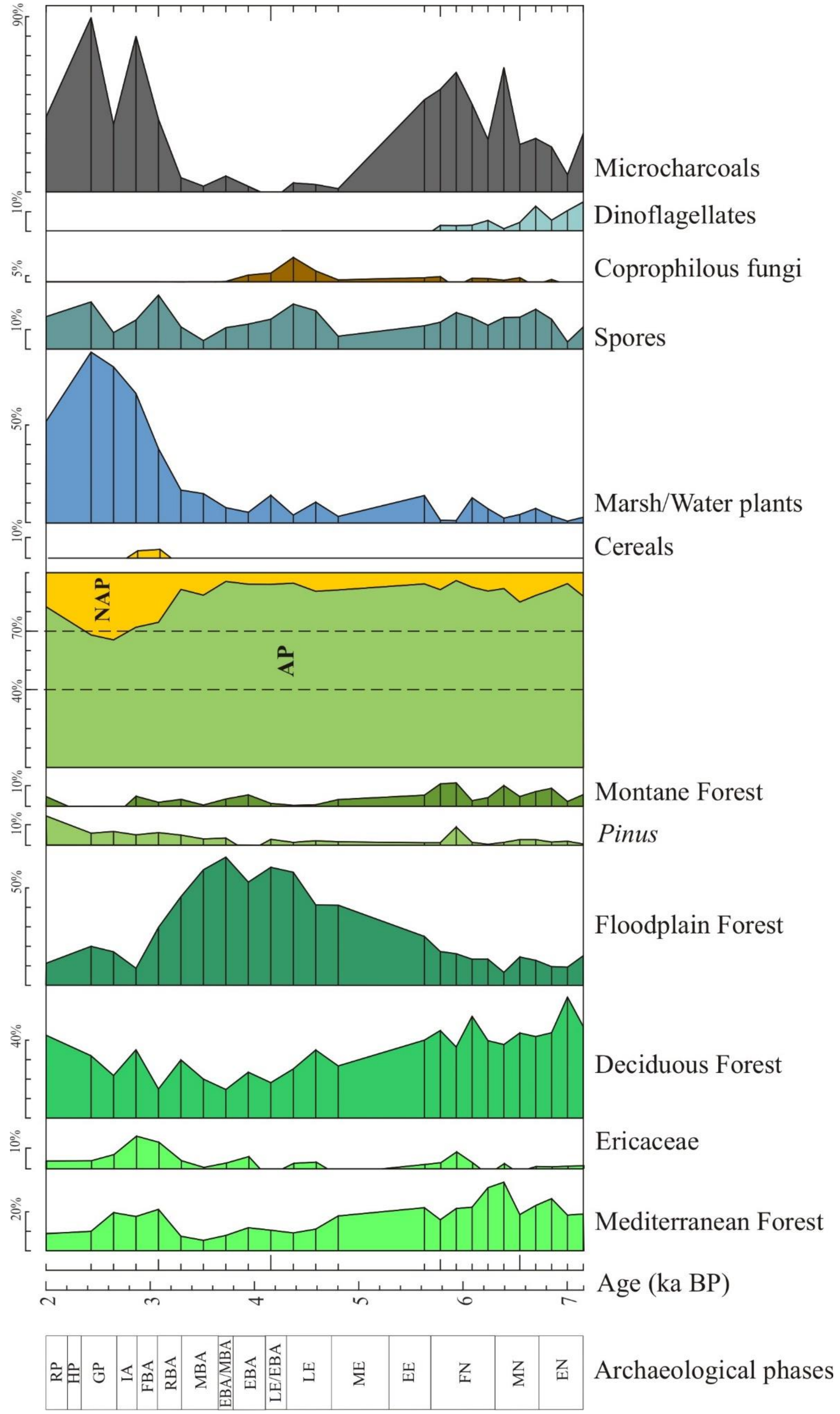

Fig. 31 - Synthetic pollen diagram of CL1 core plotted against age

5.5. Regional comparisons (Gulf of Gaeta)

This chapter summarizes the published pollen data from the Gulf of Gaeta area (Fig. 32) as compared to the results obtained for CL1 core drilling. In Fig. 33 the synthetic pollen diagrams of the cores from the Gulf of Gaeta (Di Rita et al., 2018a), of the Vindicio plain (Aiello et al., 2007), and of Marina di Minturno (C, C2, C3 - Ferrari et al., 2013; Bellotti et al., 2016) are shown.

The synthetic diagrams have been drawn by choosing various significant taxa for the interpretation of the forest cover and the anthropic impact on the territory: AP, *Olea*, *Juglans*, *Castanea*, *Vitis*, Fabaceae, *Vicia faba* and the group *Avena/Triticum* (cereals).

Being on a coastal plain, where wet environments were very developed in the past, the pollen results show an extreme abundance of marsh plants (especially Cyperaceae) in all drilling cores (C1, C2+C3, CL1). The published data for the Minturno and Gulf of Gaeta cores include these marsh plants in the total of NAP, so they obviously have influence on the AP fluctuations. Such that, in order to better visualize the rate of marsh taxa and their role in the AP/NAP variation, their curve was drawn in the AP/Total diagram (see also chapter 6.2.4.1.). Moreover, pollen data have been re-interpreted also taking into account the climatic character of vegetation changes proposed by Di Rita et al. (2017) for the Gulf of Gaeta core[55]. Despite the scarce presence of Neolithic sites in the Garigliano Plain, cereal pollen (the *Avena/Triticum* and *Hordeum* groups) was found in all Minturno cores. Moreover, between the Neolithic and the Eneolithic Period, coprophilous fungal spores and fire events in the CL1 core were detected, leading us to think, as already explained in chapter 5.4.4. that the inland area of the plain was permanently occupied during this period and that therefore the basis of subsistence for the local population was not only fishing, shellfish gathering and hunting of small game such as suggested by Aiello et al. (2018), but also included sedentary activities such as cultivation and grazing. These practices have not, however, affected the forest cover of the plain, which has very high values as can be seen in Cellole (Neolithic and Eneolithic) and the Gulf of Gaeta (Eneolithic) cores[56]. Although the high AP% of the Cellole and Minturno cores (local signal) is certainly influenced by the development of the floodplain forest on the wet soils of the coastal plain, the similar high AP% recorded in the Gulf of Gaeta marine core (regional signal), indicate the occurrence of a humid climate

[55] Di Rita et al. (2017) compared the timing of vegetation changes in Gulf of Gaeta with the climate proxy data available from the same core (planktonic foraminifera assemblages and oxygen stable isotope record) and with the NAO (North Atlantic Oscillation) index. Results obtained in this analysis suggest that the main driver for the forest fluctuations is climate, which may even overshadow the effects of human activity.

[56] In this case, the real AP values of the Minturno cores are masked by the massive presence of marsh plants.

period in which, despite the human presence, wild vegetation dominates the landscape. During this humid period, it is interesting to note, in the Vindicio core, a sudden lowering of the forest cover, whose value falls below 70%. Chronology allows this event to be interpreted as the 8200 BP climatic event.

Concerning the Eneolithic period, although archaeological discoveries suggest the presence of stable settlements, it seems that the pollen data of all cores do not show anthropic presence, though it is possible that this is only linked to a randomness, considering that cereal grains are always very few.

Around the beginning of the Bronze Age (4200 cal BP) in the Gulf of Gaeta there is a drop in AP (Arboreal Pollen) confirming the clearance recorded at many sites in Italy south of 43°N, interpreted as the 4.2 ka climatic event. During the Bronze Age anthropic attendance is testified by cereal crops (Gulf of Gaeta, Minturno and Cellole). Moreover, between the Bronze Age and the Iron Age (c. 2800 cal BP) there is a lowering of AP percentage in both the Cellole and the Gulf of Gaeta cores. Also in Minturno (C1+C3) a rapid decrease of AP value is seen, though just a little before of other cores. Di Rita et al. (2017) identified this phase as the 2.8 ka climatic event that also coincides with negative values of the NAO index. From the Archaic age to the Late Antique there is a sudden increase in anthropogenic indicators, and alongside the cultivation of cereals (Gulf of Gaeta and Minturno / C1 + C3) the cultivation of *Juglans* (CL1 and Gulf of Gaeta) and *Castanea* (Gulf of Gaeta and Minturno / C1 + C3) begins, and seemingly for the first time in the Gulf of Gaeta the cultivation of legumes is also attested (*Vicia faba* in C1 + C3). Archaeologically too, a massive presence in the Gulf of Gaeta area is attested in this period (4.1.2.1.), although it seems that the forest cover has not suffered a drastic decrease. In Medieval Times, in the Gulf of Gaeta core, there was a sudden lowering of the forest cover. The authors interpret this event as climatic, speaking mainly of two phases: the phase between 800 and 1000 AD, in which a remarkable forest decline, coeval with a decrease in the frequencies of both *Castanea* and *Olea*, matches a shift in the oxygen isotope record towards positive values, indicating cooler temperatures, and a negative NAO; and the phase between 1400 and 1850 AD, corresponding to the LIA (Little Ice Age), when the Gaeta record shows a clear decline of the forest cover, particularly evident after 1550 AD, once again in correspondence with negative NAO index.

In the light of the above, it is felt that although the two phases (800-1000 AD, 1400-1850 AD) may be linked to climatic factors, the anthropogenic component, which seems to be more marked than in the previous period, should not be neglected. In fact, the curve of the

AP seems to remain between 40% and 70%, indicating a semi-open landscape used for agricultural purposes, as evidenced by the attestation not only of the cultivations already started in Roman Times, but also of *Vitis* and from the modern age occurrence of *Olea*.

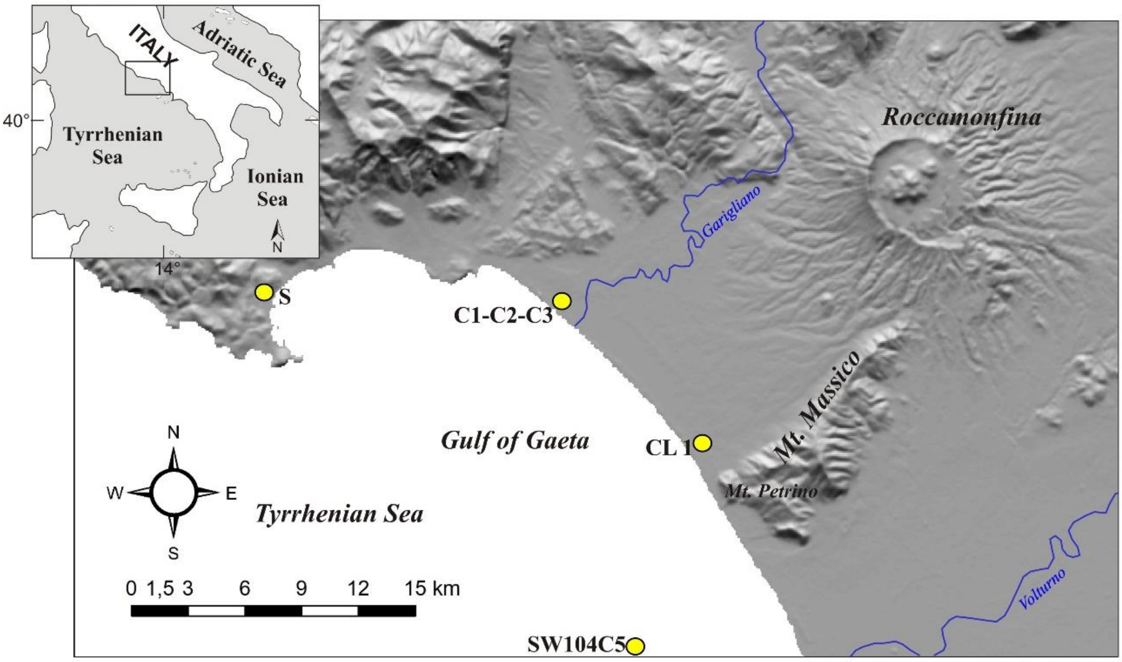

Fig. 32 - Location of cores in the Gaeta Gulf area

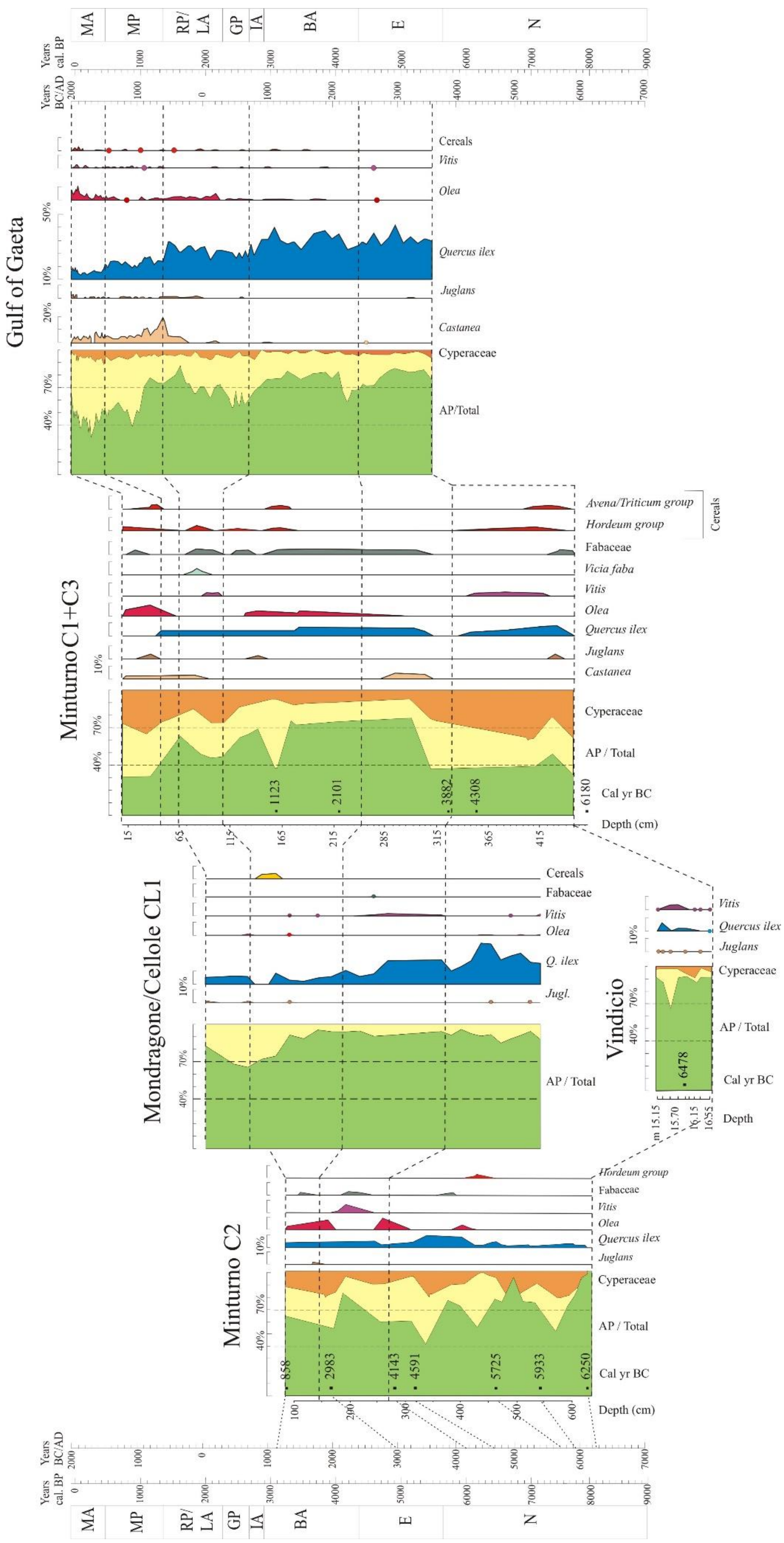

Fig. 33 - Scheme of correlation among pollen data from the Gulf of Gaeta area

6. CASE STUDIES FROM CALABRIA

6.1. Gulf of Sant' Eufemia

6.1.1. *"MSK 12-C4" core stratigraphy*

The marine gravity core MSK-12 C4 (38°46.6090'N-16°10.0070'E) was taken from the outer continental shelf off western Calabria (82 m depth), ~2.6 km NE of Capo Vaticano. The core recovered a stratigraphic succession of 4.18 m beneath the seafloor representing the last ~11.1 ka. The results of micropaleontological, sedimentological, geochemical and tephrostratigraphic analyses have recently been published in Cosentino et al. (2017).

In particular, sedimentological analysis allowed three main facies associations to be identified, including two interbedded tephra layers. From the bottom, they are described as follows (Fig. 34):

- Facies 1 (418 - 260 cm): this consists of poorly sorted sandy-silt with bioclasts and lithoclasts. At 400 cm an erosion surface separates the lower part of the interval, represented by a light grey color from the upper part, characterized by a prevailing dark-grey color. A level of *Posidonia oceanica* remains appears at 294 cm above an erosional surface, at the top of bioclastic debris that includes a thin tephra layer represented by grayish pumice. At 281 and 275 cm, two thin beds of reworked volcaniclasts also appear. A tephra layer was found at 304 – 306 cm (TL1) and was correlated to the Gabellotto-Fiumebianco event of the Lipari volcano, widely dispersed in the Ionian, southern Tyrrenian, and Adriatic seas (Caron et al., 2012), dated to 8554 ± 90 cal BP on a distal marine equivalent (Siani et al., 2004).
- Facies 2 (260 - 200 cm): this is made of relatively homogeneous, bioturbated, very poorly sorted, clayey sandy-silt. An interbedded tephra layer, a few centimeters thick, mostly of white pumices is also evident. Bioturbation is quite diffused across the interval. At 224 – 226 cm a tephra layer associated with the well-known vesuvian Pompeii eruption (AD 79) appears, which is known to have dispersed a large pyroclastic fall towards the south-eastern sector of the volcano (Sacchi et al., 2005).
- Facies 3 (200 cm– top core): this consists of grayish, poorly sorted mud (clayey silt, clayey sandy-silt), with interbedded lenses rich in bioclasts and/or lithoclasts, and volcaniclasts. The sandy fraction is generally fine to very fine grained, consisting of lithoclasts, phyllosilicates and bioclasts, as well as *Posidonia oceanica* remains. Two thin layers constituted only of *Posidonia oceanica* remains are found at 142 cm and 194 cm.

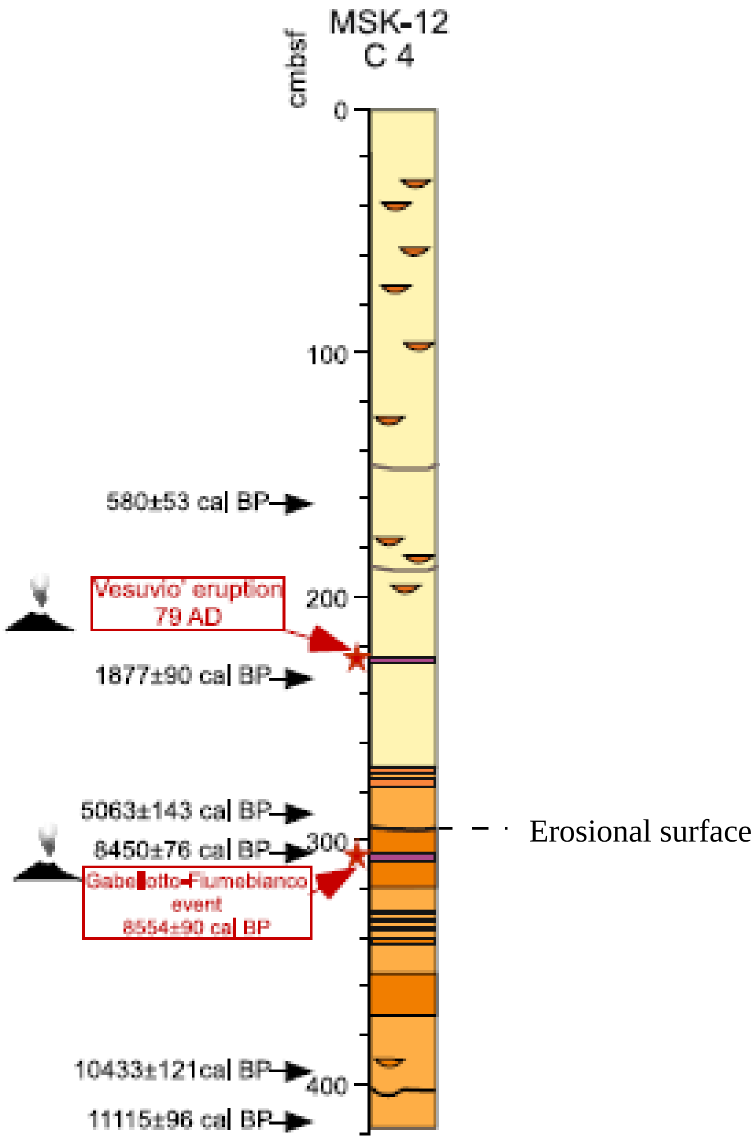

Fig. 34 - Log of core MSK-12 C4 with position of tephra layers and 14C dating (after Cosentino et al., 2017)

6.1.2. ***Pollen diagram***

Pollen analysis was undertaken on 75 silty samples collected from the MSK 12 C4 core down to a depth of 292 cm. All analyzed samples were rich in pollen grains. Pollen sums range from 100 to 351 grains; 72 taxa were identified; concentration values range from 12000 to 7000 grains/gram of sediment. Two main compositional pollen zones were identified in the detailed diagram on the basis of CCA (Pl. 4). The two upper modern samples collected at 6 and 64 cm were excluded from the zonation yet were included in both the discussion paragraph (6.1.5.) and in the palaeoclimate reconstruction, in order to explain some event that occurred during those years:

- Zone 1 (292 cm - 256 cm): This zone is represented by 19 samples. In these layers, tree taxa are essentially represented by dec. *Quercus*, *Quercus ilex*, *Abies* and *Pinus*. In particular, *Quercus ilex* presents lower values between 282 – 284 cm (6%), and higher values at 270 cm (20%), with a light decrease up until 258 cm followed by another increase up until the end of the zone. The percentages of other Mediterranean taxa are very low (c. 1-2%) and are not represented all over the zone. Only the Ericaceae family is well represented, even though the percentages never exceed 5%, with an increase in corrispondence of the *Q. ilex* decrease at 282 – 284 cm.

  With regard to the deciduous forest, dec. *Quercus* is the most representative taxon that seems to possess stable percentages all over the zone (20 - 22%), even though various rapid decreases are evidenced at 288, 284 and 270 cm. Beyond 268 cm a light decrease of dec. *Quercus* is evident, which continues into Zone 2. *Carpinus* has low percentages throughout the zone, though it is interesting that the increase corresponds to the decrease of dec. *Quercus* at 270 cm. All other deciduos elements present low values all along the zone, such as all floodplain elements (less than 1%). *Pinus* percentages are very high all over the zone even though they show a light decrease between 272 and 270 cm. Mountainous forest is well represented by *Abies* that shows high values (reaching a maxium of 20%), even if a decrease is recorded from 270 cm. In general, forest cover (AP) is very abundant in this zone, with values between c. 80% and 90%. *Fagus* shows a progressive increase from 274 cm.

  Concerning the herbs, the Cichoroideae family dominates the assemblages with a value of c. 10 %, with a rapid decrease in the upper part of the zone (272 cm). This family is followed by the Asteroideae and Poaceae families. To underline the presence of cereals at 280 and 260 cm. Other herbs are poorly represented all over the zone, registering low percentages.

  Marsh taxa are mainly represented by the Cyperaceae family, of which only a few are present throughout the entire zone. Monolete and trilete spores are present over all the zone, with fluctuating values and a general decrease between 272 and 270 cm. The Dinoflagellates curve decreases progressively up until the upper part of the zone, reaching values of 30% in the deepest levels (though are absent at 290 cm), with values of 10% in the upper part of the zone.

  Coprophilous fungal spores usually occur with almost stable values (c. 5– 7%), even if they seem to increase in the upper part of the zone. High percentages of microcharcoals are present in almost all the zone, showing three rapid decreases at

286, 282 and 270 cm. It is interesting to note that the first and second microcharcoal decrease take place in correspondence with the increase of dec. *Quercus*, while the third decrease occurs in correspondence with an increase in *Q. ilex*.

- Zone 2 (254 cm – 194 cm): This zone is represented by 31 samples. *Quercus ilex* first shows a decrease in the lower part of the zone (250 – 246 cm), then a light increase, with percentages reaching a peak at 236 and 216 cm (c. 20%). Afterwards it records a constant decrease toward the end of the zone. In correspondence with the *Q. ilex* decrease, a light increase in the Ericaceae family occurs, with some *Pistacia*. To underline a stable presence (with low percentages) of *Olea* between 244 and 230 cm. Other Mediterranean elements show very low values (less than 1%).

  The same trend of the *Q. ilex* curve seems evident also for dec. *Quercus*, though it shows two peaks at 230 (45%) and 224 cm (c. 38%). *Carpinus* remains at constant values throughout the zone, even if it is absent at 246 cm. *Ostrya* seems to be consistently present in the bottom part of the zone up until 224 cm, then it almost disappears from the zone. Other deciduous forest taxa show low percentages and are not representative of this assemblage.

  Concerning Floodplain forest, all taxa seem not to change with respect to the first zone; only *Alnus*, always in low percentages, achieves a light increase in the upper part of the zone.

  Pinus percentages are stable, while *Abies*, which has stable values (10%), achieves a rapid increase in the sample at 220 cm depth. *Fagus* continues to develop in almost all the zone, though its decrease is evident from 206 cm. *Betula* is present as a single grain at 224 and 212 cm. In general, AP curve decreases with respect to Zone 1, in the deep part of Zone 2 until around 242 cm, then it starts to develop stablishing its value at 80%, while in the upper part of the diagram (202 cm) a rapid decrease is recorded, reaching values of c. 58% in the uppermost sample.

  Concerning herbs, the opposite trend of the Cichoroideae and Asteroideae curves with respect to the AP percentages is very significant. Other herb values do not seem to change with respect to Zone 1, even if cereals (always in low percentages) are almost constantly present in all the zone.

  Marsh assemblage is consistently dominated by the Cyperaceae, which show fluctuating values even if they are not really representative due to the very low values.

Monolete spores show stable values all along the zone, while trilete spores register a progressive increase, reaching c. 42% in the upper part of the zone. Moreover, up until 232 cm coprophilous fungi are stable, then they show a rapid increase (230 cm) followed by a progressive decrease interrupted by two peaks at 220 and between 202 - 200 cm. Percentages of dinoflagellates are stable, while microcharcoal values fluctuate more, even if they show a general increase with respect to Zone 1.

- Zone 3 (192 cm – 122 cm): This zone is represented by 21 samples. Here *Q. ilex* continues its progressive decrease while *Olea* seems to confirm its presence all along the zone. Also other Mediterranean taxa seem to progressively appear, such as *Cistus*, which is very poorly represented in other zones. Ericaceae do not seem to change their percentage with respect to Zone 2 even if they seem to disappear in the upper sample. Dec. *Quercus* continues its decrease, with a rapid increase only at 160 cm depth. Other deciduous taxa are very poorly represented, such as also all floodplain forest elements. *Pinus* maintains constant values, while *Abies* almost disappears in this zone followed by *Fagus*. AP percentages show a progressive decrease reaching the lowest value of all the diagram at 130 cm (40%). On the contrary, the most representative herbs (Poaceae, Cichorioideae and Asteroideae) increase progressively. Cereals are always present in low percentages. With regard to marsh taxa, only the Cyperaceae family is representative of this assemblage with an increase at 130 cm. Trilete spores and coprophilous fungi seem to increase in this zone while monolete spores mantain the same value as in Zone 2. Concerning microcharcoal, in the lower part of the zone they are usually abundant (c. 85%), while from 140 cm they reach a lower percentage.

Mediterranean forest	*Quercus ilex*, *Olea*, *Forsytia*, *Phillyrea*, *Pistacia*, *Cistus*, *Ziziphus*, *Coriaria mirtifolia*, Ericaceae, *Tamarix*, *Ficus*	
Deciduous forest	*Quercus*, *Carpinus*, *Ostrya*, *Tilia*, *Acer*, *Ulmus*, *Fraxinus ornus*, *Hedera*, *Platanus*, *Castanea*	
Floodplain forest	*Alnus*, *Corylus*, *Juglans*, *Populus*, *Fraxinus*, *Salix*, *Vitis*	
Pinus	*Pinus* spp	
Montane forest	*Abies*, *Fagus*, *Betula*	
Herbs	Poaceae, Amaranthaceae, Caryophyllaceae, *Paronychia*, Dipsacaceae, Scrofulariaceae, *Asphodelus*, *Limonium*, *Convolvulus*, *Helianthemum*, *Polygonum*, *Geranium*, *Rhamnus*, *Hypecoum*, *Ribes*, *Ephedra*, Liliaceae, *Erodium*, *Prunus*, Rosaceae, *Symphytum*, *Knautia*, Resedaceae	
Anthropogenic herbs	Cereals	Cultivation
	Rumex, *Plantago*, *Urtica pilulifera*, Urticaceae, Lamiaceae, Apiaceae, Brassicaceae, *Mercurialis*, *Artemisia*	Ruderal taxa
	Cichorioideae, Asteroideae, Ranunculaceae, Fabaceae	Grazing
Coprophilous fungi	Various sp.	
Marsh/Water plants	Cyperaceae, *Typha*, *Lythrum*	

Tab. 13 - Composition of taxa groups as plotted in the pollen diagram

6.1.3. Chronological model

The chronological framework of MSK 12 C4 core is based on six radiocarbon analyses (Cosentino et al., 2017) and tefrostratigraphic correlation of the two identified tephra layers (TL1 and TL2). Radiocarbon analysis indicates that the age of the cored succession spans from 11.1 ka to the present.

The part of the core studied through pollen analysis starts from about 5243 BP up until present, and the radiometric ages obtained in this portion of the core are summarized in Tab. 14 The apparent sedimentation rates resulting from the age-depth model show a sudden increase from c. 200 cm (Fig. 35).

cm	**^{14}C age (BP)**	**1 σ (>)**	**1 σ (<)**	**Middle value 1 σ**	**2σ (>)**	**2 σ (<)**	**Middle value 2 σ**	**Cal Age BP (1± σ)**	**Cal Age BP (2± σ)**
160-162	994	612	549	580.5	633	527	580	580.5	580
226-228	2194	1840	1740	1790	1877	1687	1787	1790	1787
288-290	4777	5082	4960	5021	5206	4920	5063	5021	5063

Tab. 14 - Age of the14C dated samples

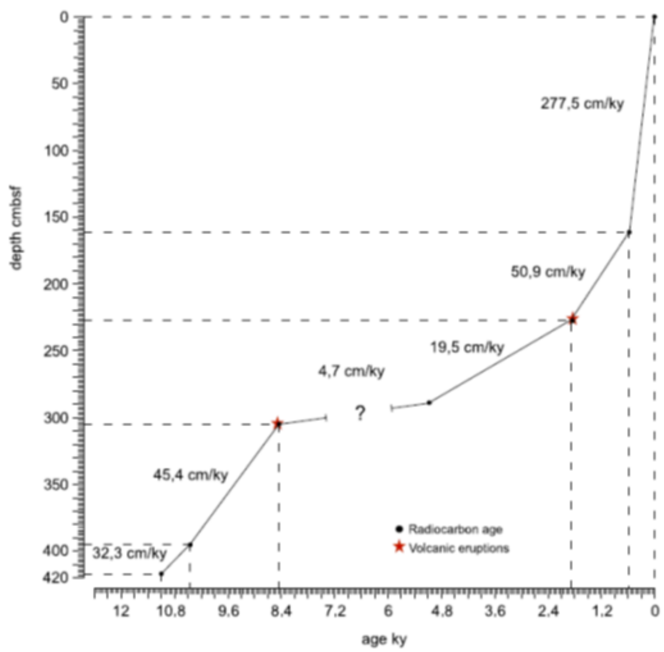

Fig. 35 - Age-depth profile for core MSK-12 C4 (after Cosentino et al., 2017)

*6.1.4. **Palaeoclimate reconstruction***

From c. 5000 BP (late phase of Middle Holocene) until c. 4200 BP, palaeoclimate curves (Fig. 36) show high humidity and low temperatures. Afterwords, during the Late Holocene (4200 BP - present), curves indicate the beginning of a warm/arid phase interrupted by a very marked cold/wet event occurred between 2500 and 2400 BP, then the aridification trend become very significative mainly from 1100 BP.

Moreover, results suggest several abrupt climatic events depicted along the entire sequence, these events are listed below:

Between c. 5050 and 4600 BP, a cold/wet phase is reconstructed with a progressive temperature decrease and high precipitation that reach respectively lower and higher values at 4600 BP (TANN: 7°C; PANN: ca. 925 mm/yr). After this event, an arid phase occurs, characterized by a rapid temperature increase and a drastic decrease in precipitation at around 4550 BP (TANN: 13.5°C; PANN: c. 675 mm/yr). A cold/wet event occurs at 4200, followed by a warm/arid period between 4100 and 3900 BP, then another cold/wet event at 3800 BP. During the arid trend recognized in the Late Holocene, a cold rapid event occurred at c. 3150 BP. Afterwords, climate conditions became relatively stable with the occurrence of three marked cold/wet events at 2500 – 2400 BP, c. 1400 BP and c. 750 BP. Reconstruction was not carried out for the most recent levels due to the overwhelming anthropic influence that makes results unreliable.

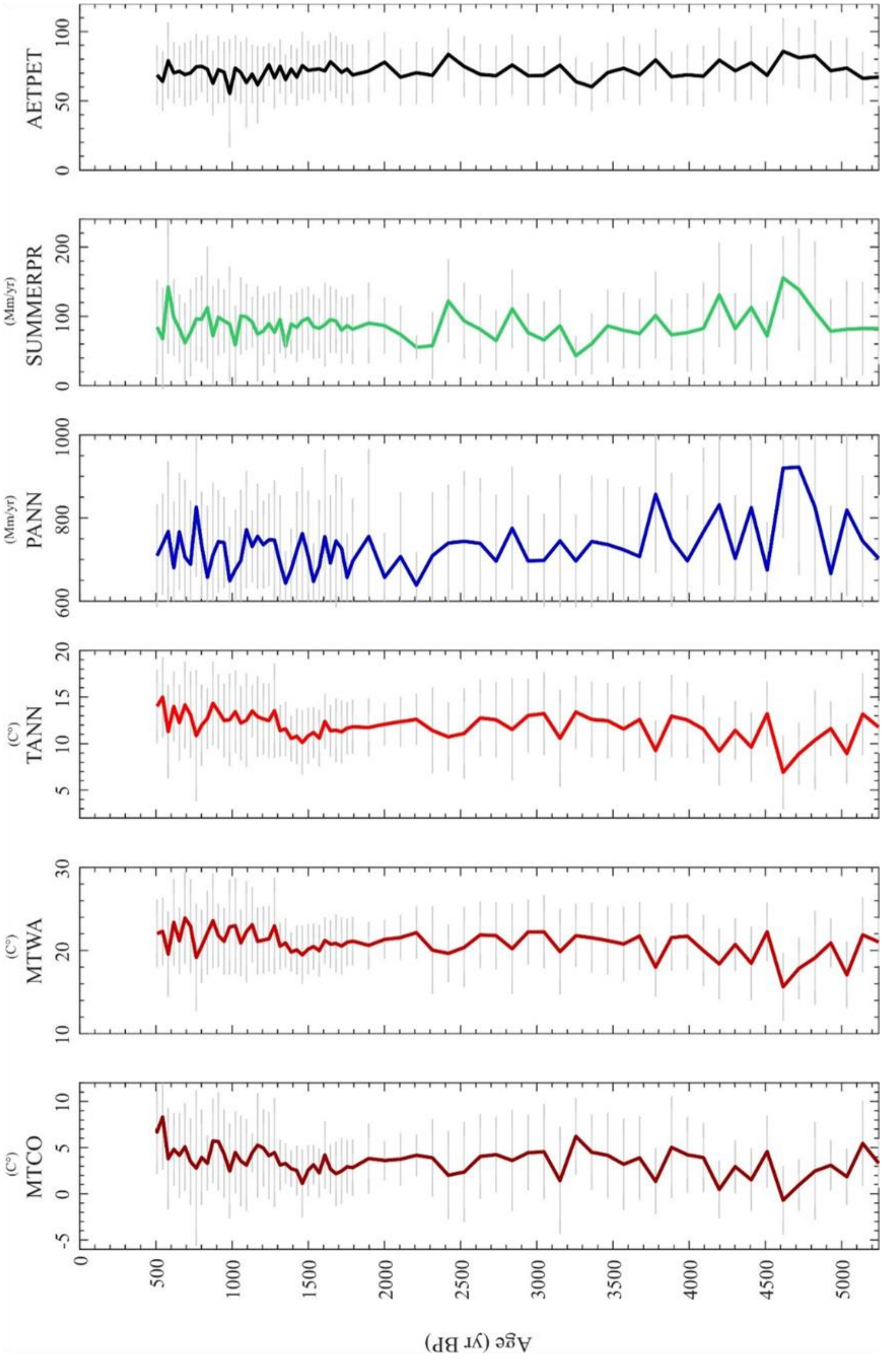

Fig. 36 - Pollen based climate reconstructions for MSK/12C4 core

6.1.5. ***Discussion***

The synthetic diagram (Fig. 37) has been constructed on the basis of the chronological model shown in the previous paragraph.

What is notable in the pollen record of Sant'Eufemia is that during the entire Eneolithic period the forest cover is very dense, indicating a mostly closed landscape. Nevertheless, it is possible to see some short and slight variations in the AP percentages, sometimes due to climatic events and sometimes to human impact. The diagram in fact shows forest cover lowerings during the Middle Eneolithic (c. 5100 BP) and Late Eneolithic (4600 BP).

In general, during the Late Eneolithic (advanced stage of Laterza facies - appearance of San Fili), Final Eneolithic (Zungri facies) and the transition between Eneolithic and Bronze Age (4450 - 4290 BP) many sites are attested on the Poro Plateau (Pacciarelli, 2001), testified by the presence of cereals in the Sant’Eufemia diagram such as also attested in the Lacco core analyzed in this work (se chapter 6.2.2.). Climatic parameters in the same period show a general cool/humid phase, also attested by large amounts of *Abies*. In sum, it is possible to link the light decrease of the AP curve to a large exploitation of the Poro Plateau and terraces surrounding it for agricultural and grazing practices, rather than to a climate shift towards aridity.

At around 4000 BP, the pollen diagram registers a general decrease in forest cover and in particular of *Abies*, testifying to an arid phase, in agreement to pollen data from Lake Trifoglietti (Joannin et al., 2012). To corroborate this climatic shift, it is interesting to note the first small peak of *Olea*, which is a good aridity indicator. Also the paleoclimate curve suggests the occurence of a climatic change that could be linked to the 4.2 ka event in its tripartite model (cold/wet phase at 4200, warm/arid phase between 4100 and 3900 BP, cold/wet event at 3800 BP). There are not many attestations on the Poro Plateau at this moment (4100 - 3800 BP), due to the difficulty in recognizing facies peculiarities in the pottery assemblage of this period. Nevertheless, the recent discoveries of Punta di Zambrone, on the coast, allow us to hypothesize that the Tropea Promontory was attended.

The presence of *Olea* also emerges from the Fontana Manca pollen sequence (Sevink et al., 2019) located on the Ionian coast of Calabria. The issue of early forms of olive utilization in some Italian contexts is widely debated. The data currently available on anthracological and carpological analysis do not allow us to have a clear idea on the olive nature (wild/crops), also because all data are limited to a few specific archaeological contexts belonging to a specific chronological period. Moreover, seeds and charcoal represent partial data mainly showing the taxa chosen by man for their physical and technological qualities, but not appropriate for palaeolandscape reconstruction. In this regard, the Sant'Eufemia diagram gives us a diachronic view of the *Olea* evolution in its natural context (Mediterranean forest). Starting from direct comparisons with our reference area (Gulf of Sant'Eufemia), paleobotanical data are currently available from Punta di Zambrone, where large quantity of *Olea* wood and little evidence of *Q. ilex* from Early Bronze Age levels were interpreted as the evidence of cultivation (D'Auria et al., 2017).

Climatic curves from the Sant'Eufemia sequence indicate a warm/arid phase between 4100 and 3900 BP characterized by a drastic *Abies* decline but a substantial stability or rise of other forest types. In the Mediterranean forest, the presence of wild olive is generally scarce, being limited to coastal rocky slopes. In this regard, according to D'Auria et al. (2017), the Punta di Zambrone community certainly had wide availability and easy accessibility of *Olea* in the surroundings, which could be explained with the use of pruned branches for firewood[57]. This opens up different hypothesis concerning the use of *Olea* in this period in the Sant'Eufemia area. Olive expansion was favored by aridity and thus it was simply used by the inhabitants of Punta di Zambrone settlement and/or they started a first form of domestication, as suggested by D'Auria et al. (2017).

Between c. 3500 and c. 2500 BP, AP% fluctuates around 70%, a gradual decline in the deciduous and Mediterranean forest cover is coupled with an increase in herbs and pines, while *Abies*, after a first recovery at the end of the Early Bronze Age, begins its progressive and continuous descent.

At the end of Middle Bronze Age, there was a sharp decline in the Mediterranean forest with a consequent decline in the forest cover. Compared to the past, there is an evolution and a change in the settlement forms; in fact, during the Middle Bronze 3 archaeological evidence suggests the presence of "microdistricts" formed by smaller centers belonging to larger settlements such as Briatico Vecchio and Tropea (Pacciarelli, 2017 and references therein). Moreover, the formation of an emerging class, as evidenced by the Gallo di Briatico findings, occurred. The development of those offshore centers in a defensible position can be interpreted as the consequence of a politically tense period (Pacciarelli, 2017 and references therein). The change of landscape in this period could suggest an intensive exploitation of Mediterranean taxa. In fact, few settlements from the Middle Bronze Age 3 were found not far from the coast, where probably the elements of the Mediterranean forest were more easily recovered. The opening up of the landscape for both agricultural and pastoral purposes is

[57] The existence of pruning practices to stimulate the production of better fruits would be further supportive evidence for cultivation (Asouti, 2003; D'Auria et al., 2017).

also suggested by an increase in coprophilous fungi and a more constant presence of cereals[58].
At the transition Middle Bronze Age - Recent Bronze Age, the presence of *Olea* is attested again in a period of general recovery of the Mediterranean forest. Also at Bagnara Calabra, in the San Sebastiano cave, charcoal analysis documented an increase in evergreen *Quercus* for the Middle Bronze Age 3 in opposition to a sharp decline in *Olea* (Martinelli et al., 2004). This new expansion of the Mediterranean forest and the slight decrease of the other forest assemblages is not by chance, as in the Recent Bronze Age there is a repopulation of the Poro Plateau, suggesting the exploitation of wooded resources coming from different altitudes.
During the Recent Bronze Age, at around 3100 BP, climatic curves record a cold event and the pollen diagram shows the first decrease of forest cover below 70%. Moreover, it is evident the progressive increase of *Fagus* with respect to *Abies* that continues its decrease. Perhaps this change in composition of mountain forest is linked to a general climatic aridification which has made beech more competitive with respect to *Abies*. Archaeologically, during this period, it is possible to hypothisize a general territorial reorganization with settlements merging forming “macrodistricts” (sensu Pacciarelli, 2017) during the development of Subappennine culture. In fact, almost all settlements were abandoned, and numerous new settlements of the Subapennine facies were implanted both on coastal (Punta di Zambrone) and inland defended positions, as well as on the open landscape of the Poro Plateau (Pacciarelli, 2001, 2017; Jung et al., 2015).
Olea pollen is not recorded during this period, as its anthracoremains in the Punta di Zambrone Recent Bronze Age levels (D’Auria et al., 2017), while the occurrence of cereals seem to be continuous such as that testified by Punta di Zambrone carporemains which show high amounts of cereals (*Hordeum vulgare, Triticum monococcum* and *dicoccum, Panicum miliaceum* – Jung et al., 2015)[59]. In the same period, olive is attested close to the Ionian coast at Broglio di Trebisacce (Nisbet and Ventura, 1994; Celant, 2002) and in Torre Mordillo (Coubray, 2001).
D’Auria et al. (2017) explain the absence of *Olea* at Zambrone with the advent of different economic bases and agronomic knowledge of the Subappennine culture. This is also supported by the appearance in the Recent Bronze Age of broomcorn millet (*Panicum*

[58] Cereals of the genus *Triticum* and *Hordeum* were also found in the Broglio di Trebisacce Middle Bronze Age levels (Nisbet and Ventura, 1994).
[59]Also at Torre Mordillo in Bronze Age levels, seeds of *Hordeum vulgare*, *Hordeum* sp., *Triticum dicoccum* and *Triticum* sp. have been found (Coubray, 2001).

miliaceum L.), absent in the previous phases (Jung et al., 2015). This cereal is very tolerant to adverse climatic conditions, suggesting that the different agronomic framework was probably developed to deal with a temporary climate crisis. In support of this, climate curves show a decrease in temperatures at c. 3100 during a period of general lower precipitations.

In the Final Bronze Age, due to a process of settlement merging, only Tropea and Mesiano Vecchio survived in the Tropea Promontory, with other scattered finds at Crista di Zungri and Torre Galli, while a new form of territory organization during the Iron Age is recognizable with the development of the Torre Galli settlement as a strategic center founded around 950-900 BC for territorial control (Pacciarelli, 2017 and references therein). Pollen data for this period do not show relevant changes with respect to the previous period, apart from a small peak of *Abies* that could be linked to human impact as suggested by an increase of fire practice (microcharcoal percentages).

Starting from the Iron Age, a rapid increase in the forest cover, in particular of the deciduous forest (dec. *Quercus*) is recorded, as in the Lamezia diagram (Russo Ermolli et al., 2018). This new structure of the forest cover will remain unchanged until 1400 BP (Early Middle Age). In 2500 BP, during the Greek period, a new cold/wet event (2500-2400) is registered in climate curves.

Despite the development of the deciduous forest, the continuous presence of cereals and a progressive increase in microcharcoals allow us to hypothisize a continuous exploitation of the land, and that therefore this new forest development is linked to a climatic stabilization with average temperatures that have allowed the development of the deciduous forest.

After all, as archaeologically attested, the foundation of Hipponion and Medma, with which the exploitation of the fertile Poro Plateau became very intensive, favored the development of small coastal towns such as Nicotera and Tropea, of which Diodoro Siculo (XXI 8) spoke.

In the time range from 1700 to 1400 BP, deciduous and Mediterranean forest start to decline but the contemporary increase in *Abies* and then *Pinus* makes the AP% curve stable.

At the same time apparent sedimentation rates start to increase (as can be seen from the contraction of the distance between samples), as also evidenced by the presence of sand lenses (Cosentino et al., 2017). Also the progressive increase in spores suggests the beginning of a phase of abundant fluvial intake and flood events. Thus, deforestation induced enhanced soil erosion and detrital arrivals to the sea through fluvial disharges. In support of this evidence, a further slight progradation of the coastline (around 300 m) and the increase in fluvial discharge in the Lamezia Plain is testified by the development of superimposed

alluvial fans, which caused the burial of Terina and of the Acconia Roman villa during the Late Antique-Early Medieval period (Russo Ermolli et al., 2018).
That the alteration of slopes morphodynamics was enhanced by climate instabilities (Russo Ermolli et al., 2018) seems supported by the climatic curves that, starting from 1600 BP, register a phase of change and in particular an aridification trend that seems to be quite accentuated in the period between 1700 and 1400 BP (Late Ancient). Globally, the dry/cold Bond 1event is placed in this period (1400 BP) and is widely recognized that during this event a general environmental degradation occurred. In fact, large archaeological and literary sources confirm a period of dramatic instability during the Late Antique period, such as the floods of Velia (Russo Ermolli et al., 2013) and the significant coastline progradation of Neapolis (Russo Ermolli et al., 2013, 2014) in South Italy. These phenomena could be linked to the synergic action of a worsening climate (Antonioli et al., 2000) and to the collapse of territorial management following the end of the Western Roman Empire (Antonioli et al., 2000; Russo Ermolli et al., 2014).
The AP curve continues to rapidly decrease, reaching values around 50% (open landscape - sensu Favre et al., 2008). At the same time, the percentages of microcharcoals also rise, certainly indicating a deforestation process, which is implemented since the Early Middle Age.
Despite the scarse archaeological evidence for this time interval, several historical sources testify to the intensive exploitation of wood resources from Calabria. The Lombard dominion had a negative influence on the exploitation of the Sila, Mancuso and Reventino mountains, and by concession of the Lombard rulers, this territory was used by the Pope for the Patrimonium Sancti Petri. Gregorio Magno (Registrum Epistularum) in AD 599 wrote about the trade of timber from Valentia to Rome for the construction of San Pietro (Sogliani, 2012; Russo Ermolli et al., 2018).
As far as possible crops are concerned, what emerges from the Late Ancient and Early Middle Age is the constant presence of cereal crops and above all of *Olea*. This happens in a period of general decrease of *Q. ilex*, testifying to the cultivation of this taxon, that will show large amounts in the last sample dated to the modern age. The beginning of intensive *Olea* cultivation chronologically corresponds to that attested in the core of Lamezia (Russo Ermolli et al., 2018).
Other data coming from the territory show the olive tree cultivation in the Middle Ages. For example, pollen analyses carried out on some sediment samples taken during the archaeological excavations of the Bishop's Palace at Tropea (Caramiello and Zeme, 1994),

although in an unclear manner, attest olive crops from the 9th cent. AD. Moreover, pollen data from the Laos Archeological Park allowed the identification of a cultivated landscape, mainly with olive trees, in the same period (Amato et al., 2012b).

Concerning *Juglans*, its percentages began to increase from the Roman Imperial period onwards, testifying to a probable first form of cultivation that seems to emerge more timidly in the Lamezia sequence. In addition, at Canolo Nuovo (Shneider, 1985) there is an increase in *Olea*, *Juglans*, *Castanea* and cereals, presumably starting in the Roman Age with an intensive cultivation starting from the Medieval Ages.

Climate curves show two cold/wet events at 1400 and 750 BP. The first event could be associated with the lake level increases of Lake Accesa that occurred at around 1400-1200 BP (Magny et al., 2007), together with glacial advances in the Alpine and Apennine glaciers (Giraudi et al., 2011).

In general, it is very intersting to note the continuous decline of *Abies* until its almost complete disappearance in the upper part of the diagram, indicating the transition from a purely wet phase in the Middle Holocene to a milder and drier climatic phase in the Late Holocene, as evidenced also by the general trend of the climatic curves and mainly by the increase of steppe elements.

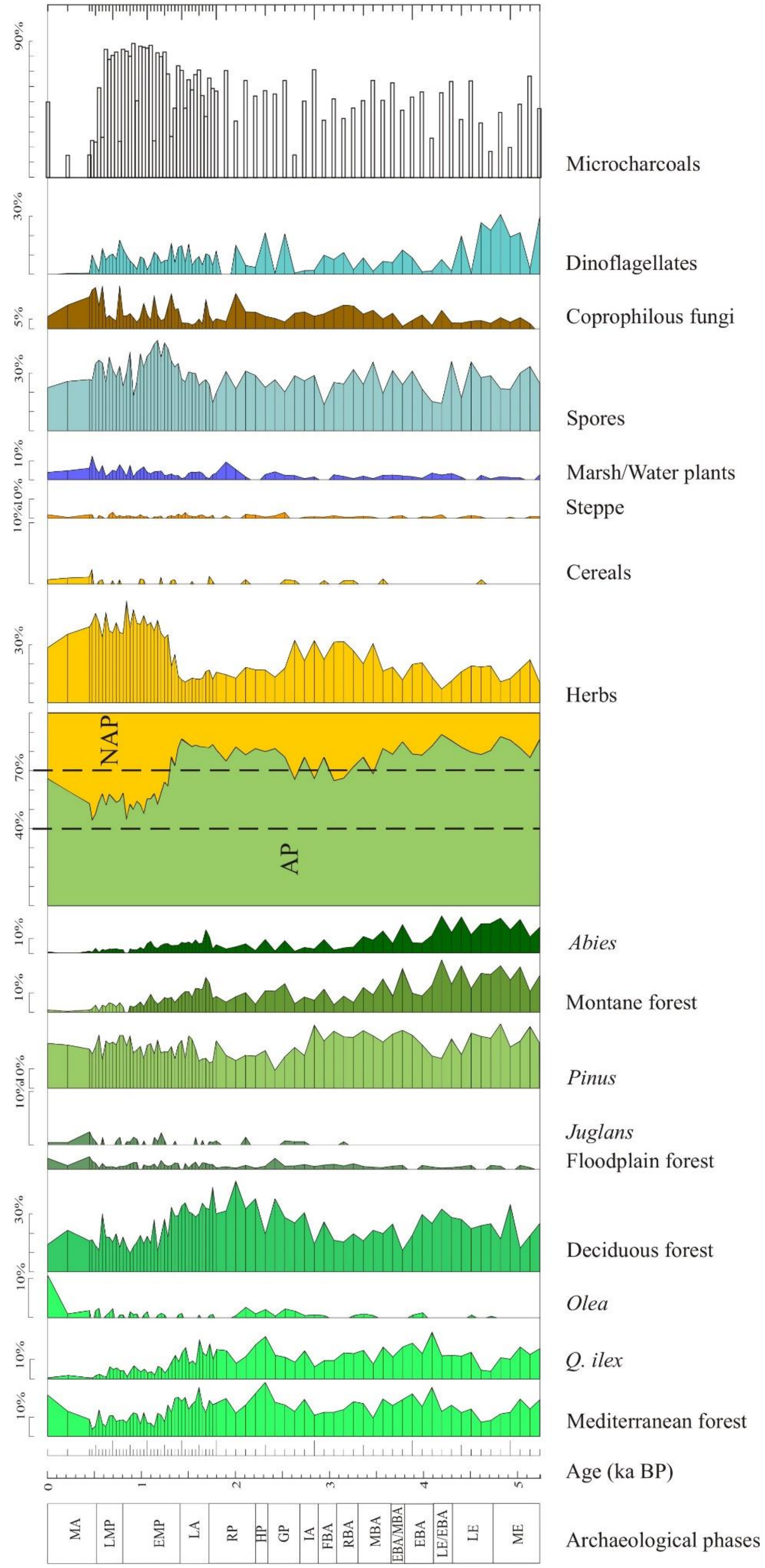

Fig. 37 – Synthetic pollen diagram of MSK12-C4 core plotted against age.

6.2. **Lacco**

6.2.1. Core stratigraphy

A 2.40 m-core was drilled at 554 m a.s.l. on top of the Tropea Promontory (Lacco core in Fig. 1), a site rich in archeological evidence dated from the Eneolithic up to the Iron Age. The site was selected on the basis of a previous study (Lo Torto et al., 2011) highlighting the occurrence of buried layers rich in Eneolithic pottery in the Passo Murato locality. The coring, realized in 2015 with a small piston corer, 5 cm in diameter, intercepted a peat deposit (from 1.10 to 2.25 m depth), covering the pre-Quaternary substratum (Fig. 38), whose base likely corresponds to the levels analyzed by Lo Torto et al. (2011).

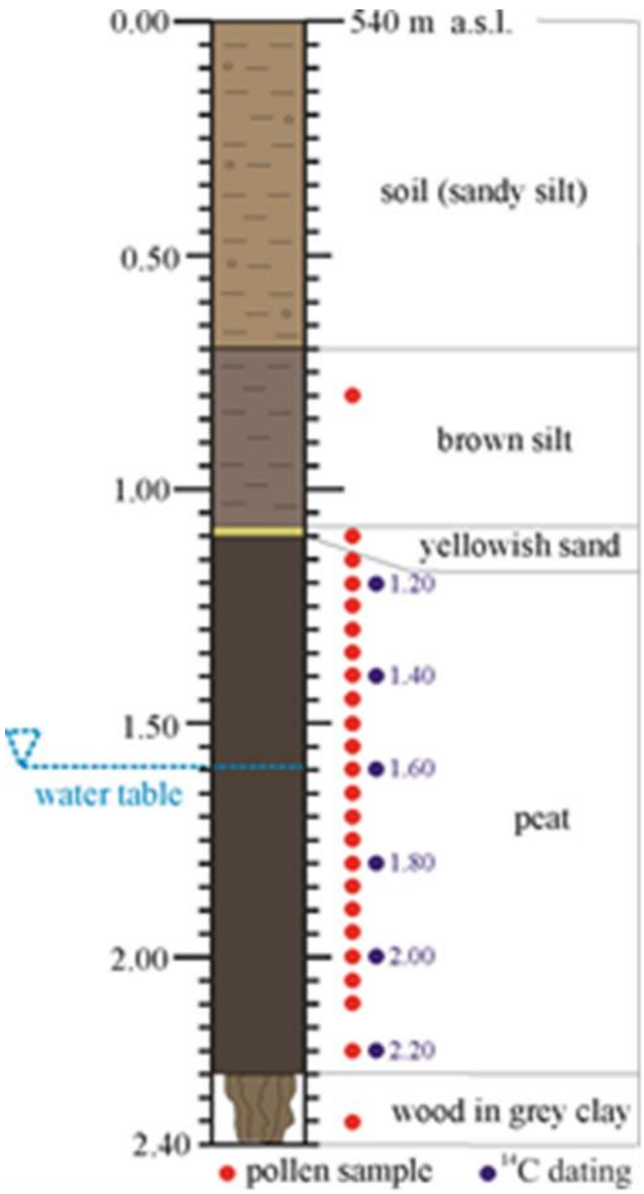

Fig. 38 - Lacco core log with position of pollen and 14C samples.

6.2.2. Pollen diagram

Pollen analysis was undertaken on 24 peat samples collected from the Lacco core as indicated in Fig. 38.

At the left-hand side of the diagram, the arboreal taxa are grouped on the basis of their ecological affinities (Tab. 14): Mediterranean trees and shrubs, deciduous forest elements, montane forest elements and floodplain taxa. At the right-hand side of the diagram, different groups of herbs and spores, as well as microcharcoals are indicated. The area chart in the mid of the diagram shows the total AP and NAP amounts.

Almost all analyzed samples resulted rich, apart from those at 0.80, 2.10 and 2.40 m depth, which proved barren. Pollen sums range from 309 to 1590 grains; 68 taxa were recognized; concentration values range from 75.000 to 740.000 grains/gram of sediment.

Three main compositional pollen zones were identified in the detailed diagram on the basis of CCA (Pl. 5):

- Zone 1 (220 cm -170 cm): This zone is represented by nine samples. In these layers, the tree taxa are essentially represented by deciduous *Quercus*, a significant presence of *Alnus* being only recorded in the deepest sample. Overall the zone, the Mediterranean taxa (*Quercus ilex*, Ericaecae and Oleaceae) and the montane elements (*Abies* and *Fagus*) show very low values. In general, the forest cover values are mainly below 40%, suggesting an open landscape. Concerning the herbs, Poaceae always dominate the assemblages followed by Lamiaceae, which display a percentage over 10% in the lowest layer and stabilizes around 4% in the other samples. Other herbs are present overall the zone in low but constant amounts, to be highlighted the continuous occurrence of Cereal type. The marsh taxa are dominated by Cyperaceae, showing an increase (above 10%) towards the top of the zone. The development of Cyperaceae, *Typha* and aquatic plants indicates marshy conditions. Microcharcoals are present in high percentages overall the zone and show two peaks at 190 and 170 cm depth. Trilete spores have low values, except for a peak over 10% at 190 cm. Coprophilous fungal spores are very abundant all along the zone.
- Zone 2 (165 cm – 125 cm): This zone is represented by eight samples. The Mediterranean elements do not show significant variations and small amounts of montane elements are recorded all along the zone. Deciduous *Quercus* exhibits an increase in the middle part of the zone and a slight decrease at the top, whereas other deciduous forest taxa are constant. The percentage of Cyperaceae notably rises and then drastically decreases towards the upper part of the zone. The middle part of the

zone is indicative of more closed environmental conditions, as testified by the increase in *Quercus* percentage coupled with a decline of Poaceae. To be underlined a peak of Fabaceae (cfr. *Trifolium patens*) at 160 cm depth. Microcharcoal percentage fluctuates with a slight peak at 155 cm and a relevant peak at 130 cm depth. Trilete spores are abundant overall the zone as well as the Coprophilous fungal spores despite their percentage inflection at 140 and 145 cm depth.

- Zone 3 (120 cm – 110 cm): three samples are included in this zone. Tree taxa are dominated by *Alnus.* The data indicate a drastic decrease in *Quercus ilex* and deciduous *Quercus*, even if some undergrowth taxa of the deciduous forest, such as *Ilex* and *Hedera*, show a slight increase. Concerning the herbs, a radical lowering of Poaceae and Cyperaceae is recorded, whereas other NAPs keep their values low as in the previous zones. The Trilete spore curve shows a decrease and the Microcharcoal percentage is relevant only in the topmost sample. Coprophilous fungal spores are only present in the lowest sample and Monolete spores show a drastic increase in this zone with respect to the previous ones.

<table>
<tr><td>Mediterranean forest</td><td>Quercus ilex, Olea, Phillyrea, Ligustrum, Jasminum, Pistacia, Cistus, Ericaceae</td><td></td></tr>
<tr><td>Deciduous forest</td><td>Quercus, Carpinus, Ostrya, Acer, Ulmus, Tilia, Ilex, Hedera, Castanea</td><td></td></tr>
<tr><td>Floodplain forest</td><td>Alnus, Corylus, Vitis, Fraxinus, Salix, Populus, Juglans</td><td></td></tr>
<tr><td>Pinus</td><td>Pinus spp</td><td></td></tr>
<tr><td>Montane forest</td><td>Abies, Betula, Fagus</td><td></td></tr>
<tr><td>Herbs</td><td>Poaceae, Amaranthaceae, Caryophyllaceae, Paronychia, Scrofulariaceae, Rosaceae, Armeria, Ephedra, Iridaceae, Asphodelus, Epilobium, Amaryllidaceae, Ribes, Knautia, Boraginaceae, Symphytum, Liliaceae</td><td></td></tr>
<tr><td rowspan="3">Anthropogenic herbs</td><td>Cereal type</td><td>Cultivation</td></tr>
<tr><td>Rumex, Plantago, Urticaceae, Theligonum, Lamiaceae, Apiaceae, Brassicaceae, Campanulaceae, Mercurialis, Artemisia</td><td>Ruderal taxa</td></tr>
<tr><td>Cichorioideae, Asteroideae, Ranunculaceae, Fabaceae - Trifolium type</td><td rowspan="2">Grazing</td></tr>
<tr><td>Coprophilous fungi</td><td>Sporomiella type, Sordaria type, Sordariaceous ascospores, Podospora, Delitshia, Cercophora, Coniochaetaceae</td></tr>
<tr><td>Marsh/Water plants</td><td>Cyperaceae, Typha, Lythrum, Myriophyllum</td><td></td></tr>
</table>

Tab. 15 - Composition of taxa groups as plotted in the pollen diagram

6.2.3. *Chronological model*

Six radiocarbon dating were carried out at the REM laboratory of Mannheim. The dated levels consist in bulk samples collected along the peat interval each 20 cm (Fig. 39). The results of ^{14}C dating are shown in Tab. 16.

Lab. Code	**Sample (cm)**	**Radiocarbon age**	**±**	**Calib. BP 1 sigma**	**Calib. BP 2 sigma**	**Median probability BP**	**Calib. BC 1 sigma**	**Calib. BC 2 sigma**	**Median probability BC**
23752	120	2910	24	2996 - 3077	2963 - 3082	**3045**	1128 - 1047	1133 - 1014	**1096**
34513	140	3496	25	3722 - 3783	3696 - 3839	**3769**	1834 - 1773	1890 - 1747	**1820**
34514	160	3657	25	3926 - 4071	3898 - 4011	**3978**	2122 - 1977	2062 - 1949	**2029**
34515	180	3864	25	4239 - 4299	4228 - 4411	**4296**	2405 - 2290	2462 - 2279	**2347**
34516	200	3973	27	4417 - 4511	4405 - 4523	**4451**	2562 - 2468	2574 - 2456	**2502**
34517	220	4378	25	4878 - 4943	4862 - 4979	**4930**	2994 - 2929	3030 - 2913	**2981**

Tab. 16 - 14C age BP and BC of the Lacco core samples.

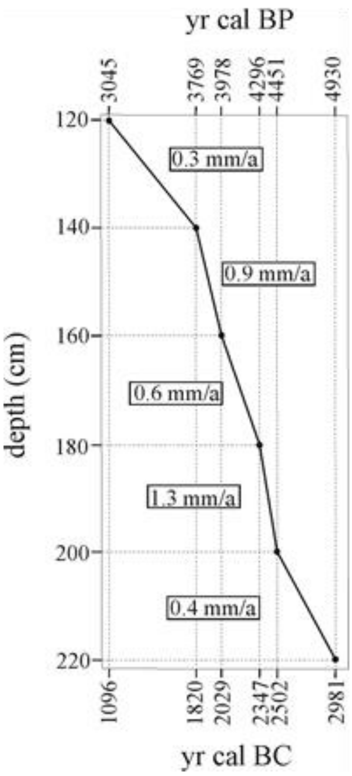

Fig. 39 - Age/depth model with apparent sedimentation rates

6.2.4. Discussion

The analyzed sequence represents the peaty infilling of a small marshy depression set on the Poro Plateau, at the top of the catchment of a small stream that flows into the Tyrrhenian Sea just north of Capo Vaticano. The upland position of the marsh, not submitted to intense washing from the surrounding flat territory, implies that the infilling is largely composed of organic material issue of the vegetation growing around the marsh. Therefore, the pollen content of such deposit reflects the composition of the closely surrounding vegetation plus a minor wind-blown amount from farer distances. This kind of deposit, characterized by very low apparent sedimentation rates, gave rise to a condensate peaty succession of ca. 1 meter. On the basis of ^{14}C ages (Tab. 16), it is possible to state that the marsh lasted about 3000 years, from the Eneolithic up to the Iron Age.

The interpretation of the vegetation cover changes recorded along the succession have to consider both the natural evolution of the marsh and the impact of climatic and/or anthropic action.

6.2.4.1.The natural evolution of the marsh

Marshes naturally tend to be infilled and to close after a certain period, depending on their extension and nature of the inputs. To understand which was the natural evolution of the small Lacco marsh, we have to look at the plants that are more influenced by the wet environments and the shallow water table, certainly present in the surrounding of the core site. Looking at pollen data, we can consider two main groups of taxa as surely influenced by such environments: the marsh/water taxa and the floodplain forest taxa. The first group represents the plants (mainly Cyperaceae) growing within the swamp and around its shores, the second group includes elements, such as *Alnus*, well adapted to the wet soils surrounding the swamp.

With the aim of better visualizing the mutual relationship between these two groups of taxa, a chart was computed (Fig. 40) by including the marsh/water plants in the AP+NAP sum in order to evaluate the contribution of such "environment" taxa in the NAP group and the consequent influence on the AP percentages.

From 220 to 165 cm depth, we can hypothesize that the marsh reaches its maximum extension, the marsh/water plants, colonizing the shores, are well represented in the pollen diagram, being among the main pollen taxa reaching the core site. On the contrary, the floodplain taxa show low amounts, due to their relative far distance from the core site. Starting from 165 and up to 140 cm depth, marsh/water plants considerably increase their pollen amounts, indicating the approaching of the shores to the pollen site: the marsh is contracting. From that moment we witness the constant increase in floodplain taxa (mainly *Alnus*), culminating at 115 cm, in concurrence with the decrease in marsh/water taxa. These results likely indicate a further contraction and final closure of the marsh, which led to the rapid development of an alder forest on the wet soils. Not by chance, the last peat levels show the lowest apparent sedimentation rates of the entire sequence (Fig. 39), being reduced the water table and the accommodation space, as well as the input of plant remains from the disappearing marsh environment.

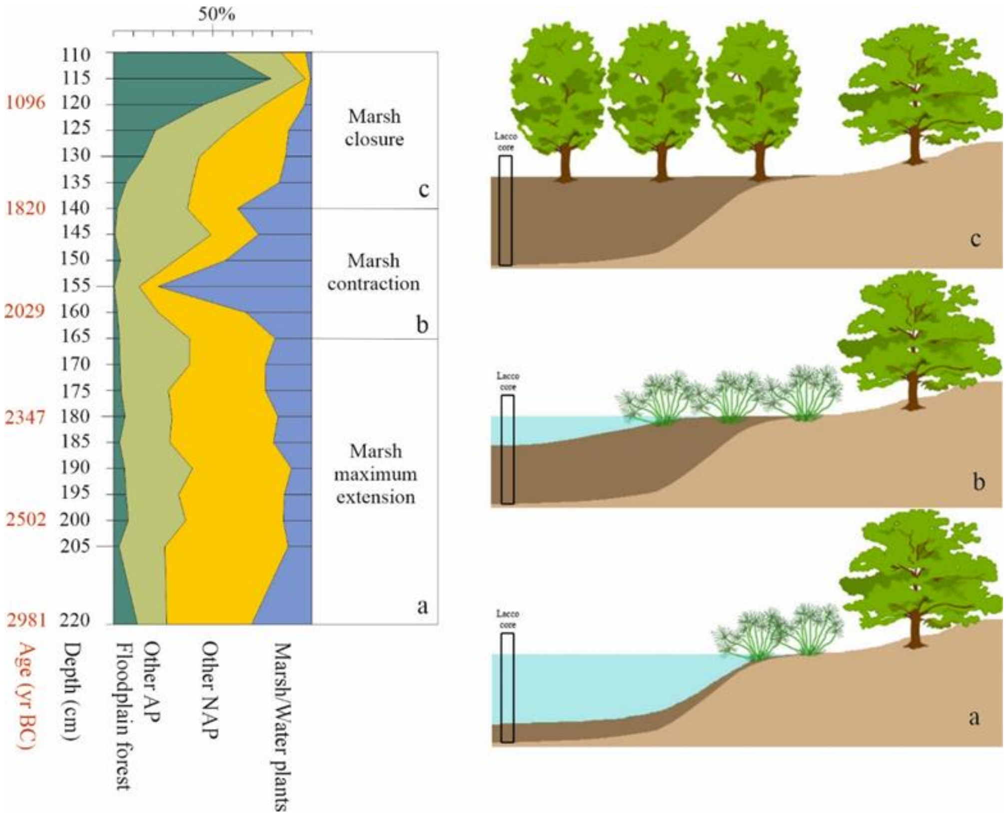

Fig. 40 - Area chart and sketches showing the main three steps in the evolution of the marsh. For the construction of this diagram, the group marsh/water plants is included in the AP+NAP sum.

6.2.4.2. Evidence of land use

A synthetic diagram (Fig. 41) with archaeological phases (left side of the diagram) has been constructed. Most taxa are grouped into ecological associations, although some taxa with interesting trends are flanked outside their ecological group.

During the Eneolithic period and the Early Bronze Age, the Poro Plateau was intensely occupied by human communities as suggested by the archaeological finds (see chapter 4.2.2.). Pollen data confirm such scenario, by showing a continuous exploitation of the highland. The fluctuation of the AP amounts around 40% indicates an open environment dominated by grasses, with some small stands of deciduous elements. The concomitant occurrence of high amounts of microcharcoals, with two outstanding peaks at 190 and 170 cm, attests to the use of anthropogenic fires to open the landscape for agricultural and pastoral practices. In fact, cereal pollen grains are recorded all along the period indicating the occurrence of cereal crops on the lush andisols of the Poro Plateau and the terraces below. As already discussed, even very few amounts of cereal pollen can be considered as a sign of cultivation due to the big dimension of grains as well as their poor production and transport. Cereal crops are attested in the Neolithic period by pollen data from the nearby Sant'Eufemia Plain (Russo Ermolli et al., 2018), where the Neolithic village of Curinga developed (Ammerman et al., 1976, 1978, 1988; Ammerman and Bonardi, 1985). The same pollen sequence seems to indicate a contraction of cereal crops during Eneolithic. At Punta di Zambrone, the Early Bronze Age levels returned cereal seeds in abundance (*Triticum monococcum* and *dicoccum*, *Hordeum vulgare* - Jung et al., 2015).

Exploitation of this territory also for animal husbandry is well testified by the high amounts of coprophilous fungi, indicative of pasturage, as well as by the significant presence of all the anthropogenic herbs (Mazier et al., 2009; Cugny et al., 2010; Ejarque et al., 2011). The pasture practice was attested in the same period (EBA) in the Fontana Manca pollen record, located near the Ionian Calabria coast (Sevink et al., 2019) where high amounts of coprophilous fungi, mainly *Sordaria* type, were identified.

Despite the absence of traces of man presence during the first phase of the Early Bronze Age, pollen data suggest a continuous attendance of the Poro Plateau. After all, the absence of settlements in this period is common in Calabria and could be related to several factors, such as the poor diagnostic nature of the ceramic repertoire of this period, and the real low presence of settlements as a result of a strong drought documented in different contexts (Pacciarelli et al., 2015; Pacciarelli, 2017).

To be highlighted a peak of *Trifolium* cfr *patens* at 160 cm depth, which could represent the occurrence of livestock dung or a near fodder storage area (Dietre et al., 2012; Miras et al., 2018). Certainly, the recovery of so high amounts of *Trifolium* just in one sample could suggest taphonomic issues, but the association of this datum with the continuous presence of coprophilous fungi could support the hypothesis of the exploitation of the small Lacco pond as a pasturage area. Another hypothesis could link such *Trifolium* explosion to seasonal drying of the pond or to the onset of the marsh closure and consequent growth of clover on wet soils. In the pollen record it is impossible to see an aridification trend in this period due to the high anthropogenic impact and environmental evolution of the swamp that masks any climate change.

Between 155 and 140 cm depth, during the last phase of the Early Bronze Age, an extension of the deciduous forest cover, coupled with the progressive decrease in coprophilous fungi, seems to point at decreased human action. However, archaeological data indicate for this period clear evidence of human presence. A possible explanation of this discordance could be the partial abandonment of the pond shores, no more suitable for the watering of livestock at that time, and the exploitation of the Poro Plateau for other activities, such as cultivation, as testified by the continuous presence of anthropogenic herbs and cereals.

The Poro Plateau has not returned archeological evidence for the Middle Bronze Age when a social reorganization was taking place, leading to the development of coastal settlements. In particular, during the Middle Bronze 3 archaeological evidence suggests the presence of "microdistricts" formed by smaller centers belonging to larger sites such as the coastal sites of Briatico Vecchio and Tropea. Moreover, the formation of an emerging class, as evidenced by the Gallo di Briatico findings, occurred (Pacciarelli, 2017 and references therein).

During the transition Middle - Recent Bronze Age almost all small scattered settlements were abandoned, and new settlement types, associated to the Subapennine facies, were implanted both on coastal and inland defended positions, also on the Poro Plateau (Pacciarelli, 2001; Jung et al., 2015). Concerning all these new Recent Bronze Age sites, Punta di Zambrone certainly represents the most important center of the Tropea Promontory due to the contacts with Aegean communities, although it is not yet possible to define its political value (Pacciarelli, 2017 and references therein).

Despite the few archeological finds of Middle Bronze Age on the Poro Plateau, the continuous presence of coprophilous fungi suggests the uninterrupted exploitation of the highland for grazing practice, maybe with a change in modality.

The sample at 125 cm depth can be between the Middle and the Recent Bronze Age, while the sample at 120 cm of depth is dated to the Late Bronze Age. Some evidence of abandonment is clearly recorded in the these last levels, in fact pollen data show a decrease in anthropogenic herbs and the demise of cereals, suggesting the absence of stable settlements. Contrary, there is a large amount of coprophilous fungi suggesting the continuous exploitation of the area around the small pond for grazing before its complete closure.

Finally, the topmost sample seems to suggest a possible recolonization, with a slight forest decline and cereal increase. It is possible that this sample is dated to the Iron Age when new villages developed, such as Torre Galli and Torre Mordillo. They were configured as economic, social and political autonomous units, able to provide for their own livelihood through the agricultural exploitation of the land located near the villages (Pacciarelli 2004).

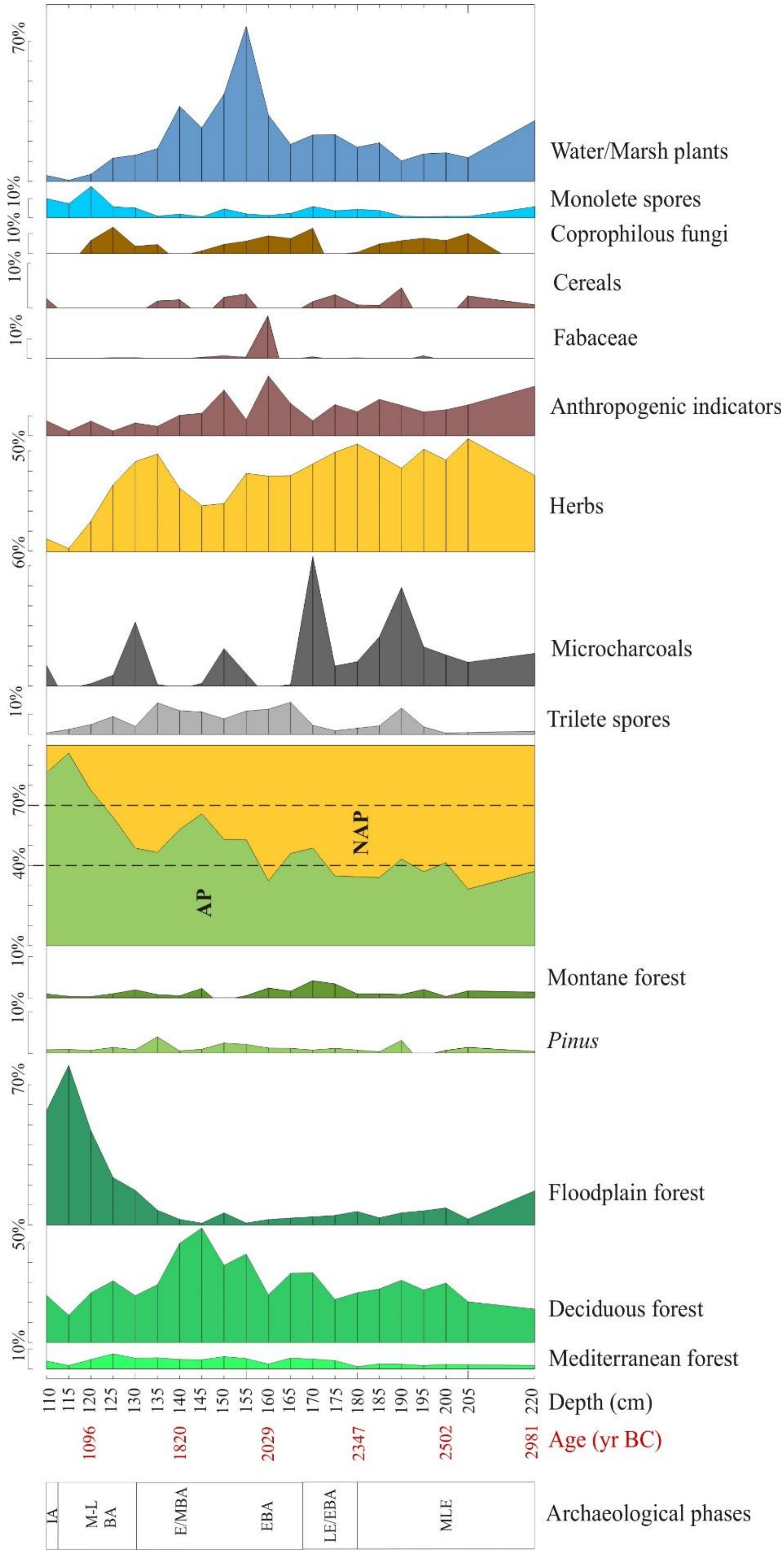

Fig. 41 – Synthetic pollen diagram of L1 core

6.3. Regional comparisons (Gulf of Sant'Eufemia)

A synthetic scheme (Figg. 42, 43) with the new pollen data obtained during this work and pollen data from various published and unpublished drilling cores (SL1 - Russo Ermolli et al., 2018; 6bis - Bernasconi et al., 2010; 4a - unpublished) carried out in the Sant'Eufemia area has been elaborated. This scheme allow us to better visualize the evolution of vegetation at a regional scale in the last 8000 years, and to distinguish the influence of human action from that of climate forcing on the landscape changes.

Fortunately, three of these cores (L1, SL1, MSK12-C2) have a very good chronology that could also help in understanding the pollen data retrieved from Core 6bis and Core 4a both not well dated.

Part of the regional discussion, also based on archaeological data mainly from the Eneolithic period, was presented in chapter 6.1.5. Therefore, in this section I will integrate into the discussion the pollen data from the Neolithic period (from SL1 core) and I will principally underline the few general aspects that are evident in almost all cores.

During the Neolithic period, the Lamezia Plain was covered by a dense floodplain forest (AP values over 70%)[60] testifying to the occurrence of a humid climate in the Early Holocene. The short and global climate shift at around 8200 cal yr BP (e.g. Mayewski et al., 2004; Alley and Agustsdottir, 2005) is recorded in Calabria, as testified by a negative annual precipitation anomaly of 150mm at Lake Trifoglietti (1048m a.s.l.; Joannin et al., 2012), though it is not evident in the pollen spectra of Lamezia, where the humid condition of soils prevailed over the decrease in precipitation inferred at higher altitudes (Russo Ermolli et al., 2018). At c.7350 cal yr BP, a decrease in AP% is recorded coincident with the first peak of microcharcoal and a sharp increase in disturbance taxa. This event chronologically corresponds to the first archaeological evidence of the Neolithic village of Curinga (Ammerman et al., 1988), in which the occurrence of crops is attested by traces of wheat, barley and legumes as well as by the recovery of lithic material including a sickle blade, indicating the practice of cutting cereals (Ammerman et al.,1976,1978,1988; Marchesini et al., 2017). The Curinga settlement is located over the flat surfaces of the Pleistocene raised marine terraces capped with wind-blown dune sands, which offered stable and fertile soils suited to cereal cultivation (Russo Ermolli et al, 2018).

[60] The lower AP % recorded by the two basal samples can be ascribed to the peculiar environmental setting of the plain at around 8300 cal BP, when the sea-level had reached the continental margin of the Gulf of Sant'Eufemia and wetlands started to replace alluvial sedimentation (Ruello et al., 2017).

During the Eneolithic Period, cereal cultivation continued (MSK12-C4, SL1, L1) and on the Poro Plateau (L1) was also combined with grazing practice, as testified by the occurrence of coprophilous fungal spores. Despite recognition of clear anthropogenic activity, it seems that the forest cover was not deteriorated in this period. Of great interest is the presence of *Vitis* with values above 2% (SL1: 6300 BP- Neolithic; 5200 and 4700 BP - Eneolithic) testifying to the first form of grapevine exploitation within its natural environment (Russo Ermolli et al., 2018).

Concerning the Bronze Age, there seems to be a similar situation as in the previous period (cereal crops, coprophilous fungal spores linked to grazing practice and high forest cover), yet it is also interesting to underline the probable occurrence of an arid phase (L1, MSK12-C4) during the Early Bronze Age that could to be linked to the 4.2 ka event.

During the rest of the Bronze and Iron Ages, the oscillating AP% around 70%, could be indicative of a fluctuating human impact in a still closed landscape.

This situation changes at least from the Greek Period (SL1) when a rapid decrease of forest cover on the coastal plain took place. This decrease is not evident from MSK12-C4 core, suggesting that the exploitation was not on a large scale. In fact, this decrease could have been partly driven by the changing environmental conditions of the Lamezia Plain. Indeed, the beginning of the Roman Period corresponds to the expansion of alluvial environments in the outer plain, which certainly led to the development of better-drained soils, less suited to maintaining a luxuriant floodplain forest (Russo Ermolli et al., 2018). This intensive forest reduction is coupled with a pronounced increase in fire events, which supports the hypothesis of local resources exploitation and/or more extensive timber production in the Sila massif. In fact, in this area, the timber trade had to respond to special demands, as evidenced by the well-known passage of Dionysius of Halicarnassus (AR, XX,15, 5e6), which gives a careful description of the tree species of the Sila and their various production systems.

Nevertheless, at a regional level it seems that a widespread deforestation takes place from the Late Ancient Period (MSK12-C4 core), confirming the more local character of the SL1 data. In this regard, it is possible to chronologically constrain the two other marine cores from the Gulf of Sant'Eufemia (4a and 6bis). In both cores, pollen data indicate that intense deforestation had already started, allowing ascribing the analyzed core interval to the last c. 1500 years.

Sedimentological analysis carried out on the MSK12-C4 and SL1 cores indicate that the deforestation process induced enhanced soil erosion and detrital arrivals through fluvial discharges. To this morphodynamic can be connected the development of superimposed alluvial fans, which caused the burial of Terina and of the Acconia Roman villa during the Late Antique-Early Medieval period (Russo Ermolli et al., 2018). These phenomena could be linked to the synergic action of a worsening climate (Antonioli et al., 2000), as well as to the collapse of territorial management following the end of the Western Roman Empire (Antonioli et al., 2000; Russo Ermolli et al., 2014).

Concerning crops, cereal cultivation is documented together with grapevine (SL1) from the Hellenistic Age. This practice was among the Brettii activities, which also exploited the terraced hill slopes (Spadea, 2009)[61]. Other tree crops begin to appear in the Roman Period such as *Juglans* (SL1, MSK12-4C, 4a) and *Castanea* (MASK12-C4), while *Olea* cultivation only appears since the Late Ancient Period (SL1, MSK12-C4, 6bis).

To emphasize the progressive decline of *Abies* in all sequences, except in core L1, until its near disappearance in the Modern Age. This vegetation change is a clear sign of the aridification trend that occurred since the Middle Holocene in the Mediterranean. The absence of *Abies* in L1 core can be ascribed to the local nature of the pollen data. In fact, *Abies alba*, spreading at high altitude (above 1000 m), was certainly absent on the Poro Plateau located at about 500 m a.s.l, while the marine cores embrace a wider pollen source area giving us a regional view of the evolution of this species (see chapter 3.1.3.).

[61] Production of Hellenistic amphorae (so-called "Graeco-Italic") is documented, for example, at Pian della Tirena (Russo Ermolli et al., 2018).

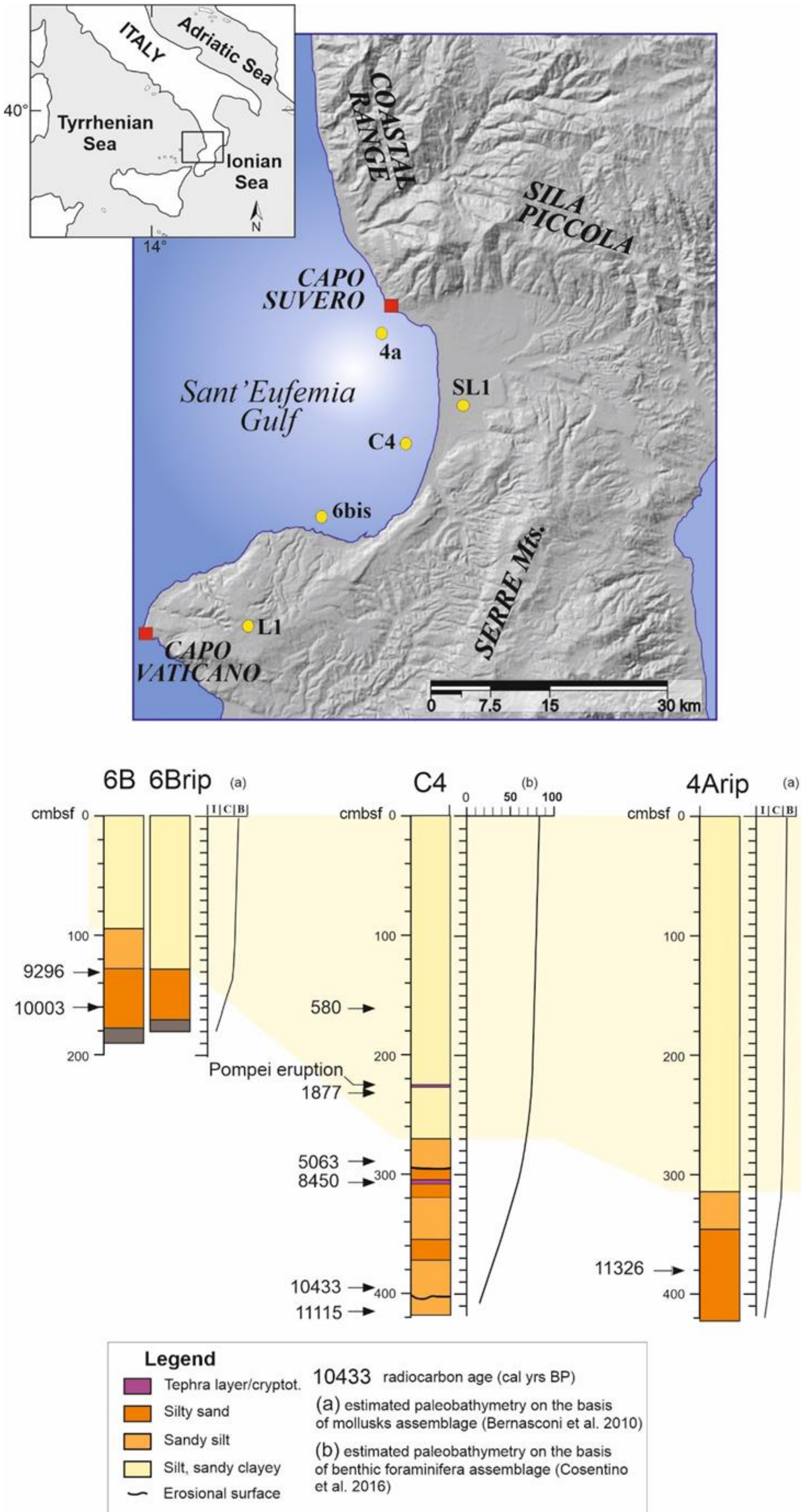

Fig. 42 - Location of cores of the of the Sant'Eufemia area and stratigraphic correlation among marine cores

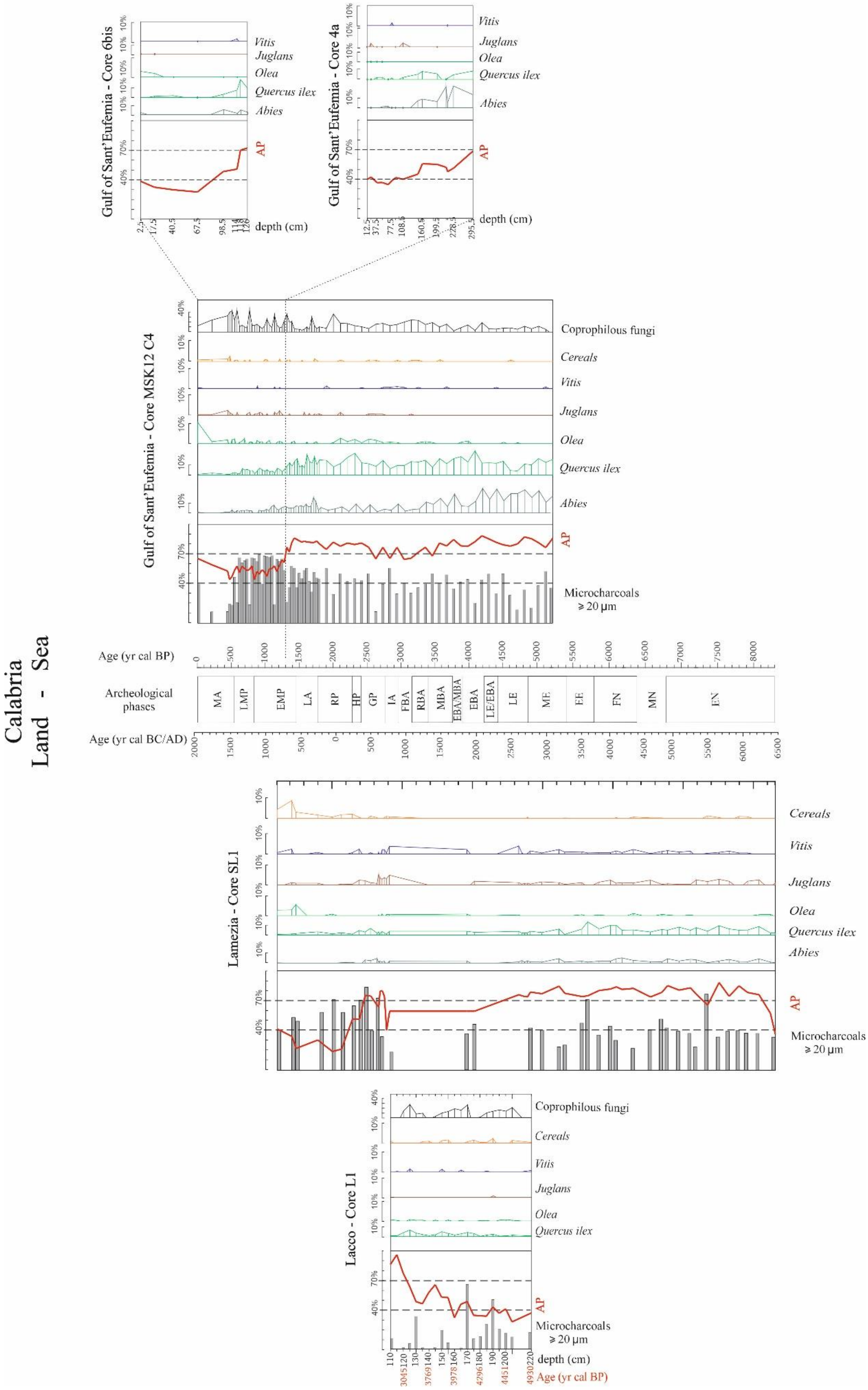

Fig. 43 - Scheme of correlation among pollen data from the Sant'Eufemia area

7. PALAEOCLIMATE EVOLUTION OF STUDY AREAS

A general feature of the Salerno (C106) and Sant'Eufemia (MSK 12 C4) palaeoclimate reconstructions is the evidence of an aridification trend since 4400-4200 BP, in agreement with other southern Mediterranean pollen records, where a similar shift from wetter to drier climatic conditions is highlighted (Peyron et al., 2011 and references therein).

The palaeoclimatic curves from Salerno and Sant'Eufemia show overall similar trends, albeit with some slight chronological differences. The latter could likely be linked to the error of chronological model, especially for the Sant'Eufemia core that only has three absolute dating.

In particular, with regard to the Middle Holocene (8200 – 4200 BP), the climate trend in the Gulf of Salerno it is not very clear. Until c. 8200, a cold/wet phase is apparent and then, until c. 4500 BP a transition phase can be recognized with stable temperatures and precipitations. Contrary, in the Gulf of Sant'Eufemia between c. 5000 and 4500 BP, high humidity and low temperatures are attested.

Concerning the Late Holocene (4200 BP - present), both sequences show the beginning of a warm/arid phase. However, in the Salerno core only summer precipitation shows arid condition. This arid trend seems to become very significative in both sequences from 1100 BP, even if it is possible that in this period a strong human impact masked the real climate status.

These results are perfectly congruent with the study carried out by Magny et al. (2013) that, throught a multidisciplinary approach, including lake level reconstruction, recognize humid conditions during the Middle Holocene (8200 – 4200 BP) and arid conditions during the Late Holocene (4200 BP – present) in Mediterranean contexts located South of 40° N.

In the Italian peninsula, the aridification trend is noted in various Holocene lacustrine sequences such as Trifoglietti in Calabria, Pergusa and Preola in Sicily (Fig. 44 - Peyron et al., 2013).

The unclear climate trend of the Salerno record, mainly recognized in the upper part of the Middle Holocene, can be possibly linked to its peculiar geographical position (40° N), in the transitional zone separating north–south palaeohydrological contrasts, as recognized by Magny et al. (2013) and Peyron et al. (2013).

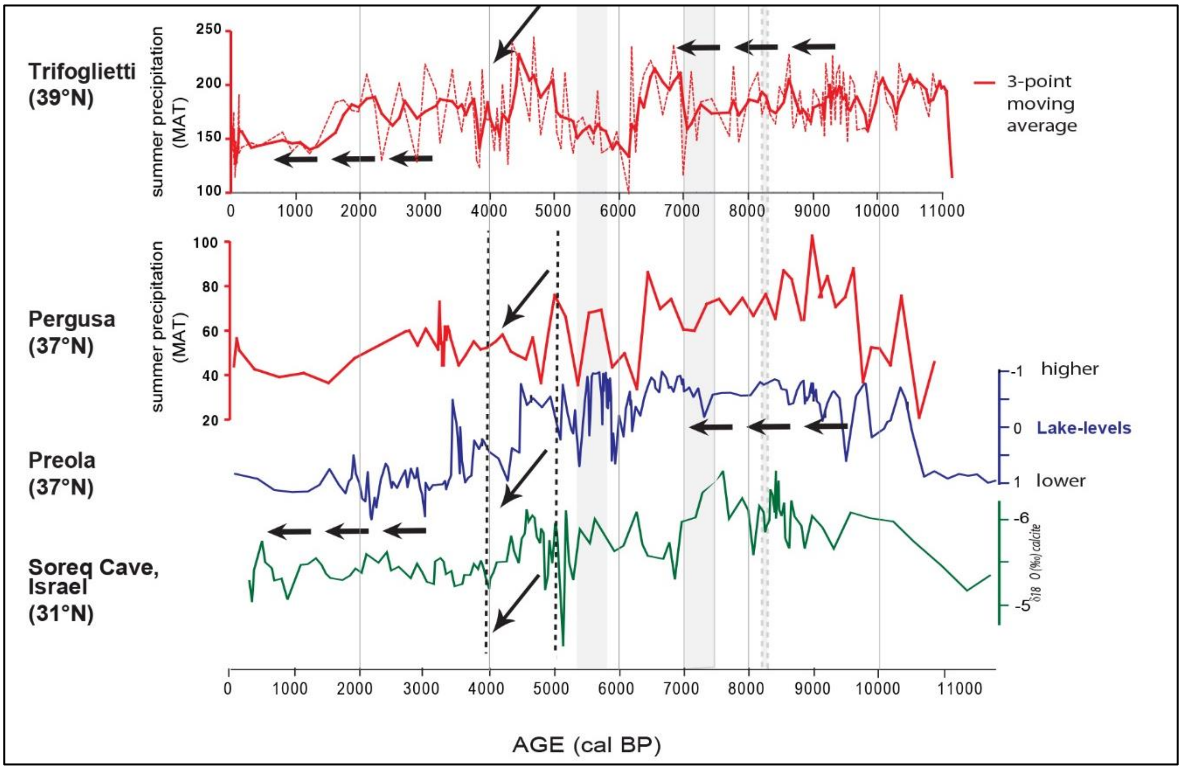

Fig. 44 – Comparison between pollen-inferred summer precipitation (MAT method) at Lake Trifoglietti (Calabria) and Lake Pergusa (Sicily), and lake-level variations at Lake Preola (Sicily). Oxygen isotope data based on speleothem from Soreq Cave (Israel) is also plotted for comparison with eastern Mediterranean sites (after Peyron et al., 2013).

Regarding the evidence of rapid climatic events, during the transition from the Early to the Middle Holocene, a substantial change is noted in the Salerno record between 8500 and 8300 BP. This earliest event could correspond to a regional expression (Pross et al., 2009 and references therein) of the 8.2 ka event (Alley et al., 1997) although the chronological discrepancy cannot be easily explained, being the age model of Salerno very robust.

The association with 8.2 BP event, whose chronology is very precise and homogeneously recognised, remains uncertain but it is possible to see some similarities in precipitation regimes with other Italian contexts. In particular, in Lake Accesa (Fig. 45) the 8.2 ka event (marked by a well-identified lithological change and by a high lake-level) as in Salerno, is caracterised by wet conditions (Peyron et al., 2011, 2013) and high lake levels (Magny et al., 2013).

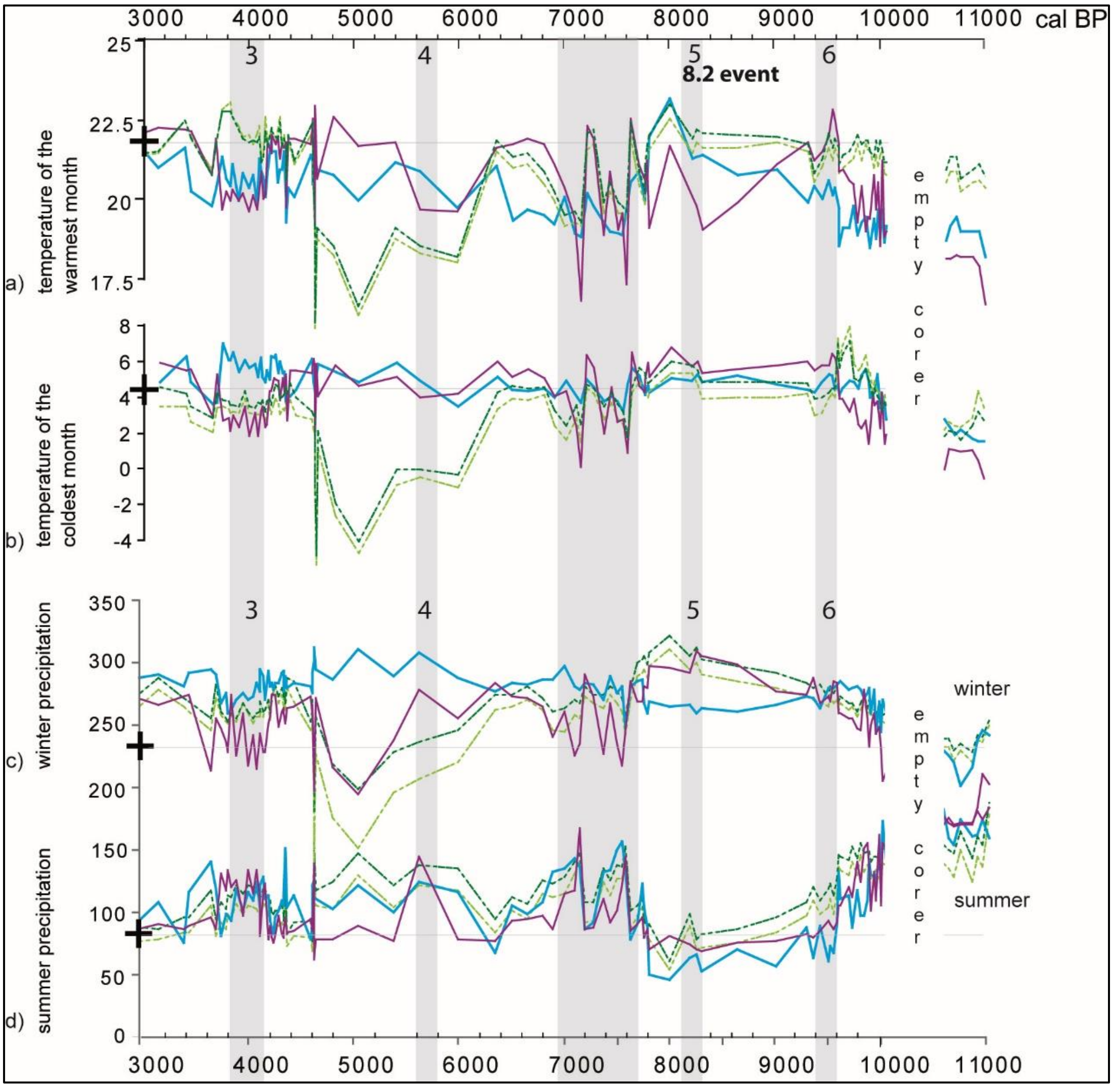

Fig. 45 – Pollen based climate reconstructions for Lake Accesa with seasonal temperature and precipitation: climate curves show results obtained with the various palaeoclimate reconstruction methods (violet: MAT, blue: NMDS/GAM, dark green: WAPLS, light green: PLS) (after Peyron et al., 2011).

It is interesting noting at Salerno a warm phase at 6500 BP, contrary to Trifoglietti and Pergusa lakes where a cold/dry event is recorded at the same time, corresponding to the termination of S1 sapropel in the southern Aegean Sea (Gogou et al., 2007).

Sant'Eufemia climate curves show a very accentuate cold/wet phase at 4600 BP that could be linked to anthropic activity as explained in chapter 6.1.5.

Another interesting climatic phase that could be connected to the global 4.2 ka event (4.3-3.8 phase sensu Bini et al., 2019 - Fig. 46) is recognized in both cores (Salerno and Sant'Eufemia). The peculiarity of this event, as already explained in chapter 1.2. is that it occurred in a diversified way in the Mediterranean Basin. At Italian sites, a general decrease in temperature is visible, especially in Lake Accesa and potentially in Lake Pergusa (Peyron et al., 2013).

Magny et al. (2009) and Zanchetta et al. (2013) recognize a complex tripartite climatic oscillation sequence at Ledro, Accesa and Trifoglietti between ca. 4300–3800 BP. The sequence is characterized two wet phases, dating to ca. 4300–4100 and 3950–3850 BP, with a dry phase in between ca. 4100–3950 BP.

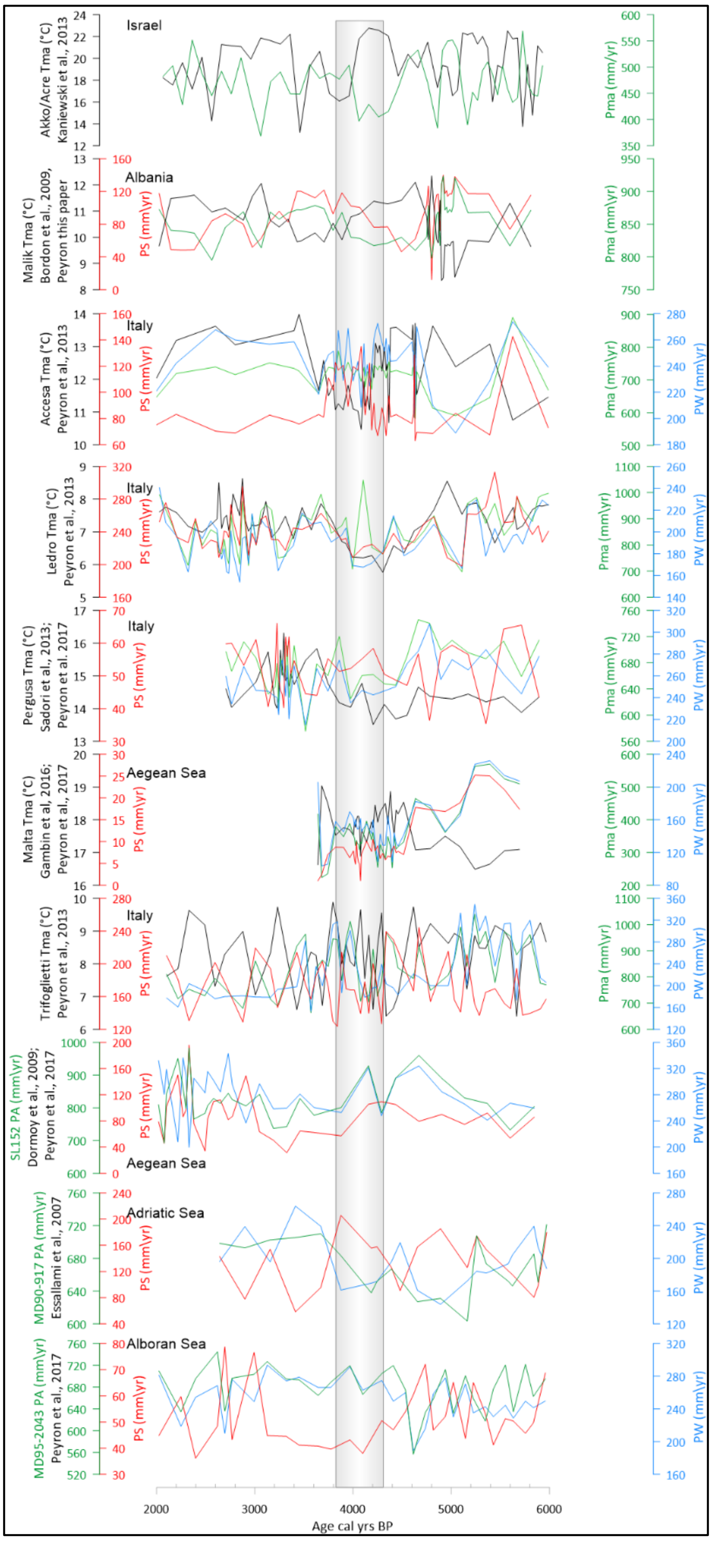

Fig. 46 – Comparison of temperature and precipitation obtained from various Mediterranen pollen records (after Bini et al., 2019)

At Salerno, cold/wet events occurred at 2600, 1600 and 1250 BP whereas at Sant' Eufemia cold/wet events occurred at 2500-2400 and at 1400 BP. These events may be associated with the advances of the Alpine and Apennine glaciers (Giraudi et al., 2011) as well as the lake level increases at Lake Accesa between ca. 2800-2600 BP and ca. 1400-1200 BP (Magny et al., 2007). This association (cold/wet events-high lake levels) is further corroborated by the fact that rise in lake levels were recorded during the widely recognized 4.2 and 8.2 ka events (Magny et al., 2007).

The 2.8 ka event seems very clearly recorded in both cores. Considering the recognition of this climate change also by other proxies (molecular proxies such as BrGDGTs - Martin et al., in press; lake level increase in Lake Accesa - Magny et al., 2007; etc.) it is possible to confirm the climatic origin of this event also in Salerno and Gulf of Sant'Eufemia, where an anthropic cause could not be excluded.

Another interesting cold-wet phase in Salerno occurred at 550 BP and in Sant'Eufemia at 750 BP, opening interesting hypothesis about a link with the so-called LIA. As exposed in chapter 1.2., the LIA has variable response in humidity at low latitudes (Bradley and Jones, 1993; Mayewski et al., 2004). In fact, Matthews and Briffa (2005) argue that the glacier advances which characterised the LIA were forced by increased precipitation in addition to lower temperatures. Consequently, they recognised a Little Ice Age in the European Alps spanning the period 1300-1950 AD. With regard to South Italy, isotope data from Lake Pergusa indicate that this area was wetter between c. AD 450 and 750 (Sadori et al., 2013). This is an interesting datum because it confirms the occurrence of wet conditions during this period in Italy, as testified by the Salerno precipitation.

Certainly, in this period the important human impact could have falsified climate results obtained from pollen data, but I will not to argue more about this topic, going beyond the chronological range covered in this work.

8. CONCLUSIONS

The results achieved during this PhD project have contributed to clarify the ways and times humans exploited a vast territory from the Neolithic to the Early Medieval Ages. Thanks to the application of the MAT to pollen data from marine cores, it has also been possible to propose a quantitative climate reconstruction for the last 8000 years, in an area poorly stocked with this kind of data.

The pollen study of two marine cores has allowed a regional image of vegetation changes to be obtained and compared to the more local and detailed pictures achieved with the analysis of continental contexts.

The following scheme lists the main conclusions achieved on the basis of the predetermined goals:

Climate:

- The climatic curves of the C106 (Gulf of Salerno - Campania) and MSK/12C4 (Gulf of Sant'Eufemia - Calabria) cores register an aridification trend starting from the Early Holocene. This aridification is very marked also in pollen diagrams with the progressive decrease in *Abies* percentages until its almost complete disappearance in modern times.
- Three cool phases have been identified and correlated to the more widely recognized climatic events of the Mediterranean area. The first is the 8.2 ka event, recognized in the C106 core; the second is the 4.2 ka event recognized in both marine cores, but more evident in Calabria than in Campania. Here, this event is more clearly indicated by pollen data, showing a slight increase in steppe taxa. The third climatic event is the one dated to 2.8 ka, which is also clearly recognized in both cores.

Human impact:

- All pollen data show the onset of widespread deforestation from the Late Ancient. Prior to this period, the AP values never decrease below 70% indicating a closed landscape despite the diffuse human presence. Therefore, the belief that Greek-Roman people overexploited wood resources seems not supported by scientific data, as supposed by Harris (2013), at least in the analyzed territory. Uncontrolled deforestation started as the Roman Empire declined, as already hypothesized by Russo Ermolli et al. (2014, 2018).
- Nevertheless, local deforestation occurred in various periods in heavily populated areas, such as the Poro Plateau (L1 core, Calabria) where intensive land use was

clearly recorded during the Eneolithic and the Early Bronze Age. At the same time, in the Garigliano Plain (CL1 core, Mondragone, Campania) and near Sarno (B24 core, San Vito, Campania), no signs of deforestation are observed due to the scant human presence. Other pollen data from Early and Middle Bronze Age archaeological sites of the Campanian Plain (see Tab. 1) indicate a strong dominance of NAP, probably induced by volcanic events but sustained by human intervention (Saccoccio et al., 2013). Chronological comparison of these data with those from the Gulf of Salerno (C106) clarifies the local character of those samples.

A similar situation is inferred from the Masseria De Carolis pollen spectrum (see chapter 5.3.) in which large amounts of anthropogenic indicators occur. Although the undeniable local relevance of this datum, acquired in a very restricted context (Roman villa with spa) in a given historical period (Late Ancient), it chronologically falls within the wide deforestation phase, identified in the Salerno and Sant'Eufemia pollen diagrams.

- Pollen data from the Garigliano Plain show the progressive disappearance of the floodplain forest as attested in other southern Italian contexts (Sele Plain - Campania and Lamezia Plain - Calabria). Although the natural progradation of the coastline led to local reduction of this forest association, its drastic reduction can be ascribed to the massive drainage works put in place since the Greek-Roman period for the gain of fertile soils for agricultural purposes.

Land use (crops and grazing):

- Evidence of grazing, surely attested in all continental contexts at least since the Eneolithic (L1 and CL1 cores, villa with spa of Pollena Trocchia), is rarely and unclearly recorded in the marine cores, as expected from a regional signal.
- Cereals have been cultivated since the Neolithic period confirming their importance as a subsistence basis for all populations.
- Evidence of grapevine exploitation seems to start from the Bronze Age in the Sarno territory. Despite the uncertain chronology of the B24 core (in progress), many other southern Italian sites have recognized the exploitation of *Vitis* in its natural environment since the Bronze Age and the subsequent domestication in the Iron Age, as also testified by archaeological and botanical finds at Poggiomarino-Longola (Sarno Plain) and by pollen data at Picentia (Sele Plain).
- According to Mercuri et al (2013), some tree crops such as *Juglans* and *Castanea* are attested from the Greek-Roman period even if the appearance of these crops is not

synchronous in all southern Tyrrhenian areas, maybe because their cultivation depended on the different development of local economies. Instead, the intensive cultivation of *Olea* does not seem to be recognized before the Late Ancient period, debunking another faith. *Olea* was certainly used since prehistory for its wood and fruits (oil?) in a territory where the Mediterranean maquis has always been very developed. Its use in prehistoric times could therefore be linked to that form of anthropic exploitation of the natural resources discussed in chapter 1.4. Pollen results of this work show a subtle discrepancy between Campania and Calabria, concerning the occurrence of *Olea*. In fact, if in Campania (C106 core) *Olea* is always poorly represented or absent in pollen spectra almost until the Greek-Roman period (when it is still not cultivated), in Calabria (MSK/12C4) it is interesting to note a greater presence of this element (always with low values) starting from the Bronze Age. This datum could be interpreted as the presence of a more arid climate in Calabria than in Campania, which would have favored the expansion of *Olea* (resistant to arid conditions) and its exploitation by local communities.

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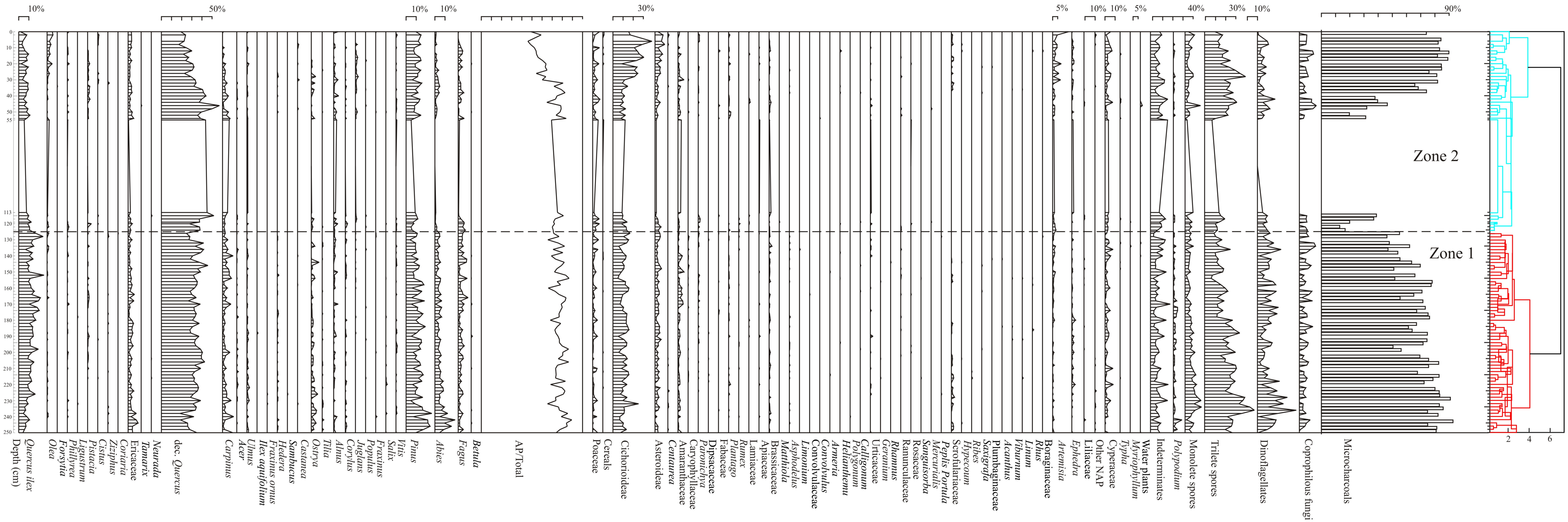
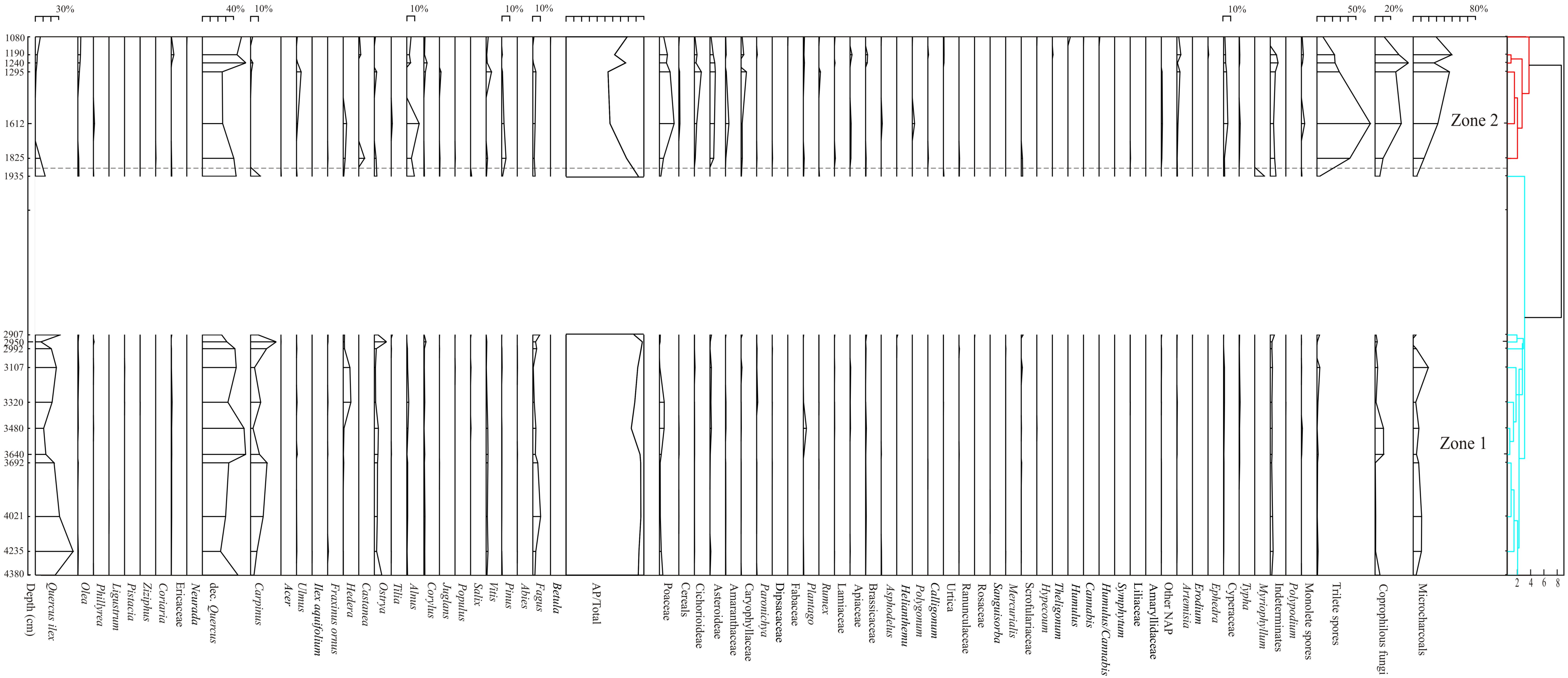
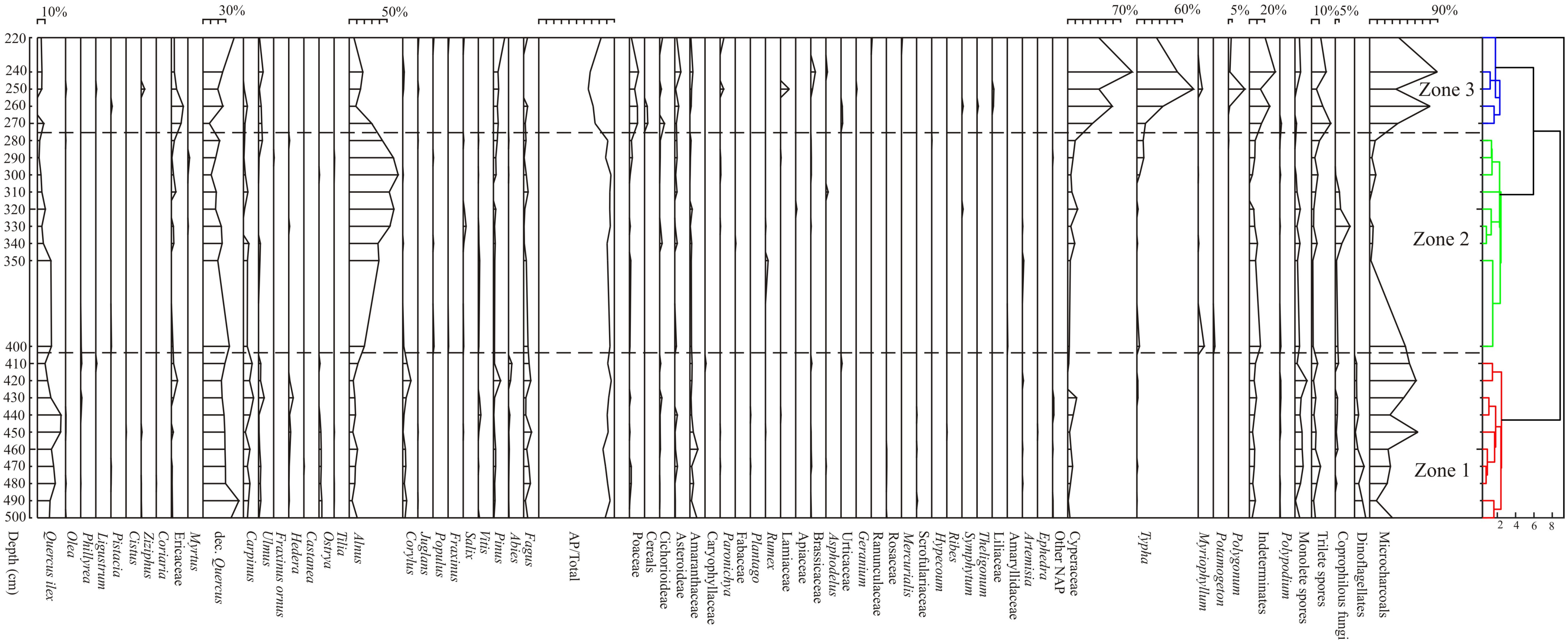


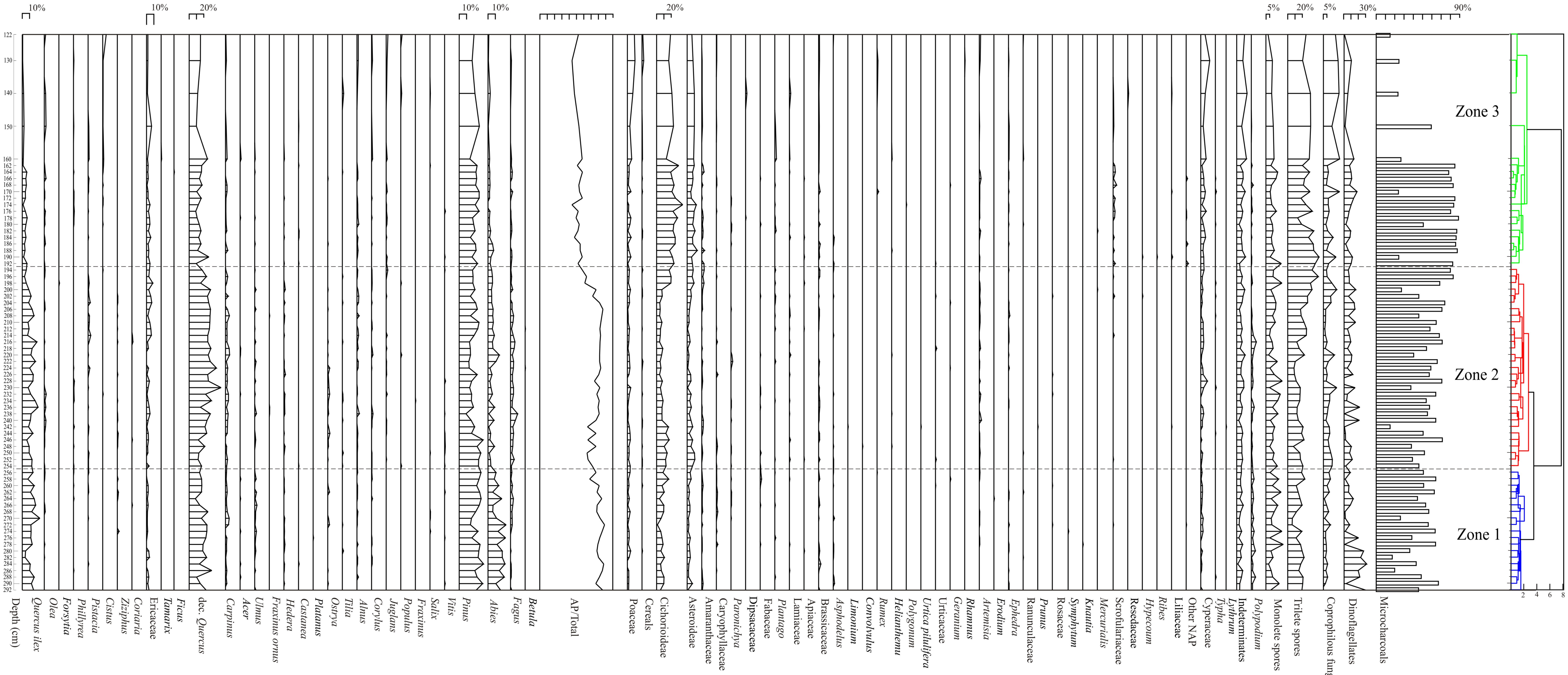
Pl. 1 - Pollen diagram of C106 core



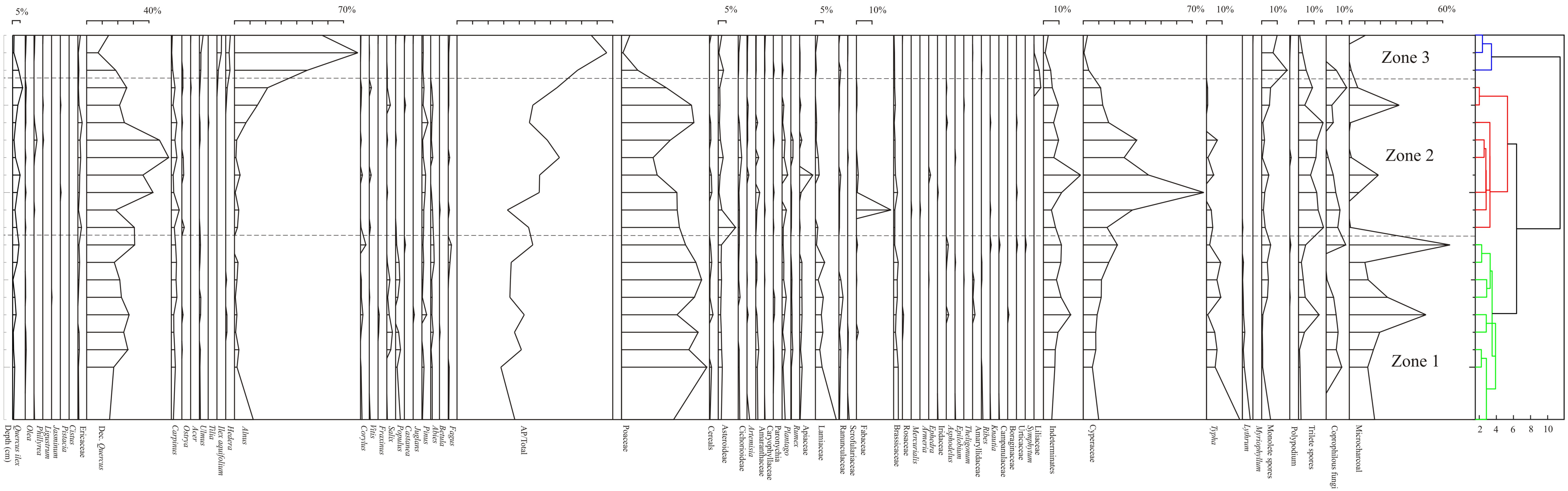
Pl. 2 - Pollen diagram of B24 core



Pl. 3 - Pollen diagram of CL1 core



Pl. 4 - Pollen diagram of MSK/12C4 core



Pl. 5 - Pollen diagram of L1 core