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Palaeovegetation from a *Homo neanderthalensis* occupation in Western Liguria: archaeopalynology of Madonna dell'Arma (San Remo, Italy)

D. Kaniewski[a,*], J. Renault-Miskovsky[b], H. de Lumley[b]

[a] *Katholieke Universiteit Leuven, Centre for Expertise for Bio & Geoarchaeology and Archaeological Image Processing, Redingenstraat 16, B-3000 Leuven, Belgium*

[b] *Muséum National d'Histoire Naturelle de Paris, Département de Préhistoire, UMR 5198 CNRS, Institut de Paléontologie Humaine, 1 rue René Panhard, F-75013 Paris, France*

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Abstract

This study presents a short local vegetation history of Western Liguria (San Remo), northwest Italy, based on a palynological analyses of an 8.30-m-long archaeological section in the dune covering Madonna dell'Arma cave. Madonna dell'Arma is one of the Mousterian caves currently located on the Ligurian coastal zone. The site contains Levallois-type Mousterian tools, four pieces of skull attributed to *Homo neanderthalensis* and fauna remains belonging to *Rhinoceros mercki*, *Elephas* sp. and *Hippopotamus amphibius*. This study is of interest as the site is situated in an area where data on palaeovegetation are scarce. In fact, the archaeopollen analyses of Madonna dell'Arma cave's surroundings provide a rare local picture of vegetation during the beginning of OIS 4, posterior to 73,100 yr BP.

The palynological taxa are grouped into three vegetation units by PCA (principal components analysis). These data suggest a huge Mediterranean pre-steppic forest (*Pinus*, *Quercus ilex* and several herbs) colonizing the area during this substage. The adjacent valleys were colonized by a caducifoliate–alluvial forest and Mediterranean scrub vegetation. These vegetation characteristics suggest a semi-arid coastal climate with an increase of precipitation according to altitude. The PCA analyses of the palynological sections inside and outside the cave suggest a nearly continuous vegetation succession from OIS 5a to OIS 4.

Keywords: Archaeopalynology; Middle Palaeolithic; PCA; OIS 4; Liguria; Italy

1. Introduction

Western Liguria, located in the northern part of the western Mediterranean area, belongs to the Ligurian Alps biogeographical zone [3]. The terrain is build up in limestone formations and is composed of steep promontories and coastal inlets with a gorge-like form. This morphology is due to a Pliocene elevation of the Ligurian Alps generating a subsidence of the Subalpine arc. This regional subsidence has engendered a relative rise in the Mediterranean sea level. The main subsidence has occurred at the Lower–Middle Pliocene boundary (between the biozones *Globorotalia margaritae* and *Globorotalia puncticulata-crassaformis*), and has continued during the Upper Pliocene [37,68].

In the Ligurian area, detailed well-dated palynological data are rare. A review, including the pioneering work of Arobba, is presented in Del Lucchese et al. [20]. Recently, several reports with palaeoenvironmental data

* Corresponding author. Tel.: +32 16 326 402; fax: +32 16 326 400.
E-mail address: david.kaniewski@bio.kuleuven.ac.be (D. Kaniewski).

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have been published [63,64,12,37–40]. The Western Liguria area is very important from a prehistoric point of view, as many sites of *Homo neanderthalensis* are present in limestone caves. Madonna dell'Arma is one of these caves located in the littoral zone of the Mediterranean area (+8 m a.s.l.) and contains deposits suitable for reconstructing the local vegetation history of Western Liguria. It is well known that palaeoenvironmental reconstructions based on palynological investigations of cave deposits cannot provide a regional history of the vegetation. Archaeopalynology can define the local vegetation characteristics and history of each prehistoric site. Nowadays, a huge database on the current vegetation assemblages is available for Northwestern Mediterranean [3,50,58,53]. This database allows us to estimate, by comparison, the correlation between vegetation structures and ecological assemblages identified on Madonna dell'Arma site. These comparisons intend to reduce the palaeoecological uncertainties of cave pollen assemblages. In fact, epiphenomenona processes, such as oxidation, increase of temperature and/or alkalinity, compaction phenomena can cause a differential preservation or a massive deterioration of certain palynomorphs [17,21,34]. Several workers [16,55,61] have stigmatised archaeopalynology as a technique with many limitations such as selective transport, differential dispersion, reworking, contamination by intrusive pollen or undetected sedimentary hiatuses [33,24,71,14,18,10]. Despite these facts, a number of authors consider that archaeopalynology is one of the potentially important sources of information on the Quaternary plant palaeoecology [10,11]. Pollen diagrams of mineral soils, particularly more or less acidic sandy soils, can provide valuable information on the vegetational history in the immediate vicinity of the investigated sections [33].

In this paper, we will provide a pollen record from an 8.30-m-long section situated in dune sands covering the Madonna dell'Arma cave. The aim of this paper is to reconstruct the local vegetation of Western Ligurian coastal zone during the Middle Palaeolithic occupation phase. This reconstruction intends to detect local vegetation particularities and to suggest characteristic of the climate in an area where data on vegetation are limited. A recent pollen diagram with six radiometric dates [69,43,8] from the infilling of the cave has already been published [38].

2. Geographic location, climate and present vegetation

Madonna dell'Arma cave (43°49′N, 7°45′E) is located in Imperia province, Western Liguria, near the seaside resorts of San Remo and Taggia, at the top of the ancient Via Aurelia, very close to the coastline. To the west, the cave is bordered by the Argentina torrent and to the east by the mouth of river Armea (Fig. 1). The cave is a 30-m deep cavity eroded in Upper Pliocene littoral conglomerates [36]. Nowadays, the elevation of the cave is about 8 m above the sea level but it is likely that the site was situated at a much higher relative altitude, as the eustatic sea level was lower during the Weichselian glacial period.

The present regional climate is typically Mediterranean with mean summer temperature above 22 °C and a mean temperature during the coldest month between 4 and 12 °C. The mean summer precipitation is less than 100 mm and increases towards 500 mm during the winter. The area belongs to the thermo-Mediterranean belt characterized by *Ceratonia*, *Myrtus communis*, *Pistacia lentiscus* and *Pinus halepensis* [3,50]. Nowadays, the Ligurian slopes facing the sea have been disturbed by human activities and have been transformed to artificial exotic gardens with lots of acclimate species such as Cactaceae, Crassulaceae, Fabaceae, Liliaceae, Polygalaceae, etc. [2,37].

3. The section

3.1. Lithostratigraphy

Of the five stratigraphical units described since 1962 [36,44,19], this paper is only related to the excavated part of unit IV containing the Mousterian artefacts (Fig. 3). It is the only stratigraphical unit situated above the infillings of the cave (units I–III) and equals the deposits covering the cave. Stratigraphical unit V concerns the remnants of a Gallo-Roman house [39]. The excavated layers of unit IV show a southeastern inclination of layers (~50°). The deposits (Fig. 2) are quite homogeneous without apparent textural differences. Thus, it is mainly fine silty sand in the lower part grading into a coarser very compact sand near the surface. Gravels and stones are randomly distributed. They originate from the locally exposed pudding stone. The stratigraphical unit IV is considered as a mixture of dune sands blown in from the beach with an admixture of locally derived water laid deposit [19].

In unit IV, different sections have been excavated (Fig. 3). As the deposits are inclined, these excavations relate to three lithological layers (layers A, B and C). From the lower layer A, only the palynological content of the top part (maximum thickness ~0.93 m, situated in the excavated section 17/18, 18/19 and 19/20) is studied. Layer B – maximum thickness ~0.64 m – is studied in five excavated sections and layer C in four sections. A nearly complete palynological profile of layer C (maximum thickness ~2.58 m) is situated in the top section *K*/*L*.

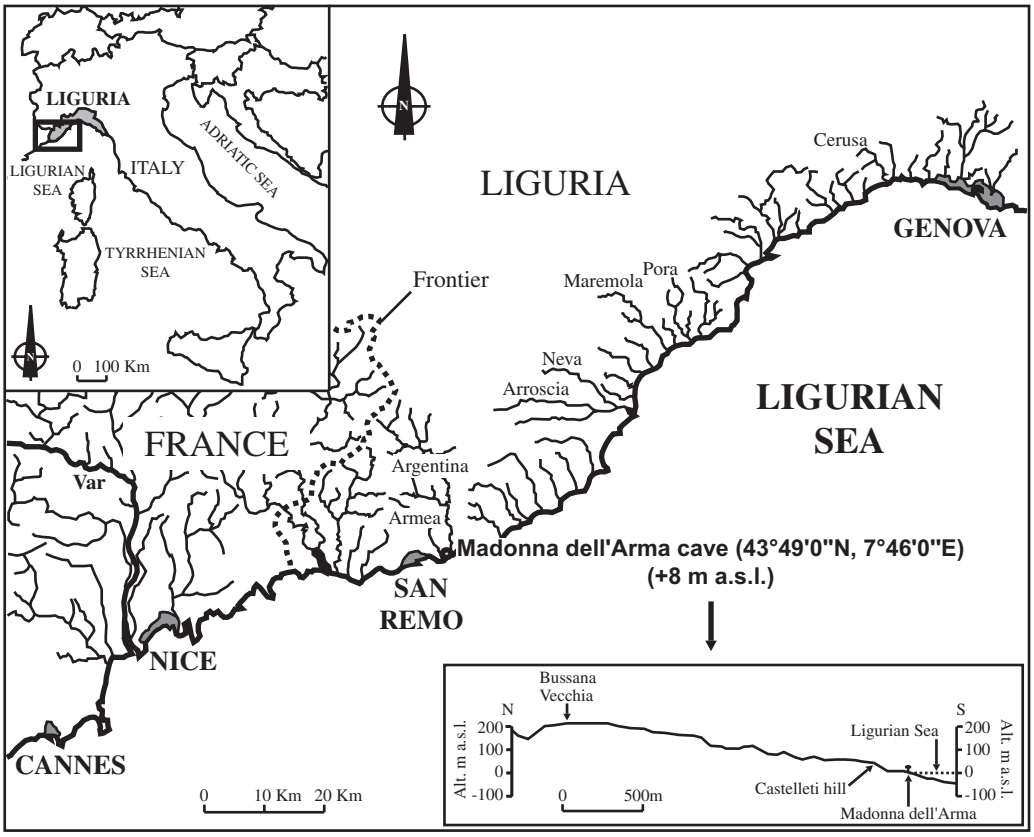


Fig. 1. Geographical location of Madonna dell'Arma cave (from [9,44]).

3.2. Dating

The oldest deposits – unit I (Fig. 2) – correspond with the Tyrrhenian seabed, containing *Strombus bubonius* associated with many Senegalese species such as *Conus testudinarius* [36]. This unit is dated between 149,000 ± 15,000 yr BP [43] and 95,000 ± 5000 yr BP [69] by U/Th [Uranium/Thorium] method applied on *S. bubonius* shells. The main archaeological level in the cave (stratigraphical unit III) is dated between 91,000 ± 5200 yr BP and 73,100 ± 4400 yr BP [8] by U/Th and E.S.R. [electronic spin resonance] methods, both applied on bones. Dating of stratigraphical unit IV is in progress. These deposits are posterior to 73,100 ± 4400 yr BP and are considered early Weichselian in age. Unit IV contains, indeed, many Levallois-type Mousterian tools in situ spanning the interval OIS 5a to OIS 4.

3.3. Archaeology

Although the excavation at the archaeological site of Madonna dell'Arma (San Remo, Liguria, northwest Italy) began in 1961 [36], unit IV has remained untouched until 1989. According to Isetti et al. [36], de Lumley-Woodyear [44] and Cauche [13], the archaeology was as follows (Fig. 2):

(1) Cave deposits: Middle Palaeolithic,
  stratigraphical unit I: sterile,
  stratigraphical unit II: Archaic Mousterian,
  stratigraphical unit III: Levallois-type Mousterian with many scrapers.
(2) Dune deposits, outer part of the cave: Middle Palaeolithic,
  stratigraphical unit IV: Levallois-type Mousterian with many nucleus and scrapers.
(3) Outside superficial levels: Gallo-roman and Mediaeval,
  stratigraphical unit V: remnants of a Gallo-roman house and ceramics (between 180 yr BC and the third century AD),
  uppermost part: Mediaeval edifices (12th to 16th century AD).

Unit III contains many fauna remains such as *Cervus elaphus*, *Bos primigenius*, *Rhinoceros mercki*, *Elephas*, *Hippopotamus amphibius*, *Sus scrofa*, *Hyaena crocuta spelaea* [36] in layers included between 88,000 ± 8800 yr BP and 73,100 ± 4400 yr BP [8]. This unit also contains human remains (four pieces of skull) attributable to *H. neanderthalensis*. The stratigraphical unit IV contains fauna remains such as *C. elaphus*, *B. primigenius*, *R. mercki*. No *Elephas* and *H. amphibius* remains were found during the excavations.

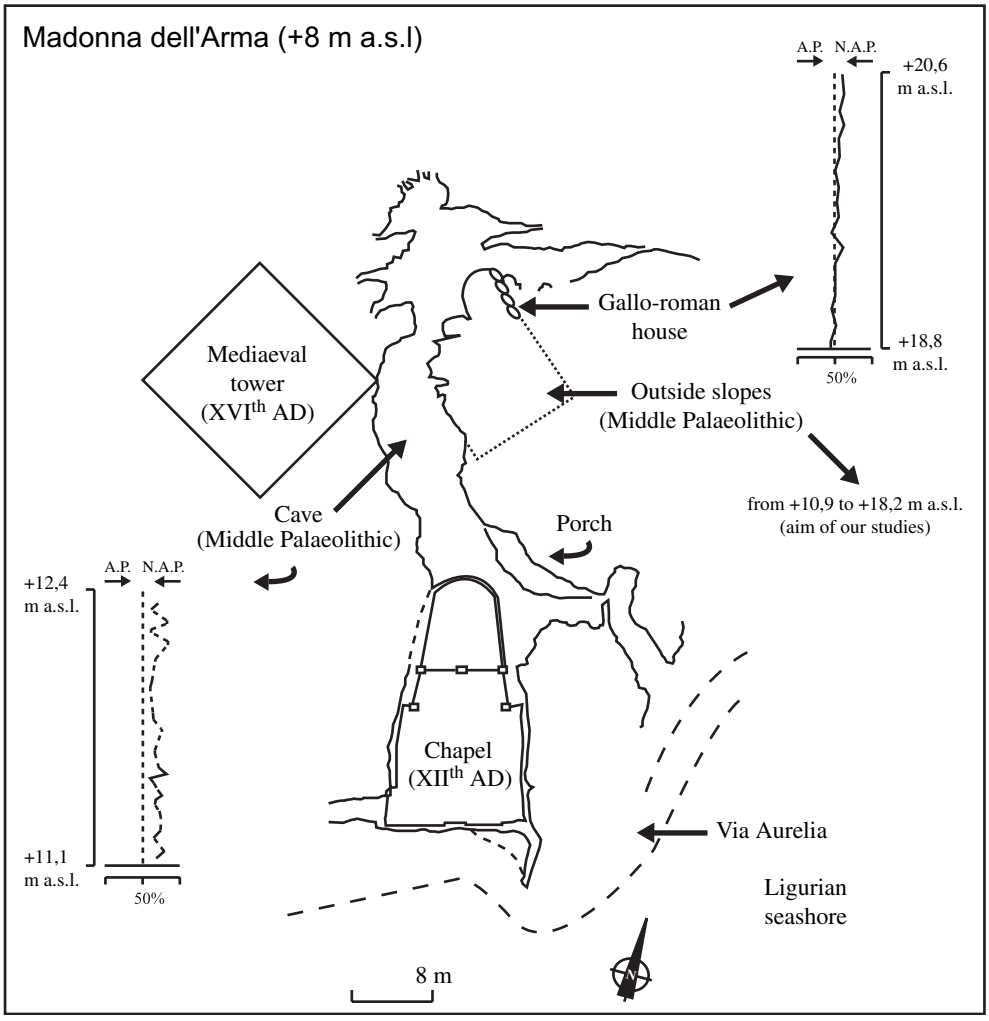


Fig. 2. Spatial location of outside slopes from Madonna dell'Arma.

4. Pollen analysis

4.1. Methods

Five vertical sections from unit IV (Fig. 3) are investigated. The samples were taken at regular intervals of 10 cm in each section. For each sample, 15–20 g of sediments are chemically treated to remove the mineral fractions. The preparation techniques followed the standard HCl, HF, KOH method, with pollen concentration in $ZnCl_2$ [67,29,30]. The acetolysis was not used to avoid the destruction of cell cytoplasm (decisive factor to recognise actual pollen contamination). The final residue was mounted unstained in bidistilled glycerine. The pollens were counted using a Zeiss microscope. A minimum of 300 pollen grains, excluding spores [17], and a minimum of 20 taxa were counted for each of the 83 levels analysed [46,61]. The taxa denominations were referred to the International Code of Botanical Nomenclature [31]. The determinations of specific range with "type" mention indicate the pollen morphology. The pollen percentages for taxa are based on the main pollen sum excluding spores, indeterminable and unknowns. *Pinus*, nowadays integrated in a lot of vegetation structures in the western Mediterranean area [4,48,53,58], was not excluded despite its over-representation in littoral deposits. *Pinus* releases indeed large amounts of pollen in the air, leading to relatively high numbers in the spectra compared to other taxa. To propose a coherent study of this *genus*, no correction was applied to its over-representation [48,58] and statistical analyses were used to replace *Pinus* in the vegetation belts and in the vegetation assemblages. Evaluation of pollen concentration notified in grains per g has been undertaken according to the P. Cour model [15]. The pollen concentration was used as a criterion to evaluate the degree of alteration and the reliability of pollen spectra in sandy soils: low pollen concentrations, fewer than 1000 grains per g, indicated deteriorated pollen assemblages [32]. In the case of pollen concentration

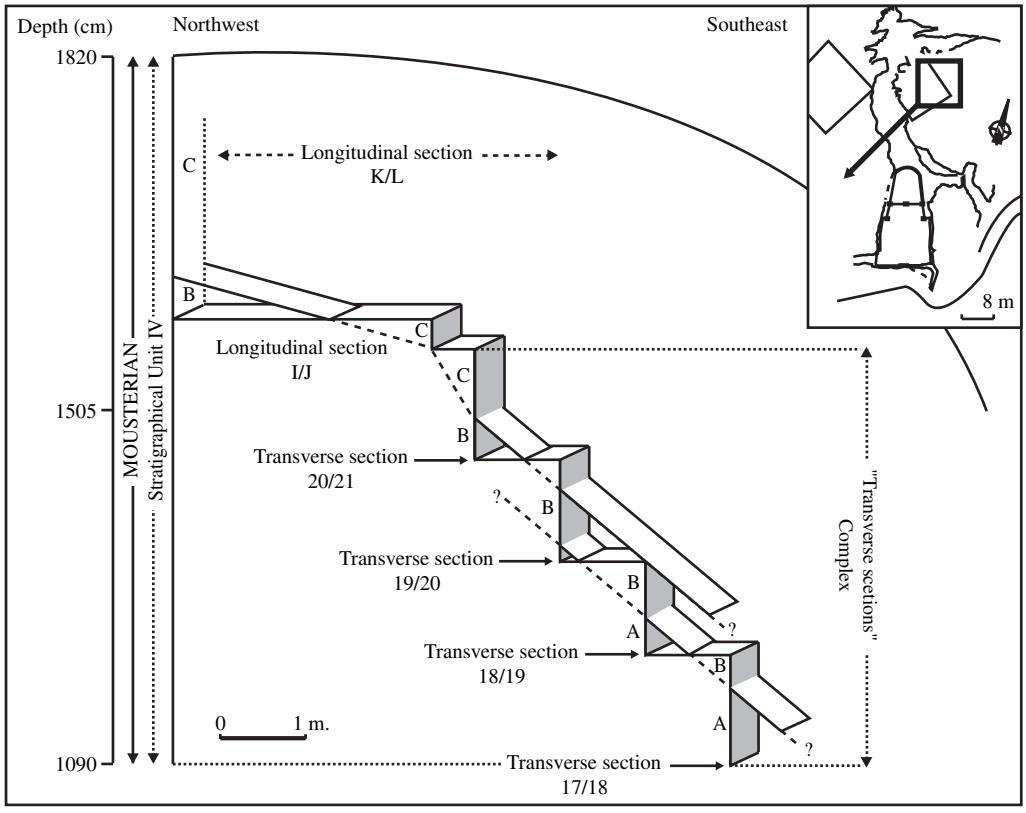


Fig. 3. Location of the outside sections from Madonna dell'Arma cave.

inferior to 1000 grains per g (common in archaeological deposits), other criterions such as the logic of statistical analyses [37–39] and the absence of rise in Asteraceae Cichorioideae curve (huge marker of alteration, [14,16,17]) were also used to evaluate the reliability of pollen spectra.

The detailed pollen diagrams of each section – five in total (see Fig. 3) – are available in Kaniewski [37]. In this study, the statistical treatments of the different sections are also available in Kaniewski [37]. As a result, we have been able to construct a synthetic detailed pollen diagram with selected taxa where the overlaps between the different palynological sections are omitted. From the 83 initial samples distributed over the different sections, 37 overlapping spectra were excluded. We want to stress that the entire lithological section (Fig. 3) may not represent a complete continuous history of accumulation. Several sedimentological hiatuses may have been included in the two apparent continuous layers. Thus, although the taxa curves in Figs. 4 and 5 appear to be continuous, hiatuses may occur. Construction of a theoretical repartition of the fossil vegetation pattern was undertaken based on a statistical treatment of the 46 selected spectra [41] with Statistica 5.0 software. The statistical matrix contains the 30 more significant taxa. A synthetic pollen percentage diagram has been developed from the pollen groups resulting from the statistical treatment.

4.2. The pollen record

Palynological analysis in this study only relates to unit IV (Fig. 4). The pollen diagrams from units I to III and unit V, the Gallo-roman sequence, have already been published in Kaniewski et al. [38,39]. A number of restrictions have to be mentioned. The interpretation of the archaeopollen profile of Madonna dell'Arma is hampered by the lack of knowledge about the value of the pollen deposit in Ligurian cave sediments. Indeed, several erosion and bioturbation processes may have disturbed the sequence. Also, a lack of archaeopollen studies in this area limit the ecological and chronological hypotheses. Consequently, one should not expect palaeoecological information from each positive or negative peak in the pollen curves. Considering, broad trends appear to be more realistic (Figs. 4 and 5). To delimit probable excessive interpretations on archaeological pollen assemblages, a statistical treatment of spectra by principal components analysis has been undertaken to suggest apparently coherent vegetation groups from detailed archaeological pollen diagrams.

4.3. Ligurian vegetation in unit IV

The elaboration of theoretical gatherings of the major taxa was determined by a statistical treatment of spectra

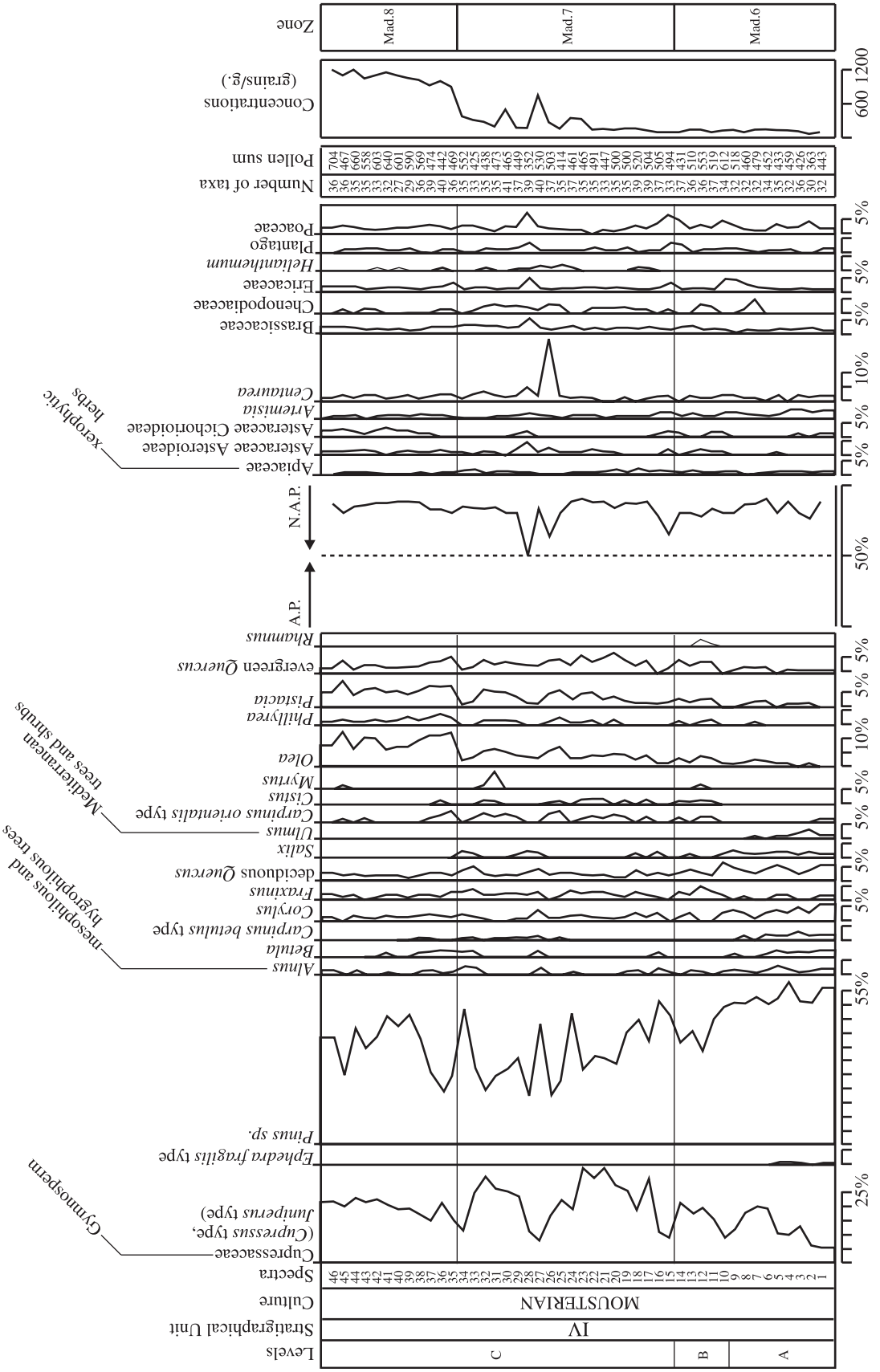
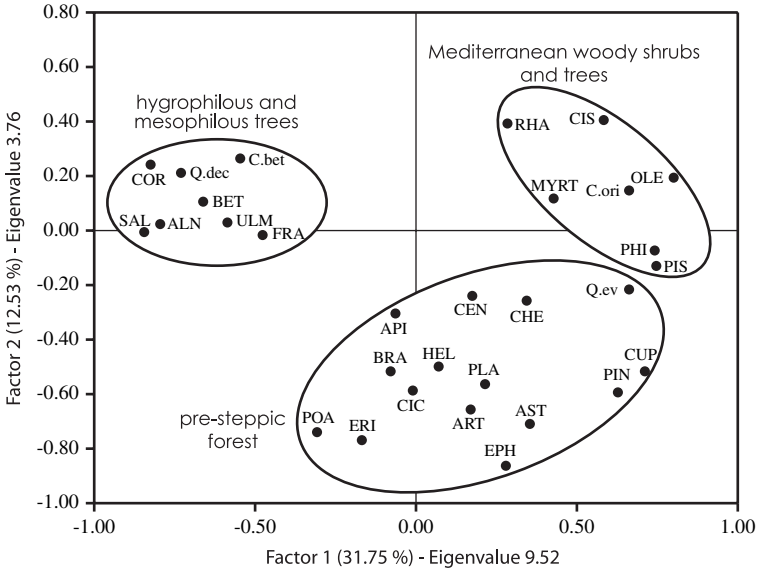


Fig. 4. Percentage pollen diagram representing the most significant taxa from Madonna dell'Arma cave.



ALN : *Alnus*
API : Apiaceae
ART : *Artemisia*
AST : Asteraceae Asteroideae
BET : *Betula*
BRA : Brassicaceae
C.bet : *Carpinus betulus* type
CEN : *Centaurea*
CHE : Chenopodiaceae
CIC : Asteraceae Cichorioideae
CIS : *Cistus*
COR : *Corylus*
C.ori : *Carpinus orientalis* type
CUP : Cupressaceae
EPH : *Ephedra fragilis*
ERI : Ericaceae
FRA : *Fraxinus*
HEL : *Helianthemum*
MYRT : *Myrtus*
OLE : *Olea*
PHI : *Phillyrea*
PIN : *Pinus*
PIS : *Pistacia*
PLA : *Plantago*
POA : Poaceae
Q.dec : deciduous *Quercus*
Q.ev : evergreen *Quercus*
RHA : *Rhamnus*
SAL : *Salix*
ULM : *Ulmus*

hygrophilous and mesophilous trees : humid to per-humid zone
Mediterranean trees and woody shrubs : semi-arid to sub-humid zone
pre-steppe forest : arid to sub-humid zone

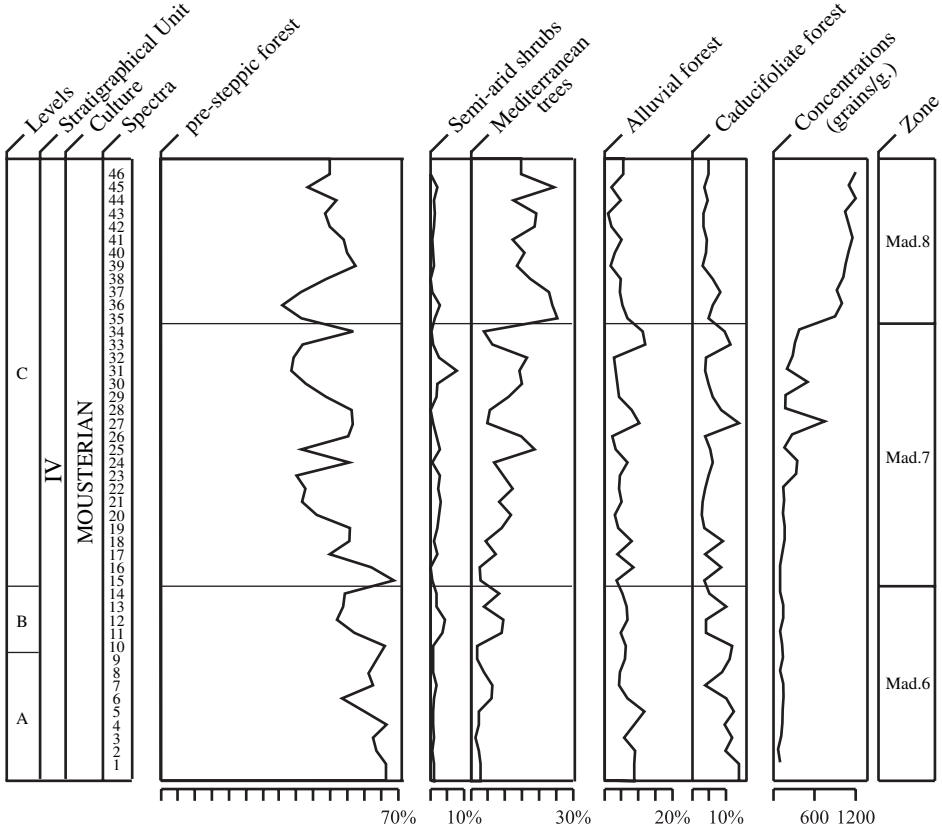


Fig. 5. Principal components analysis of the main taxa and synthetic pollen diagram from Madonna dell'Arma cave.

and by comparisons of the results with actual data on vegetation groups [3,50–53,48,56,58].

Principal components analysis (Fig. 5) has distributed the data set on seven axes representing 76.85% (eigenvalue: 23.05) of the total variance. The two main axes, F1 and F2, contained 46.82% of total variance divided into 31.75% (eigenvalue: 9.52) on axis 1 and 12.53% (eigenvalue: 3.76) on axis 2.

The distribution of taxa on the two main axes suggests three clusters. These clusters are based on our knowledge about contemporary ecology and biogeography of the taxa. They were not defined statistically and other forms of clusters are probable as it was reported for all the PCA analyses [41,22,76].

4.4. Pre-steppic forest

The first gathering contains 12 plots (Fig. 5) corresponding to an arid non-arboreal vegetation with only herbaceous taxa (Asteraceae Asteroideae, Asteraceae Cichorioideae, *Artemisia*, *Centaurea*, Chenopodiaceae, Poaceae, etc.). Only three plots of arboreal pollen (*Pinus*, Cupressaceae and evergreen *Quercus*) are included in this group. The low percentages of *Artemisia* and *Ephedra fragilis* (Fig. 4), principal components of the steppe-landscape [58,70], do not allow us to assimilate this structure as a typical arid steppe. This steppe-landscape was defined by several authors for the Mediterranean area [72,57,26–28,45]. It shows a number of divergences with our archaeopollen data. For example, the high percentages of *Pinus* and Cupressaceae (*Cupressus* and *Juniperus*) in each spectrum are never mentioned elsewhere during the Upper Pleistocene increases of Chenopodiaceae–*Artemisia*–*Ephedra* assemblages, which point to high aridity. *Pinus* is defined by a large ecological valence and does not indicate a specific environment. The genus *Juniperus* includes warm (*J. oxycedrus*, *J. phoenicea*) and cold species (*J. thurifera*) and its pollen, indistinguishable from each other and even from *Cupressus*, is often placed into the Cupressaceae taxon [66]. Moreover, evergreen *Quercus* is never insignificant in the Madonna dell'Arma profile (Fig. 4). The taxa gathered in the first group could therefore be compared with a Mediterranean pre-steppic forest [58] and could chronologically precede the Weichselian glacial steppe-landscape. This Ligurian structure of vegetation principally resulted from an important hydrous deficit and may indicate a semi-arid zone [58].

4.5. Mediterranean woody shrubs and trees: a scrub

The second gathering contains several Mediterranean woody shrubs and trees, which characterize semi-arid to sub-humid vegetations. A first subdivision may be based on three woody shrubs *Myrtus*, *Cistus* and *Rhamnus*. This first vegetation assemblage is quite similar to the present one, which is integrated in the thermo-Mediterranean vegetation belt [48]. This vegetation structure forms in Mediterranean area a semi-arid group. The second subdivision could reflect a sub-humid thermophilous vegetation with *Olea*, *Phillyrea* and *Pistacia* [58]. *Carpinus orientalis* is added to this structure. Nowadays, *C. orientalis*, mainly located in the eastern Mediterranean, is common in southern Italy and penetrates up to Tuscany. At the present time, this species is incorporated in the eastern Greece evergreen *Quercus* matorrals, in the northern Anatolian *Quercus coccifera* formations and in several groups in northern Greece. *C. orientalis* is also associated with *Phillyrea media* in the Black Sea coastal zone [59,48]. The whole Mediterranean genera from the archaeopollen profile have been attributed to a woody scrub [48,58] developed on a superficial or stony soil during the filling of the site. Such genera gather in this group may have persisted since the last Interglacial [38].

4.6. Hygrophilous and mesophilous trees

The third gathering (Fig. 5) links several hygrophilous elements such as *Alnus*, *Betula*, *Salix* and *Ulmus*. This group must have been located in the fresh water marshy zones. This vegetation structure suggests an alluvial-waterside forest [48,58] probably located in the flood plains of the rivers Armea and Argentina (Fig. 1).

This gathering also incorporates caducifoliate trees such as deciduous *Quercus*, *Carpinus betulus*, *Corylus* and *Fraxinus*. This forest structure is quite similar to the present one located in supra-Mediterranean vegetation belt [50,60,58] and constitutes a caducifoliate forest. Nowadays, only *C. betulus* is located outside the Mediterranean area except for the Esterel and Tanneron massifs, southern France, where this species are found in ripisylve or integrated in mesophilous forest [4,48]. During the Middle Palaeolithic, the expansion of *C. betulus* in Ligurian area may be the result of an increase of soil humidity.

4.7. Archaeopollen diagram

The pollen diagrams from unit IV is subdivided into three pollen zones (Figs. 4 and 5). The zonation is based on the fluctuations in the frequencies of at least two taxa considered to be important ecologically and in terms of vegetation dynamics [62]. This method is corroborated in Madonna dell'Arma by a statistical treatment of the profile [37]. AP/NAP quotient (51–89% – Fig. 4) suggests a few variations in tree density. Variations in pollen concentrations are considerable, from 80 to 1175 grains per g. The pollen sums vary from 352 to 704 grains and the number of taxa from 27 to 41. High

values of pollen concentration are located in the upper part of the profile.

4.7.1. Zone Mad.6

Zone Mad.6 – corresponding with levels A and B in unit IV – is characterized by high AP values between 76 and 89%. In this zone, the percentage of Mediterranean trees varies between 1.5% and 9% whereas the curve of the pre-steppic forest reaches a value of 67%. The dominance of the pre-steppic forest pollen is due to *Pinus* and Cupressaceae whereas *Artemisia* and *Ephedra* never reach 3%. Apart from the pre-steppic forest, caducifoliate forest (14%) and alluvial forest (11.5%) are the most important vegetation groups. Semi-arid shrubs never exceed 4%.

4.7.2. Zone Mad.7

Zone Mad.7 – corresponding with the lower part of level C in unit IV – is characterized by two major fluctuations in the AP/NAP curve. The AP percentages may decrease to values of 51–64%. The first NAP increase is due to high percentages of *Centaurea* (22%). The second NAP increase includes Poaceae, *Centaurea*, Asteraceae (and other taxa such as *Helianthemum*, Brassicaceae, Ericaceae, etc.). In this zone, percentages of Mediterranean trees increase to 15% whereas the curve of caducifoliate forest drops to values below 4%. Percentages of Alluvial forest vary between 3 and 12% and percentages of pre-steppic forest remain significant (39–70%). Semi-arid shrubs reach 8% in the upper part of this zone.

4.7.3. Zone Mad.8

Zone Mad.8 – the upper part of level C – corresponds with a period of forest expansion with AP percentages generally superior to 83%. This zone is characterized by a small decrease of pre-steppic forest (36–58%). *Pinus* reaches 45%, Cupressaceae 23%, *Artemisia* and Chenopodiaceae are insignificant (less than 2%), *E. fragilis* is not found. The percentages of Mediterranean trees (*Olea* 12% and *Pistacia* 10.5%) increase to 26% whereas the curve of semi-arid shrubs never exceeds 2.5%. Percentages of alluvial forest drop to values lower than 7% and caducifoliate forest curve never exceeds 8%.

5. Discussion

5.1. Hypotheses about the local environment

From the statistical treatment of the palynological data (Fig. 5), it results that *Pinus*, the Cupressaceae, evergreen *Quercus* (less than 50%) and several xerophytic herbs can be grouped to suggest a pre-steppic forest [58]. The percentages of the *Artemisia–Ephedra–*Chenopodiaceae assemblage (Fig. 4) are not significant enough to propose a steppe-landscape vegetation typical for a high aridity episode. Moreover, the presence of several Mediterranean trees and woody shrubs is not specified elsewhere in the Mediterranean area during the early Upper Pleistocene glacial periods. The vegetation on the seaward slopes of Madonna dell'Arma cannot be assimilated to a glacial or to an Interglacial period. The high percentages of arboreal pollen are indeed mainly due to *Pinus* and Cupressaceae and do not reflect an interglacial or an interstadial during the Upper Pleistocene. For an adequate interpretation of the palynological section, it must be taken into account that the Mediterranean sea level during the early Weichselian glacial has been much lower than today [42,54], so that the cave was situated at a higher altitude. Nowadays, the littoral zone in Western Liguria is characterized by poor halomorphic soils grading on the lower slopes into sandy conglomerates [68]. This substrate, in combination with a hydrous deficit due to low precipitations, reduces the soil water retention capacity. During the early Weichselian glacial lowering of the sea level, the area abandoned by the sea has generated an extension of the arid to semi-arid vegetation on these sandy soil surfaces. It is suggested that a dense pre-steppic forest has been established in this area.

Doubts may rise about the Upper Pleistocene origin of the Mediterranean taxa in our pollen profile. The hypothesis of a modern or late-Holocene vegetation surface as a possible source of down-washed pollen could be confirmed by the higher pollen concentrations in the upper part of the profile. A higher compaction rate in the upper part of the sandy dune could also explain this situation. Compact sand deposits reduce indeed the oxidation processes [33]. Two documents from Madonna dell'Arma could reject the hypothesis of pollen infiltration mentioned above: the Gallo-roman pollen profile [39] and the Bryophyte diagrams (Fig. 6). These late-Holocene and modern pollen diagrams show main differences with the Upper Pleistocene profile, especially in relation to the AP curves and the percentages of the Mediterranean taxa. It is suggested that the Mediterranean trees, which were already present during the St Germain II interstadial (OIS 5a) in Liguria [38], may have persisted during the early Weichselian glacial (OIS 4).

The vegetation of this area was very complex due to the presence of marshy zones in the immediate vicinity of the wide semi-arid area. These humid to per-humid zones, probably near the Armea and Argentina rivers, have shown a huge contrast with the environments marked by a hydrous deficit. This situation explains the co-existence of a pre-steppic forest and several hygrophilous trees in a limited geographical space. It is suggested that the pre-steppic forest was probably located in the close vicinity of the Madonna dell'Arma profile, as it constitutes the major part of the pollen record. The

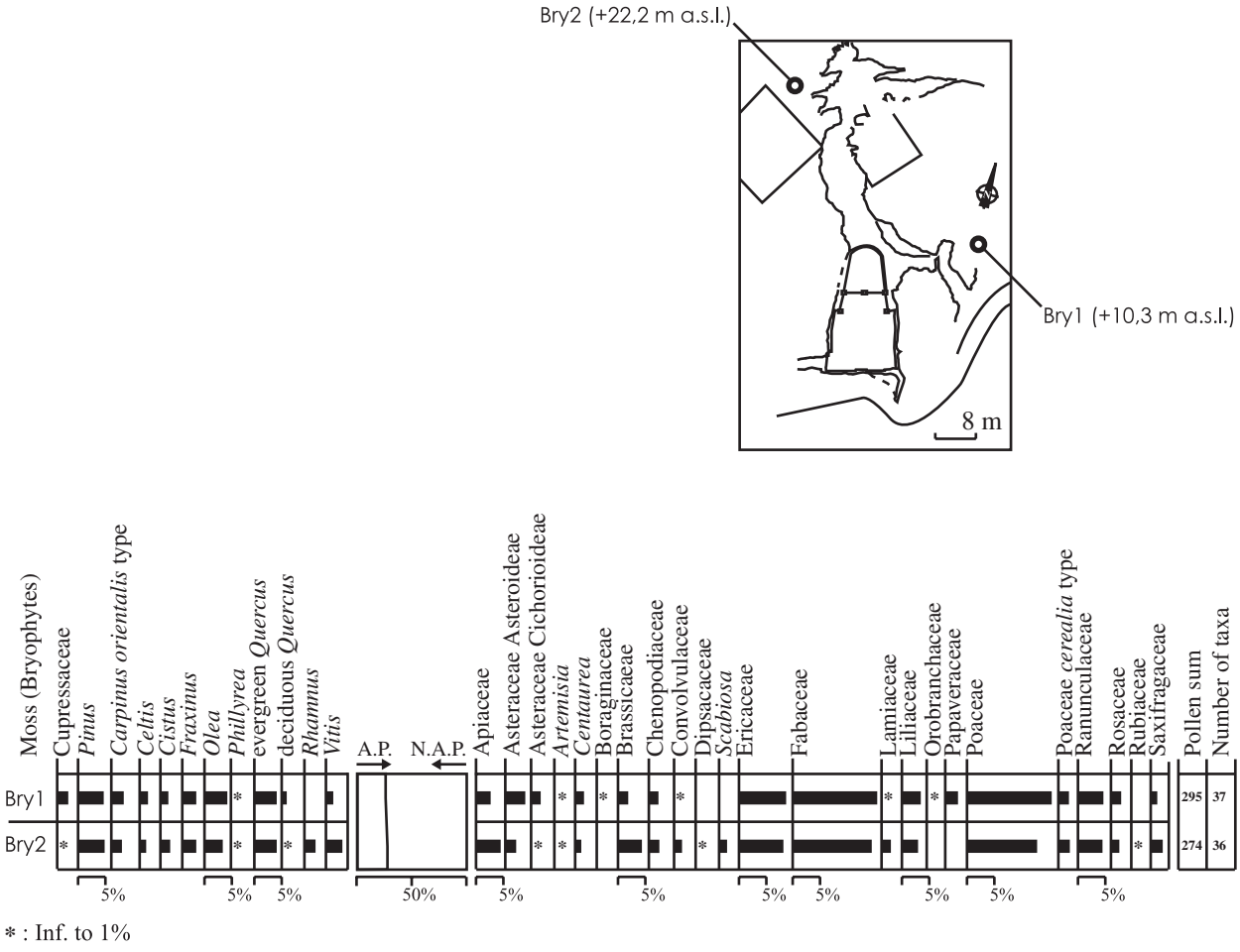


Fig. 6. Bryophyte pollen spectra: San Remo coastal zone.

hypothesis of "local pollen origin" is supported by several papers on pollen distribution [35,5,23]. It results from the hypothesis that during the early Weichselian glacial, semi-arid climatic conditions with few contrasts prevailed in Western Liguria.

Landward from the coastal semi-arid zone, the presence of fertile soils and the increase of precipitation may have generated an expansion of forest groups. These groups correspond to caducifoliate and alluvial forests. Caducifoliate–alluvial forests were probably developed in humid to per-humid zones, near the banks of Armea and Argentina rivers. From the synthetic diagram (Fig. 5), we suggest a decreasing gradient in relation to the distance from the cave [35,5,14, 23,65,47]. The pre-steppic forest, widespread in the area, is more dominant than the caducifoliate–alluvial forests and the coniferous mountain forests, both situated on lower or higher altitudes. The mountain forests are only represented by low percentages of *Abies* and *Picea* [37], caducifoliate and alluvial forests never reach 14% whereas Mediterranean trees exceed 25%. From the archaeological pollen data, we suppose that the high percentages of pre-steppic forest and Mediterranean trees in the profile are both due to the close vicinity between these vegetation structures and the cave.

The pollen profile only shows a local projection of vegetation and climate. From the pollen diagram, we are not able to detail the importance of the caducifoliate–alluvial forests and the mountain forests during the early Weichselian glacial. Even if the spectra correspond to a local approach of the environment, they show the complexity of the Mediterranean vegetation [56].

5.2. An attempt at chronological interpretation

The comparison of Madonna dell'Arma data with continuous pollen records poses the problem of ascertaining palynological correlations between two different scales (local scale and regional scale). Moreover, the biostratigraphical correlations appear uncertain because they are not firmly supported by geochronological evidences, especially considering the geographical

broadness of comparisons and the very different nature of the stratigraphical sections involved (archaeological and lacustrine sediments). Despite these major constraints, the chronological framework was established according to the main variations identified in Madonna dell'Arma profile. The characteristics of the AP/NAP curve along the whole profile seem to leave no doubt about its correlation with an interglacial or an interstadial episode. As mentioned before, despite a strong development of trees (51–89%), this expansion is mainly due to two taxa, *Pinus* and Cupressaceae. It is more characteristic for an early Weichselian glacial pre-steppic forest [58] than for interglacial or interstadial vegetation. In order to exclude each hypothesis about an interglacial or interstadial period, the archaeological pollen profile is compared to several lacustrine sequences.

The woody taxa assemblages identified in Madonna dell'Arma exclude a correlation with the Eemian interglacial [73–75,6]. The low percentages of evergreen oaks and thermophilous vegetation compared to the Valle di Castiglione [26,27,28] or Lake Kopais Eemian episode [49] exclude a correlation with OIS 5e. The succession of two important interstadial phases (St Germain I and II, correlated with the northern interstadials Brörup and Odderade; [7] following the Eemian seems to be characteristic for the early Weichselian in Europe [45,1]). The low percentages of deciduous *Quercus*, *C. betulus*, *Fagus* and *Abies* in Madonna dell'Arma [37] exclude a correlation with the St Germain Ia or Ic interstadials. The palynological profile from Madonna dell'Arma cave profile [38] has been dated in the period between St Germain II (OIS 5a) and Lanterne I (OIS 4) episodes [73–75,6]. This period precedes the first Lazio Complex interstadial during the middle pleniglacial [28,45]. The correlation between the cave profile and St Germain II–Lanterne I was corroborated by radiometric dates (91,000 yr to 73,100 yr BP; E.S.R. and U/Th).

A statistic treatment of the whole spectra from Madonna dell'Arma (Fig. 7) provides a schematic view of the relation between the cave and the dune profiles. According to these data, the dune profile is chronologically situated just after the upper spectra of the cave profile and could be situated at the onset of the Weichselian Pleniglacial where *Pinus* and Cupressaceae reach high values just before decreasing [26,6]. The problem posed by the over-representation of *Olea* and *Pistacia* in the upper part of the dune is probably related to the position of the taxa close to the profile [38,39]. Low percentages of evergreen taxa are mentioned during St Germain II episode at the Valle di Castiglione (Italy; [26–28]), in Padul (Spain; [25,57]) and in Tenaghi Philippon (Greece; [72]). We suggest therefore that the dune profile could be integrated in the early Mediterranean Weichselian glacial [1].

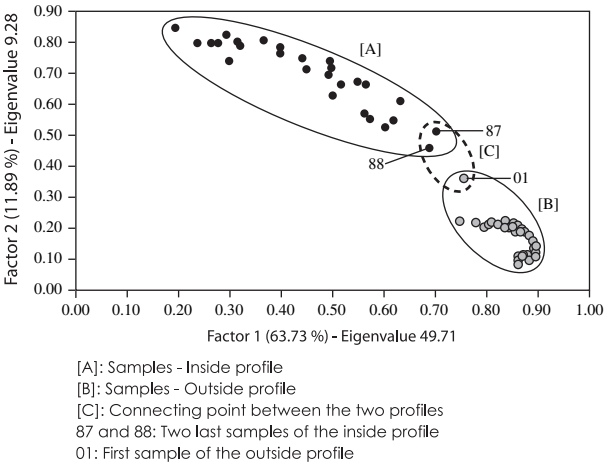


Fig. 7. Principal components analysis of the whole samples from Madonna dell'Arma cave.

5.3. Archaeological

The vegetation structures defined at Madonna dell'Arma are integrated in the archaeological context. They are in accordance with the rich fauna remains (Cervidae, Bovidae, Rhinocerontidae, etc.). The fauna shows no major changes in the dune section and excludes therefore important climate variations. The environment deduced from the fauna is a woody landscape bordered with marshy zones. These conclusions are similar to those revealed by the palynological data. The picture of vegetation also has been integrated into the multidisciplinary studies of the site and has contributed to a palaeoclimatic reconstruction similar to that based on the fauna. Despite low pollen concentrations [32], taxa identified in Madonna dell'Arma show ecological coherence all along the profile.

6. Conclusion

The pollen analysis of Madonna dell'Arma cave provides a rare picture of vegetation during the Ligurian Middle Palaeolithic. According to the taphonomic data and the nature of the deposits, we suggest that the archaeopollen profile represents a discontinuous early Pleniglacial vegetation history. Some Mediterranean trees and shrubs occurring during the St Germain II interstadial in Liguria [38] were still present during the construction of the dune above the Madonna dell'Arma cave. A chronological connection between the cave and the outside slopes is inferred (Fig. 7). The statistical analysis of the archaeo-data has allowed us to suggest three vegetation structures during this episode: a pre-steppic forest, a Mediterranean scrub and a

caducifoliate–alluvial forest. A number of restrictions have to be mentioned:

- The major part of pollen originate from the close vicinity of the site.
- This fact induces an over-representation of certain taxa generating data distortion.

These constraints have to be taken into account while comparing local profiles with continuous regional pollen records, which are considered to identify the regional vegetation picture.

Despite a strong expansion of trees and an over-representation of thermophilous taxa, which could be due to both the restrictions mentioned above, the pollen profile can be integrated in the early Weichselian glacial vegetation history. The fauna, in which genera or species like *Elephas* and *H. amphibius* have disappeared from Liguria since the end of the last interglacial period [20], corroborates the chronological hypothesis.

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