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# POLLEN ANALYSIS OF UPPER PLEISTOCENE SEDIMENTS AT CAMPO FELICE, CENTRAL ITALY

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ABSTRACT: Di Rita F. & Magri D., *Pollen analysis of Upper Pleistocene sediments at Campo Felice, Central Italy.* IT ISSN 0394-3356, 2004.
The pollen record from the lacustrine sediments of the Campo Felice Plain (Abruzzo, Central Italy) provides the first palaeovegetational data for the mountain belt of the central Apennines during the Upper Pleistocene. The estimated age of the record is 90,000 years, based on the biostratigraphical correlation with the other long pollen records from Central and Southern Italy. A wooded period at the base of the diagram is correlated with the forest phase St Germain II **s.l.**, while a long time interval of steppe vegetation in the upper part of the record is assigned to the last glacial maximum. The presence, appearance or disappearance of tree taxa (*Juniperus*, *Pinus*, *Fagus*, *Abies*, *Picea* and *Betula*) in the region is inferred from the features of the pollen diagram, which provides also information on a number of lake-level oscillations and sedimentological events.

*RIASSUNTO: Di Rita F. & Magri D.,* Analisi polliniche di sedimenti del Pleistocene superiore a Campo Felice, Italia centrale. IT ISSN 0394-3356, 2004.
*Il diagramma pollinico della Piana di Campo Felice (Abruzzo) fornisce i primi dati paleovegetazionali per la fascia montana degli Appennini centrali, al di sopra di 1500 m, durante il Pleistocene superiore. L'età stimata della base della sequenza pollinica, correlata stratigraficamente con altri diagrammi dell'Italia centrale e meridionale, è di circa 90.000 anni: un periodo con vegetazione arborea alla base del diagramma è correlato con la fase forestale St Germain II* s.l.*, mentre un lungo intervallo di tempo con vegetazione steppica nella parte superiore del diagramma è interpretato come coevo dell'ultimo massimo glaciale. La presenza, comparsa o scomparsa di alcuni taxa arborei (*Juniperus*,* Pinus*,* Fagus*,* Abies*,* Picea *e* Betula*) nella zona di Campo Felice vengono ricostruite a partire dal diagramma pollinico, che fornisce anche alcune informazioni su cambiamenti dei livelli lacustri ed eventi sedimentari.*

Keywords: pollen, Upper Pleistocene, Apennines, Abruzzo.

*Parole chiave: polline, Pleistocene superiore, Appennini, Abruzzo.*

## 1. INTRODUCTION

The palynological study on the Campo Felice Plain is part of a programme of palaeoenvironmental investigations carried out in Central Italy within a Special Project of CNR, bringing together researchers in the fields of geology, geomorphology, sedimentology, mineralogy, geochemistry, palaeontology and palynology to study the Quaternary palaeoclimate as recorded in continental successions.

This work complements the geological and geomorphological investigations already carried out in the area (Giraudi, 1998; 2001), with the aim of providing new insights into the evolution of the Campo Felice palaeolake and surrounding landscape. It represents the first palynostratigraphical investigation at high elevation on the central Apennines, offering new elements for a better comprehension of the vegetation dynamics in the mountain sectors of Central Italy, which proves to be rather different from that of middle and low elevations sites at the same latitude.

## 2. THE SITE

### 2.1. Geology and geomorphology

The Campo Felice Plain (Fig. 1), located at an altitude between 1520 and 1600 m (lat 42°13'N, long 13°27'E), occupies the ground of a closed basin of tectonic origin situated in the northern portion of the Mt Velino massif. Its catchment basin, covering a surface area of about 40 km$^2$, extending for large stretches above 2000 m and reaching 2271 m at Vena Stellante, is represented by Meso-Cenozoic limestone ridges (Accordi *et al.*, 1986).

The tectonic origin of the plain is documented by an important fault, probably active during the Holocene, oriented NW-SE in the eastern portion of the Plain (the Mt Cefalone fault) and WNW-ESE in the western portion (the Mt Orsello fault), displacing a limestone monocline raising at the northern edge of the Plain. The movement of this fault truncated a valley whose head, lying between Mt Cefalone and Mt Serralunga, is represented by the Forcamiccia Pass. This valley, that was one of the main outflow ways of the Campo Felice basin, was possibly partly covered by the sediments of Campo Felice. In fact, the survey of two deep boreholes in the Plain, in front of the Forcamiccia Pass, suggests the existence of the valley underneath the Quaternary cover (Giraudi, 1998).

Lacustrine terraces and ridges, between 1527 m and 1540 m, suggest for this basin lake level oscillations of nearly 13 m during the last 30,000 years, which are believed to have been mainly produced by climatic factors, in spite of the presence of small ponors in the Plain (Giraudi, 2001).

Most of the sediments outcropping on the Plain represent deposits of glacial, fluvioglacial, alluvial, lacustrine, and aeolian origin, datable to the Upper Pleistocene and Holocene (Giraudi, 2001). In a few restricted portions of the Plain, more ancient glacial and detritic sediments are found, probably of Middle Pleistocene age (Giraudi, 1998).

An extensive area of the basin (Cento Monti) is occupied by morains and fluvial sediments, dividing the Plain into an eastern and a western portions, where two distinct lacustrine basins were located. The present study deals with the lacustrine sediments of the eastern portion (Fig. 1), that was occupied by the widest lacustrine body and was fed by a catchment basin of nearly 24 km$^2$.

### 2.2. Present climate and vegetation

No meteorological stations are found in the Campo Felice Plain, providing direct measures for the current temperature and precipitation values. A station working at Rocca di Mezzo, a few kilometers away at an altitude of 1329 m, recorded a mean annual temperature of 8˚C in the time span of 30 years (Ministero Lavori Pubblici, 1959-1989); this value is supposedly somewhat higher than in the Plain, which lies at a higher elevation.

The mean annual precipitation recorded at Rocca di Mezzo during the same time period is 1013 mm (Ministero Lavori Pubblici, 1959-1989). The mean annual precipitation at Campo Felice may be estimated as approx. 1300 mm (Boni *et al.*, 1986).

The Campo Felice basin has never been the subject of detailed and specific botanical studies, but phytogeographic information is available for the nearby massifs of Mt Velino (Avena & Blasi, 1980) and Mt Sirente (Veri & Tammaro, 1980). The modern vegetation of Campo Felice is represented by four main features: pastures, beech forest, shrubland and grasslands above the tree-line.

The grass-covered ground represents the main vegetational landscape of the Campo Felice Plain, including both the mountain pastures and the grasslands above the tree-line. The mountain pastures extend over most of the Quaternary sediments outcropping on the Plain.

Beech represents the main natural arboreal component at Campo Felice, where it lives at an altitude from 1550 m to above 1800 m. The beech wood most likely belongs to the typical *Polysticho-fagetum* phytosociological association, assessed for the inland regions of the central Apennines. This association was also observed on the Mt Velino (Petriccione, 1993) and Mt Sirente (Veri & Tammaro, 1980) massifs.

The shrubland is mostly costituted by *Juniperus communis*, subsp. *alpina* (Suter) Celak. Other important species are: *Daphne oleoides* Schreber, *Arctostaphylos uva-ursi* (L.) Sprengel, *Cotoneaster nebrodensis* (Cuss.) C.Koch, *Rhamnus alpinus* L., *Rosa rubrifolia* Vill., *Rosa pendulina* L., *Rosa montana* Chaix, and *Chamaecytisus spinescens* (Presl) Rothm. (Blasi *et al.*, 1990). The shrubland is generally found above the forest, and reaches an altitude of 2300 m. However on the Mt Velino massif, because of deforestation for pastures, it is situated at much lower elevations, potentially belonging to the forest vegetation belt (Blasi *et al.*, 1990). In the Campo Felice area the shrub woodland is located both above and just below the beech forest, where *Juniperus* forms very wide and dense blankets.

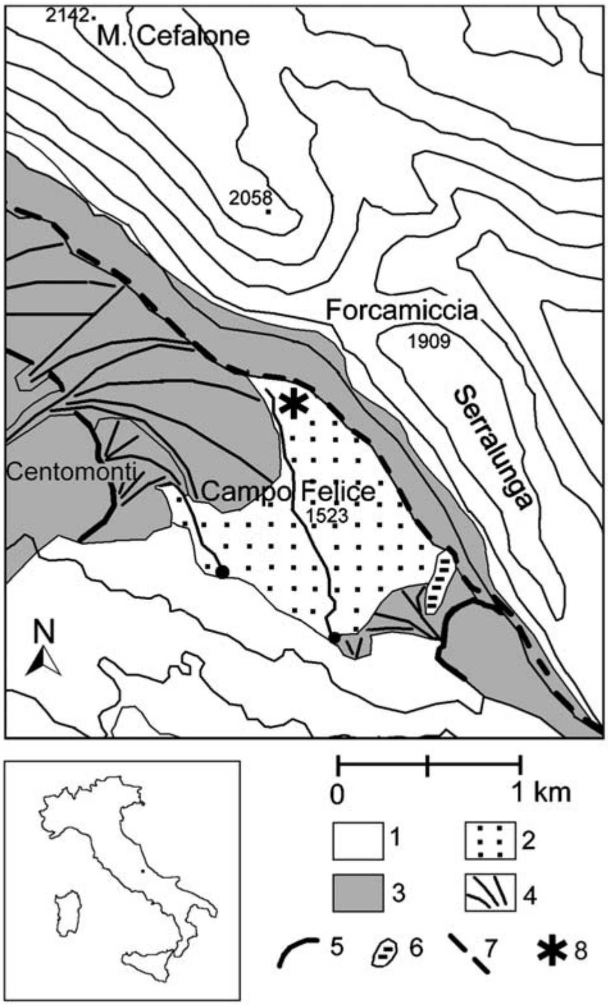



Fig. 1 -– Schematic geological map of the eastern portion of Campo Felice (simplified from Giraudi, 1998). 1. meso-cenozoic bedrock, 2. lacustrine sediments, 3. moraines, scree, breccia, 4. alluvial fans, 5. frontal moraine, 6. lacustrine beach ridge, 7. fault active during the Quaternary, 8. location of core CF7.

*Carta geologica schematica della porzione orientale di Campo Felice (semplificata da Giraudi, 1998). 1. substrato meso-cenozoico, 2. sedimenti lacustri, 3. morene, detrito di falda, breccia, 4. conoidi alluvionali e fluvioglaciali, 5. morene frontali, 6. cordone litorale lacustre, 7. faglia attiva nel Quaternario, 8. localizzazione del sondaggio CF7.*

Above the shrubland, grassland is the dominant vegetational element, characterized by *Sesleria tenuifolia* Schrader, *Gentiana lutea* L., *Pulsatilla alpina* (L.) Delarbre, *Festuca violacea* Gaudin, *Luzula italica* Parl., and *Plantago atrata* Hoppe. (Avena & Blasi, 1980).

## 3. MATERIALS AND METHODS

### 3.1. Coring and lithostratigraphy

A number of sediment cores were collected from the lacustrine plain of Campo Felice in September-November 1997. The upper 47 m of the core named CF7, the deepest core (123 m) in the eastern portion of the Plain, located just in front of the Forcamiccia Pass (Fig. 1), have been the subject of the present palynological work. The recovered lacustrine sediments mainly consist of whitish or light brown calcareous silts, intermixed by volcanic, fluvial, organic sediments and palaeosols (Giraudi, 1998). In particular, the sediments of core CF7 indicate a drying of the lake at 27.0-21.6 m where paleosols are found. At 43-42 m there is a level of dark organic sediments. From 47 m to ca. 30 m, the lacustrine sediments are frequently very rich of volcanic materials (Giraudi, personal communication).

### 3.2. Pollen analysis

The samples for pollen analysis have been selected and prepared at ca. 1 m interval from the top of the core down to 32 m and mostly at 20-30 cm interval from 32 m to 47 m, where arboreal pollen is more abundant. A total of 96 samples was analysed. They were dried and then chemically treated with HCl (37%), HF (40%) and NaOH (10%), with the aim of reducing the detrital sediments and concentrate the pollen grains. A few samples, presenting volcanic ashes even after the chemical treatment, were sieved to eliminate the particles coarser than 250 µm and finer than 7 µm. Pollen concentration values were estimated by adding *Lycopodium* tablets to known weights of dry sediment.

In all, only 55 samples presented concentration values suitable for pollen counting and representation on the pollen diagrams. In the 3 samples where Arboreal Pollen (AP) exceeds 50% the mean count was 470 terrestrial pollen grains; while in the 52 samples with more than 50% Non-Arboreal Pollen (NAP) the mean count was 199 terrestrial pollen grains. The preservation of the pollen grains was generally modest, the mean percentage of indeterminable grains per sample (degraded, corroded and broken) is 8%. Excluding the spores, 59 pollen taxa have been identified, the highest number of taxa per sample being 36 and the lowest 9.

According to the morphological characters of *Quercus* pollen described by van Benthem *et al.* (1984), two pollen types were distinguished, deciduous and evergreen *Quercus.* The pollen type named *Ostrya* type includes both *Ostrya carpinifolia and Carpinus orientalis*.

## 4. RESULTS

### 4.1. The pollen diagram

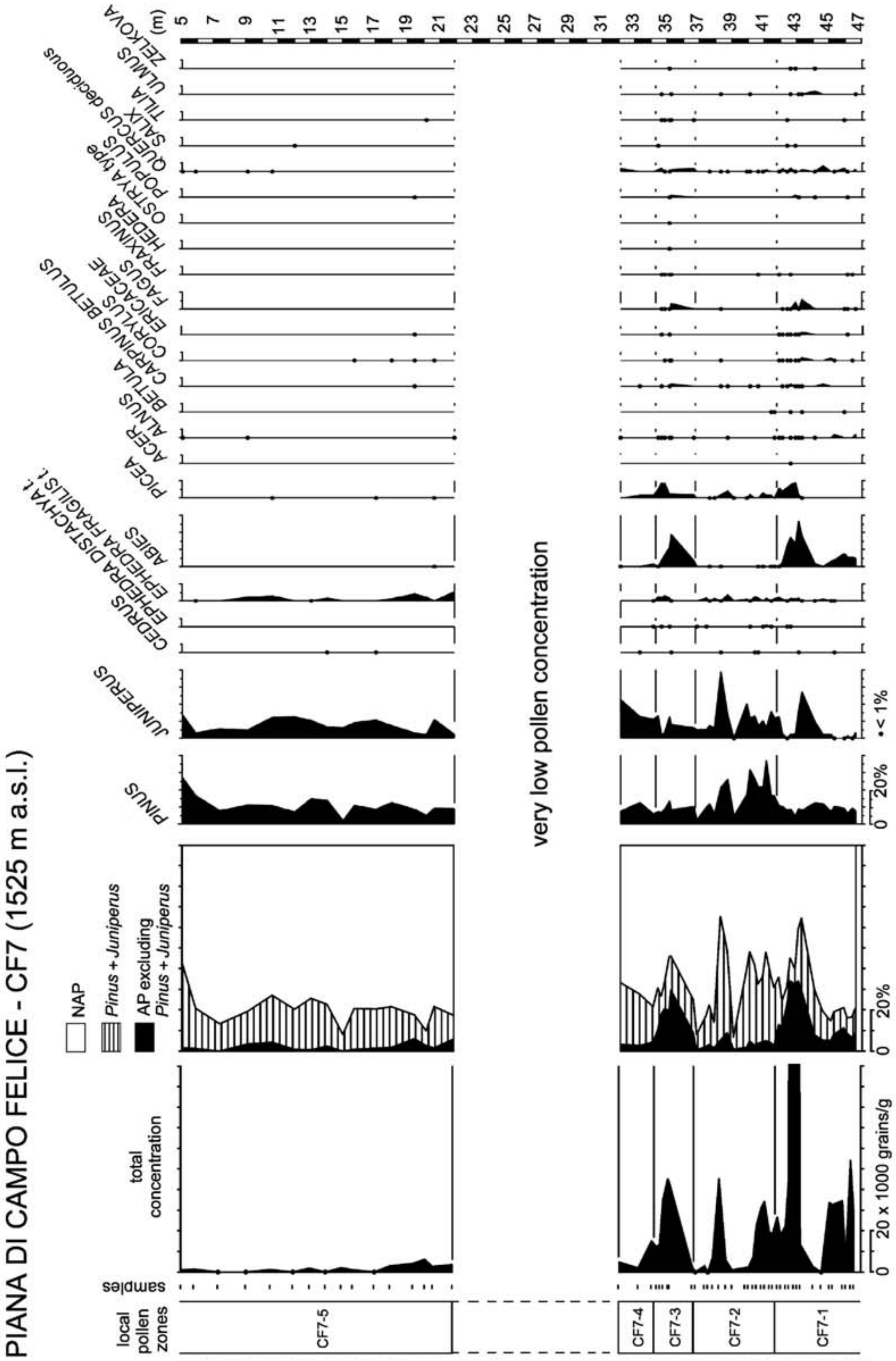
The results of the pollen analysis are represented in Fig. 2. Local pollen zones, defined by subjective zonation, are indicated by the site designation prefix CF followed by core number 7, and are numbered from the base upwards. Five pollen zones have been defined.

*Zone CF7-1 (46.57-41.70 m)* - This zone represents a wood expansion, with maximum AP percentages of 64% at the top of the zone. Total pollen concentrations are very disomogeneous, ranging from 900 to over 1,600,000 grains/g. *Abies* is the most important tree taxon. Several arboreal taxa reach the highest percentage values of the sequence, although not all at the same depth: *Alnus* (2%) at 46.57 m, deciduous oaks (3%) at 44.55 m, *Ulmus* (2%) at 44.05 m, *Corylus* (1.5%) at 43.25 m, *Fagus* (5%) at 43.25 m, *Abies* (26.5%) at 43.05 m, and *Picea* (9%) at 42.85 m. This succession clearly indicates a forest dynamics with elements of mixed oak forest at the beginning, followed by montane tree taxa (beech and fir) and finally by spruce, as it is commonly observed in many European pollen records in the course of an interglacial cycle (Birks, 1986). Several AP taxa are sporadically present, with percentages <1%: *Fraxinus, Tilia, Salix, Betula, Populus*, and *Zelkova*. *Pinus* shows values of 5-12%, which may not indicate a significant local distribution of pine, whose pollen is frequently over-represented in the pollen diagrams. Among the herbs, very high percentages of Cichorioideae (max. 66%) are recorded at the base of the zone. Gramineae (max. 21%), *Artemisia* (mostly 5-7%) and Caryophyllaceae (5%) are also well respresented.

*Zone CF7-2 (41.70-36.67 m)* - This zone is characterized by sparse presence of deciduous trees pollen, never reaching 2% altogether. Two arboreal taxa show important values: *Pinus*, with a peak of 37% at 41.05 m, is the dominant tree in the lower half of the zone, and *Juniperus*, with a sharp peak of 39% at 38.25 m, is the dominant element in the upper part of the zone. Among the other Gymnosperms, only *Picea* (4%) and *Ephedra fragilis* type (3.5%) at 38.67 m reach appreciable values. The pollen concentration of AP is generally low, except for *Pinus* (with a peak of over 17,000 grains/g) and *Juniperus* (over 12,500 grains/g). Herbs are very abundant and diversified: *Artemisia* is the most important NAP taxon, increasing from 23% at 41.55 m to 62% at 37.35 m. Other important NAP are: Cichorioideae (2-20%, with a single sharp peak reaching 44%), Gramineae (max. 10%), Asteroideae (max. 7%), Chenopodiaceae (max. 6%) and *Thalictrum* (max. 3.5%).

*Zone CF7-3 (36.67-34.23 m)* - This is a new moderate wood expansion, although less important than in zone CF7-1, as AP percentages reach 46%. Pollen concentrations range between 3000 and 45,000 grains/g. *Abies* is the most important tree taxon, peaking 18.5% at 35.18 m. Other significant tree taxa are: *Picea*, showing a peak (8.7%) at 34.58 m, *Fagus* (3%), *Quercus* (1.8%). Moreover, a number of arboreal taxa are present with very low percentages, including *Zelkova*, with its most recent appearance at 35.08 m. Similarly to zone CF7-1, in zone CF7-3 it is possible to recognize a pattern of forest dynamics with different trees expanding one after the other: first deciduous *Quercus* peaking at 36.57 m, then *Fagus, Carpinus betulus, Populus* and *Abies* at 35.18 m, and finally *Picea* at 34.58 m. Among the herbs, Cichorioideae are very abundant, together with Gramineae and *Artemisia*.

*Zone CF7-4 (34.23-32.05 m)* - This zone is characterized by high NAP values. Boadleaved trees do not reach 3% altogether. *Pinus* and *Juniperus* are the only arboreal taxa continuously present. In the lower part of the zone there is a very pronounced peak of *Artemisia* (57%), accompanied by Cichorioideae (7%); in the upper part of the zone an increase of Cichorioideae (up to 40%) corresponds to a decrease of *Artemisia* (max.


PIANA DI CAMPO FELICE - CF7 (1525 m a.s.l.)
NAP
Pinus + Juniperus
AP excluding Pinus + Juniperus
depth (m)
local pollen zones
samples
total concentration
CF7-5
CF7-4
CF7-3
CF7-2
CF7-1
20 x 1000 grains/g
20%
• < 1%
very low pollen concentration
PINUS
JUNIPERUS
CEDRUS
EPHEDRA DISTACHYA t.
EPHEDRA FRAGILIS t.
ABIES
PICEA
ACER
ALNUS
BETULA
CARPINUS BETULUS
CORYLUS
ERICACEAE
FAGUS
FRAXINUS
HEDERA
OSTRYA type
POPULUS
QUERCUS deciduous
SALIX
TILIA
ULMUS
ZELKOVA
(m)

2a)

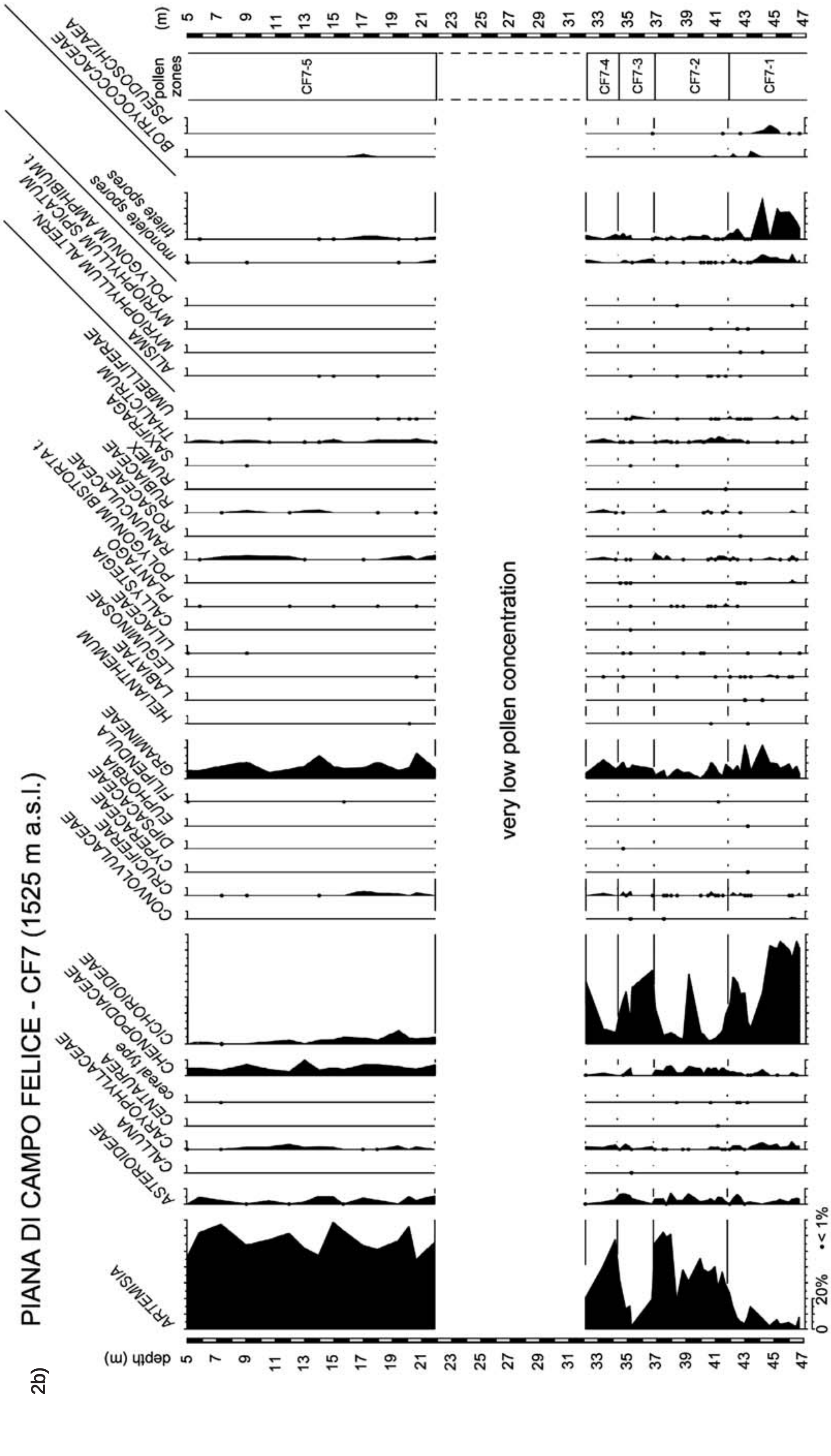



Fig. 2 – Pollen diagram of Campo Felice.
*Diagramma pollinico di Campo Felice.*

20%). Other significant NAP are Asteroideae, Gramineae and Caryophyllaceae. The mean pollen concentration is 7300 grains/g.

The sediments between 32.05 m and 21.82 m have very low pollen concentrations. For this reason the pollen counts cannot be adequately represented on the diagram, that is interrupted even if the sediment core is available.

*Zone CF7-5 (21.82-5.04 m)* – This zone represents a period dominated by herbaceous taxa with only very sporadic apparences of broadleaved trees. The mean AP percentage value is around 20%, including *Pinus* and *Juniperus*, that are the only important arboreal taxa. *Ephedra fragilis* type shows appreciable values, reaching 5% at 21.82 m. The whole zone is characterized by a considerable abundance of *Artemisia*, which is the dominant taxon (always >44% with a peak of 68% at 14.94 m). Gramineae (max. 16%) and Chenopodiaceae (max. 10%) are also important NAP. The pollen concentration values are generally very low, being comprised between 800 and 6150 grains /g.

## 5. DISCUSSION

The interpretation of the floristic data and vegetational dynamics recorded in the pollen diagram cannot omit consideration of the geographic characters of the Campo Felice Plain, in particular of its elevation, above 1500 m a.s.l., which also at present is the main factor affecting the vegetation.

### 5.1. Vegetation changes

The time period recorded by the pollen diagram of Campo Felice shows two distinct vegetational phases each characterized by a significant floristic renewal, deeply changing the landscape: zones CF7-1 to CF7-3 display a certain expansion of arboreal vegetation while zones CF7-4 and CF7-5 are typified by steppe and grassland diffusion.

Zone CF7-1 represents a vegetational phase characterized by a relatively high number of arboreal taxa (22), even if AP exceeds 50% only in the sample at 43.05 m, where also the pollen concentration is high (>600,000 grains/g). As modern palynological studies indicate that real forest conditions are associated to AP percentage values of at least 75% (Reille, 1975), zone CF7-1 cannot be considered a real forest phase, with dense tree cover. However, considering the high elevation of the site, which does not allow even at present a full forest expansion, and the clear vegetation dynamics showing a succession of peaks of deciduous tree taxa and conifers, this zone is certainly indicative of dense tree cover at lower elevations.

Zone CF7-3 is characterized by a number of arboreal taxa (both conifers and broadleaved trees) similar to zone CF7-1, but with lower AP percentages (max 46%), due to generally lower values of *Abies*, *Fagus*, and floristic elements belonging to the “Quercetum mixtum”, such as deciduous oaks, *Carpinus betulus* and *Ulmus*. Also in zone CF7-3 a clear succession of arboreal taxa, presently belonging to different vegetational belts, can be recognized, starting with few grains of deciduous *Quercus*, living nowadays at an altitude lower than at Campo Felice, followed by *Fagus* and *Abies*, and finally by *Picea*, which is presently found on the Alps beetwen 1000 and 1900 m (Pignatti, 1982). This vegetation dynamics is therefore characterized by a progressive diffusion of mountain arboreal taxa, ending with an open vegetation with *Juniperus* and *Pinus* in zone CF7-4.

Zones CF7-1 and CF7-3 are separated by a period (zone CF7-2) with steppe and grassland diffusion. AP percentages do not undergo a substantial decrease, as *Juniperus* and *Pinus* maintain high values. This zone displays a decrease of deciduous trees and *Abies* and an increase of *Artemisia* and other herbaceous taxa, such as Chenopodiaceae, that altogether are typical components of the cold and arid steppes of the Pleistocene glacial stages.

This vegetation type is also characteristic of zones CF7-4 and CF7-5, when the presence of deciduous trees and fir is further reduced to very rare appearances. Very high percentage values of *Artemisia*, Gramineae and Chenopodiaceae are presently found both in arid regions with very cold winters (e.g. in the mountainous regions of Armenia) and in arid areas between desert and Mediterranean vegetation in Northern Africa, where winters are generally mild. In both cases, the dryness of climate appears to be the main limiting factor for tree growth.

### 5.2. Floristic diversity

A comparison with the present-day flora of the Campo Felice area may help in defining which taxa have been continuously present in the vicinity of the site and which have immigrated or disappared from the area.

Apart from grasses, which are abundantly found throughout the diagram and also at present form the main vegetation type of the Campo Felice Plain, it is worth mentioning the presence of *Juniperus* pollen type in all the samples of core CF7, both in the periods with woody vegetation and with open vegetation. This indicates that the modern abundance of *Juniperus*, representing one of the main vegetational elements of the plain both above and below the beech wood belt, has a long history of local persistence, and that the geographic and climatic features of Campo Felice have been particularly favourable for the maintenance and development of juniper.

Another taxon which is continuously well represented in the pollen diagram is *Pinus*, which is however very rare in the modern flora of the area. This abundance can reasonably be interpreted as long distance transport, as pine is a huge pollen producer and its pollen is conspicuously found also in all the other Italian pollen records (e.g. Follieri *et al.*, 1988; Watts *et al.*, 1996; Magri, 1999; Magri & Sadori, 1999).

The modern diffusion of *Fagus* around the Campo Felice Plain can be shown to be relatively recent. In fact, while beech is present in zones CF7-1 and CF7-3, with values always <6%, it completely disappears in zones CF7-4 and CF7-5. This suggests that the modern beech wood was most likely reintroduced in the course of the postglacial forest expansion, migrating from refuge areas which were presumably located at lower elevations, as indicated by the more or less continuous presence of beech at other sites of Central Italy (Follieri *et al.*, 1998).

In the pollen diagram from Campo Felice three pollen taxa are recorded that have presently a broken distribution in Central Italy: *Abies, Picea* and *Betula*. The history of the distribution of these genera during the late Quaternary has been highlighted in the palynological works from Central Italy, including Valle di Castiglione (Follieri *et al.*, 1988), Lagaccione (Magri, 1999), Lago di Vico (Magri and Sadori, 1999), Stracciacappa (Follieri *et al.*, 1998), and Lago Lungo near Rieti (Calderoni *et al.* 1994).

*Abies alba* Mill., is the only fir species occurring in the Italian Peninsula; it is found on the Alps, on the Southern Appenines, and at a few isolated sites on the Central and Northern Appenines (Quezel, 1980). In the Abruzzo region *Abies is* presently found as a relic, associated with *Fagus* in a few beech-wood stands of very cold sites in the Teramo province (Zodda, 1967; Longhitano & Ronsisvalle, 1974). The long pollen records from Central Italy show that fir was very rare during the Eemian, corresponding to Marine Isotope Stage (MIS) 5e, while it characterized both the St Germain periods which are the last forest phases before the postglacial (MIS 5d and 5a) (Follieri *et al.*, 1998). After these forest phases, *Abies* pollen is only sporadically recorded, probably from far origin. In fact, *Abies* is continuously represented in pollen diagrams from both Southern Italy, at Lago Grande di Monticchio in Basilicata (Watts, 1985; Watts *et al.*, 1996), at Canolo Nuovo in Calabria (Grüger, 1977), and in a marine core from the Tyrrhenian Sea (Rossignol Strick and Planchais, 1989), and from Northern Italy in the Apennines (Bertoldi, 1980; Lowe and Watson, 1993; Watson, 1996). These pollen data show that the present-day broken distribution of *Abies* is the result of a strong reduction occurred during the last pleniglacial especially in Central Italy. At Campo Felice *Abies* shows the typical trend of the other sites from Central Italy, being an important tree taxon during the wood expansions of zones CF7-1 and CF7-3, and disappearing during the open vegetation zone CF7-5.

*Picea* is one of the most characteristic taxa of the Campo Felice record. According to the present-day pollen-vegetation relationships (Huntley & Birks, 1983; Hicks, 1994), pollen percentage values higher than 5% indicate a local presence of *Picea*. In the Campo Felice record seven samples show values of spruce above this percentage threshold. In particular, two peaks of *Picea* (attaining 9%) are recorded in zones CF7-1 and CF7-3, indicating that this taxon was one of the main floristic elements of the wooded landscape at the end of the arboreal succession. The late-Quaternary history of *Picea* in Central Italy starts with a spread at the end of the St Germain II forest phase (MIS 5a) in all the pollen sites of the Lazio region, where a second increase took place during the middle pleniglacial interstadials (Follieri *et al.*, 1998). The modest percentage values recorded around 20,000 BP at Lago di Vico and Stracciacappa represent the last expansion of this taxon in the region. In the pollen record from Lago Grande di Monticchio, in Basilicata, *Picea* is not recorded (Allen *et al.*, 2000). The presence of *Picea* pollen in zones CF7-1 and CF7-3, even if in low percentages, is very remarkable, as its present geographic distribution is very northern: in Italy *Picea abies* (L.) Karsten lives only on the Alps and in very few relic stations in the Northern Appennines (Pignatti, 1982; Jalas & Suominen, 1973). The sites from Lazio provide evidence that, from about 80 ka to 20 ka, the geographical distribution of spruce was definitely more southern than at present. The Campo Felice record, where *Picea* percentage values are the highest of Central Italy probably in relation to the high elevation of the mountain ranges, confirms that spruce was also diffused in the Abruzzo region.

Sporadic pollen grains of *Betula* are recorded in 5 samples of zones CF7-1 and CF7-2, never attaining 1%. At present, birch has its range-bulk centered at northern latitudes in Europe, but is also present at scattered sites of the Italian peninsula (Spada *et al.*, 1995). In the Abruzzo region small stands of few individuals of *Betula pendula* Roth. are found in a few restricted mountain areas. Two main hypotheses have been advanced to explain this distribution: Agostini (1981) suggests that the present geographic distribution of birch in the Italian peninsula is the result of a migration from more northern latitudes during the last pleniglacial. On the contrary, Spada *et al.* (1995) consider the present-day scantiness of birch on the Apennines as resulting from an extreme fragmentation of a previously more continuous range, due to reiterated dryness of climate during the Quaternary glacial cycles. Even if it is impossible to state whether the birch pollen of the Campo Felice diagram was produced by very sparse trees living in the landscape in the vicinity of the lake or by larger stands at a distant location, it clearly appears that the open vegetation of the upper part of the diagram, which is typical of the glacial phases of the Quaternary, was unfavourable for the development of *Betula* populations, and that, in the time span recorded by the diagram, there is a general trend towards a decrease of *Betula*, supporting the hypothesis by Spada *et al.* (1995).

Finally, a taxon is recorded at Campo Felice which is extinct in the Italian peninsula but is present as a relict in Sicily (Di Pasquale *et al.*, 1992). *Zelkova* characterizes the Eemian interglacial (MIS 5e) at Valle di Castiglione (Follieri *et al.*, 1986). It is continuously recorded during the St Germain I and II forest periods (MIS 5d and 5a), but it became rare during the pleniglacial interstadials (MIS 3), when it eventually disappared (Follieri *et al.*, 1998). A few pollen grains of *Zelkova* are recorded at Campo Felice in four samples of zones CF7-1 and CF7-3. Although these sporadic findings are most likely of far geographic origin, as *Zelkova* is a thermophilous tree, they take on a special value as they may represent an important chronological reference *ante quem*.

### 5.3. Biostratigraphy

As no radiocarbon data are available for the CF7 core, the chronostratigraphical interpretation of the record can only be based on a comparison of the floristic and vegetational features of the Campo Felice pollen diagram with the long records from Central and Southern Italy which have an own chronostratigraphical setting. The records from Valle di Castiglione near Rome (Follieri *et al.*, 1988), Lago di Vico (Magri & Sadori, 1999), Lagaccione near Lago di Bolsena (Magri, 1999) and Lago Grande di Monticchio in Basilicata (Watts *et al.*, 1996, Watts *et al.*, 2000, Allen *et al.*, 2000) may be particularly useful, even if they are located at much lower elevations (0-700 m a.s.l.)

Based on the assumption that the studied stretch of core CF7 does not include hiatuses as long as hundred thousand years, the zones at the base of the record, where woodland dominates the landscape, should most likely be correlated with the last forest expansions before the postglacial, that is with phases corresponding to substages of MIS 5. However, a correlation with the Eemian interglacial (MIS 5e) can be definitely excluded, as this was characterized by very termophilous vegetation (Follieri *et al*., 1988), not represented in core CF7. Instead, it seems resonable to assign the wooded pollen zones CF7-1 and CF7-3 to the two St Germain forest phases (roughly corresponding to MIS 5c and 5a, respectively), or with one of the two. The floristic and vegetational features of the St Germain periods recorded in the long records of Central Italy may constitute the basis for this assignment.

The St Germain I forest period is characterized, both at Valle di Castiglione (Follieri *et al*., 1988) and at Lagaccione (Magri, 1999), as well as at Lago Grande di Monticchio (Allen *et al.*, 2000) by deciduous oaks and *Fagus*, as the main components of the vegetation, accompanied by *Carpinus* and *Ulmus*. At the end of this forest expansion, *Abies* attains very high percentage and concentration values. The following non-forested phase (Melisay II, MIS 5b) is dominated by Chenopodiaceae, with very high percentages, not only in the Italian sites (Valle di Castiglione, Lagaccione and Lago Grande di Monticchio), but also in other sites of Southern Europe, such as Kopais (Tzedakis, 1994) and Tenaghi Philippon (Wijmstra, 1969).

The St Germain II *sensu lato* forest period (Fig. 4) is well-represented in the Lazio region at Lagaccione (Magri, 1999) and at Lago di Vico (Magri & Sadori, 1999) and partly recorded at Valle di Castiglione (Follieri *et al*., 1988). In these sites the St Germain II is characterized by two forest oscillations, locally named Etruria I and Etruria II, followed by a third minor oscillation (Etruria III) (Magri & Sadori, 1999). They are separated by two periods in which trees are continuously present, although clearly reduced, as only *Pinus* shows high percentage values. The first two forest phases (Etruria I and II) display very similar vegetation dynamics, starting with deciduous oaks and *Corylus*, followed by an expansion of *Fagus* and *Carpinus betulus*, and ending with an increase of *Abies*, while the third arboreal oscillation (Etruria III) is clearly distinct due to the dominance of deciduous oaks, accompanied by many trees in low percentages, and to the increase of *Picea*, which during the St Germain I had very low values.

Two hypotheses may be advanced to define the biostratigraphical setting of zones CF7-1 and CF7-3. On the basis of the importance of *Abies*, they can be correlated either with St Germain I and St Germain II, respectively, or with two different fluctuations of the St Germain II *sensu lato* forest period.

A correlation of zones CF7-1 and CF7-3 with St Germain I and St Germain II, respectively, would imply that they are considered to be two remarkable and well distinct wood expansions, separated by a very harsh steppe environment. The presence of *Picea* in zone CF7-1 would not match the floristic characters of St Germain I highlighted by the other sites of Central Italy, where *Picea* pollen is abundantly recorded only during the St Germain II and it is almost absent during the St Germain I.

The features of the Campo Felice wood phases correspond to two moderate diffusions of arboreal vegetation separated by a steppe phase in which the elements of the deciduous woodland do not completely disappear and conifers are well represented (Fig. 3). For this reason a correlation of zones CF7-1 and CF7-3 with Etruria I and Etruria II, respectively, appears much more convincing than a correlation with St Germain I and St Germain II. In fact, in the Campo Felice record, the open vegetation phase (zone CF7-2) between the two wood-

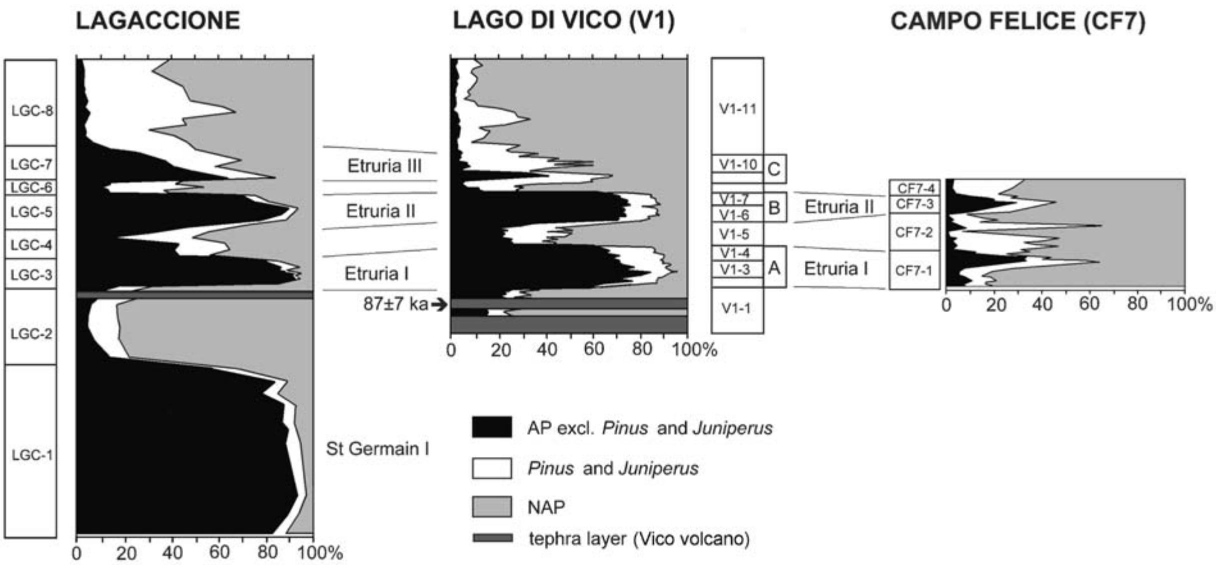



Fig. 3 – Correlation of the pollen diagrams from Lagaccione (Magri, 1999), Lago di Vico (Magri & Sadori, 1999) and Campo Felice for the Etruria forest phases (partly redrawn from Magri & Sadori, 1999).

*Correlazione dei diagrammi pollinici di Lagaccione (Magri, 1999), Lago di Vico (Magri & Sadori, 1999) e Campo Felice per le fasi forestali Etruria (in parte ridisegnato da Magri & Sadori, 1999).*

land periods is not as marked as in the Melisay II, between St Germain I and St Germain II, in the other long European pollen records. The abundance of *Picea* in zone CF7-1, typical of St Germain II in Central Italy, is a further evidence in favour of this correlation.

The main difference between the wooded zones in the CF7 record (CF7-1 and CF7-3) and those of the coeval other long records from Central and Southern Italy is the scantiness of *Fagus*, which was clearly much more abundant at lower elevations, for example Lagaccione (355 m; Magri, 1999), Lago di Vico (510 m; Magri & Sadori, 1999), and Lago Grande di Monticchio (656 m; Allen *et al*., 2000) than at the high mountain sites.

In the long Italian records (Follieri *et al*., 1998; Allen *et al*., 2000), soon after the St Germain II there is a steppe phase with no arboreal taxa, excepting *Pinus* and *Juniperus*, corresponding to MIS 4, followed by a number of more or less weak forest oscillations corresponding to MIS 3, and finally by very marked steppe vegetation during MIS 2, before the late- and postglacial reforestation. Zone CF7-5 can be easily correlated with the last pleniglacial period, that everywhere in Europe is characterized by open vegetation with very high percentage values of *Artemisia*, *Pinus* and Gramineae and very low pollen concentrations. Also the upper part of the Campo Felice diagram is represented by samples with very low pollen concentration, indicating a very poor open vegetation, dominated by *Artemisia*, *Pinus*, *Juniperus*, Gramineae and Chenopodiaceae, and almost lacking in deciduous trees. The floristic features of this period at Campo Felice are not distinctive enough to individuate the pleniglacial interstadials of MIS 3. This may be due either to the high elevation of the site, which did not allow any tree population expansion during those short climate oscillations, or to a lack of record, if the pleniglacial interstadial are chronologically correspond to the sediments from 32 m to 22 m, where the diagram is interrupted. Anyway the stratigraphical position of the lacking record would suggest that this could include the sediments corresponding to the middle pleniglacial interstadials.

On the basis of these biostratigraphical considerations, the approximate age of the base of zone CF7-1 can be estimated as 90,000 years, that is the age of the beginning of the St Germain II forest period, supported also by the 87±7 ka old Ar/Ar date of a tephra layer at the base of St Germain II at Lago di Vico (Magri & Sadori, 1999). By comparison with the age model proposed for the Lago Grande di Monticchio record (Allen *et al.* 2000), the top of zone CF7-3 may be estimated as approximately 75,000 years old. While it is difficult to define the age of the sediments poor in pollen between 32 m and 22 m, zone CF7-5 can be reasonably assigned to MIS 2. Holocene sediments, characterized everywhere in Italy and southern Europe by a rich forest vegetation, are not represented in the CF7 pollen diagram.

### 5.4. Pollen and lacustrine sedimentation

The long pollen record of Campo Felice provides some useful elements for interpreting the sedimentological events occurred in the lacustrine basin of the eastern portion of the Plain.

The lower part of the CF7 diagram (zones CF7-1 and CF7-3) presents a series of considerable peaks of pollen of Cichorioideae. This is often abundant in paleosols or in oxydized sediments, such as cultural layers from caves (Bottema, 1975), as it is very resistant to corrosion and its typical morphology can be easily recognized even in deteriorated grains. For this reason high dominance of Cichorioideae percentages may be due to differential preservation of pollen grains and may have no value as indicator of steppe or other open vegetation (Havinga, 1984). Similar resistance has been observed in *Lycopodium* and *Polypodium* spores (Havinga, 1984). Abundant trilete and monolete spores are recorded in zone CF7-1. In the same levels, very rich in detrital sediments of volcanic origin, significant amounts of *Pseudoschizaea*, a bilaterally-symmetrical cell with finger-print-like concentric striations (Christopher, 1976; Scott, 1992), are recorded. This taxon is considered to be a good indicator for increased soil erosion and possibly also for running water (Pantaleón-Cano *et al.*, 1996). The contemporary abundance of Cichorioideae, *Pseudoschizaea* and spores in zone CF7-1 brings evidence for erosional phases in the catchment basin, possibly accompanied by lowerings of the lake level.

Several reasons can explain why the sediments between 32 m and 22 m depth are very poor in pollen, including a very scarce pollen production due to sparse vegetation, very fast sediment accumulation rates, drying of the lake, or severe pollen deterioration. In fact, a combination of all these factors may have also occurred, with a drastic lowering of the lake, preventing the conservation of the few pollen grains produced by an open vegetation. This interpretation is also supported by the presence of palaeosols between 23.7 m and 21.0 m depth in core CF7. The stratigraphical position of this stretch of core, between St Germain II and the last glacial stage (corresponding to MIS 2) would indicate for this pollen hiatus an age corresponding to MIS 3 and maybe part of stage 4.

The zone CF7-5, corresponding by and large to the last glacial maximum, shows a continuous and well-represented pollen record, with no evidence for important lake lowerings. This result is in agreement with the high level stand demostrated for the Campo Felice lake by a terrace at 1540 m assigned to MIS 2 (Giraudi, 2001), and also with the general state of many lakes around the Mediterranean region, reaching their highest levels during the last glacial maximum (Giraudi, 1989; Bartov *et al*., 2002).

## 6. CONCLUSIONS

The pollen record from Campo Felice offers new insights for a better understanding of the vegetation dynamics occurred in the mountain areas of Central Italy during the Upper Pleistocene. In fact, this study represents the first palynostratigraphical investigation at an elevation of over 1500 m a.s.l. in Central Italy.

The chronological interpretation of the record indicates that the age of the sediments at 47 m in core CF7 is approx. 90,000 years. The floristic characters of the lower part of the diagram is correlated with two oscillations of the St Germain II forest period, recorded at four other sites in Italy at lower elevations. The upper part of the CF7 diagram is correlated with the last glacial maximum, characterized by steppe vegetation, as in most of Southern Europe.

Several vegetational features of the Campo Felice Plain can be interpreted as an effect of the high elevation of the site, in particular the considerable abundance of *Juniperus*, a taxon always present in the site throughout the last 90,000 years, the infrequency of deciduous tree taxa even during the main wooded phases, the sparse vegetational cover during the last pleniglacial, when Campo Felice was covered by ice sheets, as documented by the geomorphology of the site (Giraudi, 1998; 2001), the significant amount of *Picea*, a tree that during the last glacial period occupied a much more southern position than at present, finding favourable conditions for its growing on the Abruzzo mountains. The low abundance of *Fagus* during the wooded zones of the diagram (CF7-1 and CF7-3) is rather unexpected, as nowadays beech represents the main floristic element of the Campo Felice arboreal cover and is generally the most important tree of the mountain belt of the Apennines. A comparison with the other sites in Central and Southern Italy indicates that during the St Germain II phase beech dominated a densely covered vegetation belt at a lower elevation, while the areas over 1500 m were occupied by a more sparse vegetation, in which the most important trees were represented by conifers *(Abies, Picea, Juniperus*, and *Pinus*). *Juniperus* is currently the only remnant of this vegetation type.

The results obtained through this palynological study show that the Campo Felice Plain and the mountain areas of the Central Apennines deserve further attention. The multidisciplinary integration of geomorphological and sedimentological data with the CF7 pollen record, set in the palynostratigraphical framework established for Central Italy, allows some inferences to be made on the palaeoenvironmental evolution of the basin and on the reconstruction of lake level variations in relation to climatic events of the Upper Pleistocene. Besides, it would be important to support the chronology of the most significant biostratigraphical events the CF7 core by other sources of evidence, and to study through pollen analysis other sediment records from the Campo Felice Plain.

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## REFERENCES

Accordi G., Carbone F., Civitelli G., Corda L., de Rita D., Esu D., Funicello R., Kotsakis T., Mariotti G. & Sposato A. (1986) - *Lithofacies map of the Latium-Abruzzi and neighbouring areas*. C.N.R., Quaderni della ricerca scientifica**, 114**(5), 223 pp.

Agostini R. (1981) - *Contributo alla conoscenza della Betulla (*Betula pendula *Roth.) nell'Appennino centro-meridionale e in Sicilia e del suo significato fitogeografico*. Studi Trentini di Scienze Naturali, **58** (Acta Biol.), 35-56.

Allen J.R.M., Watts W.A. & Huntley B. (2000) - *Weichselian palynostratigraphy, palaeovegetation and palaeoenvironment; the record from Lago Grande di Monticchio, southern Italy*. Quaternary International, **73-74**, 91-110.

Avena G.C. & Blasi C. (1980) - *Carta della vegetazione del Massiccio del Monte Velino. Appennino Abruzzese. Scala 1:25000.* C.N.R., Collana Programma Finalizzato "Promozione della Qualità dell'Ambiente", AQ/1/35. Roma.

Bartov Y., Stein M., Enzel Y., Agnon A. & Reches Z. (2002) - *Lake levels and sequence stratigraphy of Lake Lisan, the late Pleistocene precursor of the Dead Sea*. Quaternary Research**, 57**, 9-21.

Bertoldi R. (1980) - *Le vicende vegetazionali e climatiche nella sequenza würmiana e post-würmiana di Lagdei (Appennino settentrionale)*. Ateneo Parmense, Acta Naturalia, **16**, 147-175.

Blasi C., Gigli M.P. & Stanisci A. (1990) - *I cespuglieti altomontani nel gruppo del M. Velino (Italia centrale)*. Annali di Botanica (Roma), **48** (suppl. Studi sul Territorio 7), 243-261.

Birks H.J.B. (1986) - *Late Quaternary biotic changes in terrestrial and lacustrine environments, with particular reference to north-west Europe*. In Berglund B.E. (Ed.) Handbook of Holocene Palaeoecology and Palaeohydrology. John Wiley and Sons, Chichester, pp. 3-65.

Boni C., Bono P. & Capelli G. (1986) - *Schema idrogeologico dell'Italia centrale*. Memorie della Società Geologica Italiana, **35**, 991-1012.

Bottema S. (1975) - *The interpretation of pollen spectra from prehistoric settlements (with special attention to Liguliflorae)*. Palaeohistoria, **17**, 17-35.

Calderoni G., Carrara C., Ferreli L., Follieri M., Gliozzi E., Magri D., Narcisi B., Parotto M., Sadori L., Serva L. (1994) - *Palaeoenvironmental, palaeoclimatic and chronological interpretations of a late-Quaternary sediment core from Piana di Rieti (central Apennines, Italy)*. Giornale di Geologia, **56**(2), 43-72.

Christopher R.A. (1976) - *Morphology and taxonomic status of* Pseudoschizaea *Thiegart and Franz ex R. Potonié emend*. Micropaleontology, **22**(2), 143-150.

Di Pasquale G., Garfi G. & Quezel P. (1992) - *Sur la presence d'un* Zelkova *nouveau en Sicilie sud-orientale (Ulmaceae)*. Biocosme Mésogéen, **8**(4)-9(1), 401-409.

Follieri M., Magri D. & Sadori L. (1986) - *Late Pleistocene* Zelkova *extinction in Central Italy.* The New Phytologist, **103**, 269-273.

Follieri M., Magri D. & Sadori L. (1988) - *250,000-year pollen record from Valle di Castiglione (Roma)*. Pollen Spores, **30**, 329-356.

Follieri M., Giardini M., Magri D. & Sadori L. (1998) - *Palynostratigraphy of the last glacial period in the volcanic region of central Italy*. Quaternary International, **47-48**, 3-20.

Giraudi C. (1989) - *Lake levels and climate for the last 30,000 years in the Fucino area (Abruzzo-central Italy) - A review.* Palaeogeography, Palaeoclimatology, Palaeoecology, **70**, 249-260.

Giraudi C. (1998) - *The Late Quaternary geologic evolution of Campo Felice (Abruzzo - Central Italy)*. Giornale di Geologia, **60**, 67-82.

Giraudi C. (2001) - *Nuovi dati sull'evoluzione tardo-pleistocenica ed olocenica di Campo Felice (L'Aquila - Abruzzo)*. Il Quaternario, **14**(1), 47-54.

Grüger E. (1977) - *Pollenanalytische Untersuchung zur würmzeitlichen Vegetationgeschichte von Kalabrien (Süditalien)*. Flora, **166**, 475-489.

Havinga A.J. (1984) - *A 20-year experimental investigation into the differential corrosion susceptibility of pollen and spores in various soil types*. Pollen Spores, **26**, 541-558.

Hicks S. (1994) - *Present and past pollen record of Lapland forests*. Review of Palaeobotany and Palynology, **82**, 17-35.

Huntley B. & Birks H.J.B. (1983) - *An Atlas of past and present pollen maps for Europe: 0-13000 years ago*. Cambridge University Press. Cambridge.

Jalas J. & Suominen J. (1973) - *Atlas Florae Europaeae, 2. Gymnospermae*. Helsinki.

Longhitano N. & Ronsisvalle G.A. (1974) - *Osservazioni sulle faggete dei Monti della Laga (Appennino Centrale)*. Notiziario Italiano di Fitosociologia, **9**, 55-82.

Lowe J.J. & Watson C. (1993) - *Lateglacial and early Holocene pollen stratigraphy of the northern Apennines, Italy.* Quaternary Science Reviews, **12**, 727-738.

Magri D. (1999) - *Late Quaternary vegetation history at Lagaccione near Lago di Bolsena (central Italy)*. Review of Palaeobotany and Palynology, **106**, 171-208.

Magri D. & Sadori L. (1999) - *Late Pleistocene and Holocene pollen stratigraphy at Lago di Vico, central Italy*. Vegetation History and Archaeobotany, **8**, 247-260.

Ministero Lavori Pubblici, Servizio Idrografico (1959-1989) - Annali Idrologici. Ufficio Idrografico di Pescara.

Pantaleón-Cano J., Pérez-Obiol R., Yll E.I. & Roure J.M. (1996) - *Significado de* Pseudoschizaea *en las secuencias sedimentarias de la vertiente mediterránea de la Península Ibérica e Islas Baleares. In: Estudios palinológicos*. Universidad de Alcalá de Henares, 101-105.

Petriccione B. (1993) - *Flora e vegetazione del Massiccio del Monte Velino (Appennino centrale).* Ministero Agricoltura Foreste, Collana verde, **92**, 1-126.

Pignatti S. (1982) - *Flora d'Italia*. Edagricole. Bologna.

Quezel P. (1980) - *Biogéographie et écologie des conifères sur le pourtour méditerranéen. In: Pesson*, Actualités d'écologie forestière. Paris, 205-255.

Reille M. (1975) - *Contribution pollenanalytique à l'histoire Tardiglaciaire et Holocène de la végétation de la Montagne Corse*. Thèse ès Sciences, Université d'Aix-Marseille III, 206.

Rossignol-Strick M. & Planchais N. (1989) - *Climate patterns revealed by pollen and oxygen isotope record of a Tyrrhenian sea core*. Nature, **342**, 413-416.

Scott L. (1992) - *Environmental implications and origin of microscopic* Pseudoschizaea *Thiergart and Frantz ex R. Potoinié emend. in sediments*. Journal of Biogeography, **19**, 349-354.

Spada F., Valfrè D., Conti F. & Isopi R. (1995) - *Long-term dynamics in central Apennines (peninsular Italy)*: *the case of* Betula pendula *Roth.* Colloques Phytosociologiques, 24: 859-871.

Tzedakis P.C. (1994) - *Vegetation change through glacial-interglacial cycles: a long pollen sequence perspective*. Philosophical Transactions of the Royal Society of London B, **345**, 403-432.

van Benthem F., Clarke G.C.S. & Punt W. (1984) - *Fagaceae*. In: Punt W. and Clarke G.C.S. (eds), The Northwest European Pollen Flora, **4**, 87-110. Elsevier. Amsterdam.

Veri L. & Tammaro F. (1980) - *Aspetti vegetazionali del Monte Sirente (Appennino abruzzese)*. C.N.R., Collana Programma Finalizzato "Promozione della Qualità dell'Ambiente", AQ/1/83. Roma.

Watson C.S. (1996) - *The vegetational history of the northern Apennines, Italy: information from three new sequences and a review of regional vegetational change*. Journal of Biogeography, **23**, 805-841.

Watts W.A. (1985) - *A long pollen record from Laghi di Monticchio, Southern Italy: a preliminary account.* Journal Geological Society London, **142**, 491-499.

Watts W.A., Allen J.R.M., Huntley B. & Fritz S.C. (1996) - *Vegetation history and climate of the last 15,000 years at Laghi di Monticchio, southern Italy.* Quaternary Science Reviews, **15**, 113-132.

Watts W.A., Allen J.R.M. & Huntley B. (2000) - *Palaeoecology of three interstadial events during oxygen-isotope Stages 3 and 4: a lacustrine record from Lago Grande di Monticchio, southern Italy.* Palaeogeography, Palaeoclimatology, Palaeoecology, **155**, 83-93.

Wijmstra T.A.(1969) - *Palynology of the first 30 metres of a 120 m deep section in Northern Greece*. Acta Botanica Neerlandica, **18**, 511-527.

Zodda G. (1967) - *Compendio della Flora Teramana*. Archivio Botanico e Biogeografico Italiano, **43**, 35-101.

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