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Il popolamento animale e vegetale dell'Appennino Umbro-Marchigiano

The fossil forest of Dunarobba (Umbria - Central Italy): palaeoforestry history through a palynological study

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Key words: palynology, Central Italy, «Tiberino Lake», Villafranchian stage, Coast redwood (*Sequoia sempervirens*)

SUMMARY

The discovery of the Fossil Forest at Dunarobba, situated at about 400 m a.s.l., lead to a project of interdisciplinary research which is still taking place.

The trunks from this forest (about 50) were all found in their growing position and were submerged by a considerable clay bank; they were large in size (diameter about 2 metres and up to 8 m tall) and scarcely mineralized.

All the trunks studied so far belong to a single species: *Taxodioxylon gypsaceum*, with anatomic characteristics similar to the present-day *Sequoia sempervirens* (Biondi *et al.*, 1991).

An ancient palynological flora has emerged which is qualitatively rich, with a predominance of AP.

Pollen grains of *Sequoia, Sciadopitys, Taxodium*, Cycadaceae (*Stangeria* type), *Nyssa, Celtis*, and *Eucommia* were found, along with pollens of *Tsuga, Cedrus, Carya, Pterocarya*, and *Zelkova*.

The predominant *taxa* were *Sequoia* and *Taxodium* which, along with *Alnus, Salix*, Cyperaceae, and Potamogetonaceae, spores of *Osmunda* and *Lycopodium* types, and of Polypodiaceae, gave evidence of a humid forest with marsh areas, similar to the present-day coastal forests of California, where the present-day *Sequoia sempervirens* grows.

Attention is drawn to the scientific significance of this important plant paleontological record, and the correspondence between the xilological and palynological examinations, is emphasized.

Even though the interdisciplinary research project is still being undertaken, an attempt has been made to provide a chronological interpretation for the deposit.

INTRODUCTION

During an excavation of clay for brick production by the Briziarelli kiln towards 1980 in the surroundings of the borough of Avigliano Umbro (province of Terni), at Dunarobba (within the geographical coordinates: 42°39'42"-42°39'53" lat. N and 12°27'08"-12°27'40" long. E Greenwich, 400 m a.s.l.), numerous large-size trunks were uncovered. The trunks had a diameter of about 2 meters and were up to 8 meters tall. The most striking feature of the findings was their low degree of mineralisation and especially the fact that the trunks were found in their growing position — which is really very unusual — though slightly inclined towards NE. A survey undertaken in the surrounding area showed that many more trunks lay buried in clay, also in vertical position, so that the total number of uncovered and buried trunks was about 50 (Ambrosetti *et al.*, 1987).

Following this interesting finding the Archeological Department of the Umbria Region decided to enclose about 7 hectares of the land were the fossil trunks were found as a protected area, while the Ministry of Culture and the Umbria Region placed other surrounding land under their protection.

The degree of conservation of the wood is due to two factors that we consider important: the impermeability of the clay, protecting the trunks from mineralization and decomposition (Ambrosetti *et al.*, 1988); and, as we shall see later, the quality of the wood, typical of certain plant species.

Xilological studies undertaken by Biondi *et al.* (1991) on some samples of wood taken from the various trunks in the deposit, show that at least all those examined so far belong to the species *Taxodioxylon gypsaceum* (Göppert) Kräusel, a species that is «anatomically closest to today's *Sequoia sempervirens*».

For the moment it is difficult to put forward hypotheses regarding the chronological context of the clay sediments surrounding the trunks and the trunks themselves, although some precise indications are beginning to emerge from current research. It is clear, however, that the clay and the trunks cannot be referred to recent moments in time.

It is thought, on the basis of studies of the lithological variations connected with biostratigraphic and geodynamic evolution, that the formation of the Dunarobba deposit should be attributed to one of the series of the Pliocene or to a lower Pleistocene epoch.

From the palaeo-geographic point of view, we wish to recall that the Dunarobba area was situated within the vast Plio-Pleistocene lakeland basin known as «Tiberino Lake» (Fig. 1), spreading southwards like an upside-down Y from Città di Castello (Ambrosetti, *in litteris*) or Borgo S. Sepolcro (Lippi Boncambi, 1959) to the North, with an eastern branch extending to Spoleto and a western branch to the Terni Plain. And it was on the latter branch that the fossil Dunarobba forest, was situated.

The purpose of this article is to report the results of the first palynological studies carried out on a clay bank dug laterally of trunk N. 49. The research is aimed at identifying the flora existing in the area during the period of sedimentation, the climatic and edaphic conditions characterizing the period in which these large fossil plants lived, and to attribute a chronology to the deposit and the trunks themselves.

MATERIAL AND METHODS

Surveys were undertaken in summer 1991 in order to study the type of contact between the fossil trunks and the clay surrounding them.

Stratigraphical and palaeontological studies were carried out at the same time and samples were taken for pollen analyses.

The excavation was undertaken with a scraper, digging to a depth of 3.5 meters, the maximum depth reached by the scraper arm.

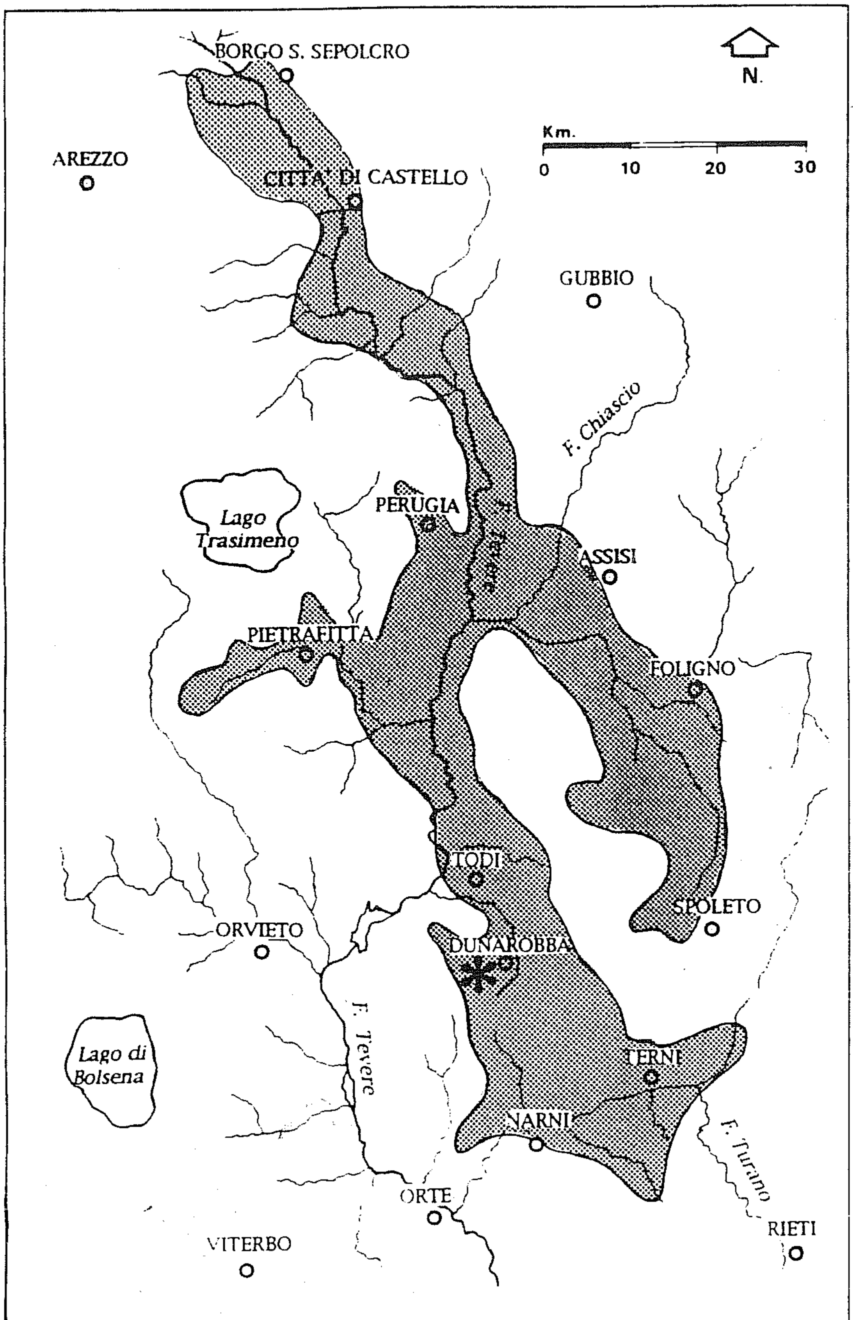

Fig. 1 - The "Tiberino Lake" during the Villafranchian stage. The different Northwards lake extension (explication in the test) is evidenced.

The top 40 cm of the sample were excluded, as this was land that had been overturned. The series consisted exclusively of clay.

Samples were taken at regular intervals of 10 cm and no animal or plant macrofossils were found.

The clay layers collected were subjected to the chemical procedure suggested by Bertolani Marchetti (1960); this procedure showed that the sediments were rich in carbonates and organic matter.

In the pollen diagram (Fig. 2) the stratigraphical column, the AP (= Arboreal Pollen, i. e. pollen from trees and shrubs) and NAP (= Non-Arboreal Pollen, i.e. pollen from herbaceous plants) percentages (with the pollen profiles of *Sequoia* and *Taxodium*), the pollen profiles of the single AP and NAP species, the pollen frequencies (expressed as number of pollen grains per slide of 24 × 32 mm), and the percentage of Pteridophyta spores, are quoted from left to right.

Under *Varia*, pollen grains and spores occurring only sporadically, are grouped.

A number of pollen grains, all similar, showed morphological features resembling both *Araucaria* and *Liriodendron*. They are indicated as *Araucaria/Liriodendron* type.

RESULTS AND DISCUSSION

The clay material collected for palynological study appeared to be very uniform (Fig. 2) showing that sedimentation had been regular; the soil texture of the sedimentary particles did not show diversified hydrological phases. Current findings thus suggest that the trunks experienced a slow period of sedimentation, causing the forest to be covered and perhaps disappear and allowing for its conservation until the present. According to Ambrosetti *et al.* (1987) the clay in which the fossil trees are immersed belong to «the clay-sand complex of continental sediments of the upper Villafranchiano». According to Basilici (*in litteris*) the clays «form part of the same lithostratigraphic unit informally known as the S. Maria di Ciciliano unit», using the term unit to mean «a geological body characterized by similar lithologic aspects and the same genetic connotation».

The pollen analyses carried out along the entire profile (Fig. 2) showed a flora rich in quantitative and especially qualitative terms, with a prevalence (of at least 57%) of AP with respect to NAP. Moreover — and this represents the peculiarity of the diagram — there is a frequent occurrence of tertiary forestry species that are no longer to be found in present-day indigenous flora in Europe and in Italy in particular. The disappearance of these species is due to climatic factors connected with glaciations taking place in the Pleistocene and even earlier, as well as changes in specific local environmental conditions. As we have seen, Dunarobba formed part of the ancient «Tiberino Lake» (Fig. 1) which obviously created a humid environment, made even more humid by its proximity to the sea, at a distance of about 15 Km

In the pollen diagram, a distinction was made in the *Pinus* curve, using Ru-

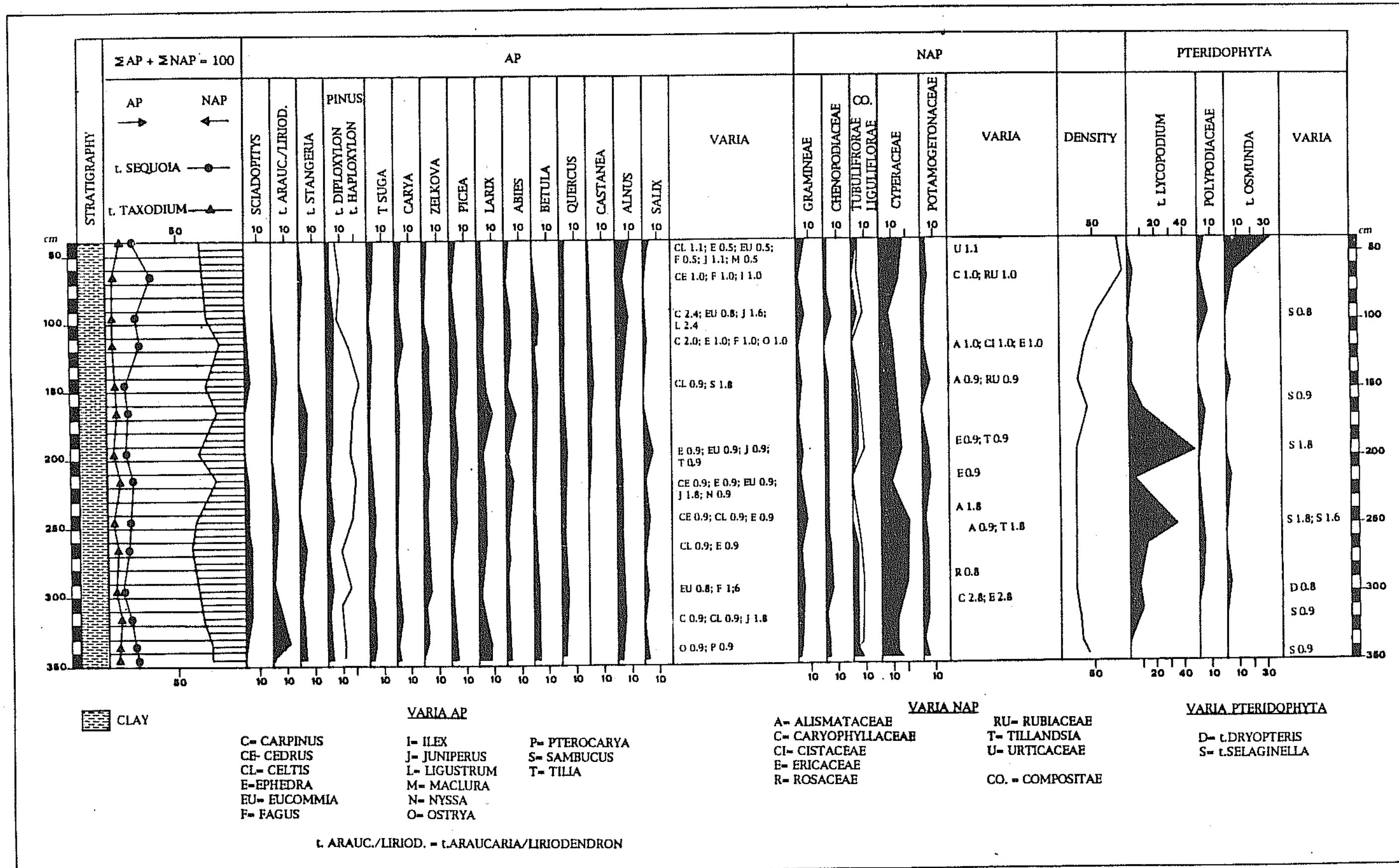

Fig. 2 - Dunarobba pollen diagram (profile N. 49).

dolph's diagnostic criterion (1935), between *Pinus* type *haploxylon* and *P.* type *diploxylon*. The former, according to Rudolph (1935), has undoubted stratigraphic significance for the Plio-Pleistocene pollen series in Europe, and hence in Italy, as this is an element of tertiary origin. Observing the two curves one can see the continual predominance of *Pinus* type *haploxylon* with respect to the other. It should be recalled, however, that the *Pinus* type *haploxylon* remains in the deposits in Central and Northern Italy until the mid-Pleistocene (Paganelli, 1961 a). Unfortunately this is not significant in climatic terms, as the two respective groups include a range of species of *Pinus* with different climatic and ecological significance.

Other tipically ancient plants, even though in some cases their frequency in the various levels is sporadic, are: *Sequoia, Sciadopitys, Taxodium*, Cycadaceae (*Stangeria* type), *Araucaria/Liriodendron* type, *Nyssa, Celtis, Eucommia, Cedrus, Tsugo, Carya, Pterocarya*, and *Zelkova*. In our view, however, the pollen grains giving the diagram a very archaic character are those of *Sequoia, Sciadopitys, Araucaria/Liriodendron* type, *Taxodium, Nyssa, Celtis, Eucommia*, as well as the *Stangeria* type pollens, whereas *Tsuga, Cedrus, Carya*, and *Pterocarya* will survive until the mid-Pleistocene (Paganelli, 1961 a; 1961 b; 1984); the only one to remain until the last Würm glaciation is *Zelkova* (Paganelli, 1961 a; 1984; Follieri *et al.*, 1986).

As can be seen, with the finding of *Sequoia* pollen, the Dunarobba Fossil Forest has not only left us evidence of the wood but also of the pollen.

Sequoia pollen is present along the entire pollen profile, ranging from a minimum of 11% to a maximum of 34%. The curve trend appears rather regular, with two apexes, one at the initial phase of sedimentation and another almost in the final phase. This is a demonstration of two aspects: firstly, that the sediment which submerged the trunks of this conifer is contemporary to the period in which the *Sequoia* forest existed at Dunarobba, and secondly, the fact that even though some of the plants were submerged by clay — and perhaps died — there were other plants in the area that continued to live producing pollen, as is shown by the continuity of the pollen curve, and the presence of the more recent apex.

Findings of *Sequoia* macrofossils are very common in Italy during Miocene, less so in the Pliocene and absent from the Pleistocene onwards (Principi, 1942). These Pliocene findings were uncovered (Principi, 1942) in Piedmont, Lombardy, Veneto, Tuscany, and Umbria, namely at Città della Pieve (the south-western area of the province of Perugia).

At this point a question arises spontaneously: why does the fossile forest appear to be mono-specific on the basis of the xilological studies carried out to date (Biondi *et al.*, 1991)? Why wood belonging to at least some of the *taxa* shown in the pollen diagram has not been found? The following answer my be given: as all the AP pollen grains recorded in the diagram have undergone anemophilous dispersion, all the species were not necessarily growing *in situ*. Pollen may in fact be transported for hundreds of metres, even covering enormous distances, up to thousands of kilometers as we have found in material from the

Antarctic Continent (Paganelli, *in verbis*). It can therefore be concluded that the other trees were present in nearby areas or the surrounding mountains.

Among these forest species we wish to pay particular attention to those plants that were extinguished first, as well as *Sequoia*. Listing them in decreasing order of pollen percentages, these are: *Taxodium, Sciadopitys, Araucaria/Liriodendron* type, *Eucommia, Celtis*, and *Nyssa*, as well as *Stangeria* type.

From the curve trends of the individual forest trees, the hypothesis can be forward that *Taxodium*: (Swamp cypresses) lived in close proximity to the area of our forest.

Today, this species grows in the South-eastern USA and in Mexico in coastal woods on marshlands, on submerged sandy and clayey soils, along riverbanks or on scarcely drained low ground. The peculiar environmental requirements make Swamp cypresses more indicative of edaphic than of climatic conditions (Bertolani Marchetti, 1978). The *Taxodium* steady occurrence in the diagram shows that it must have lived in the Dunarobba area where marshlands were present. As the sea was nearby, it may be concluded that the *Taxodium* pollen originated from the coastal marshland, perhaps along with some of the pollen grains from *Sequoia* which almost certainly also grew in those areas. The particular palaeo-geographical aspect of the land and surrounding area is confirmed, not only by *Sequoia* which we shall discuss later, but also by the occurrence of *Alnus* pollen along all the diagram (occasionally associated with *Salix*), by the high percentages of Cyperaceae and Potamogetonaceae growing on the banks of the «Tiberino Lake». Pollen from *Phragmites australis* (Cav.) Trin. was likely to be present; unfortunately, it cannot be differentiated from other Gramineae pollens.

The high frequencies of spores of *Osmunda*, and *Lycopodium* types and of Polypodiaceae seem to confirm the presence of a very moist forest.

The sporadic records, decreasing towards the upper layers, of *Sciadopitys*, and the similar trend of the *Araucaria/Liriodendron* type curve, lead one to believe that these two species grew at a long distance from the site, or else were present in the vicinity but only in a small number. As *Sciadopitys*, a spontaneous mountain plant in Japan, grows in a climate with heavy rainfalls (about 500 mm of rain per month) and cold winters (Bertolani Marchetti, 1977), we may conclude either that the amount of rainfall was decreasing, hence reducing the number of these plants, or that it had settled only accidentally in the area. The presence of other mountain forestry species in the diagram (assuming that the species had the same climatic attributes as today) such as *Tsuga, Picea, Larix, Abies, Betula, Carya, Zelkova, Quercus, Carpinus*, and *Castanea*, reveal a temperate climate at the higher altitudes and a warm humid climate in the plain and hill areas. According to Principi (1942), during the Pliocene the climate in the Italian peninsula was warm and temperate, with average annual temperatures higher than today's; we believe, however, that annual amount of rainfall must also have been higher.

To conclude, we wish to make some general remarks on this interesting deposit at Dunarobba with regard to *Sequoia* and also as an attempt to establish the deposit's age.

For the moment we can only put forward working hypotheses which will be confirmed by further research.

As mentioned above, Biondi *et al.* (1991) identified the trunks from the fossil forest as *Taxodioxylon gypsaceum*, a species with caracteristics similar to today's *Sequoia sempervirens* (Lamb.) Endl., a plant currently found in the humid coastal areas of California. However, another species, *Sequoiodendron giganteum* (Lindl.) Buchholz, grows on the Sierra Nevada in the Californian inland and shows rather different climatic and ecological features. The question arises wheter the pollen from our forest represents the coastal or the mountain species. Unfortunately we do not possess current pollen of the two species in order to ascertain the possibility of differentiating them on the basis of morphological characteristics. On the basis of the morphometric parameters of the two current pollens available in literature, we believe that the samples we found should correspond to today's *Sequoia sempervirens; Sequoiodendron* in fact has a smaller type of pollen. The wide existing literature on the climatic and of ecological requirements of the living sequoias (Bakker, 1984; Buchholz *et al.*, 1989; Jones, 1991; McKenzie, 1991; Whitney, 1979; and so on) leads to conclude that the fossil pollen of Dunarobba sediments is from *Sequoia sempervirens* (Coast redwood). This plant is one of the constituents of coastal rain forests, it thrives in areas with heavy rainfalls and mist, particularly in summer, and on soil subjected to frequent flooding; the latter favours deposits of new mud around the Coast redwood trees, thus providing soil renewal, an essential element for the plant's survival. The soil should always have a moisture content above 18%, particularly in the month of August, the hottest period of the year in those regions. Moreover, the wood from *Sequoia sempervirens* has a high capacity for conservation, a feature which the Giant sequoia (*Sequoiodendron giganteum*) lacks.

Taking account of the fact that the trunks found at Dunarobba were submerged by sediment, this would support the hypothesis that this is actually a plant with ecological, and also climatic features similar to the Coast redwood; moreover the fact that the wood has been conserved until the present appears to confirm this hypothesis.

At this point we should ask: to which chronological period should we attribute the deposit?

As we have seen, according to Ambrosetti *et al.* (1987), the Dunarobba deposit should be correlated with the higher Villafranchian stage, i. e. the lower Pleistocene. On the basis of the preliminary research carried out so far, i. e., palaeontological studies on the fauna (mammofauna and micromalacofauna) and flora (fossil trunks), and palynological studies, Ambrosetti (1991) states: «rather than reaching certainty of attribution to the Pleistocene sedimentary cycle, there is evidence that the forest may be dated to the Pliocene series».

In fact, studies of the malacofauna at Dunarobba (Manganelli *et al.*, 1989) have revealed a new species of Strobilopsidae, *Eostrobilops aloisii* Mang., attributed to a period preceding the Pleistocene, though forming part of the Villafranchian age. The studies undertaken on the fossil woods also allow us to identify them as belonging to *Taxodioxylon gypsaceum,* which leads Biondi *et al.* (1991) to believe that the deposit dates back to «the final part of the upper Pliocene».

In addition to our palynological research on Dunarobba, a series of data, reviewed by Paganelli (1982), on Plio-Pleistocene sediments of Central Italy are available: in Tuscany at Castelnuovo dei Sabbioni in the Valdarno area (Azzaroli, 1967; 1977) and at Ponte a Elsa, along the Elsa Valley (Valleri *et al.*, 1990); in Umbria at Monte Santo, near Todi (in Follieri, 1977), at Pietrafitta (included in the «Tiberino Lake» basin) in the province of Perugia (Ricciardi, 1961; Paganelli *et al.*, 1962; Lona *et al.*, 1972), in the Gubbio basin (Lona *et al.*, 1961), and at S. Maria di Ciciliano, in the province of Terni (Follieri, 1977); and in Lazio at Valle Ricca in the province of Rome (Urban *et al.*, 1983). In these deposits an evolution in the Pliocene sub-tropical forest can be seen, due to climatic fluctuations that took place gradually, however (Follieri, 1977). At S. Maria di Ciciliano, a site very close to Dunarobba, Follieri (1977) found for example a flora that was more recent than ours, with *Eucommia* and *Celtis*, and low percentages of typically tertiary plants; this deposit was attributed to the lower Pleistocene. The Pliocene sediments in fact present a palinoflora which is qualitatively richer in species, as was seen in the deposit at Monte Santo (in Follieri, 1977), where a predominance of *Taxodium* pollen was found, along with *Podocarpus, Engelhardtia, Rhamnus, Sequoia/Cryptomeria*, and *Nyssa*, with scarce occurrence of pollens from *Cedrus, Tsuga, Carya, Pterocarya, Zelkova, Carpinus, Abies, Picea*, and *Pinus*. It could be said that, if we exclude the presence of *Sequoia*, on the whole the Monte Santo palynoflora is qualitatively similar to the palynoflora from our deposit.

Thus, on the basis of the results obtained from our palynological study and thanks to the wealth of tree and shrub species (AP) found, we feel that the layers studied so far may be attributed to one of the Pliocene phases. For the moment we are unable to provide a more detailed chronology; as the various interdisciplinary studies will be over, will we be able to draw further conclusions on the palaeo-vegetational, palaeo-climatic, and palaeo-environmental evolution taking place in the Dunarobba basin and its relative chronology.

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