POLLEN ANALYTICAL INVESTIGATIONS IN THESSALY (GREECE)

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CONTENTS

1. INTRODUCTION

From 1965 on, the number of palynological investigations in Greece has constantly increased (fig. 1). Van der Hammen *et al.* (1965) and Wijmstra (1969) treated very deep cores from the Plain of Drama. Cores of Postglacial age from Philippi and Lake Kopais were studied by Greig and Turner (1974), and Turner and Greig (1975). The late Quaternary period in the northwestern part of Greece was studied by the present author (Bottema, 1974). In central Greece, in the area of Katerini and Trikkala Postglacial sediments were investigated by Athanasiadis (1975). Wright (1972) studied the younger Postglacial deposits from the Peloponnesos and adjacent mainland.

Apart from localities which have yielded palynological information already published (fig. 1) some places are mentioned which are still the subject of research. The Lakes of Trikhonis, Vegoritis and Volvi were cored by P. R. Readman c.s. (Geophysical Department, University of Edinburgh). These cores were taken primarily for palaeomagnetical analysis. It will be evident in the near future to what extent palaeomagnetic and palynological research supplement or support each other.

In 1963 a coring was performed in Lake Viviis as part of a larger expedition (Bottema, 1974) led by W. van Zeist and with the kind help of R. J. Rodden. On a second expedition in 1965, Mr. P. Petsas (Ephor of Antiquities for Western Macedonia for the Greek Archaeological Service) suggested Lake Xinias as a possible coring site. Taking part in this expedition were W. van Zeist, R. J. Rodden, D. French (now Director of the British School of Antiquities in Ankara), W. A. Casparie (Biologisch-Archaeologisch Instituut, Groningen) and the present author. In this paper the palynological results of the cores from Lake Viviis and Lake Xinias will be discussed.

The author is much indebted to Mrs. S. M. van Gelder-Ottway who improved the English and to Mrs. G. Entjes-Nieborg for the preparing of the manuscript. Drawings were prepared by Mr. H. Roelink, J. Smit, Jacq. Klein and the present author.

Fig. 1. Palynological investigations in Greece.
Open circles: published results available; Black circles: results to be published; Dotted circles: results treated in this publication.
1. Gravouna. 2. Tenagi Philippon. 3. Volvi. 4. Giannitsa. 5. Edessa. 6. Vegoritis. 7. Khimaditis. 8. Kastoria. 9. Litochoro. 10. Ioannina. 11. Pertouli. 12. Viviis. 13. Xinias. 14. Voulkaria. 15. Trikhonis. 16. Copais. 17. Kaiafa. 18. Osmanaga. 10. Aghia Galini.

2. GEOGRAPHY, GEOLOGY, CLIMATE AND VEGETATION OF THESSALY

2.1. Geography and geology

Thessaly consists of the plain of that name, the surrounding hills and mountains and inlets of the Aegean. The area is more or less delimited by the towns of Larisa, Trikkala, Lamia and Volos (fig. 2). For details on the geology the reader is referred to Schneider (1968) and Voliotis (1973).

Situated in the east (from south to north) are the Magnisia Peninsula, the Volos Plateau and the Mavrovuni Mountains. In the northeast the Ossa Mountains reach an altitude of 1978 m. Across the Tempe-valley the Olympus, consisting of a higher part (Ano

Olympus, 2917 m) and a lower part (Kato Olympus, 1587 m) can be seen. The border along the northwest is formed by the Chasia Mountains and that along the west side by the Pindus chain. Finally, situated at the southern edge are the Tymfristos (2315 m) and the Oeta (highest peak the Pyrgos, 2152 m). Peaks consisting of limestone show "Karst" influence. According to Monopolis (Voliotis, 1976a, b) traces of two glacial periods can be observed above 2000 m. The plain of Thessaly is situated at an altitude of 60-160 m above sea level. There are two parts, an upper and a lower plain, in the southwest and northeast respectively. The former Lake Viviis, at about 50 m altitude the lowest point in the plain, has no direct outlet to the sea. Most of the plain is covered with Holocene deposits. The rivers coming from the surrounding mountains partly removed sediments for instance when the gorge of the Tempe was formed.

One of the most important rivers is the Pinios. This river discharged into the plain in Lake Viviis (L. Karla) but broke through the valley of the Tempe to the sea at the end of the Würm (Schneider, 1968). At least three periods of a warm and dry climate during the Würm are indicated by Schneider, but he considers it not unlikely that the picture is obscured by tectonics. When the Pinios discharged to the sea not all the water went there. Tilting of part of the plain formed a depression, the later Lake Viviis. Schneider estimates that at some time during the Postglacial the lake must have been 20 m deep. The lake must therefore have been of large extent, which in fact could also be concluded from the distribution of the Neolithic settlements. It is, however, doubtful whether this lake was very deep during the period spanned by the pollen diagram taken there.

In the course of time the plain dried up, so finally also the lake was affected (Greece, III, 1945). The lowering of the water-table was not constant and fluctuations occurred. In 1960 the drainage of the remnants was started.

2.2. Climate

The climate of the Thessalian plain is a modified Mediterranean climate. The temperature and rainfall figures in the area show features of a continental type. The summers are suffocatingly hot (Greece, I, 1944). The winters are cold frost is common. Ossa and Kato Olympus have about the same climate. Precipitation at the northeastern foot of the mountains amounts to 600-800 mm. At the summit 1000-1200 mm is measured. Southern, southwestern and western slopes are much drier. On lower slopes next to the Thessalian plain precipitation hardly reaches 500 mm, while on the east side of the above-mentioned peaks it amounts to about 900 mm.

The mean annual temperature is 11°C. The difference between summer and winter temperature increases from east to west. Prevailing winds come from the north or northeast over the Gulf of Therma. Western slopes thus lie in the rain shadow. Meteorological stations are present in Trikkala (113 m), Lamia (69 m), Volos (100 m), Larisa (67 m) (Walther and Lieth, 1967). Rainfall is restricted almost completely to the winter months, autumn and spring. July, August and September average 20 mm. At that time temperatures are maximal, so the ecological drought is severe. The average January temperature is relatively high, 5.4°C for Trikkala, 5.5°C for Larisa (Greece, I, 1944) and about 7°C for Volos and Lamia (Walther and Lieth, 1967). The minimum January temperature ever recorded for Larisa is −13°C.

2.3. Vegetation

According to Voliotis' information (1973, 1976a, 1976b) and especially his vegetation map of Greece (1973) a tentative vegetation map (fig. 2) of the area has been composed.

In studies on the vegetation of the Mediterranean and also of the Near and Middle East a constantly repeated complaint is the absence of natural plant cover due to destruction by man. This problem is now rapidly becoming worldwide and is by no means restricted to these areas. Thus the vegetation map is in fact a reconstruction of the natural vegetation under ideal conditions, disregarding human interference. The botanical composition of the forests etc. on the various mountains is rather variable. Details can be found in Voliotis' studies.

Along the coast (fig. 2) an Oleo-Ceratonion is found. This vegetation zone remains narrow, never penetrating more than a few kilometres inland. It requires an average annual temperature of about 17-18°C and almost 600 mm precipitation. *Pinus halepensis* and *Pinus nigra* are important constituents of this zone but in practice only a very much degraded

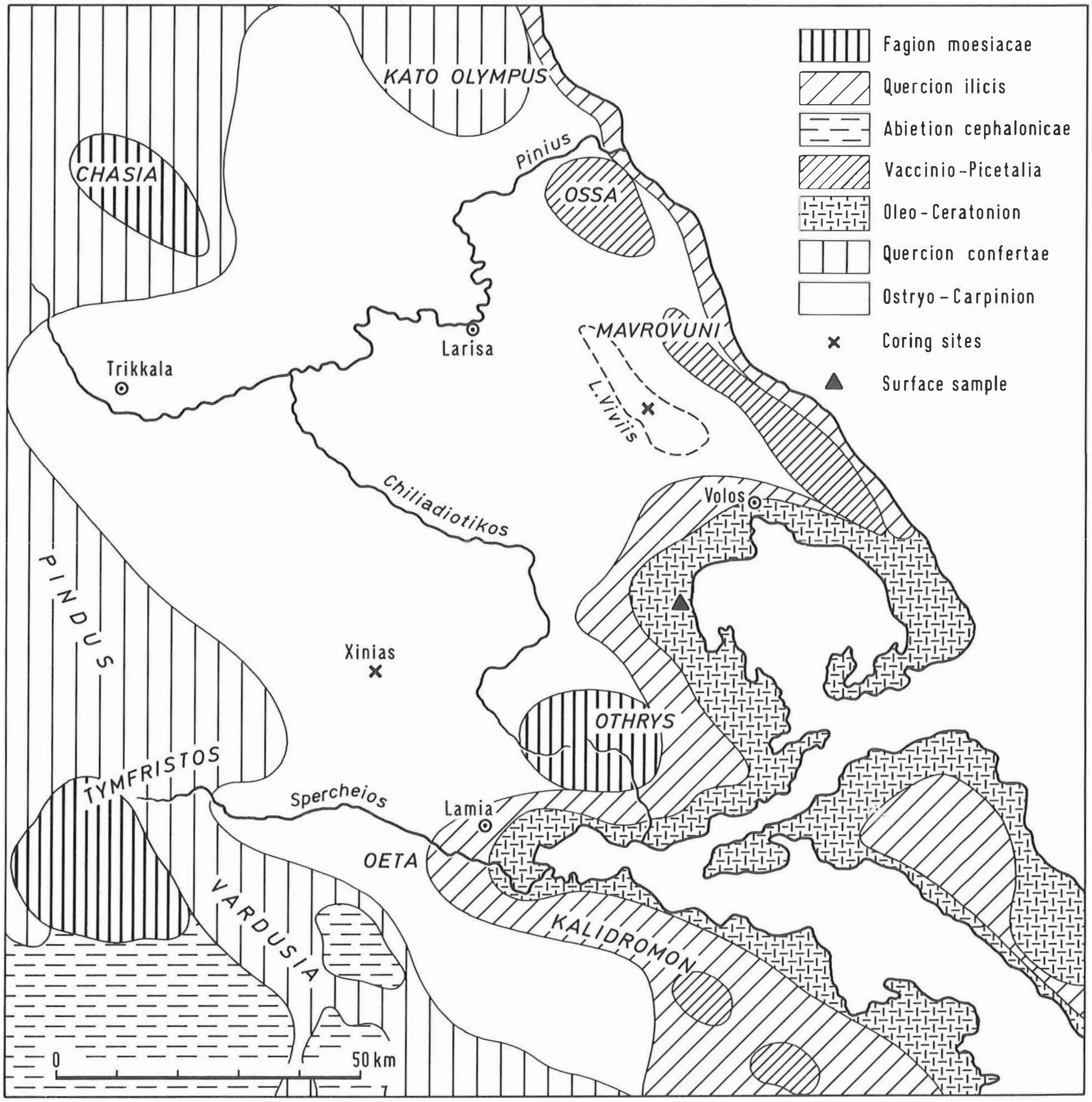

Fig. 2. Vegetation map of Thessaly (after Voliotis, 1973); coring sites and surface sample locality.

stadium is found. This stadium is known as *Phrygana*. In this zone two subzones are distinguished: the Oleo-Ceratonietum and Oleo-Lentiscetum. Along the coast at the height of the Ossa and Mavrovuni Mountains and south of the town of Volos, a Quercion ilicis is found. Here the average annual temperature is about 14-15°C.

Most of Thessaly, the plain and bordering foothills, lies in the zone of the Ostryo-Carpinion orientalis. The mean annual temperature of 12-15°C and especially winter-minima of — 10°C and even lower, limit the eu-Mediterranean vegetation. Nevertheless, the evergreen *Quercus coccifera* plays an important part in this vegetation in addition to deciduous elements such as *Quercus pubescens*, *Ostrya carpinifolia*, *Carpinus orientalis*, which partly constitute the Coccifero-Carpinetum orientalis association.

In submontane and montane areas, the Fagion moesiacum is found, subdivided into associations of a Fagetum or combinations of *Fagus* and *Abies* (*borissi-regis*). Mediterranean montane forest, dominated by *Abies cephalonica*, is found in the mountains bordering the southern part of the area studied.

A vegetation of *Pinus heldreichii* belongs to the subalpine zone. A vegetation type which can hardly be ascribed to any zone is the Pinion nigrae. *Pinus nigra* occurs from about 100-1800 m altitude in Greece. Relicts of *Pinus sylvestris* are found on the Olympus. Alpine vegetations in the area are restricted to the upper part of the Olympus. They belong to the Acantholimo-Astragaletalia zone, characterized by spiny, cushion-shaped species.

3. METHODS

Clay and gyttja samples were prepared using a flotation method (Bottema, 1974) after which sometimes a treatment with hydrofluoric acid followed depending on whether any minerals were left. Afterwards acetolysis according to Erdtman was applied. Peat samples were boiled in 10% potassium hydroxide followed by acetolysis. Samples were stained with safranine and mounted in silicone oil.

The pollen sum on which the percentages in the diagrams are based, includes all pollen types which are thought to be of non-local origin, *viz.* trees and herbs, excluding the pollen types of marsh and water plants.

In the Xinias I diagram (fig. 4) three different pollen sums were tried in order to study the effect upon the AP/NAP ratio. Pollen sum I includes the arboreal pollen types and the series *Artemisia*-Cerealia-type. Pollen sum II is formed by the AP and all non-local herb pollen types excluding the Gramineae. Pollen sum III comprises those from sum II but including Gramineae pollen. The curves run more or less parallel, only in zone Y do they show almost the same value. This is to be expected as the types which are excluded, have unimportant values. The most complete pollen sum, that including the most types, is preferred as a basis for the diagram. The Viviis diagram was calculated on the basis of such a pollen sum.

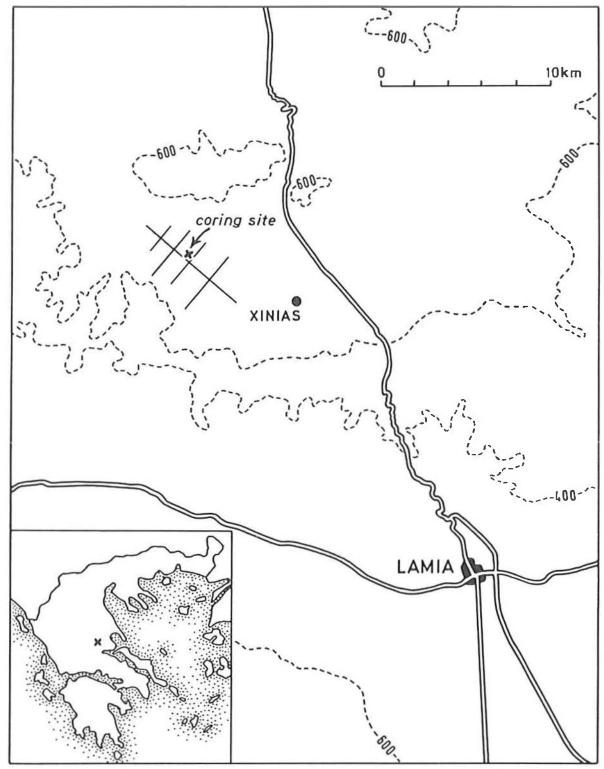

Fig. 3. Map of the Xinias area, showing the coring site.

4. RADIOCARBON DATES

Radiocarbon measurements were carried out by the Groningen C14 laboratory for four levels:

Xinias (Lamia) 1.50- 1.60 m:
(organic fraction) 10,680 ± 90 B.P. (GrN 6889)
(calcareous fraction) 11,150 ± 130 B.P. (GrN 6888)

The date of the organic fraction is considered to be the actual one, that will be referred to.

Xinias (Lamia) 3.70- 3.80 m: 21,390 ± 430 B.P. (GrN 6886)

Xinias (Lamia 5.70- 5.80 m: 25,620 ± 400 B.P. (GrN 6887)

Xinias (Lamia) 13.40-13.60 m: 46,900 $^{+5000}_{-3060}$ (GrN 6882)

5. LAKE XINIAS

5.1. Coring site

The drained lake is situated 3 km west of the village of Xinias, 30 km northwest of Lamia (figs. 2 and 3) at an altitude of 500 m. When the coring was made, in 1965, drainage canals appeared to have been dug very recently. The small plain (the former lake bottom), now agricultural land, is surrounded by hills. Of two cores collected one will be presented.

5.2. Coring

The coring Xinias I took place at the end of a drainage canal running from east to west in the centre of the area, 7 cm above the water level. A Dachnowsky ⌀ 36 mm was used up to 10.40 m. The coring was made up to 13.80 m with a Livingstone corer ⌀ 28 mm. Another core, 84 cm above the water level, was cut out of the ditch bank.

5.3. Lithology

(+)0.80-(+)0.65 m above the water level, brown soil, disturbed
(+)0.65-(+)0.60 m grey clay, with fissures due to shrinkage; filled with brown soil from above
(+)0.60-(—)1.57 m grey gyttja, at the bottom clay with organic and calcareous remains, a light brown band at 1.19-1.20 m

1.57- 1.75 m	blue-grey, sandy clay
1.75- 1.80 m	blue sand
1.80- 2.07 m	blue, sandy clay
2.07- 2.70 m	blue-green clay
2.70- 3.06 m	blue-grey clay
3.06- 5.75 m	grey clay-gyttja
5.75- 5.85 m	brown gyttja
5.85- 5.96 m	grey gyttja
5.96- 6.04 m	brown gyttja
6.04- 9.13 m	dark-grey clay-gyttja
9.13- 9.48 m	yellow-brown gyttja
9.48-12.10 m	dark-blue/grey clay-gyttja
12.10-12.57 m	yellow-brown gyttja
12.57-12.60 m	dark-grey clay-gyttja
12.60-12.87 m	brown-yellow gyttje
12.87-12.90 m	dark-grey clay-gyttja
12.90-13.60 m	dark-grey clay

6. DISCUSSION OF THE XINIAS I DIAGRAM

6.1. Pleniglacial

To facilitate the discussion the diagram will be divided into pollen zones and subzones. The division is made on the basis of the most characteristic features of the arboreal pollen (AP) curve, the curves of *Pinus* and *Quercus* and to a lesser extent on the behaviour of other tree-pollen and herb-pollen curves.

A main division into two parts can be made by means of the AP/NAP ratio. Spectra 1-76 show mostly high herb pollen percentages whereas spectra 77-91 demonstrate high arboreal pollen values.

The first part can be divided again into three parts, the lowest part showing still moderate AP values, the second part showing lower AP values which fluctuate sharply, whereas the third part demonstrates continuously low arboreal pollen percentages. Minor fluctuations make a still more detailed subdivision necessary.

The main zonation is as follows:

Zone V (spectra 1-10)
Zone W (spectra 11-37)
Zone X (spectra 38-60)
Zone Y (spectra 61-67)
Zone Z (spectra 77-91).

Zone V (spectra 1-10)

Zone V is characterized by relatively high AP values, maximally 30-60%, although NAP percentages generally dominate. Because of these fluctuations three subsones are distinguished.

Subzone V1 (spectra 1-3) demonstrates high *Pinus* values, maximally 34.1% and *Quercus cerris*-type from 10-20%. *Ulmus*, *Corylus*, *Juniperus*, *Abies* and *Fagus* are represented with low percentages.

The oak pollen mentioned with the name *Quercus cerris*-type includes all deciduous oak species occurring in Greece at the present time. This type is identical to *Quercus robur*-type (at 400 × under a light-microscope), but the name *Quercus cerris*-type is chosen as this species was regularly met with during field work in Greece (Bottema, 1974).

The herbal vegetation is represented with especially important pollen values for Gramineae, Chenopodiaceae, and *Artemisia*. The lowest part of subzone V1 is radiocarbon dated 46,900 ___. This means that the radiocarbon sample yielded an almost infinite date and thus may be much older than 46,900 B.P.

Subzone V2 (spectra 4-7). In this zone *Pinus* values have diminished whereas *Quercus cerris*-type reaches a maximum of 30%. The tree pollen maximum of subzone V1 and that of subzone V2 are separated by a herb-pollen maximum of about 70% in spectrum 3.

Comparing with subzone V1, some tree species appear or increase in pollen percentages, for instance *Carpinus betulus*, and *Carpinus orientalis/Ostrya*. Towards the end of subzone V2 a decrease in AP percentages is visible. This decrease forms the boundary with the third and last subzone V3.

Subzone V3 (spectra 8-10). Tree pollen values are lower than in subzone V2 but the general tendency is the same. At the beginning of zone V pine forest occurred at higher altitudes whereas oak was less abundant, maybe in a forest steppe together with *Artemisia*. The other trees mentioned were either rare or growing at greater distances in the mountains in favourable locations. The vegetation may have been in a state of unstable equilibrium. As soon as the climate changed slightly either steppe vegetations or forest would have gained terrain depending upon the direction of the climatical change. Precipitation would have been a major factor.

Zone W (spectra 11-37)

Zone W resembles zone V but also shows some differences. The lower AP values are conspicuous. The same fluctuations in the AP/NAP ratio, as can be seen in the preceding zone, can be found here. On the basis of especially the *Quercus* and *Pinus* values zone W can be divided into three subzones.

Subzone W (spectra 11-23) is characterized by dominant NAP values, mainly due to *Artemisia*, Chenopodiaceae, and Gramineae, but to a lesser extent also to *Centaurea solstitialis*-type, *Plantago maritima*-type, *Thalictrum*, Cerealia-type, Liguliflorae, various Tubuliflorae, and *Bunium*-type.

Subzone W2 (spectra 24-26) demonstrates an increase in AP values, mainly *Quercus cerris*-type, *Corylus*, *Abies*, *Fagus*, and *Pinus*.

Subzone W3 (spectra 27-35). The picture in this subzone strongly resembles subzone W2. The boundary of zone W with zone X is placed after the last small peak of the AP curve.

Steppe vegetations dominated the Xinias area during zone W. They extended from the level of the lake at 500 m over the slopes of the surrounding mountains and down to the Thessalian plain.

In the Balkans hardly any natural steppe vegetations are found at present. The forest steppe of the Danube lowlands (Horvat *et al.*, 1974) is still a matter of discussion and is very difficult to connect with the Greek steppe. Thus it remains obscure which plant species are represented by the pollen types in the glacial spectra.

In Ioannina on the west side of the Pindus Mountains, forest was postulated at an altitude of about 800 m during a comparable period (Bottema, 1974) lasting from about 40,000-15,000 B.P. As the east side of the Pindus catches far less rain than the west side and therefore has a more continental climate, forest must have been restricted to levels higher than 800 m. No trees were found close to the lake where the herb cover mainly consisted of *Artemisia*, Chenopodiaceae, various Compositae and other species mentioned above.

Minor climatical fluctuations probably favoured some tree growth on suitable locations closer by, as can be concluded from low AP peaks. Such periods lasted 700-1000 years, as concluded from the sedimentation rate.

Many of the AP peaks in zones V and W show a certain asymmetry. Forest seems to have spread rather abruptly, and to have disappeared afterwards more gradually. This may point to different conditions depending on whether the forest vegetation was being established or maintained. Conditions for establishing are more demanding than those for conservation. Within the forest a certain microclimate may have prevailed where germination was favoured compared to conditions in an open plain. Zone W would have lasted from about 43,000-28,000 B.P., as interpolated from the radiocarbon dates and assuming a constant sedimentation rate.

Zone X (spectra 38-60)

As mentioned above, the boundary with the preceding zone is placed after the last (minor) AP peak, which measured only 25%. In zone X the AP/NAP ratio shows no fluctuations, resulting in a smooth curve demonstrating low AP and consequently high NAP percentages. The continuous curve of *Hippophaë* draws attention, although values are under 1%. This shrub must have been rather abundant as it is very much under-represented in the pollen rain. According to Freitag (1977) *Hippophaë* would have grown along water courses. Pollen types found in zone X are the same as in the preceding zone. However, tree pollen is consistently low, suggesting that types such as *Quercus cerris*-type, *Pinus*, and probably also *Betula* can only be produced by long-distance transport. The pollen distribution of *Juniperus* is not very good and the continuous curve with values up to 1% point to a regular occurrence of some representative of this genus.

The open character of the vegetation is illustrated by a variety of herb-pollen types. Various Umbelliferae, including *Ferula*-type, Caryophyllaceae and *Helianthemum* are very well represented. In addition Tubuliflorae including the very important *Artemisia* (mainly *herba-alba*-type), Liguliflorae, *Plantago lanceolata*-type and various Chenopodiaceae reach relatively important values during this zone.

The climate must have been extreme. Temperatures were low and so was the precipitation. Only towards the end of zone X some slight improvement occurred, illustrated by the reappearance or increase of some pollen types such as *Carpinus orientalis*/*Ostrya*, *Ulmus*, and *Corylus*.

Two radiocarbon dates are available for zone X:
25,620 ± 400 B.P. (GrN 6887) for the level of 5.70-5.80 m
21,390 ± 430 B.P. (GrN 6886) for the level of 3.70-3.80 m.

Using all available dates to interpolate, zone X lasted from 28,000-15,000 B.P.

6.2. Late Glacial

Zone Y (spectra 61-67)

The discussion on this period can also be found in a treatment on the Late Glacial in the Eastern Mediterranean and the Near East (Bottema, 1978). Zone Y forms a transition between a long period with low tree-pollen values and a contrasting younger period with high tree-pollen values.

The reason for distinguishing a separate zone Y is the increase of conifer pollen and Chenopodiaceae and the decrease of *Artemisia*. Fluctuations within this zone make a further division into subzones necessary.

Subzone Y1 (spectra 61-65). *Pinus* and *Abies* percentages increase together with Chenopodiaceae; Gramineae show a decline for the first time.

Subzone Y2 (spectra 66-69). AP values decrease considerably. Chenopodiaceae are dominant, at values of about 90% whereas *Artemisia* drops from about 25 to about 10% and less.

Subzone Y3 (spectra 70-76). AP values increase again, mainly because of *Pinus*, but *Quercus cerris*-type, *Corylus*, *Abies*, *Betula*, and *Alnus* also demonstrate higher percentages.

At the beginning of zone Y coniferous forest started to spread over the mountains. Apparently conditions were not suitable for any increase of deciduous oaks. During zone X temperatures were low but steppe vegetations were favoured especially by drought. The establishment or increase of trees would have benefitted most by any increase in precipitation. An increase in temperature would have caused even more severe drought. At higher altitudes in the mountains moisture did not play such an important role as at lower altitudes. Since only coniferous species increased and not trees of intermediate or lower levels it is reasonable to conclude that there was a rise in temperature at the beginning of zone Y. At lower altitudes the increase in temperature caused the spread of steppe vegetation, in this case Chenopodiaceae. It is not impossible that some of these chenopods grew on the shores of Lake Xinias during periods of summer drought (Wasilikowa, 1967). Surface sample studies from Syria point however to high pollen values for Chenopodiaceae where no lakes are found at all (Bottema and Barkoudah, in press).

During the next subzone Y2 conditions became very unsuitable for tree growth. It is probably that trees declined in the area and only grew in more suitable parts of the Pindus Mountains. Steppe vegetation prevailed in the Xinias area, a vegetation in which Chenopodiaceae dominated. This period seems to be even more unfavourable for plant cover than the whole Glacial period discussed before. Maybe an increase in temperature caused even more severe drought. Coarse material appears in the sediment towards the end of subzone Y2 and also during subzone Y3 (see also description of lithology). Under the extreme climate of subzone Y2 plant cover must have been very sparse on the slopes around Lake Xinias. This facilitated erosion when showers, although very infrequent, transported sand, whereas in other periods the vegetation protected the soil better so that mostly clay was deposited.

Less extreme conditions were found after this period during the third subzone Y3. The conditions of subzone Y1 seem to have returned as a comparable pollen picture shows up. There is one important difference: *Artemisia* does not return to its former values but loses even more ground and is maybe replaced by Gramineae. Some deciduous species increase towards the end of subzone Y3 demonstrating the development of a different climate. Coniferous species increased again at higher elevations.

Such a situation as described must have been induced by a change in climate, in this case an increase in precipitation as well as a rise in temperature.

The beginning of zone Y is dated about 15,000 B.P. by interpolation. This date and the radiocarbon date of 10,680 ± 90 B.P. (GrN 6885), at the end of this zone, define zone Y as a parallel of the Late-Glacial as we know it from northwestern Europe. It must be stressed that the sequence of Older Dryas, Alleröd and Younger Dryas of northwestern Europe is demonstrated here as an unfavourable period between two periods with a milder climate. This is in marked contrast to northwestern Europe where in fact the reverse is found. A possible explanation for these phenomena (see also Bottema, 1978) is the difference in effect of an increase in temperature upon two areas so far apart and where the annual distribution of the precipitation is completely different. In the Xinias area, with a pronounced steppe climate, an increase in temperature caused even drier conditions, resulting in a situation as described for subzone Y2.

6.3. Postglacial

Zone Z (spectra 77-91)

The boundary between zone Y and zone Z is chosen where a rapid increase of the AP is found, between spectra 76 and 77. This level yields the date of 10,680 B.P. mentioned above.

Zone Z covers the period which in northwestern Europe is known as the Postglacial. The main characteristic is the high tree-pollen value throughout this zone. The Postglacial in Greece is studied more often and in more detail than the older periods. Thus more information is available for comparison. Zone Z displays characteristics also found in diagrams for Ioannina, Edessa, Khimaditis (Bottema, 1974) and Tenaghi Philippon (Wijmstra, 1969) etc. The following subzones have been established: Subzone Z1 (spectra 77-78), Subzone Z2 (spectra 79-81), Subzone Z3 (spectra 82-85), Subzone Z4 (spectra 86-87), Subzone Z5 (spectra 88-91).

Subzone Z1. During this subzone *Quercus cerris*-type pollen percentages increase rapidly, together with some other tree types. From the *Juniperus* curve it may be concluded that initially the forest vegetation was still open. Evergreen oaks started to play a role together with *Pistacia* and the submediterranean species *Fraxinus ornus*. Conifers were not important during this subzone while steppe plants delivering pollen types such as *Artemisia*, *Ephedra distachya*-type, and *Centaurea solstitialis*-type decreased or even disappeared. At the same time pollen is found from *Poterium/Sanguisorba minor*. It is not clear whether this pollen type belongs to the maquis-plant *Poterium spinosum* or to *Sanguisorba minor*. This type is found at the beginning of the Postglacial, not only in Greece but also in other Mediterranean and Near Eastern countries. Both species are light-demanding but according to Horvat *et al.* (1974) *Poterium spinosum* (*Sarcopoterium spinosum*) is restricted to coastal areas as it is sensitive to frost. *Sanguisorba minor*, among other species, is found in vegetations together with *Quercus pubescens*. *Sanguisorba minor* can probably be expected in subzone Z1-vegetations.

Subzone Z2 shows very high values of *Quercus cerris*-type together with relatively important values of *Pistacia*, *Juniperus*, and *Poterium*-type. Especially the last type measures up to 15%. The boundary with subzone Z3 is placed where *Carpinus orientalis/Ostrya* and *Corylus* increase. The sudden expansion of *Carpinus orientalis/Ostrya* is observed in other Greek diagrams (Bottema, 1974; Wijmstra, 1969) and dated about 6500 B.P. Interpolation of the radiocarbon date obtained for material from a depth of 1.50-1.60 m gives about the same result.

Subzone Z3. The AP percentages and the significant value of *Poterium*-type point to rather open forest. The climate responsible for this vegetation would at least have had dry and hot summers. *Pistacia* and the possibility of *Poterium* point to winters with a Mediterranean character, at least not extremely cold.

Arboreal pollen still increased during subzone Z3, although *Quercus cerris*-type had to give way to *Carpinus orientalis/Ostrya*. *Abies* and *Pinus* show somewhat higher values as is the case with *Fraxinus excelsior*. *Plantago lanceolata*-type forms a closed curve at the beginning of this subzone. As the author knows no other *Plantago* species from the area that match the *lanceolata*-type, the curve may represent this species. Using *Plantago lanceolata* as an indicator of agriculture, there are signs of such human influence at about 4500 B.C. (6500 B.P.). For part of this period, beech must have been present somewhere as very low percentages of *Fagus* pollen are found.

Subzone Z4 shows high values for *Quercus cerris*-type whereas several other arboreal types, including *Pistacia*, *Fraxinus ornus*, *Ulmus*, *Tilia*, and *Fraxinus excelsior* quite suddenly decrease or disappear. Ericaceae and *Centaurea solstitialis*-type now start continuous curves. The cause of this is as yet unknown. Man may have destroyed the trees but the Ericaceae for instance may be the sign of human as well as climatical influence, such as an increase in precipitation.

Subzone Z5 is characterized by relatively high *Fagus* values. As is often found in diagrams from northern Greece, Ericaceae increase at the same time as *Fagus* or somewhat earlier. This increase of beech is dated at about 4000 B.P. (Turner and Greig, 1975; Bottema, 1974). At the same time as the Ericaceae show up, *Centaurea solstitialis*-type, abundant during the Glacial period and up to subzone Z3, starts to appear again. Plants producing this type were probably favoured by man. The Ericaceae may form part of a maquis resulting from wood-felling activities especially in the coastal area. The increase of *Abies* (5% and more) also may be the result of secondary growth of this species where other (climax) forest had been felled (Athanasiadis, 1976).

Values for *Quercus coccifera*-type increased during subzone Z5 suggesting a spread of evergreen oak where deciduous mixed forest had been destroyed. In spectra 90 and 91 *Olea* is found in relatively important numbers (fig. 4). This pollen must have originated from olive groves somewhere in the neighbourhood and are a clear sign of increasing human occupation. The winters in the plain are too cold for *Olea* but on the southwest slopes of the Olympus olives occur up to about 1000 m. The coastal area is important for olive-oil production (Geographical Handbook, 1944).

It is difficult to ascertain whether the complete Postglacial is covered by the diagram. Spectra 90 and 91 yield *Castanea* pollen (0.3 and 0.1%) while spectra 87 and 91 show *Juglans*. The first appearance of these types together with *Platanus* takes place about 1450 B.C. or later (Readman and Bottema, in prep.). Comparing with diagrams of Edessa and Khimaditis (Bottema, 1974), Pertouli and Litochoro (Athanasiadis, 1975) spectrum 87 can be dated 3000 B.P. or younger (table 1).

On the Tymfristos there are large forests of *Castanea sativa* nowadays while on the Oeta *Juglans regia* is found. *Aesculus hippocastaneum* is found on both mountains. On the Ossa Mountains *Castanea sativa* is met with even in pure forests from 300-1200 m. On the northeast exposures of the Kato Olympus *Aesculus hippocastaneum* occurs along small streams (Voliotis, 1976a, 1976b). In prehistoric and more recent times *Juglans*, *Platanus* and *Castanea* would have been limited to the mountains around the plain. Around Lake Viviis such species were not to be found.

Aesculus is thought to be endemic in the Balkans. The tree is not abundant at the present time. As the horse chestnut is insect-pollinated it is considerably under-represented in the pollen rain. Even if this tree had been more common at one time it would be impossible to demonstrate this by means of pollen analysis. In Xinias this tree is represented only once, in spectrum 87 (table 1).

For studying the modern pollen rain in Thessaly, the results of only one surface sample are available. Mr. and Mrs. Reinders-de Roever from Lelystad (Netherlands) were so kind as to take a sample during their archaeological investigations in 1978 near Volos. The sample comes from a *Phrygana* (a degraded stadium of *Maquis* or *Pseudomaquis*) near the coast between Halos and Volos (fig. 2). AP values in the surface sample spectrum are low, as could be expected (table 3). Especially the values of *Castanea* (0.5%), *Juglans* (0.5%), and *Platanus* (1.7%) are illustrative, indicating that these trees, growing on the mountains, are distributed rather well. The fact that *Castanea* and *Juglans* are found for the first time in spectra 90 and 87 of the Xinias diagram shows that they did not play a role previously.

Comparison of the present vegetation with the upper samples of the Xinias diagram

Can we demonstrate a relation between the (partly reconstructed) natural vegetation (fig. 2) and the

TABLE 3

Surface sample (for location see fig. 2); percentages based upon

I: pollen sum including all types except for indeterminata
II: pollen sum including all the same types as I, except for Crassulaceae which are thought to be over-represented
III: pollen sum as chosen in the diagram Xinias I and Lake Viviis

	I	II	III		I	II	III
Quercus coccifera-type	6.2	8.2	9.1	Gramineae	15.9	20.9	23.3
Phillyrea	0.5	0.6	0.7	Liguliflorae	1.0	1.3	1.4
Pistacia	0.5	0.6	0.7	Senecio-type	0.2	0.2	0.2
Olea	5.7	7.5	8.4	Matricaria-type	0.8	1.1	1.2
Oleaceae	0.7	0.9	1.0	Xanthium	0.2	0.2	0.2
Quercus cerris-type	2.0	2.6	2.9	other Tubuliflorae	1.3	1.7	1.9
Carpinus orientalis/Ostrya	0.7	0.9	1.0	Ranunculus acer-type	0.7	0.9	1.0
Corylus	0.2	0.2	0.2	Lotus-type	1.5	1.9	2.2
Cupressaceae	3.6	4.7	5.3	Leguminosae	0.3	0.3	0.4
Abies	0.8	1.1	1.2	Campanula	0.2	0.2	0.2
Fagus	0.2	0.2	0.2	Umbelliferae	1.1	1.5	1.7
Pinus	5.6	7.3	8.2	Brassica-type	1.8	2.4	2.6
Alnus	0.5	0.6	0.7	Papaver	0.2	0.2	0.2
cf Salix	0.3	0.4	0.5	cf Anagallis	0.2	0.2	0.2
cf Citrus	0.3	0.4	0.5	Echium-type	1.5	1.9	2.2
Vitis	0.2	0.2	0.2	cf Labiatae	0.2	0.2	0.2
Rhamnaceae	0.2	0.2	0.2	Crassulaceae	23.3	30.5	34.1
Juglans	0.3	0.4	0.5	Lythraceae	0.3	0.4	0.5
Castanea	0.3	0.4	0.5	Galium-type	0.3	0.4	0.5
Platanus	1.1	1.5	1.7	Rumex acetosa-type	0.8	1.1	1.2
Ericaceae	0.3	0.4	0.5	Urtica	2.8	3.7	4.1
				Polygonum aviculare-type	0.8	1.1	1.2
AP	30.2	39.6	44.2	Cyperaceae	2.5	3.2	3.6
Artemisia	0.2	0.2	0.2	Sparganium-type	2.5	3.2	3.6
Chenopodiaceae	4.8	6.2	7.0	Indeterminata	6.2	8.2	9.1
Plantago lanceolata-type	1.8	2.4	2.6				
Plantago spec.	1.8	2.4	2.6				
Cerealia-type	0.7	0.9	1.0	**POLLEN SUM**	**608**	**466**	**417**

upper spectra of the Xinias diagram (or Viviis diagram)? Most of the area around Xinias belongs to the Ostryo-Carpinion but north of the Othrys evergreen elements appear in this zone (Coccifero-Carpinetum). Thus next to the very common *Quercus pubescens* from the Ostryo-Carpinion, pollen of *Quercus coccifera* can be expected. Nearer the coast *Quercus coccifera*-type pollen is produced by the Quercion ilicis.

A Quercion confertae inhabits a large part of the Pindus Mountains producing deciduous oak pollen by *Quercus frainetto (conferta)*, *Q. cerris*, and *Q. pubescens.* The mountain area covered by Fagion and Abietion is much smaller.

Although no special zone is ascribed to *Pinus nigra* one should keep in mind that this tree occurs in many places in widely divergent altitudes.

Quite understandably the bulk of the pollen is produced by the various deciduous oak species whereas the evergreen oaks have a more modest share in the pollen precipitation. *Carpinus orientalis/Ostrya* pollen is represented fairly well in the zone of that name. The share of *Fagus* and *Abies* is small but so is their share in the vegetation and they are growing further away.

Pinus, a genus that is often over-represented in the pollen rain, demonstrates unexpectedly low values. It is quite possible that the upper spectra date back to a subrecent time when deciduous oaks were still plentiful and by far outnumbered the other trees including pine.

7. LAKE VIVIIS

7.1. Coring and lithology

Coring: In one hole at the west side of the drained (dried up) Lake Viviis; c. 3 km SE of Kato Katamakion (fig. 2).

Lithology:

6- 60 cm	grey to dark-grey clay with dark patches
60-215 cm	grey clay with dark and rust-coloured patches
215-276 cm	idem dark grey
276-377 cm	idem grey
377-400 cm	idem dark grey
400-437 cm	idem light grey
437-447 cm	grey clay with many rust-coloured patches and small stones.

The Lake Viviis sediment was difficult to core as the clay was very hard. The many patches that were yellow to rust-coloured may be a sign of oxidation and in some samples a very low pollen concentration was met with. The fact that no pollen counts could be made in several places should be kept in mind when judging the diagram. When spectrum distances are over 30 cm the pollen content in between was too low to make satisfactory counts. The quality of this information is deficient compared to the Xinias diagram but hardly any information is available from the lowlands in Greece at all. For this reason it is nevertheless of some use.

7.2. Pollen sum

In preparing the diagram (fig. 5) several pollen sums were tried and provisional diagrams drawn. A diagram based upon a pollen sum including only the arboreal types could hardly be compared with the Xinias diagram. One sum was made including tree types and wind-pollinating herbs and another including tree types and all non-local herb pollen types (fig. 5). These two diagrams looked very much the same (see also Xinias I). The basic difference was that the AP/NAP ratio gave, understandably, lower AP values when more herbs were included. Nevertheless both AP curves were running parallel at some distance apart. For that reason the sum chosen to calculate the percentages was that which included all trees and non-local herbs. Nevertheless some herbs may have a local effect appearing in considerable numbers when the lake dried up, either seasonally or for longer periods. According to information from the Geographical Handbook (1944) this happened quite often in recent times.

8. DISCUSSION OF THE VIVIIS DIAGRAM

Pollen zones:

Zone 1 (spectra 1-3)

The pollen percentages of deciduous trees like *Car-*

pinus orientalis/Ostrya, *Corylus* and *Carpinus betulus* are relatively low compared with the next zone 2. Maximum values for *Pinus* are about 20%. The values for Liguliflorae are very high as are those of the unidentified grains. These two facts point to corrosion of the pollen content (Bottema, 1975).

Zone 2 (spectra 4-8)

At the end of zone 1, *Ostrya*-type had already increased, a process going on in zone 2. The increase of *Carpinus orientalis/Ostrya* is also visible in Xinias I (fig. 4). This event is dated about 6500 B.P. (Bottema, 1974). Ericaceae show a closed curve at the same time, *viz*. at the beginning of zone 2. This is much earlier than in the Xinias I diagram. A possible explanation could be the difference in elevation between the two lakes. The vegetation during zone 2 would have been composed mainly of deciduous species. *Quercus cerris* or *Q. infectoria* together with *Ostrya* and/or *Carpinus orientalis*, *Corylus*, and *Carpinus betulus* grew in the plain and the surrounding foothills. Pine must have retreated to the higher mountains, as indicated by rather low values (10-20%).

Zone 3 (spectra 9-10)

Zone 3 is characterized by a brief increase of *Pinus* resulting in the highest AP value of the diagram in spectrum 9. This increase is quite probably the result of pine spreading over the Volos plateau and the Mavrovuni Mountains. A comparable increase is not to be seen in the Xinias I diagram.

Zone 4 (spectra 11-15)

Zone 4 shows a constant decline of the AP values. *Pinus* and *Quercus cerris*-type decrease considerably and *Ostrya*-type, *Ulmus*, *Tilia*, *Corylus*, and *Carpinus betulus* disappear.

This decrease must have been caused by man as *Juniperus* occurs from spectrum 13 on. *Abies* and *Fagus* are still present in low numbers and this is an indication that the forest destruction took place at lower and medium altitudes first.

It is quite conspicuous that the (sub)Mediterranean types are found either not at all or only in insignificant numbers. There are several explanations for this absence. This group is under-represented in the pollen rain (Bottema, 1974). The preservation of the material was not ideal and some grains remained unidentified. Both explanations are, however, not enough to explain the absence of this group and it is clear that in the lower plain of Thessaly the climax vegetation was not replaced by maquis when man settled there.

Castanea (0.7%), *Platanus* (0.4%), and *Olea* (1.9%) appear in the uppermost spectrum only (table 4). Compared with the diagrams of Pertouli and Litochoro (Athanasiadis, 1975), part of the younger sediment must have disappeared or no deposit was formed (see also Xinias I). Even Cerealia-type shows up in spectrum 15 only (0.6%). In this respect the surface sample study (table 3) is illustrative. Even on the coast pollen of *Juglans* and *Castanea* is found. In the area around Lake Viviis they would not have been important before the time of spectrum 15 (fig. 5).

The dominance of the non-arboreal pollen types is striking although this may have been partly caused by the drying up of the lake. Still the Viviis area would have showed open forest or treeless vegetations especially compared to Xinias, situated at an altitude about 500 m higher. Up to now very few lake sediments from about sea level in Greece have been studied palynologically. The Drama section (Wijmstra, 1969) often reflects marshy conditions instead of open water so local pollen production is important. Unpublished information from Lake Trikhonis in Akarnania, at sea level, shows that the lower vegetation zones are represented better than the mountain belts (as is fairly predictable). NAP values are higher than their counterparts in diagrams originating from levels of 500 m and higher. Of course human influence was also greater upon the lowland vegetation (forest) than on the vegetation at higher altitudes, at least in the early stadia.

Although the plain of Thessaly was inhabited by farming cultures starting in the 7th millennium B.C. (Halstead, 1977) it is difficult to ascertain the influence of man upon the vegetation from this diagram as well as from the Xinias I diagram. Cerealia-type pollen is only represented in spectrum 15 with 0.6% (table 2). *Plantago* species, especially *P. lanceolata*-type and *Centaurea solstitialis*-type as possible indicators of farming are present throughout the whole diagram. This is not unexpected as the assumed time covered by the diagram falls within the limits of the Neolithic and later farming periods. The beginning of zone 3 shows traces of a regeneration of pine forest. Interpolating from the assumed date of 6500 B.P. for the increase of *Carpinus orientalis/Ostrya* at spectrum 3, this possible regeneration dates from about 3500-3000 B.P. However, the age of the top sample (spectrum 15) is very difficult to trace, but may be a few thousand years, because of the absence of *Juglans* and the very late appearance of *Platanus* and *Castanea* (in spectrum 15). With this assumption the interpolated date would be about 3900-4000 B.P. The brief increase of *Pinus* pollen could indicate a decrease in population pressure in the plain and adjoining mountains.

After that period the degradation and destruction of forest started again with renewed force. According to the low AP values forest occurred only on the Volos plateau and other mountains, leaving the plain almost devoid of trees (see also Turrill, 1929).

An increase in *Pteridium* is visible after the AP maximum in spectrum 9. Bracken would have spread in places where forest was cleared on the mountains.

9. LOCAL VEGETATION

9.1. Marsh and water plants of Xinias

Half the Xinias I diagram consists of curves of plants which are considered to be local. Apart from pollen, curves of spores and *Pediastrum* species are presented.

It is immediately seen that this part of the diagram not only shows high to very high values but also that most curves demonstrate pronounced fluctuations.

From spectrum 1-24 pollen curves of Cyperaceae, *Sparganium*-type, *Myriophyllum verticillatum*-type and the curve of *Dryopteris* run very smoothly. Peaks can be seen in the spectra 24-27, 32-39, 43-48, and 56-64. It is always difficult to explain the meaning of such peaks. One is inclined to implicate the water level of the lake to explain such phenomena. A plant species or a group of species would demonstrate a high pollen percentage when the water depth was optimal for their growth at the point where a core was taken later.

With a change in water-table one may expect a change in water-plants and thus in pollen types and values. In the case of a falling water-table first the plants of deeper water would appear, followed by plants of shallow water and finally by marsh plants.

At a depth of 0.5-3 m in eutrophic water a Nymphaeion (Westhoff and Den Held, 1969) may have occurred. In moderately eutrophic water to eutrophic water deeper than 1 m, something like a Potameto-Nupharetum could be found, including *Nuphar luteum*, *Myriophyllum verticillatum* or *M. spicatum*, and *Potamogeton* species.

In marshy areas, flooded all through the year and up to 2-3 m deep, typical representatives of a Phragmitetalia would have been found like *Typha latifolia*, *T. angustifolia* (included in the *Sparganium* pollen-type), *Iris pseudacorus*, and Cyperaceae, for instance *Scirpus lacustris* in deeper water and other representants of this family in shallower water or in marsh. In the vegetation along the edge of the lake *Cladium mariscus* was present. In the vegetation just above water level *Dryopteris* species occurred. The vegetation units or plant species ascribed are represented in the pollen diagrams with higher or lower percentages.

As these plants do not require the same habitat but vary in their demands with regard to water depth, water movement, light, and trophic state, the succession should be obvious from the pollen record. However, such an ideal situation is rare. When the water depth decreases, either by sedimentation or lowering of the water-table, plants of deeper water will be followed by others and finally even marsh plant-pollen will be met with. Of course the reverse of such a succession can also be encountered. A marsh vegetation will drown when the water-table rises and be succeeded by for instance a *Phragmites* vegetation.

The pollen and spore dispersal hinders the exact tracing of vegetation succession as plants growing at some distance may even confuse the production on the spot. Thus in spectra 24-27 *Sparganium*-type, *Typha latifolia*, *Myriophyllum verticillatum*-type (also including *M. spicatum*) appear together with *Dryopteris*, the spore of which represents a large group of fern species. In general Cyperaceae either precede or follow an increase in typical water plant-pollen. *Myriophyllum verticillatum*-type generally follows the same course as *Sparganium*-type, apart from spectra 52 and 54 where it is only accompanied by *Potamogeton*. Such events are not restricted to the Xinias I diagram but can also be seen in the Ioannina I diagram on the other side of the Pindus Mountains (Bottema, 1974).

During Late-glacial times a marked decrease in pollen types of aquatic origin takes place. Cyperaceae are important towards the end of this zone. Furthermore *Polygonum aviculare*, *Urtica* and *Dryopteris* indicate marshy conditions instead of open water.

The Postglacial part of the diagram shows low values for local pollen. The increased pollen production of the upland vegetation most certainly influences the percentages.

Typha latifolia still has the same values as in the previous period. *Nymphaea* is relatively important whereas *Butomus*, *Menyanthes*, and *Lemna*, met with before in low numbers, are no longer found. Spores of *Isoëtes* are now regularly encountered. As there are many *Isoëtes* species demanding different habitats, nothing can be concluded from the presence of these spores.

Pteridium, a fern from the upland vegetation and not of local origin, formed part of the undergrowth of the deciduous forest and appeared early in the Postglacial.

9.2. Pediastrum

The various *Pediastrum* species or varieties are also counted and calculated as percentages of the pollen sum. As some types sometimes have very high values they are presented in the diagram on a different scale.

At first glance the irregular character of the curves is striking. As stated previously (Bottema, 1974), hardly any information is available on the ecology of *Pediastrum*. *Pediastrum boryanum* is ubiquitous in Lake Xinias and this is true for many other (Greek) diagrams. Such Chlorophyceae indicate the presence of water, although of course the presence of water is also concluded from the fact that sediment was deposited. What else can be deduced from *Pediastrum?*

Pediastrum boryanum is met with even during the Late Glacial when all the other *Pediastrum* species are absent. *Pediastrum duplex* var. *clathratum* as usual shows the same tendency as *P. boryanum* but with lower numbers. *Pediastrum duplex* var. *arachnoidea* is rarer than the first variety. Apart from spectra 42-47 it behaves in the same way. *Pediastrum kawraiskyi* demonstrates high values for the lower and the upper part of the Glacial period presented in the diagram. It is found hardly or not at all during the Postglacial. *Pediastrum kawraiskyi* occurs in Greece during Postglacial times only in the interior lakes of Kastoria and Khimaditis at altitudes of 650 and 560 m respectively.

Lake Kastoria lies in between the 25.5°C and 26°C July isotherm (Philippson, 1948). Correcting for altitude the July temperature would be about 23°C. The 7°C January isotherm is found close to the lake, after correction the January temperature would amount to 4.9°C. The average July temperature for the nearest meteorological station of Ohrid is about 21°C, for January c. 3°C. The corresponding temperatures for Thessaly, as concluded from the meteorological stations of Volos and Lamia, are 8°C and 25-27°C for January and July respectively.

In the following table the average temperatures of some Greek sites will be given, together with the presence or absence of *Pediastrum kawraiskyi*.

Site	Average January temp.	Average July temp.	*P. kawraiskyi* present or not
Lake Xinias	c. 5°C	c. 25°C	—
Lake Viviis	c. 8°C	c. 27°C	—
Ioannina	5.1°C	24.0°C	—
Edessa	3.4°C	24.6°C	—
Giannitsa	5.6°C	26.7°C	±
Khimaditis	1.8°C	23°C	+
Kastoria	3-4.9°C	21-23°C	+

It seems that *Pediastrum kawraiskyi* is favoured by low temperatures, possibly an average of about 3°C for January and/or an average of under 23°C for July. Which of these is the limiting factor is not known. In addition to temperature other factors must be decisive for the presence or absence of this alga. For instance in Lake Vegoritis with deep and rather sterile looking water and bare banks, no *Pediastrum kawraiskyi* has been present during the last few thousand years. In the nearby Lake Khimaditis, however, this species is very common.

Pediastrum simplex is found in large numbers in some spectra and is completely absent from others. No explanation for this behaviour can be given. *Pediastrum clathratum* is found almost exclusively in

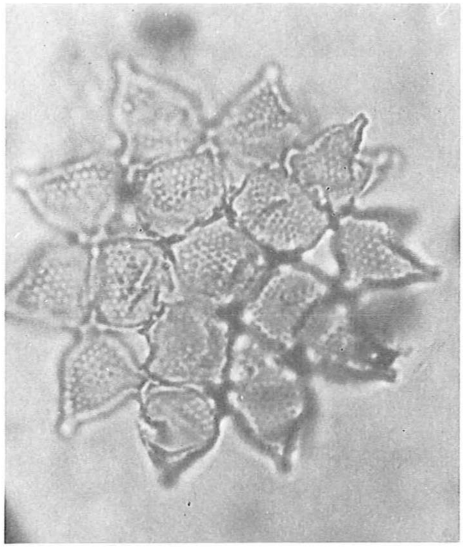

Fig. 6. Pediastrum "kawraiskyi-boryanum".

the lower two zones. There it attains very high values. The species disappears at the beginning of zone X and appears in low numbers in the first half of the Postglacial.

A *Pediastrum* species named "*kawraiskyi/boryanum*" occurred in large numbers in part of the spectra (fig. 6). No matching descriptions could be found in the literature. This type has outer cells which resemble *Pediastrum kawraiskyi*. The lobes of the peripheral cells are triangular and not elongated. They are placed one above the other or they are in one plane in which case they slightly overlap. In between the cells that form the body, openings are found like in *Pediastrum clathratum*. The cells are shaped more or less as in *P. boryanum* and are pitted in the same way. For this reason a provisional name of a combination of *P. kawraiskyi* and *P. boryanum* is given. *P. kawraiskyi/boryanum* was found in another Greek diagram before but the specimen was considered to be an artefact (Bottema, 1974). Later, however, some specimens were also encountered in samples from Lake Zeribar, Iran (van Zeist and Bottema, 1977). It was only when this type was found in such large numbers as here in samples from Lake Xinias that more attention was paid and the type was identified as a separate one. The new type correlates to some extent with *Pediastrum simplex* and not with *P. kawraiskyi*.

9.3. Miscellaneous

The curve of the indeterminata includes mostly corroded grains which could not be identified. Corrosion can be an indication of seasonal drought causing changes in water levels. This is especially the case in spectra 60-76, a period represented by pollen assemblages also indicating dry conditions.

Only quantitative information is given regarding the presence of three Chlorophyceae, *viz*. *Coelastrum reticulatum*, *Scenedesmus*, and *Tetraëdron*. During zone Y they were not found indicating different conditions at that time. No further conclusions can be drawn from the presence or absence of these Chlorophyceae.

9.4. Local vegetation of Viviis

The local marsh flora and lower plants (*Pediastrum*) growing in and along the lake show irregular pollen and spore patterns. This must be due to the changing water-table of the lake. Cyperaceae, *Sparganium*-type, *Isoëtes*, *Pediastrum boryanum*, *P. simplex*, and *P. clathratum* are clearly correlated. Their peaks suggest higher water levels, whereas low values suggest dry phases. This is also concluded from the curve of unidentified grains (indeterminata). This group covers those pollen grains which were too corroded to permit identification. In general low values for indeterminata (corroded grains) correlate with an abundance of *Pediastrum* and pollen of marsh and water plants. The correlation of corroded pollen in relation to Liguliflorae has been discussed previously (Bottema, 1975).

10. CORRELATIONS AND COMPARISONS

10.1. Correlation of Greek diagrams

Two Greek diagrams demonstrate a period that corresponds with that of Lake Xinias, *viz*. that of Ioannina (Bottema, 1974) and that of Tenagi Philippon (Wijmstra, 1969). (For a comparison of Xinias, Tenagi and Near Eastern diagrams the reader is referred to van Zeist and Bottema, 1977).

The Ionannina core was taken on the west side of the Pindus Mountains (fig. 1) at about the same altitude as that from Xinias. The very deep section of

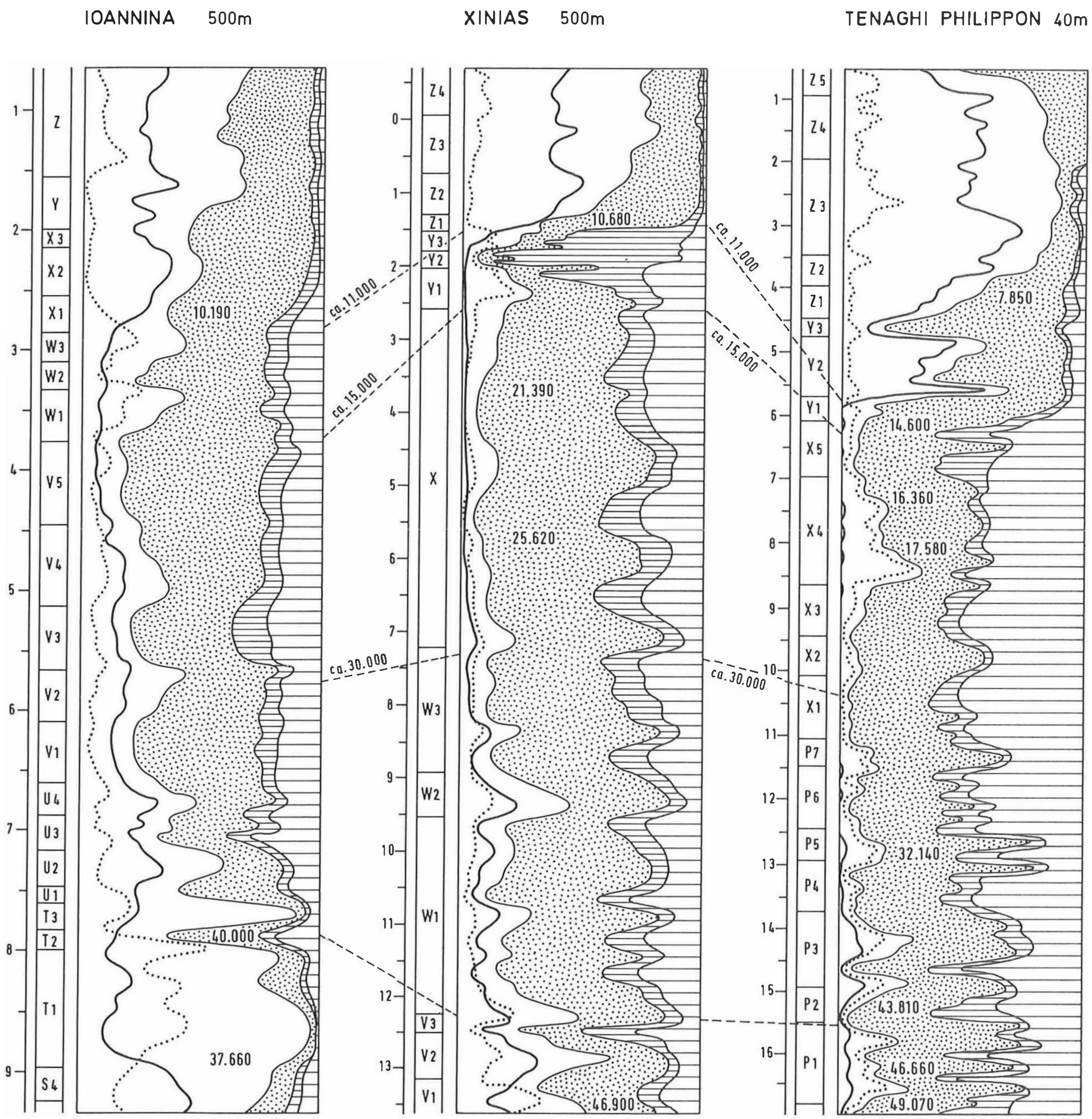

Fig. 7. Schematical diagrams of Greek sites, showing curves for *Quercus*, *Pinus*, AP/NAP ratio, *Artemisia*, Chenopodiaceae and remaining herbs; for location of the sites see fig. 1.

Tenagi Philippon was taken in the Drama Plain at about 40 m above sea level (fig. 1). The parts that correspond with the Xinias diagram are shown in fig. 7. The curves of *Quercus*, *Pinus*, total arboreal pollen, *Artemisia*, Chenopodiaceae and the sum of the other non-local herbs are schematically drawn.

The vegetation at the three locations would have differed according to altitude, exposure, distance from the sea, etc. Such differences must be kept in mind when comparing these three diagrams. An attempt has been made to connect the periods that could be recognized in the three diagrams on the basis of the shape of the curves and the radiocarbon dates. The information used is partly derived from van Zeist and Bottema (1977).

For the Glacial as well as for the Postglacial part clear similarities can be seen. The lower part, the zones Ioannina S4 and T4, Xinias V1-V3, and Tenagi P1 are thought to represent a similar period of time. During this period forest covered that side of the Pindus chain exposed to weather. On the sheltered side of these mountains forest was restricted to suitable habitats at a certain altitude. Besides this, steppe vegetations dominated. On the southern edge of eastern Macedonia, in the low-lying Drama region, there was only steppe. Any forest remnants must have occurred further inland at higher altitudes. These forests or tree stands decrease or even disappear with the passage of time, sometimes recovering during short fluctuations but on the whole constantly losing terrain. It is evident from the pollen curves that trees hold their own better on the exposed side of the Pindus than on the sheltered side whereas especially oak finally disappears from the Drama region.

Up to about 15,000 B.P. steppe conditions prevail and tree refuges were to be found especially on that side of the Pindus exposed to rainbringing winds. It is also there that certain minor ameliorations of the climate favour tree growth. This is less pronounced in Xinias, and in Drama the postulated rise in temperature would prevent any form of tree growth. The level of 15,000 B.P. is drawn somewhat lower in fig. 7 than in van Zeist and Bottema (1977).

A little after 11,000 B.P. trees, especially oak, replace the steppe vegetation. The sharp decrease of the AP values in Tenagi-zone Y3, must be due to local herbs.

The general synchronization of the three diagrams is rather obvious. It will be more difficult to correlate the fluctuations in detail. For such a correlation one has to assume that every change in climate is ubiquitous and that such a change affects the vegetation and thus the pollen spectra derived from such a vegetation, in a comparable if not exactly the same way. It is obvious that vegetations at different locations are not the same, the differences being greater as the abiotic factors diverge. This is clearly evident for locations further apart (van Zeist and Bottema, 1977).

For those who like to correlate fluctuations in detail and to give them names, a scheme is given below. Such a scheme is more meaningful when the palynological information is obtained under comparable conditions.

Table 4. Tentative correlation of the pollen zones in diagrams from Ioannina, Xinias and Tenagi. The codes used for the three diagrams refer to each diagram only and cannot be used for either of the others.

Ioannina	Xinias	Tenagi
S4	V2	P1
T1	V3	P2
T3	W1	P3
U2	W2	P5
U4	W3	P7
V2	X/W3	X2
V4	X (5.00 m)	X4

10.2. The Würm Glacial steppe vegetation of Greece

Apart from the upper parts the pollen diagrams of Xinias, Ioannina and Tenagi Philippon demonstrate steppe conditions. The open vegetations provided habitats for many herbs resulting in a wide range of herb pollen-types. Only around 40,000 B.P. is the Ioannina area covered with dense forest that prevents herb growth.

The amount of herb pollen found during the last glacial period varies from site to site. In Ioannina values fluctuate between 40 and 80% (apart from the forest phase). In Xinias NAP percentages are 80-90%, whereas in Tenagi values exceed 95%. It will be clear that apart from these values, vegetations may have differed in composition.

A translation of such NAP percentages in terms of vegetation remains difficult. The modern pollen precipitation of much overgrazed and/or destroyed steppe, forest steppe or steppe forest in Syria is quite instructive in this respect (Bottema and Barkoudah, in the press). In such vegetations NAP values amount to 80-90% of which *Artemisia* constitutes 20-50%. Vegetation cover averages 5-10% and up to about 30% in patches of vegetation.

In the first place there are quantitative differences in the various areas, secondly qualitative differences are evident. The quantitative difference applies to

Artemisia being better represented at lower altitudes and in a more continental situation. In Tenagi *Artemisia* measures 30-50%, in Xinias 20-27% and Ioannina 15-20%.

Chenopodiaceae are important during Late Glacial times in Xinias and Tenagi. Gramineae tend to be higher during the Glacial than during the Postglacial in Tenagi and Ioannina. In Xinias grasses are relatively unimportant especially during the Late Glacial. Cerealia-type pollen is found during the whole period covered by the pollen diagrams in Ioannina and Xinias. They would have been part of the steppe vegetation.

The two groups of *Ephedra* identified *viz. Ephedra distachya*-type and *Ephedra fragilis*-type behave differently. Both are present in the three cores for most of the Glacial period but *Ephedra distachya*-type became more widespread during the Late Glacial.

Thalictrum is found on all locations but in Tenagi it is also found at the beginning of the Postglacial indicating relatively dry conditions. *Plantago* behave more or less identically at all three locations, although the composition of the various types comprising the total of *Plantago* may be a little different. In Xinias and Ioannina an increase in *Plantago* is visible towards the end of the Glacial period but during the Late Glacial in Xinias, *Plantago* did not play any role.

In Xinias and to a lesser extent in Ioannina a series of different types belonging to the Tubuliflorae were identified. Comparison is not easy as in Tenagi most of these types are included in the group of Tubuliflorae, which are not identified to genus level. A striking feature is the presence of *Xanthium* in the Tenagi area in the Glacial period and especially during the Late Glacial. Not a single grain of *Xanthium* was found in the other cores. In young Holocene deposits *Xanthium* occurs in sediments from Lake Volvi in Eastern Macedonia. In Lake Vegoritis it is much rarer whereas in Lake Trikhonis in Southwestern Greece it is altogether lacking.

Cistaceae, especially *Helianthemum*, are common in Xinias and fairly common in Tenagi while in Ioannina they tend to be more rare. An increase towards the end of the Glacial is visible.

Caryophyllaceae are represented fairly well in Ioannina and Xinias, but are not represented at all in Tenagi. Umbelliferae are common in all three cores but in Xinias they attain highest values. There seven types are distinguished according to the descriptions in van Zeist and Bottema (1977). In the two remaining cores they are however grouped together.

A series of types are present on both sides of the Pindus Mountains which are not mentioned in the Tenagi core. They include: Cruciferae, *Centaurea solstitialis*-type, *Centaurea scabiosa*-type, *Knautia*, *Euphorbia*, *Teucrium*, *Campanula*, *Verbascum*-type, *Rhinanthus*-type, *Hypericum perforatum*-type, Geraniaceae, Liliaceae.

The sediments of Xinias are very rich in types, some of which are not reported for the other two sites. These include *Scabiosa*, *Dipsacus*, *Malva*, and *Convolvulus*. For the Postglacial *Cynocrambe* can be added to this list. In contrast to Ioannina however Plumbaginaceae were not met with.

Of the local water-plants and marsh flora *Butomus* and *Nuphar* were not found in Tenagi but here *Peplis* was very common whereas in Xinias only one doubtful grain of *Peplis* was met with.

When discussing the similarities and the differences of the herb pollen and especially the steppe vegetation in the three localities, the origin of the cores has to be reckoned with. Tenagi is a large marshy area with a lot of local pollen, possibly obscuring regional NAP of surrounding steppe vegetations. Besides the amount of pollen counted is not known. When large pollen counts are made the rare types tend to show continuous curves. As many herb-pollen types are insect-pollinated one has to consider the probability of under-representation.

Steppic influences in Ioannina are less than in Xinias, as can be deduced from the forest phase prevailing there at about 40,000 B.P.

The Xinias area shows more variation in types than the exposed side of the Pindus. This may be an indication for diversity in biotopes in Thessaly. The high *Artemisia* values in Tenagi show that at low altitudes lack of moisture was a limiting factor for other vegetation, resulting in a dominating *Artemisia*-steppe.

10.3 Comparison with Anatolian and Iranian glacial steppe vegetations

West Anatolia

NAP values from West Anatolian pollen diagrams (van Zeist *et al.*, 1975) amount to 40-75%, *Artemisia* 20-50%, while Chenopodiaceae average about 20%.

A difference with regard to the Greek cores under discussion is the presence of some *Calligonum/Pteropyrum* pollen. Despite a difference in altitude of 500-1000 m there is a general resemblance of the Glacial spectra of Greece and West Anatolia.

East Anatolia and Western Iran

The results of palynological investigations in East Anatolia (Lake Van) and Western Iran (Lake Zeribar) are drawn from van Zeist and Woldring (1978) and van Zeist and Bottema (1977). The authors emphasize the different development of the vegetation there compared with adjacent areas. Thus differences to the Greek/Western Anatolian pollen assemblage can be expected.

In this respect the qualitative differences are worth mentioning. The Lake Van and Lake Zeribar diagrams reveal the presence of pollen types not met with in the Greek/Western Anatolia cores. Those types include *Anisosciadium*-type, *Atraphaxis*, *Rheum*, *Rumex patientia*-type, *Statice spicata/Psylliostachys*, *Leontice*, *Bongardia*, *Prosopis*, *Haplophyllum*, and *Sysirinchium*-type.

Xanthium was not encountered in these diagrams and its presence in Tenagi may be linked with the low altitude. The differences mentioned above suggest a vegetation boundary between Western and Eastern Anatolia caused by certain conditions of which precipitation was a decisive factor.

11. ARCHEOLOGICAL IMPLICATIONS OF THE PALYNOLOGICAL INFORMATION

11.1. Palaeolithic

Milojčić (1958) considers palaeolithic artefacts found together with faunal remains found at some location along the Pinios River "als untypisch im Sinne der westeuropäischen Klassen Terminologie". Schneider (1968) concludes that these artefacts, compared with other material, should be placed in the Riss/Würm interglacial or Early Würm.

Which period is represented by the fauna found together with these artefacts? Schneider gives a table (table 5) grouping the various species according to their climatical amplitude.

Table 5.

Warm steppe climate	Warm to moderate "Waldklima"	Subarctic "Waldklima"	Cold steppe climate
Dicerorhinus hemitoechus	*Elephas antiquus*		
	Hippopotamus cf. *antiquus*		
Equus hydruntinus			*Equus hydruntinus*
Equus caballus cf. *germanicus*	*Megaceros*	(*Megaceros*)	*Megaceros*
Megaceros			
Cervus elaphus	*Cervus elaphus*	(*Cervus elaphus*)	
(*Dama* sp.)	*Dama* sp.		
Capreolus capreolus	*Capreolus capreolus*	*Capreolus capreolus*	
Saiga tatarica			*Saiga tatarica*
Bos primigenius	*Bos primigenius*	*Bos primigenius*	
Bubalus	*Bubalus*		

The following notes are made in this table. *Hippopotamus* indicates winters without freezing. For *Capreolus* during a warm steppe climate, steppe forest must be available and for *Bubalus* marshes or water must be present at the same situation.

The composition of the species is remarkable and interesting, apart from the dating problems with such a faunal assemblage. Some of these species share the same habitat, but others demand a clearly different one. Such different habitats probably would not have been available under the same climatical conditions. Seeing that these species differ so much ecologically, it is very difficult to put them together in the same period.

Schneider's statement that the bone-bearing layer was formed in a relatively short time is very important. Accumulation over a long period would in fact make it easier to provide an explanation for the divergent biotopes. What explanation can there be for this faunal assemblage brought together within a short period?

According to the available palaeobotanical information (Wijmstra, 1969), during the Riss/Würm, Thessaly should compare with the Postglacial *viz.* a closed forest must have covered the area. It is difficult to place steppe animals like *Dicerorhinus hemitoechus*, *Equus hydruntinus* or *Saiga tatarica* in dense forest.

The period during which Schneider estimates this fauna to have existed is not represented in the Xinias I diagram. Nevertheless the apparently incongruous list of fauna can be connected with the kind of short fluctuations as found in zone V of the pollen diagram. Even during the maximum extension of the forest in such a pollen assemblage there is still steppe present in the area. The difference in minimum temperature along the coast and in the plain is relatively great and resulted in a diversity of habitats at that time too. Moreover the climatical fluctuation is so rapid that several faunas may have followed each other closely.

Comparable periods as demonstrated in zone V would have occurred also during the early Würm, an idea supported by the sequence in the Tenagi diagram (Wijmstra, 1969). Thus the origin of the fauna as shown in table 3 is more likely to have occurred in the early Würm than during the Riss/Würm interglacial.

11.2. Neolithic and younger periods

It has been stated previously (Bottema, 1974, p. 165-166) that the impact of man on the vegetation is reflected rather feebly in the Greek diagrams. Only about 5000 years after the beginning of the Neolithic do clear traces appear in the pollen record. Obviously also indicators have to be looked for other than those well-known from northwestern Europe. To study the influence of early farming upon the vegetation, suitable sediments are needed. Such suitable sediments include those from rather deep lakes where local effects are reduced to a minimum. Coring in deeper water, however, causes a lot of difficulties. The Mackereth corer, although very practical for coring in deep water, has the disadvantage that its maximum reach is six metres. In many Greek lakes six metres covers only the last few thousand years. Cores from the Lakes of Volvi, Vegoritis and Thrikhonis collected by a team of the Department of Geophysics of the University of Edinburgh and studied palynologically by the present author gave promising results as also the more recent pollen rain is included, judging from the presence of *Zea mais* pollen. However, the beginning of farming in Greece is not represented in such cores.

Archaeological evidence from prehistoric Thessaly connected with the vegetation history is scanty. Halstead (1976) gives information on the settlement pattern in Eastern Thessaly, *viz.* the plain in which Lake Viviis (= L. Karla) is found. In the Early and Middle Neolithic many settlements were found, all of them situated in the northwestern part. During the Late and Final Neolithic they covered the whole plain. During the Early and Middle Bronze Age the number of settlements sharply decreased. Halstead thinks that the population increased again during the Late Bronze Age. In his maps no settlements are found in the vicinity of Lake Viviis apart from a small outcrop in the southwest. The reason for this must be the flooding that happened from time to time.

Thessaly was a well-known granary in Classical times. Halstead explains the delayed development in early times because of the isolation including the barrier with the coast. Athanasiadis (1975) describes the period after the Late Bronze Age by means of a diagram from Litochoro. The "Middle Geometric" and Helenistic cultures (900-200 B.C.) strongly influenced the vegetation through farming. During Roman and Byzantine times (200 B.C.-A.D. 900) the extent of cultivated land declined, as concluded from evidence including palynological information. The flourishing of Byzantium up to the invasion of the Turks (A.D. 900-1400) shows a renewed attack on the natural vegetation as concluded from the increase of pollen due to agriculture.

The vegetation regenerated to some extent after the invasion of the Turks. Large estates (tchifliki) developed where Turkish landowners controlled their serfs up to 1881. Part of the Greek population fled from the area because of uncertain conditions. Gradually the people settled again and human influences became stronger and stronger. This process continued after the liberation of Thessaly.

Until very recently farming was primitive because of the general inability of the people to control the water and as a result of the aftereffects of the Turkish system of land management.

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