PALYNOLOGICAL INVESTIGATIONS IN GREECE WITH SPECIAL REFERENCE TO POLLEN AS AN INDICATOR OF HUMAN ACTIVITY

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CONTENTS

1. INTRODUCTION

In this paper an attempt is made to analyse the possibilities of the use of pollen as indicators of human activity in Greek history. Several approaches will be made in this respect. New palynological information is brought forward in the form of diagrams from three lake sediments covering part of the Holocene. These sediments include the youngest periods that are often lacking in peat bogs or drained marshes where the upper parts have been ploughed or where organic remains have been oxidized.

The use of pollen as an indicator of human activity in Greece up to now has not been very successful in tracing the onset of farming. Compared with Iversen's (1941) study on the *Landnam* in Denmark such sharp indicators as Iversen was able to demonstrate do not seem to be present in early Neolithic Greece. Pollen of possible weed plants does occur in levels older than those ascribed to Neolithic times. An attempt is made to evaluate the statement 'weed' plant by comparing between a plant-sociological study of Greek forests and information on the vegetation history of Greece.

In circles of nature conservancy and nature management the idea is favoured that up to the 20th century agriculture increased the diversity of the landscape and the diversity in numbers of plant species in Western Europe. In this study attention is paid to diversity of the vegetation as well as to diversity of pollen assemblages and possible relations between the two. It is supposed that an increase in pollen diversity on some occasions might indicate human activity.

The history of a few selected species and a larger group of weeds is treated in detail. For this purpose ten pollen diagrams from Greece were selected.

In younger periods, the influence of man upon the vegetation in Greece is clearly visible. Such an impact was not the result of a constantly increasing pressure upon the environment but a phenomenon that could vary in time and in space. An attempt will be made to link the changes in vegetation derived from the pollen evidence with (pre)historic events.

2. PALYNOLOGICAL INVESTIGATIONS OF THE LAKES OF TRIKHONIS, VEGORITIS AND VOLVI

2.1. Introduction

The cores from these three lakes were taken by Professor K.M. Creer (Department of Geophysics, University of Edinburgh) *et al.* for the study of palaeomagnetism (Creer, 1981). The cores were taken using a Mackereth corer that is able to sample 6 m in one stretch in deep water. A disadvantage of the Mackereth corer is that it cannot sample more than 6 m of sediment. The sediments were studied palynologically to provide dates for the geomagnetic variation curves. It was expected furthermore, because of the origin of the material, that the samples would provide good information on the Holocene vegetation development.

As all three cores contained clay, samples were treated with a specific weight separation method (Bottema, 1974). Further processing was done according to standard methods. In chapter 2.5. the dating problems will be discussed (Bottema in Creer *et al.*, 1981).

Only a short, general reconstruction of the vegetation will be given in the discussion of the diagrams. In chapters 5, 6 and 7 a discussion of the possible relations of vegetation history and (pre)history will be presented.

2.2. Trikhonis

2.2.1. Geography, climate and vegetation

Lake Trikhonis is situated in Southwestern Greece (38° 36′N, 21° 30′E) in the province of Arkanania (fig. 1) at an elevation of about 20 m above sea-level. It forms part of a complex depression originating from late Tertiary and Quaternary times when the whole of this area was severely fractured. The main depression contains lakes Amvrakia and Ozeros; a subsidiary trough lies to the north of the Arakinthos Mountains (up to 1000 m) and holds the lakes Angelokastron and Trikhonis. Overflow of these lakes runs to the Acheloos that discharges into the Gulf of Patras. South of Lake Trikhonis, sandstones and flysch are found, in the north alluvial deposits occur (Greece, 1944).

The climate of the area is Mediterranean. In

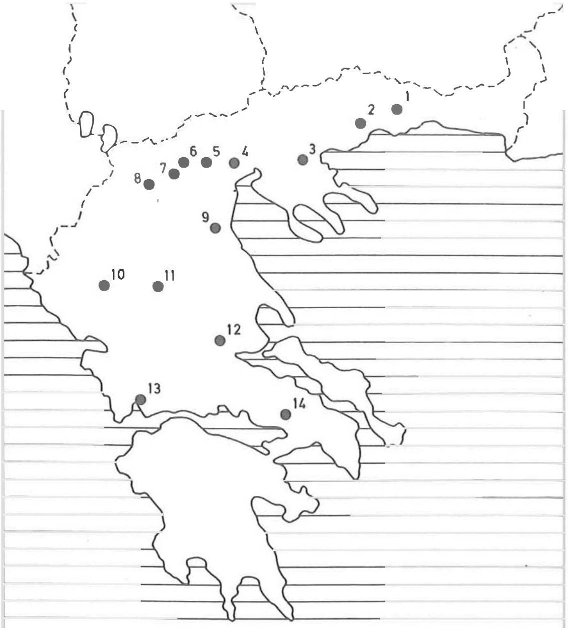

Fig. 1. Map of Greece indicating the core locations from which pollen diagrams have been used in this study. 1. Gravouna, 2. Tenagi Philippon, 3. Volvi, 4. Giannitsa, 5. Edessa, 6. Vegoritis, 7. Khimaditis (I & III), 8. Kastoria, 9. Litochoro, 10. Ioannina II, 11. Pertouli, 12. Xinias (I & II), 13. Trikhonis, 14. Copais.

January the mean temperature is about 10° C, while in July it is over 25° C. Precipitation averages 750–1000 mm of which about two-thirds falls during the winter (Polunin, 1980). The lake lies in a transitional zone of Mediterranean and deciduous forest. For a description of such vegetations, see *i.a.* Polunin, 1980; Horvat *et al.*, 1974.

2.2.2. *The diagram Trikhonis 5* (fig. 2)

From the core (code number 5) a diagram has been prepared. The pollen percentages for the various types have been calculated on the basis of a pollen sum including all types of trees and herbs apart from typical marsh and water plants.

2.2.3. *Zonation*

The Trikhonis 5 diagram is divided into five pollen zones on the basis of the curves of various typical pollen types.

Zone I (spectra 1–14). These spectra are considered a separate zone because *Platanus* and *Juglans* are not present in contrast to the upper spectra. Values of the deciduous oak type rise steeply after spectrum 14. Zone I can be subdivided into a subzone Ia (spectra 1–4) and a subzone Ib (spectra 5–14) on account of the higher vaues in the latter of *Artemisia, Plantago lanceolata*-type and *Centaurea solstitialis*-type.

Zone II (spectra 15–19). Compared with the preceding zone, high deciduous oak pollen values and lower herb pollen percentages.

Zone III (spectra 20 and 21). Lower arboreal pollen values, mainly due to lower *Quercus*.

Zone IV (spectra 22–24). Increasing arboreal pollen values.

Zone V (spectra 25–29). Again declining AP values.

2.2.4. *General vegetation reconstruction*

The geographical setting of the area is very diverse. Vegetation zonation varies from local sea-level lowlands, marshes and saline habitats to the high mountain belt further inland. The pollen precipitation caught by the lake represents these successive vegetation zones, quite probably with an over-representation of the lower zones. This last statement of course is valid inasfar as the lower zones have not been degraded too much.

Pollen types from the mountain belt display low values in the diagram. This must have been because the pollen-producing forest lays at quite a distance. That beech has low values is understandable as it is also hardly found in the area nowadays. *Abies* and *Carpinus orientalis/Ostrya* may be influenced by the long distance to the sampling location and they are thus outnumbered by the pollen production of the foothills and lowland areas.

When comparing the lowest spectra and the uppermost spectra of the Trikhonis diagram, hardly any conspicuous difference can be seen. That would be a reason to believe that the general vegetation picture of the beginning of zone I-time was the same as that visible today. Such a suggestion may hold for the general vegetation cover or species composition but some details are worth mentioning.

Compared with the lowermost spectra an increase in Mediterranean elements can be observed, a feature common in Greek diagrams. Today riverbanks are lined with plane trees, with their fresh green and characteristic bark, a sight unknown during the time of zone I. The same is true for the walnut which nuts are now a common local product.

Dating of the diagram will be discussed in chapter 2.5. To give a rough outline, lower samples date from 5000–6000 B.P. (Bottema in Creer *et al.*, 1981).

During zone I-time plant cover around Lake Trikhonis was generally Mediterranean vegetation. Deciduous or semi-deciduous oaks were present in the Arakinthos mountains and the mountains north of the lake. There also *Carpinus orientalis* or *Ostrya carpinifolia* and *Corylus* could be expected.

During subzone Ib-time farming and grazing will have affected the forest and provided open space for herbs. This is concluded from the appearance or increase of a group of pollen types discussed in chapter 6.

At the beginning of zone II a sudden change takes place. Pollen of farming indicators suddenly decrease. Mediterranean xerophytic elements demonstrate much lower values, whereas deciduous or semi-evergreen oaks markedly increase (the deciduous oak pollen type includes semi-evergreen species which occur in Southern Greece as well).

At the same time pollen of *Juglans* and *Platanus* appears (the behaviour of these two types will be treated in detail in chapter 5).

The level of this palynological change is visible in the sediment where a narrow band of volcanic ash is found (fig. 2). A discussion of the age of zone II, the volcanic band, the radiocarbon dates and the palaeobotanical results is presented in chapter 2.5.1. (see Bottema, 1980 and Bottema in Creer *et al.*, 1981).

After zone II-time herb types increase. From the tree types only deciduous types demonstrate lower pollen values. The other tree pollen types remain the same or show a slight increase. Changes in the vegetation must have taken place in the deciduous forest zone, where *Quercus* was common.

Zone III is of relatively short duration and soon AP percentages start to increase in the next zone IV. Again some form of forest regeneration takes place that comes to a definite end in uppermost zone V.

During zone V-time the final degradation of the deciduous oak forest sets in and this process lasts up to the present (or sub-recent) time. Mediterranean xerophytic vegetation must have increased either absolutely or relatively.

2.3. Vegoritis

2.3.1. *Geography, climate and vegetation*

Lake Vegoritis is situated in Northern Greece (40° 45′N, 21° 45′E) at an elevation of about 570 m above sea-level in the mountains west of the Plain of Macedonia (fig. 1). The lake forms part of the closed basin of Ptolemais. Only recently a drainage channel towards Edessa has been made.

The Voras Mountains on the west side and the Vermion Mountains on the east side of the lake are mainly composed of limestone. Towards Ptolemais in the south alluvial deposits predominate.

Details on the climate can be found *i.a.* in the study of the cores from Lake Khimaditis (Bottema, 1974) at about 20 km to the southwest. According to Polunin (1980) the area belongs to the Central European region as to climatical division. The average January temperature is between −5 and 0° C and the average for July measures 20 to 25° C.

As to the vegetation the reader is also referred to the description of the vegetation of the Khimaditis area (Bottema, 1974). At present the vegetation around the lake is very much degraded, mainly due to overgrazing. On slopes *shiblyak*-type shrub can be found. Species observed north of the lake include: *Quercus macedonica, Q. pubescens, Juniperus* cf. *oxycedrus, Carpinus orientalis, Cornus, Amygdalus, Secale montanum, Aegilops, Stipa, Bromus* and about twenty other herb species. The Voras and the Vermion Mountains have in some parts reasonably well preserved sweet chestnut, beech and pine forest.

2.3.2. *The diagram Vegoritis 8* (fig. 3)

The diagram prepared for the Vegoritis 8 core is calculated on the basis of a pollen sum including all pollen types apart from those of marsh and water plants.

2.3.3. *Zonation*

The Vegoritis 8 diagram is divided into two pollen zones.

Zone Y (spectra 1–9). The boundary between this zone and the next zone Z is laid where a sharp decline in coniferous pollen can be observed. Zone Y is subdivided into subzone Y1 (spectra 1–4) and subzone Y2 (spectra 5–9). The distinctive features of subzone Y1 compared to Y2 are very low values for *Fagus* and the absence of culture indicators. In subzone Y2 pollen of Cerealia-type, Chenopodiaceae, *Artemisia, Sanguisorba minor/Poterium* and *Polygonum aviculare*-type is met with.

Zone Z (spectra 10–27). Characteristics that lead to the establishing of this zone are, apart from the sharp decline of coniferous pollen types, the appearance or increase of *Juglans, Platanus, Vitis, Plantago lanceolata*-type, Cerealia-type, Gramineae, *Rumex acetosa*-type, *Polygonum aviculare*-type and higher values for *Pteridium* spores. The following subzones have been established: Subzone Z1 (spectra 10–15) displays low AP values. In subzone Z2 (spectra 16–20) an increase in tree pollen is visible, *i.a.* caused by *Pinus* and *Abies*. During the next subzone Z3, AP values are again lower. Whereas a decrease in *Quercus* percentages can be seen, *Juniperus* demonstrates a slight increase.

2.3.4. *General vegetation reconstruction*

The pollen curves obtained for the Vegoritis 8 core inform us about the vegetation development of the area around the lake for about the last 6000 years (see chapter 2.5.). Information on the late Quaternary vegetation development of this part of Greece can be obtained from the diagrams from the lakes and marshes of nearby Khimaditis, Edessa and Kastoria (Bottema, 1974).

During the time of zone Y1, forest was the dominant vegetation around Lake Vegoritis. Most of this forest was formed by pine and fir that probably grew on the higher ground. Deciduous forest was dominated by deciduous oaks with an admixture of oriental hornbeam and/or *Ostrya carpinifolia, Ulmus, Tilia, Corylus* and *Carpinus betulus*. Low herb pollen percentages point to forest with a generally closed canopy.

Beech is present during subzone Y1-time in very low numbers, the pollen percentages measuring about 0.3–0.8%. The change in the *Fagus* pollen curve in spectrum 5 is one of the arguments for dividing this zone into two subzones. The increase of beech pollen is dated to 3995±60 B.P. (GrN-6596) in Khimaditis I and 4080±55 B.P. (GrN-6600) in Kastoria. Together with *Fagus*, pollen of herbs like *Artemisia*, Cerealia-type, Liguliflorae, *Polygonum aviculare*-type increase. The increase of *Fagus* is not restricted to this part of Greek Macedonia but is also found southwest of the Pindus (Bottema, 1974) and in Tenagi Philippon, Eastern Macedonia (Turner & Greig, 1975). In other parts of Greece, for instance Thessaly (Athanasiadis, 1975; Bottema, 1979), Boeotia (Turner & Greig, 1975) and Akarnania (this paper), beech pollen is hardly present also after 4000 B.P.

It was stated previously (Bottema, 1974) that the increase of *Fagus* pollen percentages pointed to an increase in precipitation. In the Vegoritis diagram this hypothesis is supported by a slight increase in values of Ericaceae. This is more clearly seen in the other diagrams from Macedonia. It may sound plausible to connect an increase of beech with an increase in precipitation. At the same time an increase in farming activity is concluded from the pollen curves of a group of herb types. Is there a connection between increasing precipitation and increasing farming activities? The explanation of the pollen curves discussed here remains problematical.

The boundary between zones Y and Z is laid where a marked decrease in AP values takes place, caused by a decline of *Pinus* pollen percentages from 50% to less than 5%. *Abies* displays the same tendency, about 20% at 340 cm and a complete absence at 300 cm.

It took about 200 years (assuming a constant sedimentation rate) for the conifer forests to be destroyed. At the same time the herb types discussed in the part on zone Y2 show an important increase. Whereas the conifers seem to have disappeared from Greek Macedonia to a large extent, some other tree pollen taxa increase. Did they only relatively increase because coniferous pollen disappeared, or do they represent an increase in the number of trees? The increase of *Quercus coccifera*-type and *Olea* seems to be connected with the increase of certain herb pollen types. Deciduous oaks and juniper seem to profit from the decrease of the two coniferous types.

Replacement of *Pinus* by *Quercus* is a very common feature in Turkey (van Zeist *et al.*, 1975). Cores from Söğüt and Beyşehir demonstrate that after the destruction of pine forest, abandoned areas regenerated towards oak forest. The increase of *Quercus* pollen percentages can be either a relative increase, caused by lowered coniferous values or an increase caused by an expansion of oak invading cleared areas. The increase of *Juniperus* pollen points to open vegetation. Light-demanding juniper profits from forest clearing followed by extensive grazing.

The dominating tree pollen types in the Vegoritis diagram are accompanied by other tree types with much lower values, but with the same palynological behaviour. The appearance of *Quercus coccifera*-type (most likely representing *Q. coccifera* as *Q. ilex* is restricted to Eu-Mediterranean conditions) points to an increase in xerophytic shrub developing from over-exploitation by grazing etc. Such pollen must originate from relatively far away south of the Vermion Mountains as even today *Quercus coccifera* does not occur in the area.

The same is true for *Olea*. The nearest olives occur in small numbers in the foothills of the Vermion Mountains towards the Plain of Macedonia, where they seem to be restricted by the cold 'Vardaris' winds. Hegi (1926) suggests the 4° January isotherm as the limit for *Olea*. Lake Vegoritis has an average January temperature of about 3° C, calculated after Philippson (1948). It is very unlikely that winter temperatures were higher during zone Z1-time, as the upper spectra show about the same values for *Olea* and they represent the link with the modern climate. The *Olea* values together with those of *Quercus coccifera* must be ascribed to long-distance transport.

The changing situation also affected some tree species that grew in the deciduous forest zone. In contrast to the increasing oak pollen there is a gradual decrease of *Ulmus, Tilia* and *Carpinus betulus* which soon disappeared from subzone Z1 altogether. These three pollen types are produced by species that form part of the deciduous forest at higher elevations. They must have formed a small part of a mixed oak forest. Considering the pollen curve of *Carpinus orientalis*/*Ostrya*, there seems to be no change. Especially *Carpinus orientalis* will have occurred in combination with for instance *Quercus pubescens* at lower elevations. This type does not seem to be affected by the events. *Carpinus orientalis* can withstand grazing reasonably well and regenerates quickly (Turrill, 1929).

The increase in herb pollen values is caused by types that represent different habitats. Some of them point to agriculture and/or waste lands, others indicate grazing.

Not much can be concluded from the presence of the Gramineae pollen. They can be strictly local, but if this is the case then generally they fluctuate more widely. They may originate from the grazed areas in the mountains or from arable fields or fallow land in the valleys. In practice they originate from various sources. The increase in Gramineae is at least an illustration of the landscape becoming more open.

Some herb pollen types increase from one tenth of a percent to a few percent. These mostly belong to insect-pollinating taxa. This is an indication of an increase in the amount of open space. The increase of *Sparganium*-type is not easily explained as it has no clear connection with the other pollen types discussed. There is also no parallel found in the nearby Khimaditis cores.

In the group of spores, *Pteridium* draws attention. Soon after the decrease of the coniferous values, *Pteridium* reaches values of up to 20%. Bracken must have been growing on clearances, including places where pine and fir had disappeared as was observed in higher parts of the Pindus.

The important change in the Vegoritis 8 diagram that leads to the division into zones Y and Z is stressed yet again by the behaviour of the green algae *Pediastrum boryanum* and *P. duplex*. These are found in zone Y but are almost completely lacking in zone Z. The decrease may have been caused by a change in water depth, but a change of the mineral composition of the influx of the lake cannot be excluded. The increase in indeterminata in this case does not point to corrosion as the preservation of the pollen grains is good. The increase must be caused by a greater diversity resulting in more unidentifiable grains.

It is of course not impossible that two factors, *viz.* a climatic change and human exploitation are responsible for the important changes in the vegetation. Could human exploitation have been initiated or triggered by a climatic change? It is supposed that at the beginning of subzone Y2 an increase in precipitation took place. The course of events that led to the establishing of the zone Y/Z boundary will be discussed in chapter 6.

Subzone Z2 is a period during which forest regenerated to some extent. AP percentages increase, the group of possible indicators of farming activity decrease.

Forest from the mountain belt regenerated but only slightly compared to the previous zone Y. Compared with that period mountain forests are mainly composed of beech and the number of pine and fir trees must have been low. A deciduous species that will have played a role in forests on higher elevations is the hornbeam. *Carpinus betulus* has even the same values as it had during zone Y.

During subzone Z2 *Platanus*, that was still rare during subzone Z1, became very well established. The percentage of about 1–2% point to a normal occurrence of the plane tree that is under-represented in the pollen rain (Bottema, 1974). For a detailed discussion see chapter 5.1.

During subzone Z3 man launched a new attack on the vegetation. This was especially felt at lower elevations where deciduous oaks suffered very much. *Carpinus orientalis/Ostrya* pollen remained more or less at the same level. Maybe it was the oriental hornbeam that still survived grazing or even profited from it (Turrill, 1929). An increase in grazing pressure can also be concluded from the increasing *Juniperus* values.

When one considers the treeless, barren mountains of the present-day Vegoritis/Khimaditis area, the level of about 50% tree pollen found in the upper spectra is very high. This pollen must originate from the relatively few tree stands and scattered trees which are found in the area. The erosion and overgrazing are responsible for the relatively low pollen values of the herb species, that in fact do not profit much from the available open space.

When the same pollen sum is used for the samples of Khimaditis III, from the middle of that lake, about the same values are found. In the case of Khimaditis I much lower AP values would result from such a calculation because of the high local production of *i.a.* Gramineae which also played a part in the peat formation.

2.4. Lake Volvi

2.4.1. *Geography, climate and vegetation*

Lake Volvi is situated in the eastern part of Greek Macedonia (40° 45′N, 23° 30′E), north of the Chalkidiki peninsula (fig. 1). The elevation is about 100 m above sea-level. Lake Volvi lies in a valley that leads to the east to the Gulf of Orfanou. The southern ridge, mainly Tertiary conglomerates and crystalline rock, measures 1165 m in Mount Kholomon. In the north the valley is bordered by mountains including Mount Kerdhillion (1092 m) that mainly consists of crystalline rock.

Precipitation in the Volvi area is about 500 mm, of which about the same amount falls in winter as during the summer (Philippson, 1948; Polunin, 1980). This makes the Volvi area even drier than Thessaly. The average January temperature is about 0° C, the average for July measures over 25° C. The modern vegetation is very much disturbed. Remnants show elements of a shiblyak (Turrill, 1929). *Paliurus spina-christi* is very common. On ridges towards the Chalkidiki peninsula, *Quercus coccifera*

In 1963 W. van Zeist and the present author visited Lake Volvi but could not carry out a coring on the edges of the lake. In a dense and high marsh vegetation on the east side only 10 cm of clay was collected before coarse sand was hit.

2.4.2. *The diagram Volvi 6* (fig. 4)

From the cores the one with code number 6 was analysed. The pollen percentages for the various types have been calculated on the basis of a pollen sum that includes all types apart from those of aquatics and marsh plants.

2.4.3. *Zonation*

The Volvi 6 diagram is divided into five pollen zones:

Zone A (spectra 1–5). This zone is defined by relatively low AP values. Some herb types are found in relatively important numbers, namely *Artemisia, Plantago* spec., *Humulus/Cannabis*, Cerealia-type *Sanguisorba minor/Poterium, Rumex-acetosa*-type, *Rumex hydrolapathum*-type and spores of *Pteridium.*

Of the trees *Olea* pollen is very well represented.

Zone B (spectra 6–11). This zone is characterized by an increase of tree pollen, especially deciduous oak, *Carpinus orientalis*/*Ostrya*, *Pinus* and *Fagus*. Pollen percentages of *Quercus coccifera*-type are declining.

Zone C (spectra 12–15). Herb pollen values, especially those of Gramineae show a clear increase.

Zone D (spectra 16–18). This zone is established for the same reasons as zone B.

Zone E (spectra 19–23). AP values, especially *Quercus cerris*-type demonstrate a pronounced decrease.

2.4.4. *General vegetation reconstruction*

The Volvi diagram shows a series of stadia during which the vegetation, especially the forest vegetation, was affected by man, whereas in other episodes some regeneration took place.

At the beginning of the diagram, zone A-time, human influence upon the vegetation in the hills around Lake Volvi is clear and indicated by pollen of *Vitis, Juglans, Platanus, Artemisia*, Chenopodiaceae, various *Plantago* types including *lanceolata, Humulus*/*Cannabis*, Cerealia-type, *Rumex acetosa*-type, *Polygonum aviculare*-type, *Xanthium, Urtica* and spores of *Pteridium*. Such influence must date back from before zone A-time already, but there is no information from older deposits.

The influence of man during zone A-time must have been considerable. Maquis with *Quercus coccifera* and Ericaceae was already common. Relatively high percentages of *Olea* pollen point to olive yards. Deciduous oaks and *Carpinus orientalis*/*Ostrya* had suffered from cutting and/or grazing and probably so had *Pinus*. In degraded areas *Juniperus* must have spread as is concluded from values of about 5%. Trees like *Platanus* and *Juglans* as well as *Vitis* have been favoured by man. The various herb types mentioned above for zone A point to intensive farming.

In the following period, zone B-time, the vegetation in the Lake Volvi area regenerated to some extent. Deciduous elements increased again to dominate over Mediterranean xerophytic elements. *Pinus* and *Fagus* increased, the latter on higher elevations, further away. The increasing shade caused *Juniperus* to retreat. The role of *Vitis* and *Juglans* during zone B-time is less important than before and afterwards. An explanation for such a regeneration of natural vegetation will be given in chapters 6 and 7.

For a comparison of the Lake Volvi diagram the nearest palynological information are the diagrams from the Plain of Macedonia and adjacent mountains in the west (Bottema, 1974) and the Tenagi Philippon diagrams (Wijmstra, 1969; Turner & Greig, 1975) in the east. The study by Turner & Greig covers the period present in the Volvi core. Their study has the advantage of three radiocarbon dates. Palynological comparison does not shed much light on the dating of the Volvi diagram. In Turner & Greig's Tenagi Philippon diagram the indicator type *Juglans* is hardly present whereas *Platanus* is totally absent.

2.5. The dating of the cores of Trikhonis, Vegoritis and Volvi

2.5.1. *General*

Dating formed an important part of the study on the geomagnetic variations in Greece by Creer *et al.* (1981). In addition to dates obtained by comparison with geomagnetic studies mainly from the U.K., radiocarbon dating was done on nearby cores in the three lakes. To supply more information on the possible ages of the sediments, the cores were studied palynologically. The dates obtained by the three dating methods are plotted in fig. 5.

The radiocarbon dates, inferred dates from nearby cores, are invariably too old compared with the information obtained from the two other methods. Lack of organic material in the sediments and the effects of hard water, common in Greek lakes with water supply from limestone regions, may give unreliable results.

The palaeomagnetic dates have been obtained by comparing with dated sequences from the U.K. and some information from Southeastern Europe. Creer thinks that the Greek records are not more than 150 years older than the corresponding features in the

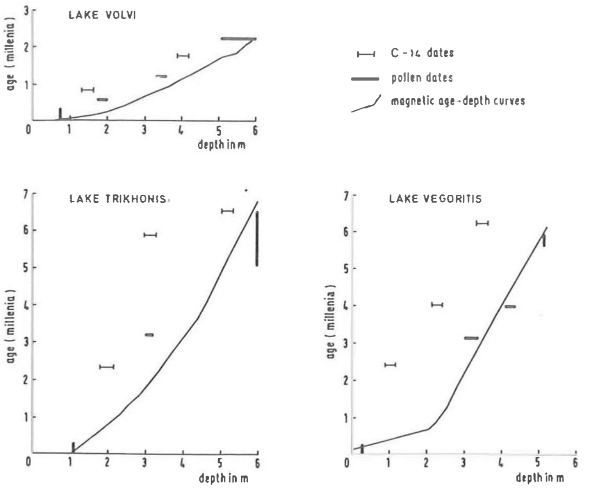

Fig. 5. Palaeomagnetic, palynological and radiocarbon age-depth curves (after Creer *et al.*, 1981) for the lakes of Vegoritis, Volvi and Trikhonis.

U.K. record. The palynological dates are either in agreement with the archaeomagnetic dates or they are older. Creer *et al.* mention sharp peaks in the intensity and susceptibility logs for all three lakes. They used one of these sharp peaks as a correlation tie-line. These tie-lines are associated with a band of volcanic material. Creer *et al.* think that the eruption that caused this volcanic band is likely to be the A.D. 79 eruption of the Somma-Vesuvius connected with Pompeii and not the Santorini eruption (dated 3370±100 and 3527±44 B.P.). They concluded this on the basis of the preliminary time-depth curves and *i.a.* the prevailing wind. The present author ascribed the volcanic band in the Trikhonis 5 core to the Santorini eruption on the basis of palynological evidence (Bottema, 1980).

The archaeomagnetic tie-lines are to be found as follows: Vegoritis 8 at 270 cm; Volvi 6 at 550 cm; Trikhonis 5 at 300 cm. It can be read from the diagrams (figs. 2, 3 and 4) that the *Platanus* and *Juglans* curves do not start at the same time with regard to the archaeomagnetic tie-line. The appearance and spread of *Platanus* and *Juglans* is thought to have happened at about the same time in Greece around 3200 B.P. (Bottema, 1974).

In Vegoritis 8 the beginning of the *Platanus* and *Juglans* curves can be dated about 3000 B.P. when the magnetic age-depth curve is used.

In Volvi 6 the archaeomagnetic tie-line is found at about 550 cm. As in Vegoritis the assumption that the tie-line represents the Pompeii eruption of A.D. 79 could be right. For one metre of sediment pollen of *Juglans* and *Platanus* is already present and could even have been present below that level, but that cannot be checked here.

In Trikhonis, however, the tie-line almost completely synchronizes with the increase of *Platanus* and *Juglans* pollen curves. The archaeomagnetic choice would be A.D. 79, the palynological choice would be 3000–3200 B.P.

Two possibilities remain, either the volcanic ash layers are not from the same eruption or the appearance of *Platanus* and *Juglans* did not occur at the same time in mainland Greece.

Palynological dating was done by comparing the three diagrams with other pollen diagrams from the area which were radiocarbon dated. Such dates were obtained mainly from peat and gyttja samples. The number of clear palynological events in the younger Holocene of Greece is very small and thus possibilities for accurate dating are restricted.

For the complete Holocene six pronounced palynological zones can be distinguished for the area north-east of the Pindus and five zones for the Epirotic side of that mountain chain. From such evidence it is concluded that the three cores only cover part of the Holocene from about 6000 B.P. onward or as is the case in Lake Volvi even much later.

The palynological ages of the three cores have been discussed before (Bottema in Creer *et al.*, 1981). In fig. 5 the estimated ages are given. The palynological argumentation is as follows:

2.5.2. *Lake Volvi*

The oldest part of this core must be younger than 4000 B.P. as *Fagus* is already present in the lowermost spectrum. In the nearest site, Tenagi Philippon (Turner & Greig, 1975), at about 80 km to the north-east, the appearance of beech pollen is dated 4193±120 B.P. (BLN-955). The presence of *Juglans* at that level in Lake Volvi dates the sediment even younger than 3000 B.P. The rather high *Olea* values, found at 400–600 cm, together with Cerealia percentages, may point to the end of the 'Classical' period and the beginning of the 'Roman' period at about 200 B.C.

(Athanasiadis, 1975). No specific indications on the basis of pollen behaviour for the last 2000 years in Greece are known at the moment. For that reason the changes in the AP/NAP ratio as suggested by Athanasiadis (1975) have been used as a possible time-scale. Thus, the decrease in tree pollen and the increase of Cerealia-type pollen at about 350 cm may represent the end of the Byzantine period and the beginning of the Turkish occupation. The level of about 250 cm which demonstrates again an increase of AP values may point to the return of Christian refugees. According to Athanasiadis, the mountain forests regenerated to some extent when the refugees returned to the low lands. Finally, the level of 120 cm must be younger than c. 250 years as can be concluded from the presence of *Zea mays* pollen.

2.5.3. *Lake Trikhonis*

The lower part of core Tr5 must be dated younger than 6500 B.P. as is indicated by the presence of *Carpinus orientalis/Ostrya*. A comparison with two diagrams from Ioannina (Bottema, 1974), 180 km to the north, suggests an age between 5000–6000 B.P. based *i.a.* on the behaviour of the *Corylus* curve. *Fagus* pollen cannot be used here for dating as the beech is and was hardly present in this area. The level of 300–320 cm is dated at 3100–3300 B.P. according to the curves of *Juglans* and *Platanus* (Bottema, 1974). The presence of *Zea mays* dates the level of 110 cm younger than about 250 years. The information of this diagram will not form part of the discussion in this study as there is no agreement on the dating.

2.5.4. *Lake Vegoritis*

Diagrams from Khimaditis, Edessa and Kastoria situated at 20, 15 and 50 km respectively, are used to date the Vegoritis diagram.

The lowest sample must be younger than 6500 B.P. as *Carpinus orientalis/Ostrya* is already present. The *Ostrya*-type increase in Edessa is radiocarbon-dated to 6385±55 B.P. (GrN-6186). Values of *Tilia* and *Ulmus* suggest that the lowest part is not much younger than 6000 B.P.

From 400–410 cm an increase of *Fagus* pollen percentages is visible. At Khimaditis, this event is dated at 3995±60 B.P. (GrN-6596) and in Kastoria at 4080±55 B.P. (GrN-6600). A date from Edessa of 5260±65 B.P. (GrN-6185) for this event may be unreliable as a hiatus occurs just above the location of the radiocarbon sample.

The level of 300–340 cm shows the appearance of walnut and plane tree. According to the dates of 3135±170 B.P. (GrN-6182) and 3280±55 B.P. (GrN-6184) for two cores of nearby Khimaditis, this event must have taken place in Vegoritis about 3100–3300 B.P.

Finally, at 30 cm, the sediment must be younger than c. 250 B.P. as *Zea mays* was found there.

3. THE REPRESENTATION OF POLLEN TYPES IN VARIOUS SOURCES

3.1. Some remarks on the practical limits of pollen analysis with emphasis on the Greek situation

In the Balkans about 6500 seed plant species occur (Turrill, 1929; Polunin, 1980). That means that the number of plant species in Greece amounts to a few thousand at least.

What is the palynological translation of a few thousand Greek plant species? From practical experience it is known that the number of pollen types identified with a light microscope is lower than the number of plant species producing such types. On many occasions pollen grains are identified above the species level.

As an example the number of plant species from a plant-sociological study of forest vegetations in Central and Southern Greece (Barbero & Quézel, 1976) is considered in terms of the number of pollen types represented. Barbero and Quézel mention 479 species. A number of these species share the same pollen type, thus lowering the number of pollen types that can be identified. Besides, the number of pollen types identified depends to a great extent on the technical expertise of the palynologist. His knowledge and personal limits to absorb morphological characteristics, the presence of a good reference collection, identification tables, key card systems and picture collections are also a decisive factor.

The present author was able to identify about 200 pollen types in the Greek sediments. Some types remained unidentified. These types were discussed with colleagues in the department, but such discussion was never very fruitful as the team members share more or less the same knowledge. The identification limits make the method not as accurate as one would like. The diversity of a pollen spectrum remains hidden when a large number of species share the same pollen type.

Under the given conditions the present author would recognize 125 pollen types in Barbero and Quézel's 479 plant species. Such types represent taxa, varying from species to family level.

In the pollen diagrams of Vegoritis, Trikhonis and Volvi (chapter 2) a fraction of the 125 pollen types from Barbero and Quézel's list were found. Compared with the 125 pollen types recognizable in the plant-sociological relevee-list, only 70 types were found in the samples of Lake Vegoritis. For Lake Trikhonis and Lake Volvi these numbers are 71 and 51, respectively.

Another source of information on the diversity is a series of surface-sample spectra from Northwestern and Central Greece (Bottema, 1974). The 110 surface samples have 73 pollen types in common with the 125 derived from the list of Barbero and Quézel. This number is of the same order as the number of types found in the sediments of the three lakes. It should be stressed that the qualitative aspect, *viz.* the number of pollen types from three completely different sources is discussed here. First, a plant-sociological relevee-list of 479 names of species of which the palynologist maintains that he could group 125 pollen types representing these 479 plant species. Then, 152 pollen types identified in sediment samples, giving an idea about the pollen rain produced by past vegetations. Finally, the modern pollen precipitation from a large part of Greece derived from samples taken from amidst the vegetation and delivering 144 pollen types, as far as the palynologist was able to identify.

As mentioned above the three sources do share a number of types, but there are also types which are characteristic for a special source only. Slightly more than 70 pollen types from lake sediment samples do not have counterparts in the relevees of Barbero and Quézel and this also holds for the Greek surface samples. In fig. 6 the presence of pollen types in the three sources is shown schematically. It can be seen that there is also a difference between subfossil and surface samples, 36 types found in the former category not being present in the latter, whereas 31 types in this latter category were not met with in the subfossil samples. The difference in composition of the three sources has several causes. The relevee-list gives exclusively forest species, translated into pollen types. The relevee-list includes for instance insect-pollinated species which pollen types were never met with in subfossil or modern surface samples. The lake-sediment samples represent the pollen precipitation from a large area as well as local water plants. In contrast surface samples catch a lot of local pollen but generally no water plants.

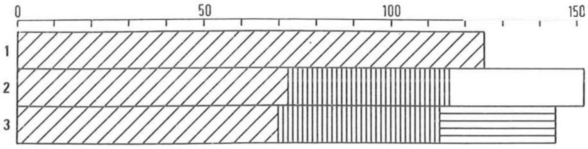

Fig. 6. Number of pollen types in three sources of origin. 1. A series of plant relevees studied by Barbero & Quézel (1976), 2. The lakes of Vegoritis, Volvi and Trikhonis, 3. 110 Greek surface samples.

Conservation of pollen grains in surface samples is never as good as that from sediments cored in the centre of a lake or a marsh that never dried up during the accumulation of organic material. On the other hand, surface-sample spectra are generally accompanied by a vegetation description that can be of important help in the identification of little known pollen grains.

Finally modern imports are found hardly or not at all in subfossil samples whereas in surface samples they may show up.

3.2. Origin of pollen

Above it is explained that differences in composition exist between the pollen types derived from a series of plant-sociological relevees, subfossil pollen spectra or modern surface-sample pollen spectra. Any specific source includes or excludes certain pollen types.

In the following, three clearly defined groups are brought forward. The third group includes the crops and weeds that will form part of the theme of this study.

Pollen derived from long-distance transport (I). The pollen types derived from Barbero and Quézel's relevee list represent herb or tree species mentioned for the various locations and listed in the relevees. In subfossil sediment samples and surface-sample spectra, pollen from local and more distant sources is present. Pollen of *Betula* and *Picea* is found with about the same values in the modern pollen rain in Greece as in subfossil samples. Apart from occurrence of *Picea abies* in the Greek Rhodope Mountains (Zoller *et al.*, 1977) there are also few indications that *Betula* occurs in Greece (Tutin *et al.*, 1964). Generally, pollen finds of *Picea* and *Betula* must be ascribed to long-distance transport.

Pollen derived from water and marsh plants (II). It is self-evident that this group of pollen types is very well represented in samples from lake sediments and absent from relevee-lists from forests. In surface samples this group is rare and highly dependent upon the selection of the surface-sample locality which is preferably in or near undisturbed forest.

Pollen derived from crop or weed plants (III). To study possible indicators of prehistoric farming, taxonomically narrow groups, preferably species, have to be traced. It is clear that such species, and pollen derived from them, do not occur in the relevee-lists compiled by Barbero and Quézel, that represent natural or fairly natural forest.

The last category, of crop and weed plants, has been looked at more closely. It is assumed that forest relevees do not include crop and weed species. If pollen originating from long-distance transport and pollen types from water and marsh plants are excluded, a group of pollen types remains that is ascribed to the last category. These pollen types, present in all three lake sediments and in the surface samples but not in the forest relevees, are shown in table 1.

Table 1. Category III pollen types, found in a series of Greek surface samples and three Holocene lake sediments. Plant species representing these pollen types were not present in a relevee-list compiled by Barbero & Quézel (1976).

Present in four sources (surface samples and three lake cores)	Present in three sources (either lakes or surface samples)
Artemisia	Aquilegia-type
Asphodelus	Centaurea scabiosa-type
Centaurea cyanus-type	Echium-type
Centaurea solstitialis-type	Heliotropium
Cerealia-type	Nigella
Chenopodiaceae	Plantago major-type
Delphinium-type	Solanum nigrum
Humulus/Cannabis	Spergula(ria)-type
Papaver	Urtica
Plantago lanceolata-type	Urtica pilulifera
Plantago coronopus-type	
Plantago maritima-type	
Plantago media-type	
Polygonum aviculare-type	
Polygonum hydrolapathum-type	
Vitis	
Xanthium	
Zea mays	

The method followed above clearly misses one group of plants or, as the case may be, pollen types. These are anthropogenic elements that escaped to or were brought to forest. Thus Barbero and Quézel listed some species in their relevees that in fact are elements of the forest at the present time, but that were originally absent from Greece.

From the palynological evidence *Juglans, Platanus* and *Castanea* all appear about 3000 B.P. As possible indicators of human activity they are included with the group of crop and weed plants. An advantage with these three types is that in the Mediterranean no relatives with the same pollen type occur.

This selected group of pollen types, as far as a more or less closed curve is present, is depicted in a scheme (fig. 22). The presence of the pollen types is given schematically in percentages for the last 11,000 years. A curve of Gramineae is added, demonstrating open landscape versus forest. This group of pollen types will be treated in chapter 6.

4. DIVERSITY OF POLLEN ASSEMBLAGES COMPARED WITH DIVERSITY OF VEGETATION

4.1. General

In the discussion of pollen diagrams or palynological information that is presented in some other way, the pollen types found are discussed for instance according to their mutual relations in the form of percentages. Diversity of assemblages is seldom a matter for discussion.

In this study diversity simply means: the number of pollen types identified in a sample or the number of plant species identified in a relevee. Diversity as an aspect of planteco-logical studies is a more complex phenomenon than in the sense in which this term is used here (Odum, 1969).

It is widely known that a natural, closed forest is less diverse than a forest in which clearings are made. When openings are made caused by wood cutting or for farming or grazing, possibilities are created for new species that did not occur or were scarce in the forest before. An important element that is added by opening up forest is penetration of light.

To what extent are these changes in the field visible in the pollen rain? When the attack upon the natural vegetation proceeds, an initial enrichment in species is later followed by degradation, a lowering of the number of species. Forested slopes are first opened then deforested, grazed, overgrazed, denuded by erosion and finally only a limited number of unpalatable or prickly herbs is left.

At a certain stage the number of pollen types, the diversity, will be maximal. The course of the diversity in time can be compared with the diversity of a regenerating forest on abandoned farmland as described by Odum (1969). There the number of species is low at first, then steadily increasing until finally, towards a more stable situation, again lower diversity is found. In the situation discussed for Greece the order of events differs from regeneration as described by Odum, but the trend is the same.

As to the origin of the diversity in a pollen spectrum the following should be remarked. The qualitative composition of a pollen spectrum does not only depend upon the local situation, as for instance pollen originating from long-distance transport may be present. Insect-pollinated trees and herbs are in practice not widely dispersed and thus under-represented. There will be practical and theoretical botanical aspects of this approach but the question asked here is rather simple; are there clear changes in the number of pollen types in time, *viz*. in palynological diversity? Can we compare pollen spectra in this way, without meticulous corrections *etc*.? To get an idea of the diversity as it is delimited here, the number of pollen types is counted for the depth of the samples and thus in relation to time.

4.2. Diversity versus pollen sum and origin of samples

If the vegetation were to remain constant over a long period of time, the number of pollen types identified would mostly depend upon the size of the pollen sum. The larger the pollen sum the more pollen types are found. However, after the pollen sum has reached certain levels the number of types will hardly or not increase any more.

One could avoid the first problem by counting a constant number of pollen grains and then study the diversity of the spectra. There are practical difficulties involved in counting a constant pollen sum. The distribution of the pollen grains under the coverglass of the counting slide is not even. In general small grains move to the edges more than large grains. In preparing a counting slide pressure is often exerted upon the cover-glass to spread the liquid (for instance silicone oil) in which the sample is embedded and this will alter an even distribution. Such experience is a warning not to stop at for instance 500 counted grains but to count the complete slide. With counted grains the number included in the pollen sum is meant. Theoretically one could count half a slide but this half will also rarely contain 500 grains. When possible a pollen sum of about 1000 or more is counted in our studies.

It is stated that the pollen sum includes only a certain number of types: those types derived from the upland vegetation. Local water and marsh plants would influence and disturb the picture very much if they were included in the sum, especially because they can and often do fluctuate independently of the pollen production of the regional vegetation. Such water and marsh plants do not form a problem when they have pollen that can be identified easily. When they share the type with plant species from the upland vegetation it will be very difficult to trace this effect. Local influences upon a pollen spectrum can be avoided at least to a large extent by the choice of the sediment. Cores from the middle of deeper lakes are very good for this purpose as they reduce the quantitative effect of large numbers of local pollen grains. Nevertheless, in the case of Gramineae and Cyperaceae, for instance, the qualitative effect remains.

Compared with surface-sample spectra it

must be said that this last group cannot escape local influence due to the manner of sampling moss cushions, often in the middle of the vegetation. In such samples the identifiability of the pollen types is increased by the description of the vegetation surrounding the sample location and lowered due to corrosion of the pollen by exposure to oxygen, a process that would not occur under water.

Detailed vegetation description is of great help with the identification of rare or conspicuous pollen types. The middle of a lake lacks this helpful detail and such pollen types found there are often included in a larger taxon.

Such factors increase or decrease the number of identifiable pollen types in the counts but they do not change the real number of pollen types or the vegetation that produces them. The method followed thus has its limits in considering the diversity in pollen types and hence the diversity of the vegetation translated from these pollen types.

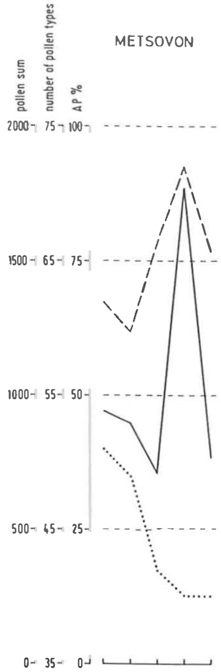

Fig. 7. Number of pollen types per sample, pollen sum and AP/NAP ratio in a short surface-sample transect near Metsovon (Pindus).

4.3. The diversity of pollen spectra compared to the diversity of the vegetation: An example

Is there any relation between the qualitative aspect–pollen types–and vegetation type? A short series of surface-sample spectra from a study on the relation between modern vegetation and pollen precipitation is very illustrative (Bottema, 1974). When collecting surface samples it is often very difficult to find suitable transects presenting well preserved vegetations with clear gradients or zonations. A short transect from the Pindus Mountains near Metsovon is very useful in this respect as it fulfils the conditions mentioned above (fig. 7).

Near Metsovon one finds at high altitude a montane forest. At the lower edge of this zone the forest has been cut down and meadows have been developed that are maintained by grazing. These meadows are partly covered with bracken (*Pteridium aquilinum*) especially with increasing elevation towards the forest. When one climbs the mountain the lower forest zone is formed by *Abies cephalonica*. At higher elevations *Fagus sylvatica* appears and soon almost pure beech forest is found with some occasional fir seedlings.

Summarizing, pollen spectra are available from five locations taken from various levels (fig. 7):

1. Cultivated area with orchards down in the valley;
2. Herb-rich meadows with bracken and forest at some distance;
3. Boundary of meadow and fir forest;
4. Within fir/beech forest;
5. Within beech forest (some fir seedlings).

In fig. 7 the number of pollen types per surface sample, the pollen sum of these samples, and the AP/NAP ratio are shown. The pollen sum of these five samples varies from c. 700 to 1800. The number of identified pollen types amounts to 51 for the cultivated area; 49 for the meadow with bracken; 42 for the boundary of meadow and forest; 20 for both the forest samples. It should be stressed that in the spectra with the lowest number of pollen types, the pollen sum is twice that of the spectrum with the highest number of pollen types.

The difference in the number of pollen types is caused by the fact that the open vegetations are not represented palynologically in the forest whereas the trees do precipitate their pollen in the open fields. It is not necessarily the case that the meadow vegetation is so much more diverse in plant species. The dense forest is simply less diverse than the same

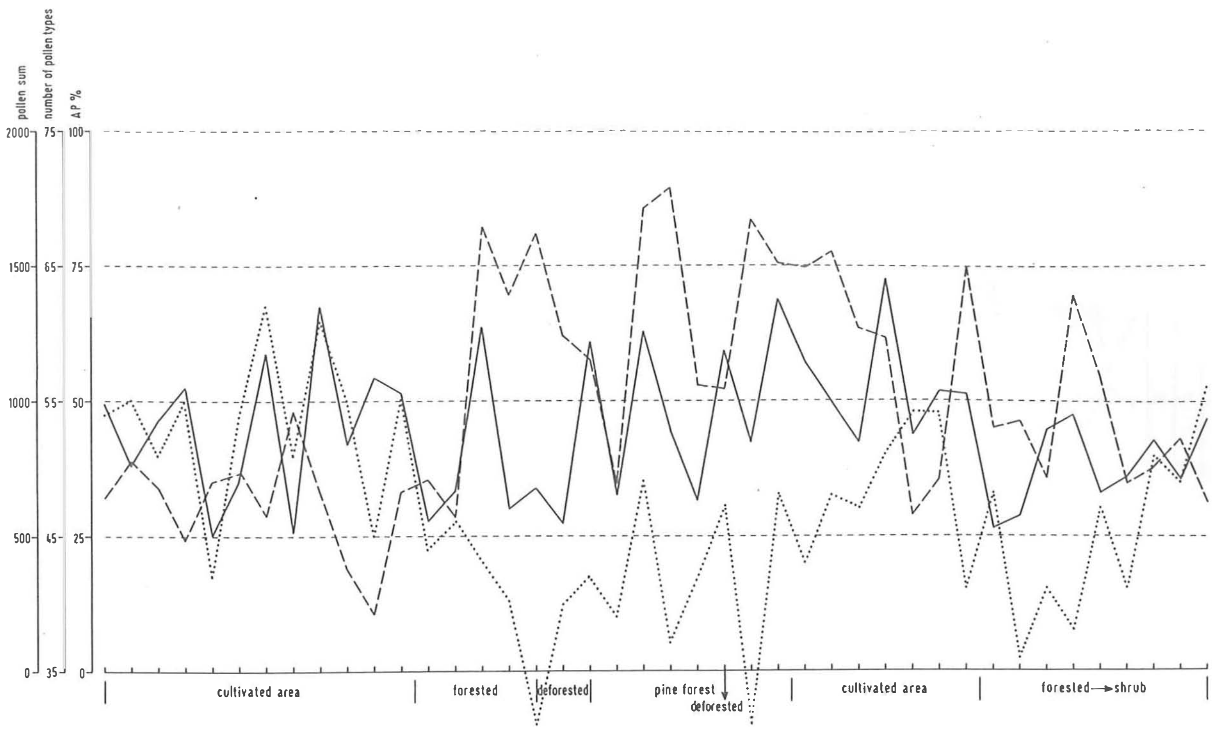

Fig. 8. Number of pollen types, pollen sum and AP/NAP ratio in a long surface-sample transect through the Greek mainland.

forest in which clearings are made. It is clear that the transition, forest to open field, is characterized by an increase in identified pollen types.

The number of pollen types is not only correlated negatively with the degree of forestation, it is also correlated with the AP/NAP ratio. This is quite logical as there will normally be a relation between the degree of forestation and the AP values.

The Metsovon example is quite clear as to the diversity aspect but other surface-sample transects show that the usefulness of this method is open to some doubt.

When a long transect through the Greek mainland is considered (fig. 8), it can be seen that in some spectra the number of pollen types is still correlated positively with the size of the pollen sum. Unfortunately, botanical diversity is not known for many surface-sample locations as not all plants were identified at all locations. In fig. 8 also the AP/NAP ratio is given. Also here this ratio is correlated negatively with the number of pollen types, thus with diversity. The lower the AP percentages are, the more pollen types are identified; a rise in AP percentages is paralleled by lowered diversity in any particular spectrum.

As the AP/NAP ratio is generally given in the kind of pollen diagrams shown here, counting of the numbers of pollen types may not even be necessary. When it is postulated that early farmers made clearings in a natural forest and thus promoted diversity, it would be possible theoretically to demonstrate this cutting activity *etc.* by counting the number of pollen types. Does the information support the idea that one might just as well follow the AP/NAP ratio to get information on diversity and thus possibly find indications of human activity?

In fig. 8 it can be read that this idea holds for some situations but fails in others. When the course of the AP/NAP ratio is compared with notes on the basis of fig. 8 that roughly indicate the state of the vegetation, discrepancies show up. Cultivated areas may have the same high AP value as nearby forests whereas sometimes also the reverse can be found.

In figs. 9, 10 and 11 from the lakes

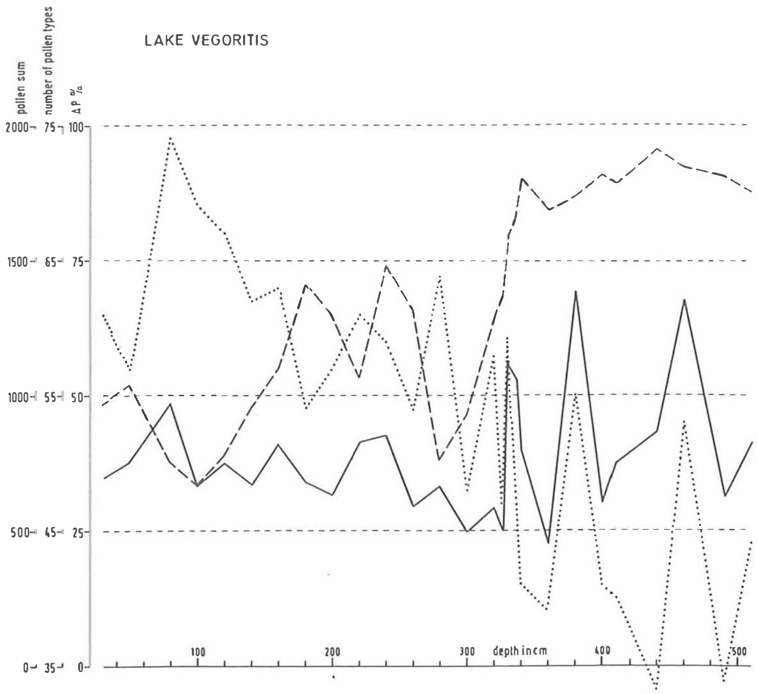

Fig. 9. Number of pollen types, pollen sum and AP/NAP ratio of the Lake Vegoritis diagram.

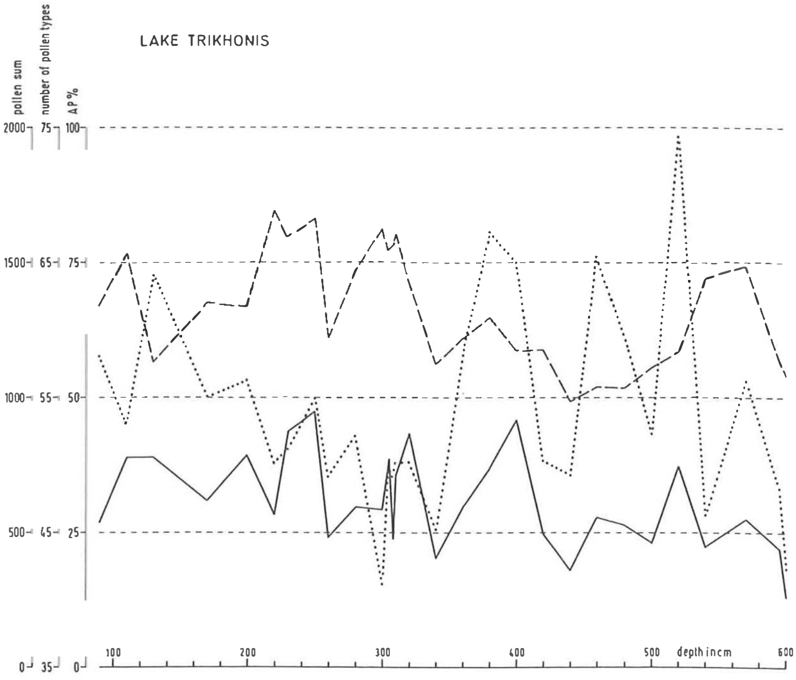

Fig. 10. Number of pollen types, pollen sum and AP/NAP ratio of the Lake Trikhonis diagram.

Vegoritis, Trikhonis and Volvi, the number of pollen types, the AP/NAP ratio and the pollen sum are plotted against depth and thus against time. In these three curves from time to time a positive relation of the pollen types with the pollen sum can be seen. Especially in the younger part of the three figures, however, the number of pollen types is increasing whereas pollen sums are reasonably constant.

Does the curve of the number of pollen types (the diversity) demonstrate a behaviour that fits into the conclusions from the pollen

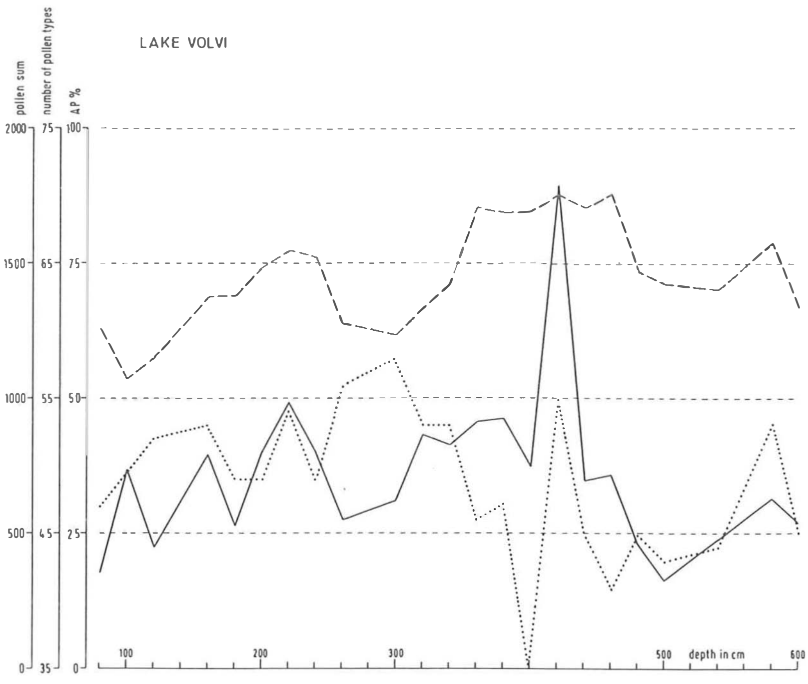

Fig. 11. Number of pollen types, pollen sum and AP/NAP ratio of the Lake Volvi diagram.

curves as they are explained in chapter 2? Is there some connection with the (pre)historical events?

Some remarks on the history of man in Greece are made in chapter 7. Human impact upon the vegetation is shown schematically in fig. 23. On the basis of the course of the AP/NAP ratio and the grouping of the types from category III an attempt is made to demonstrate anthropogenic pressure upon the vegetation (fig. 22).

4.4. Diversity of subfossil assemblages

4.4.1. *Lake Vegoritis*

The lower part of the Vegoritis diagram demonstrates little influence of man upon the vegetation (fig. 3). At the same time the diversity is low, measuring between 33 and 55 pollen types, averaging 42 types (fig. 9). Around 3100 B.P. (according to uncalibrated radiocarbon dates) the impact of man upon the vegetation rapidly increased, as did also the diversity. During the steady decline of the AP/NAP ratio, diversity numbers range from 47 to 59, averaging 52 types.

After this phase (subzone II-1, fig. 3) the remaining period shows fluctuating curves demonstrating a negative correlation between the AP/NAP ratio and diversity/number of pollen types. The size of the pollen sum is fairly constant.

4.4.2. *Lake Trikhonis*

In fig. 10 it can be seen that the diversity curve does not correlate so negatively with the AP/NAP ratio as is found in Lake Vegoritis. Maximum diversity is found in the lower part of the core up to about 360 cm although here initially it is low. The number of pollen types in the lower spectra is 42 minimally and 74 maximally with an average of 55 types. Diversity has dropped during zone II (fig. 2) where the volcanic ash layer is found. During those five spectra average diversity is 48. The AP percentages have increased during this part of the diagram.

From zone II on, above 200 cm a constant increase of the diversity is visible. The average value compared to the lower part, below 340 cm, is 54. The averages of the various zones do not differ but the course of the curves does. In the lower part important fluctuations are not always found to coincide with AP values, whereas in the upper part a regularly increasing curve can be seen, clearly linked with the AP/NAP ratio. In the lower part diversity shows maxima where AP values are low. Such maxima of 65 types and more do not occur in the upper part. A possible explanation for this behaviour (see fig. 10) is that during the time that the lower part was deposited more natural elements were still present in a vegetation that was already strongly influenced by man.

At the end of zone I diversity in the area dropped because of the formation of relatively monotonous oak forest (deciduous/semi-evergreen). In the course of time this type of forest was replaced by maquis, and thus the diversity of the vegetation had again increased.

4.4.3. *Lake Volvi*

The general trend in fig. 11 is that the diversity curve correlates, as is found above, negatively with the AP/NAP ratio. Only a spectrum at 420 cm is an exception to this trend, with a pollen sum that is twice as high as in the other spectra. The lower part (zone A-B) averages 45 types (min. 35, max. 55); the upper part (zone C-E) averages 52 types (min. 47, max. 59). Although two main zones are established some short periods can be observed. These short fluctuations are mainly caused by changes in the balance between Mediterranean maquis and Central European forest from higher elevations around Lake Volvi. During zone E the diversity decreases although the forest does not show an expansion in the form of higher AP values. It is possible that in this case the vegetation was disturbed to such an extent that barren hills, like those we see nowadays, had developed, with an accompanying loss in diversity.

4.4.4. *Conclusion*

The translation of the number of pollen types in terms of diversity seems reasonable. The practical use of this feature is, however, limited. Diversity often turns out to correlate with the AP percentages. Thus it is easier to read the AP curve, that is usually available. No sharp decline in diversity could be traced for those periods during which vegetation had almost disappeared, a widespread occurrence in many parts of Greece.

5. DISCUSSION OF SOME SELECTED TYPES

The discussion of *Platanus, Juglans, Vitis* and a group of weeds is based on information from various sources (Athanasiadis, 1975; Turner & Greig, 1975; Bottema, 1974; 1979; 1980; Filipovitch, 1977; Wijmstra, 1969).

In the study presented here the reader is referred to figs. 12–21 which give a selection of pollen curves relevant to this matter.

5.1. *Platanus* and *Juglans*

In this chapter attention is devoted to these two species which develop parallel pollen curves in the younger part of the Holocene (figs. 12–21).

It is a matter of speculation as to where plane tree and walnut originally grew at the end of the last Ice Age. There are no indications that there were refugia in Greece and there are no indications that these trees were found anywhere in Greece before 3500 B.P. This could mean that plane tree and walnut were extremely rare in Greece and the find of some stray pollen grains of *Platanus* in Greece should be mentioned. These grains could, however, be due to long-distance transport. *Platanus* pollen could have been incorrectly identified, but in the case of the easily identifiable pollen of *Juglans* this is out of the question.

A pollen diagram from former Lake Xinias (Bottema, 1979) on the southern edge of the Thessalian plain shows the presence of some *Platanus* pollen grains in sediments dating back to the first half of the Holocene. The possibility cannot be excluded that *Platanus* occurred in a few localities in Thessaly during that time. If *Platanus* did occur before the fourth millennium, it must have been extremely rare.

If both species did not occur in Greece, when did they appear in Greece and how? Were they imported by prehistoric man or did they spread over the Balkans at a time when suitable conditions had developed, or was it a combination of such factors? There are no indications that these species came via Thrace. Was there any reason for prehistoric man to import both species? One can easily understand that planting *Juglans* was advantageous for man. Furthermore *Juglans* and *Platanus* have one striking point in common that may link their history. Both tree species favour riversides (Hegi, 1957). Did the available biotope, in this case riverine forests, drastically increase? Did the newcomers simply replace riverine species that were there before

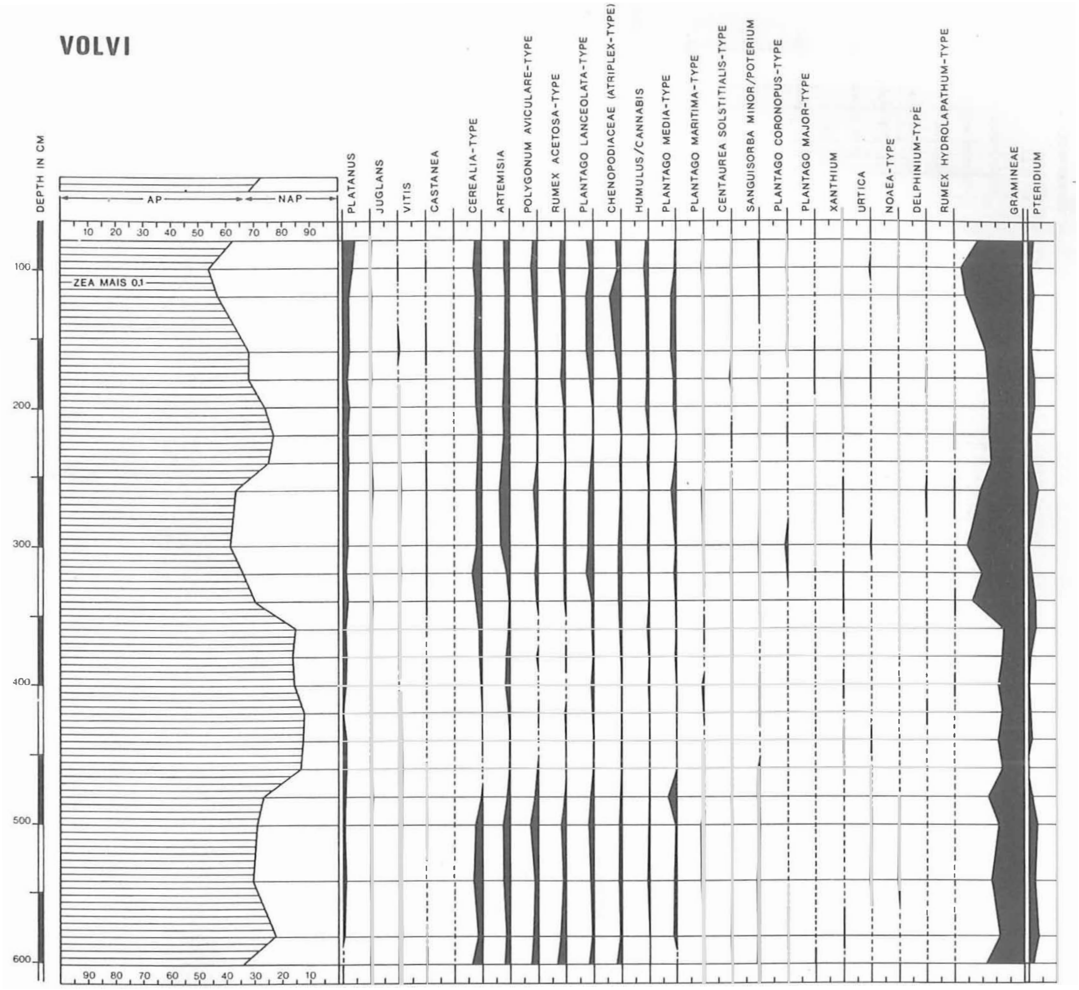

Fig. 12. Selection of pollen curves from the Lake Volvi diagram indicating antropogenic activity.

them and that had a weak competitive position?

In many Greek diagrams, especially from Macedonia but also from the Epirotic side of the Pindus near Ioannina, one species clearly decreases and is palynologically succeeded by *Platanus* or *Juglans*, namely *Fraxinus excelsior*. One may observe this fact, but how can it be explained? *Fraxinus excelsior* grows in riverine forests with deep soil and avoids *i.a.* pebble beds. *Platanus orientalis* can often be found along and in rivers with a pebble bed, a situation that is very common in Greece nowadays. The water regime of such a river is a high water transport during the winter months and little or no transport during the Mediterranean summer. Such a regime is the result of climate combined with ruthless forest destruction in the mountainous hinterland. Erosion of the valleys and a shift of water distribution over the seasons may have caused *Fraxinus excelsior* to retreat and *Platanus* to spread.

Platanus is mentioned in relation to a possible succession of *Fraxinus excelsior* but the walnut may be a more likely successor as *Juglans* prefers a deeper soil and not a pebble bed. Under (semi-) natural conditions *Juglans regia* is found in the Balkans in ravine forests at the present time.

If the hypothesis holds that river valleys changed due to a change in water regime, in turn caused by deforestation, then the cause should eventually be visible in the pollen diagrams. In part of the Greek diagrams studied such a deforestation is indeed visible

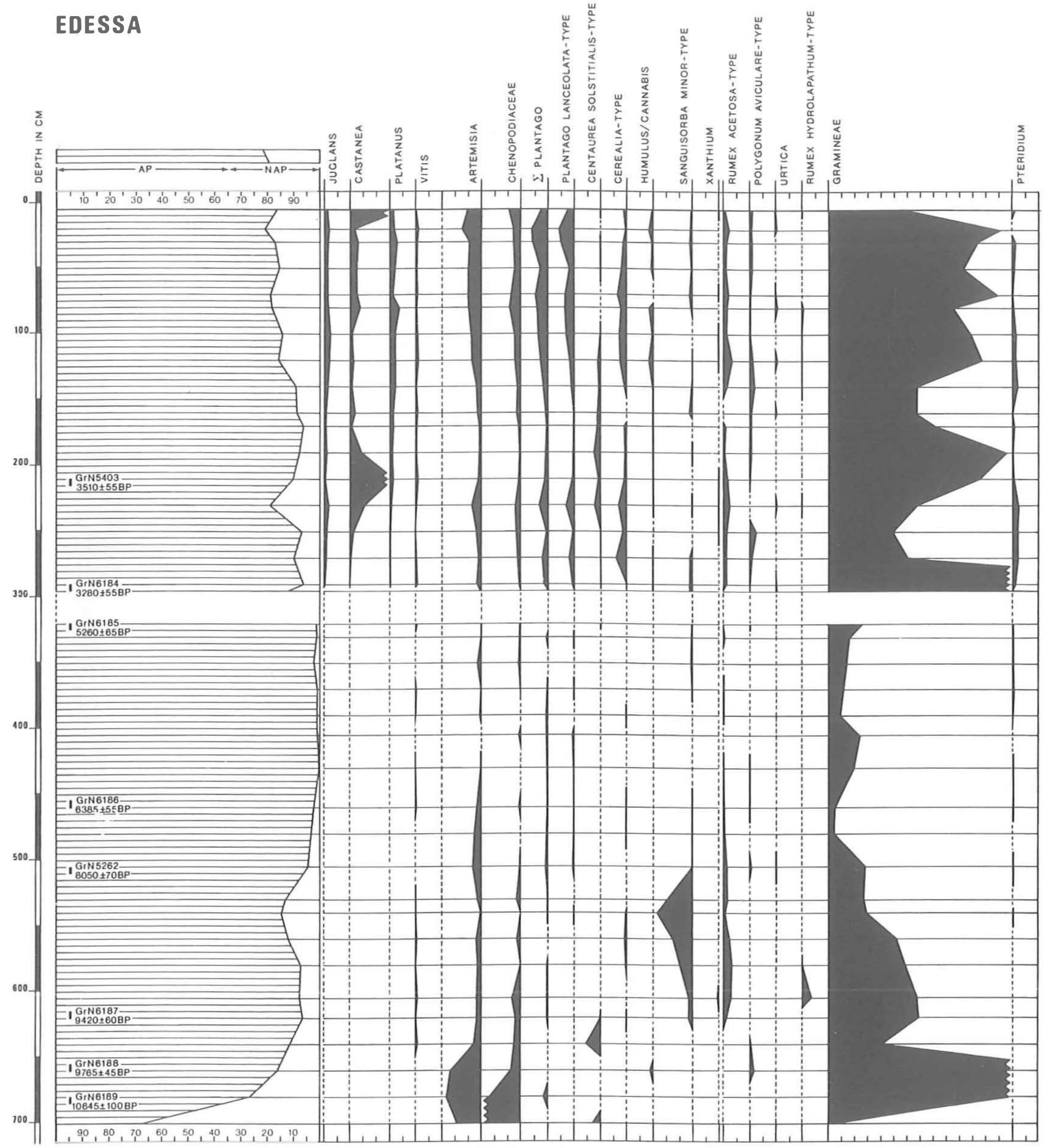

Fig. 14. Selection of pollen curves from the Edessa diagram indicating antropogenic activity.

(Bottema, 1974; 1979) and in this study for instance in Vegoritis' zone Z. This phenomenon is only found in the diagrams for Macedonia. An increase in NAP values, caused by pollen types derived from culture indicators, accompanies the beginning of the *Platanus/Juglans* phase. When climate, with increased precipitation, causing increased discharge, became established, such a change must have influenced the natural vegetation. Instead the only clear picture in the pollen diagrams is anthropogenic activity.

If climate did not cause a change in river beds then the influence of man might have led to the forming of pebble beds. When prehistoric man destroyed all the mountain forests, erosion will have taken place (as one can see nowadays). Heavy rain would have washed the soil down the slopes into the valleys and finally to the sea. As there was no vegetation of importance that held the water, providing a regular water supply to the river

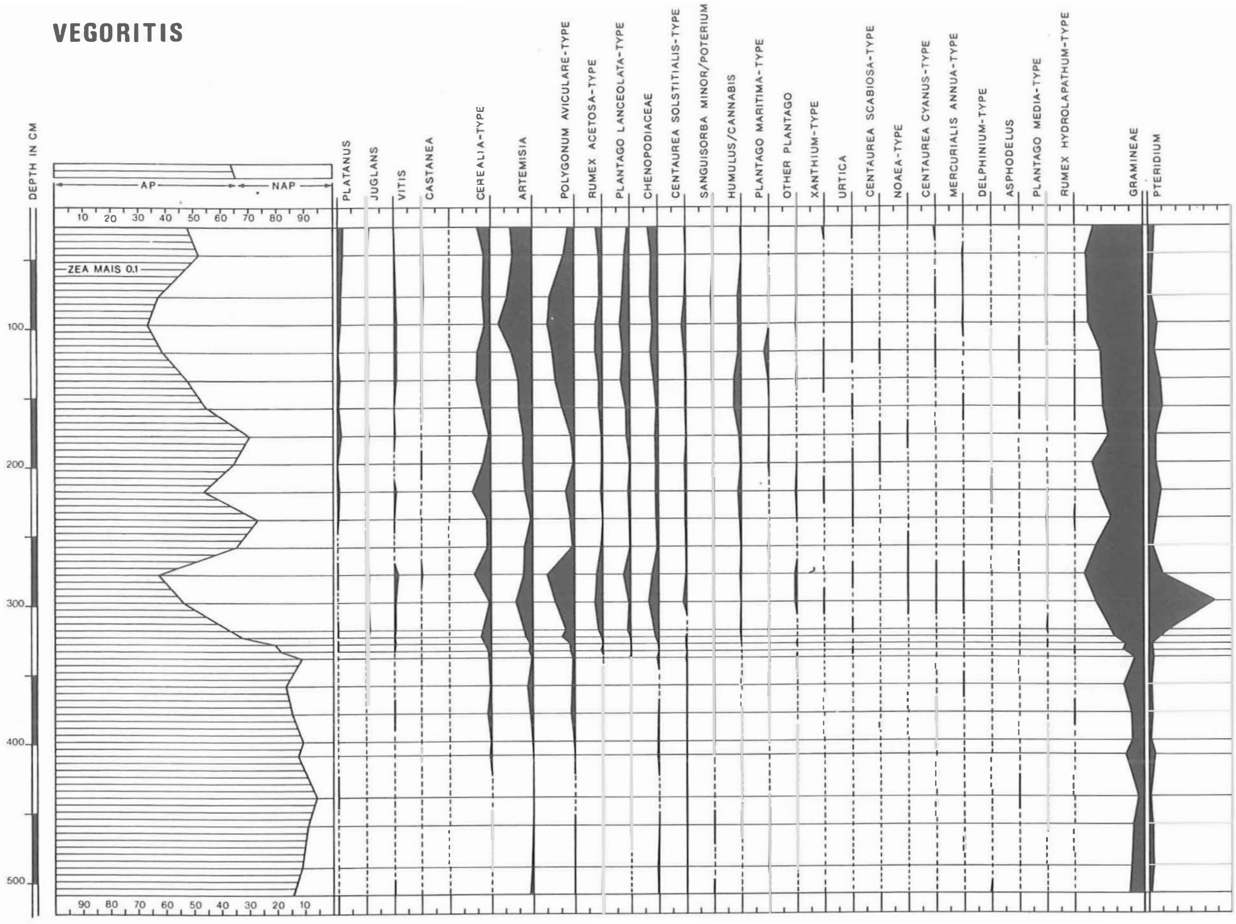

Fig. 15. Selection of pollen curves from the Lake Vegoritis diagram indicating antropogenic activity.

system, such streams would almost be torrential after heavy rain, leaving behind only bigger elements, for instance rounded pebbles. This picture would not appear suddenly, but it would develop gradually as farming practices continued. There are no signs that these activities occurred on a wide scale already before the appearance of *Juglans* and *Platanus*.

The combination and the values of pollen of types which indicate farming activities include *Platanus* and *Juglans* palynologically, but to what extent are they also linked practically? Although we may call *Juglans* a culture plant/tree, it is more difficult to consider *Platanus* as a weed. Today plane trees are of doubtful origin. They are often considered as hybrids, and grow along many roadsides in South European countries. They are planted *i.a.* because they can withstand air pollution very well as they shed their bark every year. It is, however, doubtful whether air pollution played a role during the Greek Bronze Age. Planting plane trees to provide shade seems a better suggestion, as can be appreciated in Mediterranean countries nowadays.

The geomorphological history of river valleys does not indicate any very important changes around 3000 B.P. The so-called 'Younger fill' is dated by Vita-Finzi (1969) to about A.D. 400–1800 (Bintliff, 1982). Pollen diagrams that cover the period of A.D. 400–1800 do not show special characteristic changes in the pollen curves of species that are linked with river valleys. The phenomenon and the delimitation of the 'Younger fill' in time, are seriously doubted by *i.a.* Wagstaff (1981) and Eisma (1978).

The course of the pollen curves in the pollen diagrams does not point to a climatic change that stimulated the spread of walnut and plane tree. The reverse is to conclude a climatic change from the appearance of *Juglans* and *Platanus*. The combination of pollen types and their specific significance, however, strongly points in the direction of the influence of prehistoric man. In chapters 6 and 7 we will discuss this matter.

The appearance of *Juglans* and *Platanus* is not an isolated occurrence for Greece, but is found in other countries too. For Northwestern Iran, in the area of Lake Urmia (Rezayah), the same pollen picture can be found at about the same time, although pollen assemblages from both regions differ considerably (Bottema, in prep.). In the mountainous part of Turkey *Juglans* and *Platanus* do not behave in the same way palynologically. *Juglans* is present in low percentages during the Holocene, whereas *Platanus* pollen is generally absent apart from a late appearance in coastal sites (van Zeist *et al.*, 1975). Altitude may be the limiting factor in Anatolia.

A place of natural occurrence of *Platanus* is the Ghab Valley in Northwestern Syria (Niklewski & van Zeist, 1970), where plane tree is found continuously during the last 50,000 years.

Juglans pollen appears in sediment cores from Italy and France in Roman time mainly. A diagram from Lagoa Comprida, Portugal (van den Brink & Janssen, in press) shows stray grains of *Juglans* and a continuous curve for *Castanea* long before the fifth millennium B.P. An early *Juglans* grain in Ioannina II (fig. 19) is ascribed to long-distance transport.

Pollen of *Juglans* and *Platanus* does not show the same distribution and percentages (figs. 12–21). For Macedonia, values are very much the same. Cores from Khimaditis, Edessa and Kastoria show the two tree pollen types at about 3200 B.P.

In the Plain of Macedonia, at about sea-level, both *Plantanus* and *Juglans* pollen is very scarce. This is remarkable as part of the pollen transport could be effected by rivers. The same is true for Ioannina II (Epirus). Nevertheless, at the present time on the eastern slopes of the Pindus Mountains along the road from Kalambaka to Ioannina numerous plane trees can be seen bordering the Acheloos river.

5.2. *Vitis*

There are obvious reasons for using *Vitis* as an indicator of human activity. Modern occurrence of wild vine (*Vitis sylvestris*) is restricted to the northern half of Greece, north of the line Larissa-Trikkala-Ioannina (Logothetis in J. Renfrew, 1973). Van Zeist and the present author found wild *Vitis* in rather dense shrub and small trees of *Carpinus orientalis, Cercis, Cotinus, Quercus* cf. *pubescens, etc.*, 17 km southwest of Lake Ioannina. However, there is some uncertainty concerning its occurrence in the wild. On the distribution maps stands of wild vine in the southern Vojvodina are absent, although it was frequently seen in riverine forests (Bottema & Ottaway, 1982). It is probable that wild vine occurred in many places in Greece where it seems to be absent now, and that it disappeared due to human intervention.

The palynological presence of *Vitis* during the Holocene differs from place to place. In Macedonia this type is often met with in the *Platanus*/*Juglans* phase, after about 3000 B.P. and scarcely before. The finds from before 3000 B.P. may originate from wild plants as well as from cultivated grape.

Vitis sylvestris grows at heights up to 400 m above sea-level and occasionally up to 800 m. Cultivated vine would have a more restricted distribution (Suvalesai in J. Renfrew, 1973).

Greek Macedonia, including Kastoria and the Khimaditis/Vegoritis area, lies above 500 m above sea-level. The distribution map of wild vine by Logothetis (in J. Renfrew, 1973) contradicts Suvalesai's note on the elevation. Especially in the higher part of Macedonia wild vine occurs. That would explain the presence of the early (pre-Neolithic) appearance of *Vitis* pollen. The increase during the *Juglans*/*Platanus* phase was undoubtedly caused by man.

We have discussed the situation on higher elevations, about 500 m above sea-level, but what about the behaviour of *Vitis* pollen below 500 m? In the valley west of Edessa at about 400 m above sea-level *Vitis* was present at least at about 9500 B.P. In the low lying Plain of Macedonia, *Vitis* pollen is more numerous than in other Greek cores, suggesting that in the riverine forest in the delta vine was abundant. In the Macedonian lowlands the *Vitis* curve is the reverse of the

Vitis curve in the highlands. Up to 10% *Vitis* pollen is found in the lower part of the Giannitsa diagram but during the period of the *Juglans/Platanus* phase *Vitis* pollen percentages are considerably lower. As the sediments in Lake Volvi are not old enough we cannot say how the vine behaved in that low part of Thrace. Turner and Greig (1975) do not mention *Vitis* for the Drama area.

In the Plain of Macedonia a clear negative correlation exists between the culture indicators and *Vitis* (fig. 13), whereas in the higher parts a definitely positive correlation exists. Also in somewhat lower areas like Edessa and Lake Volvi one can speak of a positive correlation. How can this be explained? When farmers entered the Plain of Macedonia wild vine was very common. Quite probably it grew in riverine forests with *Fraxinus excelsior etc.* This type of forest was soon destroyed resulting in a decrease of *Vitis* (the decrease of pollen of *Fraxinus excelsior* and *Vitis* lead to the conclusion that the riverine forest was destroyed). The assumed destruction of wild vine was not followed by domestic viticulture.

Wild vine was never very common at higher elevations as a stuitable biotope was relatively scarce there compared with the Plain of Macedonia. On such higher locations *Vitis* pollen percentages increased after about 3000–3500 B.P. due to viticulture.

On the Epirotic side of the Pindus *Vitis* occurred in the Ioannina area for most of the Holocene but as is evident from the pollen percentages it was not abundant. Sediment from the coastal area of Akarnania that represents about the last 6000 years shows a rather constant presence of *Vitis*. According to the distribution map by Logothetis this would be cultivated grape. It is however doubtful to what extent this map gives indications of past distribution of *Vitis sylvestris* or its domesticates.

The same can be said for the Thessalian part. *Vitis* occurs in the Xinias area (Bottema, 1979) soon after the beginning of the Holocene. It is clear that such finds must be attributed to *Vitis sylvestris.*

6. POSSIBLE INDICATORS OF EARLY FARMING IN GREECE

In chapter 3.2. the method is described for selecting a group of pollen types that may indicate early farming in Greece. One could imagine that in the same way as Iversen (1941) used *Plantago lanceolata* as an indicator for the *Landnam* in Denmark, one or more pollen types could be indicative for the onset of Neolithic farming in Greece.

Of course, the situation in Greece differs considerably from that in Denmark or Northwestern Europe as a whole. Because of variation in elevation, substratum, exposure and climate, vegetation types developed which undoubtedly demonstrate different reactions, when they are attacked by man and his domestic animals or replaced by his crops, than those in Northwestern Europe. These supposed vegetational changes may be visible in the pollen assemblages. Do Greek vegetations show indicators of this process and if so, are they identical all over the area studied or are they different?

In addition to the three new diagrams dealt with in this paper, other available information has been treated in the same way. A selection of ten diagrams from Northwestern Greece (Bottema, 1974) together covers the Holocene, so also pre-farming periods are present. The diagrams represent an altitudinal range from sea-level to 650 m above sea-level (figs. 12–21). The most important types discussed above are given schematically in fig. 22.

Lake sediment as well as peat is present as basic material from which the samples were taken, although this variation is advantageous only to a certain extent. As will be known, pollen curves derived from clay or gyttja tend to demonstrate smooth curves compared with curves from peat sediment or comparable deposits with a lot of organic detritus. Cores from the centre of lakes are far less influenced by local vegetation than cores from marshes or cores from locations close to (marshy) lake shores.

Thus the diagram Khimaditis III (fig. 17) taken in the lake of that name, compares well with the three new cores under discussion. It is more difficult to compare between Khimaditis III and Khimaditis I (fig. 16) taken from the nearby marsh. The remaining diagrams (figs. 13, 14, 18 and 19) from Giannitsa, Edessa, Kastoria, Xinias II and Ioannina II have been taken also from locations where local vegetation will often have been present very near to the coring site.

The pollen types from the so-called group III (chapter 3.2.) are selected from the ten

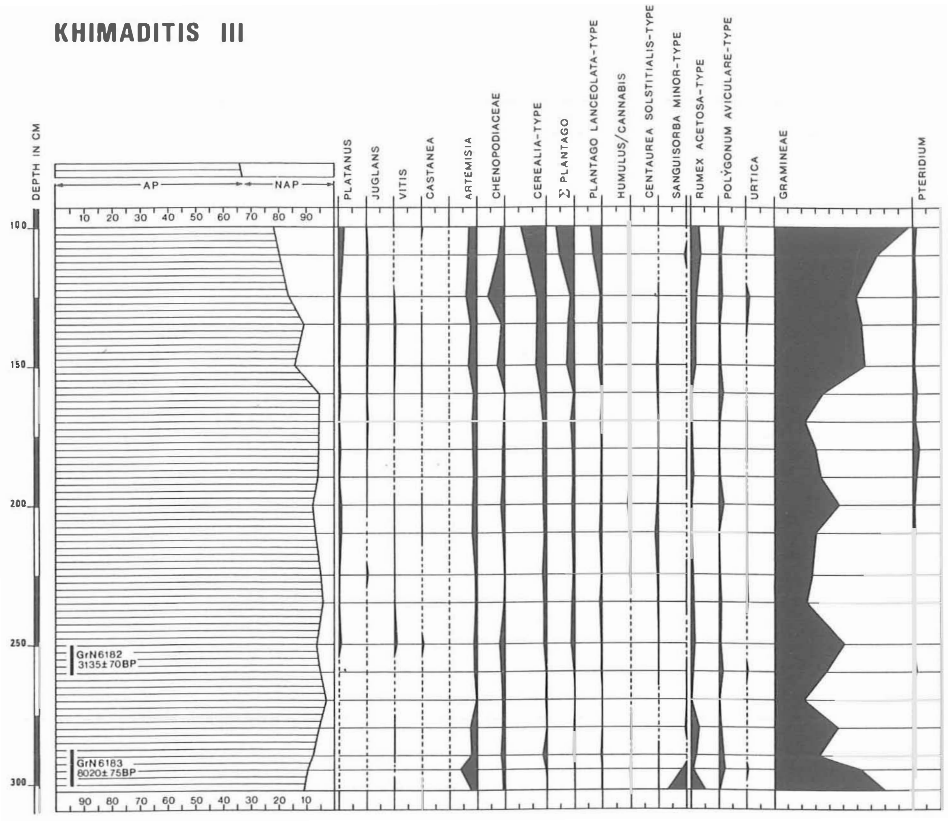

Fig. 17. Selection of pollen curves from the Lake Khimaditis III diagram indicating antropogenic activity.

diagrams and shown in figs. 12–21. In figs. 12–18 diagrams from Macedonia are shown. They originate from Vegoritis, Khimaditis (two), Edessa, Kastoria, Giannitsa and Volvi. Two diagrams originate from southwest of the Pindus, Trikhonis and Ioannina II (figs. 19 and 20). The remaining diagram (fig. 21) is from Xinias (Thessaly).

The figures are drawn in such a way that the AP/NAP ratio is shown first, followed by the curves of *Platanus, Juglans, Vitis* and *Castanea*. Then follow the types present in group III (chapter 3.2.), at least when such types are present with a curve. Only in figs. 18 and 21 are the curves calculated from a basic sum including tree types only.

The various pollen types are grouped according to the shape of their pollen curve. Finally the curves of the Gramineae and *Pteridium* are shown. At least part of the grass pollen doubtless has connections with man and his animals.

Especially in the diagrams made for the lake sediments the grouping of the various curves demonstrates a visual pattern. The diagrams that cover the complete Holocene present a picture that, starting below, shows a dense pattern caused by the presence of many types. This is followed by a less dense part (absence or low values of many types) and then again a dense pattern when the types return to higher values. In those diagrams where the younger part of the Holocene is present, it is self-evident that only part of that pattern can be found.

The black-white-black pattern is possible, because a series of types could be grouped together which show the same property. They are all found during the early Holocene, after which they disappear because they cannot tolerate the shade of forest and finally they return when man opens up the forest.

One of the results of the grouping is that types that were thought to be of local origin, growing somewhere on the edge of the marsh, turned out to have an identical behaviour to well-known weed and crop types. For instance, *Polygonum aviculare*-type pollen was for a long time considered as mostly local (Bottema, 1974), but it turns out that it is

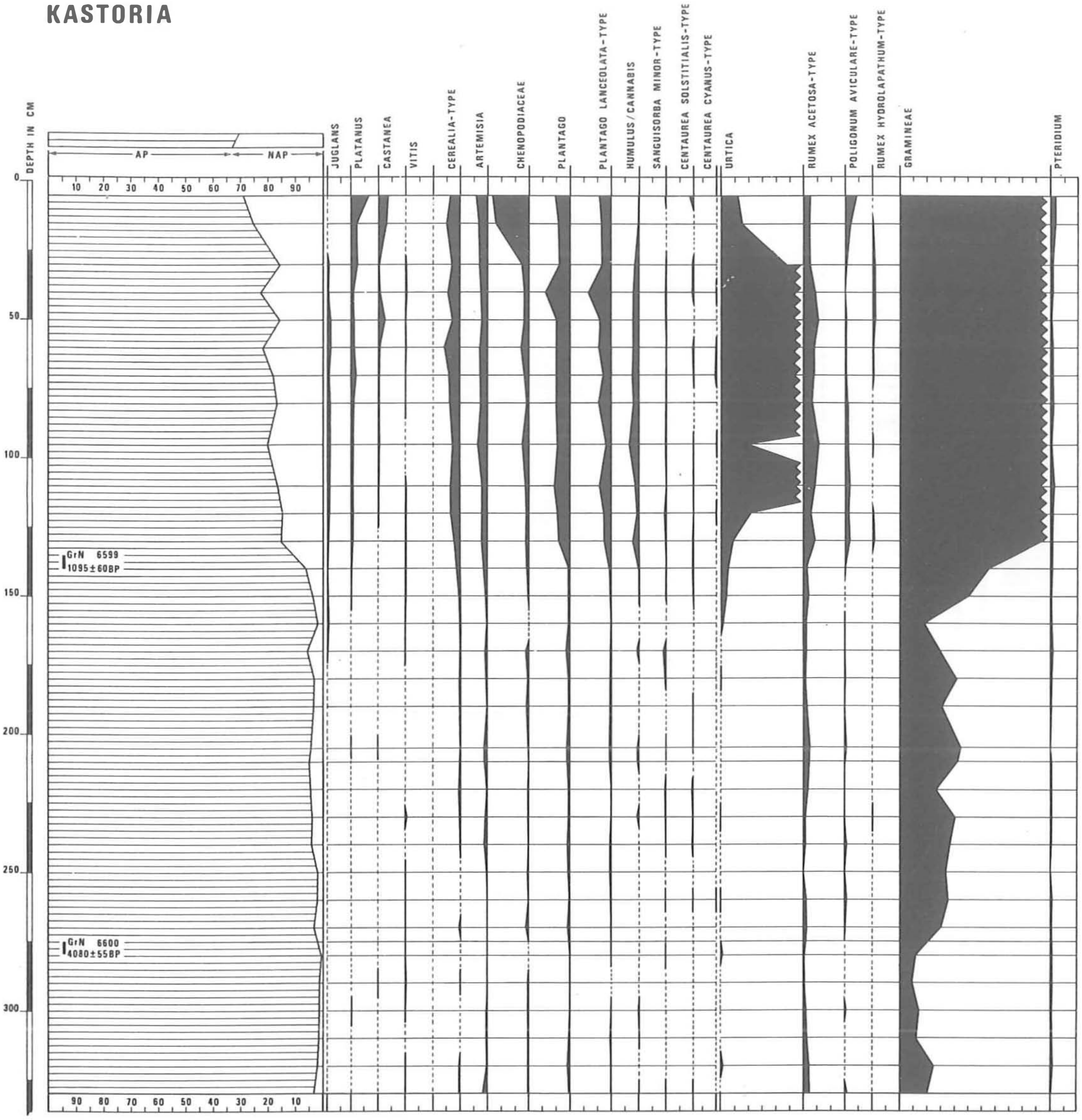

Fig. 18. Selection of pollen curves from the Lake Kastoria diagram indicating antropogenic activity.

closely linked with types indicating farming.

Pollen types that appear in the early as well as in the late Holocene are: *Artemisia*, Chenopodiaceae, *Polygonum aviculare*-type, *Rumex acetosa*-type, *Centaurea solstitialis*-type and *Sanguisorba minor*/ *Poterium*. All these types represent more than one plant species. Only in the case of *Sanguisorba minor*/ *Poterium* the number of species is known with some certainty to be limited to two.

Some of these types can be listed as predominantly steppic, for instance *Artemisia* and Chenopodiaceae. They are present during late Pleistocene and early Holocene times. Then they become rare but they do not disappear altogether. In younger Holocene times they expanded again. The fact that they do not disappear makes them unsuitable as indicators for the onset of Neolithic farming in Greece. They may indicate more wide-scale farming, but they are no subtle indicators.

A series of typical culture indicators have relatively important values in the upper parts of the diagrams representing the late Holocene period. This group includes Cerealia-

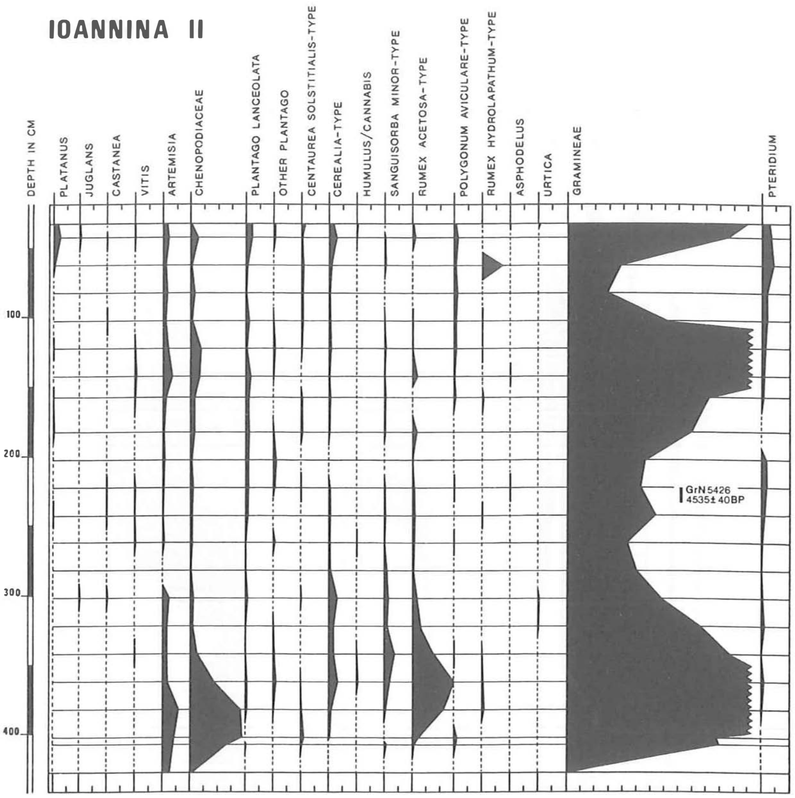

Fig. 19. Selection of pollen curves from the Lake Ioannina II diagram indicating antropogenic activity.

type, *Plantago lanceolata*-type, other *Plantago* types and *Humulus*/*Cannabis*. If we trace these curves back to periods during which early farming may have taken place, the corresponding values have diminished to values of often under 1%. Sometimes a particular type is gone altogether.

Cerealia-type indicates cereal crops only partly as the pollen type includes some wild Gramineae, which are difficult or impossible to separate from the Cerealia proper (van Zeist *et al.*, 1975). In Greece, for instance, *Hordeum spontaneum, Triticum aegilopoides* and *Secale montanum* occur in the wild. Such wild cereals and wild grasses as mentioned by van Zeist *et al.* explain the fact that the curve representing Cerealia-type pollen runs back into the Late Pleistocene.

Plantago lanceolata-type (defined as a type because the reference collection for Greece of the Biologisch-Archaeologisch Instituut is not complete as regards *Plantago* species) generally does not occur in the lower part of the diagrams. The plantain curves start about 8000 B.P. in the diagrams of Edessa, Khimaditis I and III (figs. 14, 16 and 17). The problem remains whether there were any Neolithic farmers in the mountains. There is proof of early Neolithic habitation in the Plain of Macedonia where they inhabited the site of Nea Nikomedeia (Rodden, 1962; 1965). The Giannitsa diagram (fig. 13) may give information on the Nea Nikomedeia farmers. This diagram covers about 8000 years according to the radiocarbon dates. It is thus impossible to see whether *Plantago lanceolata*-type pollen was present before that time. In Thessaly *Plantago lanceolata*-type pollen is found in low percentages from early Holocene times onward in the diagrams of Xinias I (Bottema, 1979) and Xinias II (fig. 21).

In Northern Greece *Plantago lanceolata* pollen may be an indication of early Neolithic farming, but in Thessaly and more to the south no such indicative value is apparent. The same can be said for *Humulus*/*Cannabis*. This pollen type clearly indicates human activity. *Humulus* is, on the other hand, a natural constituent of the vegetation as is indicated by the presence of *Humulus*/*Cannabis* throughout the first half of the Holocene, be it in low numbers. It is obvious

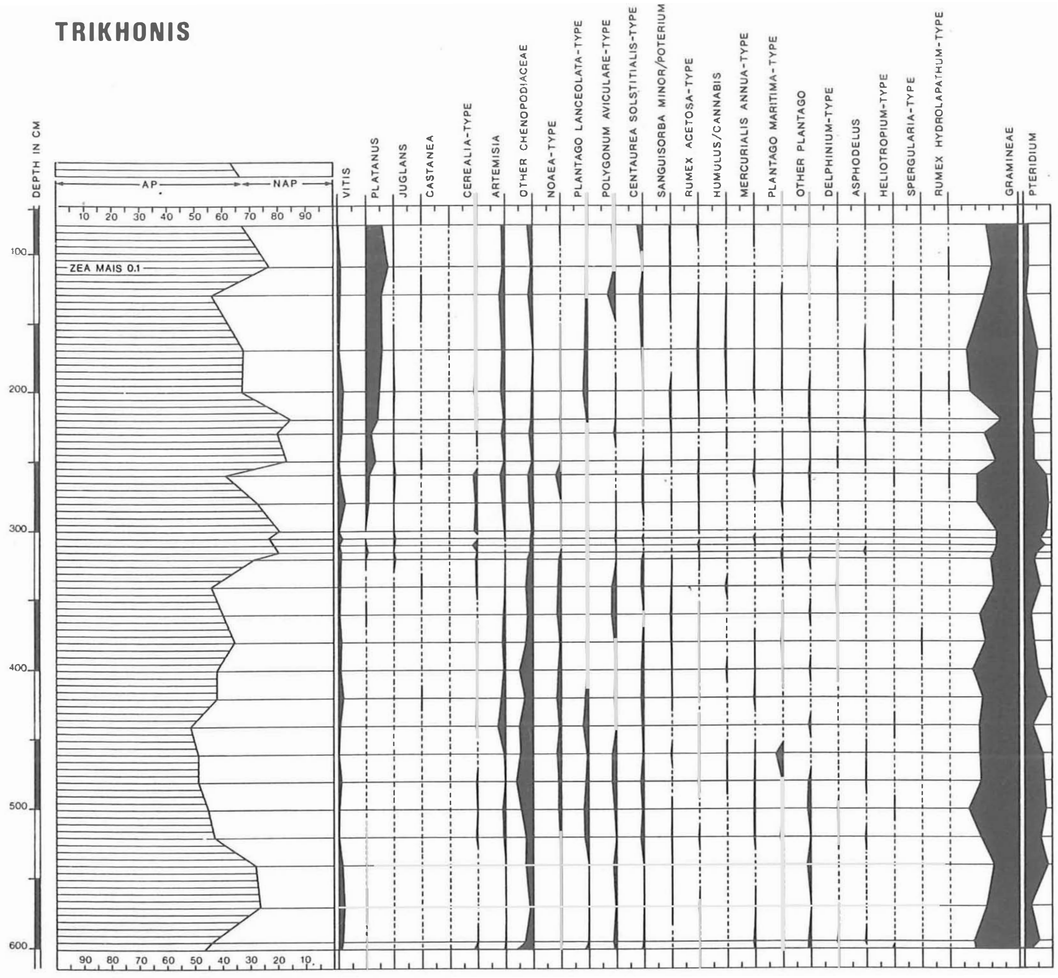

Fig. 20. Selection of pollen curves from the Lake Trikhonis diagram indicating antropogenic activity.

that also from this gradually increasing type no proof can be obtained of early Neolithic farming.

The third group consists of the remaining types. The types in this group never show important values and their appearance is irregular. Representatives are *Xanthium, Asphodelus, Mercurialis annua* and *Urtica*. *Xanthium* is restricted to the Thracian/Macedonian part. It does not show a closed curve for any period but pollen is present in early Holocene times already.

Asphodelus may indicate open, bare vegetation, or over-grazing. This type is only present in cores from lower levels or in the south (Ioannina, Trikhonis). An exception is Vegoritis (fig. 15), where a few *Asphodelus* grains are met with.

For the three lake diagrams under discussion *Delphinium*-type and *Centaurea cyanus*-type undoubtedly indicate farming activity, but they do not mark the beginning of such activities.

Urtica is found in low percentages, and with some very high values. The high values suggest that *Urtica* sometimes formed part of the local vegetation. *Rumex hydrolapathum*-type may be a local marsh plant that comes into this group also because it did not occur in the relevees of Barbero and Quézel.

The Gramineae are included in the figures, because they may indicate a trend especially when the core has been taken from deeper water. Gramineae pollen from marshes and upland species may be found together, the more local group causing the irregular pattern. Lake deposits show smoother curves than organic deposits.

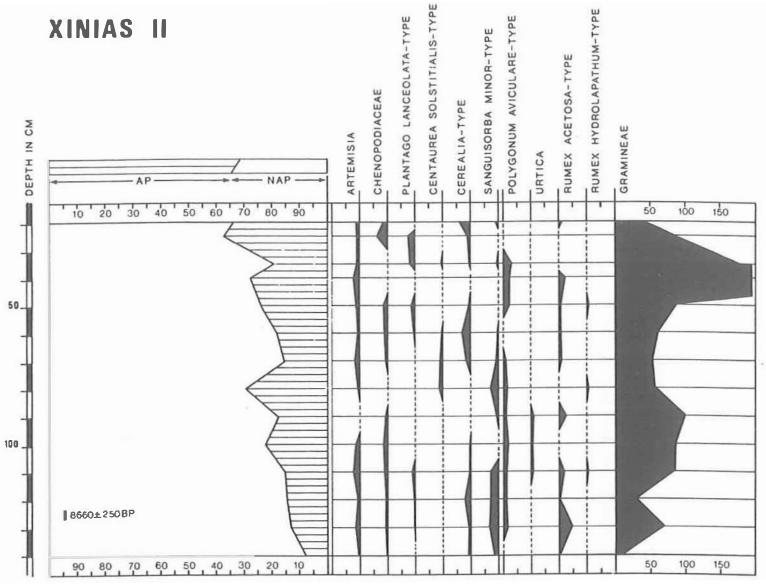

Fig. 21. Selection of pollen curves from the Lake Xinia II diagram indicating antropogenic activity.

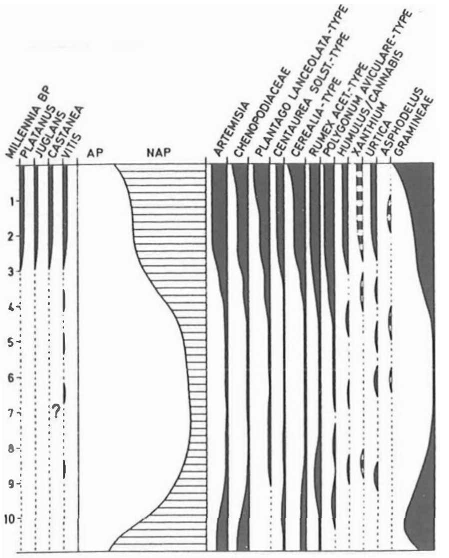

Fig. 22. Schematic pollen diagram showing a selection of pollen curves indicating human influence.

Finally one spore is added, *Pteridium*. The *Pteridium* curve closely resembles the *Plantago lanceolata*-type curve, the first finds occurring before the onset of human farming and herding activity. Although bracken and plantain must have been constituents of a natural vegetation, they seem to be sensitive indicators for an early stage of farming, although not decisive for the recognition of the first Neolithic farming activities.

Thus, the method of using the pollen types mentioned in group III fails in attempting to trace the onset of farming in Greece. It is, however, a useful method for studying the intensity of farming and the occurrence of various farming phases.

7. PALYNOLOGICAL EVIDENCE FOR DEMOGRAPHIC EVENTS IN (PRE)-HISTORIC GREECE

In this chapter it will be seen whether there are connections between demographical fluctuations, especially invasions, and palynological information. Such connections were already made by Athanasiadis (1975) when he discussed pollen diagrams for Litochoro and Pertouli in Thessaly. It is thought that in Greek (pre)history many events occurred involving displacement or invasion of smaller or larger groups of people. Some of these movements, especially in prehistoric times, are merely hypothetical or await more convincing proof. Others that are more recent have been traced in written records from that time.

The impact of such events upon the environment, or more specially upon the vegetation, is very difficult to predict or to make visible. We will see what information can be gathered from the archaeological record and what can be learned from written

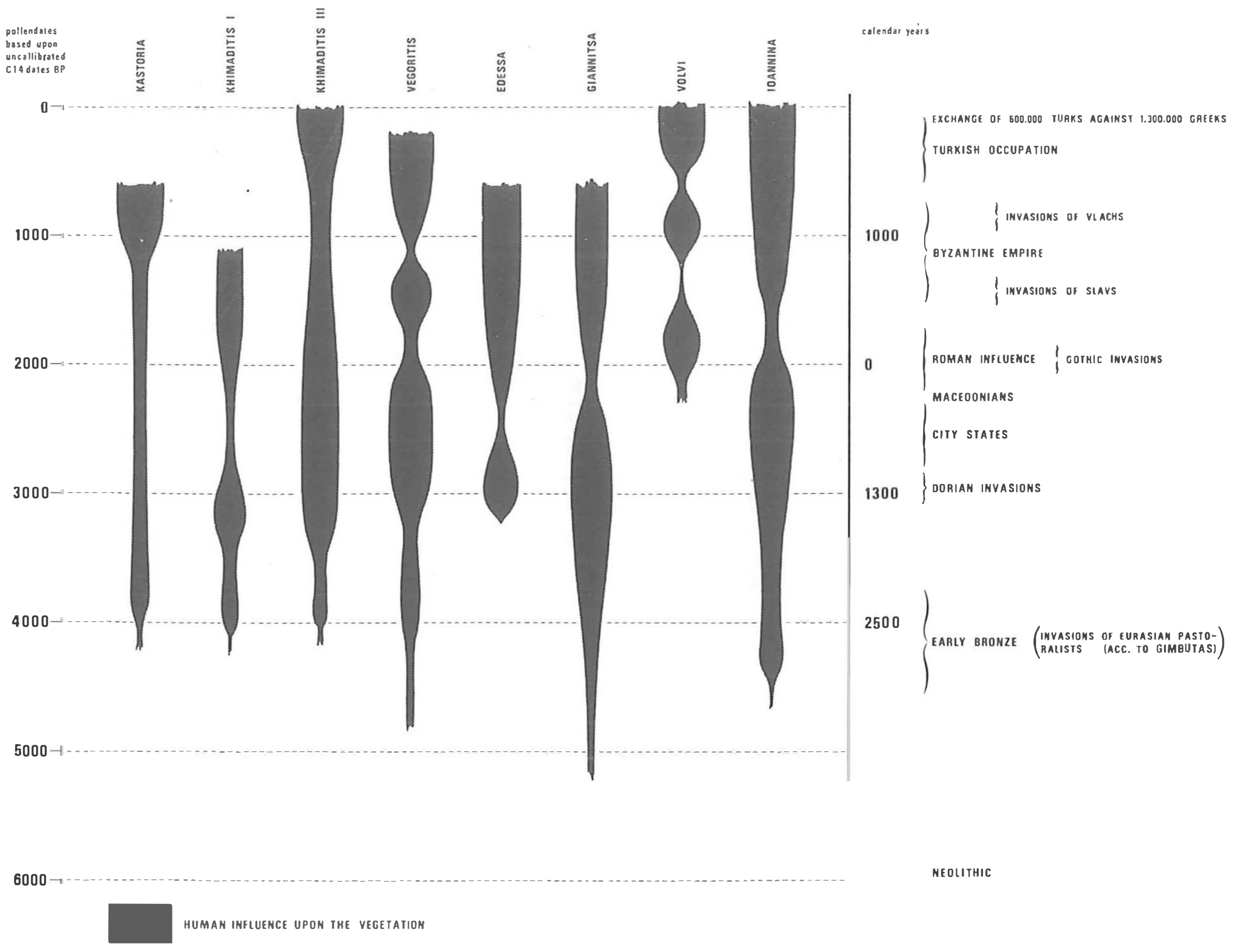

Fig. 23. Chronological table showing historical events and a scheme of human impact upon the vegetation derived from palynological evidence.

information from later periods. When reading the general outline of Greek history in the Geographical Handbook Series-Greece (1944), it turns out that quiet periods hardly occurred (see a general scheme taken from the Geographical Handbook Series-Greece in fig. 23). It should be stressed that the quantitative assessments of movements or migrations are not always equally reliable. The number of people involved is (has to be) based often upon general assumptions; especially the invasions in prehistoric times need further proof.

Apart from the number of people involved, the impact upon the environment remains highly questionable. Good studies of demographic history of the Greek interior on the basis of excavations are lacking. For the following information on the prehistoric part, the author is much indebted to Mr. A.E. Lanting. For comparison with the palynological record it is necessary that the prehistoric cultures are firmly delimited in time and space. In West and Central Greek Macedonia only very few modern excavations have taken place. The general distribution of the various cultures and their dating are based upon surveys, from the study of surface finds.

The cultural succession in Thessaly is well known but absolute dates of the Dimini, Larisa and Rachmani periods are few (Hauptmann, 1981). In East Macedonia, east of the Strymon, a better situation is found because of the excavations of Sitagroi (Renfrew, 1970; 1971; 1973) and Dikilitash (Theocharis & Deshayes, 1962; Deshayes, 1968; 1970a; 1970b; 1971; 1973) on the Plain of Drama. A series of radiocarbon dates from

Sitagroi points to a hiatus between about 3400 and 2600 B.C. According to Turner & Greig (1975) in their study on the vegetation history in the Drama area, a slight decrease in the amount of forest can be detected, indicating that, although no habitation was present on Sitagroi, prehistoric man was still present in the vicinity.

Gimbutas (1974; 1977) thinks that an invasion of Eurasian steppe pastoralists halted in Rumania around 3500 B.C. They were driven southward by another invasion around 2700 B.C. to Macedonia.

In the period from c. 2300 to c. 1900 B.C. covering part of the Early Bronze Age, many settlements were destroyed. An invasion, according to Gimbutas, came from the East European steppes. Hanschmann and Milojčić (1976) think that the invasion came from Macedonia. Best (1973) postulates Thracian tribes coming from the north. However, he confounds Greek calendar year dates with Bulgarian uncalibrated radiocarbon dates. Similarly, confounding of radiocarbon years and calendar years is also evident in Hammond (1978).

Many investigators ascribe an invasion around 2300 B.C. to the ancestors of the Greeks who spoke an Indo-European language from which the Greek dialects developed in Greece. Others think that the Proto-Greeks invaded around 1600–1550 B.C. Proof of the presence of Greek-speaking people dates from 1200–1100 B.C.

Astour (1965) suggests that Semitic tribes came from East Cilicia to Greece immediately after the Santorini eruption. Palestinian/early Phoenician names would have been abundant locally at that time in Greece. An invasion of the Dorians is postulated c. 1200/1100 B.C. coming from Northwestern Greece. In view of the many cities destroyed this must have been a turbulent time.

The cultural gap between the Mycenaean period and the period after it seems to be much smaller than was thought for a long time. Proof that the people who burned the settlements came from Northwestern Greece is not very convincing. This made some investigators (*i.a.* Thomas, 1978) think that the 'Dorians' were the lower classes in Mycenaean Greece who revolted against the ruling class and chased them away.

The political and economic effects were not necessarily the same. Especially economic factors may have been of influence upon the environment. For instance when the Roman empire collapsed some economic effects would have been ahead of this event and some may have been delayed. Some economic events can be translated into damage to vegetation and others cannot.

In the Byzantine Empire invasions of Slavs took place from about A.D. 500 to 675. Historical reports mention numbers of about 100,000.

About A.D. 1000–1100, invasions of Vlachs took place. They were less important than the Slavs. Still, as they took to the mountains, they could have exerted pressure upon the mountain forests. According to the sensus of 1928 c. 20,000 Vlach-speaking people lived in Greece. It is likely that the actual number was higher. Many Vlachs had already left for Rumania after the First World War. Still the number of invading Vlachs has to be counted in tens of thousands and not in hundreds of thousands. The fall of the Byzantine Empire in 1453 when the Ottoman Turks took over is also not an important limit for economic environmental events. In 1204 for instance a united fleet of Venetians and Crusaders conquered Greece and adjacent areas. The French Boniface de Montferrat became king of Macedonia, Thessaly and much of Central Greece. So in fact the area was free of Byzantine domination already almost two hundred years before the definitive fall of the empire. This is of importance as for instance Athanasiadis (1975) links the pollen zones with the main political events.

Apart from the supposed impact of man upon his natural surroundings, some palynological information may be derived from the method of farming. Athanasiadis points out the difference between Turkish agriculture and Greek farming. Migration, during the Turkish occupation occurs in the form of Christian refugees escaping to the mountains. The Turkish occupation did not end at the same time all over Greece; in Greek Macedonia and part of Thrace it occurred as late as in 1913.

The final demographic shifts include the return of the refugees from the mountains and the exchange in 1923 of 1.3 million Greeks from Turkey with 390,000 Turks/moslems from Greece.

From the foregoing it is clear that many proven or supposed demographic shifts have occurred in Greece. There is a lot of disagreement about these shifts especially those concerning invasions, apart from those that have happened since Roman times.

In fig. 23 a chronological table is given demonstrating a series of (pre)historic events and a tentative scheme indicating the impact of man upon the vegetation derived from pollen diagrams. These diagrams originate mainly from Greek Macedonia and one from the Epirotic side of the Pindus Mountains. The scheme for Lake Trikhonis is not given here, because there are too many dating problems with this diagram. The vegetation schemes differ from site to site considerably and in this respect they unfortunately match the archaeological record very well.

When vegetation history is concerned it is appealing to look at some historical invasions, because they were at least recorded. Of special importance is also the object of such movements. People who invaded fertile lowlands and towns will have a different kind of impact upon the vegetation than herdsman with large flocks spreading over the mountains. A disadvantage in studying the effect of subrecent migration may be the advanced state of deterioration of Greek forests. As the human influence has already been exerted for millennia the invasions of Goths, Slavs or Vlachs hardly add to the disturbance of nature.

In the diagrams of Volvi and Vegoritis such invasions are not visible from the course of the pollen curves. One may conclude that these invasions did not exert pressure upon the Greek vegetation to any marked extent.

As we do not learn much by looking at the most recent invasions, we turn to the lowest part of the scheme of fig. 23. The first indication of events that are synchronous to some extent is found at about 4000 B.P. in Kastoria and the Khimaditis area, thus in Northwestern Greek Macedonia. In Vegoritis, Giannitsa and Ioannina comparable changes are found a little earlier. In Edessa the surroundings seem to be less affected.

In calendar years this time would be about 2500 B.C. According to Gimbutas (1974), during that time (2700 B.C.) Eurasian pastoralists invaded Northern Greece. It cannot be excluded that the invasion postulated by Gimbutas is connected with the vegetation change mentioned above.

The next important change takes place around 3100–3200 B.P. (fig. 23), especially west of the Plain of Macedonia, but not over the watershed in Lake Kastoria. In the Plain of Macedonia the pollen record does not show any sudden increase of human impact. The sudden disappearance of coniferous forest (chapter 2.3.) is contemporaneous with postulated invasions of the Dorians. If we assume that Dorian tribes moved in from elsewhere, then they took a rather difficult road. If they came from the north they apparently must have avoided the Plain of Macedonia, at least the pollen record shows no reaction here. A reason for avoiding the Plain of Macedonia may have been the inaccessibility of extensive marshy areas in the centre. The edges, however, would have offered reasonable opportunities for travelling. Did they meet opposition there?

The effects upon the vegetation of the Khimaditis/Vegoritis area must have been caused by a relatively large number of people, mainly herdsmen with sheep and goats, partly settlers who took to the valleys. The palynological information supports the idea of a Dorian invasion.

Although this is not a subject treated in this study, it is worth mentioning that in Southwestern Turkey a comparable event takes place at the same time (Bottema & Woldring, in prep.).

The other fluctuations in human impact concluded from the pollen record cannot be brought into line with each other or with information on migration that we know to have happened. For the post-Roman period the rather detailed palynological information from the lakes of Vegoritis and Volvi agrees to some extent with Athanasiadis' (1975) scheme for the North Thessalian diagrams of Litochoro and Pertouli.

The general pattern proposed by Athanasiadis can be found in the two Macedonian cores mentioned above. No signs are found of any impact made by invading Slavs and Vlachs.

To resume, one may state that invasions are not necessarily reflected in the pollen record. It is of importance if human pressure is exerted upon an untouched natural forest or a long-since degraded shiblyak. Post-Roman invasions in Northern Greece are not detectable in the pollen record. Increase in anthropogenic pressure upon the vegetation in Northern Greece around 4500 and 3100 B.P. may be related to successive invasions of Eurasian pastoralists (Gimbutas, 1974) and Dorian tribes.

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9. SUMMARY

New palynological information from Greece is presented. The information of Holocene lake sediments is used to compare the representation of pollen types with those from modern surface samples and with the pollen types derived from the herb and tree species listed in plant-sociological relevees from (semi-) natural forest. Differences in the qualitative composition of pollen assemblages from these sources are used to trace types that indicate human activity and influence on the vegetation in prehistoric and historical times. The concept of diversity in vegetation is compared with that in pollen assemblages. Some pollen types from trees, herbs or weeds connected with the activity of man are dealt with in particular. It is investigated in how far such pollen types could mark the first farming activities in Greece. Attention is paid to the various demographic events that are thought to have happened in Greece and their (possible) impact upon the environment.

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