PALYNOLOGY OF THE FIRST 30 METRES OF A 120 M DEEP SECTION IN NORTHERN GREECE

T. A. WIJMSTRA

Hugo de Vries-laboratorium, Universiteit van Amsterdam

SUMMARY

In this paper the results of a palynological investigation of a 120 m deep borehole in the Tenaghi Philippon, Macedonia (Greece) are given. These data show that during the Holocene mainly an oakwood forest was present. In the most recent part of the Holocene *Fagus* and *Abies* were also present. During the climatic extremes of the Weichselian an open vegetation existed. During the early interstadials a forest with *Quercus*, *Fagus* and *Carpinus* existed, whereas in the later interstadials stands of *Pinus* predominated. In the Late Glacial a not very dense oak forest was of some importance.

1. INTRODUCTION

The Tenaghi Philippon, lying 40 m above sea level (*fig. 1*), is a part of the Drama basin (location 41°10, N and 24°20, E). The boundary of this basin is formed by faults. The western boundary is formed by a fault along the Pangeon mountains, the eastern boundary by a fault along the Ori Lekanis; these mountains are 1956 and 1298 m high, respectively. In the north, the basin is bounded by the Falakron mountains. It is separated from the Aegaean Sea in the south by the low Symvolon mountains. In this basin clay, marl and peat were deposited. The peat is restricted to the southwestern part of the basin and covers a surface area of about 55 km^2.

In the surrounding mountains schists, gneisses, marls, marbles and granits are found. Owing to the presence of the above-mentioned mountains, drainage of the plain is only possible in a western direction by way of the Angitis river. This river breaks through a low range of hills, which range is slowly rising, so that the Angitis had to cut its way into this threshold and a canyon was formed. However, because the uprising of the threshold exceeded the scouring capacity of the river, the natural drainage of the plain has gradually deteriorated. Owing to these topografical conditions peat and lake deposits could be formed. On account of the slow changes in the drainage conditions, the growth of the peat could keep pace with the decline of the drainage. The marsh was fed by a number of springs, the run-off from the adjacent mountains being particularly important.

Before 1930 the surroundings of Drama were part of an extensive marsh. After this date, land-reclamation was started and gradually the marsh became cultivated. According to TURRILL (1929), Southern Macedonia has colder winters and somewhat wetter summers than the Peleponnesos or Thessalia. The

fig. 1 Macedonia with the Tenagi Philippon.

hot weather usually commences by the middle of May and continues till the beginning or sometimes the end of September. During this period the rain usually falls in the form of local thunderstorms, July and October being the driest months in Kavalla. Thunderstorms are most frequent in May and June and increase in frequency as one moves more inland.

In the inland valleys the temperature is frequently higher than near the coast, but the nights are cooler. The early months of the winter are the wettest of the year. Snowfall may occur from November till April and is heavier and more frequent towards the interior. For a summary of the climate in Kavalla, see *fig. 3*.

2. RECENT VEGETATION

In the Tenaghi Philippon proper but little is left of the original vegetation cover owing to land-reclamation. In one place around a spring-fed pond it was possible to get an idea of the original vegetation cover. In this pond *Nymphaea alba* and *Polygonum amphibium* were found. Along the margin a belt of riparian vegetation with *Phragmites communis*, *Iris pseudacorus* and *Typha angustifolia* was observed, followed by a tree zone consisting of *Alnus* and *Populus*. The hills on the western and eastern side showed a marked difference in their vegetation cover.

On the east side to ± 250 m upwards, vegetation is present in which *Calycotome villosa*, *Paliurus aculeata*, *Juniperus sp.*, *Pistacia terebinthus* and *Cistus*

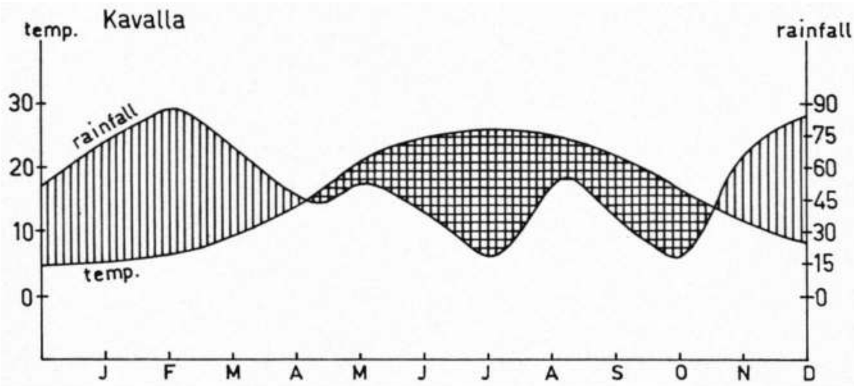

fig. 3 Temperature and rainfall at Kavalla

salviifolius are well represented. On the western side along the flanks of the Pangeon mountains, the lower slopes to 250 m upwards are covered by vegetation of *Quercus ilex, Erica arborea, Arbutus unedo, Cistus salviifolius, Cistus monspeliensis* and *Juniperus.*

Above 300 m the vegetation changes and low bushes of *Carpinus cf. orientalis, Quercus ilex* and *Quercus coccifera* are present. This scrub zone is very much influenced by grazing by goats. At 450 m the first trees appear: *Quercus coccifera, Carpinus orientalis* and, in addition, *Castanea, Vitis silvestris* and *Lonicera sp.* At 580 m the first conifers are found: *Pinus* cf. *nigra*, apart from *Quercus sessiliflora, Crataegus, Ostrya carpinifolia* and *Cornus sanguinea.*

Gradually *Pinus* becomes more abundant. Up to the timber line *Pinus nigra* is found together with *Ostrya carpinifolia* and *Acer sp.*

On the northern side of the marsh lie the Falakron mountains. The vegetation cover of this mountain was described by QUEZEL (1968), who reports the presence of *Pinus nigra* up to 1600 m and of a beautiful alpine flora above 1600 m.

3. THE POLLEN DIAGRAM

3.1. General remarks (see *fig. 2*)

In this diagram the results of the palynological analysis of the uppermost 30 metres of a 120 m deep section are shown. From 0 to 20 m down, a sample was analysed at every 10 cm. From 20 to 30 m down, the sample distance was 20 cm. The samples consisted mainly of peat, *gyttja* and clay, lake-marl occurring only between 12.50–13.50 and 14.50–15 m. All the samples were boiled with KOH and subsequently concentrated with a bromoform-alcohol mixture. The pollen grains are not corroded. For the representation of the results two general diagrams were drawn, in one of which the sum of all the arboreal and herbaceous pollen grains served as the basis of the calculations. The pollen grains of *Cyperaceae, Peplis, Rumex, Typha* and *Nymphaea* are not included in this sum.

The last elements belong either to open aquatic vegetation or to hygroseres along the margins of, or in, the marsh and must be excluded from the pollen sum if one wishes to reconstruct vegetational succession outside the marsh. In order to ascertain if *Gramineae* formed a part of the local vegetation or were only blown in from outside the marsh, another general diagram was constructed in which the pollen sum of trees, *Artemisia* and *Chenopodiaceae* formed the basis of the calculations. The percentages of pollen represented in the separate curves are calculated on the basis of the first pollen sum. In the two general diagrams the percentages of arboreal pollen are plotted from the left to the right and the percentages of herbaceous pollen types from the right to the left.

3.2. The zonation

A perusal of the general diagram shows in the first place that periods in which tree pollen dominates alternate with periods during which herbaceous pollen grains are relatively more important. The bulk of the tree pollen is provided either by *Quercus* and *Pinus*, or by *Pinus* or by *Quercus* alone (compare, for example, zone U: *Quercus* and *Pinus* – zone Y: *Quercus* only – and zone X: *Pinus* only). In periods of herbaceous pollen dominance the principal constituents of the pollen rain are *Gramineae*, *Artemisia* and *Chenopodiaceae*. The general diagram and the individual pollen curves enable the reconstruction of a zonation in the pollen sequence. The boundaries of zones Q up to and including Z are drawn where a transition is found from a period dominated by herbaceous pollen to one in which the percentages or arboreous pollen types were relatively more important. The subdivision of Q (into the zones Q1, Q2, Q3) was based on a change in the tree pollen curves, from a *Pinus-Quercus* pre-dominance to a *Pinus* or a *Quercus* pre-dominance (see R1, R2, R3). The subdivision into a, b and c was introduced to indicate individual maxima or minima of tree pollen percentages. The above-mentioned criteria serve for the following, more detailed discussion of the pollen zones:

Zone Q

In this zone the percentage of arboreous pollen varies between 80% and 60%. In the first part (Q1), the pollen percentage of *Quercus* pollen is higher than that of *Pinus*. The curve of *Carpinus* attains a value of 4%–5% and *Betula* is also of some importance. In zone Q2 the percentage of *Pinus* pollen reaches a maximum of about 60%. A decrease of *Quercus* and *Carpinus* pollen is noticeable. Throughout these two zones the percentages of herbaceous types are more or less constant, *viz*., about 20%. The chief contribuants to the percentage of herbaceous pollen are *Gramineae*, minor percentages of *Artemisia* also being present. In Q3 the percentages of *Quercus* pollen remain more or less constant, whereas the values for *Pinus* decrease from 50% to 30% and several new elements appear such as *Pistacia*, *Ulmus*, *Salix* and *Fraxinus excelsior*. The percentage of *Betula* is about the same as in Q1 and Q2, *viz*., about 4%.

Towards the end of this zone some *Tilia cordata* is present. The percentages of herbs rise gradually, which higher values are mainly caused by an increase of the *Artemisia* and *Chenopodiaceae* percentages. *Peplis* is recorded for the first time.

Zone R

This zone can be divided into three subzones, R1, R2 and R3. In zone R1 percentages of about 20% *Pinus* pollen are present, *Quercus* not being so well represented in this interval. Of the other trees and bushes only *Betula* and *Juniperus* are represented. *Artemisia* is the most important contribuant to the herbaceous pollen percentages, the values for *Chenopodiaceae* being low. In the last part of zone R1 *Ephedra* cf. *distachya* is present, and a maximum in the *Typha* and *Gramineae* curves is observed.

In the next zone (R2), a rise in the *Quercus* percentages is noticeable. The percentages of *Pinus* cf. *nigra* are as high as in the previous zone. Also present are pollen grains of *Tilia, Carpinus, Fraxinus excelsior, Betula* and *Cistus.* The percentages of *Artemisia* are considerably lower than in R1, whilst those of *Chenopodiaceae* remain more or less constant, *viz.*, 5–8%. The percentage of grass pollen is about 10%.

Zone R3 yields more or less the same picture as zone R1, *viz.*, a high representation of herbaceous pollen mainly caused by a rise in the *Artemisia* and *Chenopodiaceae* percentages. The percentages of the grasses are more or less the same as in zone R2. The principal difference between R3 and R1 lies in the tree pollen percentages, both the Pine and the Oak values being very low in R3. Just as in zone R1 some pollen grains of *Juniperus* are found in this zone, but here associated with grains of *Plantago* and *Ephedra distachya.*

Zone S

Throughout zone S the AP percentages are high (up to 80%). The NAP percentages vary between 20 and 40%. The important constituents are *Artemisia* and *Gramineae.* In zone S1 the *Quercus* percentages rise sharply to attain 37% at 26.80 m. The curve of *Pinus* is also rising, but not to such an extent as the *Quercus* curve. Also represented in this zone are pollen grains of *Tilia, Carpinus, Corylus* and *Ulmus.* The latter tree is represented by rather high percentages, the highest occurring in zone S. Pollen grains of *Vitis silvestris* are restricted in their occurrence to S1. In zone S2 the *Quercus* curve has a distinct maximum, whereas the values of Pine pollen are rather low. Other characteristics of this zone are: the first appearance of *Abies* and *Picea*, the constantly high values of *Corylus* and a low representation of *Pistacia* at the beginning and at the end of this zone.

In zone S3 the percentage of *Quercus* slowly falls off and that of *Pinus* rises. In the first half of this zone (S3a) a maximum in the *Carpinus* curve was noted, whereas in zone S3b higher values of *Abies* are present. This zone (S3) is also characterised by the first appearance of *Ostrya* which reaches its maximum value in zone 3a. *Ephedra fragilis* is restricted in its occurrence to zone 3a.

Zone S4 shows a relatively high maximum in the *Quercus* curve together with constantly high percentages of *Pinus* pollen; additional characteristics are the presence of *Ephedra distachya* and *Plantago*. In the course of this interval all thermophilous trees disappear.

Zone T

In zone T the pollen spectrum differs in that the previously recorded higher values of AP-percentages are replaced by very high percentages of NAP. In this zone the percentages of *Artemisia* and of *Chenopodiaceae* show maximum values. The occurrence of low, constant percentages of *Plantago* and *Ephedra* cf. *distachya* is observed. The percentages of *Chenopodiaceae* are high in the lower part of zone T, but gradually fall off to 10% in the upper part of this zone.

Zone U

In this zone the pollen rain is again characterized by high percentages of arboreal pollen. Also noticeable is the constant occurrence of *Nymphaea* and the rather irregular course of the *Gramineae* curve with two maxima, one at 22.0 m and one at 22.7 m. These high percentages have a considerable effect on the course of the different AP curves; therefore, diagram B is to be preferred for a description of this zone. In the lower part U1, a maximum in the *Pinus* curve is present, whereas towards the upper part of this zone the *Quercus* curve rises. Restricted in their occurrence to zone U1 are *Pistacia* and *Sanguisorba minor*, whereas *Tilia*, *Ulmus* and *Fraxinus excelsior* appear for the first time at the boundary U1–T4.

In U2 the percentages of *Pinus* are lower than in the preceding and in the next zone and a maximum in the *Quercus* curve is present. This zone is also characterized by a constant representation of *Carpinus*, *Corylus* and *Picea*. This zone can be subdivided into two parts (U2a and U2b). The curves of *Cistus* and of *Tilia* are restricted to U2a and those of *Vitis* and *Fraxinus excelsior* to U2b.

At the boundary with zone U3, a maximum in the *Juniperus* curve is present. In zone U3 the *Quercus* curve starts to fall off, whereas the *Pinus* curve shows a distinct maximum. In this zone no pollen grains of *Tilia*, *Carpinus* and *Corylus* were recorded. The curve of *Juniperus* remains high in this interval.

Zone V

In the course of the pollen sedimentation in this zone a general lowering of the percentage of *Pinus* cf. *nigra* from 19% to 3% is noticed. *Quercus* is no longer present. This zone is also characterized by high percentages of herbaceous pollen types, mainly *Artemisia*, *Chenopodiaceae*, and *Gramineae*. By means of the maxima of the Pine curve, this zone is subdivided into V1, V2 and V3. During the sedimentation of zone V1 the pine curve varies between 12 and 25% and in V2 between 5 and 25%, whereas in V3 a rather constant value of 5% is noticed. The individual maxima of the pine curve are present at the levels at V1a, V1c, V2a, V2c. The percentages of *Artemisia* pollen are more or less constant throughout this zone. The *Chenopodiaceae* curve, on the other hand, shows a constant rise from 5–10% in the lower zones to 10–15% in zone V3 (all percentages given here are those of diagram A).

Zone P

During the sedimentation of zone P a series of fluctuations in the tree pollen percentages can be observed. The NAP percentages are somewhat lower than in the last-formed part of zone V, but remain high. Zone P1 starts with an increase in the *Pinus* percentages to 15%, followed by a fall-off to 1–2%. In the last-formed part of zone P1 the *Pinus* curve increases again to 24% and falls off once more towards the boundary with the next zone. Also in this zone a maximum of 10% in the *Quercus* curve is noticed. The maxima of this *Quercus* curve coincide with the maxima of the *Pinus* curve. In zone P1a the *Juniperus* curve shows rather high values (up to 5 per cent.). Also a few grains of *Ephedra* and a continuous curve of *Xanthium* can be noticed. During the deposition of zone P1, *Betula* was present. In the interval P1b low percentages of *Abies* and in the last-formed part of this subzone a rise in the *Juniperus* curve can be observed.

In zone P2 the percentages of AP fall off and a maximum in the NAP values is present. This rise is due to an increase of the *Artemisia* and *Chenopodiaceae* percentages. In P2 also low percentages of *Helianthemum, Ephedra fragilis* and *Plantago* sp. are present.

In the part of the diagram representing zone P3 the curves of *Pinus* and *Quercus* show two maxima, separated by an interval with high *Artemisia* and *Chenopodiaceae* values. In the first maximum P3a, *Abies* and *Tilia* are present. This zone P3a begins with a rise in the *Juniperus* curve. In P3c, apart from *Pinus* and *Quercus* only a few per cents. of *Corylus* are present. Throughout this whole zone *Ephedra distachya* and *Juniperus* are well represented. Pollen zone P4 again shows low values of AP and high values of NAP. These high values are mainly caused by a rise in the *Artemisia* and *Chenopodiaceae* curves. In this interval the percentages of *Juniperus* remain rather high.

In pollen zone P5 the tree pollen curve rises to a maximum of about 20%. This is mainly caused by increasing *Pinus* values. Also noticeable in this interval is the presence of *Picea omorikoides* and *Pinus haploxylon* types of pollen grains. The values of the *Juniperus* curve are lower than in the former zone. The presence of a maximum of *Peplis* and of *Typha*, and a very high value of *Gramineae* at the end of this zone is striking. An indication of the sedimentation environment is given by the presence of diatoms in this zone.

In P6 the pollen rain was mainly composed of *Artemisia* and *Chenopodiaceae*. Small percentages of *Juniperus, Ephedra distachya, Ephedra fragilis, Xanthium, Helianthemum* and *Plantago* are also present.

The P7 interval shows higher values of *Pinus* pollen; *Juniperus* is absent. Apart from *Artemisia* and *Chenopodiaceae*, constituting the most important components of the NAP, *Helianthemum* is present.

Zone X as a whole is characterized by its continuously high values of *Artemisia* and *Chenopodiaceae* and an uninterrupted curve for *Xanthium, Juniperus, Plantago* and *Helianthemum. Pinus* is the chief component of the arboreal pollen. By means of fluctuation of this curve we can recognise 4 subzones. During the intervals X2 and X4 the *Pinus* percentages are high. At the same time the continuous presence during the deposition zone X4a of *Hippophaë* can be noticed. In zone X4 two maxima in the Pine curve are present, one at X4c and one at X4a. In X1, X3 and X5 very low values of arboreal pollen are present. In this interval the percentages of *Artemisia*, *Chenopodiaceae*, and *Gramineae* show a maximum. The percentages of *Chenopodiaceae* increase from 10% in zone X1 to 20% in zone X5. With the aid of the tree pollen fluctuations zone Y is divided into three parts, *viz.*, zones Y1, Y2 and Y3. The first part Y1 shows an increase in pine pollen percentages and a decrease in *Artemisia* and *Chenopodiaceae* values. Also a rise in the oak pollen curve can be noticed and the same applies to *Betula*. In this zone *Tilia* disappears for the first time. Both *Ephedra distachya* and *Xanthium* are still represented by rather high percentages. In zone Y2a *Quercus* attains its first maximum. Also noticeable in this zone is the first appearance of *Corylus* and the disappearance of *Xanthium* and *Ephedra*.

In Y2b a slight lowering of the oak percentages occurs. The continuous curves of *Ulmus*, *Pistacia* and *Sanguisorba minor* start at the boundary Y2a–Y2b.

In the course of zone Y2c a maximum in the *Quercus* percentage is reached and in the rising part of this *Quercus* curve a maximum in the *Pistacia* curve is present. As in the former three zones, *Vitis* is noticeable.

In zone Y3 the percentages of NAP increase again and a marked fall in the tree pollen percentages can be noticed. The rise in the NAP-percentages is mainly caused by an increase in the *Artemisia* and *Chenopodiaceae* values. This is most clearly reflected in diagram B, in which the *Gramineae* are not included in the sum. The *in-situ* presence of reed is made probable by the macro-remains of *Phragmites* in this interval.

In zone Z the NAP-percentages drop to about 10%. In the first zone (Z1a) a rise in the *Quercus* curve and higher values of *Juniperus*, *Pistacia*, *Sanguisorba* and *Betula* are noticeable. This zone can be divided into two parts, *viz.*, Z1a in which *Pistacia* is relatively more important, and Z1b in which *Juniperus* is more important.

In Z3, apart from appreciable values of the *Quercus* percentages, a clearly marked *Corylus* peak is present. This zone can also be divided into two parts, *viz.*, Z3a in which the values of *Fraxinus* are relatively lower, and Z3b in which these values are higher.

In zone Z3 the rise of the *Abies* curve starts and a maximum of the *Ostrya* curve is the most characteristic feature of this zone. In zone Z4 the curves of *Fagus* and *Ericaceae* are noticeable, whereas zone Z5 is defined by the increasing values of the *Pistacia* and the NAP-percentages. Also noteworthy is the presence of *Rhus*.

4. THE DEVELOPMENT OF VEGETATION (*table 1, fig. 2*)

From the pollen zones described in the preceding chapter the following vegetational history can be deduced.

During the period represented by zone Q, judging by the high percentages of arboreal pollen recorded, the presence of a forest cover in the surrounding hills and on the plain itself seems to be highly probably.

In zone Q1 an oak forest with some stands of *Carpinus* seems to have been present in the area. The absence of *Pistacia* and *Juniperus* points to a rather closed type of forest. This oak forest changed into an oak-pine forest during zone Q2. The presence of pollen of both *Pinus sylvestris* and *Pinus nigra* provides an indication of the composition of this forest.

In zone Q3 the *Pinus* forest changed into a more open type of forest in which *Juniperus, Pistacia, Quercus ilex* and *Q. coccifera* were important constituents. In this open type of vegetation *Artemisia* and *Chenopodiaceae* become more important during zone R1. In zone R2, climatic changes allowed the re-establishment of the oak-pine forest. In zone R3 the vegetation cover was once more of a more open character. This may be concluded from the presence of *Helianthemum, Juniperus* and *Ephedra,* and from the very low percentages of arboreal pollen. This open vegetation changed into a *Quercus-Pinus* forest during zone S1. The presence of *Tilia, Ulmus* and *Corylus* suggests a rather warm and humid type of climate. This forest in the course of zone S2 changed into an oak forest with an admixture of some *Corylus.* In this *Quercus* forest stands of *Carpinus* developed; during zone S3 also a few beeches were present in the area. In zone S3b this *Quercus-Carpinus-Fagus* forest changed into a forest-type in which *Abies, Picea,* and *Pinus nigra* occurred.

In the last zone (S4) an *Quercus-Pinus nigra* forest was succeeded by open *Artemisia-Chenopodiaceae* vegetation in which *Ephedra* and *Plantago* occurred. This open vegetation type changed into a *Pinus-Quercus* forest by the beginning of zone U. The presence of *Pistacia, Sanguisorba* and *Quercus ilex* suggests a rather open character of this woody vegetation.

In U2 this rather open forest changed into an oak forest with *Carpinus,* the presence of *Tilia, Corylus* and *Ulmus* suggesting a rather warm and humid climate. The presence of *Cistus* leads to the conclusion that this forest was not very dense. In the last part of zone U this oak forest was replaced by an open pine forest with stands of *Juniperus.* According to the pollen record, *Pinus nigra* must have been an important constituent of woody vegetation in this area.

In the zones V, P and X the chief component of the tree cover is *Pinus nigra.* Only in zones P3 and P5 some oak is present, but the lower percentages of arboreal pollen do not warrant the postulation of the occurrence of a forest cover in the area at that time. The continuous representation of *Juniperus, Artemisia, Chenopodiaceae, Ephedra* and *Xanthium* can be explained by supposing a steppe- or savanna-like character, more or less according to the relative importance of stands of trees. For specific details of this type of vegetation, compare *table 1, fig. 2.* During the deposition of zone Y, pine-oak stands established themselves again in the area, but these stands did not form a closed forest canopy. *Artemisia* and *Chenopodiaceae* gradually became less important constituents of the vegetation cover, but *Ephedra* and *Xanthium* were still present.

During zone Y2, *Quercus ilex* became more frequent and *Pinus* was not so well represented. From the presence of *Vitis, Pistacia* and *Sanguisorba* the occurrence of a rather open type of forest may be concluded. The continuous presence of *Juniperus* also leads to this conclusion. In zone Y3 this type of open forest vegetation changed for the last time into open *Artemisia-Chenopodiaceae* vegetation, but *Juniperus* and *Pistacia* could maintain themselves in the area.

During zones Z1 and Z2 open *Quercus ilex-Pistacia-Juniperus* vegetation was present in the area. This rather open type of vegetation changed into a forest in which *Quercus coccifera* was well represented. This type of forest was present during Z3 and Z4, at first with an admixture of *Corylus* to be followed by an *Ostrya*-zone.

During the period Z4 the vegetation cover assumed a more open character judging from the increasing percentages of *Ericaceae.*

In zone Z5 this open character became more pronounced by the presence of *Rhus* and *Pistacia* and by the higher pollen percentages of *Erica* cf. *arborea* and *Arbutus unedo.*

For a summary of this chapter, see *fig. 2.* From this series of vegetational changes it becomes evident that open *Artemisia-Chenopodiaceae* vegetation was not always bordered by the same type of arboreal vegetation during the development of our sequence (see *table 2*). From this table it is evident that we have three types of border vegetation:

a. one in which *Quercus* formed the chief compound;
b. one in which *Quercus* mixed with *Pinus* formed the border, and
c. cases in which *Pinus* woodland alone formed the border.

From these facts we may conclude that it is not the temperature or the humidity alone which is decisive in this connection. The table shows that three different types of arboreal vegetation penetrate into the open *Artemisia-Chenopodiaceae* zone, *viz.*,

a. open *Quercus ilex-Pistacia-Juniperus* vegetation;
b. *Quercus sessiliflora-Quercus pubescens* vegetation;
c. *Pinus nigra-Pinus sylvestris* vegetation.

In order to explain the sequences observed in our diagram we must keep in mind that *Quercus ilex* is not very frost-resistant. *Pistacia* is also indicative of an almost frost-free climate (RIVAS GODAY 1956). The combination of trees mentioned sub (b), on the other hand, has a greater tolerance to lower temperatures, but requires more humidity. Situated at higher altitudes than these two oak-belts, which do not differ so much from each other in temperature tolerance as in humidity tolerance, lies a pine belt. *Pinus nigra* and *Pinus sylvestris,* amongst others, are important trees in this belt. At this transitional zone from oak belt into pine belt, temperature changes must have been more important than changes in humidity.

In this pine forest and in the two types of oak forest open vegetation with *Artemisia, Chenopodiaceae* and grasses can most probably be established by a lowering of humidity as follows from a short literature survey. BRAUN BLANQUET (1961), for instance, gives an example of *Artemisia-Ephedra* vegetation in which *Quercus pubescens* can establish itself. WENDELBERGER (1956) gives also many examples of stands of the *Quercetum pubescens* in contact with open *Artemisia-Gramineae* vegetation.

Z	1	Quercus ilex, Juniperus, Pistacia
Y	3	open Artemisia, Chenopodiaceae veg.
	2	Quercus ilex, Juniperus, Pistacia
	1	Pinus cf. nigra, Quercus
X	5	open Artemisia, Chenopodiaceae veg.
	4	Pinus cf. nigra
	3	open Artemisia, Chenopodiaceae veg.
	2	Pinus cf. nigra
	1	open Artemisia, Chenopodiaceae veg.
P	7	Pinus cf. nigra
	6	open Artemisia, Chenopodiaceae veg.
	5	Pinus cf. nigra
	4	open Artemisia, Chenopodiaceae veg.
	3	Pinus cf. nigra
	2	open Artemisia, Chenopodiaceae veg.
	1	Pinus cf. nigra
V	3	open Artemisia, Chenopodiaceae veg.
	2	Pinus cf. nigra
U	1	Pinus cf. nigra, Quercus ilex
T		open Artemisia, Chenopodiaceae veg.
S	4	Quercus sessiliflorae, Q. ilex, Pinus cf. nigra
S	1	Quercus, Pistacia
R	3	open Artemisia, Chenopodiaceae veg.
R	2	Quercus sessiliflorae, Q. ilex
	1	open Artemisia, Chenopodiaceae veg.
Q	3	Quercus ilex, Pistacia, Pinus cf. nigra

Pollentypes at boundary with open Artemisia, Chenopodiaceae vegetation
Table II

The transition from stands of *Quercus ilex* to open *Artemisia-Chenopodiaceae* vegetation is described in RIKLI (1943) from Spain (see also SALVADOR RIVAS GODAY 1956). TROLL (1941), gives an example of pine vegetation in contact with an *Artemisia-Chenopodiaceae* belt.

From this survey it seems obvious that under natural conditions *Artemisia-Chenopodiaceae* vegetation is competing with different types of arboreal vegetation, which arboreal vegetation is apparently determined by climatical and microclimatical factors. In order to illustrate the interdependence of all these factors the following scheme (*fig. 5*) is given. By changing temperature and humidity separately or jointly it is possible to explain the changes in the vegetation cover observed in the diagram. This scheme may eventually give us an indication of the climate prevailing during the successive zones observed in the diagram, but before we can solve this problem, a more precise identification of the *Artemisia* species and *Chenopodiaceae* taking part in the formation of the particular type of open *Artemisia-Chenopodiaceae* vegetation will be necessary.

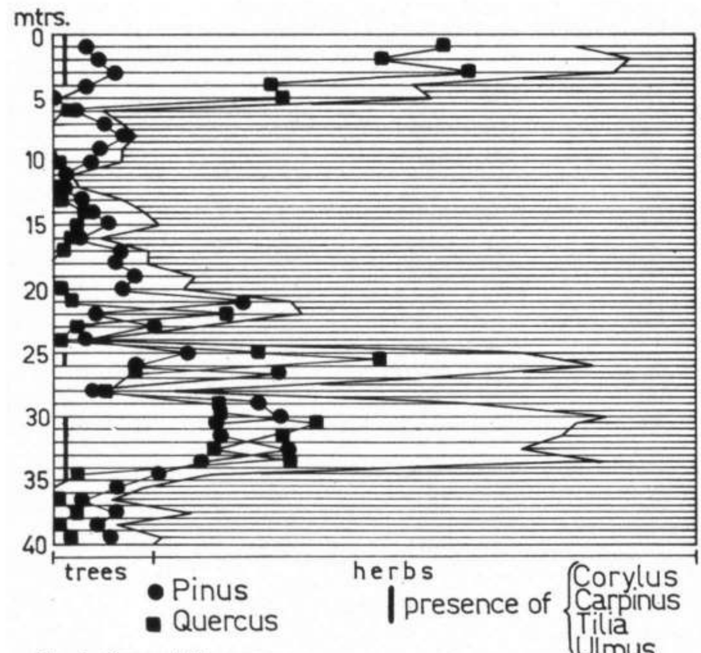

Fig. 4. General Diagram

5. ABSOLUTE AGE DETERMINATIONS

At the ^{14}C laboratory of the Groningen State University, up to now three samples from the 1964 boring have been dated. Furthermore the dating of the first three samples was available from a former drill-hole situated at a distance of about 50 m from the new drilling site. These samples yielded the following results:

GR.N. 4182	depth	4.30	age	7.850 ± 50	B.P.
GR.N. 4183	depth	6.25	age	14.600 ± 200	B.P.
GR.N. 4184	depth	15.60	age	>40.000	B.P.
GR.N. 1467a	depth	9.50–10	age	22.640 ± 165	B.P.
GR.N. 1467b	depth	11.00–11.50	age	28.840 ± 300	B.P.
GR.N. 1467c	depth	13.50–14	age	34.770 ± 580	B.P.

With these datings it was possible to make an estimation of the age of the pollen zone boundaries in the first 18 metres.
(See *table 3*).

Z1–Y3 –10.500 B.P.	P7–P6–30.000 B.P.
Y3–Y2c–10.900 B.P.	P6–P5–31.840 B.P.
Y1–Y2a–13.500 B.P.	P5–P4–33.000 B.P.
X5–X4 –16.600 B.P.	P3–P4–34.770 B.P.
X3–X4 –20.000 B.P.	P3–P2–37.000 B.P.
X2–X3 –22.000 B.P.	P2–P1–39.000 B.P.
X2–X1 –23.750 B.P.	
X1–P7 –30.000 B.P.	

Table III

6. THE AGE OF THE POLLEN ZONES AND CORRELATION WITH OTHER AREAS

In order to be able to correlate the data with those obtained in other areas it is necessary to establish criteria by which the stadial, interstadial, or interglacial character of our vegetational units can be recognised. This leads to the following description:
Interglacial: period in which in our area a forest was present with a clear-cut zonation and many thermophilous and moisture loving elements (*Quercus pubescens, Quercus sessiliflora, Carpinus, Fagus, Tilia, Ulmus, Abies* and *Picea*).
Interstadial: either an open arboreal vegetation in which at least *Quercus ilex, Pistacia* and *Juniperus* were important, or a pine forest was present in the area, which of the two depending on the prevailing average temperature in the area.
Stadial: Open *Artemisia-Chenopodiaceae* vegetation.

Subsequently criteria can be derived from the vegetation types occurring in zone Z, which is an interglacial according to the ^{14}C dating, and from the vegetation types occurring during the deposition of zones Y2 and X4, periods which can be correlated with other interstadials according to their ^{14}C dating (see below). The first pollen zone Q belongs to the last interglacial but one. This could be deduced from *fig. 4*, a diagram in which the sample distance was about 1 m. This diagram shows that periods with forest vegetation were succeeded by periods in which open vegetation was more important. The periods in which such elements as *Carpinus, Fagus, Tilia* and *Fraxinus* were present must have had a climatic type which was not very much different from that of the present time. From *fig. 4* it is clear that zone Q belongs to such a period in

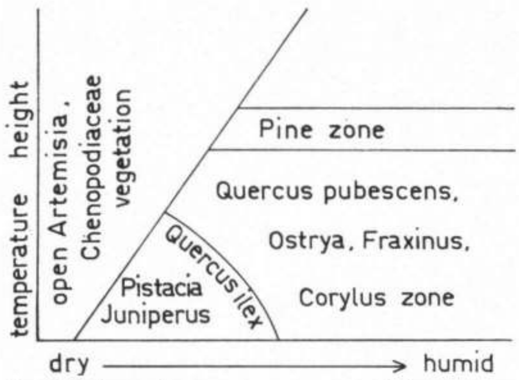

Fig. 5. Relation between vegetation and climate.

which a forest with taxa such as *Carpinus* etc. existed and had, therefore, an interglacial character according to our definition. It seems, accordingly, logical to correlate zone Q with the last interglacial but one, the Eemian. The zones preceding Z consequently belong to the Weichselian.

In the first part of the Weichsel glacial a series of interstadials have been reported: from Amersfoort (ZAGWIJN 1961); from Brørup (ANDERSEN 1961) and from Odderade (AVERDIECK 1967). The climate of the Amersfoort interstadial seems to be somewhat less mild than during the Brørup stage (FRENZEL 1967), whereas during the Odderade interstadial the climate was somewhat intermediate between the Brørup and the Amersfoort. In our section shown in *fig. 2* there are three fluctuations in which a forest had established itself after an amelioration of the climate (compare zone R2, zones S1, S2, S3 and zone U2; in the interval of zone R2 the amelioration was of shorter duration than in the other two zones. For these fluctuations of interstadial character the local names of Doxaton, Drama and Elevtheropolis were proposed. For the correlation with N.W. Europe two alternatives are given.

Elevtheropolis	Odderade	Brørup
Drama	Brørup	Amersfoort
Doxaton	Amersfoort	unknown in W-Europe

Further research is needed to solve this problem, but for the time being the first correlation is preferred.

For the two fluctuations in zone P the name Heraklitsa interstadial is chosen. This interstadial can be divided into two stages, Heraklitsa 1 and Heraklitsa 2. With the help of the sedimentation rate, this interstadial can be dated as between 42.000 and 39.000 years B.P.

In N.W. Europe, too, an interstadial is known in this range (VAN DER HAMMEN *c.s.* 1967), the Moershooft.

The next interstadial P3 is also divided into two periods and lasted from

39.000–35.000 B.P. This interstadial is locally called the Kalabaki interstadial. When we look at these provisional datings a close correspondence is noted with a series of ^{14}C datings given by Van der Hammen *et al.* for the so-called Hengelo interstadial, which was estimated as between 39.000 and 37.000 years B.P.

The next amelioration of climate took place between 33.000 and 28.000 B.P. according to the rate of sedimentation. This also coincides with an interstadial in N.W. Europe, the so-called Denekamp interstadial (see Van der Hammen *et al.*). Locally this period is called the Krinides interstadial, subdivided into Krinides I and Krinides II.

Another fluctuation is found between 9.50 m and 10.20 m, which is locally referred to as the Photolivos interstadial. This took place between 22.000 and 23.750 years B.P. In N.W. Europe no equivalent of this interstadial is found. It seems to be present in France, where it is called the Tursac interstadial (GOURHAN 1968). During the deposition of pollen zone X one major fluctuation occurred between 16.000 and 20.000 years B.P. (the Philippi interstadial). The date of 16.000 B.P. agrees fairly well with the end of the Lascaux interstadial (GOURHAN 1965), and therefore, a correlation of Philippi interstadial with that of Lascaux is plausible. The next amelioration of climate took place in zone Y2 when an open oak-forest had established itself in the area around the Tenaghi Philippon. This period falls between $\pm$ 13.500 and 10.900 B.P. Locally it is called the Xanthi interstadial, which must be correlated with the Allerød-Bølling interstadial occurring elsewhere.

The beginning of zone Z falls at 10.000 B.P. and coincides with the beginning of the Holocene. We will not attempt to a subdivision of the Holocene until more ^{14}C datings are available. In the paper on the stratigraphy of the last glacial in the Netherlands by VAN DER HAMMEN *c.s.* (1967), the combined levels and stratigraphical units Late Glacial – Upper Pleniglacial, Middle Pleniglacial and Early Glacial were recognized. The diagram from Greece under discussion indicates that these units can also be recognised in the Drama area.

In zone R till the end of zone U the periods with forest vegetation were of longer duration than the periods with open vegetation, and the percentages of *Artemisia* and *Chenopodiaceae* amount to 5–10% during the woodland phases. This period can be compared with the Early Glacial. In the next period (zone V) open vegetation was present in our area. This is the first time *Artemisia* and *Chenopodiaceae* contributed appreciable percentages to the pollen rain. This period could be compared to the Lower Pleniglacial of the above-mentioned authors.

In zone P a rapid succession of open forest and open *Artemisia – Chenopodiaceae* vegetation is present. This period might be compared to the Middle Pleniglacial.

During zone X a dry open vegetation prevailed and this phase corresponds with the Upper Pleniglacial. The boundary Upper Pleniglacial – Late Glacial is lying at the level where the percentages of *Artemisia* start to fall off. In N.W. Europe this boundary is placed where these percentages commence to rise (VAN DER HAMMEN 1964). The boundary Late Glacial – Holocene is placed at the beginning of the rise of the *Quercus*-curve after the last *Artemisia–Chenopodiaceae* rise of zone Y3.

7. CONCLUSION

In this diagram no indication of a hiatus can be found and consequently it seems to represent the first uninterrupted diagram of the Weichselian. In the second place no indication has been found of the occurrence of forest vegetation during the Weischselian. In this period a lowering of temperature and a lowering of humidity is highly probable. Furthermore, the succession in this area is readily comparable to that found in N.W. Europe.

ACKNOWLEDGEMENTS

The author likes to thank the Netherlands Organization for the Advancement of Pure Research (Z.W.O.) for the grant which made the drilling possible. He is also greatly indebted to the Gront Mij. and especially to Mr. L. J. M. Klaar for bringing the site to his attention. He likes to thank Dr. T. van der Hammen for the many pleasant discussions during the investigation and Prof. A. D. J. Meeuse for his critical revision of the text and valuable advice.

The help of Mrs. M. J. Content née Besselink, who typed the manuscript, of Mrs. R. W. Bakker née Posthumus, who prepared all the samples and of Mr. H. J. Koerts Meijer, who prepared all the figures, is gratefully acknowledged.

REFERENCES

Andersen, S. Th. (1961): Vegetation and its Environment in Denmark in the Early Weichselian Glacial. *Danmarks Geol. Unders.* II raekke Nr. **75**: 1–176.

Averdieck, F. R. (1967): Die Vegetationsentwicklung des Eemsinterglazials und der Früh-Würm-Interstadiale von Odderade/Schleswig Holstein. *Fundamenta (Monographien zum Urgeschichte)*, Reihe B, **2**: 101–125.

Beug, H. J. (1961): Beiträge zur postglazialen Floren- und Vegetationsgeschichte in Süddalmatien: Der See "Malo Jezero" auf Mljet. *Flora* **150**: 600–656.

— (1967): Probleme der Vegetationsgeschichte in Süd-Europa. *Ber. Dtsch. Bot. Ges.* **80**: 682–689.

— (1967): On the forest history of the Dalmatian coast. *Rev. Palaeobotan. Palynol.* **2**: 271–279.

— (1967): *Contributions to the postglacial vegetational history of Northern Turkey, Quaternary Paleoecology.* New Haven and London.

Braun Blanquet, J. (1961): *Die inneralpinen Trockenvegetation.* Stuttgart.

— (1964): *Pflanzensociologie.* Wien.

Frenzel, B. (1964): Über die offene Vegetation der letzten Eiszeit am Ostrande des Alpen. *Verh. Zool. Botanischen Gesell., Wien* 103 & 104: 110–143.

— (1967): *Die Klimaschwankungen des Eiszeitalters.* Braunschweig.

Hammen, T. van der., G. C. Maarleveld, J. C. Vogel & W. H. Zagwijn (1964): Stratigraphy, climatic succession and radiocarbon dating of the Last Glacial in the Netherlands. *Geol. & Mijnbouw* **46**: 79–95.

—, T. A. Wijmstra & W. H. van der Molen (1965): Palynological study of a very thick peat section in Greece and the Würm glacial vegetation in the Mediterranean region. *Geologie & Mijnbouw* **44**: 37–39.

Lavrenko, E. M. (1959): Die Felssteppen der Umgegend von Wien und des uralten Mediterrangebietes. *Veröff. Geob. Inst. Rübel*, Heft **35**: 114–127.

Leroi-Gourhan, A. (1965): Les analyses polliniques sur les sédiments des grottes. *Bull. Assoc. France pour l'étude du Quaternaire*, no. **3** (1965), **2**: 145–152.

— (1968): L'Abri du facteur à Tursac. *Gallia Prehistoire* **11**: 123–131.

QUEZEL, P. (1968): Signification phytosociologiques des Gesnériacées grècques. *Collectanea Botanica*, **8** (2), no. **54**: 947–973.

— & J. CONTANDRIOPOULOS (1968): Contribution à l'étude de la flore de la Macédoin grècque. *Candollea* **23**: 17–38.

RIKLI, M. (1934): *Das Pflanzenkleid der Mittelmeerländer*. Bern.

TEICHMÜLLER, M. (1968): Zur Petrographie und Diagenese eines fast 200m mächtigen Torfprofiles (mit Übergängen zur Weichbraunkohle) im Quartär von Philippi (Mazedonien). *Geol. Mitt.* **8**: 65–110.

TURRILL, W. B. (1929): *The plantlife of the Balkan Peninsula. A phytogeographical study.* Oxford.

RIVAS GODAY, S. (1956): Übersicht über die Vegetationsgürtel der Iberischen Halbinsel kennzeichnenden Arten und Gesellschaften. *Veröff. des Geobot. Inst. Rübel.* Heft **31**: 32–68.

WRIGHT, H. E., J. H. MCANDREWS & W. VAN ZEIST (1967): Modern pollen rain in Western Iran and its relation to plant geography and Quaternary vegetational history. *J. Ecol.* **55**: 415–443.

ZEIST, W. VAN, (1967): Late Quaternary vegetation history of Western Iran. *Rev. Palaeobotan. Palynol.* **2**: 301–311.

Note:
From the C14 Laboratory of the State University of Groningen the following dates were obtained after the manuscript was finished:

TF 3	16.360	± 90 BP	depth 7.30 m
TF 4	17.580	± 100 BP	depth 7.95 m
TF 5	32.010	± 320 BP	depth 12.75 m
TF 6	42.210	± 1195 BP	depth 15.25 m
TF 7	45.760	± 1390 BP	depth 16.25 m
TF 9	47.670	± 2700 BP	depth 16.75 m
TF 10	53.300	± 3300 BP	depth 21.75 m

These dates confirme the suggested correlation in table I with N.W. Europe

Bijlage Acta Botanica Neerlandica 18 (4) 1969
T. A. Wijmstra, Palynology in Northern Greece

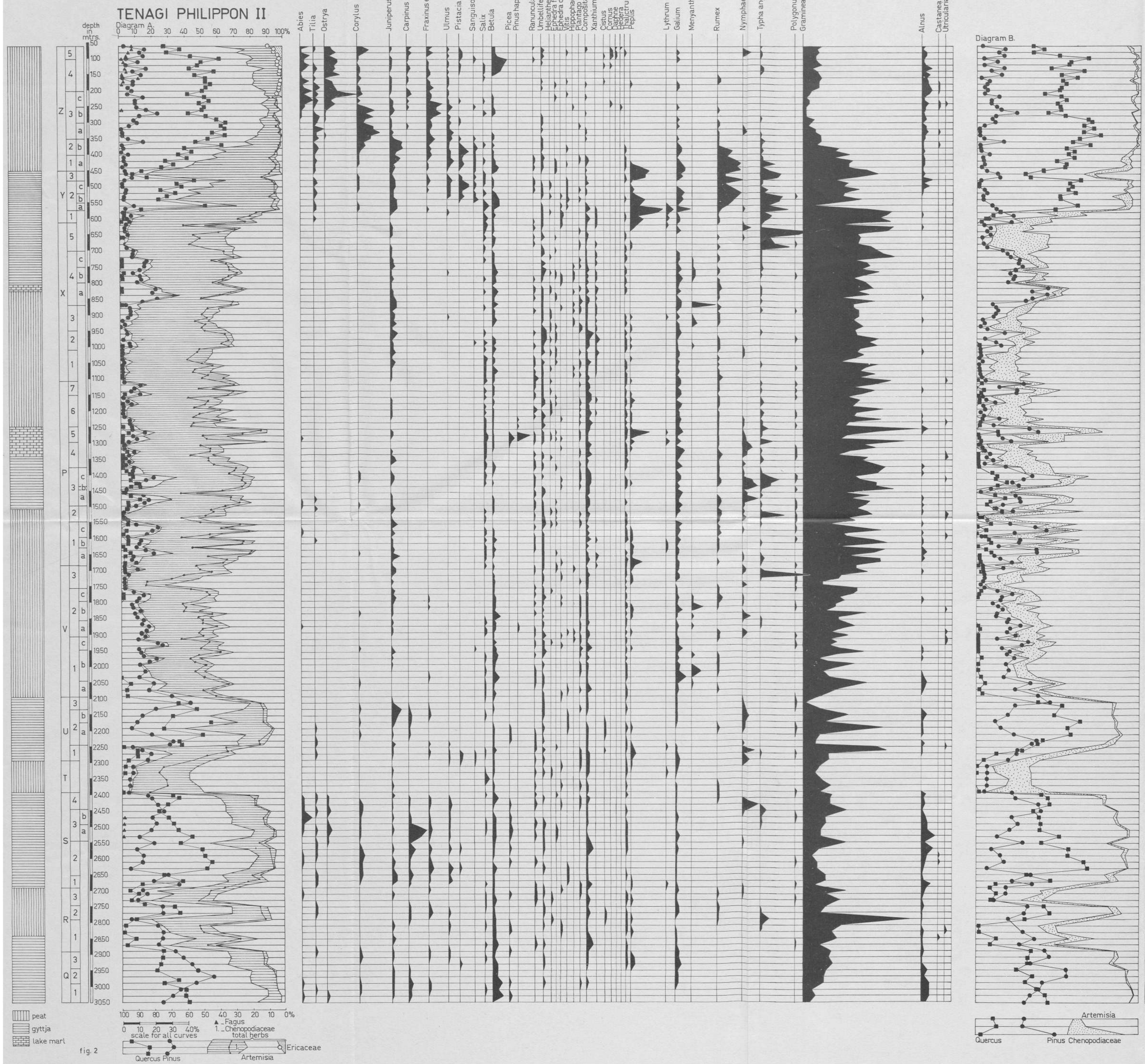

fig. 2

Table I

Zone	Subzone		Local names of Interstad.	Correlation with N.W.Europ			Absolute Ages/C14	Character of vegetation
Z	5					Holocene		Schlibjak, Rhus, Arbutus unedo Pistacia, Quercus.
Z	4					Holocene		more open oak forest with some Abies?
Z	3	c				Holocene	5000	oak forest with Ostrya zone
Z	3	b				Holocene		oak forest with Fraxinus zone
Z	3	a				Holocene		oak forest with Corylus zone
Z	2	b				Holocene		oak forest with some Pinus
Z	1	a				Holocene	10000	open oak forest with Pistacia, Juniperus
Y	3			Younger Dryas		Late glacial	10.300	open Artemisia, Chenopodiac. veg.
Y	2	c b a	Xanthi	Allerød / Bølling complex		Late glacial	10.900	open oak forest with Pistacia Juniperus Vitis Ulmus Sanguisorba.
Y	1			Older Dryas		Late glacial	13.500	Pinus, Quercus in open Art. Chenop. veg.
X	5				W E I C H S E L I A N	Upper pleniglacial	14.600	open Artemisia, Chenopodiaceae vegetation.
X	4	c b a	Philippi	Lascaux		Upper pleniglacial	16.600	open Artemisia, Chenopodiaceae vegetation. with stands of Pinus cf. nigra.
X	3					Upper pleniglacial	20.000	open Artemisia, Chenopodiaceae vegetation.
X	2		Photolivos	Tursac		Upper pleniglacial	22.000 22.640 23.750	Pinus cf. nigra bushes in open Artemisia, Chenopodiaceae veg.
X	1					Upper pleniglacial		open Artemisia, Chenopodiaceae vegetation.
P	7		Krinides II	Denekamp II		Inter pleniglacial	28.800 28.840	Pinus cf. nigra bushes in open Artemisia, Chenopodiaceae veg.
P	6					Inter pleniglacial	30.000 30.500	open Artemisia, Chenopodiaceae vegetation some Juniperus.
P	5		Krinides I	Denekamp I		Inter pleniglacial	31.840 32.010	Pinus, Picea omorikoides, Juniperus, Ephedra; open forest.
P	4					Inter pleniglacial	33.000	open Artemisia, Chenopodiaceae vegetation.
P	3	c	Kalabaki I	Hengelo complex		Inter pleniglacial	34.770 35.000	Pinus n. and oak bushes } in open Art. Chenop. veg.
P	3	b				Inter pleniglacial		Juniperus, Ephedra } in open Art. Chenop. veg.
P	3	a	Kalabaki II			Inter pleniglacial		Pinus n. and oak bushes } in open Art. Chenop. veg.
P	2					Inter pleniglacial	37.000	open Artemisia, Chenopodiaceae vegetation.
P	1	c	Heraklitsa I	Moershoofd ?		Inter pleniglacial		stands of Pinus n. in open Art. Chenop. veg.
P	1	b				Inter pleniglacial		
P	1	a	Heraklitsa II			Inter pleniglacial		stands of Pinus n. in open Art. Chenop. veg.
V	3					Lower pleniglacial		open Artemisia, Chenopodiaceae vegetation.
V	2	c b a				Lower pleniglacial		open Artemisia and Chenopodiaceae vegetation stands of Pinus cf. nigra, Juniperus.
V	1	c b a				Lower pleniglacial		
U	3					Early glacial		Pinus n. with Juniperus. with open vegetation.
U	2	b a	Elevtheroupolis	Odderade		Early glacial		oak, Carpinus, Tilia, Ulmus forest.
U	1					Early glacial	53000	open Pinus, Quercus vegetation with Pistacia, Sanguisorba.
T						Early glacial		open Artemisia, Chenopodiaceae vegetation in which Ephedra and Plantago were present.
S	4					Early glacial		oak, Pinus forest
S	3	b	Drama	Brørup		Early glacial		Pinus cf. nigra, Abies forest.
S	3	a				Early glacial		oak, Carpinus forest, Fagus.
S	2					Early glacial		oak forest with Corylus
S	1					Early glacial		Quercus, Pinus forest with Tilia, Corylus and Carpinus.
R	3					Early glacial		open Artemisia, Chenopodiaceae veg. with Ephedra, Juniperus.
R	2		Doxaton	Amersfoort		Early glacial		dry open Quercus shrub with Helianthemum, Xantium on the open spots.
R	1					Early glacial		open Artemisia, Chenopodiaceae vegetation.
Q	3			Eemien				rather open forest in which Quercus Juniperus and Pistacia were present.
Q	2							Pinus cf. nigra forest and Pinus silvestris with some Quercus.
Q	1							oak forest with Carpinus.

5000 _ calculated ages
14.600 _ age according C14 method