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PALYNOLOGY OF THE MIDDLE PART (30–78 METRES) OF THE 120 M DEEP SECTION IN NORTHERN GREECE (MACEDONIA)

T. A. WIJMSTRA and A. SMIT

Hugo de Vries-Laboratorium, Afd. Palynologie, Universiteit van Amsterdam

SUMMARY

In this paper the results of a palynological investigation of the 30–78 m interval from a deep bore hole in the Tenagi Philippon are presented. The pollen diagram reflects alternating steppe phases and phases of oak forest, some of them with an evergreen character. Taking the ^{14}C dated last interglacial-glacial cycle (resp. forest and steppe) as a model, the oak phases are interpreted as interglacials or warm interstadials and the steppe phases mostly as glacials.

The presence of pollen from evergreen oaks indicates warmer periods that might be called interglacials whereas the presence of only pollen from (semi) deciduous oak species indicates periods that might be called interstadials.

1. INTRODUCTION

The results given here are from the continuation of the pollenanalytical work on the boring from the Tenagi Philippon plain (*fig. 1*). Earlier results (from the upper 30 m, representing the Upper Pleistocene s.l.) and a detailed description of the area, its recent climate and vegetation were given by WIJMSTRA (1969), whereas the analysis of the underlying deposits (78–120 m) will be reported in a separate paper. A generalized diagram of the complete 120 m was presented in VAN DER HAMMEN, WIJMSTRA & ZAGWIJN, 1971, and the last interglacial from this section was described and discussed in WIJMSTRA & SMIT (1975).

The present data were chiefly obtained by light-microscopical observation. Pollen grains of *Quercus* species, collected by micromanipulator from samples with prominent values for oak pollen, as well as from showing differences in oak pollen under light microscopical observation, were studied with the aid of a scanning electron microscope (S.E.M.).

Criteria given by SMIT (1973) were used to distinguish 3 major types within the fossil pollen grains of Quercus:

a. *Quercus robur/petraea* type, comprising deciduous species such as *Q. pubescens*, *Q. robur*, *Q. petraea*.
b. *Quercus ilex/coccifera* type, which includes the evergreen species *Q. ilex* and *Q. coccifera (Q. calliprinos)*.
c. *Quercus suber* type, comprising *Q. cerris*, *Q. macrolepis*, *Q. trojana*, and other mainly semi-evergreen species, as well as the evergreen species *Q. suber*.

Fig. 1. Location Tenagi Philippon.

A pollen grain of these types was considered to be absent, not being found among 50–100 *Quercus* pollen grains collected per sample.

This division proved, in the opinion of the present authors, to be of considerable value for the interpretation of the pollen diagram and the reconstruction of the former vegetation cover.

2. THE POLLEN DIAGRAM (*fig. 2*, Appendix in pocket on page 3 cover)

2.1 General remarks

In the diagram the results of the palynological analysis of the 30–78 m part of the 120 m deep section are presented. The samples were analysed every 20 cm and consisted mainly of peat, gyttja, clay and lake marl. All samples were boiled with KOH and, after acetolysis, subsequently concentrated with a bromoform-alcohol mixture. The pollen grains were found to be well-preserved and not corroded. The pollen total used as a basis for the main diagram consisted of all pollen types observed except Cyperaceae, Typhaceae, *Menyanthes*, Nymphaeaceae, *Utricularia*, *Peplis* and *Rumex* since these elements, generally speaking, belong either to open aquatic vegetation or to hygroseres. In nearly all samples a pollen sum of 500 pollen was taken.

2.2 The zonation

The sequence under discussion can be subdivided into a number of pollen zones.

For the major pollen zones the dominance of either the herbaceous or the tree pollen was used. In several cases this major zonation could be subdivided into smaller units (subzones). In these cases the criteria used for subdivision included also variations in separate pollen curves such as, for instance, the *Quercus* or *Pinus* curve.

Zone VV

This zone is characterized by its high percentages of non arboreal pollen (NAP), in this case the dominance of grasses, *Artemisia* and Chenopodiaceae. Only the transition from this to zone PP is present in our diagram.

Zone PP

This zone shows very high percentages of arboreal pollen, mainly of *Quercus* and *Pinus*. Identification under S.E.M. observation proved the presence of the *Q. suber* type and the *Q. robur/petraea* type. With the help of the curves for the separate trees this zone can be subdivided into 5 subzones.

Subzone PPl shows high percentages of oak and a maximum of the *Tilia* curve. During this subzone the percentages of *Ulmus/Zelkova* and *Fraxinus excelsior* pollen are becoming more important. In the second half of this subzone the first occurrence of *Carpinus* pollen is worth mentioning.

The next subzone PP2 can be divided into PP2a and PP2b. In the part PP2a oak pollen is dominant while during part PP2b the curve of pine pollen shows higher values. Throughout PP2 *Abies* is present, reaching a percentage of up to 15, while also *Carpinus* and *Ulmus* are conspicuously represented. In zone PP2b the curve for Ericaceae starts to rise and some grains of *Bruckenthalia* were found.

In subzone PP3 the high maxima of *Pinus* and the constant low percentages of *Quercus* are the most characteristic facts. The continuous presence of Ericaceae and *Plantago* is of importance.

In subzone PP4 the percentages of *Pinus* pollen are still high although the Quercus curve shows values between 25 and 30%. In the lower part of this subzone Ericaceae are still relatively abundant. *Carpinus* and *Fraxinus* are also found in this zone with a continuous curve. In this zone all three types of Quercus pollen were found to be present (S.E.M. observation).

The main characteristic of subzone PP5 is the dominance of the *Quercus* curve over the pine curve (except for the sample at 70.2 m). In the upper half of the zone a rise in the pine curve can be noticed.

In this subzone *Abies*, *Tilia*, *Ostrya/Carpinus orientalis* are represented by continuous, closed curves. In the middle of this subzone a rise in the N.A.P. percentages is caused by a greater contribution of *Artemisia* and of Chenopodiaceae. The curves for *Salix* and *Pistacia* show maxima in this interval. In the upper part a marked rise in the curve for *Nymphaea* is noteworthy.

Zone XX

In this zone the N.A.P. percentages are higher than the A.P. percentages. This is caused by a rise in the curves for *Artemisia*, Chenopodiaceae and grasses. Some scattered grains of *Tamarix*, *Nerium oleander* and *Cressa* are restricted to this zone. A division can be made into two subzones, XX1 and XX2. In subzone XX1 the percentages of pine and oak are up to resp. 30% and 10%. Also some grains of *Fraxinus excelsior*, *Ulmus*, *Pistacia* and *Myrtus* are present, whereas the *Thalictrum* curve is continuous.

The upper part of subzone XX2 shows constantly high percentages of *Salix* and *Typha* and shows well-marked maxima of the grass curve. At the transition from XX1 to XX2 a rise in the Cyperaceae curve can be seen, preceded and followed by a maximum of the curve of monolete fern spores.

Zone YY

This zone shows a high percentage of tree pollen. In the lower part oak is dominant while higher percentages for *Tilia*, *Carpinus*, *Fraxinus*, *Pistacia* and *Poterium* are found. There is a rise in the *Salix* curve and also some grains of *Pterocarya*, *Buxus* and *Nerium* were found. The zone can be divided into 2 subzones. At the base of subzone YY1 some grains of *Hippophaë* were observed and one grain of *Arceuthobium*.

In the upper part of zone YY2 the presence of *Abies* and Ericaceae with higher percentages is worth noting. There is a maximum of the pine curve in this part of the zone followed by a maximum of *Quercus*. Throughout this zone the percentages of Cyperaceae are high.

Zone ZZ

Here the rise in the values of *Artemisia* and Chenopodiaceae cause a marked dominance of N.A.P., although some *Quercus* and pine pollen is still found. In this zone, among the pine pollen, some grains are very similar to those of *Pinus heldreichii*.

Zone A

This pollen zone shows high percentages of arboreal pollen. *Abies*, *Ulmus* and *Fraxinus* are present with low percentages throughout this zone. An interval A la may be distinguished, in which pine pollen is dominant.

In the next interval, A lb, *Pinus* and oak pollen is present in approximately equal percentages.

In subzone A2 the percentages of pine are constantly high. In the middle of this subzone is a marked but short rise of the *Quercus* curve.

Zone B

Here the N.A.P. percentages are generally high again; only in the middle part a maximum of the arboreal pollen (A.P.) can be observed. The higher percentages of the N.A.P. are caused by an increase of the values for *Artemisia* and Chenopodiaceae. In the lower part the grass percentage is slightly lower than in the upper part.

In the lower part the percentage for *Nymphaea* shows an increase, while in the upper part *Typha* attains higher values. Pollen zone B can be divided into 3 subzones. Subzones B1 and B3 show a maximum of the curves of *Artemisia* and Chenopodiaceae, subzone B2 shows higher values for pine and oak. In pollen zone B3 an increase of the percentages of Cyperaceae is present.

Zone C

This zone shows again high values for the tree pollen percentage. During subzone C1 oak pollen is dominating, while in the second half (C2), the pine percentage becomes increasingly higher. At the transition from C1 to C2 a slight increase in the percentages of *Tilia* and *Abies* is worth noting. This is also the case for *Carpinus* and *Ulmus*. *Fraxinus* is continuously present in zone C.

Zone D

In this zone the dominance of N.A.P. is caused by a marked increase in the percentage of *Artemisia* and Chenopodiaceae. In the middle of pollen zone D a maximum of the *Typha* curve is observed, preceded and followed by a rise in the curve for Cyperaceae. At the end and the beginning of this zone the percentage of grasses is high.

Zone E

The main features of this zone are an A.P./N.A.P. ratio of about 1 and a rise in the pine pollen curve. The oak percentages attain 15–20%. The curve for the psilate monolete spores shows higher values. Throughout this zone the grass pollen percentage is high, whereas a marked increase of these values takes place near the transition to zone F. Just after the grass maximum, increased values for *Typha* can be noticed. *Ulmus* is present throughout this zone.

Zone F

The main characteristics of this zone are the constantly high percentage of oak and the presence of *Abies*, *Tilia*, *Juniperus*, *Ulmus*, *Salix* and *Betula*. In the upper part of this zone an increase of the *Alnus* percentage can be noticed, which is preceded by an increase in the percentage of grass pollen. In the last part of this zone a maximum in the curve for Cyperaceae can be seen together with increasing values for *Typha*, Filices and *Salix*.

Zone G

Maxima in the curves for *Artemisia*, Chenopodiaceae and grasses cause a predominance of the N.A.P. values.

Throughout this pollen zone maxima in the fern curve can be observed. In the lower part of this zone there is a maximum in the Cyperaceae curve.

Zone H

This part of the sequence is characterized by its higher percentage of tree pollen, mainly from *Quercus*.

The zone can be divided into three subzones, H1, H2, H3. During subzone

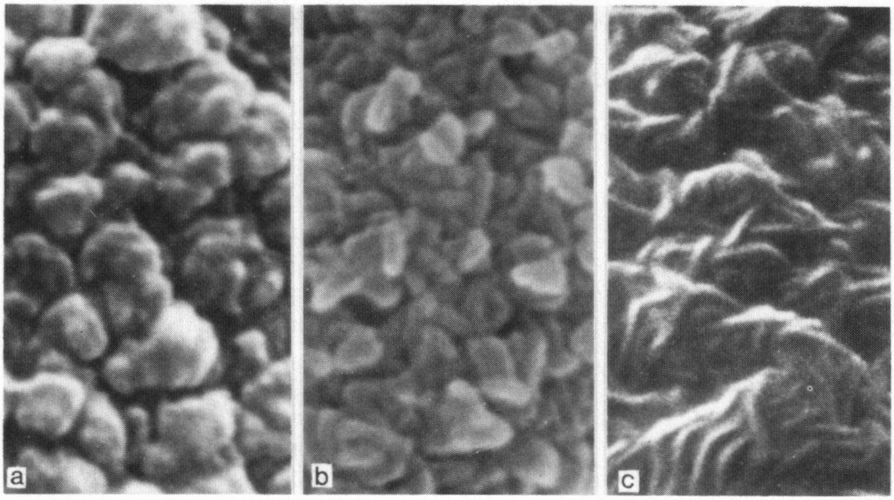

Fig. 3. Surface details of fossil oak pollen.
a. *Quercus robur/petraea* type, × 20.000 (depth 47 m).
b. *Quercus suber* type, × 20.000 (depth 47 m).
c. *Quercus ilex/coccifera* type, × 20.000 (depth 47 m).

H1 all three oak types (see *fig. 3*) were present as well as *Pistacia*. The curves of *Carpinus* and *Ulmus* are reaching higher values, especially in the middle and higher part of the zone.

At the transition to subzone H2, *Abies* reaches more than 10% and also *Salix* is increasing here. During pollen zone H2 a marked rise in the N.A.P. values can be observed, while oak pollen remains an important component of the total of arboreal pollen. In this subzone we see at first a rise of up to 18% of *Salix*, followed by a maximum of *Alnus* (c. 43%).

After this *Alnus* maximum a top in the curves of the ferns and grasses occurs. At the end of this period of N.A.P. dominance, the percentages of Cyperaceae become higher. The subzone H3 shows a rise in the pine curve, the percentage of N.A.P. pollen (mainly *Artemisia* and Chenopodiaceae) increases towards the upper part of this zone. At the lower half of the sequence a maximum in the *Juniperus* curve is present.

Zone K

The high percentages of *Artemisia* and Chenopodiaceae cause a dominance of the N.A.P. of up to 90% At the boundary between this zone and zone L a maximum of the *Nymphaea* curve occurs, while in the middle part *Typha* attains a higher percentage.

Zone L

The zone can be divided into 5 subzones. During the first four subzones the percentage for both pine and oak is somewhat higher, although *Artemisia* and

Chenopodiaceae remain the major constituents of the pollen rain. The pine curve shows four maxima (one in each of subzones L1, 2, 3 and 4).

Subzone L5 is characterized by a very high percentage of *Artemisia* and of Chenopodiaceae. At 35 m one spectrum shows a sudden rise in the percentage of pine and oak. Throughout this zone the percentage of grasses is high. In the upper part an increase in the percentage of *Typha* can be observed.

Zone M

This zone was described earlier in WIJMSTRA & SMIT, 1975. We distinguish two subzones. In subzone M1 the percentage of *Artemisia* and Chenopodiaceae is still high. The presence of *Xantium*, *Pleurospermum* and *Gypsophylla* is noteworthy. However, the A.P. percentage rises, mainly caused by an increase of the oak percentage (semi-evergreen type).

The A.P. pollen frequency is much higher in subzone M2, *Quercus* being the major constituent. There is a consistent representation of *Pistacia*, *Ulmus* and *Castanea*. The percentage of *Artemisia* and of Chenopodiaceae is much lower than in zone M1.

Zone O

This zone was already described in WIJMSTRA & SMIT, 1975. A continuous curve of Abies, a high arboreal pollen content and a presence throughout this zone of Ericaceae occurs. The subzone O1 is characterized by a maximum in the curves of *Quercus* and of *Tilia*, by the continuous high percentage of *Abies* and by the low percentage of Ericaceae. The curves of *Carpinus* and *Ostrya* start to rise.

In the subzone O2 the continuous representation of *Carpinus* with a high percentage and the presence of *Rhododendron* are worth noticing. In the interval O2a there is a lowering of the *Quercus* curve accompanied by a rise in the *Pinus* curve. In the second half of zone O (interval 2b) a maximum in the *Quercus* curve is apparent. Here also the curves of *Betula* and *Alnus* start rising whereas *Tilia* and *Fraxinus ornus* are no longer represented. The majority of the *Quercus* pollen in zone O belongs to the deciduous type (*Quercus robur/petraea* type).

Zone Q

The beginning of this zone is marked by a rise of pine pollen and a decrease of *Quercus*, the latter mainly consisting of the semi-evergreen type. The pollen percentage of the herbaceous elements like *Artemisia* and Gramineae are increasing again. The upper part of this zone (see also WIJMSTRA & SMIT, 1975), is marked by the presence of the evergreen as well as semi-evergreen oak pollen type.

3. THE DEVELOPMENT OF VEGETATION *(table 1)*

Using the A.P./N.A.P. relation a reconstruction of the local vegetation types on a physiognomic basis may be given. As discussed in WIJMSTRA (1969), a

Table 1. Reconstruction of the Middle Pleistocene vegetation sequence in Eastern Macedonia.

	Zone	Subzone	mtr	Vegetation
	Q		30	oak forest with Carpinus betulus and evergreen oaks
PANGAION	O	2 b		oak forest with Carpinus betulus
	O	2 a		oak forest on lower slopes, more upwards Abies forest with Rhododendron
	O	1		oak forest.
	M	2		open oak forest with Pistacia
	M	1		open very dry steppe with Artemisia, Chenopodiaceae.
NEAKATERINI	L	5	35	steppe with Artemisia, Chenopodiaceae.
	L	4, 3, 2, 1	40	alternating steppe and forest steppe (with oak and pine).
	K			steppe with Artemisia, Chenopodiaceae.
SYMVOLON	H	3		forest steppe with pine and Juniperus.
	H	2	45	oak forest as in zone H_1, but locally a shore vegetation with stands of alder and willow is present. in the upper part of this sub zone the oak forest is replaced by a more open forest type with Juniperus and pine
	H	1		forest with evergreen and deciduous oaks; at higher parts Carpinus and Abies, in the upper part of this sub zone a more continental forest with only deciduous oak species.
	G			steppe with Artemisia, Chenopodiaceae.
STRYMON	F		50	deciduous oak forest with some pine (Quercus cerris.confertae like association).
AXIOS	E			forest steppe with stands of oak and pine.
	D			steppe with Artemisia, Chenopodiaceae and grasses.
MAVRODAPHNI / KAVALLA	C	2	55	pine forest with some oaks.
	C	1		deciduous oak forest with some pine (Quercus cerris.confertae like association)
	B	3, 2, 1		forest steppe with stands of pine and scattered oaks.
KRIMENES	A	2	60	mixed pine.oak forest.
	A	1 b		oak forest with deciduous oak species and pine.
	A	1 a		pine forest.
	ZZ			steppe with Art.Chenop. and grasses. Salix on wet sites.
LITHOCHORI	YY	2		forest with decid. oak species and Abies at the higher locations
	YY	1	65	deciduous submediterean oak forest with Buxus and Pistacia.
	XX	2		steppe with Artemisia, Chenop., shore vegetation with willow and Tamarix.
	XX	1		forest steppe with pine and oak and some elements like Artemisia, Chenopodiaceae and grasses.
LEKANIS	PP	5	70	forest with a mixed composition: deciduous oaks, Tilia, Ostrya, Fraxinus and Acer. at higher location Abies and at lower sites Pistacia.
	PP	4		forest with in the lower parts evergreen oak species and in the upper part a mixed arboreous vegetation with Pinus, Quercus, Carpinus betulus, Fraxinus exelsior and Ulmus.
	PP	3		forest with dominance of Pinus and some scattered oaks and an undergrowth of Ericaceae.
	PP	2 b, 2 a	75	forest in which oak, Tilia, Carpinus, Ostrya and Fraxinus are replaced by pine, an undergrowth of Ericaceae is developing. at the higher location an Abies forest is present.
	PP	1		forest with (submed.) deciduous oaks, Carpinus betulus, Fraxinus, Tilia, Ulmus and Pistacia.
	VV		78	steppe with Artemisia, Gramineae, Chenopodiaceae and locally Salix bushes on wetter sites.

major subdivision in "forest", "forest steppe" and "steppe" can be made. As indicative percentages the following values, as derived from FRENZEL (1968), are used:

AP 55%: forest
30% AP 55%: forest steppe
AP 30%: steppe

This physiognomic subdivision is comparable with other divisions for the Mediterranean area proposed by BEUG (1967a), FLORSCHÜTZ & HENENDEZ AMOR (1962), BONATTI (1966), BOTTEMA (1974) and NIKLEWSKI & VAN ZEIST (1970). Within the forest formations an evergreen type can be distinguished due to the presence of pollen from evergreen oaks.

Using the indicative percentages as criteria, a closed forest vegetation seems to have prevailed in the area during zones PP, YY, A, C, F, H and O/N. The zones IIX, B, E and L had, accordingly, a rather open forest or a forest steppe ("Waldsteppe") as the characteristic vegetation type. Finally, the zones VV, XX2, ZZ, D, G, K and L5 must have been characterized by an open steppe vegetation. In *table 1* these major types and the variations in the composition of the vegetation of each zone are registered. A more detailed description is presented here.

3.1 Steppe vegetation

During zone VV an open steppe vegetation with *Artemisia* and Chenopodiaceae must have occurred, whereas *Salix* occupied wetter parts of the area. The local stands of vegetation might be comparable to the vegetation type described by Wang (1961 : 203). This steppe type was found in a cold and dry climate phase (the zones X5, X3 etc.) in the higher parts of the same boring as described by WIJMSTRA (1969). There ^{14}C dating and correlation with deep-sea cores (VERGNAUD-GRAZZINI & ROSENBERG 1969), as well as the presence of *Ceratoides* (= Kraschenninnikovia) SMIT & WIJMSTRA 1970) clearly point to a cold and dry climate period. The similar pollen contents of not only VV, but also of zones ZZ, D, G, K and L5 is, therefore, indicative of similar and dry phases.

During zone XX2 a dominance in the AP percentages suggests an open vegetation of the usual steppe type. This dominance, however, is caused mainly by the higher grass percentages, whereas *Salix* attains very high percentages, combined with the regular occurrence of *Tamarix* and *Pistacia*. This may point to a probably seasonally desiccating lacustrine environment with *Salix* and *Tamarix* growing at the remaining lower and wetter sites. The occurrence of *Tamarix* and *Pistacia* points to a somewhat raised temperature which is supported by the fact that a cold steppe element as *Ceratoides* could not be established.

The pollen rain that fell during parts of zone L is comparable with the pollen rain of the "interpleniglacial" of the Last Glacial of the same section (WIJMSTRA 1969). Therefore, the vegetation must also have been of an open type with scattered stands of *Pinus*. In these patches of forest, oak was of more frequent occurrence, which points to less dry and somewhat warmer circumstances.

3.2 Forest vegetation

During zone PP the pollen assemblages allow a subdivision of which each part corresponds with a particular type of forest. Zone PP1 is characterized by a forest composed of oaks of the *Quercus robur/petraea* group (probably *Q. robur* and other non-mediterranean species) and also of species of the *Q. suber* group (probably *Q. cerris*).

In this forest also *Tilia*, *Ulmus* and *Fraxinus* occurred. Above this forest a *Carpinus betulus* belt developed on the slopes. As compared to zone VV, PP1 can therefore be considered to have been a more humid and warmer interval.

In zone PP2a a further differentiation took place in the forest in relation to the altitudes of the forest belts. On the lower parts of the slopes the oak forest was gradually replaced by a pine forest, whereas in the higher parts a zone of an *Abies* of the *A. nordmanniana* type came into existence up to the timber line.

Zone PP2b shows a further extension of the pine forest, probably of the *Pinus nigra* type, with Ericaceae forming the undergrowth. An increasing dryness and a raise in temperature may be accepted. For a discussion of comparable fores types see QUÉZÈL & PANUKCUOUGLU (1973).

In subzone PP3 a pine forest established itself in the area, but some scattered stands of oaks may have been present. The deciduous elements in this forest were of minor importance, probably because of the increasing dryness. A clear separation in altitudinal belts was probably not present at that time, at least not in the neighbourhood of our site.

During subzone PP4 an evergreen oak forest invaded the lower belts of the pine forest. In the upper part a mixed forest developed in which deciduous oaks, probably *Q. cerris* and *Q. pubescens*, as well as *Ulmus* and *Carpinus betulus* were found higher up the slopes.

Subzone PP5 has a pollen composition that can be interpreted as the pollen rain of a mixed oak forest with *Carpinus*, *Tilia*, *Ostrya*, *Fraxinus* and *Acer* in the upper belts, evergreen oaks and *Pistacia* being more important in the lower regions. Above the oak zone an *Abies* belt was present up to the tree line.

The pollen content of the next forest phase YY can be accepted as indicative of a deciduous oak forest (probably *Q. pubescens*) with *Buxus*, *Pistacia* and *Pterocarya*.

From subzone YY1 to YY2 there is a change in the pollen content, indicating a change into a more continental forest type. Since *Q. cerris*-like pollen grains were found and other decidous oaks were present as well, a *Q. cerris-confertae* association as described by HORVAT (1954) seems probable, whereas at higher elevations *Carpinus* and *Abies* dominated.

Forests resembling the *Q. cerris-confertae* association must have occurred during the (sub) zones A lb, C1 and F.

The forest of zone H can clearly be differentiated in a lower oak belt and an upper coniferous belt. At first (zone H1 lower part) oak forest with *Q. cerris* is found, but later also mediterranean *Quercus* species (*Q. ilex*) became established. The more elevated part of this forest contained *Carpinus betulus*, whereas the timber line was formed by an *Abies* forest. Some *Fagus* pollen grains indicated the presence of this tree, also at higher elevations. In zone H2 the same kind of forest was found, but the composition of the regional forest, as reflected in the pollen samples, is somewhat obscured by the pollen produced *in situ* by the willows and alder trees in the, then swampy, lake area.

In zone H3 the oak forest gradually became replaced by a pine forest and the vegetation became more open as can be concluded from the more frequent occurrence of *Juniperus* pollen and the increasing amount of *Artemisia* and Chenopodiaceae pollen. The climate prevailing during this interval was at first a rather cool one, but became rapidly warmer, with a marked summer drought. At the end of this zone a colder and drier period started.

The different phases of the forest development in zones O and Q were dealt with elsewhere in more detail (WIJMSTRA & SMIT 1975). During the deposition of zone O, a forest was established with a resemblance to the Colchic forest types nowadays found in the eastern part of the Mediterranean area (Anatolia). This may be inferred from the presence of *Rhododendron*, *Ilex*, *Nerium*, etc. This forest type with chiefly deciduous *Quercus* species replaced the earlier forest of semi-evergreen *Quercus* species of zone M2. The closed forest vegetation of the Colchic type of zone O is replaced first by a more open forest type with Pinus (zone Q), and ultimately by a steppe vegetation (zone R, see WIJMSTRA, 1969).

3.3 Forest steppe vegetation

This type of vegetation occurred regularly at the transition from steppe to forest or *vice versa*, but in most cases its presence was of rather short duration. At several times, however, climatical circumstances permitted a more prolonged forest-steppe phase. Apart from locally developed stands of vegetation with *Salix* and some *Fraxinus*, the principal tree was *Pinus*, probably occurring in scattered patches. In this open vegetation type some *Pistacia* and *Juniperus* were present.

A rather similar situation was found in zones XX1, B, E and L.

3.4 Local aquatic and marsh vegetations

We shall end the discussion of the vegetational history with a short review of the vegetation present *in situ*. In the first place it is noteworthy that hardly any algal types, such as *Botryococcus* and *Pediastrum*, were found. In the phases with more open vegetation, stands of *Typha* were frequently found, as well as *Nymphaea* and *Menyanthes*. Sometimes a *Nymphaea* phase is followed by a *Typha* phase, suggesting a decrease in water depth. There is a tendency for the Cyperaceae curve to be positively correlated with the *Typha* curve. During the forest phases, *Equisetum* must have been present in the hydrosere although spores were hardly found. Remains of stems were frequently encountered, however.

For an indication of the temperature the presence of *Menyanthes* might be of some importance, since at present this plant occurs in the Mediterranean area only in alpine mountain bogs at an altitude of 1,800 m and over (RIKLI 1948).

4. DISCUSSION OF THE RESULTS

At first an attempt will be made to distinguish in the sequence under discussion interglacials from interstadials. In the next part, with the help of the vegetational history the climatic sequence for the area is discussed (*fig. 4*). Finally tentative correlations with the stratigraphy in N. W. Europe are suggested.

4.1 Interglacials and interstadials

WIJMSTRA (1969) concluded that the forest phases in the area corresponded

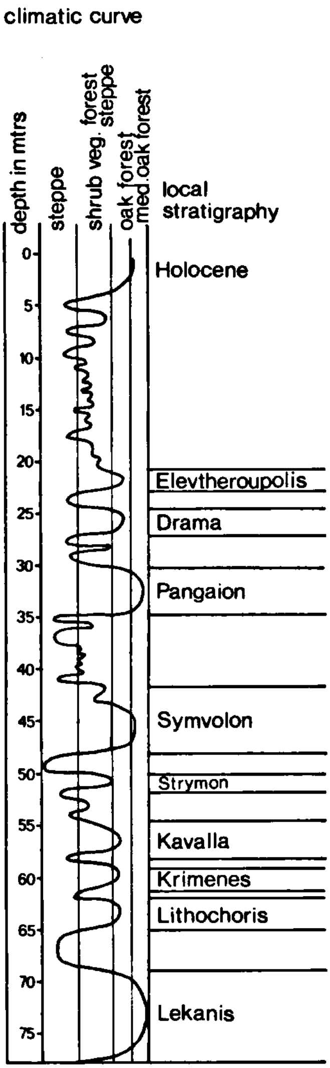

Fig. 4. Climate sequence in the Tenagi Philippon area, derived from the pollen assemblages.

with interglacials and interstadials and that the steppe phases corresponded with glacial periods. The "Waldsteppe" appeared in "interstadials", during phases with only minor amelioration of the climate.

In WIJMSTRA & SMIT (in preparation) some further criteria for distinguishing interglacials are proposed, such as the incidence of a "complete succession" in the forest leading to a mediterranean type of climax vegetation. Such a succession combined with a pollen assemblage indicating a complete series of altitudinal belts of vegetation, including especially the presence of an *Abies* belt, is considered to represent optimum climatic conditions. If we apply these two criteria, only the zones O/H, H and PP, can be considered as interglacials, for which respectively the names Pangaion, Symvolon and Lekanis are proposed.

Although, however, the forest phases YY, A, C and F are also marked by the presence of *Abies*, most probably occurring as an upper mountainous tree belt, the final local stage will have been a submediterranean type of oak forest in which *Quercus cerris* and other deciduous species, perhaps together with semi-evergreen species, dominated. We provisionally consider these phases as warmer interstadials for which the names Lithochoris, Krimines, Kavalla and Strimon are proposed.

Phases with forest steppe conditions, present in XX1, B, E and L and showing a minor increase of forest elements, mainly Pinus and to a lesser extend *Quercus*, represented by the *Quercus robur*/petraea type, may be considered as cool interstadials.

4.2 Major climatic changes

The occurrence of the different vegetation types as derived from their pollen assemblages is given in the curve of *fig. 4*. The main vegetation types in the surroundings of the drill hole were the open *Artemisia* steppe, the forest steppe, the deciduous oak forest and the mediterranean oak forest. For the mediterranean area it is assumed that the transition of one vegetation type into another is mainly governed by two parameters: temperature and precipitation. Therefore the combined effect of these two factors on the vegetation cover is reflected on the horizontal axis.

The vertical axis, the depth, can be used as a relative time base, the parameter being the unknown rate of sedimentation.

From the curve can be read that the climate of the period between the Pangaion and Symvolon stages had an extreme character comparable to the zone X in the upper part of the Tenagi diagram pointing to a dry and relatively cold climate (WIJMSTRA 1969). During the Symvolon stage the climate was comparable to the Pangaion and Lekanis phases, *vide* the development of an evergreen oak forest in those zones. This points to a climate with summer drought and winter rainfall.

Between the Symvolon and Strimon forest phases a return to extreme steppe conditions and, consequently, to a dry and cold climate took place. The forests of the Kavalla, Krimenes and Lithochoris phase must have grown under a submediterranean climate with a more even spread of the annual precipitation com-

Table 2. Tentative correlations of the Tenagi Philippon and N.W. European sequences.

<table>
<tr><th>zone</th><th>interglacial, interstadial</th><th colspan="2">1st correlation</th><th colspan="2">2nd correlation</th></tr>
<tr><td>M/O</td><td>Pangaion</td><td></td><td>Eemian</td><td></td><td>Eemian</td></tr>
<tr><td>L 3</td><td></td><td rowspan="2">Saalian</td><td>Bantega</td><td rowspan="7">Saalian</td><td></td></tr>
<tr><td>L 1</td><td></td><td>Hoogeveen</td><td></td></tr>
<tr><td>H</td><td>Symvolon</td><td></td><td>Holsteinian</td><td>Bantega</td></tr>
<tr><td>F</td><td>Strymon</td><td rowspan="6">Elsterian</td><td></td><td></td></tr>
<tr><td>C</td><td>Kavalla</td><td></td><td></td></tr>
<tr><td>A1</td><td>Krimenes</td><td></td><td></td></tr>
<tr><td>YY</td><td>Lithochoris</td><td>Cromer III</td><td>Hoogeveen</td></tr>
<tr><td>PP</td><td>Lekanis</td><td>Cromer II</td><td></td><td>Holsteinian</td></tr>
<tr><td></td><td></td><td></td><td>Elsterian</td><td></td></tr>
</table>

parable to that found nowadays in Middle and W. Yugoslavia. The steppe climate during the interim periods was not as extreme as in the other steppe phases; this may be concluded from the presence of principally grass steppes. Between the Lithochoris and Lekanis intervals, however, a severe steppe climate prevailed again.

4.3 Stratigraphical correlation

A direct stratigraphical correlation between the Tenagi sequence and the classical European sequence is hampered by the lack of absolute dating in the sequence under discussion and the uncertain dating of the type sections in N.W. Europe. The correlation between the Pangaion interglacial and the Eemian seems to be rather well established because of the fact that in both cases the first fully developed forest cycle before the last Weichselian glacial is concerned (see WIJMSTRA 1969, WIJMSTRA & SMIT 1975).

When we try to correlate the N.W. European sequence as reviewed by ZAGWIJN (1973) and our Macedonian sequence, the following remarks can be made. The occurrence of *Pterocarya* and *Nerium* during zone YY (the Lithochoris phase) is too irregular and too scarce to be a reliable criterium for correlation. Therefore, their presence cannot be used to determine a Holsteinian age. As discussed above, the Symvolon and the Lekanis warm forest phases may be interpreted as interglacials. This leaves two ways of correlation (see *table 2*). viz., one correlation in which the Symvolon phase is correlated with the Holsteinian and another in which the Lekanis forest phase is correlated with the Holsteinian. When we apply the Symvolon-Holsteinian correlation, the interstadials of Bantega and Hoogeveen (ZAGWIJN 1973) might be correlated with pollen zone L3 and L1. In the "longer" correlation the Bantega and Hoogeveen interstadials would correspond with the Symvolon and the Lithochoris of the Macedonia core. Within the "short" correlation the Lekanis forest phase may be correlated with the Cromer III phase of Zagwijn. For the time being it is not possible to decide definitely which of the two correlations is correct, although "the short" one seems to us slightly more probable.

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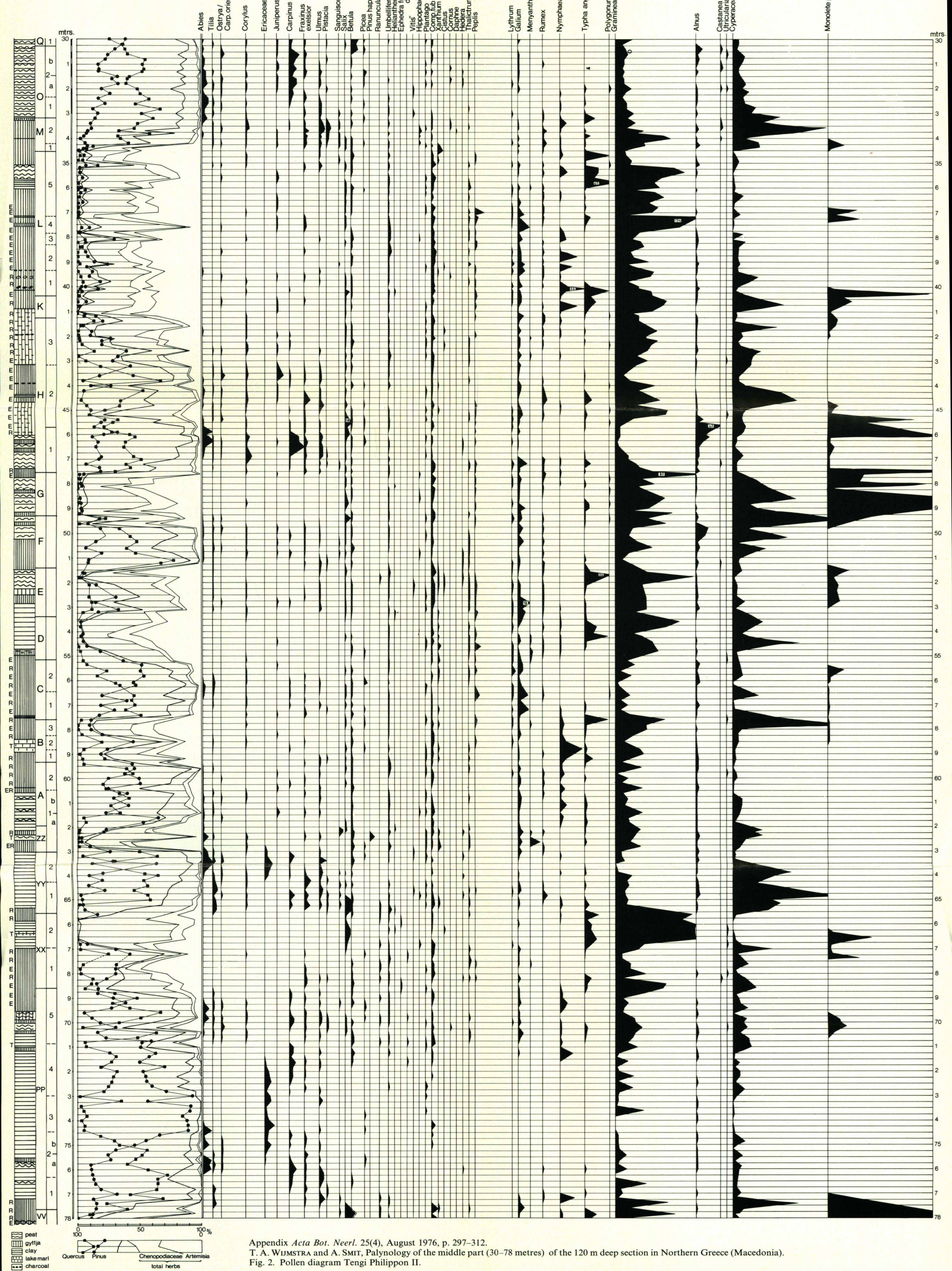
Tenagi Philippon II



Appendix *Acta Bot. Neerl.* 25(4), August 1976, p. 297–312.
T. A. Wijmstra and A. Smit, Palynology of the middle part (30–78 metres) of the 120 m deep section in Northern Greece (Macedonia).
Fig. 2. Pollen diagram Tengi Philippon II.