A LATE QUATERNARY POLLEN DIAGRAM FROM NORTHWESTERN SYRIA

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SUMMARY

This paper deals with the palynological investigation of a 12 m long core from the Ghab valley, north-western Syria. The core covers the greater part of the last glacial period and the Postglacial. The pollen diagram reflects an alternation of periods in which steppe vegetations expanded and those in which forests increased. Tree growth was determined by humidity rather than by temperature. On the whole, the second part of the last glacial was drier than the first part. The period preceding the Late-glacial was especially unfavourable for tree growth.

1. INTRODUCTION

In this paper the results of a palynological study in north-western Syria are presented. Western Syria forms part of a region which is believed to have been a locus for the domestication of plants and animals. This so-called nuclear area, includes the belt of hilly flanks on the inner side of the mountains which surround the Syrian and Mesopotamian lowland (BRAIDWOOD 1967, pp. 94–96).

In discussions of the beginning of food production and of changes in the food-gathering economy preceding the development of farming and herding (*cf.* FLANNERY 1969) prehistoric environments play an important part. The scarcity of available factual information on past vegetations in the Near East has, however, been a considerable handicap in reconstructing the environment of prehistoric man and has given rise to unjustified speculations.

The study of prehistoric environments in the Near East started in western Iran where, in 1960 and 1963, lake sediments were sampled by H. E. Wright (Minneapolis, USA) and collaborators. The results of the palaeobotanical study of these sediments are discussed in papers by WASYLIKOWA (1967), VAN ZEIST & WRIGHT (1963), and VAN ZEIST (1967). Two sediment cores from south-eastern Turkey provide information on the last 3000 years only (VAN ZEIST, TIMMERS & BOTTEMA, 1969/70). BEUG (1967) published two Postglacial pollen diagrams from the Bolu area in north-western Turkey.

In the spring of 1965 S. Bottema and W. van Zeist carried out a boring in the Ghab valley in north-western Syria. Moreover, in the valley of the Barada river, at a site about 25 km north-west of Damacus, a sediment core was taken, and surface samples were collected in Lebanon and Syria. The diagram for the core from the Ghab valley, which is the subject of this paper, was prepared by J. Niklewski during his stay in the Biologisch-Archaeologisch Instituut (1969–1970).

2. GEOGRAPHY AND GEOLOGY

In north-western Syria the Orontes river (Nahr-el-Assi) flows through the Ghab valley. This South-North oriented valley is bordered by the Djebel Alaouite to the west and by the Djebel Zawiyé to the East (*fig. 1*). The Alaouite Mountains, which form the continuation of the Lebanon Range, rise gradually from the Mediterranean coast to the East, reaching elevations of over 1300 m (4000 ft). The highest peak is about 1700 m (5125 ft) above sea level. The eastern flank of the Alaouite Mountains has a steep gradient; over a horizontal distance of about 2500 m the difference in altitude is more than 1000 m. The Zawiyé Mountains are much lower; only a relatively small part is over 800 m (2500 ft).

The Djebel Alaouite is built up of Mesozoic limestone, dolomitic limestone, dolomite, marl, and chalk marl. Extensive basalt flows South-West of Hama and East of the line Hama – Maaret el Noman are dated as Pliocene. Mesozoic as well as Tertiary calcareous rocks are found in the Djebel Zawiyé (VOÛTE 1955, *fig. 2*).

The Ghab valley itself is a graben which constitutes the northernmost extension of the great rift system. This graben is filled with lacustrine calcareous

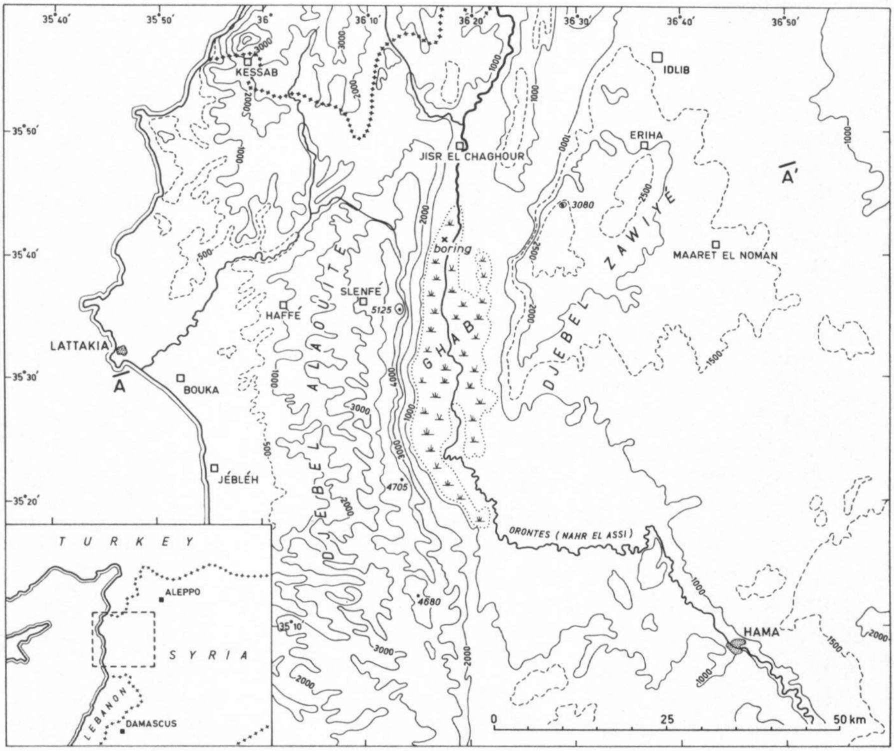

Fig. 1. Map of north-western Syria. Elevation contour lines are given in feet.

clays of still unknown thickness. A geophysical sounding to an estimated depth of about 300 m did not reveal any change in sediment (VAN LIERE 1916, p. 34). According to VOÛTE (1955) the lacustrine sediments should be of Pliocene and Quaternary age. On top of the mineral sediment peat developed in many places (VAN LIERE 1960/61, *fig. 23*).

Until recently the greater part of the valley was covered by lakes and swamps. In 1953–1955 the valley was drained.

3. CLIMATE

Climatic data for stations in the area under consideration are shown in *table 1*, while the distribution of the mean annual precipitation is represented in *fig. 2*. East of the Djebel Alaouite the precipitation drops sharply. Over a distance of about 40 km the annual precipitation decreases from over 1000 mm to 300–400 mm. In contrast to the more or less humid climate on the west flank of the Alaouite Mountains the climate East of the Ghab valley is semi-arid.

The climate in north-western Syria is characterized by a distinct summer-dry period, as in the whole of the Mediterranean region.

Table 1. Climatic data for stations in northwestern Syria (after WALTER & LIETH 1960–67).

	Altitude in m	Estimated mean Jan. temp.	Estimated mean July temp.	Precipitation in mm
Lattakia	61	10	27	788
Idlib	290	7	28	429
Aleppo	394	6	28	346

4. VEGETATION

For the interpretation of a pollen diagram in terms of vegetation patterns in the past it is indispensable to have a satisfactory knowledge of the present-day natural plant growth in the area which contributed to the pollen precipitation on the site sampled. The majority of the pollen encountered in the sediment core discussed in this paper must have originated from the Ghab valley itself, the Djebel Alaouite, and the Djebel Zawiyé (*fig. 1*). Over large areas the vegetation of the Near East has suffered seriously from cutting and grazing for thousands of years, which often makes a reconstruction of the original plant cover difficult, if not impossible. Fortunately, the conditions for the reconstruction of the vegetation in the area which is especially of importance in connection with this study are somewhat better than in many other areas. At least in the Alaouite Mountains forest remnants provide very useful indications of the original vegetation.

The vegetation of the Alaouite Mountains was studied by NAHAL (1962). Useful information on the vegetation in the area concerned is also given in PABOT's (1957) report on the vegetation of Syria. Besides, ZOHARY's "Plant life

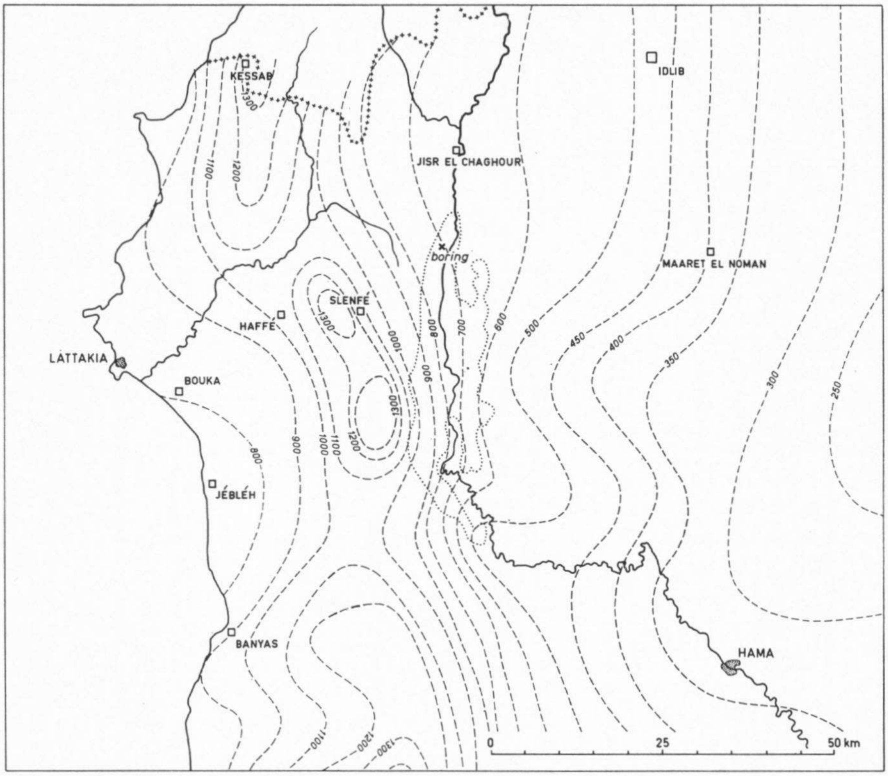

Fig. 2. Precipitation map of north-western Syria based upon information over the period from 1950 to 1964 (Meteorological Department of the Ministry of Defense, Damascus).

of Palestine" (1962) and PABOT's (1959) report on the vegetation of Lebanon provide more general information on the plant growth in the Eastern Mediterranean. The following tentative description of the vegetation is largely based on the publications mentioned above and on information provided by Dr. Y. I. Barkoudah (Department of Botany ,University of Damascus, Syria). Moreover, in a few cases the Postglacial part of the Ghab diagram – pollen assemblage zone Z – has been taken into consideration, thus anticipating the discussion of the diagram. The vegetation is discussed from West to East. A schematic representation of the vegetation along a transect A – A', indicated in *fig. 1*, is shown in *fig. 4e*.

In the lowermost zone, between sea level and 250–300 m altitude, the *Ceratonieto-Pistacietum lentisci* constitutes the natural vegetation. In addition to *Ceratonia siliqua* and *Pistacia lentiscus*, *Quercus calliprinos* and *Pistacia palaestina* play an important part in this vegetation type. Of the other shrubs found in this maquis may be mentioned here *Calycotome villosa, Phillyrea media, Myrtus*

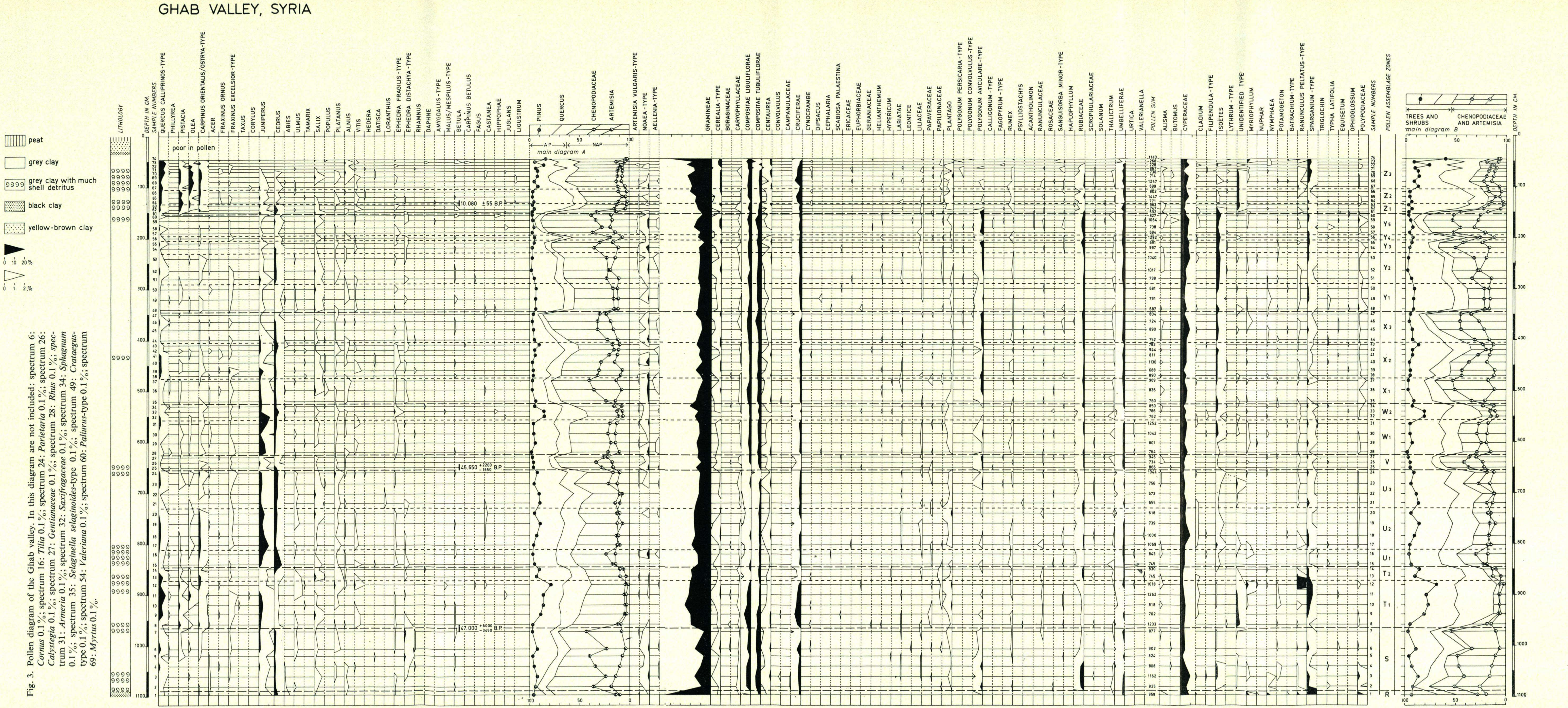

Fig. 3. Pollen diagram of the Ghab valley. In this diagram are not included: spectrum 6: *Cornus* 0.1%; spectrum 16: *Tilia* 0.1%; spectrum 24: *Parietaria* 0.1%; spectrum 26: *Calystegia* 0.1%; spectrum 27: *Gentianaceae* 0.1%; spectrum 28: *Rhus* 0.1%; spectrum 31: *Armeria* 0.1%; spectrum 32: *Saxifragaceae* 0.1%; spectrum 34: *Sphagnum* 0.1%; spectrum 35: *Selaginella selaginoides*-type 0.1%; spectrum 49: *Crataegus*-type 0.1%; spectrum 54: *Valeriana* 0.1%; spectrum 60: *Paliurus*-type 0.1%; spectrum 69: *Myrtus* 0.1%.

communis, Spartium junceum, Poterium spinosum, and *Olea europaea* var. *oleaster.*

In the zone between 250–300 and about 800 m above sea level the *Pistacieto-Quercetum calliprini* is the natural vegetation according to NAHAL (1962). *Quercus calliprinos* constitutes the dominant shrub or tree in the renmants of this vegetation type. This oak species can attain a height of 15 m, while the diameter of the trunk can amount to 80–90 cm (NAHAL 1962). Other species which are common in this forest community include *Pistacia palaestina, Quercus infectoria, Pyrus syriaca, Arbutus andrachne, Crataegus azarolus, Styrax officinalis, Phillyrea media, Rhamnus palaestina,* and *Juniperus oxycedrus.* It is not unlikely that the dominance of *Q. calliprinos* in most of the existing forest remnants in this zone is largely due to human interference with the natural vegetation. NAHAL (1962) reported that in the upper part of this zone *Quercus infectoria* becomes more common and that here more or less pure stands of this deciduous oak species occur. One could wonder whether originally *Q. infectoria* was the most important tree in the larger part of this zone, whereas *Q. calliprinos* played a dominant part below, let us say, 500 m. This would imply that *Q. calliprinos* was most common between sea level and about 500 m, whereas at higher elevations its place in the vegetation was largely taken by deciduous oaks. In northwestern Syria *Q. calliprinos* is found up to an elevation of 1500 m.

The role of *Pinus brutia* in this vegetation zone is not quite clear. In consequence of the cutting of the original forest this pine species would have expanded considerably. However, it seems justified to suppose that *Pinus brutia* formed part of the natural vegetation on the west flank of the Alaouite Mountains, at elevations between about 300 and 800 m.

In the forests above 800 m deciduous oaks seem to have been the dominant trees. In addition to *Quercus infectoria, Q. cerris, Q. brantii,* and *Q. libani* are also present at higher elevations. Of the other trees and shrubs which are found on the west flank of the Djebel Alaouite, at elevations between 800 and 1500 m, we may mention here *Ostrya carpinifolia, Carpinus orientalis, Acer hyrcanum, Acer monspessulanum, Styrax officinalis, Fraxinus ornus, Laurus nobilis, Juniperus oxycedrus,* and *Juniperus drupacea.* Moreover, *Abies cilicica* occurs above 1150–1200 m. NAHAL (1962) assumes that originally the Cilician fir was very common in the upper part of the west flank of the Alaouite Mountains, but as a result of excessive cutting was replaced by deciduous trees. However, the extreme scarcity of *Abies* pollen in the Ghab diagram suggests that this tree never played an important part in the regional vegetation during the period covered by the sediment core concerned.

As for the natural plant cover on the steep East flank of the Djebel Alaouite, the vegetation between 1500 and about 800 m would have shown much resemblance to that at the same elevations on the other side of the crest. Only *Abies cilicica* is not found on the drier East flank, being here replaced by *Cedrus libani* which occurs from about 1000 m upwards. The pollen evidence suggests that in the Postglacial there has been no zone in which cedar was the dominant tree, but that it was only a constituent of the mixed-oak forest. The absence of a distinct *Abies* and *Cedrus* zone on the West and East flanks, respectively, must very likely be ascribed to the circumstance that the Alaouite Mountains are not high enough. In Lebanon the *Cedretum libani* (the cedar zone) is found at elevations between 1500 and 2000 m (PABOT 1959).

Between about 300 and 800 m a *Pistacieto-Quercetum calliprini* should again constitute the natural vegetation type. Since on the East flank the precipitation is lower than at corresponding elevations on the West flank, it is likely that the *Quercus calliprinos-Pistacia palaestina* association on the East-facing slope would have been of a somewhat impoverished type. The same may be true for the *Ceratonieto-Pistacietum lentisci* which should be the natural vegetation type between the valley floor, at about 190 m, and an elevation of ca. 300 m. Probably the original vegetation at lower elevations on the East flank – the *Ceratonieto-Pistacietum lentisci* and the lower part of the *Pistacieto-Querceto calliprini* zone – was dominated by *Quercus calliprinos* and *Pistacia palaestina.*

Before the Ghab valley was drained, *Platanus orientalis, Fraxinus syriaca, Populus euphratica, Nerium oleander, Tamarix* sp., *Salix alba,* and *Salix babylonica* occurred there along lakes and watercourses. *Phragmites communis,* various *Cyperaceae, Typha,* and *Sparganium* were common marsh plants, while in the water *Potamogeton, Myriophyllum, Nymphaea,* and *Isoëtes* were present among others.

Most uncertain is the reconstruction of the vegetation in the Zawiyé Mountains east of the Ghab valley. Precipitation and temperature suggest that at least above about 500 m steppe forest should form the natural vegetation. *Quercus calliprinos, Pyrus syriaca, Acer syriacum, Amygdalus, Crataegus azarolus, Rhamnus palaestina, Prunus ursina, Rosa phoenicia,* and *Pistacia palaestina* were probably more or less common shrubs and trees in this vegetation type. In the ground layer, among others, *Noaea mucronata, Artemisia herba-alba,* various *Gramineae, Poterium spinosum, Centaurea, Asphodelus microcarpus,* and *Astragalus* would have played an important part. Furthermore it is not unlikely that *Pistacia atlantica* occurred in the Djebel Zawiyé.

5. BORING AND LITHOLOGY

The boring was carried out at a site about 15 km South of Jisr-el-Chaghour (*fig. 1*), along a secondary drainage canal, where the soil had not been ploughed (35°41′ N, 36°18′ E).

A Dachnowsky sampler with an inner diameter of 37 mm was used for coring the sediment between 0.65 and 8.05 m. The sediment between 8 and 11 m was cored with a Livingstone piston sampler with an inner diameter of 34 mm. In the latter case a drive frame equipped with chain hoists was used to provide greater force (CUSHING & WRIGHT 1965). In an effort to sample the sediment below 11 m the coring equipment broke and the boring could not be continued. The upper 0.65 m was sampled from the wall of a pit which had been dug for this purpose.

The following simplified lithology could be established:

0 - 8 cm	fen peat
8 - 29	yellow-brown clay
29 - 34	blackish-grey clay with charcoal and shell detritus
34 - 65	dark grey clay with shell detritus
65 - 1089	grey clay with varying amounts of shell detritus
1089 - 1098	black compact clay

6. RADIOCARBON DATING

Three samples were submitted to the Physics Laboratory of the University at Groningen for a ^{14}C dating. Since, with the exception of the upper 8 cm, the sediment did not contain any appreciable amount of organic material, the radiocarbon determinations had to be carried out on shells. Consequently, the choice of the samples was, among other things, determined by the presence of sufficient shell detritus.

The following dates were obtained:

129 - 137 cm	10,080 ± 55 B.P. (GrN 5810)
645 - 655 cm	$45{,}650 \pm \frac{2200}{1650}$ B.P. (GrN 5769)
960 - 972 cm	$47{,}000 \pm \frac{6000}{3450}$ B.P. (GrN 5811)

As for the last-mentioned sample, Dr. W. G. Mook of the Groningen Physics Laboratory informed us that there is a real statistical probability that this sample has an infinite date.

7. PREPARATION OF SAMPLES

All samples were prepared according to the following procedure:

1. After dehydration in absolute alcohol the sample was transferred to a bromoform-alcohol mixture with a specific gravity of 2.0.
2. During 5 to 10 minutes the heavy liquid with the sample was left in an ultrasonic generator (40 kc/sec) in order to disintegrate the clay matrix. In centrifuging the organic material became separated from the mineral particles which precipitated on the bottom of the tube.
3. The heavy liquid containing the organic material was diluted with alcohol, after which the organic material could be precipitated by centrifuging.
4. In order to remove remnants of bromoform the residue was washed with alcohol.
5. Subsequently the residue was gently boiled in 40% hydrofluoric acid for 1 minute to dissolve the mineral particles which had escaped gravity separation.
6. The HF treatment was followed by acetolysis.
7. After acetolysis the residue was washed with water, stained with safranin, and transferred to silicone oil.

8. CONSTRUCTION OF THE POLLEN DIAGRAM (*fig. 3*)

All identified pollen taxa are included in the basic pollen sum, with the exception of those of water and marsh plants, such as *Isoëtes*, *Myriophyllum*, *Potamogeton*, *Cyperaceae*, and *Sparganium*. The frequencies of these types are expressed as percentages of the basic pollen sum. Fern spores are not included in the pollen sum. The pollen sum is generally more than 600, amounting to more than 1000 in a number of samples. Only in the samples 72 and 73 a much lower number of pollen was counted, in spite of the fact that the whole residue was analysed. The samples from the upper 40 cm of the deposit proved to be too poor in pollen for a satisfactory result.

The ratio between tree pollen and herbaceous pollen is shown in the main diagram A, in which the curves for *Pinus*, *Quercus*, *Chenopodiaceae*, and *Artemisia* are also drawn. To the left of the main diagram A the arboreal pollen taxa are represented, to the right the herbaceous pollen types. To the right of the column with the pollen sums the types which are not included in the sum are given. The percentages are shown on two scales; the white silhouette curves are a 10 times exaggeration of the black ones (each scale unit represents 10 and 1 %, respectively).

It is very well possible that various herbaceous pollen types which are included in the basic sum originated at least partly from local marsh plants (*Gramineae*, *Cruciferae*, *Compositae*, *Umbelliferae*). In consequence of this the main diagram A may not always provide a true picture of the upland vegetation pattern, that is to say, of the ratio between forest and open vegetation. For that reason another diagram was constructed (main diagram B), the pollen sum of which is made up of trees, shrubs, *Artemisia*, and *Chenopodiaceae*.

It should be mentioned that the *Quercus* percentages (main diagram A) include the *Quercus calliprinos*-type, for which pollen type also a separate curve is drawn. In the same way *Noaea*-type and *Aellenia*-type are included in the curve for *Chenopodiaceae*, *Artemisia vulgaris*-type in that for *Artemisia*, Cerealia-type in that for *Gramineae*, and *Cladium* in that for *Cyperaceae*.

9. POLLEN ASSEMBLAGE ZONES

The pollen diagram is subdivided into a number of zones and subzones. The zoning is mainly based on changes in the Σ AP/NAP ratios, but other features are also of importance in this repect. These pollen assemblage zones, which should facilitate the discussion, are relevant to the Ghab diagram only. It must be stressed that in spite of comparable zone designations this zoning is not the same as in the diagram from Tenaghi Philippon in north-eastern Greece (WIJMSTRA 1969).

Zone R (spectrum 1)

The distinction of a separate zone R consisting of one spectrum only may appear to be a bit far-fetched at first glance. Spectrum 1 diverges from the next spectrum by higher values for *Cedrus*, *Abies*, and *Quercus*, whereas the percentages for *Chenopodiaceae* and *Artemisia* are lower. In addition to the fact there is a conspicuous change in sediment between samples 1 and 2; this suggests that spectrum 1 forms part of a pollen zone reflecting another vegetation type than that represented in zone S.

Zone S (spectra 2 to 7)

This pollen zone is characterized by high percentages for *Chenopodiaceae.* On an average the *Quercus* values in the upper part of this zone are higher than those in the lower part. *Cedrus* is fairly well represented, while *Juniperus* reaches somewhat higher values in the upper part of this zone. *Ephedra* has the highest percentages of the whole diagram.

Zone T (spectra 8 to 14)

In this zone the percentages for *Artemisia* and *Chenopodiaceae* drop to very low values. It is likely that the Gramineous pollen, which makes up most of the NAP pollen in this zone, must be ascribed at least for the greater part to local grasses. The beginning of subzone T1 (spectra 8 to 12) shows an increase of *Quercus* and *Pinus,* which latter pollen type was counted in fairly large numbers in the upper part of this subzone. *Quercus calliprinos*-type and *Pistacia* show relatively high values, whereas *Cedrus* is represented by very low percentages. Subzone T2 (spectra 13 and 14) has lower pine and higher oak values than T1. *Juniperus* is present in smaller numbers than in subzone T1 and the *Cedrus* curve starts to rise again.

Zone U (spectra 15 to 24)

The whole of pollen zone U is characterized by relatively high tree pollen percentages although they are lower than those in zone T. Subzone U1 (spectra 15 and 16), with fairly high Chenopodiaceous percentages, shows the lowest Σ AP values of this zone. Nevertheless, spectrum 15 has the highest *Cedrus* percentage of the whole diagram. A distinct rise in *Juniperus* may be observed.

Subzone U2 (spectra 17 to 20) is distinguished from U3 (spectra 21 to 24) mainly by relatively high percentages for the *Carpinus orientalis/Ostrya* pollen-type and by higher juniper values.

Zone V (spectra 25 to 27)

In the upper part of U3 *Chenopodiaceae* increase and reach a maximum in zone V, in which pollen zone *Artemisia* values are likewise high. This zone is further characterized by low values for *Cedrus* and *Juniperus.*

Zone W (spectra 28 to 34)

In zone W total tree pollen values are fairly high again. In subzone W1 (spectra 28 to 31) *Juniperus* is represented by rather large pollen numbers. In subzone W2 (spectra 32 to 34) *Pinus* shows a maximum, whereas *Artemisia* and *Chenopodiaceae* are strikingly low. In the uppermost spectrum of this subzone *Pinus* is low again, but *Quercus* is higher than in the previous spectra, as a result of which the decline in ΣAP is not very considerable. This behaviour of pine and oak is comparable to that in pollen zone T: the decline in the *Pinus* percentages is partly compensated by an increase in *Quercus.*

Zone X (spectra 35 to 47)

This zone shows fluctuating ΣAP/NAP ratios. Subzone X1 (spectra 35 to 37) has rather high herbaceous values which are mainly caused by the strong increase in *Chenopodiaceae.* After the minimum in the ΣAP in spectrum 37 a decline in the curve for *Chenopodiaceae* and an increase in the oak pollen values can be seen (subzone X2, spectra 38 to 43). Finally, in subzone X3 (spectra 44 to 47) the increase in *Chenopodiaceae* and *Artemisia* and the decline in *Quercus* result in very low ΣAP values in spectra 46 and 47. The juniper curve shows a conspicuous fall in this subzone.

Zone Y (spectra 48 to 60)

The transition to pollen zone Y is marked by a rapid decrease in *Chenopodiaceae* and *Artemisia.* Of zone Y, subzone Y1 (spectra 48 to 50) has the highest total tree pollen values, but *Cedrus* and *Juniperus* percentages are low. In subzone Y2 (spectra 51 to 53) *Cedrus* shows the highest values of the whole zone, but *Juniperus* remains low, with the exception of an insignificant peak in spectrum 51. The decrease in ΣAP values from spectrum 53 onward is interrupted by a *Quercus* maximum in spectrum 56. For that reason the upper part of pollen assemblage zone Y is subdivided into three subzones, *viz.* Y3 (spectra 54 and 55), Y4, (spectrum 56), and Y5 (spectra 57 to 60). It must be admitted that a subzone consisting of one spectrum only is not very satisfactory, especially since it cannot be excluded that the *Quercus* pollen peak in spectrum 56 is accidental and that it is not the reflection of an appreciable increase of oak in the vegetation. Subzone Y5 is characterized by very low total tree pollen values, *Chenopodiaceae* showing maximum values.

Zone Z (spectra 61 to 74)

In zone Z ΣAP reach high percentages. A very conspicuous rise in tree pollen values takes place in subzone Z1 (spectra 61 to 63). In addition to *Quercus, Pistacia, Olea,* and *Carpinus orientalis/Ostrya*-type show a striking increase. In this subzone *Cedrus* shows for the last time fairly high values. In subzone Z2 (spectra 64 to 66) cedar values are low, while the other pollen types mentioned above have rather high percentages. In subzone Z3 (spectra 67 to 74) the values for *Olea* and *Pinus* are somewhat higher than in the previous subzone, whereas *Juniperus* and *Cedrus* disappear almost completely. The *Quercus calliprinos* pollentype is fairly common in this subzone.

10. VEGETATIONAL HISTORY

An interpretation of the Ghab diagram in terms of past vegetation patterns must remain very speculative. For a satisfactory reconstruction of earlier vegetations in a region with such a diversity in topography and climate as north-western Syria more pollen diagrams are needed. However, it is not likely that in this region pollen-bearing sediments covering the Late-Quaternary will be found outside the Ghab valley.

For the following speculations on past vegetations in north-western Syria the relation between the upper part of the Ghab diagram (especially spectra 67 to 71) and the supposed present-day natural vegetation (*chapter 4. fig. 4e*) serve as a basis. Further it is assumed that *Artemisia* and *Chenopodiaceae* are particularly indicative of dry steppe vegetations and not so much of alpine vegetations. For the alpine zone of the Lebanon Mountains PABOT (1959) does not mention *Artemisia* at all, while of the *Chenopodiaceae* only *Noaea mucronata* is common there. In the steppe, on the other hand, *Artemisia herba-alba* is a common species, while various *Chenopodiaceae* (*Noaea mucronata, Haloxylon articulatum, Salsola mucronata*) play an important part.

During zone S time steppe vegetations rich in *Chenopodiaceae* would have covered the Zawiyé Mountains and at least the lower part of the east flank of the Alaouite Mountains. *Cedrus* pollen values of about 1.5% suggest that this tree was common in the upper part of the Djebel Alaouite, probably on both sides of the crest. On the East flank of this mountain range a more or less open forest, with deciduous oaks as the most important trees, would have occurred between the cedar zone near the top and the steppe at lower elevations. The climate during the period represented by this pollen zone would have been colder as well as drier than that of to-day.

In the course of zone S, oak and to a lesser extent also juniper pollen values increase, while *Pistacia* and *Carpinus orientalis/Ostrya*-type show a continuous curve in the upper part of this zone. These changes formed, as it were, the introduction to the development of the vegetation reflected in the lower part of pollen zone T. In the period between spectra 7 and 9 trees expanded considerably at the expense of steppe vegetations.

During zone T time the whole of the Alaouite Mountains would have been covered by forest vegetations. Pine would have been more common than it would be at present under natural conditions. The very low *Cedrus* pollen values suggest that very probably this tree did not constitute a separate vegetation zone. The relatively high *Juniperus* percentages in the greater part of subzone T1 indicate that on the East flank of the Djebel Alaouite juniper was a fairly important tree. In this connection it should be mentioned that a surface-sample study in south-eastern Turkey led to the conclusion that in general *Juniperus* is underrepresented in the pollen rain (VAN ZEIST *et al.* 1969/70). This conclusion is confirmed by the analyses of surface samples from the Lebanon and Anti-Lebanon Ranges (this study has not yet been completed). The low juniper pollen values in the upper spectrum of subzone T1 and in subzone T2 indicate that, at least temporarily, the share of this tree in the vegetation had diminished greatly. The pollen evidence suggests that on the lower part of the east flank of the Djebel Alaouite *Pistacia palaestina* was less common than it would have been at present. The very low *Artemisia* and Chenopodiaceous pollen values indicate that tree growth in the Zawiyé Mountains was denser than it would have been to-day without human interference. During the period represented by the spectra 9 to 12 the West flank and also other parts of the Djebel Zawiyé were probably covered by open forest types (*fig. 4a*).

During subzone T1 time the climate would have been at least as moist as it is to-day. Temperatures would have been lower than at present, as is suggested, among others, by the comparatively low *Olea* percentages (on an average 0.6 and 2.4% in T1 and Z2 + Z3, respectively).

Subzone T2 constitutes the transition to pollen zone U. During the greater part of zone U the distribution of forest and steppe would have been comparable to the present natural vegetation pattern. Only subzone U1 seems to represent a period with a somewhat larger share of steppe vegetations. As suggested by the pollen evidence, during zone U time cedar was a common tree, and at higher elevations in the Djebel Alaouite a *Cedretum libani* occurred on the East flank as well as on the West flank. *Juniperus* would have played an important part in the forest vegetation on the east flank, in particular during subzone U2 time. One could wonder whether a juniper zone was present above the cedar zone. Moreover, during he period covered by subzone U2 *Carpinus orientalis* and/or *Ostrya carpinifolia* were fairly common. *Pistacia palaestina*, on the other hand, would have been of minor importance. In the Zawiyé Mountains tree growth would have been rather scanty (*fig. 4b*).

It is likely that during the greater part of zone U time the climate was not appreciably drier or moister than it is to-day, but that temperatures were lower.

An increase in dryness caused an expansion of steppe vegetations during zone V period. The Djebel Zawiyé was probably treeless, just as the lower part of the East flank of the Alaouite Mountains. Deciduous oaks would have been dominant in the forested parts of the slopes bordering the Ghab valley to the West. Juniper was of minor importance, while at higher elevations cedar would have occurred as a component of the mixed-oak forest.

During subzone W1 time, steppe vegetations would have covered a larger area than during the greater part of zone U time. Furthermore, the share of juniper would have been somewhat higher, while the cedar zone was probably less extensive. In subzone W2 time trees expanded again, resulting in a distribution of forest and steppe comparable to the present-day natural one. The fairly high *Pinus* values in spectra 32 and 33 suggest that this tree formed part of the forest vegetations on the East flank of the Djebel Alaouite. It is likely that the climate during subzone W2 time was moister than that during the previous subzone.

The course of the pollen curves in pollen zone X reflects fluctuations in the vegetation pattern. It seems justified to assume that during the whole of this period the Zawiyé Mountains were treeless or nearly so. In subzone X1 a decrease in total tree pollen values can be observed. During the period represented by this subzone the lower part of the East flank of the Djebel Alaouite was probably treeless, while above this steppe zone open forests would have occurred. The comparatively high *Cedrus* pollen percentages indicate that cedar was

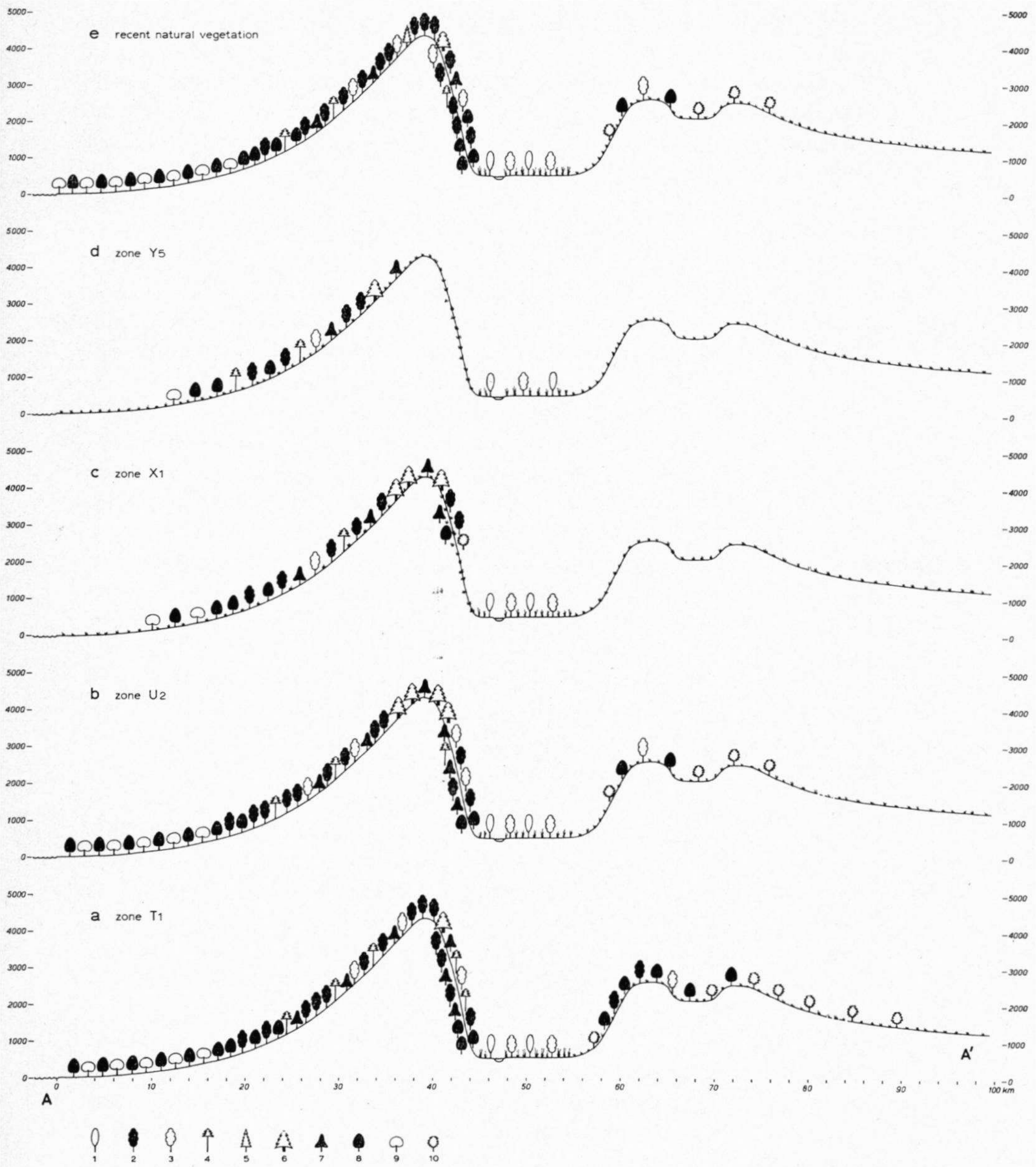

Fig. 4. Reconstructions of the present-day natural vegetation along a transect through the Djebel Alaouite, the Ghab valley and the Djebel Zawiyé (e) and of the vegetation during a few phases of the last glacial period (a, b, c and d). The location of the transect A–A' is indicated in *fig.* 1. 1: *Populus, Salix*; 2: deciduous *Quercus*; 3: various other deciduous trees; 4: *Pinus*; 5: *Abies*; 6: *Cedrus*; 7: *Juniperus*; 8: *Quercus calliprinos, Pistacia palaestina*; 9: *Pistacia lentiscus, Ceratonia siliqua*; 10: *Crataegus, Amygdalus, Prunus*. Elevations given in feet.

common at higher elevations, in spite of the fact that the climate must have been quite dry (*fig. 4c*).

Subzone X2 time would have witnessed a partial recovery of forest vegetations while during subzone X2 time a renewed expansion of the steppe took place, probably resulting in a complete deforestation of the area East of the crest of the Djebel Alaouite (spectra 46 and 47). The dry and relatively cold climate during subzone X3 time would undoubtedly likewise have affected to a large extent the vegetation on the west flank of the Alaoutie Mountains.

Pollen zone Y starts with a conspicuous rise in ΣAP, mainly caused by an increase in the *Quercus* pollen percentages. During subzone Y1 time oak woodland may have covered a large part of the slopes West of the Ghab valley. Juniper would have played a fairly unimportant part in these forest vegetations. It seems that during subzone Y1 time cedar did not recover from the losses suffered in the last phase of subzone X3 time.

On the other hand, subzone Y2 shows again higher *Cedrus* pollen values. The likewise higher ΣNAP values in this subzone could point to an increased dryness which is difficult to reconcile with the recovery of cedar. However, one must consider the possibility that the decrease in ΣAP was caused by a partial replacement of *Quercus* by *Cedrus*. Oak is generally overrepresented in the pollen rain, whereas cedar does not seem to have such a good pollen dispersal. This would imply that during subzone Y2 time the climate was not drier than during the previous subzone.

During subzone Y5 time steppe vegetations must have reached a maximum expansion (*fig. 4d*). Of the whole period covered by the Ghab diagram, the upper part of zone Y time had the most unfavourable climate for tree growth. It must have been very dry, while temperatures were considerably lower than they are to-day in this region.

In the first part of zone Z time (subzone Z1) oaks and other trees invaded the steppes of the previous period. The share of *Juniperus* in the expanding forest vegetations would not have been very prominent. The increase in humidity as well as temperature allowed a last expansion of *Cedrus* during subzone Z1 time, but subsequently cedar was largely replaced by deciduous trees.

Plant growth during subzone Z3 time corresponds with the present-day natural vegetation (*chapter 4*). Pollen zone Z2 differs from Z3 by lower herbaceous pollen values, while oak pollen percentages are considerably higher. This would suggest that during subzone Z2 time forests covered a larger area or that forest vegetations were denser than in subzone Z3 time, implying a somewhat moister climate. On the other hand, it is not impossible that at least a part of the decline in total tree pollen values was caused by the replacement of oak by trees with a less good pollen dispersal, *e.g.*, *Olea*. The larger share of *Pinus* in the forest vegetation of subzone Z3 does not provide information on differences in climate between subzone Z2 and Z3. *Pinus brutia*, which pine species is most probably concerned here, occurs in humid as well as in semi-arid environments (NAHAL 1962, p. 576). It may be wise to refrain from conclusions concerning changes in climate during the last 10,000 years in this region on the basis of the Ghab diagram only. On the other hand, it should be borne in mind that the pollen curves in this diagram seem to point to a slightly moister climate during subzone Z2 period.

As for the influence of man on the vegetation, *Cedrus* values drop to zero between spectra 70 and 71. Assuming a more or less constant sedimentation rate, cutting of cedar in the Djebel Alaouite should have taken place at about 3000 B.C. This seems too early, so that either the inferred date is not correct or the decrease in cedar was a natural one. On the other hand, the decrease in *Pistacia, Olea, Carpinus orientalis* and/or *Ostrya carpinifolia*, the almost complete disappearance of *Juniperus*, and the increase in *Pinus*, especially in the uppermost spectrum, together point to changes in the vegetation caused by man.

The uniform sediment type throughout by far the greater part of the core, *viz.* grey clay with varying amounts of shell detritus, and the good pollen preservation indicate that the site where the core was taken was under water during most of the time. This conclusion is confirmed by the presence of water plants, such as *Isoëtes* and *Myriophyllum*. More recently the water became so shallow that peat could develop, and indeed the site dried out intermittently, as is suggested by the very poor pollen contents in the upper 40 cm of the deposit.

During the period represented by the diagram the larger part of the Ghab valley would have consisted of lakes fringed by swamp vegetations. The permanent presence of open water and marshes implies that the favourable effect of the evaporation from the Ghab valley on the humidity of the air at higher elevations on the East flank of the Djebel Alaoutie (*cf.* NAHAL 1962, p. 588) would have prevailed throughout the whole of this period.

11. COMPARISON WITH OTHER POLLEN DIAGRAMS

The left side of *table 2* provides a summary of the interpretation of the Ghab diagram. The calculation of the ages at the extreme left is based on the radiocarbon dates of 10,080 ± 55 and $45{,}650 \pm \frac{2200}{1650}$ for the core sections of 129–137 and 645–655 cm, respectively. In the table the position of the radiocarbon-dated samples is indicated by a black dot. These dates allow an estimation of the ages for the part from zone V onwards. It should be stressed that the sedimentation rate would not have been constant all the time, as a result of which the actual dates may differ not inconsiderably from the inferred ones in some cases.

For an estimation of the ages for the part covering the zones T and U the ^{14}C date of $47{,}000 \pm \frac{6000}{3400}$ for the section of 960–972 cm (corresponding with the S/T zone boundary) cannot be used. It is clear that much more time than about 1500 years must have elapsed between ca. 965 and 650 cm. On the other hand, the average sedimentation rate of 10 cm per 688 years, the basis of calculation of the ages for the part between the middle and upper radiocarbon dated sample, cannot simply be assumed to be likewise valid for the part below 650 cm. For that reason no estimated ages are given for the lower part of the Ghab diagram.

For a comparison with the Ghab diagram that of Tenaghi Philippon in north-eastern Greece, which covers the whole of the last glacial period (WIJMSTRA 1969), is the most obvious one. In comparing both diagrams it soon becomes clear that they do show many similarities, but that a detailed correlation cannot be made. A tentative correlation is shown in *table 2*. The comparison is mainly based on the course of the tree pollen/non-tree pollen ratios in both diagrams.

The ages which could be established or calculated for corresponding sections in both diagrams generally agree fairly well. The age for the beginning of zone Z1 in the Ghab diagram and zone Y in the Tenaghi Philippon diagram constitutes a discrepancy. For the Tenaghi Philippon diagram an age of about 14,600 was established for the X5/Y zone boundary, whereas for the Ghab diagram an age of about 11,400 was calculated. However, the very rapid increase in tree pollen values in zone Z1 of the Ghab diagram suggests that either sedimentation was very slight at that time or that there is a hiatus, in consequence of which the inferred date of 11,400 may be wrong by a few thousand years.

The radiocarbon date of 45,650 $\pm \frac{2200}{1650}$ for the lower part of zone V in the Ghab diagram does not seem to agree with the date of 49,070 $\pm \frac{3000}{2100}$ established for the beginning of subzone P1 in the Tenaghi Philippon diagram. However, in view of the fairly large statistical uncertainty for both dates this discrepancy may only be a seeming one.

Once again, the hypothetical character of the correlation of both diagrams should be kept in mind. On the other hand, it is clear that during the last glacial in both areas fluctuations in climate caused an alteration between periods in which steppe vegetations expanded and others in which forests increased. The period most unsuitable for tree growth in both areas was that of subzones Y5 and X5, respectively.

The diagrams for Lake Zeribar in the mountains of Western Iran point to treeless vegetations during the period from ca. 22,000 to 12,000 B.P. (VAN ZEIST & WRIGHT 1963, VAN ZEIST 1967). To-day a forest consisting of oak and other deciduous trees constitutes the climax vegetation in that region. The somewhat more favourable climate suggested by the diagrams from the Ghab and Tenaghi Philippon for the period before ca. 16,000 B.P. is not expressed in the pollen precipitation in the Lake Zeribar area. A possible explanation for this phenomenon will not be offered here.

So far no other pollen diagrams covering at least a part of the last glacial period are available for the Near East. However, it seems justified to conclude that between about 16,000 and 14,000 B.P. tree growth in the Near East was confined to a few areas. It was during the last phase of the last glacial period, after about 14,000 B.P., that trees would have started to spread again over south-western Asia.

calculated ages	local zonation		GHAB VALLEY		TENAGHI PHILIPPON (GREECE)	local zonation	(calculated) ages
			east flank Djebel Alaouite	Djebel Zawiyé			
0						Z 5	
5000	Z	3	forest	steppe forest	forest	Z 1-4	
		2					
10000 C 14: 10080		1	steppe → forest	steppe → steppe forest	steppe → forest	Y	10300 14600
	Y	5	steppe	steppe	steppe	X 5	16000
15000		4					
		3	steppe and forest	steppe	steppe with pine stands	X 3,4	
20000		2					
		1	forest and steppe				22500
25000	X	3	steppe	steppe	alternately steppe and steppe with pine stands	X 1,2 P 5,6,7	
30000		2	forest and steppe				33000
35000		1	steppe and forest	steppe	steppe	P 4	37000
	W	2	forest	steppe forest	alternately steppe and steppe with pine stands	P 1,2,3	
40000		1	forest and steppe	steppe			49000
45000 C 14: 45650	V		steppe and forest	steppe	steppe	V 3	
	U	3	forest	steppe forest	steppe with pine stands	V 1,2	
		2					
		1		steppe			
	T	2	forest	steppe forest	forest	U	
		1		open forest			
C 14: 47000	S		forest and steppe steppe and forest	steppe	steppe	T	
	R						

Table 2. Tentative correlation of the vegetational history in north-western Syria and north-eastern Greece (WIJMSTRA 1969).

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