Studies in the vegetational history of Greece

Greig, J. R. A.

Greig, J. R. A. (1973) *Studies in the vegetational history of Greece*, Durham theses, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/10255/

STUDIES IN THE VEGETATIONAL HISTORY OF GREECE

By

J.R.A. GREIG

Being a thesis submitted for the degree of Master
of Science at the University of Durham

October 1973

To the best of my knowledge the content of this thesis is entirely my own unpublished research apart from text references to published works.

James Greig
J.R.A. Greig

CONTENTS

page
1. Abstract 1
2. Introduction 3
3. General considerations 9
    3.1 The fieldwork
    3.2 The laboratory work
4. Factors affecting the vegetation of Greece 20
    4.1 Introduction
    4.2 Geology
    4.3 Climate
    4.4 Human interference
    4.5 Vegetational types
    4.6 Crops
5. Pollen morphology 37
6. Lake Kopais 43
    6.1 The Kopais region
    6.2 The fieldwork
    6.3 The pollen diagram
    6.4 Main divisions
    6.5 Sub-divisions
    6.6 Interpretation
    6.7 Chronology
    6.8 Aquatic pollen diagram.
7. Lake Ladzas
    7.1 The Ladzas region
    7.2 The fieldwork
    7.3 The pollen diagrams
    7.4 Pollen diagram division
    7.5 Correlation

CONTENTS (continued)

page

- 7.6 Interpretation
- 7.7 Discussion

8. Philippi 95

- 8.1 The Philippi region
- 8.2 The fieldwork
- 8.3 The pollen diagrams
- 8.4 Radiocarbon dates
- 8.5 Correlation of the diagrams
- 8.6 Zonation of the diagrams
- 8.7 Interpretation
- 8.8 Dating the pollen zones
- 8.9 Chronology and archaeology

9. Gravouna 125

- 9.1 The Gravouna region
- 9.2 The fieldwork
- 9.3 The pollen diagram
- 9.4 Zonation
- 9.5 Interpretation
- 9.6 Discussion and comparison
- 9.7 Pollen rain data

10. The vegetational history of Greece 136

- 10.1 The Eemian
- 10.2 The Weichselian
- 10.3 The Late-glacial
- 10.4 The Post-glacial (Holocene)
- 10.5 Cultivated crops
- 10.6 Distribution of taxa

11. References 154

LIST OF FIGURES

		page
1.	General map of Greece	9
2.	Maquis vegetation on the Chalkidike peninsular	30
3.	Kopais site map	42
4.	Kopais supplementary diagram	54
5.	Kopais sediment symbols	72
6.	Kopais pollen diagram	72
7.	Map of northern Greece	73
8.	Ladzas site map	75
9.	Photograph of Lake Ladzas site	76
10.	Ladzas and Gravouna sediment symbols	94
11.	Ladzas 1 pollen diagram	94
12.	Ladzas 2 pollen diagram	94
13.	Philippi site map	95
14.	Photograph of the beginning of the Philippi 3 sampling pit	98
15.	Archaeological correlation table	116
16.	Philippi sediment symbols	124
17.	Philippi 1 pollen diagram	124
18.	Philippi 3 pollen diagram	124
19.	Gravouna site map	125
20.	Schematic representation of Gravouna vegetation	126
21.	Gravouna pollen diagram	131
22.	Inter-diagram pollen zone correlation table	136

CHAPTER 1. ABSTRACT

1. ABSTRACT

The vegetational history of Greece was studied by means of pollen analysis. Six pollen diagrams from various parts of the Greek mainland are presented, which between them cover a time from around 30,000 years ago to the present day. The development of the vegetation from a steppe during the time of the last glaciation through a transitional stage in the Late-glacial period to a Post-glacial forest, and the degradation of the vegetation to the present day scrub is represented by three main pollen assemblage zones. Zone I covers part or all of the time of the last glacial period when the dominant vegetation was an Artemisia steppe with little woodland, in response to a cool dry climate with a temperature comparable with that of northern Europe today but probably less rainfall than is usual in Greece now. Zone II covers the vegetational development during the time of the Late-glacial and early Post-glacial where evidence from southern Greece shows a pioneer scrub vegetation being succeeded by mixed-oak forest in response to a temperature and rainfall increase, with a temporary reversion to cool and dry conditions deduced from a vegetational reversion. This sequence probably corresponds to the Lower Dryas-Allerød-Upper Dryas sequence known in northern Europe. Zone III covers the degradation of the forest vegetation which appears to have taken place earlier in southern Greece than in the north, where there appears to have been substantial forest up to at least the year A.D. and possibly until Medieval times before clearance by man and animal. Two periods of olive cultivation are recognisable, one in Middle Bronze Age - Mycenean times and the other in Late Dark Age - Early Classical times. There is no sign of climatic change in the Post-glacial sequence. The pollen rain from some modern Greek vegetation shows

that taxa which are abundant there may be seriously under-represented in the pollen rain.

CHAPTER 2. INTRODUCTION

2. INTRODUCTION

Pollen analysis has been carried out in a fully scientific manner for more than fifty years. In its earliest stages, when it was being pioneered by Von Post and others, pollen diagrams were prepared from sites in Scandinavia. Then the new ideas spread rapidly so that in the twenties and thirties pollen diagrams were published from sites all over northern and central Europe. This early work provided the outlines of vegetational history in these regions for the time since the last glaciation. Pollen diagrams were also published from more distant places like America, New Zealand and Patagonia (Von Post 1946).

By 1934 Godwin had produced a fairly detailed account of vegetational changes in this country, and his system of drawing pollen diagrams became the accepted norm. In 1940 he published his eight zone division of the main pollen assemblages in the Post-glacial vegetational succession which has also become the accepted scheme in England.

In the fifties pollen analysis advanced, not only in the range and detail of the diagrams published, but also in matters of technique. Works were published on such topics as pollen morphology and identification (Iversen & Troels Smith 1950) which simplified the identification methodology for a large range of pollen types liable to be encountered in northern European material.

The radiocarbon dating method (Libby 1955) was ideally suited for application to pollen analysis as peat sediments may be suitable for both pollen and radiocarbon assay. This led to the dating of the various pollen assemblage zones more accurately than had been the case when dates were obtained from archaeological artifacts found at certain levels in the peat, and from varve counts in Scandinavia.

By the beginning of the sixties there was plenty of detailed information about the vegetational history of northern Europe, supported by radiocarbon dates (Godwin 1960). South of the Alps far less was known about vegetational history, although Dalla Fior (1969) had done much pioneer work in the Alpine region itself in the thirties, but in the Mediterranean region so little was known that Turrill's statement (1929) that many of the episodes of the history and development of the flora of the Balkan peninsular were completely unknown rang nearly as true in 1960 as it did then.

In the northern European region it was known that many plants must have immigrated back there with the onset of warmer conditions after the end of the last glaciation. The subject of the survival of arctic alpine plants as relicts has long occupied the literature, but the survival of temperate habitat plants during the last glaciation has been largely ignored, it being tacitly assumed that somewhere in the south of Europe there were places where these plants could survive in a moderate climate while the north of Europe was denied to them through glacier and tundra until the Late-glacial and Post-glacial climatic amelioration.

Thus the vegetational history of the Mediterranean is important both as a study in itself and as a means of understanding some of the factors behind the arrival of our own flora. However this region is a difficult one in which to apply pollen analysis, for peat bogs of the kind that gave up the detailed information on the history of the British flora are a great rarity in southern Europe, as the climate is too dry for blanket peats and raised bogs.

Palynologists have had to adapt their methods and evolve new ones to be able to use deep lakes with a great range of sediment types as a source of cores. A further difficulty in dealing with the vegetational history of this region is that the flora is far larger, and there is a correspondingly large pollen flora, the systematic identification of which can be problematic, likewise the ecology and description of vegetation is not so well advanced.

The first major work on the vegetational history of the Mediterranean (Beug 1961) dealt with the problem of the identification of the pollen types encountered, and provided the outline of the Post-glacial vegetational development of the Adriatic coastline. Another pioneer work was a pollen diagram from southern Spain, indicating a vegetation with <u>Artemisia</u> and <u>Pinus</u> during the time of the last glaciation, succeeded by vegetation with <u>Quercus</u> in the Post-glacial. (Menendez Amor & Florschutz 1962). Shortly after, a diagram was published from a site in Iran (Van Zeist & Wright 1963), outside the Mediterranean region but of great peripheral interest, and also the first preliminary pollen diagram from Greece (Van der Hammen et al 1965) an outline diagram from the very deep peat bed at Philippi which showed that the glacial period vegetation consisted mainly of herbs, and that of the Post-glacial mainly of trees, thus giving the basic course of Greek vegetational history just as Godwin's pioneer work had done this for Britain more than forty years previously. Subsequently the pace has increased and pollen diagrams have been published from many parts of the Mediterranean, covering various epochs, together with modern pollen rain studies as an aid to interpretation.

Palynology and archaeology have been long associated, and Dimbleby (1962) explored the possibility of recovering useful information about prehistoric environment with his small diagram prepared from actual archaeological deposits at Nea Nikomedeia in Greece, then Wright (1968b) attempted to find out about the possibility that climatic change had been the downfall of the Mycenean civilisation.

When the present work was initiated in 1968 the pollen diagrams mentioned above with the addition of a few others amounted to the sum total of the information available on this subject. One of the aims of the project was to provide detailed pollen diagrams from sites in different regions, to produce if possible a coherent pattern of vegetational changes. A further aim was to provide information about the environment in prehistoric times in connection with the archaeological excavations being carried out on a tell at Sitagroi, Macedonia, by the Universities of Sheffield and California (Los Angeles), under the direction of Professor C. Renfrew and Professor M. Gimbutas respectively.

CHAPTER 3. GENERAL CONSIDERATIONS ON COLLECTION AND ANALYSIS OF SAMPLES

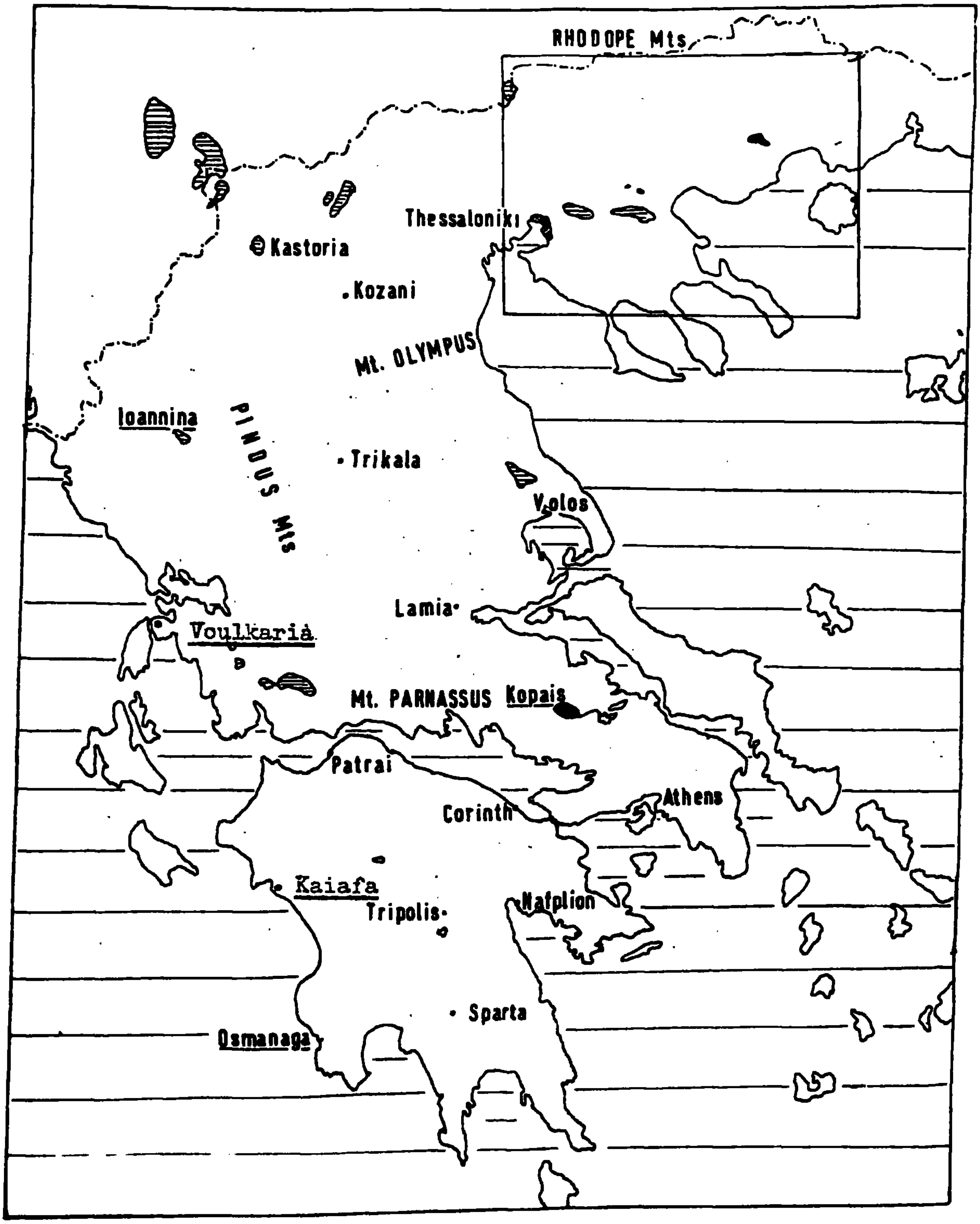


Figure 1 MAP of GREECE (general)

3.1 THE FIELDWORK

The search for sites that might be suitable for coring started with a search through the cartographic literature to try and locate probable places on the map. Well detailed maps of parts of Greece were produced by both sides in World War II, and although some of them are merely enlarged copies of much earlier maps going back to the nineteenth century, they often show the sites of lakes and marshes that have since been drained, and which are not featured on more recent maps. The Greek Ethniki Statistiki series of 1963 was also found to be a useful source of information although lacking in fine detail. Of the promising places seen on the map, some could not be visited due to inaccessibility, or because they lay in places where it was not possible to go without special permission, as in frontier zones and the Mount Athos peninsular. The sites that were accessible in northern Greece were visited and test sampled, and if found to have suitable sediments were carefully cored over a few days. Talk with farmers and other people with a good knowledge of their local countryside often proved a useful source of information about local conditions such as recent drainage of wet areas, or the periodicity of flooding.

Some places with sedimentary successions were found along the meandering courses of various rivers, or where recent embankment of a river had changed its course, but such sediments were thought to be suspect due to the possibility of uneven deposition and disturbance by the river, with complex stratigraphy.

The most useful sites were lakes which were drained, or in the process of drainage, so that the sediments could be sampled directly and fairly easily compared with the complication of sampling from a makeshift raft moored in a lake, as done by Van Zeist and others (1968). Many such lakes have been drained by the Greek Government so that the rich alluvial soils can be used for agriculture, and two of these provided good cores. Another site was provided because the water had been drained away for irrigating fields in 1968, and a fourth was the Philippi peat bed which owes its existence to an unusual set of geological phenomena (see Chapter 8).

A soil auger and a screw auger were used for the trial borings, and the latter was used for sampling the lake clays, for which it appears to be the most suitable method of hand sampling. Two head diameters were used, 1" and 1½", the smaller size being useful in hard clays when the 1½" head became difficult to pull up out of the ground.

A Hiller borer and a modified Livingstone type borer were tried, but it proved impossible to make them penetrate the hard sediments encountered. The peat at Philippi was sampled partly from an excavated pit and partly by Russian borer in four closely spaced boreholes so as to provide enough peat for radiocarbon dating.

3.2 THE LABORATORY WORK

Two main types of sediment were dealt with, peaty sediments of mainly organic origin, and clay sediments almost entirely mineral in content. The peat presented few problems in preparation for pollen analysis, although some of it was wood-hard and took a long time to break down. There were some instances of samples containing silica which had to be dissolved in hydrofluoric acid. The preparation procedure, based on that in Faegri & Iversen (1964), is as follows:

3.3 LABORATORY PROCEDURE FOR PEAT SEDIMENTS

1. Disperse the sample in 10% potassium hydroxide at 100°C for 10 minutes, then filter through 100 mesh gauze. Inspect for siliceous matter to see whether hydrofluoric acid treatment will be necessary. Centrifuge (for about 4 minutes at about 3000 rpm.) and discard the supernatant.
2. If the sample is free of siliceous matter, proceed to stage 4. If it does, take it up in the minimum amount of 20% hydrochloric acid. Then add about 40 cm^3 40% hydrofluoric acid and stand in a water bath at 100°C for 10 minutes with occasional stirring, inside a fume hood. Polypropylene test tubes and stirring rods should be used at this stage since hydrofluoric acid attacks glass. Centrifuge while hot and discard the supernatant with appropriate precautions for handling and disposing of the hydrofluoric acid. Large amounts of dilute alkali should be used to neutralise the excess acid.
3. Take the sample up in the minimum amount of 20% hydrochloric acid to ensure thorough mixing, then add a further 40 cm^3. Stand in a water bath at 100°C for 10 minutes with occasional stirring. Centrifuge hot and discard the supernatant.
4. Dehydrate the sample by taking up in about 40 cm^3 glacial acetic acid and stirring thoroughly. Centrifuge and discard the supernatant.
5. Take the sample up in about 10 cm^3 acetic anhydride, then add about 10 drops of concentrated sulphuric acid, drop by drop, and with constant stirring. Stand in a water bath at 100°C for a minute, centrifuge, and discard the supernatant into a large volume of water.
6. Take the sample up in a little glacial acetic acid, then add water until the tube is nearly full and stir. Centrifuge and discard the supernatant.

7. Take the sample up in water made alkaline in a little potassium hydroxide, centrifuge and decant the supernatant away carefully so that the pellet at the bottom of the tube is not disturbed. Stand the tube inverted to drain the last traces of water.
8. Add a quantity of melted glycerine jelly, about the same volume as that of the sample, and with the desired amount of safranin stain. Make up some slides and examine for suitability for counting. Make up further slides, adjusting the amount of stain, glycerine jelly and the slide thickness to suit the conditions.

The other types of sediment were mainly clays of various colours, some mottled, and some coloured brick red probably from the deposition in the sediment of red terra rossa clays due to erosion of soil from the surrounding land. The clays often contained other minerals, like sand, silt and schist flakes, all apparently derived from the rocks of the slopes near that particular site. Carbonate deposits seem to have been formed in situ, either from the redeposition of carbonates from the ground water or through the action of living organisms.

The organic content of the clays was very low, estimated at a few per cent of the weight, but it was difficult to measure by firing the material to burn off the organic matter because the clay is apt to lose chemically bound water at this heat and lose extra weight. Samples that were fired lost a few per cent weight, compared with the Greek peat which has a 80% weight loss on firing.

The pollen content was correspondingly low as well, and the first samples were prepared by the standard method as for peat (see above) which brought the problems to light concerning undissolved silica, low pollen content and sometimes poor pollen preservation as well, which made the counting of these early samples very difficult, apart from the problems brought about by the unfamiliar pollen types. Many of the samples were highly alkaline which might account for the poor preservation, there being no inhibition of the action of micro-organisms as in the acid hill peats of Britain for example.

To try and solve this problem of preparation various details of the standard process were systematically altered to improve its efficiency in removing the unwanted matter such as minerals from the preparations, and these alterations were tested on a variety of samples to demonstrate whether a good preparation obtained by a slightly different process was due to the process itself or to the fact that the sample had a good pollen content anyway. If a change in the process resulted in a consistent improvement in the purity of the preparations or a reduction in the time taken by the preparation procedure, the change was incorporated into the standard procedure used.

The first way in which the preparation procedure was improved concerned increasing the efficiency of the separation of the coarse mineral fraction. This can be done either by a filtration process or by, sedimentation, and in the former case it was found that very sandy samples are best filtered through a 100 mesh gauze several times, cleaning the filter each time. If only one filtration is carried out some of the sand and silt of approximately the same size as the mesh can be washed through.

Sedimentation is also a useful technique for getting rid of coarse minerals which may still pass through the filter, like very fine sand and silt. The sample is stirred up in a water suspension and briefly allowed to settle, then decanted to leave some of the silt behind, the whole process being repeated several times if necessary. It was found that the filtration and sedimentation processes could be a net time saving because they simplified the chemical treatments that followed. It was realised that care would have to be exercised to avoid separation methods that could affect the pollen recovery. For this reason the 100 mesh gauze was the finest used so as not to risk trapping the larger pollen grains like those of the Pinaceae. In the sedimentation process it was found that 15 seconds settling time was the maximum in order to avoid any risk of pollen grains settling out and being discarded with the silt.

Sedimentation can also be carried out using a heavy solution which is almost as dense as the minerals to be separated out, but on which all organic material will float. The salts of heavy metals can be used, such as zinc chloride, but there is a disadvantage that when made up into a solution with a density greater than about 2.0 it crystallises at room temperature and therefore has to be used hot, and is highly corrosive. Furthermore its viscosity is such that the separation has to be done by protracted centrifugation. Zinc chloride was used (see later) but found to be too time consuming for normal use although the results were good.

The normal chemical method for the removal of siliceous material is by reaction with hydrofluoric acid, used in various ways. Sometimes it is used cold for 24 hours, or at its boiling point at about 120°C for three minutes but both of these extremes present difficulties, the former of time and the latter of excessive fuming of the acid and possible loss in efficiency through loss of HF gas. The best way of carrying out this treatment seems to be that of Dimbleby (pers.comm.) where the process is carried out for ten minutes with stirring in a boiling water bath, giving effective acid action with the least release of HF gas, and permitting the simultaneous treatment of a whole batch of samples.

The Greek clay material contained such a small proportion of organic matter that the vast bulk of each sample had to be removed by means of theHF treatment, and even the finding of the best way of using the acid was insufficient so the persist~~a~~ence of siliceous matter through HF treatment was troublesome in several samples, which necessitated a repeat of the whole HF procedure. This difficulty led to the development of an improved HF process which was effective for all types of material provided they had first been freed of coarse mineral matter by filtration and sedimentation, as set out above. The normal two stage process of treatment first with hydrofluoric acid and then with hydrochloric was lengthened into a three stage one. After the initial HF treatment and centrifugation the samples were treated with a 1:1 mixture of HF and 20% HCl, once again at $100^{\circ}C$ for ten minutes, and this was followed with the usual hot HCl treatment. This extra stage appeared to be dissolving any traces of silica left over from the first HF treatment as well as removing most of the fluorosilicates and colloidal silicon dioxide at this stage. The final wash in hot HCl then thoroughly removed the last traces of fluorosilicates, leaving pure preparations. Although this alteration is only a small detail in the process, it was found to provide a fairly satisfactory solution to the problem of persistant silica in the Greek material, which had caused so much difficulty when using the standard methods.

While this improved HF process was being developed, an entirely different pollen preparation procedure was published (Guillet & Planchais 1969). This method combines some of the more usual treatments to get rid of non-biogenic matter with the addition of a stage using dispersive agents to break up soil aggregates and clay colloids. There are three basis stages: the dispersal and breakdown of the sample material, its flotation on zinc chloride to separate the biological from the mineral fraction, and a final HF treatment to remove any last traces of siliceous matter. This method was thoroughly tried out in its standard form but it was found that good results could also be obtained from the Greek material by using some of the Guillet and Planchais processes together with the improved HF treatment, and that this took less time and was more predictable than the original methods. Flotation with zinc chloride has already been mentioned as part of the process that was discarded, but the use of dispersive agents to break up clay was found to be useful. Sodium hexametaphosphate is the active ingredient, whose action removes cations like Fe^{+++} from the interstices of the clay micelles, or systems of layers, and replaces them with H^+ ions. The latter have a much weaker charge than the ferric ions, and the micelles tend to break up into colloidal sized particles which then can be removed in the supernat~~e~~ant after centrifugation, visible as a turbidity in the liquid. This layered structure seems to be the reason why hydrofluoric acid treatment is not always the answer to clay mineral in samples, giving them some kind of a resistance to the effects of the acid.

The pollen preparation process as finally evolved is considerably more complex and therefore time consuming tha~~t~~n the original method, but this extra time spent is worthwhile if it ensures that the samples will be silica-free and do not have to be re-processed, and that the preparations are very pure and therefore easier and quicker to count. It was found that acetolysis was not needed on some of the lake sediments, the action of micro-organisms having had the same effect, and if acetolysis was done it did not change the appearance of the pollen at all.

IMPROVED HF PROCESS FOR LAKE CLAYS

1. Disperse the sediment sample in 5-10% potassium hydroxide for 10 minutes in a water bath at 100°C, then filter through a 100 mesh gauze. Repeat the filtration if much material is retained in the first filtration. If fine silt is being carried through the sieve, stir the suspension and allow to settle for 10-15 seconds, then carefully decant the liquid from the silt in the bottom of the tube, repeating if necessary. Centrifuge for about 4 minutes at about 3000 rpm, then discard the supernatant.
2. Take the sample up in 50% cold nitric acid with a trace of hydrochloric acid. The acid should be added very gradually when there is carbonate in the material, or the froth will overflow from the tube. When no more CO_2 is being evolved, centrifuge and discard the supernatent.
3. Take the sample up in a solution of sodium hexametaphosphate (122gm./ltr.) stirring thoroughly. Centrifuge after 5 minutes, and discard the supernatant.
4. Take the sample up in water, stir thoroughly, centrifuge and discard the supernatant. (Stages 3 and 4 should be repeated if much clay mineral persists after the first hexametaphosphate treatment).
5. Take the sample up in the minimum amount of 30% hydrochloric acid, stir thoroughly, then add about 40 cm^3 40% hydrofluoric acid and stand in a water bath at 100°C for 10 minutes inside a fume hood. Polypropylene tubes must be used as the acid attacks glass, and the samples should be stirred occasionally with a plastic rod. Centrifuge while hot and discard the supernatant with appropriate precautions for handling and disposing of the hydrofluoric acid. Large amounts of dilute alkali should be used to neutralise the excess acid.

6. Take the sample up in the minimum amount of 20% hydrochloric acid to ensure thorough mixing, then add about 20 cm^3 20% hydrochloric acid and the same amount of 40% hydrofluoric acid and stand in a water bath at 100°C for 10 minutes with occasional stirring. Centrifuge and discard the supernatant as in stage 5.
7. Take the sample up in the minimum amount of 20% hydrochloric acid, then add a further 40 cm^3. Stand in a water bath at 100°C for 10 minutes with occasional stirring. Centrifuge hot and discard the supernatant.
8. Take the sample up in water made alkaline with a little potassium hydroxide, centrifuge and decant the supernatant away carefully so the pellet at the bottom of the tube is not disturbed. Stand the tube inverted to drain the last traces of water.
9. Add a quantity of melted glycerine jelly, about the same volume as that of the sample, and with the desired amount of safranin stain. Make up some slides and examine for suitability for counting. Make up further slides, adjusting the amount of stain, glycerine jelly and the slide thickness to suit the conditions.

CHAPTER 4. FACTORS AFFECTING THE VEGETATION OF GREECE

4.1 INTRODUCTION

Greece has a rich and distinctive flora, most of which could be described as eu-Mediterranean, that is, the plants are found right round the coasts of the Mediterranean, as can be seen from some distribution maps such as Meusel (1965). There are also taxa whose main distributions are Asiatic, south European, Balkan, central European and even Alpine (Turrill 1929), while in recent times plants have been introduced from many parts of the world such as the Americas and Australasia some of which have subsequently become naturalised in Greece. The origin and development of the Greek flora is a matter with which this whole work is concerned, so it will not be mentioned here, so history apart the important factors in the development of the flora and vegetational groups of Greece are the geology, climate and the effects of man and domestic animals.

4.2 THE GEOLOGY OF GREECE

Greece is a geologically unstable country. The sedimentary rocks are twisted and folded into mountain ranges, and there are volcanoes and other signs of igneous activity.

Limestones and sandstones were formed in the Oligocene and Eocene when the region was covered by a shallow sea. (Turrill 1929). These sediments were raised by subsequent mountain building, forming the ranges of mountains which go from the southern Peloponnese to northern Thrace. The geological instability of the region has given rise to dislocations and faulting systems which are responsible for occasional earthquakes. Igneous activity has driven dykes and sills through the sedimentary rocks metamorphosing some of them into marbles and mica schists, and forming outcrops of granite which are mainly found in the north.

An important geomorphological feature of the Greek landscape is the formation of dolines and poljes where there is limestone rock. These are formed when the limestone is dissolved by the groundwater, giving cave systems and underground rivers. Most of the dolines are sink holes where water drains into such systems, forming rounded depressions. The poljes are elongated valleys, probably caused by the collapse of cave systems, and may hold lakes which drain away underground, such as Lake Kopais in Boeotia. (Chapter 6). Such poljes often accumulate very fertile soil, and many of them have been drained so that this soil can be used for growing crops (Turrill 1929).

The alluvial soils in the plains of Greece are derived from the rocks of the neighbouring mountains. The limestones lose their carbonate content when they are weathered, although this may be redeposited elsewhere. The siliceous fraction forms clay soil, but in cases where the limestone is pure this may be only about 2% of the total bulk of the rock. The soil formed from this type of limestone (Karst) is thin and oxidised to a red colour, forming the characteristic "terra rossa" of the Mediterranean lands (Turrill 1929). The sandstones, which usually contain some limestone, break down to give sandy soils such as those of the plain of Drama. Erosion from the mountains leads to the formation of large outwash fans (piedmont) of a stony soil, also seen on the plain of Drama near the mountains.

One of the most important features of the soils of Greece is the rapidity with which they can be lost by erosion. The hilly topography of the country and the seasonality of the rainfall tends to encourage soil wash, especially when the protective cover of trees is lost. Once this has occurred, soil takes a long time to be replaced, and many mountains and hills now have a thin cover of shrubs with bare rock visible between them as a result.

Erosion is widespread in the lowlands, and it is a common sight to see fields which are gullied and divided by soil wash. In places where the erosion is especially severe a "bandland" topography may arise, such as that described near Kokkinopolis in Epirus (Harris and Vita-Finza 1968, Vita-Finzi 1969).

Kokkinopolis means "red mud" and this describes the appearance of the area, where the soil is being rapidly eroded so that no permanent vegetation can become established and the trees already growing there have their root systems gradually exposed so that they eventually die.

Vita-Finzi (1969) has shown that there have been synchronous periods of erosion and aggradation of soils in Mediterranean lands.

The aggradation caused the deposition of soil in valleys, and in the erosion phases these deposits were exposed. At Kokkinopolis deposits of Roman age (brick and pottery) were exposed, and also some of Upper and Lower Palaeolithic age (flint implements). A similar phenomenon was noted during fieldwork on the plain of Drama. The river Angitis had cut its way through earlier deposits, exposing small fragments of potsherds which were apparently of Classical date.

Vita-Finzi (1969) considers that the phases of deposition took place between 50,000 and 10,000 years ago and again in Medieval times. Erosion took place between 10,000 and 2,000 years ago, and over the last 500 years.

He regards climate as a probable factor in determining these cycles, and human activity as a minor factor.

4.3 THE CLIMATE OF GREECE

The climate of Greece could be described as typically Mediterranean. This type of climate is not usually described in terms of isotherms and rainfall, but by the distribution of certain characteristic vegetation. *Olea europaea* var *europaea* L. the olive, and the wild form *O. europaea* var *sylvestris* Brot. the oleaster, are considered to have a typically Mediterranean distribution, that is where the climate is Mediterranean. Although *Olea* is probably not a native of Greece, the distribution of oleaster and the places where olives can be cultivated follows the Mediterranean coastline (Polunin 1965). *Quercus coccifera* L. is also considered to be a good indicator of the Mediterranean climate. It is more widespread than *Olea*, growing as far inland as the mountains in the middle of the Peloponnese (field observation) at about 1,000m. It grows as high as about 900 m in Epirus (Higgs *et al* 1967) and in Macedonia it was not seen growing much higher than 600m. Certainly a place where *Olea europaea*, L. *Quercus coccifera*, L. *Quercus ilex* L. and *Pinus halepensis* Miller. grow can be said to have a truly Mediterranean climate (Polunin 1965).

The climate of the parts of coastal Greece where these trees flourish has a hot arid summer and a cool winter with some rain, but very little frost. The main rainfall occurs between October and April, amounting to 300-400 mm in the south of Greece, and the average temperature for January is 9-10°C (Ethniki Statistiki 1964).

In Macedonia the climate is somewhat different. The winters are cooler (4-6° January) which limits the distribution of some of the more frost sensitive taxa. On the other hand, the rainfall is more evenly distributed throughout the year. During fieldwork in July and August there were heavy thunderstorms every 10-14 days. These storms occur throughout the summer, and they partially break the drought. The total rainfall in Macedonia is also greater, with 400-600 mm in coastal regions and 600-800 mm further inland (Ethniki Statistiki 1964). In winter some of the precipitation falls as snow. In April 1969 the mountainous areas all had some snow, which was thick in the mountains near Kozani. On the Peloponnese the snow was restricted to a slight dusting on the mountain peaks.

4.4 HUMAN INTERFERENCE WITH THE VEGETATION

Human interference is perhaps the most drastic force acting on the Greek vegetation. While the climate and soils may determine the types of vegetation likely to grow in a given area, the amount of human interference is usually the deciding factor as to what vegetation actually can grow.

From the time of the beginning of written records from Greece (i.e. Homer) it is evident that timber was a natural resource which was heavily drawn upon. Timber was used for building houses, ships and for many other purposes. At certain times, such as 490-470 BC, when both the Greeks and the Persians were engaged in frantic shipbuilding prior to the second Persian War (Bradford 1971), there must have been extensive forest destruction to provide the necessary timber. Everyday use of timber would steadily reduce the amount of forest, and certainly the forests of southern Greece appear to have been depleted at an early date, for there are records that the Athenians had to have timber brought from as far away as Thrace to supply their everyday needs in Classical Times (Bradford 1971).

A large amount of forest destruction has been caused by such practices as charcoal burning. This fuel is necessary for the smelting of copper and other metals and is also used for cooking and heating. Turrill (1929) noticed the activities of itinerant charcoal burners in the first two decades of this century, and remarks that the pine and oak woods so destroyed were replaced by scrub vegetation. He also noted other destructive exploitation such as lime burning, pitch tapping from pines and the gathering of acorns for tanning. Branches of trees may be used for fodder, a process which Turrill saw continuing in the Balkans, and this practice is still carried out in some remote areas of Spain (Turner, Pers. comm.).

These activities of man are probably the cause of the initial destruction of the primeval forests of Greece. Some of this forest might have regenerated were it not for the activities of many flocks of sheep and particularly goats. These animals are more than anything else responsible for the denuded state of the Greek countryside seen today. Sheep and goats are kept in most Greek villages, from which they are driven out over the surrounding land to forage. They eat almost any plant material, especially saplings and shoots, and are agile, climbing up into the branches of trees to eat the foliage. (Harris and Vita-Finzi 1968).

Large flocks are also kept by people such as the Vlachs who practice transhumance, although this is less common than in Turrill's time. In the past transhumance allowed the maximum use to be made of summer grazing in the hills and mountains, andin winter in the lowlands. Thus there was no great shortage of winter fodder and large flocks could be kept, to the general detriment of the vegetation.

The lack of regeneration of trees was very clearly shown by some woodland in the Chortiati mountains. There were mature oak trees standing in a wood which had practically no ground vegetation apart from specimens of <u>Aspodelus</u>, which goats do not appear to eat. There was no sign of young oak trees anywhere, and it appeared that this was the result of intense grazing.

Destruction of woodland becomes permanent by the subsequent loss of soil due to erosion. When the soil is gone, trees cannot become re-established. Heth (1960) states that the most critical factor for the establishment of trees in an arid climate (such as that of Greece) is soil depth. If there is deep soil, it will hold sufficient moisture to enable trees to survive the dry summer months. With present day conditions of shallow soil in Greece, trees occur mainly where it is deeper and moister, such as watercourses and gullies.

If there is no grazing, there could be slow re-colonisation first by scrub which promotes soil formation by the penetration of the roots into rock crevices and by the accumulation of humus.

4.5 <u>THE MAIN VEGETATIONAL TYPES</u>

The inter-action of soil, climate and the activities of man and animal gives a mosaic of different vegetational types, mainly determined by the intensity of grazing. Turrill (1929) gives a very detailed account of the plant communities of this region which has not been surpassed in its comprehensive cover of the subject.

During fieldwork in 1968, 1969 and 1970 many of these plant communities were located and examined.

The montane vegetation is the simplest in terms of variety, and also the least likely to have been affected by grazing. On some of the highest mountains there is a sub-alpine vegetation such as that noted by Quezel (1967b) from about 1,600m upwards in the Falakron mountains of Macedonia, but few mountains have this type of vegetation.

Coniferous Forest

The most widespread montane vegetation is coniferous forest, which occurs above 1,500 m on mountains in all parts of Greece. The dominant species in the Pindus mountains are Abies cephalonica, Loudon, Pinus pallasiana and Juniperus foetidissima Willd. on dolomites and limestones, and Pinus nigra ssp. pallasiana Lamb. and Pinus heldreichii Christ. on serpentines (Quezel 1967a), and this may be considered as a typical example. This vegetation was noted in many places during fieldwork, such as Mt. Parnes, where there is coniferous woodland consisting of fir, pine and juniper to the summit, with a rich ground flora of bryophytes. Many of the fir-trees were parasitised by Viscum album. L.

Deciduous Forest

In the montane woods south of Thessaly the main species are conifers (Quezel 1967a). In northern Greece there are deciduous woods in the mountains between about 1,000m and the beginning of the conifer zone at about 1,500 m. The dominant species is Fagus sylvatica L, but there may also be Castanea sativa, Miller. Quezel (1967a) notes that in the Pindus the deciduous forests are usually found on Flysch (arenaceous limestone). Turrill (1929) considers the deciduous forests to be Central European rather than Mediterranean in character, which explains why they are much more widespread in Macedonia. Quezel (1967b) found beech-oak forests in the Vermion mountains. Relicts of beech-oak forests were also seen on Mt. Pangeion and in the Lekani mountains during fieldwork, but exploitation had reduced the trees to a shrubby state. No forests with fully mature beech or oak could be found. If any of these remain, they are probably in very inaccessible places where it has not been possible to cut them down and remove the timber.

Mixed woodland

Below the coniferous and deciduous montane forests there is a great variety of vegetation. It is considered that there would originally have been oak forests since replaced by the various types of scrub and woodland (Turrill 1929). In the south of Greece woods of *Quercus macrolepis* Kotschy. were seen, and some mature specimens of *Quercus coccifera* L., which may represent the natural woodland vegetation there. A thin mixed woodland was found more frequently than the oak wood, such as the example seen in the central Peloponnese with *Carpinus orientalis* Miller., *Ostrya carpinifolia* Scop., *Fraxinus ornus* L., and *Acer monspessulanum* L., with *Quercus coccifera* L. and *Phillyrea media* L. where there is grazing. Turrill notes a number of other species commonly found in this kind of woodland, such as *Juglans regia* L., *Fraxinus excelsior* L., and *Corylus avellana* L. *Aesculus hippocastanum* L. has a limited distribution, mainly in western Greece (Turrill 1929).

The same type of vegetation was found in the Chortiati mountains in Macedonia, where there was *Quercus frainetto* Ten., *Quercus petraea* Liebl., *Fagus sylvatica* L., *Ilex aquifolium* L., *Ostrya carpinifolia* Scop. and *Castanea sativa* Mill., with *Quercus pubescens* Willd. on the more stony ground.

Pseudomaquis

Pseudomaquis is a vegetation kept in its degraded state by grazing. The lower altitudinal limit of the mixed woodland is not usually determined by climate but by the amount of grazing, so this variable factor determines the extent of pseudomaquis vegetation below the woodland on hillsides. Turrill (1929) considers that much pseudomaquis covered land would revert to mixed-oak woodlandif left without grazing for some 30-40 years.

Quercus coccifera L. and Juniperus oxycedrus L. are the dominant species in this vegetation, the latter being an active coloniser, for many young plants were seen in the Chortiati pseudomaquis. Other species seen were Rhamnus alaternus L., Cornus mas. L. and species of Crataegus, and the full species list for this vegetation (after Turrill) is found at the end of this chapter.

Maquis

Maquis is the typically Mediterranean brushwood scrub, which is found all over southern Greece, but is restricted to the coastal fringe in northern Greece. In some places the maquis may be a climax vegetation, but more often it is probably the result of forest destruction. The main species are often forest understorey plants, which become the dominant vegetation when the trees have been removed (Turrill 1929). The vegetational composition of maquis varies from locality to locality, and it may merge with other vegetational types such as pseudomaquis. However the general composition of the maquis has very definite limits within the species list given (Turrill 1929). Many of these shrubs are evergreen and aromatic. They usually flower in winter or early spring and then go into semi-dormancy during the long dry summer.

A typical example of maquis, seen on the coast of the Chaikidike, consisted of scattered specimens of Pinus halepensis Miller. (This would be "High Maquis", Polunin 1965) with a thick brushwood understorey, 2-3

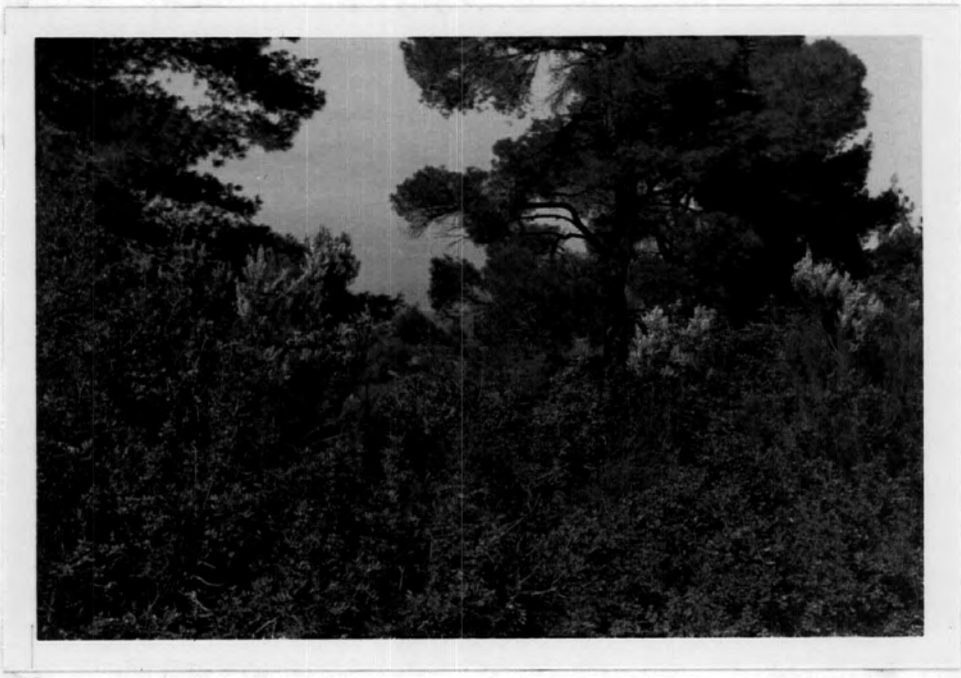


Figure 2. Maquis vegetation on the Chalkidike peninsular

metres in height. *Arbutus unedo* L. was common and *Arbutus andrachne* L. somewhat less so. There was *Quercus coccifera* L., *Erica arborea.* L. *Pistacia lentiscus* L. and *Calycotome spinosa* (L) Link with *Smilax aspera* L. twining through the thickets.

In the Peloponnese and southern Greece species of *Cistus* were common in the maquis with *Calycotome spinosa* and *Spartium junceum* L. making the vegetation dense and thorny. A more inland type of maquis was also seen which consisted mainly of *Arbutus unedo* and *Quercus coccifera.*

Phrygana

Phrygana is a more degraded scrub than maquis. Some of the typical maquis species may be found in phrygana such as *Cistus*, but in general the phrygana vegetation is more xerophytic. There are shrubs with hairy leaves (*Corydothymus capitatus* (L.) Reichenb.) and those with leaves which are greatly reduced and thorny (*Sarcopoterium spinosum* (L.) Spach.) and many which are aromatic and useful to man, such as *Rosmarinus*, *Salvia triloba* L. and *Lavendula stoechas* L. In spring and early summer a great variety of ephemeral herbs come up and flower, withering and dying down with the onset of the summer heat. Some types of phrygana are dominated by herbs as in the example seen at Piraeus which consisted mainly of *Phlomis fruticosa.* L.

The phrygana is similar to the tomillares of Spain and the garrigue of the south of France (Polunin 1965).

Shiblyak

Where forests have been destroyed a new sub-climax vegetation may develop which is not composed of forest understory species like the maquis.

This shiblyak (Turrill 1929) consists of light-demanding open habitat shrubs, and it is very common in Macedonia. The plain of Drama has large areas of this vegetation which in this case consists mainly of Paliurus spina-Christi Miller with occasional specimens of Pyrus amygdaliformis Vill. and Crataegus sp. Near the coast the shiblyak merges with maquis and garrigue, and towards the mountains with pseudomaquis.

Shiblyak may occur in the mountains of the warmer parts of Greece, but where the climate is more continental it occurs lower down on the hills and on the plains (Turrill 1929).

Asphodelus Steppe

One of the most degraded vegetational types is Asphodelus Steppe (Polunin 1965). Where the grazing pressure is very high and the soil removal almost complete there is no permanent vegetation. There is an abundance of ephemeral vegetation, mainly growing in spring and early summer, with the very prominant flowering stems of species of Asphodelus and other bulb plants. An area of such Asphodelus steppe was examined in Boeotia. Part of it was surrounded by a strong fence, and the resultant absence of grazing was allowing a rapid recolonisation of the area by scrub. Plants of Quercus coccifera and Pyrus sp. were sprouting up vigorously, and they would have formed a dense pseudomaquis within a year or two.

Quercus coccifera varies in its growth form according to the amount of grazing. When it is grazed it suffers apical damage and so the shoots branch out, giving the semi-prostrate habit which is characteristic of the specimens seen in pseudomaquis. When the shrubs are left unharmed, as in this fenced off area, they start sending up aerial shoots again and may even grow into trees.

LISTS OF THE MAIN SPECIES IN THE VARIOUS PLANT COMMUNITIES (Turrill 1929)

Maquis

Arbutus unedo L.
Arbutus andrachne L.
Myrtus communis L.
Erica arborea L.
Pistacia lentiscus L.
Juniperus phoenicea L.
Olea europaea L.
Phillyrea media L.
Quercus ilex L.
Quercus coccifera L.
Cercis/siliquastrum L.
Spartium junceum L.
Calycotome villosa (Poiret) Link
Cistus villosus Incanus L.
C.salviifolius L.
Rosmarinus officinalis L.
Smilax aspera L.
Laurus nobilis L.

Phrygana

Poterium spinosum L.
Corydothymus capitatus L. Reichenb.

Thymeleaea tartonraira L.
Genista acanthoclada?
Euphorbia acanthothammos Boiss
Astragalus spp.
Anthyllis hermanniae L.
Hypericum empetrifolium? Willd
Saturaea thymbra L.
Erica verticillata manipuleflora Salisb.
Quercus coccifera remnants. L.

Pseudomaquis

Juniperus oxycedrus L.
Quercus coccifera L.
Q. macedonica DC = Q. trojana Webb
Buxus sempervirens L.
Prunus laurocerasus L.
Pistacia terebinthus L.
Jasminum fruticans L.
Phillyrea media L.
Ilex aquifolium L.
Colutea arborescens L.
Paliurus spina-Christi Miller
Cotinus coggyria Scop
Calycotome villosa (Poiret) Link
Asparagus acutifolius L.
Acer campestre L.

Shiblyak

Paliurus spina-Christi L.
Cotinus coggyria Scop.
Quercus lanuginosa Thuill.
Syringa vulgaris L.
Berberis vulgaris L.
Rhus coriara L.
Petteria ramentacea Sieber C.Presl
Cornus mas L.
Acer campestre L.
Carpinus orientalis Miller
Corylus avellana L.
Cercis siliquastrum L.
Coronilla emerus L.
Colutea arborescens L.

4.6 CROPS AND INTRODUCTIONS

With the dominance of man over the landscape of modern Greece, the majority of the vegetation is entirely the result of human activities. The plains of Greece are intensively cultivated and may yield several crops a year. Mechanisation is widespread, cultivating large fields, but there is still plenty of peasant farming too.

Grain is a common crop, and when it is harvested a second crop of maize or tobacco may be planted for harvest in late summer, especially in Macedonia which has the advantage of some summer rain. Much cotton is grown, and Lake Kopais was originally drained for this crop, which was also seen growing in Macedonia.

Olives can be grown in most of Greece, but most olive production comes from the south (Ethniki Statistiki 1964). No olive groves were seen in Macedonia although the official records and the Naval Intelligence Handbook show that olives were grown there until recently. Olive groves are widely spaced as the trees have spreading roots, which leaves room between the rows of trees for growing grain, melons and other crops.

Citrus orchards are also common in the south of Greece but not in the north. A large number of plants have been introduced into Greece by man. Some of these are deliberate introductions, such as the olive, which is considered to have been cultivated originally in Palestine. Archaeological evidence shows that it probably came to Greece by way of Crete. Viticulture is thought to have come from Anatolia and probably the cultivated grains as well (Hawkes & Woolley 1963).

Later introductions such as the citrus fruits are credited to the Arabs who brought them from Asia (Bradford 1971).

The fortuitous introduction of plants is more a matter of speculation, but from the time when sea trade developed around the Mediterranean in the Bronze Age (Bradford 1971) there must have been conditions suited to the transport of plants in various forms. Seeds are the most obvious way in which plants can be unwittingly transported from one land to another but is likely that introductions into Greece could also have been made when plants were used for fodder, packing materials and a host of other purposes.

With the discovery of the Americas in Medieval times, a whole new variety of plant life became introduced into Europe. Some of these plants have since spread round the Mediterranean and have become naturalised there. In Greece <u>Opuntia</u> the prickl~~e~~y pear cactus is well established in some places, and various species of <u>Xanthium</u> are ubiquitous as weeds of cultivation.

Later introductions have come from Australasia, for example the many species of <u>Acacia</u> and <u>Eucalyptus</u> which are very widely planted in Greece. They are valuable in draining swampy land from which they draw off the water, which is important where there is liable to be malaria from the swamps. <u>Eucalyptus</u> wood is fast growing, although of low quality. Hybrid poplars are planted along roads and in rows across fields as windbreaks propagating readily by suckers. Pines are planted in woods and also in towns and parks where they are a useful amenity.

Thus the vegetation of Greece consists mainly of the fields and planted trees which form patterns of squares and straight lines over the man-made landscape. In the hills there is a degraded scrub, and it is only in the inaccessible parts of the mountains that there are the remnants of the original prim~~i~~eval forests which once covered Greece.

Several floras were consulted in this work, in particular during the examination of Greek vegetation and the collection of flowers for the pollen reference herbarium. "Flowers of the Mediterranean" (Polunin 1965) and "Flowers of Europe" (Polunin 1969) were the most useful since they are the most comprehensive and up to date works on the subject available. Also useful was "Synopsis Flora Graecae" (Diapolis 1948-9) [illegible] which is a Greek version of "Conspectus Flora Graecae (Halacsy 1900-4, 1908, 1912) the latter being the pioneer work on the subject. Latterley Flora Europaea (Ed. Tutin et al 1964, 1968, 1972) has been useful.

CHAPTER 5. POLLEN MORPHOLOGY

5. POLLEN MORPHOLOGY

Pollen analysis work in the Mediterranean region not only requires the understanding of a much larger flora than that of northern Europe, but a greatly increased pollen flora as well. Some of the earlier work in this field has included data on some of the Mediterranean pollen types encountered (Beug 1961) and this has been the main guide used. However during the course of the fieldwork the plants that were in flower were collected for their pollen which, together with herbarium material, was used for a reference collection. Some of the precise divisions and distinctions in the pollen classification in this work are worth mentioning, in the order of their appearance in the pollen diagrams:

Quercus type Although there are several common species of oak found in Greece, their pollen is not at all easy to distinguish. Some authors make a distinction between pollen from the evergreen species (Q.coccifera, and Q. ilex in Greece) sometimes leaving "Quercus indeterminate" in a separate column (Beug 1961, 1967a), and others make no distinctions between different oak pollen types in the diagram, but make a note of a change in their relative proportions in the text (Wijmstra 1969). In this work the pollen preservation was good enough in some samples for the separation of the two kinds of oak pollen, but not in others, so it has not been possible to draw separate curves for Quercus ilex-coccifera type and Quercus robur-pubescens type pollen as Beug did, but any marked changes are noted in the text.

Carpinus betulus type There are two kinds of pollen from Carpinus betulus L. one being the usual four pored grain as described in Faegri and Iversen (1964) and the other somewhat larger, with only three pores as described by Beug (1961). Both were encountered, the four pored type being the commonest.

Ostrya type This includes the pollen from Ostrya carpinifolia L. and Carpinus orientalis L. Miller. which cannot be separated on pollen morphological grounds (Beug 1961).

Oleaceae type Four members of this family are important in Mediterranean pollen analysis work, Fraxinus excelsior L., F.ornus L., Phillyrea media L., and Olea europaea L. Their pollen is similar but can be separated (Beug 1961) unless the preservation is poor, and in the latter instance pollen which cannot be ascribed with certainty to Olea europaea L. is drawn in on the pollen diagrams as "O" type. The pollen of some members of the Cruciferae bears some resemblance to that of some of the Oleaceae, so a mixed type slide was prepared with pollen from Fraxinus ornus L. Phillyrea media L. and Olea europaea L. together with pollen from a representative Crucifer, Cochlearia anglica L. In this way the pollen morphology of the various types could be examined side by side and in various orientations, a study which was a considerable aid to their sure identification in fossil material. There is an additional problem in the case of Olea pollen, for there are two varieties of Olea europaea L. which grow in Greece, O.europaea var. europaea L. the cultivar, and O.europaea var. sylvestris Brot. the wild oleaster. The pollen from these two subspecies is identical, and yet from the point of view of a palaeoethnobotanist the difference between cultivated olives and wild oleaster is critical for correct interpretation of results.

Rhamnaceae type A few grains of Rhamnaceae type pollen were counted, but none could be ascribed to the most widely distributed member of this family in Greece, Paliurus spina-Christi L. which has very large pollen grains.

Gramineae type The pollen of the cultivated grains (Gramineae sect. Cereales) is distinguished from that of the others by its greater size and some other morphological characters such as the appearance of the exine columellae with phase contrast optics (Faegru and Iversen 1964), in northern European pollen analyses. In Greece there are hazards in applying exactly the same divisions, as there are wild species whose pollen is very similar to that of the Cereales as would be expected from their close relation to that group. Some of these are ancestral forms of the cultivated cereals such as Triticum boeoticum Boiss emend Schiemann. whose present day distribution includes Iran, Turkey, Palestine and the Balkans (Helbaek 1966). It is probable that the past distribution of such plants also included parts of Greece, so that pollen spectra representing past vegetation in this area could contain pollen with all the characteristics of Cereales pollen, from wild grasses. For this reason the identification of Cereales pollen has not been attempted in the pollen diagrams presented in this work.

Polygonum type Of the various species of Polygonum in Greece, some are aquatic and some terrestrial. The pollen diagrams have been divided into sections for land pollen and that of exclusive aquatics,and since there are land species of Polygonum it has been counted in the land pollen diagrams.

cf. Consolida type This pollen type very closely resembles that of Consolida regalis S.F. Gray., a common cornfield weed in Greece today.

Ericales type The separation of Ericales pollen into the various species such as Erica, Arbutus, Rhododendron and Calluna (Oldfield 1959) was not attempted as the pollen preservation was not good enough.

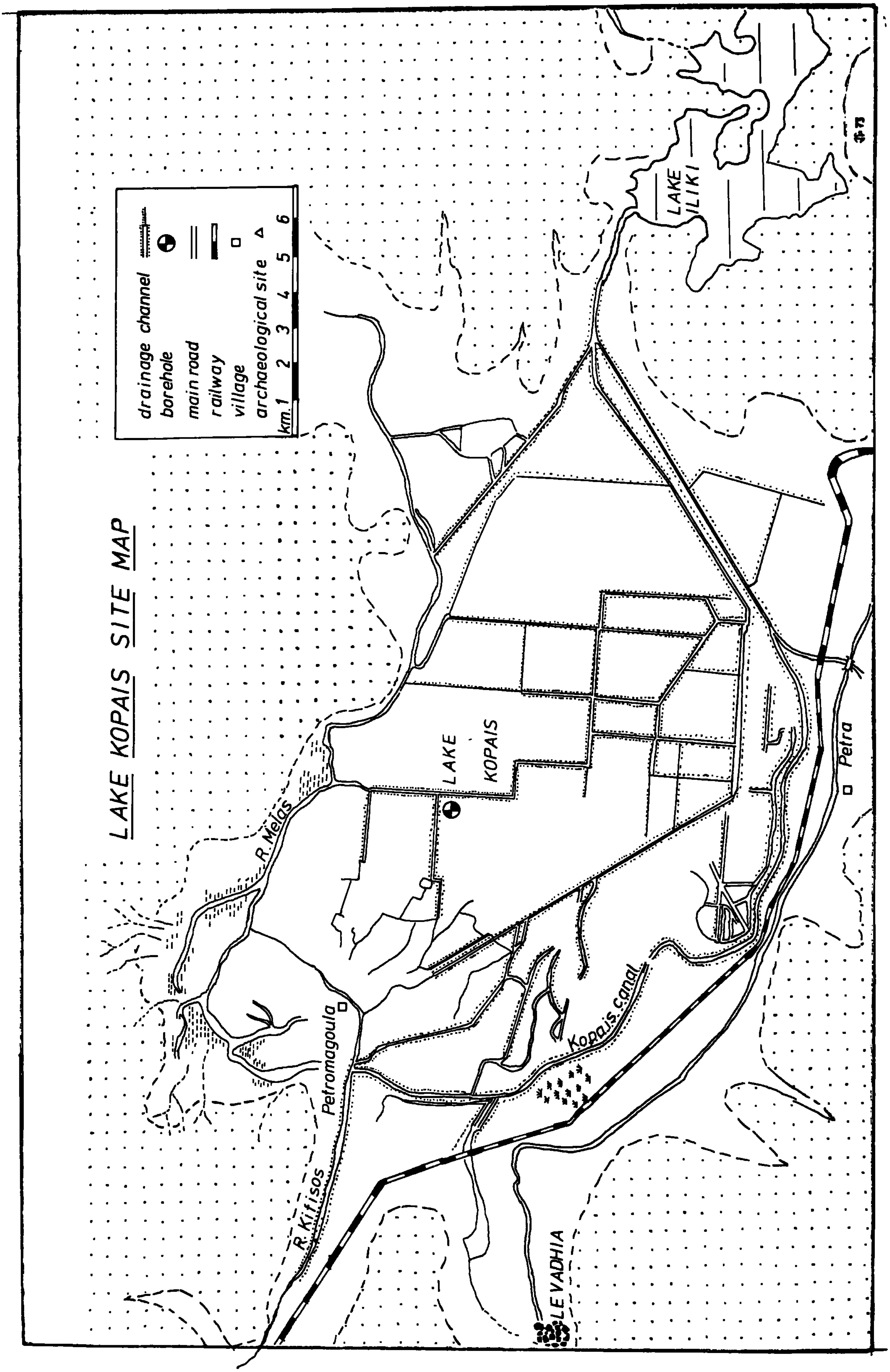
Centaurea type This is split into two groups, C.nigra type and the less frequent Centaurea cyanus type whose presence on a pollen diagram is denoted by the symbol "cy" in the appropriate place.

Cistaceae type In some cases it was possible to identify Cistus pollen more closely than to the generic level (Beug 1961), and this has been noted in the diagrams as for instance one example of Cistus incanus type pollen.

Vitis vinifera type This group includes Vitis vinifera ssp sativa Hegi. the vine and V.vinifera ssp sylvestris (G.C.Gmelin) Hegi. the wild vine. As in the case of the two subspecies of Olea europaea L. the pollen of the two Vitis subspecies is indistinguishable even though the ecological significance of being able to do so is paramount.

CHAPTER 6. LAKE KOPAIS

Figure 3


LAKE KOPAIS SITE MAP
drainage channel
borehole
main road
railway
village
archaeological site
km 1 2 3 4 5 6
LAKE ILIKI
LAKE KOPAIS
R. Melas
Petromagoula
R. Kifisos
Kopais canal
LEVADHIA
Petra

6.1 LAKE KOPAIS $23^{\circ}04'$ E $38^{\circ}26'$ N

Lake Kopais lies in a depression in the hills about 10km east of the town of Levadhia in Boeotia, southern Greece. It is about 100 metres above sea level and surrounded by low hills of shale and sandstone, while further away there are mountain ranges such as Parnassus (2457m.) to the west and Elikon (1746m.) to the south which are made up of limestones. Kopais is one of the largest polja in Greece, covering an area of 350 km^2 with a depression formed in the rocks partly tectonically and subsequently deepened by solution of the limestone by the groundwater. In the past Kopais drained some of its water to the sea through underground channels in the limestone, but sedimentation raised the lake bed to the level of the sink holes it became very shallow so that it dried up in the summer heat and filled again in the winter rains, giving a seasonal alteration between lake and swamp (Naval Intelligence 1945). There is evidence that attempts were made to drain Lake Kopais as early as the Bronze Age, in the form of a canal system connected with the Minyan settlement of the area at that time (Taylour 1964), while recent drainage operations started with the boring of a tunnel in 1886 to take the lake water through to Lake Iliki and thence to L.Paralimni and out to the sea. The lake bed itself was drained by the cutting of a system of channels in a grid pattern covering the whole lake bed at intervals of about 500m, some of which are apparently still about their original depth of 3-4m. Between these channels are intensively cultivated fields bearing a great variety of crops on the rich alluvium, such as grain, cotton maize, vegetables and fodder crops, separated by lines of <u>Populus alba</u> L. which are probably grown partly for windbreaks and partly for the low grade timber they produce.

The hills around the lake support a degraded pseudomaquis vegetation (Turrill 1929) consisting mainly of bushes of Quercus coccifera and Paliurus spina-Christi between which ephemerals would grow in the spring. The soil cover was thin and where there was too little for the pseudomaquis vegetation there was an Asphodelus steppe (Polunin 1965).

The amount of grazing pressure on the land around Kopais maintains the vegetation in its degraded state, and the thin scrub contrasts strongly with the fertile fields on the former lake bed.

The mountain ranges near the lake have a typically South European montane vegetation (Quezel 1967a) with forests of Abies growing above the upper limit of the deciduous woodland.

6.2 FIELDWORK

It was already known that the Kopais sediments contained pollen (Turner, personal communication), and a suitable site for boring was found after a search. There are farm tracks running along the sides of the drainage channels, with rough bridges across the intersecting channels. It was possible to examine a large area of the lake bed by driving along these tracks, and the sediments in various parts of the lake were duly sampled.

The place where the main core was taken was at the edge of a cornfield. The spring grain crop had been harvested, and the second crop for that year had not been planted (it would normally be maize). This left a clear area in which to work at the edge of the channel which formed one of the field boundaries.

The boring was made close to the side of the drainage channel, so that there was the least risk that the sediments had been disturbed to any depth. It was not possible to collect samples directly from an excavation into the side of the channel, even though this would have yielded the most satisfactory samples. The banks of the channel were steep and covered with loose dry soil, and the channel itself was waterfilled and contained several species of aquatic plants, and terrapins.

A screw auger was used to obtain this core, and samples were taken starting at 75cm below the ground surface where the sediments were consistent and had not dried out. It took two days work to sample down to a depth of nearly 1100 cm, after which it became impossible to pull the borer and extension rods up out of the compacted sediments. The borer sampled well in the first five metres of sediment but lower down some soft sediments caused difficulties.

The Kopais sediments were difficult to prepare for pollen counting until the better techniques had been evolved (see p. 18) but the final preparations had well preserved pollen with even some fragile _Taxus_ pollen grains in good condition. A few samples had poorly preserved and corroded pollen, but only six could not be counted due to low pollen content. The sediments were mostly clays, of several varieties, the commonest being grey clay occurring between 450 and 1070 cm. At depths of less than 450 cm. the clays were often mottled and sometimes grey-brown, orange and muddy. Peat had been found at Kopais in 1964 (Turner 1964) but only a trace was found in the 1969 core, between 210 and 215 cm, and also some dark muds that appeared to be partly organic. The stratigraphy is drawn on the pollen diagram (Fig. 6) in symbols which are described in figure 5 , after Troels Smith (1955). The sediments encountered are as follows:-

THE STRATIGRAPHY OF THE CORE

Depth (cm)	Sediment
75-112	Blackish brown peaty mud
112-125	as above, changing to brown-grey clay
125-145	Brown-grey clay
145-150	Brown-grey clay with organic lumps
150-158	Black organic mud
158-165	Brown clay
165-190	Brown clay with some organic matter
190	Piece of wood at 190 cm
190-200	Grey-orange mottled clay with some organic material
200-210	Brown-grey clay
210-215	Brown peat
215-225	Brown-grey mud with some peat in the top 5 cm
225-250	Grey-brown clay
250-370	Grey clay
370-382	Dark grey clay
382-390	Dark brown mud
390-394	Grey silt with brown mud
394-400	Black peaty mud
400-425	Grey mud, with organic matter at 412 cm
425-450	Dark grey mud with organic matter at 450 cm
450-500	Mid-grey clay, with a layer of shells at 488 cm
500-1080	Soft grey clay

6.3 THE POLLEN DIAGRAM

The Kopais diagram has been drawn up on the basis of 55 counted samples. Originally samples were prepared from even intervals of depth, and detail was then filled in from further samples where the outline pollen diagram showed interesting pollen frequency changes. The main pollen diagram (Fig. 6) has been drawn up in percentages of total land pollen, and features the pollen records of trees and shrubs, herbaceous plants and finally those plants which are exclusively aquatic in Greece. The decision to present pollen frequencies on the basis of percent land pollen was made so that the pollen diagram would show regional pollen rain changes without too much influence from the lake-side plant communities, the pollen record from which shows some sharp fluctuations. In the three sections of the main diagram the taxa with the most abundant pollen records are presented first, and the rest follow in taxonomic order (Polunin 1969), while sporadic or rare pollen records are denoted by letters in the appropriate place.

The supplementary pollen diagram (Fig. 4) shows changes in tree pollen frequency in much more detail than can be seen in the main diagram, between 300-450 cm.

The presentation and discussion of the results comes under three main headings; first the division of the diagram is made into a series of pollen assemblages and sub-assemblages, which are described and defined in order. Then these pollen assemblage zones are interpreted in terms of the vegetation they might represent and as a result of what factors (such as climate, mankind etc), and finally the scheme of vegetational history is discussed in relation to likely chronology, and compared with the results of other pollen diagrams. This layout is employed in the treatment of all the pollen diagrams in this work.

6.4 THE MAIN DIVISIONS OF THE POLLEN DIAGRAM

Three main pollen assemblages can be recognised in the Kopais diagram, on the basis of the proportion of the various pollen types present. The pollen assemblages define the zones into which the diagram is divided, and sub-assemblages define the various sub-zones. The pollen assemblage zones have been given Roman numerals in order starting at the base of the diagram, and the sub-zones letters in a similar order.

Zone KI (1080cm-428cm)

This zone covers more than half the diagram, although the evidence comes from only 17 of the 55 samples counted in the preparation of the diagram. Its main characteristic is the low level of tree pollen, averaging 18% land and aquatic pollen sum. There is most Pinus pollen, some Quercus and a small amount from Salix, Betula and Juniperus and no significant records from any other tree genera. The large amounts of herbaceous pollen also serve to characterise this zone, with average values of 36% Gramineae, 17% Chenopodiaceae and 10% Artemisia (land pollen sum) and there are also significant records from other herbaceous taxa such as Caryophyllaceae, Rubiaceae and Compositae.

Zone KII (428 cm - 290cm)

This zone is characterised by the large amounts of tree pollen (about 70% total pollen sum) and by the large variety of types represented there. Quercus is the most dominant pollen type at an average of 40% land and aquatic pollen sum, and there are varying amounts of Juniperus pollen. Also present are small amounts of pollen from Betula, Alnus, Corylus, Ostrya type, Pistacia, and Tilia. Herbaceous pollen is correspondingly reduced, Gramineae being the most abundant type.

Zone KIII (290 cm - 75 cm)

Here there is a moderate amount of tree pollen, some 33% total of which the most part is Quercus but Olea pollen is also abundant. The herbaceous pollen is mainly Gramineae, but many other taxa are represented.

6.5 THE SUB-DIVISIONS OF THE POLLEN DIAGRAM

It is possible to divide the pollen diagram still further into sub-zones, on the basis of correspondingly small differences in pollen frequencies; Zone KI has however not been divided as there is insufficient information there to form the basis of a sub-zone system, although certain pollen frequency changes there are worth mentioning. Quercus and Pinus values are slightly increased at 1080cm, 783cm, 633cm, and 581cm, while in the intervening levels there are slight increases in Juniperus pollen, 708cm, 583cm, 558cm, and 468cm, giving a faint pattern of alternating increases in Quercus and Pinus pollen and increases in Juniperus, individually not very significant, but amounting together to some evidence for a cycle of pollen value changes.

Zone KII has been presented in far greater detail than KI because there are sharp pollen frequency changes in this part of the diagram, see Fig. 4 .

KIIa (398cm - 428cm) is characterised by moderate tree pollen values which increase steadily although the average is 41% total pollen. Most of this is Quercus and Juniperus, with small records from Ostrya type, Pistacia and Ulmus, three taxa which appear for the first time as continuous records at this point on the diagram.

KIIb (378cm - 398cm) is defined by reduced tree pollen values, an average of 28% total pollen, and in particular a great reduction in Juniperus pollen values from 13% in sub-zone KIIa down to 5% in KIIb.

KIIc (346cm - 378cm) is similar to KIIa in pollen values although the total tree pollen level is 64% total pollen. Most of this is Quercus and Juniperus, with smaller records from Pistacia, Ulmus and Tilia.

IIId (290cm - 346cm) has the highest tree pollen values in the diagram at an average of 73% total pollen, of which the principle component is Quercus, followed less by Juniperus, Pistacia, Ulmus and Tilia in a descending scale of representation, and traces of pollen from other tree taxa. The herbaceous pollen values are at their lowest, a 10% record of Gramineae pollen being the main component.

KIIIa (224cm - 290cm) has high tree pollen values, at 68% total pollen not significantly different from those of the preceding sub-zone, but the amount of Quercus pollen has fallen by 16% some of which is now Q.coccifera type and there is practically no pollen record from Juniperus. Corresponding to these reductions there are increased values of Pinus pollen, twice those of the previous sub zone, and Corylus and Ostrya type appearing in the pollen record for the first time in any significant amount.

KIIIb (162cm - 224cm) is defined by a further reduction in Quercus pollen which now appears at half the average value for that of KIIIa. There are pollen records from Abies, Carpinus betulus, Fraxinus ornus and Olea europaea of which the latter is considered to be very important as it is a possible cultivar. There are some increases in herbaceous pollen values, especially Gramineae.

KIIIc (112cm - 162cm) is distinguished on the basis of the disappearance from the pollen record of the taxa whose appearance was noted in KIIIb; Abies, Carpinus betulus, Fraxinus ornus and Olea europaea, all of which are virtually absent.

KIIId (75cm - 112cm) is generally similar to KIIIb, with the addition of pollen records from Phillyrea, and with a greater amount of Olea pollen which averages at 25% tree pollen here.

6.6 THE INTERPRETATION OF THE POLLEN DIAGRAM

Zone KI clearly represents a period of time when the Kopais region was largely treeless, and what woodland there was seems to have been mainly comprised of pine, oak and juniper. The woodlands in present-day Greece are much disturbed, but even making allowance for that, the vegetation represented by the KI pollen assemblage does not seem to have any present-day parallel in Greece. It does, however, compare very closely with results obtained in modern pollen rain studies in Eastern Anatolia (Wright et al 1967) where pollen in moss polsters is rich in Chenopodiaceae and Artemisia but poor in tree pollen, in regions clad in an Artemisia steppe vegetation. This vegetation, as indicated by the pollen spectra obtained, and verified by field studies, is dominated by species of Artemisia while members of the Chemopodiaceae become more common on saline soils, and trees rare. It therefore appears that the KI pollen assemblage can be interpreted as an indication of a prevailing Artemisia steppe type of vegetation, and if this vegetation type was determined by the prevailing climate, conditions in Greece must have been somewhat like those of the Artemisia steppe regions of Eastern Anatolia today, a dry continental regime of cold winters (1°C January average), hot summers (15°C July average) and a rainfall of

LAKE KOPAIS: SUMMARY OF ZONATION AND INTERPRETATION

Depth cm	Zone	Summary of interpretation of vegetation and chronology
112-75	KIIId	Temperate woodland with evidence of clearance and olive cultivation. ? Classical times.
162-112	KIIIc	Temperate woodland, part cleared, no signs of olive cultivation. ? Dark Age.
224-162	KIIIb	Temperate woodland with signs of olive cultivation and clearance. ? Bronze Age.
290-224	KIIIa	Temperate woodland with slight signs of clearance.
346-290	KIId	Forest maximum
378-346	KIIc	Developing forest with pioneer scrub vegetation; early Post-glacial period.
398-378	KIIb	Some forest, but signs of resurgence of steppe, from a relatively cool/dry climate. Late-glacial period.
428-398	KIIa	Pioneer scrub with <u>Pistacia</u> and juniper, and increasing mixed oak forest in response to a warmer and moister climate. The beginning of the Late-glacial period.
1080-428	KI	<u>Artemisia</u> steppe and very restricted oak woodland, cool dry climate, Weichselian period.

about 300mm annually falling mainly in the winter months in the form of snow, (UNESCO 1970) very different from the ocean modified Mediterranean climate of present day Greece.

The faint changes in the pollen frequencies, with alternate increases in *Pinus*/*Quercus* and *Juniperus* pollen values could be a response to some corresponding subtle cyclical modification of the climate, perhaps in the form of increased rainfall leading to a slight extension of woodland away from watercourses, followed by drier phases with replacement of woodland by juniper scrub.

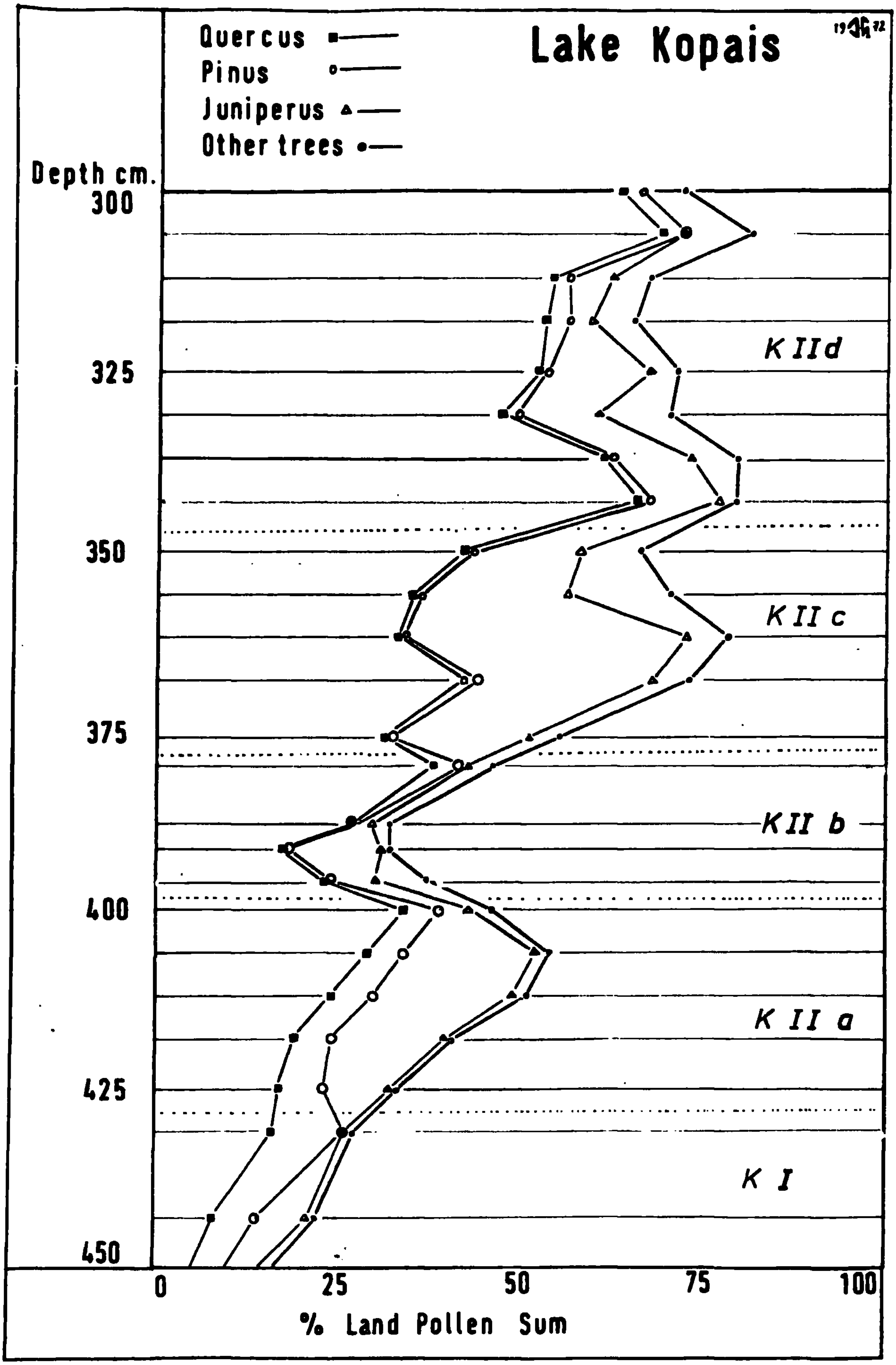
Zone KII, in contrast to the treeless steppe conditions of KI, appears to represent a phase of woodland vegetation not in a steady state, but gradually increasing in importance from a relative rarity as in KI to fully developed forest. There is no present-day pollen rain study available to give an exact relation between pollen rain and vegetation, and with the great scarcity of forest of any type in Greece today it is doubtful that modern pollen rain results from vegetation heavily affected by man and animal would produce results useful in the interpretation of past vegetation which may have been spared these influences, and which may not have developed into modern communities (Janssen 1970). The only vegetation seen during the fieldwork which might be expected to give a pollen rain rich in *Quercus* and *Juniperus* pollen was a pseudo-maquis growing on some hills where the vegetation appeared to be regulated by severe grazing pressure and thin soils. The oak/juniper vegetation which the KII assemblage apparently represents might bear some resemblance to the pseudomaquis mentioned above. Further afield, in E. Turkey, modern pollen spectra from this kind of vegetation confirm that it produces a similar type of pollen rain (v.Zeist 1970).

The presence of pollen from thermophilous taxa in this assemblage suggests that the climate was warmer than that suggested for KI, at least as warm as present day Greece. *Pistacia*, whose pollen appears for the first time in this part of the diagram, only grows where there is rarely any frost (Rivas Goday 1956) and was only found where the vegetation could be described as fully Mediterranean during the fieldwork. *Quercus coccifera*, which has similar requirements for warmth, was also noticed as a proportion of the *Quercus* pollen from this point, which serves to confirm that the climate was warm.

There is evidence that the climate was wetter as well; a mere increase in temperature would not be sufficient change of climate to account for the evidence for spreading woodland, for oak woods, such as they exist in Greece today, are restricted to regions with considerably more rainfall than the 300mm suggested for KI. An increase in temperature alone might give rise to an oak/pistachio savannah such as that noted in parts of Iran today (Wright et al 1967).

In addition to a response of the vegetation to a warmer and a wetter climate, it appears that soil development was also an important vegetational determinant, for *Juniperus* spp., *Quercus coccifera* and *Pistacia* spp. grow on thin rocky soils today, but do not appear to tolerate much shading, and their abundance in the pollen record at this point might suggest that suitable ecological niches were freely available for them compared with their rather patchy distribution today. An incidence of greater rainfall and temperature might be expected to have led to the free development of closed forest if there was no limiting factor, yet the pollen record suggests a gradual development of woodland and forest. This might be partly due to a gradual increase in rainfall

Figure 4 Supplementary Diagram



making water availability partly limiting to the free development of forest, but it seems much more likely that the shallow rooted herbaceous steppe vegetation did not promote much soil development nor stability, and that the woodland was originally restricted to places where there ey/ was more soil, as in vall~~ie~~s, and that a pioneer vegetation consisting of the taxa mentioned which tolerate thin soils on hillsides today occupied a similar niche then, being gradually shaded out by forest trees when the soil their deep roots had developed became sufficient. At the same time new areas were being colonised by the pioneer scrub, reducing the extent of the steppe vegetation still further.

In summary it appears that the vegetation represented by the KIIa pollen assemblage represents a transition phase between *Artemisia* steppe and closed oak forest, regulated by the availability of soil deep enough for the growth of trees in a climatic regime that may have been similar to that of Greece today.

Sub-zone KIIb appears to represent a halt in the spread of pioneer vegetation and probably a reversal, as indicated by the reduced values of tree pollen, and the great reduction in *Juniperus* pollen values. There is a corresponding rise in Gramineae pollen which might be a sign of a replacement of scrub by grassland, but this is not unequivocal and could represent a change in lakeside vegetation. The steady record of *Pistacia* which is thermophilous suggests that a cooler climate is unlikely to be the cause of the changes noted, but a reduction in rainfall might have halted the spread of the pioneer scrub suggested, and that of the succeeding oak forest, or even caused some reversal of progress, and seems to be a likely factor.

Sub-zone KIIc, with increasing tree pollen values in a similar pattern to that of KIIa suggests that a parallel can be drawn between the pattern of vegetation development suggested for KIIa and that for KIIc, but in the latter case reaching a far greater extent of afforestation as evidenced by the high level of pollen from oak-mixed forest taxa, notably Quercus, Ulmus and Tilia, and the fainter signs of the steppe taxa, Artemisia and Chenopodiaceae. The signs of afforestation would be in response to suitable climatic conditions of warmth and particularly of rainfall as suggested before, and the abundant records of Pistacia pollen give a hint of an eu-Mediterranean climate with strongly seasonal rainfall, conditions in which Pistacia flourishes today in southern Greece, compared with the more evenly distributed rainfall in norther Greece giving a less Mediterranean vegetation. KIId, with its very high oak pollen values, appears to represent the final stage of the development of forest in the time covered by the pollen diagram. The pioneer scrub may have been restricted to the few places still with soils too thin to support oak woods, as on steep slopes, and the herbaceous vegetation is not much in evidence as if there was little open land.

KIIIa, has many of the signs of mixed-oak woodland as the dominating vegetational type, but there are signs of a thinner coppice type woodland with Corylus and Ostrya type spreading at the expense of the oak wood, and also spreading pine wood. Corylus and Ostrya-Carpinus wood grows today in places that appear to have formerly been forested, as indicated by relict forest trees, and the thin woodland certainly regenerates well when it is not shaded over land with sufficient soil and moisture, but it is less successful in the type of rocky habitats where *Juniperus* and *Pistacia* flourish. The reduction in oak pollen frequencies together with the increase in pollen from light-demanding woodland plants suggests the possibility of some type of forest clearance. There are some signs of forest change even in the oak pollen itself, for there is a large proportion of evergreen oak pollen at this stage, even though the identification difficulties (see page 38) did not allow this to be quantified, and this change of oak type could represent the beginnings of the more Mediterranean type of oak wood consisting mainly of evergreen species such as *Quercus ilex* and *Q.coccifera* (cf. Beug 1967a). A study of herbaceous pollen frequencies reveals little change, although it is relevant here that there is a peak in *Consolida* pollen in the previous sub-zone, this plant being one of the commonest cornfield weeds in present day Greece. KIIIa might well represent some kind of forest clearance phase, even if not of the classical Landnam type (Iversen 1941), for a change to lighter forest is evident even if there are not signs of open land and agriculture apart from the isolated *Consolida* record.

KIIIb, with further reductions in oak pollen, increases in shrubby woodland taxa such as *Carpinus betulus* and *Fraxinus ornus*, and in herbaceous taxa, particularly Gramineae appears to represent a continuation of the trend towards thin woodland and perhaps open ground, established for KIIIa. The appearance of the pollen of *Olea* marks KIIIb apart from KIIIa, for *Olea* is a possible cultivar. It has already been mentioned (page 39) that pollen from the cultivated olive, *Olea europaea* ssp. [illegible] var. europaea L. cannot be distinguished from that of the only other *Olea* species found in Greece today, the oleaster *Olea europaea* var.sylvestris, Brot.

Thus there is no direct evidence whether this pollen record should be interpreted as olive cultivation or wild oleaster in the maquis, but some recent work on modern pollen rain throws some light on the problem. Taking surface samples in the vicinity of olive groves in Mallorca, Beug (1962a) found that between 5% and 8% of the tree pollen in the samples was that of Olea. He points out that oleaster is a minor component of the maquis, so its pollen would only be a small fraction of the total pollen rain, so pollen records with more than about 5% Olea pollen can safely be regarded as representing the cultivated olive. The KIIIb record of Olea pollen has an average value of 7.2% tree pollen for the five counted samples in this sub-assemblage, well within the figures for olive cultivation.

Another line of evidence helpful in distinguishing between the likelihood of a pollen record of Olea representing wild or cultivated olives is in the ecological associations of the two varieties. The oleaster association includes such maquis shrubs as Quercus coccifera, L. Erica arborea, L. Arbutus species, Juniperus phoenicea L. and Cistus species, which should be evident in a pollen record. There is not much sign of pollen from such taxa in the KIIIb assemblage although some pollen types are present, such as Ericales, which could have come from maquis vegetation. Olives are grown in different surroundings, with well spaced trees so that other crops can be grown between the rows of trees, and the pollen record from this kind of vegetation might be expected to include pollen from weeds of cultivated ground. There are slight indications in the pollen record that there may have been vegetation like this, Umbelliferae and Compositae increasing here, adding a slight amount of support for the view that the Olea pollen record represents olive groves.

Abies pollen appears in KIIIb for the first time in any quantity. Fir is a component of the montane Greek forest cover today, being abundant on Mt. Parnes today, above the upper limit of the Mediterranean vegetation of about 500m. This is the first sign of montane forest, suggesting for the immigration or spread of the fir forests, possibly in response to some climatic change that did not affect the lowland vegetation much, or possibly human intervention of some kind favoured the spread of fir.

KIIIc has some signs of vegetative reversal in that both the *Olea* and the *Abies* pollen records cease temporarily; the disappearance of the former is the more easily explained, as it appears to have been grown as a crop and then in the time represented by KIIIc its cultivation in the Kopais basin would seem to have been abandoned, whether due to human factors or others such as less favourable climate it is hard to say on the basis of the evidence available. Certainly the disappearance of fir from the record would favour a climatic explanation or even uneven pollen transport since it grows high in the mountains and probably relatively unaffected by the vagaries of mankind, unlike *Carpinus betulus* and *Fraxinus ornus* which also apparently disappear or become much reduced in range.

KIIId has a pollen record similar to KIIIb and the vegetational implications are similar, with olive cultivation the shrinking woodland being replaced by a scrub more characteristic of present day Greece, with evidence of maquis in the Ericales and herbaceous pollen increases, also a single grain record of *Cistus*. The amount of *Olea* pollen is even greater, amounting to an average of 25% tree pollen, although this could be taken as either evidence of increased olive cultivation or of the reduction in tree pollen from the by now relict forest.

6.7 THE CHRONOLOGICAL FRAMEWORK

So far the Kopais pollen diagram has been discussed in terms of the vegetational record without any reference to the absolute chronology of the events portrayed. The sediments of this lake were mainly mineral in nature, unsuitable for radiocarbon assay, and could only be penetrated by a screw auger giving small samples, so not even the most organic of the sediments yielded a date on which to base the chronology. Material taken from a surface exposure by Dr. J. Turner in 1964 was available, including some peat, and a sample of this was radiocarbon dated at the Scottish Radiocarbon Reactor Centre at East Kilbride. A sub-sample of this peat was prepared for pollen analysis and the resultant count of 424 grains was matched to the part of the pollen diagram presented here, between about 200cm and 220cm (KIIIb) and the outline diagram prepared from the 1964 core confirmed this arrangement (Turner pers. comm.)

The main features of the peat block pollen spectrum associating it with this part of the Kopais diagram are as follows: the moderate values of <u>Ostrya</u>, <u>Carpinus</u>, <u>Olea</u> and Ericales pollen show that the spectrum could hardly correspond with any point lower than 220cm on the Kopais diagram, as these pollen types only appear there in any quantity above this level. Likewise, the small values of the pollen of the various Compositae in the spectrum show that it is unlikely to correspond with any point on the diagram above about 180cm where these pollen types become abundant.

There is corresponding evidence from the aquatic pollen record; the value of <u>Sparganium</u> pollen is moderate in the spectrum, such as that on the diagram below the sharp peak starting at 194cm. The spectrum has a large amount of <u>Nymphaea</u> pollen, which could correspond to the peak at 218cm on the diagram. The date given for the peat sample is 5200 b.p. ± 100 (radiocarbon years), 4000-4200 B.C. corrected, corresponding to the time of the Final Neolithic in archaeological terms (Renfrew 1970). This date, from a spectrum with signs of olive cultivation is surprising since the earliest evidence of olive cultivation in mainland Greece is at least two thousand years later than this date.

On the other hand the date could be interpreted as showing that substantial deforestation had occurred by this time, but the conflict of the evidence of the olives makes it hard to place much reliance on this date until there is more evidence on the dates of deforestation and olive cultivation.

A possible explanation for a radiocarbon date being far older than expected such as this may be seen in the fact that carbon dioxide used by the living organisms around the lake may have partly been derived from limestone rock rather than from the atmosphere, and therefore relatively deficient in the radioactive $^{14}CO_2$. If the vegetation photosynthesised carbon dioxide poor in the radioisotope the peat so formed would give an older date than expected.

In the absence of seemingly reliable dating evidence from Kopais itself, a chronological framework is best derived by a comparison of the Kopais results with those obtained from other sites in Greece. The results from Lake Philippi in northern Greece appeared in a preliminary paper (Van der Hammen et al 1965) and then in greater detail (Wijmstra 1969) where it is called by its Greek name, Tenagi Philippon. This has been well provided with radiocarbon dates, and is a good means of dating by correlation inasmuch as vegetational changes in northern Greece can be unequivocally correlated with those in the South.

Starting at the base of the Kopais succession, Zone KI with its small amounts of tree pollen and large records from Gramineae, Chenopodiaceae and Artemisia seems to correspond most exactly with zones P, X, and YI in the Tenagi Philippon diagram. The minor features of these parts of the two diagrams also seem to correspond where in both cases there are small pollen records from Juniperus, Compositae (tubuliflorae) and Rubiaceae. Wijmstra noted some fluctuation between Quercus/Pinus values and Juniperus, which are also detectable in KI.

Cap

There is likely to be a correlation between the ages of zones dated in Tenagi Philippon and those in Kopais, although it is difficult to choose the point of the Philippi diagram corresponding to the beginning of Kopais. Zone P begins about 48,000 years ago, ending at 13,600, and Zone KI probably begins part way through Zone P, perhaps 30,000 years ago, and ends at the same time, 13,600 years before the present day.

Several other pollen diagrams show evidence of steppe-type pollen assemblages changing to woodland assemblages at about this time; in western Iran the pollen record is dominated by Chenopodiaceae and Artemisia up to about 14,000 years ago (Van Zeist & Wright 1963, Van Zeist 1967). In central Greece a similar change is dated to some time before 10,000 years ago (Bottema 1967), while in Spain the evidence suggests a change of this kind at around 13,000 years ago (Florschütz et al 1971) where the dominance of Chenopodiaceae and Artemisia gives way to one of Quercus and other tree species.

In all cases this phenomenon has been interpreted as the vegetational response to the climatic change which in northern Europe expressed itself as the end of the last Full-glacial period. While the glaciers retreated in northern Europe the vegetational response in the regions where there are pollen records covering this time was immediate, and forest vegetation spread.

During the time of the full-Weichselian the climate around the Mediterranean appears to have been cool, dry and continental, but there seem to have been fluctuations in this regime, with slightly warmer and wetter periods alternating with slightly cooler and drier ones. The evidence for this comes mainly from the Tenagi Philippon and Padul diagrams (Wijmstra 1969, Florschütz et al 1971) where vegetational fluctuations are evident in this part of the diagrams and have been correlated with climato-vegetational changes of stadial and interstadial magnitude which are known and dated from northern European deposits. It is possible that these changes are also represented in KI where there are some signs of cyclical vegetational change of a similar nature.

Zone KII can be related to the dated sequence in the Tenagi Philippon diagram in the same way as KI. The beginning of zone KII and of zone Y2 on the Tenagi Philippon diagram agree well, for not only is there an increase in Quercus pollen and a decrease in herbaceous pollen (especially Gramineae, Chenopodiaceae and Artemisia), but both diagrams show the more subtle increase in Juniperus and the beginning of continuous records from Ostrya type, Pistacia and an almost continuous record from Ulmus. The aquatic records have some measure of correlation, with peaks of Typha in Tenagi Philippon and of Sparganium in Padul (Florschütz et al 1971) starting just before zone Y (both diagrams were zoned on the same system), and in the latter there is a corresponding sediment change. It seems likely that the changes in pollen record and sediment type in these two diagrams match the imcreases (mainly in Sparganium pollen) and change in sediment type mentioned in the case of the Kopais diagram, in time character and cause as suggested on page 72 .

A more detailed examination of the similarities between the Kopais and Tenagi Philippon diagrams allows a tentative dating of the sub-zones of KII. Sub-zone Y2 has high Quercus values, increased Juniperus and the appearance of Ulmus, Pistacia and Fraxinus at this point, corresponding well with KIIa which has increases in Quercus and Juniperus with the appearance of Ulmus and Pistacia. Ostrya type is present at this point in the Kopais diagram although appearing much later in the Tenagi Philippon record, while Fraxinus excelsior type pollen is scarcely present other than in the Tenagi Philippon diagram. A point of note is that the values of Juniperus pollen which are interpreted as a sign of pioneer scrub in the case of the Kopais diagram are much higher there than in Tenagi Philippon, and this could be interpreted as a sign that the Kopais region then as now has less rainfall, and therefore more restriction on forest development so that the scrub development was greater. The extent of this scrub may have been very great, for its representation on the diagram is probably far less than its importance in the vegetation, in which it could have been the dominant element, for Juniperus can be under-represented in pollen diagrams as the present-day pollen rain studies of Van Zeist and others (1970) have shown, and also Pistacia which also features in this pioneer vegetation. In both diagrams there are decreases in pollen records from the steppe elements like Gramineae, Artemisia and Chenopodiaceae, showing the decline in steppe vegetation in the region of the lake.

The Tenagi Philippon diagram sequences have been dated, the beginning of sub-zone Y2 being about 13,600 B.P. and its end at 10,900 B.P. and this time span probably applies to KIIa since its pollen evidence is so comparable. On the same basis Y3 and KIIb appear to correspond on the basis of decreased amounts of tree pollen and increased Gramineae although there are so few spectra at this point that a detailed comparison is impossible, and the dates obtained for Y3, 10,900 - 10,300 B.P. probably apply to KIIb as well.

These dates obtained for KIIa and KIIb by reference to the Tenagi Philippon diagram agree fairly closely with those obtained for the early Late-glacial in northern Europe even though the concomitant vegetational changes are different; the date for the first sign of the Late-glacial, marked by the first rise in Artemisia pollen in northern Europe is very similar to the date obtained for the beginning of Y1 and hence of KIIa at 13,600 B.P. (Van der Hammen et al 1967). There is also agreement in data from northern Italy in which the first rise in Quercus pollen heralding the beginning of the Late-glacial has been dated to 13,200 B.P. interpreted as the beginning of the Bølling interstadial (Bertoldi 1966). The span of the Allerød interstadial is currently dated to approximately 11,900 - 10,700 B.P. from which it can be seen that the climatic improvement deduced from KIIa might start a little earlier than the northern Allerød, but covers the same time sequence of this interstadial as far as can be seen from the evidence, so the climatic change expressed in the Allerød appears to have had a similar effect in Greece, although not perhaps of the same magnitude. Likewise the temporary reversion to a Full-glacial type climate as deduced from KIIb appears to correspond in both date and effect to the Upper Dryas of northern Europe.

KIIc, on the basis of the chronological framework argued above, represents the beginning of the Post-glacial period equivalent in Greece.

The increasing values of Quercus pollen, high Juniperus and the presence of Pistacia, Ulmus and Tilia in the record in KIIc are reflected in similar features of sub-zones Z1 and Z2 which have increasing Quercus values and the presence of Juniperus and Pistacia as important features, but there are no dates from this part of the section.

KIId represents the attainment of a "forest maximum" and KIIIa the start of forest degradation, and there seems to be a divergence here between the Kopais diagram and Tenagi Philippon although they both represent to some extent similar events of forest thinning and replacement by thinner vegetation more like that found in Greece today. Quercus pollen decreases, more obviously in the Kopais diagram, while Pinus, Ostrya type Carpinus, Fraxinus, Gramineae pollen values increase in both diagrams. Ericales pollen is a particular sign interpreted as marking the beginning of maquis development, and its arrival, almost at the same point as the first record of Abies pollen is dated at 5,000 b.p. The Kopais diagram differs in that Fraxinus excelsior pollen is not present, whilst F.ornus, Phillyrea media and Olea europaea are, but there is probably enough similarity between the two diagrams to suggest that the beginning of sub-zone KIIIa might correspond to the point on the Tenagi Philippon diagram dated to 5,000 b.p.

There is difficulty in correlating the two diagrams beyond this point, for the next pollen zone KIIIb, with Olea pollen, has no counterpart in the Tenagi Philippon diagram. Perhaps KIIIb represents some later stages of vegetational history than recorded by the Tenagi Philippon diagram.

The periods of olive cultivation suggested in KIIIb and KIIId are very interesting, and a possible date for the first one would be Bronze Age, in the light of conventional archaeological opinion (Taylour 1964) formed on the basis of the earliest finds of oil presses and storage jars presumed to be for olive products. The earliest finds of olive stones are also Bronze Age although there are very few records of olive stones in archaeological material, possibly because they have not actively been searched for, and the example mentioned above is from Crete (Warren 1972). It was thought that the sophistication of the Mycenean period (c. 1400 - 1200 B.C.) equated well with organised agriculture and olive growing, compared with the Dark Age (c.1150-800 B.C) which was considered to be a time of trouble and unrest in which olives, which need about 20 years growth before bearing fruit, would not be grown much as the farmers would have less chance of seeing the fruits of their labour. (cf. the later destruction of the olive orchards round Athens in the Peloponnesian wars).

In the Classical period it was thought that olives would be grown once more, with the resumption of a fairly organised way of life beginning around 800 B.C.

It has been stated (Wright 1968b, 1972) that the above pattern of olive growing in times of peace was not the case, using results from the Peloponnese. The whole matter is made more complex by the recalibration of radiocarbon dates (Suess 1967, Renfrew 1971a), and is best discussed in connection with evidence from the Philippi diagrams on page 120 . It is sufficient to say at this stage that Wright's views are not entirely vindicated by the evidence from northern Greece, for the other data presented in this work tends to favour the conventional view of olive cultivation during the Mycenean and Classical periods rather than mainly in the Dark Ages.

The pattern of afforestation and subsequent deforestation and spread of Mediterranean plants as shown in the Kopais diagram can be seen in some other diagrams from the region, although generally in less detail. The diagram from Ioannina (Bottema 1967) shows the change from Gramineae, Chenopodiaceae and Artemisia dominated pollen assemblage to one dominated by Quercus and other tree pollen, but no clear sign of oscillation can be seen in the early stages as in Kopais and Tenagi Philippon. In the upper part of the diagram evergreen oak pollen appears and Ostrya type with some reduction in overall Quercus values, some sign of deforestation, and a similar pattern of rise and fall of tree pollen values can be seen in a diagram from central Italy (Frank 1969). Beug's diagram from Jugoslavia (1961, 1967a) seems to still be unique in that his pollen zones appear to have no equivalent in any other diagram covering the Post-glacial in southern Europe, although the general outline of replacement of deciduous oak by the evergreen types can be seen.

6.8 THE AQUATIC POLLEN DIAGRAM

The aquatic pollen diagram carries a record of pollen frequency change with sharply fluctuating values: between 437cm and 500cm there is a peak in Sparganium pollen, which corresponds to the uppermost parts of Zone K I in the land pollen diagram. A second peak in aquatic pollen, between 378cm and 398cm features high values of Sparganium pollen and some increase in Myriophyllum, and corresponds to KIIb. Even greater values of aquatic pollen are attained in the third and fourth peaks, between 162cm and 224cm (corresponding to Zone KIIIb) and between 130cm and 75cm (corresponding to Zone KIIId).

It can be seen from the stratigraphic column on the left margin of the diagram that the sediments from which these high aquatic pollen levels were attained are those which were found to be muddy and organic in nature sometimes with silt, while the intervening parts of the diagram with low aquatic pollen levels come from clay sediments with a very low organic content so that the caustic soda part of the preparation process showed no signs of humic material being dissolved. It would appear that there is some link between the state of the lake, and therefore the sediments being laid down at a particular time, and the aquatic vegetation in and around the lake. That three out of the four peaks of aquatic pollen correspond exactly to the pollen zones proposed on the basis of the land pollen values suggests that there may also be a link between changes in the regional vegetation and those changes affecting the immediate surroundings of the lake.

The corresponding increases in the organic content of the sediments and the larger values of aquatic pollen contained in them can be interpreted as the result of the spread of hydrosere plant communities in shallow water conditions, which would have contributed the organic products of their decay to whatever sediments were being brought in with the water feeding the lake. The larger amounts of sand and silt together with the muddier nature of the sediments here suggest that there was also a change in the type of material being brought into the lake, as well, fine clays giving way to muds and silts.

An increase in the extent of hydrosere communities growing in and around a lake must be brought about by factors increasing the amount of shallow waters capable of supporting them, such as a lowering of the water level. It has already been stated that prior to drainage in 1886

Lake Kopais dried out in the summertime, filling with water in the winter rains (Naval Intelligence Handbook 1945). Lake conditions such as these would appear to be suitable for the growth of large amounts of aquatic vegetation while preventing hydrosere development by the winter floodings, and lake sediments laid down in this manner might be expected to contain large amounts of aquatic pollen, but in this case the dry alkaline lake surface in summer would probably have resulted in pollen corrosion and destruction as well, and this was not evident in the samples with large amounts of aquatic pollen. Neither would a lake regime such as this explain the presence of muds and sands in the sediments.

The muddy silty sediments associated with the greater aquatic pollen values may be one of the factors giving increased extent of hydrosere plant communities. If the rivers feeding the lake carried more waterborne material, deltas would form in the lake with the deposition of silt, giving muddy shallows suitable for colonisation by aquatic plants, and laying down sediments of the type encountered which might be expected to be rich in aquatic pollen, and containing the organic detritus of these plants.

The consideration of soil wash as a factor tending to increase the amount of aquatic plant life in the lake appears to be a valid one, in the light of evidence presented by Vita-Finzi (1969) on the geomorphology of erosion cycles in the Mediterranean region. He found that there is a uniform pattern of soil accumulation and erosion which can be detected right round the Mediterranean over a time span of at least 50,000 years. ey/ Soil accumulated in vallies between 50,000 and 10,000 years ago followed by erosion from about 10,000 years ago through to Roman times (1,500 years ago). Then in Medieval times there was another phase of accumulation of soil, with further erosion in modern times, the effects of which are all too evident in present day Greece. The valley soils were derived from the surrounding hills by the action of frost, wind and water, and washed down into the deposits during deposition phases. These beds were dissected by rivers during erosion phases, the soils being spread over the plains or washed into the sea or into lakes such as Lake Kopais. This soil movement might be expected to have given rise to muddy shallows around the river deltas, providing a habitat for a range of aquatic vegetation. Vita-Finzi tentatively links the periods of erosion and deposition to climatic changes, which is an interesting suggestion in the light of the results presented here.

The first peak in aquatic pollen corresponds to the last signs of Artemisia steppe vegetation, a period of time immediately before the spread of woodland deduced from the pollen record of sub-zone KIIa, during which a climatic change from cool and dry conditions to somewhat warmer and wetter has been suggested (page 54), the woodland starting off as a scrub, gradually being succeeded by mixed-oak wood, with the development of deeper soils. An increased rainfall on land with only a thin vegetational cover such as that of the Artemisia steppe could be expected to lead to erosion of the unprotected soils from hillsides down into vallies and lakes, and this seems to have been the case, resulting in the stratigraphic changes in the lake sediment and its aquatic pollen content. The spread of woodland appears to have stabilised the soils as well as promoting more soil formation, thus reducing the amount of soil wash and resulting in a reversion from muddy to clean lake margins, and a reduction in the extent of aquatic vegetation.

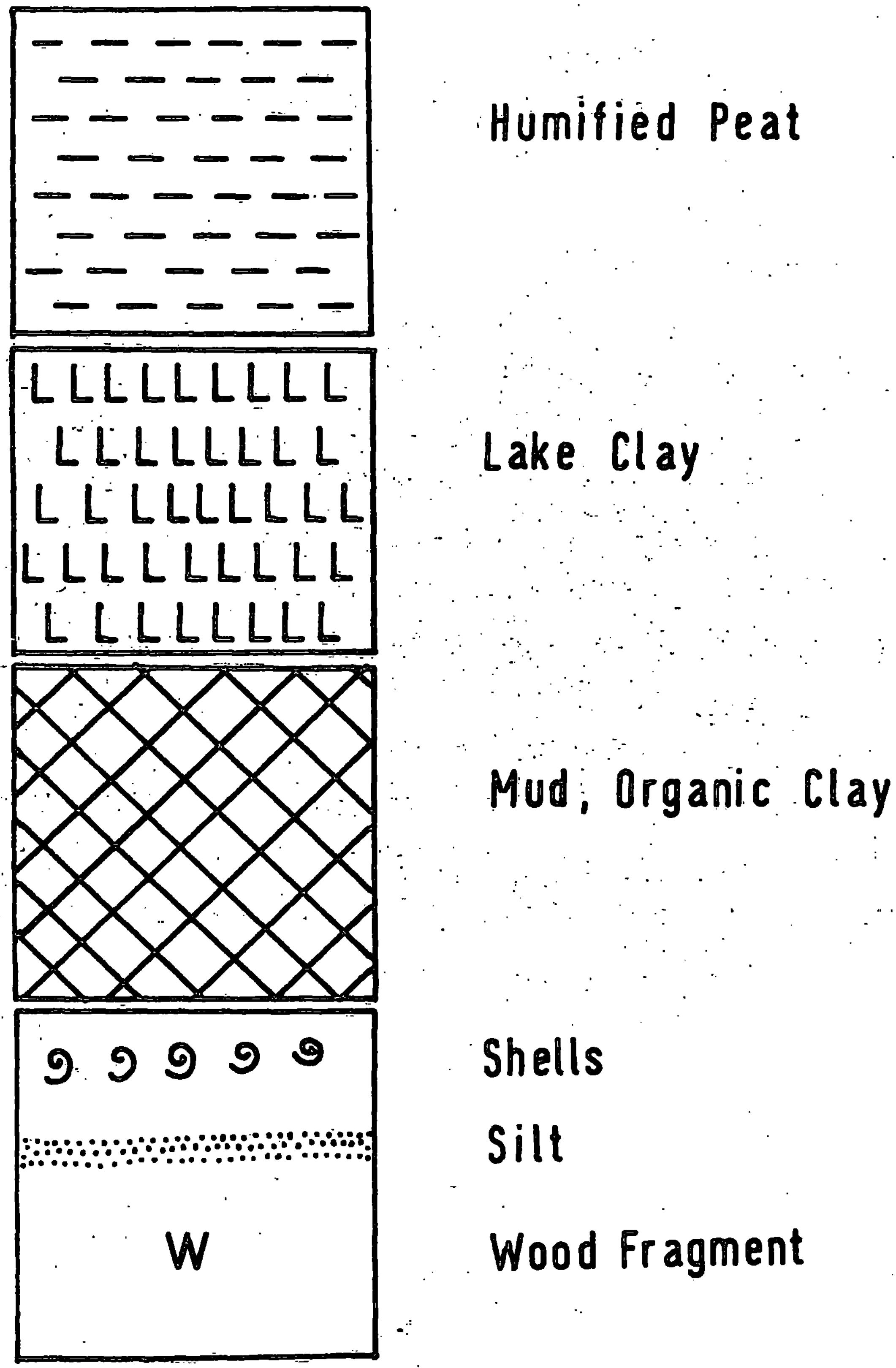
The second peak in aquatic pollen seems to have been due to a similar turn of events, but on a smaller scale, as there are also signs of increasing afforestation interpreted as the result of warmer and wetter climatic conditions following the cooler and drier episode.

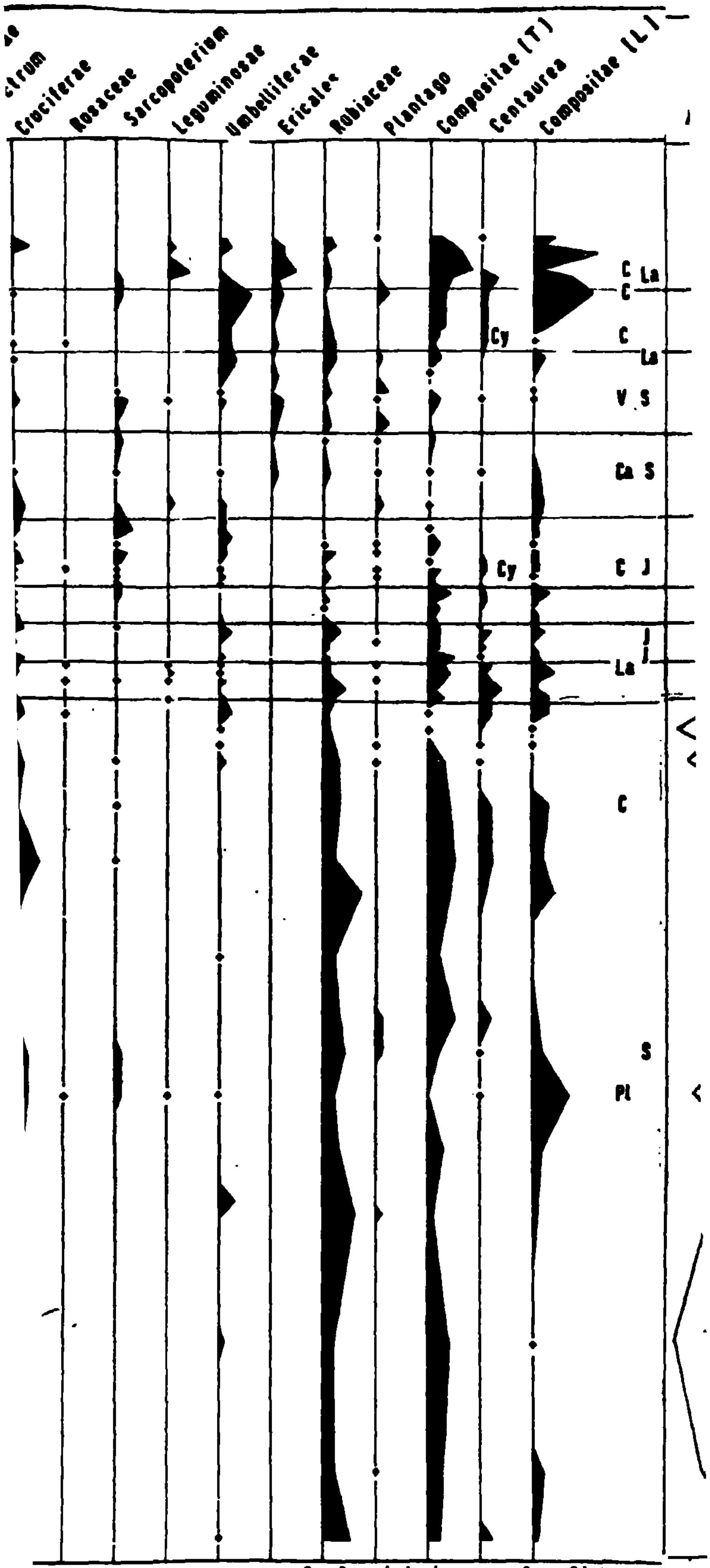
The third and fourth peaks in the aquatic pollen record do not correspond to evidence of spreading forest like the first two; instead there are signs of forest reduction which could be solely due to clearance by man, and also some signs of olive cultivation, but no indication of climatic change. Forest clearance leads to widespread erosion, as can be seen in Greece today where it may go as far as to form a "badland" topography (Harris and Vita-Finzi 1968), and the evidence from the sediments, the land and the aquatic pollen record suggest that 162cm - 224cm and 130cm - 75cm represent such episodes of erosion in the past, leading to muddy lake conditions.

There is some evidence of interference with the lake itself, for a canal system in the North-west part of the lake has been acribed to the activities of the Minyan settlement of the region in the fourth millenium B.C., connected with various occupied sites such as Orchomenos, on the edge of the lake (Taylour 1964). It is not known whether these canals had any more than a very local effect on that part of the lake, or even if they affected the general lake level, and none of the stratigraphic or palynological changes noted appear to be affected by the work of the Minyans.

Figure 5

Kopais Sediment Symbols

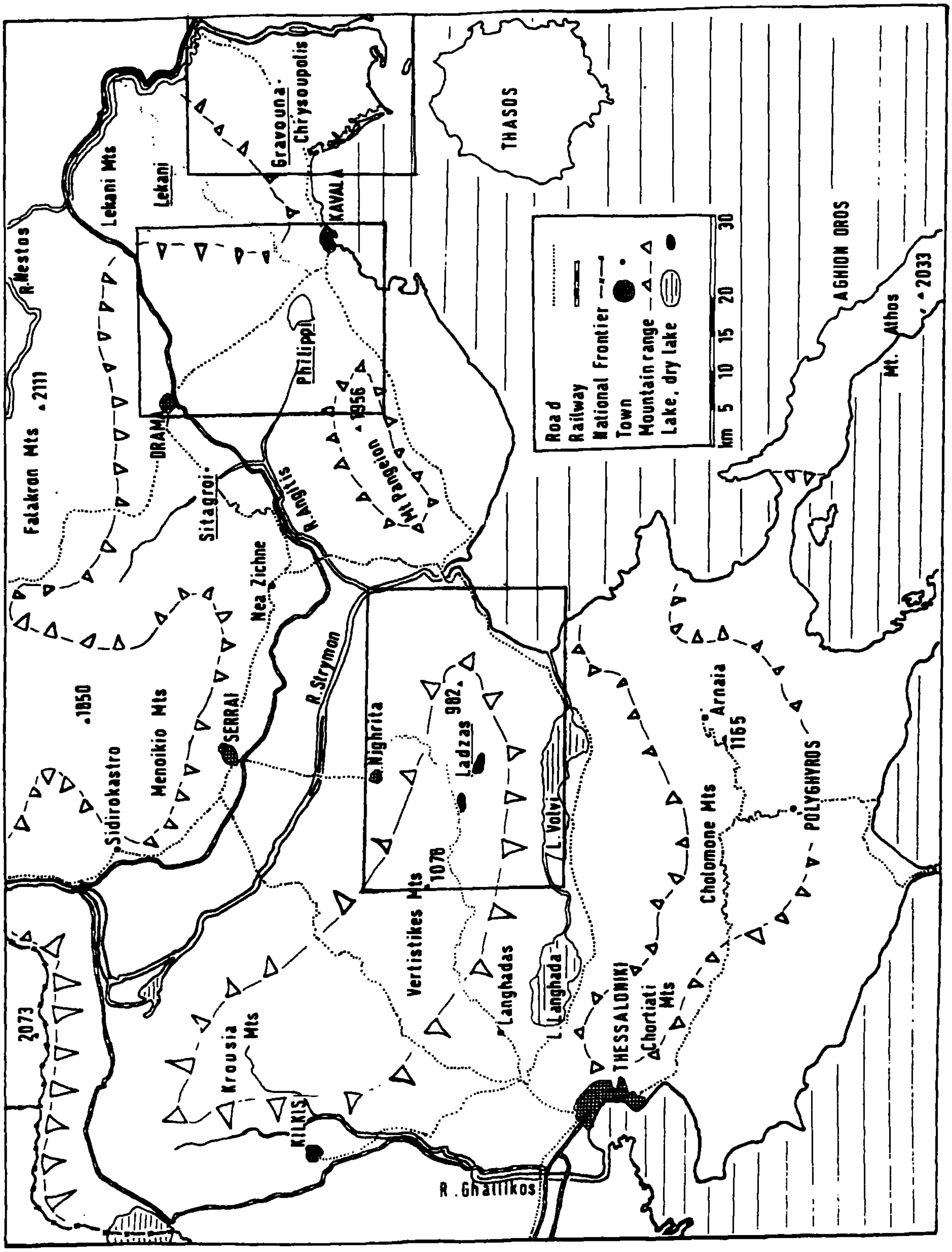




S = Scrophulariaceae C = Cistaceae
Cy = C.cyanus Pl = Plumbaginaceae La = Labiatae
V = Vitis Ca = cf. Cannabinaceae J = Jasione

CHAPTER 7. LAKE LADZAS

Figure 7



[illegible] [illegible] (Macedonia)

[illegible]

7.1 THE LADZAS REGION

Lake Ladzas was the first site found which appeared to be really suitable for coring. It is shown as a small lake on old maps of the area, such as the War Office maps which were used in this work. Next to Ladzas is the smaller Lake Mavroutha. The name Ladzas is often printed in English texts as "Lantzas". This apparent inconsistency in the nomenclature of Greek places is due to the ambiguities that arise in pronounciation and spelling in Greek. The alternative spelling, "Lantzas" signifies the fact that the Greek alphabet, having no hard "d" sound, uses the combination "nt" to produce the hard "d".

The two lakes lie in a hollow in the outlying hills of the Kerdylion and Vertistikes mountains, between the towns of Nighrita and Sochos. These mountains and hills are made up of gneisses, gabbros, serpentines and granites. The predominant rock type in the hills around the lakes in schist. (Naval Intelligence 1945).

The lakes have no outlet on the land surface, and they are thought to have drained through subterranean channels in the underlying belts of marble rock (Naval Int. 1945). Ladzas used to be about 7 km^2 while Mavroutha was about 4 km^2 before the lakes were drained. When the boring was being done, it could be seen that Mavroutha was still in the process of being drained, and channels were being dug in the lake bed. At Ladzas, the lake bed had dried out, and the heaps of spoil from the cuttings had started to slump in the winter rains.

Drainage channels at intervals of about 250m formed a grid pattern over both lake beds. Each channel was about 2m deep and 5m wide at the top.

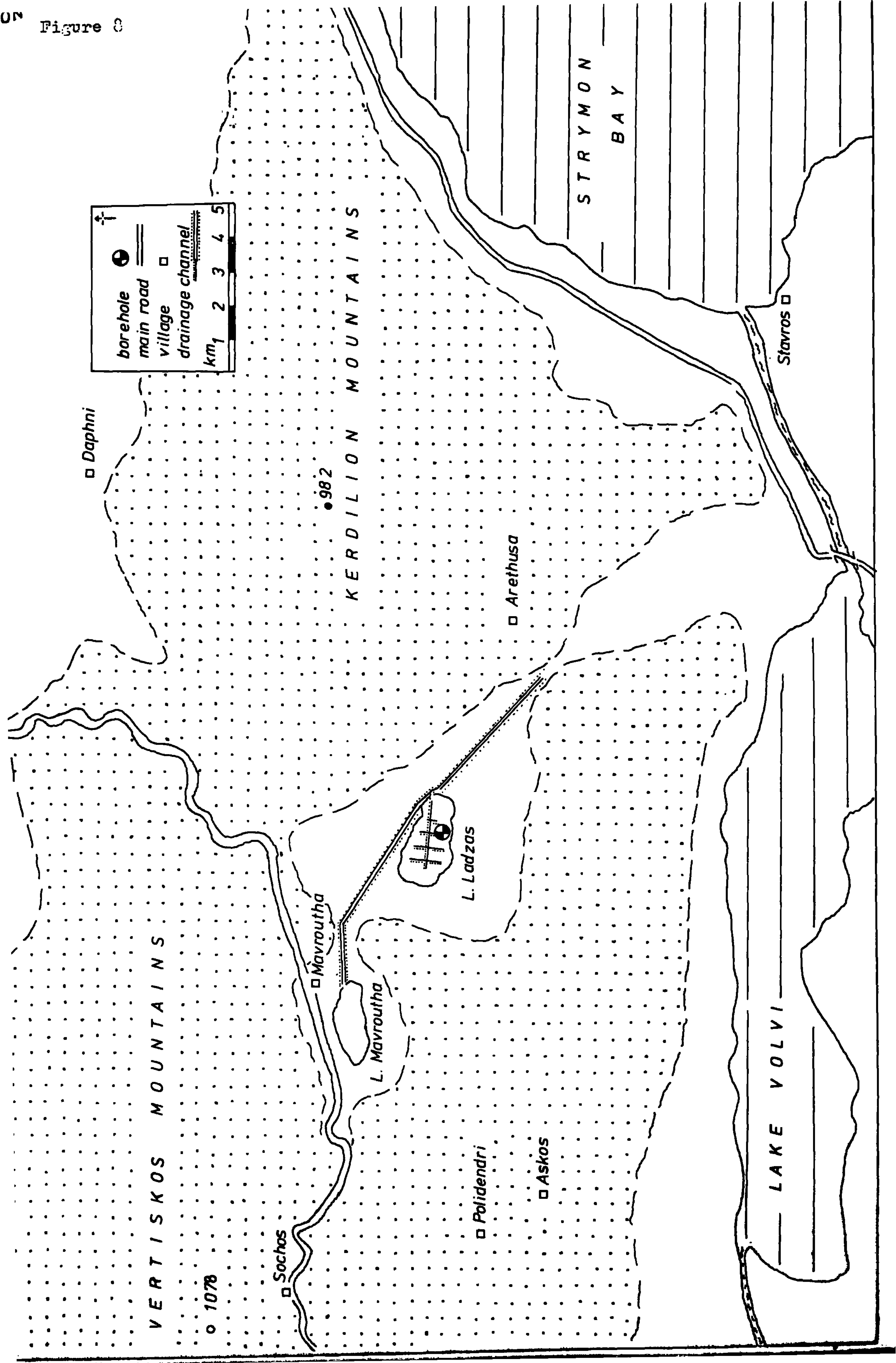
Trial coring was done at both lakes, and this showed that the sediment types were all similar grey clays. Ladzas was chosen for sampling because there was better access to the lake. Furthermore there was a military exercise being carried out in the vicinity of Mavroutha, which made it wiser to sample from Ladzas in order to avoid the possibility of trouble with the authorities.

The dry lake beds were being slowly colonised by pioneer plants, especially that of Lake Ladzas which had had more erosion to remove the salts. There were scattered specimens of Plantago coronopus which is a ruderal and a halophytic plant, and the groundwater at that point was distinctly brackish and quite undrinkable. In the nearest village the water supply was slightly brackish and, although used by the population, unpleasant to taste.

Outside the immediate environs of the lakes the halophytic and lacustrine affinities of the vegetation disappear. Reeds are restricted to the former lake edge, and there are some stands of poplar trees nearby, which give a small amount of shade and shelter, but this type of plant cover quickly gives way to fields of grain, maize, tobacco and vegetables, with a few shade trees like Crataegus sp. in the middle of the fields.

Where the land rises above the level of the plateau where the lakes lie, the increasing rockiness of the soil prevents the use of the land for fields, so there is a pseudomaquis type of plant cover, hardly a natural vegetation in itself, but maintained in this form by the attentions of the flocks of sheep and goats which forage around the villages. The dominant shrub is Paliurus spina-Christi which among the Mediterranean vegetation is probably the most viciously thorny, it probably owes its

Figure 8


borehole
main road
village
drainage channel
km 1 2 3 4 5
STRYMON BAY
KERDILION MOUNTAINS
Daphni
982
Arethusa
Stavros
L. Ladzas
Mavroutha
L. Mavroutha
VERTISKOS MOUNTAINS
1078
Sochos
Polidendri
Askos
LAKE VOLVI

wide distribution to the fact that it seems to be practically immune from damage by grazing animals. The thorny umbrellas of the Paliurus plants give protection for many herbaceous plants growing in the spring, such as Helleborus sp., Anemone sp. and members of the Liliaceae.

As the land rises still further and becomes even rockier, the Paliurus scrub gradually gives way to a Quercus coccifera scrub, possibly connected with the increasing distance from villages and a corresponding decrease in grazing pressure. This in turn becomes what is, for Greece, a well developed woodland with a mixture of hardwoods and shrubs, principally Quercus pubescens, with Ostrya carpinifolia Fraxinus ornus and Crataegus monogyna, all growing where there is a sufficient depth of soil. On the more bare and rocky exposures the tree cover becomes more scattered, with isolated specimens of Quercus coccifera, Juniperus oxycedrus and Pyrus amygdaliformis with Ruscus aculeatus and Asparagus acutifolius growing under the trees.

The oaks are well developed, many with trunk diameters of 15-20cm, and from its appearance and mixture of species the woodland here might have regenerated naturally from earlier and possibly thicker woodland. There are some tree stumps showing that there has been a certain amount of exploitation of the woodland in the past, but no signs of recent forestry work. Some of the local names are interesting, for example a nearby village called Polidendri or "Many Trees" from which one could infer that this area has been wooded at some time.

Where the hills become lower to the south of the two lakes, the oakwood becomes pseudomaquis once again, which in turn gives way to fields on the alluvium around Lake Volvi.

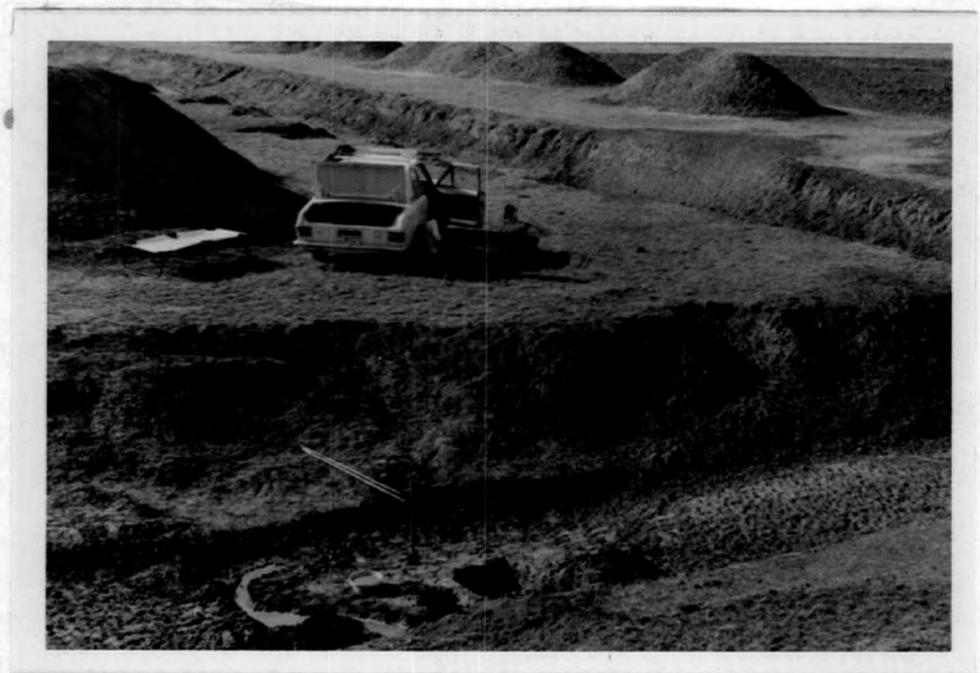


Figure 9. Lake Ladzas

7.2 FIELDWORK

Several borings were made at Ladzas. First of all pit samples were collected from a vertical face exposed by digging into the side of a drainage channel which happened to be dry, at a place about 100m from the former lake edge. This series, from 0cm (ground level) to 135cm (level with the bottom of the channel) was continued with the screw auger down to 460cm. At this depth the sediments were so hard and compacted that the borer, once it had been driven into them, could not be withdrawn without the use of excessive force on the instrument, so boring was stopped at that point and the borer brought up by turning it in an anti-clockwise direction.

A few days after the Ladzas 1 boring had been made, a second boring was started in the same dry channel, but about 300m further out towards the middle of the former lake. This core started from 130cm below the lake bed, level with the bottom of the channel but at its side so that undisturbed sediments would be sampled from the start. This Ladzas 2 boring went through harder and softer sediments (see page 78) down to a depth of 1070cm. at which point it was failing to sample properly.

The stratigraphy recorded from the different borings is drawn in symbol form on the pollan diagram using the conventions of Troels Smith (1955) for the sediment types, adapted to cover the particular range of sediments encountered during the coring operation at Ladzas. There is also a key to these symbols (Fig. 10).

The stratigraphy is as follows:

STRATIGRAPHY OF THE CORES

Boring 1 pit excavation samples:

Depth(cm)	Sediment
0-40	Light brown alluvium, dry at the very top
40-47	Silt, olive brown in colour with mottled orange patches, merging gradually into the next layer
47-48	Sand, fine in texture, olive brown
78-100	Silt, olive brown with rust coloured streaks
100-135	Clay, olive brown in colour and plastic in texture, with slight orange mottling

Boring 1, screw auger samples:

135-320	Clay, olive brown, becoming softer and with black patches at 260cm
320-325	Particularly soft clay
325-345	Firmer clay, becoming lighter grey
345-370	Firm grey clay
370-400	Firm grey clay
400-430	Firm grey clay, lighter in colour. Some lumps of possibly reworked material of whitish colour from 420cm
430-460	Firm grey clay, becoming harder. End of boring 1.

Boring 2, screw auger samples:

130-154	Clay, olive grey and mottled brown in colour
154-165	Clay, olive grey steaked with black
165-205	Firm clay, mid-grey and streaked with black
205-230	Firm clay, dark grey. The dark colour is the same as the streaking seen in the sediments above, now evenly distributed
230-255	Hard clay, blue grey in colour
255-280	Harder clay, blue grey

<u>Boring 2, screw auger samples</u> continued

280-295	Clay as above, but slightly lighter in colour
295-305	Clay as above, with the addition of white matter possibly from reworking
205-330	Hard crumbly clay, grey in colour with no white matter
330-355	Crumbly clay, light grey with white streaks
355-370	As above, but the borer was not sampling very well
370-380	Soften grey clay with a very little white material
380-405	Soft grey clay
405-430	Light grey and white clay
430-485	Hard greenish-grey clay, no white material
485-490	Dark greenish-grey clay heavily mottled with brown-orange lumps
490-495	As above but with less mottling
495-505	As above but with some silt present
505-530	Silty clay, greenish grey with a little orange mottling
530-555	Silty clay, greenish grey
555-580	Silty clay, softer than before and becoming more grey with depth
580-590	Dark grey silty clay
590-593	Mid grey silty clay
593-605	Silt with clay, lighter grey than the above
605-630	Clay with silt, mid grey
630-638	Grey clay with silt
638-655	Silt with grey clay
655-680	Silt and grey clay getting harder towards 680cm
680-705	Silt and grey clay

<u>Boring 2, screw auger samples</u> continued

705-730	Grey clay with much reworked material
730-805	Grey silt/clay

At this point sampling was continued in another borehole a foot or so away from the original one. This changeover was necessitated by the borer being pushed in too far.

805-830	Clay, slightly silty, dark grey in colour
830-855	Muddy sediment, brown grey in colour
855-880	As above, but very soft
880-905	Grey silty mud, very soft
905-930	As above but firmer
930-960	Silty clay, grey, firm in texture
960-980	Silt with grey clay
980-1005	Grey clay with silt
1005-1030	Borer failed to sample properly
1030-1055	Grey sand
1055-1105	Grey silty clays, but borer failing to take clean samples

7.3 THE POLLEN DIAGRAMS

The Ladzas diagrams are drawn up with the pollen frequency curves expressed as the percentage of the total pollen sum (AP+ AP+AQ). The taxa have been arranged, as in the Kopais diagram, in a basically taxonomic order in two sections; one is for the trees and shrubs, and the second for the herbs and aquatics.

The spores and infrequent pollen types are denoted by letters in the diagram margin, or where relevant, in the column of a particular plant group. The key to these abbreviations is as follows:

Cy	Centaurea cyanus type	Centaurea column
E	Fraxinus excelsior	Fraxinus column
F	Filicales	margin
L	Lycopodium	margin
M	Myriophyllum	Sparganium column
N	Nymphaea	Sparganium column
"O"	"O" type, resembling Olea	Olea column
P	Polypodium	margin
Po	Polygonum	margin
R	Ranunculus	Thalictrum column
S	Sarcopoterium	Umbelliferae column

In bore 2 the Sparganium appears as the pollen frequency curve under the "other pollen types" while in the diagram from core 1 it appears in its own column.

Apart from pollen and other lignified material, the grey clay and clay/silt samples from Ladzas contained practically no organic matter. Some samples contained no pollen at all, or too little to be worth counting. This absence of pollen accounts for the gap in the

Ladzas 2 diagram between 323cm and 505cm, where none of the 20 samples prepared from this zone contained enough pollen for a count. The difficulty with the poor preservation and general scarcity of pollen was increased by the preparation method; the Ladzas 2 core was analysed using the standard (unmodified) preparation method.

The Ladzas 1 core was on the whole much better preserved, and its samples were prepared using the Guillet & Planchais (1969) method, which would partly account for the good pollen recovery.

In both cores the silt types were the same, flakes of schist ranging from very small ones, which were washed through the 100 mesh sieve in the preparation, to ones the size of sand grains. The mineral type to which the schists belonged was recognisably the same as that seen in the outcrops of rock in the hills around the lake. The appearance of such large flakes in the sediments well away from the old lake shoreline shows that there must have been a large amount of hillwash. The schist particles would have travelled in fairly swiftly flowing streams to be carried far out into the lakes.

The lumpy clays which were found in various parts of the core seem to be peculiar to Ladzas. The lumps consist of either reworked particles of hardened clay, of lumps of minerals such as calcium carbonate which have precipitated out of solution from the lake water. These mineral particles show that Ladzas may have dried up or become shallow at some time in its history.

There is a mottled clay in the upper parts of the core which appears to contain soil from the surrounding countryside.

7.4 THE DIVISIONS OF THE LADZAS DIAGRAMS

The Ladzas diagram from Boring I can be seen to comprise a single pollen assemblage which has a striking similarity to the KIII assemblage already described from the Kopais diagram. Tree pollen, mainly Quercus, is dominant, and there are records from degraded woodland taxa like Ostrya type and Carpinus, and from possible cultivars like Olea. The likeness between the Ladzas Boring I and Kopais KIII assemblages is so close that they are zoned on identical schemes, with four sub-zones each of corresponding characteristics.

The diagram from Boring 2 is in two halves with a gap in the middle where pollen was not preserved. The lower half of the diagram resembles Kopais KI, while the top half resembles KIII although there is not much detail. This diagram is also best divided with reference to Kopais, the zones and sub-zones being distinguished by the prefix "L".

Such an interpretative zonation scheme might be open to criticism on the grounds that the Ladzas diagram is being pre-judged to some extent, but some degree of standardisation helps in the understanding of the diagrams, especially when one of them, Ladzas, is obviously fragmentary.

The diagram from Boring 2 is best dealt with first since it is the least detailed. As stated above, two main pollen assemblages can be seen, LI and LIII.

BORING 2

Zone LI (1070-500cm) This zone is characterised by a fairly low level of tree pollen, of which Pinus is the most abundant at about 7%, followed by Quercus at 5% with trace pollen records of trees like Betula

Alnus and *Ulmus*. Herbaceous pollen is dominant with about 25% Chenopodiaceae, 10% *Artemisia* and 8% Chenopodiaceae, while there are Cap appreciable records from Compositae (tubuliflorae), Rubiaceae, *Thalictrum* amd a few other types.

The LI assemblage can be divided into two on the basis of slight differences.

Sub-zone LIa (1070-838cm) The level of tree pollen is moderate at 26% and there are records of a number of taxa concentrated in this sub-assemblage which are rare in LIb, like *Abies*, *Tilia* and *Ulmus*. Herbaceous pollen includes 16% Gramineae, 28% Chenopodiaceae and 12% *Artemisia* with smaller amounts from *Plantago* and Compositae (Liguliflorae).

LIb (838-500cm) There is less tree pollen than LIa, 13% average and the record of tree pollen is sparser. There is a correspondingly important change in the herbaceous pollen record, with Chenopodiaceae increased to 42%.

Zone LIII (336-142cm) Here the significant features are the high values of tree pollen, mainly *Quercus* and *Pinus* with appreciable amounts of pollen from *Abies*, *Alnus*, *Corylus*, *Ostrya* type and a little from *Phillyrea* and *Olea*. There is not enough detail to form the basis of a sub-division scheme.

BORING 1

This, as already mentioned, consists of a single main pollen assemblage type of Zone III, and there is enough detail to sub-divide it as follows:

LIIIa (445-345cm) This sub-zone has high tree pollen values which are mainly *Quercus* and *Pinus* with several other tree taxa represented in lesser amounts such as *Carpinus*, *Ostrya* type and *Corylus*. The herbaceous pollen values are low, Chenopodiaceae and Gramineae being the most abundant types.

LIIIb (345cm-218cm) The features of this sub-zone are lower Quercus values (down to 34% average) some of it being Quercus coccifera type and a corresponding increase in the record from some shrubby taxa, notably Carpinus and Ostrya type. The record of Fagus pollen is mainly restricted to this sub-zone, and there is also pollen from Olea and Phillyrea in small but significant amounts. There are increases in records of open-land taxa like Plantago, Compositae and Gramineae and Ericales pollen appears at about this level.

LIIIc (218-137cm) This sub-zone resembles LIIIa in character, but it is not very clearly defined. Many of the herbaceous taxa which increased in LIIIb persist in LIIIc, and Gramineae show an increase.

LIIId (137cm-48cm) This sub-zone resembles LIIIb in that the Quercus pollen values are lower, but it appears to have been replaced by Pinus, with small amounts of Abies pollen and a few other taxa represented, while in the herbaceous record there is a sharp reduction in Gramineae, a great increase in Chenopodiaceae and a smaller increase in Compositae (Liguliflorae).

7.5 THE CORRELATION OF THE POLLEN DIAGRAMS

The results from the two Ladzas borings should overlap for both cores start at ground level going down to 445cm in the case of Boring 1 and to 1070cm in the case of Boring 2. Zone LI is clearly represented in Boring 2 while Zone LIII is most detailed in the diagram from Boring 1. If therefore the exact relationship between the two pollen diagrams can be deduced from the stratigraphy and the pollen content,

THE ZONATION OF THE LADZAS DIAGRAMS

Depth (cm)	Zone	Depth (cm)	Zone	Vegetational Interpretation
-	-	137-40	LIIId	Oak forest and open land ? agricultural
-	-	218-137	LIIIc	Oak forest, open land, less sign of cultivation
223-142	-	345-218	LIIIb	Oak forest, some cleared, olive growing
336-223	-	445-345	LIIIa	Oak forest
838-500	LIb	-	-	*Artemisia* steppe, little woodland
1070-838	LIa	-	-	*Artemisia* steppe, some woodland

the best results from each core can be used to give a composite account of vegetational change.

The stratigraphy is the first basis for correlation between the cores; of the few discernable horizons in the clay sediments from this site are some black layers at 260cm in Boring 1 and at about 165cm in Boring 2. In both cases there are firm grey clays below the black coloured horizons, which are in turn underlaid by lumpy clays. This stratigraphic evidence suggests that sediments from Boring 1 may match those from Boring 2 at 100cm higher up.

There is further information from the pollen records; in the first diagram the black sediment corresponds to the middle of the LIIIb pollen assemblage, while in the second diagram it corresponds with the undivided LIII at a point where the pollen is clearly of a LIIIb assemblage type, with <u>Olea</u> and <u>Phillyrea</u> represented, as well as Ericales and <u>Plantago</u> peaks as the major similarities. Other features of the two diagrams can be matched on the basis of pollen evidence, like the decline in Cyperaceae at 340cm in diagram 1 corresponding to a similar decline in diagram 2 at 220cm.

One way of making the two diagrams match exactly is to plot diagram 2 on an uneven scale. If the part immediately below the black sediments were plotted on a scale expanded three times, 100cm would be added to the diagram, and both diagrams would then start at 440cm, and theirstratigraphy and pollen zonation would correspond up to the end of diagram 2 at 140cm. The fact that one of the diagrams has to be stretched to make it fit the results from the other one suggests that the stratigraphy from this site may be disturbed, or perhaps uneven. Disturbed and possibly truncated sediments have also been noted by Beug (1967a) who presents a pollen diagram from Malo Jezero which is the synthesis of the results of two cores. The Ladzas results are discussed in terms of the Zone 1 assemblage from the second diagram, and the Zone LII assemblages from the first.

7.6 INTERPRETATION OF THE DIAGRAM

LIa (1070-838cm)

The LIa type pollen assemblage is clearly derived from a vegetation with some pine and oak woods, and some Artemisia steppe like that described in the interpretation of the Kopais diagram on page 51. These vegetational types probably formed a kind of mosaic with some pine wood, some oak wood, some steppe, and other vegetation growing in patches in response to local conditions, and the suggestions that oak woods were probably concentrated where there were heavier valley soils, with the steppe vegetation on the lighter soils of the valley sides and uplands (Higgs and Webley 1971), is probably as true for the Ladzas basin as for the Ioannina valley.

The vegetation represented is not so exclusively of steppe character as that of KI for there are appreciable signs of mixed-oak woodland with Tilia and Ulmus. Perhaps the climatic conditions in this region were not quite so severe at this time, or this period is not represented on the Kopais diagram.

LIb (838cm-500cm)

The LIb assemblage represents a much truer Artemisia steppe type vegetation, small in the variety of taxa represented, with Pinus, Quercus, Juniperus, Alnus, Betula and Salix almost the only tree species represented. There is some difference in the proportion of the main steppe components from those of LIa, with especially large amounts of

Chenopodiaceae pollen which suggests that there were saline soils, because Chenopodiaceae grow mainly in saline habitats on present day steppes (Wright et al 1967). Some of the Plantago pollen could also be from halophytic species such as P.coronopus which is abundant at Ladzas today, but the state of the pollen did not allow its determination to species level. The present day groundwater of Ladzas is certainly saline and the wells are brackish, so perhaps in time past the basin immediately round the lake supported some kind of a salt pan vegetation.

LIIIa (445cm-345cm)

The large amount of tree pollen, an average of 68%, suggests oak mixed forest as the premominant vegetation, as oak is the most abundant pollen type at 41%. total pollen sum. The present day woodland around Ladzas is mainly oak with other tree species represented in this sub-zone such as Ostrya, Corylus and Juniperus, the latter growing in the rockier places. The woodland that gave rise to the LIIIa assemblage must have been far more extensive than the scattered woods today, and may have had a conifer forest above the deciduous tree line.

LIIIb (345cm-218cm)

The reduction in oak pollen and the corresponding increase in pollen values from shrubby tree taxa such as Carpinus and Ostrya type suggest a more open type of woodland than that obtaining previously. Fagus and Abies, whose pollen record is mainly restricted to this sub-zone, may have formed the montane woodland as they do today, but their appearance and disappearance does not fit with ideas of immigration and woodland development, and remains enigmatic.

The amount of Olea pollen is sufficient to count as clear signs of olive cultivation (see p. 58) as it reaches a value of 7% tree pollen, yet there is no place in the plateau that would seem suitable for olive groves. This part of Greece is at today's extreme northern limit for *Olea*, and no signs of either olives or wild oleasters were seen within some 15km of Ladzas, which would make the lake surroundings beyond the limit for either natural or cultivated olives now. Perhaps the climate was warmer than today, permitting the spread of olives further north to grow on the hill slope towards Lake Volvi and the coast (see Fig.7), for olive pollen has been shown to travel far (Wright, 1972).

The appearance of Ericales pollen could be taken to be a sign of maquis type vegetation, although Beug (1967a) did not consider a similar occurrence of Ericales pollen to be due to this as other maquis taxa were absent from the pollen record, *Plantago* pollen which is abundant here could also be a sign of open land, but whether this represents arable land or salt tolerant vegetation round the lake is not clear, since the state of pollen preservation did not permit the critical determination of the various *Plantago* pollen types.

LIIIc (218cm-137cm)

Here the increased tree pollen percentages suggest a partial resurgance of forest, and the absence of the olive pollen could mean a corresponding reduction in agricultural activity. The appearance of *Juglans* pollen at this point is notable.

LIIId (137cm-40cm)

There is a reduction in tree pollen values that once again represents reduction in forest, especially oak forest. The increase in *Pinus* pollen values could represent montane pine woods or more possibly the spread of an open maquis type vegetation with species such as *P.brutei* and *P.halepensis*.

There is slight evidence of open type vegetation in the records of Ericales and Plantago pollen, and especially the great increase in Chenopodiaceae although, as mentioned earlier, this could also represent a local halophytic vegetation.

7.7 DISCUSSION

The parts of the Ladzas diagrams as presented here fit into the scheme of vegetational development and degradation worked out for the Kopais diagram, on the basis of the scheme in the Tenagi Philippon diagram. As the Ladzas record is fragmentary it cannot be as unequivocally interpreted, however, and as the lake is in a basin in the hills rather than on a lowland plain as are Kopais and Tenagi Philippon the pattern of vegetation in response to climate might be expected to be a little different.

The LIa pollen assemblage with its moderate tree pollen values and the presence of thermophiles may be compared with several points of zones P and X in the Tenagi Philippon diagram (Wijmstra 1969) where there are small peaks in tree pollen and records of Abies and Tilia although Ulmus does not appear. Sub-zone P3 demonstrates these features most clearly, and seems the most likely correlation for LIa, but there is not sufficient evidence on which to base a firm conclusion, although it seems likely that LIa represents a period of modified climate perhaps of an interstadial nature.

LIb appears to represent a period of full-glacial or stadial climate as seen in the Tenagi Philippon diagram, in which there is no sign of the fluctuations in Juniperus and Pinus/Quercus noted in the Kopais diagram and at least faintly discernable in the Tenagi Philippon one.

Poor pollen preservation was a problem during the preparation of the Ladzas material, and this might have caused the destruction of the fragile Juniperus grains, or otherwise Juniper rich vegetation may not have been a feature of the upland and inland vegetation at this time, for it does not appear on the Ioannina diagram either.

There is no evidence of vegetational development of the kind associated with the Late-glacial and Post-glacial equivalents in the case of Kopais, and presumably the part of the core that contained no pollen was laid down during this stage, leaving a gap in the diagram here.

LIIIa seems to correspond closely with KIIIa in that they both represent forest with the first signs of degradation and replacement by a more open and Mediterranean kind of woodland, a Post-glacial development, LIIIb seems to continue this close parallelism with the signs of further forest reduction and olive cultivation, and might therefore be possibly of Bronze Age date. There is little evidence of climatic change, so human activity must be the changing force behind the thinning of the forest, and this process does not appear to have been fully reversed as in the case of classical "Landnam" episodes (Iversen 1941). Similarly LIIIc seems to correspond to KIIIc, LIIId to KIIId, with apparent reduction of pressure on the forest followed by another clearance phase. In LIIId there is little sign of more olive cultivation save for one pollen grain not quite certainly identified as Olea, but the usual signs of thinner woodland and more open vegetation can be detected.

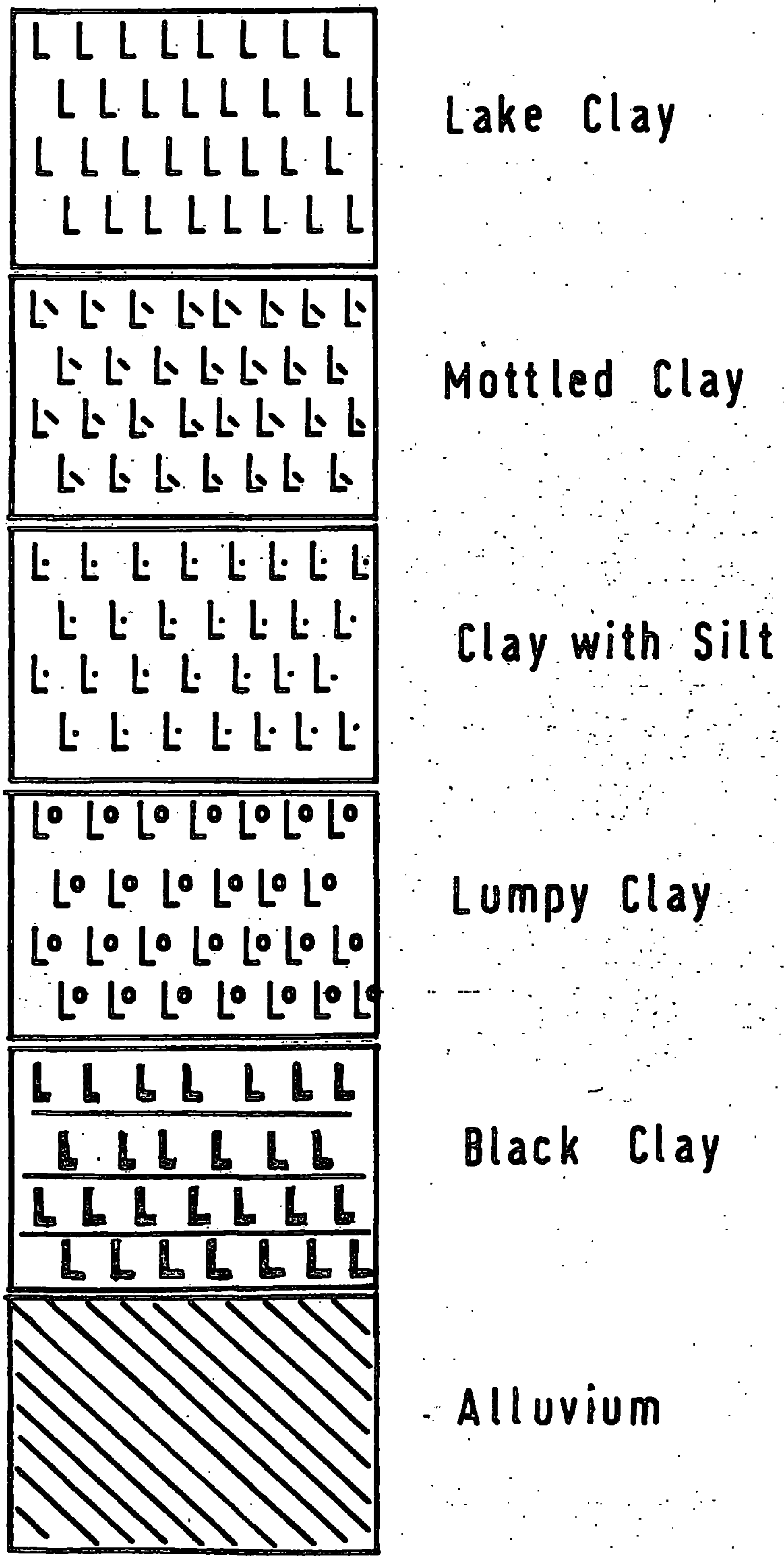
The present day climate of the Kopais and the Ladzas regions differ considerably and it might be expected that the climates of these two regions differed in the past too, giving rise to differences in the vegetation. The fact that there is an appreciable record of *Olea* pollen from Ladzas has been mentioned already, although olives do not grow near there today. This may suggest that the climate has been warmer than today, but the lack of *Pistacia* pollen could be interpreted in the opposite way, for this shrub is also thermophilous and frost sensitive (Rivas Goday 1956) and *Fraxinus ornus* which is also fairly frost sensitive is also rare in the Ladzas record. It is difficult to reach a conclusion from this conflicting evidence, although the *Olea* evidence is better than that from the rarity of *Pistacia* and *Fraxinus ornus*.

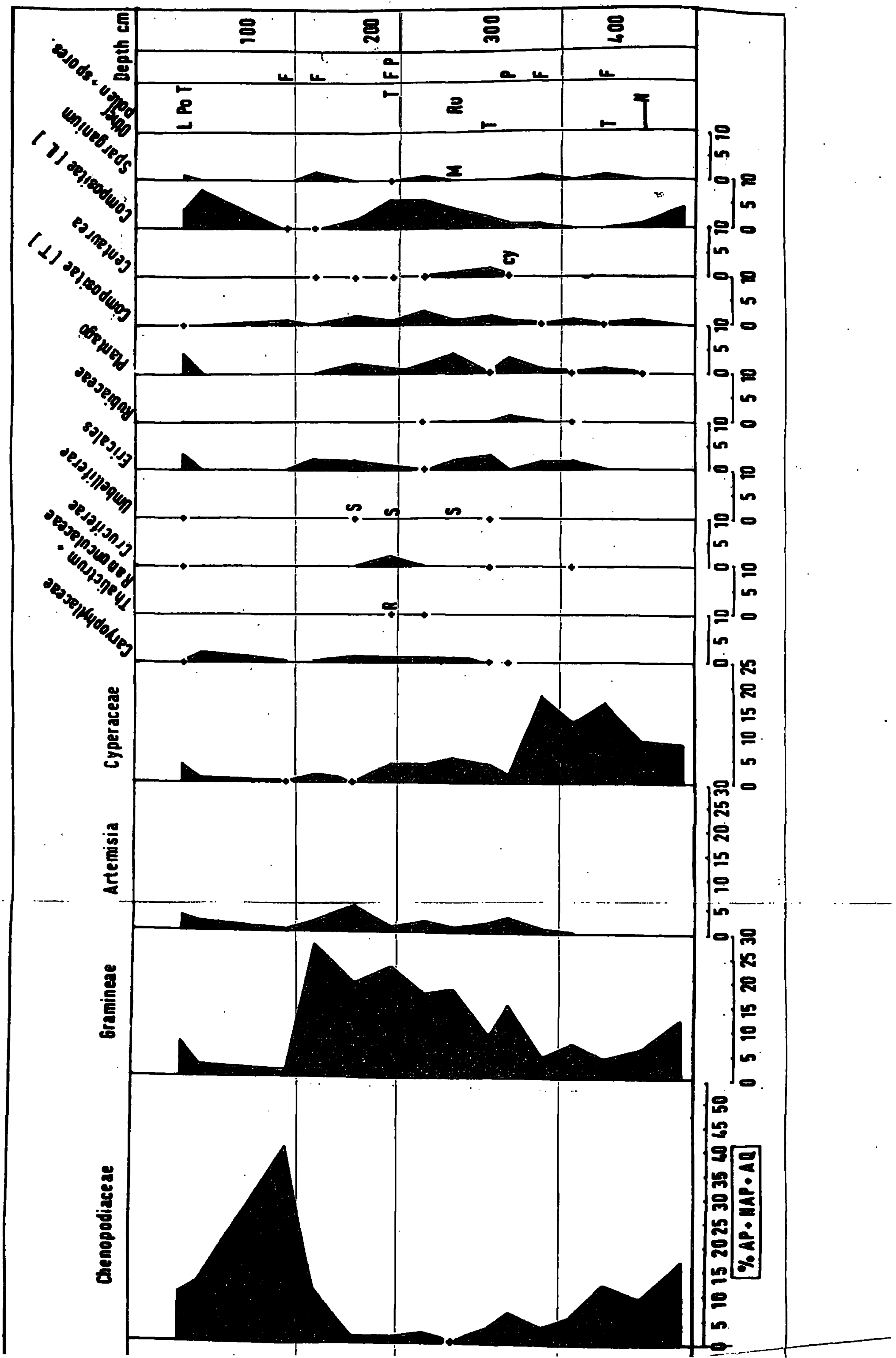
There are some taxa in the Ladzas record that are absent from Kopais, like *Fagus* in LIIIb and LIIIc. Beech is a usual constituent of montane forests, particularly in the north of Greece (Quezel 1967b) and this seems to have been the case in the past. The Ioannina and Tenagi Philippon diagrams have small records of *Fagus* pollen, and in Post-glacial records from Italy such as Frank (1969) large amounts of *Fagus* pollen have been recorded. Beug (1967b) found that beech appears in the vegetational record of Turkey about 2500 B.C. It does appear to have a rather sporadic pollen dispersal (Bottema 1967) so its appearance in some diagrams but not in others may not be exclusively connected with its distribution.

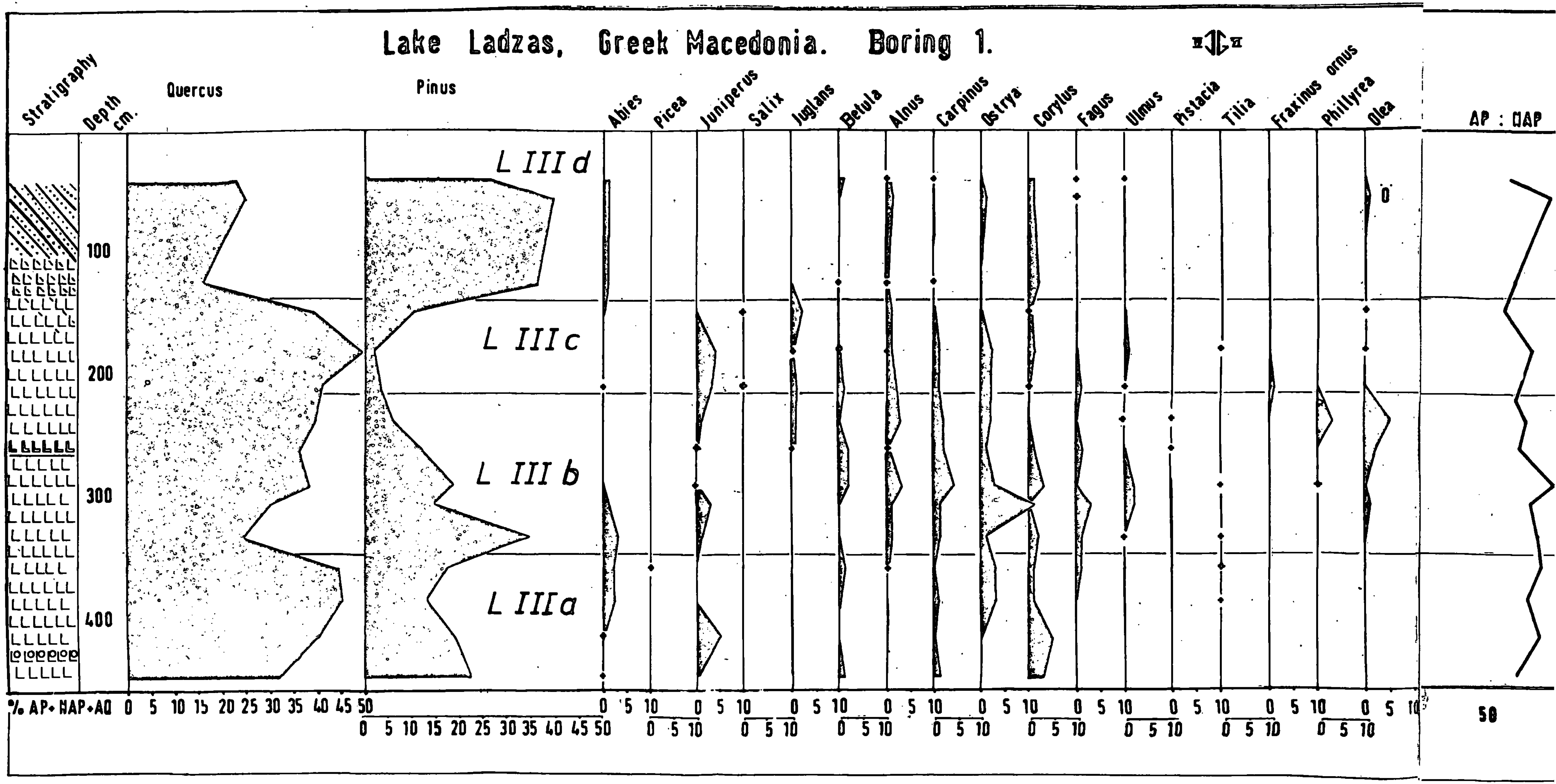
The record of *Juglans* pollen in LIIIc and LIIId could represent some kind of cultivation or encouragement of walnuts, or an abundance of that tree in the forest. Theophrastus, writing in the first millenium B.C. considered that it was not a wild species in Greece at that time, but introduced, and it is considered to have been introduced into other parts of Europe, such as Jugoslavia in Atlantic times and towards the Alps somewhat later (Beug 1961, 1962b). The appearance of Juglans in part of the pollen record that already shows considerable signs of interference suggests that its status at that time may not have been entirely that of a wild tree.

Figure 10

Ladzas and Gravouna Sediment Symbols




Depth cm
100
200
300
400
Other pollen + spores
L Po T
F
F
T F P
Ru
T
P
F
T
F
M
Sparganium
M
Compositae (L)
Centaurea
cy
Compositae (T)
Plantago
Rubiaceae
Ericales
Umbelliferae
S
S
S
Cruciferae
Thalictrum + Ranunculaceae
R
Caryophyllaceae
Cyperaceae
Artemisia
Gramineae
Chenopodiaceae
0 5 10
0 5 10 15 20 25
0 5 10 15 20 25 30
0 5 10 15 20 25 30 35 40 45 50
% AP + NAP + AQ



Lake Ladzas, Greek Macedonia. Boring 1.

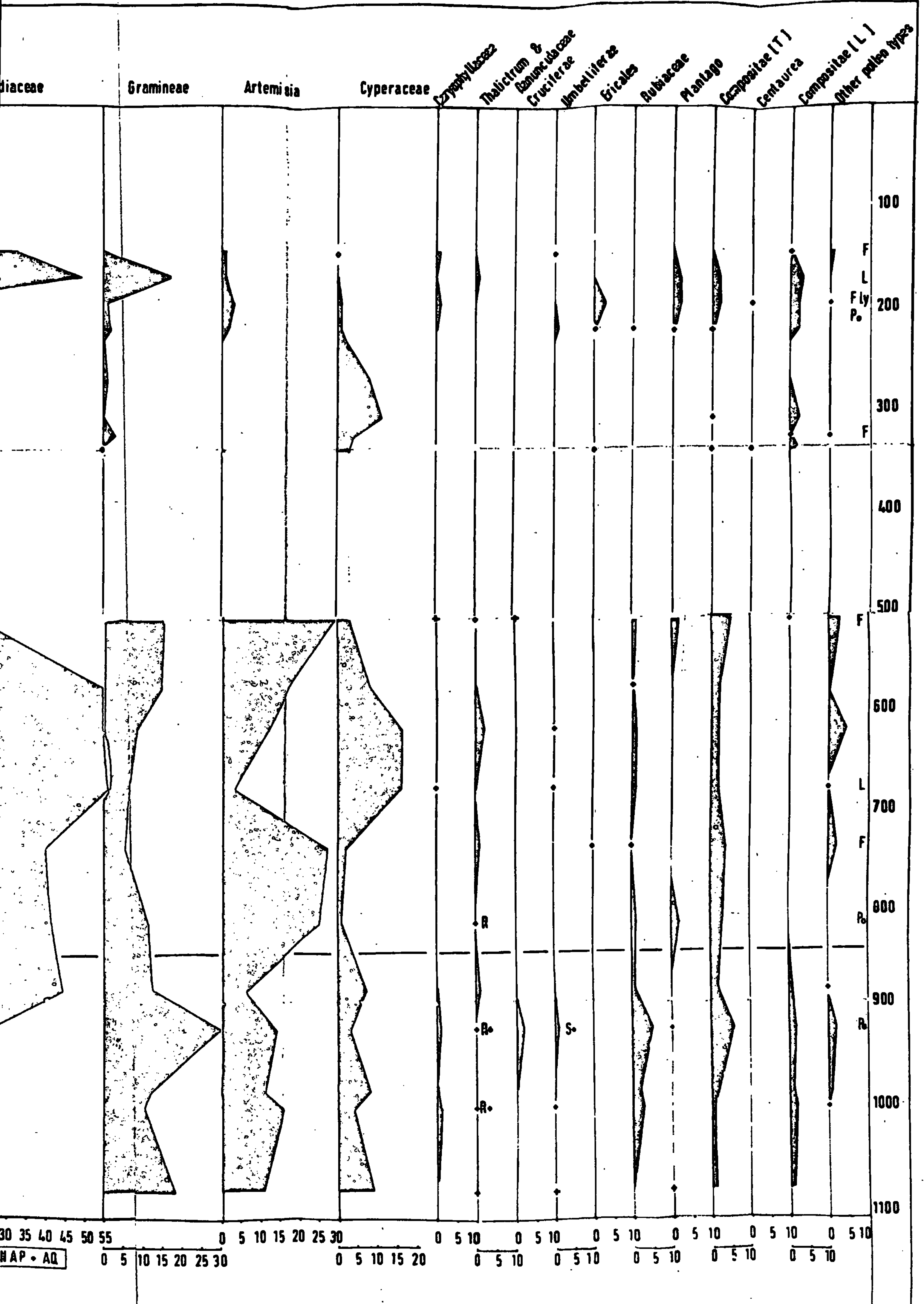
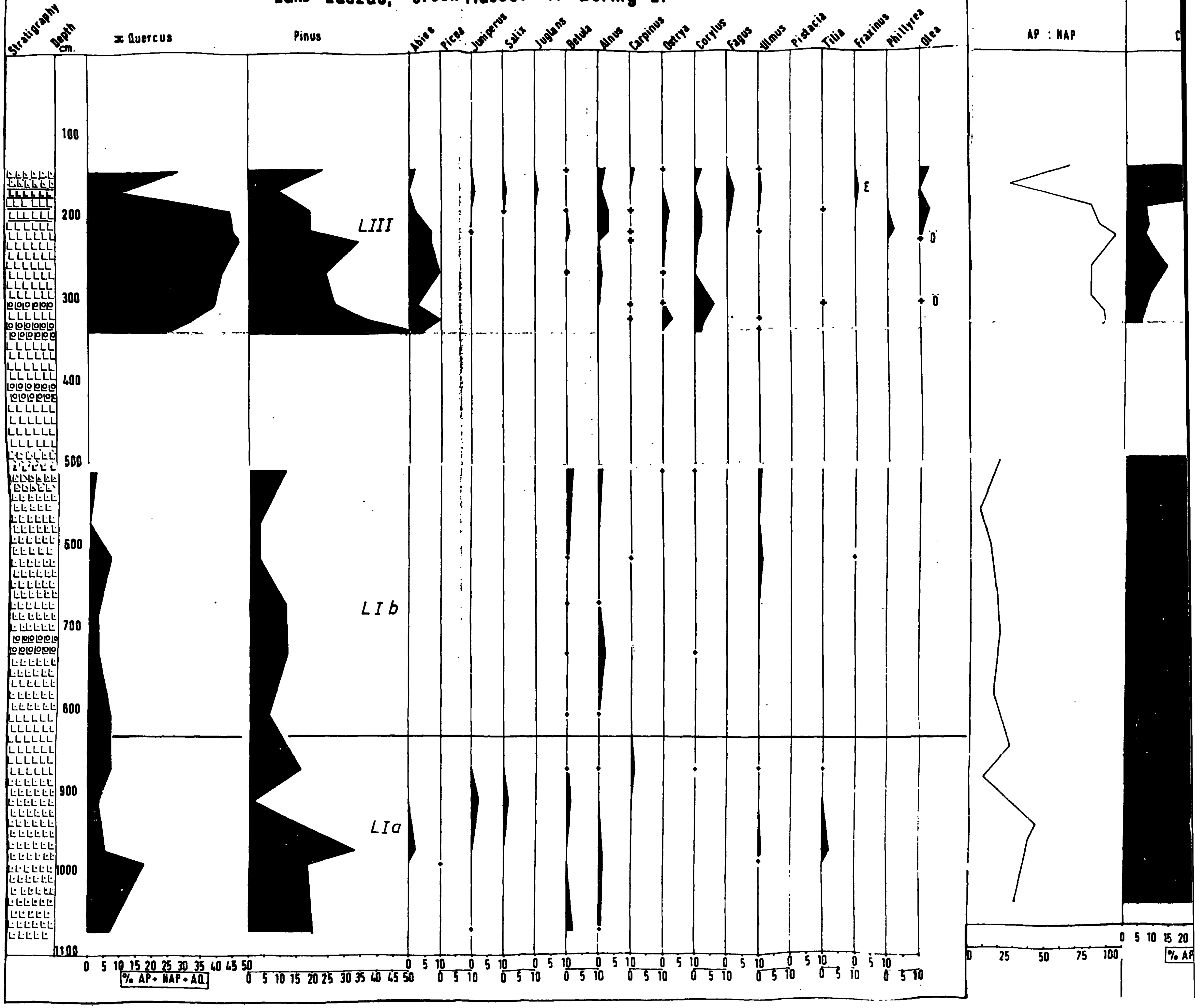

diaceae
Gramineae
Artemisia
Cyperaceae
Caryophyllaceae
Thalictrum & Ranunculaceae
Cruciferae
Umbelliferae
Ericales
Rubiaceae
Plantago
Compositae (T)
Centaurea
Compositae (L)
Other pollen types
100
200
300
400
500
600
700
800
900
1000
1100
F
L
F ly
Po
F
F
L
F
Po
R
R
R
S
R
R
30 35 40 45 50 55
HAP + AQ
0 5 10 15 20 25 30
0 5 10 15 20 25 30
0 5 10 15 20
0 5 10
0 5 10

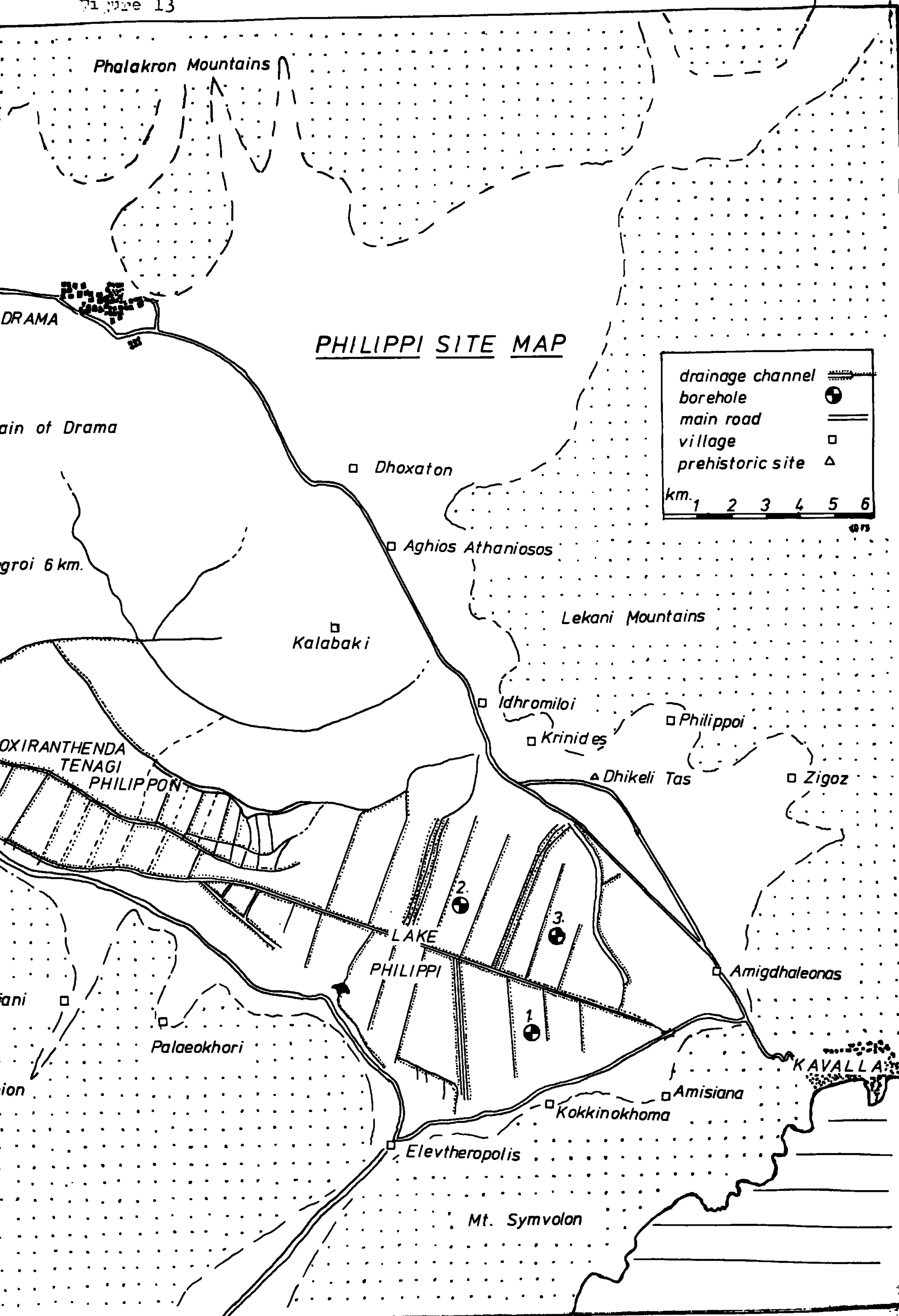
Figure 12

Lake Ladzás, Greek Macedonia. Boring 2.



CHAPTER 8. PHILIPPI

Figure 13


Phalakron Mountains
DRAMA
PHILIPPI SITE MAP
ain of Drama
Dhoxaton
Aghios Athaniosos
grói 6 km.
Lekani Mountains
Kalabaki
Idhromiloi
Krinides
Philippoi
OXIRANTHENDA
TENAGI
PHILIPPON
Dhikeli Tas
Zigoz
2.
3.
LAKE
PHILIPPI
1.
Amigdhaleonas
ani
Palaeokhori
KAVALLA
ion
Amisiana
Kokkinokhoma
Elevtheropolis
Mt. Symvolon
drainage channel
borehole
main road
village
prehistoric site
km.
1
2
3
4
5
6

8.1 THE PHILIPPI REGION

Lake Philippi lies in a depression at the eastern edge of the plain of Drama, enclosed by Mt. Pangeion (1956m) to the west and the Lekani mountains to the north and east, while a lineof hills separates it from the coast. This geomorphological basin has formed over the years by the sinking of the underlying rocks, and it has been fed by several rivers, giving an extensive area of wetland. At Philippi the underground subsidence has taken place at such a rate that peat has been able to accumulate to a depth of 120m (Van der Hammen 1965). A large programme of land improvement was carried out between the wars, resulting in the drainage of the marshy parts of the plain of Drama, the re-routing of several rivers, and the drainage of Philippi. A grid system of channels was cut across the surface of the swamp, and the water was pumpedaway via the new rivers, giving a present day water table about 2m below the ground surface. Today the former swamp is intensively cultivated in fields between the drainage channels. The principle crop is maize, and many poplar trees are also grown for low-grade timber.

The vegetation on the land around the lake has very little about it that could be called natural. There are many trees such as the poplars, and exotics such as robinias, acacias and eucalypts, and thorny shrubs such as the wild pear and *Paliurus*. The soil is red and sandy, and is suitable for many crops such as maize, cotton, tobacco, grain and grapes. There is not much olive cultivation in this part of Greece, and it is mainly concentrated in the Drama and Kavalla *nomoi* according to the map in Ethniki Statistiki (1964). Olives can be grown far inland in some places, such as Elaion which is 45km from the sea and at an altitude of 400m (Naval Intelligence 1945).

On the hill slopes there is a thin pseudomaquis scrub (Turrill 1929). *Quercus coccifera* and *Paliurus spina-Christi* are common, and on the higher slopes there are bushes of *Ostrya carpinifolia* and *Carpinus orientalis*. In the mountains to the north there are pine woods from about 600-1600m. generally found above the altitudinal limit of the deciduous trees (Quezel 1967a). On Mt. Pangeion, to the west
S/ of Philippi, there are relicts of beech woodland, superceded by a conifer zone with pine, fir and juniper. Much of the plain of Drama has a shiblyak vegetation consisting mainly of *Paliurus spina-Christi*. Near the coast there is some maquis vegetation, but it is not very well
l.c developed, and some of it is more like Phrygana.

Cores were taken from Philippi in 1960 by a Dutch firm under contract to the Greek government, and samples from these have been analysed giving two pollen diagrams (Van der Hammen et al 1965, Wijmstra 1969). These cover the top 30 m of peat. Philippi was re-sampled in 1970 for the present work. It is one of the few places in Greece where there are organic sediments which can be radiocarbon dated, thus dating the pollen horizons and providing a chronology for some of the more recent vegetational changes. The other sites sampled in this work were, almost without exception, lacking in carbon containing sediments.

A great effort was made to find the most recently waterlogged sediments near the centre of the lake, so that the peat would be as undisturbed as possible. Philippi was extensively explored in the search for suitable sediments, via tracks across the lake surface following the drainage channels. Many of these tracks have fallen into disuse, and some of the bridges have become unusable. The height of the vegetation adds to the difficulty of travelling there, and makes it hard to fix positions by means of compass readings on landmarks around the lake. There are few points of access on to the lake surface, but one leading from the village of Kokkinochoma on the south side allows one to reach most points to the south of the main east-west drainage channel and the site of the Philippi 1 core. Likewise, a track from the village of Krinides gives access to much of the north part of Philippi and the site of the Philippi 3 core. The lake bed is completely dry, and covered with a black peat soil. In some places this has caught fire, which burnt hollows into the top layer of the peat, smouldering for days. In other places the peat has been ploughed and exposed to the action of micro-organisms which must have caused some loss of material.

8.2 FIELDWORK

The first core, Philippi 1, was taken from the only site which appeared to be suitable for sampling on the south half of the lake, and it was apparently fairly close to the area which was marked as being water covered on the 1915 map. There was a track next to a maize field with a waterfilled drainage channel on the other side.

The sampling pit was dug between the track and the channel, about $2m^2$ at the surface and almost 2m deep. Samples were cut from a clean face exposed in the side of this pit by means of a sharp knife. This proved difficult in the top 65cm because the peat was hard and crumbly, and contaminated by roots and ants. Lower down the peat was still dry and hard, but uncontaminated. Below about 100cm the peat was in good condition and could be cut away in slices as required. The water table was at about 150cm below the ground surface and direct sampling was not

Figure 14. Starting the Philippi 3 sampling pit

possible below this depth. A Russian borer was used to take the deeper samples until at a depth of 200cm it proved impossible to drive it any further into the sediment. Three borings were made so that sufficient material would be recovered for radiocarbon determinations starting as close as possible to the original section from which the samples down to 150cm had been taken.

The Philippi 2 core was taken towards the north-west side of the lake, but there was poor pollen preservation in some of the samples, so this core has not been used.

The Philippi 3 core has produced a good diagram. The site of this core is on the northern side of the main drainage channel, near the centre of the former lake, where there was a patch of open ground which was not cultivated. Old tree trunks suggested that there had not been any ploughing recently if at all, and there was a swampy thicket of trees nearby. A pit was dug for sampling, about 2 metres square and 1.5 metres deep and direct samples cut from the section, and the following day another similar pit was dug immediately next to the first, and a series of cores taken with the borer going down to just under 350cm at which point the combined weight of three people could not make it penetrate any further. The sediments recovered were peats that appeared well preserved and damp apart from the top 40cm which was not sampled, and there were some bands of lake marl with shells, as follows:

PHILIPPI STRATIGRAPHY

PHILIPPI I

Depth (cm)	Sediment
5-30	Peaty topsoil with roots and insects
30-50	Hard crumbly peat
50-65	Peat with worm casts, otherwise intact
65-90	Hard dry peat
90-120	*Phragmites* peat
120-145	*Phragmites* peat with shells in patches
145-180	Muddy *Phragmites* peat with shells
180-200	Muddy *Phragmites* peat, no shells

PHILIPPI STRATIGRAPHY

PHILIPPI 3

Depth (cm)	Sediment
0-20	Peaty topsoil with roots
20-30	Grey peat with roots
30-50	Hard peat
50	Peat with quartz crystals
50-68	Hard peat
68-95	Soft moist peat
95	Peat with silt
95-110	Soft moist peat
110-130	*Phragmites* peat with shells and some wood
130-140	Light coloured material - ? gyttja
140-150	*Phragmites* peat with shells and some wood
150-160	Darker peat with shells
160-225	Darker peat, no shells
225-235	Dark peat with some wood
235-270	Dark peat, no wood
270-290	Dark peat with shells
290-300	Dark peat, no shells
300	Peat with wood
300-347	Dark peat, no shells

8.3 THE POLLEN DIAGRAMS

The peat sediments contained large amounts of well preserved pollen which could be extracted by the ordinary preparation method (see page 12), and counts of about 400 grains per spectrum were made.

The pollen diagrams have been drawn up on the same basis as the Kopais diagram, with the pollen frequencies appearing in taxonomic order (Polunin 1969) with major constituents such as Quercus appearing first. The percentages have all been calculated from the land pollen sum, so that the local pollen rain (i.e. that of the aquatic taxa) does not affect the representation of the more regional pollen rain, such as that from the forests.

8.4 RADIOCARBON DATES

Seven levels have been dated on the Philippi diagrams, and it can be seen that the dated horizons do not coincide with the zonation divisions, for the peat samples had to be sent off to be dated at a stage when only an outline diagram was available. It was thus decided to date samples from fairly even intervals of depth, but then there was the problem that some of the peat from shallow depths had been affected by modern living material such as roots even though undisturbed stratigraphically, so the top parts of the diagrams are deficient in dated horizons.

The expression and discussion of radiocarbon dates requires some clarification in view of the state of flux arising from recent developments in methodology. One of the basic assumptions upon which the radiocarbon dating method depended for its validity was that the amount of ^{14}C isotope in the atmosphere and thence being incorporated into all living matter remained constant. Recently it has become possible to test this hypothesis with material of known date from very long lived trees such as Pinus aristata which grows in the White Mountains in California. Some specimens of this tree have been shown to be as much as 4,600 years old by counting their tree rings, and by a system of matching series of tree rings from different specimens of P.aristata growing in the same region it has been possible to obtain enough wood for dating, going from the present day back to nearly 8,200 years ago. The results of this work (Suess 1967) show that the date of the wood samples and the radiocarbon date obtained agree fairly closely in the time after 1500 B.C. but before that there is a discrepancy whereby the radiocarbon dates are younger than the actual dates. This difference has been quantified in the "Pinus aristata correction curve" so that radiocarbon dates can be corrected back to about 5500 B.C. (Suess 1967, Renfrew 1971a).

This advance in technique does not render a chronology in radiocarbon years (i.e. uncorrected) obsolete where there is a correction scale between 5500 B.C. and the present day, for radiocarbon dates are fully inter-comparable except where perhaps a very great amount of precision is required. It does however permit accurate comparisons to be made between dates obtained by radiocarbon and from other sources, such as historical ones which may have been used for dating archaeological cultures. One such source is the documentation of dynasties and historical events in the early Egyptian kingdoms which provides a chronology linked to astronomical happenings such as eclipses whose dates can be back-calculated in the same way that these can be predicted for the future. The artifacts characteristic of these various dynastic periods can then be dated, not only the objects from Egypt itself but the imports from around the Mediterranean including some from Greece. In this way dates could be given to phases of Greek archaeology covered by this Egyptian chronological system, and before the advent of radiocarbon dating this was almost the only source of dates for the Greek prehistoric period.

The fact that radiocarbon dates and those from historical sources, previously thought to be identical, diverge their most during the critical Bronze Age sequence, has caused some stir among archaeologists concerned with this period (Renfrew 1969, 1970, 1971a, 1971b, MacKie et al 1971). Apart from this there is a need for standardisation in the way in which dates are presented so as to avoid confusion. Up to this point dates have been given in years before present (1950) or b.p. which is usual when dealing with the time of the last glaciation and the Late-glacial.

Archaeological dates are often given in dates B.C. or A.D. and since the results of this work are connected with archaeology it is better to use these dates as well so as to facilitate any comparisons. With the correction of dates there is a need to prevent confusion, and although there have been various systems proposed such as MacKie et al (1971) no single standard appears to have been accepted. The system that seems to find most favour in the archaeological literature is to give uncorrected radiocarbon dates in years b.p. or years b.c. while corrected dates are given in years B.P. or more usually years B.C. (or of course years A.D.). Historical dates and others in "real years" are expressed in the same way as corrected radiocarbon dates. This system is used here.

RADIOCARBON CHRONOLOGY TABLE

PHILIPPI I

Depth(cm)	Lab.No.	Radiocarbon yrs.		Corrected yrs.		Variation (years)
		b.p.	b.c.	b.p.	b.c.	
90	Bln 953	3255	1305	3450	1500	100
90	Bln 953a	3320	1370	3600	1650	100
90	mean	3288	1338	3550	1600	100
90*	Bln 965	3053	-	-	-	100
120	Bln 954	3722	1772	4100	2150	100
145	Bln 955	4193	2243	4870	2920	120
200	SRRC	5031	3081	5750- 6150	3800- 4200	180

PHILIPPI 3

70	SRRC	2867	917	3060	1110	60
140	SRRC	3740	1790	4130	2189	60
345-50	SRRC	7556	5606	-	-	85

NOTES

"Bln" refers to the Berlin Laboratory, "SRRC" to the Scottish Research Reactor Centre, East Kilbride. The determination marked with an asterisk was made with humic material, a check for contamination.

8.5 THE CORRELATION OF THE DIAGRAMS

The Philippi 1 core goes from 5-200cm and the Philippi 3 cores from 40-347cm in each case measured from the present day ground surface and since the stratigraphy overlaps to such a great extent it might be expected that there might be some overlap in the age of the sediments collected, notwithstanding the probable differences in ground level, peat shrinkage, amount of cultivation and other differences between the two sites.

The two diagrams can be related by evidence from the radiocarbon dates, the stratigraphy and the pollen assemblages, but the dates provide the clearest case; 347cm on Philippi 3 is far older than 200cm on Philippi 1 while the date at 140cm on Philippi 3 is similar to that at 145cm on Philippi 1 although there is some discrepancy. There is a better fit between the date at 140cm on Philippi 3 and 120cm on Philippi 1 where the difference between the two dates is less than the standard deviation and they can therefore be regarded as effectively the same date.

The meagre information derived from this comparison suggests that similar depth horizons may have a similar age on each diagram with a difference of perhaps 20cm. Further information comes when the sedimentation rate between dated horizons is calculated, as for example in the case of Philippi 3 where there is a date of 3060 B.P. at 70cm and another of 4130 B.P. at 140cm, both with a variation of ± 60 years. So 70cm sediment represents some 1070 years ± 60 deposition, or 15 years per cm assuming a fairly even rate of deposition and compaction. The sedimentation rates between the other dated horizons are set out as follows:

SEDIMENTATION RATE TABLE

Core	Depth Range	Date Range B.P. (corrected)	Sedimentation rate (years/cm)
Philippi 3	70-140cm	3060-4130	15
Philippi 3	140-350cm	4130-7560	17
Philippi 1	90-120cm	3550-4100	18
Philippi 1	120-145cm	4100-4870	31
Philippi 1	145-200cm	4870-5750	35
		or: 4870-6150	51

The last example has an ambiguous date range due to the steepness of the correction curve.

Using the sedimentation rate table, approximations can be made of the age of other horizons on the diagrams which are not directly dated, from which it can be seen that the dates for the 70cm level on both diagrams are similar, that level on Philippi 1 coming out at 3190 years compared with the direct date on Philippi 3 of 3060± 60 years. On the same basis the 200cm level dated to 5750 or 6150 ± on Philippi 1 appears to be younger on Philippi 3 at 5215 ± 60. From this dating evidence it appears that horizons of similar sediments at similar depths have very similar dates in the top of the succession but there is a discrepancy that increases with depth, with the Philippi 1 dates coming out older.

The stratigraphic evidence confirms this relation between the two diagrams in that shell bands at 120-180cm on Philippi 1 can be recognised in Philippi 3 but at a somewhat shallower depth, 110-160cm.

There is more precise confirmation from the examination of pollen assemblage changes. The horizon with an increase in Fagus pollen at 150cm in Philippi 3 has a parallel at 130cm in Philippi 1, and a decrease in Ulmus and Tilia values at 130cm in Philippi 3 may correspond to a decrease in Tilia at 120cm in Philippi 1. This comparison is not unequivocal, for there is an increase in Ericales pollen at 130cm in both diagrams, but it does appear that the range 130-150cm on Philippi 3 is similar to 120-130cm on Philippi 1.

The next point of comparison is the peak in Olea pollen at 112cm on Philippi 3 and at 80-110cm on Philippi 1 which indicates near uniformity of depth for pollen horizons at this point, and the Olea pollen peaks at 40-50cm on Philippi 3 and at 40-60cm on Philippi 3 with peaks in Pinus and Gramineae pollen seem to indicate close correspondence.

This very close relationship between the two diagrams suggests that the same zonation scheme can be applied to both where they overlap between about 40 and 200cm depth.

8.6 ZONATION OF THE DIAGRAMS

The most obvious features of these diagrams is they have large tree pollen values, mainly Quercus at around 85% (AP + NAP), with lesser amounts of Pinus, Alnus, Carpinus and Ostrya type. Herbaceous pollen is present in small amounts, mainly Gramineae and Ericales. Changes in pollen assemblage are subtle and the basis for the discussion of these diagrams are small pollen assemblage changes such as those mentioned in connection with the correlation. The diagrams have Zone III type assemblages with tree pollen being mainly from forest trees but with small amounts from light woodland taxa such as Ostrya type, and possible cultivars like Olea. The small pollen assemblage changes form the basis of the sub-zonation scheme in which both diagrams are discussed together as befits their very close similarity.

SUMMARY OF THE ZONATION

Sub Zone	Depth cm.	Diagram	Main Characteristics
Sub-zone p	35-5	Ph 1	Increase in Pinus and weedy pollen types
Sub-zone o	62-40	Ph 3	Olea
	57-35	Ph 1	
Sub-zone n	87-62	Ph 3	Increase in weedy pollen types, Cyperaceae
	77-57	Ph 1	
Sub-zone m	121-87	Ph 3	Olea; reduction in Tilia and Ulmus
	107-77	Ph 1	
Sub-zone l	155-121	Ph 3	Fagus, Ericales
	137-107	Ph 1	
Sub-zone k	347-155	Ph 3	Maximum tree pollen
	200-137	Ph 1	

Sub-zone k (347-155cm) Philippi 3
(200-137cm) Philippi 1

There is a very large amount of oak pollen with a large number of small records from other trees amounting to an average of 82% (Philippi 3) and 84% (Philippi 1). There is a steady record from Gramineae, and small records from Ericales, Artemisia, Chenopodiaceae and Plantago.

Sub-zone l (155-121cm) Philippi 3
(137-107cm) Philippi 1

This is defined by the appearance of Fagus and the doubling of the percentage of Ericales pollen. It is interesting to note a slight difference between the two diagrams here, for there is more Fagus pollen

(4% instead of 2%) and less Ericales pollen (4% instead of 6%) in the Philippi 3 diagram, which may point to uneven pollen dispersal. There is a notable increase in Cyperaceae pollen at this point.

Sub-zone m (121-87cm) Philippi 3
(107-77cm) Philippi 1

The values of *Quercus* pollen which were more than 60% in sub-zone a have now declined to 49% in a (Philippi 1). *Olea* pollen appears at values of 2.3% AP (85cm) and 1.1% AP(105cm) on Philippi 1 and 1.8% AP (112cm) on Philippi 3. There is also some increase in *Artemisia*, and the Philippi 1 diagram has an increase in *Plantago*. *Tilia* and *Ulmus* decrease, the former almost disappearing from both diagrams, the latter from Philippi 3.

Sub-zone n (87-62cm) Philippi 3
(77-57cm) Philippi 1

The distinctive feature of this sub-assemblage is the absence of the *Olea* pollen records, and some increase in *Pinus*, Chenopodiaceae, *Artemisia* and Cyperaceae.

Sub-zone o (62-40cm) Philippi 3
(57-35cm) Philippi 1

Here there are significant amounts of *Olea* pollen, at values of 4.2% AP (40cm) 5.0 AP (50cm) and 4.3% (55cm) in Philippi 1. They are lower in Philippi 3, 1.3% AP (40cm) and 2.3% AP (60cm). There are increases in pollen records from Gramineae, Cruciferae and Rubiaceae.

Sub-zone p (35-5cm) Philippi 1

There is an increase in *Pinus* from 5% to 14% and increases in several herbaceous types such as Compositae, *Sarcopoterium*, Chenopodiaceae etc.

8.7 THE INTERPRETATION OF THE DIAGRAMS

Sub-zone k represents a period of time when the Philippi region was thickly afforested, with a cover mainly of oak, but with some temperate forest elements such as Carpinus, Ulmus and Tilia. There is little sign of vegetation of a Mediterranean nature with evergreen oak, Phillyrea, Fraxinus ornus and Ostrya as they are present in only small amounts in the pollen record. They could represent limited areas of more open woodland, and the Ericales pollen record confirms this. There may well have been some places where the forest could not establish itself, for example on the steep slopes of the mountains rising to the immediate north of Philippi. There may also have been a certain amount of human activity which would also have the effect of promoting open land.

Sub-zone l represents much the same kind of vegetational pattern, with the addition of the Fagus record which could be due to the local development of montane woodland of the kind that still survives in Mt. Pangeion and the other mountains round the lake site. The increased Ericales record and the slight decline in the proportion of Quercus pollen suggests some more openings in the forests, and the development of true Mediterranean vegetation is attested by the appearance of Pistacia, a characteristic maquis plant. The very small record may be more significant than its presence here suggests, for Pistacia has been found to by under-represented in pollen records (Horowitz 1971), and the place where this grew seems likely to have been the belt of land between Philippi and the coast where there is a good maquis today, probably due to some modification of the local climate by the sea. The increase in Cyperaceae pollen would be due to some change in the lake environment, as would the presence of shells in the sediment at this point. Perhaps forest clearance caused erosion of soils from the surrounding land into the lake, giving rise to swampy conditions suitable for the spread of sedge communities, as was suggested for the cause of similar features of the Kopais diagram (p. 72).

Sub-zone m shows some signs of further forest clearance in decreased oak pollen values. The reduction in the values of Tilia and Ulmus which is very clear in the Philippi 3 diagram suggests the selective felling of these trees which may have grown in stands in the forest to give a mosaic of different types of woodland amongst the oak wood (Pennington 1969). The presence of Olea in the record is smaller than the 4-8% AP which Beug (1962a) found in the vicinity of present day olive groves in Mallorca, but there is a great difference between the vegetation of Mallorca today and that suggested for the Philippi region at this stage. Mallorca is almost devoid of trees while Philippi must have had thick forests, and in the latter case the statement by Wright et al (1967) is probably very valid, that "Oak pollen in great quantities travels far from its source blanketing unwooded areas with a regional pollen rain that obscures the less abundant pollen production from local sources". It therefore seems likely that the Olea pollen record may be important despite its low percentage, being diluted by the large amounts of oak pollen from the forests, and might still represent olive cultivation rather than oleaster.

Sub-zone n is not very clearly defined, but there are signs of further reduction in forest, and its replacement by open vegetation. The increase in pine pollen could represent some maquis with mediterranean pines rather than the montane pine woodland as there are other signs of open vegetation here, an increase in Gramineae pollen for example, and in Philippi 1 the presence of *Centaurea* pollen hints at the exist~~a~~ence of open land in the form of fields, for *C.solstitialis* is a common cornfield weed at the present time.

Sub-zone o has more *Olea* pollen than was noted in the case of sub-zone m and this is a much more certain indication of olive cultivation which could add confirmation to the suggestion that the *Olea* pollen from sub-zone m also represents olives rather than the wild oleaster. There are still increased signs of open and perhaps arable land in the increases in pollen records from taxa which are common as weeds today, like *Chenopodiaceae*, *Compositae* and Cruciferae.

Sub-zone p is only seen on the Philippi 1 diagram, and has further signs of the spread of open land at the expense of forest in the increased values of pollen from *Pinus* and "weedy" herbaceous types. Even though there are abundant signs of forest reduction the large amount of oak pollen still present shows that there must still have been considerable forest in the vicinity, by no means all cleared, and evidently the final and complete removal of woodland from this part of Greece must have taken place at a time after that represented by the span of this diagram.

The description and interpretation of two pollen diagrams from the same site not only makes the results fairly well corroberated, but permits interpretation of the vegetation in terms of the places in which it grew as well. The main vegetational differences today are found between the north side of the lake where the land rises sharply with the foot of a mountain range, covered with vegetation of a Balkan nature, and the south side where there is a low range of hills covered with an eu-Mediterranean scrub which goes from the hills to the sea. The Philippi 1 core was taken from fairly near this south side and might therefore be expected to show a bias to this particular vegetation, in the resultant pollen diagram, and likewise the Philippi 3 diagram from a core from the north side of the lake could show more of the mountain vegetation. A close examination of the two diagrams reveals that there are some differences in pollen percentages represented. Fagus pollen for example is more abundant on Philippi 3, also Corylus and Ostrya. The beech woods would certainly be expected to the north of the lake, up in the mountains, but if Corylus and Ostrya type are considered as representing a thinned woodland following felling of forest trees, a kind of coppice, they might be expected to be found all round the lake where there had been forest. It has already been suggested that they could well have thrived on the rocky hillsides on the north side, and perhaps such suitable habitats were not available to the south. The pollen of taxa considered to belong to open land and typical Mediterranean vegetation appear to be concentrated in the Philippi 1 diagram, Ericales, Pinus to a slight extent, weedy taxa and Olea. This is just as might be expected and it would appear that the south side of Philippi was more affected by human activities in the time covered by the diagram, and that olive cultivation was mainly or exclusively carried out there.

8.8 THE DATING OF THE POLLEN ASSEMBLAGE ZONES

The earliest part of the combined Philippi pair of diagrams is the base of Philippi 3 which is directly dated at 5610 b.c. ± 85, establishing that they begin well into the Post-glacial period. Apart from this date and that at the base of the Philippi 1 succession none of the pollen assemblage boundaries is directly dated, and the dates used in the discussion here are all derived from dated horizons by means of the sedimentation rate calculation (p. 107). The first such boundary is at k/l and its age can be estimated by extrapolating dates from the nearest directly dated horizons on both diagrams and comparing the estimates obtained in this way. On the Philippi 3 diagram the nearest dated level to k/l at 155cm is at 140cm (2180 B.C. ± 60), and with a sedimentation rate for this part of the diagram of 16 years per cm deposit the difference in ages should be 15 (the depth difference) times 16 (the sedimentation rate) or 240 years, resulting in a date of 2420 B.C. ± 60. This date can be confirmed by calculating the age of the k/l horizon on the Philippi 1 diagram as well, and likewise all the other horizons can be dated by extrapolation as follows:

EXTRAPOLATED RADIOCARBON DATES

Horizon	Depth	Diagram	Dated Horizon		Sedimentation	Date ±150 years	
	cm.		cm.	B.P.	Rate Years/cm.	B.P.	B.C.
k/l	155	3	140	4130	17	4370	
k/l	137	1	120	4100	31	4400	2500
k/l	137	1	145	4870	31	4622	
l/m	121	3	140	4130	16	3826	
l/m	107	1	120	4100	18	3866	1900
l/m	107	1	90	3550	18	3856	
m/n	87	3	70	3060	15	3315	
m/n	77	1	90	3550	18	3316	1360
n/o	62	3	70	3060	15	2940	1000
n/o	57	1	90	3550	18	2956	
o/p	35	3	70	3060	15	2535	550
o/p	40	1	90	3550	18	2650	

DATES CONNECTED WITH THE HISTORY OF GREECE

A.D.	
1827	Battle of Navarino; the end of Turkish rule in Greece
1485	Fall of Constantinople to the Turks
1204	Fall of Constantinople to the Crusaders
1200	Rise of Venetian power
1000	Rise of Ottoman Turkish power
630-680	Zenith of Arab power
400	Germanic raids through Greece
324	Byzantium enlarged by the Emperor
263	Gothic raids through Greece
B.C. (actual years)	
30	Romanisation of Greece
30-130	Hellenistic times; Macedonian rule
130-800	Classical times
800-1200	Dark Age
1240	Sack of Troy VII
1200	Zenith of Mycenean power
2100-1600	Middle Bronze Age
3000-2100	Early Bronze Ages 1-111
4800-3000	Final Neolithic : Chelcolithic
5500-4800	Middle Neolithic

Figure 15

ARCHAEOLOGICAL CORRELATION TABLE

VEGETATIONAL RECONSTRUCTION	POLLEN ZONE	Sitagroi phases	DATE B.C.	CORRELATION
			0	
Mixed oak forest, some thinner woodland and open land.	p			Classical Period
			550	
Mixed oak forest etc. Olive cultivation	o			Dark Age
			1000	
Mixed oak forest	n			
			1350	Mycenean Period
Mixed oak forest, thinner woodland. Olive cultivation, elm and lime decline	m			Middle Bronze Age
			1900	
Lowland mixed oak forest, thinner woodland and some maquis. Montain forest with beech and fir.	l	Vb		Early Bronze III
		Va	2500	Early Bronze II
Mixed oak forest	k			Early Bronze I
		IV		Final Neolithic
			4000	
Mixed oak forest	k	III		Middle Neolithic
		II		
		I	5500	

(after Renfrew 1971)

8.9 CHRONOLOGY AND ARCHAEOLOGICAL CORRELATION

Sub-zone k (5600-2500 B.C.) seems to cover the Middle Neolithic, Final Neolithic and Early Bronze Age I, but there is very little sign of vegetational change or anything that could be attributed to human influence in the region. Some of the earliest evidence of domesticated crops and agriculture on an organised basis in Greece comes from sites belonging to this period, like Nea Nikomedeia in western Macedonia, dated to around 6200 b.c. (Rodden and Rodden 1964) and Argissa in Thessaly at 6000-5000b.c. (Hopf 1962) from which remains of einkorn, emmer, barley, lentils and peas were extracted, a convincing demonstration of some degree of arable farming. The part of the pollen diagrams that corresponds to this period has little indication of human interference with the vegetation, since the evidence from cereal type pollen is liable to be ambiguous and the signs of forest clearance in the Mediterranean region are not as well known as those in northern Europe, so that the increased pollen record from shrubby tree taxa could either be interpreted as vegetation growing where full forest could not grow, as on steep slopes, or as the vegetational response to forest clearance with replacement by thinner woodland.

One archaeological site of especial interest and relevance in the consideration of these results is Sitagroi, a mainly Neolithic tell site some 30km from Philippi which has been excavated in great detail providing a wealth of closely dated information on cultural change in this period (Renfrew 1971b, and in preparation). Philippi has proved to be the nearest place to this tell from which a pollen core has been successful, and although the distance between the two sites might be too great for the effects of occupation there to show in the Philippi diagrams, there might have been a pattern of similar tell occupation in the region which would.

One nearby site is Dhikilitas, right on the edge of Philippi.

The upper part of Sub-zone k is dated to a similar period to the first three phases of occupation deduced from Sitagroi (4700-3200 b.c.) representative of the Later Neolithic (Renfrew 1971b) and also Dhikilitas (Renfrew 1970), but this evidence of human activity in the region seems to have no counterpart in the vegetational record from Philippi in the form of signs of forest reduction. Although a certain proportion of the plant and animal remains from these phases at Sitagroi were domesticates, there was evidence that hunting and gathering still contributed an important part of the food supply, so perhaps there was no need for the wasteful "Landnam" (Iversen 1941) type of economy known from northern Europe where fresh areas of forest were cleared every few years when the old fields, made by earlier cutting and burning of forest, became exhausted of nutrients and weed infested, necessitating the eventual movement of the settlement to a fresh area for exploitation. Perhaps the availability of wild food plants saved pressure on the forest from being cleared for agriculture, which in turn allowed the long term settlement of the tell for thousands of years.

In the final phases of occupation at Sitagroi (Va and Vb, 2700-2200 B.C.) there is evidence of fishing, for bones were found which were identified as those of a species of tench that is found in muddy waters (Renfrew, pers. comm.) which is interesting in view of the change in sediment type and increase in Cyperaceae pollen noted in the corresponding part of the diagrams, suggesting as the result of muddier lake conditions due to inwash of forest soil following clearance. If the details elucidated from the Sitagroi excavations apply to sites of a similar type in the whole region around Philippi the archaeological evidence of the fish bones and the pollen record can be linked together as showing similar facets of land disturbance.

The k/l horizon at about 2500 B.C. corresponds to the last two phases at Sitagroi as mentioned above, and in a wider regional context at the end of Early Helladic II where there is a point of archaeological discontinuity (Clark & Piggott 1965).

This picture of an important archaeological horizon corresponding to a noticeable change in the pollen diagram which can be at least partly connected with human interference with the natural vegetation is paralleled by the results of a pollen diagram from central Turkey, (Beug 1967b) who noted a number of changes taking place at about 2500 B.C. such as an increase in Ericales and a decrease in Fagus and Abies. He considered that these changes could either be the result of a warmer and drier climate or to human activities and supported the latter suggestion by citing the archaeological evidence for invasion of Indo-European peoples at that time into the region. This could be true of Greece as well, for there is also evidence of a great archaeological change from the tell cultures to the early Bronze Age ones that replaced them such as the Minyans. It is certainly tempting to suggest that the arrival of more advanced techniques of metal working, and more organisation of life as evidenced by the cities they made like Orchomenos, near Kopais (Taylour 1964), implies that the agricultural expertise and extent was similarly enhanced, and that more rapid forest clearance would have resulted. A culture with specialist skills such as metalworking needs to be able to provide enough food from a proportion of the populace working on the land in order to free the artisans from this necessity so that the necessary skills could be acquired and developed. In the tell cultures this division is not evident, and the economy was at least partly dependent upon hunting and gathering of wild foodstuffs, such as acorns, while the more advanced economies are almost fully dependent upon staple crops the cultivation of which will provide a more certain yield than that from wild plants.

The next notable change is the l/m horizon marked by the beginning of evidence of olive cultivation. As in the case of the k/l horizon, a date for this change can be extrapolated from other dated horizons on the diagrams, although it is worth remembering that the radiocarbon dates themselves are only representations of a degree of probability that the age of the dated material lies within the limits of the standard error cited. Since there is this latitude in the original dates, it will be transmitted to the calculated sedimentation rate with additional error if the rate has not been constant as assumed. Thus extrapolated dates need to be interpreted with caution even when they are, as is the case here, checked by calculation from more than one dated horizon.

The l/m horizon has had its date estimated from an older and a younger dated horizon on the Philippi 1 diagram, and from an older dated horizon on the Philippi 3 diagram, and the derived dates are all within less than the standard error of one another suggesting that they are likely to be valid, giving in round figures a date of 1900 B.C. ± 150 years. This associates the first phase of olive cultivation with the Aegean Middle Bronze Age which began somewhat before 2000 B.C. (Renfrew 1971b). The Middle Bronze Age is not known for records of olive cultivation from archaeological contexts on the Greek mainland, but this lack of evidence may be occasioned by not having been actively sought, for olive stones have been recovered from sites in Crete of this age (Renfrew 1973).

The end of this phase, where signs of olive cultivation cease, the m/n horizon has been dated by extrapolation on each diagram giving a result so closely matched as to be coincidental, of 1365 B.C. ± 150. This probably represents a Mycenean period date since archaeological records suggest that the Middle Bronze Age gave way to the Mycenean around 1400 B.C. (Renfrew 1971a). The chronological association is tenuous since the Mycenean culture arose, reached its zenith and then decayed in the space of a few hundred years, and it is near the limit of the radiocarbon dating method to resolve such a short episode. The derived dates are subject to even more variation such as this one which could at one end of its range represent a time a century earlier than the Mycenean period, or at the other extreme a half century before the most reasonable date for the end of the Mycenean civilisation at 1150 B.C. (Snodgrass 1971). Suffice it to say that Sub-zone m seems to represent in archaeological terms part of the Middle Bronze Age and possibly some of the Mycenean period as well, so that the vegetational changes detectable in pollen diagrams do not here seem to be exactly paralleled by archaeological events.

Sub-zone n. is already dated at its beginning to a time possibly in the Mycenean period, ending at the n/o horizon which is estimated at around 1000 B.C. by calculation from both diagrams. Here there is no evidence of olive cultivation at a time associated with the abrupt disintegration of a civilisation, and the beginning of the Greek Dark Age. Sub-zone o goes from about 1000 B.C. to some date around 550 B.C. with its small amount of evidence for olive cultivation during this apparently Late Dark Age and Early Classical period. The top of the Philippi 1 diagram may represent a date some 500 years after this although the extrapolation method of obtaining dates is probably inaccurate at this point.

The chronological interpretation of the diagram shows that some pollen changes in the diagram, notably the k/l horizon can be tentatively linked with known archaeological changes, in this case the end of Early Helladic II.

The pattern of evidence for olive cultivation is two distinct peaks in the Philippi diagrams (which may correspond to the two *Olea* pollen peaks noted in the Kopais diagram), and the Philippi dating evidence suggests that the earlier one could be about 1900-1360 B.C. and the latter about 1000-500 B.C. with a margin of some 150 years for standard error.

This is at variance with the conclusions drawn by Wright (1968b). The data used for this ~~is~~ are published in Wright (1972) with the addition of further results. In the later article Wright presents two overlapping pollen diagrams from the Osmanaga lagoon in the southern Peloponnese together with radiocarbon dates, and interprets a pollen diagram from Voulkaria in western Greece although the diagram itself does not appear in the text. He places the maximum *Olea* pollen peak on the Osmanaga diagrams at 1100-700 b.c. and states that a rise of *Olea* pollen on the Voulkaria diagram is later than 1270 b.c. and that on this basis the major period of olive cultivation in these two parts of Greece appears to be clearly Dark Age rather than Mycenean in date.

Examination of the pollen diagrams from Osmanaga (Wright 1972) shows that there is scope for re-interpretation of much of this data. In the first instance the diagrams are not very detailed, for pollen spectra are at intervals of 20cm. (Compared with the 10cm interval on Philippi 2 and 5cm interval on Philippi 1) and the pollen zones are not at all clear from the diagram. Furthermore only six pollen curves are plotted, albeit the most important ones. The original interpretation of the diagram stretches the available data beyond its limits, for the peak in *Olea* pollen dated to the Dark Age is confined to one pollen spectrum in each diagram, and in one diagram there is a gap immediately below this horizon due to lack of pollen.

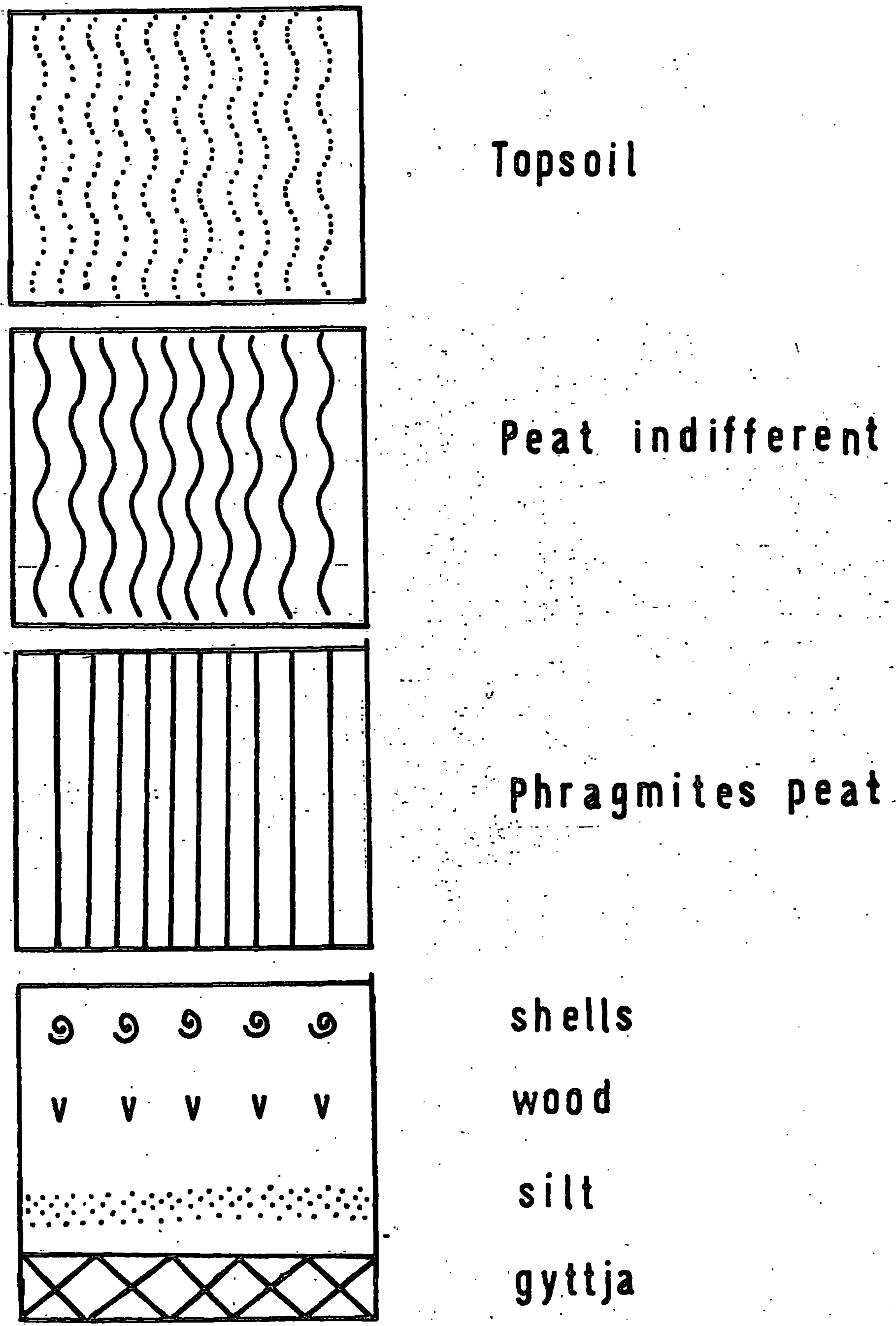
Another point is the question of the accuracy of the interpretation of the peaks in Olea pollen as representing times when there were more olives growing. The peaks in Olea pollen appear to correspond to dips in the oak pollen curve, and it may be that clearance of oak woodland leading to a reduction in the oak pollen rain is affecting the changes in Olea pollen representation more than the changes in the pattern of olive cultivation. To quote Wright and others (1967) again: "oak pollen in great quantities travels far from its source blanketing unwooded areas with a regional pollen rain that obscures the less abundant pollen production from local sources". Olives have good pollen production and dispersal as shown by modern rain studies (Wright 1972) but the oak pollen might well be obscuring Olea pollen changes by its sheer abundance.

The radiocarbon dates for the different pollen zones are also in need of re-interpretation, for current chronologies of the Mycenean and Dark Age periods are based on historical records and are therefore in actual years. The radiocarbon dates from Wright's pollen diagrams falling within this critical period all turn out to be older when they are corrected on the Pinus aristata scale (Suess 1967). The dates at horizons associated with increase in Olea/decrease in Quercus such as 1270 b.c. and 1190 b.c. ± 120 then become much more Mycenean at 1500 B.C. and 1350 B.C. ± 120.

In conclusion it can be said that the evidence from Wright's work does not seem to contradict that from Philippi even though the former needs to be considerably re-interpreted from the original data. There is evidence of olive growing from perhaps the Middle Bronze Age, and from about Mycenean times there appears to have been more land given over to olives, or more woodland clearance, and the truth is probably a combination of both these factors. There is also increasing evidence of the spread of maquis type vegetation which is much more clear than in the pollen diagrams from northern Greece.

Figure 16

Philippi Sediment Symbols



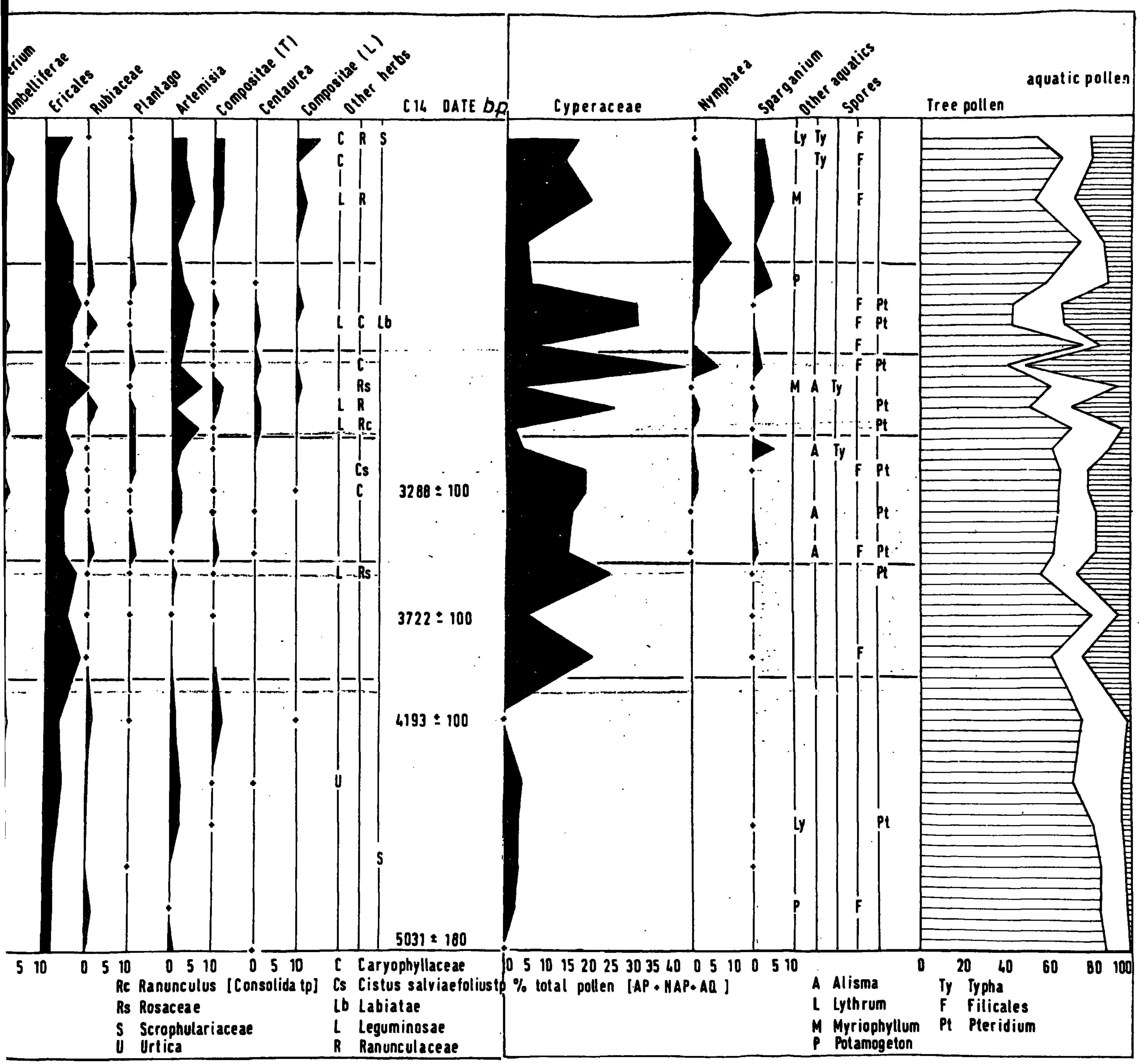
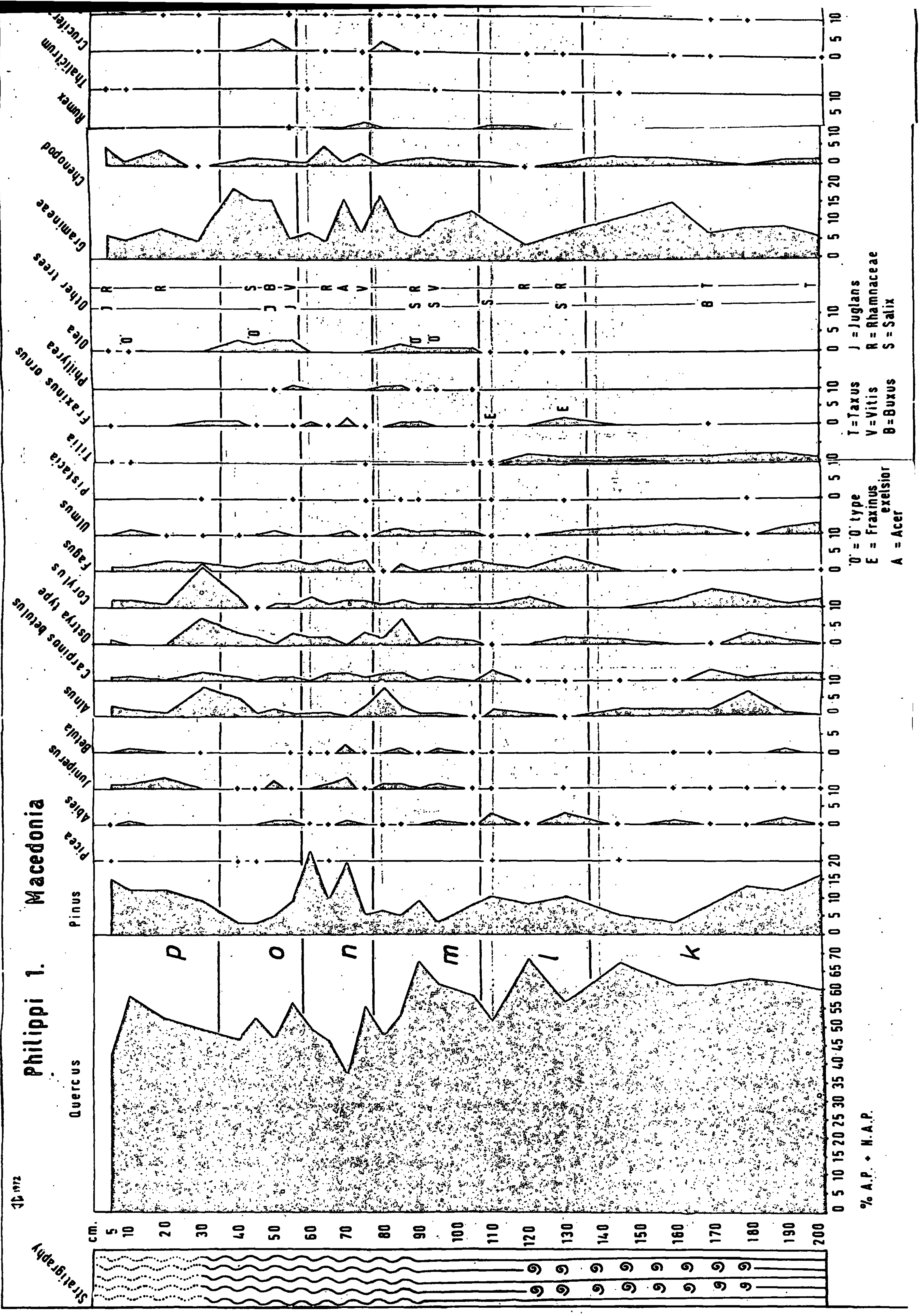
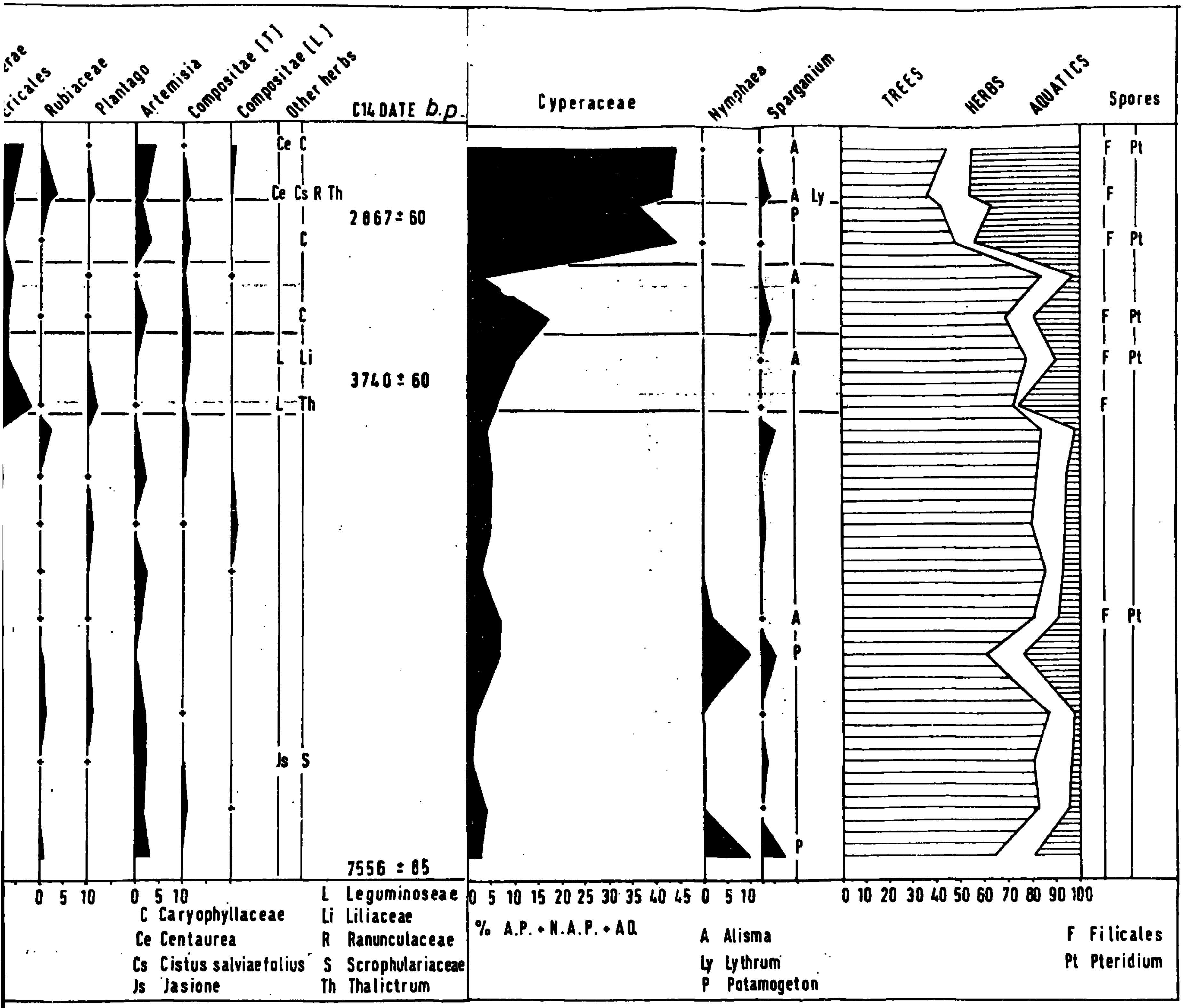

erium
Umbelliferae
Ericales
Rubiaceae
Plantago
Artemisia
Compositae (T)
Centaurea
Compositae (L)
Other herbs
C14 DATE bp
Cyperaceae
Nymphaea
Sparganium
Other aquatics
Spores
Tree pollen
aquatic pollen
3288 ± 100
3722 ± 100
4193 ± 100
5031 ± 180
5 10
0 5 10
0 5 10
0 5 10
0 5 10
0 5 10 15 20 25 30 35 40
0 5 10
0 5 10
0 20 40 60 80 100
% total pollen [AP + NAP + AQ]
Rc Ranunculus [Consolida tp]
Rs Rosaceae
S Scrophulariaceae
U Urtica
C Caryophyllaceae
Cs Cistus salviaefoliustp
Lb Labiatae
L Leguminosae
R Ranunculaceae
A Alisma
L Lythrum
M Myriophyllum
P Potamogeton
Ty Typha
F Filicales
Pt Pteridium

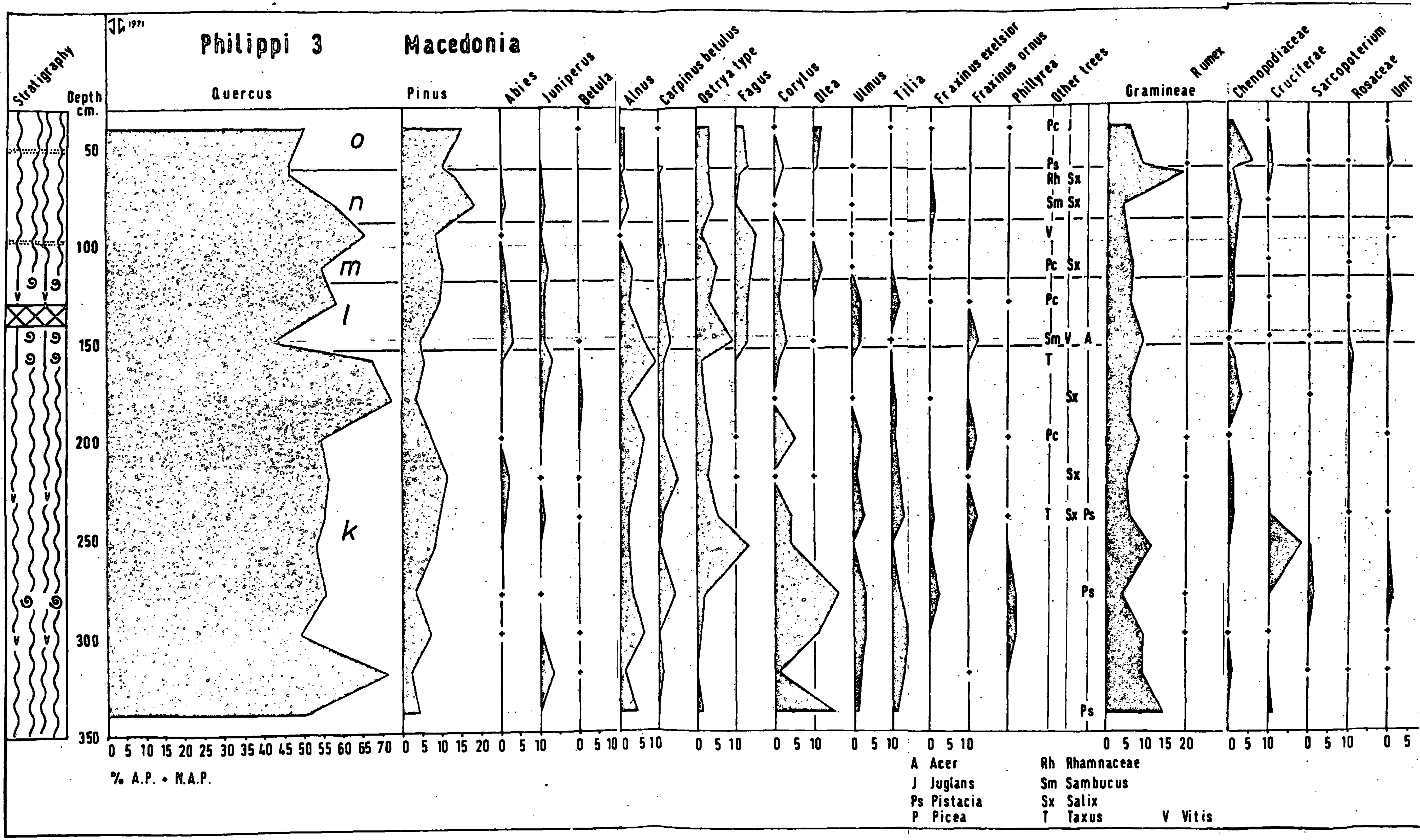
Figure 17


JC 1972
Philippi 1. Macedonia
Stratigraphy
cm.
5
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
Quercus
Pinus
Picea
Abies
Juniperus
Betula
Alnus
Carpinus betulus
Ostrya type
Corylus
Fagus
Ulmus
Pistacia
Tilia
Fraxinus ornus
Phillyrea
Olea
Other trees
Gramineae
Chenopod
Rumex
Thalictrum
Cruciferae
p
o
n
m
l
k
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
% A.P. + N.A.P.
'O' = 'O' type
E = Fraxinus excelsior
A = Acer
T = Taxus
V = Vitis
B = Buxus
J = Juglans
R = Rhamnaceae
S = Salix



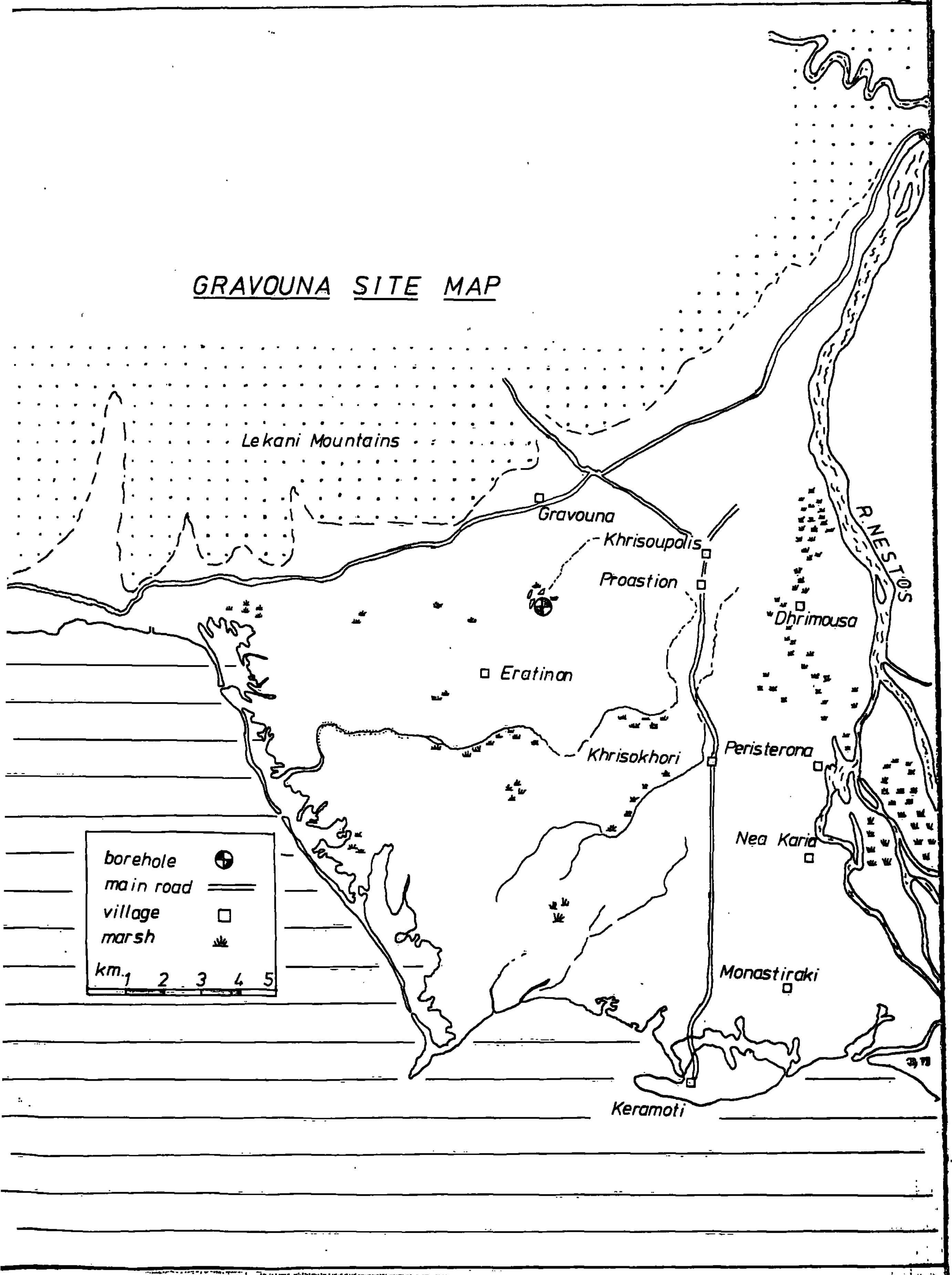
…rae
…ricales
Rubiaceae
Plantago
Artemisia
Compositae [T]
Compositae [L]
Other herbs
C14 DATE b.p.
Cyperaceae
Nymphaea
Sparganium
TREES
HERBS
AQUATICS
Spores
Ce C
Ce Cs R Th
C
C
L Li
L Th
Js S
2867 ± 60
3740 ± 60
7556 ± 85
A
A Ly
P
A
A
A
P
P
F Pt
F
F Pt
F Pt
F Pt
F
F Pt
0 5 10
0 5 10
0 5 10 15 20 25 30 35 40 45
0 5 10
0 10 20 30 40 50 60 70 80 90 100
% A.P. + N.A.P. + AQ.
C Caryophyllaceae
Ce Centaurea
Cs Cistus salviaefolius
Js Jasione
L Leguminoseae
Li Liliaceae
R Ranunculaceae
S Scrophulariaceae
Th Thalictrum
A Alisma
Ly Lythrum
P Potamogeton
F Filicales
Pt Pteridium

Figure 18


JL 1971
Philippi 3
Macedonia
Stratigraphy
Depth cm.
50
100
150
200
250
300
350
Quercus
Pinus
Abies
Juniperus
Betula
Alnus
Carpinus betulus
Ostrya type
Fagus
Corylus
Olea
Ulmus
Tilia
Fraxinus excelsior
Fraxinus ornus
Phillyrea
Other trees
Gramineae
Rumex
Chenopodiaceae
Cruciferae
Sarcopoterium
Rosaceae
Umb
o
n
m
l
k
Pc J
Ps
Rh Sx
Sm Sx
V
Pc Sx
Pc
Sm V A
T
Sx
Pc
Sx
T Sx Ps
Ps
Ps
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
0 5 10 15 20
0 5 10
0 5 10
% A.P. + N.A.P.
A Acer
J Juglans
Ps Pistacia
P Picea
Rh Rhamnaceae
Sm Sambucus
Sx Salix
T Taxus
V Vitis

CHAPTER 9. GRAVOUNA

Figure 19


GRAVOUNA SITE MAP
Lekani Mountains
Gravouna
Khrisoupolis
Proastion
Eratinon
Khrisokhori
Dhrimousa
R. NESTOS
Peristerona
Nea Karia
Monastiraki
Keramoti
borehole
main road
village
marsh
km. 1 2 3 4 5

9.1 THE GRAVOUNA REGION

One of the main rivers of Macedonia, the Nestos, cuts its way southwards through the Lekani mountains to the coast, forming the boundary between Macedonia and Thrace. Where the mountains end there are piedmont fans spreading out across the coastal plain. Between the plain and the sea there is an expanse of river alluvium which is damp and swampy.

There is a series of ponds on the piedmont plain near the village of Gravouna, about 1km from the main Kavala-Xanthi road. They are about 1000 m^2 in area and rounded, lying in sunken areas. The existance of ponds here is unusual. They do not appear to be connected with the river and are therefore not ox-bow ponds. The only explanation which seems to be at all satisfactory is that dolines have formed in the underlying limestone, causing the gravel above to sink into rounded depressions. These may have had their drainage impeded by soil washed into them, thus forming the ponds.

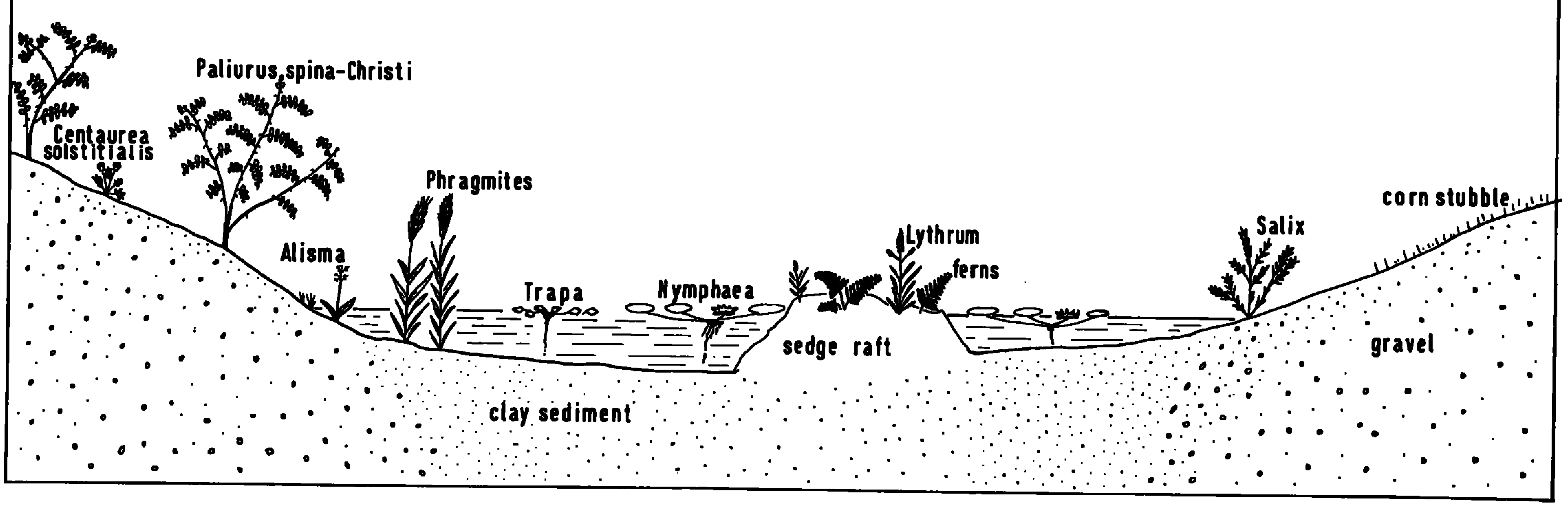
Three ponds were examined for sediment content and accessibility as soon as they were found (1968). One had been partly drained that summer, the water having been pumped out and used for irrigation of the adjacent fields. The water level was about 1 metre lower than usual and an expanse of mud was exposed. It was possible to take the core from near the new water edge, some distance from the old shoreline.

There was a rich aquatic vegetation in and around the ponds (see Fig. 20). The standing water was mostly covered by the floating leaves of Trapa natans where it was shallow, and Nymphaea alba where it was deeper. There were rafts of vegetation in the middle of the ponds, and also to some extent at the edges. These supported thick growths of

Figure 20

Gravouna

A schematic section showing the plant communities and sediments [not to scale]



ferns and Lythrum salicaria as well as sedges. There were thickets of reeds round the pond margins. Among their stems there were floating plants including Myriophyllum and Utricularia. There were also some isolated specimens of Alisma. The ponds were used for watering flocks, and where flocks were watered the vegetation was beaten down and destroyed, and the water muddy.

At the edge of the ponds were stands of shrubs; Salix and Corylus grew nearest the water, with Pyrus amygdaliformis and Crataegus sp. and intertwining brambles (Rubus fruticosus agg.) further up the slope.

Outside the immediate environment of the ponds the vegetation is a shiblyak (Turrill 1929 p.153) dominated by Paliurus spina-Christi with scattered trees of Crataegus and Pyrus. Some of the land, a stony red soil, is cultivated for crops such as grain and tobacco. Where the land rises into foothills at the edge of the plain the vegetation gradually becomes a pseudomaquis (Turrill 1929) consisting mainly of Juniperus oxycedrus and Quercus coccifera.

To the north of the plain are the Lekani mountains, which rise to about 1000m. This range is limestone, and has a thin cover of pseudomaquis on the lower slopes. High up are remains of oak and then beech woods, but the trees have been cut down, and only large bushes remain on the impoverished soil. There is some coniferous forest on the highest slopes. South of the plain is the river Nestos delta, with swampy alluvial soils. There is very little natural or semi-natural vegetation here, but before the delta was drained it had thickets of swamp vegetation (Naval Intelligence 1945). There is some maquis on the rocky coastline to the west of the delta. When this region was Turkish ruled, the Lekani mountains were well populated, and the remains of terraced fields and orchards were seen there. The plain was settled to some extent, but this was limited by the presence of malaria carrying mosquitoes which made the coastal part of the plain unhealthy. In modern times, the pattern of settlement has shifted from the mountains to the plain and the coast.

9.2 FIELDWORK

The core was taken using the screw auger, and samples were taken from 0 - 180cm. At 180cm the sediments contained sand and gravel, and this depth therefore probably represents the bottom of this part of the pond. In 1970 an attempt was made to obtain a deeper core from Gravouna, and to find whether there were any sediments that could be radiocarbon dated. That year the pond had not been drained at all, and the piston corer would not penetrate the clays, so the attempt was not successful.

The Gravouna sediments listed in the stratigraphy table, were mainly clays, some of which seemed to be coloured by the terra rossa from the surrounding land, and underlain by a coarse gravel into which the screw auger would not penetrate. The samples were treated by the improved HF process and pollen preservation found to be excellent despite the fact that the appearance of the sediment had not allowed any such high hopes at the time of coring. The land pollen sums counted are almost all in the range of 250-350 grains.

The stratigraphy is as follows:

GRAVOUNA STRATIGRAPHY

Depth cm	Sediment type
0-15	Brown mottled clay with plant remains
15-25	Brown grey silty clay
25-63	Grey silty clay
63-83	Grey clay
83-120	Grey clay with some brown streaks
120-130	Grey green with brown streaks
130-165	Grey clay with brown streaks
165-180	Grey silty clay with increasing amounts of gravel

9.3 THE POLLEN DIAGRAM

This diagram has been drawn up in a similar way to the others presented in this work, with the land pollen percentages drawn in as the percentage land pollen (AP + NAP) and the aquatic pollen percentages on the basis of the total pollen sum. Alnus is here considered as aquatic pollen since the large amounts recorded suggest damp-habitat vegetation of a local nature which would tend to obscure changes in regional pollen records if included in the land pollen sum. A distinction has been made between Gramineae type pollen grains over 40µ diameter, which are termed "C type" and could possibly be those of cultivated cereals, and those less than 40µ diameter which are counted as true Gramineae. Polygonum features in both the land and the aquatic pollen sum, for grains identified as those of Polygonum amphibium L. are counted as aquatics, while the other Polygonum type grains which could be from terrestrial species have been counted as land pollen.

9.4 ZONATION

Three pollen assemblages can be recognised and form the basis of the division of the diagram.

Sub-zone x (180-134cm) This is defined by the high tree pollen values of which Quercus is the main component. There are small records from a variety of other trees such as Fagus, Ostrya type and Carpinus, while herbaceous pollen is principally Gramineae with small amounts from Compositae (Liguliflorae), Chenopodiaceae and a variety of other plants. Aquatic pollen includes a moderate amount from Alnus, some Cyperaceae and a little Sparganium and Myriophyllum.

Sub-zone y (134-78cm) Pinus and Corylus have become more important at 8% and 6% respectively. The herbaceous pollen record is dominated by Gramineae, present in greater amounts here, although the "C Type" pollen record is still sporadic, Compositae (Tubuliflorae) and Plantago. A large increase in Alnus and a smaller increase in Sparganium pollen occur in the aquatic record.

Sub-zone z (78-3cm) Quercus pollen values are very small, 5% average, Pinus not significantly changed and small records from Juniperus, Corylus, Ulmus and Olea. There is plenty of Gramineae pollen (41%) some of which is "C Type", Artemisia and type X (cf. Artemisia), Compositae (both Liguliflorae and Tubuliflorae) Plantago, Sarcopoterium and Plantago in decreasing order, and a range of other herbs. There is very little Alnus pollen, but moderate amounts from Nymphaea, Cyperaceae and Sparganium.

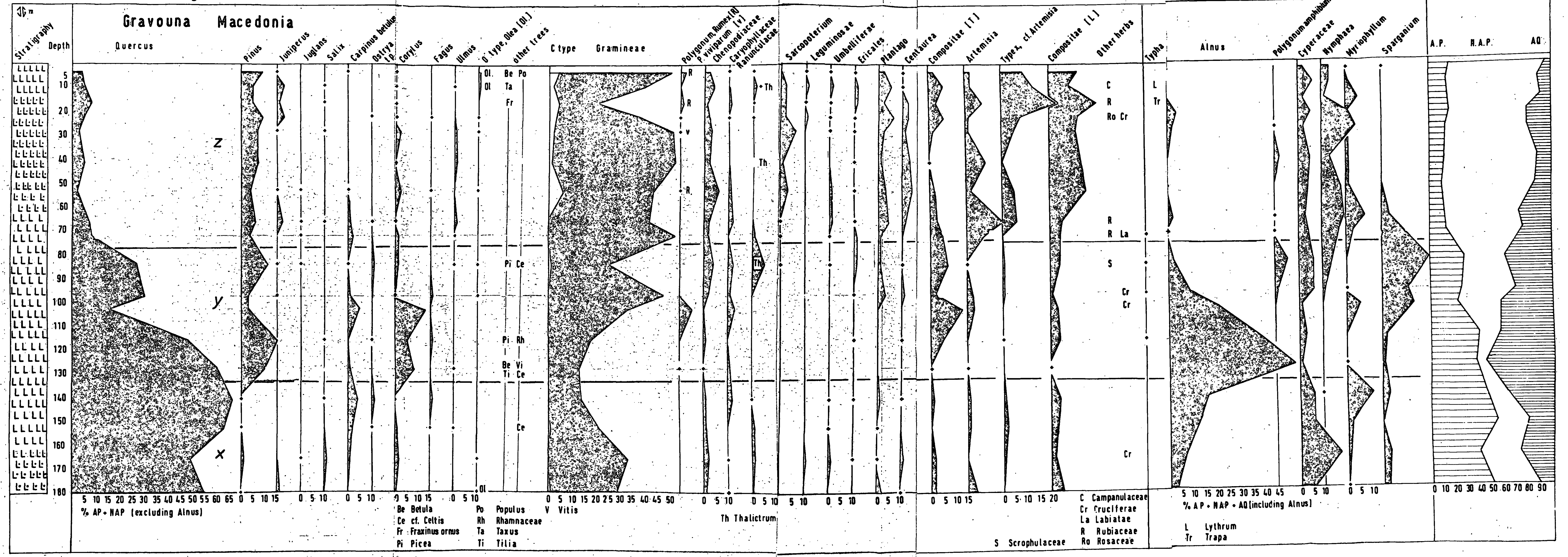
9.5 INTERPRETATION OF THE DIAGRAM

Sub-zone x is clearly indicative of "Forest Maximum" conditions where oak forest is the predominant vegetation, and would have covered much of the coastal plain round Gravouna with little sign of other vegetation. Around the pond itself there was probably a local vegetation from which much of the Gramineae pollen may have come, and with alders in wet places. The small record from Plantago and "C Type" pollen could be indicative of some farming in the region.

Sub-zone y is distinguished by features that can be linked with forest clearance and the replacement of oak forest by some lighter woodland with hazel, some pine wood and possibly some cultivated land judging by the increased importance of Compositae and Plantago. The clearance of forest seems to have been only partial at this stage, and y can be regarded as a transition between x and z.

Sub-zone z represents the final stage of forest clearance with a small tree pollen record that is sparse in forest types like oak. The pollen record shows the presence of scrub to a slight extent, but the dominant vegetation is open land as shown by the quantity and variety of herbs in the record. The "C Type" pollen is on a coherent peak which is a probable indication of cereal cultivation in view of the strength of the record and associated signs of open land, and of plants which may be found in today's cornfields. The Olea pollen record is not sufficient for it to be a clear sign of olive cultivation, although it remains as a possibility.

Figure 21


Gravouna Macedonia
Stratigraphy
Depth
Quercus
Pinus
Juniperus
Juglans
Salix
Carpinus betulus
Ostrya T.P.
Corylus
Fagus
Ulmus
O type, Olea (Ol.)
other trees
C type
Gramineae
Polygonum, Rumex (R)
P. viviparum (v)
Chenopodiaceae
Caryophyllaceae
Ranunculaceae
Sarcopoterium
Leguminosae
Umbelliferae
Ericales
Plantago
Centaurea
Compositae (T)
Artemisia
Type, cf. Artemisia
Compositae (L)
Other herbs
Typha
Alnus
Polygonum amphibium
Cyperaceae
Nymphaea
Myriophyllum
Sparganium
A.P.
N.A.P.
AQ
Z
Y
X
% AP + NAP (excluding Alnus)
% AP + NAP + AQ (including Alnus)
Be Betula
Ce cf. Celtis
Fr Fraxinus ornus
Pi Picea
Po Populus
Rh Rhamnaceae
Ta Taxus
Ti Tilia
V Vitis
Th Thalictrum
S Scrophulaceae
C Campanulaceae
Cr Cruciferae
La Labiatae
R Rubiaceae
Ro Rosaceae
L Lythrum
Tr Trapa

9.6 DISCUSSION AND COMPARISON

The lowest part of the succession can be clearly correlated with the period of maximum afforestation in northern Greece as established in the Tenagi Philippon and the Philippi ones, the former fixing the beginning of the period to about 8000 B.C. and the latter showing that there was still probably extensive forest around Philippi by the year A.D. The widespread extent of the Greek forests at this time is shown in the corresponding, but not dated, records from Ladzas and Ioannina, and Philippi and Ladzas show the alternation between periods of forest clearance with olive cultivation and intervening periods without, which would also appear to have been fairly universally expressed in Greece. Nothing like this can be deduced from the Gravouna diagram and on the tenuous basis of argument from negative evidence the lack of the alternate cultivation episodes might place the start of the period represented by this diagram at some date later than the year A.D. Sub-zone y forms the basis of a more positive argument, for this sharp transition between forest and open land is not evident from any other of the diagrams from northern Greece, reason perhaps for considering that this certainly represents events at a later date than the periods they cover. Such a forest decline could be due to clearance after which tree regeneration was inhibited by some factor, which immediately calls to mind the records of invasion and occupation that might have caused such a change. A distinct possibility seems to be the beginning of Turkish occupation since these people are credited with inefficient farming practi~~s~~ce and in particular an economy based on flocks of goats which spread over Greece following the fall of Byzantium (Constantinople) in 1485 A.D. (Bradford 1971). It can be very clearly seen today that goats almost completely stop the regeneration of woody plants except those which are tolerant of grazing, or which are protected by spines.

Sub-zone z is uniform right up to the end of the diagram,and since the uppermost level is at 3cm this effectively represents the present day pollen rain, and hence the whole of z represents the present day type of vegetation, open land with cornfields in which there are isolated shade trees, scattered patches of scrub and the local vegetation round the ponds.

The pollen diagram from Kaiafa in the Peloponnese (Wright 1972) which is dated from the first few centuries A.D. until the present day without any obvious breaks shows a similar pattern of decreasing oak and increasing pine and open vegetation pollen types, but there is not a sudden change as in the Gravouna record.

9.7 COMPARISON OF THE POLLEN RAIN DATA WITH THE VEGETATION

The open vegetation suggested by the pollen spectrum at the top of the diagram is well in evidence in the country round Gravouna, although when the cores were taken most of it had died back in the summer heat with the exception of the thistle-like Centaurea solstitialis L. and Echinops ritro L. and the tiny Centaurium tenuiflorum (Hoffmans and Link). Spring fieldwork, although not in the immediate surroundings of Gravouna, showed a rich open ground vegetation of ephemerals. There were members of the Compositae such as species of Bellis, Taraxacum, Chrysanthemum and Tragopogon, Ranunculaceae including Ranunculus, Anemone and Helleborus. Other common families represented are Orchidaceae, Liliaceae, Leguminosae and Boraginaceae Caryophyllaceae with an invariable carpet of grasses.

Apart from the Gramineae most of these taxa are insect pollinated and might not be expected to feature to any extent in the pollen rain, however they still have a fairly wide pollen dispersal (Wright 1967).

In the Gravouna pollen assemblage the Gramineae, Compositae and Centaurea pollen, and traces of Ranunculus, Caryophyllaceae and Umbelliferae, appear as expected. Artemisia and Chenopodiaceae species were less common on this open land but they are wind pollinated and should disperse their pollen freely. Sarcopoterium was not noticed growing near Gravouna, but it would not be unexpected there, as the pollen diagram suggests.

Some plants that are abundant in the present day flora are absent from the pollen record, including the vegetational dominant Paliurus spina-Christi, whose very small and inconspicuous flowers could be the key to poor pollen dispersal in the atmosphere. Pyrus amygdaliformis and Crataegus sp. are also common, but like other members of the Rosaceae they are known to have poor pollen distribution and are therefore under-represented on pollen diagrams (Wright 1967) which might account for their absence here but for a single Rosaceae type pollen grain. The fieldwork carried out, and the results of the exhaustive studies of Turrill (1929) give a thorough account of the recent vegetation around the pond at Gravouna, and the recent pollen assemblage from the uppermost part of the core lacks evidence of some of the most prominent aspects of this plant life, although its general character in the form of open vegetation can still be deduced. This divergence between pollen rain assemblage and the vegetation producing it shows the value of pollen rain studies in situations such as this, although it is probable that some past vegetational groups are not parallelled by anything to be found today so that pollen rain work may not provide all the answers to this particular problem in pollen diagram interpretation.

The aquatic vegetation noted in the pond is also only partly represented in the pollen record; the Cyperaceae, *Myriophyllum* sp. and *Nymphaea alba* L. which were found in the pond appear in the pollen record in the upper part of the diagram as expected. *Trapa natans* L. *Lythrum salicaria* L., *Alisma plantago-aquatica* L. and *Utricularia vulgaris* L. were also fairly abundant, but the pollen record has only one grain each of *Trapa* and *Lythrum*, so these taxa may also be greatly under-represented in pollen records.

CHAPTER 10. THE VEGETATIONAL HISTORY OF GREECE

Figure 22.

INTER-DIAGRAM CORRELATION TABLE

KOPAIS	LADZAS	PHILIPPI	GRAVOUNA	DATE	CORRELATION
			z		recent times
			y		? Medieval period
			x		? Classical - Byzantine
		p		550 - 0 B.C.	Classical - Hellenistic
KIIId	LIIId	o		1000 - 550 B.C.	Dark Age - Classical
KIIIc	LIIIc	n		1350 - 1000 B.C.	Mycenean - Dark Age
KIIIb	LIIIb	m		1900 - 1350 B.C.	Middle Bronze Age-Mycenean
KIII a	LIII a	l		2500-1900 B.C.	Early Bronze Age I & II
KIIIa	LIIIa	k		8000 - c.2500 B.C.	Neolithic
KIId				? - 8000 b.c.	
KIIc				12,300 - ?	Early Post-glacial
KIIb				12,900 - 12,300 b.c.	Upper Dryas
KIIa				15,600 - 12,900 b.c.	Allerød
KI	LIb			c. 30,000 - 15,600 b.c.	Weichselian glacial period
	LIa				ditto.

10.1 THE EEMIAN

Our knowledge of Greek vegetational history goes back to the Eemian as represented on the lowest part of the Tenagi Philippon diagram (Wijmstra 1969). The vegetational interpretation is that there was a mainly forest vegetation dominated by oak, but with eu-Mediterranean elements such as Pistacia represented as well. It appears that the last interglacial period as it is known from northern European material is paralleled by that from Greece, since the vegetational interpretation in both cases suggests that the climate was somewhat similar to today's in each region.

10.2 THE WEICHSELIAN

After the Eemian comes the Mediterranean equivalent of the Weichselian, also well represented on the Tenagi Philippon diagram. The woodland vegetation interpreted for the Eemian gives way to an Artemisia steppe with very reduced signs of forest, and thus it appears that the change in climate which in northern Europe went from temperate to arctic or peri-arctic was here expressed as a change from warm and probably Mediterranean (irregular rainfall) to cooler and above all drier. The Weichselian pollen assemblage as seen in the Tenagi Philippon diagram has some signs of slight variation, considered to be a response to climatic fluctuations with periods with more warmth and rainfall alternating with cooler and drier periods. Since the major climatic changes, of glacial/interglacial magnitude, appear to be recognisable in both northern and southern Europe, it is possible that some of the minor changes of stadial/interstadial magnitude might be detectable in results from the Mediterranean region. In the case of the Tenagi Philippon results the slight pollen assemblage changes on the diagram have been matched with northern European events with the aid of radiocarbon dating evidence.

This elegant correlation scheme may be shown to be correct with future work, but at present the evidence for some matched interstadials comes from Scandinavia, some from Holland and some from France, and therefore local and widespread events in the vegetation may not be distinguished from one another. Also, the Padul diagram from Spain (Florschütz etaal 1971) which also comes from a very deep core, differs in details from the Tenagi Philippon succession, showing that a unified scheme for the succession of changes during the Weichselian needs more detailed evidence from such deep cores as these before it can be applied to the whole of Europe.

The Ioannina diagram (Bottema 1967) appears to cover the whole Weichselian succession and possibly some of the Eemian as well on the basis of the pollen assemblage evidence and that from a radiocarbon date of 40,000 b.p. mear the base of the succession. The main point of note is that the evidence of woodland during the Weichselian is much greater than in the case of Tenagi Philippon, both mixed-oak wood characteristic of lowlands today, and the montane forest with beech and fir of which there is practically no sign in the equivalent part of any of the Greek pollen diagrams to date.

The Kopais and Ladzas diagrams have successions reaching back into the Weichselian although the lack of radiocarbon dates makes it uncertain how far back they go. Nor has it been possible to make more than a guess on the basis of detailed comparisons with the dated pollen assemblage changes in the Tenagi Philippon diagram (Wijmstra 1969). The Kopais diagram shows signs of slight climato-vegetational changes which have been interpreted as cyclical climatic fluctuations giving rise to alternate colonisation and retreat of woodland and shrubs, although the total extent of wood seems to have been small compared with the dominant <u>Artemisia</u> steppe. The pollen assemblage changes are slight, and the corresponding climatic

changes

causing them must have been subtle, even though it could be a parallel climatic cycle to that causing the series of stadials and interstadials in northern Europe.

It has been already stated (page 51) that the climate during the glacial period in Greece was much cooler than it is today, and all the diagrams covering this period give similar evidence; there are the slightest traces of pollen from thermophiles (in the northern European sense) such as Carpinus, Tilia and Ulmus with some Fagus from Ioannina, but no sign of Mediterranean taxa. Thus it appears that the climate cannot have been cooler than that of north central Europe today in either northern, southern or central Greece, and it may well have been warmer than this although obviously not much warmer than northern Italy today, the present day northern limit of the Mediterranean taxa.

The limiting factor on the Full-glacial period vegetation in Greece appears to have been the rainfall, which must have been too slight or too sporadic for the growth of trees, resulting in a landscape dominated by Artemisia steppe as argued in connection with the Kopais diagram on page 51 . As in the case of temperature there seems to have been some degree of uniformity between the different regions of Greece although the central montane area, around Ioannina, appears then as now to have had more rainfall than the rest of the country so that the forest, although reduced, does not appear to have been reduced to the small extent suggested by Tenagi Philippon, Kopais and Ladzas.

Under a rather dry climatic regime such as that postulated for the Full-glacial period in Greece, soil depth becomes a critical factor in vegetation determination since deep soils retain moisture and shallow ones are deficient in it. It would appear that woodland was limited to places with deeper soils along valleys and watercourses, spreading out to where there was less soil if the rainfall increased or became more regular, as could have happened in the equivalents of interstadials. The *Artemisia* steppe type pollen assemblages are very similar to one another in Tenagi Philippon, Kopais and Ioannina, but in the Ladzas diagram this assemblage is dominated by Chenopodiaceae resembling the Full-glacial type pollen assemblage from Zeribar (Van Zeist & Wright 1963), perhaps due to locally saline soil conditions like those today.

The other pollen diagrams from around the Mediterranean show that steppe vegetation with local modifications was widespread during the time of the last glaciation; a dated pollen diagram from north-western Syria (Niklewski and Van Zeist 1970) shows this clearly together with the suggestion that minor climatic fluctuations gave rise to minor spreading and retreating of woodland, as noted in the case of Tenagi Philippon, Kopais and Ladzas. In Spain (Florschütz et al 1971) the Full-glacial steppe appears to have been modified somewhat, perhaps by the influence of the ocean, and there is evidence of pine woods as well as steppe during the most extreme phases of the glacial period, which are considered to correspond to those with practically no sign of woodland in the Tenagi Philippon diagram. There may well have been some variation in the climate of different parts of Greece itself, and the greater evidence of woodland in the Ioannina diagram at this point has already been mentioned. That there was steppe in central Italy is shown by Frank (1969) in a pollen diagram without dates, but which seems to cover most of the last glacial period and the present interglacial. Most of the components of the steppe noted from Greek sites are present, Gramineae, *Artemisia*, *Juniperus* but Chenopodiaceae are much rarer. There is some sign of *Pinus*/*Artemisia* steppe/woodland from Bertoldi (1966), a diagram from northern Italy. It appears on present evidence that Europe south of the Pyrenees and Alps may have all had some kind of steppe vegetation during the time of the last glaciation, with some pine woodland in some parts of Spain and northern Italy, and modified by salt-pan vegetation in parts of Greece (i.e. Ladzas) and Iran (Van Zeist and Wright 1963, Van Zeist 1967). This evidence from around the Mediterranean seems to correspond in its broad outlines with little contradiction, but when attempts are made to link each and every climato-vegetational change as deduced from one site with each change from another site in another region, difficulties may arise. In the same way difficulties arise when such changes are compared too closely with changes deduced from sites north of the Alps.

10.3 THE LATE-GLACIAL

The Zone II sequence from Kopais has been interpreted as the equivalent in Greece of the Late-glacial and early Post-glacial events of northern Europe, the result of parallel climatic changes with amelioration, deterioration and subsequent amelioration taking place at a similar time. This appears to be one stadial/interstadial type change that can be safely associated with matching phenomena north of the Alps, and the comparison is made easier by the fact that it takes place between the end of the last Pleni-glacial and the beginning of the Post-glacial sequences, and that it is a most marked change in the Kopais diagram compared with any other possible interstadial fluctuations noted in Zone I (see page 53). The best evidence comes from the matching pollen assemblage sequences with dates in the Tenagi Philippon diagram, allowing comparison with Kopais.

The sequence of change deduced from KII and zone Y in Tenagi Philippon is not evident in other diagrams. The Ladzas diagram does not have this zone II assemblage at all, probably due to truncation of the sediments, nor does the Ioannina diagram have much to add, for the number of pollen spectra covering the transition from steppe to forest is small, and does not permit a detailed interpretation.

The Zone II sequence has been interpreted in terms of the development of the végetation in the Kopais region in response to a warmer climate with more rainfall, when a pioneer scrub vegetation with *Juniperus* and *Pistacia* species colonised the hillsides that had hitherto been covered in an *Artemisia* steppe vegetation, and a mixed-oak forest spread from the vallies and their deep soils, and eventually on to land that had been improved by the scrub in terms of soil development and stability. A climatic reversal led to a revertance to steppe vegetation and the restriction of oak forest to suitable deep-soil habitats until another climatic amelioration permitted a second colonisation phase with development of widespread mixed-oak forests containing temperate-climate taxa such as *Ulmus* and *Tilia*. The general outline of this series of vegetational changes can be deduced from the Tenagi Philippon diagram although the colonisation of steppe land via a *Juniperus*-*Pistacia* scrub phase is not very evident, nor is it in the Ioannina diagram. These two pollen diagrams come from regions which have more rainfall than is usual in Greece, and a possibility is that, then as now, moisture availability was not such a crucial matter for the development of forest vegetation if there was appreciably more rainfall than in the Kopais region, and mixed-oak forest was able to spread over what had previously been steppe land without much of an intermediate scrub stage.

Signs of this climatic-vegetational oscillation and Post-glacial vegetational development are evident in several pollen diagrams from sites around the Mediterranean. In northern Italy it is very marked and has been dated (Bertoldi 1966) demonstrating a synchroneity with the Allerød sequence from northern Europe, while in central Italy there are signs of oscillation (Frank 1969), less marked and not dated directly This equivalent to the Allerød has been detected in the western Mediterranean from a pollen diagram from southern Spain (Florschütz et al 1971) although the signs of it are very slight, and in the opposite corner of the Mediterranean there are also slight signs (Niklewski and Van Zeist 1970). An interesting point in the latter is that there is a change in the lithology to peaty sediments at this point, which could be a similar phenomenon to that mentioned in connection with the Kopais aquatic diagram (page 69 f) thought to have some connection with increased rainfall leading to erosion until the vegetational cover had developed sufficiently. This evidence for climatic-vegetational oscillation corresponding to the Allerød is dependent partly on the detail in which pollen diagrams have been prepared for its evidence, and there is not very much detailed information about the expression of these changes in various regions. It is clear that its effects seem to have been felt all round the Mediterranean to some extent although it does not seem to be detectable in Iran (Van Zeist and Wright 1963). The fact that the vegetational effects seem to be marked in some pollen diagrams such as Kopais and faint in others like Padul could be regarded as a dying-out of the effects of a climatic change from some hypothetical epicentre. Alternatively and more probably, the oscillation which in northern Europe had the most marked climatic expression of arctic to temperate and back to arctic, with a correspondingly great change in the vegetation, was in southern Europe expressed as cool-dry-temperate to warm-moist-temperate and back again with a vegetational response far less spectacular inasmuch as the evidence from pollen diagrams can tell us. The apparent effects of the climatic oscillation may also have been increased in northern Europe with the delay in the arrival of various taxa with slow migration rates. So a climatic change may leave clear records from the pollen rain of a marginal plant community such as peri-glacial tundra of northern Europe or a semi-desert community such as may have existed round Kopais in the Full-glacial period, but much less clear signs from a less than marginal community like woodland which may respond by a change in detail but not in overall composition. The detailed change may or may not be of such a kind to be noticeable in pollen records and to be interpreted as such.

10.4 THE POST-GLACIAL

The final main division applied to Greek vegetational history in the pollen diagrams presented here begins when full forest development has been reached, indicated by maximum oak pollen values. In northern Greece it appears that woodland was able to spread until it reached an equilibrium with its surroundings, occupying all the habitats it was able to in the prevailing climate, as can be seen in the lower part of the Philippi diagram (and the uppermost part of the Tenagi Philippon diagram, Wijmstra 1969) where there are high values of oak pollen which do not appreciably change. In southern Greece the evidence from the Kopais diagram suggests that the process of afforestation may not have quite reached its climax, or if it did so only for a very short time, for the signs of maximum afforestation in the diagram are immediately followed by signs of forest reduction. The Ioannina diagram (Bottema 1967) does not permit a very detailed interpretation, but the degree of afforestation judged from the oak pollen values seems to make it comparable with the Philippi diagrams.

All the diagrams show signs of forest degradation in some form or other, which in north and central Greece is expressed in the appearance of some evergreen oak pollen and of trees of more open woodland such as Carpinus/Ostrya, interpreted as the effects of human intervention rather than a change to a more Mediterranean climate. The question of climatic change is a difficult one, already mentioned in connection with the Late-glacial succession, and it is possible that climatic changes may have accompanied such vegetational change. Evidence from Turkey (Beug 1967b and Van Zeist et al 1970) suggests climatic stability over the last 3000-4000 years there, or perhaps rather a lack of evidence of change, yet vegetational events from Jugoslavia (Beug 1967a) are at least partly interpreted as the effects of climatic changes over this period.

The Kopais diagram demonstrates a rapid decline in forest that could be taken to show that the region around the lake may have been exposed to more severe clearance because of easy access from the Boeotian plain, or possibly that some factor rendered the survival of mixed oak forest marginal in the region so that it disappeared rapidly with the onset of clearance without much regeneration, a situation similar to that suggested by Smith (1970) where certain woodlands in Britain appear to have led a somewhat marginal existance, disappearing completely when exposed to man's activities.

In northern Greece the forest appears to have been more resilient or was exposed to less exploitation. The former explanation can be linked with the possibility that northern Greece always tended to have more rainfall than the south, from perhaps the Post-glacial to the present day, and the latter explanation can be justified by stating that northern Greece may have been less populated than round the major cities of the Mycenean and classical period in the south.

There is not very much evidence about vegetational change in the last 5000 years from other pollen diagrams in the Mediterranean region to compare with the results obtained from Greece. Pollen diagrams from Malo Jezero on the Adriatic coast (Beug 1961, 1967a) show some similarities to the sequence of events deduced from the Greek diagrams, with mixed-oak forest giving way to deciduous and evergreen mixed-oak forest, followed by signs of forest vegetation being replaced by a more "Mediterranean" vegetation. The fact that these stages seem to take place at a different time at Malo Jezero could be taken as evidence that the changes are not entirely climatic. In other aspects the pattern of change is markedly different to that of Greece. In particular the "*Juniperus/Phillyrea* period" from 5600-4300 b.c. seems to have no Greek equivalent, and the signs of olive cultivation in the Greek diagrams are not paralleled here. One explanation for this anomaly in the results could be that Malo Jazero is a coastal site on an island where the vegetation is fully Mediterranean, while the Greek sites are (except Voulkaria, Osmanaga, Kaiafa, Wright 1972) all inland and from regions without typical Mediterranean vegetation, whose vegetational history may have been somewhat different from coastal Mediterranean sites. A further point is that the Adriatic coast may have been isolated from the main-stream of history, in effect a back-water, so that this region may have had a small population with a correspondingly small effect on the landscape; Greece on the other hand appears to have been one of the main paths of colonisation from Asia into Europe, and although the fact that its archaeology is well known leads to a bias, it is probably true to say that Greece was much more affected by successive culture-groups than the Adriatic coast where Beug (1967a) considers the first signs of human influence on the vegetation to be due to Greek colonisers in Classical times.

Around Lake Garda in northern Italy there is a disjunct Mediterranean flora which appears to have immigrated there during a period when the climate was warmer than now, and which has subsequently become isolated. Pollen diagrams from there show the development of this vegetation (Beug 1964) although as in the case of Malo Jezero, there are a few points of similarity and many differences. The spread of Abies and Fagus at around 2500 B.C. is one apparent similarity between the Greek and Italian pattern, although these taxa finally dominate the tree pollen sum together with Picea (which is not recorded from Greek diagrams) while in Greek diagrams they are less important. Perhaps topography plays a part here, for beech/fir forest is typically montane today, and as expected in the pollen diagram from the most mountainous region is well represented in the Ioannina diagram, slightly represented in Philippi which is a site bordered by mountains to the north, just noticeable from Malo Jezero but hardly represented from Kopais which could be called the least northern-montane site. In Italy the montane forest may have been more widespread on lower ground than in Greece because a somewhat cooler climate. Another difference between Italy and Greece seems to be that Juglans appears to have been cultivated there much later at 800-600 B.C. and olives later still at 800-1100 A.D. although these dates are estimates (Beug 1964).

Pollen diagrams from the Eastern part of the Mediterranean, in Turkey also seem to correspond in some details to those from Greece, and to differ in others; in a diagram from central Turkey the increase in fir and beech is also dated to about 2500 B.C. (Beug 1967b) so this spread of montane forest seems to have been a widespread event inasmuch as it is detectable in Italy, northern Greece and Turkey.

10.5 CULTIVATED CROPS

Information about the history and prehistory of agriculture is still very sparse. The earliest suggestion of this is made by Frank (1969) in connection with the Plantago lanceolata curve in the Vico pollen diagram which he considers to represent human occupation of the region from the Upper Palaeolithic onwards. However there is Plantago pollen in the Kopais and Tenagi Philippon diagrams in the Late- and Post-glacial parts without this being interpreted as being anthropogenic, for plantains could easily have been part of the circum-lacustrine vegetation, and also a set of circumstances which have been interpreted in a particular way in northern Europe, such as the appearance of P.lanceolata pollen, will not necessarily bear the same interpretation in southern Europe.

Much clearer evidence comes from the Lake Garda diagram (Beug 1964) where cereal grains first appear in significant amounts around 2200 B.C. and again from around 1300 B.C., the latter being interpreted as coming from Bronze Age lakeside settlements. There is no corresponding evidence from Greece as only sporadic grains of the appropriate size were found when the Kopais, Ladzas and Philippi cores were being prepared, and owing to the risk of confusing them with the pollen of certain wild grasses which are found in Greece these were not differentiated from Gramineae type grains when the diagrams were prepared. However there is some evidence which appears to represent cereal cultivation in Eastern Turkey between about 900 B.C. and 200 A.D. (Van Zeist et al 1970). The Gravouna core has signs of probable cereal cultivation, but these are fairly recent. This lack of evidence of cereal cultivation is somewhat surprising considering the wealth of evidence of cereals in the form of carbonised grains found during archaeological excavations (c.f. Renfrew 1973).

In contrast the palynological evidence of olive cultivation seems to equal or exceed that from the rare archaeological finds of olive stones (Renfrew 1973 p.132) either because they are not often preserved by carbonisation as is grain, or because they have not been looked for. The evidence from Philippi suggests that olives were grown in Middle Bronze Age times, somewhat earlier than might be expected from the admittedly scanty evidence from archaeological sources. Then in the Mycenean period olives seem to have been grown as conventional archaeological opinion has long suspected, and in northern Greece at least there appears to have been some break in the continuity of olive cultivation in the Dark Age before resumption for a while in Late Dark Age and Early Classical times. Maybe olive cultivation in northern Greece, more marginal due to the cooler climate, has been interrupted more easily than that in the Peloponnese where there is no sign of discontinuity in the record of olive cultivation (Wright 1972), and also in western Greece, although the diagram itself has not been published and the evidence of this cannot be weighed independently. The Gravouna diagram does not have anything which can be interpreted as olive cultivation, but then the region does not seem to have much land suitable for olives today, being bordered by a marshy area of deltaic deposits.

The only other pollen diagrams so far with evidence of olive cultivation are Malo Jezero (Beug 1961, 1967a) where there is some evidence interpreted as signs of olive growing at a time when the Greeks colonised the Adriatic coast around 400-200 B.C., but without radiocarbon dates to support this hypothesis. The diagrams from Lake Garda, in northern Italy, show signs of olive cultivation interpreted as being even later, around 800-1100 A.D. on grounds of historical evidence.

10.6 DISTRIBUTION OF TAXA DURING THE WEICHSELIAN

The problem of the survival of temperate-climate taxa during periods of hostile conditions like the Weichselian cool-continental regime can now be examined in the light of the pollen diagrams from the Mediterranean, and the outline of plant distributions traced for different epochs. Our knowledge of these plant distributions depends first upon the often patchy information from pollen diagrams, for the Mediterranean region is not yet even barely covered by pollen analyses for the major parts of its vegetational history. The second problem is that there have been changes of topography, and the lower sea level during the last glacial period (Horowitz 1971) means that the exact extent and area of the land masses would have altered relative to the sea.

Although all the pollen diagrams covering the Full-glacial period have a mainly herbaceous vegetation indicated for this period (with the exception of Lake Garda where pine pollen is predominant which could represent significant areas of pine wood) there are indications of the presence of taxa whose present day distribution is limited to regions with a temperate climate approximating to a northern limit in southern Scandinavia, and in England. The records are often sporadic and comprise only a very few pollen grains in some cases, but as indicators of the probable presence of these taxa in the region around the cored site they are important. Kopais has evidence of *Tilia* and *Acer*, the latter probably more important than the small record would suggest since it is under-represented in pollen diagrams, while Ladzas even though further north has records of *Carpinus*, *Ostrya* type, *Ulmus* and *Fagus*, and similarly Ioannina (Bottema 1967) has records of *Carpinus*, *Ostrya* type and *Fagus*. The Tenagi Philippon diagram only has records of *Tilia* to add to this list.

The presence of these taxa suggests that at various places in Greece, both inland and near the coast, at low altitude and in the hills, small amounts of vegetation was able to survive in places where the prevailing conditions amounted to a marginally temperate climate, for the evidence so far presented from so many sites seems to rule out long distance transport of pollen.

From this it appears that temperate type vegetation was sufficiently well distributed through Greece that it was able to spread quickly to take advantage of new habitats made available by a slight climatic amelioration. There are unfortunately no pollen diagrams so far covering this period from an eu-Mediterranean coastal site, perhaps on the south coast of the Peloponnese, to test the hypothesis that an extensive temperate climate vegetation with some of the taxa mentioned above flourished in the warmer parts of Greece during the last glacial period.

There is very little sign of taxa with an eu-Mediterranean distribution in the pollen diagrams, except for a single record of Pistacia from Kopais. The presence of records of this shrub may be taken as an indication of a largely frost-free regime (Rivas Goday 1956) but such a slight record is tenuous evidence that there may have been places near Kopais which were so warm during the glacial period.

The pollen diagrams from the northern half of the Mediterranean confirm this account of survival of forest trees through the Weichselian, albeit sporadically, and even in the Garda diagram (Beug 1964) there are some signs of Ulmus in the earliest part of the diagram representing the glacial period. From Vico in central Italy the signs are clearer, with records of Oleaceae (probably Fraxinus) Carpinus, Ostrya type, Tilia, Ulmus, Acer and Fagus. (Frank 1969). From Padul (Florschütz et al 1971) there is evidence of Oleaceae, Acer and Ilex, the latter being considered by the authors to represent a component of an oceanic forest with Atlantic elements.

The south Mediterranean presents a different picture from the evidence from Syria (Niklewski and Van Zeist 1970) and from Israel (Horowitz 1971) where many elements of the Mediterranean flora are much in evidence in pollen spectra dated to the time of the last glacial period - in the former case Quercus calliprinos type (Q.coccifera L. includes Q.calliprinos Webb., Flora Europaea), Phillyrea, Pistacia, Olea, Ostrya type and Fraxinus ormus, in a pollen diagram bracketed with radiocarbon dates at 10,000, 46,000 and 47,000 B.P. Some taxa, like Corylus, Carpinus and Ulmus whose pollen occurs in these Weichselian age spectra, are not found in Syria today as they have a more northerly distribution (Meusel et al 1965).

It would appear that the eu-Mediterranean floristic elements persisted in the south Mediterranean and perhaps elsewhere during the last glacial period, spreading around the coast when the climate became sufficiently warm, but the vegetation that is regarded today as typically Mediterranean did not become widespread in the region until the comparatively recent destruction and degradation of the forest together with depauperation of the soils. At present there is little evidence that the climate may have had much effect on this development of present day type vegetation in Greece even though it appears to have been natural in Turkey and Syria.

11. REFERENCES

11. REFERENCES

BERTOLDI, R. (1966) L'oscillazione di Bölling riscontrata in um deposito lacustre tardo-glaciale della Valle Padana per mezzo di studi pollinologici e datazione con il metodo del Carbonia radioattivo, *Studi Trent. Sc. Nat.* sez. B *XLII* 193-221.

BEUG, H-J. (1961) Beiträge zur postglazialen Floren- und Vegetationsgeschichte in Süddalmatien; der See "Malo Jezero" auf Mljet, parts I & II *Flora* *150* 600-656.

BEUG, H-J. (1962a) Uber die ersten anthropogenen Vegetationsveränderungen in Süddalmatien an Hand eines neues Pollendiagrammes vom "Malo Jezero" auf Mljet, *Veröffentl. Geobotan. Inst. Rübel.* *37* 9-15.

BEUG, H-J. (1962b) Pollen analytical arguments for plant migrations in South Europe, *Pollen et Spores* *4* 333-334.

BEUG, H-J. (1964) Untersuchungen zur spät- und postglazialen Vegetationsgeschichte im Gardaseegebiet unter besonderer Berüchsichtigung der mediterranean Arten, *Flora* *154* 401-444.

BEUG, H-J. (1967a) On the forest history of the Dalmatian coast, *Rev. Palaeobotan. Palynol.* *2* 271-279.

BEUG, H-J. (1967b) in Cushing, E.J. & Wright, H.E. (eds), Contributions to the postglacial vegetational history of Turkey, *Quaternary Palaeoecology* New Haven 349-356.

BOTTEMA, S. (1967) in Higgs et al, The climate, environment and industries of Stone Age Greece Part III, *Proc. Prehist. Soc.* *XXX* 26-29.

BRADFORD, E. (1971) *The Mediterranean*, Hodder & Stoughton.

CLARK, J.G.D. & PIGGOTT, S. (1965) *Prehistoric Societies* , the history of human society series (ed. Plumb, J.H.) Hutchinson.

DALLA FIOR, G. (1969). Analisi polliniche di torbe e depositi lacustri della Venezia Tridentina. Mem. Museo. St. Nat. Ven. Trid. sez B. XLVI 1-158.

DIAPOLIS, K.A. (1948-9). Synopsis Flora Graecae I & II Athens.

DIMBLEBY, G.W. (1962). in Rodden, R.J. Excavations at the Early Neolithic site at Nea Nikomedeia, Greek Macedonia (1961 season) Proc. Prehist. Soc. XXVIII 267-279.

ERDTMANN, G., PRAGLOWSKI, J. & NILSSON, S. (1963). An introduction to the Scandinavian pollen flora I & II, Almqvist & Wiksell.

ETHNIKI STATISTIKI (1964). Economic and Demographic Atlas of Greece. Athens.

FAEGRI, K. & Iversen, J. (1964) Textbook of Pollen Analysis Munksgaard.

FLORSCHUTZ, F., MENENDEZ AMOR, J., & WIJMSTRA, T.A. (1971) Palynology of a thick Quaternary succession in southern Spain. Palaeogeography, Palaeoclimatol. Palaeoecol 10 233-264.

FRANK, A.H.E. (1969). Pollen stratigraphy of the Lake of Vico, (Central Italy) Palaeogeography, Palaeoclimatol. Palaeoecol. 6 67-85.

GUILLET, B. & PLANCHAIS, N. (1969) Note sur une technique d'extraction des pollens des sols par une solution dense. Pollen et Spores 11 141-145.

GODWIN, H. (1934). Pollen analysis: an outline of the problems and potentialities of the method. New Phytol. 33 278-358.

GODWIN, H. (1940). Pollen analysis and forest history in England and Wales. New Phytol. 39 370-400.

GODWIN, H. (1960). Radiocarbon dating and Quaternary history in Britain. Proc. Roy. Soc. B. 153 287-320.

VAN DER HAMMEN, T., WIJMSTRA, T.A. & VAN DER MOLEN, W.H. (1965). Palynological study of a very thick peat section in Greece, and the Würm-glacial vegetation in the Mediterranean region. Geol. Mijnbouw, 44 37-39.

VAN DER HAMMEN, T., MAARLEVELD, G.C., VOGEL, J.C. & ZAGWIJN, W.H. (1967) Stratigraphy, climatic succession and radiocarbon dating of the last Glacial in the Netherlands. Geol. Mijnbouw 46 79-95.

HARRIS, D.R. & VITA-FINZI, C. (1968) Kokkinopilos --- a Greek badland. *Geog. Jo.* *134* 537-546.

HAWKES, C. & WOOLLEY, L. (1963). *Prehistory and the Beginnings of Civilisation* Allen & Unwin.

HELBAEK, H. (1966). Commentary on the phylogenesis of *Triticum* and *Hordeum*. *Econ. Bot.* *20* 350-360.

HETH, A. (1960) in Kaplan et al., *Afforestation in Arid Zones*, *Monographiae Biologicae* *20*.

HIGGS, E.S., VITA-FINZI, C., HARRIS, D.R. & FAGG, A.E. (1967). The climate, environment and industries of Stone Age Greece. *Proc. Prehist. Soc* *XXXIII* 1-29.

HIGGS, E.S. & WEBLEY, D. (1971). Further information concerning the environment of Palaeolithic man in Epirus. *Proc. Prehist. Soc.* *XXXVII* 367-380.

HALACSY, E. VON, (1900-1904). *Conspectus Florae Graecae* Leipzig. Supplements Leipzig 1908, Budapest 1912.

HOPF, M. (1962). Bericht uber die Untersuchung von Samen und Holzkohlenesten von der Argissa-Magula aus den präkeramischen bis mittel-bronzezeitlichen Schichten, in Milojcic, V., Boessneck, J. & Hopf, M. *Die deutschen Ausgrabungen auf der Argissa-Magula in Thessalien* Bonn.

HOROWITZ, A. (1971). Climatic and vegetational developments in north-eastern Israel during Upper Pleistocene - Holocene times. *Pollen et Spores* *8* 255-278.

IVERSEN, J. (1941). Landnam i Danmarks Stenalder. *Danm. geol. Unders* II

IVERSEN, J. & TROELS SMITH, J. (1950). *Pollenmorfologiske Definitioner og Typer.* *Danm. geol. Unders* IV rk 3,8.

JANSSEN, C.R. (1970). Problems in the recognition of plant communities in pollen diagrams, *Veg. Acta. Geobot.* *20* (1-4) 187-198.

LIBBY, W.F. (1955). *Radiocarbon Dating* Chicago.

MACKIE, E., RENFREW, C. & SUESS, H. (1971). Thoughts on radiocarbon dating. Antiquity 45.

MENENDEZ AMOR, J. & FLORSCHUTZ, F. (1962). Un aspect de la végétation en Espagne méridionale durant la dernière glaciation et l'Holocène. Geol. Mijnbouw 41 131-134.

MEUSEL, H. JÄGER, E. & WEINERT, E. (1965). Vergleichende Chorologie der zentraleuropäischen Flora. Jena.

NAVAL INTELLIGENCE (1945). Handbook for Greece, vol III.

NIKLEWSKI, J. & VAN ZEIST, W. (1970). A Late Quaternary pollen diagram fro northwestern Syria. Acta Bot. Neerl. 19 (5) 737-754.

OLDFIELD, F. (1959). The pollen morphology of some of the west European Ericales. Pollen et Spores 1 19-47.

PENNINGTON, W. (1969). The History of British Vegetation, English Universities Press.

POLUNIN, O. & HUXLEY, A. (1965). Flowers of the Mediterranean, Chatto & Windus.

POLUNIN, O. (1969). Flowers of Europe, Oxford.

VON POST, L. (1946). The prospect for pollen analysis in the study of the world's climatic history. New Phytol. 45 193-217.

QUEZEL, P. (1967a). La végétation des hauts sommets du Pinde et de l'Olympe de Thessalie. Veg. Acta Bot. 14 127-228.

QUEZEL, P. (1967b). Some beech forests of Greek Macedonia. Bull.Bot. Soc. France 114 5-6.

RENFREW, C. (1969). The autonomy of the south east European Copper Age. Proc. Prehist. Soc. XXXV 12-47.

RENFREW, C. (1970) The tree ring calibration of radiocarbon —— an archaeological evaluation. Proc. Prehist. Soc. XXXVI 280-311.

RENFREW, C. (1971a) Carbon 14 and the prehistory of Europe. Scientific American 225 63-70.

RENFREW, C. (1971b) Sitagroi, radiocarbon and the prehistory of south-east Europe. Antiquity XLV 275-282.

RENFREW, J. (1973) Palaeoethnobotany Methuen.

RIVAS GODAY, S. (1956) Übersicht über die Vegetationsgürtel der Iberischen Halbinsel kennzeichnenden Arten und Gesellschaften. Veröffentl. Geobotan. Inst. Rübel 31 32-68.

RODDEN, R.J., & RODDEN, J.M. (1964) A European link with Çatal Huyuk: uncovering a seventh millenium settlement in Macedonia. Part I Illustrated London News 11th April 565.

SMITH, A.G. (1970) in Walker, D. & West, R. (eds), Studies in the Vegetational History of the British Isles. Cambridge.

SNODGRASS, A.M. (1971) The Dark Age of Greece Edinburgh.

SUESS, H. (1967) Bristlecone pine calibration of the radiocarbon time scale from 4100 B.C. to 1500 B.C. in Radioactive dating and methods of low level counting. International Atomic Energy Agency, Vienna.

TUTIN, T.G. et al (eds) (1964, 1968, 1972) Flora Europaea volumes I - III Cambridge.

TAYLOUR, Lord W. (1964) The Myceneans Thames & Hudson.

TROELS SMITH, J. (1955) Karakterisering af løse jordater. Damm. geol. Unders. 4 rk 3, 10.

TURRILL, W.B. (1929) The Plant-life of the Balkan Peninsular Oxford.

UNESCO (1970) Climatic Atlas of Europe.

VITA-FINZI, C. (1969) The Mediterranean Vallies: Geological Change in Historical Time. Cambridge.

WARREN, P. (1971) Myrtos British School at Athens supplementary paper No. 7. Thames & Hudson.

WIJMSTRA, T.A. (1969) Palynology of the first 30 metres of a 120 m deep section in northern Greece. Acta Bot. Neerl. 18(4) 511-527.

WRIGHT, H.E., McANDREWS, J. & VAN ZEIST, W. (1967) Modern pollen rain in western Iran and its relation to plant geography and Quaternary vegetational history. J. Ecol. 55 415-443.

WRIGHT, H.E. (1968a) The natural environment of early food producers north of Mesopotamia. Science 161 334.

WRIGHT, H.E. (1968b) Climatic change in Mycenean Greece Antiquity 42.

WRIGHT, H.E. (1972) in McDonald, W.A. & Rapp, G.R. (eds) The Minnesota Messenia Expedition --- Reconstructing a Bronze Age Regional Environment. University of Minnesota Press, Minneapolis.

VAN ZEIST, W. & WRIGHT, H.E. (1963) Preliminary pollen studies at Lake Zeribar, Zagros mountains, southwestern Iran, Science 140 65-69.

VAN ZEIST, W. (1967) Late Quaternary vegetational history of western Iran, Rev. Palaeobot. Palynol. 2 301-311.

VAN ZEIST, W., TIMMERS, RIA. W. & BOTTEMA, S. (1968) Studies of modern and Holocene pollen precipitation in southeastern Turkey, Palaeohistoria 14 19-39.

ACKNOWLEDGEMENTS

This research was financed by the Natural Environment Research Council, with a travel grant from the Royal Society, and was supervised by Dr. Judith Turner of the Botany Department, University of Durham. I also wish to thank Professor D. Boulter, of the Botany Department, University of Durham for the useof the facilities of his department, Professor Colin Renfrew for facilities in the field and advice on archaeological matters, Professor (emeritus) Papaioannou of the Department of Forestry, University of Thessaloniki, Greece for his help in vegetational studies, and many others.