EPISODES IN THE QUATERNARY HISTORY OF SOUTH-WEST FRANCE.

by Frank Oldfield M.A. 1962.

A thesis presented for the Degree of Doctor
of Philosophy in the University of Leicester.

" .... this land is not the sweet home that it looks,
Nor its peace the historical calm of a site
Where something was settled once and for all .... "

W.H.Auden.

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PART I. INTRODUCTION.

CHAPTER I. Aims and Methods.

The main aim of the project, of which the evidence included in this thesis forms a part, is to investigate the Quaternary history of the coastal fringes of the Biarritz area of South West France, by examining the stratigraphic and biological evidence contained within local deposits dating from the period. It is hoped that such a study will provide a context and a basis for further research into the geomorphology, phytogeography and prehistory of the area. This thesis is an account of some of the data so far obtained, together with a discussion of some of their implications.

Five main techniques have been used :-

i). the examination and recording of stratigraphical data,

ii). the analysis of the pollen, spore and macroscopic plant content of organic deposits,

iii). the recording of geomorphological evidence,

iv). the systematic description of the pollen morphology of various taxa of particular biogeographic interest (notably West European members of the families Ericaceae, Pirolaceae, Monotropaceae and Empetraceae).

v). the observation and simple description of plant communities in the west-central Pyrenees.

A brief discussion of each technique follows :-

i). At one site, Le Moura, most of the stratigraphical data were obtained by means of borings carried out with a Hiller peat sampler,or a recent modification of the Hiller (Appendix I). Elsewhere, all the stratigraphical evidence has been obtained by digging, cleaning and describing vertical sections, many of them on the sea cliffs and foreshore. In most cases, the field notes taken on the spot at the time of doing the work form the basis for the descriptions and diagrams included in the present text, though use of the modified Hiller during later stages in the project has made it possible to defer detailed stratigraphical description until the return to the laboratory.

ii). Pollen samples were taken in the field either from cleaned peat and mud faces or from the chamber of the borer used, care being taken to reduce and wherever possible eliminate any chance of contamination during sampling. Pollen samples were kept in sealed glass tubes until used. With the modified borer, it was possible to bring cores back to the laboratory and take pollen samples from them there. Bulk samples for macroscopic examination were almost always kept in polythene bags, although where one of the main aims was to obtain post-glacial radiocarbon samples from peat, biscuit tins were used.

For purely organic samples, the simplest preparation technique was used, involving merely boiling in 10 percent caustic soda, washing and centrifuging twice , staining and mounting in glycerine. This preparation has been preferred because it makes possible the detection of contaminating pollen from atmospheric sources. This is an important point since the preparations have had to be completed in three different laboratories, only one of which, in Paris, was used exclusively for pollen-analytical work, and since the pollen content of the samples was, for the most part, rather less predictable than is the case with similar work in Britain. Samples containing any appreciable amount of silica were treated with hydrofluoric acid also. In Biarritz and Leicester, the samples were boiled for three to five minutes in acid, in Paris, where no fume cupboard was available, they were left in unheated acid for 12 to 48 hours. Material retained by a fine mesh sieve (c. ·2mm.) in the early stages of each preparation was saved and examined for its macroscopic plant content. The bulk samples were usually broken up in nitric acid though occasionally caustic soda has been used.

The critical identification of all the pollen types recorded has frequently posed problems, especially in Biarritz and Leicester, where the work has been done without a pollen herbarium at hand. It has thus not always been possible to pursue identification to the full limits.

iii). No attempt has been made to do more than outline aspects of the geomorphology of the area. Most of the features referred to have been plotted from map evidence and analysis and confirmed for selected but widespread points in the field, by simple observation. The results form no more than an introduction to the main part of the work.

iv). The families listed were chosen for pollen analytical study in view of the number of species contained within the group (mainly in Ericaceae) possessing problematical disjunct West European distributions usually including nearby localities (ie. the so-called 'Lusitanian' species). Moreover, pollen of the group has been abundantly recorded in the sub-fossil analyses from the area. These factors pointed to the need for a close examination of the pollen types representative of all the West European species within these related families. Details of this aspect of the work are given in Oldfield (1959).

v). Relatively little literature is available on the plant communities of the western high Pyrenees. It was found necessary, in trying to interpret some of the analyses considered below, to refer to the Pyrenean vegetation communities at high altitudes. Examination of these was coupled with the taking of moss polster samples of living Sphagnum in order to relate these communities to their present day pollen rain. The results are given in Chapters III and IV below.

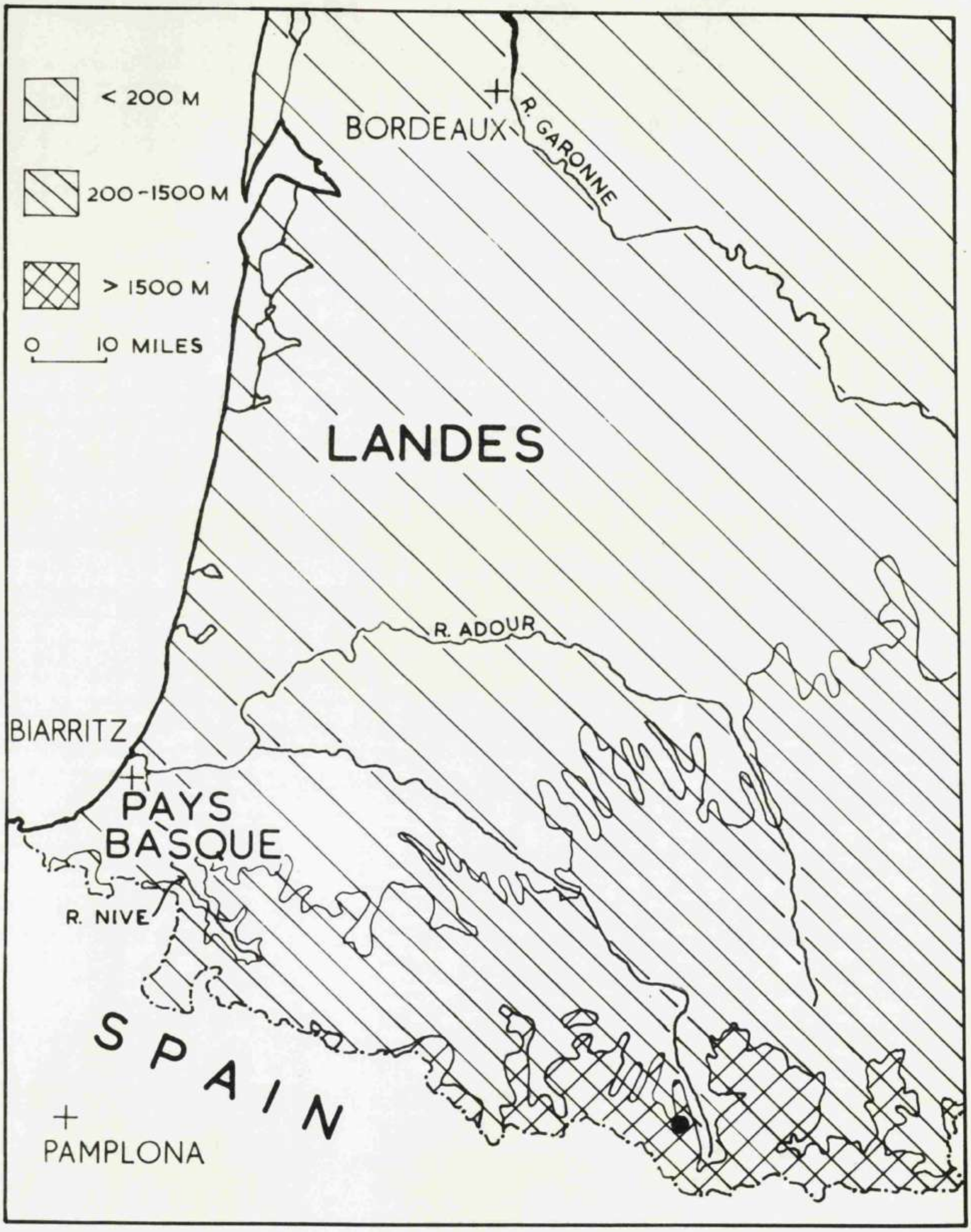

Figure 1. The situation of the French Pays Basque.
The black disc marks the position of the Pyrenean areas studied, (Chapters III and IV).

CHAPTER II. The coastal fringes of the French Pays Basque.

(i). The situation of the area. (Fig. 1).

The present study is concerned with deposits along and near to the coast of the French 'Pays Basque', within a triangular piece of land west of the river Nive, south of Biarritz and Bayonne, and north of the river Ouhabia (Fig.2). This area lies in the corner of the Bay of Biscay, none of it rises above 90 m. (c. 300') and none of it is more than 10 km. (c. 6 miles) from the sea.

To the north, across the Adour, the land level falls to the plain country of the 'Landes' with its triple division of recent,high and partly active coastal sand dunes,extensive marshy flats and lagoons and higher sandy inland areas based on the 'Sables des Landes', late-Pleistocene deposits tentatively dated to the last glaciation (Enjalbert1950)

South of the Ouhabia and east of the Nive, the land level rises gradually to the western foothills of the Pyrenees, the high hills coming closest to the area just to the south in the shape of La Rhune, an isolated 3,000' high massif which completely dominates many of the local views. A little further south, near Hendaye, land over 2,000' almost reaches the coast and away from the narrow coastal strip, the routes into Spain become increasingly mountainous from west to east.

Sea-wards,there is little or no development of a continental shelf. The 50 m. submarine contour lies everywhere within 5 miles of the coast, the 200 m. contour within c. 15. In this respect, the area contrasts sharply with the south western fringes of Britain.

(ii). Local geology, drainage and denudation chronology.

The bedrock within the area discussed is virtually all of Eocene limestone (Daguin 1949) and limestone marls, though earlier sedimentary rocks crop out along the foreshore and are exposed at low tide (Jacquot 1864). The only extensive outcrops of any sold rock are along the coast, between the promenade du Côte des Basques in Biarritz and the mouth of the Ouhabia, whilst almost everywhere else in the area the solid rock is covered by more recent superficial deposits of late Tertiary or Quaternary age, the latter forming the subject of the present study.

South of the Pointe de Biarritz, a rugged projection into the sea, the result of resistent Oligocene rocks trending at right anges to the normal wave attack, the coastline is fairly straight and more or less continues the line of the 'cordon littoral' of the Landes. The Ouhabia is the only stream of any size reaching the sea along this stretch and none of the other coastal valleys extend back more than 2½ km. inland. In consequence, much of the area drains east to the Nive or north to the Adour via the Ruisseau de l'Aritxague, as does the valley in which one of the principal sites to be discussed, Le Moura, lies. Many of the minor valleys reaching the coast between Biarritz and the Ouhabia carry no permanent streams and are partly choked with sediments which can be clearly seen from the beach in section in the cliffs, as by the Villa Marbella, the site of other investigations.

PLATE 1. La Rhune. The photograph is taken from a point on the 75 m. platform just south of the Lac de Mouriscot. The platform is seen again in the middle distance beyond the valley of the Ouhabia.

PLATE 2. The 75 m. platform dissected by the valley of the Lac de Mouriscot.

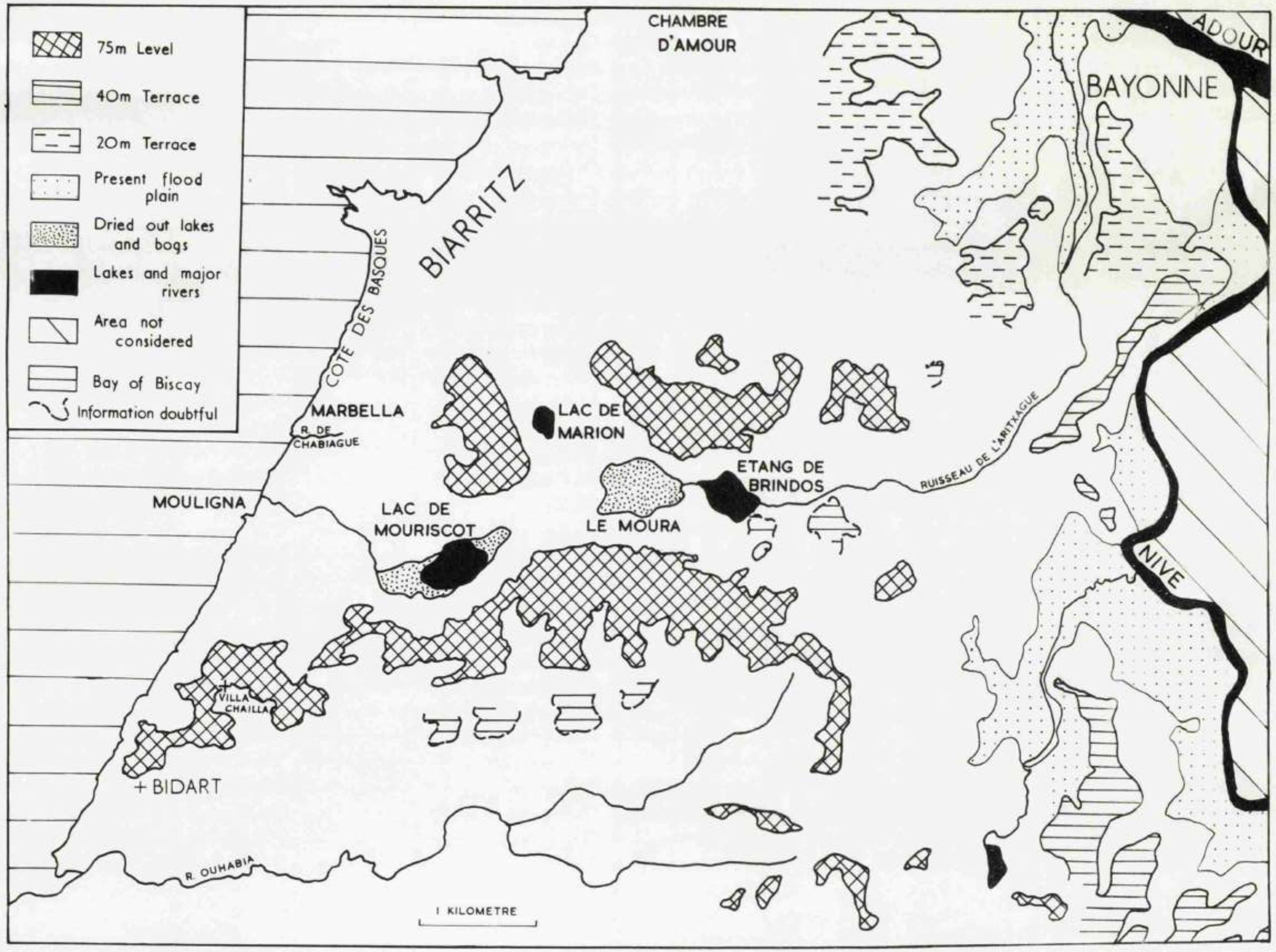

Figure 2. The Biarritz area. Erosion surfaces and general location.

The cliff sections along the coast show that in certain places, the bed rock of Eocene limestone has been dissected by deep valleys trending normal to the coast and going below present day sea level. One such valley, reaching the coast between the mouth of the Ouhabia and the coast opposite the Villa Chailla (Fig.2), is partly filled in by the oldest post-Oligocene sediments in the area, late-Tertiary (Miocene-Pliocene) torrent gravels probably contemporaneous with a late stage in the uplift of the western Pyrenees and resulting from their denudation. At Bidart, the summit of these deposits is truncated at c. 75 m. to form a level steep sided plateau which continues at approximately the same level north and east away from the limits of the gravel filled channel. Throughout the area, there is a sharply dissected summit plain at between 75 and 85 m. of which this forms the most south-westerly part. No hills rise above this level and it is remarkably uniform in height. Deler (1932) has drawn attention to it and considers it to be a dissected platform of marine origin.

Below this platform, on the eastern edge of the area, river terraces fringe the present floodplain of the Nive, forming flat-topped spurs at c.40m. above sea level. Further north, and forming much of the site of Bayonne, between the Nive, the Adour and the Ruisseau de l' Aritxague, a low steep sided terrace at c. 20m. can be seen.

More recent phases in the local morphological development can be traced from the coastal area around Mouligna (Oldfield 1960 b). Post-glacial deposits were here found lying in a valley cut partly into

Pleistocene deposits of unknown age. The post-glacial sediments themselves were being eroded by the sea. They point to a phase of infilling during post-glacial times, probably culminating with the local maximum of sea- level, preceeded by downcutting and erosion and followed by a period of rapid coastal recession which still continues at the present day.

The above geomorphological evidence, in so far as it can be co-ordinated at this stage into a local scheme of denudation chronology may be summarised as follows :-

Downcutting below present day sea level (Late Tertiary),
Deposition of torrent gravels (Late Tertiary),
Planation,probably marine, at 75 - 85 m.,
Downcutting to unknown levels,
Formation of the 40m. river terrace on the Nive,
Downcutting,
Formation of the 20 m. terrace at Bayonne, @
? ? ? ? ? ?
Downcutting to below present day sea level (? last glaciation).
Post-glacial coastal aggradation at Mouligna,
Recent coastal erosion, cliff formation and recession.

@. These heights are quite close to those recorded by Passemard (1924), although in addition, he records an intermediate terrace level at 26-34 ~~k~~m. which he finds at one point only, near Maignon,c.3km. south of Bayonne.

TABLE 1. Climatic statistics. Temperature and precipitation (Gaussen 1941). Others figures (Parrot 1960)

TEMPERATURE		J.	F	M	A	M	J	J	A	S	O	N	D	Av.	ABS.M.	abs.m
Biarritz (1851 - 1900). °C.		7.7	8.7	10	12.4	14.9	17.9	20.3	20.5	18.2	15.1	10.5	8.2	13.7	39.5	-10
°F.		46						69						57	103	14
St.Sebastian (1851 - 1900). °C.		8.3	9.1	10.1	12.4	14.6	17.6	19.6	20	18.4	15.3	11.6	8.8	13.8	40.4	-8.2
°F.		47							68					57	105	17
PRECIPITATION	Alt.m.	J	F	M	A	M	J	J	A	S	O	N	D	Total mm.	Total in.	No. Days.
Bayonne (port).	35	99	83	99	95	84	92	63	74	109	139	137	104	1178	51	140
Bayonne (seminaire).	20	110	90	111	108	102	110	72	84	124	160	148	118	1337	57	
Biarritz(grande plage).	34	97	81	102	95	89	92	64	74	109	143	131	105	1182	51	
Abbadia (Hendaye).	42	160	136	163	140	136	133	93	102	153	213	194	170	1793	77	
Irun.	20													1746	75	150
St.Sebastian.	23	107	96	120	114	105	111	78	77	121	164	157	127	1377	59	170
BIARRITZ. 1. Insolation. a).Mean no.sunshine days per month.(1890-1920).		J 19.6	F 18.7	M 20.9	A 22.5	M 22	J 24	J 24.2	A 24.5	S 25.2	O 25.9	N 17.8	D 18.3			
b).Hours of sunshine as % of max. (1901 - 1916).		42	44	45	41	42	43	50	55	58	48	40	63	Annual. 46		No.Days 278
2. Cloud cover. (1890 - 1920).		6.8	6.7	5.9	6.1	6	6.1	5.5	4.6	5.2	6	6.6	7.1			
3. Relative Humidity. (1890 - 1920).		78	78.1	73.7	77	75	76	77.9	76	77	74.8	77.9	80.4			

(iii). Local Climate.

Table 1 summarises some of the available climatological data for the area and its surroundings. The average temperature for the coldest month is some 4°F. above the threshold of vegetative growth. The ample rainfall is evenly distributed throughout the year, between a third and a half of the days being rain days and the average monthly cloud cover seldom falling below 50 percent. Whilst October is one of the wettest months, it is also one of the sunnier, has the second lowest relative humidity coefficient and is warmer than May. This prolongation of late summer is characteristic of extremely oceanic climates and the winter in the Pays Basque is very short, with snow never lying on the coastal parts of the area for a full day at a time (Gaussen 1941). Gaussen also stresses the importance of the wind along the coast, which can be an extremely stormy one with the beaches changing in height and aspect strikingly from day to day, even in summer and early autumn. At most times, the prevailing westerly winds bear a rapid succession of weather types inland, often bringing moisture laden and potentially unstable air into contact with the western edge of the Pyrenees, the situation usually resulting in high winds, thunderstorms and heavy showers.

(iv). Flora and Vegetation. (q.v. Allorge et alia, 1941).

The dominant characteristics of the flora and vegetation of the Pays Basque are the overall western, Atlantic affinities. The Most widespread local plant community, the 'touya' is a type of heathland

TABLE 2. The characteristic species of the Atlantic siliceous heath communities of La Rhune, French Pays Basque. Jovet (1941), p.70.

Pteridium aquilinum	10
Agrostis setacea	6
Avena sulvata	2
Arrhenathrum thorei	7
Danthonium decumbens	4
Nardus stricta	1
Carex binervis	2
Asphodelus albus var. pyrenaicus (Jord) R.	2
Asphodelus albus var. sphaerocarpus GG.	4
Allium ericetorum	1
Simethis planifolia	2
Scilla verna	3
Narcissus bulbocodium	2
Crocus nudiflorus	2
Romulea bulbocodium	1
Euphorbia angulata	4
Viola canina ssp. lactea Sm.	4
Ulex nanus	4
Ulex europaeus	10
Ulex gallii	2
Sarothamnus scoparius	1
Lathyrus montanus v. angustifolius Rouy,	3
Polygala serpyllifolia	6
Carum verticellatum	2
Laserpitium pruthenicum ssp. dufourianum Rouy et Camus	4
Daboecia cantabrica	4
Erica tetralix	6
Erica ciliaris	6
Calluna vulgaris	8
Erica cinerea	8
Erica vagans	10
Lithospermum diffusum	2
Veronica officinalis v. minor GG.	5
Prunella hastifolia	2
Galium hercynicum	7
Galium verum	4
Jasione perennis	4
Cirsium tuberosum ssp. filipendulum Lange	3
Serratula seoanei	4

Numbers record frequency of occurrence for 10 localities.

which, especially near the coast, contains many Atlantic and eu-Atlantic species, e.g. *Ulex nanus*, *gallii* and *europaeus*, as well as some of the Lustianian species, *Erica vagans*, *Daboecia* etc., which the Pays Basque shares with other areas to the west and north west along the shores of the Atlantic. The touya is not a natural plant community but is preserved artificially, often by quite a rigid system of exploitation and it usually contains species which the French phytosociologists consider indicative of former woodland cover, e.g. *Euphorbia amygdaloides*, and *Teucrium scorodonia*. Stands of semi-natural woodland are rare in the small area delimited above, but in the surrounding countryside, more are to be found. At low levels, *Quercus robur* forms the dominant woodland species, associated with *Fraxinus excelsior* in damper and richer situations and with *Q. toza*, whose extent has been much reduced recently by fungal attack and exploitation, on the drier, poorer acidic soils. *Quercus petraea* does not grow in the area and *Q. robur* is found locally on very acidic soils. The former role of *Q. suber* and *Pinus pinaster* in the local woodland is hard to determine since both species are subject to planting and exploitation in and around the area. *Quercus pubescens*, *Pinus sylvestris* and *Abies alba* only reach the eastern-most edges of the Pays Basque, the first on base rich soils, the second in the driest situations and the last at relatively high altitudes. Other native forest trees tend to be restricted to the rich woodland and scrub communities of the local ravines (Table 14), save for *Alnus glutinosa* which is limited to moist soils and seldom rises above 600 m. and *Fagus sylvatica* which seldom descends below 4-600 m.,

TABLE 3. *Mediterranean species growing on the Atlantic slopes of of the Spanish Pays Basque.* Allorge (1941b), p.53.

i). Species faithful to the association *Quercetum Ilicis galloprovincialis*, (9 species out of a total 16).

Quercus ilex
Ruscus aculeatus
Phillyrea media
Rosa sempervirens
Viburnum tinus
Stachys officinalis
Asplenium adiantum-nigrum ssp. *onopteris*
Calamintha adscendens
Moehringia trinervia
Luzula forsteri

ii). Species characteristic of the alliance *Quercion Ilicis*.

(3 species out of a total 12).

Smilax aspera
Pistacia terebenthinus
Euphorbia characias

iii). Species characteristic of the order *Quercetalia*, (5 out of 7).

Rubia peregrina[+]
Rhamnus alaternus
Pistacia lentiscus
Phillyrea angustifolia
Daphne gnidium

[+] Although included in this group with the other 4 species (all evergreen shrubs), this species is south-European rather than truly Mediterranean.

the usual level at which the transition from oak to beech woods takes place on the western edge of the Pyrenees.

As well as the oceanic and Lusitanian elements in the flora, the surrounding area contains scattered localities for a number of Mediterranean species, reaching here the western limits of their European range. Allorge (1941 b) and Du Pont (1955) refer to these species, and the main ones are listed in table 3. There are also species of tropical affinities, *Prunus lusitanica* and the ferns, *Woodwardia radicans* and *Gymnogramma totta.* Recently, the area has received many introduced exotic species some of which have spread sub-spontaneously and become quite conspicuous in the local landscape, e.g. *Robinia pseudo-acacia*.

PART II. THE SITES INVESTIGATED.

CHAPTER III. LE MOURA. Stratigraphical and pollen-analytical evidence.

i). Physical setting and present day aspect.

From a brief survey of the coastal sections south of Biarritz it appeared that some at least of them were probably Interglacial or Interstadial in age. In order to distinguish these deposits from the Post-glacial sediments in the area, it was necessary to produce a reliable local post-glacial diagram. Dubois' reported pollen analyses (1938), were not adequate, and moreover, as subsequent data will show, they are themselves certainly not post-glacial.

For this purpose, a site known as Le Moura was chosen,(Fig.2), a valley bog lying c.40 m. above sea-level and only 2½ km. from the coast. Despite this short distance, the outflow from Le Moura is eastwards and then north via the Ruisseau de l'Aritxague to the Adour, a total distance from the bog to the sea of some 13 km. Only a low col reaching 49 m. separates Le Moura from the Lac de Mouriscot to the west and sea-wards. The water level of the latter is at 13.5m. and it drains directly to the sea, at Ilbarritz. Both basins lie within what is, but for this low divide and other minor constrictions a continuous through valley from the coast to the Adour immediately northwest of Bayonne. The divide and the other constrictions in the valley are composed at the surface of sandy deposits. The one natural tributary of the westerly flowing drainage from the Lac de Mouriscot is 'barbed' in the typical manner indicative of reversal of drainage. From this fact, from the sandy nature of the obstructions within the valley and from what has been said above about the rapid rate of coastal erosion in the area, it is possible to deduce a certain amount about the origin of the basin within which Le Moura lies.

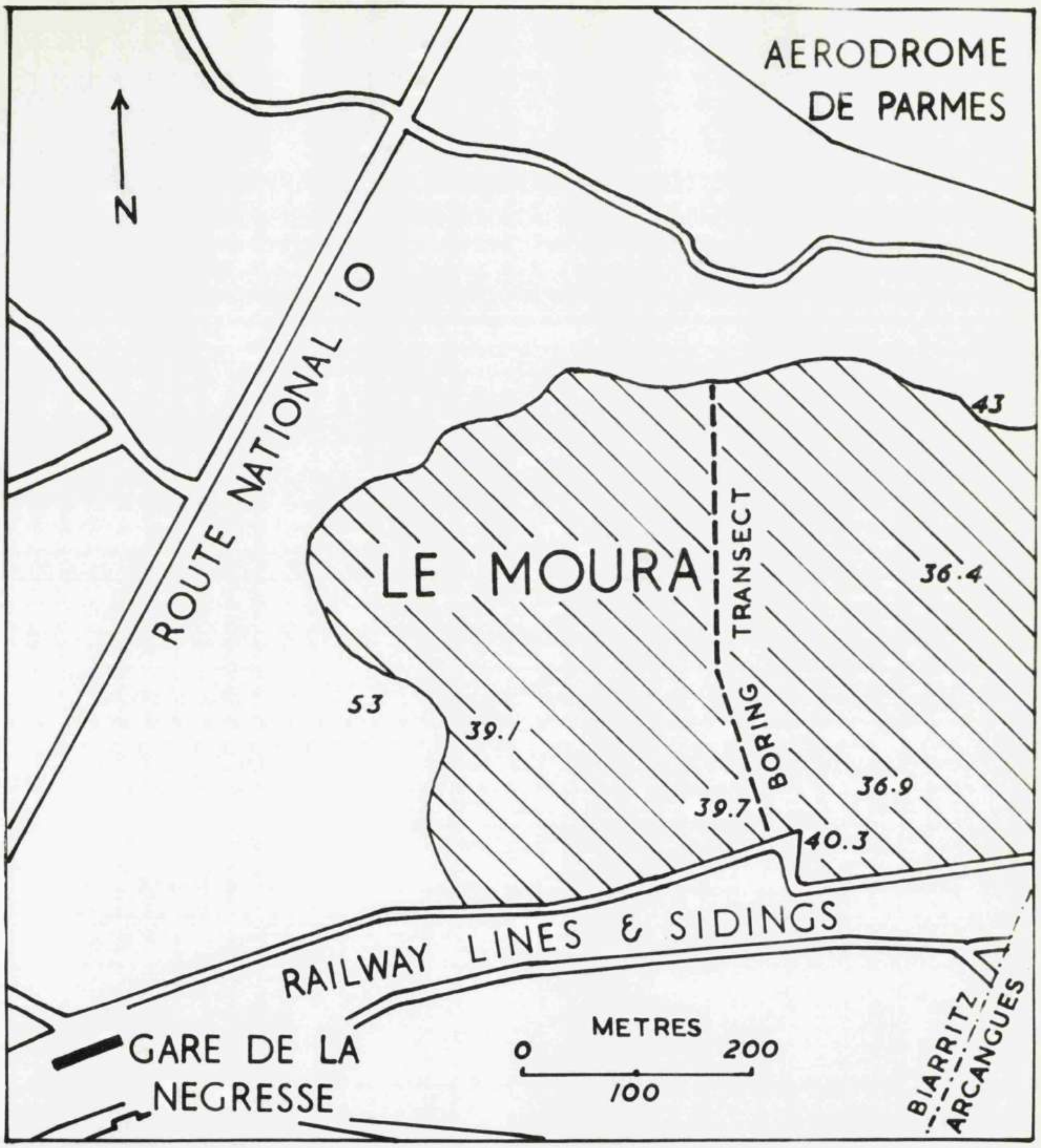

Figure 3. The site of Le Moura. Spot heights are in metres.

It is suggested that the through valley once extended further west and drained entirely towards the east and that this pattern was disrupted partly by sandy deposits giving the valley its present beaded form, partly by drainage reversal through coastal erosion into the head of the valley giving rise to headward erosion penetrating to the east as far as the present watershed.

The surface of Le Moura at the present day, is scored and pitted by artifical recilinear channels and ponds. The western edge is used as a municipal tip heap, whilst roads, buildings and the main-line railway obscure most of the southern edge of the organic infill. The eastern end of the basin is separated by a sandy area from the lower basin in which the Etang de Brindos is situated. The sandy northern rim of the bog slopes up steeply to the main Route National 10 and the Aerodrome de Parmes, both lying on the 75m. platform.

The uneven surface of the bog makes parts of it very difficult to penetrate, especially at times when the water table is high. The open water of the ponds is covered by *Nymphaea alba*, *Nuphar luteum*, and species of *Potamogeton* and *Utricularia*, and bordered by *Typha latifolia* and *Phragmites communis*. The highest and driest areas of the bog are covered by birch thicket interspersed with extensive areas of *Rubus fruticosus* agg., and *Pteridium aquilinum* with, at slightly lower levels, areas of luxuriant *Osmunda regalis*, of *Molinia coerulea* and *Deschampsia caespitosa* and of the heathers, *Calluna vulgaris*, *Erica tetralix*, *Erica ciliaris* and *Erica cinerea*. Many of the ditches contained almost impassable head high swards of *Cladium mariscus*.

ii) Stratigraphy.

A. GENERAL TRANSECT.

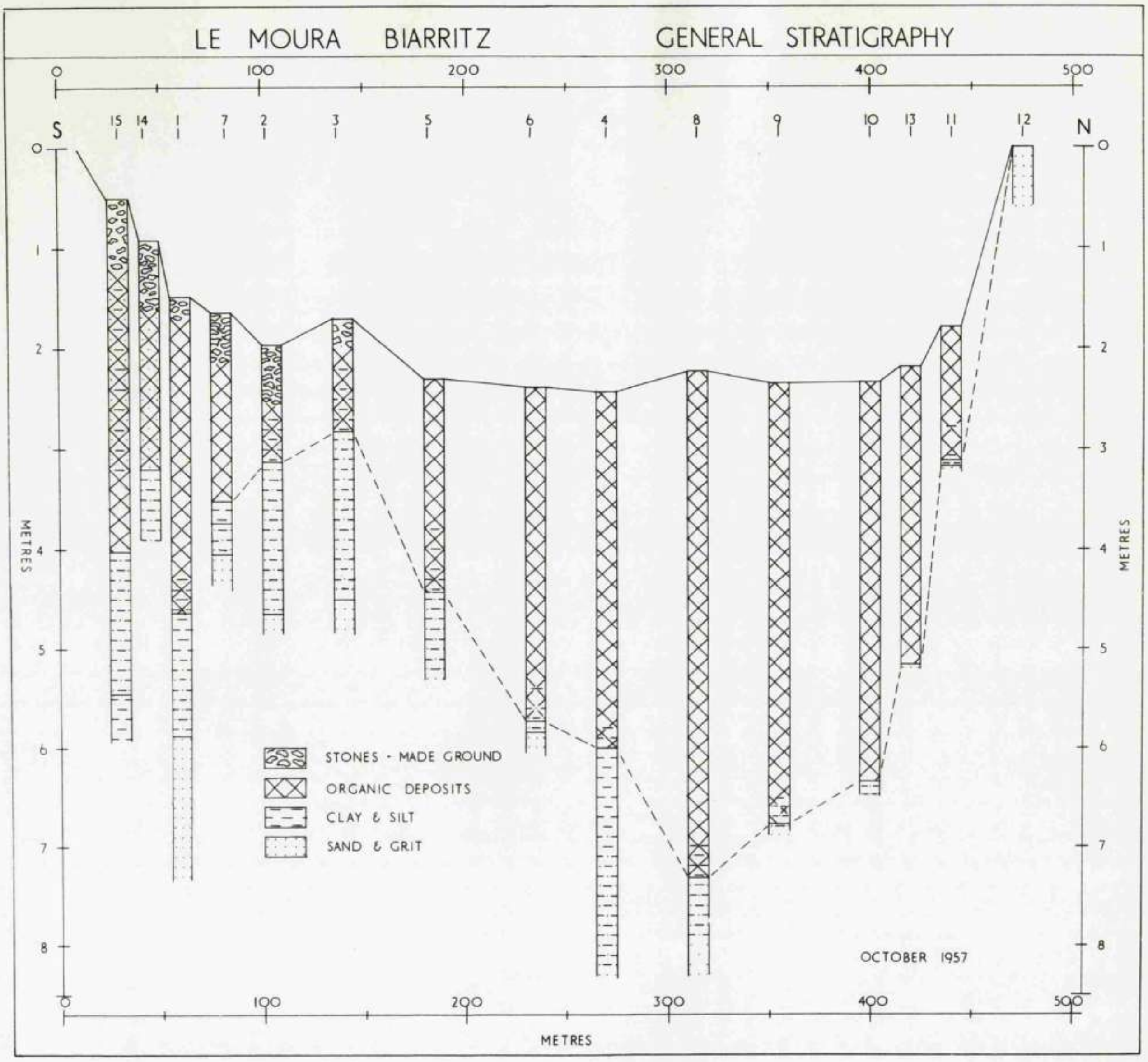

Figure 4. Le Moura. General stratigraphy transect. The pecked line does not represent a synchronous horizon, (Chapter IV).

In October 1957, Borings were carried out along the line of transect marked on Fig. 3. The results of this transect are plotted on Fig. 4. Many of the peat types were found to be very humified and some were unfamiliar to the author at the time when the work was done. The digging and sampling of deep pit sections close to borings 7 and 8 in 1958 convinced the author that much of the stratigraphy had previously been imperfectly recognised and wrongly named and interpreted. On returning to the site in 1960, an attempt to repeat most of the more important borings failed, because the very high water table during what was an exceptionally wet summer made most of the bog inaccessible. The results of the pit sections of 1958 and the repeat of boring 8 in 1960 are given in the next section. It was found impossible to re-interpret with certainty all the 1957 borings in the light of later experience and so they are represented here very simplified, with only the completely unambiguous distinctions shown.

The northern edge of the transect abuts onto a steep slope covered by superficial sand deposits, and between borings 10 and 11, the peats rest directly on a sloping sand substratum, the continuation of the bank above the bog edge. Further south, along the line of transect, between borings 6 and 9, uninterrupted organic sediments, mainly *Cladium* and *Calluna* peats alternating, are underlain by detritus muds which become clayey below and pass down into blue-green silty clays and finally into impenetrable sand. Clay-mud almost reaches the surface in borings 2, 3, and 5, where there is very little organic accumulation above the mineral sediments. Boring 1 gives a greater depth of peat accumulation once more, but in borings 14 and 15, the organic deposits are interrupted by clay and sand lenses which, south of boring 15 become so thick and persistent as to make further boring to any depth impossible, even were the road and railways not there. The top layer between borings 3 and 15 is stoney and [redacted] includes made ground.

B. DETAILED STRATIGRAPHY NEAR TO BORING 8.

A monolith was collected in biscuit tins from a 2.8 m deep pit section, 2m. south east of boring 8, in 1958, and the stratigraphy and macroscopic remains collected were examined subsequently in the laboratory. The stratigraphy of the monolith was as follows ;-

<u>Series 8a.</u>

0 - 65 cm. Not sampled.
65 - 105 cm. Sedge peat with abundant remains of <u>Cladium mariscus</u> and <u>Potentilla</u> sp.
105 - 162 cm. Very oxidised <u>Calluna</u> peat.
162 - 186 cm. <u>Cladium</u> sedge peat.
186 - 198 cm. Not sampled.
198 - 276 cm. <u>Cladium</u> sedge peat.

In 1960, field notes were made on a boring made 1m. south east of boring 8, and from the same place the top $5\frac{1}{2}$ m. out of a total depth of 6 m. was collected as a complete core in zinc liners using the modified borer (Appendix 1) . This core was cut into 5 cm. lengths in the laboratory and the macroscopic content of each length was examined. the succession of stratigraphic types recorded at this point from the two borings was as follows ;-

<u>Series 8b.</u>

0 - 8 cm. Unsampled.
8 - 30 cm. Oxidised peaty soil.
30 - 50 cm. Sedge peat with <u>Cladium</u> and <u>Potamogeton</u> fruits. Oxidised wood fragments at base.

50 - 55 cm. Very oxidised woody peat with *Calluna* twigs.

55 - 65 cm. Rather less oxidised but still slightly woody *Cladium* peat.

65 - 95 cm. *Cladium* sedge peat with no wood fragments.

95 - 100 cm. Not critically sampled.

100 - 150 cm. Very oxidised *Calluna* peat.

150 - 335 cm. Mainly *Cladium* sedge peat with little change. Occasional unidentified wood fragments.

335 - 358 cm. *Carex*-*Sphagnum* peat with a little *Calluna* and abundant *Menyanthes*.

358 - 365 cm. Woody peat with cf.*Betula* remains and occasional seeds of *Nymphaea alba* and fruitstones of *Potamogeton* sp.

365 - 370 cm. Brushwood peat with large twigs of *Betula* and some silt and sand.

370 - 390 cm. Woody peat with *Calluna* twigs.

390 - 395 cm. Large wood fragments of.*Betula*.

395 - 406 cm. *Carex* peat.

406 - 460 cm. Reedswamp peats with abundant *Phragmites* and coarse plant detritus in a pale brown muddy matrix.

460 - 486 cm. Detrital clay-mud.

486 - 550 cm. Clay silt becoming coarser to base. Almost completely without plant detritus.

In so far as the above two stratigraphic series, 8a and 8b overlap, they present a consistent picture of *Cladium* peats below 160 - 150 cm., succeeded by highly oxidised *Calluna* peat up to c. 105 - 95 cm. which is in turn overlain by *Cladium* peat.

C. OTHER PIT SECTIONS.

A shallow pit was dug at the site of boring 3. Biscuit tin samples were taken between 80 and 127 cm., and they recorded clay-mud above 110cm., silty clay with little plant detritus below. In view of data obtained from the third of the pit sections, discussed below, no further examination of these samples was undertaken.

The stratigraphical record from the third pit, that close to boring 7, was as follows ;-

Series 7a.	0 - 82 cm. Unsampled.
	82 - 192 cm. Rather oxidised sedge and Calluna peats.
	192 - 215 cm. Clay-mud becoming increasingly clayey towards the base.
	215 - 250 cm. Detrital clay, becoming sandy at base.

iii) The pollen diagrams.

A. THE MAIN SERIES, (boring 8).

Figs. 5 to 13 include all the pollen analytical evidence from the main series. None of the usual West European schemes of Zone numbering has been used initially since the possible chronological significance of the episodes will only emerge after ecological discussion and interpretation. The letters and numbers chosen are thus primarily for descriptive purposes.

ZONE F. 600 - 554 cm.

In this zone, tree pollen never forms more than 2.5 percent of the total nonaquatic pollen sum (Fig. 11). No Betula pollen is recorded through occasional grains of Quercus, Alnus, Fagus and Corylus pollen are found. Definite bog and aquatic types are completely absent and the most abundantly recorded taxa are Gramineae, Liguliflorae and

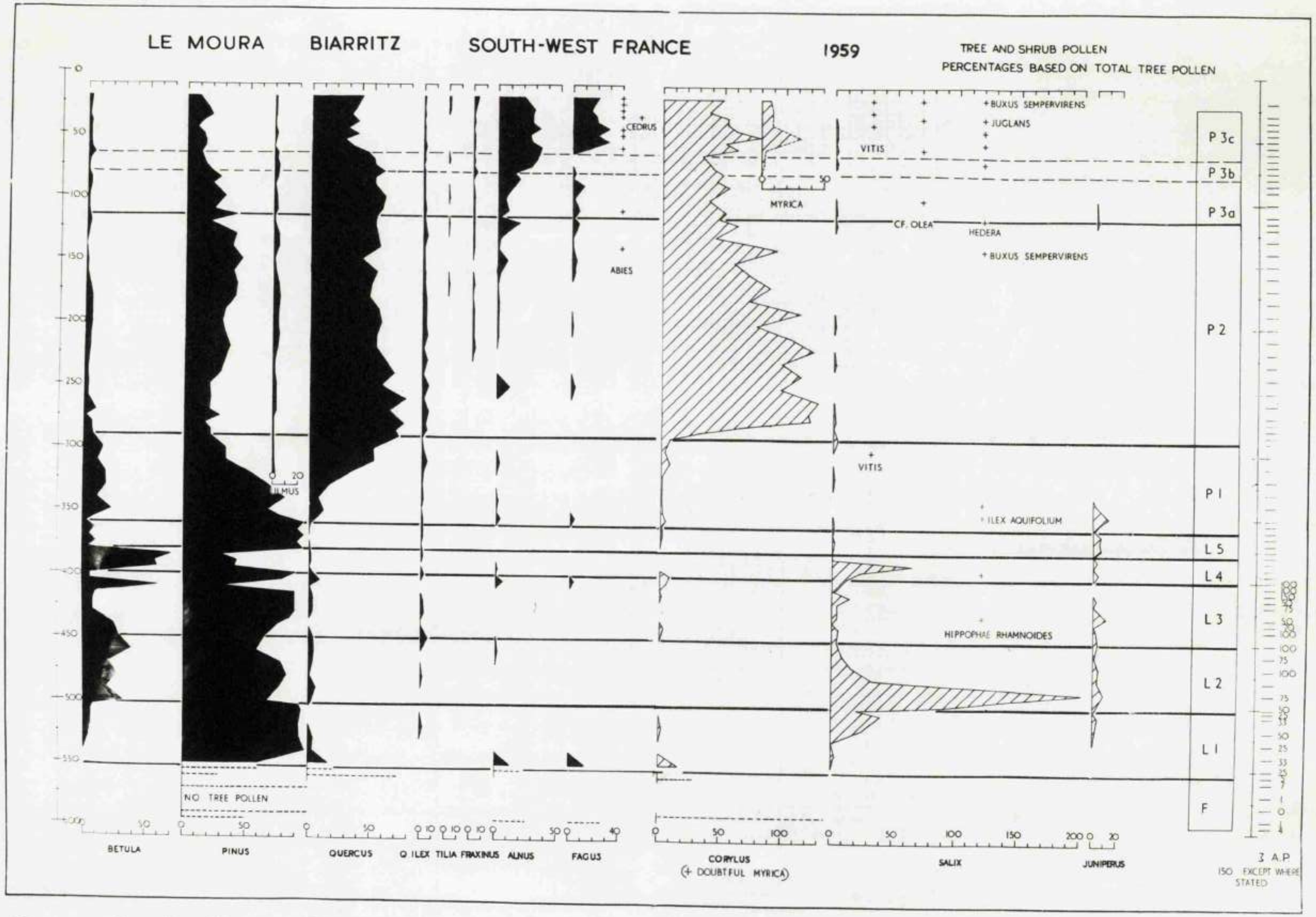

Figure 5. Le Moura. MAIN SERIES. Tree and shrub pollen types.

Percentages based on total tree pollen less Corylus and Salix.

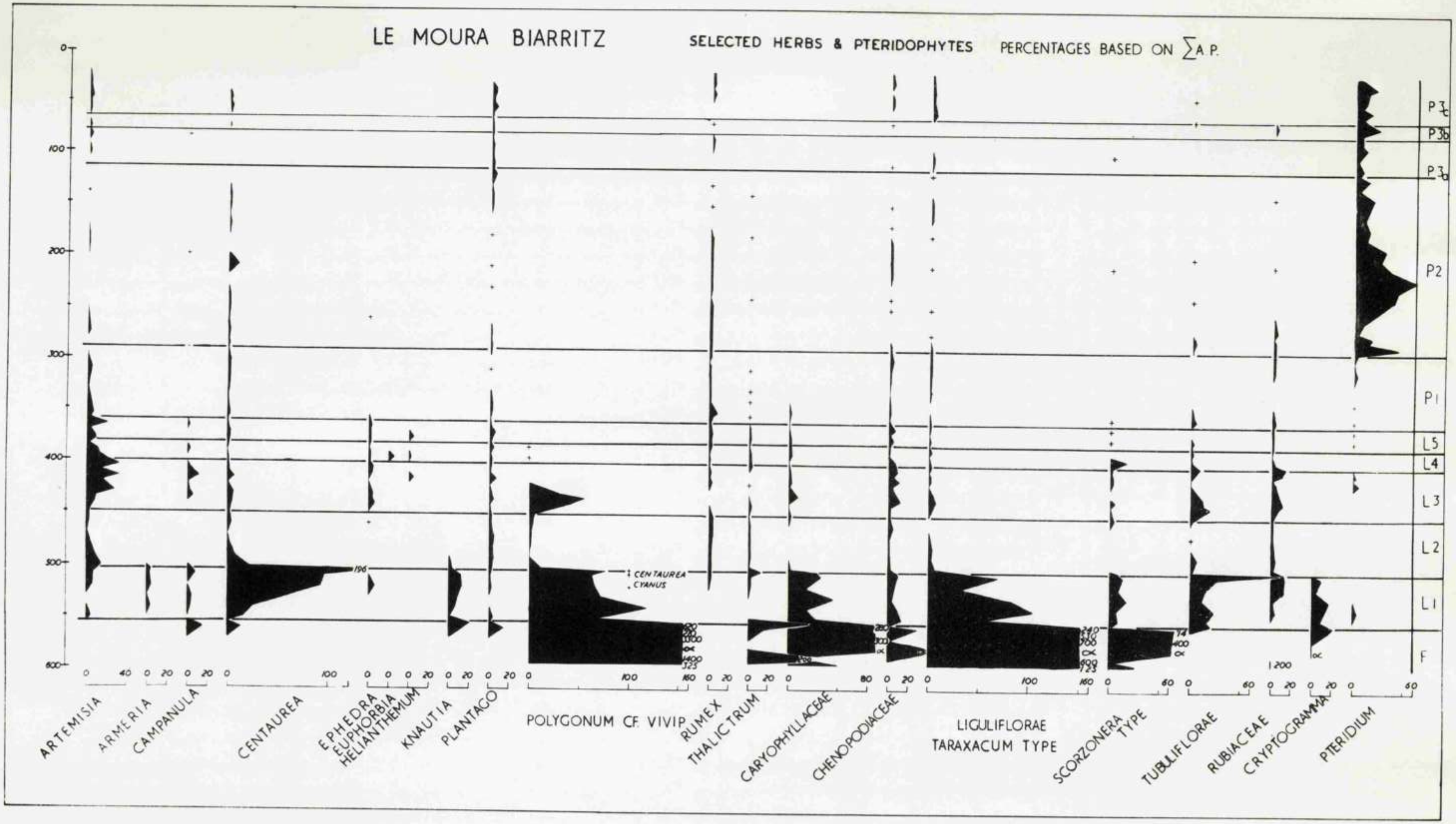

Figure 6. Le Moura. MAIN SERIES. Non-aquatic and mainly heliophilous taxa.

Percentages based on total tree pollen less *Corylus* and *Salix*.

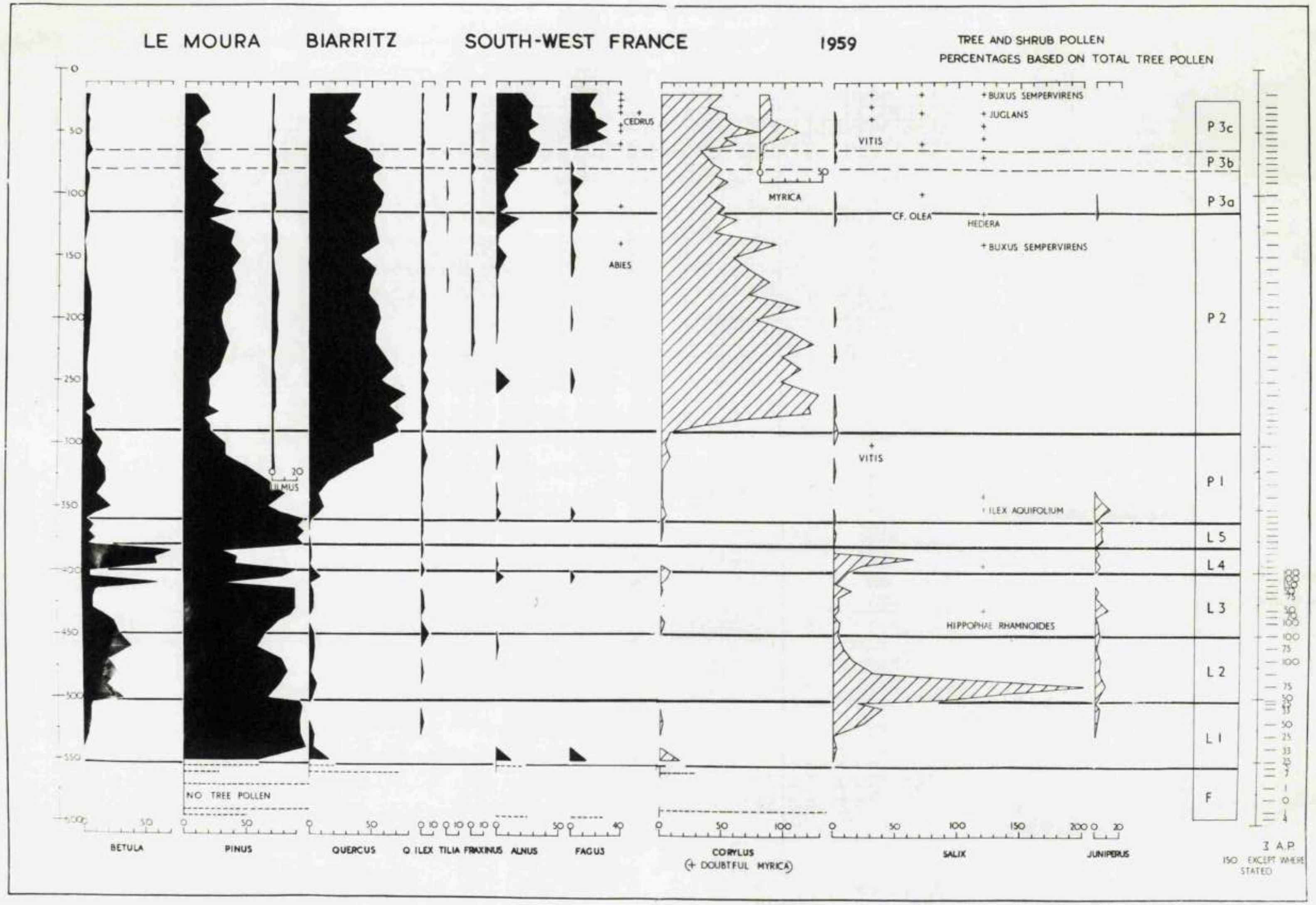

Figure 5. Le Moura. MAIN SERIES. Tree and shrub pollen types.

Percentages based on total tree pollen less Corylus and Salix.

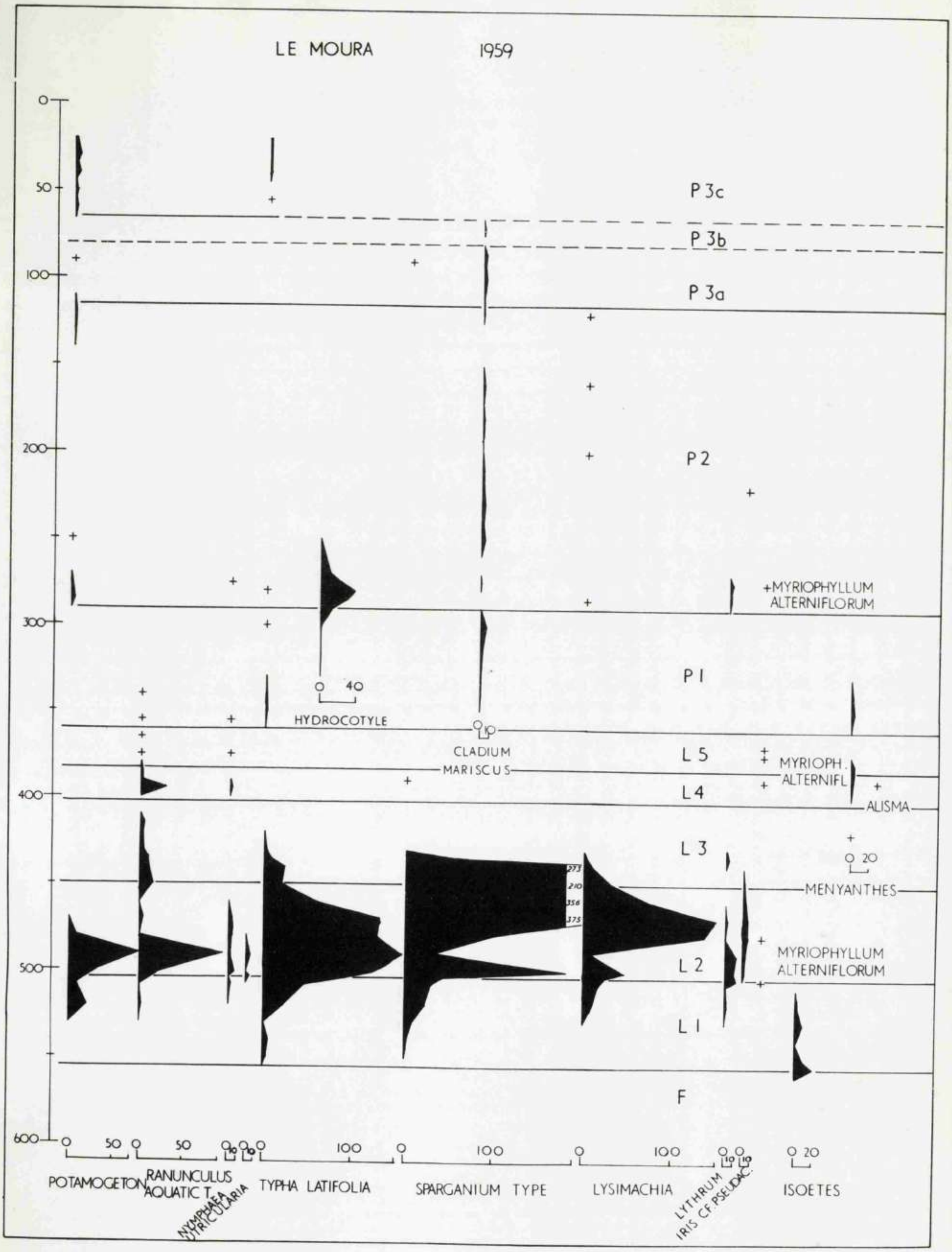

Figure 7. Le Moura. MAIN SERIES. Aquatic and semi-aquatic types.

Percentages based on total tree pollen less Corylus and Salix.

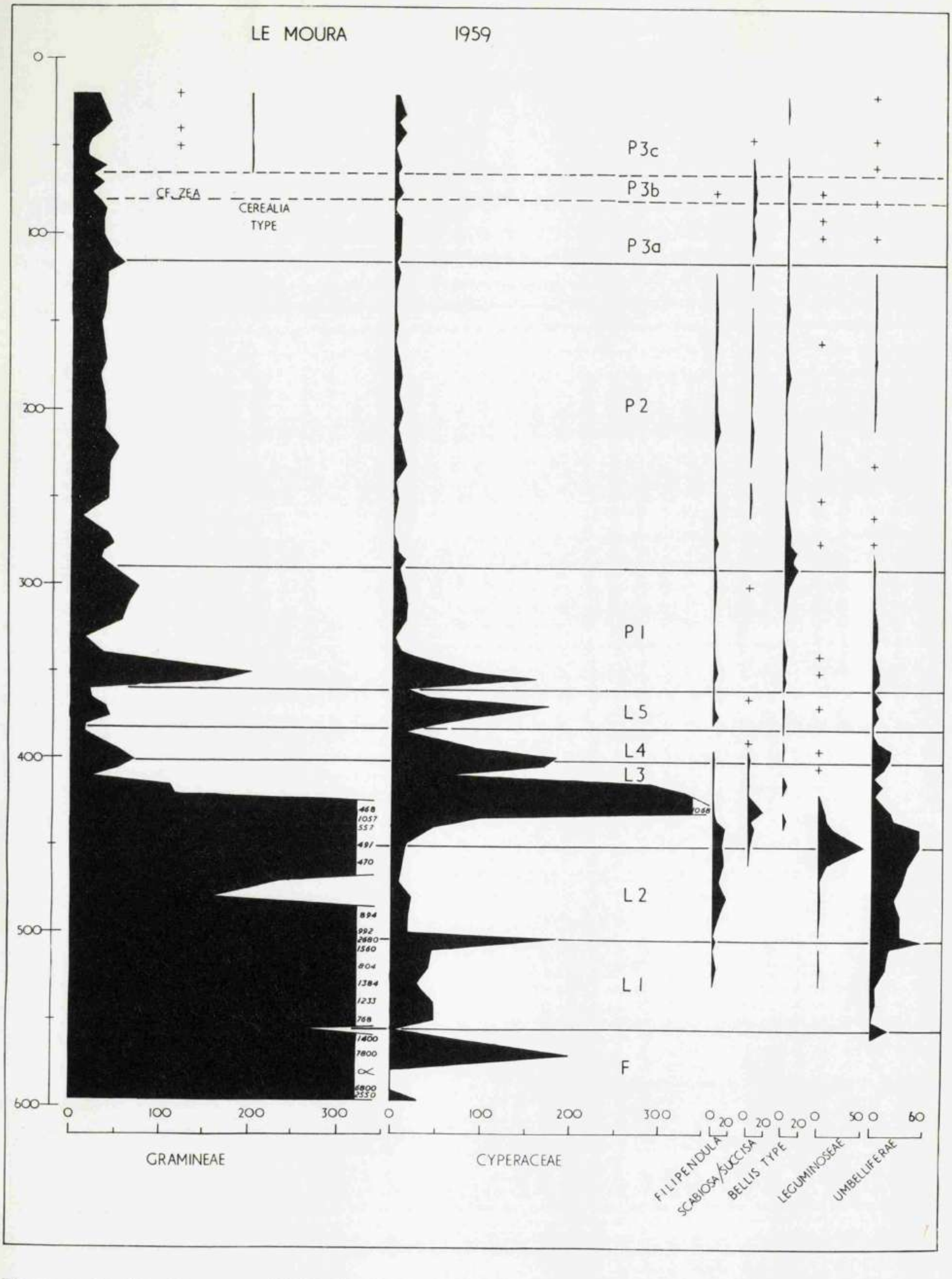

Figure 8. Le Moura. MAIN SERIES. Grasses, sedges and some probable aquatics. Percentages based on total tree pollen less Corylus and Salix.

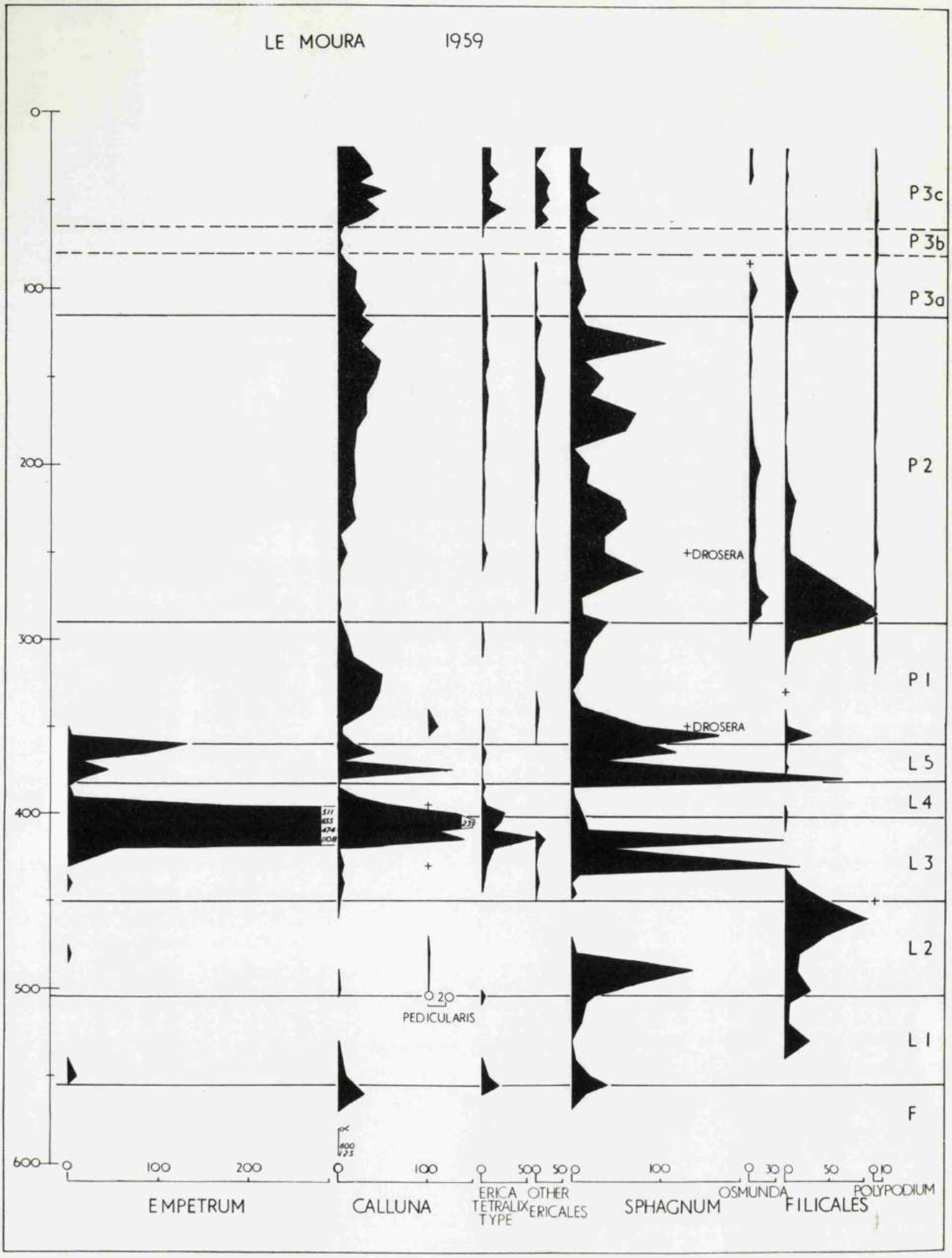

Figure 9. Le Moura. MAIN SERIES. *Ericales*, bog types and pteridophytes.

Percentages based on total tree pollen less *Corylus* and *Salix*.

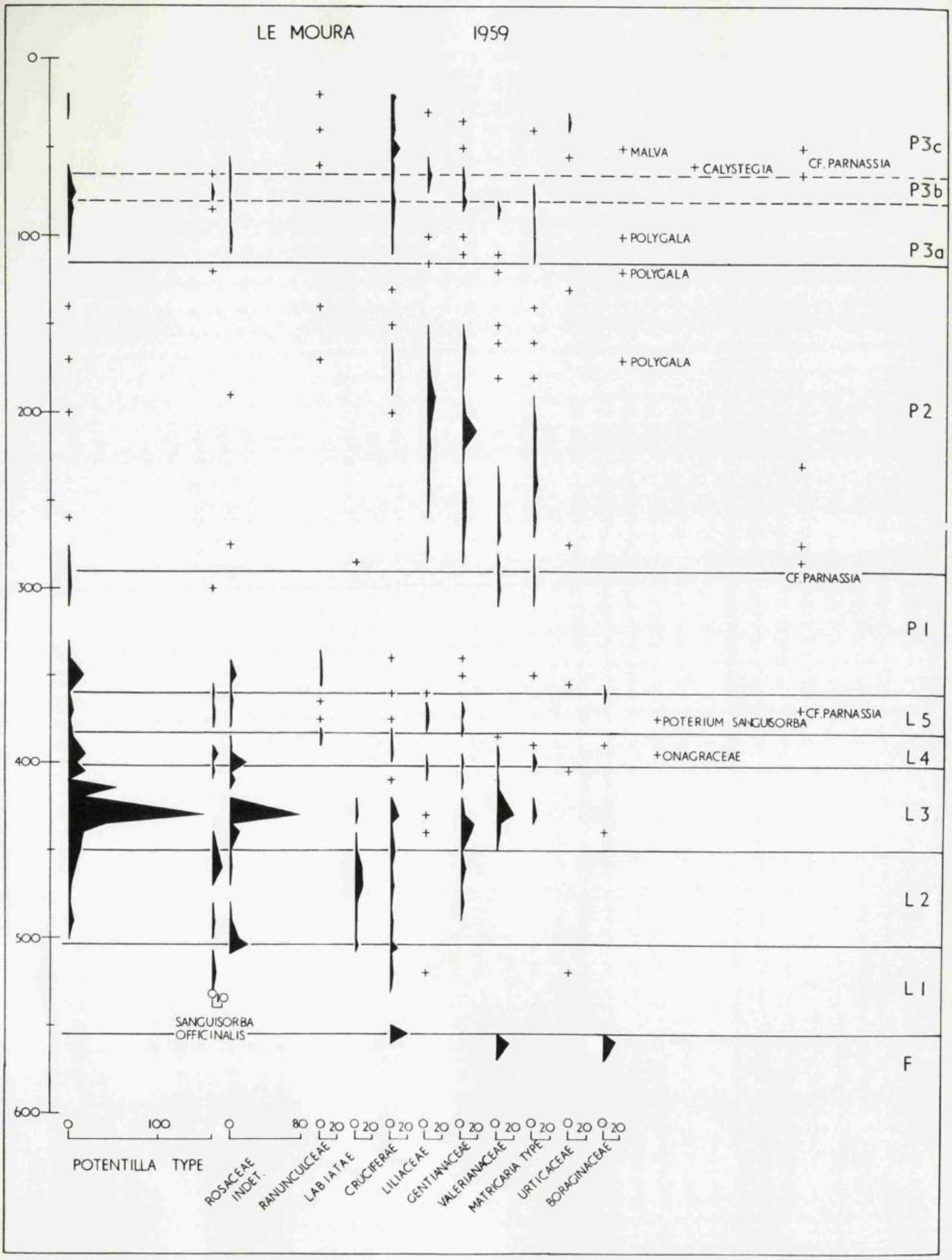

Figure 10. Le Moura. MAIN SERIES. Remaining herb pollen types.

Percentages based on total tree pollen less *Corylus* and *Salix*.

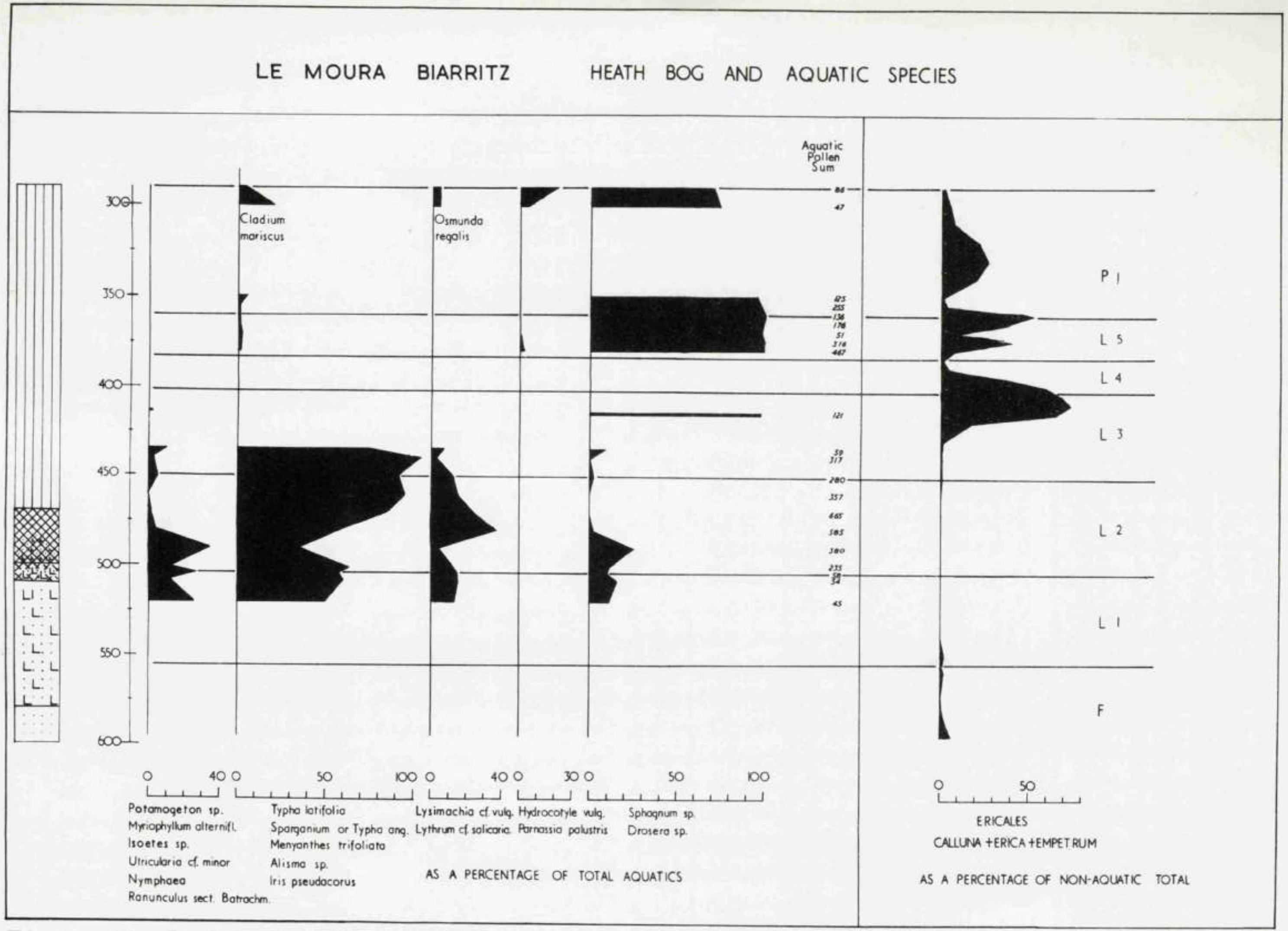

Figure 11. Le Moura. MAIN SERIES. Heath, bog and aquatic types recalculated.

Stratigraphic symbols :- Vertical shading - peats. Cross-hatching - detritus muds. Dots - sand. L - clay and silt. Based on field notes for Boring 8 (General transect). For fuller detail see Ch. III & IV.

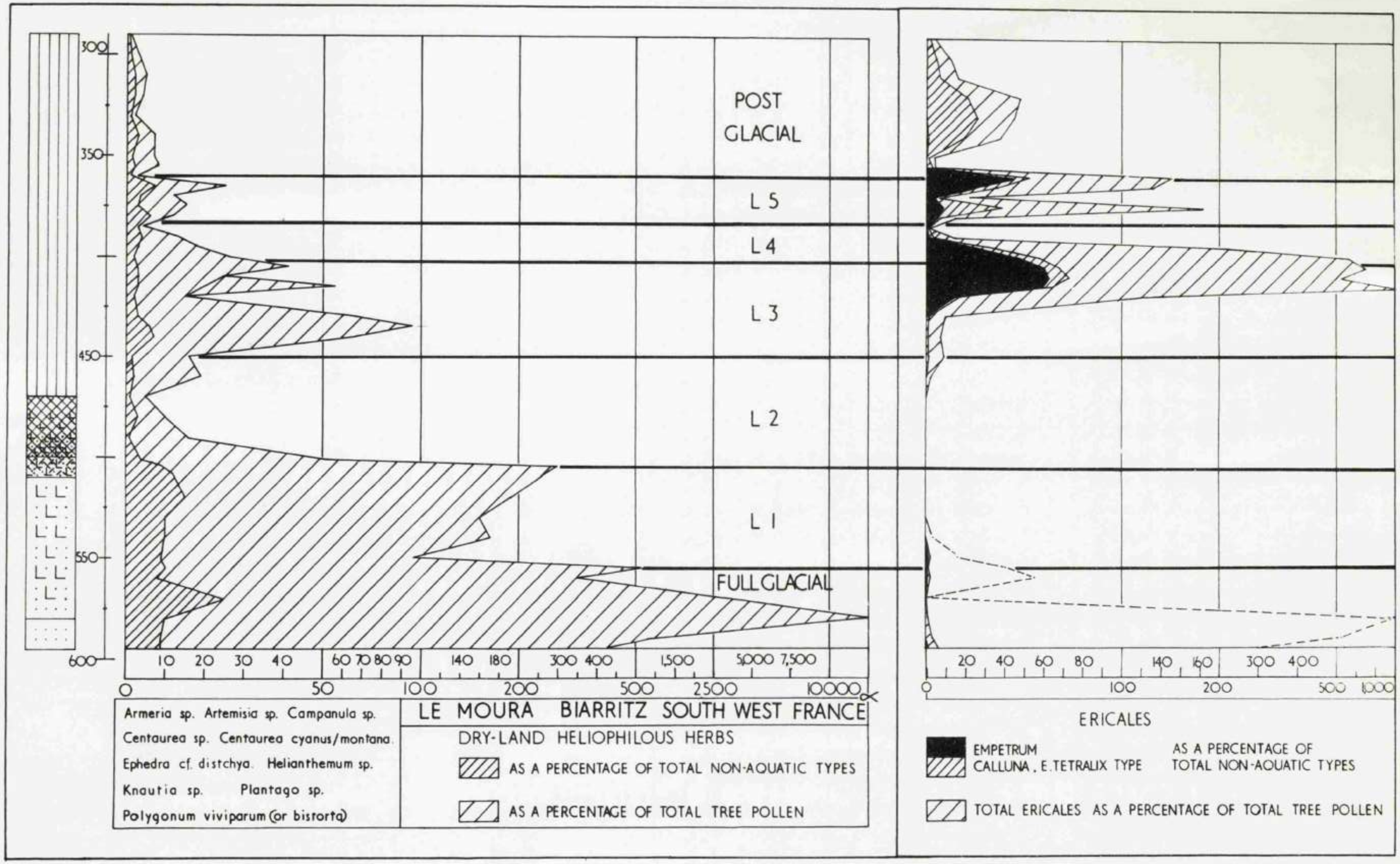

Figure 12. Le Moura. MAIN SERIES. Heliophyte ratios and Ericales. (Late-glacial).

Stratigrapgy as for Fig. 11.

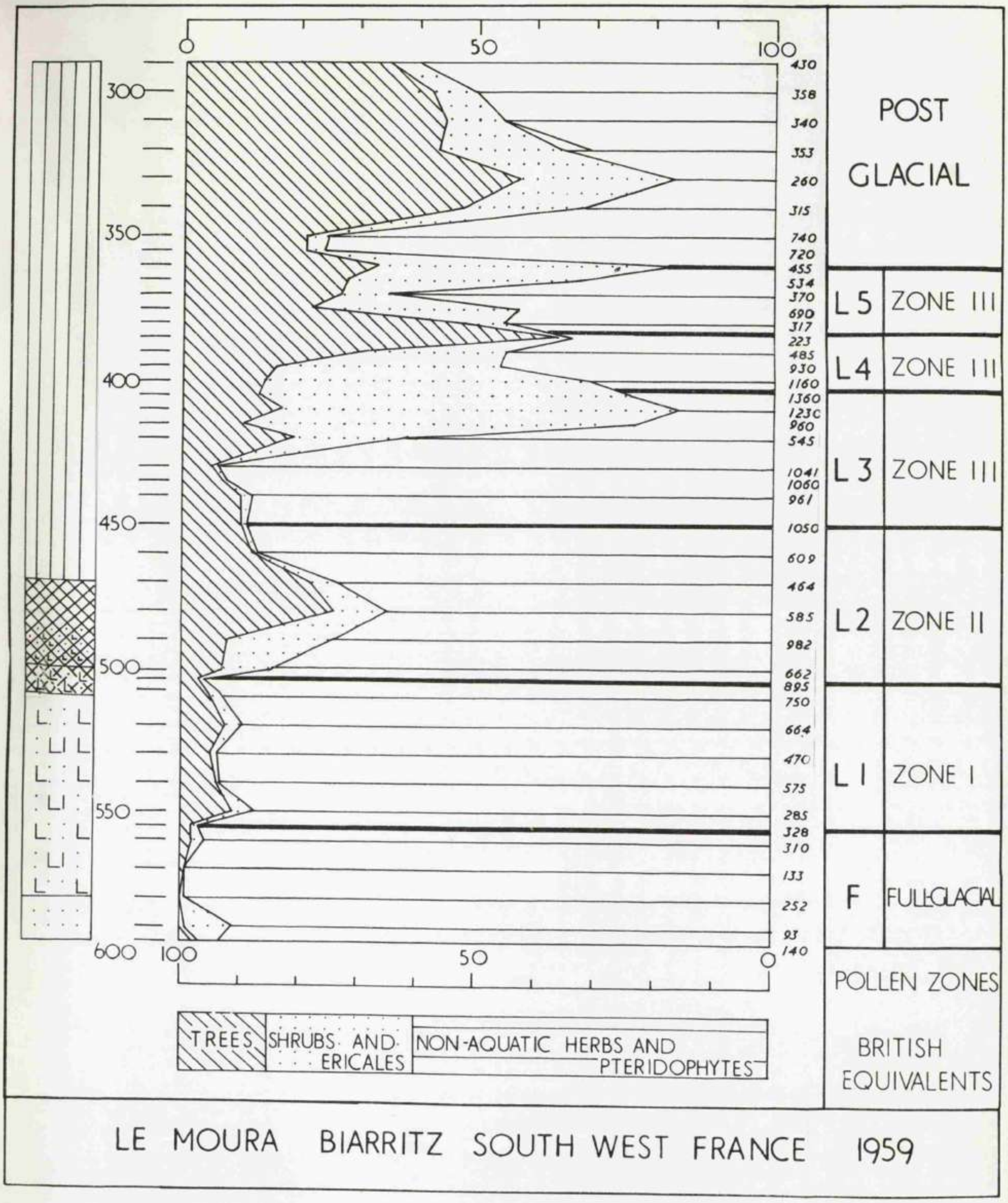

Figure 13. Le Moura. MAIN SERIES. Total pollen diagram, (late-glacial). Percentages based on total non-aquatic pollen sum.

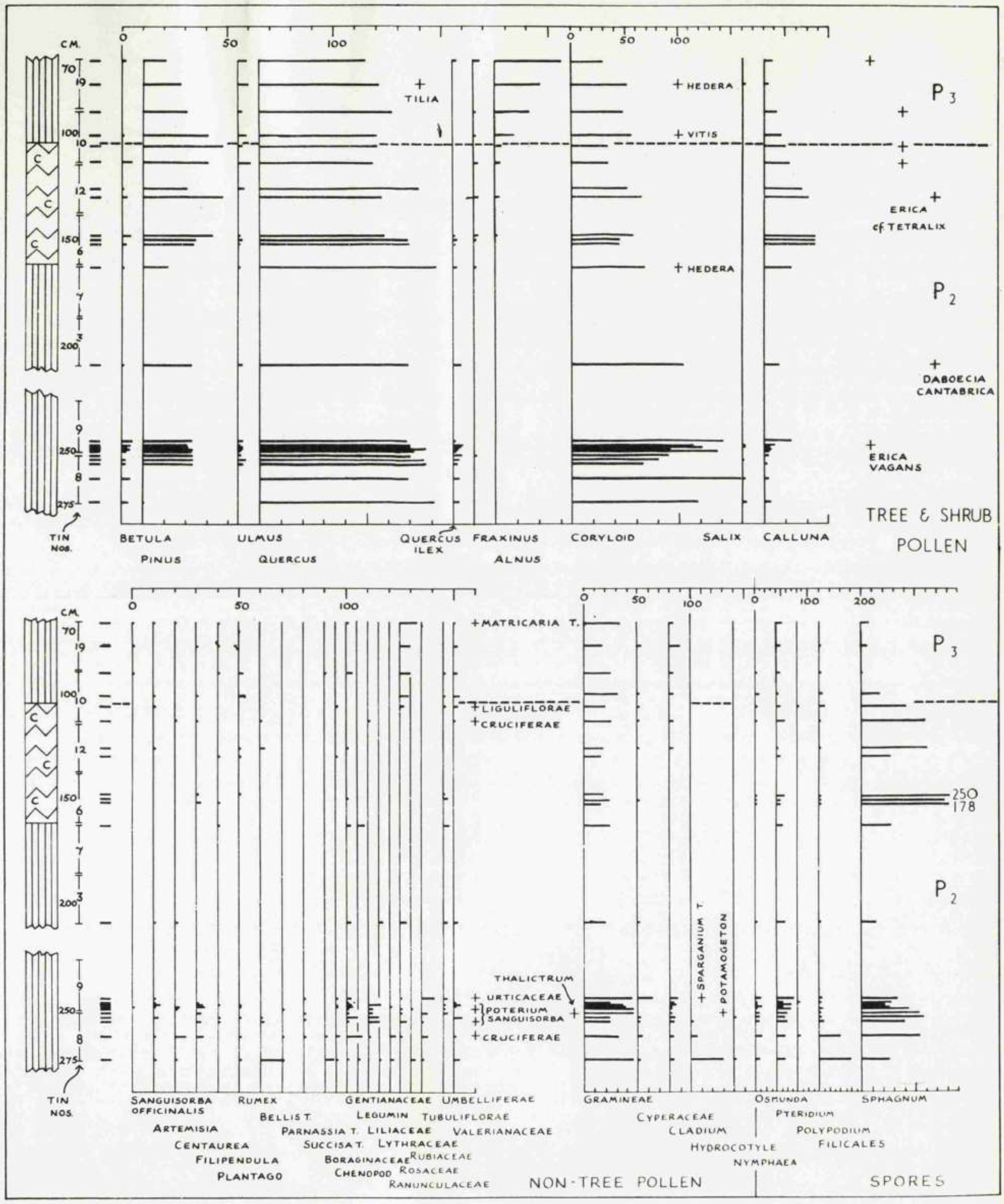

Figure 14. Le Moura. POLLEN SERIES 'B'. (Stratigraphical Series 8a). Percentages based on total tree pollen less Corylus and Salix. Stratigraphy :- Vertical lines - Sedge peat (mainly Cladium). Diagonal lines - Calluna peat, (C). Radiocarbon dates on the samples taken from this section are not yet available.

Polygonum cf. *viviparum*.

ZONE L_1. 554 - 501 cm.

At the base, tree pollen frequencies rise from 2 to over 8 percent of the total non aquatic pollen sum and *Betula* pollen makes its first appearance just above this level as do many of the aquatic types. The non-aquatic herbaceous flora is also greatly enriched at about this level by eg. *Tubuliflorae* types, including *Artemisia*,*Centaurea* and others, *Cryptogramma crispa*, *Armeria maritima* and, at the top of the Zone *Ephedra* cf. *distachya* and *Centaurea cyanus* [illegible].

ZONE L_2. 501 - 450 cm.

At the base of this Zone, *Betula* frequencies rises to 25 - 30 percent of the tree pollen sum and non-aquatic herb pollen frequencies fall very steeply. High *Salix* pollen values accompany the beginning of the *Betula* maximum but they fall steeply before the middle of the Zone. Aquatic and reedswamp species are represented by very high pollen frequencies during the period. In the middle of Zone L_2 the frequency of the heliophilous herbs shown in Fig. 6 falls below 8 percent of the tree pollen sum.

ZONE L_3. 450 - 403 cm.

The beginning of the Zone is marked by falling *Betula* frequencies, offset by rising pine. Heliophyte frequencies also increase relative to both the tree pollen sum and the total non-aquatic pollen sum (Fig.6), reaching almost 100 percent of the former and 8 percent of the latter. The heliophyte flora is rich and varied and the pollen frequencies of aquatic species greatly reduced. *Sphagnum* and the *Ericales* are much more important than in the previous Zone.

ZONE L_4. 403 - 382 cm.

Three samples record a striking *Betula* maximum during this Zone; a *Salix* peak is also recorded and the heliophyte tree pollen ratio falls through the heliophyte non-aquatic pollen sum ratio hardly changes (Fig.6)

ZONE L_5. 382 - 360 cm.

Betula frequencies fall once more and pine dominates the tree pollen rain. Heliophyte frequencies rise and *Sphagnum* and the *Ericales* pollen types also increase in abundance.

ZONE P_1. 360 - 290 cm.

Quercus pollen frequencies increase fairly steadily fron nil at the base of the Zone, to c. 70 percent of the tree pollen sum at the top. At the same time, heliophyte frequencies fall rapidly. *Betula* pollen frequencies rise slightly and remain between 10 and 20 percent of the tree pollen sum for the whole Zone.

ZONE P_2. 290 - 130 cm.

Corylus pollen frequencies rise sharply at the base of the Zone, to over 120 percent of the tree pollen sum. During the rest of the Zone, they fall gently, along with those of *Quercus*,whilst *Pinus* frequencies rise.

ZONE P_{3a}. 130 - 80 cm.

From the base of the Zone to the top, *Alnus* frequencies rise irregularly and *Pinus* frequencies fall.

ZONE P_{3b}. 80 - 65 cm.

During this phase, the trends noted in 3a are continued, but *Quercus* and *Corylus* pollen frequencies also fall quite steeply.

ZONE P_{3c}. 65 - 20 cm.

At the base of the Zone, Fagus values rise steeply to over 20 percent of the tree pollen sum, mainly at the expense of Quercus. Pollen records of Cedrus sp., Cerealia type, Zea and Juglans may be noted from this Zone.

B. - POLLEN SERIES 'B', (Fig. 14).

This series was constructed from pollen samples taken, in the laboratory, from the monolith of the pit section (Series 8a.) close to boring 8. The lowest pollen samples from near to the base of the series at 276 cm. included high frequencies of Corylus. Filicales and Hydrocotyle vulgaris, which relate them to the early Zone P_2 analyses between 260 and 280 cm. in the main series. The remainder of this Zone, as well as Zone P_{3a} and P_{3b} are also represented. No samples were taken from above 65 cm. because of the danger that fresh rootlets from the present day surface may have penetrated the upper layers of peat, so ruining them from the point of view of radiocarbon assay. Differences between series 'B' and the main diagram are discussed below.

C. - POLLEN SERIES 'C'.

Table 4 records the pollen analyses from the monolith (Series 7a), collected close to the site of boring 7. All the analyses from top to bottom of the monolith fall within Zone P_2 as defined on the main series.

D. - POLLEN ANALYSES FROM THE STRATIGRAPHICAL SERIES .

The core (Series 8b), collected from near to boring 8, in 1960, for the purpose of detailed stratigraphic and macroscopic examination in the laboratory was related to the main pollen series by means of 3 pollen analyses (Table 5) from 40, 365 and 440 cm. They can be shown to compare with the pollen frequencies in the main series at 60, 385 and 460 cm. respectively.

Table 6 compares and correlates by means of the pollen analyses the data from the main series, series 'B' and 'C' and the stratigraphical core.

Table 7 records measurements carried out on the 'bodies' of pine pollen grains from parts of the pollen diagrams and also from contemporary moss polster samples under stands of Pinus sylvestris and Pinus uncinata near the tree line between the Pont d'Espagne and the Lac de Gaube just south of Cauterets in the Central Pyrénées (Fig.15).

iv). Records of macroscopic plant remains.

Table 8 includes all the macroscopic records from the site. They come principally from the monolith near to boring 8 and from the cores taken from the later boring near the same point. By means of the correlations discussed above and summarised in Table 6, they are related in Table 8, to the pollen zones defined on the main diagram.

v). List of photomicrographs.

Appendix III includes photographs of the following pollen grains from the deposits at Le Moura :-

Daboecia cantabrica (Zone VIIa), Erica vagans (Zone VIII), Empetrum nigrum, (Zone III), Erica cf. tetralix (Zone VIII), Pinus cf. sylvestris (Zone VI), Pinus cf. uncinata (Zones I and III), Euphorbia sp. (Zone III), Polygonum cf. viviparum (Zone III), Knautia sp. (Zone I).

TABLE 4. Pollen Series 'C'. Pollen analytical data from stratigraphical series 7a.

The figures are percentages of total tree pollen less *Corylus* and *Salix*.

	82	94	118	142	166	180	250 cm.
Betula	2		4	4	6	9	2
Pinus	41	37	45	24	35	25	42
Ulmus	1		5	6	1	3	
Quercus	51	66	40	64	56	58	54
Quercus ilex	5		5	1	2	4	
Tilia				1			
Alnus	1	2	1			1	2
Corylus	12	16	38	93	100	61	76
Salix			1				
Hedera						1	
Vitis	1						
Calluna	1		2	2			
Erica sp.	1			1			
Gramineae	14	16	18	63	74	69	49
Cyperaceae	19	72	111	2	1		4
Polygonum bist/viv.							1
Poterium sang.						1	
Sanguisorba offic.	8	6					
Artemisia			1	1			1
Centaurea	1					2	20
Euphorbia					1		5
Filipendula	55	38		3	1		9
Bellis T.				1			
Matricaria T.	8	8		1			
Potentilla T.	1			1		5	
Rumex				1			
Scabiosa/Succisa		2	2				
Scorzonera T.					4		2
Thalictrum							2
Boraginaceae		2					2
Campanulaceae							1
Caryophyllaceae					1		4
Chenopodiaceae							1
Cruciferae	4				2		3
Gentianaceae				1	1		1
Liguliflorae	8	8					1
Liliaceae	1						12
Ranunculaceae						3	1
Rosaceae						2	2
Rubiaceae	1		3				
Tubuliflorae						1	6
Umbelliferae				4		4	3
Valerianaceae	1		6				
Cladium mariscus							1
Lythrum cf.salic.							1
Sparganium T.			20	1	2		
Filicales	164	66	121	1	3		
Osmunda	9	8	6				2
Polypodium			1		1		7
Pteridium	6	14	11	13	2	5	190
Sphagnum	1	2	61	33	11	17	
TREE POLLEN TOTAL	100	50	100	100	100	100	100

TABLE 5. Pollen analyses from the Stratigraphical Series, (Boring 8b), Le Moura.

Sample depth, cm.	40	365	440
Betula sp.		66	12
Pinus sp.	10	34	76
Quercus	43		12
Ulmus	1		
Alnus	36		
Fagus	10		
TREE POLLEN SUM	100	30	33
Corylus	61		3
Salix		66	18
Calluna vulg.	33	93	
Daboecia cantab.	1		
Erica tet.	7		
Erica vagans.	1		
Vaccinium T.		7	
Empetrum nigrum		80	
Boraginaceae		14	
Chenopodiaceae		7	
Cruciferae	2		
Gentianaceae			6
Leguminosae			6
Liliaceae	2		

Sample depth, cm.	40	365	440
Artemisia		20	
Centaurea			9
Euphorbia		7	+
Filipendula		7	3
Plantago	1		
Potentilla T.			6
Rumex			6
Thalictrum			3
Cerealia T.	1		
Lysimachia			48
Menyanthes		7	
Nymphaea	1		
Potamogeton	3		
Sparganium T.			183
Typha latifolia			36
Gramineae	44	93	318
Cyperaceae	1		
Ranunculaceae		7	
Tubuliflorae		7	
Umbelliferae			18
Filicales			72
Pteridium	12		
Sphagnum	27	140	3
Total number of pollen and spores -	300	100	275

All figures are precentages based on total tree pollen less Corylus and Salix. Counts have been continued only to the point where the analyses permitted approximate correlation with the main series. The samples relate to those in the Main Series at 60, 385 and 460 cm. respectively.

TABLE 6. Correlations between different pollen-analytical and stratigraphic series at Le Moura.

A. POST-GLACIAL. Relationship between stratigraphic and pollen zone boundarie

Pollen anal. Horizons.	Boring 8 Main series. Figs.5-13.	Pit section 8a Pollen series B Fig. 14.	Boring 8b Pollen series Table 5.	Pit section(7). Pollen series C Table 4.
			Sedge peat	
P 3b/c.	65 cm.	Not sampled.	50 cm.	Not recorded.
			Oxid. *Calluna* peat.	
	Cladium peat	*Cladium* peat	*Cladium* peat	
P 2/3a.	120 cm.	105 cm.	c.100 cm.	Not recorded.
↑	Oxid. *Calluna* peat.	Oxid. *Calluna* peat.	Oxid. *Calluna* peat.	↑
				Sedge and *Calluna* peats
P 2	*Cladium* and *Calluna* peats			192 cm.
↓				Clays and clay muds ↓

B. LATE-GLACIAL. Correlation of stratig.series (8b.pp.25-26) with Main series.

Stratigraphical series.		Main series.	
Stratigraphic type.	Depth.	Depth.	Pollen analytical features.
Cladium peat			
	335 cm.	c.360 cm.	L5/P1 boundary
Carex-*Sphagnum* peat			High *Sphagnum*, *Cyperaceae* and *Ericales*.
	358 cm.	c.382 cm.	L4/5 boundary
Betula remains, (cf).			*Betula* maximum.
	370 cm.	c.395 cm.	early zone L 4.
Calluna peat			*Calluna*-*Empetrum* maximum.
	390 cm.	c.412 cm.	late zone L3.
Betula twigs, (cf).			Single *Betula* peak.
	395 cm.	c.417 cm.	late zone L3.
Carex peat			*Cyperaceae* peak.
	406 cm.	c.425 cm.	mid-zone L3.
Reedswamp peat			*Typha*, *Sparganium* etc.
	460 cm.	c.485 cm.	early zone L2.
Detrital clay-mud			Aquatic and swamp species
	486 cm.	c.510 cm.	late zone L 1.

TABLE 7. Pine pollen measurements.

1 division = 1·8 microns.	<20	20	21	22	23	24	25	26	27	28	29 divisions
A	2		2	9	3	24	20	10	8	8	5
B	4	9	17	21	18	19	11	5	3	1	
C			4	7	3	4	7	9	7	11	7
F 1	1	2	3	1	4	4	2	5	6	8	3
F 2			2	2	5	9	11	9	5	2	4

1 division = 1·8 microns.	30	31	32	33	34	35	36	37	38	39	40+ divisions.
A	3	3	1					1			2
B		2	2	1							
C	6	7	1			4	6	2	2	2	3
F 1	3		1								
F 2	1				2						

Site A. At c. 1680 m., in Pinus sylvestris zone near to Cauterets.

Site B. At c. 1800 m., in Pinus uncinata zone near Lac de Gaube, Cauterets.

Site C. At c. 1850 m., near summit of Col de Pourtalet.

Series F 1. Le Moura. Pine pollen from the stratigraphical series (boring 8b) at 440 cm. (= 460 cm., Main Series).

Series F 2. Le Moura. Pine pollen from the stratigraphical series (boring 8b) at 365 cm. (= 385 cm., Main Series).

The feature measured is the longest dimension of the pine pollen body, excluding air-sacs.

TABLE 8. *Macroscopic plant remains from Le Moura.*

Pollen Zones.	L2	L3-5	P1	P2	P3a-b.	P3c.
Probable British equivalents-	II	III	IV-V	VI	VIIa	VIII (qv.Ch.IVc).
Betula sp. (fr).		@				
cf.*Betula* sp. (wd).		@				
Calluna vulgaris (wd).	@	@	@	@	@	@
Carex sp. (fr).	@	@			@	@
Cladium mariscus (fr).			@	@	@	@
Eleocharis multicaulis (fr).	L2/3					
Equisetum sp. (st).						@
Erica cf.*tetralix*.(s).		@		@	@	@
" " (f).		@				
Euphorbia amygdaloides (fr).	L2/3					
Hippuris vulgaris (fr).		@				
Hydrocotyle vulgaris (fr).			@			
Menyanthes trifoliata (s).		@	@			
Myrica gale (l).				@		
Phragmites communis (l).	@					
Polygala sp. (s).				@		
Potamogeton coloratus (fs).					@	
Potamogeton natans (fs).			@	@		
Potamogeton sp. (fs).	@					
Potentilla palustre (s).		@	@	@		
Potentilla sp. (s).	@	@		@	@	
Ranunculus sp. (s).				@		
Salix sp. (bs).	@	@				
Sparganium cf. *simplex* (fr).					@	
Sphagnum sp. (st.and l).	@		@	@		
Valeriana dioica (s).		@				
Viola sp.		@				

f - flower; fr - fruit; fs - fruit-stone; bs - bud-scale; st - stem; l - leaves; s - seed; wd - wood.

CHAPTER IV. LE MOURA. Discussion.

i) General stratigraphy.

In the deeper central parts of the basin, around boring 8, the stratigraphical record points to the relatively rapid overgrowth of the open water areas present during the early stages in the accumulation of the deposit, since only 80 cm. of lake muds and reedswamp peats were recorded above the top of the basal clay-silts. Above these swamp peats various changes in the plant communities on the mire are recorded in the stratigraphy. The two main types of deposit indicate, at certain times dominance by heathers and other acid bog species, at others, the prevalence of sedge-fen communities dominated by Cladium mariscus. The significance of these changes and their effect on the pollen diagrams are discussed in the sections below.

Where the mineral sediments, clays, silts and sands, approach the surface between borings 7 and 5, they are similar in nature to those found below 500 cm. in boring 8, and it was supposed that the transition to organic deposits was probably roughly contemporaneous over the whole length of the transect. Accordingly, on stratigraphical grounds, it was hoped that the pit dug down to 250 cm. by the site of boring 7 would permit the sampling of layers contemporary with the bottom 2m. or so of boring 8. The pollen analyses from the pit section (Table 4), show that the sediments between 82 and 250 cm. below the surface there all date from pollen Zone P_2 in which at some stage, the transition from mineral to organic sediments took place. The same stratigraphic transition in boring 8 takes place in

Zones L_1 and L_2 . This shows that the stratigraphic boundary in question is not a synchronous one. The most likely explanation for this is that during the period between Zone L_2 and P_2 a stream flowed through the valley depositing mineral sediments around the site of borings 5 - 7. Almost all the basin is surrounded by uniform sandy superficial deposits and it is not suprising that mineral sediments from different periods and parts of the basin should resemble each other so closely. Whilst the stream flowed through this part of the bog, organic accumulation continued uninterrupted further north.

ii). Major pollen-analytical bounderies.

A. FULL-GLACIAL / LATE-GLACIAL.

Zone F contains no evidence for the nearby presence of any tree or shrub species. The herbaceous pollen flora is rather sparse and, like the Full-glacial floras of eg. the Netherlands (Van der Hammen 1951, Zagwijn 1961) devoid of the heliophytic 'steppe-element' types such as Artemisia so commonly associated with spectra of Late-glacial age in northwest Europe. It is therefore proposed to consider it as representing a late stage of the Full-glacial period in the area.

The transition to Zone L_1 is marked by the first increase in tree pollen frequency (pine) in the diagram suggesting the possibility of nearby presence, and also by the first record of Artemisia pollen. The latter criterion was suggested by Van der Hammen (1951) as a definition of the Full-glacial/ Late-glacial boundary in the Netherlands. During the Zone, other tree and shrub types make their appearance and the herb flora is greatly increased by the advent of many new taxa. All these changes are consistent with climatic amelioration permitting the spread into the area of a richer and more thermophilous flora. They are the diagram's first indications of climatic improvement and they parallel quite closely changes used by the northwest European workers quoted above to define the Full-glacial/ Late-glacial boundary. It is therefore proposed to consider Zone L_1 as representing the beginning of the Late-glacial period in the area.

B. LATE-GLACIAL/POST-GLACIAL.

As late as pollen Zone L_5 frequencies of the heliophytic herbs such as *Artemisia*, *Chenopodiaceae* and *Ephedra* are quite high and birch and pine species are the only trees significantly represented in the pollen rain. At the transition to Zone P_1, *Betula* and *Quercus* frequencies rise, the latter permanently and steadily, and the heliophytic herb frequencies fall (Fig.12). This horizon also sees the first records from the site of such relatively demanding thermophiluos species as *Ilex aquifolium* (Iversen 1944) and *Cladium mariscus* (Von Post 1925, Conway 1938). The coincidence between the local establishment of a largely continuous forest cover and the first records of the above two species as well as *Quercus* indicates an horizon of important climatic improvement above which there is no pollen-analytical indications of possible regression until the very top of the diagram. The characteristics of the horison are thus similar to those which mark the transition from the end of Late-glacial to early Post-glacial times in diagrams from north-western Europe and it is proposed to consider it as the local Late-glacial/Post-glacial boundary. This latter has been proved contemporary over a wide area in north-west Europe and it is unlikely that its date at Le Moura should differ very markedly from that of c.8, 300 B.C. now current, (Godwin and Willis, 1959)

iii). Zone F. The Full-glacial period.

At the point of sampling for the pollen series, the Zone F sediments consisted of sand and sandy clay of uncertain origin. They contained very little plant detritus and no recognisable macroscopic remains.

The pollen types recorded in these lowest analyses were often poorly preserved so that identification is, in some cases, more tentative than in the higher parts of the diagram. The Zone F analyses contain so little tree pollen, and that comprising mainly very badly preserved pine and deciduous tree pollen types of uncertain origin (q.v. Ch.4. v. B.), that a totally treeless landscape may be safely inferred. Representation of shrubs and of aquatic plants too is totally lacking whilst the herbaceous flora is poor and without types giving very clear and precise ecological indications. The only specific identifications for the period are Cryptogramma crispa and, more tentatively Polygonum viviparum. Neither species grows in the area today and neither c/ desends below c. 2,500' in any part of France. Neither will tolerate dry continental conditions.@ Almost every other taxon recorded has a wide range of ecological tolerance and includes species growing under true tundra conditions.

iv). The Palaeo-ecology of the Late-glacial period, (Zones L_I = 5).

A. STRATIGRAPHY.

The Full-glacial/Late-glacial boundary is not perceptibly reflected

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@. Dahl (1951) has shown that Cryptogramma is one of the species which appear to be restricted by high summer temperature in Scandinavia, where it is not found in areas with a mean daily maximum temperature for July of 27°C or more.

in the stratigraphy, and clay-sand deposits continue to the LI/L2 horizon at about which point, the transition to predominantly organic deposits begins. Throughout Zone L2 these comprise a series of peats formed close to but just below the water table - drift peats and reedswamp peats with abundant very coarse plant detritus, including Phragmites leaves, in a matrix of shallow water lake-mud. During Zone L3, further hydroseral developments are recorded by a Carex fen peat passing into a series of brushwood and Calluna peats. Through Zones L2 and 3, a fairly simple succession is recorded in the stratigraphy, passing from open water with fringing reedswamps through a fen stage to a relatively dry bog. During Zone L4, there seems, from the macroscopic remains of Potamogeton and Nymphaea, to have been some redevelopment of open water. During Zone L 5, this was succeeded by oligotrophic fen or very wet bog conditions in which Menyanthes trifoliata was extremely abundant, judging from the number of its seeds recovered from this level. These local developments which are deduced from the stratigraphic evidence and macroscopic records will also be considered in more detail later in the light of the bearing they have on changes in the pollen rain during the period.

B. THE ECOLOGICAL INTERPRETATION OF THE POLLEN RECORD.

In Oldfield (1961) reasons were advanced for turning to the high western and central Pyrenees for the closest present day analogies with the Late-glacial vegetation around Le Moura. These reasons were based on various parallels, notably:-

i). The presence of Pinus uncinata type pollen in the Late-glacial samples, (q.v. Section C).

ii). The absence of Betula nana type pollen in the analyses, the dwarf birch being present in the Alps and Massif Central locally, as well as in the mountainous and circum-polar areas of northern Europe, but completely absent from the Pyrenees[@].

From section (iv)A of this chapter it is clear that an aquatic succession involving a variety of plant communities took place close to the site of boring 8 during the Late-glacial period. Evidence for vegetational changes on the dry-land as a result of climatic changes must inevitably be mixed up in the pollen analytical record with reflections of the local hydroseral developments during this period, and one of the first problems presented by the diagrams involves the separation of these two largely unrelated themes.

For this purpose, the taxa represented in the pollen diagram have been divided into six groups:-

i). trees and shrubs (Fig 5).
ii). aquatic, semi-aquatic and bog types (Figs. 7 and 8)
iii). Definitely non-aquatic or bog, and predominantly heliophilous taxa (Fig. 6)
iv). pollen types which by their variations in frequency and the species which they represent, are very likely to be reflecting the presence of plants. taking part in the aquatic succession (Fig. 8 and some types on Fig.10)
v). pollen types which, using the same kind of arguments as in (iv) probably represent taxa of open dry land habitats(Fig.6)
vi). pollen types reflecting the presence of taxa of wide or divergent ecological preferences,eg. Calluna vulgaris and Empetrum nigrum,both of which could be growing on the mire, or in heaths round about, or both.

The interpretation of the variations in frequency of the first three groups forms the basis for the palaeo-ecological reconstructions to follow.

[@] A third indication, the presence of pollen of Taxus baccata, can no longer be considered valid. Recent re-examination of the material suggests that the pollen in question was not of yew; the 'gemmae' were too large (qv.Jessen, Anderson & Farrington, 1959). Its identification has not yet proved possible.

C. THE ROLES OF PINE AND BIRCH.

Betula. As stated above, no evidence for the presence of *Betula nana* was found. The pollen, single fruit and wood fragments could have belonged either to *B. pubescens* or *B. verrucosa*. Both are rare today in the Pays Basque whilst in the Pyrenees, they do not ascend as high as *Pinus uncinata*. From Gaussen (1948) and Fournier (1946) it appears that birch occurs as high as *Pinus silvestris* quite commonly in the Pyrenenees and elsewhere, and the present author recorded *Betula pubescens* locally in ill-drained areas in the *Pinus silvestris* zone of the central Pyrenees near Cauterets, at about 1700 m., though both birch species were seen more commonly at much lower altitudes in the oak woods of the valleys.

Pinus. Of the three species native to south west France, *Pinus pinaster* (= *maritima*) is a lowland south-west European and west-Mediterranean species, present in the Pays Basque especially on poor sandy soils (Allorge 1941a) but absent from the most exposed coastal situations (Jovet 1955). *Pinus silvestris*, which is common in the eastern and central Pyrenees, does not reach beyond the eastermost edge of the Pays Basque. Allorge (1941a) stresses the dry continental character of its habitats in southern France and the Pyrenees, where it forms dry south and east facing montane woodland in contrast to *Fagus* and *Abies* which cover the moister north and westward facing slopes (Gaussen 1948,Rey 1955). Thus where *Fagus* and *Abies* are absent, *Pinus silvestris* decends to the upper limits of oak woodland, where they are present, it may, as at Cauterets (Fig.15), form a closed stand in an intermediate belt between the highest limits of the *Abies* forest and the lower limits of *Pinus uncinata* park

TABLE 9. Ecological notes on plant communities near the tree line in the Cauterets area.

(i). Species list from south-west facing slope near Lac de Gaube.

Alt. c.1900 m. Dry rocky schost slopes of 20-30 degrees.

TREES. Pinus uncinata. Scattered forming a total cover of less than 15%.

SHRUBS.

Calluna vulgaris	C	
Vaccinium myrtillus	C	
Juniperus communis	C	
Arctostaphylos uva-ursi	L.	on bare rocks
Rhododendron ferrugineum	L	

HERBS.

Festuca ovina agg.	C
Poa alpina	C
Polygala alpestris	L
Helianthemum chamaecistus	L
Potentilla erecta	L
Alchemilla alpina	L
Trifolium alpinum	L
Lotus corniculatus agg.	L
Saxifraga sp.	L
Saxifraga aizoides	C
Silene nutans	
Silene cucubalus agg.	
Stellaria holostea	C
Sempervivum montanum	
Galium asperum	
Euphrasia salisburgensis	
Campanula rotundifolia	L
Gentianella campestris	L
Knautia arvensis	
Bellis perennis	
Crepis vesiculosus	
Sedum atratum	
Melampyrum sylvaticum	
Salvia pratensis	
Calamintha alpina	L
Thymus communis	
Teucrium scorodonia	L
Epilobium montanum	
Urtica dioica	L
Beupleurum falcatum	L
Laserpitium latifolium	L
Selinum pyrenaicum	
Plantago alpina	L
Plantago montana	L
Galium verum	L
Hieracium laevigata	
Hieracium pilosella	L
Cryptogramma crispa	L
Polypodium vulgare	L
Blechnum spicant	
Asplenium trichomanes	

C - Common. L - Local or scattered. Others - only one record.

(ii). Species conspicuous below forest canopy in Pinus sylvestris zone:-

Festuca ovina agg.
Gramineae indet.
Potentilla erecta
Calluna vulgaris
Vaccinium myrtillus
Juniperus communis

TABLE 10. Contemporary pollen rain in the central Pyrenees.

	A	B	C	D		A	B	C	D
Pinus spp.	93	82	75	91	Abies alba	1	5	3	3
Picea sp.			+	1	Betula spp.		1	2	(1 Ulmus)
Quercus spp.	5	7	15	3	Fagus sylv.	1	3	4	1
Alnus glut.		1	1		TreePollen Sum	120	150	150	150
Calluna v.	5	2	3	1	Corylus av.		5	1	2
Empetrum nig. s.s.		2			Juniperus sp.		1		1
Vaccinium myrt.	1	1			Rhamnaceae			1	
Erica vagans		1	1	1					
Poterium sang.				1	Gramineae	4	45	54	56
Artemisia sp.			1	1	Cyperaceae			3	
Helianthemum sp.			1	1	Campanulaceae				1
Iris sp.				+	Chenopodiaceae		1	3	3
cf. Lotus sp.			3		Cruciferae	1		12	
Plantago sp.		12	16	5	Liguliflorae		3	2	
Rumex sp.		1	8		Ranunculaceae		1	1	
Cerealia type.			3		Rosaceae	1		1	
					Rubiaceae			1	
Cryptogramma c.			1		? Saxifragaceae		47		25
Filicales.		2	1		Tubuliflorae			1	
Equisetum				1	Umbelliferae		1	1	2
Isoetes				1	Urticaceae/Cannab.			5	1
Selaginella s'oides		1			Valerianaceae		1		
Pteridium	1								

Site A. In the Pinus sylvestris zone at c. 1680 m., near to Cauterets. A small Sphagnum lawn in fairly closed woodland.

Site B. Bryophyte flush at c. 1800 m. in the Pinus uncinata zone above Cauterets and on the edge of the Lac de Gaube.

Site C, Near summit of Col de Pourtalet at c. 1850 m. Bryophyte flush. In a grazed and deforested area below the regional treeline.

Site D. At c. 2200 m. on the slopes of the Pic du Midi de Bigorre. Sphagnum lawn covering a shallow kettle hole in moraine above the tree line.

Figures are percentages of tree pollen sum.

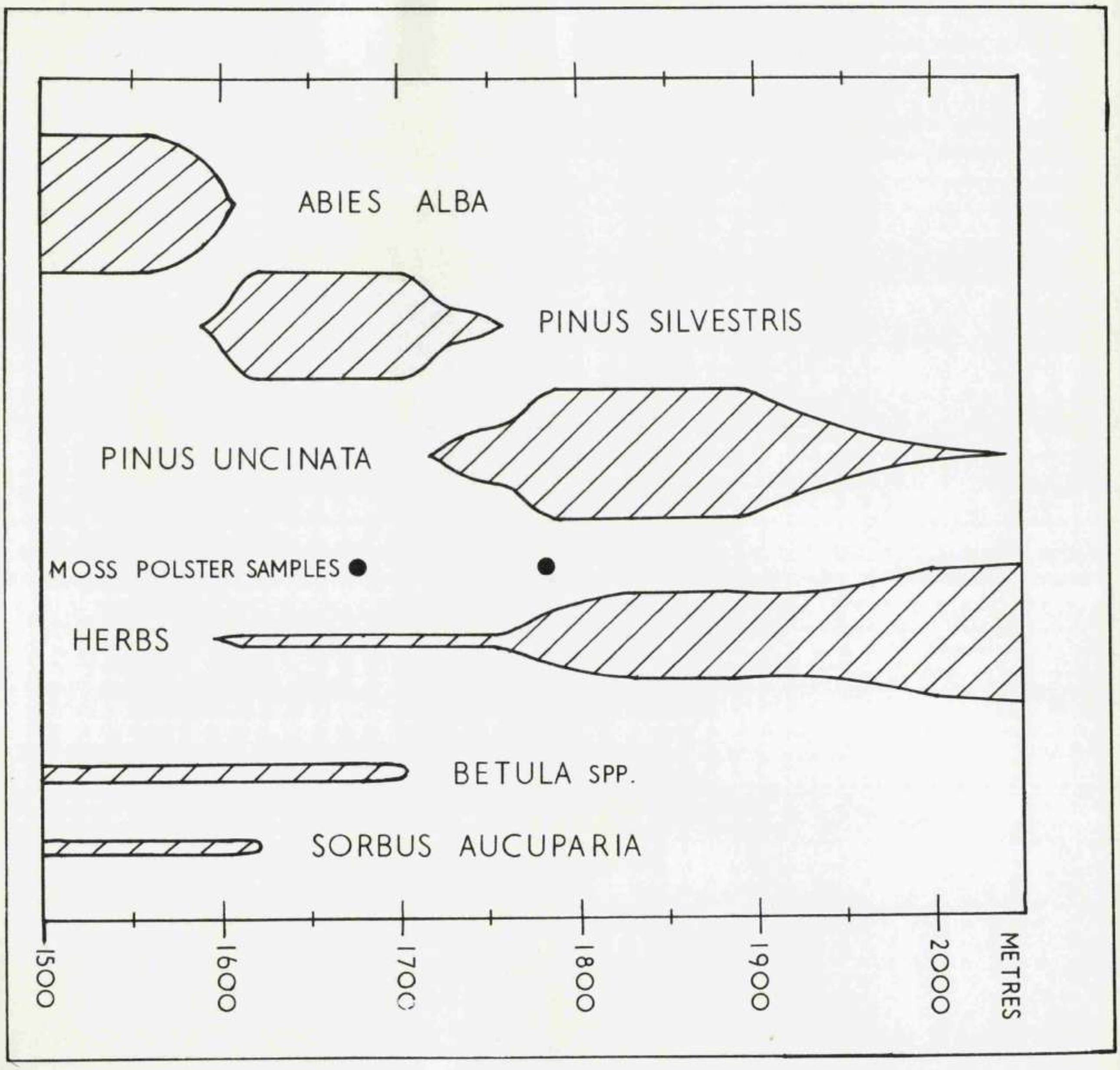


Figure 15. Altitudinal ranges of the main trees in the Cauterets area.

PLATE 3. The Valley above the Lac de Gaube, Cauterets. On the south facing slope (left hand side), open <u>Pinus uncinata</u> woodland ascends to over 2000 metres.

woodland, i.e. between c. 1600 and 1730 m. The lower limit of *Pinus silvest~~a~~ris* here is fairly clear cut, but at the upper limit *P. silvestris* and *P. uncinata* intermingle as the canopy becomes less continuous. *Pinus uncinata* is described by Fournier (1946) as a race of *Pinus montana.* Evidence from Gaussen (1948), Rey (1955) and personal observations in the Cauterets area suggest that it forms the natural tree line throughout most of the Pyrenees, ascending to well over 2000 m. Whilst the *Pinus silvestris* woodland near to Cauterets formed a relatively dense canopy and did not possess a particularly rich herb layer, the *P. uncinata* woodland above was much more open, hardly giving rise to any continuous areas of shade and allowing a relatively rich herb flora to flourish (Table 9), similar tothat found above the tree line.

Samples of growing *Sphagnum* were taken from two sites in the Cauterets area in order to provide details of present day pollen rain. Sample (a) was from a wet bryophyte flush at c. 1800 m. in the lower part of the *Pinus uncinata* zone, sample (b) from a small *Sphagnum* lawn at 1680 m. in the *Pinus silvestris* zone, (Table 10). The pine pollen in each sample as well as in a third sample from the Col de Pourtalet (Table 7) was measured.Van Campo (1950), using acetolysed type material, has pointed out a difference in size between the bodies of the pollen grains of *Pinus uncinata* and *Pinus silvestris*, though some overlap was found. The present samples were not acetolysed and so their sizes may be expected to compare more closely those found in the fossil preparations from Le Moura. The main size frequency peak in the sample from the *Pinus uncinata* zone falls at

22 div and c. 65 percent of the grains are 23 div or less. The main size frequency in the *Pinus silvestris* zone is 24 div and 85 percent of the grains are 24 div or over. The bulk of the pine pollen from the latter sample from the midst of a densly wooded tract may be taken to represent *Pinus silvestris* pollen produced by the surroding trees, un and we may conclude that very little *Pinus silvestris* pollen falls below 24 div in size. The pine pollen rain at the higher site may be expected to be somewhat more mixed since the woodland is an open one and the site only 70 m. above the edges of the *Pinus silvestris* zone. Nevertheless, there can be no doubt that the large quantities of small grains found represent *Pinus uncinata*. The sample from near the summit of the Colde Pourtalet, at 1850 m. is 2 - 3 miles distant from any forested areas. South of the summit of the Col, pine woods occur, mainly *P. silvestris*; to the north, there are few if any pine woods in the valley and the tree line comprises rather stunted *Fagus* woodland. The size of the pollen rain here varies a great deal and there are no clear peaks as in the Cauterets samples, although the highest frequencies occur within the *Pinus silvestris* range.

Similar measurements were carried out on Late-glacial pine pollen from sample 440cm., close to the boundary between Zones L_2 and L_3. The results are shown in Table 7. Although most of the grains are 24 div or larger and the main size range (26 - 28 div) falls clearly within the limits of *P. silvestris* sizes, 25 percent of the grains measured 23 div or less and 14 percent, less than 22 div This is a higher percentage of small grains than in the lower sample at Cauterets. Another sample from the main series at 380 cm. (L5) contained 19 percent less than 24 div. These measurements suggest the probable predominance of *Pinus silvestris* pollen during the period, but the definite presence of *Pinus uncinata*. The same conclusion was reached by morphological examination of the pollen grains. In typical *Pinus uncinata* pollen, the body of the grain is smaller relative to the air sacs than is the case with *P. silvestris*, whilst the airsacs are borne more directly below the grain. All the pine pollen grains of 23 div. or under, whether from fresh moss polsters or from the Late-glacial analyses possessed these characteristics, (q.v. photomicrographs).

Pinus pinaster pollen exceeds in size (c. 40 div.) that of the other two species (Van Campo 1950) and the network on the air sacs tends to be larger. Nevertheless, the distinction is not a clear one. Seldom more than one or two grains with both these characteristics were found in any of the pollen samples from le Moura and these from Post-glacial and mainly fairly late post-glacial samples (of Oldfield 1960b).

From the above information, *Pinus uncinata* and to a lesser extent *P. silvestris* may be expected to have played a dominant role in the relatively colder Late-glacial episodes, the tree birches in the relatively warmer. Also, since the highest treeless slopes as well as the *Pinus uncinata* park woodland communities are richer in light demanding herbs than the lower more closed forests of *Pinus silvestris* with local stands of birch, it seems reasonable to take the relative abundance of light demanding herbs too as some indication of the severity of the climate. The relationship between these various elements have been expressed as ratios, in Fig. 12:- (i). $\frac{\text{Dry land heliophytic herb pollen}}{\text{total tree pollen}}$

(ii). $\frac{\text{Dry land heliophytic herb pollen}}{\text{total non-aquatic pollen}}$

D. LATE-GLACIAL SUCCESSIONS.

ZONE L I. The rise in tree (mainly pine) pollen frequency at the base of the zonemay record the spread of pine into the area. It has already been noted that the rich herb flora of Zone L I includes species of continental and steppe affinities. *Centaurea cyanus* (cf. Iversen 1954) and *Ephedra* cf, *distachya* are especially indicative, whilst the genera *Artemisia*, *Centaurea* and *Knautia* also contain many other continental heliophytic species. The representation of these groups and other elements in the open ground herb flora (Fig. 6) is highest at the end of this Zone and the transition to Zone L 2, whilst at the same time, heliophyte percentages as a whole, whether expressed in relation to tree pollen or to total non-aquatic pollen, reach a maximum, (Fig. 12).

Pollen of *Potamogeton*, *Typha latifolia*, *Lysimachia* (almost certainly *L. vulgaris*), *Lythrum* and *Isoetes*, appearing for the first time during this zone, confirm the suggestion from the stratigraphy that nearby open-water and reedswamp habitats existed at the time.

ZONE L 2. Whilst low birch frequencies are recorded in the second half of L I, the sharp increase in birch frequency at the L I/2 boundary probably records the first expansion of birch in the area. There are no macroscopic remains of birch from this phase and the stratigraphic type suggests that conditions on the mire were not suitable for birch colonisation. It seems certain that some spread of birch trees in the surrounding area is recorded. The peak in *Salix* frequency coinciding with the early part of the birch maximum probably represents the local spread of some arctic-alpine willow as a pioneer species over former herb dominated communities. Throughout the zone, the low herb pollen frequencies (Fig. 6) point to a striking reduction in the extent of open insolated habitats coinciding with birch's spread into the area. Mixed birch-pine woodlands covering almost all the dry land are indicated. From the size statistics of the pine pollen from the end of the zone, (Table 7) it is clear that the most abundant pine species was *P. silvestris* though *P. uncinata* was present. The steppe elements in the flora are almost completely lacking during this phase whilst, *Filipendula* values rise significantly and are maintained throughout the zone. All the pollen analytical evidence suggests that Zone L 2 was a relatively forested mild temperate episode during which the steppe and tundra elements in the vegetation were severely reduced.

During this phase, the representation of the aquatic species reached its maximum (Fig. 7). The peaks in reedswamp and probable reedswamp types at the beginning of the zone are followed by a short phase in which open water aquatic types are more strongly represented - *Potamogeton*, *Ranunculus aquatilis* type, and *Utricularia*, suggesting that the early part of Zone L 2 may have been marked by a local rise in water level. *Typha latifolia* frequencies remain unchanged by this, and following the peaks in open water pollen frequencies, the other reedswamp types return. Above 470 cm., *Typha* and *Lysimachia* values begin to fall and the semi-aquatic pollen flora becomes dominated by *Sparganium* type and *Gramineae*, high frequencies of both persisting in early Zone L 3.

ZONE L 3. The return of pine to dominance of the tree pollen rain coincides with an increase in dry land herb pollen representation and these changes together indicate an opening of the forest cover and a return to more severe climatic conditions. The indications of pine's local dominance during L 3 are interrupted by only one single sample in which birch pollen frequencies reach c. 60 percent of the tree pollen sum. Oldfield (1961) has already drawn attention to the fact that the birch pollen in question was slightly but uniformly aberrant on the slides from this sample and it seems valid to consider this peak as the result of local birch growing on the mire, with one tree (perhaps one anther) producing the bulk of the birch pollen. Close proximity of tree birch to the site of sampling at this time is confirmed by the presence of quite large twigs of birch in the borer samples.

At 430 cm., reedswamp conditions end, with a rapid change in the local pollen flora to dominance by *Cyperaceae*, *Sphagnum* and *Succisa*, and in the peat type to a sedge peat with *Carex* nutlets, suggesting the onset of fen or flushed bog conditions. Fruits of *Potentilla palustre*, *Potentilla* sp. (? *erecta*), *Potentilla* pollen and pollen and fruits of *Valeriana dioica* also occur at this level, suggesting some variety of local conditions during this transitional stage from reedswamp below to bog above (qv). The birch pollen peak considered above, and the birch twigs, come from the top of this phase recording perhaps some local temporary fen-carr stage quickly superseded. High frequencies of

Calluna, Empetrum nigrum and Erica cf. tetralix pollen coincide with and continue beyond the birch pollen peak. Calluna twigs and the seeds and a floret of Erica cf. tetralix occur at this level suggesting that these two species at least were important elements in the vegetation of the mire at this stage. The Empetrum frequencies parallel so closely those of these other Ericales types that there can be little doubt that all three were growing together forming shrub dominated bog. To what extent Calluna and Empetrum nigrum may have been growing on the surrounding dry land too is impossible to tell, but there is no certain evidence here that they grew elsewhere than on the mire, in the neighbourhood of the point of sampling. During Zone L 3, there is thus evidence for a fairly rapid transition from reedswamp to shrub bog, though it may not be justified to deduce any change in actual water level from this.

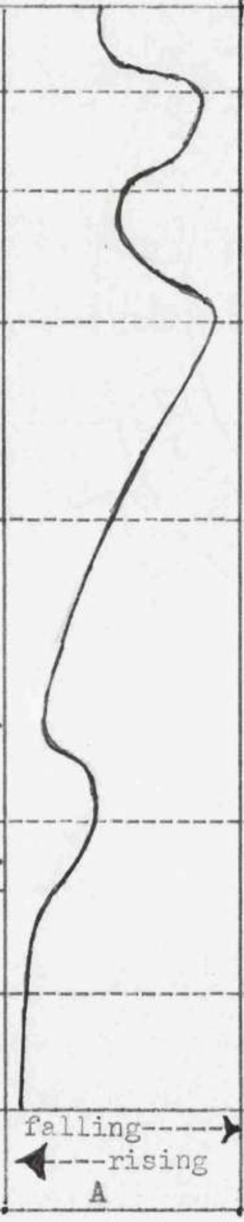
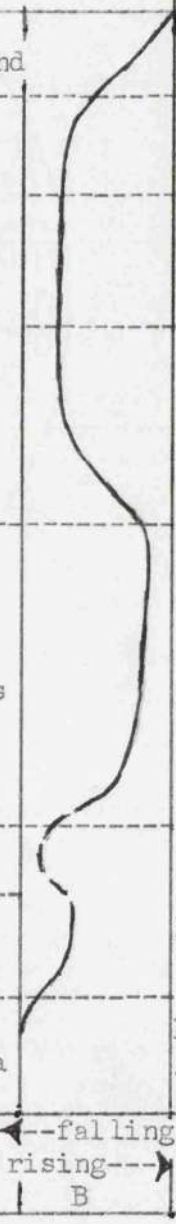
ZONE L 4. Three samples with high birch frequencies mark this zone and it is important to try to discover whether these values are the result of Betula growing in woodlands surrounding the site (as in L 2) or as an element in one of the communities on the mire (as with the birch peak in L 3).

During Zone L 4, dry-land herb pollen frequencies, expressed as a percentage of tree pollen, decline sharply, but they remain steady when expressed as a percentage of total non-aquatic pollen. The former effect would be expected whether the birch was growing on the mire or on the surrounding dry land, the latter effect would not be expected if the birch pollen were coming from extensive stands on the dry land.

Contemporary with the rise of Betula frequencies, the shrub pollen types which were thought to have dominated the mire vegetation in Late Zone 3 are quickly reduced in representation, suggesting that there must have been some change in local conditions at this point. The macroscopic remains at this level (Table 8) as well as the presence of various pollen types of aquatic and semi-aquatic species point to the development of areas of open water on the former bog surface. The abundant pollen and seeds of Menyanthes are especially notable too, indicating rather swampy mesotrophic or oligotrophic conditions. Birch wood and budscales of Salix are also recorded at this level, whilst a peak in Salix pollen frequency is recorded in the middle sample of the zone. All this evidence suggests that the Late L_3 bog surface was flooded at the opening of Zone L_4, stretches of open water were created along with swampy areas and patches of Betula and Salix carr. There seems no cause for deducing any significant change in the nature of the vegetation on the surrounding dry land during this period.@

@ In Oldfield (1961), the alternative interpretation, that Zone L_4 records some spread of Betula onto the surrounding dry land, was put forward. The evidence upon which this earlier interpretation was based was less complete than now since at the time of reading the paper (Dec.1959) samples for detailed macroscopic analysis had not been obtained.

TABLE 11. Late-glacial plant successions at Le Moura.

Phase.	Bog and aquatic successions.		Dry land successions.		British Pollen Z'
P1	*Cladium* fen		Oak woodland Oak-birch woodland		IV-V.
L5	*Sphagnum*-*Calluna* *Empetrum* bog.				
L4	Birch-willow carr and open water.		Open pine woods		III
L3	Shrub bog Fen-bog trans.				
L2	Reedswamp Open water & reed. Reedswamp		Birch-pine woods		II
L1	Open water & reed. ~~Op~~ Open water		Steppe tundra Park tundra		? c. ? I ? ? b.
F	Open water		True herb tundra		Full-glacial.
		 falling----> <----rising A		 <--falling rising---> B	

The curve in column A seeks to represent approximately the variation in water level in relation to the level of deposition.

The curve in column B is some indication of the climatic trends which may be inferred from the dry-land vegetational successions. The line is discontinuous where the inferrence seems least secure.

ZONE L 5. There are no indications in the pollen diagrams of any changes on the dry-land between pollen Zones L_4 and L_5. The fall in birch pollen frequency at the base of the zone coincides with rapid increase in Sphagnum values succeeded immediately by peaks in Calluna, Empetrum nigrum and Cyperaceae with twigs of Calluna, and Sphagnum leaves, all this suggesting the redevelopment of bog conditions at the point of sampling, as at the top of Zone L_3.

The full Late-glacial hydroseral developments at the point of sampling are summarised tentatively in Table 11 along with concurrent changes in the dry land plant communities.

E. CLIMATIC CHANGES AND CORRELATIONS.

Above the transition to Late-glacial conditions, the broad pattern of vegetational development on the dry land is threefold, from open herb communities with possible scattered pine (L 1), to more or less continuous birch-pine woodland (L 2), back to open herb communities with pine (L 3-5). Such a simple division very closely parallels familiar Late-glacial successions over the whole of north-west Europe in which a temperate Allerød phase (pollen Zone II) is found preceded and succeeded by cooler episodes, the Lower and Upper Dryas periods (Zones I and III). This suggests the following correlation between the present Late-glacial series and more familiar often radiocarbon-dated ones from north-west Europe :-

L 3 - 5. - Zone III. Upper Dryas.
L 2. - Zone II. Allerød.
L I. - Zone I. Lower Dryas.

Although it may not be justified to consider the zone bounderies as defined at Le Moura as the precise chronological equivalents of those defined and radiocarbon dated further north, the degree of parallelism with dated sites suggests at least approximate synchroneity of episodes.

In view of the tentative equation of Zone F with the end of the Full-glacial period and L_2 with the Allerød, the question arises of whether the diagram contains any evidence for a pre-Allerød warm phase as do many sites covering this time interval in North west Europe (Iversen 1954, Anderson, De Vries and Zagwijn 1960, Walker in Clark et al. 1954, Walker 1957, Oldfield 1960 a).

The middle of Zone I, marked by heliophyte/tree pollen ratios of c. 100 - 160 % and heliophyte/ non aquatic pollen ratios of c. 10% is succeeded, during the final part of the zone by large increases in the representation of the more or less steppic heliophyte taxa. The heliophyte/tree pollen ratios reach 250%, and the heliophyte/non aquatic ratios reach c. 14%. It seems certain that such a change in flora reflects a rather brief climatic oscillation probably involving a shift to drier and perhaps cooler more continental conditions. Without more evidence from the area and also from places between this site and those in N.W. Europe, it would be rash to suggest that the pre-Allerød climatic oscillation detected here rather tentatively could be correlated with any of those found further north. However, the apparent magnitude of the change, its position and general importance in the Le Moura diagram compare quite closely with evidence for pre-Allerød oscillation in some of the other north west European sites referred to above e.g. at Hawes Water in Oldfield (1960a).

At this last site, the immediately pre-Allerød 'cold' phase is characterised by especially high Artemisia frequencies and there, as in many North west European diagrams, it is the episode in which pollen of Hippophäe rhamnoides appears most consistently (Iversen 1954, Godwin 1956).

Table **11** summarises and correlates the deduced changes on the mire and on the dry land, and relates them to the British Late-glacial pollen Zonation. It is interesting to note that the steppe tundra phase at the end of Zone I appears to coincide with lowered water level, whilst the beginning of each major mild period (Zone II and the Post glacial) is marked by an apparently sharp rise in water level, as indeed is the middle of Zone III.

It is not possible to correlate this series satisfactorily with that from Poueyferre (Lourdes) described by De Vries, Florschutz and Menendez Amor (1960), since the highly simplified diagram based on total pollen sum and not subjected to detailed ecological interpretation does not provide a satisfactory basis for pollen analytical comparisons.

The diagrams of Lang and Trautmann (1960) from the Lac des Salhiens at 1220 m. in the centre of the Massif Central near to Nasbinals include a very full record of Late-glacial pollen analytical changes. The ecological roles of birch and pine species in the Massif Central differ from those in the Pyrenees and the zonation criteria adopted by Lang and Trautmann differ so much from the ones used in the present study as to make correlation between the two series almost impossible. On the other hand, the diagrams of Florschutz and Menendez Amor (1961) from the Laguna de Sanguijuelas on the Spanish/Portuguese border do show some points of comparision with the present one. The clearly marked period which the authors relate on pollen-analytical and radiocarbon grounds with Zone II begins with very high Betula values, and the earliest episodes recorded, containing little or no Betula pollen, some Pinus and relitively high Artemisia values seem quite comparable with the beginning of Zone L I at Le Moura. At Sanguijuelas though, Zone II proceeds with a notable peak in Quercus frequency!

V). The Post-glacial period.

A. STRATIGRAPHY.

The non synchroneity of the clay/peat contact along the line of transect has been discussed and the present section deals only with the details of postglacial stratigraphy close to boring 8, the main pollen series.

The main changes in stratigraphy consist of alternations between Cladium peats and Calluna peats. The earliest post-glacial Calluna peats are in Series 8b, at 150 cm.(= 170 cm. in the main pollen series) and they become increasingly structureless and oxidised up to c 100 cm. (= the P2/p3 boundary@), where there is an abrupt transition to relatively fresh unoxidised Cladium peat. This same change takes place at 105cm. in the nearby monolith series, and there too it coincides with the P 2/3 boundary. The marked oxidation of the upper layers of the underlying Calluna peat in the main series,series 8b, and the monolith, and the extremely poor state of preservation and overall sparsity of pollen at the same depths suggest that the bog dried out for a while at this stage. The abrupt transition to Cladium peats suggests the sudden development of eutrophic fen contitions on the formerly dried out bog surface.

d/

@ This stratigraphical change was detected in the original boring for the pollen series and so it is possible to relate it exactly to the pollen diagram at the P2/3 boundary.

Almost exactly the same sequence of changes takes place again at 50 cm. in Series 8b, (= 65 cm. in the pollen diagram. i.e. P 3b/3c boundary). Here the evidence for the flooding of a formerly dried out bog surface includes the presence of Potamogeton fruits and pollen in the overlying deposit. Oxidised woody fragments typical of the underlying peat are also found mixed into the lowest 5 cm. of the overlying fresh sedge peat, recording some incorporation of the crumbled former bog surface in the more recent deposits as a result of the flooding. Both these stratigraphic boundaries coincide with pollen zone boundaries, P 2/3 and P 3b/c, and from their appearance it seems reasonable to infer that both probably reflect temporarily discontinued deposition at the point of sampling for the pollen series.

B. THE POLLEN DIAGRAMS AND VEGETATIONAL HISTORY.

During the preparation of the main pollen diagram it was noted that there were horizons, e.g. at 120,150,250,355,405 and 550 cm., where frequencies of Alnus and Fagus pollen were recorded, well before the main increase in frequency of either species. Some doubt was cast on these records for the following reasons ;-

i) the almost invariable association of the two types together,

ii) their occurrence mainly at 50 cm. intervals or multiples of 50 cm. approximately, and so from depths from which the pollen samples would be taken from the very top or bottom of the Hiller sample chamber (qv. Faegri and Iversen 1950).

iii).the presence of relatively high *Alnus* and *Fagus* values at the top of the series permitting downcarriage of both pollen types from the topmost levels of the series with each insertion of the borer.

iv).the failure to distinguish clearly many of the stratigraphical types at the time of taking the samples for the main pollen diagram (1957).

v), the fact that the peaks of each species only occurred in one sample each time.

As a result, close and often contiguous or overlapping samples from levels in the nearby monolith series equivalent to 120,150, and 250 cm. in the main series were taken and analysed, the method of sampling in this case precluding the possibility of contamination by downcarriage. The analyses, Fig.14, show that *Alnus* and *Fagus* did not contribute to the contemporary pollen rain during the phases in question, thus the conclusion that the peaks are the result of downcarriage from upper levels with each insertion of the borer is, however unpleasant, inescapable.

The bulk of the pine pollen, and virtually all of it during Zone P2 was of *Pinus silvestris* type. The few grains which, on a account of their size and the large network on their air sacs, were of the *Pinus pinaster* type, were mainly found above this level. The *Quercus* pollen recorded was very mixed and a minimum number of *Quercus ilex* grains has been distinguished and plotted separately, including only those which could be identified to this species with complete certainty (Van Campo and Elhai 1956).

Quercus pubescens pollen is similar to that of *Q. ilex* but appears more lobed in polar view and more coarsely ornamented. The few grains of this type that were observed were thought not sufficiently distinct from the possible range of variation within the other *Quercus* species to merit separate recording. The *Corylus* curve includes doubtful grains which could equally well be *Myrica* whereas the *Myrica* record is a minimum number of certain identifications.

The sharp reduction in pine and heliophyte pollen frequencies at the L5/P1 boundary coincides with increases in birch and juniper pollen values suggesting pioneer colonisation of former herbaceous communities, a familiar feature of many north west European diagrams at the Late-glacial/Post-glacial transition. Oak seems to have shaded out the local juniper quite quickly and then steadily colonised formerly pine and birch covered areas throughout the rest of the zone, ending up by almost completely dominating the local tree pollen rain. There are no certain indications that any of the other trees of the mixed oak forest reached the area during this phase.

Hazel's spread into the area, marking the beginning of Zone P2, coincides with a further reduction in birch pollen frequencies. Where, as in most of north west Europe, hazel spreads before the oaks, it does so mainly over predominantly pioneer type plant communities (Iversen 1960), often largely dominated by birch. Its rather modest though rapid rise in representation in the present diagram is more problematical, since it is hard to imagine which localities open to hazel had not been previously colonised by oak. Some of the pollen may be coming from hazel growing as an undershrub to oak, though this is not likely to be much (Faegri and Iversen 1950), in view of the great reduction in hazel pollen production in shaded situations. The increases in pine frequency and reduction in oak and hazel which follow and culminate at the end of Zone P2, almost certainly point to increasingly dry continental conditions in view of the behaviour of Scot's pine in southern France today.

The monolith pollen diagram (Fig. 14) shows the gradual steady rise of alder frequencies during P3a and 3b at the expense of pine and oak. Alder is a lowland and especially a damp river valley species in the Pays Basque today (Allorge 1941) and it probably spread into the area at this time along valley and streamside habitats, wherever sufficient moisture and lack of dense shade permitted (McVean 1955). The increase in beech pollen values immediately above the stratigraphic and pollen analytical boundary at 65 cm. seems to come about mainly at the expense of oak.

Since there are hardly any points of contact between the ranges and habitats of beech and alder in the area at the present day and since the role of pine during this final episode if clearly much reduced and probably somewhat changed by the admixture of P. pinaster, this is only to be expected.

The records of Cedrus, Juglans and Zea pollen in this final episode give some indication of date. Cedars are relatively recent historical introductions into western Europe from the Middle East and Himalayan regions. Juglans pollen has been found in other French post-glacial deposits, but always during very recent episodes, along with high Fagus values (Becker 1952, Lamee 1942, Braun-Blanquet,1933, Elhai 1959). Elhai quotes evidence and authorities suggesting its possible Roman introduction and spread, a view which is supported by sub-fossil evidence from Britain (Godwin 1956). Zea mays was introduced into Europe from the New World in 1520 (Fournier 1946) and is the commonest cereal crop of the Pays Basque at the present day. Its pollen is highly characteristic, (Barghoorn 1954), its longest dimension often exceeding 80 mi. Whereas cereal pollen grains of any kind are totally lacking during the earlier periods, they are represented by a continuous curve during this last episode, though weed and bracken frequencies are little higher than during the earlier periods.

C. CORRELATION OF THE POST-GLACIAL POLLEN ZONES.

The order of arrival of the tree species into the area is not typical of most of western Europe, oak coming and spreading well before hazel. Under such circumstances, it would seem pointless to seek precise chronological equivalents for the early post-glacial bound~~e~~ries here, a/ without independent dating evidence from radiocarbon. The spread of hazel into north west Europe appears to have been relatively rapid though, and there is some likelihood that the hazel increase in the Moura series will be approximately synchronous with those further north, in which case Zone P1 may be tentatively correlated with British pollen zones IV/V.

The stratigraphic and pollen analytical evidence from the top of Zone P2 indicates a tendency towards drier more continental conditions which can be paralleled in many north west European sites (e.g. Godwin and Tallantire 1951, Godwin and Seagrief 1960). Along with the foregoing evidence it supports very strongly a close correlation of Zone P2 with British pollen Zone VI, as defined by Godwin (1956) for south east England.

TABLE 12. Summary of Post-glacial Zonation at Le Moura. Correlations with Britain.

Pollen Zones at Le Moura.	Some vegetational and stratigraphic characteristics of the Zones at Le Moura.	Pollen Zones Britain.
Zone P 3c.	Quercus,Alnus and Fagus dominate the tree pollen rain. Recently introduced species present. Begins with flooding horizon and rapid rise of Fagus.	Late Zone VIII
---------------- HIATUS	--------------- Episodes missing contemporary with ---	Mid Zone VIIa to Late VIII.
Zone P 3a-b.	Quercus values maintained whilst Alnus rise and Pinus fall. Begins with flooding horizon.	Early Zone VIIa.
---------------- Possible minor break in deposition---		
Zone P 2.	Quercus values maintained,Pinus frequencies ~~fall~~ rise,Corylus ~~rise~~ fall. Culminates in pine maximum contemporary with a dry Calluna phase on the mire. Begins with rapid Corylus rise.	Zone VI.
Zone P 1.	Pinus replaced by Betula temporarily and Quercus permanently.	Zone IV-V.
Zone L 1.	Late-glacial period.	Zone III. Late-glacial.

The top 40 cm. of this zone do include low Alnus frequencies even in the monolith series where downcarriage was impossible, and this is a common feature in British pollen diagrams.

The steady rise of alder frequencies above this suggests a date early in Zone VIIa, though the chronology of alder's spread into western Europe seems neither so simple nor so well-known (qv. Oldfield unpub.) as to give such a correlation much significance in terms of absolute age. Above the P 3b/c boundary, the high Fagus values and the presence of the recently introduced pollen types point to a quite recent historical date, late in pollen Zone VIII. This being so, the break in deposition at the 3 b/c horizon, already inferred from the stratigraphy, must cover a span of time including the whole of pollen zone VIIb, much of VIII, and possibly the later parts of VIIa. Radiocarbon evidence from Mouligna (Oldfield 1960b), only 2½ miles seaward of Le Moura showed that the mud bed there dated from late Zone VIIa and early VIIb times. A comparison of the present pollen diagrams with the Mouligna succession shows that the episodes recorded at the coastal site, phases of sustained high alder and negligible beech frequencies, are completely absent at Le Moura. Table 12 summarises the post-glacial correlations made between the present diagram and the British scheme of pollen zonation.

vi). Further comments on the plant record at Le Moura.

Species dealt with completely in the above sections are not further considered here. In order to make the following discussion more readily comprehensible in familiar terms of reference, the plant records are dated in terms of the British pollen zones to which the local episodes have been correlated in the above sections (qv. summary in Table 12). The comments must therefore be viewed in the context of the qualifying remarks made in these foregoing sections.

Abies. Pollen frequencies of Abies (presumably A.alba) are restricted to late Zone VI and subsequent episodes. They never exceed 1% of the tree pollen sum (cf. Oldfield 1960b), and give no sure indication of the local presence of fir at any stage, especially in view of its high pollen production. There is thus no evidence that it grew any further west than at present during any part of the post-glacial period. Firbas (1949) shows that Abies pollen may form up to 2% of the tree pollen sum 20 km. beyond the border of its distribution, and as much as 1% at 70 km.

Armeria. sp. Armeria maritima occurs between 1800 and 2900 m. @ on French mountains, whilst A.cantabrica and montana are recorded by Allorge (1941a) between c. 700 and 1550 m. on calcareous cliffs in the Pays Basque.

Restriction of Armeria records to Zone I suggest that the species in question was a member of open tundra communities.

Buxus sempervirens. The first record of Buxus pollen comes in late Zone VI, as with Abies. Though present in the Pays Basque, the box becomes commoner eastwards on dry slopes at low altitudes in the central Pyrenees and especially in the Mediterranean region.

@ Altitudinal ranges in France are, unless otherwise stated, quoted from Fournier (1946).

Calluna vulgaris. From the macroscopic remains listed above (Table 8) and the foregoing ecological interpretations, it seems likely that most, if not all the Calluna pollen records from both post-glacial and late-glacial levels can be attributed to patches of ling growing on the mire from Zone III times onwards.

Calystegia sp. C.sepium is a common hedge and roadside weed in the area and it is not surprising that the one grain of Calystegia recorded should come from the topmost Zone contemporary with recent historical times and human activity.

Campanula sp. The relatively large size of the pollen grains suggested identification to the genus whilst the absence of Campanula records for Zone II and the whole of the post-glacial period point to probable identification with a light demanding cold tolerant species within the genus. Most French Campanula spp. are herbs of non-shaded dry-land habitats and C.rotundifolia is very common indeed above the tree line in the central Pyrenees where it ascends to c. 2,100 m.

Centaurea cyanus. Iversen (1954) and Godwin (1956) gives Late-glacial pollen records of this species from north west Europe, and discuss it as a steppe element in the Late-glacial flora. It reaches 1,800 m. in France at the present day.

Centaurea sp. The species referred to above as well as C.scabiosa, produce distinct pollen types easily separated from the type considered here referred simply to the genus. From the associated flora at the time, the high peak in Centaurea frequencies at the end of Zone I probably indicates heliophytic species within the genus, which is composed for the most part of light demanding herbs. *C.jacea* and *C.pratensis* both ascend to 2,000 m. in France.

Cladium mariscus. Fruit, rhizomes and pollen of the sawsedge occur in each pollen zone from IV/V onwards and the species is still common over parts of the mire of the present day.

Daboecia cantabrica. The characteristics of this pollen type have been described by Oldfield (1959) and by Watts (1959). Of the two isolated Zone VI and Zone VIIa pollen records of this species from the site (Fig. 14), the lower one was of especial morphological interest since it possessed transverse endo-apertures crossing the furrows and costae between the true pores and the polar ends of the furrows, a characteristic noted for a few of the type specimens of *Daboecia* pollen considered in Oldfield (1959). St. Daboec's heath is a relatively common element of the inland acid heaths of the area (Allorge 1941) and a notable member of the 'lusitanian' element of the Irish flora, the native status of which has been recently demonstrated for Ireland by Watts. tr

Eleocharis multicaulis. A single fruit of this species was recorded at the Zone II/III boundary, immediately before the first stages of inferred bog overgrowth. This species has been recorded by Jovet from the *Sphagnum* flushes on the nearby hill massif of La Rhune (Jovet 1941). Fournier (1946) limits its French altitudinal range to 1,500 m. at the present day. Walters (1949) points out that this species is restricted in Britain to base-poor, acidic habitats.

Empetrum nigrum. No pollen grains (cf. Jessen 1949) of *E. hermaphroditum* were found and the identification is to the species *sensu stricto.* From the above evidence it is clearly not justifiable to infer any colonisation of the surrounding dry land by *Empetrum* during any of the episodes, since the irregularly high pollen frequencies in Zone III can satisfactorily be explained in terms of crowberry growing on the bog at the time, along with heather etc. Two sites recently examined in north Lancashire have given pollen diagrams in which equally high values for *Empetrum* could be related with complete certainty to dry shrubby bog communities, in one instance in Zone VIIa (Oldfield and Statham, in the press), in the other in Zone VIII (Oldfield and Statham unpub.). This kind of evidence contrasts sharply with that from Ireland (Jessen 1949), and the Netherlands (Van der Hammen 1951) where very high *Empetrum* values in Zone III over quite large areas have prompted the authors to deduce the presence of extensive 'oceanic' *Empetrum* heaths during Zone III. Since, despite the position of the Pays Basque, no such reconstruction would be acceptable on the basis of the present evidence from Le Moura, then it would be unjustified to infer strongly oceanic conditions at the time from the high *Empetrum* values. In Britian and on the continent, *Empetrum nigrum* grows in isolated bog situations much further east and south than it does as a heath species, though it is not tolerant of strongly continental conditions in any kind of situation. In France, it is entirely an upland species , tr not decending below 1300 m. and totally absent from the Pays Basque.

Erica cf. *tetralix.* Both the pollen (cf. Oldfield 1959) and seed (cf. Watts 1959) identifications from Zone III are fairly confident. The pollen types highest frequency during the zone is at the deduced transition from *Sphagnum* to *Calluna*-*Empetrum* dominated bog. *Erica tetralix* is a west European species absent even from eastern France and Spain, though spreading as far as Poland at higher latitudes. It ascends to 2200 m. in France. It seems that like *Empetrum*, its presence in Zone III would not be compatible with strongly continental conditions at the time, a conclusion also reached by Godwin (1956) in connection with British Late-glacial records for the species.

Erica vagans. The distinguishing features of this pollen type are described in Oldfield (1959). The isolated records from Zones VI and VIIa represent certain identifications. This species is extremely abundant especially along the coastal fringes of the area where it may dominate large stretches of heathland. The first record, quite early in Zone VI suggests that *E. vagans* could have spread northwards along the Atlantic coast of France into S.W. England before the culmination of post-glacial sea-level. Thus it may be possible to account for its presence in Cornwall without postulating per-glacial survival.

Ephedra cf. *distachya.* The first records come from the phase at the top of Zone I along with other types indicative of dry continental conditions. Only one grain was found in Zone II whereas

Zone III has a continuous *Ephedra* curve. Whilst in other parts of France e.g. Brittany (Van Zeist unpub.) and the Massif Central (Lang and Trautmann 1960) *Ephedra* records continue into the post-glacial period, they are completly lacking above Zone III at Le Moura. The earliest record of *Ephedra* in Britian is from the I/II boundary (Godwin 1956) whilst Iversen (1954) lists a single grain from Zone Ic in Denmark. The Moura record fits easily into this context.

Euphorbia amygdaloides. Two seeds were found at the Zone II/III transition. The wood spurge is a central and south European species of damp woodlands, ascending to only 1400 ft. in Britain, with markedly southern distribution (Clapham, Tutin and Warburg 1956) and to 1300 m. in France. Allorge (1941) records it as a rather rare element in the open heaths of the Pays Basque, but he regards it as an indication of the status of the heaths as degraded former woodland. It may represent a rather southern, thermophilous and rather sciophytic element in the local flora at the end of Zone II.

Euphorbia sp. The *Euphorbia* pollen from the main series was found at a higher level than the seeds referred to above, though the grain found at 440 cm. in the stratigraphical series is from exactly the same level as the seeds. The same pollen type was found from Zone VI levels in series C. (Table 4).

Fagus sylvatica. From the evidence above, it is clear that the suddenness of the genuine increase of *Fagus* frequencies at 60 cm. from 0 to over 25% of the tree pollen total, is probably the result of flooding and resumed accumulation after a long period without any bog growth. In southern France, Fagus is essentially a submontane tree, forming, in moist situations, a forest zone above the altitudinal limit of the oaks. At Moura, the high Fagus values seem to come about largely at the expense of oak frequencies and it is thus tempting to suggest that climatic deterioration is reflected by beech's expansion. In the Pays Basque, the change from Q. robur to Fagus dominance takes place usually between c. 400 and 600 m. (Allorge 1941). Le Moura, at 40m. above sea level, is many miles from any area of moderate extent above these altitudes. It thus seems most unlikely that climate alone could have accounted for the spread of Fagus into the area of the lowland Pays Basque and near enough to the site to have given rise to such strong pollen representation. It seems much more likely that man, in clearing and destroying the natural forest cover during episodes totally lacking at Le Moura played a major role in beech's penetration of the area. In this connection, it is interesting to note that at Mouligna (Oldfield 1960b), the first Fagus values come immediately after the clearance phase recorded there and dated to c. 3000 B.C.

Filipendula. Godwin (1956) makes out a strong case for identifying British Late-glacial pollen records of Filipendula with F. ulmaria. As is characteristic of many Late-glacial sites (e.g. Oldfield 1960), the bulk of the Filipendula pollen from Le Moura is found from Zone II onwards. Here though, the control seems not to be purely climatic, since the main increase in Filipendula frequency takes place some way above the I/II boundary and at the deduced transition from open water to fen, whilst relatively high values are maintained into Zone III until the onset of bog development. In the post-glacial samples, its frequencies are highest in series C (Table 4) which was taken from the part of the mire where minerogenic, supposedly river, sediments occur mixed with the organic deposits, thus providing a more favourable habitat for meadowsweet than the bog peats of the central areas, away from mineral deposition.

Fraxinus exelsior. Pollen records for *Fraxinus* in early and mid Zone VI (Figs. 5 and 14) are interesting in view of the close relationship between the spread of ash and human interference demonstrated in Britain (e.g. Oldfield 1960a) and also in the Pays Basque (Oldfield 1960b), at Mouligna, and in view of the lack of pre Zone VII records for *Fraxinus* in Britian,(Godwin 1956).
It will be noted that the Zone VI record at Le Moura is not restricted to contaminated samples and so, especially in view of ash's low pollen production, may be taken to record ash's presence in the area. Allorge (1941a) and Jovet (1941) consider it as an associate of *Quercus robur* in the richer damper mixed woodlands of the area.

Gentianaceae. The pollen type in question was indistinguishable from that of *Gentiana pneumonanthe*. The Late-glacial maximum in early Zone III close to the deduced transition from fen to bog would be in keeping with this wet heath and bog species which is locally present among the surface vegetation of Le Moura at the present day.

Helianthemum. sp. The pollen recorded here can be distinguished from that of species within sect. Tuberaria, having much finer collumellae and fainter striations.

Hippophäe rhamnoides. Whereas in Britian, pollen of Hippophäeis often associated with the Zone I/II boundary, at Le Moura, it is found only in Zone III. The Large areas covered by superficial sand deposits would, under the unshaded conditions of the time, have certainly provided suitable habitats for the sea buckthorn. At the present day it is not found native along the Atlantic sea bord of France south of the English Channel.

Hippuris vulgaris. The record of Hippuris from Zone III can be compared with numerous Late-glacial records for the species from north west Europe (e.g. Walker and West in Louseley 1953). It ascends only to 1600 m. in France at the present day.

Juniperus. Although the Late and early Post-glacial records for juniper are nowhere near so abundent as is often the case in north west European diagrams, its status at the III/IV boundary, apparently as a pioneer species over herbaceous communities, is very typical of its behaviour at the time over a wide area in northern Europe.

Hyrocotyle vulgaris. The high frequencies of Hydrocotyle pollen and finds of fruit from early Zone VI presumably reflect abundance of this species in the local fen and marsh communities on the mire.

Ilex aquifolium. From evidence on the continent, Iversen (1944) suggested that holly may have been very late in migrating into western Europe during the post-glacial period. However, Jessen (1949) has demonstrated its presence in Ireland from Zone VI onwards whilst Godwin (1956) quotes a single Zone IV record from Hampshire, followed by more established Zone VI records in England. The two pollen records from Le Moura immediately after Zone III thus becoming rather interesting. Ilex is a eu-oceanic species intolerant of winter frost (Iversen 1944) with a strongly southern and western distribution in Europe. The early post-glacial records from the Atlantic coast of Europe and especially the immediately post-Zone III records from Le Moura point to the possibility of holly having survived the last glaciation in south west Europe, not too far away, and perhaps in Iberia.

Knautia sp. Fournier (1946) lists 22 French species of Knautia and all but one (an Auvergne endemic) are dry land species, mainly heliophytic and with a preference for minerogenic soils and dry conditions. All the records are from Zone I, where other taxa represented indicate dry insolated habitats. Lang and Trautmann (1960) record the only other fossil Knautia pollen from France, in the Zone III analyses from a site in the Massif Central.

Libiatae. The pollen type recorded in Zone II was of the stephanocolpate reticulate type represented by Thymus and its close relatives within the tribe Saturejeae. Mentha and Lycopus fall into this group and from the coincidence of the records for this type and those for other marsh and swamp species, it seems likely that the pollen in question represents some species from these genera.

Leguminosae. The pollen types fall into two sorts, one small and smooth and closely resembling pollen of Lotus spp., one much larger and clearly reticulate. The highest frequencies of the former type (Zone II/III) coincided with high frequencies of swamp and fen species and this suggests a possible identification with Lotus uliginsus.

Liliaceae. The pollen type recorded from Late-glacial levels is very characteristic, being monocolpate with a reticulum large and clear around the equator of the grain and becoming finer and less distinct towards the more or less pointed poles. The closest parallel is with the photograph of the type described by Lang and Trautmann (1960) as cf. Veratrum. In the post-glacial sediments a smaller monocolpate type occurs, identical with that tentatively identified as Narthecium ossifragum by Watts (1959) and Oldfield and Statham (in the press), as well as an inaperturate type (indet.) with three vague 'poroid areas'. Narthecium is a common element in acid valley bog situations in south west France (Rallet and Jovet 1955), and Jovet (1941) records it in the Sphagnum flushes on La Rhune.

Lysimachia sp. The very high frequencies of this pollen type in the reedswamp and fen peats of Zone II, along with many semi-aquatic species points to an identification with L. vulgaris which ascends to 1200 m. in France at the present day, or less probably to the rarer L. thyrsiflora a lowland marsh species of S.W. France, or

L. ephemerum a doubtful, native marsh species of the east Pyrenees and west Mediterranean area only ascending to 800 m.

Lythrum sp. The Zone II *Lythrum* frequencies coincide with high *Gramineae* and *Cyperaceae* percentages in a *Phragmites* swamp peat. *Lythrum hyssopifolia* and *L. salicaria* are the only two likely species, the latter and much more likely one reaching 1400 m. in France, the former only 500m.

Malvaceae. As with *Calystegia*, the late record almost certainly indicates nearby presence of one of the mallow species of wayside and wasteland which are a common feature of the local weed flora.

Myrica gale. The tentative pollen counts of *Myrica* in Zone VIII begin above the point of resumed accumulation after a long hiatus and they coincide with increased frequencies of *Calluna*, *Erica*, cf. *tetralix* and *Sphagnum*. *Myrica* leaves were found at lower levels towards the top of Zone VI and so there is the likelihood that some of the pollen counted at this level as *Corylus* refers to *Myrica*.

Myriophyllum alterniflorum. Occasional records from the base of Zone II up into early Zone VI suggest the persistence of base poor open water habitats even during this period of local shrubby bog development in Zone III. Jovet (1955) records *M. alterniflorum* from the Etangs of the Landes and Allorge (1941) refers to it as the dominant species in the open water areas of the Lac de Mouriscot (Fig. 2). It is recorded as ascending to only 1000 m. in France.

Nymphaea sp. Nymphaea pollen records are highest during the open water phase of Late Zone I and Zone II though they persist through Zone III and to the beginning of Zone VI. No Nymphaea species extends above 600 m. in France at the present day.

Olea sp. The pollen morphology of European Oleaceae species has been described by Aubert, Charpin and Charpin (1959) and by Beug (1960). In Olea, the pollen of which but for its short furrows might readily be mistaken for a Cruciferae type, the exine is thick and the reticulum strong with clearly visible collumellae in the encircling muri. The genus in Europe comprises a cultivated form, Olea europaea var. sativa and a genuinely wild or reverted shrub form O. europaea var. silvestris (= oleaster), though Turrill (1952) seems to doubt the cytogenetic and taxonomical validity of such a distinction which is based mainly on economic and ecological reasoning. The status of this taxon in Europe is rather obscure, and Turrill casts doubts on European tertiary records of the genus and also on the genuinely native status of the 'wild' oleaster type which he considers may easily be a degenerated and neglected form of the cultivated type wherever it occurs. This would point to the olive's introduction into Europe by man, and Turrill suggests that the ancestral stock may have been either or both of the closely related African species, O. chrysophylla and O. laperrini. Recent pollen analytical evidence from Mljet in the south Dalmatian area (Beug 1960) shows records of Olea pollen throughout the post-glacial period and although this seems to point to the native status of the genus there, more records would be needed to establish this as a certainty especially in view of the possibility of long distance transport of the pollen and also of very early introduction close to the middle eastern areas of early culture the ages of which, on the latest evidence begin to approach the end of the late-glacial period. Du pont (1955) has recorded the wild form of olive in north west Spain beyond the normal limits of cultivation and along with other Mediterranean plants (*Lavandula* spp. and *Phillyrea media* and *angustifolia*), growing in sites far away from the nearest direct cultural interference at the present day. @ The single pollen record from Zone VIIa at Le Moura, prior to the introduction of any form of cultivation into the area thus becomes interesting in the light of the various views and lines of evidence summarised above. More records would be needed though to add any real force to Beug's tentative indications of the olive's native status in Europe or to Du Pont's possible evidence for its indigenous status in north west Spain.

Onagraceae. The Zone III pollen record was not of *Circaea* but of the *Epilobium*/*Chamaenerion* type.

Osmunda regalis. Spores of *Osmunda* are found in each of the post-glacial zones, as they were in the Zone VIIa/b transition series from Mouligna (Oldfield 1960b). The royal fern covers quite large areas on Le Moura at the present day and it is likely that these post-glacial records for it reflect its presence in local fen communities.

@ Guinea (1949), in contrast, doubts the natural status of the oleaster in Vizcaya, and attributes his single record to former plantation.

Pedicularis cf. *palustris*. The syncolpate pollen type was too small for *P.sylvatica* . As well as *P.palustris*, a common bog species, the French flora includes a number of endemic Pyreneen and Alpine species within the genus.

Polygonum cf. *viviparum*. Tentative indentification to this species was made on the best preserved grains, though most could not be distinguished from pollen of *P.bistorta*. The high frequencies of this pollen type in Zone F and to a lesser extent in Zones I and III may be paralleled by records of *P.viviparum* from Full-glacial deposits in Britain (Godwin 1956). Connolly has recently recorded it (1961) as part of the Late-glacial flora from Whitrig Bog, Berwickshire. *Polygonum viviparum* is a very widely distributed circum-arctic and alpine species of damper tundra communities, wet rocks and especially snow patches, ascending to 4,000 ft. in Britain and to 3,000 m. in France. It is interesting to note that its maximum frequencies at Moura do not coincide with those of the continental 'steppic' taxa.

Potamogeton coloratus. The early VIIa record of this species coincides with other indications of flooding and fen development over the formerly dry *Calluna* covered bog surface of Late Zone VI. *P. coloratus* is especially characteristic of shallow pools in base rich fen situations and its occurrence in peats rich in *Cladium* remains is quite in character.

Poterium sanguisorbra. In France, as in Britian this species is mainly one of calcareous grassland. The Zone III record is paralleled by many European Late-glacial finds (Van der Hammen 1951, Godwin 1956, Lang and Trautmann 1960) whilst the Zone VI grain (Table 4) may indicate survival of open habitats in this coastal area at the height of the post-glacial,a supposition supported by the records of *Artemisia*, *Plantago* and heath species in Zones VI and VIIa. Allorge records it as a present day element in rather dry calcareous *Brachypodium pinnatum* dominated grassland communities of the Pays Basque.

Pteridium aquilinum. Bracken frequencies increase at the Zone IV-V/VI boundary, along with those of *Osmunda* and other *Filicales.* The highest post-glacial bracken frequencies come from 250 cm. in series C, close to boring 7 (Table 4) and they are far in excess of bracken values in other parts of the series and other diagrans from the site, and unaccompanied by any indication of openings in forest cover or of human interference. This points to the presence of bracken locally in the plant communities on the mire (cf. Turner unpub.). The changes in frequencies of the fern types and mire plants about the IV-V/VI boundary may be summarised as follows:-

i). *Pteridium* and *Filicales* peak (*Hydrocotyle* and *Osmunda* rising).
ii). *Hydrocotyle* and *Osmunda* maximum with marsh and swamp spp. *Pteridium* and *Filicales* reduced.
iii). *Sphagnum* increases, as does *Pteridium.*
iv). *Pteridium* maximum.

It has not been possible to relate those pollen analytical changes to stratigraphic changes though no doubt they reflect changes in plant communities on various parts of the mire surface presumably in response mainly to changes in water level. *Pteridium* seldom if ever grows at a soil level below the water table and it is to be found only on rather dried out and often artifically drained or cut over peat in Britian. Its maximum representation here does not coincide with that of the true marsh or fen species and it seems reasonable to suppose that it indicates rather dry conditions over parts of the mire for a while. At the present day, the irregular surface of Le Moura gives rise to a close juxtaposition of contrasting bog and fen communities (Ch. III) and no doubt the presence of localised stream channels in it led to a diversification of habitats in earlier times, (qv. *Filipendula* and *Sanguisorba* also).

Sanguisorba officinalis. There are pollen records for every Late- and Post-glacial zone for this species. In Zone VI it reaches relatively high frequencies in series C at 82 and 94 cm. (Table 4) and is unrecorded for the same period in the other diagram. This suggests the development of a local fen-meadow community, especially since extremely high *Filipendula* frequencies are recorded in the same samples. Since this series is only 240 m. from the main series and also the main monolith analyses, this evidence suggests that the pollen of the entomophilous *Sanguisorba officinalis* was not widely dispersed at the time. The only mention of this species in Allorge (1941) refers to its presence in a *Molinietum* on Monte Jaiz quibal in the Spanish Pays Basque, at c. 1580 m. It is a rare and disjunct mountain species in most of Spain.

Scabiosa/Succisa type. This pollen type, recorded from Zone II onwards almost certainly refers to *Succisa pratensis*. Its highest frequencies occur in Zone II at the top of the fen stage.

Scorzonera type. Faegri and Iversen (1950) describe this rather peculiar type of *Compositae* pollen. It seems doubtful whether in this instance it refers to the genus *Scorzonera* only.

Tilia sp.The scanty pollen records never exceed 1 percent of the tree pollen sum and, as in southern England, they begin in late Zone VI. Such low frequencies leave in doubt the native status of the lime in the area where, at the present day it is hardly if ever recorded from natural situations.

Typha latifolia. Records for this species begin in Zone I at Le Moura, whereas Iversen has shown that in Denmark, they do not begin until Zone II. Godwin (1956) lists two pollen analytical records for it from Zone I in eastern England. Iversen (1954) takes its presence to indicate July temperatures of at least 14°c.

Ulmus sp. The low frequencies of such an abundant and anemophilous pollen producer as elm give little cause for considering it an important element in the local woodland at any stage during the post-glacial period (cf. also Oldfield 1960b). *Ulmus levis* and *Ulmus glabra* occur but are rare in the Pays Basque at the present day, being mainly restricted to the local often precipitous valley sites (the 'ravines à fougères of Allorge 1941) where they grow as part of an extremely mixed and floristically rich woodland, (Table 14).

Umbelliferae. The concentration of high Umbelliferae values within the deduced swamp and fen stages of Zone II and early Zone III makes it very likely that the pollen in question is that of some semi-aquatic species (perhaps of Oenanthe or Apium) growing locally.

Valerianaceae, Valeriana diocia. Coincidence of relatively high pollen frequencies of this type with the seed identified to the species in Zone III points to the marsh valerians' having been a member of the fen flora of the time. British records for this species are almost completely restricted to the Late-glacial period (Godwin 1956). It is notable that it does not reach the tree line in France, nor does it extend northwards in Scandivavia beyond southern Sweden. From this and from many of the other Late-glacial records of aquatic and semi-aquatic taxa discussed above, it is clear that the suprisingly rich and rather thermophilous nature of Late-glacial pond and mire vegetation noted in North West Europe (Iversen 1954) is paralleled here.

Vitis sp. The earliest pollen record of vine, Zone IV-V, clearly predates any period of possible introduction by man as do the Zone VI and VIIa records from the various monolith series. These latter records are especially significant since the method of sampling precludes the possibility of downcarriage of pollen from higher levels. Jovet (1955) records apparently wild vine growing with hazel forming wind pruned scrub on the cliffs in the St. Jean de Luz area.

CHAPTER V. MARBELLA. Stratigraphy, pollenanalyses & plant remains.

i). Introduction.

The deposits to be considered outcrop on the coast near the southern limit of the administrative area of Biarritz, close to the Villa Marbella (Fig. 2). The present account is concerned mainly with deposits occurring north of the outlet of the Ruisseau de Chabiague (Fig. 16), and only these are discussed in detail. The relationship of the northern deposits to those south of the stream is considered briefly in Chapter VI, section 2 below.

The deposits at Marbella extend inland for at least 1 km., and badly obscured and crumbling sections have been noted by the side of the R. de Chabiague close to the main road by Duperier (unpub.)½ No attempt has been made to trace the deposits inland by boring. The former topography of the basin has been greatly obscured by deposits of recent superficial sand, dissection by minor streams and human interference.

ii). Stratigraphy.

A. NORTH OF THE RUISSEAU DE CHABIAGUE.

In view of the precarious and continuously changing nature of the cliff face and the infrequency with which the lowest deposits can be seen, no singly section from top to bottom of the series could be recorded. The following annotated succession is a compound of sections from adjacent parts of the same major coastal exposure (Fig. 16, Site I), save for the data from stratum F, the exact

e

position of which has not been observed by the present author. Those strata which have proved to contain pollen in countable quantities are labelled with letters which relate to the ones used in the pollen diagrams (Figs. 17 and 18). The intervening deposits are given numbers. Heights above sea-level are quoted for certain critical horizons[@].

1	0 - 30 cm.	Present day soil.
	30 - 50 cm.	Dune sand with modern rootlets.
	50 - 60 cm.	Brown slightly organic loose dune sand.
2	60 - 130 cm.	Muddy sand with occasional layers of clay with pebbles, especially between 100 and 110 cm.
	130 - 155 cm.	Ochre coloured sand, less organic than above and with fewer pebbles.
	155 - 195 cm.	Light cemented sand with some stratification. Clayey at 170 cm. Iron pan at 195 cm.
3	195 - 230 cm.	Very hard cemented sand, narrowly bedded with coarse grit and pebble layers. Pebbles angular and unsorted, bedding much disturbed.
4	230 - 311 cm.	Loose white and pale grey sand with red oxide layers at 270 and 290 cm. and unindurated ferric staining elsewhere. Clayey between 255 and 265 cm.

[@] Levelling was carried out with a quickset to an accuracy of 2 cm., though the datum to which the determined heights were related was a spot height the level of which could only be determined to the nearest .5m. Thus all heights are plus or minus half a metre.

	311 - 313 cm.	A persistent but much contorted black muddy layer with clay below. (STRATUM O).
	313 - 316 cm.	Iron pan.
5	316 - 360 cm.	Almost pure white sand with lenses of gravel.
	360 - 460 cm.	Coarse ungraded angular gravel in lenses, with clay, sand and grit between. Solifluction head. Lower contact clean with no transition.
6	460 - 495 cm.	White beach sand. (460 cm. = 16.7 m. (c.55') above mean sea level).
	495 - 500 cm.	Faint horizon of unhardened iron oxide accumulation.
	500 - 630 cm.	Yellow beach sand becoming white and leached below.
	630 - 640 cm.	As above becoming iron stained and clayey.
	640 - 815 cm.	Dark brown compact fibrous laminated peat with numerous *Carex* nutlets, becoming muddy at the very top. (STRATUM A. 0 - 175 cm.).
	815 - 850 cm.	Laminated peat with abundant fronds of *Osmunda regalis*. (STRATUM A. 175 - 210 cm.).
	850 - 960 cm.	Medium brown sandy detritus muds. (STRATUM A. 210 - 320 cm.).
7	960 - 1050 cm.	Beach sand.
	1050 - 1080 cm.	Contorted mud layer with fruitstones of *Potamogeton pectinatus*. (STRATUM B. 0 - 30 cm.).
8	1080 - 1330 cm.	Beach sand. 1330 cm. = 8 m. (c.26') above mean sea level.

1330 - 1480 cm.	Olive green clay-mud with numerous fruits and leaves of aquatic plants towards the top. (STRATUM C. 0 - 150 cm.).
1480 - 1550 cm.	Grey sand with silt and clay. Drift wood at 1550 cm. (STRATUM C. 150 - 220 cm.).
1550 - 1702 cm.	Grey clay-silt with sand throughout. (STRATUM D. 0 - 152 cm.).
1702 - 1720 cm.	Grey unconsolidated grit. (STRATUM D. 152 - 170 cm.).

c. I metre hiatus. Depths below approximate.

1820 - 1850 cm.	Heavy grey clay silt with marine molluscs. (STRATUM E. 0 - 30 cm.).
1850 - 1870 cm.	As above with coarse rounded grit. (STRATUM E. 30 - 50 cm.).
1870 - 1910 cm.	Gritty clay with shells. (STRATUM E. 50 - 90 cm.).
1910 - 1940 cm.	Coarse rounded grit in a watery matrix. Section flooded. (STRATUM E. 90 - 120 cm.).

1940 cm. = c. 2m. above mean sea level.

--------- Hiatus of unknown depth ---------

STRATUM F. 3 samples collected by R. Duperier in Feb. 1958 (Oldfield 1960c).

The bottom metre of stratum C and the whole of strata D and E have only once been observed by the author, after a rough storm in August 1958. They are usually covered by present day beach deposits

PLATE 4. Marbella. The northern edge of the basin. Recent dune sands overly Stratum A, at its thickest here. Little intervenes between stratum A and Stratum C, which is seen to rise against the edge of the solid rock.

PLATE 5. Marbella. Just north of site I. Stratum A, with the narrow contorted mud band of Stratum B below.

and so it is not possible to trace their lateral continuations to north and south of the point of sampling. The top of stratum C and its transition to stratum 8 can be traced clearly to north and south of site I. Northwards the C/8 contact rises as it approaches the edges of the basin, which are in solid rock, and stratum C becomes progressively narrower so that eventually only 50 cm. of rather gritty clay mud overlie bedrock. At this point, compaction of Stratum C must have been minimal and the height of the C/8 contact a good indication of its original level. The height recorded was 9 m. 30 cm. above mean sea level, i.e. 130 cm. above the height of the same contact at site I, only 160 metres further south, suggesting a compaction of stratum C and the underlying deposits of that order of magnitude at site I, since deposition.

Stratum B is found only in the northern half of the cliff face, and south of site I it quickly thins out and disappears, being continued as a zone of iron staining in the beach sands. Stratum A continues south of site I to the location of the Villa Marbella itself. On the cliff face north of the concrete apron below the terrace of the Villa, the top of stratum A is subdivided by a layer of coarse beach sand and stratum A as a whole is only c. 2 m. thick. South of the concrete apron there are no traces of stratum A and 9 metres of beach sand, interrupted only by iron stained layers are found above the top of the southern continuation of stratum C. Moving north from site I towards the edge of the basin, stratum A becomes thicker reaching a maximum depth of c. 5 m. about 30 m. from

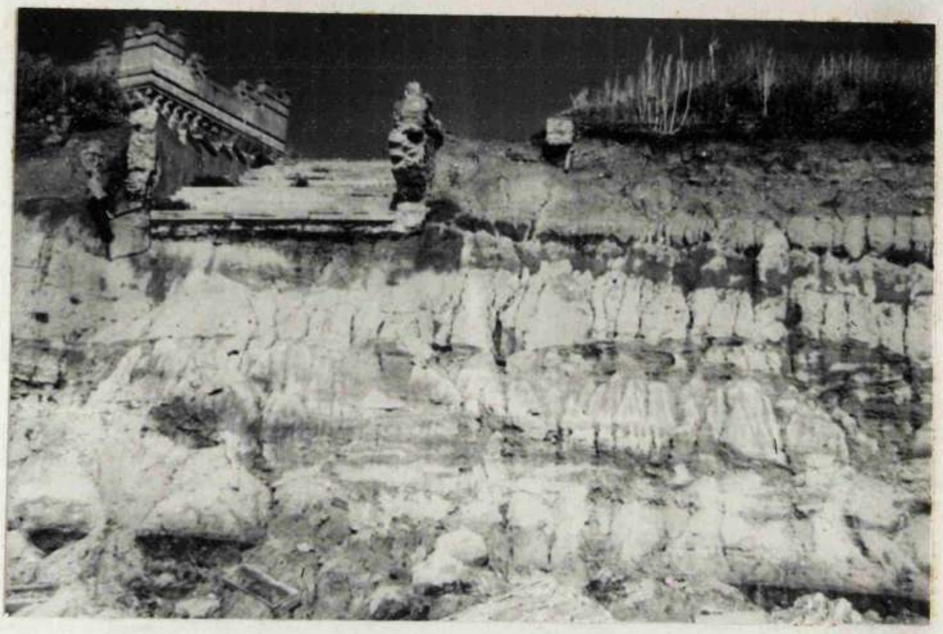


PLATE 6. Marbella. Uninterrupted beach sands above Stratum C, between the concrete apron and the mouth of the Ruisseau de Chabiague.

PLATE 7. Marbella. The continuation of Stratum C, with overlying beach sands, just south of the Chabiague. The roof of the abattoir can be seen in the top right hand corner.

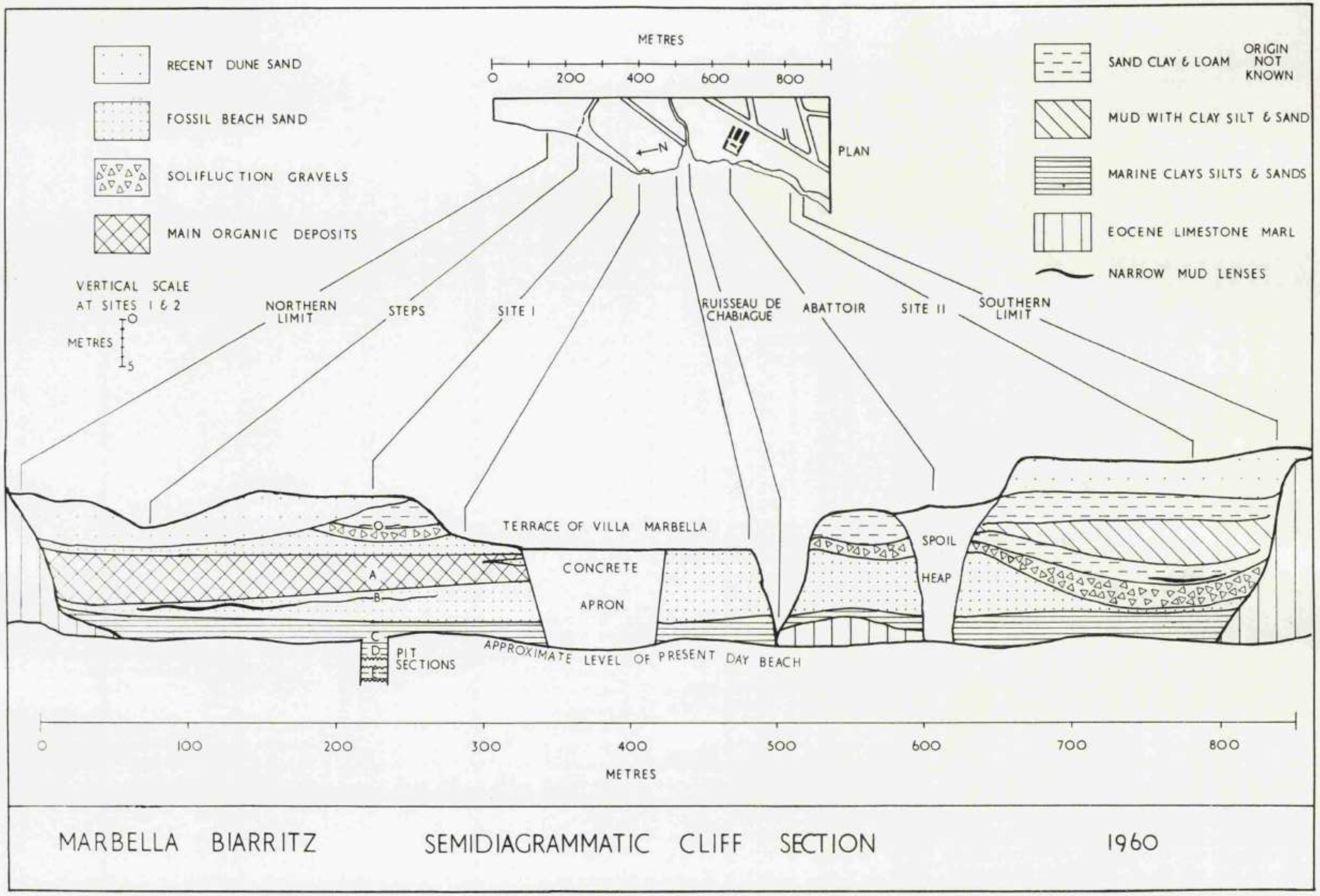


Figure 16. The stratigraphy of the Marbella deposits.

the edge of the basin.

The deposits recorded as overlying stratum A are well exposed only close to site I. North of there they have been washed out and recent dune sand comes into contact with the lower levels of stratum 6. To the south, the construction of the terrace of the Villa Marbella has both removed and obscured them from view.

B. SOUTH OF THE RUISSEAU DE CHABIAGUE.

The only strata recorded north of the stream which can be traced confidently southwards towards the southern limits of the basin are the lower levels of stratum 7 (beach sands) and the upper part of stratum C. Immediately to the south of the stream, bedrock approaches the surface and only c. 1.5 m. of stratum C are present. As at the northern end of the basin, the top of stratum C is at a higher level (8.5 m.) than at site I. At this point, the deposits overlying the beach sands of stratum 7-8 are mainly loams and dune sands of uncertain age and origin which cannot be related to the succession at either side since they are cut off to the north by the Valley of the Ruisseau de Chabiague and to the south by the site and extensive spoil heaps of the former municipal abattoir of Biarritz. South of this latter building, good sections are again exposed and the following succession was recorded at site II, (Fig. 16).

(3 - 4 m. of superficial soil and recent dune sand.)

0 - 175 cm.	Sands with coarse gravel around 100 cm.
175 - 270 cm.	More or less pure sand, yellow above, leached white below and strongly iron stained at the base.

270 - 295 cm.	Grey-brown clay mud with sand layers at 276, 278 and 288 cm. This bed is truncated by later sands immediately to s. of section.
295 - 302 cm.	Bedded grit.
302 - 338 cm.	Clayey mud with sand layers at 311 and 333 cm. This bed is truncated by later sands a little s. of section.
338 - 340 cm.	Gravel.
340 - 349 cm.	Grey sand.
349 - 355 cm.	Pale grey-brown sandy-silty-mud. Truncated to s. by a bed of gravel older and coarser than that which truncates the organic horizons above this.
355 - 385 cm.	Pale grey and white sands with iron stained horizons and coarse gravel at base.
385 - 389 cm.	Dark brown fine-detritus mud.
389 - 402 cm.	Clay-mud.
402 - 414 cm.	Grey sand and grit.
414 - 416 cm.	White clay.
416 - 442 cm.	Clay-mud.
442 - 445 cm.	Dark grey sand.
445 - 469 cm.	Olive-brown clay-mud.
469 - 534 cm.	Sandy clay-mud.
534 - 547 cm.	Dark grey sand.
547 - 714 cm.	Very smooth detrital clay-mud, interrupted by sand layers at 564-6 cm. and 614 - 9 cm. and becoming increasingly clayey below 655 cm.

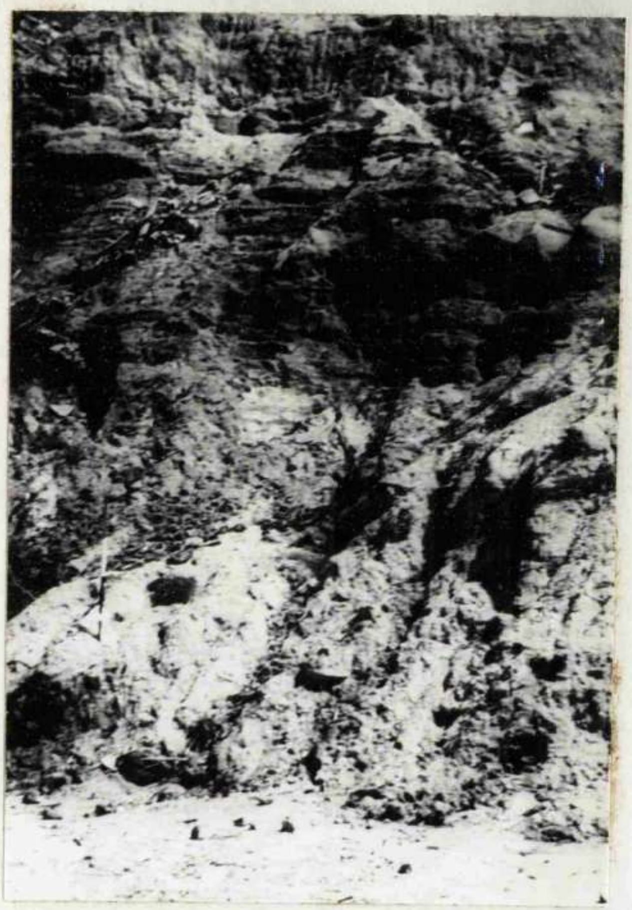


PLATE 8. Marbella. The cliffs at Site II.

714 - 880 cm.	Leached white sand with clay and iron stains. Gravelly especially at c. 850 cm.
880 - 920 cm.	Pale brown sandy clay-mud.
920 - 1190 cm.	Coarse gravels and sands in a clay matrix - solifluction head. (equivalent to stratum 5 at site I ?).
1190 - 1215 cm.	Iron stained gravel and grit in a clay-mud. (top of stratum C.)
1215 - 1270 cm.	Green Marine Clay = Stratum C.
1270 +	Marine sands and gravels.

Most of the sediments between 270 and 355 cm., 385 and 714 cm. and 880 and 920 cm. are quite rich in pollen and a set of preliminary analyses from various depths has been completed. The results are given in Appendix II, but since they are not yet sufficiently numerous to permit detailed discussion, they are not interpreted closely in the present study. Their general implications are considered in Chapter VI section 2.

Figure 16 is a diagramatic representation of the stratigraphic successions both north and south of the R. de Chabiague.

iii). Pollen Zonation (Site I).

PHASE I. (Stratum F.) The tree pollen spectra in the lowest and highest samples are dominated by *Alnus*, *Quercus*, *Corylus*, *Tilia* and *Abies*, whilst in the middle sample *Pinus*, *Betula* and *Fagus* assume greater importance.

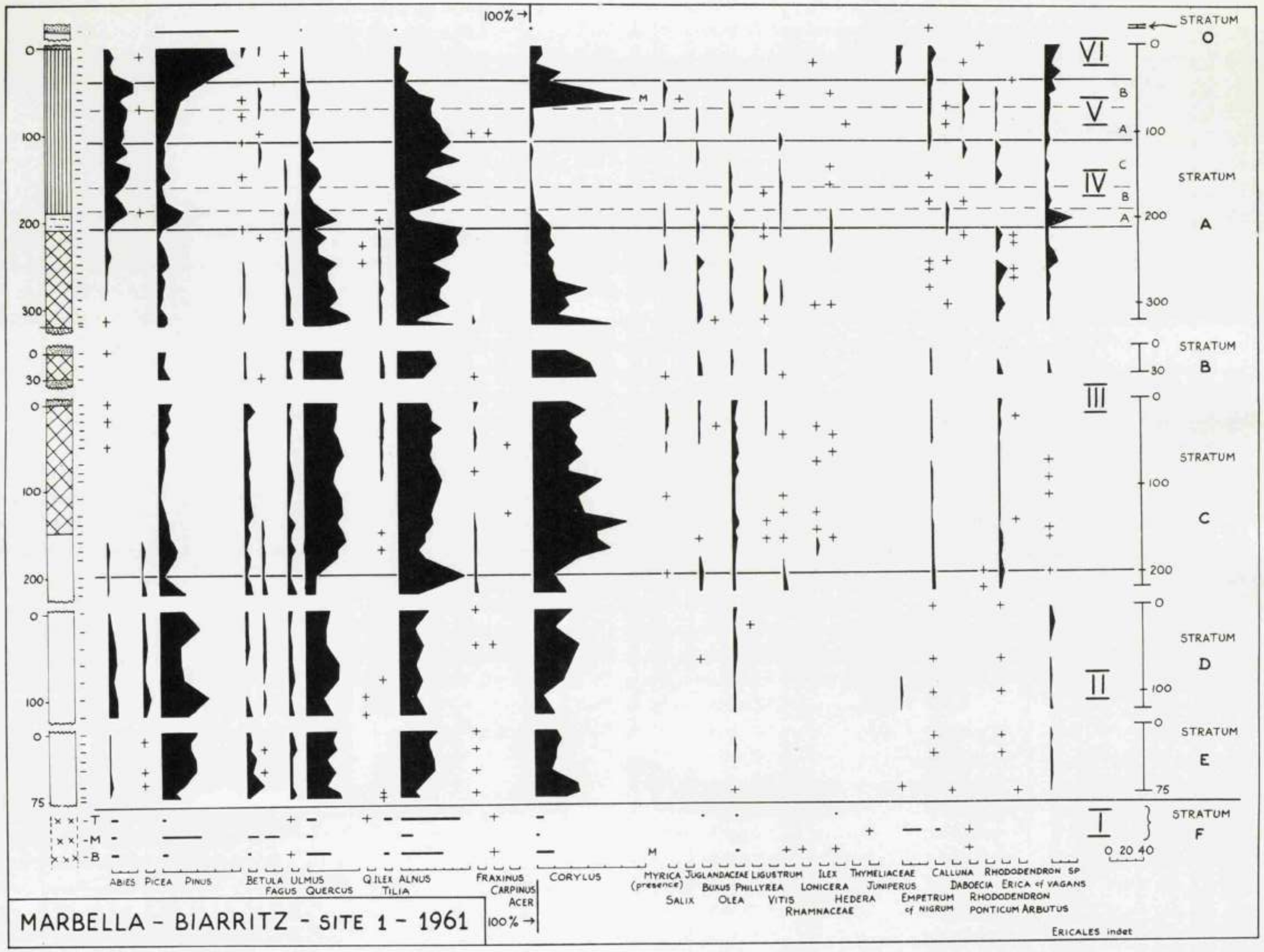


Figure 17. Marbella. SITE I. Tree and shrub pollen diagram. See text for stratigraphy.

Percentages based on total tree pollen less Corylus and Salix.

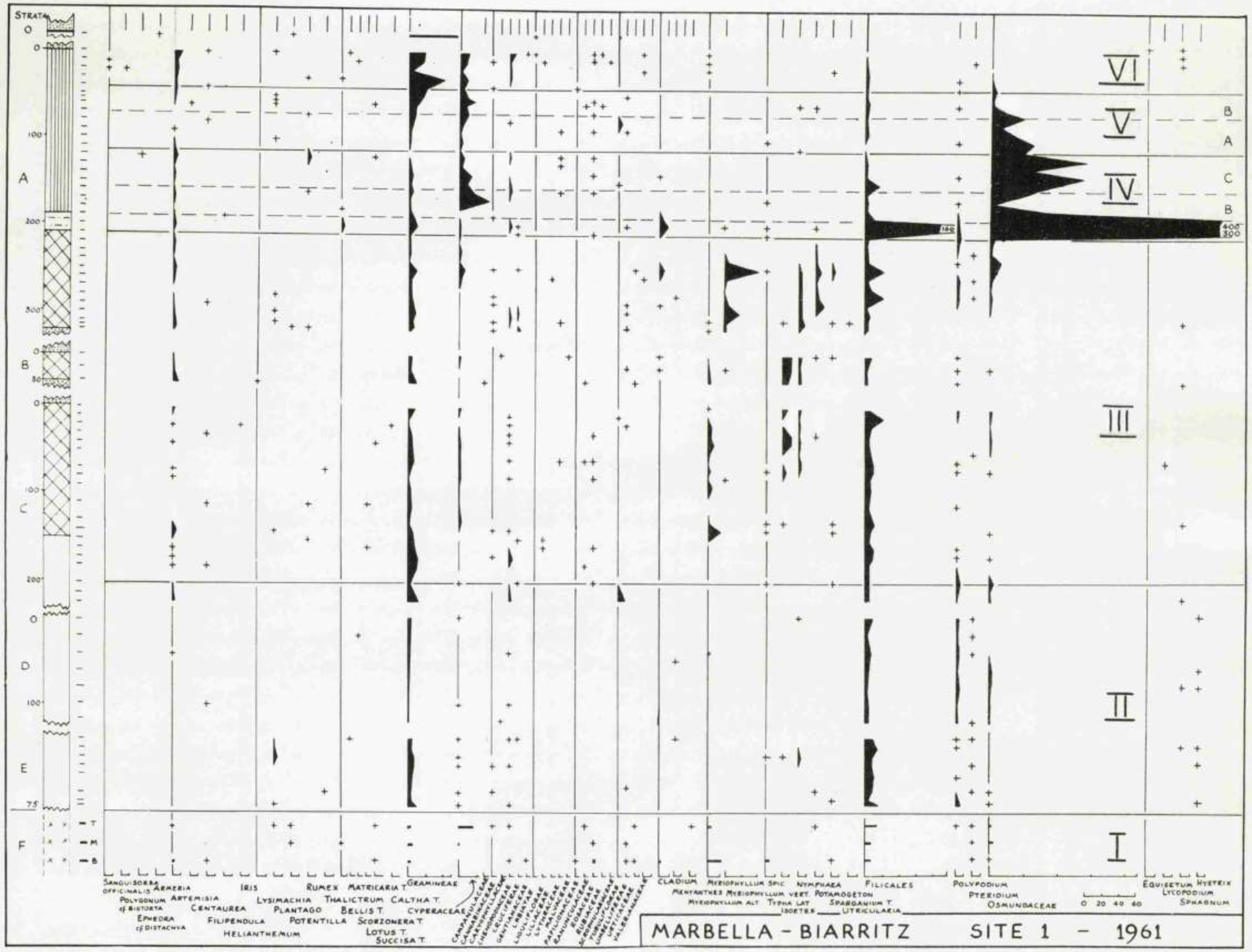


Figure 18. Marbella. SITE II. Non-tree pollen diagram. For stratigraphy see text.

Percentages based on total tree pollen less Corylus and Salix.

PHASE II. (Strata E and D: Stratum C, 220 -200 cm.). Pinus, Quercus, Alnus and Corylus are almost equally represented, with other trees rather scarce.

PHASE III. (Stratum C, 200-0 cm. Stratum B. Stratum A.320-210 cm.). Pinus frequencies fall, those of Quercus and Corylus reach their maximum during this period.

PHASE IV. (Stratum A. 210-110 cm.). Abies values rise sharply to c. 20 percent of the tree pollen total, whilst Corylus frequencies fall to c. 2 percent. Quercus frequencies decline steadily throughout the period.

On the basis of changes in the non-tree-pollen rain, this phase has been subdivided into - IVa). 210 - 180 cm. Maximum of Osmunda and Filicales.

b). 180 - 160 cm. Maximum Cyperaceae frequencies.

c). 160 - 110 cm. Return of high Osmunda values.

PHASE V. (Stratum A. 110 - 40 cm.). Pinus values rise as Alnus declines. High Abies and low Quercus frequencies are maintained.

Subdivided into - V a). 110 - 70 cm. Relatively high Osmunda values persist.

b). 70 - 55 cm. Coryloid (= Myrica) values reach a maximum.

c). 55 - 40 cm. Coryloid values decline, Gramineae rise.

PHASE VI. (Stratum A. 40 - 0cm. Stratum 0). Pinus frequencies rise rapidly to dominate the tree pollen spectra completely. Herbaceous pollen frequencies rise.

(iv). Macroscopic plant remains.

As yet, the only levels for which a through and systematic analysis of macroscopic reamins from the site has been carried out are the three lowest samples of phase I (Oldfield 1960c) and the top 50 cm. of Stratum C (Phase III). The results are given in Table 13.

TABLE 13. MACROSCOPIC PLANT REMAINS. MARBELLA SITE I

	Phase I.	Phase III (Stratum C, 0-50cm)
Abies alba (L)	@	
Carex sp. (fr.).	@	
Erica cf. *lusitanica* (s).	@	
Myriophyllum spicatum (fr).		@
Najas flexilis (fr).		@
Najas marina (Fr).		@
Nymphaea sp. (s).		@
Potamogeton natans (fs).		@
Potamogeton obtusifolius (fs).	@	
Potamogeton pectinatus (fs)		@
Potamogeton sp. (fs).	@	
Ruppia maritima (f).		@

Abbreviations as in Table 8.

(v). List of photomicrographs.

Appendix III includes photographs of the following pollen grains from the Marbella deposits at Site I:-

Arbutus sp. (Phase III, two grains), Rhododendron ponticum (Phase V and Phase VI), Rhododendron sp. (Phase V and Phase VI), Erica cf. vagans (Phase III), Quercus ilex type (Phase III), Olea sp. (Phase III), Phillyrea sp. (Phase III), Oleaceae indet. ? Fraxinus ornus (Phase III), Fagus (Phase V).

CHAPTER VI. DISCUSSION. The deposits at Marbella.

(i). The age of the deposits at site I.

The phase of vegetational revertence to coniferous woodland in the higher pollen-analysed layers, numerous other contrasts with the series from Le Moura, in succession and flora, and the presence of overlying solifluction deposits, confirm that the successions at site I do not belong to the post-glacial period, whilst the record of long lasting deciduous warm temperate woodland during the middle episodes and the many thermophilous evergreen taxa recorded show that most of the deposits may be referred to an Interglacial rather than an Interstadial period.

The topographical and stratigraphical context of the polliniferous sediments gives no further indication of their age since no other similar successions have been described or dated within hundreds of miles of the site. Thus the basis for correlating the deposits with others has to be a purely biological one, and in view of the nature of the data, mainly a botanically one. To this end, account may be taken of the overall flora of the deposits and of the vegetational successions portrayed by the plant remains, especially the pollen analyses. West (1955) has summarised the main characteristics of the vegetational successions in the various known Interglacial periods in Western Europe. In the light of his comments and of more recent evidence published by Jessen, Andersen and Farrington (1959), Watts (1959) and Zagwijn (1960 and 1961), the following aspects of the Marbella flora may be noted ;-

i). The absence of 'tertiary' pollen types in all analyses other than those from the marine deposits of strata C, D and E, in which derived Pinus 'haploxylon' type was found @.

ii). The presence of Abies pollen in relatively large quantities.

iii). The presence of pollen of many evergreen shrubs, including various Ericaceae, with Lusitanian or Mediterranean affinities, e.g. Rhododendron ponticum, Arbutus and Daboecia cantabrica.

The notable features of the pollen anlytical successions are:-

iv). The gradual rise of Corylus pollen frequencies to a relatively late culmination.

v). The sustained importance of Alnus pollen values throughout most of the period recorded.

vi). The succession from the middle phase of oak-alder dominance to a coniferous stage in which Abies was important.

vii). The absence of any zone of high Picea or Carpinus values.

These various points refer the deposits to the Hoxnian period @@ with complete certainty and there are quite close parallels in vegetational development between the Marbella series and those from Hoxne itself (West 1956), which suggests that roughly the same span of time may be encompassed at the two sites, Hoxne including much more of the earlier episodes of the Interglacial, Marbella coming further up

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@ In the same category may be placed a jawbone of Elephas meridionalis found by Duperier in the marine sediments and at present in the Musee de la Mer, Biarritz.

@@ Here the term Hoxnian is preferred to 'Great Interglacial' since it carries with it no connotation of particular length or magnitude. The same Interglacial has been variously referred to as Needian, Holstein, and Penultimate.

towards the succeeding glacial period. There are also extremely close parallels in the composition of the flora between Marbella and the Irish deposits of Hoxnian age at Gort and Kilbeg, where a similar assemblage of shrubs has been recorded.

In view of the similarity between the Marbella and Hoxne successions the following tentative correlation between the phases and zones defined at the two sites is proposed, though with much the same reservations as qualify the correlation of the postglacial pollen sequence at Le Moura with those for southern England.(Ch.IV)

Marbella. Hoxne.

PHASE I. - ? Zone I, c - e (see section v).
PHASE II, and III up to c.280cm. stratum A. - Zone II,c - d.
PHASE III. c. 280 - 210 cm.stratum A.- Zone III.
PHASE IV - V. - Zone IV.
PHASE VI. - Not represented.

(ii). The relationship between the deposits north and south of the Chabiague

At site II, the sands of strata 6 - 8, have been totally removed and solifluction gravel comes down almost to the top of stratum C. Although direct continuity cannot be demonstrated it seems very probable that these gravels are contemporary with stratum 5 at site I. Above the gravel at site II, over 9 metres of river-borne sands, silts and clays occur intercalated with laminated lacustrine muds and clay-muds. Of these deposits, a total of 4 - 5 metres have been found to contain pollen, and 31 samples have been analysed

(Appendix II). Although from these few it is not possible to deduce the detailed vegetational successions through the period, sufficient information has been obtained to permit the following generalisations:-

i). Throughout the period, pine and birch remain the dominant tree species, and for large parts of the time, their representation is completely overshadowed by that of the herbs. Thus none of the deposits is demonstrably interglacial and they are almost certainly all glacial or interstadial in age.

ii). Even the highest episodes cannot be correlated with any part of the Full-and Late-glacial successions at Le Moura (Ch. IV).

iii). Many samples contain pollen and spores belonging to species and genera abundantly represented in the Site I series and hence probably the result of derivation from these earlier deposits.

From this and the stratigraphical record, it seems that a large part of a complex major glacial phase post-dating the Hoxnian is represented. There is no conclusive evidence to relate it to either the last glaciation (Würm, Weichsel) or the preceding one (Riss, Saale). The complete lack of intervening deposits or weathering horizons between this series and the Hoxnian deposits, and the absence of parallels with the north European Weichsel successions (Andersen, de Vries and Zagwijn 1960 and Zagwijn 1961) in so far as the completed analyses permit comparison, make a correlation with the Riss more likely. It is probable though not certain that the single pollen sample from stratum O is contemporary with some of the lower analyses just above the solifluction gravel at site II.

(iii). Comments on the flora at Site I.

Abies alba. The most diagrostic remains were the leaf tips from the lowest sample, discussed in Oldfield (1960 c). Like the ones described from Gort @, these were identical in every way with material from present day Abies alba. In view of this and the parallel records from Ireland, identification to the species seems quite justified. The role of silver fir in the vegetation of southern France at the present day, and its post-glacial record in the area are referred to in Chapter IV. At Marbella, the clear indication of its presence in the immediate neighbourhood during the later parts of the Interglacial represent only a slight transgression of the present Western limits of the species.

Picea. In view of the low pollen production of spruce (cf. Simpson and West 1957), there is some reason for supposing that it was present locally especially towards the end of the Interglacial, despite its sparse representation. This conclusion is reached at Gort and Kilbeg on the basis of macroscopic remains, which latter permit an identification to the species Picea abies, the Norway spruce. Indications as to spruce's tolerance of oceanic conditions are rather contradictory but its presence in south-west France at this time, as in Ireland, shows a striking westerly extension beyond its present day range.

@ In this and succeeding sections the deposits at Gort and Kilbeg are, for the sake of brevity, referred to without citing the authors, Jessen, Andersen & Farrington (1959) & Watts (1959) respectively.

Arbutus, The pollen tatrads of the west European *Arbutoideae* are characterised by their large size and globular shape. *Arbutus unedo* produces the largest and smoothest tetrads with exceptionally long furrows, striking 'endo-cracks' and hardly discernible ektexinal columellae (Oldfield 1959). *Arbutus andrachne*, an east Mediterranean and Asia Minor species produces similar pollen with a size range of 46.4 - 52.7 microns (Beug 1960) as compared with that of *A. unedo*, 48.7 - 61.2 (acetolysed grains). The sub-fossil grains recorded here measured c. 45 - 50 mi. and so fell into the range of overlap. Although the measurements on the fossil pollen should certainly be augmented to make them camparable with the types, since the use of H.F. and the absence of acetolysis would both tend to give the pollen a smaller size, nevertheless, it is not possible to say with complete certainty from the pollen analytical evidence which of the two species is represented. *Arbutus unedo*, would on phytogeographical grounds be much the more likely, although the two species are closely related (producing a hybrid, *Arbutus andrachnoides*) and *Arbutus andrachne* will survive in western Europe at the present day, but only as a horticultural plant.

The pollen is recorded sparsely in each phase from the beginning of phase II through to the V/VI transition. *Arbutus unedo* is one of the Lusitanian species occurring locally in Brittany and southwest Ireland, but more extensively in south west France, Spain and the Mediterranean region. It would appear from its present distribution to be a rather frost sensitive species, the more so since, unlike

Rhododendron ponticum, it does not have an extensive area of introduced and sub-spontaneous habitats beyond its indigenous localities. Sealy (1950) points out that at Kew, this species has only once in the last 50 years fruited as profically as in Killarney. Although once established, *Arbutus* is hard to kill, as a seedling it is very sensitive to winter cold, and Sealy suggests that the limiting temperature for its regeneration is 40° F, for the month of January. Both on the continent and in Ireland, *Arbutus unedo* is not a true woodland species, being restricted rather to scrub and woodland margins. In the Mediterranean area it forms a characteristic component of the scrub woodland or maquis (macchia), along with other evergreen shrubs.

Buxus cf. *sempervirens.* Box pollen is present in every episode save the last. This accords well with its occurrence at Gort where it is recorded as persisting to the top of the diagram in which a final pine dominated phase is lacking, and at Kilbeg, where *Buxus* is absent from the final zone of pine-birch dominance. This evidence suggests that box may have been eliminated from much of western Europe during the final phase of the Interglacial, presumably as a result of climatic deterioration. At the present day it has only a limited tolerance of frost. Jessen, Andersen and Farrington (1959) point out that despite its present day continental southern distribution and preference in much of western Europe for rather dry insolated slopes, it flourishes under oceanic conditions when planted. In south eastern France it is a frequent element in the 'garrigue' communities, floristically rich calcicole vegetation typically furnishing only a partial and mainly herbaceous plant cover. It is most abundant where soil erosion and instability on relatively steep slopes has eliminated many of the other garrigue species. Its preference for rather steep unstable base rich habitats can be seen in southern England also (Pigott and Walters 1953) though it is quite capable of surviving on base poor soils.

Calluna vulgaris. The highest frequencies are contemporary with the final phase of pine dominance though low but consistent percentages occur throughout the whole of the record. In the final phase, ling may have been growing along with *Empetrum nigrum* in heath communities round the mire.

Carpinus betulus. The very sparse records for hornbeam are similar to those in other west European Hoxnian sites. It cannot have been a very important element in the forest at any time during the Interglacial.

Cladium mariscus. No other west European Hoxnian records for this species are known to the author. West (1957) has recorded it from deposits of Last Interglacial age in Britain and Welsch (1917) from coastal 'Lignites' in south west France of uncertain but probably Interglacial or Pliocene age. The pollen of *Cladium* is smoother and more yellowish-brown in colour (when stained with safranin) than that of other *Cyperaceae* and it often tapers at one end to a narrow 'tail'.

Daboecia cantabrica. On the basis of the characteristics described above (Ch. IV) and in Oldfield (1959) and Watts (1959) a few pollen grains of this species were recorded from all but the first and last phases. This evidence contrasts with that at Kilbeg where *Daboecia* pollen was found only in the final zone of high pine values. The present day ecology and distribution of *Daboecia* are summarised in C. IV and in Watts (1959).

Empetrum nigrum. As with the Late-glacial pollen described in Chapter IV, and for the same reason, the identification refers to the species *sensu stricto.* The early peak is contemporary with other indications of more open and cooler conditions and the consistent records from phase VI coincide with the period of pine dominance and apparently rapid climatic revertence. There is no evidence to suggest that *Empetrum* was growing on the mire during either phase and it seems likely that it formed an element in open heath communities during these phases of reduced forest cover. It may,in this case, be justified to infer quite oceanic conditions during these periods, a conclusion which would not be contradicted by any of the pollen records comtemporary with the *Empetrum* values.

Ephedra cf. *distachya.* The single pollen grain from Phase IV appears to be the only west European records for this type from this Interglacial period.

Erica cf. *arborea*. This single pollen record is not quite certain, despite the presence of the rather characteristic ornamentation of this species (Oldfield 1959). It is a species typical of the Mediterranean 'Maquis' where it often grows with *Erica scoparia*, *Arbutus unedo* and other evergreen shrubs. Its presence in the Spanish Pays Basque is undisputed (Guinea 1949, de Benito 1948, Rikli 1943) though authorities appear to disagree about its presence in south west France (cf. Fournier 1946 and de Benito 1948). As well as being widely distributed in southern Europe, the same species dominates one of the characteristic montane plant communities in East Africa (Hedberg 1951). A post-glacial record exists for this species in France (Braun-Blanquet 1933), though it is hard to say how reliable the identification is.

Erica cf. *lusitanica*. This record of a single seed is discussed in Oldfield (1960 c). Until some more material of a similar type can be found at the site, it seems wisest to consider the identification rather tentative, especially since the distinction between this seed type and material of *Erica tetralix* is only slight.

Erica cf. *vagans*. Pollen of this type was fairly frequent, though the state of preservation did not permit identification with complete certainty. Confirmation of its existence would be especially interesting in view of its presence in the post-glacial levels at Le Moura and its disjunct distribution in north west Europe (Chapter IV). *Erica vagans* pollen can be distinguished from that of *E. mediterranea* only on the basis of its shape, the former being lobed, the latter subtriangular. With poor preservation, the *Erica vagans* tetrads tend to 'Collapse' and this gives rise to forms intermediate between the two. Such types were observed throughout the series and it is thought that those referred to as *E.cf. mediterranea* in Oldfield (1960c) may in fact be poorly preserved grains of *E.vagans.*

Ericales indet. Most of the tetrads within this group were almost certainly very battered specimens of *Rhodendron ponticum,* with their ektexinal ornamentation, completely altered by decay. A few grains resembled those of *Erica scoparia*. This predominantly west Mediterranean sandy heath species has been recorded macroscopically at both Gort and Kilbeg, and it will be interesting to see whether further macroscopic analyses at Marbella will confirm the tentative pollen identification.

Fagus sylvatica. Beech pollen values reach 16 percent of the tree pollen sum in the middle of the three basal samples. The association of beech with birch, pine and *Empetrum nigrum* at this level, coupled with the absence of many of the thermophilous species present in the samples above and below is taken to indicate a cool climatic phase discussed more fully in section (v). A continuous curve for *Fagus* is recorded during phase II and the early part of III, though it must be remembered that the sediments during this period are marine clays and silts etc. and so the *Fagus* pollen could be derived from earlier deposits. Above this level the only consistent representation of *Fagus* is contemporary with the high *Abies* frequencies of phases IV and

V and comes in part from peat deposits where derivation could not have taken place. Although Fagus frequencies are low at this time, reaching 2 percent in only one sample, the association with Abies is interesting in view of the close ecological links between beech and fir at the present day.

This evidence comprises the only firmly established record of Fagus on the mainland of western Europe between the early Quaternary Tiglian period and the latter half of the post-glacial. In Britian, the only comparable record is of cupule fragments from layer B at Gort. This stratigraphical horizon is roughly contemporaneous with the final recorded phases of the Interglacial there, in which Abies is consistently recorded. This is an interesting parallel with the record at Marbella. In conclusion, it seems justified to admit Fagus sylvatica to the Hoxnian flora of Western Europe.

Fraxinus excelsior. Identification to the species on the basis of pollen would seem to be justified (Beug 1960). Pollen of Fraxinus is a regular constituent of Hoxnian spectra from north west Europe.

Hedera helix. As at Kilbeg, ivy is missing from the final pine dominated episode. It is a frost sensitive species at the present day (Iversen 1944).

Ilex aquifolium. Holly is recorded regularly from Hoxnian deposits. Its presistence into the final zone at Marbella is something of an anomaly in view of its present day extreme sensitivity to heavy frost (Iversen 1944), and the behaviour of most of the other evergreen species in the diagram.

Juniperus sp. The single pollen record for the middle sample in Phase I can be matched by much higher frequencies in Irish Hoxnian deposits. The associated flora, here as in Ireland, suggests an identification with J. communis, since the evergreen thermophilous species which would be the probable associates of J. oxycedrus and other Mediterranean species, are totally lacking in this sample.

Ligustrum. This large reticulate grain probably refers to Ligustrm vulgare, a south European and north African calcicolous shrub quite common in southern England.

Myrica gale. The peak of Coryloid frequencies at 60 cm. (Stratum A) comes towards the top of a fen stage and the bulk of the pollen in question was undoubtedly that of Myrica,(Jentys-Szafer 1928). Part of the Coryloid frequency in the bottom sample of all was of the same type. Bog myrtle is also recorded at Kilbeg. Recently, a number of post-glacial sites have come to light where a striking increase in Coryloid (cf. Myrica)frequencies coincides with the earliest stages of bog development above fen and carr peats - e.g. at Cockerham Moss (Oldfield and Statham unpub.), Ellerside Moss (Oldfield and Statham in the press) and Racks Moss (Nichols unpub.). The role of Myrica at this stage in the hydrosere can be observed at Woodwalton Fen at the present day, whilst Pearsall has noted this in the Lake District (1918) in such areas as North Fen, Esthwaite and Blelham Tarn Bog. Not until the macroscopic remains from this depth have been examined can this tentative indication of temporary ombrogenous development be confirmed. In the Landes at the present day, Myrica grows on damp base poor sand and in shallow terrestrial peat close to the margins of some of the Etangs.

Myriophyllum spicatum. Both pollen and fruit records exist for the brackish horizon at the top of stratum C whilst pollen occurs in both earlier and later episodes. Like *Najas flexilis*, *Myriophyllum spicatum* is not characteristically a species of brackish water. It shows a strong preference for base rich lakes at the present day.

Myriophyllum verticellatum. The lower part of stratum A includes high pollen frequencies of this species which, like the above, is mainly found in base rich waters today. It has not been recorded in any British deposits of Hoxnian age.

Najas flexilis. Hoxnian records for this species exist at Gort and Kilbeg. It was much rarer than *N. marina* at the top of stratum C, and it is not recorded today from brackish waters.

Najas marina. Godwin (1956) lists finds of *Najas marina* from English sites representing all three interglacial periods. It occurs at Marbella along with other remains of aquatic plants at the top of stratum C, where the indications are of a brackish water environment. At the present day, within Scandinavia, it is restricted to brackish water habitats through during the post-glacial period in Britain and on the continent, it thrived in base rich lakes in inland situations.

Olea sp. The identification of the pollen and doubtfully native status of the olive in Europe has been discussed in chapter IV. The two pollen grains recorded here are found in association with those of other evergreen scerophyllous types e.g. Phillyrea. The only sub-fossil records of olive other than these and post-glacial ones, are from late Tertiary deposits (quoted in Turrill 1952), More records are needed, and preferably macroscopic ones, before these isolated Interglacial records may be evaluated.

Osmunda regalis. Most of the pollen of Osmunda type was quite definitely of this species and further more, its fronds are common in the peat from phase IVa. It is also recorded at Gort and Kilbeg, though West (1956) refers the material at Hoxne to Osmunda claytoniana. Some few of the Osmunda type spores could not be certainly referred to O. regalis. They may represent O. claytoniana or a species of Hymenophyllaceae. In view of the restriction of Osmunda regalis to southerly coastal situations in Norway at the present day (Faegri 1960), it is interesting to note its persistence up to the phase V/VI transition but not beyond.

Phillyrea. Beug's comments on Oleaceae pollen (1960) have helped to confirm these initially tentative records (Oldfield 1960 c). Whereas all three European species are importent elements in Méditerranean plant communities including the characteristic 'garrigue' of south east France, P. media and P. angustifolia may also be found in south west France and North West Spain in sand dune and bare limestone habitats (Rallet and Jovet 1955). Like Buxus, the records cease before the final zone. In addition to the various specific and generic identification within *Oleaceae* listed here, a few unidentified grains of this family remained, some with long furrows, a characteristic feature of the pollen of *Fraxinus Ornus*.

Pinus sp. The pollen record here was almost all confidently referable to *Pinus sylvestris* (cf. Ch. IV). Once again, the Irish Hoxnian sites include identifications to this species on the basis of macroscopic remains. From the Marine sediments of phases 2 and early 3, a few '*haploxylon*'type grains were recorded, presumably from earlier Tertiary material. They help to account for the higher pine values during this period.

Quercus ilex type, The few isolated records hardly constitute a firm basis for considering the holmoak a certain ingredient of the local vegetation, especially in view of possible confusion with pollen of *Quercus coccifera* (Beug 1960).

Potamogeton obtusifolius. West (1956) gives a tentative record of this species from the 'Late-glacial' layers at Hoxne. Its presence in the lowest sample from the site is interesting in view of this and of the concentration of British sub-fossil records in the Allerød period (Godwin 1956). It reaches 69° north in Scandinavia at the present day and does not occur south of northern Spain.

Potamogeton pectinatus. This is an almost cosmopolitan pondweed characteristic of brackish (or base rich) water, so that its abundance (over 250 fruitstones were recovered) along with other brackish water species at the top of stratum C is not suprising. Godwin (1956) lists it from each interglacial in Britain.

Rhamnaceae. Lack of any really distinctive and well preserved grains made it impossible to attempt identification to the generic level. The pollen type could thus represent either *Frangula alnus* (recorded at Gort and Kilbeg) or a species of *Rhamnus*, some of which, e.g. *Rh. alaternus*, are common associates of the other evergreen shrub taxa recorded here.

Rhododendron ponticum. The characteristics of the pollen of this species are described in Oldfield (1959). The records come mainly from the earliest and latest phases and the highest and most continous representation is during phases IV and V, with high *Abies* values. At Gort, seeds and capsules of this species were found contemporary with the phase of *Abies* representation towards the end of deposition there and pollen frequencies of almost certainly the same species also fall into the *Abies* zone. Even higher pollen values come from the contemporary phase at Kilbeg. The highly disjunct range of *Rhododendron ponticum*, around the Black Sea, in Lebanon and round the southern tip of Iberia makes these fossil Interglacial occurrences (among many others summarised by Jessen, Andersen and Farrington) of great phytogeographical interest. Clearly the present day distribution of this species is exceptionally disjunct as a result of fragmentation since the Hoxnian of a formerly wider and more continuous area embracing much of Western Europe at least.

As an introduced species into western Europe, *Rhododendron ponticum* shows a wide range of climatic tolerance with however a preference for rather moist conditions and acid soils. Its climatic tolerance certainly exceeds that of many of the other Lusitanian and Mediterranean species recorded here as is illustrated by both its present day naturalised range and by its concentration into the latest stages of all the Hoxnian sites considered (most of the Ericales records from Phase VI at Marbella are almost certainly very badly preserved tetrads of this species). The question thus inevitably arises of why its present day area should be by far the most restricted and disjunct. The answer may lie in its strong preference for acid humus soils, since the phases of solifluction activity recorded during glacial and late-glacial episodes appear to have limited the occurrence of such habitats over very wide areas of western Europe at the end of each glaciation. Other less obvious factors of dispersal and competition may also be involved though presumably not biotype impoverishment.

Rhododendron sp. The single grain in question was similar to the above but much smaller (c. 35 mi.). Rhododendron ferrugineum and lapponicum produce tetrads of this appearance and size.

Ruppia maritima This species, which is exclusive to brackish water at the present day, has not been recorded in any British Hoxnian deposits.

Sanguisorba officinalis. In view of the disjunct montane distribution and overall scarcity of this species in the area today and especially to the south in Spain, it is interesting to note that its only frequencies at Marbella are from the highest levels of more open vegetation communities and probably cooler climate. The Irish Hoxnian deposits do not include records of this species though its fruit was recorded at Hoxne by Reid.

Thymeliaceae. This family, predominantly one of evergreen shrubs (e.g. *Daphne* spp.) includes species which together embrace an extremely wide range of tolerance at the present day. The thick-walled spherical pollen is periporate and reticulate with the pores about the same size as the lumina in the reticulum.

Vitis sp. Although there are no British parallels for this Interglacial occurrence, vine remains have been recorded in Hoxnian and earlier Interglacial period on the continent (Van der Hammen 1951). The absence of pollen of this species in the final phase is noticeable.

(iv). Stratigraphical and hydroseral successions at site I.

The lowest deposits recorded are those yielding the three samples discussed in Oldfield (1960c), and referred to as stratum F. Neither their thickness nor their depth below the other sediments is known. They represent deposition in open fresh water, and from the presence of *Cladium* and *Myriophyllum spicatum* pollen in the upper and lower samples it may be inferred that they were laid down under eutrophic conditions. The middle sample lacks any indication of the base status of the lake water at the time.

The sands, silts and clays of strata E, D and the lowest 70 cm. of stratum C contain, at various levels, remains of molluscs, notably species of *Ostrea*, *Cladium* and *Scrobicularia*, clearly indicating the ?Cardium marine origin of the deposits. Throughout most of these sediments, '*haploxylon*' type pollen and '*Hystrix*'were found, suggesting derivation from Tertiary sources (qv. Iversen 1942).

Between 150 cm. and the top of stratum C, there is a gradual transition from estuarine clay-silts to lake muds. The later stages in the transition are marked by macroscopic remains of predominantly brackish water plants.listed in Table 13 and discussed separately in section (iii). The layer of beach sand overlaying this horizon of temporary marine regression suggests that the fresh-brackish water body recorded at the top of stratum C can have been no more than a temporary coastal lagoon quickly overcome by marine sediments through either a further rise in sea-level or the onshore advance of a bay bar or spit.

These overlying beach sands are interrupted in the northern half of the section by a narrow contorted mud bed, stratum B. The field records of *Potamogeton pectinatus* from the deposit and its position between the beach sediments, as well as its small lateral extent suggest that this mud layer too reflects an ephemeral coastal lagoon feature. Similar conclusions have been reached for analogous postglacial 'buried peats' forming lenses in marine sediments in many parts of Britain (e.g. Oldfield in Gresswell, 1958).

The onset of organic accumulation above the upper beach sands, at the base of stratum A is marked by rather sandy lake muds which persist up to 210 cm. The presence of *Myriophyllum verticellatum* and *Cladium mariscus* pollen during this phase points to eutrophic lake waters with a fringing *Cladium* reedswamp.

The transition to fen deposits is very sudden and coincides with the Phase III/IV boundary. The pollen record suggests that during the early stages of overgrowth, *Osmunda regalis* was associated with other fen species and *Cladium*. *Bellis* type pollen is recorded at this level and it is worth noting that the pollen of *Bidens* falls within this type (cf. West 1956).

The high *Osmunda* and *Filicales* values (IVa) are followed by a peak in *Cyperaceae* pollen frequency (IVb) which, in view of the peat type almost certainly represents a *Carex* species, whilst the contemporary peak in *Alnus* may represent participation of *Alnus glutinosa* in the local succession, perhaps forming, along with the sedges, a local fen carr.

From this horizon to the top of Va, high *Osmunda* and *Alnus* values persist and there is a continuous *Cyperaceae* curve. The peat type indicates fen conditions. The rapid rise in *Coryloid* (*Myrica*)pollen frequencies in Vb suggest the spread of bog myrtle thickets over the preceding fen. Elucidation of the succeeding hydroseral developments will depend on a more detailed examination of the macroscopic remains from the top 40 cm. of stratum A, though it is certain that some species of *Carex* remained an important constituent of the local vegetation, since the nutlets are expecially frequent. It is not possible to say with certainty yet whether the *Myrica* peak reflects incipient bog development as was tentatively suggested may have been the case (section iii). The reappearance of *Myriophyllum spicatum* and *Sparganium* type pollen at the top of the stratum may indicate a rise in water level. In this connection it has already been noted (Ch.V) that the upper part of this stratum as it thins out southwards towards the Villa

Marbella, occurs intercalated with beach sand. The whole of the stratum is overlain by beach sands (stratum 6) eventually.

In order to deposit beach sands above the fresh water and fen deposits of stratum A, the sea-level must have risen either more or less pari-passu with organic accumulation during the deposition of stratum A, but excluded from the fresh-water area by some obstruction, or suddenly somewhere towards the end of the period. Since the deposits are mainly fen and open water sediments, their deposition implies some obstruction of drainage. The rapid alternation of fresh water, brackish and marine sediments between stratum A and st. C, and the presence of continuously deposited beach sands to the south west of stratum A are both indications that the estuary in which the sediments were accumulating was not separated from the sea by any solid or permanent obstruction. Impeded drainage below stratum A was certainly produced only by ephemeral coastal features such as bars and spits and it is difficult to see how the same effect could have been achieved at a later stage and a higher level in any other way. It thus seems more than likely that the obstruction to free drainage allowing the accumulation of stratum A was a bar or spit. In this case, sea-level during the period of deposition of stratum A is not likely to have fallen far below the level of deposition of the organic sediments, otherwise it is difficult to see how the drainage could have remained impeded.

The solifluction gravels which truncate the beach deposits overlying stratum A become less continuous at higher levels and occur as lenses in more sandy deposits. Above these, between 311 and 316 cm., the succession of narrow bands may be interpreted as a highly compressed podsol profile. The topmost band of black muddy material represents the former humus layer, the underlying white sandy clay a leached 'A' horizon and the underlying iron pan, the 'B' horizon of mineral accumulation. Bearing in mind Dimbleby's comments on pollen preservation in acid humus (1957) it is not suprising to find a good pollen flora from this level (stratum 0). This narrow layer is discontinuous and highly contorted. From its context, it would seem reasonable to relate this to cryoturbatic processes.

The origin of the overlying deposits of strata 3 and 4, comprising mainly sands and clays with beds of coarse grit and pebbles, is not clear. They must be redominantly water-borne P/ and they seem to be rather similar to the deposits described by Van der Hammen (1951) from periglacial melt-water channels.

The cemented iron pan layer at 195 cm., separating strata 2 and 3 is probably the 'B' horizon of a truncated soil profile similar to stratum 0, in which case, it represents a period free from local solifluction, melt water activity or deposition, permitting some degree of sub-aerial chemical weathering. The overlying deposits of stratum 2 are very similar to those of strata 3 and 4. Only 60 cm. of loose dune sands overlie stratum 2, and these are very recent in origin.

(v). Vegetational and climatic successions at site I.

PHASE I.

It has already been suggested that the changes in pollen frequency between the three samples of phase I record a climatic oscillation, a warm period followed by a cooler phase and then another warm phase. The lowest and uppermost samples do not include any taxa more thermophilous than members of the present day flora of south west France though the presence of Mediterranean types along with Tilia, Carpinus and Abies all trees commoner further north or east in Europe than in the area itself, led Oldfield (1960c) to postulate rather more continental conditions than those prevailing in the Pays Basque at the present day. It would perhaps be safer to say that neither summer nor winter temperatures can have been lower than at present nor the climate as a whole less favourable. The only species recorded in these samples with a northerly or upland distribution are Abies and Potamogeton obtusifolius.

The pollen spectrum from the middle sample suggests local plant communities similar to those at middle altitudes in the Pyrenees at the present day, particularly those at c. 1600 m. where beech and fir woodland begins to give way to less densely shaded pine forest with scattered birches and some development of Calluna and Empetrum heaths, though analogy with present day communities must not be carried too far or taken too literally. Certainly the vegetation recorded indicates lower temperatures than in the preceding or succeeding samples, the absence of Tilia and the Mediterranean element, together with the presence of Rhododendron ponticum, suggesting that a decline in summer warmth and perhaps insolation took place rather than any notable fall in winter temperatures. Thus the changes deduced would accord well with a tendency towards cooler but especially more oceanic conditions. The records of pine and the heath species at this time and the lack of *Cladium* and *Myriophyllum spicatum pollen*, both present in the bottom sample, may reflect some local decline in base status.

At the base of the Hoxne series, West (1956) describes a brief climatic oscillation. A period during which birch appears to have migrated into the area and to some extent spread over existing *Hippophaë* scrub is succeeded by a phase of reduced birch cover, redevelopment of *Hippophaë* dominated communities and solifluction round the lake's edge. West suggests rather tentatively that the factor responsible for the revertence from birch woodland back to scrub may have been increased wind pressure whilst that responsible for the return of solifluction may have been higher precipitation. He also suggests that at no stage during the period was the climate truly arctic nor even probably sub-arctic (i.e. cooler than areas at the present day limit of forest). The high *Hippophaë* values are considered to be a reflection of especially favourable edaphic conditions and low competition pressure.

The birch phase at Hoxne also includes records of *Quercus*, *Almus* and *Alnus* pollen in very small quantities, not sufficient to indicate local presence, but suggestive rather of long distance u/

transport. Their occurrence in this phase and not in those above and below marked by high frequencies of derived spores and pollen and by solifluction activity suggest that their presence is not the result of derivation.

Szafer (1953)records three Polish Hoznian Interglacial sites at the base of which a phase of birch dominance is sandwiched between pine-spruce episodes. The sites are widely separated and it is difficult to escape the conclusion that the changes recorded reflect some climatic oscillation, though the author makes no attempt to interpret them in the English section of the paper.

On the basis of the evidence from Hoxne and Poland, it seems safe to say that some climatic oscillation or oscillations took place towards the beginning of the Hoxnian period. There is no question of detecting close parallelisms between the evidence from Marbella and that from Poland, though it would seem justified to make some preliminary mention of certain points of resemblance with the episodes described at Hoxne:-

i). At both sites, during the cool phases, the climatic is thought to have been far from severe, and the changes at each site are consistent with increased oceanicity.

ii). The thermophilous tree pollen recorded in very small quantities in the 'warm' phase at Hoxne are all represented in the bottom sample at Marbella, Quercus and Alnus being the most abundant tree pollen types there.

iii). Potamogeton obtusifolius has been recorded (tentatively at Hoxne) from each series at this point and not above, though investigations of macroscopic remains at Marbella are not completed.

The parallelisms seem not sufficiently close or indicative to justify a correlation between the series at this point though it remains a possibility, the implications of which are considered further in the final chapter. More evidence is needed from these inaccesible lowermost layers at Marbella, especially the means for taking closer pollen samples.

PHASE II.

Since the values for conifer pollen types, Abies, Pinus and Picea, during this phase have almost certainly been augmented as a result of the mineral nature of the sediments, partly through derivation from older deposits, it would not be valid to consider this period as an early temperate stage in the sense used in West (1956). Unsampled deposits, and perhaps a considerable span of time intervene between the analyses of stratum F (Phase I) and these and besides in the top sample of phase I, the non-marine sediments contain little pine pollen, no spruce and a good many thermophilous types, most of which are also recorded in phase II. Since the pollen frequencies in phase II are undoubtedly affected by the conditions of deposition, since the general indications are in the main similar to those in phase III and since, during phase III the representation of shrub and herb pollen types is fuller, largely as a result of better preservation and hence more critical identification, there seems little point in discussing the vegetational development in Phase II separately.

PHASE III.

There are few consistent changes in non-aquatic pollen flora throughout the whole of this phase. Oak and hazel gradually rise and fall, birch and elm frequencies are lowest at the end of the phase, whilst no *Fraxinus* pollen is found in the top 100 cm. or so. The changes in *Alnus* frequency are rather sharp and irregular with a slight tendency to consistently higher values towards the end of the phase.

It is possible to go some way towards dividing the taxa present into ecological groups in an effort to understand the nature of tthe climax plant communities during this the cumination of the Interglacial period.

i). Alder woodland. The very rapid changes in alder frequency suggest that some of the pollen rain comes from local stands of *Alnus* *glutinosa* around the edges of the lake. It is unlikely that any other *Alnus* species is represented during this part of the series and moreover, *Alnus glutinosa* has been recorded macroscopically from the same interglacial at Gort and elsewhere. It is impossible to say to what extent alder contributed to the plant communities beyond bordering carr woodland around the edge of the lake. No other pollen types show synchronous variations with alder and it seems unlikely that the steep rather well drained slopes of the surrounding area provided extensive habitats for alder.

ii). Oak woodland. As in the same area throughout most of the post-glacial period (Ch. IV) the other forest trees of the mixed oak woodland remain permanently subsidiary to the oaks themselves. The relatively high elm and lime values found during episodes in the middle of the Hoxne series are not found here, nor are the abundant yew pollen records characteristic of the western Irish Gort series. The close association between Quercus and Corylus indicated by the parallel trends in each is interesting in the local context in view of the equally close relationship between the two demonstrated during the course of the post-glacial Asturian 'clearance phase' at Mouligna (Oldfield 1960b). Doubtless, in both cases, hazel was forming the understorey of oak woodland, though it is a little suprising to note the extent to which, under such a situation, its pollen is recorded in the analyses, since it is well known that hazel pollen production is greatly reduced under shade (Faegri & Iversen 1950). The oak-hazel element throughout almost all phase III forms consistenly over 70 percent of the total pollen rain and no doubt temperate deciduous woodland, very similar to that recorded in the area during the post-glacial period, formed the most extensive plant community in the area.

iii). Evergreen shrub communities. The pollen of evergreen shrub taxa is extremely abundant, much more so than in post-glacial deposits from the area. In terms of present day geographical ranges and edaphic preferences, the group is a rather heterogeneous one, with contrasts between Mediterranean, predominantly basiphilous genera such as *Olea* and *Phillyrea* and eu-oceanic heath species, *Erica* a/ e/ cf. *vagans* and *Debocia cantabrica*. Other types of wider present day geographical edaphic affinities include *Buxus sempervirens*, *Ilex aquifolium*, *Hedera helix*. At the present day, species in the first group are pften associated with members of other taxa recorded in the pollen diagram e.g. species of *Rhamnaceae* (*Rhamnus alaternus*), *Thymeliaceae* (*Daphne gnidium*), *Lonicera* (*Lonicera etruscus*) as well as *Buxus* and *Quercus ilex* and *coccifera* in the mediterranean calcicole 'garrigue' communities, though most of the taxa in question do occur beyond the strict limits of mediterranean climate and the 'garrigue' phytocenoses. It would therefore be unjustified to deduce the presence of garrigue communities, especially since these latter at the present day are certainly anthropogenic (qv. Marres 1955) in large measures. Equally, and for much the same reasons, it would not be valid to deduce 'maquis' communities from the presence of *Arbutus*, *Erica* cf. *arborea* and *E.* cf. *scoparia*. Nevertheless, many of the taxa recorded are at the present day considered faithful species to the *Quercus ilex* association and degraded stages of this by the French phytosociologists of the 'Montpellier' school (Braun-Blanquet 1936). This is not to say necessarily that the associations have, as envisaged by Braun-Blanquet and his followers, survived as associations in his strict sense, more or less unchanged through the Quaternary vicissitudes of climate (qv. Poore 1955).

The presence of these taxa, as well as *Artemisia* spp. and *Plantago* certainly point the existence of areas of reduced shade and probably some fully insolated slopes. Sealy (1950) points out that Arbutus unedo, even in South-west Ireland, is not a shrub of dense woodland but of rather more open shrub communities. The areas of scanty tree cover almost certainly existed along the steep sides of the local valleys and ravines, rather than on the plateau tops. Such steep and only partially forested slopes would provide suitable habitats for all the evergreen species considered, as they still do for many of these same plants in the Spanish Pays Basque today (Table 14). Thus, it is suggested that the oak-hazel woodland dominated the plateau areas and gentler slopes whilst evergreen basiphilous shrub communities covered less densely forested areas on steeper valley sides. At the present day, even after a long period of disturbance and human interference, the most floristically rich habitats in the area are the ravines where very rich mixed woodland survives along with rarer herbaceous and cryptogrammic species and an extremely rich evergreen shrub flora in sheltered sites of discontinuous forest cover (V. and P. Allorge 1941).

The decline in oak and hazel frequencies towards the end of this phase is accompanied by an increase in alder representation. Although this could mean merely that alder expanded in nearby habitats, became over-represented in the tree pollen rain and hence reduced oak and hazel frequencies, it will be noted that the oak and hazel decline is a gradual and irreversible trend in the diagram and, moreover, the period of falling oak and hazel values is the one in which most of the records for the ericaceous heath species begin. The increased representation of these heath species is contemporary with the persistence of

TABLE 14. List of evergreen shrubs and low trees recorded in the rich woodland and scrub of the ravines in the Spanish Pays Basque.

(V. and P. Allorge 1941 pp.93-94).

Arbutus unedo
Calluna vulgaris
Cistus salveifolius
Daboecia cantabrica
Daphne cneorum
Daphne gnidium
Daphne laureola L.ssp.*Philippi* G.G.
Erica ciliaris
Erica cinerea
Erica arborea
Erica lusitanica
Erica scoparia
Erica tetralix
Erica vagans
Genista decipiens
Genista hispanica L.ssp.*occidentalis* Rouy.
Genista pilosa
Hedera helix
Hypericum androsaemum
Ilex aquifolium
Juniperus communis
Phillyrea angustifolia
Phillyrea media
Pistacia lentiscus
Quercus ilex
Quercus suber
Rhamnus alaternus
Sarothamnus cantabricus
Sarothamnus scoparius
Rosa sempervirens
Smilax aspera
Ulex europaeus
Ulex gallii
Ulex nanus
Vaccinium myrtillus
Viburnum tinus

In addition, the following species (non-evergreen) are recorded by Allorge and the genera to which they belong are recorded at Marbella.

Acer campestre
Alnus glutinosa
Betula verrucosa
Corylus avellana
Fagus silvatica
Fraxinus excelsior
Ligustrum vulgare
Lonicera periclymenum
Quercus, *Ulmus* and *Salix* species.
Tilia cordata

32 out of the 81 tree and shrub species listed by Allorge are either recorded at Marbella or belong to genera which are recorded there.

many of the mediterranean thermophilous and basiphilous taxa and the problem of reconstructing the ecological and environmental changes recorded during and beyond this phase is considered in the next section, for the same trend continues into phase IV. During no part of Phase III do the plant communities reconstructed enforce the deduction of climatic conditions differing radically from those prevailing in the area at the present day. Unless the recorded taxa included at the time, much less demanding biotypes than they do at present, it would seem safe to conclude that neither winter nor summer temperatures can have been lower nor the climate in any way less favourable than at the present day.

PHASE IV.

The transition to this episode coincides with stratigraphic and pollen analytical indications of fern dominated plant communities spreading over the open water and reedswamps of the previous period. During Phase IV, the wide and rapid variations in *Alnus* frequency, presumably as a result of local successions involving alder-carr, obscure some of the changes in the other tree pollen curves.

The expansion of *Abies* in the area is accompanied by indications that pine too (almost certainly *Pinus silvestris*) increased in importance locally. Although *Corylus* and *Tilia* appear to have virtually disappeared from the local vegetation at this time, oak species persisted along with quite a few of the evergreen thermophilous shrubs, notably *Buxus*, *Phillyrea* and, for the earlier part of the period, *Vitis* and *Hedera*. It thus seems unlikely that the ecological changes were the result of climatic deterioration, since hazel is a good deal less sensitive to frost or to low summer temperatures than many of the surviving species. At first sight, an explanation in terms of soil deterioration seems equally unacceptable, for although both *Tilia* and *Corylus* prefer relatively base-rich soils, *Corylus* is certainly no more demanding in this respect than either *Buxus* or the *Phillyrea* species. This anomaly would appear to resolve itself in the context of the palaeo-ecological reconstructions of the various plant communities during the previous phase. It was suggested that the evergreen shade intolerant shrubs probably grew on the steep valley sides, leaving the plateau tops to oak woodland. If, as would be expected, soil deterioration proceeded more rapidly on the gentler slopes and plateau tops than on the most precipitous slopes, where constant mechanical exposure of bed-rock would maintain a high base status, then some replacement of the oak-hazel woodland by more acidophilous species would be expected to take place at the same time as survival of the basiphilous shrubs in the ravines. That species of oak survived longer than hazel under such circumstances is only to be expected from the ability of species such as *Quercus petraea*, *toza* and more locally *robur* to tolerate extremely base poor conditions. The persistence of the heath species *Rhododendron ponticum*, *Daboecia cantabrica* and *Erica* cf. *vagans* which began to expand towards the end of the last phase, up into this period, is consistent with this theory. It is not possible to say to what extent the deduced deterioration in soil base status was the result of climatic change or the culmination of a trend towards acidification inherent in the nature of the local bedrock, the pre-existing climate and the climax vegetation of the Interglacial. If climatic change were the cause, the trend would probably be towards increased oceanicity, in which case, it would be difficult to explain the coincidence between the beginning of the phase and the onset of fen development over reedswamp and open-water at the point of sampling.

PHASE V.

It is difficult to suppose that the increase in pine frequencies and decline in alder represents an actual ecological replacement over the same ground. The decline in alder frequencies may be related to hydroseral changes, in which case, the expansion of pine must be viewed as something independent. Since records for *Hedera* *Phillyrea* and *Osmunda regalis* still persist into this phase and since there are no sure indications that the local woodland was interrupted by anything more than occasional patches of ericaceous heath, it would not seem correct to infer that the climate had become significantly more severe. All the evidence from the pine-fir phases towards the end of Hoxnian diagrams from Gort, Kilbeg, Hoxne and Clacton (Pike and Godwin 1953) tends to reinforce this deduction.

PHASE VI.

The return to pine dominance with the virtual exclusion of the other tree species seems surer evidence of climatic deterioration, especially when coupled with the records for *Empetrum nigrum* (cf. Ch. IV) and increased frequencies of *Artemisia* and *Chenopodiaceae*, predominantly heliophilous taxa. The isolated pollen record of *Ilex* thus appears as something of an anomaly. *Rhododendron ponticum* certainly persisted into this episode though and most of the *Ericales* grains are almost certainly very poorly preserved tetrads of this species.

The final sample from stratum C also records pine woodland with some open areas and a rather cool though not an arctic climate. A layer of solifluction deposit intervenes between this sample and the top of stratum A, therefore stratum O must represent some episode later than the Hoxnian Interglacial. Although there is no cause on either floristic or stratigraphic grounds to place it later than the ensuing glaciation (Riss, Saale), it could conceivably relate to some cool phase during the last Interglacial or the last Glaciation, (see section i of this chapter).

(vi). Changes in sea-level.

In phase I, the deposits certainly accumulated above the highest tide level, perhaps considerably above. Allowing something like the present tidal range for the period, this means approximately 5m. above mean sea-level at the time. Since, at the present day, the deposits fall well within the February tidal range, thus permitting their exposure for sampling, once an exceptionally severe storm has uncovered them, they must be no more than I or 2 metres below present mean sea-level, though, since they occur lower than stratum E, they cannot be higher than 2m. above present mean sea-level. From this it is clear that at the time of deposition, sea level must have been more than 3 metres below its present height during phase I. It has already been tentatively inferred that these episodes date from an early part of the Interglacial period, perhaps contemporary with the Late-glacial phase at Hoxne. No doubt the low sea-level at the time is in part a reflection of eustatically lowered sea-level before the complete melting of the ice-sheets of the preceding glaciation.

The top of stratum C records temporary marine regression during the middle, apparently optimum part of the Interglacial. The level of the brackish deposits at this horizon reaches 9.3 m. above mean sea-level at the edge of the basin where compaction is least. At the time of deposition, these sediments must have been quite close to mean high tide level and so mean sea-level at the time must have been something like 6 metres higher than at present. Beach sands are recorded hardly interrupted for a further 3.6 m. above the top of this temporary 'regression' horizon. The fresh water deposits above this do not indicate any substantial marine regression since deposition of beach sands continues interrupted to heights greater than the top of stratum A just to the south of the Villa Marbella. (qv. Section IV). The highest beach sands above stratum A show that even after the final phase of pine dominance and apparent climatic deterioration, sea-level continued to rise, giving beach sands up to 16.7 metres above present sea-level. Allowing for some settling and compaction, mean sea-level at the time must have been at least 15 metres above its present height and perhaps considerably more, since the beach sands are everywhere truncated by solifluction gravels or more recent sediments.

Evidence of sea-level variations during the same period has been obtained in Eastern England from Clacton (Pike and Godwin 1953) and the Nar Valley (Stevens 1959). At Clacton, a transgression horizon at 9' O.D. occurs at the end of a pollen-analytical phase which can be correlated with late Zone III at Hoxne (late phase III at Marbella). Marine deposits persist to 27' O.D., and from 14' to 25' O.D. they fall into a phase of Abies dominance contemporary with Hoxne Zone IV (Phases IV and V at Marbella). The deposits in question probably formed something like 10' below sea-level (Stevens 1959) and so mean sea-level at some stage during zone IV at Clacton must have stood at 35' or more above its present height.

At Nar, the latest fresh-water beds date from the end of Zone IId (late II or early phase III at Marbella), and they occur up to 19' O.D. The marine transgression at Nar has affected the pollen frequencies. Also, the diagram, when compared with that from Hoxne, seems as though it may not contain a full and uninterrupted sequence at this point. Thus it is difficult to fix the transgression horizon in exactly relation to the pollen zone. The Nar Valley Clays, the marine deposits overlying the freshwater beds, have been pollen analysed between 16' and 42' O.D. Stevens suggests that the samples from these depths fall within Hoxne Zone III, though it is debatable whether the higher Abies frequencies above 34' would not support a correlation with Hoxnian phase IV. It seems safe to say that during Zone III and possibly IV deposits

TABLE 15. Rough indications of mean sea-level (related to present day M.S.L) during the Hoxnian period at Marbella, Nar and Clacton.

	Marbella	Clacton	Nar Valley
Maximum.	Post Phase VI. >15m. c.50'.	>11m. c.37'.	>75' in Zone IV or later.
Hoxne IV Marb.IV-V.	Very little less than 14m. c.47', at the end of the period.	Up to 10.5m. c.35', at least.	Up to a maximum of 52'.
Hoxne III Marb.III above c.280 cm.St.A.	Little less than 12m. c 40'.		At least to 22' above.
Late IId.Hoxne. Marb.III.	Rising to c.9m. (c.30').		Below 20' then rising above this height during or soon after this phase.

Where the evidence from the site contains no means of estimating compaction, this factor has been ignored.

Deposits are related to mean sea-level in the following way :-

i). Beach sands are assumed to accumulate up to c.5 m. above M.S.L.

ii). Brackish lagoon silts are assumed to form at c. 3 m. above M.S.L.

iii). The marine clays and silts in the Nar Valley and at Clacton are supposed to have accumulated c.3m. below M.S.L. (Stevens 1959).

TABLE 16. The sequence of fresh-water and marine sediments at Marbella, in the Nar Valley series (Stevens I959) and at Clacton (Pike and Godwin (1953).

Zone	Marbella Site 1.	Site 1b.[@]	Nar Valley.	Clacton
IV+	Marine ------------- Fresh-water	Marine	? Marine	
IV	Fresh-water	Marine	Marine	Marine
III	Fresh-water	Marine	Marine -?-?-?-?-	Fresh-water
IId	Brackish lagoon conditions ------------- Marine	 ------------- Marine	Fresh-water	
I	? Fresh-water		Fresh-water	

The zones used,with the exception of 'zone VI' are taken from West's zonation at Hoxne (1956),to which the other successions have been tentatively related. 'Zone' VI is phase VI as defined on the Marbella diagram.

[@] Site 1b. refers to the Marbella succession immediately to the south of the terrace of the Villa Marbella (Fig.16).

accumulated at Nar indicating a sea-level rising to at least 52', since the sediments in question are laid down under at least 10' of water. In fact Nar Valley Clay occurs (not pollen-analysed) to at least 65' O.D. and possibly to 80', suggesting a final maximum sea-level, probably during Zone IV or a later period, of 75' or even 90'.

None of the estimated heights from the English sites or from Marbella can claim to be really precise since factors such as compaction, relation of particular deposits to tide level,&the effects of local topographical peculiarities (cf. Oldfield 1960d) can never be adequately assessed. Within broad limits though, they comprise a tentative summary of the approximate indications of contemporary sea-level at each site. Tables 15 and 16 attempt to correlate the various data, though in this context, the tentative nature of the pollen-analytical correlations must be borne in mind.

Table 16 shows that for each period, the indication of the height of sea-level at Marbella and in the Nar Valley are roughly parallel, often quite closely so in view of the number of approximations, assumptions and guesses involved. The indications from Clacton are of perhaps rather lower levels stage by stage and this fact has been noted by Stevens (1959) and ascribed to post-Hoxnian downwarping in the Clacton area as part of the known long term subsidence of the southern part of the North Sea basin. It is difficult to say whether this explanation is wholly necessary, especially in view of the imprecission of the relative chronolgy used to link the evidence from each site.

In all three sites there is unequivocal evidence that the sea-level was rising during the later stages of the Interglacial period, and the data from both Marbella and the Nar Valley suggest that the peak of sea-level clearly post-dated pollen-analytical evidence of climatic regression with the onset of the next major cool phase. It would seem unwise to attempt to explore the implications of such an anomaly in terms of glacioeustatic theory until parallel evidence from more sites comes to light.

One of the interesting points to emerge from the Marbella evidence is the potential confusion which could have arisen from inferring land and sea-level changes from the site had only part of the section been preserved. Thus a major regression horizon at the top of stratum C may have been deduced had all the overlying deposits been removed. Its occurrence somewhere about the optimum of the Interglacial would have supported any supposition that it represented the culmination of sea-level during that Interglacial, and so a plausible but erroneous conclusion would have been reached. Comparison between the Nar and Marbella successions shows that the incidence of transgression and regression horizons is far from comparable at each site, largely because deposition at Marbella seems always to have been so close to the contemporary sea-level as to have been controlled largely by local ephemeral factors such as the development of bars, spits and lagoons etc. There is an analogy with the post-glacial buried peats and 'forests' around the British coast. The Nar Valley succession is comparable to those found where a local hollow in bed rock or drift is filled in by fresh-water deposits until, with the post-glacial

? might

rise in sea-level, transgression takes place and, for as long as the sea-level continues to rise, marine sediments accumulate above the former hollow@ The situation at Marbella is comparable to one which was common in many bays and estuaries in Britian during the early post-glacial period, e.g. at Swansea, Southampton and Barrow, as well as in some of the Estuaries around the head of Morecambe Bay (Oldfield in Gresswell, 1958). At these sites, the rising sea-level periodically produced temporary obstructions to free drainage from the land, thus giving rise to ephemeral lagoons, marshes and fens which are now preserved as irregular and discontinous lenses of fresh-water muds and peats in much greater thicknesses of marine sediments.

Since the 40m. and 20m. river terraces recorded in the Nive Valley and discussed in Chapter II have not been recognised in any situation along the coast in the neighbourhood of Marbella itself,it is not possible to relate the Marbella high sea level closely to the local denudation chronology as summarised in Chapter II. All the Marbella deposits lie in a broad channel (qv. Fig.16) which is cut into the 75m. summit plain. The cutting of the channel must be contemporary with the 'Mindel' (Elster) glaciation or,less likely,an earlier probably glacial

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@ Two such sites are known to the author along the Fylde coast of North Lancashire and both are mentioned briefly in De Rance (1875).

phase. The 75m. summit plain must therefore date from the Cromerian (Gunz/Mindel) or some previous probably interglacial period.

The marine deposits at Marbella are everywhere truncated and so the high sea level recorded there could be contemporary with either the 20m. or the 40m. terraces,or even the isolated intermediate terrace at 26-34m. recorded on the Nive by Passemard (1926). There is a certain amount of evidence suggesting a world-wide sea level during the Hoxnian of c.100' above present height (Zeuner 1960),and the Nar Valley evidence seems to support this to some extent. Until the evidence from Marbella has been more closely related to the local Quaternary geomorphology,its bearing on this supposition remains a matter for conjecture.

(vii). The relation of the Marbella successions to previously described local deposits.

Two earlier palaeobotanical investigations of Quaternary deposits in the sea cliffs of the area have been referred to,the earliest reported in Welsch (1917),the second in Dubois (1948). Welsch describes deposits from Bidart and Cenitz (Senix) near Guethary,and quotes seed and fruit determinations by Clement Reid. Neither of these sites can be the Marbella section for this latter lies within the Commune of Biarritz. The Cenitz deposits have been re-identified and it is hoped to proceed to an examination of them in due course. Three peat sections have been rediscovered in the cliffs within the Commune of Bidart,appart from the shore mud-bed at Mouligna (Oldfield 1960b). Two of these lie between Mouligna and Marbella and one close to Bidart village,just north of the mouth of the Ouhabia. It is not yet known with certainty which of these is the original site of Welsch's investigations. The macro-flora of the Bidart deposit included *Proserpinaca reticulata*,a species characteristic of late-Pliocene deposits.

Dubois describes the location of the supposedly post-glacial deposit which he examined as being close to the Cuisine des Barons de l'Espee,a ruined building c.100 yards north of the northern edge of the Mouligna valley. Peat and mud deposits occur stratified in the cliff face to either side of this building and their stratigraphical context and included pollen-flora, in so far as it has been subjected to a very preliminary examination, preclude the possibility of a post-glacial date. No diagram is given in Dubois' brief note,and his findings and conclusions call for no further comment.

PART III. GENERAL DISCUSSION.

CHAPTER VII. Some biogeographical implications.

As long as only one post-glacial and one Hoxnian site provide the sum total of the detailed palaeo-ecological evidence from the area, any conclusions reached must remain tentative and subject to future confirmation. One of the main aims of the project is to make some contribution to the understanding of various discontinuous plant distributions in Western Europe. The reasons underlying the disjunct distribution of arctic-alpine species in Europe and Britain were the subject of much speculation and controversy until factual palaeobotanical evidence from the late-Quaternary period recorded the antecedents of the present day distribution patterns and so pointed to their raison d'etre. Similarly, the problem of the presence of species with Lusitanian and Mediterranean affinities in South West Ireland, despite their absence from the rest of Britain and most of Western Europe north of the Pyrenees, has provoked much the same kind of dispute. It is only with the publication of first Jessens's work on the Late-Quaternary period in Ireland (1949) and then of subsequent evidence culminating in the recent papers on the Hoxnian deposits at Gort and Kilbeg, that any really useful factual information has come to light, other than what little could safely be inferred from present day conditions and situations.

Many of the species in this Lusitanian-Mediterranean category occur also in the Pays Basque, *Arbutus unedo*, *Daboecia cantabrica* and *Erica mediterranea* for example, and so the question of whether they survived the last glaciation there arises, or whether nearby, onshore or offshore north of the Pyrenees, or whether they immigrated into the area during the Late- or Post-glacial period, and if so, from where. *Daboecia cantabrica* and *Erica mediterranea*, as well as Erica mackaiana,found in Iberia but not in France, are truly South-west European or 'Lusitanean' species, with their range eastwards stopping short of the Mediterranean. Arbutus unedo[@] is both a Lusitanian and a Mediterranean species, and forms a link between the Lusitanian species in the narrower sense and many Mediterranean plants which do not reach Britain or north-west Europe at all,but do occur locally in favoured situations on the Atlantic slopes of the Pays Basque. Some of these have already been listed in Tables 3 and 14. As is the case with the Lusitanian species,these are virtually all evergreen. Most French phytosociologists follow Braun-Blanquet (eg.1933) in considering their present isolated western Atlantic occurrences the result of restricted and isolated survival from a 'periode xerothermique' during the post-glacial (see eg.Van Campo and Elhai 1956). This phase is thought to have allowed the north-westerly extension of Mediterranean species,their present localities representing disjunction and selective survival during subsequent less favourable periods.

Although the two groups considered above,the truly Lusitanian and the disjunct peri-Mediterranean types include most of the discontinuously distributed evergreen thermophilous taxa to which attention is devoted here, there are other species with rather similar distributions posing slightly less striking problems,notably Erica vagans,not recorded between Western France and Cornwall, and Erica ciliaris,not recorded between Western France and Dorset-Cornwall. Neither species occurs elsewhere in the British Isles.

All these taxa,along with the more continuously distributed

[@] Distribution maps of Arbutus unedo,Daboecia cantabrica,Erica vagans, Rhododendron ponticum, Buxus sempervirens and balaerica, and Quercus ilex are included at the end of this Chapter.

evergreen elements in the west European flora (*Ilex aquifolium*, *Hedera helix*, *Buxus sempervirens* etc.) have long been considered relics from a Late Tertiary flora of evergreen trees and shrubs, disrupted by the climatic fluctuations of the Pleistocene period and largely replaced by deciduous types. These evergreen species are the so-called 'arcto-tertiary relics' forming part of the 'Lauro-cerasus Gürtel' of Schmid (quoted in Jessen, Andersen and Farrington, I959), and most fully represented at the present day in the plant communities of the Caucasus and Black Sea areas, less completely around most of the Mediterranean and more locally in Iberia.

In the past, the problem of the Lusitano-Hibernian species has excercised the Irish botanists much more than the French, whilst the problem of the Atlantic outliers of the Mediterranean flora has been mainly the concern of the French botanists. All problems of distribution and disjunction change their nature and their affinities with changes in the size of the regional and phytogeographical framework within which they are viewed. Thus although on a local scale, the distribution problems referred to above fall into the two main types, on taking a broader regional view, they are seen to be related aspects of the same major problem, the post-tertiary fortunes of the ~~ver~~ evergreen forests in the temperate latitudes of Europe.

The bearing of the present evidence on this problem may be summarised in the following statements:-

i). During Hoxnian times, numerous thermophilous taxa, many of them evergreen were present in the local flora. Today, some of these have disjunct Lusitanian and peri-Mediterranean distributions in Western Europe, including localities in the immediate neighbourhood (Arbutus unedo, Daboecia cantabrica) and most belong to the group of plants, the arcto-tertiary relics, discussed above.

ii). Some species from this ecologically rather heterogeneous group of plants are recorded in the present study, but to a much lesser extent, from the post-glacial period, prior to any possibility of artificial introduction (Daboecia cantabrica, Erica vagans) whilst others, for which Hoxnian but no post-glacial sub-fossil records have been found, do nevertheless exist in native situations in the area (qv. Tables 3 and 14). All these plants must, on this evidence, have either survived the last and perhaps the last two glaciations in the area, or migrated into it during the Late- or post-glacial period.

iii). Evidence from Full-glacial (Würm) pollen analyses shows that climatic conditions in the area were then such as to inhibit totally the growth of trees of any kind. A severely impoverished and probably truly tundra type of vegetation existed in the area during even a quite late stage in the last glaciation. Zagwijn (1961) has suggested that these kind of communities reflect mean July temperatures of no more than 6°C.

It is highly improbable that any of the relatively thermophilous species considered survived these conditions and so the conclusion that they migrated into the area from elsewhere is inescapable. Unless the severity of the Full-glacial climate in the Pays Basque was a local phenomenon, due perhaps to the proximity to the Pyrenees, it seems impossible to envisage survival of these species any further north in Western France. Ters (1961) has shown that periglacial conditions prevailed for certain periods along the west French coast to the north, and all the available evidence points to some locality south of the Pyrenees as the region of perglacial survival. The coastline in the area slopes far too steeply to have allowed offshore survival. .

From the evidence in the early post-glacial layers at Le Moura and the late-glacial levels at Sanguijuelas, on the Spanish-Portuguese border (Menendez Amor and Florschutz 1960), it is clear that species of Quercus survived in Iberia and migrated north with climatic amelioration reaching Sanguijuelas in Zone II and Le Moura in Zone IV. Some species of oak, probably Q. robur, reached the Dartmoor area before Corylus (Simmons 1961). The extremely early record of Ilex aquifolium at Le Moura suggests that holly also survived in Iberia and spread early into south west Europe. Here then is evidence confirming the presence of perglacial refugia in Iberia and suggesting that they were the points of dispersal for some early arrivals among the thermophilous species recorded at Le Moura. From their present day areas and their presence in the Pays Basque during Zone VI, there can be little doubt that Daboecia cantabrica and Erica vagans survived and spread in a similar manner, whilst the pre-cultural records for Vitis, Olea and Quercus ilex suggest a similar history. In this case, it is possible that the outlying localities of Mediterranean species in north west Spain and south west France referred to in Chapters II and IV and immediately above can be explained in terms of early post-glacial spread from Iberian refugia rather than as relic habitats from a so-called xerothermic post-glacial period which favoured the westward extension of species from the north west Mediterranean area. In this connection, it is interesting to note that the earliest and only recorded pollen analytical phase which could be identified with the xerothermic period is the late Zone VI phase of pine expansion and drier mire communities, whilst the earliest records for Quercus ilex, Vitis and Erica vagans clearly pre-date this period. The first Buxus and Abies grains come from the late Zone VI levels though, and it is just possible that both these species extended their ranges westwards at this time.

From the above evidence, it seems likely that both the Lusitanian and much of the Mediterranean element in the local flora migrated into the area during the early post-glacial period, after having survived the previous glaciation in Iberia. It is not possible yet to assess fully the bearing of this conclusion on the presence of some of these species in south west Britain In the case of Erica vagans at least, the evidence from Le Moura suggests that it could have reached Cornwall easily whilst sea-level was very low early in the post-glacial period. The same explanation may serve for the presence of some of the Lusitanian species in Ireland, especially Daboecia cantabrica recorded quite early at Le Moura, though much more evidence is needed from this and intermediate areas, and the possibility of off-shore survival around south west Ireland must be borne in mind.

The above evidence and deductions may contain a partial explanation for the presence and the disjunction of these species in Western Europe at the present day, but there is still the remaining problem of why they were so much more frequently and abundantly represented and more widely distributed in Hoxnian times than in the post-glacial. The explanation may be in terms of a contrast in climate between the Hoxnian and the present, a difference in factors of land and sea-level change or a difference in the location, population of, and diffusion from plant refuges during and after the relevent glacial periods.

In so far as the Lusitanian and Mediterranean species were late arrivals to Ireland during the Hoxnian, as seems to have been the case with some, it is tempting at first sight to relate the contrast between Hoxnian and post-glacial plants there to the late culmination in sea-level discussed in the previous chapter. This does not explain the contrast between the Marbella flora and that at Le Moura though, since the sites are close together on the European mainland. Also, it is clear from the Marbella series that sea level in south west France in the middle of the Hoxnian was as high or higher than at present. Thus it would be wrong to infer that because the culmination in sea level came so late, more land area was emerged in the middle of the Interglacial period than at the maximum of sea-level during the post-glacial. It may not have been any simpler for species to migrate into Ireland in mid-Hoxnian times than during the mid-post-glacial.

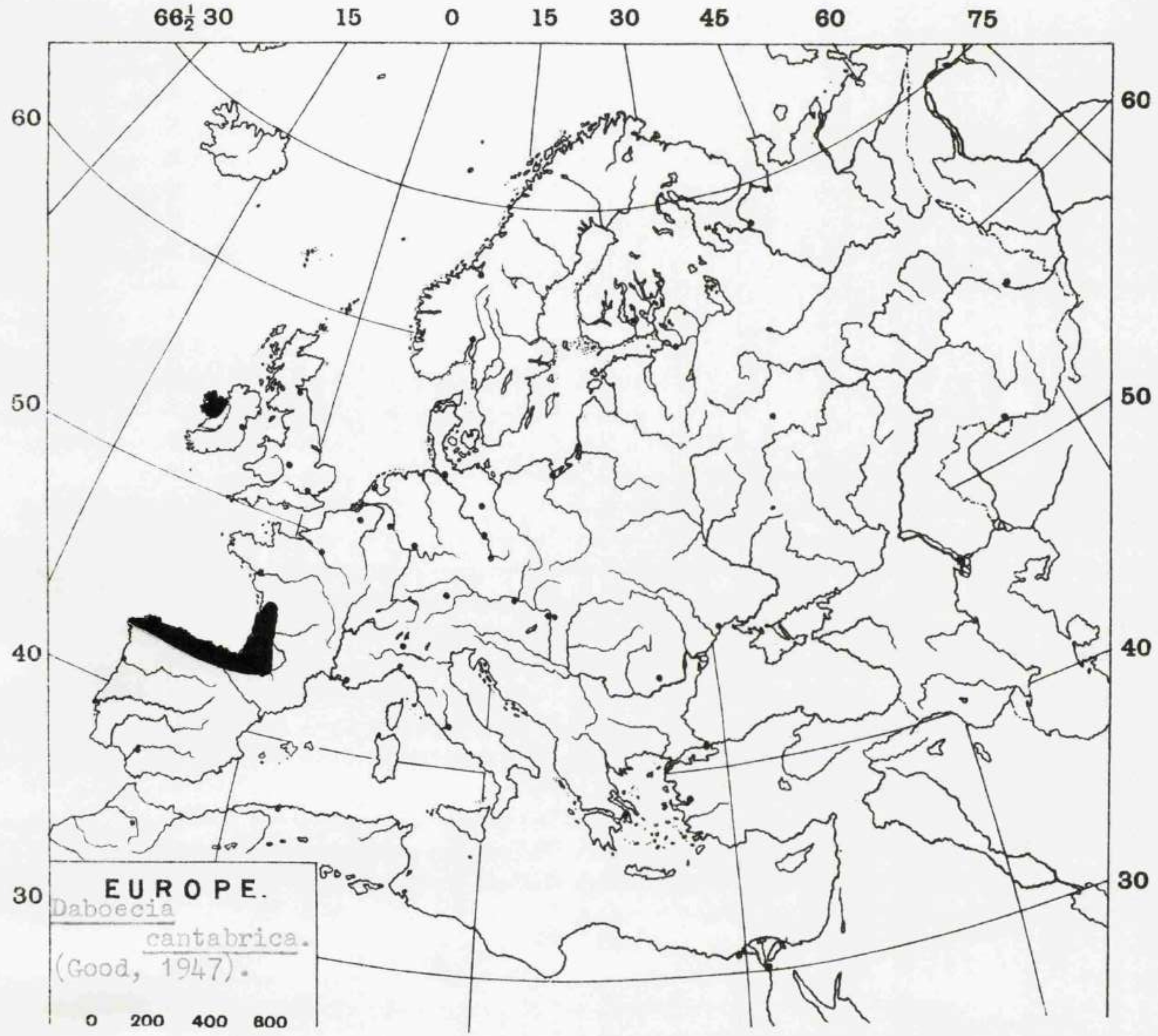
Jessen, Andersen and Farrington, and Watts, have suggested, on the ~~b~~ basis of the evidence at Gort and Kilbeg respectively, that the climate during the optimum phases of the Hoxnian may have been exceptionally mild and oceanic, perhaps, according to Watts, slightly warmer than the post-glacial. This supposition is based partly on the flora represented, with its many thermophilous evergreen species, partly on the basis of the vegetation communities deduced from the pollen frequencies by palaeo-ecological arguments.

Any conclusion of this kind based on biological evidence is bound to have a certain amount of circular reasoning at its core, though this does not necessarily vitiate the conclusions totally. More serious are the largely insoluble problems of palaeo-ecological reconstruction using taxa whose biotype composition may have altered since the period studied. It has been suggested that this problem is reduced when species of related present day climatic tolerance are seen to respond in a similar manner, or when conclusions are based on the presence or absence of an assemblage of similarly indicative species rather than one or two. In practice, this seems a harder attitude to uphold objectively than it would appear to be in theory, for much depends on the extent to which and the impartiality with which one is prepared to group species into ecological assemblages. Thus it would be as easy, from the Marbella flora, to compose a group of species of continental northern affinities (in south west French terms) as one of Mediterranean-Lusitanian affinities, and it would be biased to regard one group as an assemblage of species giving parallel indications of climate and to treat the individual members of the other group separately and hence conclude that each was either a minor anomaly, a result of different competition pressure or the former possession of a wider range of genotypes. It seems unlikely that such fossil floras of mixed geographical affinities can ever be used with complete objectivity to afford unambiguous and detailed indications of climate. Thus it seems safest to conclude that although a certain amount of circumstantial evidence may support the inference of a milder climate during the Hoxnian than the post-glacial, it is not sufficiently certain to preclude the desirability of seeking for other possible supplementary or alternative factors to explain the peculiarities of the Hoxnian flora.

The final possibility concerns the location of perglacial refugia,variations in their species content from glaciation to glaciation and the spread of plants from them. The discussion in Chp. VI considers the possibility that phase I at Marbella can be correlated with the last three sub-stages of Zone I at Hoxne. If this is so, then it means that a large proportion of the thermophilous flora of the interglacial had arrived in the Biarritz area at a time when it was totally absent from south-east England. This could only mean that it had survived much closer to the Pays Basque than to Britain and so, almost certainly in Iberia or in south west France itself. If a much richer flora survived the Mindel (Elster) glaciation more extensively in south west Europe than survived the Riss and Würm, then this would help to explain the peculiarly thermophilous nature of the Hoxnian flora in Western Europe, and its failure to reappear there to the same extent in subsequent periods. The pollen analytical evidence from Site II at Marbella is beginning to testify to the severityof what is probably the Riss glacial period in the area. Greater survival in Iberia during Mindel times than during the Riss and Würm could have been the result of milder conditions south of the contemporary west European ice margin, or it could merely indicate the progressively diluting effect of successive glacial phases on the thermophilous element discussed.

The inference of conditions in the Mindel permitting more plants to survive in south western refugia rests solely on the evidence from Phase I at Marbella and on the possibility of its correlating with Zone I at Hoxne. Thus the suggestion is a highly spectulative one and it reinforces the need to resample and re-examine those lowest strata,if necessary by boring.


66½ 30
15
0
15
30
45
60
75
60
50
40
30
60
50
40
30
EUROPE.
Arbutus unedo.
(Sealy 1949).
0 200 400 600



EUROPE.

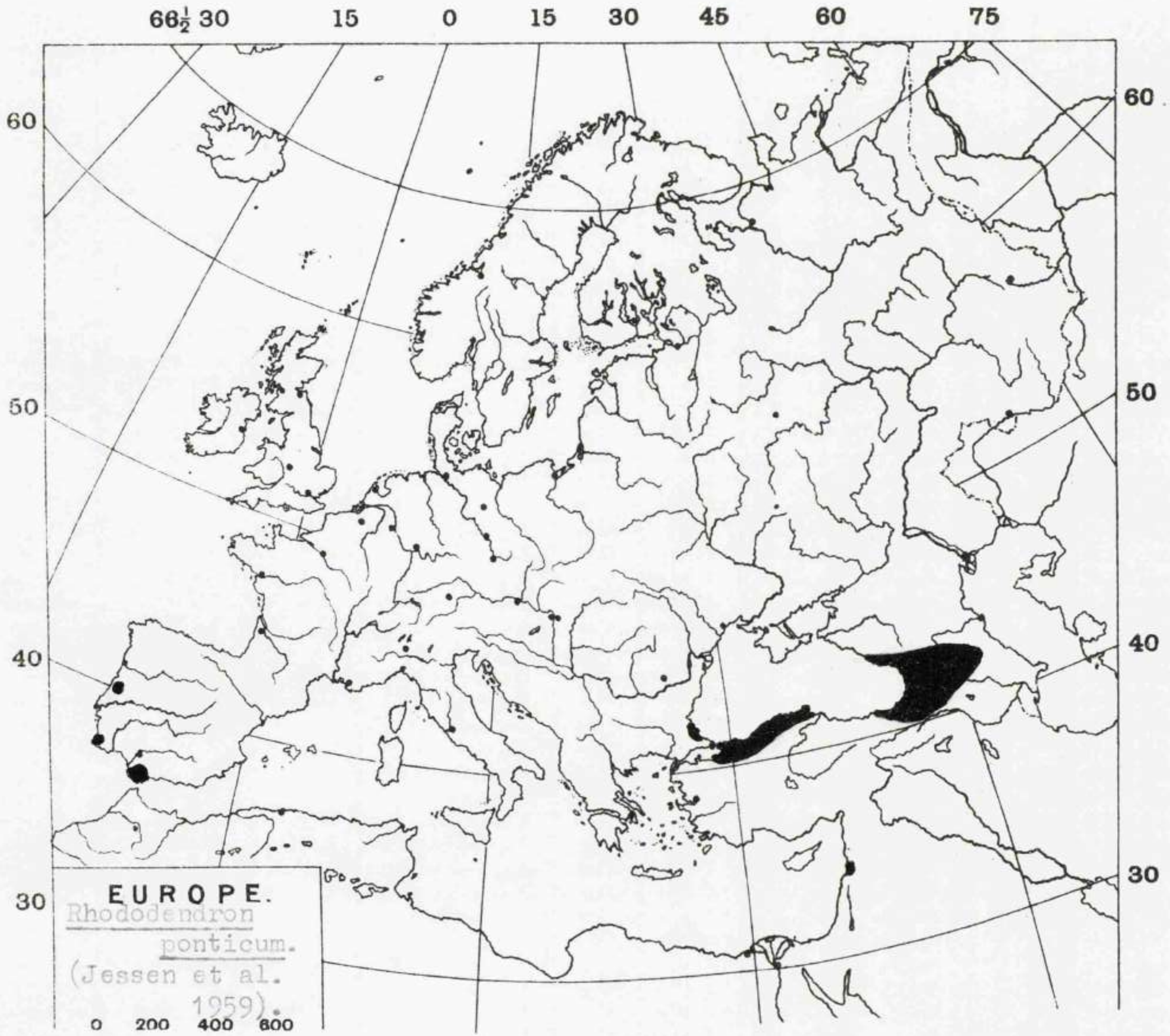
Daboecia cantabrica.

(Good, 1947).

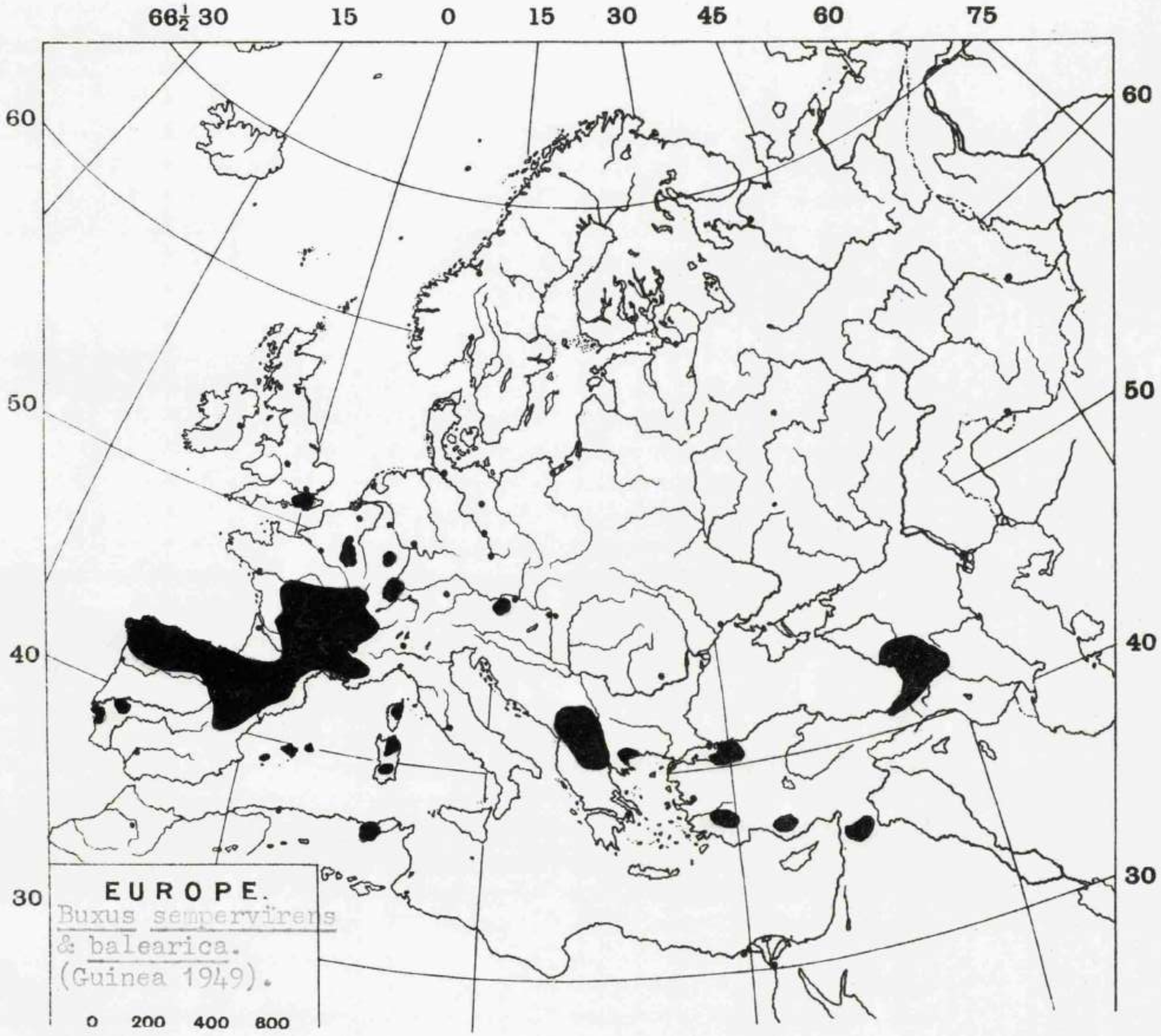
EUROPE.

Erica vagans.

(Guinea 1949).



EUROPE.
Rhododendron ponticum.
(Jessen et al. 1959).

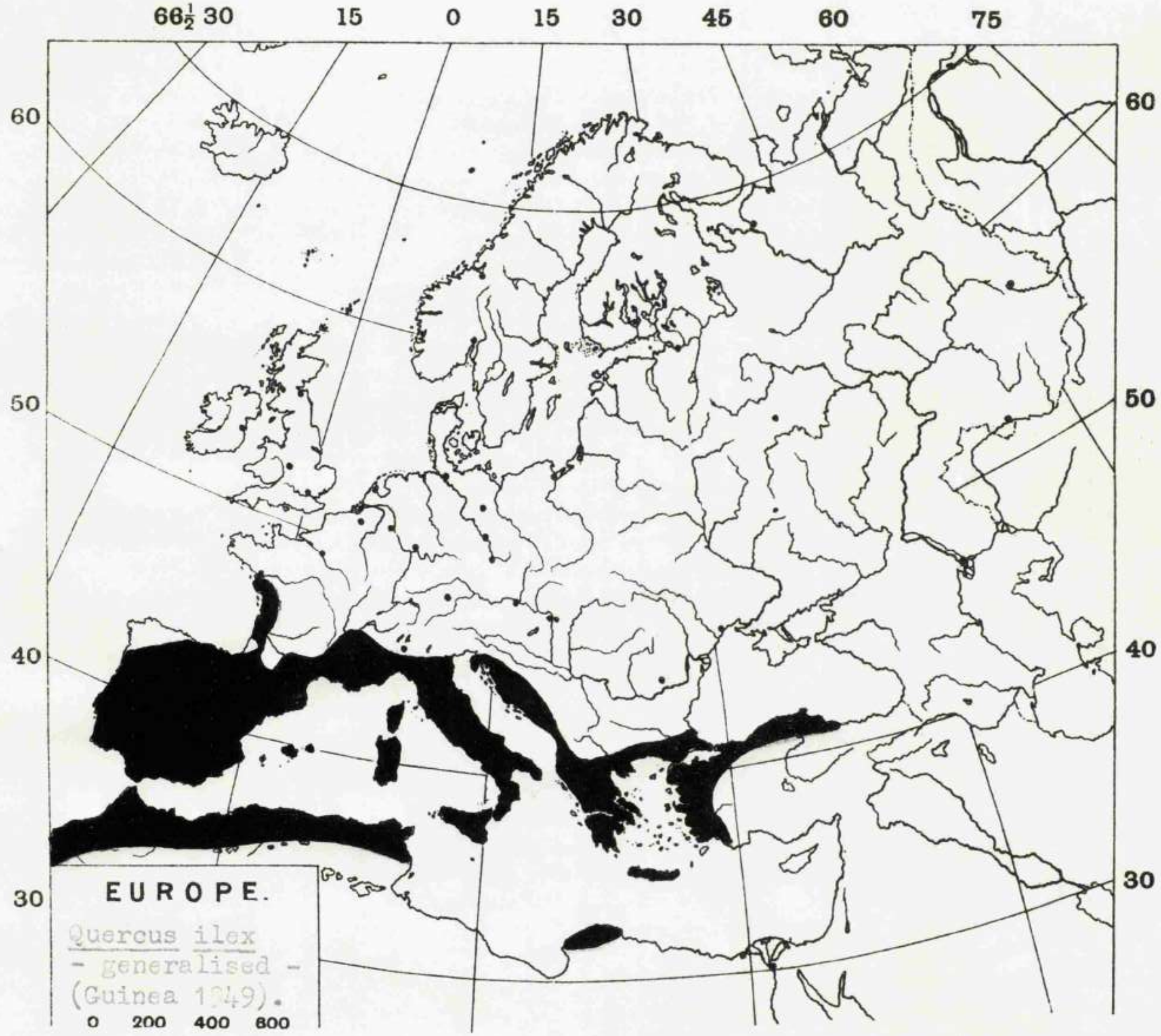


EUROPE.

Buxus sempervirens

& balearica.

(Guinea 1949).



EUROPE.

Quercus ilex
- generalised -
(Guinea 1949).

Summary and Conclusions.

i). Attention is concentrated on two quaternary sites close to Biarritz, one, Le Moura, giving evidence from the Full- Late- and Post-glacial periods the other, Marbella, dating mainly from the Hoxnian (Great) Interglacial. The stratigraphy, pollen analysis and macroscopic plant remains from the deposits at these sites are discussed.

ii). The last part of the Full-glacial (Würm) period probably saw the existence of true tundra conditions in the area whilst during the Late-glacial period, pine (including Pinus uncinata) and tree birches spread into the area and forested episodes alternated with periods of park woodland and steppe-tundra.

iii). Pollen-analytical indications of hydroseral and terrestrial vegetational successions intermingle in contrapuntal fashion in the Late-glacial deposits at Le Moura, and not until a detailed palaeo-ecological analysis of the evidence was carried out did any satisfactory indication of climatic change during the period emerge.

iv). The main episodes of the Late-glacial period closely parallel those from north-west Europe, a mild forested phase, presumably contemporary with the Allerød (Zone II) occurs preceeded and succeeded by less wooded cooler episodes. A pre-Allerød climatic oscillation of apparently small length and amplitude is tentatively detected which may be contemporary with similar phases in north west Europe.

v). Among the Full- and Late-glacial plant records, Armeria sp., Cryptogramma crispa, Centaurea cyanus, Ephedra distachya, Euphorbia amygdaloides, Polygonum cf. viviparum and Valeriana dioica may be noted.

vi). The post-glacial record is incomplete, there being a discontinuity in deposition giving rise to the absence of any records from the whole of British pollen zone VIIb, early VIII and late VIIa. The dominant woodland species throughout thez earlier part of the post-glacial period are oaks and pine, with hazel, whilst alder and later beech appear. Other mixed oak forest elements are very scarce.

vii). Both the stratigraphic and the pollen-analytical record show that the end of phase P 2 (Zone VI) at the site was a relatively dry period as appears to have been the case in Britain also.

viii). Whilst the highest levels include records for recently introduced plants such as maize and a species of cedar, earlier pre-cultural levels include pollen records of *Vitis*, *Olea*, *Daboecia cantabrica*, *Erica vagans* and *Quercus ilex*.

ix). On the basis of the evidence from Le Moura and recently published work from Spain, it is concluded that some oak species survived the last glaciation in Iberia and spread northwards to reach Le Moura at the very beginning of the post-glacial period. The evidence from Le Moura suggests that *Ilex aquifolium* and most if not all of the species listed in parag. (viii) above probably did likewise.

x). The vegetational successions and plant record at Marbella show interesting parallels with British Hoxnian sites. Evergreen shrub taxa are especially abundant in the pollen analyses (eg. *Rhododendron ponticum*, *Arbutus*, *Daboecia cantabrica*, other *Ericales*, *Olea*, *Phillyrea*, *Buxus*, *Ilex* and *Hedera*) and there are also clear traces of the presence of *Fagus* in the area.

xi). The first phase at Marbella records a climatic oscillation and may be contemporaneous with that found towards the base of the deposits at Hoxne.

xii). A reconstruction of the plant communities during the middle part of the Interglacial period suggests that oak woodland dominated the flat plateau areas around the site whilst the evergreen shrubs, most of which are fairly light demanding grew in more open communities on the steeper valley slopes.

xiii). It is tentatively suggested that a decline in soil base status at about the Phase III/IV boundary gave rise to a reduction of the oak woodland element in the vegetation and the advent of acidic heath communities and fir woodland. It is supposed that subsequent climatic deterioration at the very end of the period of deposition led to a final phase of pine woodland and open heath.

xiv). Deposits overlying and to the south of the Hoxnian successions record part of a major complex glaciation (probably the 'Riss') involving at least one phase of solifluction activity in the area.

xv). Sea-level appears to have risen throughout the period of deposition of the Hoxnian deposits at Marbella, as in the Nar Valley and at Clacton in eastern England. It reached its maximum height after the final phase of inferred climatic revertence mentioned in parag. (xiii).

xvi). Since all the deposits of an organic nature formed during the Hoxnian at Marbella appear to be lagoon sediments developed locally and close to the contemporary sea-level at various stages in its rise, most of the individual horizons of marine transgression and regression recorded have no general significance beyond the confines of the single estuary.

xvii). It is concluded that the Lusitanian and Mediterranean elements in the local flora could not have survived the last, let alone last two glaciations in the immediate neighbourhood of Biarritz. They probably survived in Iberia whence they spread into the Pays Basque again during the early and middle post-glacial period. For the most part, they are thought not to be the result of an extension westwards of Mediterranean species during some 'xerothermic' post-glacial phase.

xviii). Although there is some evidence that a more favourable climate in Hoxnian times may have been one reason for the richness of the flora of that period in evergreen species and 'tertiary relics', it is suggested that greater survival of these species in Iberia during the preceeding glaciation could also have been an important factor.

APPENDIX I.

The modified peat borer.

The modified borer used to collect the continuous core samples from Le Moura in 1960 was designed by Dr.K.Thomas of Hatfield Technical College and Mr.L.Farnell in collaboration with the present author,and produced by Leonard Farnell & Co.,Hatfield. It followed an earlier proto-type designed by Dr.Thomas and Mr. Farnell alone.

In the standard Hiller borer,the outer casing of the sampling chamber rotates and carries the cutting blade,whereas the inner casing is fixed to the end of the first metal rod. The screw-auger which forms the end of the borer is firmly fixed to the sampling chamber and not readily detatchable in the field.

In the modified borer,the outer casing is fixed and the inner casing rotates and carries the blade. The auger end is detatchable allowing the inner casing to be removed readily in the field. In this way, 50 cm. long zinc or aluminium liners may be introduced into the inner casing,this casing and the liner together inserted into the outer sleeve from below,the auger end re-attached and the borer used in the normal manner. Thus 50 cm. long continuous samples are obtained and the business taking individual pollen samples from each depth deferred until the return to the laboratory. It may be carried out pari passu with the actual analysis and it permits close sampling for both pollen analysis and macroscopic examination at leaisure without loss of time or hasty decisions in the field.

At the site of sampling, the cores once taken are labelled and wrapped in strong polythene sheet tightly secured by broad rubber bands. In this state the cores remain moist almost indefinitely.

APPENDIX II.

Pollen-analytical data from Site II, Marbella.

APPENDIX II.

Pollen-analytical data from Site II, Marbella.

161

	cm. 275	280	290	299	310	320	352	357	360	365	385	388	390	395	401	420	430	
PINUS	65	49	46	66	63	68	64	52	51	48	78	81	76	72	72	75	75	
ABIES		1	1	1	3	3	+	+	+	1	2	1	2			1	1	
PICEA		1	1	1	2	1	+			+						1		
BETULA	24	43	40	21	24	19	29	40	39	38	8	14	14	12	18	15	20	
ALNUS	5	3	9	5	8	8	5	4	6	10	8	2	4	12	8	7	4	
ULMUS								1										
QUERCUS	5	2	2	4			1	2	3		2		2	4	2	1		
TILIA						+						2						
FAGUS		1	1	1		1		1			2		2					
CARPINUS										1								
CORYLUS	16	7	23	13	14	17	5	10	10	25	20		16	20	30	12	17	
SALIX	3	3		5					1	1	4	2					4	2
cf. FRANGULA		1								(Daphne - 2)				2				
JUNIPERUS			2					1					2					
CALLUNA	9	9	7	4		5	18	18	26	13	12	6	8	12	8	21	21	
EMPETRUM NIGRUM	1	2	3	3	6	3							6	2	2			
VACCINIUM sp.				3		+	2	1	2	1						1	3	
RHODODENDRON cf.FERRUG.						1			1									
RHODODENDRON sp.				(Erica sp.1)					+								(Eric	
ERICALES indet.	8	1			3	2	6	2			2			2	2	1		
GRAMINEAE	91	305	67	65	153	50	113	97	62	68	3004	932	148	128	102	23	120	1
CYPERACEAE	240	345	96	101	47	74	51	66	64	100	1080	670	940	724	726	38	79	2
ARTEMISIA	55	13	4	24	9	7	7	10	10	6	80	38	26	44	62	8	16	
ARMERIA				1						1	2					1		
CENTAUREA	5	3	6	3		3	2	2	2	9	2		2			4	1	
PLANTAGO	18	9	4	7	5	2	1	2	3	2	18	22	14	92	8	2	18	
RUMEX	(1- Ephedra fragilis type)							1	1		(4- Ephed.frag.T.2).							
EPHEDRA cf.DISTACHYA	2		3	2			1	1		1	2	2						
HELIANTHEMUM		1						2			2	2			2	1		
POLYGONUM cf.VIVIPARUM	3	1	1	2	3	+	24	38	22	9				2	2	1	2	

430	435	440	450	455	465	475	550	565	585	595	605	680	890	915
5	60	68	70	82	77	66	72	77	74	76	68	94	88	91
1		2	1				8	3	4	2		1	4	2
														+
0	32	22	19	14	18	30	6	2	5	5	14	+	3	3
4	4	6	6	2	3	1	9	12	9	8	14	3		4
							1							
	4		2	2	2	4	4	6	5	5	4	+	2	
			1											
										3			3	+
		2	1							1		+		
7	14	14	22	10	22	38	13	12	16	32	22		19	12
4	258		1	7	2			14		2	2			
													1	
1	24	14	14	8	43	30	4		6	13	12	18	7	13
			2	1	1	1	3	2		44	22		2	
3		4	3	1	1	2				2			2	
rica sp.2)														
													4	1
0	104	134	105	45	36	92	11	150	42	35	502	44	138	29
9	218	752	81	352	65	47	7	106	129	58	242	51	50	24
6	16	32	23	48	2	4	5	122	5	28	40	11	4	3
						1		2					+	1
1			5		6	2	1		3	3	2	1	2	+
8	6	12	13	14		2		8	6	7	144	11		+
		2	2						1	1	(2 Eph.frag.T)			
														+
								2						+
2	2				3	2				1				

Relative frequencies of selected pollen types in the preliminary analyses from Site II, Marbella. Depths refer to the stratigraphical section described in Chapter V. Frequencies based on total tree pollen less *Corylus* and *Salix*.

Appendix.III. Photomicrographs of pollen grains.

1. Arbutus sp. Marbella Site 1, stratum A, 317 cm. x 1000.
Note the large size, smooth exine, long furrows and the irregular and complicated system of endocracks forming and radiating from the 'pore' (i.e. endo-aperature) which is roughly transverse to the furrow.

2. Arbutus sp. Marbella Site 1, stratum C, 60 cm. x 1000.
Though somewhat crushed from the original globular shape, the characteristic triangular outline of the individual grains can be seen, as well as the features noted on (1).

3. Rhododendron ponticum. Marbella Site 1, stratum A, 70 cm. x 1000.
Optical section shows the typically complex exine stratification and the thickening of the ek-texine towards the grain poles.

4. Rhododendron ponticum. (as for 3). x 1000.
One short double furrow can be seen along with its associated pattern of costae, transverse endo-aperatures and endo-cracks.

5. Rhododendron ponticum and Rhododendron sp. Marbella Site 1, stratum A 0 cm. x 250.
The smaller grain ressembles the adjacent Rhododendron ponticum pollen in most aspects of its fine morphology and must belong to some other Rhododendron species.

6. Rhododendron ponticum. (as for 5). x 1000.
The features associated with the short furrow are clearly seen, as in (4), and also the faint granular ektexinal ornamentation.

7. Rhododendron sp. Marbella Site 1, stratum A, 70 cm. x 1000.
The short furrow and clear endo-cracks are found on a similar, but much smaller tetrad than Rhododendron ponticum.

8. Daboecia cantabrica. Le Moura, Series 'B'. Zone VIIa. x 1000.
Note especially the regularly granular ektexine and the long tapering costae.

9. Daboecia cantabrica. (as for 8). x 1000.

10 and 11. Daboecia cantabrica. Type slide. x 1000.

12. Erica vagans. Le Moura, Main Series, 50 cm. x 1000.
Note the small, smooth polar area with arcuate circum-costal endo-cracks.

13. Erica vagans. (as for 12). x 1000.
Optical section.

14, 15. Erica vagans. Type slide.

16. Erica cf. vagans. Marbella Site 1, stratum C, 40 cm. x 1000.
Note the smooth polar area with endo-cracks as in 12 and 14.

17. Erica cf. vagans. Marbella Site 1, stratum C, 40 cm. x 1000.
Optical section. The collapsed triangular shape leads to confusion with Erica mediterranea.

18. Empetrum nigrum. Le Moura, Main Series, 375 cm. x 1000.
Note the evenly granular exine and short slit furrow.

19. Empetrum nigrum. (as for 18). x 1000.

20. Empetrum nigrum. Le Moura, Main Series, 410 cm. x 250.
Pollen grains clumped together suggesting nearby origin.

21. *Erica* cf. *tetralix*. Le Moura, Main Series, 35 cm. x 1000.
Note the long, straight, untapering costae clearly demarcated by endo-cracks, the small polar area and the intercolpial ornamentation.

22. *Erica tetralix*. Type slide.

23. *Pinus* cf. *sylvestris*. Le Moura, Main Series, 190 cm. x 1000.
Note the long body and relatively small, obliquely situated air-sacs.

24. *Pinus* cf. *uncinata*. Le Moura, Main Series, 508 cm. x 1000.
Note the small body and rather large air-sacs.

25. *Pinus* cf. *uncinata*. Le Moura, Main Series, 410 cm. x 1000.

26. *Quercus ilex* type. Marbella Series 1, stratum A. 220 cm. x 1000.
Polar view showing typical sub-traingular shape.

27. *Quercus ilex* type. Marbella , as for 26. x 1000.
Surface ornamentation.

28. *Quercus ilex*. Type slide. x 1000.

29. *Olea* sp. Marbella Site 1, stratum A. 317 cm. x 1000.
In the large polar area, the individual columellae whichform the muri of the reticulum may be clearly seen.

30. *Olea* sp. (as for 29). x 1000.
Polar view with columellae in optical section.

31. *Phillyrea* sp. Marbella Site 1. Stratum C. 60 cm. x 1000.
Optical section showing columellae.

32. *Phillyrea* sp. (as for 31). x 1000.
The reticulum in the large polar area.

33. *Oleaceae* indet. ? *Fraxinus ornus*. Marbella Site 1, stratum C, 60 cm.
Note the rather prolate shape and long furrows. x 1000.

34. Fagus. Marbella Site 1. Stratum A. 70 cm. x 1000.

35. Euphorbia sp. Le Moura, Main Series. 395 cm. x 1000.
Optical section. The beaked effect at the furrow is the result of an ektexinal bridge which interrupts the margo in the middle of each furrow.

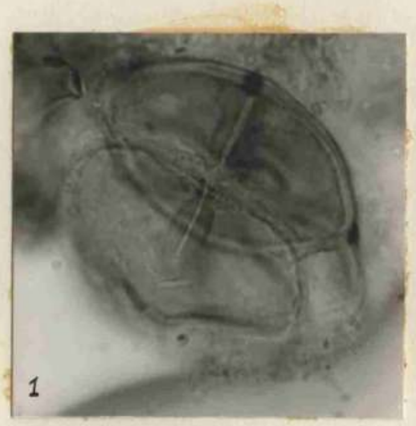
36. Euphorbia sp. (as for 35). x 1000.

37 - 39. Polygonum cf. viviparum. Le Moura, Main Series, 440 cm. x 1000.
When comparing these photographs with those of the type material, (40 and 41) it must be remembered that the sub-fossil grain has been prepared by heating in caustic soda and standing in hydrofluoric acid, whereas the type material has been acetolysed. This is an important factor in the difference in size observed, though type material of P. viviparum varies greatly in size and overall shape, as does the sub-fossil material.

40 and 41. Polygonum viviparum. Type slide. x 1000.

42. Knautia sp. Le Moura, Main series, 508 cm. x 400.

43. Knautia arvensis. Type slide. x 400.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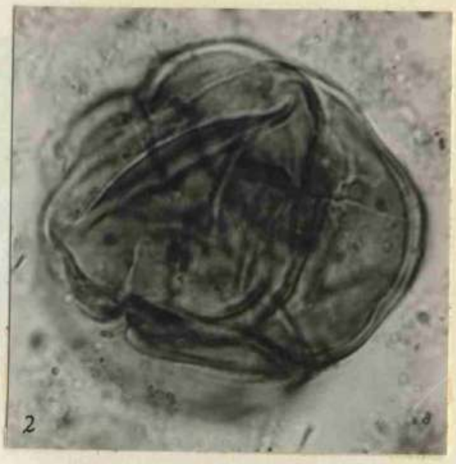
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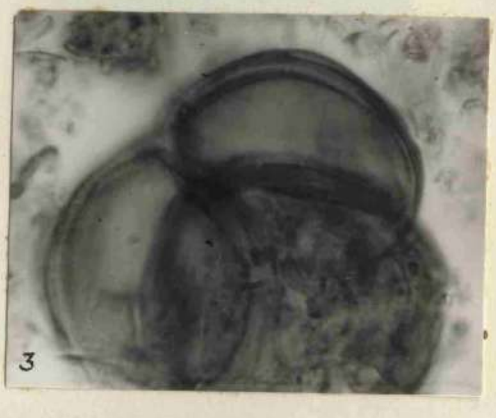
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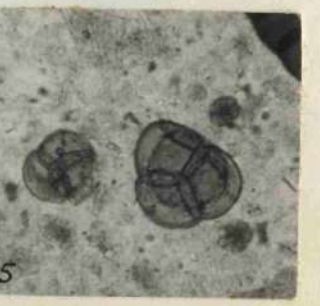
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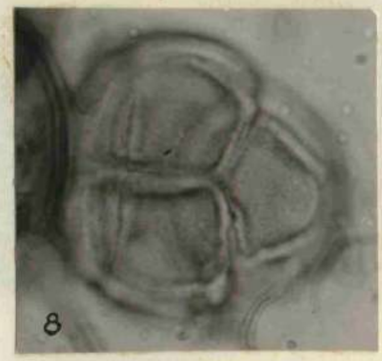

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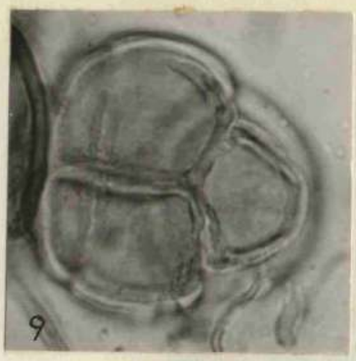

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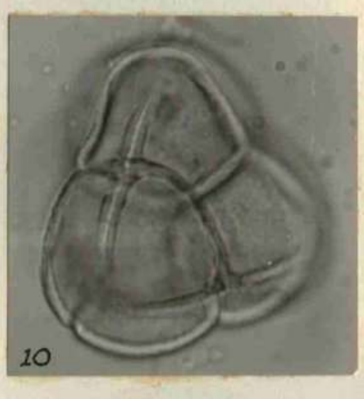

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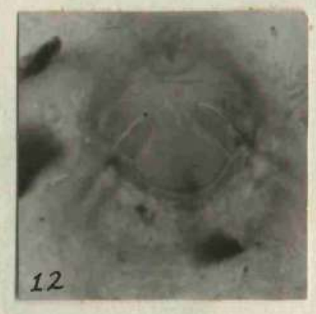

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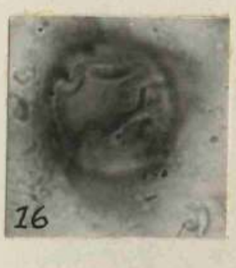

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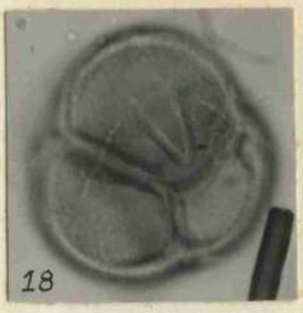

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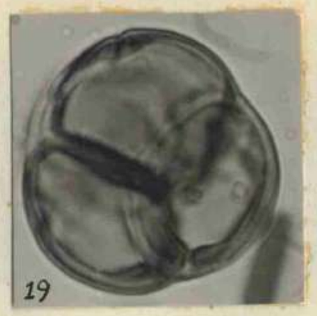

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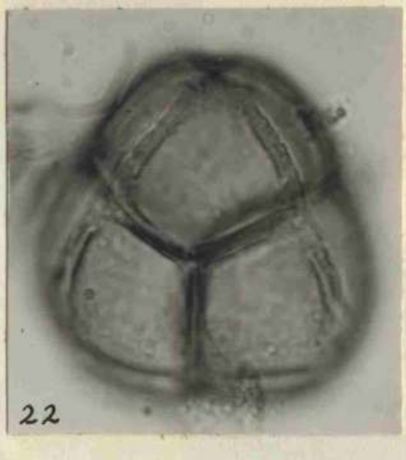

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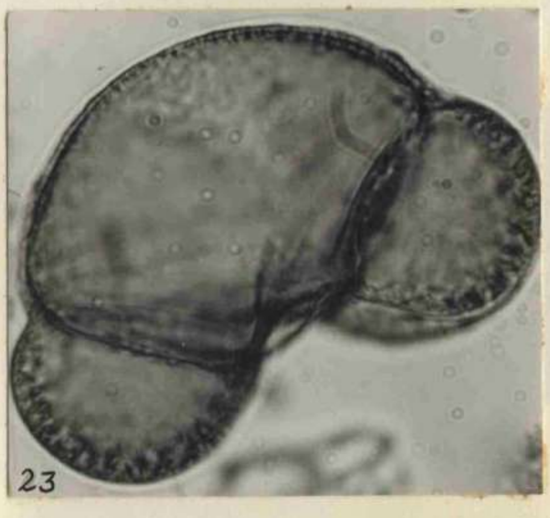

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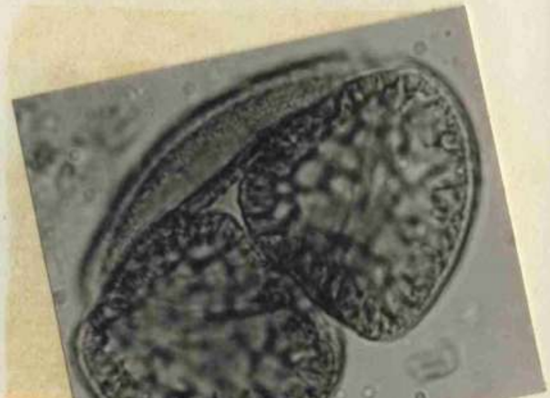

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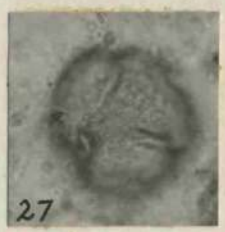
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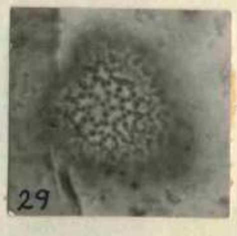
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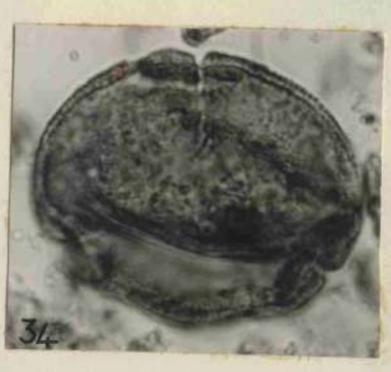
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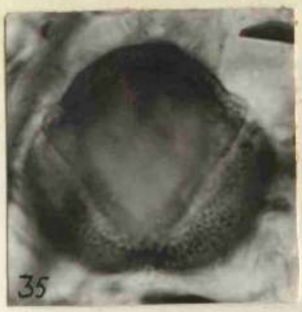
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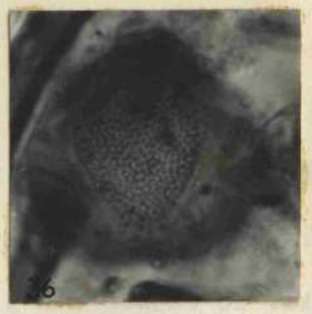
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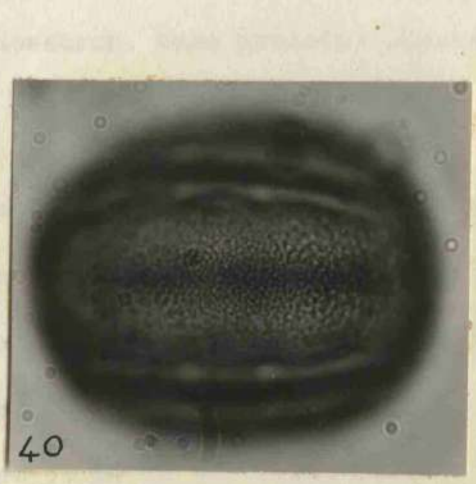
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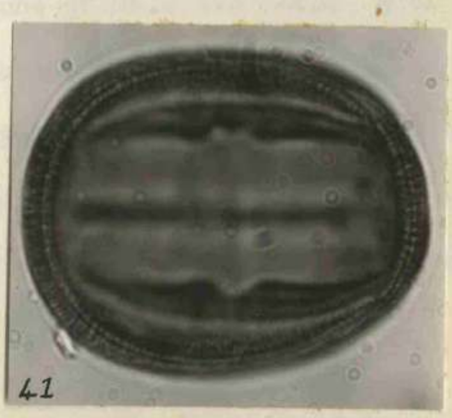
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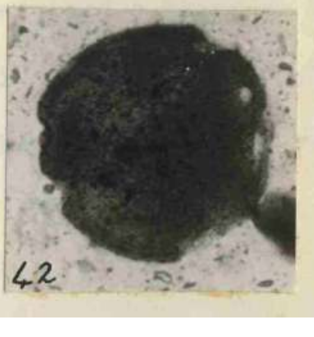
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ACKNOWLEDGEMENTS.

This research project was originally supported by the Centre National de la Recherche Scientifique, France,as part of the exchange scheme with the British Council. During the course of the work,financial support has been obtained from the University of Liverpool,of which the author was a Research Fellow,the Research Board of the University of Leicester and the Department of Scientific and Industrial Research. Most grateful thanks are due to all these authorities.

During the early stages of the project,the work was supervised by Dr. D.Walker,then of Cambridge,and his help and encouragement is enormously appreciated. Throughout the work,the stimulus of fruitful discussion with Professor H.Godwin,F.R.S. has proved invaluable,and I am also greatly indebted to him for suggesting the project to me in the first place. Whilst working in Paris,the helpful guidance of Dr.M.Van Campo made that part of the research most pleasant and profitable. Whilst at Leicester the help and advice of Dr. W Tutin and Miss. A.P. Conolly has been most valuable and is much appreciated. At all stages,the completion of much of the work has depended upon the help and endless forebearance of my wife.

In addition to stating my indebtedness to the above,it is both a privilege and a pleasure to acknowledge help and encouragement received from Miss.R.Andrew, Dr.L.Barriety,Mr.R.Duperier,Prof.H.Gaussen,Prof. F. Florschutz,Mr.F.Gohier,Dr.P.Jovet,Miss.C.A.Lambert,Mlle.D.Samuel,Dr.H.Straka, Dr.T.Van der Hammen,Dr.W.Van Zeist,Prof.H.T.Waterbolk,Dr.R.G.West,Dr.E.H. Willis and Dr.W.H.Zagwijn. I am also very grateful to the technicians of the Geography Department,Leicester for help with pollen preparations and diagrams.

REFERENCES.

ALLORGE,P. (1941a). Essai de synthese phytogeographique du Pays Basque. *Bull. de la Soc. Bot. de France*. T.88.pp.291 - 265.

ALLORGE,P. (1941b). Le chene-vert et son cortege au versant atlantique du Pays Basque espagnol. *Bull.Soc.Bot.de France*.T.88. pp.45 - 60.

ALLORGE,P. (1941c). A propos du *Prunus lusitanica* de la vallee de la Hayra (Basses Pyrenees). *Bull.Soc.Bot.de France*.T.88. pp.61 - 69.

ALLORGE,V.and P. (I941). Les ravines a fougeres de la corniche vasco-cantabrique. *Bull.Soc.Bot.de France*. T.88.pp.92-111.

ANDERSEN,S.T.,DE VRIES,H. and ZAGWIJN,W.H. (1960). Climatic change and radiocarbon dating in the Weichselian Glacial of Denmark and the Netherlands. *Geol.en Mijnbouw*, Vol, 39. pp.38 - 42.

AUBERT,J.,CHARPIN,H. and CHARPIN,J. (1959). Etude palynologique de quelques oleacees de Provence. *Pollen et Spores*. Vol.1. No.1. pp.7 - 14.

BARGHOORN,E.S.,WOLFE,M.K. and CLISBY,K.H. (1954). Fossil maize from the Valley of Mexico. *Bot.Mus.leaflets. Harvard*.Vol.16.No.9.

BECKER,J. (1952). Etude palynologique des tourbieres flandriennes des Alpes Francaises. *Mem.du Service de la Carte Geol. d'Alsace et de Lorraine*. No.11. pp.1 - 64.

BEUG,H.J. (1960). Beitrage zur postglazialen Floren- und Vegetationsgeschichte in Suddalmatien ; Der See "Malo Jezero" auf Mljet. tiel II. Häuzigkeit und pollenmorphologie der nachgewiesenen Pflanzensippen. *Flora*.Bd.150.H.4.pp.632-656.

BRAUN-BLANQUET,J. (1933). Analyse pollinique et'periode xerothermique' dans les Cevennes Meridionales. *Bull*.*Soc*.*Hist*.*Nat*. *Toulouse*.No.23. pp.327 - 341.

BRAUN-BLANQUET,J. (1936). La chenaie d'Yeuse mediterraneenne (*Quercion Ilicis*). SIGMA. Comm.No. 45.

CLAPHAM,A.R.,TUTIN,T.G. and WARBURG,E.F. (1952). *Flora of the British Isles*. Cambridge.

CONOLLY,A.P. (1961). Unpublished data from Whitrig Bog,Berwickshire.

CONWAY,V.M. (1938). Studies in the Autecology of *Cladium mariscus* R.Br. V. The distribution of the species. *New Phytol*.37.p.312.

DAGUIN,F. (1948). Geologie regionale de la France. V. *L'Aquitaine occidentale*. Paris.

DAHL,E. (1951). On the relation between summer temperature and the distribution of alpine vascular plants in the lowlands of Fennoscandia. *Oikos*. 3.no.1. p.22.

DELER,Y. (1932). Esquisse morphologique de la Cote Basque francaise entre l'embouchure de l'Adour et celle de la Bidassoa. *Rev*. *Geog*.*des Pyrenees et Sud-ouest*. p.18.

DE BENITO,C.(1948). *Brezales y brezos*. Inst.Forestal de Madrid.

DE RANCE,C.E. (1875). The geology of the country around Blackpool,Poulton and Fleetwood. *Mem*.*Geol*.*Surv*.*Eng*.*Wales*.

DE VRIES,H.,FLORSCHUTZ,F. and MENENDEZ AMOR,J. (1960). Une diagramme pollinique simplifie d'une couche de "gyttja" situee a Poueyferre pres de Lourdes (Pyrenees Centrales Francaises), date par le methode du radiocarbone. Koninkl.Nederl.Akad. van Wetenschappen, Proc. B. 63 (4). pp.498-500.

DIMBLEBY,G.W. (1957). Pollen analysis of terrestrial soils. New Phytol. 56. pp.12 - 28.

DUBOIS,G. and C. (1938). Premiers examens polliniques de tourbes littorales du sud-ouest de la France. Co.Rend.Soc.Geol.de France. No.16.pp.317 - 319.

DUPONT,P. (1955). Contribution a la flore du nord ouest de l'Espagne (2). Bull.Soc.Nat.Hist.Toulouse.T.90.

ELHAI,H. (1959). Analyses pollinique de deux tourbieres normandes. Pollen et Spores. Vol.1. No.1. pp.59 - 76.

ENJALBERT,H. (1950). Observations morphologique sur les Landes de Gascoygne. Rev.Geog.Pyr.et Sud-ouest. Vol.21.

FAEGRI,K. (1960). Maps of the distribution of Norwegian vascular plants. 1. Coastal Plants. Oslo.

FAEGRI,K. and IVERSEN,J. (1950). A textbook of modern pollen analysis. Cop.

FIRBAS,F. (1949). Spat- und nacheiszeitliche Waldgeschichte Mitteleuropas nordlich der Alpen II. Jena.

FOURNIER,P. (1946). Les Quatre Flores de la France. Paris.

GAUSSEN,H. (1941). Le climat et le sol du Pays Basque francais. *Bull. Soc. Bot. de France*. 88. pp. 5 - 16.

GAUSSEN,H. (1948). Carte de la vegetation de la France. *Perpignan.* (1/200,000)

GODWIN,H. (1956). *The History of the British Flora*. Cambridge.

GODWIN,H. and TALLANTIRE,P.A. (1951). Studies in the post-glacial history of british vegetation. XII. Hockham Mere,Norfolk. *New Phytol*. 39 (2). p. 285.

GODWIN,H. and SEAGRIEF,S. (1960). Post-glacial pollen diagrams from the Hampshire basin. *New Phytologist*.Vol,59.

GODWIN,H. and WILLIS,E.H. (1959). Radiocarbon dating of the Late-glacial period in Britain. *Proc.Roy.Soc*. B.150. pp.199 - 215.

GUINEA,E. (1949). *Vizcaya y su paisaje vegetal*. Bilbao.

HEDBERG,O. (1951). Vegetation belts of the East African Mountains. *Svensk Bot. Tid*.45(1). pp.140 - 202.

IVERSEN,J. (1942). En pollenanalytisk tidsfaestelse at Ferskwanslagene ved Nørre Lyngby. *Medd.Dansk.Geol.Foren*. 10. p.130.

IVERSEN,J. (1944). *Viscum,Ilex* and *Hedera* as climatic indicators.*Geol. Foren.Stockh.Forh*.66. p.463.

IVERSEN,J. (1954). The late-glacial flora of Denmark and its relation to climate and soil. *Dansk.Geol.Unders*.II.No.80.pp.87-119.

IVERSEN,J. (1960). Problems of the early post-glacial forest development in Denmark. Dansk.Geol.Unders.Ser.4.Vol.4,(3). 6 - 32.

JACQUOT,M.E. (1864). Description geologique des falaises de Biarritz, Bidart,Quethary et St.Jean de Luz (Basses Pyrenees). *Actes de la Soc.Linneenne de Bordeaux*.XXV.pp.1 - 58.

JENTYS-SZAFEROWA,J. (1928). La structure des membranes du pollen de Corylus,de Myrica et des especes europeennes de Betula et leur determination a l'etat fossile. Bull. Int.Acad.Polon.Sci.et Lettres. Sec.B.

JESSEN,K. (1949). Studies in Late Quaternary deposits and flora history of Ireland. Proc. Roy.Irish.Acad. 52.B. (6). p.85.

JESSEN,K.,ANDERSEN,S.T. and FARRINGTON,A. (1959). The Interglacial deposts near Gort,Co.Galway,Ireland. Proc.Roy.Irish Acad. 60 B. p.1.

JOVET,P. (1941). Vegetation d'une montagne Basque siliceuse.La Rhune. Bull.Soc.Bot de France. 88.pp.69 - 92.

JOVET,P. (1955). Landes et Pays Basque occidental. Excursion Guide. VIII Int.Bot.Cong.

LANG,G. and TRAUTMANN,W. (1960). Zur spat- and nacheiszeitlichen vegetationsgeschichte der Auvergne (Franzoisches Zentralmassiv). Flora. Bd.150.H.1. p.42.

LEMEE,G. (1942). Recherches sur l'histoire forestiere postglacial en Auvergne III. Monts Dore. Revue des Sciences Naturelles d'Auvergne. Vol.8. pp.84 - 125.

MARRES,P. (1955). Phenomenes actuels de surface et de l'equilibre du tapis vegetal dans la region medtierraneenne. Ann.Biol. T.31. F. 5-6. pp.117 - 123.

McVEAN.D.N. (1956). Ecology of Alnus glutinosa (L).Gaertn. III Seedling establishment. J.Ecol. 44(1). 194 - 218.

MENENDEZ-AMOR,J. and FLORSCHUTZ,F. (1961). Contribucion al conocimiento de la historia de la vegetacion en Espana durante el Cuaternario. Estudios Geologicos. Vol.XVII. pp.83 - 99.

NICHOLS,H. Unpublished pollen analytical data from post-glacial deposits at Racks Moss (Dumfries) and Aros Moss (Campbelltown).

OLDFIELD,F. (1958). Appendix 1. Pollen analytical data. In Gresswell,R.K., The post-glacial raised beach in Furness and Lyth,north Morecambe Bay. Trans. Inst, Brit.Geog. 25. pp.79 - 103.

OLDFIELD,F. (1959). The pollen morphology of some of the west European Ericales. Pollen et Spores. Vol.I. No. I. pp.19 - 48.

OLDFIELD,F. (1960a). Studies in the post-glacial history of british vegetation. Lowland Lonsdale. New Phytol. 59. pp. 192-217.

OLDFIELD,F. (1960b). The coastal mud-bed at Mouligna,Bidart and the age of the Asturian industry in the Pays Basque. Pollen et Spores II (1). pp.57 - 70.

OLDFIELD,F. (1960c). Three pollen analyses from an integlacial mud bed on the foreshore near Biarritz,South West France. Bull.Cent. d'Et. Res. Scient. Biarritz. 3(1). pp.53 - 62.

OLDFIELD,F. (1960d). Late Quaternary changes in climat,vegetation and sea-level in Lowland Lonsdale. Trans. Inst.Brit.Geog. 28. pp. 90 - 117.

OLDFIELD,F. (1961). The Full- and Late-glacial period in South West France. Proc. Linn. Soc. Lond.

OLDFIELD,F. The post-glacial ecological history of the South East Lake District. Manuscript in preparation.

OLDFIELD,F. and STATHAM,D.C. (1962). Pollen analytical data from Urswick Tarn and Ellerside Moss,North Lancs. In the press.

OLDFIELD,F. and STATHAM,D.C., Unpublished pollen analytical evidence from Cockerham Moss,North Lancs.

PARROT,A.G. (1960). Le climat en Pays Basque Francais de 1851 - 1940. Pt.ii. *Bull.Cent.d'Et.Rech.Scient.Biarritz*.3(1).pp.131-137.

PASSEMARD,E. (1924). *Les stations paleolithiques du Pays Basque et leurs relations avec les terrasses d'alluvions*. Thesis.Strasbourg.

PEARSALL,W.H. (1918). The aquatic and marsh vegetation of Esthwaite Water. *J.Ecol*.6.pp.53 - 74.

PIGOTT,C.D. and WALTERS,S.M. (1953). Is the box tree a native of England? in Louseley,J. Arbroath.

PIKE,K. and GODWIN,H. (1953). The Interglacial at Clacton-on-sea,Essex. *Quat,Journ.Geol, Soc.Lond.* 108.(3).pp.261 - 272.

RALLET,L. (1955). Vendee,Saintonge,Poitou.Etude phytogeographique. Excursion Guide. VIII *Botanical Congress*.

REMY,P. (1955). L'analyse ecologique des cartes de la vegetation. *Report*, VIII *International Botanical Congress*. p. 150.

RIKLI,M. (1943). *Das Pflanzenkleid der Mittelmeerlander*. Bd.1. Bern.

SEALY,J.R. (1949). *Arbutus unedo*.*J.Ecol*.37. pp.365 - 388.

SIMPSON,J,M. and WEST,R.G. (1958). On the stratigraphy and palaeobotany of a late pleistocene organic deposit at Chelford,Cheshire. *New Phytol*. 57. 239 - 250.

STEVENS,L.A. (1959). The Interglacial of the Nar Valley,Norfolk. *Quat.Jorn. Geol. Soc.Lond*.CXV.pp.291 - 315.

SZAFER,W. (1953). Pleistocene stratigraphy of Poland from the floristic point of view,(Summary). *Ann.Soc.Pol. Geol.* 22(1).p.77.

TURNER,J. Unpublished pollen analytical data from Hatfield Moors,Yorks.

TURRILL,W.B. (1952). Wild and Cultivated olives.*Kew Bulletin*.3.pp.437-442.

VAN CAMPO,M. and ELHAI,H.(I956). Etude comparative des pollens de quelques chenes. Application a une tourbiere normande. *Bull.Soc. Bot.*de *France*. 103 (5-6).pp. 254 - 260.

VAN CAMPO,M. (1950). Recherches sur la phylogenie des Abietinees d'apres leurs grains de pollen. *Travaux du Lab.Forest. Toulouse.* I,(4). 184 p.

VAN DER HAMMEN,T. (1951). Lateglacial flora and periglacial phenomena in the Netherlands. *Leid.Geol.Meded.* 17. p.71.

VAN ZEIST,W. Unpublished pollen analytical data from Brittany.

VON POST,L. (1925). Gotlands-agen (*Cladium mariscus* R.Brit.)i Sveriges postarkticum. Ymer.45.295.

WALKER,D. (1954). In Clark et alia,*Excavations at Star Carr*.Cambridge.

WALKER,D. and WEST,R.G. (1953). Some Late-glacial plants. In Louseley,Arbroath

WALKER,D. (1957). Pollen analytical data from Moorthwaite Tarn.Paper delivered to Quarterbot. Taggung Zurich.

WALTERS,S.M. (1949). Biological flora of the British Isles. *Eleocharis* R.Br. *J.Ecol*.37.pp.192 - 206.

WATTS,W.B. (1959). Interglacial deposits at Kilbeg and Newtown,Co. Waterford. *Proc.Roy.Irish Acad.* 60B. pp. 79 - 134.

WEST,R.G. (1956). The Quaternary deposits at Hoxne, Suffolk. *Phil. Trans. Roy. Soc. Lond.* B. 239. p. 265.

WELSCH,J. (1917). Les lignites du littoral du sud ouest de la France. *L'Anthropologie.* Vol. XXXVIII.pp.201 - 234.

ZAGWIJN,W.H. (1960). Aspects of the Pliocene and early Pleistocene vegetation in the Netherlands. *Mededelingen van de geol. sticht.* C III (1). No.5.

ZAGWIJN,W.H. (1961). Vegetation,climate and radiocarbon datings in the Late Pleistocene of the Netherlands. Pt. I. Eemian and Early Weichselian. *Mem.Geol.Found. Neths.* N.S.No.14. pp.15 - 46.

ZEUNER,F.E. (1945). *The Pleistocene period.* London: Ray Society.

Additions.

SIMMONS,I.G. (1962). *The ecological history of Dartmoor.* Ph.D. Thesis. University of London.

TERS,M. (1961). *Le Vendee littorale.* Paris.