A contribution to the study of the elm decline in the southern Lake District

Garbett, Geoffrey

Garbett, Geoffrey (1980) *A contribution to the study of the elm decline in the southern Lake District*, Durham theses, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/7952/

Time present and time past
Are both perhaps present in time future,
And time future contained in time past.

T.S.Eliot

A CONTRIBUTION TO THE STUDY OF THE ELM DECLINE IN THE SOUTHERN LAKE DISTRICT.

By
Geoffrey Garbett
(B.Ed. Wales)

A Dissertation submitted as
part of the requirement for
the Degree of
Master of Science (Ecology)
at the
University of Durham.

Departments of
Botany and Zoology

October 1980

ACKNOWLEDGEMENTS

I would like to acknowledge the considerable assistance of Dr. Judith Turner under whose supervision this study was made. Her patient guidance and encouragement at every stage provided the framework upon which the work was built.

I would also like to thank Professor Frank Oldfield for his advice on the access to and suitability of the raised bog sites of the Southern Lake District, Joyce Hodgson for assistance with pollen identification and peat stratigraphy, Dr. Tim Gleaves for advice on the statistical analysis and Mr. Geoff Banbury for looking at the fungal spores. Considerable thanks are also due to my many other colleagues at Durham University for practical assistance, many helpful discussions and for drawing my attention to a number of useful references.

Finally, I gratefully acknowledge the financial support provided by the Manpower Services Commission during the production of this study.

CONTENTS

PAGE

ACKNOWLEDGEMENTS i

LIST OF FIGURES iv

LIST OF PLATES v

LIST OF TABLES v

SUMMARY vi

CHAPTER 1

INTRODUCTION 1

Section:

1.1 General Introduction 1

1.2 The Disease Theory 5

1.3 Aims of Study 8

1.4 Choice of Site 10

CHAPTER 2

THE SITE 12

Section:

2.1 Location and Geological and Geomorphological Background 12

2.2 Present Day Vegetation and Climate ... 14

CHAPTER 3

METHODS 15

Section:

3.1 Collecting the Core 15

3.2 Freezing and Sectioning 15

3.3 Slide Preparation and Counting 16

CHAPTER 4

RESULTS 20

Section:

4.1 Stratigraphy 20

4.2 The Diagrams 20

4.3 Zonation 21

4.4 The Hedera Curve 25

4.5 Occurances of Fly Blown Charcoal 28

4.6 Fungal Spores 28

CHAPTER 4 (cont.) PAGE

Section:

4.7 Buxus sempervirens 29
4.8 Dating the Diagram 29

CHAPTER 5

INTERPRETATION OF DIAGRAM 31

CHAPTER 6

DISCUSSION 41
CONCLUSION 47
BIBLIOGRAPHY 49

APPENDIX

Access to Ellerside Moss 53

LIST OF FIGURES

PAGE

FIGURE 2.1
The raised beaches of Furness 12

FIGURE 2.2
General locational map 13

FIGURE 2.3
Greenodd Estuary & Holker
Mosses 13

FIGURE 3.1
Sledge Microtome drawn
actual size 17

FIGURE 4.1
Ellerside Moss pollen diagram. Tree, shrub
and selected herb pollen frequencies ...... Between 20 & 21

FIGURE 4.2
Ellerside Moss pollen diagram. Remaining
pollen frequencies .... Between 20 & 21

FIGURE 4.3
Tree/Shrub/Herb/Spore ratio .... Between 20 & 21

FIGURE 4.4
Episode B: 95% confidence limits of
principal tree taxa .... Between 22 & 23

FIGURE 4.5
Occurances of fly blown charcoal 27

FIGURE 4.6
Unidentified spore 28

LIST OF PLATES

PAGE

PLATE 1.1
Dead Hedgerow Elms, Somerset .... Between 8 & 9

PLATE 1.2
A Copse of Dead Elms on the Polden
Hills, Somerset .... Between 8 & 9

PLATES 1.3 & 1.4
Dead Elms on the Purbeck Coast, Dorset .... Between 8 & 9

PLATE 2.1
General View of Ellerside Moss .... Between 14 & 15

PLATES 2.2 & 2.3
Ivy Flowering near Ellerside Moss .... Between 14 & 15

PLATE 3.1
Russian Borer showing Base of Peat .... Between 15 & 16

LIST OF TABLES

PAGE

TABLE 4.1
2 x 4 contingency table of <u>Hedera</u> occurances
in episodes A,B,C and D 26

TABLE 4.2
2 x 3 contingency table of <u>Hedera</u> occurances
in episodes A,B and C 26

SUMMARY

Using very close sampling and Hedera pollen as an indicator of standing dead trees this analysis of the elm decline at Ellerside Moss provides no evidence for the involvement of disease in the initial stages of the reduction in elm pollen. The diagram does provide evidence of a period of leaf-fodder gathering involving all the major forest trees during the early stages, and later of elm only. It is argued that this resulted in a near destruction of the elm and thus initiated the partial clearance of the elm dominated regions and later the production of small temporary clearances throughout the dry areas of the forest. The possible role of disease in the depression of the elm curve immediately before the first clearances and subsequent to it is discussed, but no evidence for this interpretation is offered here.

An interpretation of the available palynological, palaeontological and archaeological evidence, with particular reference to the Southern Lake District, is offered in explanation of the cultural and economic basis of the elm decline in the light of the present findings.

——— oOo ———

CHAPTER 1

INTRODUCTION

1.1 General Introduction

One of the most important changes on the pollen diagrams of North West Europe is the decline of the *Ulmus* pollen frequency which generally occurs at about 3000 B.C. and without corresponding drops in the curves of the other tree taxa. The consistency of this feature is made more outstanding by the synchroneity of its radiocarbon dates throughout Europe. Sims (1973) reports them as falling between 3,800 B.C. - 2,500 B.C. and most between 3,400 B.C. - 2,800 B.C.

Godwin (1948) considered the drop in *Ulmus* frequency to be climatically induced and he used it to define the Atlantic/Sub-Boreal zone boundary, citing a drop in temperature as the cause. This view was supported by the work of Iversen (1941, 1944) in Denmark who noted a significant drop in *Hedera* pollen at the *Ulmus* decline, and using the modern vegetation he showed that ivy is sensitive to low temperatures, being unable to flower when the coldest monthly mean is less than 1.5°C. As the quantity and detail of the pollen analytical evidence has accrued, however, the wholly climatic interpretation of the event has become less tenable.

Smith (1961) has shown that the vegetational changes associated with the decline of the elm vary significantly in different regions of Europe, and neither the ivy fall noted by Iversen, nor the *Tilia* pollen reduction noted by Godwin are consistent features of the horizon. In Ireland both these curves rise at the fall of elm (Jessen, 1949; Mitchell, 1956; Morrison, 1959). Another problem encountered with the climatic interpretation is that of the species of elm concerned. Iversen suggests that the southern distributed Ulmus carpinifolia would be adversely affected by a fall in winter temperature, but in Britain the dominant species is more likely to have been the more hardy Ulmus glabra. Willutzki (1962) suggests that the fall in the elm pollen frequencies in the Oberharz (Germany) cannot be explained by the suppression of one species only.

The role of man in these gross vegetational changes was initially not considered as it was felt that his technology in 3000 B.C. would have been inadequate to produce such dramatic changes in his environment. Very many pollen diagrams, however, have distinct evidence of cultural activity just above the elm decline horizon with increases in Plantago sp., Gramineae, Pteridium spores and other 'cultural' pollen. After an initial suggestion by Faegri (1944) Troels-Smith (1960) made an important contribution to the debate by offering convincing evidence that semi-agriculturalists of the Ertebolle culture in Denmark selectively used elm leaves and twigs as fodder for stalled animals. Both he and Heybroek (1963) have discovered considerable historical evidence for the use of leaves as fodder. In addition Heybroek has found such fodder gathering still forming an important part of the economy of the people of the Indian Himalayas, Ulmus being a widely utilized genus. His observations provide a convincing argument against those who are unable to credit a technologically primitive people with such a distinctive change in forest composition. He observed large trees being lopped and noted that this made them suseptible to rot and crowding out by other trees. As a result elm was almost absent from the forest but, apparently due to the quality of its fodder, it was often planted, sometimes alongside apricot and peach, near the villages where it was lopped systematically to provide a sustained yield.

The use of elm leaves for fodder is not accepted by all workers as a sufficient explanation for the elm decline at all the sites it occurs, nor for the maintenance of low elm pollen values throughout North West Europe from 3000 B.C. Mitchell (1965) has suggested the the early farmers ring barked the pure stands of elm which were growing on the best, base-rich soils. The opening of the canopy thus effected encouraged the growth of grass and other fodder plants for cattle. Smith and Willis (1962) discovered that only an increase in grass was synchronous with the elm decline at Fallohogy. This they interpreted as showing that elm was growing in relatively pure stands and was killed to allow pasture to develop. In addition they suggest that the presence of pasture would rule out the need for the use of elm leaves as fodder. They feel that ring barking (after Iversen 1960) was the most likely method of tree clearance for this purpose.

Despite the recognition of man's role in the elm decline climatic factors cannot be ignored. Iversen (1944) has used the frequencies of <u>Viscum</u> and <u>Ilex</u> pollen in addition to that of <u>Hedera</u> as indicators of a cooling of the climate in the Sub-Boreal (ie. after the elm decline) in N.W.Europe. Van Zeist (1959) comes to the conclusion that ".... although the <u>Ulmus</u> decline cannot be credited to a climatological cause, it still marks a change in climate." He bases this view particularly on the decrease of ivy at the elm decline in N.W.Europe. Frenzel (1966) has identified Alpine climatic oscillations which resulted in a lower temperature phase at the time of the elm decline and he sites these as being a possible cause of the elm decline in the central German mountains recorded by Steckham (1961) and Willutzki (1962). Smith (1965) drew evidence from the differential spread and retreat of <u>Alnus</u> and <u>Pinus</u> in Britain to show that forests have an 'inertia' which may have made it difficult for early men to have changed them until forest stability was decreased by climatic change. In a later study however, (Smith and Pilcher 1973) it is pointed out that ^{14}C dates show that with the exception of elm and to a lesser extent pine, most species limits are diachronous and that inertia is probably less important to the decline of a species than its establishment. Sims suggests that man and climatic change could have had a synergistic effect with the spread of an incipient farming culture (fodder-gathering) being initiated by a change in climate. The resultant population increases would have led to the primary elm decline and later 'landnam' clearances before the exhaustion of the soil forced a break up of the high density populations into smaller, nomadic groups. Although there is a lack of trend of elm decline ^{14}C dates from a central point, Sims believes that the Suess correction provides sufficient flexibility of dating for the theory to hold. If an anthropogenic explanation of the elm decline is accepted then there must have been large movements of people and/or cultural ideas at that time. Godwin (1975) refers to the problem of understanding how small human populations can produce such great changes and Pilcher (1969) quotes archaeological evidence from the Irish Neolithic at Newferry and Ballynagilly contempary with the first forest clearances which suggest a large influx of people. There is, therefore, a possibility that these migrations were associated with climatic change.

Contrary to this view, Pennington (1964) in her study of six upland tarns in the Lake District found no evidence of climatic change at the level of the elm decline which is very pronounced on some of her sites. She suggests that an anthropogenic interpretation is sufficient with edaphic changes following clearance sufficient to prevent the elm recovery noted elsewhere in the region. She recognizes that this explanation requires a large influx of people but draws on archaeological evidence (which will be refered to later) to suggest that this was the case.

1.2 The Disease Theory

Another possible, and in many ways attractive explanation of the elm decline at 3,000 B.C. is that it was caused by a disease which selectively attacked elm. This particular idea was first hinted at by Aletsee (1959) and Troels-Smith (1960), and developed by Watts (1961) and Smith (1961). Watts, in a discussion of post Atlantic pollen zones from the central plain of Ireland, suggests that the enormous forest destruction indicated by a drop in the elm pollen frequency from 20% to 1% cannot convincingly be attributed to human interference in the form of fodder gathering. If, however, the elm had been destroyed by disease, small numbers of farmers could have moved into the area bringing pasture weeds with them and then have retreated to the coastal or upland areas when the elms recovered. Smith also suggests that the possibility of disease should not be ruled out. He points out that the synchronous drop in other tree taxa at the same horizon could be the result of non-specific diseases such as 'die-back', a virus disease which affected three tree species in the forests of Eastern Canada. The recovery of elm after the decline on many diagrams, particularly those from Ireland, he suggests could be the result of both the recovery of injured trees and the spread of resistant types. He also stresses the importance of other factors in the spread of the disease such as the movement of animals, particularly insects which may be the vectors, as beetles of *Scolytus* sp. are of Dutch Elm Disease (*Ceratocystis ulmi*) and the elm leaf hopper (eg. *Scaphoidens luteolus*)is of the virus causing phloem necrosis. The increase and spread of such insects could be the result of a succession of climatically favourable years, the presence of large amounts of dead wood due to felling, fire or storms, or a combination of these factors.

The very fact of the movement of people with their domestic animals and cultural objects would provide a route for tree diseases from an area where resistance had been developed to one where it had not. It is this last factor which is largely responsible for the devestating tree epidemics of this century, most particularly the virulent strain of Ceratocystis ulmi whose arrival in this country can be traced to the international shipment of barked elm logs (Gibbs 1974, 1978b). The concept of man moving "...faster than nature" and being a transporter of plant pathogens is mentioned in "A Textbook of Pollen Analysis" (Faegri and Iversen 1975, p148), and it seems reasonable to assume that this factor which is so important now was equally important during the first rapid migrations of people.

The suggestion that disease could have played a role in the elm decline has been rejected by Heybroek (1963). He suggests that Ceratocystis ulmi is a disease of this century since there have been no previous records of it and even very old elm trees have no resistance to it. The elm disease Phloem Necrosis which has produced a serious epidemic in Ulmus americana in Kentucky U.S. only affects U. laevis among European elms and the vector is absent, so this is also ruled out by Heybroek who can think of no other likely diseases. He does suggest, however, that several diseases and parasites such as slimeflux, may assist in shortening the life of a lopped tree. Sims accepts the argument of Heybroek to rule out the possibility of disease as a factor in the elm decline but there is now evidence to suggest that Dutch elm disease, in particular, is older than Heybroek calculated, and that elms do have resistance.

In his discussion of the history and ecology of Hayley Wood, Cambridgeshire, Oliver Rackham (1975) has used evidence from tree ring streaking of fourteen felled elms to show that all of them have been infected at least three times by C. ulmi, five had been infected ten or more times, and one sixteen times. This infers that woodland elms do possess resistance and that the disease, although often followed by a damage cycle of narrow rings, is rarely fatal. The earliest record of the disease in these fourteen trees is 1926 but even the oldest tree of the group was only sixteen years old at that time. Rackham suggests that if older trees had been felled the disease would have been found earlier and he quotes a case from Buff Wood where tree ring streaking goes back to 1876. This is in sharp disagreement with the 'officially' held view of the arrival of C. ulmi in this country in about 1927 (Gibbs 1974, 1978a and b).

Gibbs (1978a) has shown that woodland elms, particularly U. glabra which is thought to have been the predominant Ulmus species in the post glacial forests, do have a quantitatively evidenced degree of resistance to the current elm disease epidemic. The factors which make C. ulmi less lethal in woods than outside them may be ecological or dependant upon the strain of C. ulmi involved. Nevertheless, these observations appear to show this particular infection to be a "......chronic and long-standing parasite of woodland elms, invading trees extensively but doing relatively little damage," (Rackham). Such an endemic condition would almost certainly have been overlooked by the early writers which Heybroek consulted for his historical evidence of the disease.

Another factor in favour of accepting disease as a possible factor in the elm decline is the great difference in virulence of different strains of the same disease as shown by C. ulmi. Trees which had shown resistance to the 1920s epidemic succumbed to a later epidemic brought about by a more virulent strain of the same disease. This means that increases in the movement of people could be a major factor in the destruction of trees by well established diseases. It would appear, then, that the possibility of disease as a factor in the elm decline cannot be ruled out, but is extremly difficult to verify, a conclusion reached by Hove (1968). According to Pennington (1974) the disease hypothesis only becomes less tenable as evidence connecting the elm decline with Neolithic farming and changes in other species accumulates.

1.3 Aims of Study

The principal aim of the present study is to determine whether or not the disease theory, as an explanation of the elm decline, is supported with evidence from the pollen rain of the period. My observations in South West England following the recent destruction of the English elm (Ulmus procera) population by C. ulmi leads me to believe that this would be possible if Hedera pollen is used as an indicator of standing dead trees. Mature trees, once killed by the disease, may remain standing for as long as twenty years giving any ivy which may be growing on them an opportunity to expand and flower more profusely. This results from the removal of the elm leaves and hence their competition for light with the leaves of ivy. I have observed this to be a very common feature of dead elms in hedgerows (see Plate 1.1) but also of dead woodland elms in Somerset and Dorset, on the few occasions I have observed them, (see Plates 1.2, 1.3, 1.4). A smaller proportion of these trees, however, have a luxuriant ivy covering.

My observations also revealed that many living trees have a heavy covering of ivy (which may inhibit the development of the host tree), and that many dead trees do not have ivy growing on them. Nevertheless, it is assumed here that there would be an overall increase in ivy biomass and flowering if a large number of standing dead trees were to appear in the forest. This increase should be detectable by a small increase of ivy in the pollen rain. The theory gains support

PLATE 1.1 A very characteristic sight in the hedgerows of South West England. Ivy growing abundantly on large, dead elms. Somerset, January 1980.

PLATE 1.2 A copse of dead elms on the Polden Hills, Somerset 1980. Ivy is growing abundantly on these young trees which have been standing dead for approximately eight years.

PLATE 1.1

PLATE 1.2

PLATES 1.3 & 1.4 Dead elm trees on the Purbeck Coast, Dorset, April 1980. These trees are in the army artillary range and form a large unfelled stand. Ivy is well established in many areas of it.

PLATE 1.3

PLATE 1.4

from the observation of Walker (1966) that *Hedera helix* flowers freely when not shaded (as would be the case when it was able to reach up from the forest floor and out of the canopy on dead trunks) and the unpublished work of Sims quoted by Godwin (1975) where ivy increases were recorded during Mesolithic clearances as a result, it is argued, of forest disturbance.

It is important to note that an increase in the ivy can only be used as an index of standing dead trees. The death of the trees could have resulted from either disease or ringbarking as suggested by Mitchell and Iversen (ibid). Ringbarking, however, would probably also destroy the ivy stems and, since it would only be a useful clearance technique if the elms were growing in pure stands, ringbarking would always be accompanied by an increase in grass and other 'pasture' pollen. It should therefore be possible to distinguish between ringbarked and diseased standing dead trees from the pollen rain.

Initial studies of published diagrams show sharply varying behaviour of ivy at the elm decline. Iversen (1941) in his pollen diagrams from Denmark shows a drop in the ivy curve at the elm decline from which it seldom recovers. This is interpreted as a climatically induced change. In a diagram from Schaffhausen, Switzerland, Troels-Smith (1960) shows a distinct drop in ivy pollen across the elm decline followed by a recovery. This drop coincides with considerable evidence from excavations for the use of ivy as a fodder plant by the Michelberger culture of this region. Walker, using data from five sites in the Cumberland lowland, also found a significant drop in the number of ivy grains at the level of the elm decline. He makes a "superficial" suggestion that ivy was rarer during felling clearing and maintenance than subsequent regeneration.

Other diagrams do show slight increases in ivy pollen at the elm decline such as those from Hockam and Seamere, East Anglia (Sims, 1973) and Helton Tarn, Southern Lake District (Smith 1958). In his study of man's role in the ecological history of the S.E. Lake District Oldfield (1963) found two phases in the elm decline, a primary elm decline in which the ivy remains steady, and a secondary elm decline in which the ivy pollen dropped. The detailed diagram from Thrang Moss shows an increase in ivy pollen through the elm decline before it drops.

1.4 Choice of Site

If the frequency of Hedera pollen is to be used as an indicator of an episode which may have spanned at most twenty years, and very probably less, it is clear that much closer sampling of the peat would be necessary than has been used hitherto, the closest sampling in the diagrams just mentioned being the 2cm. intervals used by Troels-Smith, Oldfield (at Thrang Moss) and Walker. Close sampling would also provide the opportunity for small, but possibly very significant fluctuations in the pollen representation of other taxa to appear on the diagrams.

For very close sampling to have the possibility of representing real vegetational changes lake deposits would be unsuitable due to the resuspension and mixing of pollen which takes place in the surface layers before sedimentation (Moore & Webb 1978). The following criteria were therefore used to enable the most suitable site to be selected for the study:

1. A raised bog site.

2. A good representation of tree taxa to provide maximum possible evidence of associated forest changes.

3. A distinctive drop in the elm curve at the elm decline.

4. The presence of a continuous ivy curve at that horizon.

5. A site where carbon dates had been taken. This would enable an estimation of the rate of deposition to be made and hence a timetable of events to be constructed.

The choice of site was therefore limited to those which already have been investigated and have diagrams in the literature. On almost all these five points the South East Lake District appeared to be the most suitable. The area has been well studied (Smith 1959, Oldfield 1960a+b, 1963, Oldfield & Statham 1963, Pennington 1970) and the diagrams show, in general, a good representation of ivy and a distinct elm decline which Oldfield divides into primary and secondary by the appearance of'cultural' pollen at a time after the initial fall in the elm frequencies.

The two most suitable raised bog sites were at Ellerside Moss and Thrang Moss. The former site was chosen because of its easier access. Unfortunately, ^{14}C dates were not available for the site but by matching radiocarbon dates from other sites in N.W.England with characteristic features on the published diagram of Ellerside Moss (Oldfield & Statham) an approximate timescale has been established (see section 4.8.)

CHAPTER 2

THE SITE

2.1. Location and Geological and Geomorphological Background

Ellerside Moss (National Grid Ref. SD 33504800) is situated in the Lonsdale drainage basin of the Southern Lake District, directly to the west of the Greenodd estuary. It forms part of the Holker mosses, a large raised bog system which runs down the eastern side of the peninsula formed between the Greenodd and Kent estuaries. These drain into Morecambe Bay (see Figs. 2.1, 2.2, 2.3).

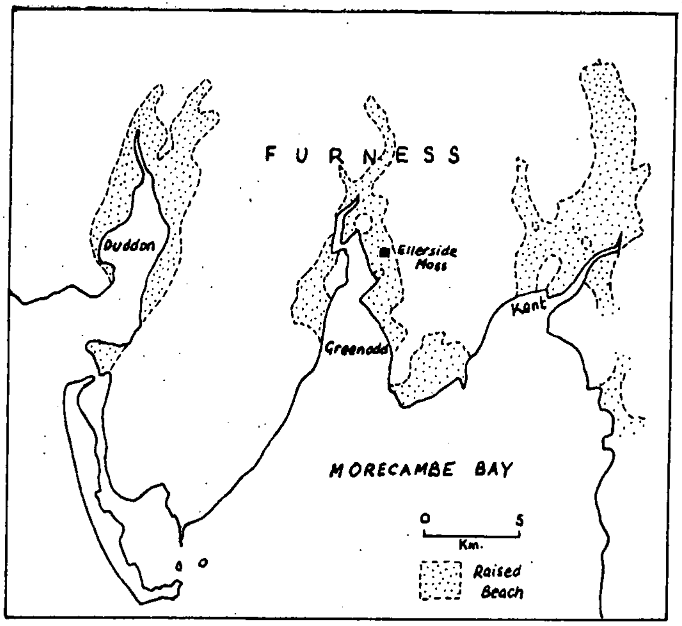


FIG. 2.1

The raised beaches of Furness (after Gresswell 1958).

Munn Rankin (1910, 1911) made the first important study of the 'Peat Moors of Lonsdale'. He describes them as lying between three ancient uplifts and Morcambe Bay. To the north is the Cumbrian ridge ('A' on Fig 2.2) built up from the various rocks of the silurian and ordovician, to the east the limestone Pennine ridge ('B' on Fig. 2.2) and to the south the Bowland anticline ('C' on Fig. 2.2) of upper carboniferous grits and shales. The rock structure of the lowland region reflects this diversity in its surroundings

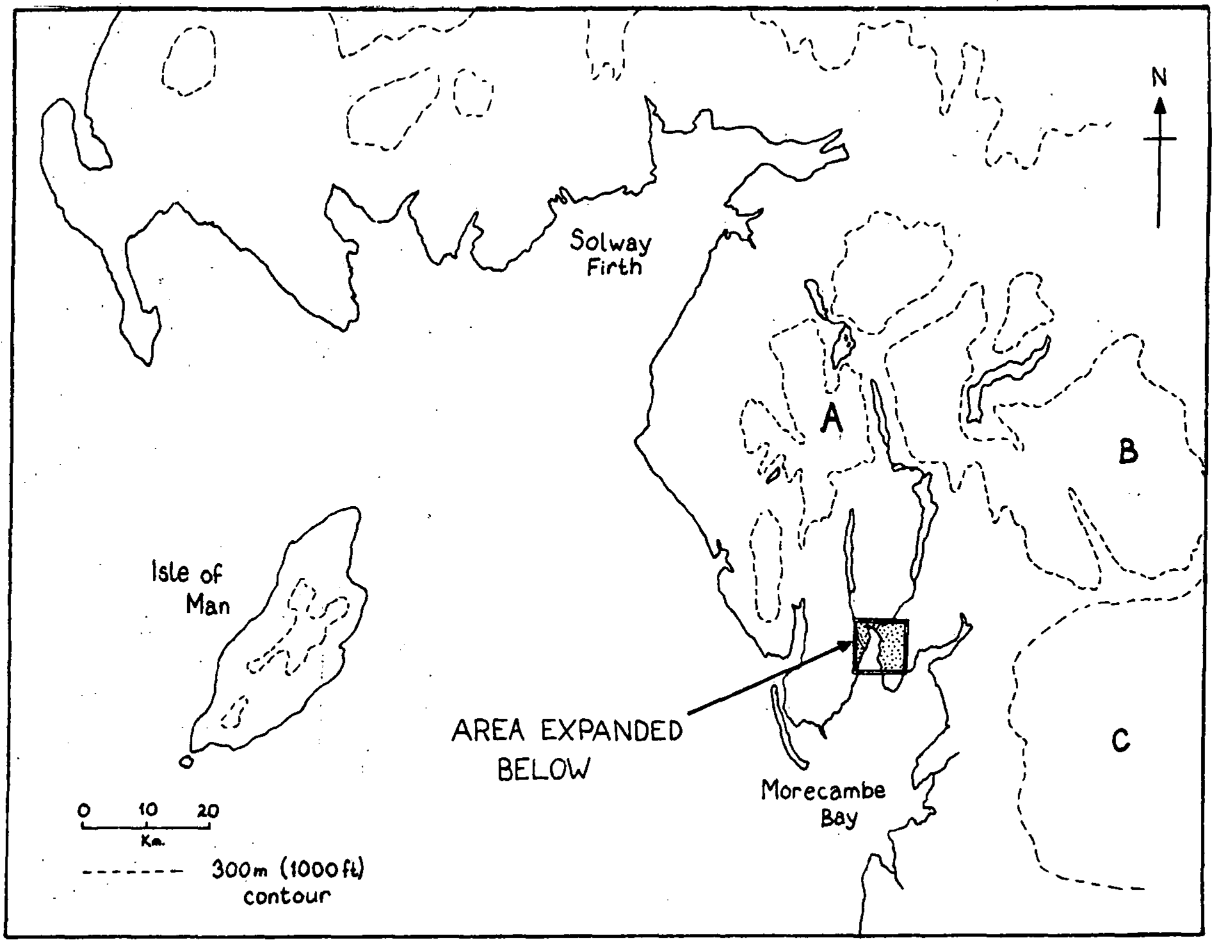


FIG. 2.2 General locational Map (see text for expl. of A,B,C).

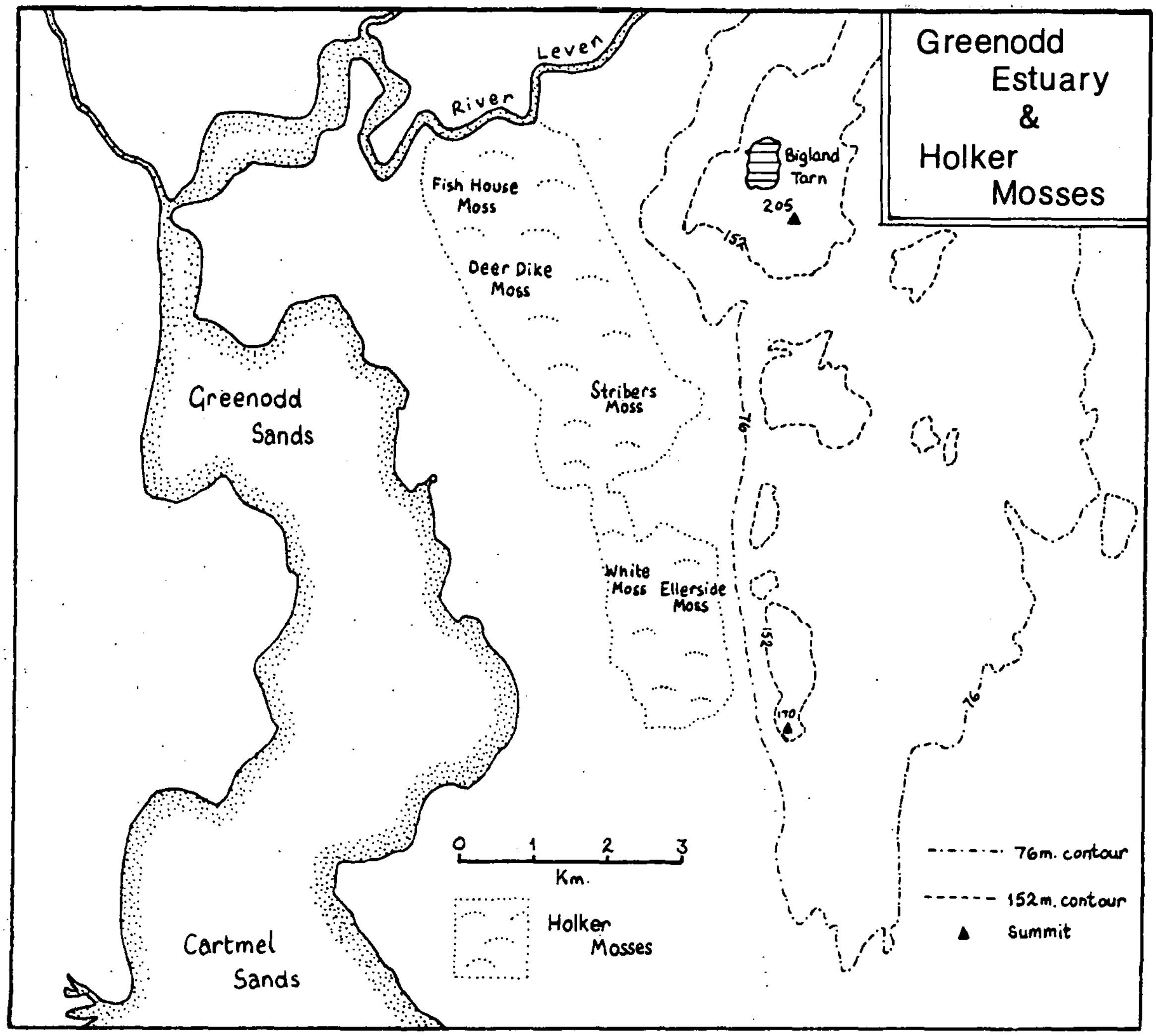


FIG. 2.3 (Source: O.S. Sheet 97)

and is extensively glaciated. Gresswell (1958) examined the nature of this glaciation and the marine transgression which followed it. He has identified a series of raised beaches (Fig. 2.1) formed by unconsolidated deposits laid down as a result of marine action on the open coast or in estuaries. Godwin and Willis (1961) have dated the end of this marine transgression to about 3,800 B.C. and from that time to the present peat deposits, initially of reedswamp and later of ombrotrophic raised bog, have formed resting on the tidal clay to a depth of about 5 metres. The surface of the Holker Mosses now lies at about the 8 metre contour. One of the largest of these mosses is Ellerside Moss.

2.2 Present Day Vegetation and Climate

There has been very little peat cutting on Ellerside Moss but drainage ditches have been dug at the edges and land reclaimed for farming at the southern extremity. Along the slightly raised eastern edge of the bog the drier conditions have resulted in the development of a mixed woodland of alder, pine and birch, but when visited in May 1980 the flora of the bog surface had been almost totally destroyed by fire (see Plate 2.1). It appeared to have been Calluna dominated with some wet pools of Sphagnum and Eriophorum. To the east a steep 'barrow' covered in poor acidic pasture rises from the edge of the bog. The southern part of the barrow has been planted with, largely, deciduous trees which show at the right of Plate 2.1.

The area is well sheltered by its basin location and has an unusually mild winter for the region with a relatively low rainfall (100cm/yr.), fairly evenly distributed. Its present day climatic conditions appear to be ideal for the flowering of Hedera (see Plates 2.2 and 2.3) and the area's geographical location would always have ensured it a milder climate than the higher land surrounding it.

PLATE 2.1 A general view of the burnt out, raised bog surface at Ellerside Moss, 9th May 1980. The 'barrow' to the right shows its sparce tree coverage and the mixed plantation on the extreme right. The _Pinus_, _Alnus_ and _Betula_ woodland on the drier areas of the moss can be seen along the lower horizon.

PLATE 2.1

PLATES 2.2 & 2.3 Ivy flowering profusely in the present day climate of Lowland Lonsdale.

PLATE 2.2

PLATE 2.3

CHAPTER 3

METHODS

3.1 Collecting the Core

To take the peat cores the track across the Moss to High Frith was taken and then a point chosen which appeared to be the crown of the bog, about 150 metres south of the centre of the track. A Russian borer was used to obtain four cores of peat, all lying between 200cm. to 500cm. depth, in order to cover the period surrounding the elm decline. Two bore holes were used for each core to avoid contamination by the head of the borer. The estuarine clays were encountered at approximately 450cm. (see Plate 3.1). The cores were then transported back to the laboratory in plastic liners and polythene bags.

3.2 Freezing and Sectioning

In the laboratory the cores and their liners were put into thick polytene bags, to prevent adhesion of the polythene to the peat, and placed in the bottom of a 'deep freezer' at a temperature of approximately -20°C. After at least 24 hours freezing, one of the cores was transferred to a 1°C room where samples were removed with a section cutting blade at 20cm. intervals. These were treated and counted in the manner described in section 3.3. Further samples were taken at closer intervals until a 'skeleton' diagram had been produced and the position of the elm decline could be judged with some confidence. It was found to be about 300cm. below the peat surface.

The close sampling was then carried out on another core selected

PLATE 3.1 The Russian borer and the core from the base of the peat. The Phragmites peat from 425cm. has changed to the marine clays of the raised beach at about 470cm.

PLATE 3.1

to ensure that the 300cm. point was in the middle of the 50cm. length. It was transferred to the 1°C room and, starting at 270cm., 5cm. lengths were cut off by means of a sharp blow from the sectioning blade. Each length was trimmed with cuts horizontal to the axis of the core to avoid movement of material from one level to the next. The trimmed core, with a diameter of about 2.5cm. was then cut into two lengths of approximately 2.4cm. and 2.6cm. and these, in turn, were transferred to a sledge microtome (Fig. 3.1). Throughout the period of cutting and trimming chalk marks were used to label the orientation of the small lengths of core.

The rachet mechanism of the microtome had been marked in 0.2cm. intervals so that after levelling the surface of the peat sample with the top of the microtome 0.2cm could be pushed up above the surface by screwing the piston up through one interval. This length of peat was then sliced off in the usual manner with the section cutting blade resting firmly on the surface of the microtome. The removed 0.2cm. slice of the peat section was transferred to a numbered bottle, the blade and microtome surface were wiped free of peat and the process repeated. The last 0.5 to 0.6cm. of each 2.4cm. section of core had to be sliced by inserting one and then two five pence pieces under it since the microtome piston did not extend over these last few millimetres. Provided that the core stayed frozen it cut very cleanly, but difficulties were experienced when a similar procedure was attempted in a 5°C room due to the rapid softening of the peat. The samples did vary slightly in thickness between about 0.18cm. and 0.22cm. and this has been allowed for in the construction of the diagrams.

3.3 Slide Preparation and Counting

A total of 227 samples were taken in this manner so that the entire core between 270cm. and 315.2cm. in depth had been sectioned into

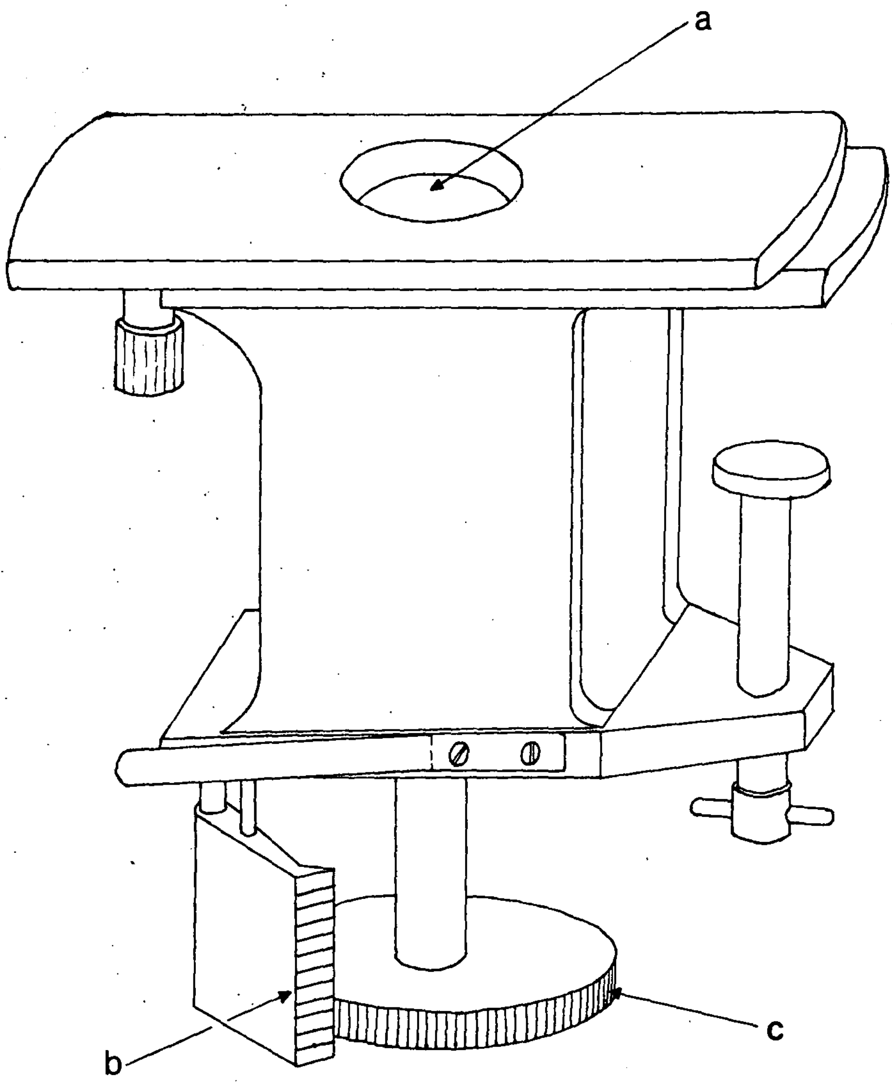


FIG. 3.1 Sledge Microtome drawn actual size.

a. Sample chamber.

b. 0.2cm. interval markings on ratchet mechanism.

c. Piston screw.

samples of approximately 0.2cm. width. The samples were then treated in the laboratory by digestion in sodium hydroxide and acetolysis, and mounted in glycerol jelly stained with safranin, (Faegri & Iversen p.109). The slides were counted with a Watson microsystem 70 binocular microscope using a magnification of x100 for scanning and x400 for identification. Oil immersion was used for the examination of critical grains.

Initially it had been intended to count all the levels to 500 arboreal pollen grains (excluding <u>Corylus</u>) in order to bring out the <u>Hedera</u> curve with a greater degree of confidence. To prevent unnecessary counting at non-critical levels, however, it was decided to count all levels to 250 A.P. before counting the critical levels up to 500 A.P. In the event so many levels were counted that it became both impractical and unnecessary to increase the count at any particular level since close sampling was bringing out sufficient detail in the more scarce taxa of non-arboreal pollen (or so it appeared). This method of obtaining good resolution on a pollen diagram by counting many levels rather than a very high number of pollen grains is supported by Walker (1966).

In the final diagram, therefore, a conventional tree pollen sum of between 250 and 290 A.P. was used which corresponds to a total pollen sum of between 550 and 700. Between 300.2cm. and 310cm. consecutive samples were counted, and from 294.4cm. to 300.2cm., and from 310cm. to 315cm. every second sample was counted (where possible) giving a sample interval of approximately 0.4cm. With an estimated peat growth rate of 1cm. in 8 years (see section 4.8) each sample represented a period of between 1 and 2 years. This will enable the counting of consecutive samples to reveal changes in the pollen rain between seasons, assuming a minimal downward movement of pollen before sedimentation. This degree of resolution should be ample for the identification of the 10 to 20 year period of increased ivy representation which standing dead trees may have produced.

Samples at 270cm. and 284.6cm. were also counted before the elm decline was firmly located at 310cm.

CHAPTER 4

RESULTS

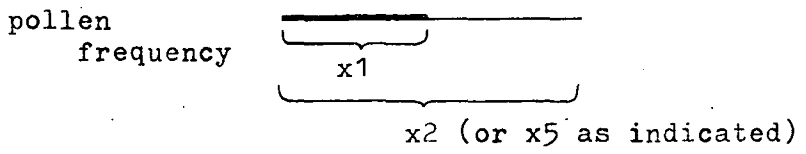
4.1 Stratigraphy

Examination of the core from 294cm. to 315cm. showed it to consist of very well humified *Eriophorum* peat with some macro-remains of *Calluna* at about 300cm. and from 310cm. down. No other macrofossils were found and no changes in stratigraphy suggestive of climatic change were noted.

4.2 The Diagrams

The pollen count for 81 levels between 294.4cm. and 315cm., expressed as a percentage of the conventional tree pollen sum, is presented in figures 4.1 and 4.2.

Figure 4.1 shows tree, shrub and selected herb pollen frequencies. Coryloid frequencies are drawn to half scale and taxa represented by relatively low pollen counts are drawn x5 (*Hedera*, *Ilex* and *Plantago*) or x2 (Gramineae, *Pteridium*). In both cases the true percentage frequency is shown as a thick line and the magnified percentage as a thin line as shown below:



The remaining herb frequencies are presented in figure 4.2 with the poorly represented taxa drawn x2, (but with no difference in line thickness.)

Figure 4.3 shows the ratio of dry land trees, shrubs and herbs to the total of this group. It is an attempt similar to that of

FIGURE 4.1 Ellerside Moss Pollen Diagram.

Tree, Shrub and Selected Herb Pollen Frequencies.

ELLERSIDE MOSS – THE ELM DECLINE (1980)

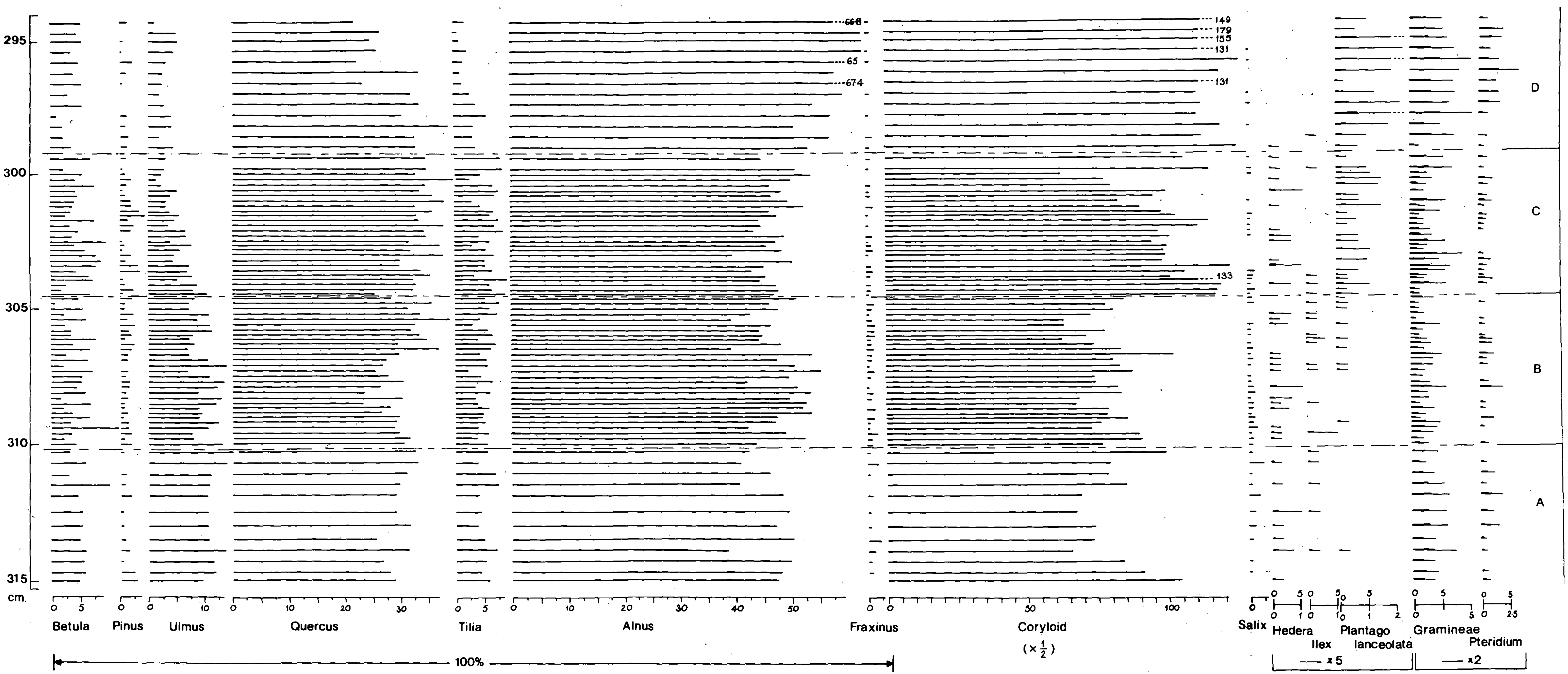


FIGURE 4.2 Ellerside Moss Pollen Diagram.
Remaining Pollen Frequencies.

ELLERSIDE MOSS – THE ELM DECLINE (1980)

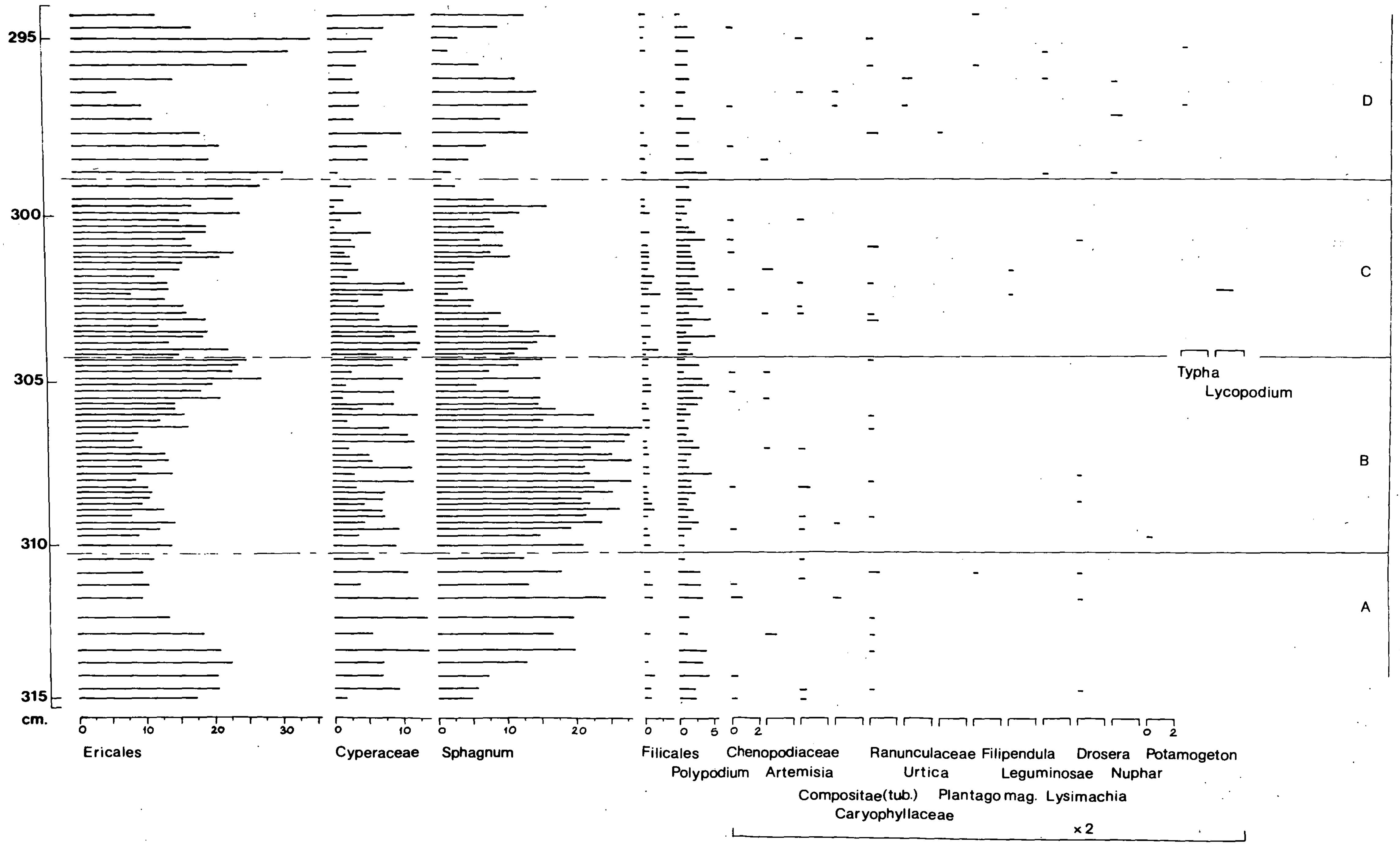
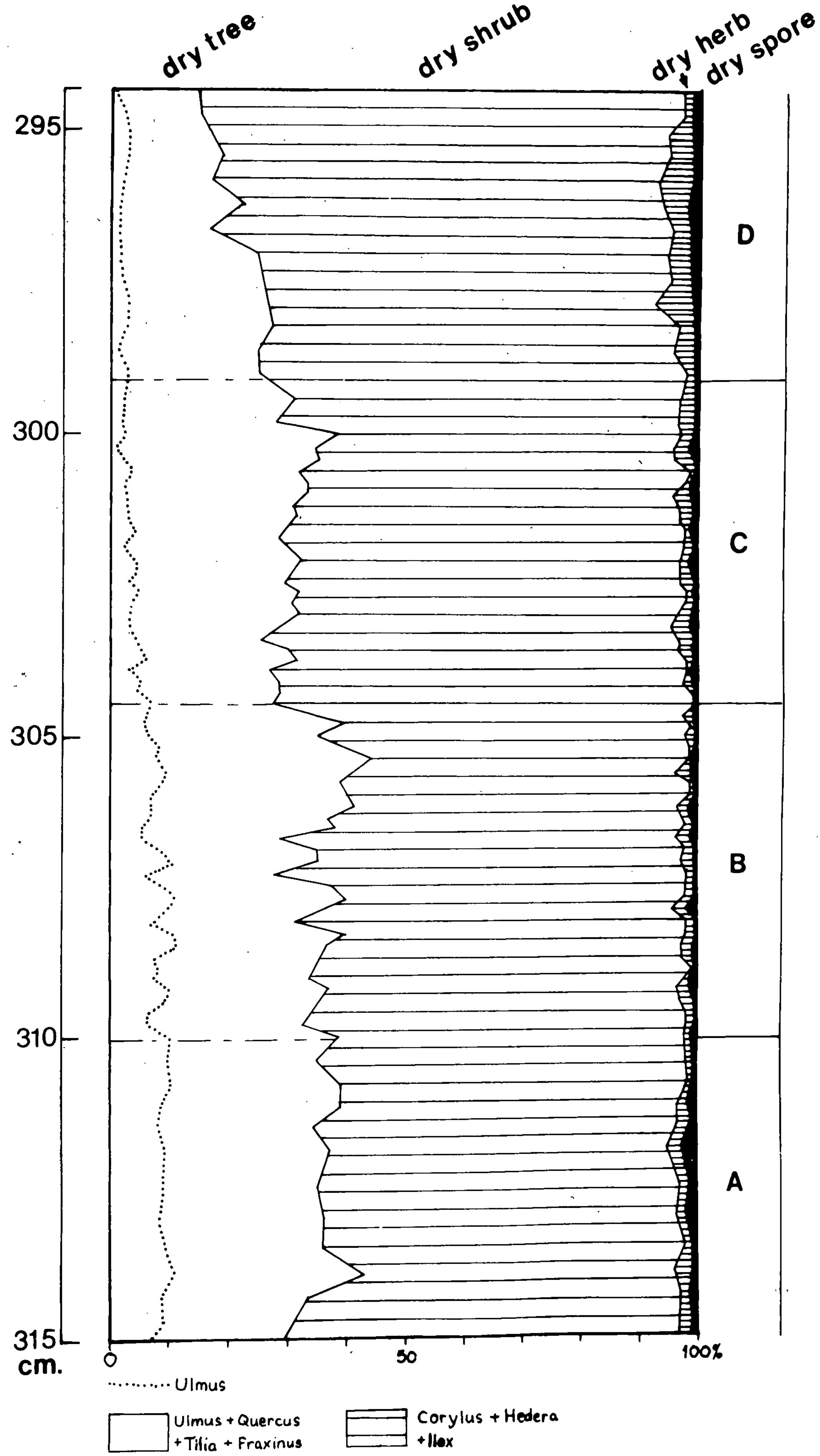


FIGURE 4.3 Tree/Shrub/Herb/Spore ratio.

(For full explanation see text.)


dry tree
dry shrub
dry herb
dry spore
295
300
305
310
315
cm.
0
50
100%
D
C
B
A
Ulmus
Ulmus + Quercus + Tilia + Fraxinus
Corylus + Hedera + Ilex

Oldfield and Statham to eliminate the effect of the local contribution to the pollen rain from communities on the poorly drained mire margins, and so reveal the changes in the forests and the effects of man more clearly. To this end Birch and Alder have been excluded from the tree pollen sum as has Pine since its consistantly low representation is considered to be the result of long distance pollen transport. *Salix* has been excluded from the shrub count, and *Polypodium* from the spore count since this is most likely to have been an epiphyte of the alder carr growing around the mire margins. *Pteridium* has been included in the spore count since, as explained by Oldfield and Statham, its spread is a good indicator of forest clearance. The taxa included in the four catagories are therefore as follows:

'DRY TREE' - *Ulmus*, *Quercus*, *Tilia*, *Fraxinus*.

'DRY SHRUB' - *Corylus* (Coryloid), *Hedera*, *Ilex*.

'DRY HERB' - Gramineae, Compositae, Ranunculacae, Chenopodiacae, Carophyllacae, Leguminosae, *Plantago*, *Urtica*, *Filipendula* (this species was included as one which is both a fen and a meadow plant).

'DRY SPORE' - *Pteridium*, undifferentiated Filicales.

4.3 Zonation

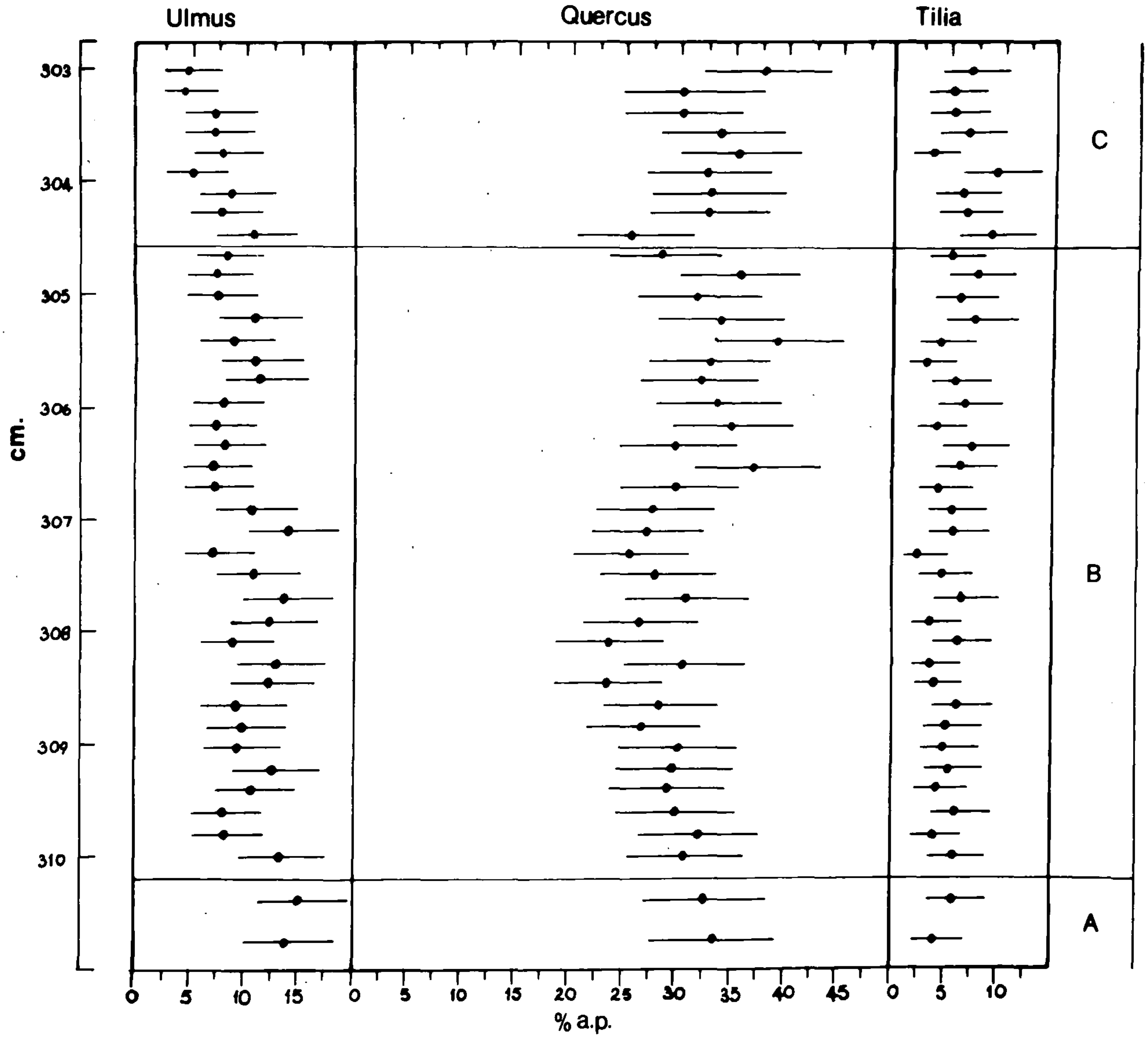
As an aid to the discussion of the events taking place during the time period represented it was decided to divide the diagram into 'episodes' representing distinctive differences in the constituents of the pollen rain. Computer zonation as described by Gordon and Birks (1972) using CONSLINK, SPLITINF and SPLITLSQ constrained cluster analyses was applied to the pollen data of the principal taxa (the seven tree taxa, Coryloid, *Plantago* and Gramineae pollen frequencies). The lack of agreement between the three methods, however, suggests that statistical differences between levels are obscuring the minor changes that are taking place in the pollen rain over the relatively short time represented.

Four episodes, labelled A,B,C and D have been identified by a visual analysis of the diagrams, and with reference to the 95% confidence limits calculated by assuming a multinomial distribution in the manner described by Mosimann (1965) and reported by Moore and Webb (1978). Although produced independently of the computer generated zonations there is, nevertheless, a high degree of agreement between the numerically and the subjectively selected episode boundaries.

The boundary between A and B is drawn at what is considered to be the start of the elm decline and this was not indicated by any of the constrained cluster analyses. The boundary between B and C was selected as the first division in the data by both SPLITINF and SPLITLSQ and the boundary between C and D is only one level above the first split in the data recognized by CONSLINK. The distinctive features of each episode are described below.

Episode A - This episode is characterised by Ulmus pollen frequencies which remain very steady at about 10% before increasing up to 15% at the end of the episode. The Tilia curve remains fairly steady and the Quercus curve increases slowly from a low of 25% up to 32% at the close of the episode. The Coryloid frequencies drop sharply at the beginning of the episode and then partially recover. Gramineae and Salix percentages are relatively high, Ilex and Hedera curves are steady and Plantago pollen is almost absent. The reduction of 'Ericales' frequencies is complemented by an increase in Sphagnum frequencies which suggest a replacement of Calluna by Sphagnum. Since the former species requires a drier bog surface than most Sphagnum species this could be taken as an

FIGURE 4.4 Episode B: 95% confidence limits of Principal Tree Taxa.


Ulmus
Quercus
Tilia
cm.
303
304
305
306
307
308
309
310
C
B
A
0
5
10
15
0
5
10
15
20
25
30
35
40
45
0
5
10
% a.p.

indication of increasing wettness through the episode. It could also be explained, however, by small scale local changes on the mire surface at the point at which the peat core was taken. (It is assumed that the Alnus is ecologically independent of the other tree taxa and changes in its curve result largely from it 'taking up the slack' from the pollen representation of the remaining trees in the pollen sum.)

Episode B (310-304.6cm.) Figures 4.1 and 4.3 show the most significant characteristic of episode B as one of short term fluctuations in the tree pollen, particularly that of elm, culminating in the permanent drop in elm frequency and the recovery of oak. Figure 4.4 gives an indication of the degree of confidence with which the dip in the Quercus curve between 310.8cm and 307.7cm. can be taken as a real change in the constituents of the pollen rain. 2x2 contingency tables give values of χ^2 which show the drop in oak pollen from 310.8cm. to 308.5cm. to be significant ($p=<0.05$) and the subsequent rise to a high at 306.5cm. to be very significant ($p=<0.001$). Elm pollen proportions fluctuate steeply with proportions as high as 14% dropping in the next level to proportions as low as 7%. These fluctuations are also significant ($p=<0.05$).

The Tilia curve does not show a statistically verifiable drop during episode B but there is a hint of decrease in pollen production in the first half of the episode compared to episodes A and C. During the first half of episode B (310-307.3cm.) the average proportion of Tilia pollen is 4.7%, compared to 5.4% in episode A, 5.7% in the second half of episode B and 6.3% in episode C. Had the pollen contribution of Tilia remained constant the drops in both Ulmus and Quercus during the period would be expected to produce an apparent increase in Tilia.

During this episode Hedera and Ilex remain constant, the Gramineae curve drops slightly and Plantago lanceolata pollen begins to make more frequent appearances towards the end. Sphagnum frequencies remain high throughout most of the episode but drop towards the end with a corresponding increase in 'Ericales' frequencies.

Episode C (304.4-299.4cm.) The single most important feature of this episode is the large increase in the Coryloid frequencies from about 80% to 120% of the A.P. at the start of the episode with frequencies of about 100% being maintained for most of the rest of it. It is almost certainly this feature which is picked out by the SPLITINF and SPLITLSQ constrained cluster analyses. This Coryloid increase shows clearly on figure 4.3 as a suppression of the tree ratio but since there is no corresponding increase in Alnus frequencies it is unlikely that this is an indicator of forest clearance (unless the Alnus carr also contributed to the clearance). Ericales and Sphagnum frequencies do not change dramatically at this horizon but continue to fluctuate in complementary curves. Cyperaceae are at their highest. This does not suggest that Myrica gale had invaded the mire surface at this time and it is therefore assumed that the Coryloid curve represents an increase in Corylus only. The fact that the bog species present are those of an ombrotrophic mire, and M. gale tends to be a plant of transitional mires supports this view.

Could

Other important features of this episode are the continued decline of elm to its lowest recorded frequency of 1.2% after which it increases slightly, and an increase in the frequencies of Quercus and Tilia which is maintained throughout the episode. Plantago lanceolata pollen now forms a regular part of the pollen diagram with an increase in Gramineae pollen to pre elm decline levels. The Hedera curve remains steady and the Ilex curve almost disappears. The drop in Sphagnum and increase in Ericales pollen during episode

C may suggest a drier period than that during episode B.

Episode D (299cm. - top) This episode is equivalent to the 'secondary elm decline' of Oldfield (1963) and is characterised by a severe drop in Tilia pollen, a decline in Quercus pollen to almost half its level during episode C and the fluctuation of Ulmus around an average of about 2% of the A.P. Both Alnus and Coryloid frequencies increase dramatically towards the top of the diagram but, again, it is assumed that the Alnus increase is largely a statistical feature resulting from this taxon 'taking up the slack' in the pollen sum as the contribution from other taxa decreases. Also of considerable significance during this episode is the increase of Plantago lanceolata to up to 4% of the A.P., the increase in Gramineae and Pteridium representation, the appearance of such cultural indicators as Urtica and Plantago major pollen and the abrupt disappearance of the Hedera curve.

4.4 The Hedera Curve

The original aim of this study is the use of the Hedera curve as an indicator of standing dead trees in the forest. To ensure that slight changes are not overlooked, therefore, statistical tests have been applied to the pollen data from the diagram.

The occurance of Hedera pollen at any particular level conforms well to a Poisson distribution with a χ^2 value of 4.0 (d.f.=3) suggesting that there is no significant deviation. Using a 4x2 contingency table of Hedera pollen and the remainder of the Total Pollen Sum in the four episodes it is shown that the distribution of ivy pollen does not conform to a Null Hypothesis of random distribution, the probability of this being greater than 95%. Table 4.1 shows that the greatest deviation from expected frequencies comes from the appearance of only one Hedera pollen grain in episode D.

Table 4.1 2x4 contingency table of Hedera pollen occurances in episodes A,B,C and D.

EPISODE	HEDERA	OTHER POLLEN	TOTAL
D	1 (9.4)*	9582 (9573.6)	9583
C	18(16.4)	16830(16831.5)	16848
B	20(16.8)	17180(17183.2)	17200
A	10(6.4)	6539 (6542.6)	6549
	49	50131	50180

*Numbers in brackets are expected nos. of pollen grains.

$\Sigma\chi^2 = 8.7$ d.f. = 3 $p = <0.05$

Table 4.2 2x3 contingency table of Hedera pollen occurances in episodes A,B and C.

EPISODE	HEDERA	OTHER POLLEN	TOTAL
C	18(19.9)	16830(16828.1)	16848
B	20(20.3)	17180(17179.7)	17200
A	10(7.7)	6539 (6541.3)	6549
	48	40549	40597

$\Sigma\chi^2 = 0.52$ d.f. = 2 $p = >0.1$

Table 4.2 shows that if episode D is excluded from the table there is no significant deviation from a random dispersal of pollen between the remaining three episodes.

The statistical tests therefore confirm a visual interpretation of the diagram that Hedera pollen occurs randomly throughout episodes A,B and C and then dissappears abruptly in episode D.
It is important to note that the amount of Hedera pollen encountered, a total of 49 grains, may be insufficient to reflect increases in the pollen production of ivy of much less than 30%.

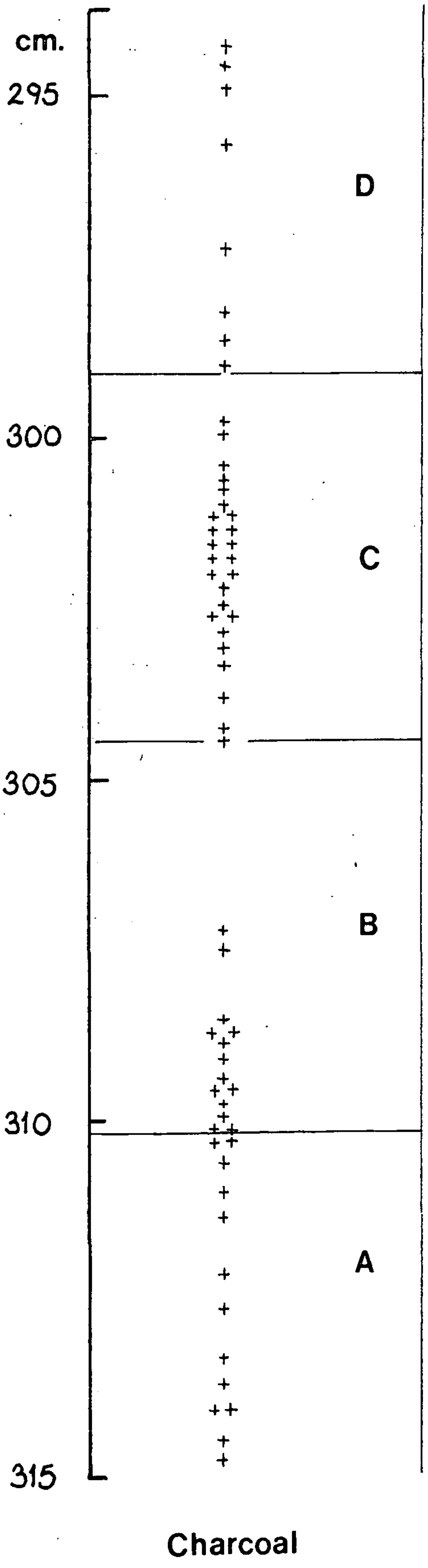


FIG. 4.5

Occurances of Fly Blown Charcoal

4.5 Occurances of Fly Blown Charcoal

Slides from all 81 levels were examined for fly blown charcoal. If specks of charcoal appeared in 2 out of 4 vertical traverses of the slide then it was registered as'present'. If the occurances were greater than this and the charcoal was then visible on the slide to the naked eye it was registered as 'frequent'. Figure 4.5 shows the distribution of fly blown charcoal which appears to be concentrated around two regions of the diagram, from 310-308.5cm., but more prominently from 301.5-303cm., some levels in this area having abundant charcoal specks present on the slide.

4.6 Fungal Spores

It had been intended to count fungal spores on the slides but difficulties with identification and the probability of large numbers originating from the bog surface flora made this both impractical and of doubtful value. One particular spore, however, which was sufficiently large to be mistaken for a pollen grain initially, was found in frequencies of up to 20% of the A.P. from 302cm. upwards, being particularly frequent at 297cm. Figure 4.6 is a diagram of the spore. It has been identified provisionally as a 'downy mildew' but the possibility of it being a spore of a fungal tree disease has not been ruled out, and Phytophthora has been suggested.

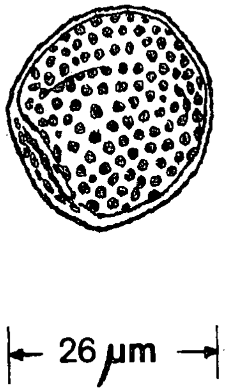


FIG. 4.6

Unidentified spore.

4.7 *Buxus sempervirens*

Despite careful checking no pollen of this species was found to consolidate the finding of a single grain of *Buxus* at the elm decline by Oldfield and Statham.

4.8 Dating the Diagram

As stated in the introduction, no radiocarbon dates are available from Ellerside Moss, but using radiocarbon dates from the nearest sites available and matching them with Oldfield and Statham's full diagram from the Moss, a very approximate growth rate for the peat has been calculated as follows:

	^{14}C DATE (B.P.)		ELLERSIDE MOSS		SOURCE
	2472∓50		60cm	Increase in *Pteridium*, *Plantago*, Grass, 'weeds'.	Dickinson (1975) Rusland Moss, S. Lake Dist. (Mean of 3 sites used).
8.4 y/cm	2528y	300cm			
	5000∓ 100		360cm	*Ulmus* decline	Godwin et al (1957), Scaleby Moss (Cumberland). Hibbert et al (1971), Red Moss (Lancs.) (approx. date used).
7.5 y/cm	865y	115cm			
	5865∓ 115		475cm	*Alnus* rise *Pinus* decline.	Godwin & Willis (1961) Silverdale Moss, S. Lake Dist.

From this data the time taken for the deposition of 1cm. of peat at Ellerside Moss has been taken as approximately 8 years (∓1 year).

The section of core under study therefore formed over 168±20 years, and each 0.2cm. sample of peat represents between 1 and 2 years of peat growth. This means that the central part of the diagram where consecutive 0.2cm. samples were counted represents the changes in the pollen rain of 1 to 2 seasons. This high degree of resolution is sufficient to pick up the changes that may have been associated with disease and the resulting short term increase in ivy growth on the standing dead trees. It will also enable the detailed analysis of other changes in the vegetation across this horizon.

CHAPTER 5

INTERPRETATION OF DIAGRAM

This detailed diagram of the elm decline at Ellerside Moss has revealed a number of hitherto unexpected changes in forest composition at this much discussed horizon, as well as confirming some long held views.

The period represented by episode A in the diagram, and characterised by a steady *Ulmus* curve above 10% is thought to be a period of dense forest cover with, at the most, only minor interferences from man with the use of fire. This view is supported by the relatively low values of Coryloid pollen throughout most of the episode which could have resulted from both the depression of the Coryloid curve by high arboreal pollen levels and from the relative scarcity of hazel shrub under a dense canopy. The *Alnus* frequencies are also lower during this episode than elsewhere in the diagram tending to confirm the view of the high contribution of the dry land trees to the pollen rain. The high Coryloid frequencies at the start of the episode could have represented the tail end of a period of fire clearance and this could explain the slight increases in both *Ulmus* and *Quercus* at the end of the episode. Specks of fly blown charcoal were found on most of the slides from this episode.

Herb frequencies do not conform as closely to the view of episode A being one of dense, virgin forest as both grass and 'weed' frequencies are higher than in episode B. This is shown most clearly in figure 4.3. *Plantago lanceolata* frequencies are very low, however, only two grains appearing in a total of twelve levels, and this tends to confirm the view of the forest at this time having a dense, closed canopy. The slightly higher herb frequencies of episode A are therefore most adequately explained as resulting from colonisation of patches of fire cleared land which, as will be argued later, may have formed an important part of the Mesolithic economy. The dip in the Quercus curve at 313.5cm is not statistically significant and there is insufficient detail for it to be confidently regarded as indicating a real change in the vegetation.

The first signs of forest interference occur in episode B with a simultaneous drop in elm and oak frequencies accompanied by an increase in alder frequencies as they assume a larger proportion of the pollen sum, this not necessarily representing an actual increase in alder. Despite the evidence for a disturbance of two of the major forest taxa the difference in their subsequent behaviour through episode B is striking. While the Ulmus curve fluctuates steeply before dropping more or less permanently to lower levels at 306.8cm., the Quercus curve dips sharply but has recovered by the time the elm is permanently depressed. It may also be significant that the fluctuations in oak and elm during the first half of episode B coincide closely, and that this episode occurs at a time when the mean Tilia pollen level is depressed as explained in section 4.3.

These short term changes, spanning a period of about 30 years and culminating in total recovery of two of the three taxa involved, can only be explained satisfactorily as being the result of the collection of leaves for fodder as described by previous workers (ibid). Given a sample time span of approximately two years the fluctuations of the Ulmus pollen frequency correspond to a timescale in the order of that suggested by Van Zeist (1959) for the recovery of elm from fodder-lopping. He suggested that after cutting seven or eight years are required before the elm will produce new flower buds. During the initial stages of fodder gathering it would appear that the semi-agriculturalists involved were not very selective in their choice of trees and all three major dry land tree taxa were exploited to some extent. This mirrors the finding by Guyan (1955) of leafy shoots of elm, birch, oak and lime on the floors of huts of the Michelsberg people at Schaffhausen, Switzerland. If it is assumed that small parties of men gathered leaves from a wide area this could explain the apparent fluctuations during this early phase as areas of the forest were left untouched for several years before being lopped again. The haphazard nature of this exploitation shows no evidence of having opened up the forest canopy sufficiently to encourage shrubs or herbs with no significant increases in the pollen of either the shrub species or herb types on the diagram during the first half of the episode. The drop in grass pollen could suggest the dis-garding of fire clearance by the inhabitants of the area.

From 306.8cm. upwards it appears that elm is being selectively lopped in a much more regular and systematic way, and that this change in forest exploitation has enabled the oak to completely recover, with the lime also reaching proportions significantly higher than it had achieved in episode A. The selective utilization of elm appears to have opened up the canopy sufficiently for the regular appearance of Plantago lanceolata pollen for the first time. This infers that the elm trees in the forest were growing in relatively pure stands, a possibility which gains further support from the events of episode C.

During episode C Quercus and Tilia expand to their greatest extent within the period under study, doing this at the expense of Ulmus which continues to decline to its lowest frequencies. Since the

Alnus curve remains steady rather than expanding to take up the slack in the tree pollen sum as the elm declines it is likely that there was a real increase in oak and lime pollen reaching the bog at this time. But the taxon which benefits most from the opening of the canopy caused by the continuing demise of elm appears to be Corylus as indicated by a leap in the Coryloid curve of up to 40%. Godwin (1975) suggests that Corylus flowers sparcely or not at all under heavy tree canopy so its sudden increase at the start of this episode can only be interpreted as a considerable opening of the forest canopy enabling under storey hazel to flourish. The increase of Corylus following clearance has been recorded by Smith and Willis at Fallahogy (1962) and by Turner at Tregaron (1964a). The increase in Plantago lanceolata and, to a lesser extent, Gramineae pollen during episode C also point to an opening up of the forest, and the only curve on the diagram which can explain this is that of elm. What, then, was the cause of the continued decline in the elm at a time when other tree taxa were thriving and which resulted in an opening of the forest as indicated by shrub and herb pollen increases?

In order to answer this question it may be useful to consider the behaviour of the Hedera curve during this episode. Despite the change in the forest composition indicated and the decline in Ilex, Hedera pollen shows no significant change from its episode A and B occurances. This lack of ivy increase may indicate that the decline in elm is not resulting in a large number of standing dead trees either as a result of ring-barking or disease. Had there been standing dead trees, even for a period of only ten years for example, the resolution of the diagram would have picked up any ivy increases produced. Had the increase in ivy production been less than about 30%, however, there is a strong likelihood that it would not have made a significant difference to the ivy curve. However, the lack of an ivy increase does tentatively suggest that the elm decline in episode C was the result of the felling and clearance of elms with no long period of standing dead trees. The frequent appearance of charcoal specks on slides from this episode infer that fire was involved, but the controlled use of fire which did not affect the remaining tree taxa. This still leaves the problem of deciding why the elms were selectively cleared in this way.

In his report of fodder lopping in the Himalayas Heybroek (1963) has shown how very large trees have been cut back to little more than tall leafy trunks by men armed only with hand held axes and knives. It is therefore quite possible that the elms of Lowland Lonsdale were devestated in a similar fashion once the particular value of their leaves for fodder had been recognized and the other forest trees had been left to recover. As pointed out previously, the open canopy species which are encouraged by the drop in elm indicate that the trees were growing in relatively pure stands, probably on the best, base-rich soils around the foot of the steep slopes rising to the east of the moss, and along the river valleys to the north. Such a habitat would be typical of Ulmus glabra, the most likely species of these forests. At this elm clearance stage the Betula curve also shows a statistically significant depression and since this taxon would have grown with the elms on the poorly drained low-lieing areas it would have suffered during felling but not necessarily during fodder gathering.

Over-exploitation of the elms over a period of about 50 years may have made further lopping unproductive, but regeneration of elm sapplings, and possibly those of other tree species, and the slight increase in grass indicated by increasing Gramineae frequencies may have encouraged true pastoral activity, animals being brought to eat rather than the fodder being taken to them. P. lanceolata may also have been an important pasture plant during this period (Milton 1933). Arable farming is not indicated in the pollen record with no increase in the 'weed' pollen associated with arable farming such as the Chenopodiaceae and the Compositae (Turner 1965). The one possible cereal pollen grain found is believed to have been the result of contamination.

By 'accident' rather than design, then, it was these low-lieing, base-rich areas with their remaining severely damaged stands of wych elm which were the first areas to be cleared by the stone axes of Neolithic man in order to further encourage the growth of pasture, and to improve access for animals. This view is similar to that of Mitchell (1965), although he felt that elm regions were sought out because of their location on the best soils. The fluctuations in the Ulmus curve after the initial depression, and its later recovery shown by Oldfield and Statham suggest that some elm trees were left standing and used periodically for fodder. The permanent depression of the elm pollen production after the elm decline horizon can therefore be seen as a combination of the sustained use of its leaves for fodder and the coincidence of its preference for low-lieing, base-rich soils with that of the early farmers. In some areas, particularly on high ground, edaphic changes as suggested by Pennington (1964) would have prevented regeneration of felled elm regions of the forests.

It is before and during felling that disease, if it is to have played a part, may have further damaged the lopped trees due to the weakening of the trees themselves, the opening of the canopy allowing free movement of insect vectors, the increased movement of people and, possibly, the presence of felled dead wood. If disease did have a role it was a secondary one, but the continuing depression of the elm curve shown on most diagrams after the initial decline may well have been linked to increased suseptibility to disease resulting from continual disturbance of elms by man.

The increase in oak and lime pollen during this episode suggests that there might have been some lopping of elms in mixed stands which provided openings in the canopy to be exploited by the surrounding trees. The work of Tauber (1965), however, offers another explanation. He suggests that the trunk space is an important area of pollen transport so, in this case, the removal of the elms in the lowland areas between the bog and the higher land would increase the amount of oak and lime pollen reaching the bog surface.

The explanation for the selective felling of elm during episode C is dependent on the oak species involved being *Quercus petrea* which is usually found on well drained acid soils on slopes and hilltops and not on the lower slopes and valley floors preferred by *Quercus robur* and *Ulmus glabra*. Unfortunately there is no general agreement as to the distribution (or even presence) of particular oak species in the post glacial forests (Gardiner 1974). The dominance of *Q. petrea* in upland regions of the modern vegetation, however, particularly around the Pennines and Lake District, lends some support to the view that this was the species in Lowland Lonsdale at the time of the elm decline, and that it grew predominantly on the poorer acid soils of the higher slopes.

There is little doubt that the species of lime involved here is *Tilia cordata* (Godwin 1975, Pigott & Huntley 1980) but despite the value of its leaves for fodder it escapes serious exploitation until episode D. Although its pollen rarely exceeds 5% of the tree pollen sum it is certainly underepresented in the pollen record, and using Andersen's correction factor (reported in Pigott

& Huntley 1980) it would appear to be about equal in abundance to Quercus and Ulmus. Pigott and Huntley show that it was at its maximum in N.W.England at this time and that the milder climate than today's probably enabled it to regenerate from seed, something it can no longer do. Iversen (1960) suggests that in the forests of Jutland it grew on the higher, well drained land and Pigott and Huntley (1978) have found it in the modern vegetation growing in its greatest abundance on cliffs and other steep ground, and especially on well developed karst. They suggest that this may represent its original forest habitat as a result of the competition from the other deep soil preferring species, or it may be the only type of topography on which it has avoided human interference. If the first suggestion is correct it is tempting to infer that lime trees were less accessible than those of the other two major forest species, but the rapid decline in Tilia pollen during episode D, interpreted as clearance, suggest that this cannot be the whole story. The fact that its pollen reduction was only minimal during the hapazard stage of fodder gathering can therefore best be explained in part as a statistical effect since minor changes in the pollen production of low pollen producers do not show clearly in the pollen record. The average 1% drop noted during the first half of episode B represents a 20% drop in the rate of Tilia pollen production and this approaches the reduction in pollen production of elm and oak at the same point. If this observation is coupled with the possibility of the lime being less accessible than the other forest trees then its avoidance at a time when leaf fodder was in abundance may be explained, at least in part.

The disappearance of Ilex pollen during this phase is not the result that would be expected since it was found to expand during clearance phases at Shapwick Heath (Godwin 1948) and Plyn-limmon (Moore 1968). Fire may have played a part since its thin bark makes it very sensitive to this (Peterken & Lloyd 1967). Its very low representation however, (22 grains) and its absence from Oldfield and Statham's diagram at the elm decline suggest that great significance should not be attached to the behaviour of the *Ilex* curve. The possibility of its flowering being suppressed by low winter temperatures, however, cannot be ruled out, and this would fit with the later suppression of *Hedera* which is slightly more frost tolerant (Iversen 1944). Some form of anthropogenic explanation of the temporary dissappearance of both species, however, seems much more likely.

Episode D is well into Oldfield and Statham's 'Secondary Elm Decline' which they compare closely with the 'Landnam' phases recorded by Iversen (1941) in Denmark, and Smith (1958) in Ireland. No suppression of oak is recorded by Oldfield and Statham although this is clearly recorded during the latter part of episode D on the present diagram, the drop being a very significant one ($p = <0.05$). The severe drop in the *Tilia* and *Betula* curves, and the continued suppression of *Ulmus*, coupled with very large increases in *Alnus*, Coryloid, *P. lanceolata* pollen, and some increase in Gramineae pollen and *Pteridium* spores clearly point to this as a period of clearance for pastoral activity. The appearance of *Urtica* and *Plantago major* pollen at the time of the deepest suppression of the forest taxa tends to confirm this. Greig-Smith (1948) describes *Urtica* sp. as the "....universal follower of man" and *Plantago major* is a common species of trackways, where it withstands trampling, and waste ground (Sagar & Harper 1964).

The clearance probably took the form of small temporary clearances over a wide area as described by Turner (1964, 1970) and, as Oldfield and Statham's diagram shows, all three major tree taxa recover temporarily to almost pre-elm decline levels at the end of this period of forest exploitation. The 150 - 200 years covered by the diagram therefore takes us from the forest maximum of the Atlantic period to clear signs of temporary forest clearance by Neolithic pastoralists.

CHAPTER 6

DISCUSSION

The events described in Chapter 5 have a timespan of, very approximately, 100 years and therefore indicate a period of cultural turmoil and population expansion unprecedented in previous records of human prehistory. We are not involved here with a straightforward change from the hunter-gathering economy of Mesolithic man to the pastoral activities of Neolithic man, but the evidence from the pollen rain of the period appears to show the various steps in the development of a new economy based on domesticated animals. The short, initial phase of about 20 -30 years appears to have involved haphazard leaf fodder gathering, probably for stalled animals. This is followed by a period of systematic lopping of elm leaves only for a further 30 or so years. (This time scale agrees with Pilcher's estimate of 1 - 50 years for the elm decline at the Beaghmore Stone Circle site, 1969.) When elm leaf fodder lopping is no longer 'economic' clearance takes place, first of the damaged elms on the low-lieing, base-rich soils and later of the oak and lime on the higher ground. The opening of the canopy affected encourages the growth of sapplings, grass and shrubs for the cattle of these early pastoralists which were allowed to graze freely in the clearances. When they had 'eaten the clearance out' it may be assumed that they were lead to a new clearance which had been prepared previously.

These events fit the pollen evidence from Ellerside Moss, but at different sites events will have varied around this theme as is shown by the different types of elm decline. A very steep drop, as shown for example at Hawes water not far away (Oldfield 1963), may have been the result of an immediate exploitation of elm leaves without the initial period of haphazard fodder gathering. The period of relatively indiscriminate fodder leaf use can be considered as constituting the 'primary elm decline' of many sites, and as soon as the elm is exploited intensively pasture plants begin to take advantage of the opening of the canopy so producing the 'secondary elm decline'. The structure of the forest, whether it is in clearly defined pure stands, a mosaic as suggested by Morrison (1959) of the Northern Ireland forests, or if it is well mixed will have a considerable effect on the exact form of the elm decline and the subsequent behaviour of the forest after the initial decline.

The major difficulty in accepting this picture of events is that it requires not only a complete change of cultural activity but also a large increase in the local population. Waterbolk (1968) has established the presence of a Neolithic culture, identifiable in the pollen record by the elm decline, which spreads along the coastal regions of Europe from the Middle East, starting at about 6000 B.C. The fact that the pastoralists at Ellerside Moss do not immediately exploit elm as the preferred fodder leaf suggests that this new form of forest exploitation arrived by cultural diffusion, as preferred by Waterbolk, rather than by the arrival in the region of people of a quite different culture who might be expected to exploit the most nutritious fodder from the start. Pennington (1970) suggests that the lack of evidence for forest clearance at upland West Cumberalnd sites points to the settlement on the coast of seaborne immigrants followed by a more widespread settlement. If this was the case the number of immigrants need only have been small, it was the ideas they brought which would have been the important factor. As Waterbolk showed, it is the accessible coastal folk who will be the first influenced by new ideas, even if they adopt them incompletely at first, as the pollen record shows. The presence of Mesolithic people in the study area is shown by the C.B.A. Research Report No. 20 (Wymer & Bonsall 1977) which lists three sites within a 10 km. radius of Ellerside Moss.

Such a drastic change in cultural behaviour amongst a primitive hunter-gatherer people would have appeared unlikely ~~unlikely~~ until recently. There is now a growing school of thought which suggests that the cultural activities and economy of Mesolithic people were considerably more complex than has been considered hitherto. In "Introduction to British Prehistory" Megaw and Simpson (1979) hint at the imminent uncovering of substantial evidence to support the claims of such people as Mellars (1976). In a scholarly treatice he suggests that controlled burning of patches of forest would have advantaged Mesolithic hunter-gatherers by improving mobility, and the economic potential of the environment. He calculates an increase of ten times in ungulate productivity and the improvement in a number of important plant crops, the most obvious of which would be hazel. Since the animals would be attracted to the fire cleared areas haunting would have been greatly facilitated and probably resulted in the development of a far more complex man-animal relationship than Mesolithic hunters are usually credited with, possibly similar to those of 'herding' economies. Evidence in support of this comes from Simmons and Dimbleby (1974) who suggest that very large proportions of <u>Hedera</u> pollen (over 50%) at two Mesolithic sites in Britain can be interpreted as the collection of ivy for fodder or as a hunting lure. This could also explain the unpublished findings of Sims (ibid) who found ivy increases at Mesolithic clearances. Episode A in the present diagram tends to support the view that fire was occuring in the pre elm decline forests as explained in Chapter 5, but the overall effect of this on the arboreal pollen rain is minimal.

If Mellar's treati~~c~~se is accepted we have a suitable cultural base for the changes necessary for the elm decline to have been caused by an economy based on the collection of leaves for fodder. This does not explain, however, the considerable increase in population that would have been necessary to produce such great changes in vegetation. Here again, Mellars provides a clue to the possible mechanism by suggesting that the relative ease of hunting large mammals by means of burning patches of the forest would have resulted in a reduction in their numbers at a rate faster than their ability to recover. This could lead to cyclic periods of shortage as described of present day hunter-gatherer folk - the !Kung of Dobe, Botswana by Richard Lee and others (Lee & DeVore 1976). The insecurity inherent in the hunter-gatherer economy in even the most productive environments is believed by many workers to have resulted in very strict forms of population regulation. Anthropologists have recognized female infanticide in both the Canadian Eskimos (Schrire & Steiger 1974) and the Australian aborigines (Birdsell 1977) and these are regarded as a means of population regulation in response to hardship. Since both these populations are subject to extreme 'emergencies' resulting from dislocation by European influence it is argued that the behaviour noted may be rare. But there is little doubt that infanticide, abortion and abstention play an important role in the regulation of hunter-gatherer populations, and it is probable that this was the case among the people of the post-glacial forests.

With the arrival of a new type of economy based on the feeding of stalled animals, most probably domesticated cattle but just possibly red deer, such population regulation would no longer be necessary as more hands meant the greater exploitation of what was almost certainly regarded as an unlimited resource - the leaves of the forest at its maximum. During a period of 200 to 300 years, about the spread of elm decline dates of N.W.England, and assuming a generation time of 20 years, an exponential increase in population size could quite feasibley have occured in response to this 'unlimited' resource. But, of course, like all our resources ultimately the resource was limited. Yet in the almost vandalistic destruction of the forests there was the seeds of a new type of land use and this finds its expression in the pollen rain by the 'small temporary clearances'. Nevertheless, the collapse of the fodder resource must have caused considerable upheaval wherever it occured and this may have been the cause of the considerable movements of people during this period which a number of workers have commented upon (ibid). It is, perhaps, instructive to compare this exploitation of a resource considered to be unlimited by our own exploitation of oil, now finally recognized as limited. We too have developed a highly 'successful' economy based on this resource but have yet to face the inevitable upheaval and dislocation which its exhaustion will bring.

The over-exploitation of resources by primitive people has been studied by a number of workers (eg. P.S.Martin 1967) and these are drawn on by V.L.Smith (1975). He argues that Pleistocene extinctions of large mammals was the result of 'overkill' and that this initiated the rise of agriculture in some areas and the development of conservationist ethics and controls in more recent primitive cultures. These take the form of myths, eg. - "....take sparingly of the bounties of nature." or 'taboos' such as the need to eat the whole of a hunted animal to stave off bad luck. He uses mathematical models to show how this may have occured but points out that there is no evidence of conservationist practices in Paleolithic cultures.

The archaeological evidence quoted by Pennington (1964) of a stone axe factory site at Pike of Stickle, Great Langdale (Bunch & Fell 1949) and the discovery by Cummins of axes from this source at their greatest density around the Humber (Anon 1977) suggest that the rich elm forests of the Lake District provided the basis upon which developed a centre of cultural activity in Neolithic Northern England.

CONCLUSION

The aim of this study has been the elucidation of the events in the post glacial forests of the Southern Lake District which lead to the decline of Ulmus at 3,000 B.C. By very close sampling, relatively high pollen counts and an attempt to use Hedera as an indicator of certain types of forest disturbance I believe that this has been achieved.

The value of ivy as an indicator of standing dead trees has not been established conclusively in this study due to its low representation in the pollen rain and its possible use as fodder. It does appear to respond very rapidly to forest clearance by disappearing from the pollen record, a factor noted by Oldfield (1963) and Walker (1966).

Despite the failure of the ivy curve to offer distinctive evidence of certain forest changes the detailed diagram of the elm decline at Ellerside Moss has shown, first of all, the viability of very close sampling in producing a high resolution diagram. The increased detail of vegetational change revealed can be judged from looking only at every tenth level of figure 4.1 and noting the important changes which this obscures. And yet this represents 2cm. sample separation, usually considered as close sampling! Statistical analyses show that pollen in consecutive 0.2cm. samples does come from different populations (see section 4.3) and confidence can therefore be attached to many of the changes shown. These may be interpreted as seasonal changes since each sample represents a period of peat growth of about 1 to 2 years. This method therefore offers the pollen analyst a very useful technique for studying, in particular, man's role in vegetational history in such little understood periods as the Mesolithic.

In the present study this high resolution has provided the basis for the detailed explanation offered of the events covered by the diagram. Before this interpretation can gain general acceptance as an explanation of the elm decline, however, a similar pattern of elm exploitation would have to be recognized from detailed analyses of other sites. In particular these should show the severe exploitation of the elm which resulted in the need for a move to true pastoral activity by making clearances. It would also need to repeat the steep fluctuations of the elm frequencies indicating fodder gathering and recovery.

With this reservation I believe that the explanation offered here has the potential of explaining the elm decline throughout Europe and the British Isles and overcomes the problem of quite different explanations being offered for the same pollen record event in different regions. It draws our attention once again to our arrogance in believing that prehistoric men were not capable of taking command of their surroundings in the way that even small groups of men in recent times have, (eg. the clearance of the forests of New Zealand by European settlers). It is also cautionary in that it suggests that our present problems of over exploitation of resources are far from new but have accompanied man probably from the moment he began to make tools and hence start to take control of his environment. It appears that our ingenuity has enabled us to overcome the problems this has created many times in the past, but almost certainly not without great cost in human suffering.
As our population expands exponentially into the 21st century we should all be aware that the problems of over exploitation created may overtax the ingenuity of even our advanced technological culture.

——— oOo ———

BIBLIOGRAPHY

ALETSEE L. (1959) Zur Geschichte der Moore and Walder des nördlichen Holstein. Nova Acta Leop. Carol., 21; 1-51

ANON. (1977) Stone Axes: The Second Revolution. Current Archaeology. No. 57. Vol. V; pp294-302

BIRDSELL J.B. (1977) Spacing mechanisms and adaptive behaviour of Australian Aborigines. In: "Population Control by Social Behaviour" Institute of Biology: Symposium Proceedings, Sept. '77

BUNCH B. & FELL C.I. (1949) A stone-axe factory at Pike of Stickle, Great Langdale, Westmorland. Proc. Prehist. Soc. 15; 1-20

DICKINSON W. (1975) Recurrence surfaces in Rusland Moss, Cumbria (formerly North Lancashire). J. Ecol. 63; 3; 913-935

FAEGRI K. (1944) On the introduction of agriculture in Western Norway. Geol. Foren. Forhandl. 66; 449-462

FAEGRI K. & IVERSEN J. (1975) "Textbook of Pollen Analysis" 3rd. Edition. Blackwell Scientific Publications.

FRENZEL F. (1966) Climatic change in the Atlantic/Sub-Boreal transition on the Northern Hemisphere: Botanical evidence. In: "World Climate from 8000 to 0 B.C." Ed. J.S.Sawyer. Roy. Meteorological Soc. London. pp 99-123

GARDINER A.S. (1974) A history of the taxonomy and distribution of the native oak species. In: "The British Oak". Eds. M.G.Morris, E.H.Perring. B.S.B.I. (E.W.Classey Ltd.)

GIBBS J.N. (1974) "The Biology of Dutch Elm Disease." Forestry Commision, Forest Rec. Lond. 94.

GIBBS J.N. (1978a) Development of the Dutch elm disease epidemic in Southern England, 1971-6. Ann. appl. Biol. 88; 219-228

GIBBS J.N. (1978b) Intercontinental epidemiology of Dutch elm disease. Annual Review of Phytopathology 1978. p 287-

GODWIN H. (1948) Studies of the post-glacial history of British vegetation, X. Correlation between climate, forest composition, prehistoric agriculture and peat stratigraphy in Sub-Boreal and Sub-Atlantic peats of the Somerset levels. Phil. Trans. R. Soc. B. 233; 275

GODWIN H. (1975) "The History of the British Flora" 2nd edition. Cambridge University Press, London.

GODWIN H., WALKER D. & WILLIS E.H. (1957) Radiocarbon dating and Post-Glacial history: Scaleby Moss. Proc. R. Soc. B. 147, 352

GODWIN H. & WILLIS E.H. (1961) Cambridge University nat. radiocarbon measurements III. Radiocarbon, 3; 60

GORDON A.D. & BIRKS H.B.J. (1972) Numerical methods in Quaternary palaeoecology. New Phytol. 71; 961-979

GREIG-SMITH P. (1948) Biological Flora of the British Isles - Urtica L. J. Ecol. 36; 339

GRESSWELL R.K. (1958) The post glacial raised beach in Furness and Lyth, North Morecambe Bay. Trans. Inst. Brit. Geog. 25; 79

GUYAN W.V. (1955) Das jungsteinzeitliche Moordorf von Thayngen-Weier. In: "Das Pfahlbauproblem." Basel. pp 223-272

*HADINGHAM E. (1979) "The Secrets of the Ice Age." Walker and Company. New York. Ch. 7, pp 127-140

HEYBROEK H.M. (1963) Diseases and lopping for fodder as possible causes of a prehistoric decline of Ulmus. Acta. Bot. Neerl. 12; 1-11

HIBBERT F.A., SWITSUR V.R. & WEST R.G. (1971) Radiocarbon dating of Flandrian pollen zones at Red Moss, Lancashire. Proc. R. Soc. B. 177; 161-176

HOVE H.A.TEN (1968) The Ulmus fall at the transition Atlanticum/Subbboreal in pollen diagrams. Palaeogeography, Palaeclimatology, Palaeoecology. 5; 359

IVERSEN J. (1941) Land occupation in Denmark's Stone Age. Denmark Geological Survey II No. 66

IVERSEN J. (1944) Viscum, Hedera and Ilex as climatic indicators. Geol. For. Stockh. Forh. 66; 463-483

*IVERSEN J. (1949) The influence of prehistoric man on vegetation. Danm. Geol. Unders. (IV), 3; 6; 1-25

IVERSEN J. (1960) Problems of the early Post-Glacial forest development in Denmark. Danmarks Geol. Unders. (IV) 4; 3; 6-32

JESSEN K. (1949) Studies in the Late-Quaternary deposits and flora-history of Ireland. Proc. Roy. Irish Acad. 52 B; 185-251

LEE R.B. & DE VORE I. (eds.) (1976) "Kalahari Hunters and Gatherers". Havard University Press.

*Mc VEAN D.N. (1956) Ecology of Alnus glutinosa (L.) Gaertn. III. Seedling establishment. J. Ecol. 44; 194

MARTIN P.S. (1967) Prehistoric overkill. In: "Pleistocene Extinctions" eds. P.S.Martin & H.E.Wright Jr. Yale Univ. Press

MEGAW J.V.S. & SIMPSON D.D.A. (1979) "Introduction to British Prehistory." Leicester Univ. Press.

MELLARS P.A. (1976) Fire, ecology, animal populations and man; a study of some ecological relationships in prehistory. Proc. Prehist. Soc. 42; 15-46

MILTON W.E.J. (1933) The palatability of the self-establishing species contributing to the different types of grassland. Emp. J. Exp. Agric. 1; 347-360

MITCHELL G.F. (1965) Littleton bog, Tipperary: an Irish agricultural record. J.R.Soc. Antiq. Ir. 95; 121-132

MOORE P.D. (1968) Human influence upon vegetational history in North Cardiganshire. Nature, Lond. 217; 1006

MOORE P.D. & WEBB J.A. (1978) "An Illustrated Guide to Pollen Analysis." Hodder & Stoughton, London.

MORRISON M.E.S. (1959) Evidence and interpretation of 'Landnam' in the North East of Ireland. Botaniska Notier. 112; 185-204

MOSIMANN J.E. (1965) Statistical methods for the pollen analyst. Multinomial and negative multinomial techniques. In: "Handbook of Palaeontological Techniques." B.G.Kummel & D.M.Raup (eds.) Freeman, San Francisco. pp 636-673

MUNN RANKIN W. (1910) The peat mosses of Lonsdale. Naturalist, 119; 153

MUNN RANKIN W. (1911) The lowland moors of Lonsdale and their development from fens. In: "Types of British Vegetation" A.G.Tansley. Camb. p 246

OLDFIELD F. (1960a) Late Quaternary changes in climate, vegetation and sea-level in Lowland Lonsdale. Trans. Inst. Brit. Geog. 28; 99

OLDFIELD F. (1960b) Studies in the Post-Glacial history of British vegetation: Lowland Lonsdale. New Phytol. 59; 192

OLDFIELD F. (1963) Pollen analysis and man's role in the ecological history of the South East Lake District. Geogr. Annlr. 45; 23-40.

OLDFIELD F. & STATHAM D.C. (1963) Pollen analytical data from Urswick Tarn and Ellerside Moss, North Lancashire. New Phytol. 62; 53-

PENNINGTON W. (1964) Pollen analysis from the deposits of six upland tarns in the Lake District. Phil. Trans. R. Soc. B. 248; 205

PENNINGTON W. (1970) Vegetation history in the North-West of England: A regional synthesis. In: "Studies of Vegetational History of the British Isles." H.J.B.Birks & R.G.West (eds.) Blackwell, Oxford.

PENNINGTON W. (1974) "The History of British Vegetation." (2nd edition). Hodder and Stoughton Educational, London.

PETERKEN G.F. & LLOYD P.S. (1967) Biological flora of the British Isles - Ilex aquifolium L. J. Ecol. 55; 841-858

PIGOTT C.D. & HUNTLEY J.P. (1978) Factors controlling the distribution of TILIA CORDATA at the northern limits of its geographical range: I - Distribution in N.W.England. New Phytol. 81; 429-441

PIGOTT C.D. & HUNTLEY J.P. (1980) Factors controlling the distribution of TILIA CORDATA at the northern limits of its geographical range: II - History in N.W.England. New Phytol. 84; 145-164.

PILCHER J.R. (1969) Archaeology, palaeoecology and radio-carbon dating of the Beaghmore Stone Circle site. Ulster J. Arch. 32; 73

RACKHAM O. (1975) "Hayley Wood, its history and ecology." Cambridgeshire and Isle of Ely Naturalists' Trust Ltd. pp 117-119.

SAGAR G.R. & HARPER J.L. (1964) Biological flora of the British Isles - Plantago magor L., P. media L. and P. lanceolata L. J. Ecol. 52; 189-221

SCHRIRE C. & STEIGER W.L. (1974) A matter of life and death: an investigation into the practice of female infanticide in the Artic. In: "Man" Vol. 9; No. 2; 161

SIMMONS I.G. & DIMBLEBY G.W. (1974) The possible role of ivy in the Mesolithic economy of Western Europe. J. Arch. Science 1; 291-296

SIMS R.E. (1973) The anthropogenic factor in East Anglian vegetational history: an approach using A.P.F. techniques. In: "Quaternary Plant Ecology" Eds. H.J.B.Birks and R.G.West. p223. Blackwell, Oxford.

SMITH A.G. (1958) Two lacustrine deposits in the south of the English Lake District. New Phytol. 57; 363

SMITH A.G. (1959) The mires of South-Western Westmorland: stratigraphy and pollen analysis. New Phytol. 58; 105

SMITH A.G. (1961) The Atlantic/Sub-boreal transition. Proc. Linn. Soc. Lond. 172; 38

SMITH A.G. (1965) Problems of inertia and threshold related to post-glacial habitat changes. Proc. Roy. Soc. B. 161; 331-342

SMITH A.G. (1970) The influence of Mesolithic and Neolithic man on British Vegetation. In: "Studies in Vegetational History of the British Isles" Eds. D.Walker and R.G.West. Cambridge University Press, London. pp 81-96.

SMITH A.G. & PILCHER J.R. (1973) Radiocarbon dates and vegetational history of the British Isles. New Phytol. 72; 903-914

SMITH A.G. & WILLIS E.H. (1962) Radiocarbon dating of the Fallohogy landnam phase. Ulster J. Archaeol. 24-25; 16-24

SMITH V.L. (1975) The primitive hunter culture, Pleistocene extinction and the rise of agriculture. J. Political Economy 83; 727-755

STECKHAM H.V. (1961) Flora. 150; p514

TAUBER H. (1965) Differential pollen dispersion and the interpretations of pollen diagrams with a contribution to the interpretation of the elm fall. Damn. Geol. Unders. II 89; 1-69

TROELS-SMITH J. (1960) Ivy, Mistletoe and Elm: climatic indicators - fodder plants. Damn. Geol. Unders. IVR, 4, 4; 1-32

TURNER J. (1964a) The anthropogenic factor in vegetational history I, Tregaron and Whixall Mosses. New Phytol. 63; 73-90

TURNER J. (1964b) Surface sample analysis from Ayrshire, Scotland. Pollen et Spores. 6; 583-592

TURNER J. (1970) Post-Neolithic disturbance of British vegetation. In: "Studies of Vegetational History of the British Isles" Eds. D.Walker and R.G.West. Cambridge University Press, London. pp 97-116

TURNER J. (1965) A contribution to the history of forest clearance. Proc. Roy. Soc. Lond. B. 161; 343

WALKER D. (1966) The late Quaternary history of the Cumberland lowland. Phil. Trans. R. Soc. B. 251; 1-210

WATERBOLK H.T. (1968) Food production in prehistoric Europe. Science, N.Y. 162; 1093

WATTS, W.A. (1961) Post-Atlantic forests in Ireland. Proc. Linn. Soc. Lond. 172; 33

WILLUTZKI H. (1962) Zur Waldgeschichte und Vermoorung sowie uber Rekurrenzflachen in Oberharz. Nova Acta Leopoldina, 25(160); 1-52

WYMER J.J. & BONSALL C.J. (Eds.) (1977) A gazetteer of Upper Palaeolithic and Mesolithic sites. Council for British Archaeology, Research Report No. 20.

ZEIST W. Van. (1959) Studies on the post Boreal vegetational history of South East Drenthe (Netherlands). Acta Botanica Neerlandica, 8; 156-185

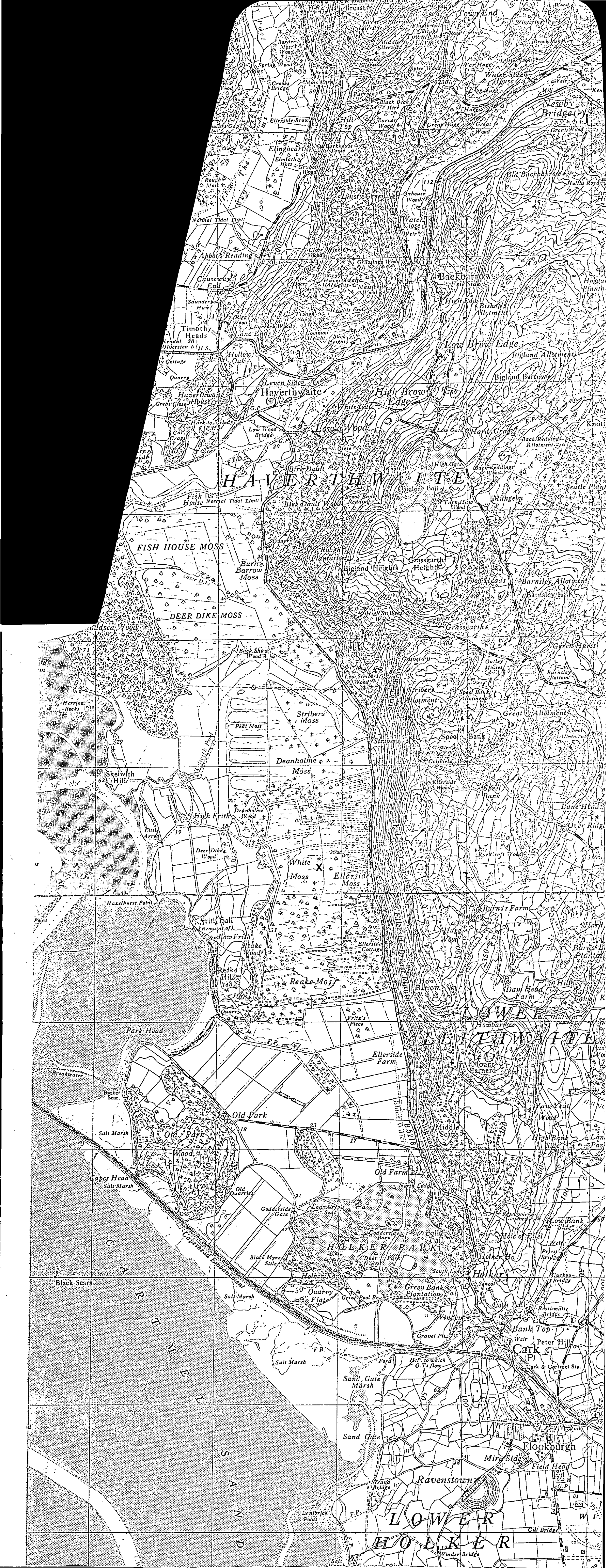
* Not quoted in text.

APPENDIX

Access Map to Ellerside Moss

Source: O.S. 1:25,000
S.D. 37
S.D. 38

X = Sampling Point


Town End
Newby Bridge
Great Wood
Old Backbarrow
Crooks
Crooks Bridge
Spring Wood
Ellerside Brow
Elinghearth
Hill Top
Rough Moss
Linsty Green
Oxhouse Wood
Water Close
Weir
Normal Tidal Limit
Abbots Reading
Causeway End
Backbarrow
Fell Side
High Row
Bisland Allotment
Timothy Heads
Hollow Oak
Low Brow Edge
Bigland Allotment
Bigland Barrow
Leven Side
Haverthwaite
High Brow Edge
Low Wood
Low Wood Bridge
Hark-to-Melody
Great Close
Back Reddings Allotment
HAVERTHWAITE
Birk Dault
Birk Dault Wood
Bigland Hall
Fish House
Mungeon
Seatle Plantation
FISH HOUSE MOSS
Burn Barrow Moss
Rough Plantation
Bigland Heights
Grassgarth Heights
Wood Heads
Barnsley Allotment
Barnsley Hill
DEER DIKE MOSS
Grassgarth
Great Hurst
Back Shaw Wood
Low Stribers Wood
Stribers Allotment
Speel Bank Allotment
Great Allotment
School Allotment
Herring Rocks
Peat Moss
Stribers Moss
Stribers
Speel Bank
Skelwith Hill
Deanholme Moss
Ellerside Wood
High Frith
Deanholme Wood
Lane Head
Deer Dike Wood
Rye Croft Wood
White Moss
X
Ellerside Moss
Hazelhurst Point
Frith Hall
Burns's Farm
Hagg Wood
Reake Wood
Ellerside Cottage
Reake Hill
Reake Moss
How Barrow
Dam Head Farm
Park Head
Frith's Piece
LOWER ALLITHWAITE
Ellerside Farm
Howbarrow
Breakwater
Old Park
Yew Tree Wood
Salt Marsh
Old Park Wood
High Bank Side
Capes Head
Old Farm
Old Quarries
North Lodge
Goddersgate Gate
Lady Grey's Seat
HOLKER PARK
Hole of Ellel
Deer Park
Low Bank Side
Holker Hall
Black Myre Stile
Holker
C A R T M E L S A N D
Black Scars
Quarry Flat
Green Bank Plantation
Cuckoo Bridge
Salt Marsh
Cark Hall
Bank Top
Peter Hill
Cark
Cark & Cartmel Sta.
Sand Gate Marsh
Sand Gate
Flookburgh
Mire Side
Field Head
Ravenstown
Strand Bridge
LOWER HOLKER
Winder Bridge
Cut Bridge