ASPECTS OF THE VEGETATION HISTORY OF SOUTH-EAST PERTHSHIRE

C. J. Caseldine

A Thesis Submitted for the Degree of PhD
at the
University of St Andrews

1980

Please use this identifier to cite or link to this item:
http://hdl.handle.net/10023/14125

ASPECTS OF THE VEGETATION
HISTORY OF SOUTH-EAST PERTHSHIRE

by

C.J. Caseldine

Submitted for the
degree of Ph.D in the
Faculty of Science,
University of
St. Andrews,
April, 1980.

DECLARATION

I declare that this work, unless otherwise stated, is the result of my own independent investigations. It has not already been accepted in substance for any degree and it is not being concurrently submitted for any degree.

Signed

Date 1 . 4 . 80

I declare that Mr C.J. Caseldine has fulfilled the conditions of the Resolution and Regulations pertaining to the Degree of Doctor of Philosophy of the University of St. Andrews in terms of Ordinance General 12 and Resolution of the University Court, 1967, No. 1.

Signature: 1. 4. 80

Supervisor

PREFACE

The work submitted in this thesis was carried out under a University of St. Andrews Research Scholarship. Between 1973 and 1976 this was held in the Department of Geography at the University of St. Andrews and the work was finally completed in the Department of Geography at the University of Exeter.

I would like to acknowledge the assistance of the following during the course of the research:

Prof. V.B. Proudfoot, who took over as supervisor when Dr. J.A. Soulsby took up a temporary position in Malawi in 1976, Prof. Proudfoot's encouragement and discussion helped considerably during the writing of the thesis. Dr. J.A. Soulsby for his supervision over the first three years and his help in the field, and Dr. K.M. MacIver for her initial help and encouragement in getting the scholarship.

Dr. J. Jarvis for his considerable help both in the field and in the laboratory, and many other people who helped with various parts of the fieldwork, especially Astrid Caseldine, Neil Walker, Martin and Adrian Hall. Assistance and advice in the laboratory were given by Astrid Caseldine, Dr. Kevin Edwards and Michael Cain.

Dr. Allan Gordon for offering to help in the statistical analyses and running the programs, as well as for discussing possible ways in approaching the problems set by the surface pollen analysis work.

Mr. J. Stevenson for allowing the use of unpublished archaeological field surveys and Dr. Margaret Stewart for allowing me to work on her excavations as well as providing the drawn sections of the relevant excavations.

Mrs. Joan Fry for typing the manuscript and Peter Adamson in St. Andrews and Andrew Teed in Exeter for photographing the figures.

The assistance of Bert Bremner and Rodney Fry in the Drawing Offices of the two departments is also gratefully acknowledged.

Several landowners kindly allowed permission to work on sites on their land: the Scottish Wildlife Trust at Bankhead Moss, Lord Lansdowne at Stormont Loch, the Forestry Commission at Loch Mharaich and the several farmers who used the commonty on which Heatheryhaugh is situated.

Part of the work on surface pollen analysis (Chapter 3) has been published in: C.J. Caseldine and A.D. Gordon, 1978, 'Numerical analysis of surface pollen spectra from Bankhead Moss, Fife' New Phytol. 80, 435-453. An outline of the early land clearance phases at Heatheryhaugh and Loch Mharaich has appeared in: C.J. Caseldine, 1979, 'Early land clearance in South-East Perthshire' Scott. Arch. Forum, 9, 1-15.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

"It is of the opinion of eminent men, that the whole habitable earth was originally covered with wood; and that it continued to be until mankind formed themselves into societies, and subdued these by fire and steel. In proportion to the progress of agriculture forests decrease ...... and the more rapid the progress ...... forests would disappear in proportion."

(Rev. R. Rennie, 1807, p.18)

"It turns out that the extreme ease with which pollen can be recovered, identified and counted, is one of nature's more seductive tricks. It has permitted a valid and useful stratigraphic division of late-Pleistocene deposits, now largely superseded by radiocarbon-dating, while the changing pattern of vegetation remains as elusive as ever."

(Deevey, 1965, p.648)

Interest in understanding how the natural environment has changed over time is by no means a recent phenomenon but it has only been during this century that the development of techniques of microfossil analysis and chemical analysis of sediments, coupled with the application of radiometric dating techniques, has enabled a more accurate determination of former environments. Reconstructing earlier environments, although often studied within a geographical context, is by no means restricted to geographers and as Crabtree states "the geographer involved in palaeoecological work must be interdisciplinary in approach"

(1975, p.279). Indeed the time is fast approaching when, because of the diversity of the techniques now available, the contribution individual studies can make will be limited and interdisciplinary studies with contributions from several fields will prove a necessary approach. Such studies have already been carried out in several areas (Case, Dimbleby, Mitchell, Morrison and Proudfoot, 1969; Davidson, Jones and Renfrew, 1976; Dimbleby and Evans, 1974). Pollen analysis is but one technique available for understanding former vegetation communities but it has been a cornerstone of palaeoenvironmental research, particularly in areas of predominately acidic parent materials, for the last sixty years. Although many palynological studies have rested on pollen evidence alone combination with other techniques of microfossil or chemical analysis is now commonplace (Pennington, Howarth, Bonny and Lishman, 1972; O'Sullivan, Oldfield and Battarbee, 1973; Dimbleby and Evans, 1974). Many problems still surround the use of pollen as an indicator of former patterns of vegetation communities. As Barber (1976) has commented,

> "The accuracy of our reconstructions is dependent upon a great many interrelated factors, from the statistical and other assumptions inherent in the techniques themselves to the fragmentary nature of many of the deposits investigated." (p.6)

Recent developments in pollen analysis such as the derivation of 'absolute' values of pollen influx into lake sediments (Davis, 1965; Jorgensen, 1967; Bonny, 1972) and the evaluation of fossil pollen assemblages against other indicators of environmental change have improved our understanding of the meaning of pollen assemblages although not all would agree that advances have necessarily been made,

> " ...... it remains this author's opinion that save in exceptionally simplified ecological situations, the recent

> "quantification of much pollen-analytical data on an absolute rather than a relative basis ...... can still do no more than enhance the essentially subjective reconstruction of communities and their variation and not the secure quantification of any pattern or process directly related to the influx rate."
>
> (Oldfield, 1977, p.479)

However, the placing of pollen evidence within a chronological framework, provided especially by radiocarbon dating, has certainly allowed a clearer understanding of the synchroneity and diachroneity of environmental change.

This thesis explores two principal themes related to the use of pollen analysis as a means for understanding environmental change over the last 14000 years. Firstly, the possibility of establishing the regional character of vegetation change during this period is examined for the chosen study area in eastern Perthshire. The development of a sound regional background of vegetation change is an important first step in the study of any area. It provides a means of comparison between different areas as well as establishing characteristic trends and changes within the chosen region. This approach has now been used throughout Britain for both the Late Devensian and Flandrian periods (Hibbert, Switsur and West, 1971; Pennington et al., 1972; H.J.B. Birks, 1973a; Hibbert and Switsur, 1976) and as studies continue the jigsaw of regional patterns may be pieced together. Interpretation of significant events in vegetation history from such studies and from analyses of single sites has already allowed several general syntheses to be attempted (Godwin, 1975a and b; H.J.B. Birks, Deacon and Peglar, 1975; H.J.B. Birks, 1977).

In order to develop a regional vegetation sequence it is necessary to examine several sites and identify local pollen assemblage zones describing the characteristics of the regional vegetation patterns. In many cases the record from one site which has a particularly complete and detailed pollen record can provide the basis for such a regional sequence (Hibbert, Switsur and West, 1971; Barber, 1976). Radiocarbon-dating of zone boundaries to provide chronozones is important in this context and provides an independent time scale allowing direct comparison between different areas, but even without dating it is possible to establish the fundamental character of a regional pattern which, on the basis of the assemblages discovered, may be approximately dated by comparison with the nearest dated sequence. The definition of what constitutes a region in this context is one which has not yet seriously taxed palynologists. Regions so far examined have been isolated, as with Skye (H.J.B. Birks, 1973a), or differentiated in terms of geology and topography within a large areal scale (Pennington et al., 1972).

In the present study the region has been chosen to encompass three distinctive local environments across the southern edge of the Grampian Highlands. The areas covered vary from the northern margins of the wide lowland area of Strathmore, to the areas of upland plateau of the Forest of Alyth and the higher Strathardle-Glenshee watershed. It may be expected that the form of the vegetation communities and their response to changes which are either climatically or anthropogenically induced, would have differed within these environments, but at a regional level there should still be some uniformity of patterns and trends. It is quite possible that such regional components would however become less evident following the earliest impact of man. Most attempts at the development of regional pollen assemblage zones have therefore concentrated on the Late Devensian and Early and Middle Flandrian (FL I - FL II, West 1970) with the

Late Flandrian (FL III) only being divided by severe breaks in the vegetation sequence. In Northern Scotland for instance NWS VII covers the entire period from 5000b.p. to the present (Pennington et al., 1972). An attempt will be made here to discover whether it is possible to establish the regional character of vegetation change in eastern Perthshire or whether the differences between the three local environments are such that they preclude such a synthesis. In the absence of radiocarbon-dating correlation between different sites is difficult and it will not be possible to produce chronozones but, particularly in the period preceding the appearance of human communities, some similarity of vegetation succession may be expected. Plant immigration and community changes may not have been synchronous between each local environment (indeed they would not be expected to have been so) but the fundamental directions of change should have been relatively uniform.

Definition of regional pollen assemblage zones is of particular importance for the Late Devensian as during this period of considerable climatic oscillation there was great instability within the biotic environment, and it now seems possible that an understanding of the differences between regions, or the close definition of what comprises a region with a uniform vegetational sequence, may lead to the isolation of those environmental parameters which most closely respond to specific climatic changes. Areas which may be considered uniform in terms of trends of environmental change during the Late Devensian could well be different to those which appear during the Flandrian due to changing thresholds related to altitude, oceanicity or proximity to refugia. However, by the definition of distinctive regional elements the individual character of Late Devensian environments may be understood and the most important gradients isolated.

In the Early and Middle Flandrian the sequence of succession of the principal plant communities usually has a noticeable regional character. Because of the local complexity of vegetation change and modification associated with the appearance of man in the Late Flandrian the establishment of such a regional pattern is difficult and investigation of this period requires a different and more localised approach. The second theme of the thesis therefore is to look at the impact of human communities on the vegetation of eastern Perthshire to see how the pattern of land utilisation varied both in the nature and intensity of land use, and in its effects. The use of pollen evidence to trace the development of human communities and their agricultural activities has been widespread throughout Europe (e.g. Iversen, 1956; Hafsten, 1965; Vuorela, 1970, 1975; Pennington, 1975; Smith, 1975) but there are still limitations to the degree of information available from such an approach. Although the effects of man are clearly identifiable within the pollen record there are still several problems relating to the detailed interpretation of any pollen assemblage and how it changes in terms of the character of the changes in the vegetation communities. These problems may be summarised under three headings - scale, process and duration.

1) Scale - because of the difficulties involved in understanding the precise source area of pollen collected from any one location (Oldfield, 1970; Janssen, 1970) it is impossible to accurately determine the scale of the area affected by human activity. Following disturbance by man the increased diversity of vegetation communities makes this even more difficult. Through time as these communities change so too does the source area for the pollen assemblage. Attempts have been made to locate areas of activity by means of three dimensional pollen diagrams (Turner, 1970) but only the use of pollen influx rates

into lake sediments within relatively simple catchments provides any real hope of determining the scale of change rather than the approximate location of the changes (Sims, 1973). Evidence for particular changes may also be found in pollen spectra from soil profiles which show the more exact location and character of plant and soil modification. Such records are more difficult to interpret but can produce an extremely local picture although sometimes within a rather indistinct time scale. In environments where it is reasonable to believe that plant communities directly comparable to those present during early periods of human interference still exist and their present pollen production can be monitored such monitoring associated with detailed calibration of pollen influx rates can provide an accurate estimation of the location and areal extent of modification (Hicks, 1974). Areas where such an approach is feasible are rare and probably absent in the British Isles.

2) Process - although the pattern of change in the pollen curves, either expressed as influx, concentration or proportion, can be interpreted in terms of the sequence of changes taking place in the vegetation communities, understanding of the processes involved, especially the relative importance of man or natural agencies in vegetation and soil development often remains unclear (e.g. Moore, 1968, 1973, 1975; Taylor and Smith, 1972). It is quite possible that similar changes in pollen curves could occur given either man-induced or climate-induced processes and adequate understanding of which was more important requires other corroborative evidence. The considerable debate over the Elm Decline bears witness to this particular problem. Interpretation of the processes involved, therefore, often relies heavily on analogy with observed practices among human communities thought to have a similar way of life to those living during prehistoric

periods, or on observations of the rate and form of present day pedogenic or vegetation change consequent upon certain stimuli such as woodland removal, cultivation or burning.

3) Duration - understanding of the duration of events relies heavily on radiocarbon-dating and is therefore dependent upon the availability of such dating and its accuracy. The use of radiocarbon-dating has produced something of a revolution in the time scales now postulated for the earliest periods of human interference with the landscape (Pennington, 1975; Smith, 1975) but the pollen record must present a composite or cumulative picture of a sequence of events occurring over an area. The number of dates required adequately to cover a long time period is not always possible to obtain and where dates overlap the length of any particular event can only be estimated to within maximum and minimum dates and their associated errors. Without radiocarbon-dating duration can only be determined by the estimation of accumulation rates and by comparison with dated profiles, although it is often the practice to substitute length of time for amount of sediment covered, a reasonable assumption perhaps in lake sediments where sedimentation is often regular, but dangerous in upland peats where rates may be extremely variable.

Individual workers have adopted different approaches to solving the rather intractable fundamental problems outlined above. Close sampling of deposits has provided a much more detailed record of changes in the pollen curves and hence provided a sounder, more accurate data base (Turner, 1965, 1970, 1975; Atherden, 1976) so that each pollen assemblage recognised records the smallest possible unit of time. Investigations of lake sediments which derive from a clearly defined catchment allows closer identification of the scale and location of change (Sims, 1973; Peck, 1973) but such sites are not common and in large areas of the British Isles lake sediments are not available for analysis. Improvements in techniques, especially the ability to calculate pollen influx rates, can only improve the data base, as does close sampling, but this does not necessarily help in improving the interpretive process which rests still on analogy and experience. The development of methods of calculating pollen influx rates relates principally to lake sediments and although attempts at such calculations have been made on peat in the Somerset Levels (Beckett and Hibbert, 1976) they have proved very variable and require a blanket of radiocarbon dates. Despite the improvements that have taken place in pollen analytical techniques to refine the raw data it seems unlikely that we are yet at the stage where we can treat these data to the sort of rigorous analysis apparently suggested by Evans:

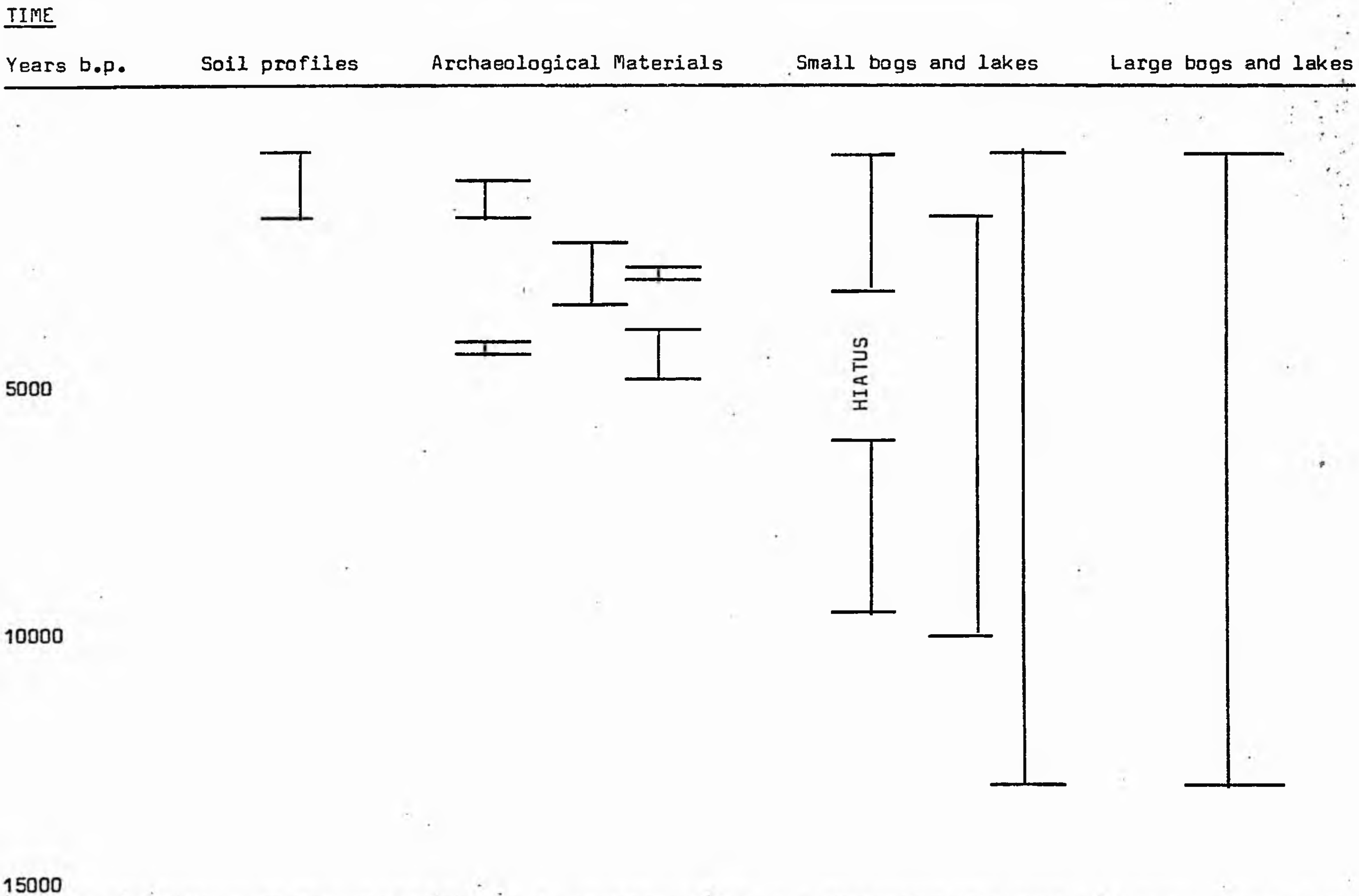
> "There has perhaps been too strong a tendency in the past to ask the wrong questions with regard to ...... early episodes of forest utilisation. Rather than enquiring too closely into the cultural status of the people who brought about these changes in the vegetation and soil, we should perhaps define them in terms of the changes themselves. There is no doubt that a wide variety of land use phenomena took place, and while some aspects of this variation may be attributed to differences in aspect, soil, climate etc. from site to site, others may be of fully cultural significance. The precise definition of these changes, their accurate dating and their classification into groups - in fact their treatment as artefacts - would go a long way to furthering research into the way of life of these early communities." (1975, p.110)

The combination of themes examined in this thesis means that the very detailed local scale work which is required to provide the precise data preferred by Evans can only be carried out to a limited extent. It is therefore of necessity that the overall approach is only of a preliminary nature which attempts to determine the broad scale similarities and differences between the three areas investigated. Close sampling is used where possible as is the close juxtaposition of sites, but the final interpretation of the pollen results is still likely to be at a general level providing more of a regional picture. Within the three areas an effort is however made to use different sediment types to provide assemblages relating to different source areas. Assuming that pollen can be defined as originating from three main sources, local, extra-local and regional (see Figs. 3.1 and 3.2), then the crude relative proportions of these sources will vary depending upon the type and size of deposit as hypothesised by Tauber (1965; West, 1973). For the deposits used in this study the same variations may therefore be expected and combination of different sediment types should complement the records of others if they are closely located (Fig. 1.1). Apart from having different source areas for their pollen assemblages different sediments will also reflect different time periods as hypothesised in Fig. 1.2. Soil profiles have a predominantly local pollen assemblage and usually only represent a relatively brief time period but they can contain pollen of some age (Keef, Wymer and Dimbleby, 1965). Like soils, archaeological deposits provide a very local pollen record but only cover very brief, although often well dated time periods. Unless represented by palaeosols there can also be problems in determining the origin of the material. Small peat deposits reflect the vegetation from a slightly wider area but are often predominantly affected by local plants or those fringing the bog. They too can cover only a recent time scale but do extend back sometimes into the Late Devensian if in an overdeepened depression such as a kettlehole. They

FIGURE 1·1 Pollen source area characteristics for the type of deposits examined (after Tauber, 1965)

SOURCE AREA	Dominantly Local	Mainly Extra-Local and Local	Dominantly Regional
DEPOSITS	Soil Profiles Archaeological Site Materials	Small peat bogs Small lakes with little definable input of sediment	Large peat bogs Large lakes with definable input from catchments

FIGURE 1•2 Hypothetical time periods covered by the deposits outlined in Figure 1•1



are however very susceptible to local hydrological changes which may not have very wide significance (Pears, 1969). Small lakes tend to act similarly to small peat deposits except for the absence, unless very shallow, of local species, and can be dominated by air-borne local and extra-local pollen where there is no significant input of allochthonous sediment. Large bogs and lakes, especially the latter, are likely to provide the most complete and extensive record. Both show a dominance of regional pollen but with lakes this is representative of the catchment and the sediment it produces rather than being derived from the air (Peck, 1973). The problem with both types of sampling environment is however the subdued nature of the pollen changes usually represented which makes interpretation of the detailed processes difficult. Because of the variability in source areas and time scale between these different classes of deposits an attempt is made here to incorporate data from different deposits where possible, in particular examining peat profiles and adjacent soil profiles. The integration of results from different deposits is an important factor in environmental reconstruction but is too often defeated by the fragmentary nature of the available deposits or difficulties involved in getting suitable samples, and similar restrictions operated in eastern Perthshire, with an absence of suitable lake sediments in one of the upland areas and the destruction of soil profiles by afforestation in the other upland area, as well as the absence of excavated archaeological sites within the study area as a whole. As Davidson et al. comment, "although the objectives of environmental reconstruction may be clear, the paucity of evidence is usually a major practical constraint." (1976, p.350)

Because of the reliance on one particular technique, pollen analysis, part of the work is also concerned with examining the technique itself. As stated earlier there have been many significant advances since the pioneer work of von Post (1916), especially in the last two decades, but there are still areas where refinement is necessary. Crabtree (1975) has produced a breakdown of the steps involved in the preparation and interpretation of fossil pollen assemblages (Fig. 1.3) and investigation could be carried out at any of these stages. The diagram is itself a generalisation and includes as only one step 'interpretation' which involves many procedures and assumptions. Because of the use of peat profiles and the interest in the relationship between fossil pollen assemblages and former patterns of vegetation in the prehistoric period an examination was made of the present day pattern of pollen deposition within a small tree-fringed raised bog surrounded by cultivated land. The analysis was designed to provide an indication of how well the pollen deposited on the bog surface reflected the surrounding vegetation communities, thereby assisting in the interpretation of fossil pollen records from similar deposits which cover periods of early land clearance when there would still have been considerable local woodland and a mosaic of cleared land less extensive than that found today. It is questionable whether it is possible to relate such evidence directly to the interpretation of fossil pollen records although H.J.B. Birks (1973a) for instance has been able to detect at present a close relationship between percentage pollen frequency and percentage canopy cover for _Betula_ and _Corylus_ in woodland on Skye. Such work does however add to the background knowledge which forms the basis for much 'intuitive' pollen analysis and surface pollen work so far carried out has rarely sought to help answer the problems posed by the interpretation of the effect of early man on the landscape.

Apart from the surface pollen work the use of different sorts of

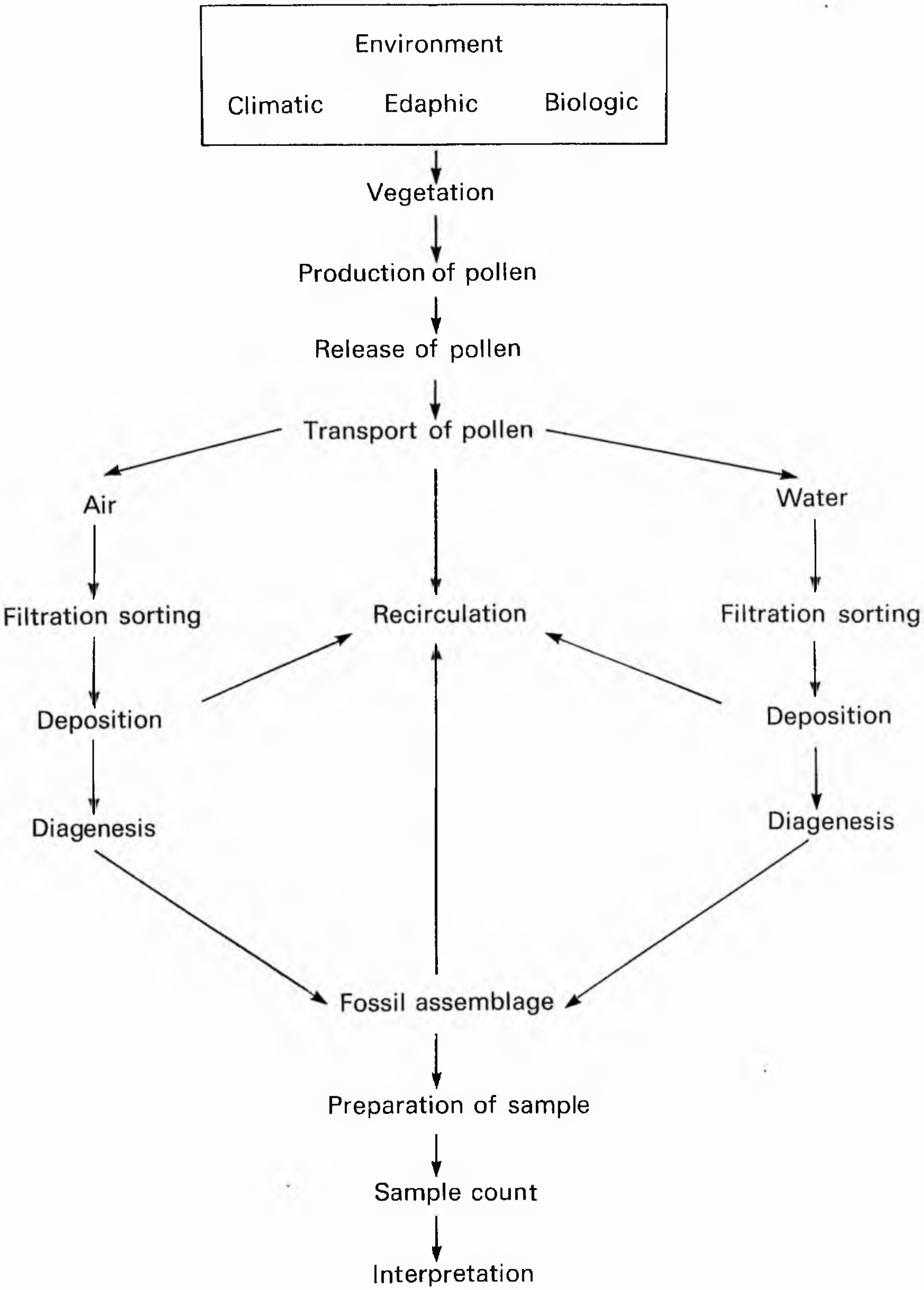


Fig.1.3 The preparation and interpretation of pollen assemblages (Crabtree 1975)

sediments also allows investigation of the differential preservation of pollen within them. Differential preservation is mainly a feature of soils and deposits which are either aerobic, biologically active or rather alkaline but some degree of pollen deterioration is found in all deposits and general counts of deteriorated pollen have been used as evidence of changes in the character of sediment accumulation.

The organisation of the thesis falls into three parts. The first part, comprising Chapters 1 and 2 is introductory, the second Chapter presenting the background to the development of pollen analysis in Scotland and detailing the general picture of vegetation history over the last 14000 years in Scotland. In the second part, Chapter 3, the details of the surface pollen work undertaken on Bankhead Moss in Fife are presented and the main results summarised. The third part, Chapters 4 to 9 which provides the main body of the work, covers the results from the three environments within the study area. Chapter 4 discusses the background characteristics of the area, its geology, soils, climate, archaeological and historical records. Chapter 5 presents the results from cores taken from the margins of Stormont Loch in Strathmore and shows the pattern of vegetation change on lower ground throughout the Late Devensian and Flandrian periods. Chapter 6 discusses results from two peat sites and three soil pollen sites on the higher plateau of the Forest of Alyth north of the Highland Boundary Fault which together cover all the Flandrian, and Chapter 7 deals with the results from a short core taken from Loch Mharaich, the highest site analysed, on the Strathardle-Glenshee watershed. In Chapter 8 the results from analyses carried out at two archaeological sites at Moncreiffe House in southern Perthshire and Queen's View in western Perthshire are considered and related to the results from the eastern area. Finally in Chapter 9 the patterns of vegetation change during the Late Devensian and Early

and Middle Flandrian are discussed in terms of regional pollen assemblage zones, and the effects of man on the vegetation of the area during the later Flandrian are summarised.

CHAPTER TWO

VEGETATIONAL HISTORY OF SCOTLAND

i) The development of pollen analysis in Scotland

The development of pollen analysis in Scotland has been the subject of a paper by Edwards (1974) in which, with the aid of a comprehensive bibliography, he discusses the progress of pollen analysis since the publication of the first Scottish pollen diagrams by Erdtman in 1923. Prior to the work of Erdtman, studies of past vegetation patterns were based on the analysis of peat macrofossils. Geikie (1866, 1894) and Lewis (1905, 1906, 1907, 1911) both studied peat deposits throughout Scotland and related changes in peat composition to climatic oscillations suggesting a system of alternating warm and cool periods. Samuelson (1910) also examined many Scottish peat deposits, especially those visited by Lewis, and he attempted to correlate the Scottish chronology with that of Scandinavia as outlined by Blytt and Sernander. Erdtman (1923, 1924, 1928) was also interested in establishing common ground between the climatic development of nothern Britain and Scandinavia and by means of the identification of the pollen of several arboreal species he was able to determine the sequence of the immigration of trees into Scotland following the last glaciation.

It was not until the Second World War that Fraser (1943) and later Fraser and Godwin (1955) published pollen diagrams for Aberdeenshire and Lanarkshire which seemed to show a development of vegetation similar to that already demonstrated by Godwin in southern Britain (1940). The history of woodland throughout Scotland since Boreal times was the subject of a doctoral thesis by Durno (1967) in which he analysed over fifty sites throughout the country, using widely sampled, generalised diagrams. In his study, Durno succeeded in establishing regions of different forest composition, showing birch to be found consistently all over Scotland throughout the Flandrian, albeit secondary to pine in the north and to oak in the south. Durno's diagrams and those of Newey (1967) from southeast Scotland continued to use the Godwinian system of zonation. Doubts concerning the value of this method of zonation for use in Scotland had been raised as early as 1946 by Blackburn who discovered that from an island site, in this case Barra, non-arboreal pollen rather than arboreal pollen was the dominant feature of the pollen diagrams. These findings were confirmed on Canna by Flenley and Pearson (1967), on Orkney by Moar (1969a) and on Shetland by Hawksworth (1969). On the mainland, both Vasari and Vasari (1968) and Donner (1962) used Godwinian zones but expressed doubts over their utility, Donner especially having difficulty in defining any boundaries between zones V and VI, and between VIIb and VIII. Pears (1969), in the light of his investigation into the former altitudinal variations of pine in the Cairngorms, expressed further concern;

> "It could be that it is a serious mistake to try to fit Highland pollen diagram zonation too closely into the well established lowland sequence." (Pears, 1969, p.541)

Studies in the Orkneys, Sutherland and southwest Scotland by Moar (1969a, 1969b, 1969c) and in the Cairngorms, Ross and Cromarty and Galloway by H.H. Birks (1970, 1972a, 1972b) abandoned the use of Godwinian zones. Moar developed a system of biostratigraphic zones, based entirely on pollen content, zones which, especially during the Devensian, were independent both of lithostratigraphy and established pollen sequences. H.H. Birks (1970) introduced into Scotland the idea of the pollen assemblage zone as outlined in the American Code of

Stratigraphic Nomenclature (American Commission, 1961),

> "An assemblage zone is defined on the presence and relative proportions of the contained fossils, and named after the most abundant and characteristic taxa. It is independent of any ecological, chronological or climatic interpretations."

Using this method, local assemblage zones for a particular site and regional assemblage zones based on information from several sites within a region may be determined. Such regional assemblage zones may be further refined by radiocarbon-dating their boundaries to produce chronozones. So far, only sites in northern Scotland and southeast Scotland have been subjected to such analysis (Pennington et al., 1972; Pennington, 1975a; Switsur and West, 1976). The work of Pennington et al. (1972) and Pennington and Lishman (1971) also remains as the only use of the analysis of sediment chemistry as an adjunct to pollen analysis in Scotland, except for work on Skye for the Late Devensian period by H.J.B. Birks (1973a), and in Aberdeenshire where Edwards (1977, 1979) has also included evidence of the magnetic properties of sediments.

The problems of regional disparity in vegetation development and the non-synchroneity of apparently similar events in the pollen record are very apparent from many Scottish pollen diagrams. Recently, however, there has been a spatial bias in the analysis of sites, which has left certain areas better understood than others. Interest has centred on areas of relict oakwood in the northwest and southwest (H.H. Birks, 1972a, 1972b) and in areas of relict pinewood, the remnants of the Caledonian pine forest (H.H. Birks, 1970; Pennington et al., 1972; O'Sullivan, 1974a, 1975). Large areas of eastern and central Scotland have yet to be covered by any detailed studies although the foundations for such studies have already been laid by

Durno (1956, 1959) and Donner (1962).

Despite the patchy nature of our knowledge with regard to the Flandrian there has been considerable interest in Scottish Late Devensian environments culminating in the recent work edited by Gray and Lowe (1977). Following early work by Mitchell in Berwickshire and near Glasgow (1948, 1952), Donner (1957, 1958) investigated several Late Devensian profiles and considered their relationship to supposed Zone III, Loch Lomond Stadial, limits. This theme has since been expanded, especially in the southeast Grampians, under the influence of Sissons (Sissons and Walker, 1974; Walker, 1975a, 1975b; Lowe and Walker, 1977) so that a clearer picture of vegetation changes associated with the oscillations of the last ice caps is now emerging. Pennington et al. (1972) concentrated on the Late Devensian in northwest Scotland and in several papers Pennington (1973, 1975a, 1975b, 1977b) has investigated this period by the use of absolute pollen techniques, the first person to publish diagrams using this more refined counting technique in Scotland. Further information on the Late Devensian in northwest Scotland has been ascertained from Skye by H.J.B. Birks (1973a) who used an analysis of the present flora and its characteristic pollen spectra to aid the interpretation of former vegetation assemblages. Inextricably linked with the extent and effects of the last glaciation is the question of sea level changes, a subject reviewed by Donner (1970). One benefit for the interpretation of Flandrian environments to emerge from work in this area has been the analysis of peats below the Carse clay of the Forth valley, (Newey, 1966; Brooks, 1972), analyses carried out ostensibly to help date the onset of the major Flandrian marine transgression.

Interest in Scotland in the Late Flandrian period and in the anthropogenic factor in vegetation history has been limited. Indeed it would be fair to say that in many areas vegetation changes associated with the final stages of the last glaciation, over 10000 years ago, are better understood than those associated with the human activity of the last 5000 years. Except for a brief paper by Knox (1954) and the recognition of human influences in rather generalised pollen diagrams for Perthshire and Ayrshire by Durno (1965), only Nichols (1967) and Turner (1965, 1970, 1975) have consciously investigated the effects of early man on his environment. It is true that many others, such as Donner (1962) and Moar (1969b), have observed what they assumed to be anthropogenic interference with the vegetation cover, but their sampling interval was too great to note the precise changes taking place and the interpretation of such phenomena was not the main object of their work. H.H. Birks (1972a) only found it possible at one site, Snibe Bog in Galloway, to establish a pattern of human clearances, based on a varying sample interval of 5 cm and 10 cm. By selective close sampling of profiles from Aros Moss in Kintyre and Racks Moss in Dumfries Nichols (1967) was able to demonstrate probable Mesolithic and definite Neolithic and later interference with the forest cover in the form of several small scale clearances for both pastoral and arable agriculture. Turner (1965), sampling at intervals of only 0·5 cm, also discovered a series of clearances from the post-Neolithic period at Bloak Moss in Ayrshire and Flanders Moss in Perthshire. In Ayrshire, she was able to differentiate between 'small temporary clearances' and 'extensive clearances', and attempted to locate the areas in which clearance was taking place. The absence of studies of the effects of man on the prehistoric landscape in the east of Scotland is perhaps surprising considering the interest shown in the principal upland areas of the rest of the British Isles but analysis is made more difficult by the uncertain nature of the types of forest communities that dominated the landscape here in the period before the immigration of human communities.

Apart from the examination of pollen spectra in the mor humus layers of soils within Abernethy Forest, Invernesshire by O'Sullivan (1973b), there has been scant attention paid in Scotland to the possibilities of soil pollen analysis. Deposits associated with archaeological sites were examined as early as 1939 at Fendoch by Raistrick (Raistrick, 1939) and in 1956 by Godwin at Maes Howe on Orkney (Godwin, 1956b). Durno has contributed analyses of buried soils and peat profiles related to excavations in Perthshire (Durno, 1961-62), Jura (Mercer, 1967) and Angus (Romans, Durno and Robertson, 1973). More recently Pilcher has reported on the pollen content of soils from Dun Mor Vaul on Tiree (1974), Caseldine and Whittington have examined ditch material from the Standing Stones of Stenness on the mainland of Orkney (1975-76) and a buried plough soil from excavations in St. Andrews (Whittington, Caseldine and Bogdan, 1976) and there has been a multidisciplinary approach to paleoenvironmental reconstruction on Orkney (Davidson et al., 1976). In Argyll there has been a combined palynological and pedological analysis of a buried soil associated with field boundaries discovered beneath the Moss of Achnacree (Ritchie, Ritchie, Whittington and Soulsby, 1974), but as yet there has been no concerted effort to combine palynological and pedological analyses at Scottish archaeological sites.

ii) Regional vegetation development

The preceding discussion of the development of pollen analysis in Scotland has served to note the themes adopted by various workers and also to define areas where studies are badly needed. It is only recently that a 'preliminary synthesis' has been made of the Flandrian forest history of Scotland (H.J.B. Birks, 1977), and a collection of papers on the Late Devensian in Scotland has appeared (Gray and Lowe, 1977), but with advances in technique and changes in emphasis the complexity of this history increases. Our knowledge is inadequate not only for particular periods but also for particular areas. Nowhere is this problem more acute than in the lowlands that border the Highland edge from Edinburgh north to Aberdeen. As a background to the study of vegetation history in any new area it is, however, necessary to examine the former regional vegetational patterns as they are at present understood and this is undertaken here.

a) <u>Late Devensian</u>

The study of late Devensian events in Scotland has important implications for Britain as a whole due to the presence of major ice masses in the country during this period. Thus, in a climatic sense, results from Scottish sites should provide some of the best evidence for changing environmental conditions as ice first disappeared during Zone I, and later redeveloped during Zone III (sensu Godwin/Jessen), at the time of the Loch Lomond Stadial. The earliest limnic-terrestrial sediments so far examined and radiocarbon-dated in Scotland from the Late Devensian vary in age from 13151±310b.p. at Loch Ettridge (SRR-304, Sissons and Walker, 1974) to 12510±310b.p. at Drymen in Stirlingshire (HEL-160, Vasari, 1977), but it seems likely that much of the mainland of northern Scotland was ice-free by 13000b.p. (Pennington, 1977a). The opening phase of the climatic amelioration now known as the Lateglacial Interstadial (Gray and Lowe, 1977) or the Windermere Interstadial (Pennington, 1977b), reflects a period of low pollen production with species-rich grassland developed on base-rich parent materials characteristic of recently deglaciated areas. This is represented in pollen assemblages by the presence of Gramineae, Cyperaceae, Chenopodiaceae, Caryophyllaceae, Salix (probably Salix herbacea) and Lycopodium spores. A feature of the vegetation of this period, as in the ensuing early stages of the Flandrian, is the rich aquatic flora which shows a quick response to improving climatic conditions. This sort of assemblage can be found throughout Scotland and adds weight to the idea that the early part of Zone I, although presenting a pollen flora characteristic of open tundra conditions, did in fact see a relatively quick return to temperate conditions with terrestrial vegetation developing more slowly than aquatic vegetation and representing pioneer communities whose composition was associated with edaphic and biotic factors rather than with climate. This is further suggested by fossil coleoptera, for, at Roberthill in southwest Scotland there occurred by 13000b.p. species indicative of mean July temperatures as warm as the present day (Bishop and Coope, 1977), evidence that accords well with coleopteran studies elsewhere in Britain (Coope, 1970, 1975; Coope and Brophy, 1972).

From the palynological evidence it would appear that Scotland as a whole experienced a very similar pattern of vegetation development from grassland communities through Empetrum heath to a dwarf-shrub Juniperus heath and eventually to the establishment of scattered birch copses. The rate and degree of this succession did of course vary with altitudinal, latitudinal and edaphic factors but many sites produce pollen diagrams exhibiting successive peaks for Artemisia, Rumex, Empetrum, Juniperus and Betula with Gramineae, Cyperaceae and often Salix consistently present. There is evidence, however, in the continued presence of such taxa as Artemisia and in the minerogenic character of many limnic sediments, for soil instability, and open communities remained in some areas throughout the interstadial (Lowe and Walker, 1977). The basic zonation of I, II and III representing pre-interstadial, interstadial and stadial as developed originally by Godwin and Jessen has been questioned seriously on several grounds and there is evidence from Scotland for a fundamental dichotomy, not only between different strands of evidence, the floral as against the faunal, but between the same class of evidence for different areas at the same time.

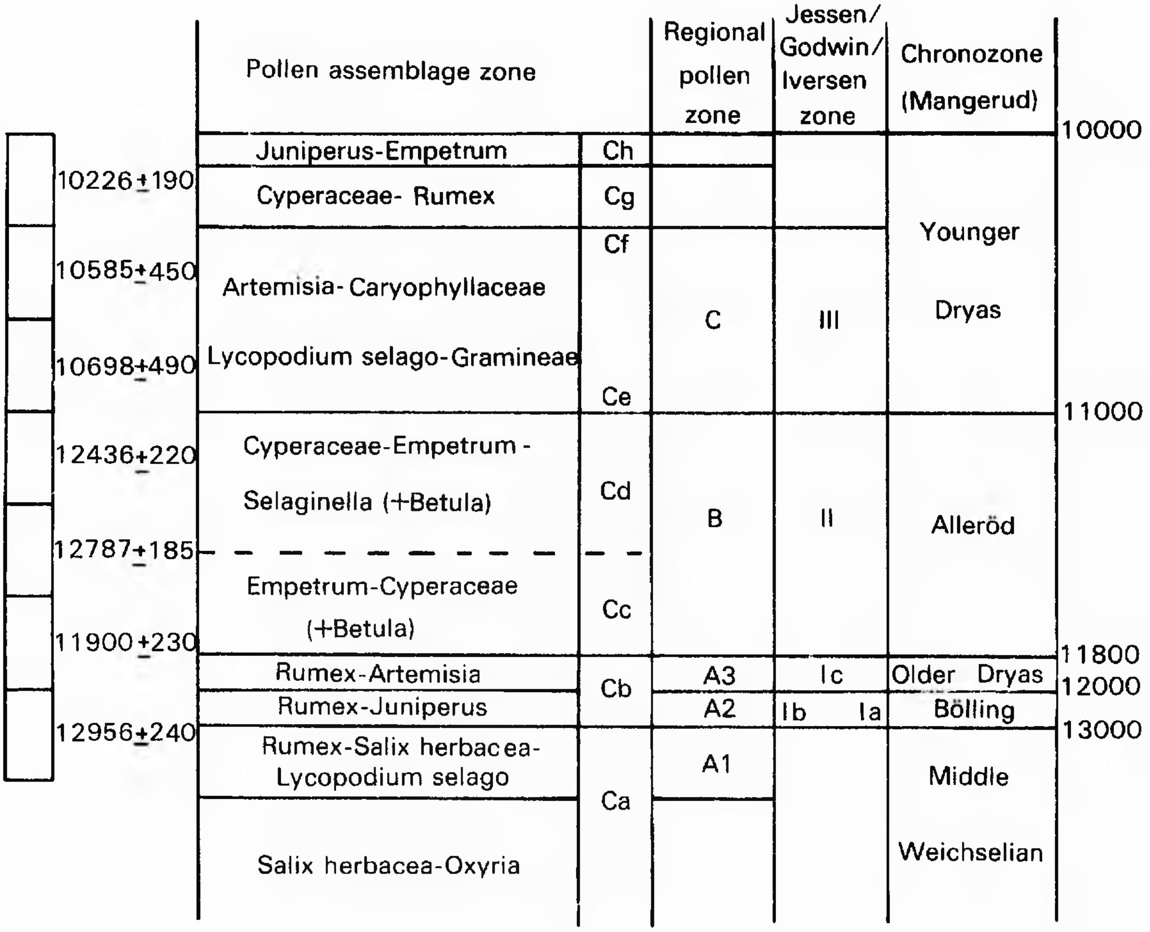
Mention has already been made of the implications of coleopteran evidence with regard to climatic conditions after 13000b.p. Coope, (1975), while confirming the existence of a major climatic oscillation between 13000b.p. and 11000b.p., could find no evidence for any further subdivision of this period and, in contrast to the palynological evidence, suggested a thermal maximum at around 13000b.p. This was followed, just prior to 12000b.p., by a gradual decline in summer temperatures which lasted until 11000b.p. and the onset of the Loch Lomond Stadial period, as seen in the increasing dominance of coleoptera with distinctly northern affinities. The pollen evidence shows a broadly comparable sequence, although in interpretative terms not to the same stage of development, and the succession is consistently slower when measured in radiocarbon years. Coope (1975) accounts for this change as a difference in rates of response between coleoptera and plants as the physical and climatic environment changed rapidly. Without more detailed study of these disparities under experimental conditions such a hypothesis cannot be adequately confirmed, although it seems inherently probable.

There is still some disagreement within the pollen evidence itself as to the nature of the development of vegetation prior to 11000b.p. The period between 13000b.p. and 11000b.p. has been seen as one of continued climatic improvement culminating in the thermal maximum of the Allerӧd between 11800 and 11000b.p., as summarised by

Lowe and Walker,

> "On the basis of radiocarbon-dated pollen profiles from the Grampian Highlands, (we) ...... agree with Birks' concept that vegetational succession and soil development progressed without interruption from about 13000b.p. until the beginning of the Loch Lomond Stadial (1977, p.170-171)."

There is however increasing evidence for a minor recession within this general trend. A radiocarbon-dated absolute pollen profile from Cam Loch, statistically verified (Pennington and Sackin, 1975; Pennington, 1975b), relative pollen diagrams from Loch of Park (Vasari and Vasari, 1968; Vasari, 1977), and Glenshee in eastern Scotland (Walker, 1977), and three other sites in northern Scotland (Pennington et al., 1972) all exhibit a revertence in the pollen record, usually equated with the Older Dryas of continental Europe (Mangerud, Andersen, Berglund and Donner, 1974). At Cam Loch Pennington (1977a) describes the evidence as 'weak but consistent' and points to a slight climatic deterioration within the general trend of increasing warmth throughout the pre-Allerőd period. The pollen evidence for this deterioration is presented in Fig. 2•1 which describes the pattern of vegetation change for all the Late Devensian at Cam Loch. The revertence is characterised by increased values for <u>Artemisia</u> subsequent to the extension of juniper and is approximately dated to 12000b.p., the onset of deteriorating climatic conditions according to the coleopteran studies. The pattern at Cam Loch may be compared to that established for selected sites in the southern Grampians (Fig. 2•2) where a continuous succession has been established. The number of sites at which a pattern similar to that at Cam Loch has been found in Scotland is limited, and Gray and Lowe (1977) have suggested that such a pattern could be related to the collapse of sediments from the edge of basins due to the erosion of



	Pollen assemblage zone		Regional pollen zone	Jessen/ Godwin/ Iversen zone	Chronozone (Mangerud)	
	Juniperus-Empetrum	Ch			Younger Dryas	10000
10226±190	Cyperaceae- Rumex	Cg				
10585±450 10698±490	Artemisia- Caryophyllaceae Lycopodium selago-Gramineae	Cf Ce	C	III		
12436±220	Cyperaceae-Empetrum - Selaginella (+Betula)	Cd	B	II	Alleröd	11000
12787±185	Empetrum-Cyperaceae (+Betula)	Cc				
11900±230	Rumex-Artemisia	Cb	A3	Ic	Older Dryas	11800 12000
	Rumex-Juniperus		A2	Ib Ia	Bölling	13000
12956±240	Rumex-Salix herbacea-Lycopodium selago	Ca	A1		Middle Weichselian	
	Salix herbacea-Oxyria					

Fig.2.1 Late Devensian pollen assemblage zones at Cam Loch (Pennington 1977a)

<table>
<tr><th>SITE</th><th>CAMBUSBEG</th><th>TYNASPRIT 2</th><th>AMULREE 2</th><th>TIRINIE</th><th>ROINEACH MHOR</th><th>BLACKNESS</th></tr>
<tr><td rowspan="6">INTER
STADIAL</td><td>C1a
Gramineae-Salix</td><td rowspan="2">T2a
Rumex-Empetrum-Salix</td><td rowspan="2">Am2a
Lycopodium-Selaginella</td><td>T1
Rumex-Artemisia</td><td rowspan="3">RM1
Rumex-Artemisia-Gramineae</td><td>B1
Gramineae-Rumex</td></tr>
<tr><td rowspan="2">C1b
Rumex-Gramineae</td><td rowspan="2">T2
Empetrum-Betula</td><td rowspan="2">B2
Empetrum-Rumex</td></tr>
<tr><td rowspan="2">T2b
Betula-Juniperus-Gramineae</td><td rowspan="2">Am2b
Cyperaceae-Rumex</td></tr>
<tr><td rowspan="2">C1c
Empetrum-Betula-Gramineae</td><td rowspan="2">T3
Betula</td><td rowspan="3">RM2
Betula-Salix-Rumex</td><td rowspan="2">B3
Betula-Salix-Gramineae</td></tr>
<tr><td rowspan="2">T2c
Betula-Juniperus</td><td rowspan="2">Am2c
Rumex-Cyperaceae-Juniperus-Empetrum</td></tr>
<tr><td>C1d
Betula-Juniperus</td><td>T4
Betula-Juniperus-Empetrum</td><td>B4
Betula-Juniperus</td></tr>
<tr><td rowspan="2">STADIAL</td><td rowspan="2">C1e
Rumex-Cyperaceae-Selaginella</td><td rowspan="2">T2d
Rumex-Artemisia-Selaginella</td><td>Am2d
Cyperaceae-Rumex-Lycopodium</td><td>T5
Rumex-Selaginella</td><td rowspan="2">RM3
Salix-Cyperaceae</td><td rowspan="2">B5
Gramineae-Cyperaceae</td></tr>
<tr><td>Am2e
Artemisia-Rumex-Lycopodium</td><td>T6
Artemisia-Rumex</td></tr>
</table>

Fig.2.2 Late Devensian pollen assemblage zones for selected sites in the Grampians (Lowe and Walker 1977)

these unconsolidated deposits. They believe that the occurrence of any oscillation prior to the Allerőd is unlikely considering the lack of comparable biostratigraphies from sites in the Grampians (Fig. 2•2) where, close to areas of ice accumulation, such an oscillation might be expected to be more clearly monitored. Despite these arguments the presence of absolute pollen evidence for such a phenomenon must cast doubt on some of the relative pollen evidence for its absence. However, the "complex mosaic of plant communities and extremely variable soil depths and degree of stability" (Gray and Lowe, 1977) presented a landscape within which responses to climatic change on such a scale as that experienced in Scotland during the Late Devensian varied greatly from site to site with relevant thresholds rarely overcome.

The degree of vegetation development attained during the Lateglacial Interstadial, essentially during the equivalent of the Allerőd, varied throughout Scotland. In the Northwest at Cam Loch there is no concrete evidence for the existence of tree birches, only juniper appearing in scattered groups within dwarf-shrub heath and grassland. In contrast, in the coastal areas of Aberdeenshire there were scattered copses of birch with possibly even some pine (Vasari and Vasari, 1968), and in the southern Grampians, on purely palynological grounds, Lowe and Walker (1977) suggest a similar picture with birch in the valley floors and a closed grassland with juniper and dwarf birch and willow on sheltered slopes. On Skye the existence of birch woodland is indicated by both palynological and macrofossil evidence at one site, Loch Meodal (H.J.B. Birks, 1973a). It seems likely that juniper, willow and dwarf birch were the dominant features of the vegetation of Scotland during the optimal climatic conditions of the Lateglacial Interstadial within closed grassland or ericaceous dwarf-shrub communities, and that, in agreement with the contention of Pennington (1970), the maximum extent of birch woodland lay to the south in the Lake District. Continued soil instability cannot be ruled out for higher slopes as seen in the continuous curves for Artemisia and Caryophyllaceae at several sites e.g. Amulree 2, Cambusbeg (Lowe and Walker, 1977).

Indications of a severe climatic deterioration after 11000b.p. are to be found in both the floral and faunal records. Pollen diagrams in general show a revertence to low pollen production and the virtual exclusion of all trees, shrubs and aquatic species, the latter accompanied by a change in deposits from organic to minerogenic sediments. At many sites the Loch Lomond Stadial is represented by very high frequencies for Artemisia and the appearance of species associated with instability in soils, those characteristic of the earliest sediments from the Lateglacial Interstadial. The climatic revertence was severe enough to see the recrudescence of glaciers in Scotland (Sissons, 1967) and at sites within the limits of the Loch Lomond Stadial the period is represented by thick, coarse minerogenic sediments. Outwith the ice, conditions varied according to such factors as snow depth and insolation, and these differences are reflected in variable frequencies for Artemisia and Rumex (probably including Oxyria) between sites, and in the presence or absence of Juniperus and Salix.

b) Flandrian

The base of the Flandrian is defined where there is a consistent rise in values for Betula with the gradual reduction in the presence of species characteristic of open ground habitats. Despite the variability of the available information and the somewhat uneven distribution of pollen work throughout Scotland an attempt can be made to summarise the history of Scottish vegetation for the Flandrian period as it is at present understood. A representative series of the principal analyses of Flandrian deposits is outlined in Fig. 2•3, which is arranged so that sites from the same region are grouped together. (The sites are mapped in Fig. 2•4 which shows the location of all sites mentioned in the text, either directly or indirectly.)

Presentation of the data in this manner suffers from several drawbacks, but it gives an overall impression of the similarities and differences between areas within Scotland. Where possible regional assemblage zones or site assemblage zones have been used, e.g. N.W.S.I.-N.W.S.VI (Pennington et al., 1972), but for earlier studies, zoned according to Godwinian principles, this was not possible. In this case the traditional zone boundaries have been retained but the zones themselves have been redefined as if they were assemblage zones, e.g. Loch Kinord and Loch of Park (Vasari and Vasari, 1968) for which Zone V is defined as a *Betula*-*Corylus* assemblage zone. The main weakness of the diagram as a tool for comparing different sequences is the inferred time scale. Where zone boundaries have been dated these have been included and are defined with bold lines, but the dates of many boundaries are interpolated and in the case of those sites interpreted in terms of Godwinian zones, zone boundaries are dated according to Godwin (1956a). These boundaries are defined by dashed lines. For most Scottish sites these dates are probably inaccurate, but in the absence of radiocarbon-dates they provide the only possible reference points. The main benefit therefore of using the diagram is as an illustration of the sequence of vegetation change, rather than as a chronology.

1) Vegetation development before 5000b.p.

The climatic amelioration which caused the end of the Devensian

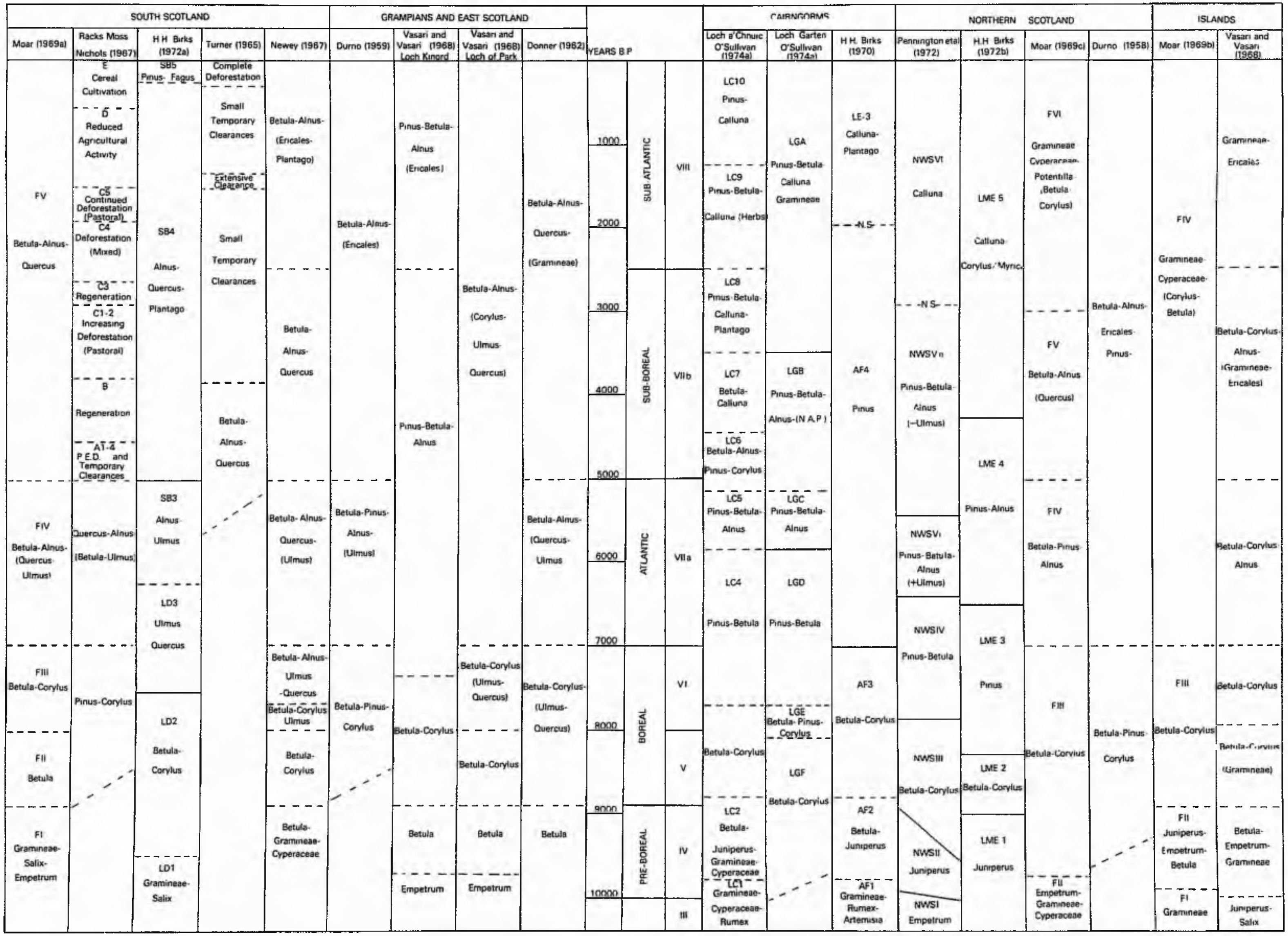


Fig.2.3 Summary diagram of Flandrian pollen assemblage zones for Scotland

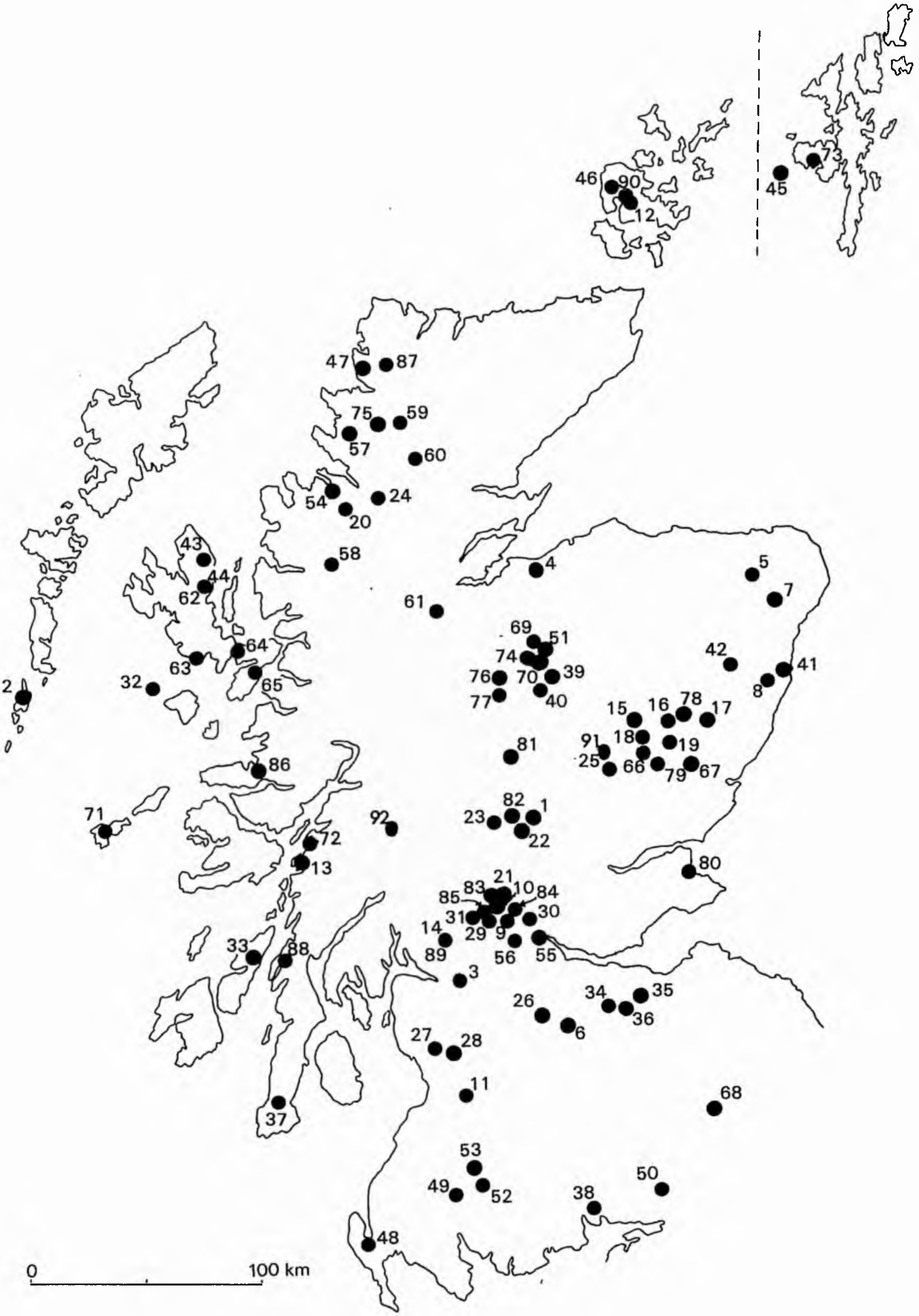


Fig.2.4 Location map of pollen sites in Scotland

Key to Fig. 2·4

1. Fendoch (Raistrick, 1939)
2. Barra (Blackburn, 1946)
3. Garscadden Mains (Mitchell, 1952)
4. Kingsteps Quarry (Knox, 1954)
5. Strichen Moss (Fraser and Godwin, 1955)
6. Carnwath Moss (" " " ")
7. St. Fergus Moss (Durno, 1956)
8. Netherley Moss (" ")
9. Flanders Moss, East (" ")
10. Darnrig Moss (" ")
11. Airds Moss (" ")
12. Maes Howe (Godwin, 1956b)
13. Oban (Donner, 1957)
14. Drymen (" ")
15. Monelpie Moss (Durno, 1959)
16. Allachy Moss (" ")
17. Goyle Hill (" ")
18. Muckle Cairn (" ")
19. Laidwinley (" ")
20. Beinn Eighe (Durno and McVean, 1959)
21. Loch Mahaick (Donner, 1962)
22. Loch Creagh (" ")
23. Lochan nan Cat (" ")
24. Loch Droma (Kirk and Godwin, 1963)
25. Dalnaglar (Durno, 1965)
26. Peelhill (" ")
27. Bloak Moss (Turner, 1965)

Key to Fig. 2·4 (continued)

28. Kennox Moss (Turner, 1965)
29. Flanders Moss (" ")
30. Kippen (Newey, 1966)
31. Flanders Moss, West (" ")
32. Canna (Flenley and Pearson, 1967)
33. Jura (Mercer, 1967)
34. Kitchen Moss (Newey, 1967)
35. Side Moss (" ")
36. Upper Keddleston Valley (" ")
37. Aros Moss (Nichols, 1967)
38. Racks Moss (" ")
39. Carn Mor (Pears, 1968)
40. Loch Einich (" ")
41. Loch of Park (Vasari and Vasari, 1968)
42. Loch Kinord (" " " ")
43. Loch Cuithir (" " " ")
44. Loch Fada (" " " ")
45. Foula (Hawkesworth, 1969)
46. Yesnaby (Moar, 1969a)
47. Duartbeg (" " b)
48. Little Lochans (" " c)
49. Nick of Curlywee (" ")
50. Bigholm Burn (" ")
51. Abernethy Forest (H.H. Birks, 1970; H.H. Birks and Mathewes, 1978)
52. Snibe Bog (H.H. Birks, 1972a)
53. Loch Dungeon (" ")
54. Loch Maree (" " b)
55. Bield (Brooks, 1972)
56. Homesteads (" ")

Key to Fig. 2·4 (continued)

57. Loch Sionascaig (Pennington et al., 1972)

58. Loch Clair (" " ")

59. Loch Borralan (" " ")

60. Loch Craggie (" " ")

61. Loch Tarff (" " ")

62. Loch Fada (H.J.B. Birks, 1973a)

63. Loch Coir' a' Ghobbainn (" ")

64. Loch Cill Chroisd (" ")

65. Loch Meodal (" ")

66. Corrie Clova (Caseldine, 1973)

67. Dalladies (Romans et al., 1973)

68. Din Moss (Switsur and West, 1973b)

69. Loch Garten (O'Sullivan, 1974a)

70. Loch a' Chnuic (" ")

71. Tiree (Pilcher, 1974)

72. Achnacree (Ritchie et al., 1974)

73. Murraster (Jonansen, 1975)

74. Loch Pityoulish (O'Sullivan, 1975)

75. Cam Loch (Pennington, 1975a)

76. Loch Ettridge (Walker, 1975a)

77. Drumochter (" ")

78. Blackness (" " b)

79. Roineach Mhor (" ")

80. St. Andrews (Whittington et al., 1976)

81. Tirinie (Lowe and Walker, 1977)

82. Amulree (" " ")

83. Cambusbeg (" " ")

84. Tynasprit (" " ")

85. Mollands (Lowe and Walker, 1977)

Key to Fig. 2·4 (continued

86. Claish Moss (Moore, 1977)

87. Lochan an Smuraich (Pennington, 1977a)

88. Drimnagall (Rymer, 1977)

89. Drymen (Vasari, 1977)

90. Stones of Stenness (Caseldine and Whittington, 1975–76)

91. Corrydon (Walker, 1977)

92. Kingshouse 1–3 (Walker and Lowe, 1977)

glaciation produced a fundamental change in the basic environment of Scotland, for, with the disappearance of the ice of the Loch Lomond Stadial, between 11000b.p. and 10300b.p., plants such as *Artemisia* and *Rumex*, which had flourished on the unstable soils of the tundra landscape disappeared as a more stable soil and vegetation cover developed. Throughout Scotland the Early Flandrian is characterised by a transition period between Zones III and IV (Vasari and Vasari, 1968) with successive peaks of *Empetrum* and *Juniperus* preceding the expansion of *Betula*. The dominance of *Empetrum* heath, composed of both *Empetrum nigrum* and *E. hermaphroditum*, during the early stages of the climatic amelioration is considered to be an important element in the vegetation succession of oceanic northwest Europe (Iversen, 1954), although claims made by Jessen (1949) for the extent of *Empetrum* heath in Ireland are now thought to have been exaggerated due to his failure to identify *Juniperus* pollen (Watts, 1963). The succession in northwest Scotland (Pennington et al., 1972) is similar to that of the central Grampians (Walker, 1975b), the sequence of *Artemisia* - *Rumex* - *Empetrum* - *Juniperus* at the end of the Late Devensian and the beginning of the Early Flandrian mirroring the succession from the pre-interstadial to the interstadial, the pattern of the early Lateglacial Interstadial. Vasari and Vasari (1968) found great variability in values for *Empetrum* between Loch Kinord on Deeside, which had very high values, and sites in Skye, at Drymen in Strathclyde and on the Aberdeenshire coast, which had low values. They agreed with Iversen (1954) that the distribution of *Empetrum* is largely determined by edaphic factors, its preference for acidic soils, not by oceanicity. *Empetrum* is known to be a poor disperser of pollen, despite its high pollen production (H.H. Birks, 1970), so it may be dangerous to generalise from what are normally low frequencies of its pollen. In Galloway (H.H. Birks, 1972a), although

Empetrum is present, the dominant vegetation type before the expansion of Juniperus was a species-rich grassland comparable to communities now found on steep, flushed sites below cliffs, usually above 700 m (2300 feet), where they are subject to a fairly prolonged snow cover (McVean and Ratcliffe, 1962). The survival and depth of snow cover is also thought by Bell and Tallis (1973) to affect the success of Empetrum so it is possible that the distribution of Empetrum heath in Scotland during the Early Flandrian was dependent on this factor as much as on soil acidity.

The importance of the expansion of juniper has in the past been underestimated due to the difficulty in identifying its pollen in the fossil state, but it has now been recognised throughout the country (e.g. Vasari and Vasari, 1968; Moar, 1969b; H.H. Birks, 1970, 1972a, 1972b; O'Sullivan, 1974). Its development as a plant of wide edaphic tolerance and quick maturation has now been traced all over northern Europe.

> " ...... the peak in the Juniperus curve is widely regarded as an important reference level in the early Postglacial marking a transition stage in the development from the open habitat vegetation of the late-glacial to the closed forests of the Postglacial climatic optimum." (Walker, 1975, p.278, from Iversen, 1960)

The belief that the appearance of Juniperus was more marked in the west than the east (Vasari and Vasari, 1968; Pennington et al., 1972) is difficult to substantiate because its pollen production is influenced by its growth form and flowering (H.J.B. Birks, 1973b). The increase in Juniperus pollen was not necessarily due to its immigration, for it probably represented a change from prostrate Juniperus communis L. ssp. nana, which was known to be present during the Stadial

(Walker, 1975a), to a more erect form allowing greater flowering and pollen dispersion above the snow cover (Iversen, 1954). There are few dates for the rational limit of Juniperus, i.e. the point at which its curve begins to rise to sustained high values (Smith and Pilcher, 1973), and often it cannot be separated from the rational limit of Betula in radiocarbon years (Fig. 2·5), but there appears to be a similarity between the dates for both Irish and Scottish sites which range from c10100 to 9500b.p. The date for Din Moss in Roxburghshire of 10337±200b.p. (Q-1078 Switsur and West, 1973, 1976) is, however, one of only a few dates for northern Britain occurring before 10000b.p. This shows a difference of up to 1000 years between events here and in northern Scotland where, at Loch Sionascaig, the mid-point of the Juniperus rise has been dated to 9474±160b.p. (SRR-15 Pennington et al., 1972), but it agrees well with the date of 10254±220b.p. (Q-955) at Lochan Coir A'Ghobhainn on Skye (H.J.B. Birks, 1973a) which has been used as evidence for the persistence of birch on the island throughout the period of the Loch Lomond Readvance. At Cam Loch (Pennington, 1975a) the date of 10226±190b.p. (SRR-247) which marks the first organic deposition above the Stadial clay was calculated from a sample which included the rational limit for Juniperus and hence it may yet be that the date at Sionascaig is late.

With the dominance of Juniperus the formerly flourishing Empetrum heaths were severely restricted and only survived at higher altitudes just as juniper itself was to be affected by the subsequent immigration of tree birches. Wetter areas were probably dominated by willow scrub, with the pollen of shrub willow appearing as the dwarf variety, Salix herbacea, disappeared. The species-rich grasslands of the transition period between Zones III and IV were also severely reduced (H.H. Birks, 1972a). The expansion of tree birches saw a reduction in

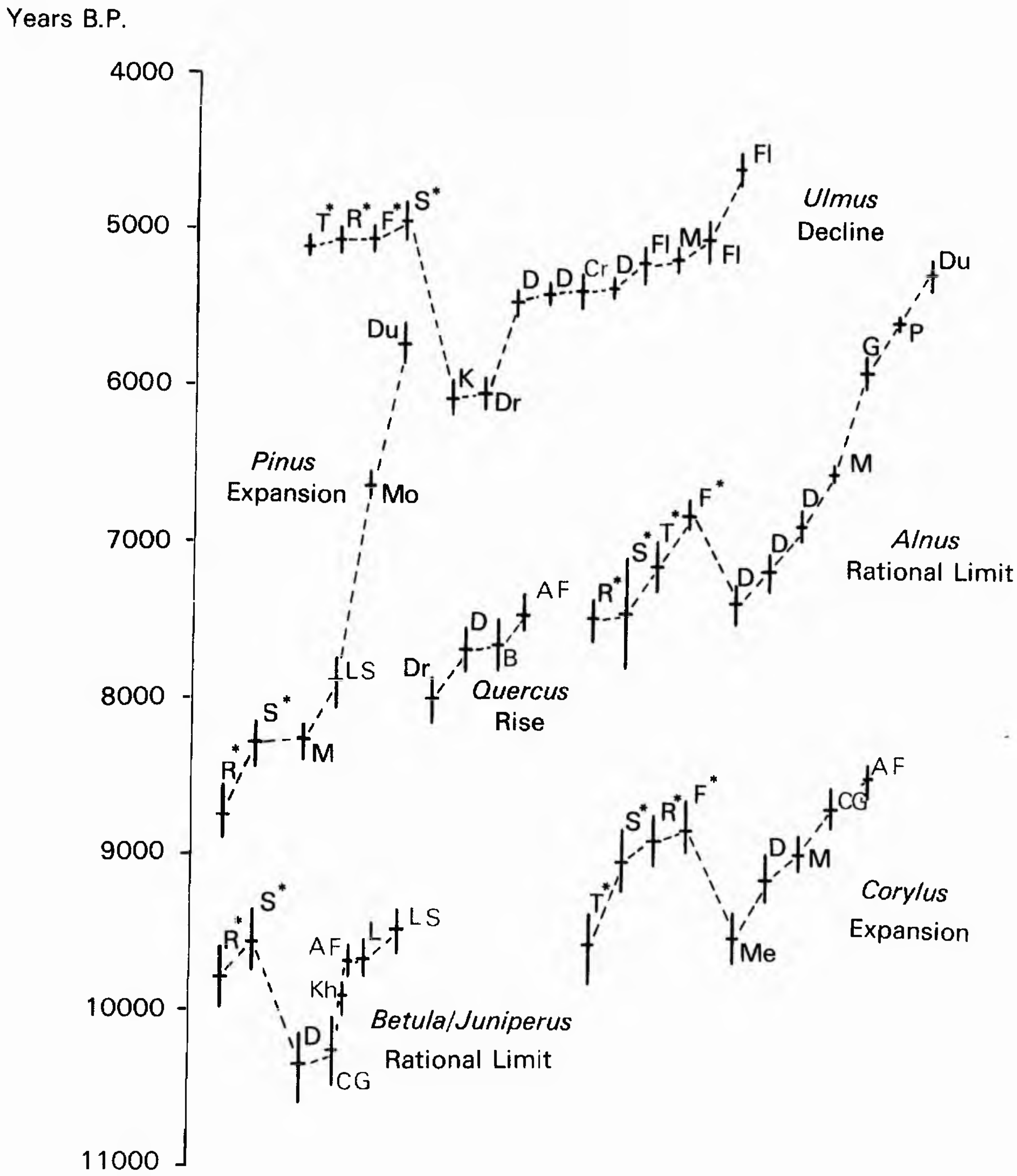


Fig.2.5 Radiocarbon dating of major events in the vegetation record of the Early and Middle Flandrian

Key to Fig. 2·5

S* - Scaleby Moss (Godwin, Walker and Willis, 1957)

Fl - Flanders Moss (Godwin and Willis, 1962)

Du - Duartbeg (Moar, 1969b)

B - Bigholm Burn (Moar, 1969c)

R* - Red Moss (Hibbert et al., 1971)

M - Loch Maree (H.H. Birks, 1972b)

LS - Loch Sionascaig (Pennington et al., 1972)

Cr - Loch Clair (" " ")

T* - Tregaron Moss (Switsur and West, 1972)

CG - Loch Coir'a Ghobhainn (H.J.B. Birks, 1973a)

Me - Loch Meodal (" ")

L - Loch Cill Chroisd (" ")

F* - Nant Ffrancon (Switsur and West, 1973a)

D - Din Moss (Switsur and West, 1973b)

G - Loch Garten (O'Sullivan, 1974a)

P - Loch Pityoulish (" ")

Kp - Knapdale (Switsur and West, 1975)

Dr - Drimnagall (" " ")

Kh - Kingshouse 2 (Walker and Lowe, 1977)

AF - Abernethy Forest (Birks and Mathewes, 1978)

(* denotes reference sites from outside Scotland included for comparison) juniper as it was shaded out, for although it can exist under a tree canopy its flowering is reduced and its contribution to the pollen rain would have been swamped by that of Betula (Vasari and Vasari, 1968). Overall, the transitional phase between the Late Devensian and the Flandrian has been estimated at 300 to 500 years (Pennington and Bonny, 1970).

In northern Scotland at Loch Maree the expansion of Betula occurred at 8951±120b.p. (Q-1009 H.H. Birks, 1972b) almost 900 years after the same event at Red Moss in Lancashire (9798±200b.p., Q-924 Hibbert, Switsur and West, 1971; Fig. 2·5). Despite the difficulty in separating the rational limits for Betula and Juniperus a pattern of dates for the development of the first real woodland is emerging. At Loch Clair a date of 8910±130b.p. (I-4872 Pennington et al., 1972) appears to confirm the evidence from Loch Maree while in the Central Grampians, on the basis of unpublished data from Loch Kinord, Walker (1975a) suggests that birch became dominant between 9500 and 9000b.p. The seemingly early date of 9655±150b.p. (Q-959 H.J.B. Birks, 1969) from Loch Cill Chroisd on Skye would be in keeping with the evidence from Bigholm Burn in southwest Scotland (Moar, 1969c), dates once thought to be too young, and would also appear to raise the question of whether Betula immigrated from the south or from local refugia, for it was thought to be locally present during the Allerød. Betula, almost certainly Betula pubescens Ehrh., became established throughout Scotland by c9500b.p., even reaching the islands to the north and west of the mainland. Arboreal pollen, predominantly Betula, reached values in excess of 50 per cent of the total land pollen at Yesnaby on the Mainland of Orkney (Moar, 1969a), and there is macrofossil evidence for tree birches on the island. Few authors comment on the nature of the community in which Betula was dominant, but it does appear that, as the woodland became increasingly dense, those species characteristic of the open conditions of the Late Devensian and Early Flandrian gradually disappeared. The increasing warmth of the period can be traced at several sites by the change in sedimentation from minerogenic to organic as soils developed and the ecosystem stabilised. This protocratic stage of increasing warmth and shade (Iversen, 1958) appeared throughout Scotland, except in the northwest where the arrival of birch was so late that, at Lochs Sionascaig and Clair, it expanded almost simultaneously with Corylus (Pennington et al., 1972) lengthening the transitional phase. In the northwest in the thousand years between the cessation of low level solifluction and the arrival of tree communities, Pennington et al. have suggested that, there was considerable leaching with the development of an acid humus leading to a retrogressive, rather than a progressive vegetational development.

The effect of an early and prolonged period of leaching can be seen in the difficulty Corylus avellana had in establishing itself in northern Scotland, as elsewhere it spread rapidly from the south. As with Betula and Juniperus, the rise in pollen frequencies of Corylus was a response to the increasing warmth of the Flandrian, notably a reduction in spring frosts and relatively high summer temperatures (H.H. Birks, 1972a), but its pattern of distribution was strongly related to edaphic factors, showing a preference for base-rich soils (H.J.B. Birks et al., 1975). The extremely rapid immigration of hazel has been a matter for debate as to the mechanism involved and the reasons for its absence in certain locations, e.g. Skye (H.J.B. Birks, 1973a), during the Allerød. This has recently been the subject of comment by Rymer (1977) who argues for a hazel refugia in Western Scotland during the Devensian on the basis of the appearance of Corylus/Myrica pollen either contemporaneous with, or prior to, the expansion of *Juniperus* in the Knapdale area. The solution of these problems is of course further complicated by the similarity between the pollen of *Corylus* and *Myrica*, a plant characteristic of bog environments, particularly in the west, as few analysts attempt to distinguish between the two taxa. On Skye the range of dates for the expansion of *Corylus*, usually the opening of the *Betula*-*Corylus* assemblage zone, varies from c10200b.p. at Loch Meodal and Loch Fada to 9200b.p. at Lochan Coir a Ghobhainn (Fig. 2•5). The implications of such a range are uncertain, but the possibility of local edaphic or micro-climatic effects predominating over general climatic conditions, within an area close to a possible refugia, cannot be ruled out. Elsewhere in Britain the empirical limit for *Corylus*, that point at which it first consistently appears, is often found well before the rational limit, suggesting that the sudden explosion in values marked by the rational limit could be related to a climatic threshold. At sites as far distant as Din Moss in Roxburghshire and Loch Clair in Western Ross dates for the rational limit of *Corylus* are very similar, 9120±170b.p. (Q-1075 Switsur and West, 1973) and 9030±140b.p. (I-4967 Pennington et al., 1972) respectively; while at Din Moss *Corylus* had first appeared in the pollen record as early as 9824±190b.p. (Q-1077). Variations in the success of *Corylus* within the Central Highlands indicates the influence of broad climatic gradients rather than local factors. Walker (1975a) discovered much lower values for hazel at Loch Ettridge and Drumochter than appeared south of the main Grampian watershed, supporting the earlier views of both Durno (1956) and Donner (1962) who suggested that the importance of hazel in the early forest cover lessened considerably north of the watershed. In southwest Scotland Moar (1969b) only recovered very low frequencies for hazel and even these varied greatly from site to site. On fertile soils in suitable climatic conditions Corylus could well have developed as pure stands, but over large areas, especially of Speyside, Deeside and the southern Grampians it seems to have appeared as a component of mixed, at first rather open, Betula-Corylus woodland. The continuous high frequencies for birch throughout this period seem to negate the idea that it was prevented from regenerating by a Corylus canopy as advocated by Iversen (1960).

Another important arboreal species of the Early Flandrian was probably aspen, Populus tremula L., whose presence has been underestimated due to the susceptibility of its pollen grains to destruction during sedimentation (Sangster and Dale, 1961). Grains of Populus have though been found in Early Flandrian deposits from Speyside (O'Sullivan, 1974a) and Skye (H.J.B. Birks, 1973a).

Thus, by 9000b.p., much of Scotland had experienced similar patterns of vegetation development leading to the establishment of birch, hazel or birch-hazel woodland, as Moar (1969b) concludes,

> "The transitory nature of the early Flandrian vegetation, emphasised by Godwin (1956a) and Walker (1966) is clearly illustrated ...... although the rate of change varies considerably ......" (p.463)

The period between 9000 and 7000b.p., the Boreal period of Zones V and VI, was characterised by the immigration of those tree species, both deciduous and coniferous, that were to constitute the forests of the later Atlantic period. In most parts of Scotland, Betula, which had already been present for almost a thousand years, remained well represented, and, in parts of eastern Scotland, it is thought to have been the dominant arboreal species. However, " ...... it appears that birch was probably a major forest tree only in north and eastern Scotland at 5000b.p., presumably where pine was not dominant."

(H.J.B. Birks et al., 1975a, p.91) The immigration of *Pinus sylvestris* L. and its competition with *Betula* and *Corylus* poses the same sort of problem as those set out for the immigration of the earlier species. In comparison with southern Britain, where *Pinus* preceded *Corylus*, Scotland generally shows *Pinus* arriving much later. At Abernethy, the arrival of *Pinus* has been given an interpolated date of c7000b.p. (H.H. Birks, 1970), whereas established pine forest around Loch Garten has been dated to 7585±335b.p. (UB-852 O'Sullivan, 1975). In northwest Scotland *Pinus* values increase at Loch Maree at c8250b.p. (H.H. Birks, 1972b) and at Loch Sionascaig at 7880±160b.p. (Y-2364 Pennington et al., 1972). Although the difference between dates for northern and southern Britain may be explained by the slow immigration of pine as a result of the low success rate of seedlings more than 100 yards from the source tree (McVean, 1963), this fact alone cannot account for the variability in the Scottish dates (Fig. 2·5), especially on Speyside. The Speyside evidence has recently been explained by the prevalence of lowered lake levels between 8000 and 6000b.p., causing a break in sedimentation at many sites, particularly in marginal, shallow environments (O'Sullivan, 1975). The effect of this would have been to show an apparent rapid increase in pine as sedimentation increased after 7000b.p. masking the true picture of the gradual spread of pine forest. There is some support for this hypothesis from the Lake District (Pennington, 1970) and East Anglia (Godwin, 1956a), but the majority of sites show no evidence of such an environmental change. The increase in *Pinus* pollen usually took place at the expense of either *Betula* or *Corylus*, especially the latter. In the Abernethy Forest it appears that *Corylus* was successfully ousted on well-drained soils due to the advanced state of leaching providing base-deficient soils suitable for pine. The same argument has been used to explain the success of *Pinus* elsewhere. Pennington et al. (1972) have, for instance, suggested,

> " ...... a gradual and non-synchronous replacement by pine-birch of birch-hazel woods on both upland and poorer soils in northern England and Scotland, as these soils deteriorated, between c6000 and 5000b.p. ......" (p.280)

At Loch Maree the rise in *Pinus* percentages is accompanied by increased evidence of waterlogging and the appearance of species indicative of acidic soils, such as Ericaceae, a further example of the retrogressive nature of vegetational change in this area.

By 5000b.p. pine forest dominated an area from the northern Grampians and Cairngorms towards Ross and southwest Sutherland (H.J.B. Birks et al., 1975a), a distribution comparable to the proposed natural extent of pine forest at present as postulated by McVean and Ratcliffe (1962). The limit of *Pinus* dominance to the south was marked by the watershed on the southern side of the Dee valley (Durno, 1959), but outside the area pine was still locally dominant (Caseldine, 1973) and certainly present at higher sites in the Grampians (Donner, 1962). During the Boreal period Scottish forests reached their maximum altitudinal limit, which in the Cairngorms was thought to be at 2600 feet (793 m) (Pears, 1968), and it is likely that pine or birch would have been growing up to this level. The evidence for such high level forests comes mainly from pine stumps embedded in peat which have been of interest to botanists and geologists since the middle of the nineteenth century. Geikie (1865) studied these deposits extensively and developed a system of glacial and inter-glacial phases, equating the periods of peat growth with glacial conditions and the pine stumps with inter-glacial conditions, which was subsequently modified to system of post-glacial phases by Lewis (1905, 1906, 1907, 1911).

Samuelsson (1910) sought to bring the Scottish chronology into line with the work of Blytt and Sernander in Scandinavia who argued for alternating wet, oceanic, and dry, continental cycles in the post-glacial. By this method pine stumps of the Upper and Lower Forestian and the peat layers of the Upper and Lower Turbarian were equated with the Sub-Boreal, and Boreal, and Sub-Atlantic and Atlantic periods respectively. This rather simplistic model was disproved by the radio-carbon-dating of several pine stumps from the Cairngorms (Pears, 1969), but only after an initial interpretation of the evidence, without dates, in agreement with the earlier hypothesis (Pears, 1968). Pine stumps in peat from outside areas of former pine dominance have also aroused interest and produced similar results in terms of dates scattered through the Middle Flandrian and H.H. Birks (1975) concludes,

> " ...... that no simple climatic model can be proposed to explain the geographical and temporal distribution of the pine stumps ...... and that those remains, particularly pine stumps, cannot be used as direct evidence of climatic change without a detailed modification of their palaeoecological circumstances." (p.222)

These results tend to confirm the general diachroneity of events in Scotland, emphasising the local effects of latitude, altitude and site characteristics, but by looking at places where a clustering of dates occur, as in the case of tree stumps between 4000 and 4500b.p. and between 6000 and 7500b.p. (Fig. 2·6), further information regarding the influence of climatic thresholds overcoming local conditions may be forthcoming.

Detailed palynological analyses in Scotland have concentrated on areas of pine forest rather to the detriment of the other forest types which became established during the Middle Flandrian. Although

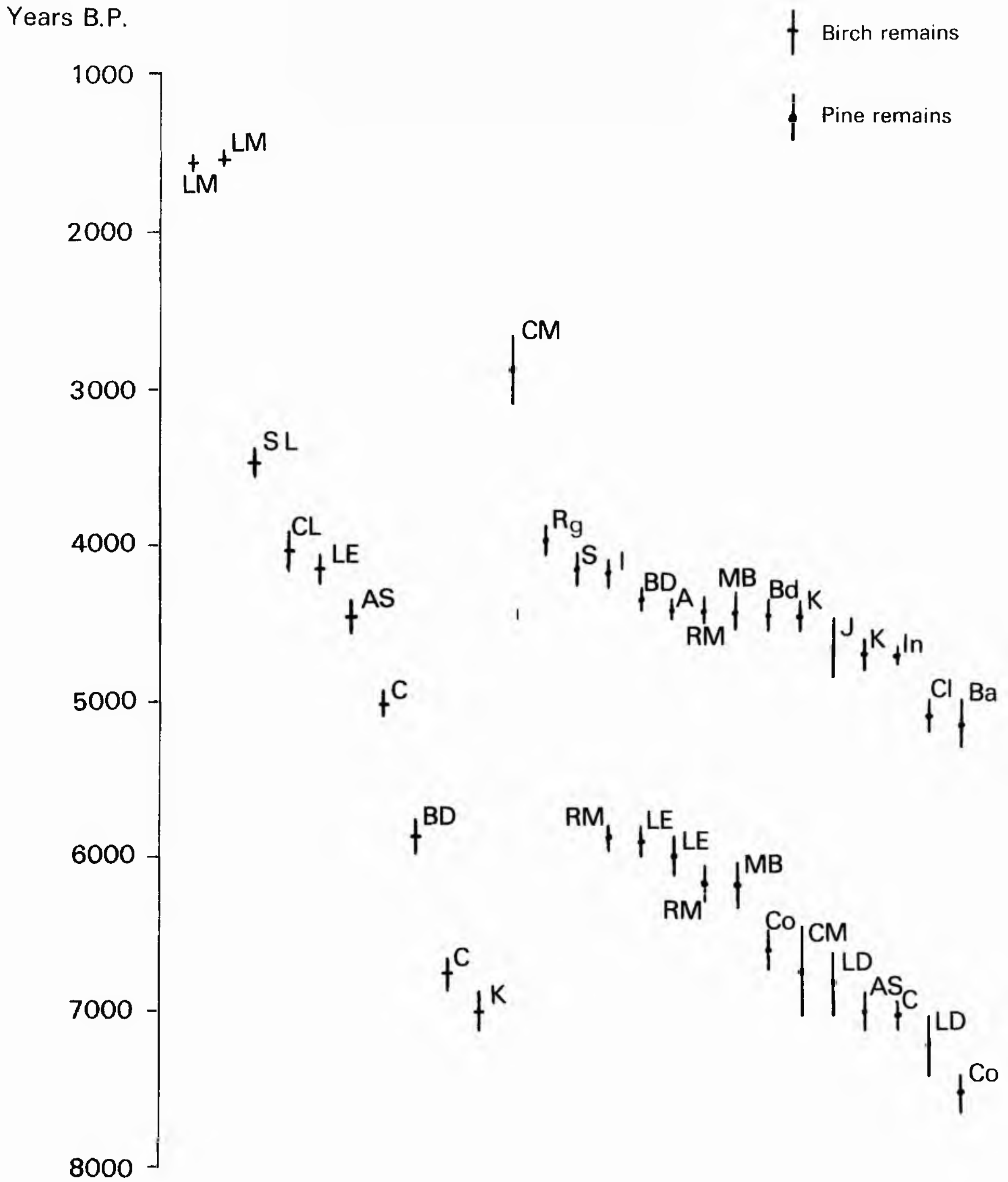


Fig.2.6 Radiocarbon dating of tree remains in peats (H.H.Birks 1975)

Key to Fig. 2·6

Bd - Badentarbert Lodge (Callow, Baker and Pritchard, 1963)

Cl - Clatteringshaws Loch (Moar, 1969c)

Co - Cooran Lane (" ")

LD - Loch Dungeon (" ")

CM - Carn Mor (Pears, 1969)

SM - Sgor Mor (" ")

J - Jean's Hut (" ")

LS - Loch Sionascaig (Pennington et al., 1972)

LE - Loch Einich (H.H. Birks, 1975)

AS - Allt na Feithe Sheilich (" ")

CL - Coire Laogh Mor (" ")

C - Coire Bog (" ")

I - Inchnadamph (" ")

In - Inverpolly (" ")

MB - Meall a' Bhuachaille (Pears, 1975)

Ba - Bans of Bynach (" ")

LM - Loch Morar (Switsur and West, 1975)

K - Kinlochewe (" " ")

BD - Beinn Dearg (" " ")

Rg - Rogart (" " ")

A - A Mhoine (" " ")

RM - Rannoch Moor (" " ")

birch was widespread in northern and eastern Scotland very little is known about the type of community it formed and there is probably a lack of comparable communities remaining in the same areas at the present time. In large areas of lowland and southern Scotland mixed oak forests developed, but very little is known about their form and extent. The pollen of Quercus and Ulmus usually appears at about the same time in Scottish pollen diagrams but their rational limits vary and in some cases, due to their continued low frequencies, they are not discernible. Both Pinus and Quercus appear at Loch Maree at c8800b.p. (H.H. Birks, 1972b) but despite the proximity of relict oakwoods no real expansion of these species can be traced. In southern Scotland at Din Moss Quercus pollen appears at 8684±170b.p. (Q-1073 Switsur and West, 1973), compared with 9456±200b.p. (Q-822) at Red Moss in Lancashire (Hibbert et al., 1971). Very little may be derived from the few dates available for the rational limit of Quercus in Scotland (Fig. 2·5) because, with the exception of Din Moss, they are all based on very low frequencies. The arrival and spread of oak in Scotland illustrates what H.J.B. Birks (1977) has called "the complex chronology of the early Flandrian forest succession in Scotland".

At present Quercus petraea (Mattuschka) Liebl. is more characteristic of western Scotland and Quercus robur L. of eastern Scotland (Jones, 1959), but it is uncertain which was dominant in the Middle Flandrian as their different pollens cannot be consistently distinguished. An understanding of their northern limits based on their present distributions has been made difficult by planting, but Quercus petraea is known to grow to higher altitudes than Q. robur. The distribution at 5000b.p. (H.J.B. Birks et al., 1975) closely conforms to the present limit of oak woodland suggested by McVean and Ratcliffe (1962), a limit based largely on a July mean of 13°C, as greater cold limits the ability of oak to flower.

The rational limit for Ulmus glabra Hudson has yet to be dated in Scotland but it is commonly found in association with Quercus, expanding at the same time on many diagrams. Its distribution was affected by both climatic and edaphic factors and the relationship between values of this pollen and rich soils derived from base-rich parent materials is very noticeable by 5000b.p. (H.J.B. Birks et al., 1975a). The importance of oak and elm has been underestimated due to the lack of analysed sites in lowland Scotland and such questions as whether they existed in predominantly moist oakwood or dry oakwood (Anderson, 1967) remain largely unanswered, except in Galloway (H.H. Birks, 1972a). When high values of Ulmus occur they tend to be found at upland sites (H.H. Birks, 1972a), a feature explained by Pennington (1970) as due to the ability of steeper slopes to retain a higher base status. Tilia was never more than a scattered member of the mixed oak community. Its natural northern limit at present lies in the Lake District, although it might have been native in Galloway between Zones VI and VIII (Godwin, 1975a).

The area of the Midland Valley and the coastal lowlands of Scotland available for woodland growth during the Boreal was severely reduced by the main Flandrian marine transgression. The onset of this transgression is estimated on the basis of radiocarbon dates from both the eastern and western coasts to have occurred between 8000b.p. and 7000b.p. (Fig. 2·7). Closer definition of these dates is difficult because they mainly derive from peats buried beneath marine or lacustrine deposits and many of these may have been truncated by the transgression. It is only where pollen evidence of the transition from terrestrial to estuarine conditions has been dated that an accurate date and altitude for a particular transgression is possible (Newey,

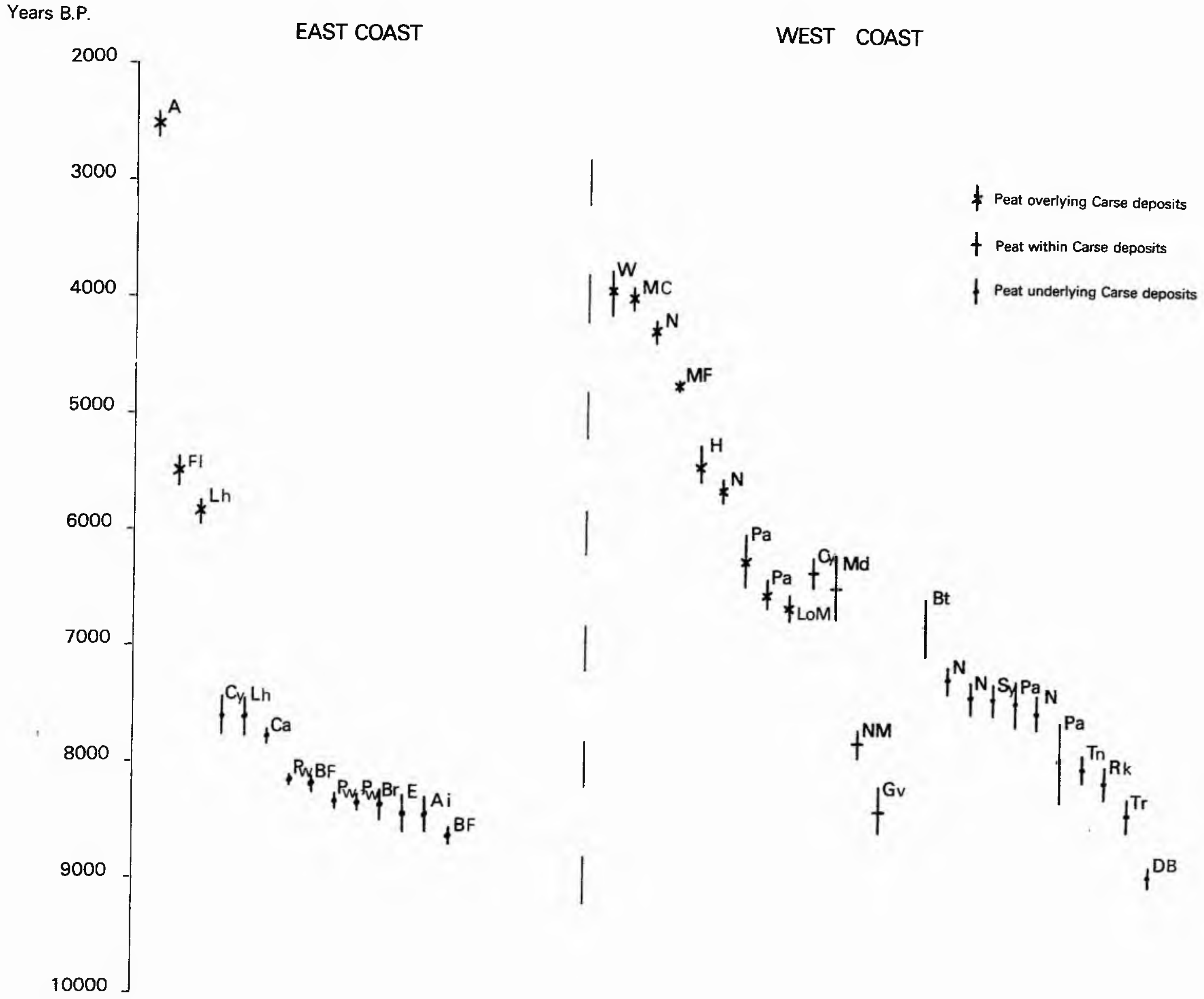


Fig.2.7 Radiocarbon dating of the Main Postglacial Marine Transgression in Scotland

Key to Fig. 2·7

Br - Broombarns (Godwin and Willis, 1961)
E - Eastfield of Dumburney (" " ")
Ai - Airth (" " ")
Fl - Flanders Moss (Godwin and Willis, 1962)
LoM - Lochar Moss (" " ")
Rk - Redkirk Point (" " ")
Sy - Sandyknowe (Baxter, Ergin and Walton, 1969)
Cy - Carey (Callow and Hassall, 1970)
W - Woodside (Shotton and Williams, 1971)
Pa - Palnure (" " ")
Gv - Girvan (" " ")
Tr - Turnberry (" " ")
Ad - Aberlady (Welin, Engstrand and Vaczy, 1972)
Lh - Leuchars (" " " ")
Tn - Troon (" " " ")
N - Newbie Cottages (Buckley and Willis, 1972)
NM - Newbie Mains (Ergin et al., 1972)
DB - Dundonald Burn (" " ")
Mc - Moss of Cree (Buckley, 1973)
Ca - Carsemichael (" ")
MF - Muirfad Flow (Harkness and Wilson, 1973)
Md - Midtown (Shotton and Williams, 1973)
Bt - Battlehill (" " ")
H - Horseholm (" " ")
Pw - Powgavie (Harkness and Wilson, 1974)
BF - Burnside Farm (" " ")

1966, Brooks, 1972). The same problem occurs in reverse in trying to date peat overlying the carse deposits of the transgression, but sea levels were probably falling again by 6000b.p. at the latest.

A further marked event in Scottish vegetation history is the arrival of Alnus glutinosa (L.) Gaertn. (Fig. 2·5). The timing of its arrival is difficult to determine but research into the factors affecting the dispersal of alder (McVean, 1956; Tallantire, 1974) has proved a useful ecological background against which the fossil evidence may be evaluated. At Din Moss there is a double alder peak, the mid-points of which have been dated to 7146±120b.p. (Q-1070) and 6708±100b.p. (Q-1071 Switsur and West, 1973) respectively. In north-west Scotland the rational limit for Alnus has been used to define the boundary between zones NWSIV and NWSVi (Pennington et al., 1972) and has been dated at Loch Sionascaig to 6250±140b.p. (Y-2363) and at Loch Clair to 6520±145b.p. (I-4813). From these dates it is apparent that alder was no slower in spreading through Scotland than any other species. Although its fruits are sometimes water-borne the predominantly east-west drainage system did not prove a significant barrier to its expansion (McVean, 1956). Dates obtained for the rational limit of Alnus on Speyside seem therefore to be anomalous. Loch Garten has produced a date of 5860±100b.p. (UB-851) and Loch Pityoulish 5548±50b.p. (Lab. no. unknown), a situation explained by the persistence of pine-birch forest during a period of lower water levels with alder only increasing as the water table rose (O'Sullivan, 1975). It is quite possible that such discrepancies in the dates may be a function of comparing different phenomena, for the increase in pollen frequencies at its rational limit in southern Scotland is far more distinct than the low fluctuating frequencies found on Speyside. The traditional view of the position of alder in the Middle Flandrian forest has been expounded by both Tansley (1939) and Pennington (1970),

> " ...... we may picture the flatter lowlands of post-glacial Britain as studded with lakes and meres bordered by wide stretches of swamp, marsh and fen which were probably largely occupied by alderwood ...... " (Tansley, 1939, p.460)

> " ...... there must have been considerable general extension of alder as a streamside tree and as hillside alder woods on flushed soils ...... " (Pennington, 1970, p.63)

This view has been challenged by Dimbleby (1978) who has proposed that alder only requires adequate water, not necessarily a waterlogged site, the sort of conditions to be found commonly within the dense forest of the Middle Flandrian.

Although Hilary Birks' view of an 'overall equilibrium' between the forest components of Galloway between 7000b.p. and 5000b.p. may be a little optimistic in terms of its duration when applied to other regions, there is no doubt that by 5000b.p. Scotland was covered by a dense, internally stable mosaic of forest communities, as indeed was most of Britain, a situation which occurred as,

> " ...... a polyclimax rather than a monoclimax situation ...... in which the local conditions of altitude, aspect, drainage and geology could determine variation from the broad climatic climax ...... " (Godwin, 1975a, p.65)

There is abundant archaeological evidence for the existence of Mesolithic communities on both southwestern (Mercer, 1970) and south-eastern coasts (Coles, 1971), but virtually no pollen evidence of any interference with the vegetation cover. In southwest Scotland at Aros Moss in Kintyre (Nichols, 1967) there is a possible indication of forest modification by fire preceding 5000b.p., but there is no firmly dated evidence here, or elsewhere in Scotland, for any

Mesolithic clearances.

The picture of the development of Scottish vegetation from the end of the Late Devensian to 5000b.p. is one where the sequence of communities and the immigration of major species has been established (see Table 2•1 for a summary of Flandrian forest succession by Moore, 1977), albeit with different chronologies for different regions. However, the internal community structure and the reasons for changes in the vegetation patterns, such as the importance of particular thresholds, are still unclear.

2) Vegetation development after 5000b.p.

The changes in vegetation distributions after 5000b.p., the time covered traditionally by Zones VIIb and VIII, developed as a result of the interplay between natural and anthropogenic forces. Few pollen analysts have looked at these changes in Scotland in any detail, as may be quickly discerned from Fig. 2•3. Inadequate sampling or the unsuitable nature of the evidence make the detection and interpretation of anthropogenic influences difficult. As H.H. Birks has commented,

> " ...... the activities of man accelerate vegetational changes so much that separate events are no longer easily detectable in slowly accumulating deposits." (H.H. Birks, 1970, p.843)

In many parts of Scotland there is no clear difference between the vegetation either side of 5000b.p. but because of a drop in what were in many cases only low frequencies of Ulmus pollen the VIIa/VIIb boundary was inferred (see Fig. 2•3), Durno, 1959; Newey, 1967. It is true however that, from various dates after 5000b.p. there has been steady deforestation with increasing frequencies for Gramineae, weed species and Calluna. The varied nature of the fluctuations in the pollen curves makes zonation very difficult without very close sampling and also makes it impossible to decide with certainty whether such

TABLE 2·1

Sequences of tree pollens as indicators of variations in Scottish regional vegetational history (after Moore, 1977)

Group	Tree Pollen Sequence
A	Betula/Pinus – Betula/Pinus/Ulmus/Quercus – Alnus/Ulmus/Quercus/Betula – Alnus/Quercus/Betula
B	Betula/(Pinus) – Betula/Pinus/Ulmus/Quercus – Alnus/Ulmus/Quercus/Pinus/Betula – Alnus/Betula Pinus/Quercus
C	Betula/(Pinus) – Pinus/Betula
D	Betula/(Pinus) – Pinus/Betula – Pinus/Betula/Alnus/(Ulmus) – Pinus/Betula/Alnus
E	Betula – Betula/Pinus/Quercus – Betula/Pinus/Quercus/Alnus – Betula/(Quercus)/(Alnus)
F	Betula – Betula/Pinus/(Quercus)/(Ulmus) – Betula/Alnus/(Pinus)/(Quercus)/(Ulmus)

*Brackets indicate low frequencies of the species concerned.

changes were natural or anthropogenically initiated. Neither Durno (1956) nor Donner (1962) felt able to identify the VIIb/VIII boundary from their analyses but Vasari and Vasari (1968) suggested that indications of extensive deforestation and/or an increase in ericaceous species could be used to identify the onset of the climatic deterioration, the decreasing warmth and increasing precipitation of the Sub-Atlantic. The emphasis of much early work which sought to extend Godwinian zonation into Scotland was to establish the onset of the Sub-Atlantic, exemplified by the spread of heather moorland and bogs, and the increased representation of birch in the forest communities (Fraser and Godwin, 1955; Godwin, 1956a). The influence of man as an agent of vegetation change was recognised (Durno, 1956) but not rigorously examined (Durno, 1965).

The regional differences in both the type and stability of the vegetation cover were of paramount importance in determining the sort of changes which would occur should man disturb the forest ecosystem. In northwest Scotland " ...... the 3000B.C. horizon is the latest at which a regional change ...... is detectable" (Pennington et al., 1972), the change being a distinct transition into the telocratic phase of increasing acidity and podsolisation with the development of blanket bog (Iversen, 1958). The sedimentary record of Loch Sionascaig shows an increase in iron and manganese transported in solution which has been interpreted, in association with the pollen evidence, as indicative of accelerated peat formation due to waterlogging of the thick humus which covered most of its catchment. This then reduced the habitats suitable for pine and over the next 2000 years much of this region reverted to moorland and bog. There is evidence from the pollen record at Loch Clair for the influence of man as early as 5360±110b.p. (I-4874), but the overall changes in northern Scotland were thought to be predominantly natural. A cuntinuous curve for Plantago lanceolata does not appear here until 2900b.p. At Loch Maree a similar development may be traced, although P. lanceolata was present at the time of the Elm Decline (H.H. Birks, 1972b). Values for both Pinus and Quercus decrease slowly but Betula remains relatively constant and, unlike sites in the Lake District where there is a rapid inwash of material into some lakes as a result of clearances by prehistoric communities, the sedimentation rate does not change, providing further evidence for a basically natural vegetation reversion. No study has yet been made of other factors influencing the onset of blanket peat in Scotland as a whole, unlike the situation in Northern Ireland or Wales where Goddard (1971) and Moore (1973) have attacked this problem. At Badentarbet and Strath Oykell blanket peat was already forming by 5000b.p. (Pennington et al., 1972) as was probably the case in the eastern Grampians (Durno, 1959), but at lower altitudes in the west peat initiation took place much later. At the Moss of Achnacree near Connel in Argyll, over 2 m of peat has accumulated since 2930±80b.p. (N-1468, Ritchie et al., 1974) but even at this altitude it is not clear whether man was the chief agent of peat initiation.

Percentages of Ulmus pollen are generally low in Scotland but even with figures of less than five per cent of the arboreal pollen count absolute pollen frequencies have shown "a numerically significant fall in the absolute pollen deposition of Ulmus ...... just before 3000B.C." (Pennington, 1973, p.96). This is taken as a reflection of the synchronous decrease in Ulmus pollen found throughout Britain at this date, but although this is "the most extensively dated horizon in the British post Glacial" (Smith and Pilcher, 1973, p.910) there are few dates for Scotland (Fig. 2·5). In Galloway the first drop in the elm curve has been dated to 5080±100b.p. (Q-878 H.H. Birks, 1972a), comparable to the date of 5150±65b.p. at Loch Maree (H.H. Birks, 1972b) and the bracketing dates for Flanders Moss of 5192±120b.p. (Q-578) and 4570±120b.p. (Q-577 Turner, 1965). At Din Moss the onset of the Elm Decline starts as early as 5441±70b.p. (Q-1064 Switsur and West, 1973) and in the west, Drimnagall and Knapdale have produced even earlier dates, but based on very low elm frequencies. In much of Scotland low elm frequencies make the identification of the Elm Decline difficult and hence there is little sound evidence on which any general interpretation of this phenomenon may be made.

At Snibe Bog in Galloway there is a fall in *Ulmus* pollen at c5000b.p. which is followed by a period of low elm frequencies and then the later appearance of such species as *Plantago lanceolata*, *Artemisia* and *Rumex*, accompanied by a rise in Gramineae (H.H. Birks, 1972a). This pattern conforms well with the idea of a Primary Elm Decline and ensuing landnam phase as interpreted from deposits of this date in Lancashire, e.g. Thrang Moss (Oldfield, 1963). The same pollen sequence has also been found near Snibe Bog at Loch Dungeon (H.H. Birks, 1972a). After this sequence of selective utilisation of elm preceding limited forest clearance there is in Galloway a period of overlapping 'small temporary clearances' (sensu Turner, 1965) representing the effects on the forest of a shifting, mainly pastoral economy. There is then a change, seen in large decreases in the contribution of tree pollens, to the first 'extensive clearances' (sensu Turner, 1965), when much larger areas of forest were cleared, again for mainly pastoral purposes. This started the progressive, complete deforestation of this area, for later periods of abandonment only resulted in slight forest regeneration and many trees, e.g. *Quercus*, never recovered to their former frequencies. None of these episodes has been dated so that their timing and duration are unknown, although inferences have been made from the known archaeological chronology. Nevertheless, from the pollen record alone it is possible to decipher clearances taking place on different scales, both temporal and spatial, all having an effect on the progressive deforestation of Galloway, one noticeable feature being the inability of many tree species, elm in particular, to recover their position in the forest community which existed before 5000b.p. Interference with the forest equilibrium in this area of oceanic climate almost certainly caused a reduction in soil fertility severely reducing conditions suitable for forest regeneration.

Further detailed analyses of the effects of man's interference with the vegetation of the Late Flandrian have been carried out at Racks Moss, near Dumfries, and at Aros Moss in Kintyre (Nichols, 1967). The Elm Decline here appears as two distinct drops in value and the later one is accompanied by the appearance of Plantago lanceolata, another example of a Primary Elm Decline with a later landnam. This is followed by a pattern of small scale clearances prior to 'a considerable period' of forest regeneration, but elm never regained its pre-Elm Decline position in the forest. There is the suggestion of crop raising from a second period of clearances which terminated in forest regeneration associated with peat of a reccurrence horizon thought to represent the Grenz Horizont of RYIII at c800-400B.C. (Godwin, 1960). The interpretation of this form of agriculture is based largely on the presence of Cereal pollen grains with only low values for pastoral indicators. A feature of both diagrams investigated by Nichols is the appearance of Matricaria type pollen which was believed to have been associated in North Lancashire with "agricultural activity in post-Christian times" (Nichols, 1967, p.183, Oldfield and Statham, 1963).

The most detailed interpretations of anthropogenically induced clearances have been undertaken for Central Ayrshire by Turner (1965, 1970, 1975) using several neighbouring sites, all closely sampled. At Bloak Moss and Kennox Moss she identified 'six small temporary clearances' occurring between 1875±110b.c. (Q-727) and a.d.415±90 (Q-722), on the basis of peaks in the curve for Gramineae, <u>Pteridium</u> and <u>Plantago lanceolata</u>, and a corresponding decrease in arboreal pollen. The short duration of these clearances, possibly the results of an economy based on shifting agriculture, is underlined by the fact that these clearances were dated to 1220±105b.c. (Q-724), 1100±105b.c. (Q-725) and 1270±105b.c. (Q-723) respectively, showing that the technique of radiocarbon-dating and its associated standard error (as defined at the time of sampling) could not separate these events. Furthermore, a short phase of 'extensive clearance' has been established for both Flanders Moss in Perthshire and Bloak Moss, bounded by dates of a.d.415±90 (Q-722) and a.d.580±90 (Q-72a). After a.d.580 there was forest regeneration with only spasmodic small clearances occurring prior to complete deforestation by the eighteenth century.

By carrying out pollen analyses on the humus layers of mor soils O'Sullivan (1973b) has been able to trace the more recent ecological history of the Forest of Abernethy. The analysis of several dated profiles showed, perhaps surprisingly, that,

> " ...... in the Dark Ages and later, a dynamic relationship between forest and moorland existed with perhaps several vegetation changes occurring in any one part of the Forest over the last 1500 years ...... " (O'Sullivan, 1973b, p.270)

These results emphasise the potential of the use of such techniques in Scotland, especially in areas of 'relict' forest, and clearly reflect the human factor in recent vegetation history.

H.J.B. Birks (1977) has commented that,

> "Forest clearance was extensive from about 5000b.p. but detailed palynological investigations in relation to the local archaeological history are required before man's influence on the woodland can be fully elucidated." (p.127)

For much of eastern and central Scotland such studies have yet to be carried out. Work from Ayrshire and Perthshire (Turner, 1965) have shown changes which are almost certainly anthropogenic in origin, but have also shown the difficulties involved in understanding the duration of these effects and hence the actual sequence of events. The retrogressive nature of vegetation change in Scotland as a whole, especially in upland areas, seems nevertheless to have been the result both of human and natural influences, the balance between them being perhaps largely determined by the status of the vegetation communities prior to the interference of human groups. The northwest to southeast gradient, apparently so important in determining the development of vegetation in the Early and Middle Flandrian, is just as noticeable in the Late Flandrian, but it remains to be seen whether such a feature is the result of assumptions made on the basis of the evidence of either too few sites or of sites from atypical environments.

CHAPTER THREE

SURFACE POLLEN ANALYSIS STUDY AT BANKHEAD MOSS

i) Approaches to surface pollen analysis

> "The impressive successes of European analysts in duplicating pollen sequences over broad areas has tended to preoccupy investigators there with searching for and interpreting minor differences in the pollen sequences, to find evidence for climatic change, human disturbance of the landscape, disease or other factors. The basic principles of ecological pollen analysis have not been extensively tested." (Wright, 1967, p.222)

Before identifying the community or groups of communities represented by fossil pollen spectra it is necessary clearly to understand the relationship between pollen production and its accumulation in various deposits, yet it is in this area that pollen studies have long been deficient. The 'basic principles of ecological pollen analysis' on which the technique is based are, as yet, poorly understood. The idea of a homogenous mix of pollen forming an atmospheric pollen rain which either settles out or is washed out by rain is a long recognised over-simplification which masks the true complexity of pollen dispersal and deposition, and it is only by examining the present day relationships between origin, dispersal and deposition of pollen that a clearer understanding of the meaning of fossil pollen assemblages will emerge. In a previous chapter the discussion of the problems inherent in the interpretation of pollen assemblages and changes in pollen frequencies thought to be related to human interference underlined the inadequacies in our understanding of pollen deposition and accumulation, particularly when considering the evidence from bogs rather than lakes. It was with this problem in mind that the experiment outlined here was set up to investigate pollen transfer onto the surface of a raised bog. Previous studies using the pollen evidence provided by traps, moss polsters or surface soil have taken many forms, each looking at slightly different aspects of either pollen production or pollen dispersal and their relative merits have been discussed in several papers (Wright, 1967; Walker, 1972; Crabtree, 1975). Here these techniques are considered under three main headings:-

a) Direct correlation with vegetation parameters.
b) Identification of characteristic pollen assemblages.
c) Dispersal and collection.

a) Direct correlation with vegetation parameters

Because of the differential pollen productivity of species it is difficult to correlate pollen frequencies directly with phytosociological parameters. In North America, where there are still areas of 'natural' vegetation in contrast to the greatly disturbed nature of the European flora, attempts have been made, chiefly in forest communities, to discover the relative influences of different tree species in surface pollen assemblages. In Vermont, Davis and Goodlet (1960) correlated pollen frequencies from recent lake mud samples with the basal area percentages of the main tree species within various forest types. From this, they established that certain trees were over-represented, some were under-represented, and others were proportionally represented. These findings were later refined into 'R' values (Davis, 1963), which could be applied to fossil pollen data to give a more accurate representation of the relative importance of individual tree species within the area of study. The 'R' values may be calculated from the following formula:-

$$R_S = \frac{\text{Species s pollen percentage}}{\text{Species s vegetation percentage (basal area covered by species s)}} \qquad 3\cdot1$$

From the application of 'R' values in Minnesota (Janssen, 1966 and 1967a), it became clear that, although the ratios of the 'R' values to the 'R' value of a reference species remained constant, the values themselves varied depending on the region and the overall composition of the forest.

Both Davis and Janssen concentrated on regional vegetation groups for developing a system of 'R' values but their application at a local scale has been demonstrated by Andersen (1967, 1970, 1973) working in the forests of Draved and Longelse in Denmark. Andersen discovered significant correlations between tree pollen deposition and tree crown area for circular plots of a radius of 30 m. From these data, which he presented in the form of a regression equation, he was able to calculate pollen productivity factors which, when normalised to the values of a reference species, provided relative pollen productivity values (P_{rel}). For a consistent pollen sum he used exotic pollen derived from outside the forest as this was shown to be constant throughout the sampling area. Using P_{rel} values and similar figures obtained for relative pollen representation within the forest stands, Andersen suggested his own correction factors which he applied to the interpretation of a pollen diagram from Eldrup Bog in Eastern Jutland. He did, however, emphasise that such correction factors only applied to deposition within the forest and not to deposition within clearings or onto bogs and lakes. Correction factors have been calculated for many species from locations throughout the world (e.g. Tsukada, 1958; Curtis, 1959) and several of these are summarised by Faegri and Iversen (1975, p.185). In Minnesota, McAndrews (1966, 1967) was able to reconstruct the pre-settlement vegetation by comparing the fossil record with quantitative values from the witness tree records of the early land surveyors and modern pollen rain figures. His work also formed the basis on which Janssen (1967b) was able to establish local variations in pollen deposition and detect a regional pollen rain which remained constant for the area of Minnesota under study.

The value of calculating 'R' values or detecting any direct relationship between pollen frequency and species frequency, either by cover area, basal area or crown area, has been in emphasising consistent under-representation or over-representation of certain plants in widely differing areas and assigning quantitative measures to these discrepancies (Iversen, 1947; Potzger and Courtemanche, 1956; Potter and Rowley, 1960). The values themselves are not universally applicable and need to be established for each new site under investigation. They are, at present, also largely restricted to use in forested areas.

b) Identification of characteristic pollen assemblages

> "Where a pollen analysed site is surrounded by a source area composed of clearly defined and contrasted bioscopes, the presence in a particular fossil assemblage zone of phyto-sociologically characteristic taxa with known ecological preferences may allow the pollen analyst to ascribe to the taxa represented, particular habitats within the same area."
> (Oldfield, 1970, p.168)

A second approach to the problem of placing the interpretation of pollen statistics on a more secure footing is to look for analogies between fossil pollen assemblages and those assemblages derived from the vegetation communities they are thought to have represented. As Oldfield states above it is often possible from the pollen record to suggest the type of community or range of communities which existed by the identification of characteristic dominant taxa. The analysis of pollen deposition within these communities today should therefore indicate whether such interpretations are warranted. Although this requires the clear definition and analysis of the vegetation communities to be sampled, it does not entail any direct correlation between phytosociological values and pollen values, it rather requires the elucidation of a representative pollen assemblage.

Analyses of this kind have been carried out at various scales from those covering thousands of square kilometres (Wright, McAndrew and van Zeist, 1967; Lichti-Federovitch and Ritchie, 1968; Ogden, 1969; H.J.B. Birks, Webb and Berti, 1975) to local studies within one small area of forest (O'Sullivan, 1973a). On Skye, H.J.B. Birks (1973a, b) studied a variety of communities from Corylus avellana and Betula pubescens woodland to summit vegetation in order to try and discover assemblages comparable to those present on the island during the Late Devensian. Chosen groupings need not be defined solely on phytosociological grounds for the method has been used considering only broad vegetation categories in an attempt to define different degrees of openness within a predominantly forested area (O'Sullivan, 1973a; O'Sullivan and Riley, 1974). It is also possible to use several scales of enquiry within an area to systematically reduce the vegetation pattern into representative pollen assemblages,

> " ...... our approach is to attempt to characterise large landscape areas in terms of present day pollen spectra, and subsequently to refine the investigations by more intensive sampling with progressively smaller geographical units."
> (Ritchie and Lichti-Federovitch, 1967, p.255)

It is at a local scale that the identification of characteristic pollen assemblages should be of most value but the results from Skye (H.J.B. Birks, 1973b) were not as encouraging as might have been expected, even when pollen counts were expressed as a percentage of a local pollen sum, thus excluding the effects of long distance transport which are commonly discernible in open communities. Evaluation of the usefulness of subjectively derived representative pollen assemblages has been improved by the application of multivariate statistical techniques to test the homogeneity of the groupings established for modern pollen spectra (H.J.B. Birks, 1973b; O'Sullivan and Riley, 1974). The value of the statistical analysis has been to confirm the differences between groups which had previously been explained subjectively and also to confirm or reject suspected within-group homogeneity. In the results from Skye for instance "there is as much variation in pollen composition in samples from one plant community as there is in samples from different but related communities" (H.J.B. Birks, 1973b, p.166), although at a more general level these communities could be separated into distinctive units.

Any study which purports to identify characteristic pollen assemblages is closely concerned with the problems of dispersal and collection, especially the overlap in pollen deposition between neighbouring communities and there have been several studies which have utilised transects across communities to determine these effects and to discern differences in pollen frequencies between adjacent vegetation types (Jonassen, 1950; Heim, 1962; Mullenders, 1962; Salmi, 1962; Tinsley and Smith, 1974). A by-product of these transect studies has been an increase in data available for defining pollen assemblages within the differing vegetation communities the transects cross. They also show up the representation of individual species under various environmental conditions, especially the under-representation of non-arboreal pollen in forested areas and the variability of pollen deposition in non-forested areas. As Heim concludes,

> "Les pollens d'Artemisia, Plantago et Rumex sont répresentés pratiquement dans tout les placeaux, éloignés des cultures et des prairies, mais les pourcentages sont très faibles et généralement inférieurs que 1%. Quand, dans les analyses polliniques on trouve des pourcentages plus élevés, on peut conclure que le site étudié se trouvait à proximité des établissements humains et des champs." (Heim, 1962, p.87)

These remarks are also borne out by recent work in Finland which looked in some detail at the relationship between agriculture and forest vegetation in the pollen rain of an area of less then four square kilometres (Vuorela, 1973). In a further Finnish study Hicks (1974) used an assemblage approach based on pollen influx values to provide a time-scale for pollen diagrams from shallow peat deposits.

The main drawback in using data from supposedly analogous communities is that there is no guarantee that similar communities existed in either the Late Devensian or the earlier part of the Flandrian, for the successive changes in climatic, edaphic and biotic conditions may well have produced different competitive conditions (Janssen, 1970) and hence different vegetation communities (Iversen, 1954). Although there may be evidence for believing that conditions in the Late Devensian in Britain were comparable to present areas of Alpine or Sub-Alpine vegetation this is questioned by Rymer (1977). There are, however, thought to be few recognisable analogies for the forest communities of the Early and Middle Flandrian in the British Isles. A further drawback to the establishment of pollen assemblages representative of plant communities is that, as with the calculation of 'R' values, unless the assemblages are ascertained at a recognised scale they only represent dispersal and collection within a particular community and do not take account of transport onto bog surfaces or into lake sediments. Nevertheless,

> "Despite these limitations and problems, the comparative approach to the reconstruction of past vegetation from fossil assemblages is considered the soundest basis currently available."
> (H.J.B. Birks, 1973b, p.166)

c) Pollen dispersal and collection

Few analysts have investigated the general concepts underlying pollen dispersal and collection, the 'basic principles of ecological pollen analysis'. Long distance transport of pollen grains is a well documented phenomenon (e.g. Bassett and Terasmae, 1962; Maher, 1963; Ritchie and Lichti-Federovitch, 1967; Tyldesley, 1973a, b, c), but the number of grains transported in this manner rarely contribute significantly to the pollen sum, except in treeless environments with few pollen producing plants. The rapid decline in frequency of occurrence of most pollen types away from their source is another well known feature, notably for various tree species (Ludi, 1947; Turner, 1964; Tinsley and Smith, 1974). Both Federova (1956) and Jensen and Blogh (1942) have demonstrated a severe reduction in the amount of cereal pollen retained in the atmosphere within 300 metres of the source fields. In Ayrshire, using a narrow pine plantation within a moss as an origin, Turner (1964) showed the effects of prevailing wind direction on the distance pine pollen was transported away from the plantation. Although distance varied with wind direction the overall results agreed well with previous observations made by Faegri and Iversen (1964) and Salmi (1962) and the pattern of dispersal remained constant. The decline in pine values with distance (y) could be described by a curve of the form

$$y = a + be^{cx} \qquad 3\cdot2$$

In this equation the constant, a, represents pollen derived from other sources and b, the value of pollen from the local source, is dependent for its value on a function of the distance from the edge of the dispersal point as defined by e^{cx}, where e and c are constants and x is the distance from the pollen source. The effect of the b component is only felt over the first 300-500 metres from the woodland edge after which its values remain virtually constant, but it seems likely that the actual distances quoted from this study may be uncharacteristically high due to the use of pine pollen which is winged and capable of travelling longer distances than other tree pollens. However, these sorts of results are valuable in demonstrating pollen transport within relatively simple, concise vegetation patterns and contribute to the definition of a 'pollen source area' which yet remains "neither well defined nor properly speaking definable except in general terms on the basis of each individual site." (Oldfield, 1970, p.170)

Following the rather involved ideas of Firbas (1949) regarding the relative representation of pollen from varying distances away from the sampling site, Janssen (1966) suggested a simple, flexible model in which he divided the pollen sum at any one point into three components, local, extralocal and regional. From Fig. 3•1 it can be seen that local pollen values are always high but will change from site to site, as environmental conditions alter. The part of the curve describing the influence of regional pollen is almost parallel to the abscissa reflecting its constant nature. The transitional part of the curve represents the contribution of extralocal pollen whose values, while higher than those of the regional components, do not locally change to the same extent as local pollen. It is the proportion of

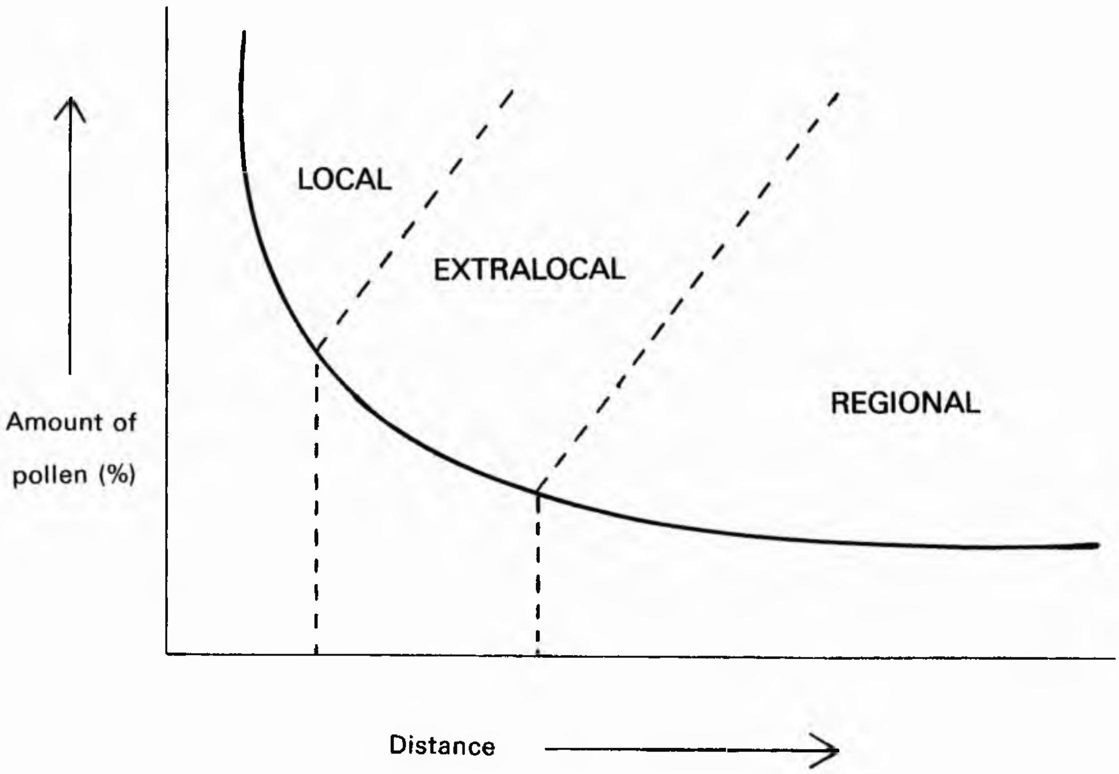


Fig.3.1 Pollen source areas (Janssen 1966)

the contribution of extralocal pollen which is perhaps the most difficult to identify, for it can vary considerably depending on the sampling site, and it is this which Janssen has tried to isolate by studies in both America and Europe (1966, 1972, 1973).

Perhaps the most important contribution to the study of pollen dispersal has been made by Tauber (1965) who applied data derived for the air transport of small particles to the movement of pollen in forested areas. Tauber recognised three categories of pollen transfer, trunkspace transfer (f_t), above canopy transfer (f_c) and high level transfer or rain out (f_r). The relative contribution of these three components will vary with the size of the collecting basin, from the ratio 8:1:1 ($f_t:f_c:f_r$) for a small lake or bog to 1:2:7 for a very large lake or bog (Fig. 3•2). Tauber also emphasised the importance of the relationship between the time of flowering and the time of leafing of various species as filtration of pollen grains can greatly affect the representation of the surrounding vegetation in a lake or bog. The representativeness of a site would therefore depend not only on pollen dispersal and the relative productivity of species but also on the structure of the vegetation and the wind speed within it. These theoretical ideas were tested in Denmark (1967) where he discovered that 50 per cent of the pollen collected over a small lake derived from the littoral vegetation which had filtered it out during the flowering season. The ideas of Tauber are still not completely accepted as a valid explanation of a complex problem (Faegri and Iversen, 1975), but, along with the work of Janssen, they form the only theoretical basis so far proposed and tested to describe widespread pollen dispersal and collection.

Experimental work using exotic pollen (Ogden, Raynor and Hayes, 1971) or easily traceable pollen from a particular species (Tampieri,

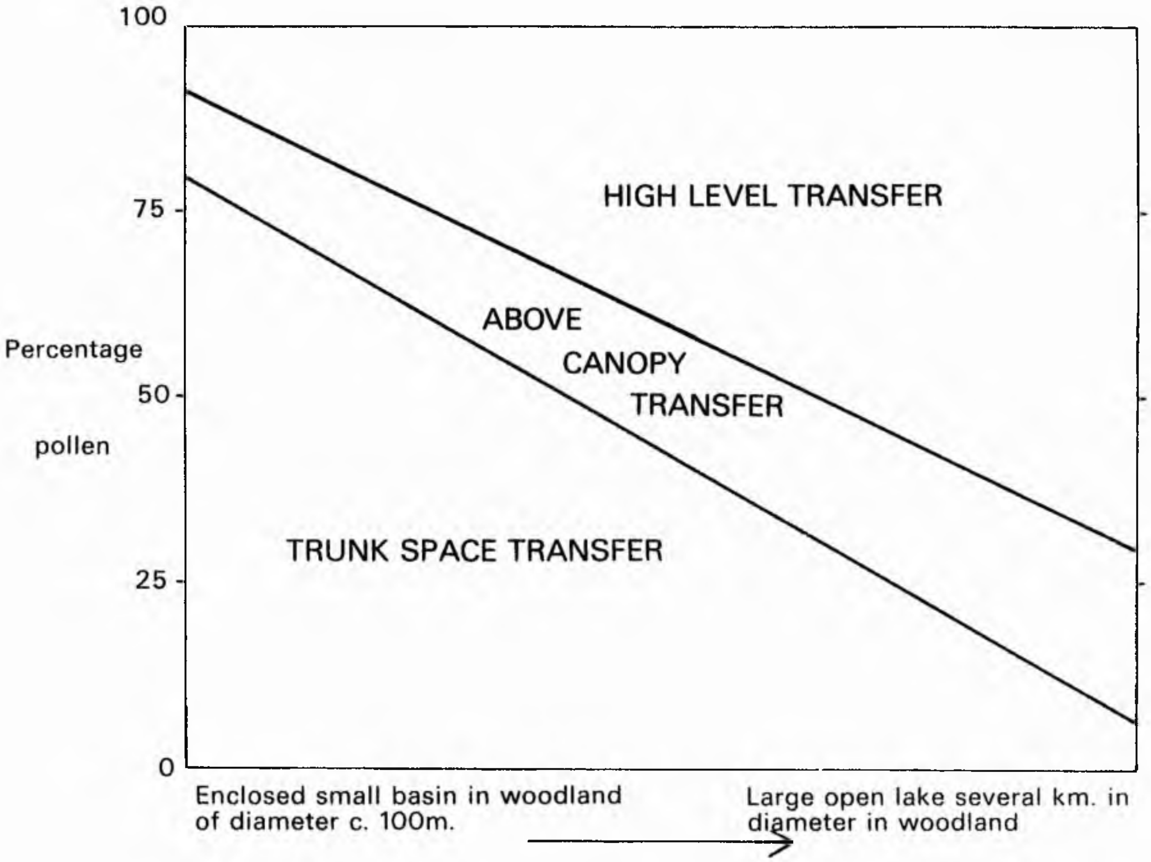


Fig.3.2 Patterns of pollen transfer (Tauber 1965)

Mandrioli and Puppi, 1977) has been of value in testing theories of small particle transfer as they apply to individual pollen grains but there is an increasing need for measurement in absolute terms, in grains deposited per square centimetre per year. This sort of approach requires a much greater time commitment than the use of moss polsters and relative pollen counts, for observations have to be taken over several years to produce results comparable to fossil records.

The increasing use of lake sediments rather than bogs for palynological work, despite the more easily determined source area for bog pollen (Oldfield, 1970), has encouraged investigation into the mechanisms of pollen deposition into lakes (Peck, 1973; Crowder and Cuddy, 1973; Bonny, 1976). The use of air traps over the centre of a reservoir in Yorkshire has shown that only 4-10 per cent of the total pollen reaching the surface mud is directly released from the air and that the assemblage collected in this way differs from that entering the reservoir from its catchment (Peck, 1973). Deposition within lakes will also vary with lake size and morphometry (Pennington, 1973; Berglund, 1973). The problems of delineating the source area for pollen deposited in lakes are, if anything, more complex and less well understood than those associated with pollen deposition in terrestrial sediments.

It is difficult to appraise the relative merits of the many approaches employed which use modern pollen rain studies as an aid to the interpretation of pollen diagrams. In their different ways, they have all contributed to the understanding of pollen dispersal, but few analysts, with the exception of Tauber, have examined the basic principles involved. The valid testing of these principles will require a long period of study, preferably in both forested and non-forested areas. There is however a limit to the extent to which these principles can be applied to the fossil record of the Flandrian and Late Devensian because of the probable difference between present-day environments and those of the past, not only caused by changes of ecology but possibly of physiology in the plant as well. This weakness is inherent in any use of modern pollen rain studies. Because of this, it seems that, perhaps, the best way of gaining an insight into the comparability of past and present vegetation is the comparative approach adopted by H.J.B. Birks (1973a and b), although the danger of equifinality must not be overlooked. As Walker states,

> " ...... it may be possible to infer something about the mechanism by which variations in ...... pollen catches are achieved, but it is rarely necessary to open that particular black box in order to use the result effectively in the interpretation of fossil data." (Walker, 1972, p.100)

This emphasis on the representativeness of the community must be seen in the light of the representativeness of the sites under analysis, a factor which will itself vary over time, but once the nature of the characteristic pollen assemblage of any community at any particular point is known then its influence at a collecting site can be more easily discerned.

ii) Aims of the surface pollen analysis study

The study at Bankhead Moss was designed to investigate jointly the problems of pollen transport onto a bog surface and the recognition of plant communities in terms of their pollen assemblages. Firstly, it was hoped to examine the movement of pollen from a cultivated area surrounding a raised bog onto the bog surface itself to see just how representative the pollen assemblage incorporated in the bog is of the surrounding vegetation. Interpretations of former vegetation patterns rely heavily on the pollen record from terrestrial peats and it is often necessary to assume that they record the presence of species growing some distance from the site. During early periods of land clearance when small clearings would probably have been made in a continuous forest cover, small raised bogs would almost certainly have been separated from the cleared areas by woodland. It is difficult to reproduce such conditions in the present but the choice of a bog surrounded by a mixture of cultivated land and pasture, yet still retaining its own belt of continuous birch woodland, comes close to the postulated prehistoric situation. A further difficulty associated with the attempt to reproduce earlier conditions lies in the vegetation of the bog itself. At Bankhead Moss areas of the peat are suffering from attempts at drainage, and in the main the bog vegetation consists largely of heather and sedges, the bog is not actively developing as might have been the case in a much earlier period. This can however be allowed for by adjusting the pollen sum to exclude the present surface vegetation.

The second aim of the study was to see whether it is possible to identify pollen assemblages characteristic of particular vegetation groupings within such a small area, both on and off the bog surface, or whether the close proximity of different communities produces a rather uniform mix of pollen with no clear cut distinctions. The raised bog at Bankhead does provide a good example of several very different communities existing within only two square kilometres, thus fulfilling Oldfield's requirement of "a source (area) composed of clearly defined and contrasted bioscopes".

Any investigation of present day pollen transfer should, ideally, use as a data base pollen collected by pollen traps measured on an absolute scale over a number of years. In such a small study as this the provision of a large number of traps was not feasible, and the time limitation would not allow for a number of years sampling to even out the effects of freak seasons on pollen collection. The use of moss polsters to determine the pollen rain of several, or at the very least two (Vuorela, 1973), years has been demonstrated by many authors and this approach was adopted here. Indeed Vuorela (1973) comments on some of the difficulties associated with the use of pollen traps to establish a truly representative picture of the pollen rain. In using moss polsters care was taken to avoid possible differential filtering errors (Crowder and Cuddy, 1973). Where there was no moss available for sampling, surface litter or soil was used although this brings into question the comparability of results obtained from different collecting media. In the absence of similar sampling material throughout the experimental area it has to be assumed that results from different media will be consistent.

iii) Study site - Bankhead Moss

The site chosen for analysis was Bankhead Moss in east Fife, a small raised bog only 150 x 80 metres in extent, lying 8 kilometres south-west of St. Andrews and 0•5 kilometres from the village of Peat Inn (NT445101). Due to the disturbance of the margins for peat cutting and the surface for flax retting, and also to repeated attempts at drainage, the bog appears to be drying out although the centre is still waterlogged. Bankhead Moss does however retain the classic dome shape, its centre rising 1•5 metres above the level of the surrounding land and there is a pronounced lagg at the eastern end now colonised by willow carr. Recent work at Bankhead Moss has shown that it still represents " ...... a good example of an oligotrophic, calcifuge habitat in the form of a small raised bog ...... even poorer in species than Ratcliffe's species-poor raised bog type" (Burgess, 1975, p.199).

The bog is encircled by a belt of Betula pubescens Ehrh. of varying thickness with a small plantation of Pinus sylvestris L. on the southern edge, and it is bordered by cultivated land to the north and pasture to the south, east and west (Fig. 3·3). The centre of the bog is treeless, not solely due to its high water content but due to the production of ethylene in the anaerobic conditions inhibiting root growth (Honours Botany Class, 1971).

The present area covered by peat has gradually been reduced in size by draining and the removal of peat to extend surrounding fields. The surface of the peat is pitted with small, Sphagnum covered 'peat pots' or 'lint holes' used for flax retting until the early nineteenth century. Since then they have only been used as a source of Sphagnum for wound dressings during the First World War.

The vegetation of the bog has been described by Burgess (1975) for, although species-poor, it supports an interesting bryophyte flora. The discussion by Burgess was concerned mainly with the treeless central area and the carr, with only a brief comment on the birch woodland and the surrounding areas outwith the peat. In this study it is the dominant species of the area as a whole that is of interest, defining as they do very contrasting communities, and there is little concern with the lower plant forms. Five main vegetation groupings were identified from field survey and aerial photographs. Samples were taken for pollen analysis along three transects (Fig. 3·3) at 10 metre intervals and details of the vegetation at each sample point were noted (see Appendix I). The vegetation categories are outlined below:

1. Pasture (samples A20-31) - this area is dominated by grasses including Agrostis tenuis Sibth., Anthoxanthum odoratum L., Holcus lanatus L. and Deschampsia caespitosa L. Beauv., and represents an irregularly grazed damp meadow. There are also patches of Juncus spp.

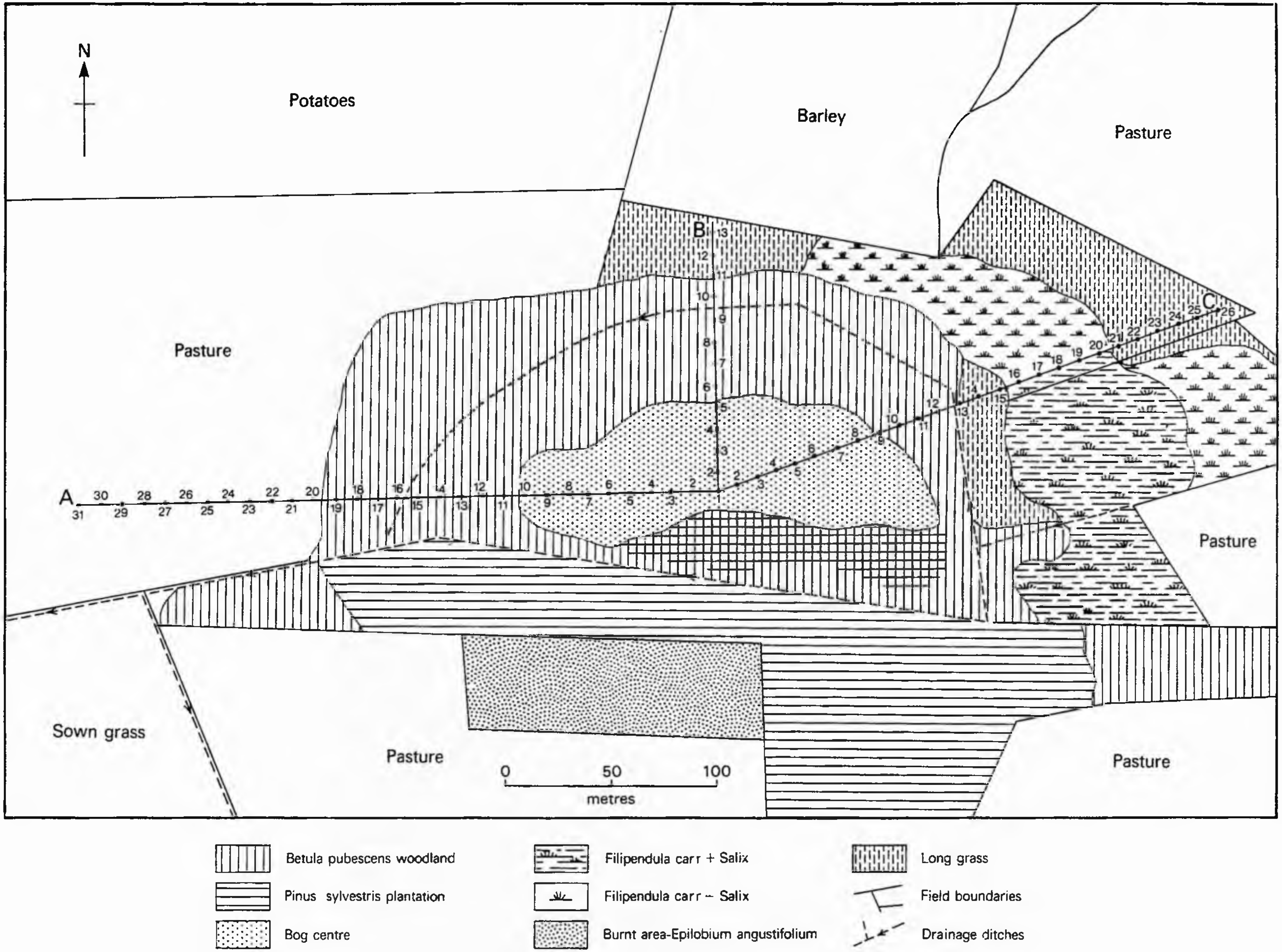


Fig.3.3 Vegetation map of Bankhead Moss

(particularly *Juncus effusus* L.) which become denser away from the edge of the bog towards areas of intermittent open water found in the centre of the field. Other species which occur locally along the transect include *Potentilla erecta* L.Rauschel, *Stellaria graminea* L., *Cirsium arvense* (L.)Scop., *Rumex acetosa* L. and *Bellis perennis* L.

2. *Betula pubescens* woodland (samples A11-19, B6-10 and C9-13) - the woodland is found on the fringe of the bog growing on the peat, which is itself in parts eroding, and has a ground flora of low diversity. Under much of the birch canopy there is a dense layer of *Dryopteris austriaca* (Nat. Conservancy pers. comm.) and locally there are patches of *Calluna vulgaris* L. and *Galium saxatile* L.

3. Centre of the bog (samples A1-10, B2-5 and C2-8) - the treeless centre of the bog is dominated by *Calluna vulgaris* with *Eriophorum angustifolium* Honck., *E. vaginatum* L. and *Erica tetralix* L. around the many 'peat-pots'. The only grass found in the centre is *Molinia caerulea* L.Moench. which is sparse in its occurrence. As stated earlier the vegetation, and particularly the bryophytes, of this treeless central area have been described by Burgess (1975).

4. *Salix*-*Filipendula* carr (samples C16-20) - this lagg area to the east of the bog takes the form of a very dense growth of *Filipendula ulmaria* (L.)Maxim. with occasional trees of *Salix* sp. Within this cover *Cirsium arvense*, *Epilobium palustre* L., *Chenopodium album* L., *Stachys palustris* L., *Ranunculus acris* L., *Deschampsia caespitosa* and *Lolium perenne* L. occur, but nowhere do they dominate. Over the carr as a whole a distinction may be made between areas where willow appears and those where it is absent.

5. Tall grassland (samples B11-13, C14-15 and C21-26) - this category forms the treeless fringe to the bog itself. In the area crossed by transect B it is possible to define a further boundary

isolating areas where Urtica dioica L. is dominant on the boundary of the cultivated field (samples B12–13), but for reasons of scale this is not located on Fig. 3·3. This vegetation category comprises the largest variety of species including Rumex acetosa, Cirsium arvense, Heracleum sphondylium L., Epilobium palustre, Chenopodium album, Senecio jacobea L., Stachys palustris, Trifolium repens L., Lathyrus pratense L., Vicia cracca L. and Centaurea nigra L. It is however largely dominated by Deschampsia caespitosa and Juncus sp. with Holcus mollis towards the woodland edge.

iv) Pollen analysis of transect data

Samples were prepared for pollen analysis as outlined in Appendix II and the results are presented in Fig. 3·4 and Fig. 3·5. The results shown are based on a pollen count of at least 500 grains which includes all land pollen except Pinus. Pinus was omitted from the sum as it was assumed that it derived mainly from the plantation on the southern edge of the bog, an area avoided by the transects, and a factor which could affect the 'natural' pattern of pollen transfer onto the bog, especially as it does in part border the open bog centre. Although occasional grains of Juncaceae were identified in the surface samples they were very poorly preserved and excluded from the pollen sum as they are also highly unlikely to be found in the fossil state. Sampling along the transects in such varying environments necessitated using different sources, in this case moss polsters, litter and surface soil and these are differentiated in Figs. 3·4 and 3·5.

A visual interpretation of the results suggests fairly distinctive pollen assemblages related to the different vegetation categories, assemblages which rely heavily on the dominance of one or more taxa such as Betula, Calluna, Gramineae or Filipendula. Although the arboreal component is largely dominated by Betula it is noticeable

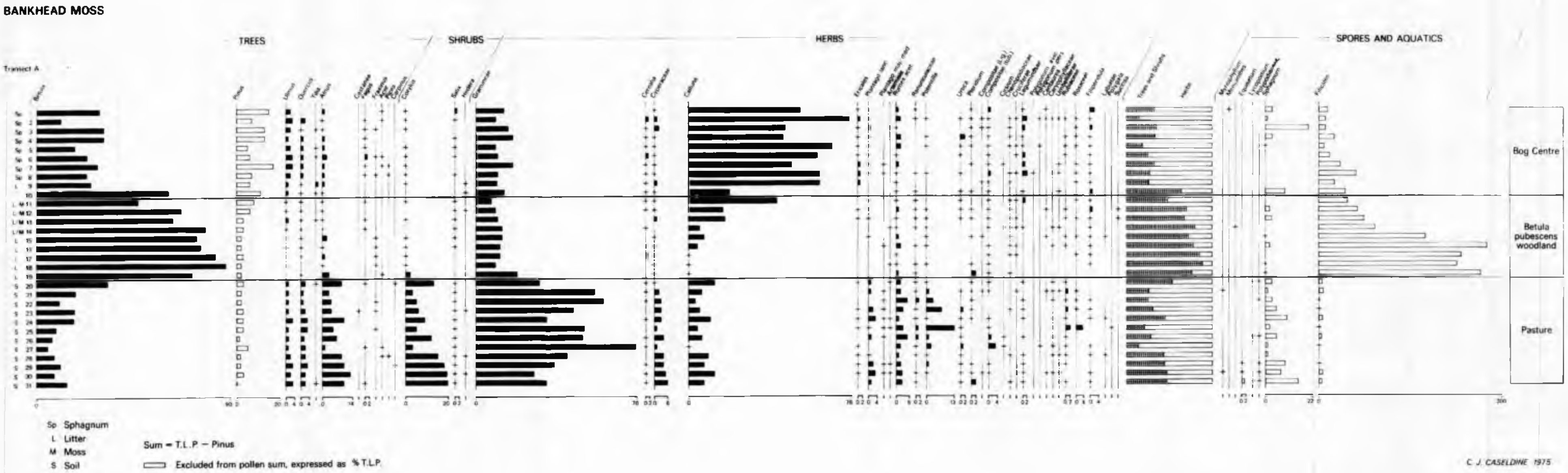
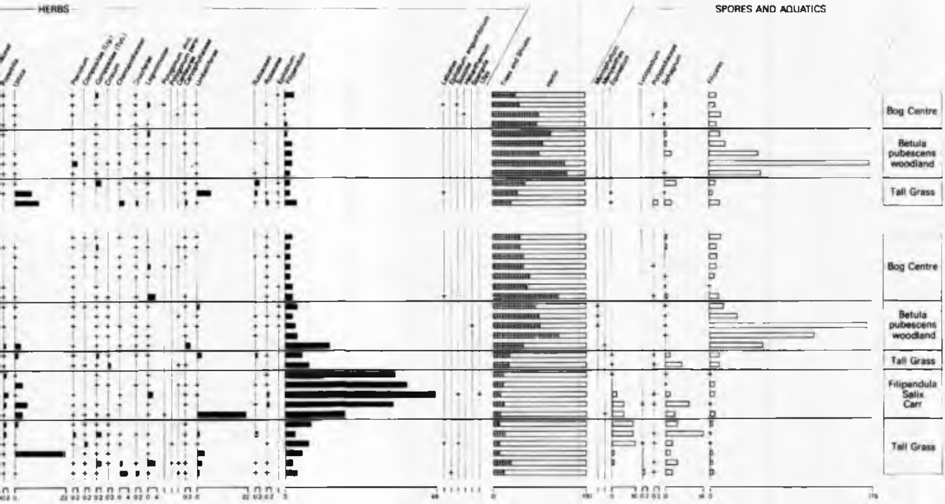


Fig.3.4 Pollen diagram for Bankhead Moss, transect A, expressed as a percentage of T.L.P. excluding Pinus

BANKHEAD MOSS



C. J. CASELDINE 1975

Fig.3.5 Pollen diagram for Bankhead Moss, transects B and C, expressed as a percentage of T.L.P. excluding Pinus that both Alnus and Corylus are found in increasing quantities away from the bog, especially along transect A, with values of 13 per cent and 19 per cent for Alnus and Corylus respectively in A30, pollen derived from hedgerow occurrences and regional sources. The behaviour of Corylus pollen confirms the comments of Tinsley and Smith (1974) who stated that,

> " ...... very little ecological significance can be attached to the occurrence of Corylus values of 20 per cent of total pollen or less in pollen spectra dominated by non-arboreal species."

Similarly, Alnus pollen was described as 'unpredictable' in comparable spectra. Other tree species remain consistently low despite mixed woodland with beech to the north of the site but both Quercus and Ulmus increase in frequency in the centre of the bog, whereas Corylus, and to a lesser extent Alnus, are hardly represented despite their high percentages further along the transects. The reason for this is unclear but may be due to eddies over the bog surface affecting the slightly heavier grains of Quercus and Ulmus present in the canopy space causing them to settle out. Pinus pollen from the plantation only reaches a maximum of 21 per cent (T.L.P.-Pinus) on the bog surface which is surprisingly low considering the extent and position of the woodland.

Apart from Corylus the only other shrub pollen found at values of more than one per cent was Salix, and, although an important constituent of the carr vegetation, it is poorly represented in almost all the samples. Only where samples were taken from within 5 metres of a bush, in C16 and C17, does its frequency rise before declining quickly away from the source. As Vuorela (1973) comments, its low resistance to oxidation and insect pollination make it an unreliable indicator species. It is tempting to ascribe the higher tail off of values to the east of the source bush to the influence of prevailing wind direction but this may also be a function of the collecting medium with the Filipendula to the west excluding more pollen from outside sources.

The pattern of Gramineae percentages is of interest and the implications of this pattern will be discussed in more detail later for it seems clear that, although a good indicator of the openness of the vegetation, grass pollen counts remain relatively high throughout all the samples, with the lowest values appearing in the area dominated by Filipendula, not in the woodland or the open bog centre. The presence of grass pollen counts of up to 19 per cent in the woodland and on the bog implies considerable transport of pollen of this type onto the bog. The dominance of Calluna vulgaris on the bog surface is adequately mirrored in the pollen record where it comprises up to 70 per cent of the total pollen count but pollen of Erica tetralix, represented in the Ericales curve, only appears sparsely. The occurrence of high percentages of ericaceous pollen, even when the site is closely encompassed by birch woodland, must suggest caution in the interpretation of fossil pollen records where heather is one of the peat-forming plants, especially in later periods on bogs experiencing very slow rates of growth. Because of its dominance Calluna and Ericales pollen were excluded from later analyses investigating pollen transfer onto the bog surface thus necessitating high pollen counts to achieve a sum of 500T.L.P. - Calluna, Ericales and Pinus.

The rest of the non-arboreal pollen record emphasises the local over-representation or under-representation of certain herbaceous species. Over-representation of a single species is demonstrated by Potentilla in A25, Urtica in C24, B12 and B13, and by Umbelliferae in C20, although in the last case the source plants did not occur within 1 metre of the sampling point and it is possible that the pollen may have been either insect transported or derived from the deposition by wind of an anther. In the carr Filipendula contributes consistently high percentages, especially where it is the dominant species, reaching 65 per cent in C18. This again complements the findings of Vuorela (1973) who discovered that a local stand of Filipendula was quite successful in excluding the pollen of other species with very high pollen counts still only producing insignificant levels of other non-arboreal species. In contrast the presence of some species in the vegetation at a sampling point is not indicated in the pollen record. This happens with Stellaria graminea in A23-26, Senecio jacobea in A23, Cirsium arvense in A24, Galium saxatile in C18 and Lathyrus pratense and Vicia cracca in C26. This non-appearance of species is a more serious problem than over-representation when considering the interpretation of fossil data for their possible occurrence can only be presumed on the basis of other species characteristic of a particular community and can thus rarely be confirmed. The behaviour of Plantago and Rumex pollen is important to consider because of the interpretations placed upon their appearance in a fossil context. Although not present at any of the sampling points Plantago is consistently found in the surface pollen record at up to 3 per cent and Rumex, which does occur quite widely, particularly in the pasture, is also well represented, reaching 12 per cent in B12. Tinsley and Smith (1974) and, indirectly, Heim (1962) have considered that the importance of Plantago in pollen diagrams may have been underestimated. From the evidence at Bankhead Moss it would appear that both Plantago and Rumex disperse very easily from modern grassland and are much more likely to be picked up in the pollen record than other non-arboreal pollen types.

Irregularities in the spore production of Sphagnum are manifest from the variable spore frequencies encountered across the bog, particularly in the centre where it dominates the 'lint-holes' and Sphagnum polsters were used for collecting modern surface pollen. The curve for Filicales, mainly Dryopteris type, does however show a striking correspondence with the occurrence of Dryopteris austriaca in the woodland understorey. It may be possible therefore that certain species are predictable in their spore production and should be included in the pollen sum, except that where they are found they do tend to occur at very high percentages.

v) Detailed analysis of the results of the surface pollen analysis

Further, more detailed analysis of the data took two forms. Firstly, the patterns of pollen transfer both onto and off the bog were examined, and, secondly, the possibility of establishing characteristic pollen assemblages related to the different vegetation categories crossed by the transects was investigated using statistical techniques.

a) Pollen transfer across the bog

Any consideration of pollen transport onto the bog and hence the representativeness of the pollen assemblage of the bog in relation to the surrounding vegetation must also recognise the process of pollen dispersal from the bog into the surrounding area. Where the bog vegetation is dominated by only a few species their influence can often quite clearly be recognised beyond the bog. At Bankhead Moss this can be seen by the occurrence of both Calluna and Betula pollen deposited outside the bog.

The pattern of pollen frequencies of certain species across the bog can be seen in Fig. 3·6 and Fig. 3·7. Fig. 3·6 comprises both transect A and transect C thus representing a west-east cross-section through the area under study. Fig. 3·6 shows pollen frequencies expressed as a percentage of the T.L.P. including all ericaceous taxa

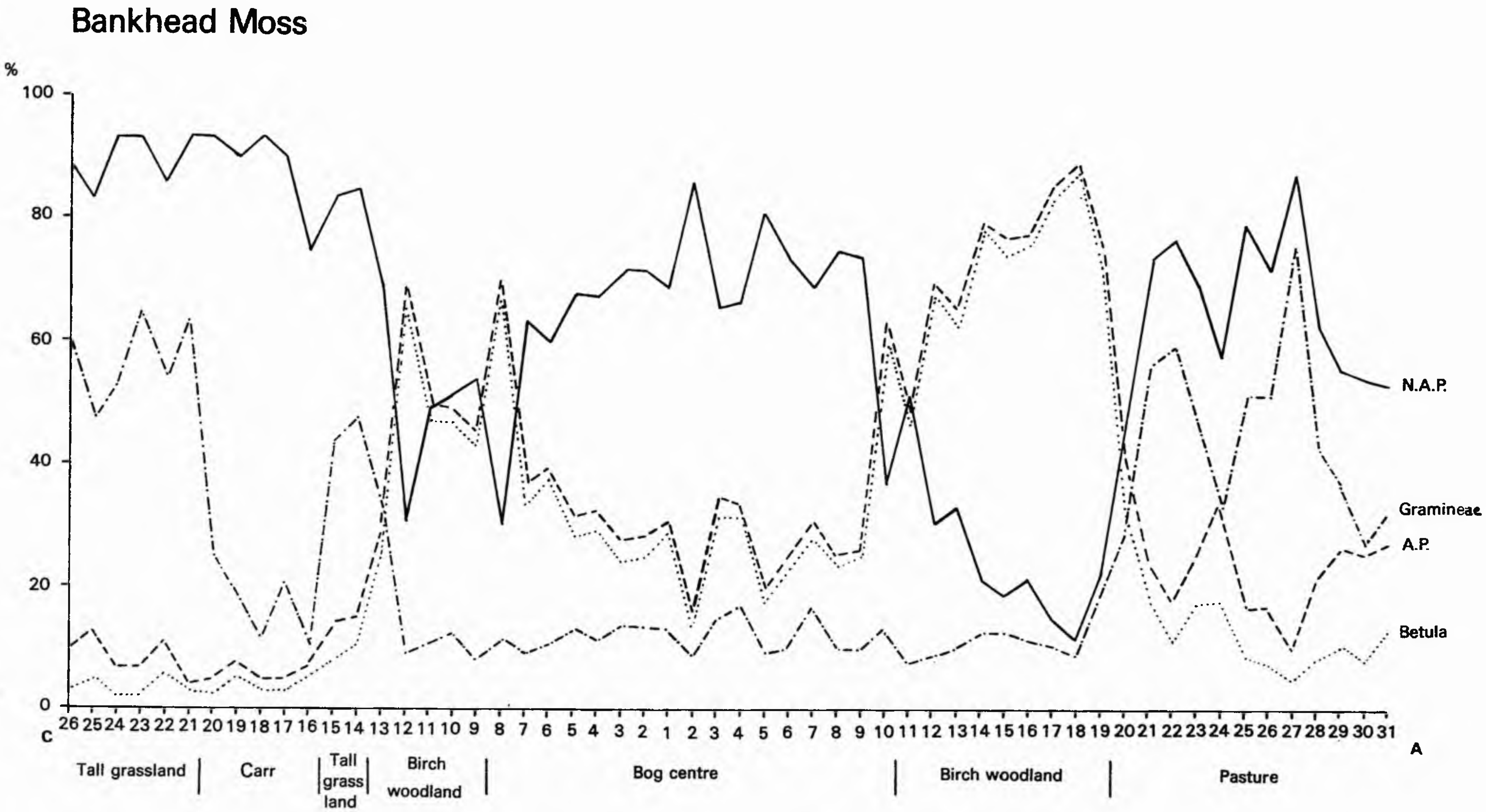


Fig.3.6 Frequencies for selected pollen types, transects A and C, expressed as a percentage of T.L.P., excluding Pinus

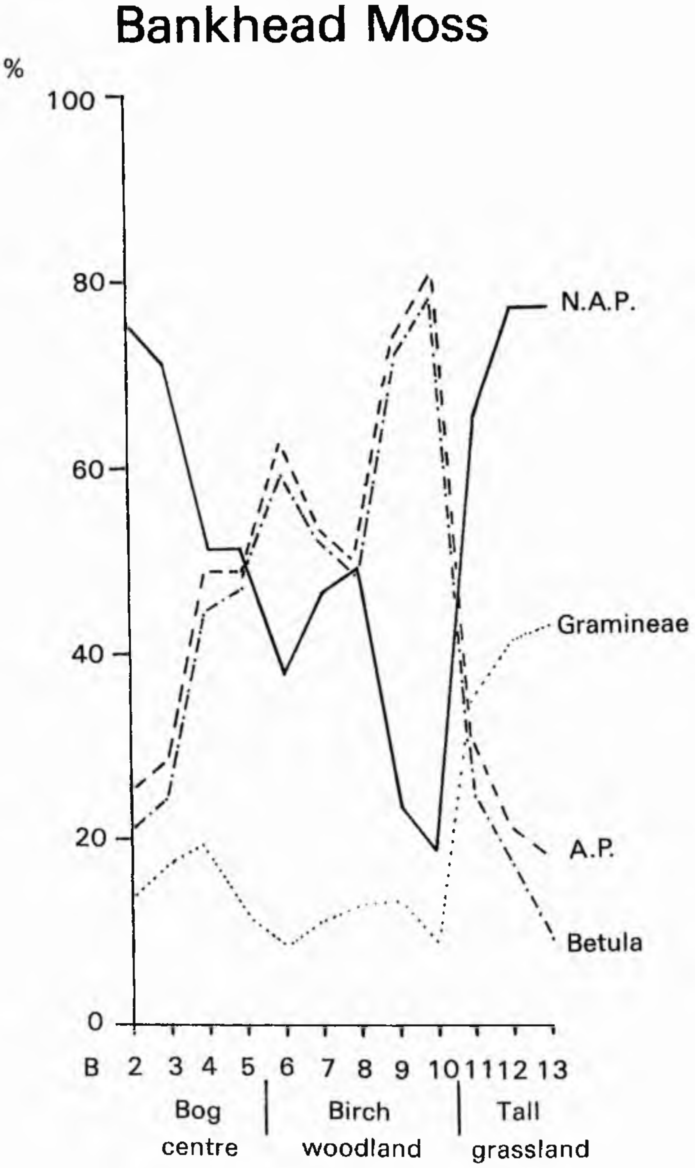


Fig.3.7 Frequencies for selected pollen types, transect B, expressed as a percentage of T.L.P. excluding Pinus

and, while clearly showing the variations in A.P. and N.A.P. across the bog, especially through the woodland areas, presents a somewhat erratic picture for Gramineae due mainly to the influence of non-arboreal pollen types such as Calluna and Filipendula. Nevertheless, with the exception of C9–11, the pattern of A.P. shows increases in the woodland with a rapid fall off away from the woodland edge and low, variable values in the open bog centre. The same variability in A.P. and Betula is seen along transect B (Fig. 3•7) where the boundary between the treeless bog centre and the birch woodland has fluctuating A.P.:N.A.P. percentages.

The somewhat erratic frequencies described above are in contrast to the smoother curves which derive from the use of a pollen sum excluding Calluna and Ericales (Fig. 3•8 and Fig. 3•9). The use of this particular sum shows that the fluctuations in A.P. are mainly due to the local production of heather pollen on the surface of the bog and in the woodland fringe. Percentages of Betula in the centre of the bog are lower than in the woodland but are remarkably consistent and in the woodland itself there is a contrast with higher Betula percentages for the western end than for the eastern end, due probably to a difference in the width of the belt of trees, the thicker woodland to the east excluding more extra-local and regional pollen thus presenting a more local picture. This could also be related to canopy cover as demonstrated by H.J. Birks on Skye (1973a) who found a high degree of correlation (0•87) between Betula as a percentage of the local pollen sum and percentage canopy cover. Maximum values for Betula pollen and for A.P. in general occur either at, or within 10 metres of the woodland edge on all three transects with a rapid fall off in percentages away from the woodland edge (Figs. 3•10, 3•11, 3•12).

The rapid decline in A.P. away from its source woodland has been

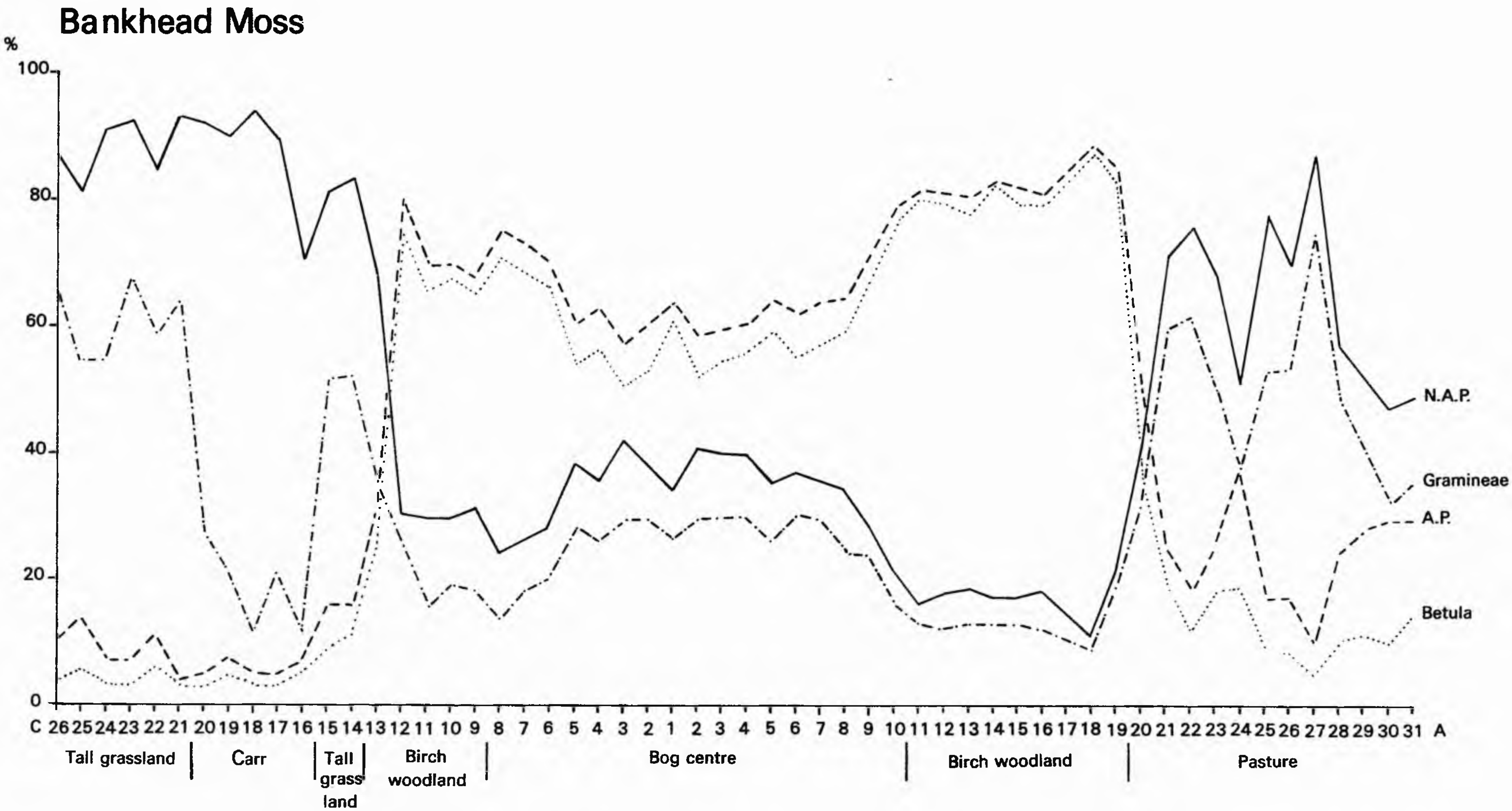


Fig.3.8 Frequencies for selected pollen types, transects A and C, expressed as a percentage of T.L.P. excluding Pinus, Calluna and Ericales

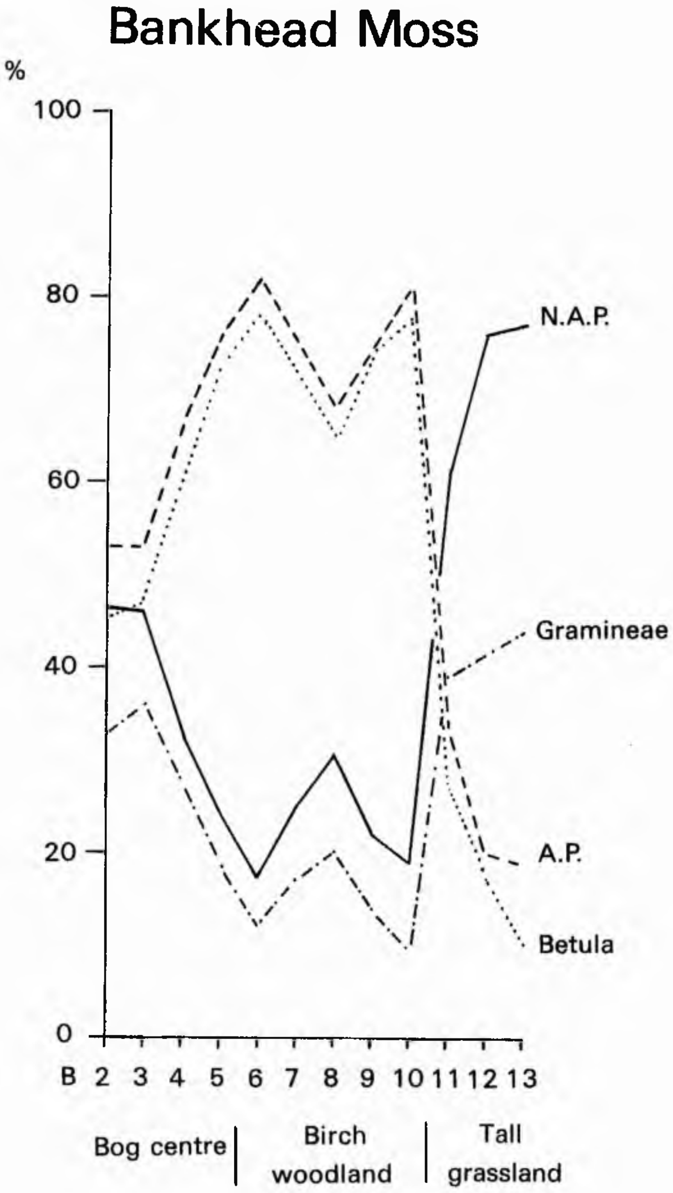


Fig.3.9 Frequencies for selected pollen types, transect B, expressed as a percentage of T.L.P. excluding <u>Pinus</u>, <u>Calluna</u> and Ericales

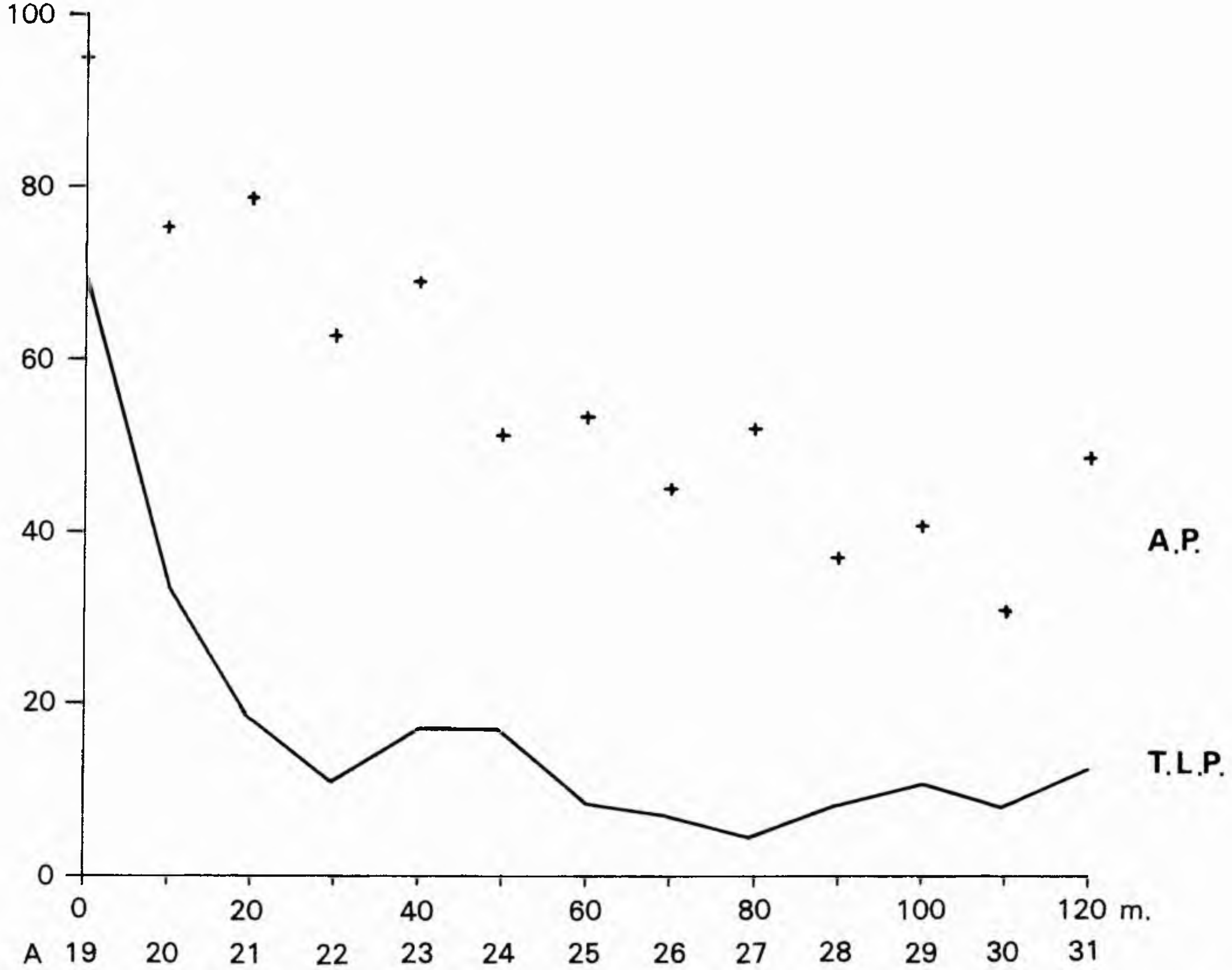


Fig.3.10 Decline in percentages of Betula pollen with distance away from the woodland edge, transect A (expressed as a percentage of T.L.P. excluding Pinus)

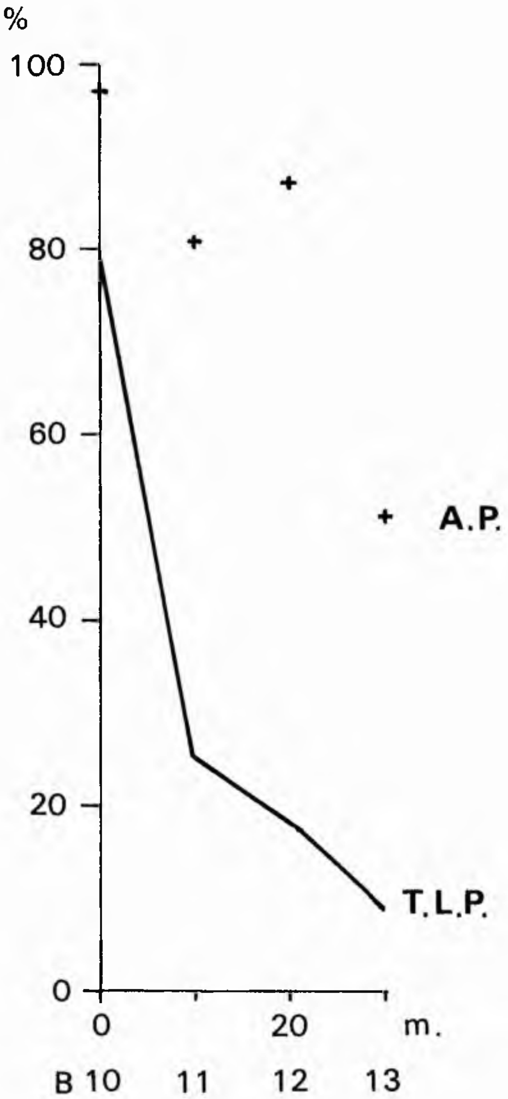


Fig.3.11 Decline in percentages of *Betula* pollen with distance away from the woodland edge, transect B (expressed as a percentage of T.L.P. excluding *Pinus*)

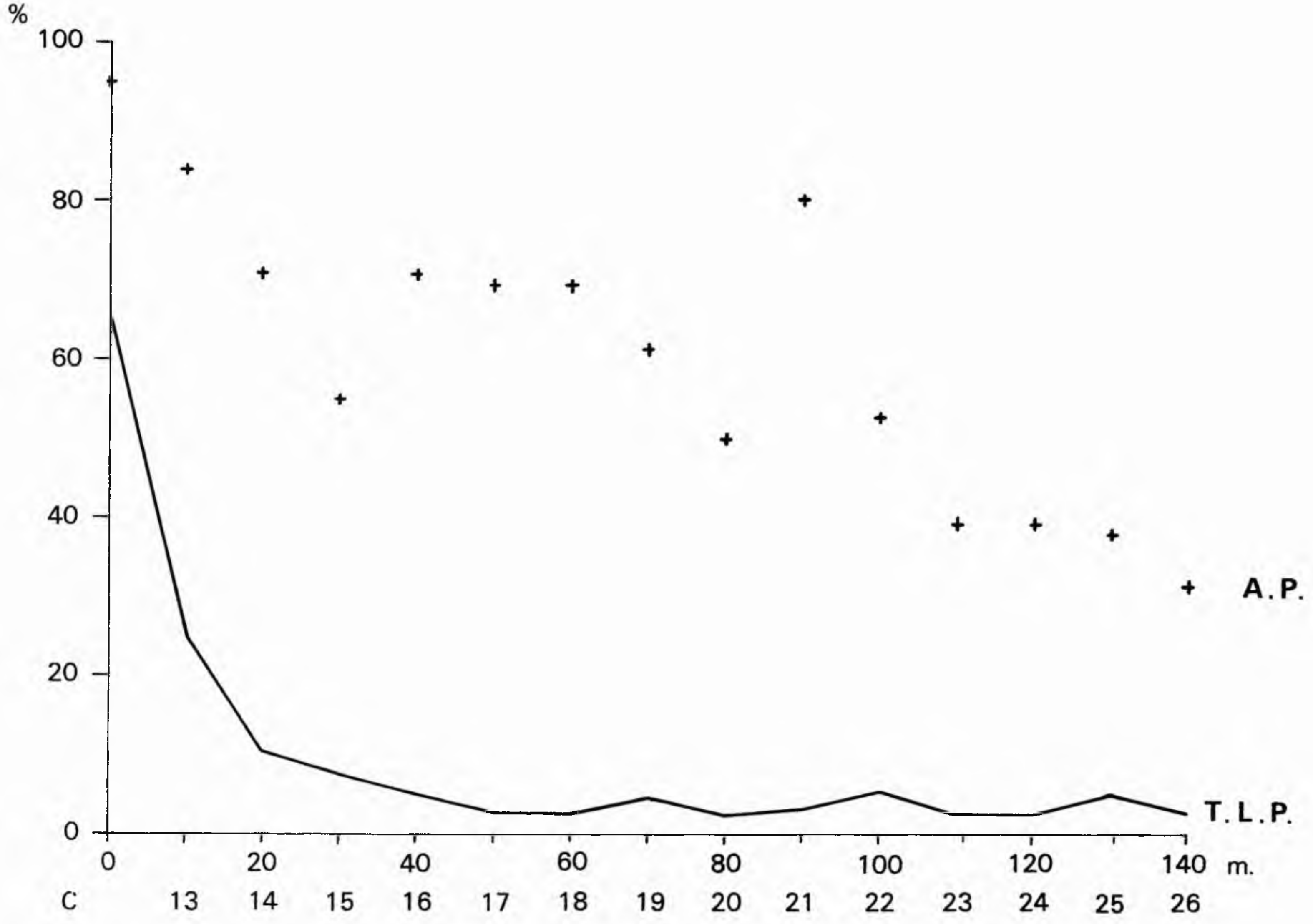


Fig.3.12 Decline in percentages of Betula pollen with distance from the woodland edge, transect C (expressed as a percentage of T.L.P. excluding Pinus)

noted by many authors (Faegri and Iversen, 1975) but few have attempted to describe the exact nature of the distance-decay function. The exceptions to this have been Turner (1964) and Tinsley and Smith (1974). Using a very good experimental site with a clear single pollen source and little interference from other tree pollens Turner examined the nature of the reduction in pine pollen frequencies away from the edge of a pine plantation in Cameron's Moss, Ayrshire. She used as raw data figures for Pinus pollen expressed as a percentage of A.P. assuming that all other A.P. would be regional and hence constant, thus overcoming the possible effects of local over-representation of non-arboreal pollen types concomitant with the use of a T.L.P. sum. In contrast Tinsley and Smith (1974) favoured the use of a T.L.P. sum because of the varied species composition of their woodland source area. The functions derived for the distance-decay curves from the two experiments varied, probably as a result of the use of different pollen sums. As discussed earlier, Turner described the decay in Pinus by,

$$y = a + be^{cx} \qquad 3{\cdot}2$$

where a represents pollen from other sources and be^{cx} expresses pine pollen as a function of the distance from the source. Tinsley and Smith described the decay in both A.P. and Quercus by a curve of the form,

$$y = a + \frac{b}{x} \qquad 3{\cdot}3$$

where a again represents pollen from other sources and A.P. or Quercus is merely considered to behave in a simple inverse relationship with distance.

The derivation of functions to describe the distance-decay mechanism inherent in pollen deposition from a woodland source needs to take into account certain theoretical considerations:

1) It is not necessary to assume that y, the frequency of the

pollen type under review, should be equal to 100 per cent at 0 distance. No matter what pollen sum is used there will always be a mix of pollen at any point in space. At 0 the pollen type released will dominate but its frequency will vary from site to site and species to species. It is however necessary to consider a value at 0 and not to take the first reading at 5 metres or 10 metres as used on the Nidderdale Moors (Tinsley and Smith, 1974).

2) In theory the x axis should not be crossed. Values of y should be asymptotic in that they never actually reach zero. It is assumed that the percentage of source pollen would be continually and very slowly reduced after a certain distance when, as a component of the regional pollen rain, it becomes, for all intents and purposes, constant. Because this value is usually so small this may be relaxed to focus attention on the early part of the decay curve.

3) In the absence of absolute values for pollen deposition the type of pollen sum used will vary and thus so will the form of the function. The sum used may vary from total exotic pollen (Andersen, 1967) i.e. pollen from outside the sampling area, where it is possible to obtain such a figure, to either total A.P. or T.L.P. The choice will depend on the characteristics of the site under investigation. The use of absolute values expressed in pollen grains/m^3 of air per hour enabled Tampieri et al. (1977) to use an empirical equation of exponential decay for airborne particles to describe the transportation of airborne pollen of Castanea sativa in the Po valley in Italy and eventually predict concentrations based on wind speed, direction and distance but this was dealing with an extraneous and easily identifiable source of pollen. In terms of concentrations caught directly from the atmosphere a particular species may appear to be well represented but when seen in terms of a pollen sum collected at the surface local

factors will assume greater importance, hence at Bankhead and at the other sites investigated in the literature there appears to be a very rapid distance decay mechanism. So far in this country studies have concentrated on describing an observed phenomenon as a prelude to explanation recognising the inherent and perhaps impossible complexity of the problem.

In the case of Bankhead Moss several points need to be considered and foremost among them is the pollen sum to be used, as this will affect the form of the curve. In theory it may be possible to use as a sum a number of grains of exotic pollen derived from outside the sampling area but with such variability in the flora within a small area this would be very difficult to achieve satisfactorily. Despite being concerned with an area of birch woodland with a clear pine component the presence of further mixed woodland within only a few kilometres of the bog makes the use of an A.P. sum also unreliable. This can be recognised by the variability in the values for Alnus found along transect A although previous studies have noted the apparent inherent variability in Alnus frequencies (Janssen, 1959). (The points for Betula expressed as a percentage of A.P. are however plotted on Figs. 3•10, 3•11 and 3•12 and do show a similar scatter to that described by Turner but with a relatively gentle slope to the curve.)

Because of the limitations involved in using an arboreal pollen sum a total land pollen sum was used to look at the form of the reduction in Betula pollen from the edge of the bog with the knowledge that aberrations in the curve will almost certainly be due to the effect of local pollen production. Presented in this form the results and figures should approximate to those of Tinsley and Smith (1974) rather than Turner (1964).

For the purpose of the study only transects A and C were used because transect B had too few points to make the fitting of any curve worthwhile. Emphasis was placed on the description of the first part of the curve and its slope to see whether there was any difference between the two main transects rather than on comparing these results with previous work. Several types of distance-decay functions were fitted to the values for Betula on transects A and C and the best fit was provided by a function of the form

$$\log y = a - b \log x \qquad 3{\cdot}4$$

which is a linear transformation of the function of the Pareto model (Taylor, 1975),

$$\log y = ke^{-b \log x} \qquad \text{(where } a = \log k\text{)} \qquad 3{\cdot}5$$

Linear transformation of the data allowed the use of curve fitting by linear regression techniques (Ezekiel and Fox, 1959; Ebdon, 1977) deriving the constants a and b from,

$$b = \frac{(xy) - n\bar{x}\bar{y}}{(x^2) - n(\bar{x})^2} \qquad 3{\cdot}6$$

and

$$a = \bar{y} - b\bar{x} \qquad 3{\cdot}7$$

respectively. The transformed curves and their regression lines are presented for transect A in Fig. 3·13 and transect C in Fig. 3·14 together with lines for one standard error around the regression line (the error lines have been drawn in a generalised parallel form rather than in the true curved manner).

For A the derived curve took the form,

$$\log y = 1{\cdot}8802 - 0{\cdot}4748 \log x \qquad 3{\cdot}8$$

which gave a correlation coefficient of $r = 0{\cdot}8414$, and a coefficient of determination of $r^2 = 0{\cdot}708$. The regression line thus explains approximately 70 per cent of the variation in the data. Although sample A18 has the highest value for Betula along the transect, A19, the sample

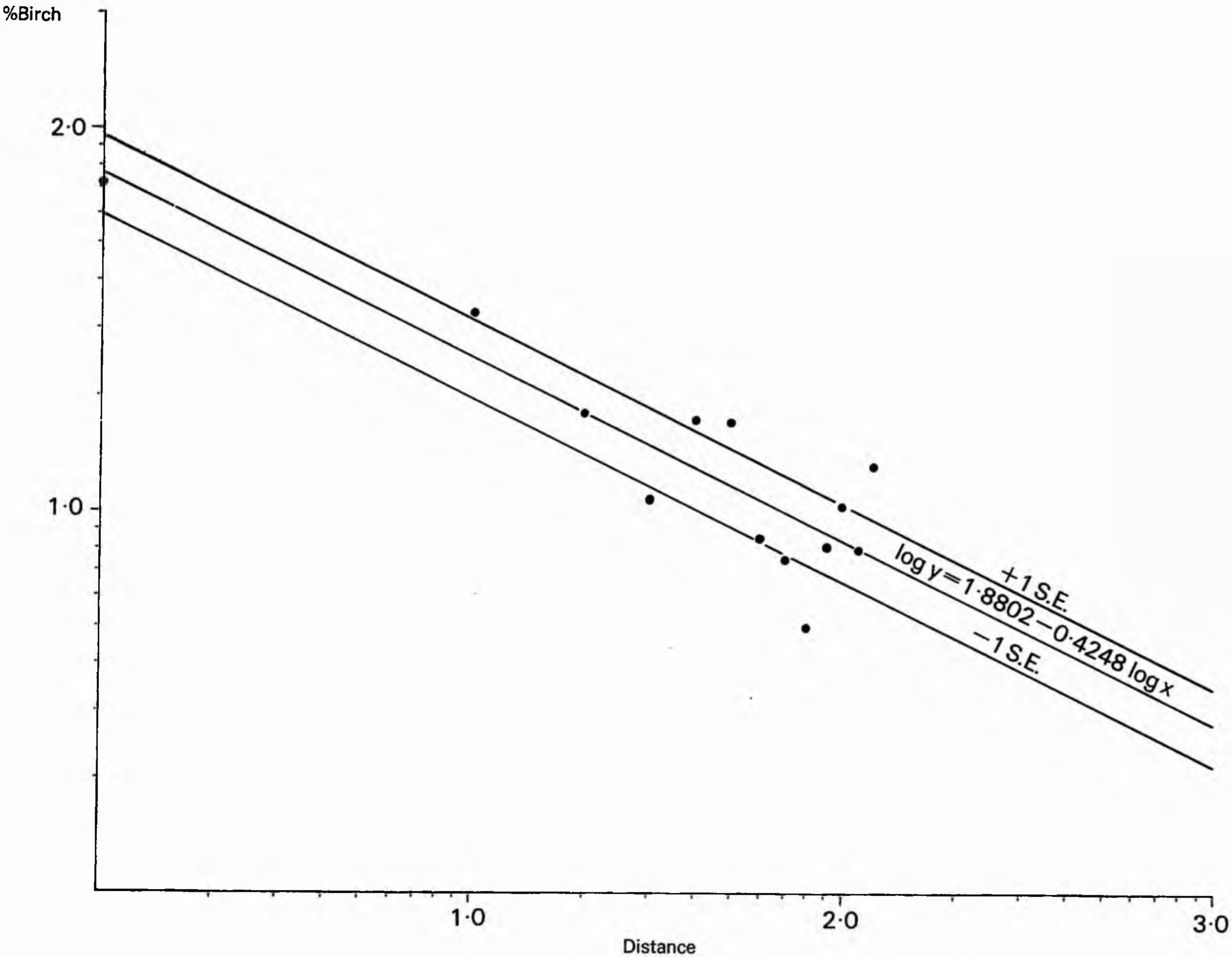


Fig.3.13 Transformed curve showing the relationship between percentage Betula and distance from woodland edge, transect A

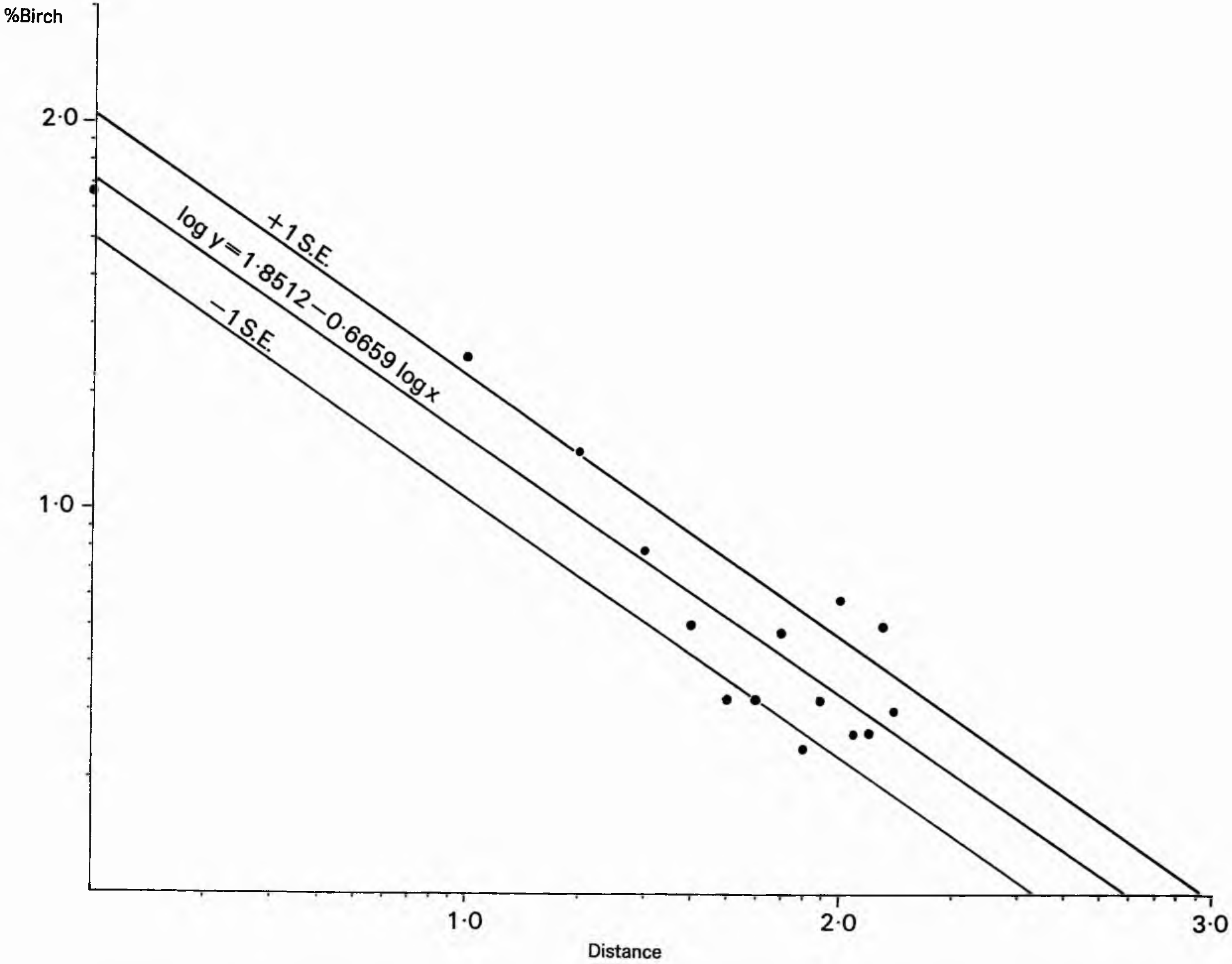


Fig.3.14 Transformed curve showing the relationship between percentage Betula and distance from woodland edge, transect C

from the edge of the woodland was taken as the first reading as the process under study is the form of dispersal from the woodland edge.

For transect C a similar curve was derived of the form,

$$\log y = 1{\cdot}8512 - 0{\cdot}6659 \log x \qquad 3{\cdot}9$$

with $r = 0{\cdot}7086$ and $r^2 = 0{\cdot}502$, the regression line thus only explaining 50 per cent of the variation.

The similarity between the curves is immediately apparent. The calculated values for A are within 0•03 of each other suggesting very similar values for Betula at the woodland edge despite the differences in the character of the woodland at the two points. There is also great similarity between the values for the gradient of the lines with transect C showing a slightly steeper gradient than A. This difference can be explained by the non-arboreal species which occur along the transects, the tall grassland and the Filipendula carr reducing the amount of incoming Betula pollen. It is therefore factors of accumulation rather than dispersal that are important in this instance. On all transects, including B, percentages start to level out at 30 metres before reducing only gradually over the next 50 metres or more. This tends to agree with the findings for Quercus at Nidderdale (Tinsley and Smith, 1974) where percentages become relatively constant at a similar distance although there the sampling interval was wider and the transects longer. The use of a log-log curve suggests a more extreme distance-decay mechanism than those previously derived. The explanation for this would seem to lie again in the nature of the vegetation at the collecting points but the results for transect A, from samples taken within pasture give a better fit to the data than those from C in the taller vegetation communities. In comparison with Nidderdale there should be more species competition at Bankhead and hence a steeper decline but results from the centre of the bog show that where Calluna is present it can dominate a surface pollen spectra, as occurred at Nidderdale. If the disparity in the goodness-of-fit between transects A and C is explained by the uniformity of the vegetation crossed by A as against the variability encountered along C then the form of the collecting medium would appear to adequately explain differences in the form of the decay and the relatively rapid fall off in Betula pollen.

Because of the size of the open area in the bog centre no attempt was made to look at the decline in birch frequencies away from the woodland into the centre, although there is a visible reduction. The values for Betula pollen from the open bog centre have a mean of 58•25 per cent (Table 3•1) which becomes 55•34 per cent when all samples from within 10 metres of the woodland edge are excluded. The coefficient of variation for this reduced set of samples has a very low value of only 7•57 per cent which is better than the 9•3 per cent for Betula within the woodland samples, again excluding samples from within 10 metres of the woodland edge. From this it may be argued that for the central open part of the bog Betula frequencies are virtually constant. When seen in comparison with other species, as in Table 3•1, the differences in the coefficients are striking. It is however difficult to compare these results directly because of the low counts from non-arboreal pollen types, even for the composite N.A.P. counts. The homogeneity of the pollen samples from the different vegetation groups will be considered later but at this point it is necessary to consider the representativeness of the pollen assemblage from the bog surface in terms of the surrounding vegetation. It would appear that there is a certain area in the very heart of the bog that is heavily influenced by birch but which shows little variability in the extent of this influence. Pollen from further away, from outside the woodland is not however either so well or so uniformly distributed. The low mean

Table 3·1 Means, standard deviations and coefficients of variation for selected taxa from the bog samples

	Betula			Gramineae			Calluna plus Ericales		
	$\bar{x}$	s	c.v.%	$\bar{x}$	s	c.v.%	$\bar{x}$	s	c.v.%
Bog Centre									
Total	58·25	±6·49	11·1	27·61	±4·72	17·11	51·47	±10·79	20.96
Reduced	55·34	±4·19	7·57	29·80	±2·95	9·89	54·40	± 8·96	16·46
Birch Woodland									
Total	75.46	±6·52	8·63	13·78	±3·4	24·68	16·02	±13·63	85·05
Reduced	75·87	±7·05	9·30	13·99	±3·22	23·04	14·35	±12·03	83·85

	N.A.P. less Calluna and Cyperaceae			A.P. and Corylus less Betula		
	$\bar{x}$	s	c.v.%	$\bar{x}$	s	c.v.%
Bog Centre						
Total	7·58	±1·68	22·1	5·94	±1·57	26·49
Reduced	8·80	±1·52	19·0	6·27	±1·48	23·51
Birch Woodland						
Total	6·61	±3·54	53·55	3·16	±1·28	40·61
Reduced	6·30	±3·40	53·94	2·77	±0·98	35·27

All figures are based on a pollen sum excluding Ericales, Calluna and Cyperaceae; except for the Calluna and Ericales values which are based on a sum including Calluna and Ericales. Reduced counts refer to the exclusion of samples from within 10 metres of the woodland edge.

values and high coefficients of variations for certain non-arboreal species have just been mentioned and it is clear that they are poorly represented on the bog surface. Even Filipendula which occurs at frequencies of up to 60 per cent in the carr is only spasmodically found on the bog (see Figs. 3•4 and 3•5). The exception to this pattern is made by the pollen of Gramineae which consistently occurs at 8 per cent or more when expressed as a percentage of T.L.P. and greater than 10 per cent (20 per cent in the bog centre) when expressed as a percentage of the T.L.P. without Calluna and Ericales. Gramineae, like Betula, shows remarkable consistency in its frequency for the reduced number of samples from the bog centre with a coefficient of variation of only 9•89 per cent, but it is much more variable within the woodland.

It is noticeable from Fig. 3•8 that percentages for Gramineae pollen rise considerably in the centre of the bog yet the only species present, Molinia caerulea, is but poorly represented in the present vegetation. This must indicate considerable transport of grass pollen from the area surrounding the bog but the pattern of this transfer is difficult to discern. This problem is heightened by the difficulty in separating the pollen of different grass species in terms of morphology thus producing a single curve for grass pollen. In order to try and overcome this problem the diameters of all well preserved i.e. not broken, crumpled or corroded, grass pollen grains were measured to try and isolate different species or combinations of species on their size characteristics. This approach is obviously a simplification of the problem but it was expected that crude figures might point to the exclusion of certain size ranges and reflect any differential filtration of pollen grains. The mean diameters of all the measured Gramineae grains are presented in Fig. 3•15, Fig. 3•16 and 3•17 for the three transects and though erratic they do appear to show some

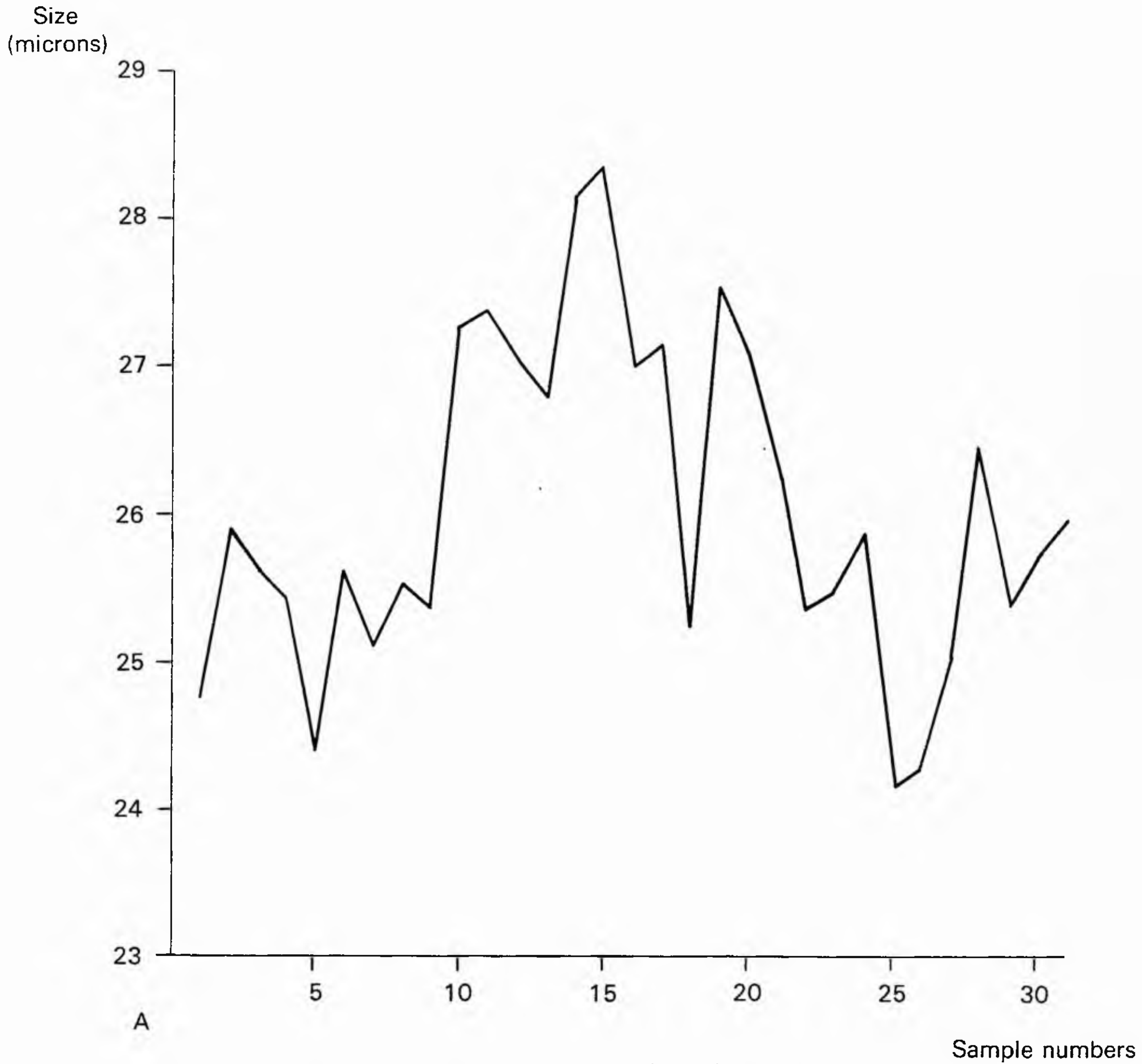


Fig.3.15 Mean diameters of Gramineae grains, transect A

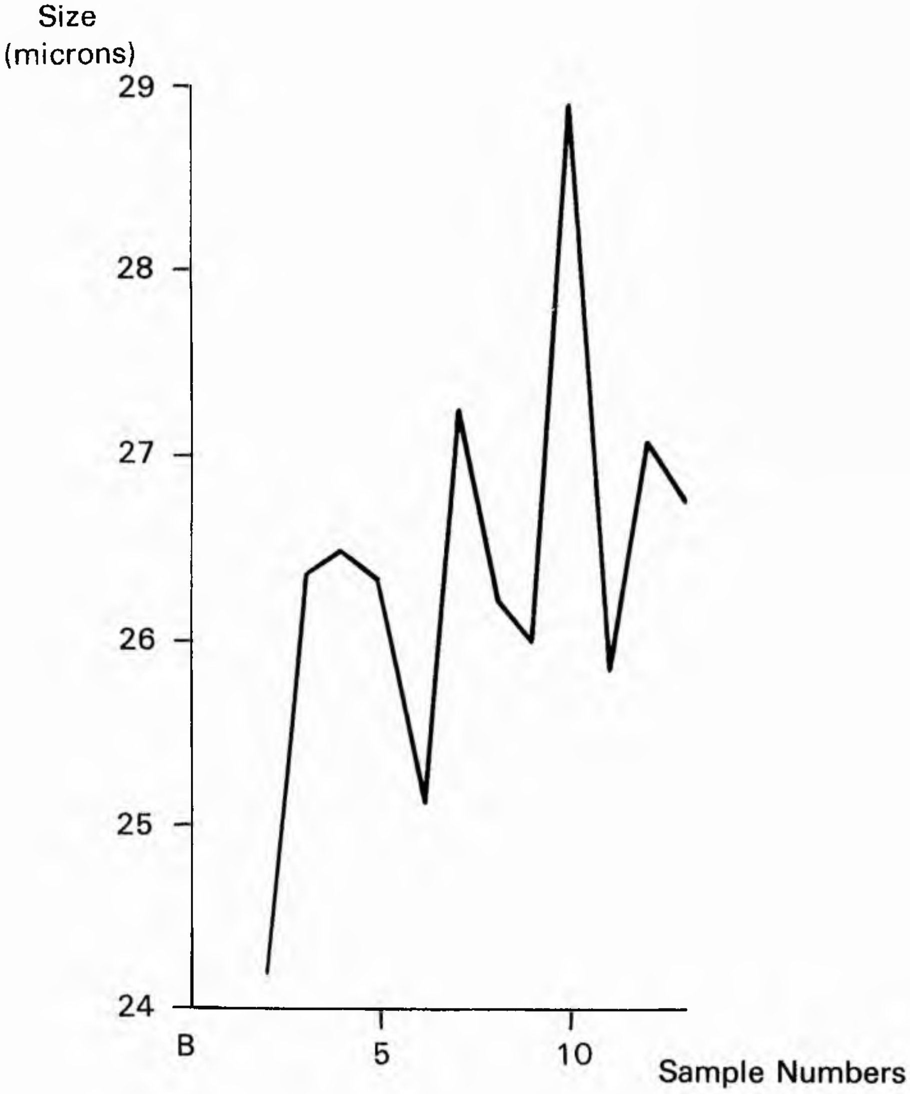


Fig.3.16 Mean diameters of Gramineae grains, transect B

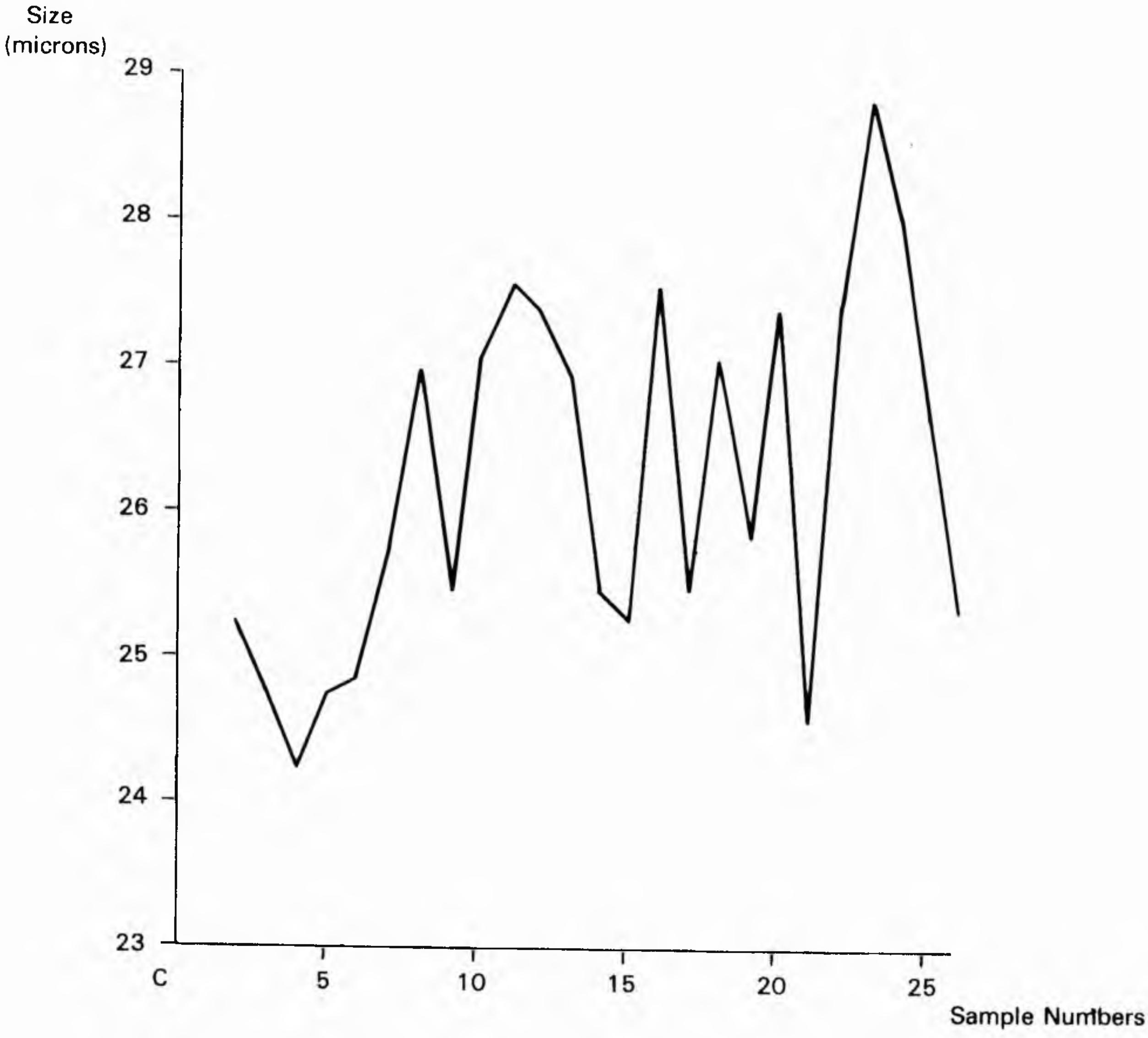


Fig.3.17 Mean diameters of Gramineae grains, transect C

relationship between location on the transect and diameter, a feature which is clarified by the summary in Table 3•2. Statistical analyses using X^2 show that there is a significant difference in the distribution of diameters between the groupings. The low mean value for the open bog centre suggests that many of the larger grass pollen grains have either been filtered out by the surrounding woodland or, if present above the bog in canopy or high level transfer do not settle out as they pass over the bog and are affected by eddies over the woodland/open centre boundary. The first hypothesis is strengthened by the very high figure of 27•00μ for Gramineae diameters in the woodland in which there is very little grass, except for occasional small clearings and by the earlier evidence for differential removal over the bog centre of heavier arboreal pollen grains from canopy or high level transfer. Although such a hypothesis seems likely on this evidence it is noticeable from Fig. 3•15 – Fig. 3•17 that there is no gradual decline in diameters within the samples from the woodland away from the woodland edge as might be expected if differential filtration was taking place. This therefore implies that some of the grass pollen is being transported above the canopy as well as in the trunk space and the larger grains are not removed differentially from above the trees. On a rough estimate from Fig. 3•8 subtracting the value for Gramineae in the woodland from that in the centre of the bog this proportion travelling above the canopy may be of the order of between 35 and 55 per cent.

Conclusions based on mean values can be misleading and because of this the modal classes of Gramineae pollen diameters have been calculated for each sample to show the individual distribution of diameters. These classes are presented in Table 3•3 with a fuller description in Appendix III. Although the results are affected by

Table 3·2

Mean diameters of measured grains of Gramineae

	Number of grains	Sum of diameters	Mean diameter (μ)
Bog Centre	1283	31550	24.59
Birch Woodland	1107	29891	27.00
Pasture	2645	67367	25.47
Salix-*Filipendula* carr	407	10813	26.56
Tall Grassland	2711	71753	26.46

Table 3·3 Modal classes of Gramineae diameters for each sample

Transect A		Transect B		Transect C	
Sample	Classes	Sample	Classes	Sample	Classes
1	18/19;24/25;30/31	2	20/21	2	24/25;30/31
2	20/21;26/27;32/33	3	24/25;30/31	3	24/25
3	22/23;32/33	4	24/25;30/31	4	22/23;30/31
4	22/23;30/31	5	24/25;30/31	5	24/25
5	20/31;24/25;32/33	6	22/23;26/27	6	22/23–26/27
6	20/21;24/25;32/33	7	24/25;26/27	7	24/25;28/29;32/33
7	22/23	8	26/27	8	24/25;30/31
8	22/23;26/27;30/31	9	24/25;30/31	9	20/21;24/25;30/31
9	20/21;24/25;32/33	10	24/25;36/37	10	18/19;20/21;24/25;30/31;34/35
10	20/21;26/27;30/31	11	24/25;32/33;36/37	11	26/27;30/31
11	26/27;32/33	12	24/25;30/31	12	24/25;28/29
12	24/25;32/33	13	24/25;32/33	13	24/25;34/35
13	24/25;30/31			14	24/25
14	24/25;30/31			15	20/21;24/25
15	24/25;30/31			16	26/27;32/33
16	28/29			17	24/25;34/35
17	26/27;30/31			18	20/21;24/25;26/27;30/31
18	26/27			19	20/21;24/25;30/31

continued.......

Table 3·3 (continued)

Transect A		Transect B		Transect C	
Sample	Classes	Sample	Classes	Sample	Classes
19	26/27;30/31			20	20/21;24/25;26/27;30/31
20	24/25;30/31;34/35			21	24/25;30/31
21	24/25;30/31			22	24/25;30/31
22	24/25;30/31;34/35			23	26/27;30/31
23	24/25;32/33			24	20/21;24/25;30/31
24	20/21;24/25;30/31			25	24/25;28/29;32/33
25	20/21-24/25;30/31			26	20/21;24/25
26	24/25;30/31				
27	24/25;30/31				
28	24/25;30/31				
29	24/25;30/31				
30	26/27;30/31				
31	24/25;30/31				

the accuracy of the micrometer, which only measured accurately to 2μ (one division equalled 2·1), the results do show some interesting and relevant patterns. The modal frequencies for the centre of the bog are tri-modal, bi-modal and uni-modal showing the presence of more than one population of diameters thus confirming the belief that much of this pollen was derived from outside the bog. The woodland, especially along transects A and B, exhibits bi-modal frequencies with occasional uni-modal samples but the diameter in the latter is usually $26/27\mu$ or more, as against the 20/21, 22/23 or 24/25 found in the bog centre. There is nevertheless no clear occurrence in the woodland of consistent modal frequencies at the higher end of the scale, i.e. greater than 30μ, which would have confirmed differential filtration of larger grass grains. This shows how misleading the investigation of mean values can be and further suggests that a great deal of the grass pollen transported onto the centre of the bog must travel above the canopy. The removal of this pollen from the atmosphere and its deposition within the woodland is therefore a function of conditions above the tree cover. The results from the samples taken from the boundary between woodland and open communities e.g. B11, C10 and A10, show greatest diversity in their modal frequencies probably more on account of their location in a situation where turbulence is to be expected rather than the local pattern of vegetation. There is similar diversity within the samples from the Filipendula group, notably C18 and C20, an area where there is little local development of grasses. This finding once again emphasises the important role played by the collecting medium in such studies with Filipendula filtering a variety of sizes of grains.

Rather than clarifying any of the problems associated with pollen transport onto the bog the results from the study of grass pollen deposition have served to suggest new difficulties. From the modal frequencies it is clear that most of the Gramineae grains found in the centre of the bog derive from outside the peat and both very large and very small grains are well represented. The role of the woodland as a filter of pollen is but poorly reflected in the results and it appears that a large proportion of pollen reaching the bog centre travels above the canopy rather than in the trunk space, perhaps between 35 and 55 per cent. It is disappointing that the low frequencies for Cereal type pollen prevented any investigation of the movement of these very large Gramineae type grains. Even the areas bordering the cultivated fields only exhibit very low percentages and there is no discernible regular pattern of Cereal type pollen deposition within the bog.

In terms of the frequencies of grass pollen the bog centre provides quite a good mirror of the openness of the surrounding area but the appearance of grass pollen and that of other extra-local, non-arboreal species is still masked by local pollen, in this case Calluna. This does of course emphasise the need to account in fossil pollen records for the possible influence of local pollen types but this influence is not simply limited to the effect of heather. The proximity of the birch woodland also influences pollen assemblages from the open centre and in most fossil contexts this could rarely be omitted as a local pollen type. Moreover it seems likely that during the earliest periods of forest clearance woodland would be left close to damp boggy sites as small areas were cleared for cultivation and would thus similarly influence pollen assemblages in their vicinity. There is therefore a danger of either not noticing early small scale forest clearance, or underestimating the extent of clearance, particularly when considering evidence from small raised bogs or similar deposits.

It is as much the poor dispersal of non-arboreal pollen as the influence of local species or filtration effects that governs the representation of cleared areas in a forest mosaic, but with high values for grasses and low but consistent occurrences of species such as Plantago or Rumex it is necessary to assume, with Heim (1962), that this represents the close proximity of human settlements and openings in the forest, and to agree, at least in part, with Tinsley and Smith that,

> "Plantago lanceolata values appear to be less subject to marked fluctuations suggesting a fairly even dispersal from this plant ...... it is possible that peaks in the pollen of P. lanceolata may reflect more extensive activities than peaks in pollen of some of the other weeds of cultivation." (1974, p.564)

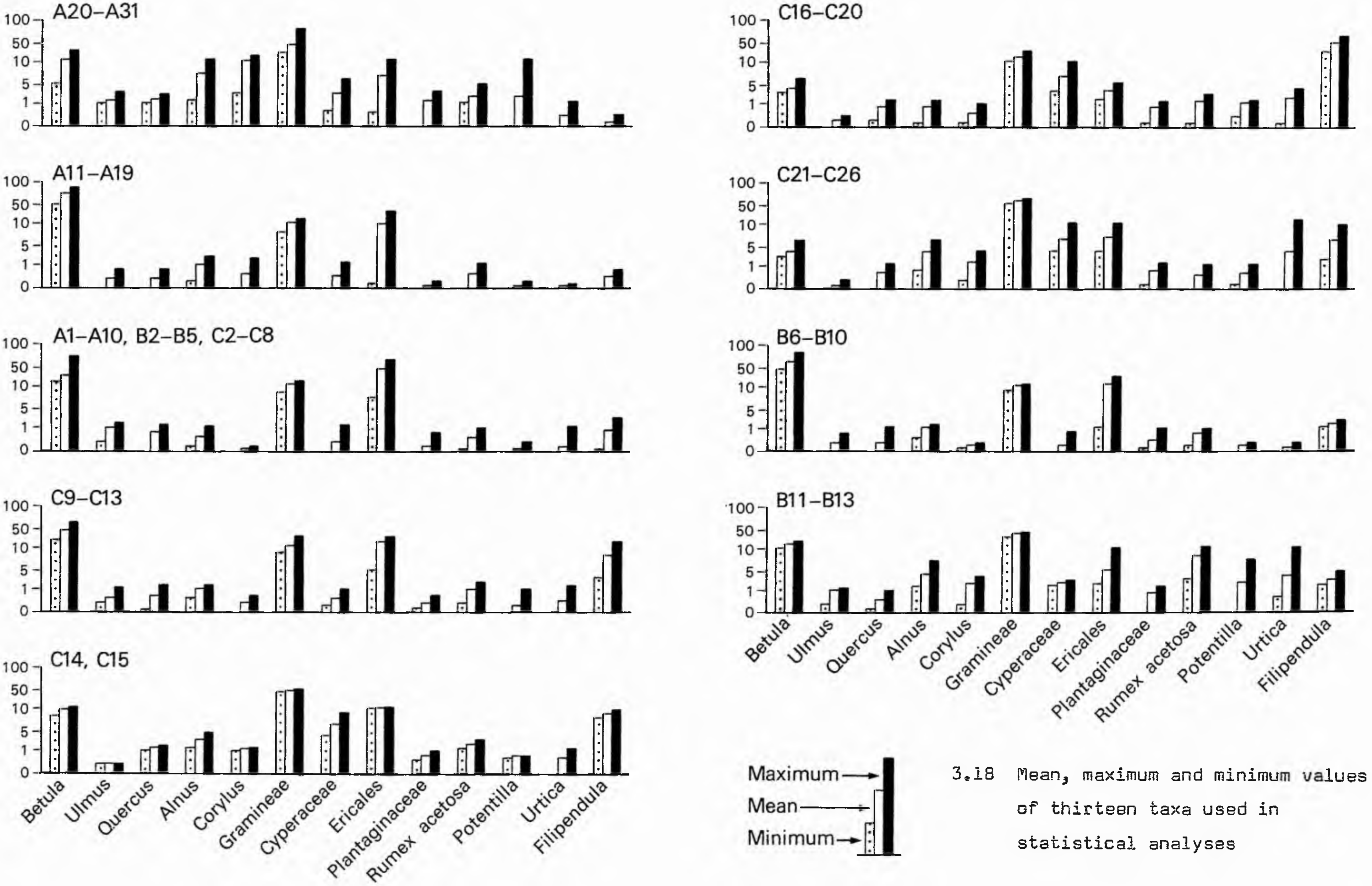
The question remains as to whether it is possible to apply the model of pollen transfer adopted by Tauber (1967) to the data from Bankhead Moss. For a small raised bog equivalent to Bankhead Moss a relationship of the order 8:1:1 for $f_t:f_c:f_r$ would be expected. Although it is not possible to fit exact figures to the model it would appear, on the basis of a pollen sum excluding local pollen such as Calluna and Cyperaceae that in the centre of the bog Betula, derived mainly by trunk space movement, contributes between 50-60 per cent of the total pollen and Gramineae between 25-30 per cent, with at least half of the latter moving in the canopy space or above. The remaining arboreal and non-arboreal components, though appearing in very low frequencies, presumably derive from all the possible sources with most movement probably taking place above the canopy rather than through the trunk space. This would mean in crude terms that, at the centre of the bog, the trunk space component would contribute, at a minimum, 65 per cent of all the pollen deposited and, at a maximum, possibly

90 per cent, apparently confirming Tauber's suggestion. It is not possible on this evidence to try and distinguish between the canopy and rain-out components. Thus, to return to the prehistoric situation, during early periods of forest clearance it might be expected that at the very least 65 per cent of the pollen collected on a bog surface, omitting immediately local sources, would have as its source area the forest edge surrounding the bog.

b) Statistical analysis and the determination of characteristic pollen assemblages

The collection of surface pollen data in this form presents a good opportunity for examining whether it is possible to determine characteristic pollen assemblages representative of the different but closely grouped vegetation communities at Bankhead Moss. Examination of the pollen diagrams and the knowledge that vegetation categories were defined largely in terms of one or two dominant species suggests that a close correlation between vegetation type and pollen assemblage might exist. In recent years increasing use has been made of multivariate statistical techniques in the study of present day pollen assemblages (H.J.B. Birks, 1973a; H.J.B. Birks et al., 1975b; O'Sullivan and Riley, 1974; Webb, 1974) and techniques have been adopted which were originally used for the zonation of pollen diagrams (Gordon and Birks, 1972). The use of various forms of statistical analysis to try and establish whether groups exist and whether they correspond with vegetation categories is however still only a preliminary step in an attempt to understand the relationship between patterns of pollen production and patterns of plant distribution. The results of such techniques are largely descriptive determining certain characteristics of the data set and cannot be considered as explaining the processes involved. Whether analysis seeks to locate clusters by the proximity of samples in multi-dimensional space or to partition them into a set number of groups there will still be a large element of subjectivity in the final interpretation of the results. In order to reduce this subjective element it is best to combine several different numerical approaches (H.J.B. Birks, 1973b; H.J.B. Birks et al., 1975b; O'Sullivan and Riley, 1974) in order to see whether techniques based on different criteria produce similar groupings. The availability of data here in transect form provides an opportunity for the use of techniques which build a contiguity constraint into the division of the data set, as used in pollen diagram zonation procedures, thus allowing a further measure of comparison, not only between different unconstrained methods, but between unconstrained and constrained methods.

Using computer programs developed by Gordon and Birks (1972) and with the assistance of Dr. A. Gordon in the implementation of these programs, the data from Bankhead Moss were subjected to various statistical techniques to examine groupings in the surface pollen record. Before computation the pollen sum was reduced omitting those taxa which failed to contribute more than 4 per cent to the T.L.P. sum. Although of interest in the ecological interpretation of the data such frequencies would not be significant in the statistical analysis (Gordon and Birks, 1972). Where certain species are considered ecologically significant because of their sensitivity to certain factors such as light or temperature it may be possible to weight their values for inclusion in the analyses but this only adds a further subjective element to the use of techniques whose aim is to present a more objective assessment of the data. The introduction of threshold percentages reduced the number of taxa considered to 13 and their values (maximum, minimum and mean) are described in Fig. 3·18. In this pollen sum Ericales



3.18 Mean, maximum and minimum values of thirteen taxa used in statistical analyses includes the pollen of all ericaceous species and Plantaginaceae includes both Plantago lanceolata and P. media/major. Certain exceptions were however made to the 4 per cent threshold:

a) Pinus - pollen of this species was excluded from the sum for the same reason that it was omitted from the earlier discussion on pollen transfer.

b) Salix sp. - in two samples, C16 and C17, taken from within 5 metres of single bush, Salix pollen is highly over-represented in contrast to its extremely low percentages elsewhere.

c) Umbelliferae - this family pollen type again reflects the problem of local over-representation. In a single sample, C20, it comprises 21 per cent of the T.L.P., never exceeding 4 per cent in any other sample and because of this isolated occurrence, not reflected in the vegetation pattern, it was excluded. In contrast the pollen of Urtica, which approaches similar percentages in C24, was included because of its consistent appearance in other samples.

d) All spores were excluded from the pollen sum. This is contrary to the approach of Birks (1973b) but considered valid on inspection of the variability and magnitude of their frequencies.

1) Unconstrained analysis

The analysis of the data in an unconstrained form was carried out using two basic approaches. The first approach uses a technique which produces a geometrical representation of all the samples in Euclidean space, and the second approach uses techniques which partition the data into set numbers of groups.

Several statistical techniques based on the geometrical representation of data have been used in pollen analysis, for the purpose of zonation (Pennington, 1975b), for the regional comparison of pollen statistics (H.J.B. Birks, Deacon and Pegler, 1975) and for the analysis of surface pollen samples (H.J.B. Birks, 1973b; H.J.B. Birks et al., 1975b; O'Sullivan and Riley, 1974; Webb, 1974). For the data set from Bankhead Moss principal components analysis was used, a technique which sets up a correlation matrix of all the pollen data and proceeds, in this case, to present it all as points in 13-dimensional space, with each taxon defining a co-ordinate axis. The first principal component, or new co-ordinate axis, is chosen along the direction of greatest variability in the data and subsequent axes are chosen orthogonal to the preceding axis along the direction of greatest residual variability. Usually it is hoped that the first few axes will explain most of the variability in the data set thus summarising the fundamental groups that occur. One of the advantages that has been claimed as far as palynology is concerned is that it increases the importance of minor taxa by standardising the data to unit variance and thus it should not really be used with any weighted values.

The results of the principal components analysis for the first six axes are presented in Table 3•4 and from the component loadings it is clear that minor species are relatively important in defining groups, even in the early axes. The first two axes only explain 53•33 per cent of the variability, but by the fourth axis 72•86 per cent, almost three-quarters, of the variability is accounted for. The value of principal components analysis lies also in the possibility of graphical representation of the groupings (Fig. 3•19). This shows how the first two axes divide the pollen samples into two distinct groups, a fairly compact group of 39 samples derived from the bog surface, and a rather diffuse group of 29 samples bringing together all the samples from outside the bog. The third and fourth axes (Fig. 3•20) are mainly responsible for separating out the group of 39 samples, seemingly into four groups. There is continuous variation

Table 3·4

Principal components analysis of the transect data

	Component					
	1	2	3	4	5	6
Component loadings						
Betula	0·310	0·187	0·183	0·607	−0·058	0·104
Ulmus	−0·225	0·465	−0·023	−0·213	0·004	0·267
Quercus	−0·309	0·215	0·069	−0·068	−0·255	0·265
Alnus	−0·406	0·208	−0·064	0·196	0·093	−0·044
Corylus	−0·371	0·285	−0·043	0·168	−0·035	−0·009
Gramineae	−0·340	−0·227	0·135	−0·048	0·348	−0·374
Cyperaceae	−0·290	−0·343	−0·294	0·023	−0·131	−0·377
Ericaceae	0·237	0·277	−0·175	−0·662	0·084	−0·101
Plantaginaceae	−0·348	0·129	−0·253	0·078	−0·121	0·011
Rumex acetosa	−0·196	−0·133	0·549	−0·111	0·014	0·079
Potentilla	−0·168	−0·188	0·574	−0·219	−0·113	0·164
Urtica	−0·095	−0·281	−0·243	0·033	0·651	0·614
Filipendula	−0·050	−0·429	−0·258	−0·082	−0·570	0·379
Per cent of total variance	35.48	17·86	11·25	8·29	7·55	5·38
Cumulative per cent of total variance	35·48	53·33	64·58	72·86	80·41	85·78

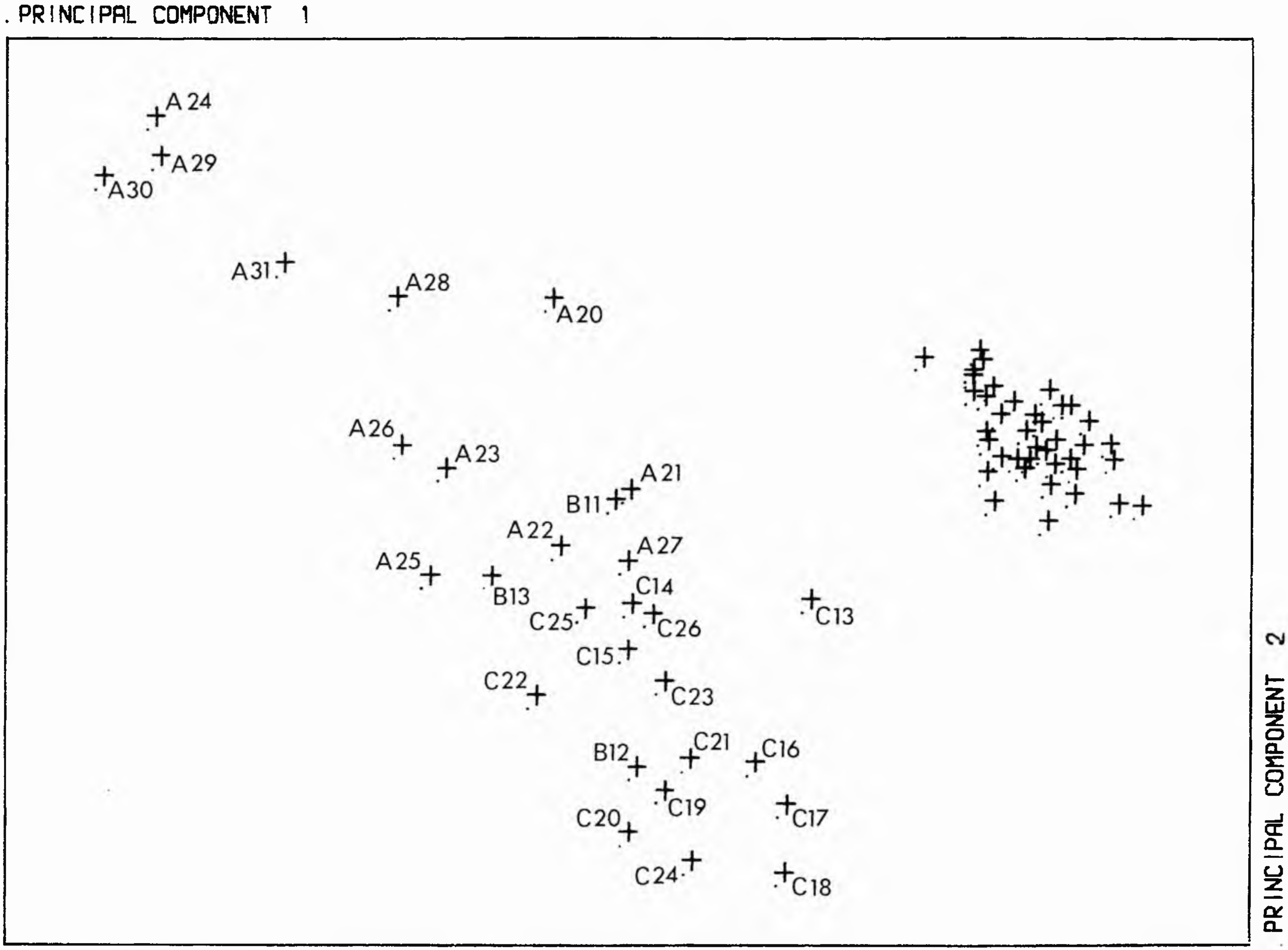


Fig.3.19 Representation of transect data on the first and second principal components axes

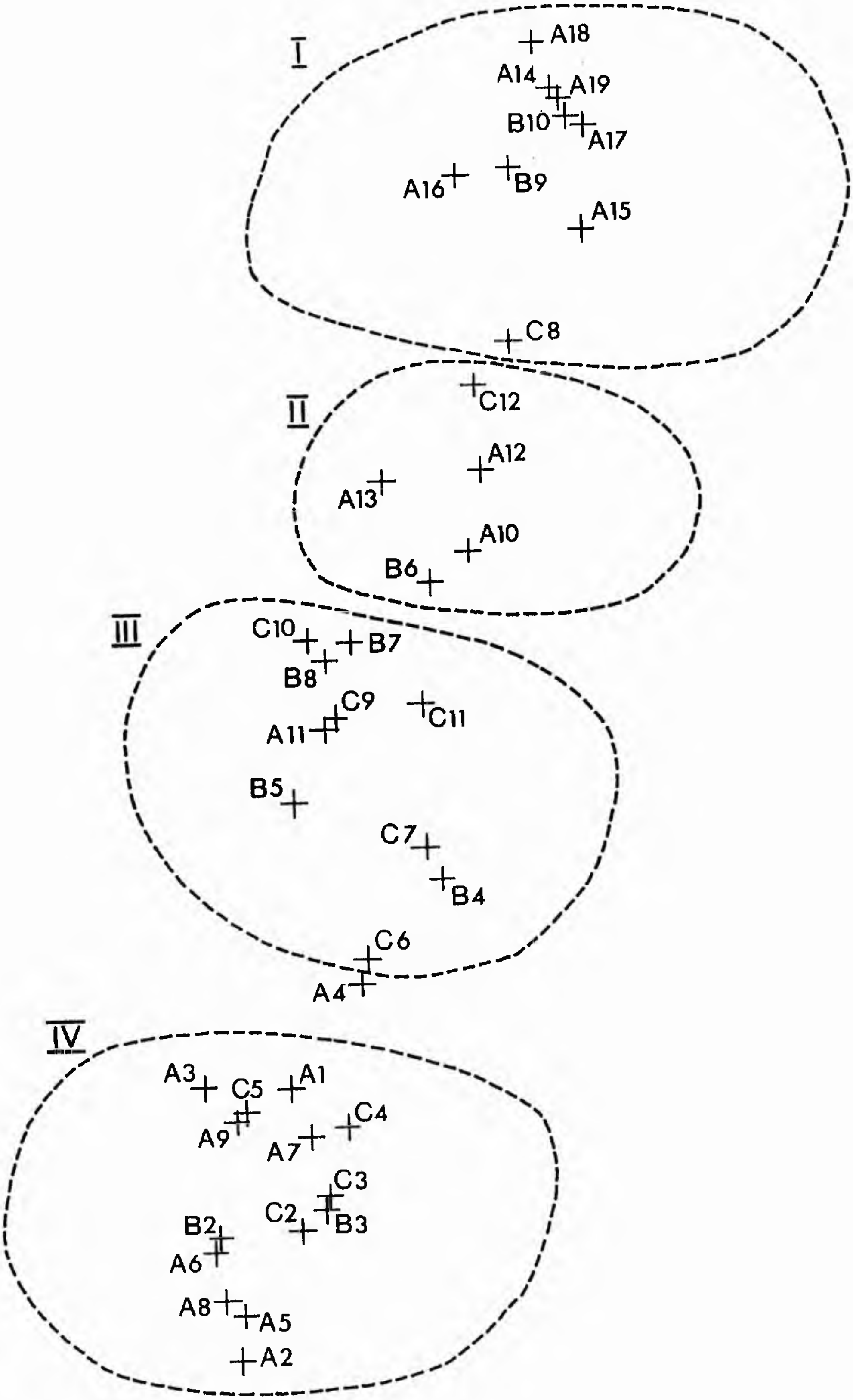


Fig.3.20 Representation of transect data on the third and fourth principal components axes

within these samples but a clear gradation appears between low sample numbers, those from the bog centre, and high sample numbers, those from the woodland. From the component loadings it can be seen that the fourth axis is largely affected by *Betula* and Ericaceae separating the large group of samples. Although subjectively derived the suggested groupings defined in Fig. 3·20 do seem to correspond to the pattern of vegetation on the bog surface. Further division of the samples outside the bog takes place along the fifth axis, defined as it is by high component loadings for *Filipendula* and *Urtica*, separating out (C16–19) and (C24, B13). This division is continued by the sixth axis which divides off C24 from (C15, C21–23, C25, C26) with high component loadings for *Urtica*, *Filipendula*, Gramineae and Cyperaceae.

The second approach to an unconstrained division of the pollen samples involves partitioning the data set into a given number of groups. Because this is, to some degree, placing an artificial structure onto the data set it is important to use techniques which rely on different criteria for recognising different forms of group structure. Here two methods were used, one based on the single-link criterion and a second based on the minimum sum-of-squares criterion.

The single-link method has been used for the analysis of surface samples from Skye by H.J.B. Birks (1973b) and its application is outlined in that paper. It requires the definition of a measure of dissimilarity, d_{ij}, between each pair of objects i and j, utilising the squared Euclidean distance between the values. This is defined by

$$d_{ij} = \sum_{k=1}^{13} (p_{ik} - p_{jk})^2 \qquad \text{where } p_{ik} = \text{the proportion of the ith sample which belongs to the kth taxon (for k 1,2..... 13)} \qquad 3{\cdot}10$$

The results of this analysis are usually presented in graphical form as a dendrogram or tree diagram and this practice is adopted here. One of the advantages of single-link analysis is its ability to join apparently dissimilar objects through a chain of intermediate objects. In pollen analysis such an apparently forced procedure has disadvantages but it allows for the identification of the order in which samples are grouped together.

The results of the single-link analysis of the transect data are presented in the dendrogram in Fig. 3•21. There is a clear cluster formed at a low level consisting of the bog samples, A1–19, B2–10 and C2–12, a grouping which remains consistent for a long time thus emphasising the partition of the data along the first two principal axes by principal components analysis. Within this group five sub-groups may be defined corresponding to the groups I–IV as detailed in Fig. 3•21 with A4 as a separate single-sample group. Again the samples from the <u>Filipendula</u> carr, this time C16–20, are isolated with C16–19 appearing at a very early stage in the division. Of all the samples the single-link analysis found C13 the most difficult to combine, only adding it to the diffuse grassland group at a very high level. This sample comes from the boundary of the woodland and the narrow belt of tall grassland and was one of the most difficult to place in terms of the vegetation categories. Despite its proximity to the woodland and its inclusion in the woodland vegetation category, it is grouped, eventually, with grassland samples. The results of the single-link cluster analysis conform well with the earlier results, particularly in the separation of pollen assemblages from on and off the bog and in the division of the bog samples themselves.

As a check on the results obtained by the single-link analysis a further unconstrained technique was implemented which partitions the

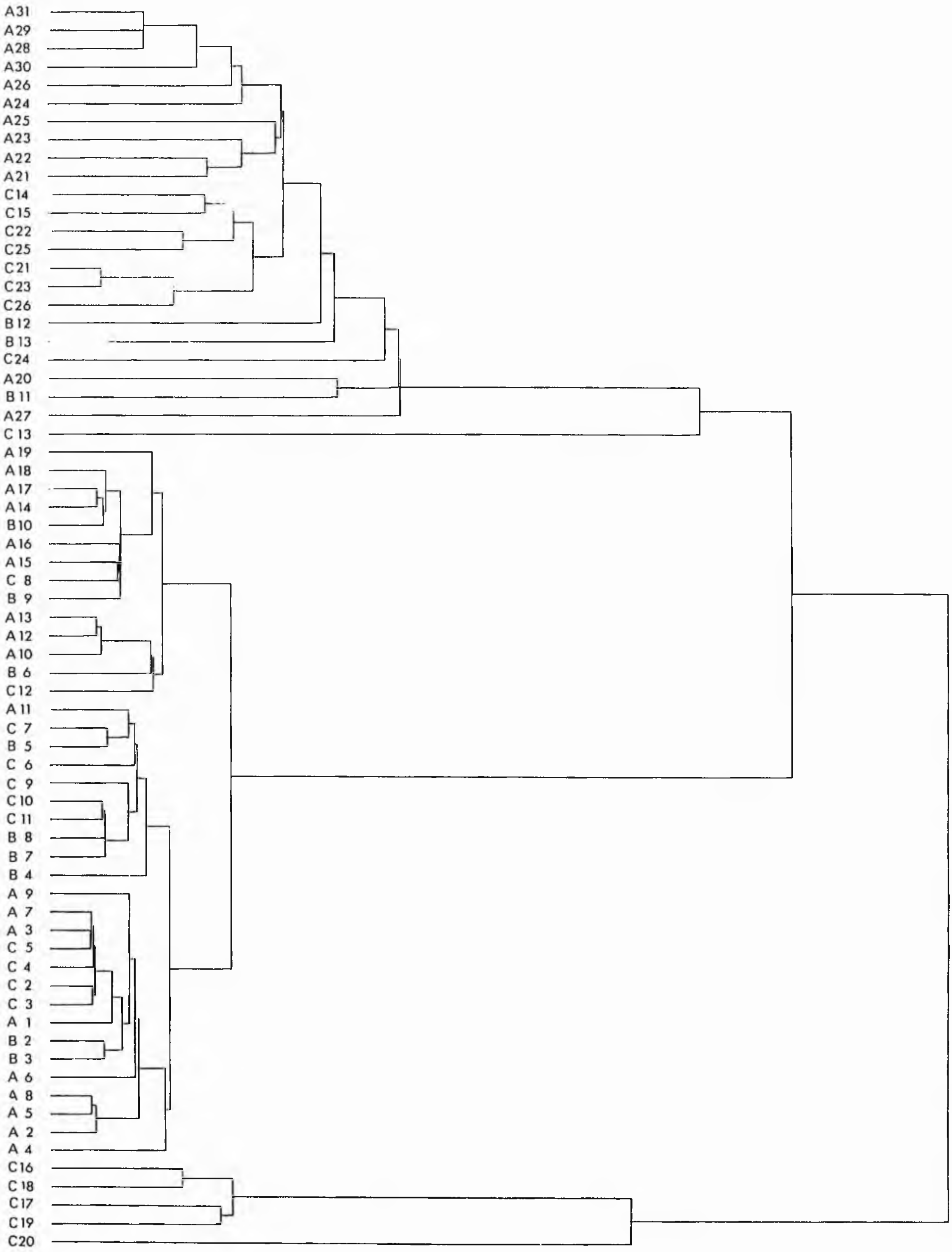


Fig.3.21 Single link dendrogram for transect data

data, in Euclidean form, into a set number of groups, g, so as to minimise the total within-group sum of squared distances about a number, g, of centroids. The centroid of the group is defined by

$$Q_i = (q_{i1}, q_{i1} \ldots\ldots\ldots q_{i3}) \qquad \text{for } i = 1,2,3\ldots\ldots\ldots 68 \qquad 3{\cdot}11$$

The aim of the partition is to minimise

$$\sum_{i=1}^{68} \sum_{j=1}^{13} (p_{ij} - q_{ij}) \qquad 3{\cdot}12$$

Because of the difficulty in examining all possible partitions approximating algorithms are used to find the optimal number and their application has been discussed by Gordon and Henderson (1977). Here two algorithms have been used.

The first algorithm is one which, at each stage of the computation, amalgamates groups which produce the minimum increase possible in total within-group sum-of-squares. The results of the use of this algorithm are presented in the dendrogram in Fig. 3•22. By this technique the <u>Filipendula</u> samples, C16–19, are defined as a clear group at a low level as are the grassland samples as a whole, A20–31, B11–13, C13–15 and C20–26. Although this confirms the fundamental division of the samples into two or three major groups there is less difference in the level of division and ease of agglomeration than previously encountered due mainly to the nature of the technique forcing a partition onto the data. There are also no real outlier samples which are difficult to incorporate. Within the bog, divisions follow the same pattern as that already established with four main groups; I, II, II plus B5 and IV plus A4 and C6.

The second algorithm used was a hybrid non-linear programming algorithm (Gordon and Henderson, 1977) the results of which are presented in Table 3•5. They tend to confirm those groups obtained by use of the agglomerative algorithm but with lower within-group

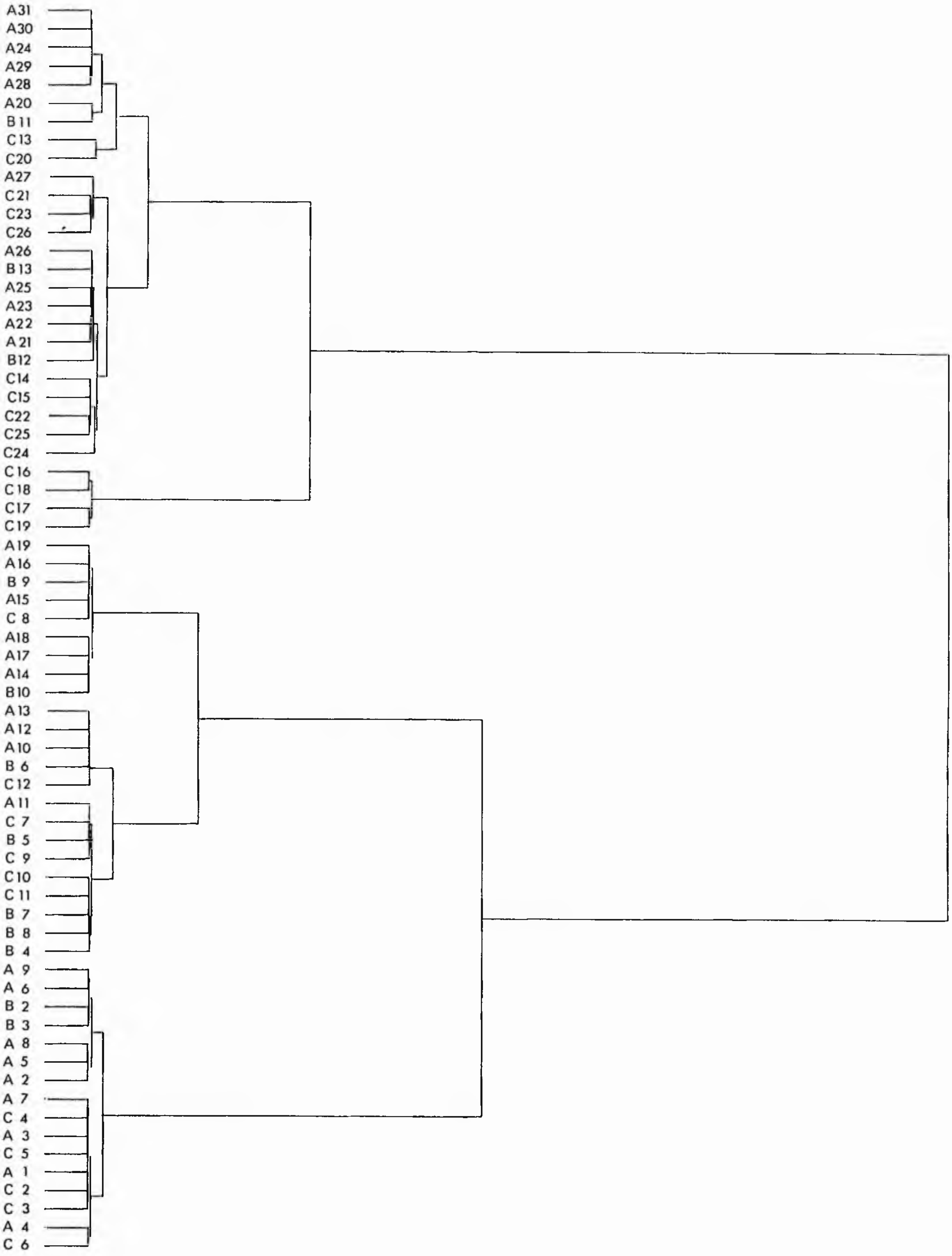


Fig.3.22 Minimum sum-of-squares dendrogram for transect data

Table 3·5

Minimum sum-of-squares partitions into
g groups produced by the two algorithms

g	Agglomerative algorithm	Hybrid algorithm
2	(I,II,III,IV,A4) (A20-A31,B11-B13,C13-C26)	(I,II,III,IV,A4,A20), (A21-A31,B11-B13,C13-C26)
3	(I,II,(III-C6)),(IV,A4,C6), (A20-A31,B11-B13,C13-C26)	(I,II),(III,IV,A4), (A20-A31,B11-B13,C13-C26)
4	(I,II,(III-C6)),(IV,A4,C6), (A20-A31,B11-B13,C13-C15,C20-C26), (C16-C19)	(I,II),(III,IV,A4), (A20-A31,B11-B13,C13-C15,C21-C26), (C16-C20)
5	(I),(II,(III-C6)),(IV,A4,C6), (A20-A31,B11-B13,C13-C15,C20-C26), (C16-C19)	(I,(II-B6)),(III,A20,B6),(IV,A4) (A21-A31,B11-B13,C13-C15,C21-C26), (C16-C20)

sum-of-squares values. The main difference lies in the slight alterations to the group structure of those samples from the bog surface, the lower sample numbers, but these only really affect four samples, A4, A20, B6 and C6, samples which, except for A4, derive from the fringe of the birch woodland.

Overall the results of the unconstrained analyses of the surface samples suggest the occurrence of three very distinct groups. The first comprises those samples from the bog surface, including both the open bog centre and the birch woodland. Within this group reasonably consistent sub-divisions occur which separate out the woodland from the treeless area but the exact definition of the boundary between woodland and open bog is less clearly defined. The second group consists of all the grassland samples and is more diffuse with less clear cut divisions which can be related to vegetation patterns. Because of the dominance of grass pollen, assemblages from different transects and different vegetation categories are seen as similar. Samples A20 and C20, both taken from boundaries between vegetation categories are seen as outliers and in the former case A20 is often considered part of the woodland in the light of its pollen assemblage. The final group relates to the small area dominated by Filipendula ulmaria and usually comprises C16-19, with, occasionally, C20, and is isolated almost completely because of its very high frequencies of Filipendula pollen.

2) Constrained analysis

The collection of data in transect form presents the opportunity for analysis using techniques constrained to divide up the data so that contiguous samples are joined into groups. This not only enables a comparison of constrained and unconstrained groupings but also treats the data as it would if the individual pollen assemblages were taken from a core, substituting the spatial variation along the transect for the temporal variation down a core. Constrained classification has been used on stratigraphical evidence in both palynology (Gordon and Birks, 1972) and geology (Hawkins and Merriam, 1973) but has not been applied to surface pollen analysis despite the number of studies based on transect evidence (e.g. Heim, 1962; Janssen, 1973). The use of three transects, rather than one, or two which are continuous (as would be the case with A and C) presents a problem. To overcome this a procedure has been devised which is explained in graphical terms in Fig. 3·23. If all contiguous points are joined by a line, as in Fig. 3·23b, then the removal of a line divides the points into two groups, hence the removal of (g-1) lines would produce g groups. Elimination of the lines may be achieved by the use of either of two methods and here both are used in order to compare the results and check on the established groups.

The two methods employed for partitioning the data are, firstly, one which minimises the sum-of-squares,

$$\sum_{i=1}^{68} \sum_{j=1}^{13} (p_{ij} - \bar{q}_{ij})^2 \qquad 3 \cdot 13$$

where (p_{ij}) and (q_{ij}) are defined as in 3·12.

Secondly, one which derives the information content of the data,

$$\sum_{i=1}^{68} \sum_{j=1}^{13} p_{ij} \log \left(\frac{p_j}{q_{ij}} \right) \qquad 3 \cdot 14$$

The contiguity constraint follows the method of binary division used by Gordon and Birks (1972) which removes lines one at a time. In the same paper the authors emphasised the need for using more than one method to partition the data to ensure that different structures are not obtained. The removal of a line is defined by a 'marker' which

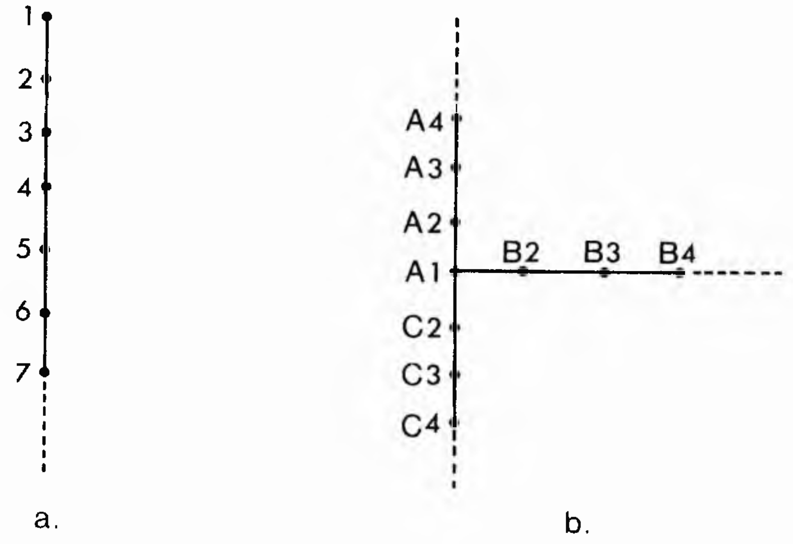


Fig.3.23 Graph representation of contiguity constraints imposed by (a) a transect or core (b) the set of three transects

takes its number from the point closer to the central point A1, e.g. a marker at C12 produces a boundary between C12 and C13.

The results of both methods are presented in Fig. 3•24 and Table 3•6. In the latter the residual variability left after each partition is also presented showing that up to seven divisions the information content approach is more efficient but that after this the position is reversed with only 8•98 per cent residual variability left by the use of the sum-of-squares after eleven divisions. There are few differences in the groups except for the order in which they are produced, the main disagreement being the location of a boundary betweel A11 and A12 by sum-of-squares but between A13 and A14 by information content, divisions which had rarely been considered by earlier analyses. The groups also very closely correspond with those developed by unconstrained analyses showing a clear three-fold division into assemblages from the bog, from the surrounding grassland and from the Filipendula carr. Comparison with the vegetation categories was taken further by the application of a coefficient developed by Rand (1971) for the comparison of two partitions and which, for the comparison of partitions p_1 and p_2 of n objects, is defined by

$$R = 1 - \frac{\left(\frac{1}{2}\sum_i \left(\sum_j n_{ij}\right)^2 + \frac{1}{2}\sum_j \left(\sum_i n_{ij}\right)^2 - \sum_i \sum_j n_{ij}^2\right)}{n(n-1)/2} \qquad 3{\cdot}15$$

where n_{ij} number of objects which fall into ith group in p_1 and jth group in p_2.

The application of this coefficient resulted in a value of 0•9636 as against perfect agreement which is defined by 1, thus confirming the very strong relationship between vegetation categories and their

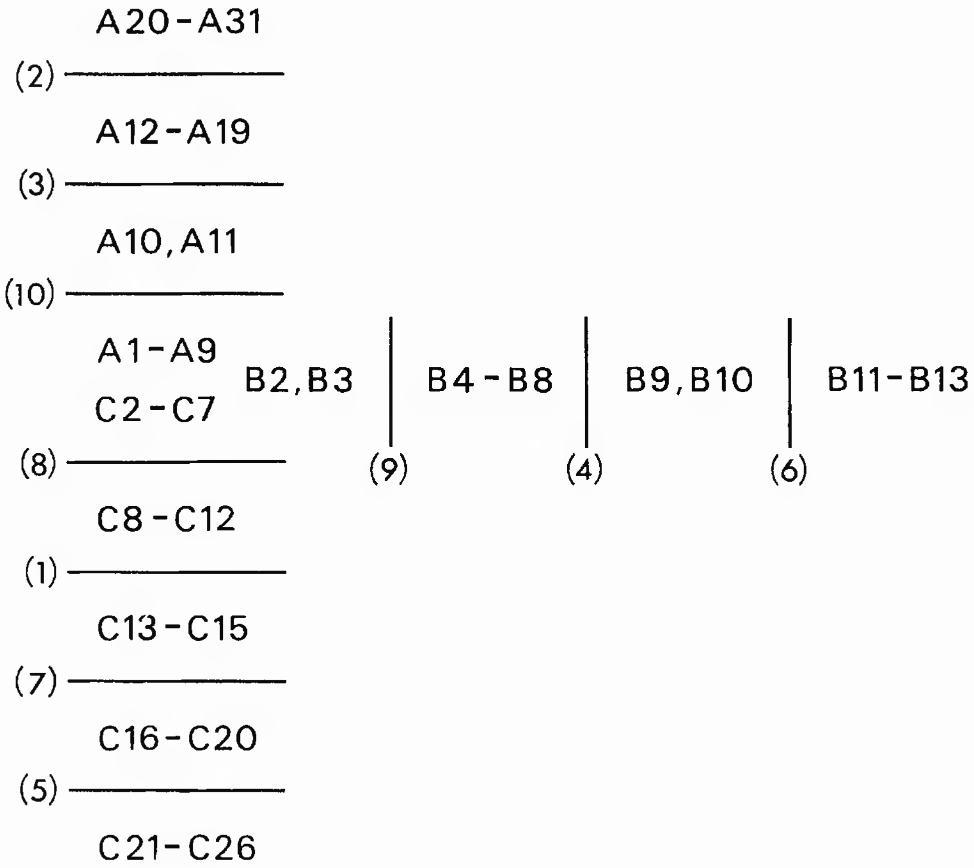


Fig.3.24 Representation of transect data after the 10th. division in the constrained sum-of-squares analysis

Table 3•6

Constrained binary divisive analysis of transect data

Sum-of-squares New marker	Sum-of-squares Residual variability (%)	Division	Information content New marker	Information content Residual variability (%)
C12	76•34	1	C12	69•29
A19	53•86	2	A19	44•81
A11	40•75	3	B10	36•78
B8	33•86	4	A13	28•91
C20	27•60	5	C20	24•23
B10	22•78	6	B8	21•17
C15	18•89	7	C15	18•33
C7	15•00	8	C7	16•26
B3	12•30	9	A9	14•28
A9	10•08	10	B3	12•58
A27	8•98	11	A27	11•11

respective pollen assemblages.

3) General conclusions on the results of the statistical analyses

All the results of the statistical tests are summarised in Table 3•7 which compares groupings defined by the fourth division or its equivalent i.e. into five separate groups, the number of vegetation categories. With the single link method and the principal components analysis only the division into five groupings has been described due to the difficulty in interpreting the order of divisions up to this point.

The close agreement between the results obtained by all the techniques, both unconstrained and constrained, is encouraging, as is the close relationship between the vegetation categories and the pollen assemblages. The definition of a major discontinuity in the data set dividing samples from the bog surface from those outwith the bog occurs at a very early stage in all techniques and reflects the importance of local pollen over pollen derived from neighbouring communities, even from woodland within 10 metres of the sampling site. The division further emphasises the contrasting character of these two areas with the surface samples from the bog showing much less diversity among themselves than those from the open communities away from the peat. The close similarity of the bog samples rests chiefly in the low species variety and, particularly, on the dominance of birch and heather. Nevertheless, within the group as a whole, most techniques detected a gradient in the samples which separated out those of the open bog centre from those taken within the birch woodland and even detected differences within the woodland based largely on birch frequencies and the exclusion of outside pollen. Although samples from similar vegetation categories along different transects are often grouped rogether, those from transect A, A14-19, are consistently

Table 3·7 Comparison of divisions produced by all analyses up to the fourth division into five groups

	Unconstrained				Constrained	
			Minimum sum-of-squares		Minimum sum-of-sq.	Information content
g	P.C.A.	Single link	Agglomerative	Non-linear		
2			(I,II,III,IV,A4) (A20-31,B11-13, C13-26)	(I,II,III,IV,A4, A20) (A21-31,B11-13, C13-26)	(A1-31,B2-13, C2-12) (C13-26)	(A1-31,B2-13,C2-12) C13-26)
3			(I,II,III-C6) (IV,A4,C6) (A20-31,B11-13, C13-26)	(I,II) (III,IV,A4) (A20-31,B11-13, C13-26)	(A1-19,B2-13, C2-12) (A20-31) (C13-26)	(A1-19,B2-13,C2-12) (A20-31) (C13-26)
4			(I,II,III-C6) (IV,A4,C6) (A20-31,B11-13, C13-15,C20-26) (C16-19)	(I,II) (III,IV,A4) (A20-31,B11-13, C13-15,C21-26) (C16-20)	(A1-11,B2-13, C2-12) (A12-19) (A20-31) (C13-26)	(A1-19,B2-9,C2-12) (A20-31) (B10-13) (C13-26)

continued........

Table 3·7 (continued)

	Unconstrained				Constrained	
	P.C.A.	Single link	Minimum sum-of-squares		Minimum sum-of-sq.	Information content
g			Agglomerative	Non-linear		
5	(A1-3,A5-9, B2-3,C2-5) (A10,A12-13, B6,C12) (A11,B4-5, B7-8,C6-7, C9-11) (A14-19,B9,C8) (A20-31, B10-13,C13-26)	(A1-9,B2-3, C2-5) (A10,A12-19,B6, B9-10,C8,C12) (A11,B4-5,B7-8, C6-7,C9-11) (A20-31,B11-13, C13-15,C21-26) (C16-20)	(I) (II,III-C6) (IV,A4,C6) (A20-31,B11-13, C13-15,C20-26) (C16-19)	(I,II-B6) (III,A20,B6) (IV,A4) (A21-31,B11-13, C13-15,C21-26) (C16-20)	(A1-11,B2-8, C2-12) (A12-19) (A20-31) (B9-13) (C13-26)	(A1-13,B2-9,C2-12) (A14-19) (A20-31) (B10-13) (C13-26)

*For explanation of I,II,III and IV see Fig. 3·17.

separated from those taken along transect C, apart from C8. The boundaries between the woodland edge and the outside samples are very clearly defined at A19/20, B9/10 or 10/11 and C12/13, agreeing to within 10 metres from the actual vegetation pattern, but the boundaries on the inside of the woodland are rarely clearly defined, largely due to the influence of Calluna growing within the woodland fringe. The uniformity of the pollen samples from the birch woodland does demonstrate that such communities, even though relatively small areally, do have characteristic pollen assemblages, especially where the form of the vegetation cover is such that it is able to act as a filter to exclude pollen from outside.

The same argument based on growth form can be proposed to explain the isolation of the Filipendula carr samples from the diffuse grassland group. Here a single species dominates both the community and the pollen assemblage and its tall growth form helps to exclude pollen from neighbouring communities. It is only this group of samples, C16-19/20, which consistently emerged from the analyses as a compact small group; more subtle changes in the vegetation such as the local importance of Urtica were rarely detected and never instrumental in structuring pollen assemblage groups. The difficulty in separating grassland samples lies in the dominance of grass pollen in all samples outweighing the influence of all other species which, though perhaps significant in ecological terms, did not produce and disperse sufficient pollen to be of significance in the quantitative analysis of the pollen sums. In this case it could be argued that such species should be weighted so that the numerical analyses could take their occurrence into account. It is, however, not just the presence of species such as Urtica, Rumex and Potentilla which defines different communities but also the change in dominant grass species from Agrostis in the pasture to tall grasses such as Deschampsia in the carr or on the fringe of the cultivated fields. Until the pollen grains of the many different species of grass can be consistently separated and the problem of the under-representation of non-arboreal pollen overcome then more rigorous interpretation remains elusive.

The results of the statistical analysis must be considered within the limitations of the data used, for the groupings established only relate to clusters discovered within this particular data set. The similarity between the results of several different techniques promotes confidence in the existence of characteristic pollen assemblages which are highly correlated with vegetation communities, but only within the rather limited number of samples analysed.

vi) Summary of all the results from Bankhead Moss

In drawing together all the results of the work outlined in this chapter several comments may be made:

1) In the interpretation of pollen results from deposition onto small, raised bogs care must be taken to account for local pollen representation and if necessary the species involved should be excluded from the pollen sum. In the case of Bankhead Moss, an ageing peat bog, this applies particularly to Calluna but the effect of other species such as Cyperaceae should be considered if present as macrofossil remains. This can cause problems in interpretation with for instance the elucidation of the onset of soil acidification in upland areas where Calluna would be an important constituent of the local land-based communities as well as the bog community, and during the early Flandrian and Late Devensian when sedges would most probably have played an important role in the establishment of pioneer plant communities on open ground.

2) Consideration should also be taken of the effect of local

woodland on pollen deposition at a small sampling site. Although values for Betula pollen have been seen to decline rapidly away from the woodland edge, especially within the first 30 metres, the birch woodland can still provide a large component of the pollen collected at the centre of the bog and act as a barrier to pollen movement onto the bog surface from other source areas.

3) Due to poor pollen dispersal of non-arboreal pollen it is possible to underestimate the size of source area represented by the grains that are deposited, and also the nature of the vegetation in these source areas. The exception to this appears to be pollen of Gramineae which, probably because of the large number of source plants, acts as a reliable indicator of open areas around the bog. Of all the indicator species of human activity Plantago and Rumex tend to be well represented even though they are not the only or even the major weed species in the source area. The non-appearance of other pollen types such as Leguminosae, Umbelliferae or Rubiaceae can not be taken as evidence of their absence from the vegetation cover. The results from Bankhead also confirm the very poor dispersal of Salix pollen and the unpredictable nature of Sphagnum spore production.

4) It would appear that the model of pollen transfer devised by Tauber applies to a raised bog such as Bankhead Moss even though the results only provide rather crude support for his ideas. The majority of pollen reaching the centre of the bog from the surrounding area was derived locally and was transported in the trunk space but the percentage of grass pollen involved prevented any clearer identification of either source area or path of transfer. Despite the relatively easy recognition of local pollen (sensu Janssen, 1966), the contribution and definition of extra-local pollen remained difficult and no consistent regional pollen component could be identified.

5) Where communities are dominated, in both their species composition and their pollen assemblage, by one or two dominant species then it is possible to detect consistent characteristic pollen assemblages, even where very different vegetation communities exist in close proximity, and clear boundaries which exist on the ground are expressed in the pollen frequencies. Where changes in the pollen frequencies are more subtle, especially in herbaceous communities, these are less likely to be picked out in an analysis of surface pollen assemblages.

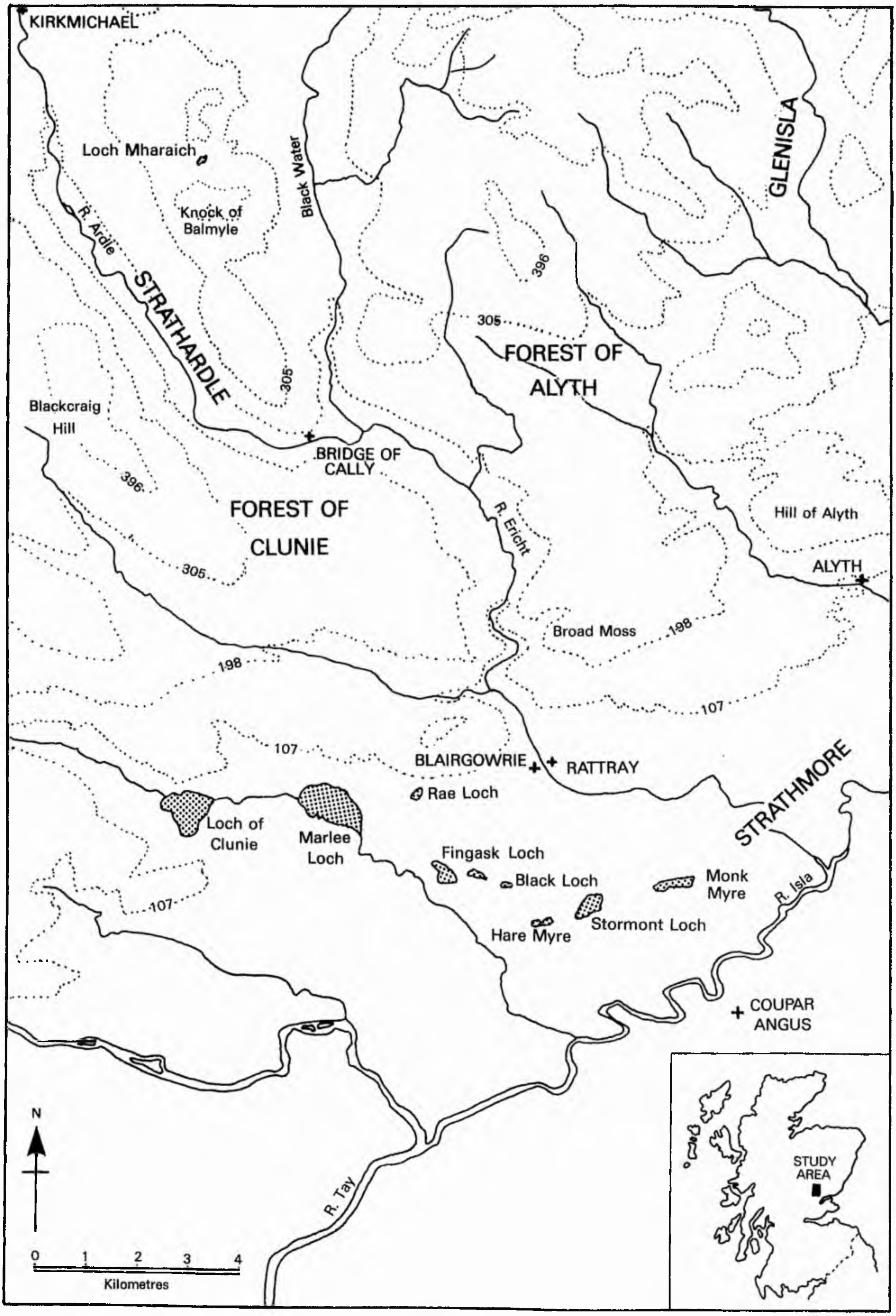
CHAPTER FOUR

STUDY AREA

The area chosen for study comprises part of south east Perthshire around the town of Blairgowrie, now part of Tayside Region (Fig. 4·1). This area presents a transect from lowland Strathmore over the Highland Edge and into the Grampian foothills terminating at the edge of the Higher Grampians. Thus several contrasting environments are encompassed in a relatively small area, the low flood-plain of the Isla, the lowlands of the Vale of Strathmore, the footslope of the Highland Edge, the Edge itself which is of variable width and steepness, the plateau areas of the Forests of Alyth and Clunie and the higher edge of the Central Grampians. Such an area should reflect considerable variation in responses to changing environmental conditions and should have presented different opportunities to human communities for settlement and land utilisation. While the nature of the overall techniques used precludes examination of deposits in all of these areas there are sufficient suitable sampling sites to give an adequate representation of the major environments.

i) Geology and Geomorphology

The dominant geological structure in this area is the Highland Boundary Fault which separates the older Dalradian metamorphic complex of the Grampians from the younger Lower Old Red Sandstone of Strathmore (Fig. 4·2) (Read and MacGregor, 1948; MacGregor and MacGregor, 1961; Walker, 1961; Jones, 1968). Near Blairgowrie the Lower Old Red Sandstone, a sequence of fluviatile and lacustrine sediments with interbedded lavas, has a synclinal form with its asymmetrical northern limb against the fault line, although it does stretch for a few miles



4.1 Study area.

4.2 Geology map of south east Perthshire (Geol. Survey of Scotland ¼" to 1 mile).

north of the Boundary Fault, resting unconformably on the Dalradian metamorphic complex. This syncline underlies the broad sweep of the Vale of Strathmore, up to ten miles wide at this point, bounded to the north by the fault zone and to the south by the Sidlaw Hills which form the southern limb of the syncline.

North of Blairgowrie the Highland Boundary Fault is represented by a broad, poorly defined complex of smaller faults with alternating strata of Lower Old Red Sandstone, slates, phyllites and andesitic lavas. The main displacement along the fault took place in the mid-Devonian when the Grampians rose relative to Strathmore but further lateral displacement occurred in the Hercynian. It was also during the Middle and Upper Devonian that the Lower Old Red Sandstone cover was removed exposing the Dalradian rocks north of the fault leading to the erosion of the Highland grits. Physiographically the geology of the fault zone is manifested by a series of ridges parallel to Strathmore which eventually run into the plateau areas of the Forest of Alyth and the Forest of Clunie, thus providing great local variability in soil parent material and aspect. The fault edge is cut by the Ericht, the Alyth Burn and the Isla, but usually in fairly narrow valleys, especially in the case of the Ericht which, just north of Blairgowrie, flows in an incised valley as much as 75 metres deep in places.

To the west and north of the fault zone, in what many authors term the Grampian Foothills (e.g. Laing, 1976), there is a broad dissected plateau surface largely composed of metamorphic, predominantly schistose, altered grits of the Dalradian series formed between the Pre-Cambrian and Middle Cambrian. It is this surface which comprises most of the Forest of Alyth and the Forest of Clunie. In general the altitude of the surface varies from 750 feet (250m) in the south to 1300 feet (400m) in the north with isolated higher summits such as

Meall Mor (1804 feet, 550m - NO174603), Knockton (1605 feet, 489m - NO196584) and Black Hill (1454 feet, 443m - NO204567). The Forest of Clunie tends to be more steeply dipping with higher summits, especially to the north and west of Blackcraig Hill (1573 feet, 480m - NO093530). The grits are dissected by the two main valleys, Strathardle and Lower Glenshee. The former is clearly glacially overdeepened with relatively parallel truncated sides whereas in Lower Glenshee, below Dalrulzion (NO136583), the Black Water is more incised and there is little evidence of an overdeepened form. The effect of the incision of these valleys, which meet at Bridge of Cally (NO148516), has been to isolate the hill mass of the Knock of Balmyle (1459 feet, 445m - NO115562) and the Hill of Cally (1131 feet, 345m - NO128529) which is composed of the same grits as the surrounding plateau areas. The contortions of the Dalradian complex, produced particularly during the Caledonian Orogeny, are more noticeable in the higher northern areas with bands of hornblende schist, hornblende gneiss, mica schists, the green beds, calcareous schists and limestone, the latter appearing to the east of Kirkmichael where it is quarried. These bands may be taken as the edge of the Grampians proper with evidence of more complex folding, the appearance of granite and an increase in relative relief.

From the middle of the eighteenth century (Geikie, 1865) the plateau-like surfaces of the Grampians have excited interest and their origins debated. The Forests of Alyth and Clunie and the northern edge of Strathmore have been in turn ascribed to the 'Intermediate Surface' (Peach and Horne, 1930), the 'summit surface' and 'higher lowland peneplain' of the 'Intermediate Surface' (Ogilvie, 1928) and the 'Grampian Lower Surface' and 'Grampian Valley Benches' (Fleet, 1938). These ideas were developed by Bremner (1924) and Linton (1951) who considered the relationship of the surfaces to the initiation of the present drainage pattern. The problem of the origin of these surfaces has also been considered by Sissons (1967) who developed the hypothesis of intermittent uplift and warping in Tertiary times thus producing a series of marine platforms with sub-aerial processes acting inland for the Grampians as a whole. Whatever their origin they are a notable feature of the landscape and represent to some degree the exhumation of a former surface (Ramsay cited in Jones, 1968).

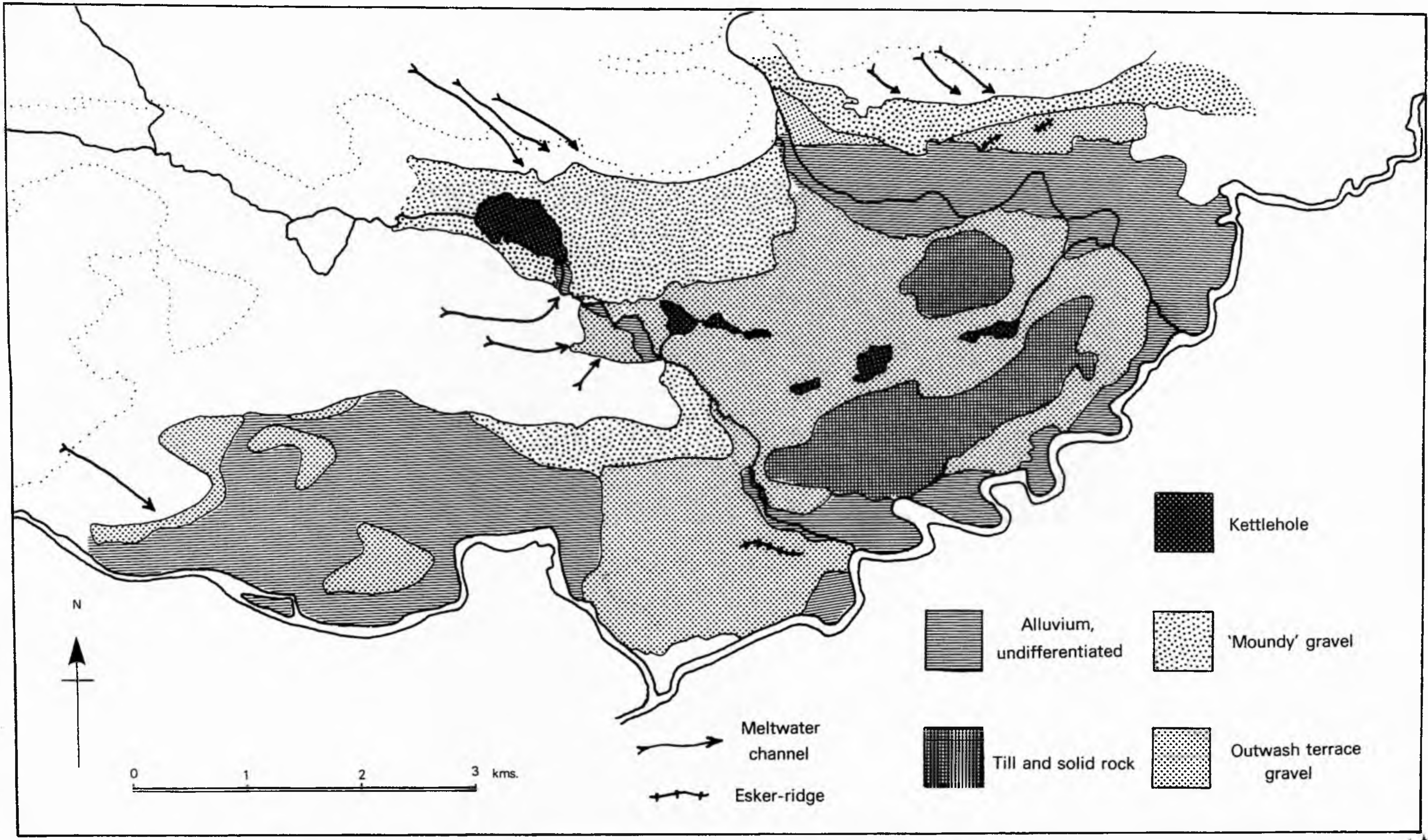
Although the solid geology and its exhumation dominates the structural form of the landscape the upper glens and the general spread of surface material owe their existence to glaciation during the Pleistocene. The valleys of the Ardle, Black Water, Ericht and the Isla all cut across the geology and are related to ice movement from centres in the Grampian Highlands. There has been little published work on the glacial history of this part of the south-east Grampians but many of the landforms can be interpreted in relation to the present state of knowledge concerning the advances and wastage of Highland ice, particularly within the last 20,000 years (Sissons, 1974a, 1974b, 1976). There is ample evidence of glacial activity in the form of meltwater channels and the overdeepening and truncation of valleys but the principal legacy of the ice has been the spread of deposits, especially fluvio-glacial sands and gravels which choke the valley floors and spread out in fans as the valleys disgorge into Strathmore.

Following the ideas of Simpson (1933), Sissons (1963, 1967) postulated the presence of a Perth Readvance ice limit, marking a major readvance during the wastage of the main Devensian ice sheet at about 13500 to 13000b.p., lying to the east of the large kettleholes in the outwash terrace south of Blairgowrie. Recent work on this postulated limit, by Paterson (1974) and by other workers throughout

Scotland has caused Sissons to abandon this idea in favour of a possible extended stillstand of the ice (Sissons, 1976). Paterson mapped the area of Strathmore to the south of Blairgowrie (Fig. 4•3) and identified two series of sands and gravels, a hummocky deposit with many ice-contact deposits largely to the south of the Isla or on the foot of the slopes above Blairgowrie, and a dissected spread of outwash between Blairgowrie and Meikleour pitted with large kettle holes. Although chronologically different the two sets of deposits are seen as a part of the general pattern of deglaciation affected by the degree of ice wastage in Strathmore as a whole. Fluvio-glacial deposits and thin spreads of till deposited by ice of Highland origin are also common north of Blairgowrie but these have yet to be mapped. As this part of the Grampians lay well outside the limits of the Loch Lomond Advance (Sissons, 1974a) all the deposits of glacial origin can be assigned to the general wastage of the main Devensian ice sheet prior to c12500b.p., if not much earlier (Sissons, 1976).

ii) Climate

The contrasts in environment mentioned earlier in the chapter are not mirrored in the available meteorological data for records only exist for two stations in Blairgowrie between 1916 and 1960 (Table 4•1). Blairgowrie is in the rain shadow of the Grampians and as such only receives an annual average rainfall of 31•12 inches (790•5 mm). This amount is extremely variable as an examination of the figures for 1901-1930 has shown rainfall totals for stations in Strathmore to exhibit a higher coefficient of variation than other areas in Scotland (Gregory 1955). At Glenshee Lodge (NO133684) the annual precipitation rises to 45•4 inches (1153 mm) and obviously the higher ground between the two locations will receive varying but higher amounts of precipitation. Because of its inland location Blairgowrie, at 200 feet (61 m), also



4.3 Glacial and fluvio-glacial deposits around Blairgowrie (Paterson 1974).

Table 4•1

Meteorological data for Blairgowrie (alt. 440 feet, 134 metres)

	J	F	M	A	M	J	J	A	S	O	N	D	Annual or Mean	No. of Years
Precipitation (")	3•27	2•33	1•84	1•69	2•33	1•93	2•89	2•98	2•58	3•27	2•99	3•02	28•97	1916–1950
Days rain 0•01+	16•3	14•0	13•7	15•2	14•0	13•6	12•7	17•6	16•7	16•9	16•4	16•7	184	6–7 yrs
Days rain 0•04+	11•5	8•8	9•2	10•2	11•8	10•1	9•3	13•9	13•0	11•6	11•9	12•1	133	6–7 yrs
Days snow fell	2•8	3•0	2•5	0•7	0	0	0	0	0	0	2•0	3•3	14•3	4 yrs
Mean max. temp.*	5•2	6•1	8•5	11•9	15•2	18•3	19•4	18•4	16•5	12•3	8•6	6•2	12•2	1931–1960
Mean min. temp.*	–1•1	–0•8	0•9	2•5	4•8	8•0	10•4	9•6	7•4	4•9	1•8	0•2	4•1	1931–1960

*Denotes station at 200 feet (61 metres) records a higher mean annual maximum temperature than much of Tayside (12•2^{0}C), but again temperature will quickly decrease with altitude for, assuming a dry adiabatic lapse rate of 1^{0}C/100m, by Tullymurdoch (NO198526) at an altitude of 247m, mean annual maximum temperature will be reduced by almost 2^{0}C to 10•3^{0}C. In the higher valleys this relationship could be accentuated by the loss of sunshine hours as relative relief increases.

Climatically therefore there is a considerable contrast between the land north and south of the Boundary Fault with temperature decreasing and precipitation increasing as latitude increases, a contrast made all the more marked by the exposure of the Grampian Foothills. This obviously manifests itself in a reduced growing season and were the data available it would be valuable to look at its variation between Strathmore and Lower Glenshee. It is doubtful whether any land would appear as climatically limited under the parameters outlined by the Soil Survey for Land Use Capability mapping (Bibby and Mackney, 1969) in the southern parts of the Forest of Alyth or the Forest of Clunie but these areas and the upper glens must be considered as marginal for agriculture in a climatic sense.

In the Southern Uplands using the climatic requirements for the growth of oats as both a subsistence and commercial crop Parry (1975) suggested that there were three principal climatic restrictions which determined the success of oats and hence defined the upper limits for successful cultivation. These were exposure, summer wetness (the excess of the middle- and late-summer water surplus) and summer warmth as calculated in accumulated temperature. Of these he suggested that accumulated temperature over 4•4^{0}C (the Soil Survey use 5•6^{0}C) was perhaps the most critical with exposure and summer wetness of lesser importance. Because of the distance between the Southern Uplands and the Southern Grampians it is difficult to use his figures directly to determine such limits for the Forest of Alyth. In the Lammermuirs between 1865 and 1895 the limit of cultivation lay between 320-350m, but, as Parry has shown, this limit varied greatly between 1100 and 1900. Climatic parameters and their effects on patterns of land use must, however, also be seen in terms of local environmental conditions, especially pedological limitations. The effect of economic and socio-economic forces on the extent of cultivation could also mask such environmental influences.

iii) Soils

Information on soils is restricted to the area south of grid line 43, sheets 48 and 49 surveyed by Laing (1976) for the Soil Survey of Scotland (Fig. 4•4) and now published in the memoir for the Soils of the Country round Perth, Arbroath and Dundee. Nevertheless Laing (Jones, 1968 and pers. comm.) has produced a map of Soil Associations for the Dundee region which covers land to the north of the Boundary Fault based on an interpretation of parent material and brief field survey. This is represented in Fig. 4•5 but must be seen as only a tentative and rather general statement.

To the south of the Boundary Fault seven soil associations have been identified (Table 4•2). The complexity of soils and the close relationship between soil type and parent material, drift deposits rather than solid geology, can be clearly seen from the soil classification in Table 4•2 and from a comparison of the maps showing the distribution of soil associations and the map of glacially derived deposits produced by Paterson.

In Strathmore a distinction is drawn between the soils of the Corby and Boyndie Associations derived from fluvio-glacial material of Highland origin and the Balrownie and Forfar Associations which

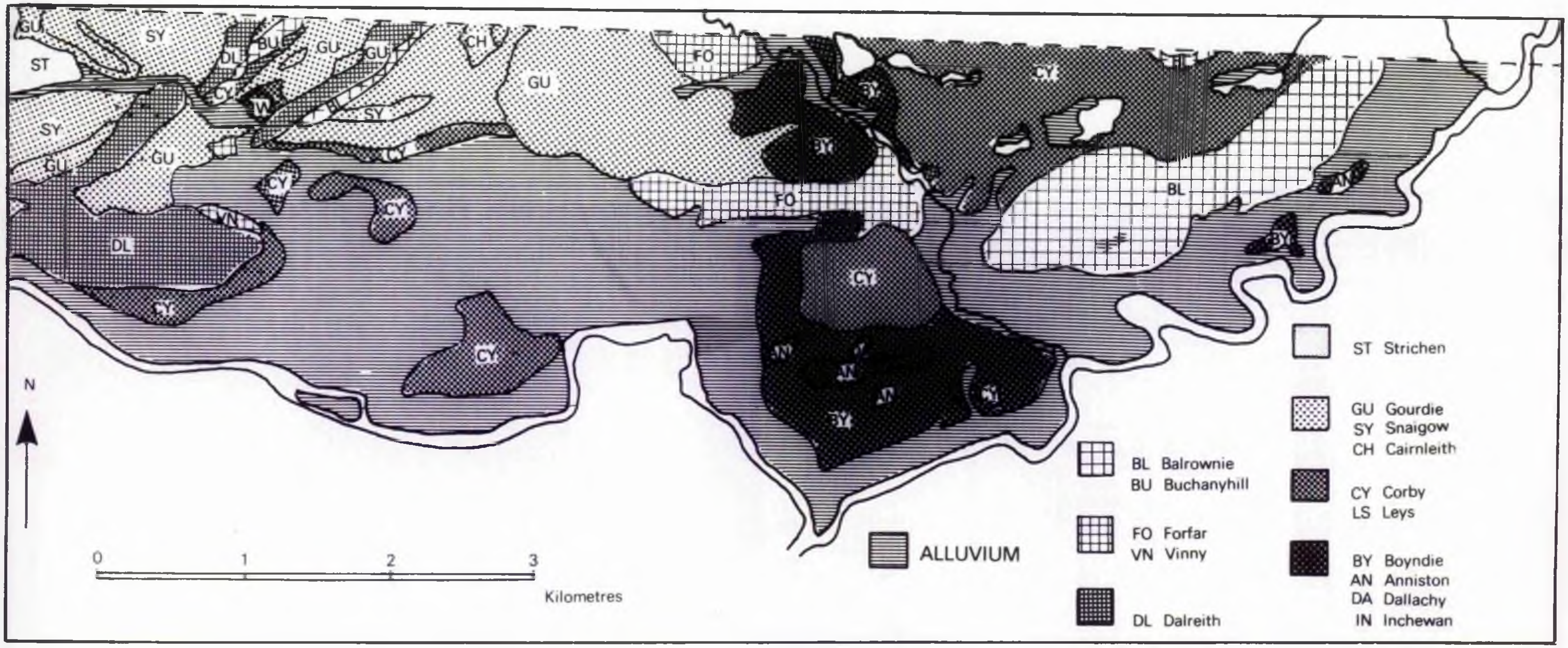
Table 4·2 Soil Associations in Strathmore (after Laing, 1976)

General Origin	Association	Parent Material	Series	Characteristics
Highland Schist	STRICHEN	Till from acid schists and schistose grits	ST Strichen	Freely drained podsol
	GOURDIE	Till from schists and Old Red Sandstone sediments and some lavas	SY Snaigow	Freely drained brown forest soil
			GU Gourdie	Imperfectly drained brown forest soil
			CH Cairnleith	Poorly drained non-calcareous gley
Old Red Sandstone	BALROWNIE	Till from Old Red Sandstone sediments.	BL Balrownie	Imperfectly drained brown forest soil
		Partially water sorted in upper layers.	BU Buchanyhill	Freely drained brown forest soil
		Residual Old Red Sandstone.		
	FORFAR	Water sorted or colluvial material 2'+ in depth over O.R.S. till	FO Forfar	Imperfectly drained brown forest soil.
			VN Vinny	Freely drained podsol
Basic and Intermediate Igneous lavas	DARLEITH	Drifts from basaltic lavas and basic intrusive lavas	DL Darleith	Freely drained brown forest soil

continued ....

Table 4·2 (continued)

General Origin	Association	Parent Material	Series	Characteristics
Fluvioglacial and morainic material	CORBY	Gravel of Highland rocks	CY Corby	Freely drained podsol
			LS Leys	Imperfectly drained podsol
	BOYNDIE	Medium and coarse sand from Highland rocks	BY Boyndie	Freely drained podsol
			AN Anniston	Imperfectly drained podsol
			DA Dallachy	Poorly drained non-calcareous gley
		Fine sand from Highland rocks	IW Inchewan	Freely drained podsol



4.4 Soil map for the area around Blairgowrie (Laing 1976).

4.5 Generalised soil association map for south east Perthshire (Jones 1968).

developed on Old Red Sandstone till, till derived locally in Strathmore and not of Highland origin. This major distinction which at present divides predominantly podsolic soils from brown forest soils provides a clear boundary and leads to very different pedological environments appearing in close proximity.

The podsols of the Corby and Boyndie Associations which dominate the fluvio-glacial outwash terrace between Blairgowrie and Meikleour vary largely in terms of their local drainage characteristics, the major difference between the two associations being that the Corby soils are on the coarser gravels whereas the Boyndie soils appear on predominantly sandy outwash. The outwash itself is composed of acid igneous and metamorphic rocks of Highland origin, although the effect of Old Red Sandstone and lavas is felt further away from the Highland edge. Because the soils of the Corby Association are largely found on gravels they are usually freely drained iron podsols. The imperfectly drained Leys series are only of limited extent, and also comprise an iron podsol. Even on cultivated soils the presence of a bright illuviated B horizon suggests that an earlier soil was an iron podsol or humus iron podsol. According to Laing the Corby Association extends into the upper valleys, particularly that of the Ericht, on the fluvio-glacial outwash that covers the valley floors. Although still predominantly iron podsols the several series of the Boyndie Association show more humus enrichment with a less obviously illuviated B horizon and covers soils in damper locations showing signs of gleying or, as in the case of Dallachy series, comprising a poorly drained non-calcareous gley.

The Balrownie Association is the most extensive in Strathmore and the Lower Sidlaws and is derived from the variable depths of till covering the Lower Old Red Sandstone. The Balrownie series, although classified as a brown forest soil, is usually gleyed in the B and C horizons and in northern Strathmore there is evidence of water movement in these horizons leading to the removal of the clay and silt fraction and manganese dioxide staining. The soils of the Forfar Association are found in close proximity to Balrownie soils as the parent material is Lower Old Red Sandstone till resorted by water action during the Flandrian and localised colluvial deposits. In uncultivated examples these freely drained soils take podsolic forms sometimes with mottling in the lower horizons. When cultivated however they approximate more to acid brown earths.

From the mapping of Laing it would appear that the Strichen and Gourdie Associations, although occurring only in isolated patches in Strathmore, dominate the higher land to the north of Blairgowrie with tongues of Corby soils in the valley floors. The Strichen Association is widespread in the Grampians (Glentworth and Muir, 1963) as it develops on the shallow, acidic schistose and grit till which covers much of the middle and lower slopes of the hills. As altitude increases and on exposed summits these soils become skeletal. The Strichen Association is typified by a freely drained iron podsol with a bleached A_2 horizon and often an indurated B_3 horizon, similar to uncultivated Corby profiles. The origin of this indurated horizon has been a matter of debate for many years (Fitzpatrick, 1956; Glentworth and Muir, 1963) and a recent rather than periglacial explanation is now favoured in the light of soil profiles discovered in eastern Scotland in an archaeological context (Romans, 1963; Romans and Robertson, 1975). The Gourdie Association is considered to be "transitional between the Strichen and Balrownie Associations" (Laing, 1976, p.48). Soils of this Association have developed where there is an admixture of Highland schistose till and till of Lower Old Red

Sandstone producing a more loamy texture. Except for the gleys of the Cairnleith series which occur on former areas of peat moss the characteristic profile is of a brown forest soil often showing podsolic characteristics (e.g. Laing, 1976; Profile No. 12, p.47).

The Darleith Association, which is a feature of the Sidlaws, only appears spasmodically north of the Isla, but due to its parent material, 'drifts' derived from basaltic lavas and basic andesitic rocks, it is found within the Boundary Fault. Because of its basic nature and sandy loam texture the principal soil series, the Darleith series, is represented by a freely drained brown earth and in land capability terms provides good Class 2 land (Bibby and Mackney, 1969).

This rather summary discussion of what is known of the present distribution of soils shows the importance of parent material and hence the patterns of glacial landforms and deposits in this part of the Grampians and emphasises the predominantly acid nature of the pedological environments to the north of the Boundary Fault and where deposits of Highland origin encroach into Strathmore.

iv) Archaeology

> "The number and variety of the Druid remains in North Britain are almost endless. The principal seat of Druidism seems to have been in the recesses of Perthshire, near the Grampian range." (Chalmers, 1807, p.72)

> "In this county are to be found considerable numbers of what are accounted relics of druidism, that is, circles of great rude stones. In the cultivated parts of the country these have in general been destroyed, for the purpose of building and enclosing, but in the Highland districts many of them remain entire."
> (Forsyth, 1806, p.324)

> "In the recent past unrecognised as antiquities by antiquaries and peasants alike, and vulnerable to the agriculture that has so heavily exploited the Scottish east coast for a couple of centuries, our known long barrows of the region may well represent only a portion of the original total." (Piggott, 1971-1972, p.23)

Despite the early attempts of Chalmers and Forsyth to focus attention on the abundant archaeological remains of Perthshire, the eastern part of the county has excited little attention from archaeologists, and in particular there has been virtually no excavation. Yet it seems probable that the higher areas which "may have been abandoned by agriculture since the Bronze or Iron Ages" (Stevenson, 1975, p.107) may present a distribution of remains apparently quite complete, so much so that "their remoteness and good state of preservation seems to have made archaeologists wary" (Stevenson, 1975, p.107). Much of the work that has been done has been descriptive suggesting origins on the basis of the distributions of monuments (Stewart, 1959; Coutts, 1971; Cottam, 1974). This sort of analysis in such an area of contrasting land uses that have changed spatially over time, falls open to criticism of bias due to the effects of the likelihood of survival and discovery as outlined by Stevenson (1975) and as indicated by Forsyth above. Thus their conclusions must be treated with caution. Even a cursory examination of, for instance, the distribution of cinerary urns or short cists shows a strong correlation with arable land whereas hut circles predominate in uncultivated environments. Because of the lack of excavation and critical analysis there is as yet no established chronological framework within which monuments can be confidently placed and their interpretation rests on rather general comparison with known evidence and dates from elsewhere in

Scotland. There is no published inventory of monuments and most of the distribution maps used here are derived from unpublished field surveys by Mr. J. Stevenson of the R.C.A.H.M. in Edinburgh and, as they are just field surveys, must be treated with caution as to the precise definition of the monuments. Through the impact of aerial photography these distributions are under continual review and reassessment with recognisable structures appearing, especially in lowland areas where field surveys failed to find any traces of monuments (St. Joseph, 1973).

Apart from occasional reports of the finding of microliths in some of the more northerly glens there is no direct evidence of Mesolithic occupation in south-east Perthshire. The important Mesolithic site in eastern Scotland at Morton, on Tentsmuir in Fife (Coles, 1971) shows evidence of spasmodic, temporary settlement between 8000 and 6200b.p. and artefacts suggest that the occupants travelled at least into Fife to obtain flints. Any artefacts derived from rocks of Highland origin probably originated as river gravels or reworked beach pebbles. A pine dug-out canoe found at Friarton brickworks near Perth underlying the Carse clay of the main Flandrian transgression (Geikie, 1880) and two shell middens at Stannergate, Dundee (Mathewson, 1879) and Broughty Ferry (Hutcheson, 1886) show that communities were using the Tay and travelling upstream as far as Perth but there is little published evidence to suggest that they penetrated as far as the Isla.

Evidence pertaining to settlement during the Neolithic, especially the early and middle Neolithic, is also sparse in this part of eastern Scotland. There are scattered finds of artefacts such as leaf-shaped and petit tranchet arrowheads, stone axes (such as a banded hornfels axe from Alyth) and carved stone balls (Coutts, 1971) but there are few monuments. Eastern Perthshire apparently lay to the west of the influence of the groups which built long cairns, as at Dalladies and Capo, and to the east of those groups which built the chambered cairns found in Strathtay, and which are usually assigned to the Clyde group (Henshall, 1974). The idea of an uncolonised area separating these two forms of structures has been brought into question by the excavation of the round barrow at Pitnacree (Coles and Simpson, 1975) as it was found to contain an early mortuary structure, dated to 2860±90b.c. (Gak-601), and showed affinities with the eastern long barrows (Henshall, 1974). The implications of this are that round barrows identified close to the Tay-Isla confluence (Coutts, 1971) may perhaps, on excavation, reveal early Neolithic rather than Bronze Age characteristics. The site also provided examples of hand axes originating from Tievebulliagh, Northern Ireland and Great Langdale. Local axes from Craig na Caillach, Killin were also found, and using dates on peat underlying and overlying levels indicating axe production, the manufacture of these seems to have taken place between 2510±90b.c. (UB-371) and 2250±90b.c. (UB-372). Although excavations at Pitnacree suggested burning of the vegetation cover and disturbance, possibly even cultivation, of the land surface under the barrow, clearer indications of land utilisation at this period were derived from the excavation of the long barrow at Dalladies, in Angus (Piggott, 1971-72), a site lying on a gravel terrace at the foot of the Highland Edge. The construction of the long barrow shows three phases of a timber-posted mortuary structure, a similar stone structure aligned at an angle to the timber frame and finally the introduction of an elaborate stone setting and completion of the barrow. The second phase, a mound of turf and soil overlying the light timber frame with its birch-bark roofing, was deliberately burnt and, from the charcoal discovered, dates of 3240±105b.c. (I-6113), 2710±50b.c. (SRR-289) and 2585±55b.c.

(SRR-290) were obtained. Of these Piggott argues that the last two are the most reliable. He suggests that the free-standing mortuary structure compares favourably to that at Pitnacree and also to Lochhill in Kirkcudbrightshire (3160±110b.c., I-6409) and that the later phases, with Capo and other barrows in Aberdeenshire, comprise a distinct local group showing affinities to the Caithness and Sutherland, and Orkney-Cromarty chambered cairn group (Henshall, 1972). On the evidence of the turves used in construction and the general character of the monument Piggott suggests that,

> "At Dalladies forest clearance had already taken place before the barrow's construction, and in no instance would one expect that such monuments, with their implications of co-ordinated communal labour, would be the products of colonists in their initial entrance phase of settlement" (1971-72, p.44).

Although there is no direct evidence of cultivation the turves used in the construction of the barrow represented a clearing at least 0·73ha. in extent. Bearing in mind the extent of the area concerned with this particular monument, its recent identification as a long barrow and the dates from Pitnacree, it may well be that Neolithic, even early Neolithic, occupation of the south-eastern Grampians and Strathmore was more widespread than is at present realised.

In spite of the lack of archaeological material of the earlier Neolithic there is ample evidence of early Bronze Age, perhaps even late Neolithic, communities, especially in the form of stone circles, single standing stones, stone pairs and four-posters. Simple interpretation of the age of these features is difficult. Excavation of a stone circle at Croft Moraig in the upper Tay (Piggott and Simpson, 1971) found pottery in Phase II of the monument similar to the early Neolithic local ware found at Pitnacree and dated to the early third millennium b.c. (Coles and Simpson, 1965) and, as Burl (1976) comments,

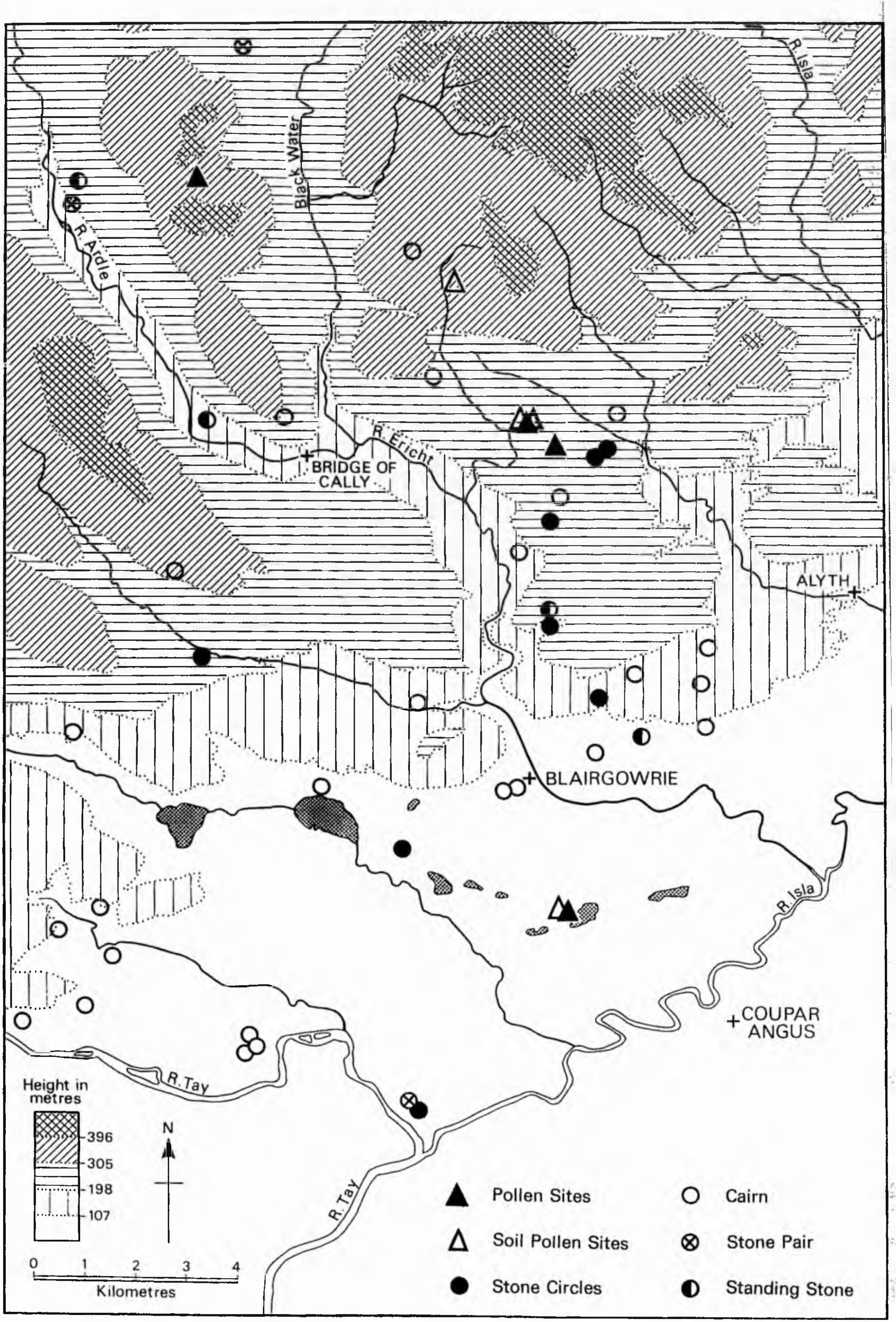
> "...... here the revealed sequences of phases emphasises the naiveté of assuming that the visible features of any circle are contemporary" (p.200).

Excavation of a stone circle at Moncreiffe House near Bridge of Earn (Stewart, 1974) has exemplified the same problem, for there the circle was preceded by a henge on the same site, and this site has also brought up the problem of the relationship between henges, of which there are few in Perthshire, and stone monuments.

The overall distribution of stone circles and standing stone monuments of various forms has been examined by several authors (Stuart, 1866; Coles, 1908, 1909; Stewart, 1959, 1966a, 1966b; Burl, 1976) and several hypotheses as to their builders and period have been put forward. Fig. 4•6 shows their local distribution based on published and unpublished evidence. Burl (1976) emphasises the importance of the group of monuments to the north of Blairgowrie,

> "The varied Glenshee group is a microcosm of Perthshire in which circles and ovals and rectangles mix" (p.90).

He suggests similarities between the Perthshire forms and the recumbent stone circles found in Aberdeenshire (Burl, 1972, 1976), separating however the circles of Highland areas from those found in Strathmore and further to the south. Whatever the origin of these monuments, their development and their relationship to other monuments, as for example at Croft Moraig, they do form very distinctive and important features in the landscape and almost certainly in their principal stone phase date to some time during the second millennium (e.g. 1810±90b.c. NPL-69 for the change to stone at Croft Moraig and 1200±150b.c. Gak-787 for a cremation associated with the stone circle at Scone (Stewart, 1966a)). In terms of their location those remaining are found either

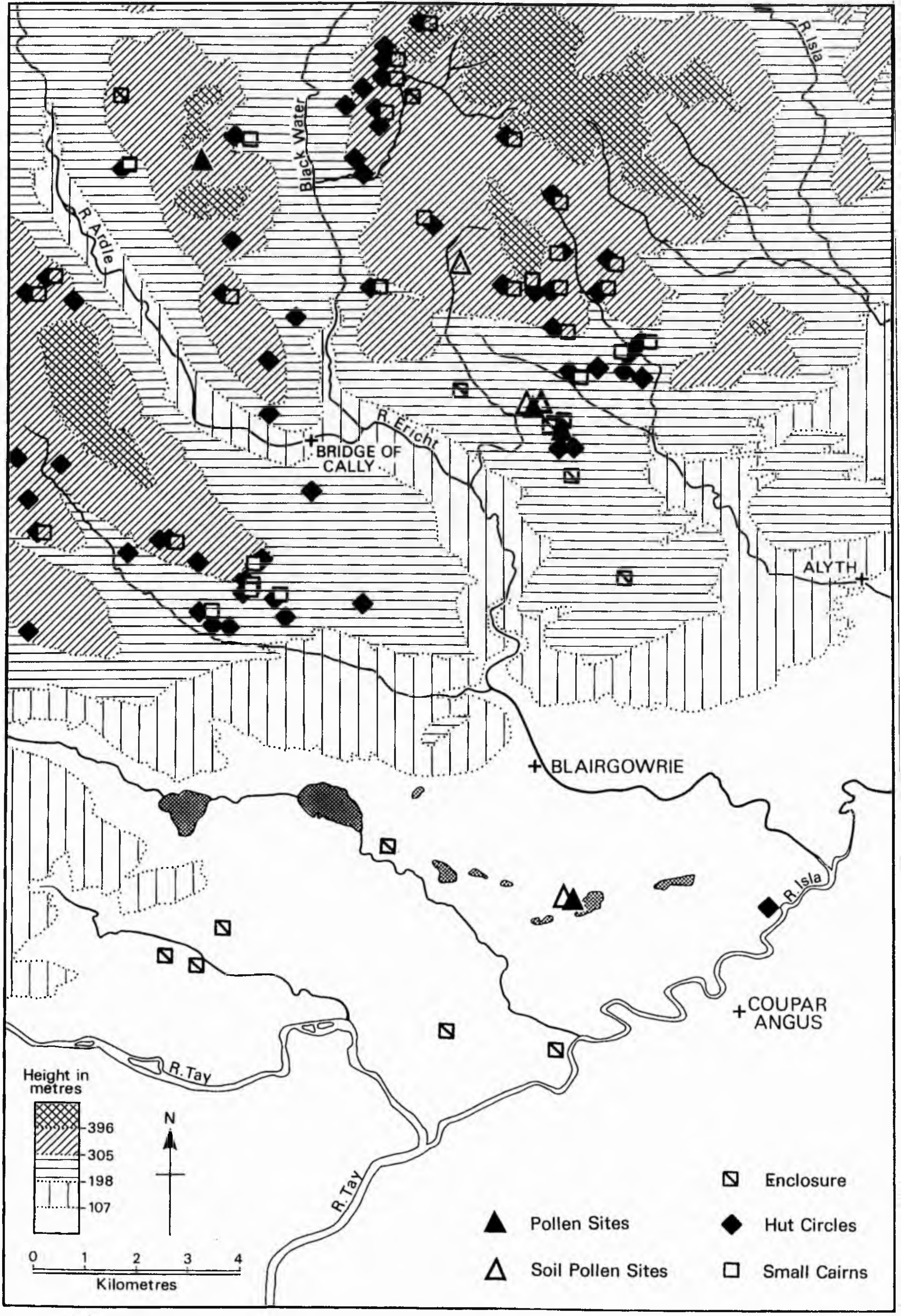


4.6 Distribution of stone circles and standing stones (Coutts 1971, Burl 1976, Stevenson pers. comm.).

on ridge sites, as at the Heatheryhaugh complex (NO0951) or along the valley floors, as in Strathardle,

> "...... and here as on Dartmoor or in Caithness there arises the impression of families settling on tracts of unexploited land late in the second millennium b.c." (Burl, 1976, p.190).

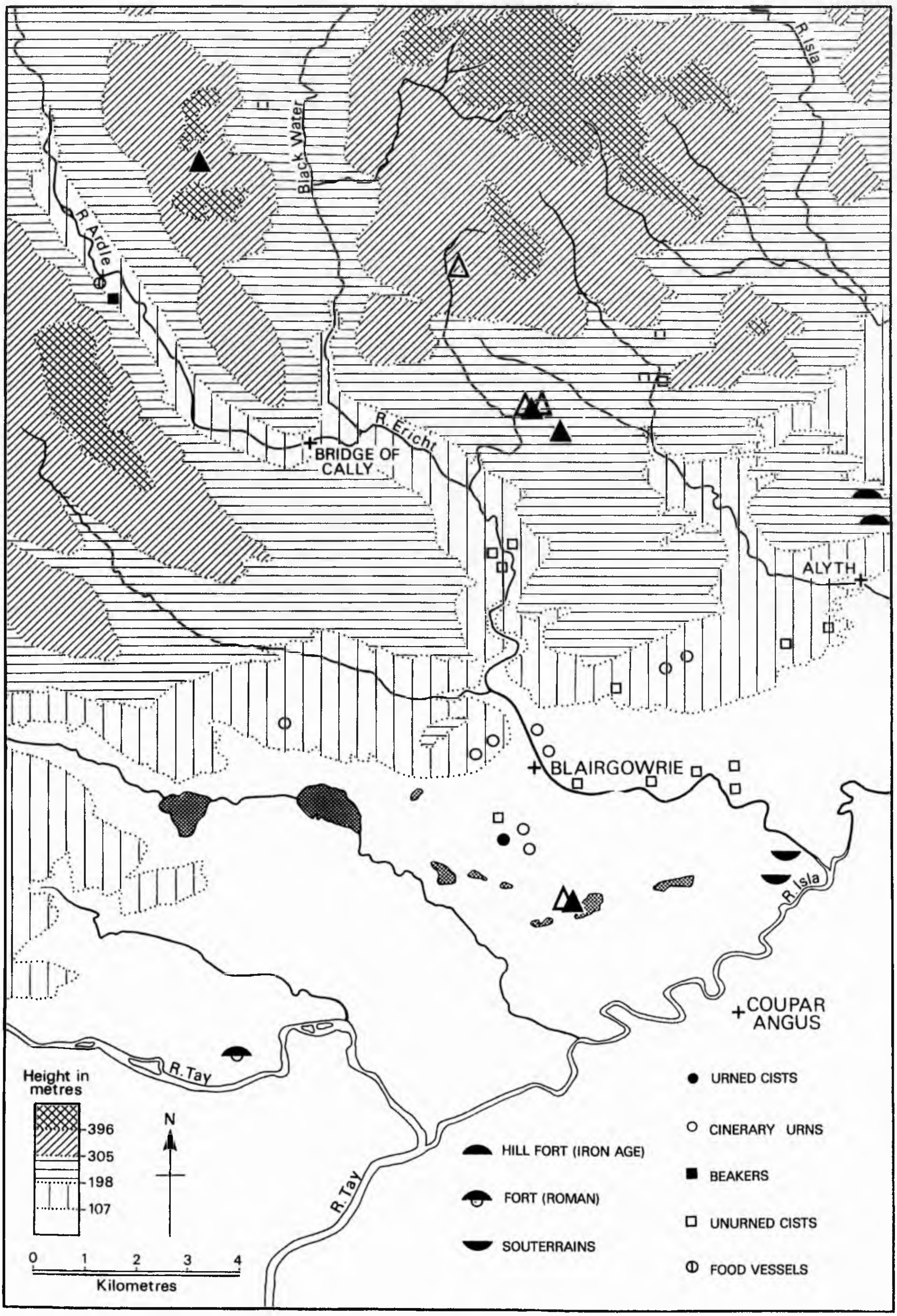
Of a slightly later period, and certainly thought of in a Bronze Age context, are the various cairns found in several different locations throughout eastern Perthshire. These are described merely as cairns in Fig. 4•6 to distinguish them from the much smaller cairns, thought to be probably clearance cairns, plotted in Fig. 4•7. On field evidence many of those defined in Fig. 4•7 would fall into the category of ring cairns (Ritchie and MacLaren, 1972), notably the very fine example of Cairn Gleamnach (NO158554). It is however possible that those on the flood plain or terraces above the Tay may not be of this form, and as no excavation of this type of cairn has taken place in eastern Perthshire their internal complexity and chronology is unknown. Ritchie and MacLaren (1972) define ring cairns as having a genuine bank of material surrounding an open space in which burials were deposited and suggest possible affinities between the Perthshire examples and the Clava cairns. Such cairns have been found in close conjunction with four posters, as in Glen Almond (Henshall and Stewart, 1954-56). A twofold chronological division of the ring cairns has been suggested, an early group associated with Beaker remains and dating to the early second millennium b.c., and a later group, consisting mainly of enclosed cremation cemeteries. The origins of the Perthshire cairns are difficult to establish, especially in the absence of excavation and associated Beaker remains, but there is a possible enclosed cremation cemetery at NO166582. No cairns have the large kerbs sometimes found elsewhere as part of their construction, although such



4.7 Distribution of hut circles, enclosures and small cairns (Stewart 1964, Stevenson pers. comm.).

kerb cairns are a feature of other areas of Perthshire (Burl, 1972; Ritchie and MacLaren, 1972). The spread of quartz pebbles which is often discovered on excavation of large cairns is a common feature throughout the county (e.g. Piggott, 1971-72; Stewart, 1974).

Evidence of Bronze Age and later occupations in the form of pottery or individual inhumations is very variable and appears to have been greatly affected by the discovery factor of Stevenson's synthesis. Very few Beakers have been found north of the Tay and Isla (Fig. 4·8). In eastern Scotland as a whole they have a very eastern distribution with early examples from Tentsmuir and only late types from further north. The type of single grave burial adopted in Perthshire seems to have been very localised. To the south and west of Alyth Food Vessels have been found but again these seem more numerous further east and south. The agricultural lands north of the Isla have however provided quite numerous finds of urned and unurned cists, and cinerary urns, with only rare finds within the Highlands (Fig. 4·8). There is a particular preponderance of urned short cists east of Alyth whilst between the Isla and the Ericht mainly unurned short cists appear. This division does not seem to have resulted simply as a factor of discovery and hence probably marks a genuine difference in burial practice between the two areas. However the different burial practices need not necessarily have been contemporary. Both types of cists show a widespread distribution in eastern Scotland although urned short cists are commoner north of the Tay and towards the coast (Coutts, 1971). Apart from the hoard at Balmashannar near Forfar which contained late Bronze Age metalwork of North German origin (Coles, 1962), burials have produced few grave goods and little pottery. In the absence of dates it has been suggested that short cist burials may span not only the Bronze Age but also extend into Iron Age and Pictish times (Taylor, 1968).



4.8 Distribution of urned and unurned cists, cinerary urns, beakers, forts and souterrains (Coutts 1971, Stevenson pers. comm.).

By far the most numerous monuments and the most difficult to date and interpret are the remains of hut circles, enclosures, small cairns and field systems (Fig. 4•7). These are found very widely, especially above 300m and the individual symbols used on the distribution map often refer to several hut circles apparently arranged as a group. As is also clear from the map, hut circles and small cairns are usually found in close proximity. The distribution mapped here represents a much larger group than that defined by Thorneycroft (1932) or by Stewart (1964). The earliest study of hut circles in Strathardle was undertaken in the middle of the last century by Stuart (1866) but since that time only two excavations have taken place, at Dalrulzion (Thorneycroft, 1932) and Dalnaglar (Stewart, 1964). At Dalrulzion (NO125575) on the eastern slopes of Cnoc Eirionnaich Thorneycroft discovered three forms of hut circle; a circular hut form with a double wall of concentric rings, a similar form but with only a single wall and a double form of tangential rings. He made several observations on the Dalrulzion forms and the groupings in general but found little that helped to date them. He suggested that in general the groups of hut circles seem to be located at about the 1000 feet (c300m) contour, a feature later commented upon by Stewart. From the field survey by Stevenson it would appear that this is not strictly true in that they are distributed between the 300m and 400m contours, with few over 400m. Thorneycroft also commented on the vegetational differences of the sites in relation to the landscape in general, in particular the local presence of thistles and foxgloves. He himself found documentary evidence for the re-use of some of the Dalrulzion features in the sixteenth century and Medieval or later occupation of hut circles is found elsewhere in Scotland.

At Dalnaglar (NO150641) Stewart excavated what she preferred to call enclosures, the term hut circles implying a use which may not be valid, and found inconsistencies between the two enclosures as well as differences with those found at Dalrulzion. Archaeologically the excavation at Dalnaglar throws doubt on the usefulness of any classification of hut circles or enclosures on strictly structural grounds. An investigation of the pottery showed great dissimilarity with the Dalrulzion sherds which Thorneycroft, on the basis of an analysis of the clay used, thought to be entirely of local origin. The fabric was coarse and some pots were cordoned leading Coles (p.154 in Stewart, 1961-62) to argue that they were a local eastern Scotland form of the late Bronze Age or early Iron Age, suggesting occupation of the site around the first century b.c. Results of pollen analyses from Dalnaglar (Durno in Stewart, 1961-62; Durno, 1965) suggests that there had been several periods of interference with the vegetation cover, none dated, any of which could refer to the occupation of the enclosures. Soil analyses showed the enclosures to have been built on well developed freely drained podsols characteristic of the local till (presumably Strichen series) while phosphate determinations showed a variation in values between the inside and the outside of the enclosures. However, even on the phosphate evidence it was not possible to establish the function of the features, whether they were in fact huts and therefore family settlement sites (there is some evidence of post holes suggesting they might have once been roofed) or whether they were merely enclosures for cattle or livestock in general.

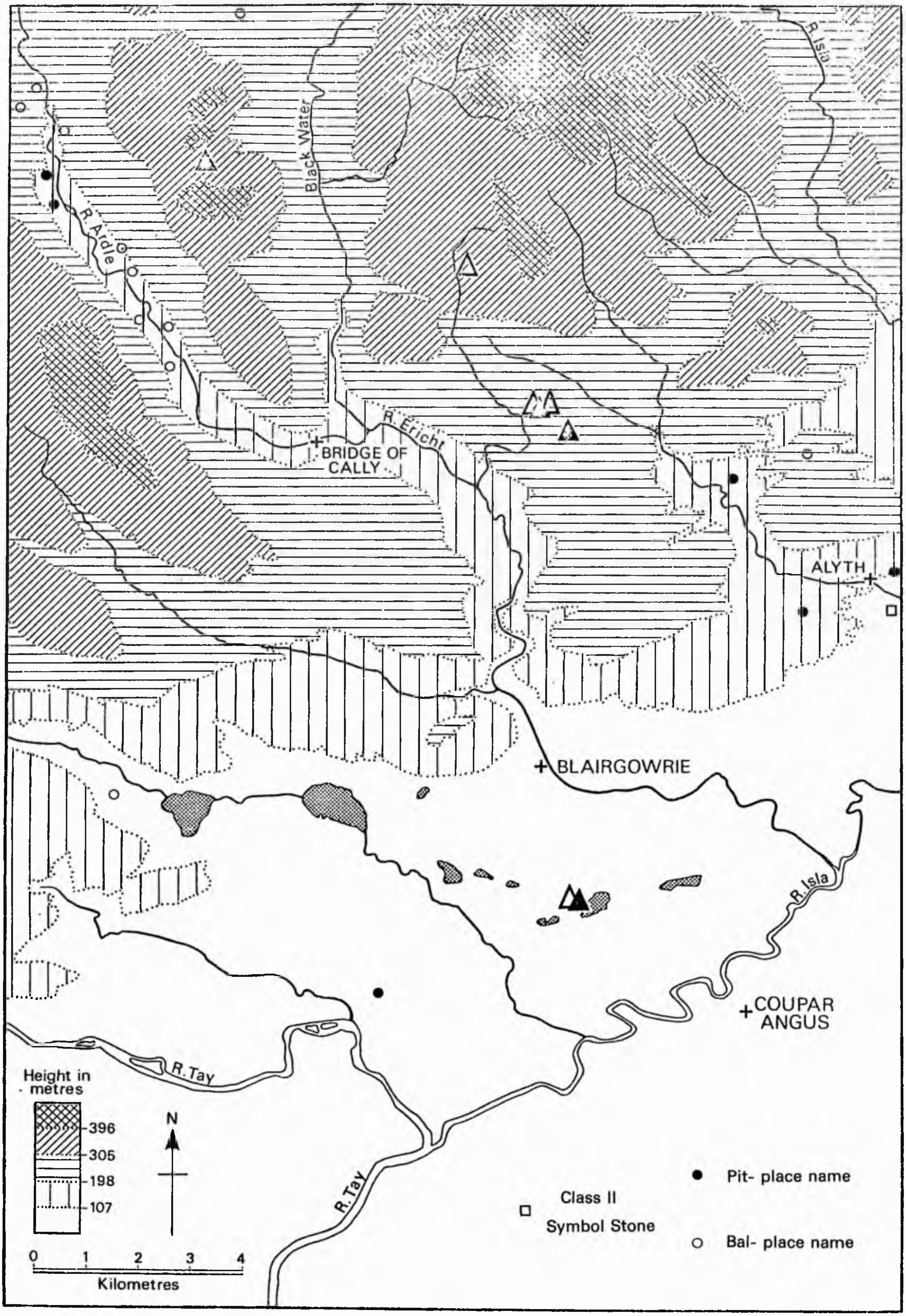
The closest analogy to the hut circles and enclosures at Dalrulzion and Dalnaglar is to be found in the excavations at Kilphedir in Sutherland (Fairhurst and Taylor, 1970-71). The first occupation of the hut circles at Kilphedir occurred at 2370±40b.p. (GU-299) and there is evidence of further occupation perhaps 400-500 years later. The hut circles were constructed within a small parcel of cultivated land although Fairhurst suggests that the economy of the settlers was still predominantly pastoral. From the effort required to construct the floors he argues that the huts would have been in use over many years but the overall duration of the phases of settlement is still unclear. Soon after their final occupation the huts were overwhelmed by blanket peat. Without dated sites, but on the available limited pottery evidence, it seems reasonable to assume that the spread of hut circles and enclosures in eastern Perthshire were constructed at a similar time to those in Sutherland and were late Bronze Age - early Iron Age, at least in their initial phase, extending from the first millennium b.c. into the first centuries a.d. In the absence of excavation it does, however, remain possible that some were either constructed earlier or on sites occupied at an earlier time. The differences in construction and verious styles of pottery so far discovered make it appear likely that the building of hut circles and their utilisation covered a relatively long period. The mere number of monuments in Perthshire also adds weight to this view. Their function must still remain unclear for there is as yet no excavated evidence of the association of hut circles and field systems in Perthshire as at Kilphedir, or as in the Dartmoor context (Fleming and Collis, 1973). They may just be livestock enclosures, perhaps even shielings used by a population whose permanent settlement sites lay elsewhere. Whatever their function they do represent "a remarkable concentration in a relatively small area" (Stewart, 1961-62, p.144).

Apart from the hut-circles and enclosures there are few sites of Iron Age provenance. There is a hillfort on Barry Hill above Alyth (Fig. 4•8) which is timber-laced and has been ascribed to the late

Bronze Age – Iron Age transition (Coutts, 1971) and shows affinities to the string of hillforts on the northern edge of the Ochils of which Abernethy is the most important example. A palisaded enclosure has been discovered below the Roman remains at Inchtuthil and it may be that further sites will be discovered on the gravels or on the flood-plain of the Tay and Isla by aerial photography. Stevenson (1975), from his analysis of the distribution of ring forts by Loch Tummel, has argued that their distribution may give a false impression of the distribution of Iron Age and later settlement, with original sites now underlying settlements having acted as the original foundation for later settlement patterns. The same may of course be true for eastern Perthshire where singular features such as hillforts may not give a correct impression of former settlement distributions. A further enigmatic feature, apparently of this period, are the souterrains (Wainwright, 1963), underground chambers found throughout eastern Scotland and of uncertain use (Fig. 4•8), except that it has been argued that they may have been used for storage of grain or cattle.

The impact of the incursions by the Romans into Strathmore seems to have been very localised. The fort at Inchtuthil at the Tay-Isla confluence (4•8) is Flavian and was a marching camp on the line between western Perthshire and Aberdeenshire. It was first occupied by Agricola in his campaign starting in A.D.80, a campaign which terminated with his victory over the native Caledonians at Mons Graupius, possibly in Aberdeenshire, in A.D.84. The fort at Inchtuthil was one of the most important in this part of Scotland as it acted as a guard for the Dunkeld gap and also provided a secure basis for further movement through Strathmore. Inchtuthil and the land north of the Earn was abandoned in A.D.87 but the area was reoccupied in the Severan campaign of A.D.209, a campaign instituted to defeat both the Maeatae, a confederacy of Scottish tribes which had extended its influence south of the Antonine Wall, and the Caledonii, who controlled Moray and Buchan. Pottery remains from Carpow on the Tay suggest that there may have been a final Roman campaign in cA.D.306, this time against the Picts. The effect of the Romans, apart from their military presence, is difficult to establish, especially in considering the area they occupied although there is evidence from the eighteenth and nineteenth century Statistical Accounts of Roman finds in eastern Perthshire (e.g. N.S.A.S. for Blairgowrie for 1845 which reports a Roman spear-head and coins from Cochrage Muir).

Eastern Perthshire lay at the northern margins of southern Pictland, the division between the concentrations of the northern and southern Picts extending roughly eastwards from the Mounth (Whittington, 1974-75). The activities of the Picts, or 'Picti', between the second and ninth centuries A.D. which are outlined in the Pictish Chronicle and at second hand in such documents as Bede's 'Historia Ecclesiastica Gentis Anglorum', are scarcely represented in the Perthshire landscape. Like most of Scotland there are no definite Pictish settlements (Wainwright, 1955) and the only monuments of known Pictish origin are symbol stones (Henderson, 1967; Thomas, 1963; Jackson, 1971). Examples of both Class I symbol stones, roughly dressed boulders with the symbols only in shallow relief, and Class II stones, dressed stones with higher relief, have been found to the southwest of Alyth (Fig. 4•9). The main grouping of stones discovered in Strathmore however lies south of the Isla at Meigle. The presence of these stones suggests occupation both between 500 and 700A.D. (or perhaps 650-700A.D.) and after 750A.D. (Henderson, 1967) but as their purpose is still unclear, whether they were funerary monuments (Thomas, 1963) or represented marriage arrangements or alliances (Jackson, 1971), the actual distribution of settlement



4.9 Distribution of Pictish monuments and placenames (Cottam and Small 1974, Whittington 1974-75).

remains unknown. The presence of the stones in Strathmore is far more restricted than the place-name evidence for Pictish settlement which suggests settling along the glens that finger into the south east Grampians as well as in Strathmore (Fig. 4·9). The distribution of *Pit-* place-names, thought to be of Pictish origin deriving from the term *Pet-*, a share or a portion of land, has been studied by Whittington and Soulsby (1968) and Whittington (1974-75), who conclude that there is a strong relationship between their distribution and well sheltered, well drained land of good agricultural potential. This interpretation was made on the assumption that soil potential had changed little since the Pictish period, a belief that may be questioned given the increasing evidence for soil change over relatively short time periods (Evans, 1975), a fact however noted by Whittington. Nevertheless the claims for the interpretation of Pictish settlement based solely on place-name and symbol-stone evidence proposed by Cottam and Small (1974) must be treated with caution. A recent suggestion by Nicolaisen (1975) that the use of *Pet-* may only have occurred in the later Pictish period when areas were becoming bilingual between P-Celtic and Gaelic, has been refuted by Whittington on the evidence of the widespread occurrence of *Pit-* place-names south of the Forth, an area which was Anglicised by the seventh century.

It thus seems clear that the presence of *Pit-* place-names does reflect the location of settlements from perhaps the earlier Pictish period but it must be remembered that the distribution now known is incomplete for even some records of *Pit-* place-names from Medieval charters can now no longer be traced with any certainty. The actual definition in terms of land holding represented by the term *Pet-* is uncertain but there is some correspondence between it and the later areal unit of the 'davoch'. Whittington and Soulsby (1968) examined the likelihood of the Gaelic Bal- having become the Gaelic equivalent of Pet- as tenurial systems changed and as Whittington (1974-75) comments,

> "The most exciting feature to emerge is the high probability of a link between the medieval land assessment units and those of prehistoric times" (p.109).

Despite the paucity of Pit- place-names in eastern Perthshire those names prefixed by the Q-Celtic term Bal- are widespread, especially along the valley floors, as along Strathardle (Fig. 4•9). Of the Pit- place-names few have suffixes which give much insight into the form of the landscape. Pitcrocknie (first noted as Petcrockno in 1506, NO488260) derives from Pet - croicneath, finished with skins, Pitdrey (noted as Petdreyne in 1232, NO208502) from Pet - drudhaith, of welling water, and Pitlea (location unknown) from Pet - liath, grey steading (Meikle, 1925). Many of the Bal- place-names also take their names from natural features, especially locational factors, as with Balduff from -dubh or dark, and Balwhyme, from -chuim, at the breast of the hill.

The occupation of eastern Perthshire throughout prehistoric time is therefore but little understood. The remains, in many different forms, are numerous, but due to the scarcity of excavation and the preliminary nature of the field survey much has yet to be discovered. Though archaeologically rich in respect of some kinds of monuments, notably stone circles, standing stones, cairns and hut circles it is impossible to do more than hypothesise about pressure on land at different periods and about the likelihood of any continuity of settlement over long periods. It is this inadequacy of information that makes the application of techniques such as pollen analysis useful in trying to test these hypotheses prior to adequate archaeological enquiry.

v) Documentary Period (twelfth century to the end of the eighteenth century

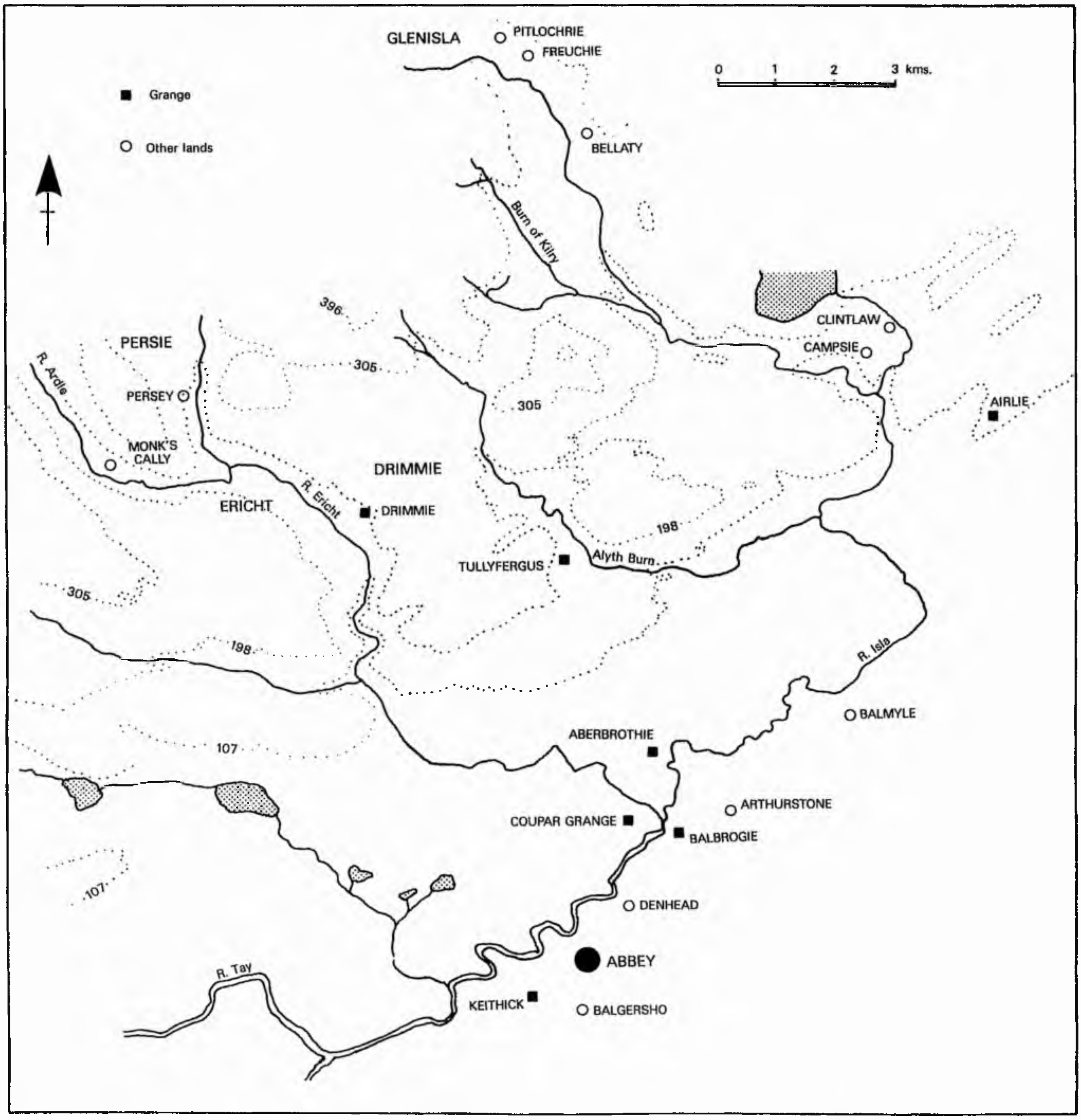
Documentary records concerning settlement and land use exist from the twelfth century onwards but, as with the archaeological record, they provide only a partial picture, both spatially and temporally. For the period between the middle of the twelfth century and the late seventeenth century there are two principal sources, one ecclesiastical and the other secular. By far the most useful of these is the former, the Rental Book of the Cistercian Abbey of Coupar Angus (Vols. I and II, Rogers, 1879) which includes information on the growth and eventual decline of the abbey and its lands and provides a very valuable insight into the land use practices associated with monastic control. The main secular source, Bamff Charters and Papers (Ramsay, 1925), although it covers a longer period of almost 500 years, is less useful in chronicling land use than it is in tracing the fluctuations of the Ramsay's estate boundaries, but it does give occasional glimpses of tenurial rights and husbandry.

Barrow (1962) envisaged the twelfth and thirteenth centuries as " ...... a period of steadily growing population ...... (with) pressure on available land and a steady process of winning new arable from waste" (p.127). The documentary record for this is scanty and presents certain anomalies so that it is difficult to establish the degree of settlement and land use continuity between this period and its predecessors. North of the Forth the 'davoch' was still the main unit of landholding, relating to both pastoral and arable usage, a unit probably of some age. Blairgowrie suffered a reduction in its land assessment by Scone Abbey from six to five davochs in 1232, equivalent to a removal of two-and-a-half carucates, a feature which Barrow interprets as the implementation of a newer measure of landholding which, in Blairgowrie, "represented the hard facts of the agricultural situation as it obtained in the 1230's" (1962, p.139). Nevertheless the picture of this part of eastern Scotland during the twelfth century and thirteenth century appears to have been one of increased arable cultivation as witnessed by the growth of multure and the building of new corn mills, but still with a considerable pastoral influence as "the arable tail seems to have wagged the pastoral dog" (Barrow, 1962, p.137).

By far the greatest impact on the agriculture and landscape of Strathmore in the Medieval period was the establishment of the Cistercian abbey at Coupar Angus (Rogers, 1879, Franklin, 1952). The effects were felt most in those areas controlled by the monks but the change in husbandry they brought must have had wider repercussions. The abbey was granted its site in 1161 by Malcolm IV who gave his lands at Balbrogie, Tullyfergus and Drimmie and granted rights in the forests of the Ericht and the Isla as well as freedom of passage through his other neighbouring estates. The Cistercians developed sites in 'loca deserta', areas of marsh and unreclaimed land, bringing them under the plough, and the low lying flats of the Earn and the Tay proved excellent for their needs. By 1164 the abbey had been established and over the next two centuries gradually extended its control through endowments from the crown and from local families, often either as penance or for the provision of prayers said for the givers benefit. Between 1172 and 1178 they gained Aberbrothie, Campsie and Keithock, all held in frankalmoigne, free and perpetual. Endowments continued throughout the thirteenth century. Alexander II gave land in the Forest of Isla in 1233 and in 1250 Alan, the kings' usher, gave a further 800 acres in Glenisla. By 1300 Coupar Angus was at the height of its power and ownership with lands in Strathmore, the Forests of Alyth, Drimmie, Persey and Glenisla, and rich agricultural land which they had reclaimed in the Carse of Gowrie. The influence of the Cistercians extended from as far north as Monks Cally in Strathardle to as far south as the north bank of the Tay in the Carse of Gowrie (Fig. 4·10).

Originally the land was held and farmed by the monks with a number of lay brethren or 'conversi'. This system was successful up to the beginning of the fourteenth century but after this date as the prestige of the abbey fell, they had difficulty attracting new monks and 'conversi' and began to feel the effects of the wars with England, albeit indirectly through a loss of revenue and tenants. The monks therefore began to lease out their lands to tacksmen in return for rent in kind, money and service, a system previously only practised in marginal areas of the estate. This process continued throughout the fourteenth, fifteenth and sixteenth centuries and gradually all the abbey lands were broken up until in 1596 they were all handed over to the king, although even by 1408 the abbey at Citeaux had agreed a remission of dues "hearing with pitying ears the lamentable desolation of the Abbey at Coupar" (Franklin, 1952).

The principal achievement of the abbey was the intake of wastes and the establishment of centralised arable agriculture, especially in lowland Strathmore. The heart of the monastic lands revolved around nine granges at Coupar, Keithick, Balbrogie, Aberbrothie, Drimmie, Tullyfergus, Airlie, Kincreich and Carse Grange, all of which were established between 1201 and 1225. These were located approximately three miles apart and acted as centres from which the 'conversi' organised the new style of husbandry introduced by the Cistercians. The use of runrig (Adams, 1976) was abolished in monastic lands and a crop rotation introduced, an element of husbandry outlined in many leases as "one boll corn and pease corresponding". Manure (comprising not only dung but also ash and old roofing thatch) was used more widely



4.10 Extent of the lands of the abbey at Coupar Angus in the 14th. century.

on the crops of barley. The corn was milled at mills owned by the estate, as at Monks Cally, with the twenty-first sheaf going to the miller as thirlage. Fulling mills for the production of cloth were also introduced at Keithick, Kincreich and Balgersho. The style of husbandry adopted by the Cistercians tended to precede the attempts by the Scottish Parliament to improve agriculture, as in the Rotation Act of 1472 which required a rotation of wheat, peas, rye and beans and was mainly disregarded in the country as a whole, but all relevant Acts often found their way into monastic leases. At Coupar they were particularly concerned to keep 'goold' or corn marigold (Chrysanthemum segetum) at bay to improve corn yields and strictures to this effect appeared in many leases, again also at the insistence of Parliament. At Coupar Grange it is mentioned in 1473 that the tacksman " ...... sal defend the toun fra guld under the pane of the parliament", at Cragnenady, also in 1473 " ...... he sal kepe his land clene fra guld", and at Cotyards in Forfarshire in the same year the tacksman " ...... are to wyn the land fra guld with wedying, removying and syftyng of seid". Under the law it was possible to forfeit sheep should corn marigold be found in a tenant's field.

It would appear that, at least around the granges, a variety of crops was grown in single fields, not in runrig, and probably in some form of rotation, albeit elementary. The variety is seen in the rents in kind demanded in the leases of the fourteenth century which, throughout the lands, required meal, bear, oats and oaten straw as well as hens, capons, hogs, calves, lambs, kids, butter and cheese. Rents in service usually consisted of casting and winning peats, providing reapers for the harvest and making nets and fishing tackle. During the earlier period of leasing there was still a degree of control over the actions of the bondmen and in particular they were directed as to the number of cottars they could employ, thus keeping the size of the population restricted to that which the land could support. Leases varied in their length from five or seven years to up to nineteen years and one tenant during the fourteenth century held the same land for sixty years. It was this relative security of tenure which also made for better use of the land and a more settled form of agricultural production. The monks were not only reclaiming lowland marshes for cultivation but there is evidence for them taking in land from the moors for arable purposes, possibly helped at first by the greater probability of harvest success at higher altitude during the thirteenth century (Parry, 1975), but it is not clear exactly where land was improved.

Although arable cultivation was of great importance in Strathmore and the more fertile areas of land held to the north of the Boundary Fault, cattle and sheep were still an important part of the economy of the abbey. The monks held extensive lands in Glenisla and on the Forest of Alyth at Drimmie, lands which backed onto the common lands of the Forest. In these predominantly pastoral areas, which were largely unfenced, the monks installed a storemaster to keep account of the number of sheep and black cattle pastured, and also, as with the land officers in the lower areas, to check that the terms of the leases were being adhered to. Wool was important, as in most Cistercian abbeys, for its export value and in 1255 there are records of excess wool being sent as far as Douai. Shielings were developed, particularly in Glenisla, where the cattle were moved to after the sowing of the spring corn, but suffered from the predation of wolves. In a lease of 1552 from Glenisla it was stipulated that two hounds should be kept for protection against the wolves. Apart from domesticated animals the monks were allowed to take deer from their forest lands and also cherished their fishing rights on the Ericht and the Isla with eighty salmon a year being taken at Cally and Drimmie.

Forest lands were an integral part of the monastic economy and those in Glenisla, Persie, Drimmie and Cally were held in free forest thus allowing the monks the rights to wood for building and fuel, to pasture animals and to take game, rights previously held in those areas by the Crown. There were Foresters appointed to all main Forests. The Forest of Alyth was under the control of the Earl of Crawford in 1499 but by 1566 the position was in the hands of a local family, the Lindsays, who were charged with controlling the forest barony of Alyth, held in free forest, "where there were woods". The Forestership of the Forest of Clunie in the fifteenth century was held by the Earls of Atholl who owned extensive areas in central Perthshire. Woodlands were under great pressure during the Medieval period as a whole and at Campsie 'assarting', the taking in of woodland for agriculture, was organised. At Campsie the first cleared areas provided 45 acres of corn and 90 of grass but there they were faced with the problem of keeping animals off the crops and a series of tacks refer to this problem. By 1471 much of the woodland at Campsie had been felled and the Forester General put in four tenants to prevent cattle from encroaching on the regenerating trees and to stop all moor burning. By 1494 the woodlands were walled and in 1551 there is a lease which mentions further walling and suggests that coppicing was practised. In a lease of 1578 to John Craigo the Campsie woods are described as both open and closed or 'hanynt'.

Problems of diminishing woodland were by no means restricted to Perthshire for between 1424 and 1594 the Scottish Parliament passed a number of Acts to try and enforce woodland management (Anderson, 1967). This began in 1424 with restrictions on moor burning and the cutting of greenwood and in 1457 James II proposed that woods, hedges and broom should be planted on pain of sentences ordained by the local lord or baron. By 1503 there was an Act 'anent the artickle of greenewood, because the wood of Scotland is utterly destroyed' with a £5 fine as the retribution for anyone caught. This appeared to have little effect and by 1579 the third time anyone was caught cutting greenwood or broom they faced 'hangyng to the death'. By 1587 death was the punishment for "quhatsumever person or persones wilfully destroyis and cuttis grewand treese and cornes", but even this failed so that at the Parliament of 1594 it was commented that,

> "The kings whaill Wooddes, Forestes, Parkes, Hanynges etc. are gretumly destroyd ...... and the various acts were not put into execution" (Anderson I, 1967).

At Coupar many of these laws were enforced and embodied in tacks or terms of tenure. A tack of 1548 outlines,

> "Give ony of thame ...... cuttis or destroyis ony of our said wood, without thai be conveyait thairto be our forestaris ...... it sal be tinsall of thair takkis" (Rogers II, 1879).

In 1549 James Henry received the 'forestership and keiping of woods of Drymmie' and was to,

> "keip the samyn fra thameself, servands, and tenantis, and fra all utheris at thai may stop at thair utar power, except and to the vphald of the said grund alanerlie, vnder the pane of ane vnlaw of grene wod" (Rogers II, 1879).

Tenants were encouraged to plant timber as at Coupar Grange in 1471 when the tacksman was bound to "plant in his gardens, at least on the edge, timber, viz, ashes, sauchs (birches), and osiers", and orchards also became part of the general pattern of husbandry. The abbey itself fined wrongdoers under the Parliamentary Acts as in 1460 when two men were fined for cutting and selling wood from one of the abbey's forests.

Despite the attentions of the abbey reduction of woodland was taking place continuously for timber for building had to be brought from the distant forests of Athole and Murthly, the local trees apparently being unsuitable for the purpose.

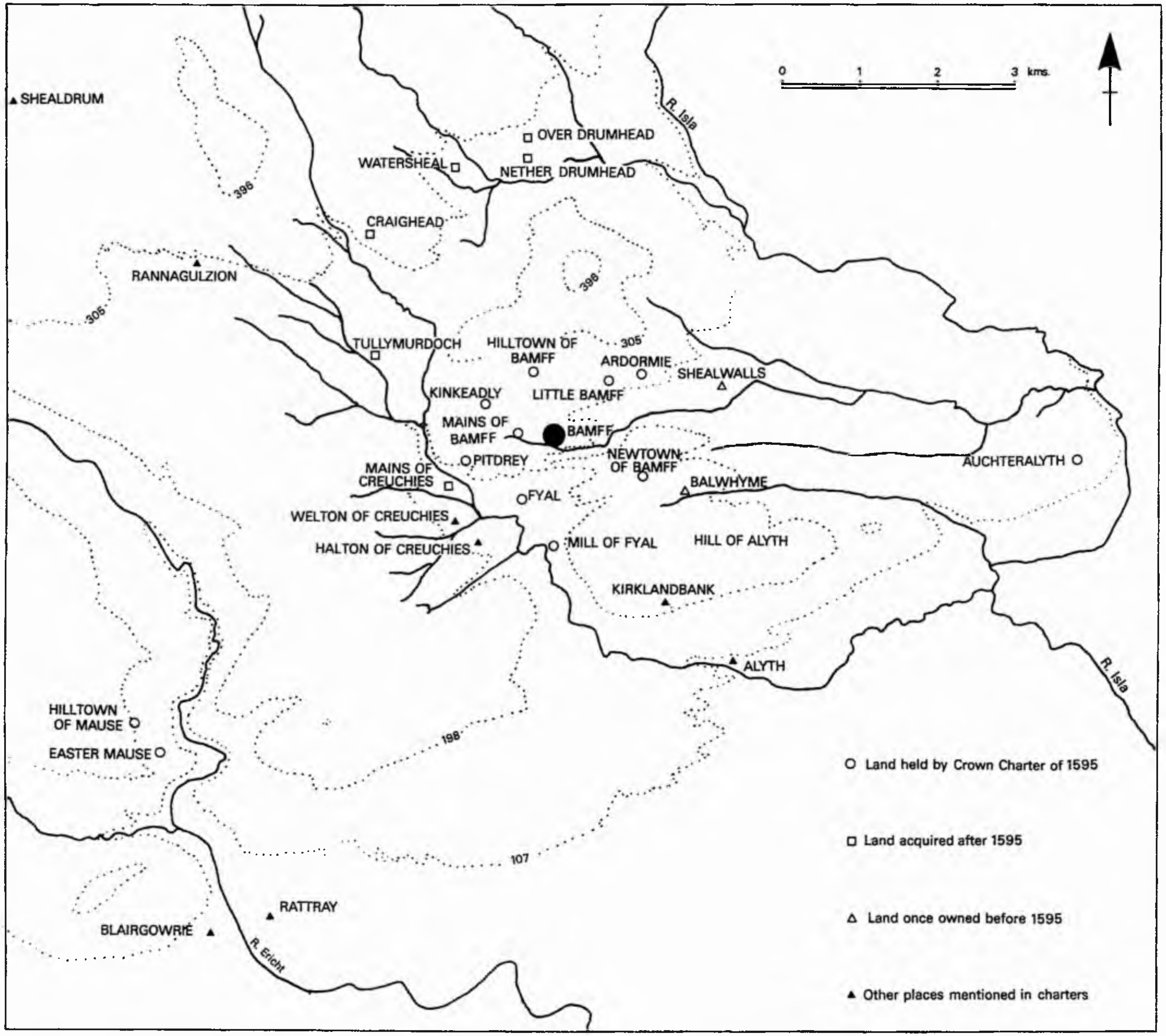
In the absence of sufficient wood and with the general utilisation of peat for fuel, digging and carting of peats was an important part of the local economy. Peats and turves were used throughout the country and on the monastic lands those who owed service often paid by cutting and carting peats to Coupar, 33 peats for the abbey to 40 for the cutter. Some peat was still available in Strathmore, as at Ardblair, but most had to be transported from the Forest of Alyth, Persie, Cally or Glenisla and the whole process was very time consuming. As in most aspects of agriculture the monks exercised control of the peat cutting and instructed cutters to leave the basal part as a basis for new soil development, and on wetter areas they encouraged the planting of trees as a means of drying out the surface to make it useful for fuel.

The impact of the changes introduced by the abbey at Coupar Angus was felt in all aspects of the rural economy but was only really noticeable in the first two centuries of the abbey's development, for as central control weakened so the standard of husbandry fell. Nevertheless at its zenith at the start of the fourteenth century Coupar,

> "consisted of the abbey ringed around by its nine granges with outlying forest lands in the upper valleys of Ericht, Isla, Ardle and Tay and possibly amounting to 8000 acres altogether" (Franklin, 1952, p.38).

The information that can be derived from the main secular documentary source for the Medieval period, Bamff Charters and Papers, is restricted largely to documents affirming the right of ownership of the Ramsays to their estates and to marriage contracts. Hence, although it is possible to trace the fluctuations of estate boundaries, it is rarely possible to establish in what way the land was worked. In the original charter of 1232 Alexander II granted to 'Nessus medicus noster' Bamff and the lands of Pitdrey, Ardormie and Kinkeadly. The Earl of Atholl then gave Dunfallandy near Pitlochry which in turn was given to the abbey at Coupar Angus by Neis in 1244-45 for the benefit of the souls of the Earl and his wife. Over the next two hundred years the Ramsays acquired further lands at Easter Mawes, Balwhyme and Auchteralyth, and between 1460 and 1513 took over Drumheads to the north of Bamff but also released some land, such as part of Kinkeadly to the Rattrays, and lost Ardormie. Several charters attest to the fluctuating ownership of the marginal lands of the estate as in 1531 when Alexander Ramsay (II) had to repurchase Easter Mawes which had been forfeited for non-entry over 50 years, i.e. relief had not been paid, the equivalent of one years rent, when a new Ramsay took over formal possession from his predecessor.

Between 1509 and 1565 there was conflict between the Ramsays and the tenants of Kirklandbank and Alyth, the former tenants renting their land from the Bishop of Dunkeld, over the use of pasturage on the Hill of Alyth which the tenants held to be their common land "beyond the memory of man". The marches were ridden between Bamff and Alyth in 1509, 1534 and 1565 but friction still remained. The Bamff charters also show great interest in the area to the west and south of Bamff held by Scone Abbey, the Mains of Creuchies, Welton of Creuchies and Muirtown of Creuchies, and record the changing tenancies of the relevent thirds of these holdings from 1559 onwards but the Ramsays never gained complete control of them. In 1595 James VI resettled Bamff on George Ramsay and the crown charter records the extent of the barony at this time (Fig. 4•11). The barony comprised,



4.11 The barony of Bamff in the period up to the 17th. century.

> "the towns and lands of Banff, Littill Banff, Hiltoun of Banff, Mains of Banff, Kinkedley, Petdrey, Foyell, mill and milltoun thereof, Newtoun of Banff, lands of Adormey ...... lands of Eister Mawis and town and lands of Hiltoun of Mawis ...... "
> (Ramsay, 1915, p.142).

By 1612 Waterscheal and Craighead had further extended the barony to the north, the former being purchased from the Earl of Crawford. Gilbert Ramsay (II) also gained land in Forfarshire and Little Keithock and in 1652 Gilbert Ramsay (III) acquired Couthie, Bendochie and appeared to have control of one third of the Mains of Creuchies. In 1672 the Ramsays split part of the estate when another Gilbert Ramsay took over Tullymurdoch Over and Nether and the Brawlands of Creuchies, property which on earlier charter evidence was once held by the Crawfords. Although the barony continued to expand its area up to the end of the seventeenth century there was a change in tenancies as more were amalgamated rather than leased in thirds or even sixths, as had previously been the practice, perhaps due 'to the difficulty of obtaining satisfactory economic results from the cultivation of patches of poor soil under an uncompromising sky' (Ramsay, 1915, p.274). This period corresponded with the abandonment of high lying cultivation in south-east Scotland (Parry, 1975) and the cold epoch (1550-1700) of Lamb (1966). Bamff itself lies at 650 feet (198m) with many of its outlying properties up to 350 feet higher (e.g. Watersheal at 1000 feet (300m)).

Although the Bamff charters convey much information on land holding over five hundred years, emphasising in particular the division of land into thirds and sixths and into sun-wise portions (Dodgshon, 1975b), hence a charter of 1591 selling and deponing 'his sunny half of the lands of Lawis, and his shadow half of the lands of Baldowie' (Ramsay, 1915, p.139), there are very few references to the economy by which the Bamff barony was sustained. Most of this sort of information that can be found comes from the several marriage charters detailing the settlements to be made on the newly married couple. There are few references to runrig but this does not necessarily mean that the practice was rare around Bamff. In a contract of 1550 reference is made to "a fourth part of the lands of Middle Mawis, by way of runrig" (Ramsay, 1915, p.128) and a second reference appears in 1563 when the notary Alexander Ramsay served notice to quit on a man wrongfully occupying "one third rynrig" of lands at Rannagulzion. According to Ramsay this paucity of runrig is perhaps not surprising as,

> "the rolling slopes of the land at Bamff, intersected by little burns and gullies, was not at all suited to the big open fields required for cultivation in common" (1915, p.123).

It is noticeable that the only extant references concern lands in higher areas on relatively open sites but the available information adds little to present understanding of the idea of runrig, as to whether it was both a unit of land holding and of agricultural practice (Whittington, 1973, Dodgshon, 1975a).

A system of husbandry based on the cultivation of infield for oats and bear, outfield for three to four years of oats and pasturage of the moorland beyond (Whittington, 1973, Dodgshon, 1973) was almost certainly widely practised on the Bamff lands. A marriage contract of 1596 between Isobel Ramsay and Patrick Blair makes mention of "50 bolls of oats, half infield and half outfield oats', emphasising the difference in quality between the two crops, the latter often only being used for straw (Whittington, 1973); in 1627 a wadset on part of Hatton of Creuchies gives its extent as 14 acres of infield land with the whole pertinents, "and the equal third part of the whole outfield land pertaining to the said lands of Haltoun" and also mentions the "mosses, muirs, commonties and pasturage belonging to the lands of Haltoun of Creuquhy", and in 1672 the marches of Shealwalls were in part defined by three outfield butts. There is no evidence in any of the Bamff papers for crops other than oats and bear despite the greater variety grown in Strathmore around Coupar Angus but several contracts refer to sheep and cattle and to pasturage or rights of commonty. The legal wrangle over the pasturage between Bamff and Alyth also served to highlight the importance of common land, a position made clear by Adams (1973),

> "The commonty in pre-enclosure Scotland held an important place in the peasant's everyday life. It was essential in providing vital elements of a subsistence economy - food, fuel and shelter - at the sole expense of peasant labour. It was important in providing a reservoir of land that could be exploited in response to fluctuations of population without any formal restrictions, as were found with private property" (p.290).

Almost 8000 acres of the northern part of the Forest of Alyth were held as common land and were mainly under shielings, the development of which with the free range of animals, especially along the Angus to Braemar drove road, had finally destroyed what woodland remained. Parliamentary pressure for the division of commonties had begun as early as 1647 but only gained momentum towards the end of the eighteenth century. In the Forest of Alyth pressure on the land had become so strong that in 1719 a summons of division was brought by James and David Rattray of Rannagulzion and others against Thomas Graham and others. The process of division was a slow one and in 1726 Dr. J. Wilson was appointed to map the area concerned. Very little then happened and in 1760 local people from Bleaton and Blacklunans lost patience and destroyed the mill and shieling at Drumturn. The process of law was then restarted and eventually the Forest of Alyth was divided and registered in 1792 (Adams, 1973).

The system of husbandry based on the infield, outfield and common land must have been widespread throughout eastern Perthshire for much of the later Medieval period and after the demise of the abbey at Coupar Angus. With few documentary sources it is difficult to get much more than a general view, other accounts such as those of travellers are often too general or unreliable, for as Hume Brown (1891) commented,

> "Even to the close of the seventeenth century Scotland was still a kind of 'terrae incognitae', which men thought of as a half-mythical country, where strange things might exist which it was irrational to look for in any place nearer home" (p.ix).

Maps by Stobie (1783), Ainslie (1789) and General Roy (1755) provide quite accurate pictures of settlement and natural features such as rivers and woodland but little more (Moir, 1973). The social and economic problems faced by the people of Scotland prior to the period of enclosure have been outlined by many authors (Franklin, 1952; Symon, 1959; Smout, 1969), as has the procedure of enclosure (Handley, 1953; Hamilton, 1963). In Perthshire the impact of poor climate is for instance documented in the Book of Garth and Fortingall (Campbell, 1888), a record kept by the curate of Sir James at Fortingall in "slipshod Latin and queer English", and which provides virtually complete details between 1554 and 1577. At the end of the eighteenth century the series of parish records in the form of Old Statistical Accounts and the county agricultural surveys (Robertson, 1799) provide a view of the progress of enclosure and the form of husbandry that preceded it.

The information derived from the local Old Statistical Accounts, all from the last decade of the eighteenth century are presented in Table 4·3. The quality of the information varies from parish to parish

Table 4·3 Summary of parish records from Old Statistical Accounts

Parish and Date	Main Crops Mentioned	Evidence of Former Husbandry and Degree of Enclosure	State of Mosses
Rattray (1792)	Oats, grass, some wheat	———	Exhausted
Kinloch (1796)	Wheat, barley, oats, peas, flax, potatoes, turnips, clover, rye	———	Cochrage becoming exhausted
Lethendy (1796)	Oats, barley, potatoes, turnips, pease, lint – in rotation	Recently changed from sheep, has suffered from over use of marl	Little left
Alyth (1793)	Oats, barley, wheat, grass, turnips, potatoes, lint. Sheep and black cattle pastured in Forest of Alyth	'New husbandry' introduced. Former use of oats and bear in infield and 3 oat crops from outfield then into ley	Distant but plentiful
Glenisla (1793)	Bear, oats, turnips, potatoes. Shielings still used	Old four horse Scots plough still used	———
Clunie (1791–97)	2555ac. of 8000 arable. Oats and bear (1554ac.); peas, potatoes and turnips (205); flax (44); cultivated grass (375); pasture (377) – in rotation. 200 cattle and 1000 sheep on moor	Change from oats and bear in infield unenclosed only recent. Old plough still used	Distant but some still available

(continued)

Table 4·3 (continued)

Blairgowrie (1796)	Barley, oats, peas, turnips, sown grass, lint. Poor rotation	Most still unenclosed and infield-outfield still, with old plough	Exhausted
Bendochy (1797)	Oats (896ac.), barley (421), wheat (148), peas (129), potatoes (58), lint (43), turnips (87), fallow (130), sown grass (1230), natural grass (158), 1229 cattle	Few enclosures, runrig only ended 30 years ago	Used Cochrage
Caputh (1791-99)	Oats, barley, peas, flax, potatoes, turnips, clover, rye grass. 2061 sheep	Runrig lost 50-60 years ago, one rig oats, one barley, one lint. 3 years of oats in outfield then ley	Distant

and minister to minister, but all show the principal crops and expound on the changes seen in the parishes over the last fifty or more years. In particular they show the gradual introduction of crop rotation, often in varied forms, with root crops such as potatoes, peas and turnips becoming more widespread. They also detail the amount of enclosure which varied greatly usually depending on the presence of a local landowner interested in improvement, as with John MacKenzie of Delvine in Caputh. Even the grange lands of Coupar Angus at Aberbrothy were barely enclosed and had only recently been under runrig. The earlier presence of runrig is attested in several parishes, as in Clunie where,

> "The farmer, if he may be called so, had his crooked ridges everywhere warped through the crooked ridge of his neighbour" (O.S.A.S. IX 1791-99, p.245).

Flax was everywhere grown and processed, especially in Blairgowrie which, by the early years of the next century had outgrown its neighbour, Rattray. The importance of sheep and cattle in those parishes such as Clunie, Alyth and Caputh which comprised large areas of moorland, sometimes in detached portions, can be seen from the numbers of livestock mentioned. Horses were widely used and in some parishes, as in Glenisla, were used with the old Scots plough. Perhaps the most serious comments referred to the depletion of local mosses and the time spent in collecting peats from the higher areas where mosses still remained was excessive, and even some of these sources, as at Cochrage, were being rapidly depleted. By the time of the New Statistical Accounts in the 1840's many parishes had to rely on coal brought from Dundee.

By the nature of the available sources of information the picture of this part of eastern Perthshire during the Medieval period and up to the end of the eighteenth century is patchy but it would appear that there was little change in farming practice until the period of enclosure. The effect of the abbey at Coupar Angus brought new ideas but with the collapse of central authority in the fifteenth and sixteenth century old practices continued, runrig returned into abbey lands and forests were depleted due to the needs of the local people. The effects of the eighteenth and nineteenth century enclosure and improvement must have been considerable although it is difficult to agree with the view of the Honourable Mrs. Murray who, in 1799, on visiting Blairgowrie standing below the gorge at Craighall said that she fancied herself "at the end of the world, and at the gate of Paradise" (p.195).

CHAPTER FIVE

THE AREA SOUTH OF THE BOUNDARY FAULT

Much of the area south of the Boundary Fault between Blairgowrie and the Tay-Isla confluence is now cultivated, especially those parts which are on the brown forest soils of the Balrownie Association. Most of the deposits suitable for sampling lie within basins in the fluvio-glacial sands and gravels which cover the northern and western margins. The final choice of sampling site was at Stormont Loch (Fig. 5•1) (NO1942) on the fringe of the Blairgowrie outwash fan within soils of the Corby Association where it abuts onto the undulating areas of till whose soils now form the Balrownie Association. The open loch proved difficult for sampling but a mire in a subsidiary basin provided a complete recoverable record through the Late Devensian and Flandrian. Other possible sites lying wholly within the till or in basins nearer the slopes on the northern margin of Strathmore proved unsuitable either due to the lack of recoverable sediments or, as in the case of the shallower lochs such as Monk Myre (NO4220), the removal of sediments when the lochs were drained in the eighteenth century for the recovery of marl.

The core from Stormont is discussed in two sections, covering first the Late Devensian period and then the complete Flandrian record. After this the analysis of a soil pollen site adjacent to the mire is outlined, especially as it concerns the interpretation of the main pollen diagrams.

i) Late Devensian profile

a) Stratigraphy and sampling

The sampling site from which the lower sediments were analysed was located four metres from the main Flandrian Stormont profile and

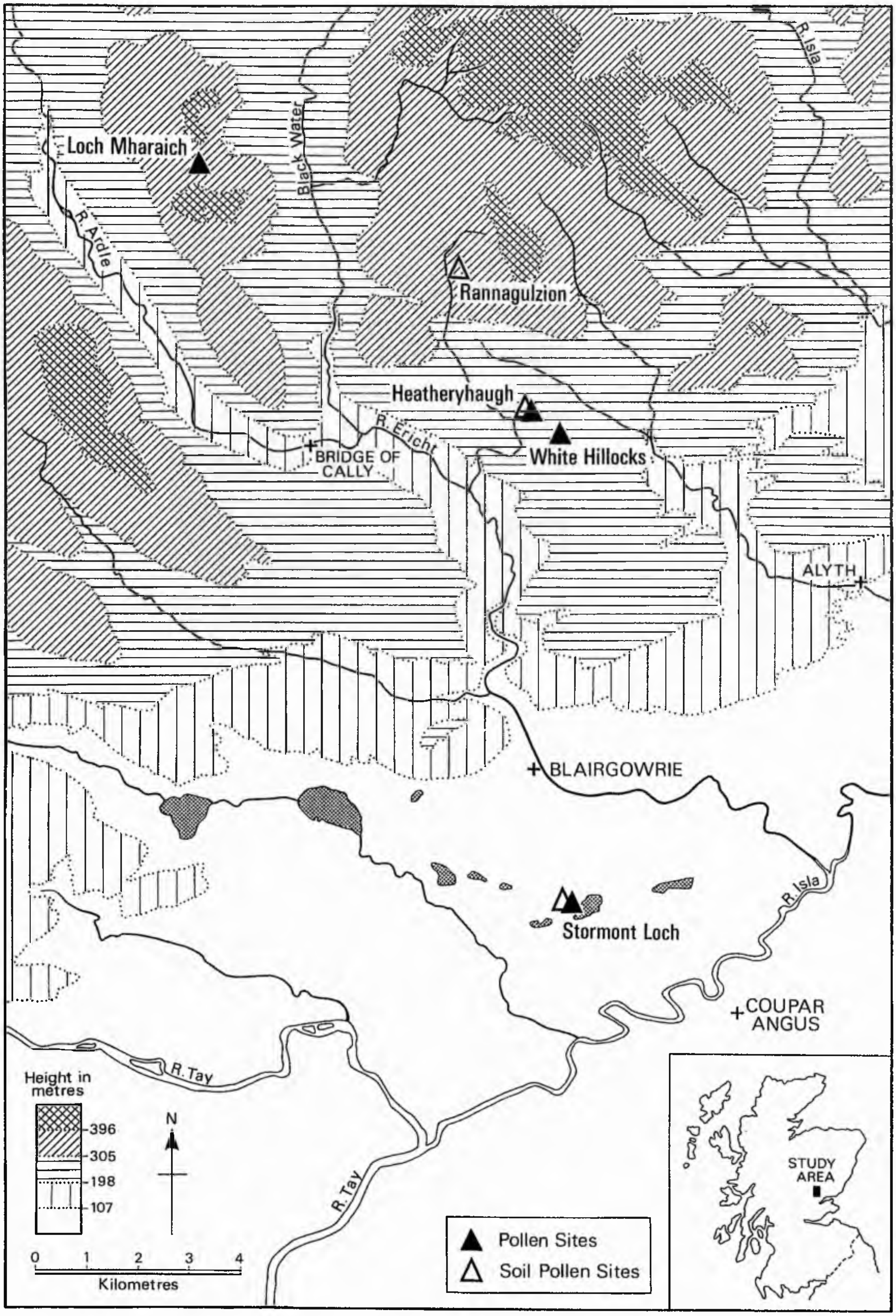


Fig.5.1 Pollen sites in the study area

its position is marked on Figs. 5•2 and 5•3. The core was taken with a Russian peat sampler which failed to recover the very bottom levels. The sampler was not able to penetrate further than 525cm, the lowest sample coming from 516cm. Attempts to recover material from below this depth with a Hiller borer proved unsatisfactory because of the coarse nature of the deposit and the difficulty encountered in getting a suitable uncontaminated sample. At the sampling point the detailed basal stratigraphy was as follows:

469 - 482cm	Coarse grey clay fining downwards with few observable organic remains, especially coarse in the upper 5cm.
482 - 483cm	Transitional between fine and very fine clay where roots and organic remains appear.
483 - 485.5cm	Very fine dark grey clay with some silt and light organic flecks.
485.5-486.5cm	Thin brown organic layer
486.5 - 488cm	Coarse grey clay.
488 - 488.5cm	Fine grey clay.
488.5 - 492cm	Fine grey-green silty clay.
492 - 498cm	Dark brown organic mud with a slightly micaceous appearance, becoming almost peaty towards the base.
498 - 500cm	Light grey-green gyttja with lenses of silty clay.
500 - 511cm	Predominantly organic sedge peat with occasional fruitstones of Potamogeton and faint silty bands.
511 - 514cm	Light grey silty clay with organic flecks.
514 - 516cm	Dark grey clay with fewer organic flecks, becoming increasingly coarse with depth.

Because of the complex nature of the stratigraphy and the rapidity of change often experienced in Late Devensian profiles, one centimetre

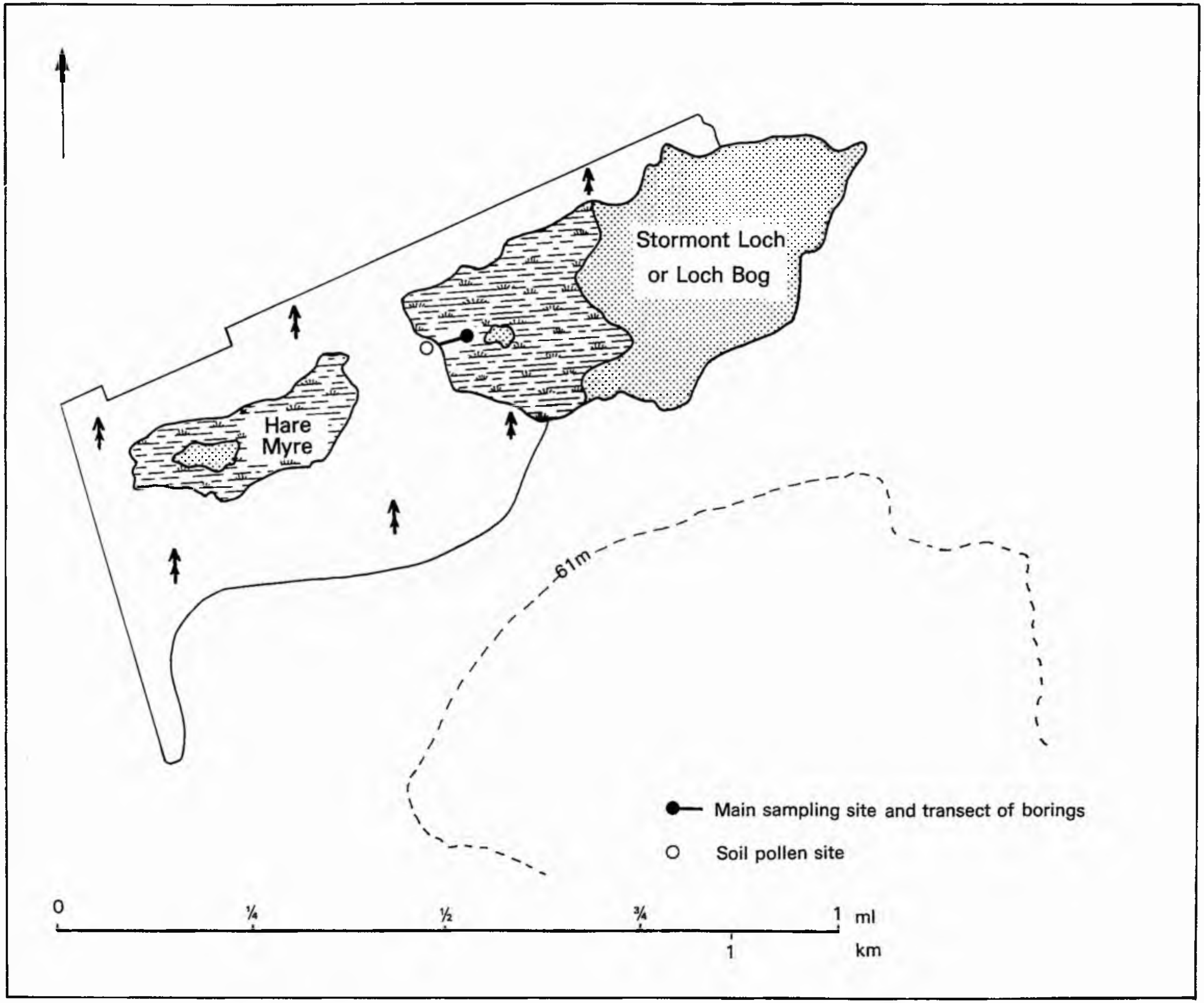


Fig.5.2 Location of pollen sites at Stormont Loch

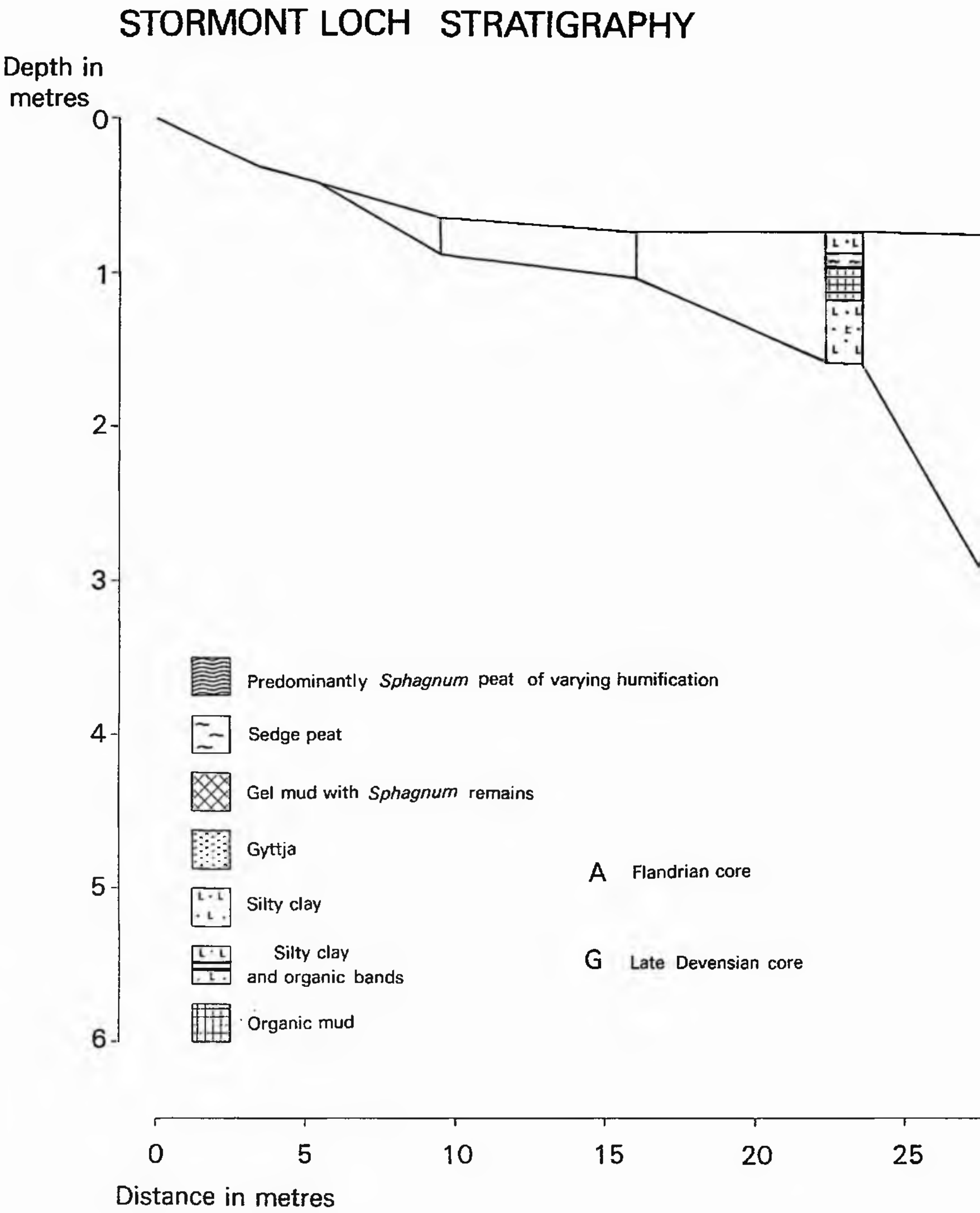
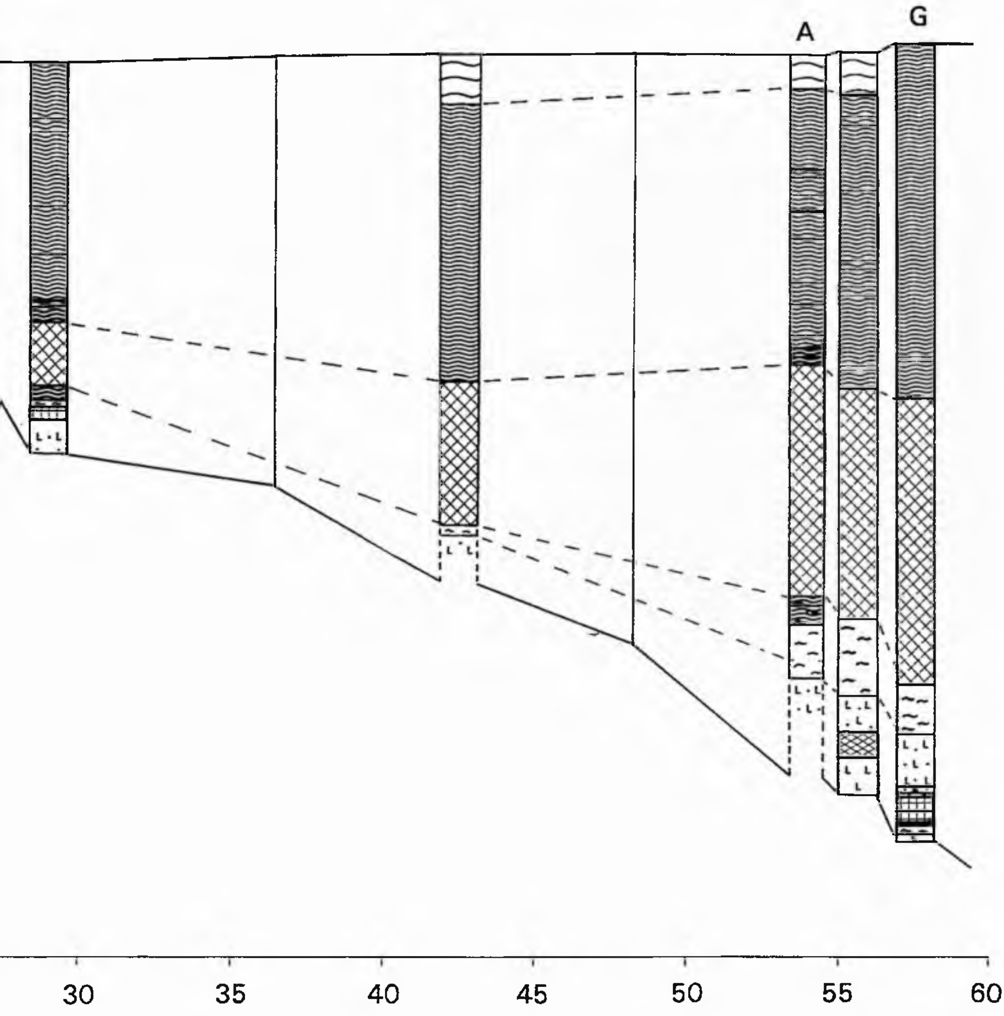


Fig.5.3 Transect showing stratigraphy at Stormont Loch


A
G
30
35
40
45
50
55
60

thick contiguous samples were used in the analysis and where changes in the lithostratigraphy occurred at less than one centimetre intervals thinner samples were used. After an initial preliminary count of 200T.L.P. to establish the nature of the pollen stratigraphy a further 150 grains were added to the count and for these additional grains details were taken of their preservation.

The method used to extract the pollen and mount it is included in the later discussion on pollen extraction in Appendix II.

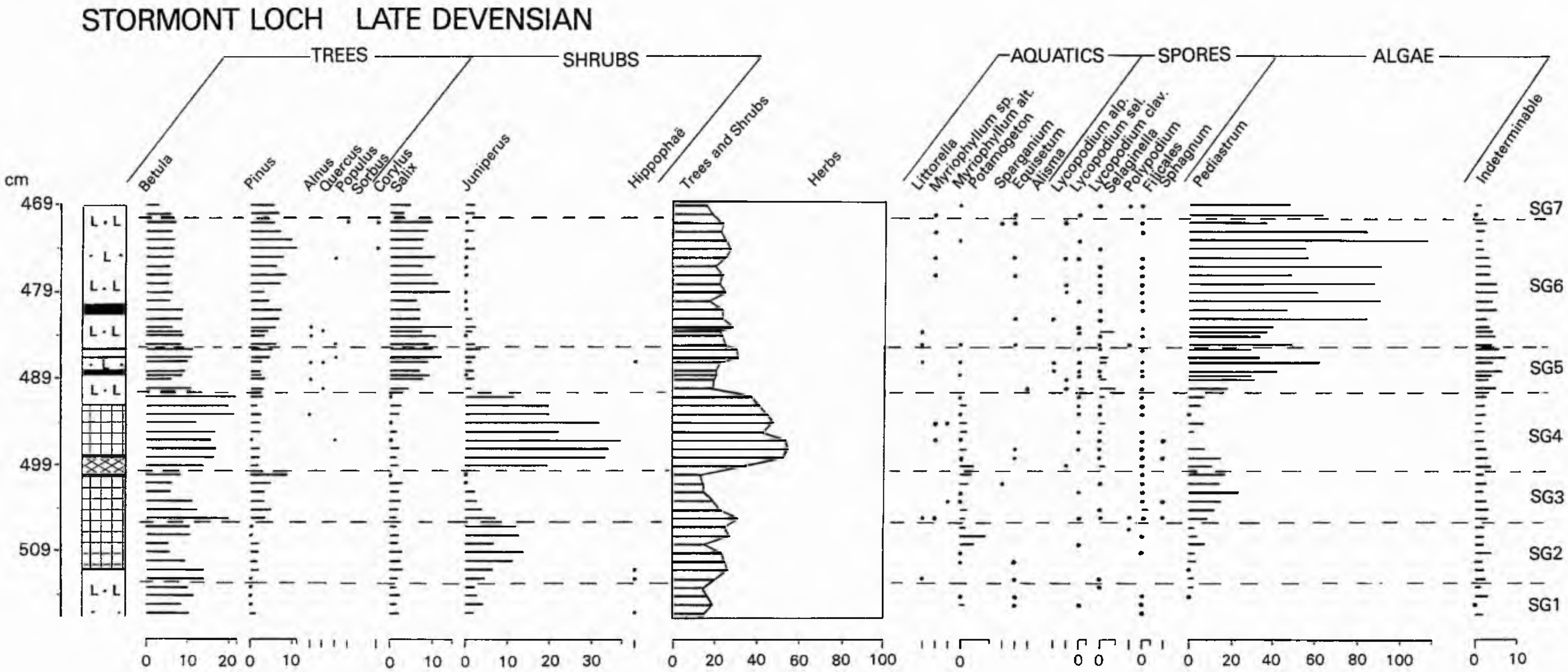
b) Pollen assemblage zones

As at the other sedimentary pollen sites pollen assemblage zones have been defined based on either dominant or characteristic taxa (Am. Comm. Strat. Nomen., 1961) and here seven zones have been defined to cover what is considered to be the Late Devensian period. They are prefixed SG- and details of the pollen composition of each of these zones are given below. The pollen diagram for the Late Devensian is presented in Figs. 5•4a, b and c.

SG-1 516 - 512•5cm Gramineae - *Rumex* zone

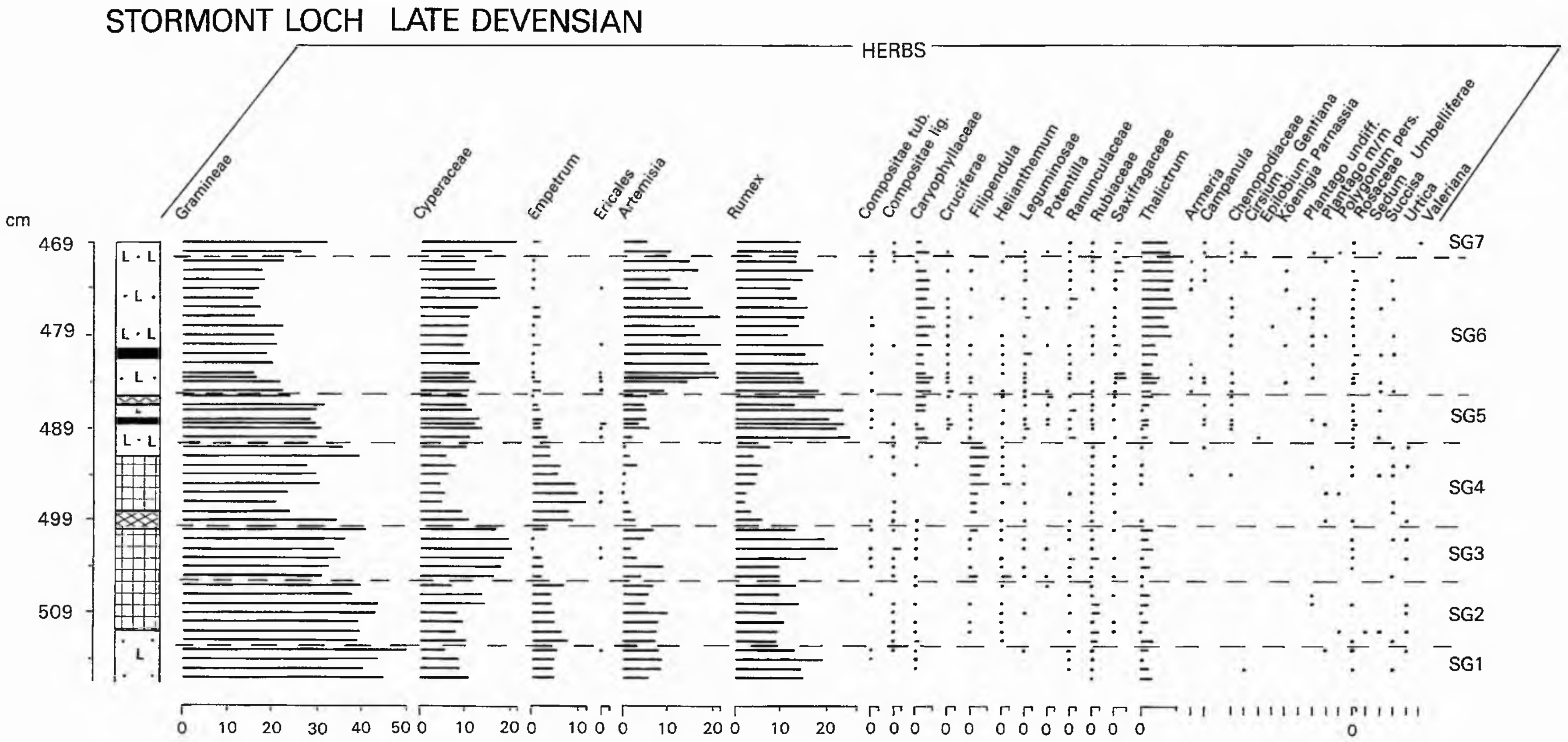
The upper boundary of this zone is marked by increasing values of *Juniperus* and *Empetrum*, decreases in Gramineae and *Rumex* and the continuous presence of *Helianthemum*.

The upper boundary defined on pollen assemblage characteristics precedes the major lithostratigraphical boundary. The whole basal zone is dominated by Gramineae at values of up to 50%T.L.P. with high frequencies for *Rumex acetosa* type pollen. Many of the pollen grains assigned to *Rumex acetosa* type were very coarse and probably represent *Oxyria digyna* although, as with other authors (Walker, 1974), in the absence of adequate reference material all have been assigned to a general *Rumex acetosa* type curve. The pollen of woody species is low



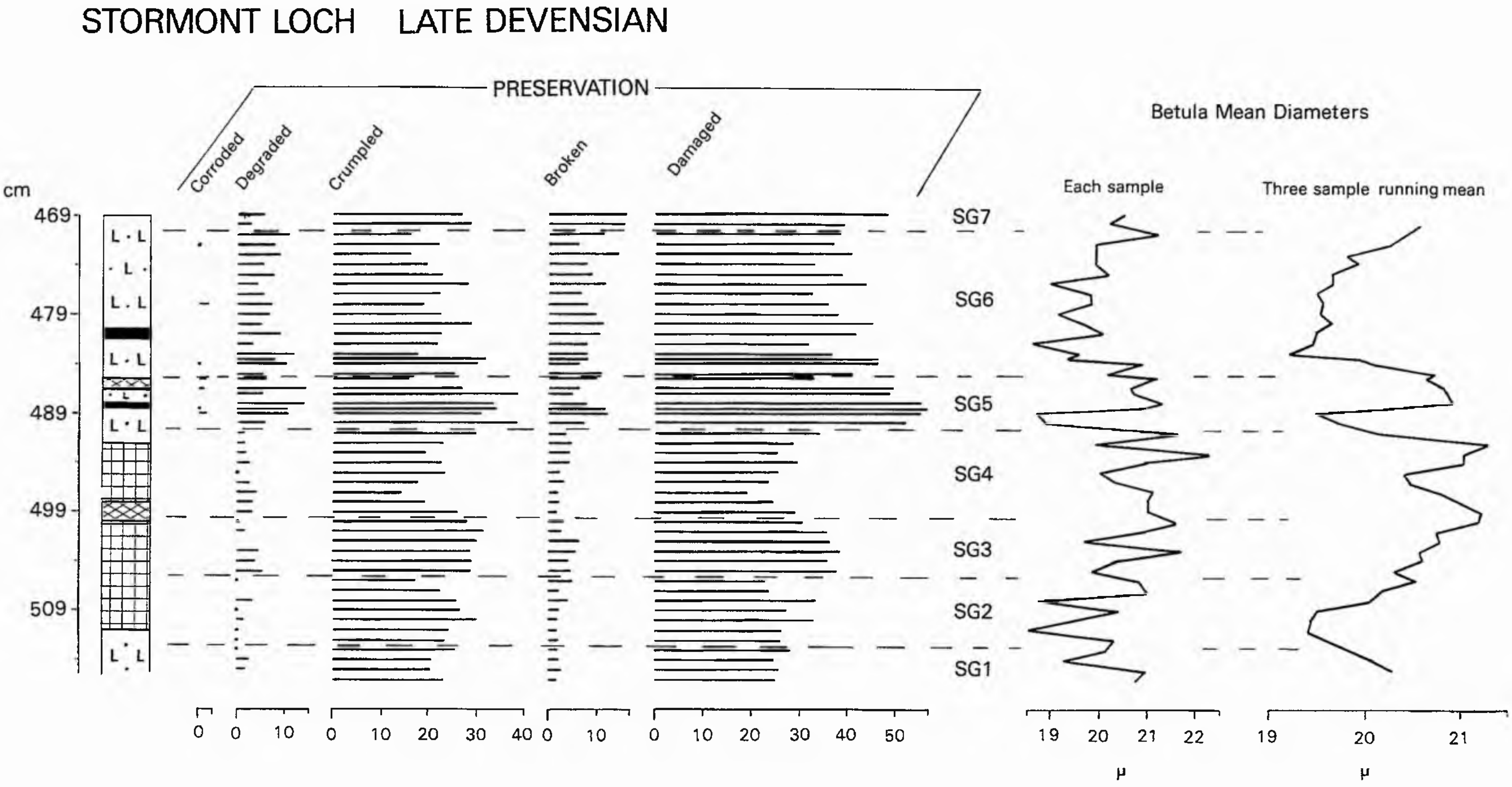
All species are expressed as % Σ T.L.P.

Fig.5.4a Stormont Loch pollen diagram for the Late Devensian, trees, shrubs, aquatics, spores and algae



All species are expressed as % Σ T.L.P.

Fig.5.4b Stormont Loch pollen diagram for the Late Devensian, herbs



All species are expressed as % Σ T.L.P.

Fig.5.4c Stormont Loch pollen diagram for the Late Devensian, preservation and <u>Betula</u> measurements although *Betula* and *Empetrum* are consistently present at 10% and 5%T.L.P. respectively. No distinction was made between the pollen of tree birches and *Betula nana* for individual grains but as an aid to establishing the dominant birch pollen type measurements of the diameters of all measurable *Betula* grains were made (see Appendix V). The results of these measurements are outlined in Fig. 5·4c where mean diameters and three sample running mean diameters are plotted. This sort of analysis gives an idea of the changing populations of diameters and hence the relative importance of different birch species as the low number of measurable grains usually precluded the construction of frequency distributions for examination of their modal characteristics (Johansen, 1975). Overall SG-1 is characterised by low mean diameters of 20μ, suggesting a predominance of *Betula nana*. Values for *Salix* pollen, although consistent, are very low and probably represent *Salix herbacea*. Apart from *Rumex* the major herbaceous taxa represented are *Artemisia* and *Thalictrum* and, relative to later levels there are a low number of taxa represented. Many of the *Thalictrum* grains are very small and could represent *Thalictrum alpinum* but even with reference material it is difficult to separate the different *Thalictrum* species (H.J.B. Birks, 1973a).

SG-2 512·5 - 505·5cm *Juniperus* - *Empetrum*

The upper boundary is defined by decreasing values of *Juniperus* and *Empetrum* with increasing frequencies of *Rumex*, Cyperaceae and *Pinus*.

This zone spans the lower part of the predominantly organic deposits and shows successive peaks for *Empetrum*, *Juniperus* and eventually *Betula* with a general increase in the pollen of trees and shrubs, although there is a small *Betula* peak in the early part of the zone. Throughout SG-2 the running means for *Betula* diameters show an increasing size suggesting a greater proportion of tree birches. At its maximum Juniperus comprises 14%T.L.P. and pollen of Hippophaë appears at 512cm and 511cm. Gramineae is very high and Cyperaceae is consistently present as are Artemisia, Rumex and Thalictrum, although at lower levels than in SG-1.

SG-3 505•5 - 499•5cm Rumex - Cyperaceae

The upper boundary is placed where there is a quite abrupt change in pollen content. There is a particularly sharp increase in Juniperus with increases in Betula, Empetrum and Filipendula, and decreases in Pinus, Rumex, Artemisia, Gramineae and Cyperaceae.

Values for both Juniperus and Betula are depressed to the point where the former comprises less than 1%T.L.P., but corresponding to this is a small peak in Pinus pollen. At the end of the zone N.A.P. values reach almost 90%T.L.P. consisting mainly of Gramineae, Cyperaceae and especially Rumex. Although Artemisia is still an important part of the pollen assemblage it peaks only at the end of the zone, as does Thalictrum. Despite the considerable pollen changes found in SG-3 the zone precedes any change in lithostratigraphy. Pollen preservation changes very little from that found in SG-2 although there is a slight increase in the number of broken and crumpled grains. There is a noticeable peak in the algal content of the sediment as seen in the curve for Pediastrum.

SG-4 499•5 - 490•5cm Juniperus - Betula (+Filipendula)

The upper boundary of SG-4 is defined by a sharp decrease in the values for Juniperus, Betula and Filipendula, and by increases in Cyperaceae, Rumex and Caryophyllaceae. There is in general a significant drop in the pollen of trees and shrubs. Potamogeton disappears as Pediastrum rises and there is a higher level of pollen deterioration.

This zone shows the highest values for *Betula* and *Juniperus* to be found in the lower sediments at 21% and 37%T.L.P. respectively, and their peaks are preceded by a peak for *Empetrum*. Throughout the zone the diameters of the *Betula* grains are higher than elsewhere in the profile. In the lower levels of SG-4 the pollen of trees and shrubs reaches over 50%T.L.P. *Salix* values are very low as are most herbaceous taxa except *Filipendula* which occurs consistently for the first time. The percentages of *Artemisia* fall below 1%T.L.P. There is also a noticeable depression in the curve for *Pediastrum* whereas *Potamogeton* is present as is *Selaginella* which appears consistently. Overall pollen preservation is better than in any other zone with fewer Degraded (Amorphous) grains (see Appendix IV). Although SG-4 spans a predominantly dark brown organic mud which is almost peaty towards the base there is also a thin grey-green gyttja between 498 and 500cm, the deposition of which corresponds with the first increase in *Juniperus*. The boundary between SG-4 and the overlying SG-5 has been defined after the change to a fine grey-green silty clay.

SG-5 490·5 - 485·25cm *Salix* - *Rumex* (+*Selaginella*)

The upper boundary is defined by a sharp increase in *Artemisia* and gradual increases in *Pinus* and *Thalictrum*, with a decrease in Gramineae.

This zone covers the most complex part of the lithostratigraphy but there are few comparable variations in the pollen stratigraphy. Although *Juniperus* is severely reduced *Betula* occurs consistently at about 10%T.L.P. and its diameters are only slowly reduced in size although at the change from S-4 there is an initial trough of low mean diameters. Throughout the zone *Salix* and *Pinus* gradually increase as does *Artemisia*. *Rumex* reaches very high levels, up to 20%T.L.P., and there is a continuous curve for Caryophyllaceae and *Thalictrum*.

Pediastrum also rises steadily. There is a clear peak in the Indeterminable and deteriorated pollen curves between 490cm and 487cm with increases in all categories of deteriorated pollen, including the first Corroded pollen grains. Within the clays and the silty clays is a thin organic band between 485•5 and 486•5cm and a clay with some organic flecks.

SG-6

i) 485•25 - 479•5cm Salix - Artemisia - Rumex

ii) 479•5 - 470•5cm Salix - Artemisia - Rumex - Thalictrum

The upper boundary is defined by a drop in values for Salix and Artemisia, and by increases in Gramineae and Cyperaceae. The distinction between the two zonules or sub-zones is made solely on the change in Thalictrum values which remain constant either side of the zonule boundary.

SG-6 is characterised by high consistent values for Salix, Cyperaceae, Artemisia and Rumex. Gramineae still contributes an important proportion of the pollen sum but only at percentages between 15 and 20%T.L.P. Betula, although consistently present at around 5%, shows a predominance of relatively small diameter grains and most may be assigned to Betula nana. There is a greater variety of herbaceous taxa present than in any previous zone with continuous curves for Caryophyllaceae, Thalictrum and Rosaceae, and almost continuous curves for Cruciferae, Leguminosae, Ranunculaceae, Rubiaceae, Saxifragaceae and Plantaginaceae. The most interesting feature of SG-6 is the change in percentages of Thalictrum which defines the zonule or sub-zone boundary and the high values of Thalictrum found in SG-6ii, consistently between 7% and 8%T.L.P. Pollen preservation in the predominantly minerogenic sediments remains relatively poor and values for Indeterminable grains are only reduced gradually. Values for Pediastrum remain very high.

SG-7 470·5 - top of diagram. Gramineae - Cyperaceae - Rumex - Thalictrum

The upper boundary of this zone is artificial in that it is represented by the top of the sampled core. The assemblage deposited within SG-7 agrees well with that found in S-1 at the base of the main Flandrian Stormont diagram.

Although brief this zone reflects a distinctive change in pollen representation with a decline in Artemisia and Salix in favour of Gramineae and Cyperaceae. It is similar in composition to S-1 which, because of a wider sampling interval, comprises components of both SG-7 and SG-6ii. Apart from changes in the taxa represented there is a distinct improvement in pollen preservation with a decrease in Degraded grains and a slight increase in Crumpled grains. There is no noticeable change in lithostratigraphy.

c) Statistical zonation of the profile

In order to provide more objective divisions of the pollen diagrams into assemblage zones all the principal diagrams have been subjected to several multivariate statistical techniques recently developed to zone pollen diagrams from Britain and America (Gordon and Birks, 1972). For this particular profile fifteen of the major taxa which contributed at least 2%T.L.P. were used and in a second analysis values for Indeterminable pollen and Pediastrum were also included. Whilst the addition of the frequencies for Indeterminable pollen was of value in providing an element of change somewhat independent of species composition, the addition of Pediastrum, which contributes a large and erratic sum, clearly biased the results in favour of algal fluctuations.

The results of the first analysis using SPLTINF and SPLTLSQ (Gordon and Birks, 1972) are presented in Table 5·1 up to the sixth

Table 5•1

Statistical zonation of the Late Devensian Profile

(taxa excluding Pediastrum and Indeterminable Pollen)

Division	SPLTINF	Residual Variation %	SPLTLSQ	Residual Variation %
1	(469 – 489•5) (489•5 – 517)	53•22	(469 – 489•5) (489•5 – 517)	59•60
2	(469 – 489•5) (489•5 – 498•5) (498•5 – 517)	35•00	(469 – 489•5) (489•5 – 498•5) (498•5 – 517)	36•20
3	(469 – 483•75) (483•75 – 489•5) (489•5 – 498•5) (498•5 – 517)	27•79	(469 – 483•75) (483•75 – 489•5) (489•5 – 498•5) (498•5 – 517)	27•58
4	(469 – 483•75) (483•75 – 489•5) (489•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	23•77	(469 – 483•75) (483•75 – 489•5) (489•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	23•74
5	(469 – 483•75) (483•75 – 489•5) (489•5 – 498•5) (498•5 – 505•5) (505•5 – 510•5) (510•5 – 517)	21•22	(469 – 483•75) (483•75 – 489•5) (489•5 – 492•5) (492•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	20•61
6	(469 – 470•5) (470•5 – 483•75) (483•75 – 489•5) (489•5 – 498•5) (498•5 – 505•5) (505•5 – 510•5) (510•5 – 517)	19•34	(469 – 470•5) (470•5 – 483•75) (483•75 – 489•5) (489•5 – 492•5) (492•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	17•59

division, thus forming seven groups. The table shows that up to the fourth division the two methods agree on the principal groupings, a feature which is endorsed in the use of a CONSLINK analysis (Gordon and Birks, 1972), the dendrogram for which is not presented as it only confirms earlier divisions. The first boundary to be established is the equivalent of that between SG-4 and SG-5 where there is a very sudden change in pollen frequencies, especially for *Juniperus* and *Rumex*. The second division agrees with the SG-3/SG-4 boundary and again relies heavily on the changes in *Juniperus* and *Rumex*, as well as *Betula*, Gramineae and Cyperaceae.

The third division differs from that defined subjectively appearing one centimetre above the interpreted SG-4/SG-5 boundary. The distinction here is rather unclear based as it is on the curves for *Betula* and *Artemisia*, where the former falls and the latter rises. Because of the composite nature of the *Betula* curve the subjective division based largely on fluctuations in *Artemisia* has been retained.

The fourth division defining the SG-2/SG-3 boundary also diverged from that originally defined subjectively, the latter appearing above the statistical boundary. On reinspection of the diagram the statistical division was accepted as it reflected changes in several taxa, *Juniperus*, *Pinus*, Cyperaceae and *Empetrum*, whereas the original boundary had been defined largely in terms of *Betula* and *Artemisia* only. The only other division common to both analyses is equivalent to the SG-6/SG-7 boundary thus serving to emphasise the reality of this division despite it affecting very few samples at the top of the diagram.

Although later divisions established by the statistical analyses do vary and do not agree with those defined subjectively only the division established by SPLTLSQ at 493·5cm has no eventual equivalent in the SPLTINF analysis. The only subjective boundary not clearly represented in the statistical results is that between SG-1 and SG-2. This is perhaps not surprising because the changes in pollen frequencies are not as sharp as elsewhere and the subjective zone boundary was defined largely in terms of *Juniperus*. It also emphasises the fact that the SG1 and SG2 sediments reflect only a transitional phase in terms of their pollen content and that major changes in assemblage reflecting initial organic accumulation were probably not sampled.

From the values for the residual variation left in the data set by the partitioning processes it appears that although SPLTINF gives a better initial breakdown of the data into two groups there is little to choose between the two techniques except that by the sixth division SPLTLSQ leaves slightly less residual variation. Inspection of the table of the groupings defined by the addition of *Pediastrum* and Indeterminable pollen frequencies (Table 5•2) suggests a much improved partition of the data set but the low residual variation values are due to the overemphasis the statistical techniques place on the high *Pediastrum* values. Certain boundaries are still common to all analyses, SG-4/SG-5, SG-3/SG-4 and SG-2/SG-3, but the results in Table 5•2 then concentrate on divisions in the upper part of the profile where *Pediastrum* dominates. Because of its erratic frequencies the results determined in Table 5•1 are considered more useful.

d) Late Devensian vegetation history

The pollen assemblage from the base of the sampled core, although obtained from predominantly inorganic sediment becoming coarser with depth, almost certainly does not reflect the earliest vegetation on the site following the retreat of the main Late Devensian ice sheet, the wastage of which left the kettle holes now filled by Stormont Loch and Hare Myre. The assemblage represented in SG-1 shows woody species such as *Betula*, *Juniperus* and *Empetrum* to be well represented but is

Table 5•2

Statistical zonation of the Late Devensian profile

(taxa including *Pediastrum* and Indeterminable Pollen)

Division	SPLTINF	Residual Variation %	SPLTLSQ	Residual Variation %
1	(469 – 489•5) (489•5 – 517)	43•58	(469 – 488•5) (488•5 – 517)	36•59
2	(469 – 489•5) (489•5 – 498•5) (498•5 – 517)	30•41	(469 – 488•5) (488•5 – 498•5) (498•5 – 517)	26•47
3	(469 – 489•5) (489•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	24•38	(469 – 482) (482 – 488•5) (488•5 – 498•5) (498•5 – 517)	21•54
4	(469 – 483•25) (483•25 – 489•5) (489•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	19•11	(469 – 482) (482 – 488•5) (488•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	17•52
5	(469 – 483•25) (483•25 – 489•5) (489•5 – 498•5) (498•5 – 505•5) (505•5 – 510•5) (510•5 – 517)	16•94	(469 – 482) (482 – 488•5) (488•5 – 489•5) (489•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	14•38
6	(469 – 483•25) (483•25 – 489•5) (489•5 – 493•5) (493•5 – 498•5) (498•5 – 505•5) (505•5 – 510•5) (510•5 – 517)	15•80	(469 – 482) (482 – 488•5) (488•5 – 489•5) (489•5 – 493•5) (493•5 – 498•5) (498•5 – 505•5) (505•5 – 517)	12•79

still dominated by Gramineae and herb taxa, especially Rumex. The absence of significant amounts of Lycopodium selago (Pennington, 1977b), Compositae (Walker, 1977) or Artemisia (Lowe and Walker, 1977) suggest that the very earliest vegetation records from the site have not been collected as suspected during the sampling. Nevertheless elements of the early plant colonisation of the area are still present in the pollen record and overall the zone gives an impression of varied edaphic environments. The presence of Artemisia, Rumex, Thalictrum and Caryophyllaceae reflect areas of open ground dominated by herbaceous taxa within a general grassland cover and suggests, as does the lith-stratigraphy, that there was still some instability in the soil cover due to continuing periglacial activity, but the contribution of Empetrum, Juniperus and Betula shows increasing stability and soil development and the spread of dwarf-shrub heath.

It is difficult to find direct analogies either in pollen assemblage zones from other areas or in present day vegetation communities for the assemblage recognised in SG-1. The dominance of Rumex and Gramineae shows strong affinities with the Rumex-Gramineae p.a.z. at Lake Windermere (Pennington, 1977b) dated to between ca.14000 - 13000b.p. but many of the thermophilous taxa which appear in this zone at Windermere are missing at Stormont. A fundamental difference between SG-1 and many other Scottish sites is the low Salix pollen count. Pennington has commented that "Salix values in the Younger Dryas deposits of Britain are usually much lower than in early Late Devensian deposits" (1977b, p.264), but at Stormont the reverse is true, hence the difficulty in finding comparisons. The most comparable assemblages are to be found from other parts of eastern and central Scotland, and from some lowland sites. At Tirinie in the central Grampians (Lowe and Walker, 1977) T1 is very similar, with high Gramineae and Rumex and increasing pollen of woody taxa but this zone only spans one sample and there is, as at Stormont, no pollen record from the bottommost sediment. Low *Salix* values in a Gramineae and *Rumex* dominated zone are also characteristic of Loch of Park and Loch Kinord in Zone I (Vasari and Vasari, 1968; Vasari, 1977) dated at the latter to 11480±40 (HEL-174), and it would appear that this absence of significant *Salix* frequencies, usually assigned to *Salix herbacea*, is an eastern phenomenon, for at several sites in the eastern Grampians or surrounding lowlands *Salix* values are consistently higher in the Younger Dryas or Loch Lomond Stadial (Blackness, Roineach Mhor and Amulree - Lowe and Walker, 1977). This may be due to different environmental conditions, in particular the absence of snowbeds dominated by *Salix herbacea* (Pennington, 1973) or to the poor pollen representation of *Salix* despite their local presence, especially where dwarf shrub heath has developed to further filter out the pollen (H.J.B. Birks, 1973a and the results from the work on Bankhead Moss), but whatever the explanation it also has to account for the reversal of patterns of *Salix* representation between the pre-interstadial and the Younger Dryas. A further possible explanation lies in the high frequencies for Gramineae pollen. From his analyses of modern surface samples on Skye, Birks (1973a, p.290) commented on the "distinctive modern pollen rain" of a tall herb nodum dominated by *Deschampsia caespitosa* or *Salix*, characterised by high Gramineae values and the consistent presence of *Rumex*, Ranunculaceae and *Thalictrum*, and by the low species diversity reflected in the pollen assemblage. This compares well with the assemblage of SG-1 and the dominance of tall grasses, as seen at Bankhead Moss, could well explain the absence or low frequencies of other pollen, especially *Salix*. Although values for Gramineae at the other eastern sites with low *Salix* counts do not reach the levels recorded at Stormont they do conform to the lower levels recorded by Birks on Skye (26+%).

The status of woody species during SG-1 appears to have been one of early colonisation. *Betula*, *Empetrum* and *Juniperus* all show small increases but never individually rise above 10 per cent. In general most of the *Betula* grains measured had diameters of 20µ or less and many of them can probably be assigned to *Betula nana*. There appears to be little evidence for the long distance transport of tree pollens into the site for, unlike several other sites (e.g. Roineach Mhor, Blackness and Amulree - Lowe and Walker, 1977; Loch of Park and Abernethy Forest - Vasari, 1977) there is no early peak in *Pinus*, but this absence may have been enhanced by a relatively tall local community filtering out incoming pollen.

SG-1 clearly represents part of the early vegetational development phase described by Lowe and Walker (1977) or the pre-interstadial (Pennington et al., 1972) of the classical Zone I. It obviously postdates deglaciation of the area which, on the basis of dates of 12750±120b.p. (HV-4989) at Tynaspirit near Callander and 13151±390b.p. (SRR-304) at Loch Ettridge, must have occurred at Stormont by c.13000b.p. The slow wastage of ice in the large kettle holes in the Blairgowrie outwash fan may however have delayed sedimentation, although the sampling site is on the periphery of the main basin. The assemblages recorded in SG-1 postdate deglaciation and initial plant colonisation by some time but the date of a comparable assemblage at Loch Kinord of 11480±440b.p. (HEL-174) seems rather young, as the fall in *Rumex* pollen at Loch of Park lower down the Dee valley has been dated to 11900±260b.p. (HEL-417) ending the classic Zone I. Nevertheless these dates with their associated errors could still represent either synchroneity or a thousand year difference. On this evidence it seems likely that the early part of SG-1 dates from c.13000b.p. and the zone could have lasted up to a thousand years.

The change to SG-2 is reflected not only in differences in the pollen assemblage but also in a change to a more terrestrial deposit, the predominantly inorganic grey clay giving way to a mostly organic sedge peat with only a little evidence of any inwashed mineral material. This stabilisation is marked in the pollen record by a peak in *Juniperus* with smaller rises in *Betula* and *Empetrum*. The expansion of woody species is largely at the expense of grasses and sedges but a variety of vegetation communities is indicated by the continued presence of *Artemisia*, *Thalictrum*, Compositae lig. and Caryophyllaceae with very little change in *Rumex* values. Increased temperature is nevertheless indicated by the presence of *Hippophaë* as part of the shrub communities (Godwin, 1975b) and the first expansion of aquatic taxa, in this case represented by *Potamogeton*. Although little is known of the ecology of *Juniperus* in the Late Devensian it seems likely that its expansion was usually due to a change in growth form from a dwarf form, *Juniperus communis* ssp. *nana*, to a more erect form which could disperse pollen more widely (Vasari and Vasari, 1968). Where juniper is found in a tall, dense shrub form it is possible for its pollen to reach values of 45 per cent (Iversen, 1954; Vasari and Vasari, 1968; H.J.B. Birks, 1973a) and the appearance of values of more than 10 per cent at Stormont suggests that there were areas of juniper scrub surrounding the loch. The brief peak in *Betula* pollen at the end of SG-2 is associated with an increase in the mean diameters of the grains and it is therefore postulated that this reflects an increasing representation of tree birches. A contribution of 20%T.L.P. would be enough to suggest the local presence of tree birches (H.J.B. Birks, 1973a) but with a composite curve for *Betula* and in the absence of macrofossils this cannot be confirmed. Information on the establishment of tree birches in Scotland is variable. They are known to have been present during the Allerød from both pollen and macrofossil evidence (Vasari and Vasari, 1968; H.J.B. Birks, 1973a) but its earliest appearance is still unclear due to the contribution of Betula nana. After the initial period of vegetation development Lowe and Walker (1977) assume that a rising birch curve at lower sites near Callander and Tirinie represents the presence of tree birches and it does seem unlikely that an expansion of Betula nana was responsible.

Both the pollen and the stratigraphical evidence points to increasing temperature and to a stabilisation of the vegetation cover. Although it is dangerous to use palaeobotanical evidence to infer climatic parameters (Pennington, 1977b; Lowe and Walker, 1977) the presence of tree birches would imply a mean July temperature of 12°C. This temperature would be quite acceptable on consideration of the fossil coleopteran evidence for a similar stratigraphic level (Coope and Brophy, 1972; Coope, 1977) but would perhaps be considered a little early in a palynological context. It may well be that the response of Betula and Juniperus is not so much a direct reflection of improving climate but more a feature of better soil conditions. The delayed immigration of Betula after that of Juniperus need not have been climatically controlled but could have been due to insufficient soil development (Iversen, 1954). The continued presence of Rumex and herbs usually associated with open and even unstable conditions need not be due to the perseverance of severe climatic conditions but may be a function of the local environment. The sides of the basin would have been the last to stabilise and would therefore show a delay in the response of the local vegetation to climate. With an apparent reduction in the amount of open water in the basin these areas would have been colonised in SG-2 with the species removed by competition from the deeper soils surrounding the loch.

Although most sites show increases in Betula, Juniperus and Empetrum at this stage of vegetation development after deglaciation very few show this increase as an isolated peak, especially in eastern Scotland. The general trend at Stormont closely parallels zone A2 at Loch Sionascaig and at Loch Tarff (Pennington et al., 1972), the early part of Cb at Cam Loch (Pennington, 1975a) and A2 at Lochan an Smuraich (Pennington, 1977a), except for the reduced frequencies of Empetrum at Stormont. Empetrum, both E. nigrum and E. hermaphroditum, characteristically occurs at higher percentages in central and western areas with higher precipitation and generally more oceanic conditions (Brown, 1971; Walker, 1975a). Similar early peaks for Juniperus appear in northeast Scotland at Loch of Park, Loch Kinord and Garrall Hill (Vasari, 1977) and in southern Scotland at Corstophine (Newey, 1970). Such a pattern is also found in other British sites in the Lake District (Oldfield, 1960; Pennington, 1970) and in northern Britain (Bartley, 1962). There is a noticeable lack of similar assemblage zones in the Grampians although at Tynaspirit and Tirinie (Lowe and Walker, 1977) there are double peaks for Juniperus in the pre-Stadial period. At Corrydon in lower Glenshee (Walker, 1977), only 25km north of Stormont there is a very similar sequence with zone C2, a Betula-Juniperus - Empetrum assemblage zone, closely paralleling SG-2. This zone Walker equates with the classic zone Ib, or the Bölling interstadial.

SG-2 appears to represent therefore a period equivalent to the Bölling chronozone (Mangerud et al., 1974) and if this is so it is only the third site in the eastern half of Scotland to be interpreted as showing this particular pattern, the others being Corrydon (Walker, 1977) and Loch of Park (Vasari, 1977). On the basis of radiocarbon dates from Cam Loch Pennington has suggested a general duration of

13000b.p. to 12000b.p. for the Bölling in western Scotland thus encompassing the date of 12810±155b.p. (Q-457) for an <u>Empetrum</u> peak thought to reflect the Bölling at Loch Droma (Kirk and Godwin, 1963). At Tynaspirit (Lowe and Walker, 1977) the first <u>Juniperus</u> peak at the T2a/T2b boundary has been dated to 12750±120b.p. (HV-4989) but it is not clear whether this oscillation in juniper reflects a genuine Bölling pattern and the authors do not interpret it as such. Given the postulated dates for SG-1 it appears likely that at Stormont SG-2 covers the period between 12500 and 12000b.p. However it is unlikely that any amelioration in Strathmore would postdate the same event in northern Scotland, especially as "dwarf-shrub tundra ...... was the prevailing vegetation of the northern Scottish mainland during the Bölling chronozone" (Pennington, 1977b, p.261) whilst at Stormont there was a considerable expansion of juniper with some birch. Given this and dates for later events at Tynaspirit of 12395±195b.p. (HV-4988) and at Loch of Park of 11900±260b.p. (HEL-417) a later bracketing date of at least 12350b.p. seems likelier and thus SG-1 may yet date from before 13000b.p. The absence of dates for the pre-interstadial period makes such estimations difficult, as does the latitudinal variation in the sites which have been dated, such as Loch Droma (Kirk and Godwin, 1963), where a thin organic band attributed to the Bölling interstadial has produced a date of 12810±155b.p. (Q-457), and Glanllynnau where early organic deposits with thermophilous coleoptera are dated to 12556±230b.p. (Birm-276, Coope and Brophy, 1972). This problem is not helped by the large standard errors often encountered in these 'old' dates and the difficulties encountered in dating gyttja (Lowe and Walker, 1977).

The gradual development of a more closed vegetation cover dominated by woody taxa seen in SG-2 is disturbed by a distinct revertence in the vegetation recorded in SG-3 with the decline and almost disappearance of Juniperus and Empetrum and a reduction in Betula. There is an expansion of species characteristic of open ground, particularly Rumex and Artemisia, with a significant increase in Cyperaceae. There is a diminution in the contribution of Potamogeton and the first peak for Pediastrum. Although there is no immediate change in the lithostratigraphy there are indications of inwashing at the end of SG-3. From the pollen evidence it appears that the areas of dwarf-shrub heath and the thickets of juniper and possibly birch virtually disappeared, although in the latter case there is no real indication of a change in species contribution based on grain diameters. The disappearance of these taxa seems to have been to the benefit of sedges and Rumex with some expansion of Thalictrum. The absence of any distinctive peak for Artemisia suggests that although there was some revertence in the development of vegetation this was not accompanied by any increased movement of soils due to periglacial activity. The presence of high Cyperaceae values with high Rumex presents difficulties in determining which vegetation communities replaced the areas of dwarf-shrub heath and juniper thickets. The higher Cyperaceae counts suggest communities similar to those found on the summits of Scottish mountains today (H.J.B. Birks, 1973c) whereas the increase in Rumex implies an expansion of those species found during the earlier grassland phase of the Gramineae - Rumex assemblage zone. There are probably no directly analogous communities which can be used here and the period must have been one in which there was a general reduction in plant productivity leading to greater discontinuity in the vegetation cover but no significant substitution of communities. In such an environment species like Rumex would expand as would those forms of Cyperaceae which prefer a less dense vegetation mat.

One feature of particular interest in SG-3 is the increase in Pinus pollen. High counts of Pinus have been recorded at the base of several pollen diagrams obtained from kettle holes (e.g. Blackness, Roineach Mhor - Walker and Lowe, 1977) and they are thought to have been due to the melting out of pollen rich ice masses (Pennington, 1977b). This explanation cannot be used here as the high pine counts come from levels above the base and it seems that they must be due to the influence of long distance transport from the continent as found in open environments today (Tyldesley, 1973a,b,c). In this particular period the change in growth form of the surrounding vegetation from an erect form of juniper scrub and dwarf-shrub heath to much lower and more open communities unable to filter out extraneous pollen would also help to inflate the Pinus count. Should the change in vegetation recorded in SG-3 reflect a change in climate to more severe conditions this would also have changed the predominant airflow over this part of Scotland, the change in wind patterns bringing in pollen from different source areas and possibly leading to increased Pinus representation.

From its pollen assemblage and stratigraphic position SG-3 correlates with the Older Dryas chronozone of the continental stratigraphy (Mangerud et al., 1974) and in Scotland compares with NWS A3 at Loch Sionascaig, Loch Tarff, Cam Loch and Lochan an Smuraich (Pennington et al., 1972; Pennington, 1975a), the Rumex - Artemisia p.a.z. of northern Scotland, although at Stormont there is consistently less Artemisia. At Corrydon its equivalent is C3, a Selaginella - Rumex - Compositae p.a.z., which shows a higher degree of revertence in the vegetation communities towards colder, more chionophilous forms as would be expected at the higher altitude (Walker, 1977). At Loch of Park (Vasari, 1977) this period is defined in classic terms as Zone Ic, and, as at Stormont, the change is mainly noticeable in the curve for *Rumex*, with little change in *Artemisia* and no real evidence in either the pollen record or the lithostratigraphy for increased soil instability. Loch of Park and Corrydon remain the only other sites in eastern Scotland which show this pattern and in their recent book Gray and Lowe (1977) argue that on the basis of their work in the Grampians they agree with Birks' findings on Skye,

> "that vegetational succession and soil development progressed without interruption from about 13000B.P. until the beginning of the Loch Lomond Stadial" (p.170).

While they find the evidence for an Older Dryas recession from Cam Loch convincing (Pennington, 1975a, p.977) they argue that elsewhere, and particularly in Perthshire, such a stratigraphy may represent the collapse of sediments from the basin edge and their subsequent erosion, a feature also noted at Blelham Bog. In their conclusions however they find the evidence overall for this climatic recession in Scotland to be equivocal.

The interpretation of this part of the pollen profile from Stormont therefore raises several interesting questions. Is the pattern a genuine response to climatic deterioration or is it due to the redeposition of older sediments? Could it also be a statistical artefact of relative pollen counting? If this pattern is genuine then why does a lowland site such as Stormont respond to climatic change to a greater degree than many higher sites in the Grampians which were presumably at the limits of ecological tolerance for many species?

The validity of the sequence can neither be adequately proved nor disproved on the evidence available but there are several points which make redeposition unlikely. The assemblage recorded in SG-3 does not accord well with earlier assemblages found in the profile, the principal taxa of which would presumably be well represented given the redeposition of older sediments. Betula, Juniperus and Empetrum are quite well represented in both SG-1 and SG-2 but these are almost absent from SG-3. Were the redeposited sediments to be earlier than these two zones, i.e. equivalent to the basal material which was not collected, then on the basis of p.a.z.'s from other sites which represent this period there should be a dominance of taxa such as Artemisia, Lycopodium selago, Compositae or Selaginella selaginoides, but these are either absent or poorly represented. There is no immediate change in the lithostratigraphy to indicate inwashing of slumped material although there is band of gyttja between 500cm and 498cm at the end of SG-3. There is also no noticeable abrupt change in the pollen curves representing a hiatus or unconformity either here or at any other part of the stratigraphy. It must be stated that the sampling site is not in the deepest part of the basin which contains the Loch but on a shoulder above the main depression thus it may be argued that such a phenomenon would be represented here by an erosional phase rather than a depositional one. Should slumping and reworking be the basic cause underlying the pollen stratigraphy here and elsewhere in the Grampians then it would appear unusual for such a process to be active at several sites at the same time (at least in a stratigraphical sense) were there no fundamental extraneous factor initiating movement such as a change in climate. This change is amply demonstrated at sites in western Scotland from absolute pollen counting, a technique yet to be used in the east on sediments of this age, and in north west Europe as a whole.

The possibility of the variations in pollen curves being statistical artefacts has always to be considered with relative counts as there are no absolute counts from the eastern half of the country which confirm the pattern established on absolute evidence from the west. Where the evidence is from such a brief zone a statistical explanation appears even more likely. At Stormont SG-3 covers only six centimetres, but at Cam Loch, Lochan an Smuraich, Loch Sionascaig and Loch Tarff (Pennington, 1977b) NWS A3 is even briefer and it may be this brevity that accounts for its non-identification at many other sites. Here it was only identified by the use of contiguous one centimetre samples and such a detailed sampling framework is not always found in the published literature. It is true that where close sampling has been used elsewhere a comparable sequence does not appear, e.g. Tynaspirit 2 (Lowe and Walker, 1977), but at this site there are elements which could be indicative of a similar vegetational response to that seen at Stormont and in the west but they are partly masked by the rather erratic curves.

The occurrence of a deterioration in climate in the Older Dryas has been established at sites throughout northern Europe and Britain on both palynological and coleopteran evidence, with the main difference being the interpretation of a subsequent amelioration in the Allerød on pollen evidence as against a cooler but stable climate preceding the Stadial on the basis of coleopteran remains (Coope, 1977). The deterioration has also been indicated by the analysis of diatoms in northern Scotland (Haworth, 1976). In northern Scotland Pennington (1977a) suggests a chronology of two hundred years for the Older Dryas between 12000b.p. and 11800b.p. and this short time scale may also account for its absence at many sites, especially where there was a slow accumulation of sediment. At Loch of Park a date of 11900±260b.p. (HEL-417) for the Ic/II boundary would appear to agree with Pennington's synthesis based on dates from sites in the north west, with Godwin's chronozone limit at 11950b.p. and that of 11800b.p. accepted by Mangerud et al., (1974). The dates for the onset of the Older Dryas above also agree with the dates for the change to cooler temperatures in the interstadial seen in the records of fossil coleoptera, 12135±200b.p. (Birm-158) at Church Stretton (Osborne, 1972), 12160±140b.p. (Birm-127) at Red Moss, Lancashire (Ashworth, 1972), and 12290±250b.p. (Q-816) at Redkirk Point in south west Scotland (Bishop and Coope, 1977). The close proximity of all these dates, itself quite unusual for dates of such an age, suggests that at Stormont SG-3 would have opened just before 12000b.p. and terminated by 11800b.p.

Following this brief phase of revertence there is a sudden expansion of woody taxa at the expense of those of open ground. *Artemisia*, Caryophyllaceae, *Thalictrum* and Ranunculaceae disappear as there are successive peaks for *Empetrum*, *Juniperus* and *Betula*. *Empetrum* approaches values of 12%T.L.P., a frequency comparable with those at Blackness and Morrone but much less than at sites to the north and west (H.H. Birks and Mathewes, 1978), emphasising the oceanic characteristics of both *Empetrum nigrum* and *Empetrum hermaphroditum* and the importance of snow lie in determining its success (Walker, 1975a). The initial *Juniperus* peak is very high reaching 37%T.L.P., values rarely achieved elsewhere in Scotland and stands of juniper scrub must have been widespread during the early part of SG-4. SG-4 appears to indicate the period of highest temperature in the Late Devensian for many of the taxa indicative of chionophilous conditions such as *Artemisia*, *Thalictrum* and Saxifragaceae are absent and there is a continuous curve for *Filipendula* probably representing growth on the margins of the site as the frequencies are not high enough to suggest any immediate dominance (cf. values from Bankhead Moss). SG-4 also sees a consistent presence for *Helianthemum* which first appeared in SG-2. Although there is little evidence for instability in the sedimentary record the presence of *Rumex* and the high Gramineae values show that there were still considerable areas of open ground which acted as reserves for taxa such as *Rumex* which remained present at Stormont throughout the Late Devensian. The deposition of the organic mud and the recurrence of Potamogeton with occasional grains of Myriophyllum alterniflorum and M. spicatum shows that there was open water at the site and the improved preservation of pollen also attests to a decrease in mineral inwash and an increase in local productivity. Pediastrum, which had previously expanded in SG-3, is much reduced but this may not represent a reduction in influx so much as a change in the relative pollen and spore production of local plant taxa (H.H. Birks and Mathewes, 1978).

The character of the vegetation during SG-4 suggests a gradual closing of the dwarf-shrub and juniper-birch cover as sedimentation progressed. The pollen of trees and shrubs, excluding Empetrum, reaches over 50%T.L.P. at the height of the zone but within this cover remained relatively large open areas of grassland with, in particular, Rumex. There is no question that on the basis of present day pollen assemblages the amount of Juniperus recorded reflects dense stands of its erect shrub form but the status of Betula is more difficult to ascertain. The highest values for Betula are only just over 20%T.L.P. but SG-4 shows the highest mean diameters indicating an increasing presence of tree birches. There is ample macrofossil as well as pollen evidence from more northerly areas for the occurrence of Betula pubescens in the Alleröd (H.J.B. Birks, 1973a; Vasari, 1977) but it never grew in Scotland as a closed community and only formed scattered copses with dwarf-shrub heath and species-rich grassland.

SG-4 shows all the characteristics of a Zone II or Alleröd deposit as found throughout Scotland and now described as the culmination of either the Lateglacial Interstadial (Gray and Lowe, 1977) or the Windermere Interstadial (Pennington, 1977b). Its assemblage is very similar to T2c, the Betula - Juniperus p.a.z. at Tynaspirit 2

(Lowe and Walker, 1977) and can be correlated on a wider scale with the Betula – Juniperus p.a.z. of Pennington (1977b). It differs from most of the northern Scottish Allerӧd assemblages in its higher Betula values as it also does from the main interstadial zone, C4, at the nearest site at Corrydon (Walker, 1977) where neither Betula nor Juniperus achieve more than 15 per cent of the total counts. Walker considers that Corrydon lay above the zone of birch copses for most of the Betula pollen at Corrydon is referable to Betula nana. Thus, tree birches must have been restricted more to Strathmore and the lower ends of the glens as seen from the diagrams from Blackness and Roineach Mhor (Lowe and Walker, 1977). It is during the Allerӧd that Stormont most closely correlates with Loch of Park and Loch Kinord in Aberdeenshire (Vasari, 1977) but there is only one sample at Stormont at 493 cm which could be assigned to a later Allerӧd Juniperus peak as recognised at Loch Kinord and at Abernethy (H.H. Birks and Mathewes, 1978). This later expansion, which has been interpreted as a rather late additional climatic improvement in Scotland and North Wales (Burrows, 1974), may be indicated at other sites by double maxima for Empetrum (Pennington et al., 1972; Walker, 1974, 1975a) but this is not apparent here.

The Betula – Juniperus chronozone (Pennington, 1977b) has been dated to 11800 – 11000b.p. in the Lake District and its equivalent in northern Scotland has produced similar dates. At Abernethy a date of 11115±220b.p. (Q-1267) was recently obtained for the AFP-2/AFP-3 boundary, the Allerӧd/Stadial boundary (H.H. Birks and Mathewes, 1978), and most other Scottish dates for Allerӧd sediments fall between 11800 and 11000b.p. (e.g. 11385±290b.p. for the onset of the revertence at Tynaspirit – HV-4987, Lowe and Walker, 1977; 11520±220b.p. for a IIa/IIb boundary at Loch Kinord – HEL-418, Vasari, 1977) agreeing well with dates for English and Welsh sites (Burrows, 1974; Pennington, 1977b).

There are a few apparently young dates for the end of the Allerød, 10764±120b.p. at Loch Ettridge (SRR-352 Walker, 1975a), 10640±360b.p. at Loch Kinord (HEL-419 Vasari, 1977) and 10808±230b.p. at Garrall Hill (Q-104, Godwin and Willis, 1959) apparently confirming the early view that Zone III lasted from 10800 to 10300b.p. (Sissons, 1967) but most of these dates were from gyttja and the more recently analysed dates tend to fall before or around 11000b.p. At Stormont therefore there seems no reason to suspect that SG-4 spans any other period than ca.11800 to ca.11000b.p.

There is as yet no satisfactory answer to the question as to whether the period between 11800 and 11000b.p. represented the thermal maximum of the interstadial or whether, as the coleopteran evidence elsewhere suggests, this occurred before 12000b.p., prior to the less temperate phase of the Allerød (Coope, 1977). The pollen evidence from Stormont supports that from other sites in showing the period to have been one in which birch copses developed and soil stabilisation occurred to a greater extent than before but this need not have reflected temperature as much as other ecological factors, especially the status of the soil (Iversen, 1954) and the time required for tree immigration and establishment (Persson, 1964). On sedimentary grounds the development of a thin peat band in SG-2 could be interpreted as a response to improved climate in the form of warmer and drier conditions leading to a reduction in the water level but such local hydroseral conditions are not always determined by climatic events on a regional scale. At Stormont it is only the response of the aquatic flora, usually a good indicator of increasing warmth, itself rather limited in extent, that suggests that temperature may have been higher in SG-2 prior to the Allerød.

The redevelopment of ice masses in the Grampians is marked by sudden changes in both lithostratigraphy and pollen content. SG-5, in marked contrast to the preceding zone, shows considerable inwashing of sediment and a reduction in the woody taxa that were previously dominant. There is a change to more inorganic deposits and a resurgence in taxa absent or reduced during the interstadial, especially *Rumex*, Caryophyllaceae, Ranunculaceae, *Thalictrum* and *Artemisia*. Although some changes are sudden, such as the drop in *Juniperus* and *Betula*, and the increase in *Rumex*, many of the others are gradual. The *Betula* curve remains relatively constant through SG-5 but examination of the diameters shows great fluctuations with an increase in low measurements indicative of *Betula nana* expanding onto the more unstable margins of the kettle hole. The opening of SG-5 sees the first significant rise in *Salix* but overall it is very much a transitional zone between the communities reflecting interstadial conditions and those of the stadial. The almost complete disappearance of *Filipendula*, *Helianthemum* and *Potamogeton* also serve to emphasise the change to colder conditions. Despite the low *Artemisia* values the stratigraphy clearly indicates instability in the soil cover as does the peak for *Selaginella selaginoides* which prefers base-rich conditions in rills and flushes (H.H. Birks and Mathewes, 1978).

The opening up of the vegetation cover did not lead to any significant development of the grassland communities which spread in the pre-interstadial but the increased diversity of taxa represented and the increasing values for Cyperaceae suggest analogies with present day Alpine summit vegetation, e.g. the *Cariceto-Rhacomitretum lanuginosi* community (H.J.B. Birks, 1973a), rather than sub-Alpine communities. It is however difficult to accept this as a direct analogy in view of the high *Salix* frequencies which must imply a considerable local presence. High counts for both *Salix* and Cyperaceae are found at Loch of Park (Vasari, 1977), Roineach Mhor and Tynaspirit (Lowe and

Walker, 1977) and appear to be restricted to eastern and central Scotland during this period. Their interpretation in terms of known pollen assemblages from present day communities is difficult as there is no direct analogy but what such an assemblage may represent is a progression to dwarf-shrub Salix herbacea communities through a sub-Alpine grassland containing Salix lapponum and Luzula sylvatica (H.J.B. Birks, 1973a) for Selaginella selaginoides is characteristically found in the latter community at present. The increasing openness is further attested by higher values for Pinus pollen derived from long distance transport and the apparent increase in Pediastrum, although the latter could be due to the change in local conditions and restricted local productivity in the kettle hole.

Because of the transitory nature of the assemblage zone few direct comparisons can be made with assemblage zones elsewhere except for those already mentioned. At many sites the deposits covering the stadial are often represented by a single relatively uniform pollen assemblage, or by no substantial pollen record at all, especially close to areas of ice accumulation. In her synthesis of the Late Devensian in western and northern Britain Pennington (1977) suggests a twofold division of pollen assemblage zones for the stadial depending on the amount of Artemisia represented at different sites. Stormont, along with Corrydon (Walker, 1977), Tirinie and Amulree 2 (Lowe and Walker, 1977) appears to show a variant between these two types. At all these sites an earlier zone with lower percentages of Artemisia is noticed associated with the immediate deterioration in climate. The relative locations of the sites preclude any closer comparison but they all make a distinction between at least two different zones within the stadial. Because of the lack of organic material associated with these deposits and the danger of inwashed redeposited carbon-rich sediments, dating of this early phase is lacking but it seems obvious that it represents the immediate response to the deterioration of climate at the onset of the stadial or Loch Lomond Advance (Sissons, 1976). In this area of Perthshire there is little evidence for any significant glacial advance in Upper Glenshee but an ice cap did develop further to the east on the Gaick Plateau above Glen Clova and Glen Esk (Sissons, 1974).

The p.a.z. SG-6, a Salix - Artemisia - Rumex zone, which covers the main part of the stadial period is divided into two zonules on the basis of changes in the curve for Thalictrum. The assemblage represented shows similarities to that of SG-5 but Juniperus and Empetrum only occur spasmodically and Betula shows consistent low percentages with predominantly small mean diameters, indicating a dominance of Betula nana in the count. There is also a reduction in Gramineae while Cyperaceae and herbaceous taxa in general increase. Perhaps the most noticeable feature of SG-6 is the contribution of Artemisia, which reaches up to 21%T.L.P., and the expansion of Thalictrum, Caryophyllaceae, Chenopodiaceae, Saxifragaceae and Cruciferae. This increase in taxa indicative of open ground is also seen in the greater diversity of species present. Within the Caryophyllaceae there are grains referable to Silene type, probably Silene acaulis, and Cerastium alpinum type, and within the Saxifragaceae curve there is a dominance of Saxifraga aizoides/stellaris type. Other taxa either appear for the first time in this zone or appear more regularly than in previous zones. These include Gentiana, Parnassia, Armeria and Koenigia. The consistent relatively high counts for Pinus are not unusual in Scottish sites at this period and presumably serve to emphasise the openness of the local environment allowing in pollen derived from pine refugia to the south in southern Britain or on the continent. This continual presence may be used to assume a dominance of air flows from the south or southeast but with the early appearance of Pinus in pollen diagrams from western Scotland in the Flandrian, usually with Corylus, the possibility of a refugia further north has been postulated although its location is not known. Nevertheless with the expansion of ice in Scotland and Scandinavia and the icing over of the North Sea for much of the year with lower sea levels a change in pressure patterns would have occurred. It must however be remembered that the rises in Pinus and Pediastrum are more apparent than real and are probably strongly dependent on the changes in the local environment which would be producing far less pollen and filtering out less extraneous pollen. The ecological implications of the change in the Thalictrum curve are as yet uncertain because of the lack of knowledge of the response of Thalictrum flavum and T. alpinum to different environmental factors. Although frequently found in Late Devensian deposits (Godwin, 1975a) it rarely attains the levels found here and as it is not possible to separate the two species this also makes any further explanation difficult. The consistency of values and sudden change at 480 cm have been considered significant in terms of zonation but may however only reflect a local change in environment, the enlargement of the niche for Thalictrum on the unstable kettle hole margins, an explanation made more tenable by the relatively high frequencies which indicate a very local presence.

It is only recently that frequencies for Artemisia pollen during the stadial have excited any detailed consideration (Pennington, 1977b; H.H. Birks and Mathewes, 1978). While acknowledging the importance of Artemisia at most sites throughout Britain during the stadial Pennington noted the existence also of sites with low Artemisia counts as on Skye (H.J.B. Birks, 1973a), at Blackness, Roineach Mhor and Cambusbeg (Lowe and Walker, 1977) and in Cornwall (Brown, 1977).

H.H. Birks and Mathewes showed how in eastern Scotland and the Grampian - Cairngorm massif frequencies of Artemisia tended to increase towards the Cairngorms (see Table 2, p.462, H.H. Birks and Mathewes, 1978). The difficulties associated with the interpretation of the significance of Artemisia frequencies are centred upon the lack of present day analogies which have high Artemisia counts and in its known preference for rather xaric, well drained conditions (Iversen, 1954) and dislike of long snow lie. The problem is to reconcile these known ecological preferences with the period of rapid glacier initiation during which high counts are found. H.H. Birks and Mathewes explain the high Cairngorm values in terms of a rain shadow effect reducing the precipitation from south and south west winds, a feature interpreted from a reconstruction of firn lines (Sissons, 1976), and imply higher precipitation for the south and east Grampians on the basis of lower Artemisia percentages at Roineach Mhor and Blackness (Lowe and Walker, 1977). At the present time the Blairgowrie area does experience low rainfall relative to the rest of the south east Grampians, but it is difficult to reconcile values for Artemisia of 20%T.L.P. with higher values to the north and therefore necessary to suggest higher precipitation here than in the Cairngorms during the stadial. In defence of the hypothesis proposed by Birks and Mathewes the fluvio-glacial outwash fan in which the loch is situated would be a suitable parent material for the development of Artemisia were the climate suitable and the wind dispersal of its pollen could inflate fossil counts. The latter point would of course apply to most sites and with high Salix counts it is difficult to compare Stormont with many other sites to elucidate the form of the communities present', and hence the local importance of Artemisia. The distribution of Artemisia values can however perhaps be explained in a different way. At all the sites along the edge of the south east Grampians and at Corrydon in Glenshee the main peak in Artemisia pollen tends to be late in the stadial. At Stormont and at Tirinie and Amulree this has led to the definition of more than one p.a.z. covering the stadial. It seems likely that, at least in this area, this could reflect an early period of higher precipitation accompanied by a decrease in temperature at the onset of the stadial adequate to initiate glaciation in the heart of the Grampians and Cairngorms followed by a much drier phase after the ice had developed. This could even have been partially responsible through the reduction in precipitation for the cessation of ice advance and subsequent deglaciation. At more westerly sites the influence of the Atlantic would have served to retain a higher precipitation level and therefore reduced the extent of Artemisia throughout the Stadial.

The fluctuations within the stadial have not been dated at any site although they must take place within the generally accepted period of the Loch Lomond Readvance, ca.11000 to between 10300 and 10000b.p. The division between SG-6 and SG-7 does not necessarily mark what is usually accepted as the Devensian - Flandrian boundary but the assemblage in SG-7, a Gramineae - Cyperaceae - Rumex - Thalictrum zone, shows great similarity to the basal assemblage S-1 defined in the main Flandrian profile (see later) and as such denotes the end of the stadial. In SG-7 there is a significant reduction in Artemisia and Caryophyllaceae with an expansion in Gramineae and Cyperaceae and to a lesser degree Juniperus. Although there is no change in the inorganic nature of the sediment this is taken to represent the expansion of species-rich grassland to form a more complete ground cover with a consequent reduction in soil movement as a response to the ameliorating climate which caused the disappearance of the ice masses generated during the Loch Lomond Advance. This period will be discussed later in this chapter in a consideration of the Flandrian record from Stormont.

The importance of the Late Devensian record from Stormont lies in two principal findings, firstly the apparent indication of a pre-Allerød climatic oscillation which follows the Bølling-Older Dryas pattern, and secondly the opportunity it presents to look more closely at the pollen record for the stadial which indicates more detailed climatic changes than are usually found. Both these phenomena were identified largely through close sampling of the core and both present problems of interpretation when compared to other sites in eastern Scotland. When faced with a similar problem at Corrydon in Glenshee Walker (1977) was able to account for the apparent lack of evidence for an oscillation in the pre-interstadial elsewhere by noting that due to its altitude and location the site could be considered marginal and inherently unstable thereby responding to even a small change in climate. The same explanation cannot however be inferred for a low-land site such as Stormont which, compared with other Grampian sites, would have developed a relatively stable vegetation cover prior to the Older Dryas. In this case it is still considered that the results are valid, especially when seen in comparison to Corrydon, and it is therefore necessary to look more closely at the previously interpreted sites to see whether wider sampling or erratic curves are masking the indication of an Older Dryas recession. The fact remains however that in the absence of absolute counting few firm conclusions can be made concerning the reality of the recession as seen in pollen influx rates. Absolute counting does however face problems when used at such sites for it would be difficult to produce suitably calibrated influx rates where there is a juxtaposition of varying sediment types and presumably sedimentation rates and there is always difficulty in getting accurate dates, especially in sequence, from such deposits (e.g. Cb at Cam Loch, Pennington, 1977a). Nevertheless absolute analysis with a number of radiocarbon dates is an obvious progression and one which has yet to be adopted in eastern Scotland.

The Late Devensian pollen assemblage zones from Stormont are summarised in Table 5•3 where they are compared with the results from Corrydon, two representative sites from the Grampians and the regional chronozones from north west Scotland. A much fuller comparison of British Late Devensian assemblages appears in Pennington (1977b).

ii) Flandrian profile - Stormont A

a) Stratigraphy and sampling

The samples from the Flandrian part of the Stormont profile, Stormont A, were collected with a Russian peat sampler from close to where the Late Devensian stratigraphy was sampled (Fig. 5•3). A check was made in the field to ensure that material was collected down to and including the change from organic to predominantly inorganic sediments which at this site was assumed to reflect the transition between Late Devensian and Flandrian material. The point of sampling was within a flatter area of the *Salix* carr to the west of a slight rise in the surface adjacent to open water and away from the disturbance of the upper peat by shrub growth. Although not flooded at the time of sampling this part of the marginal loch vegetation is subjected to intermittent flooding and it was impossible to sample the upper 46 cm of the deposit because of its higher water content and virtually unhumified state. The stratigraphy at the point of sampling, marked A on Fig. 5•3, was as follows;

0 - 24 cm	Unhumified, stringy light brown *Sphagnum* peat with densely packed *Juncus* roots and *Molinia*. This part of the profile was occasionally penetrated by several *Phragmites* roots.

Table 5·3 Comparison of selected Scottish Late Devensian pollen assemblage zones

Mangerud et al., 1974 (Dates b.p.)	Jessen/ Godwin/ Iversen	Stormont	Corrydon (Walker, 1977)	Grampians (Walker and Lowe, 1977) N. Roineach Mhor	Grampians (Walker and Lowe, 1977) S. Tynaspirit 2	North West Scotland (Pennington et al., 1972)	
10000	III	SG-7 Gramineae-Cyperaceae-*Rumex*-*Thalictrum*	C6 *Artemisia*				
Younger Dryas		SG-6 *Salix*-*Artemisia* *Rumex* ±*Thalictrum*		RM3 *Salix*-Cyperaceae	T2d *Rumex*-*Artemisia*-*Selaginella*	C *Artemisia*-*Rumex*	Loch Lomond Stadial
11000		SG-5 *Salix*-*Rumex* (+*Selaginella*)	C5 *Lycopodium*-*Selaginella*-Compositae-Cyperaceae				
Allerőd 11800	II	SG-4 *Juniperus*-*Betula* (+*Filipendula*)	C4 *Betula*-*Juniperus*-*Rumex*	RM2 *Betula*-*Salix*-*Rumex*	T2c *Betula*-*Juniperus*	B *Empetrum*-Cyperaceae-*Juniperus*	Windermere or Lateglacial Interstadial
Older Dryas 12000	Ic	SG-3 *Rumex*-Cyperaceae	C3 *Selaginella*-*Rumex*-Compositae		T2b *Betula*-*Juniperus*-Gramineae	A3 *Rumex*-*Artemisia*	
Bölling 13000	Ib	SG-2 *Juniperus*-*Empetrum*	C2 *Rumex*-*Empetrum* ±*Juniperus*	RM1 *Rumex*-*Artemisia*-Gramineae	T2a *Rumex*-*Empetrum*-*Salix*	A2 *Rumex*-*Empetrum*-±*Juniperus*	
Middle Weich-selian	Ia	SG-1 Gramineae-*Rumex*	C1 *Rumex*-Compositae			A1 *Rumex*-Gramineae	

24 - 76 cm	Poorly humified darker brown *Sphagnum* peat with some penetration by *Phragmites* roots and remains of sedges, becoming gradually more humified with depth.
76 - 104 cm	Moderately humified *Sphagnum* with more sedge remains.
104 - 191 cm	Well humified peat with occasional rootlets and *Betula* twigs at 152 cm.
191 - 195 cm	Banded well humified greyish-brown and less well humified reddish-brown layers.
195 - 198 cm	Very well humified dark brown *Sphagnum* band.
198 - 326 cm	Light brown highly organic gelatinous mud (dy) with few recognisable remains. *Betula* twigs were found at 246 cm and nuts of *Corylus* at 284 cm and 309 cm.
326 - 350 cm	Moderately humified *Sphagnum* peat with occasional remains of sedge.
350 - 391 cm	Light grey moderately humified sedge peat becoming micaceous towards the base.
391 - 409 cm	Dark grey organic silty clay becoming coarser with depth and containing fruits of *Potamogeton*.
409 - 410+cm	Coarse grey clay.

The present vegetation at the sampling point is that of a *Salix* carr with occasional bushes of *Salix* sp. forming a dense cover towards the southern edge of the loch. There are frequent tussocks of *Juncus squarrosus* L., with *Equisetum fluviatile* L., *Molinia caerulea* and *Sphagnum* spp. The mixed fen vegetation also includes *Potentilla palustris* L., *Epilobium latifolia* L., *Filipendula ulmaria*, *Scutellaria minor* L., *Galium palustre* L., *Carex rostrata* Stokes and, towards the margins *Agrostis canina*. Nearer to the open water there is a narrow band of *Phragmites communis* L. and an outer band of *Menyanthes trifoliata* L. To the west the land above the carr is covered by a plantation of 20 to 30 year old pines and between the plantation and the carr there is a fringe of older *Pinus sylvestris* woodland with *Betula pubescens*, *Quercus robur* L. and *Fagus sylvatica* L. The ground vegetation is mainly of a heath form and is dominated by *Calluna vulgaris*, *Erica tetralix* and *Vaccinium myrtillus* L. with *Deschampsia flexuosa* L.

Because of the possible regional importance of the site as the first lowland site in the area to be investigated the upper 2·5 m of the core was sampled regularly at every 2 cm. Below 2·5 m samples were only taken every 4 cm and after 2·8 metres at 10 cm intervals. Preparation of the samples followed that outlined in Appendix II. On the whole, pollen preservation was good and pollen was abundant throughout the profile. Details of pollen preservation for each level are presented as part of the pollen diagram in Fig. 5·5c and are discussed in more detail in Appendix IV. Apart from the samples below 340 cm where pollen was less abundant a count of 500T.L.P.–Cyperaceae was used. Between 340 cm and 360 cm the count total was 400 and below 360 cm only 300. A pollen sum excluding Cyperaceae was chosen because of the latters local importance in the profile, especially in the upper half. Apart from Cyperaceae no other land pollens appeared to be significantly over-represented, except perhaps Gramineae, and no other land pollens were excluded from the final sum. The pollen diagram from Stormont A is presented in Fig. 5·5a,b,c. In this diagram and all ensuing diagrams *Pteridium aquilinum* is included within the herb pollen section because of its importance as an indicator of agricultural activity but it is excluded from the pollen sum. The final values for *Pteridium* are however expressed as a percentage of the sum of T.L.P.

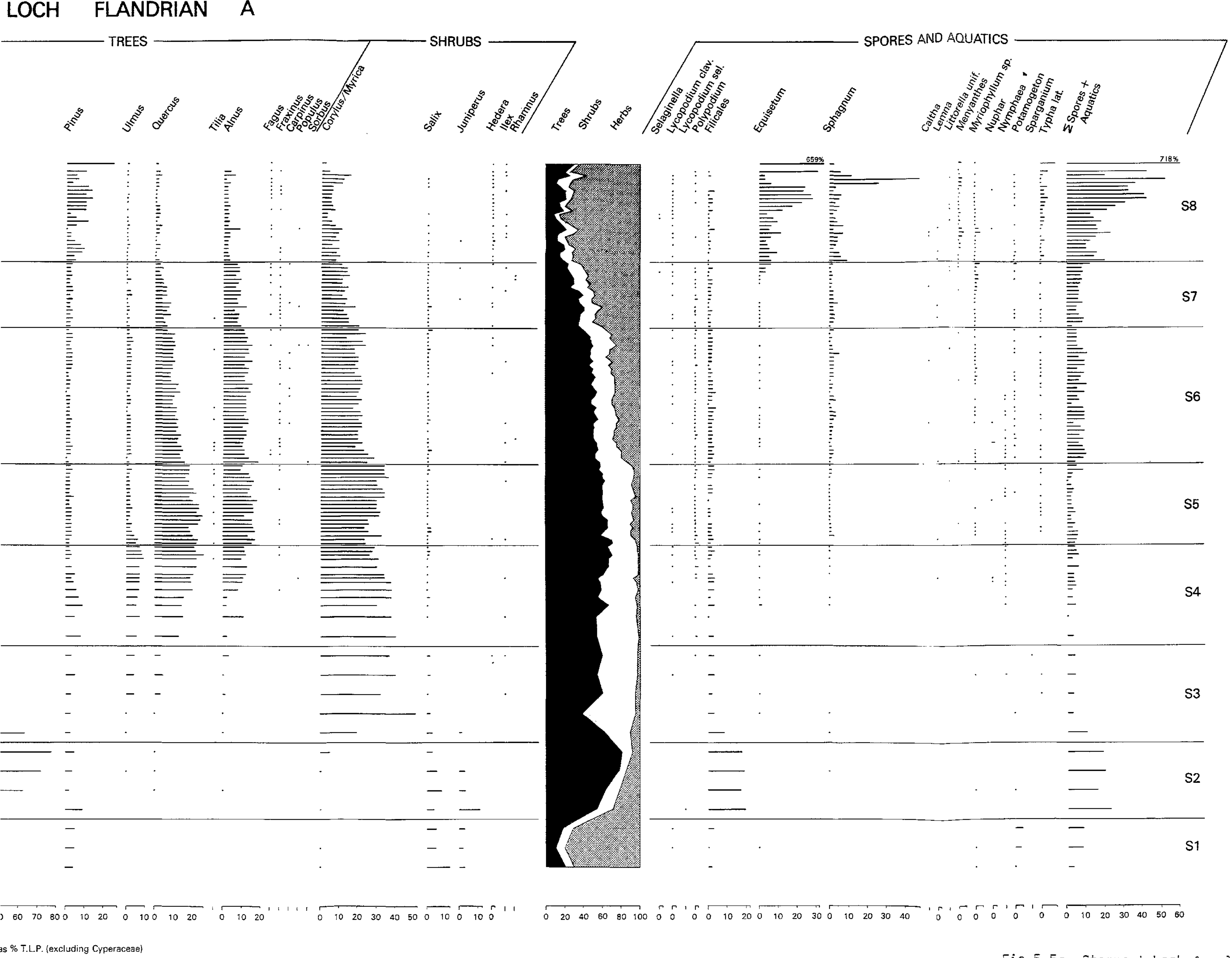


Fig.5.5a Stormont Loch A pollen diagram for the Flandrian, trees, shrubs, spores

STORMONT LOCH FLANDRIAN A

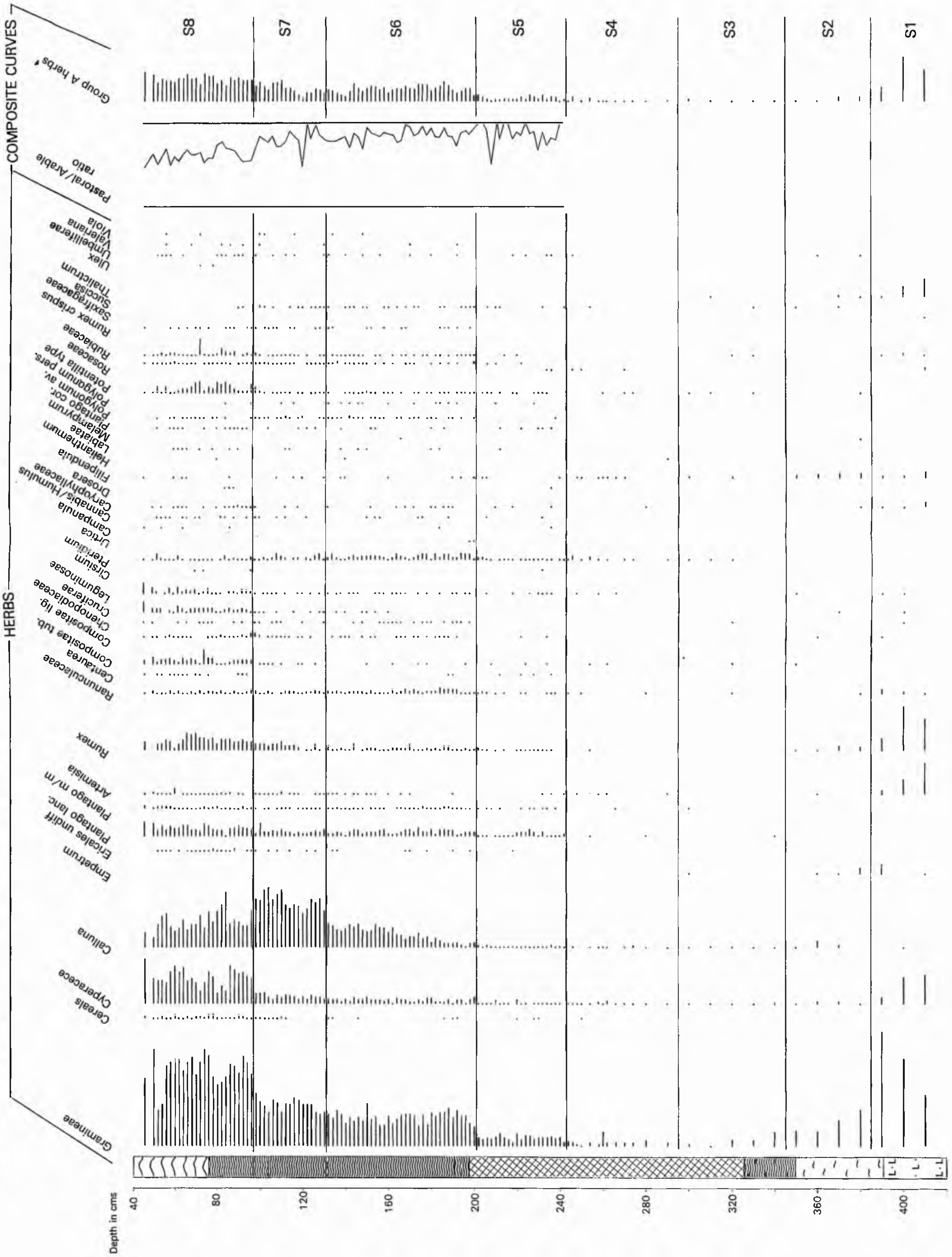


Fig.5.5b Stormont Loch A pollen diagram for the

STORMONT LOCH FLANDRIAN A

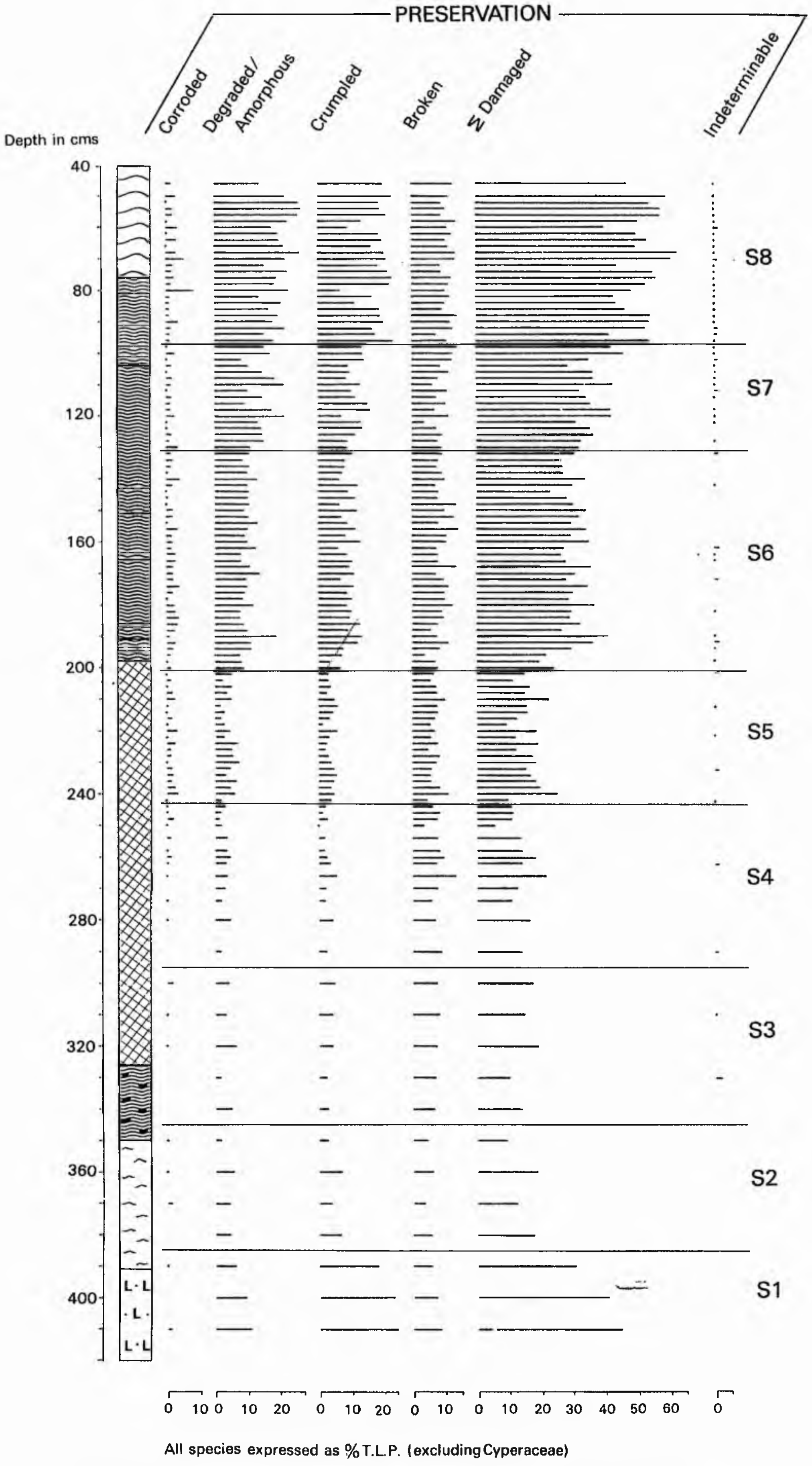


Fig.5.5c Stormont Loch A pollen diagram for the Flandrian, preservation

b) Pollen assemblage zones

Eight local pollen assemblage zones have been identified for this diagram and they are labelled S-1 to S-8. Although zones S1-S4 are defined as suggested by the American Commission on Stratigraphic Nomenclature (1961) in terms of characteristic and dominant taxa, a form of zonation now widely used (e.g. H.H. Birks, 1970; H.J.B. Birks, 1973b; O'Sullivan, 1974a; Pennington et al., 1972) the same terms of definition could not strictly be used for the later zones, S-5 to S-8. In the study of the nature of human interference with the vegetation cover it is the pattern of change rather than the homogeneity of the assemblage that indicates a phase of activity hence it is a suite of fluctuations in the pollen curves that is defined as a pollen assemblage zone in contradistinction to the stability recognised at earlier levels. The zone may still be distinguished in terms of dominant or characteristic taxa but there may be great variability in frequencies within individual curves. Changes between zones are then usually made where there is a distinct break either due to a change in the taxa affected or in the scale of modification envisaged. When there is only a slight change in scale then this is defined as a sub-zone or zonule within the principal pollen assemblage zone. In adopting this method the zones are labelled as usual by a number prefixed by a site code but no attempt is made to give the zone a title i.e. as in a Gramineae - *Rumex* assemblage zone. In the initial description of these later zones, S-5 to S-8, a detailed explanation of the pollen changes is included prior to the interpretive discussion.

S-1 410 cm - 385 cm Gramineae - Cyperaceae - *Rumex* - *Artemisia*

The upper boundary is marked by increases in *Betula* and *Juniperus* and a general rise in A.P. There is a corresponding decrease in *Rumex* and Cyperaceae and the disappearance of *Artemisia*.

S-1 is very similar to a combination of SG-6ii and SG-7 for it is dominated first by Cyperaceae and then by Gramineae with a wide variety of N.A.P. taxa present. All three levels show decreasing Rumex, Artemisia and Thalictrum with Ranunculaceae, Caryophyllaceae and Filipendula present at more than 1%T.L.P. Salix peaks in the lowest sample but is consistently present above this at between 3 and 4%T.L.P. as is Betula, which rises slowly through the zone, and Pinus. There is an isolated peak for Empetrum before the boundary with S-2. Although Potamogeton increases through S-1 there is no general expansion in aquatic taxa despite the predominant sedimentary unit being an organic silty clay which fines upwards. The boundary between S-1 and S-2 lies just above the change from the organic silty clay to a sedge peat with some Sphagnum.

S-2 385cm - 345cm Betula

The upper boundary is defined by a slight decrease in Betula with a steeply rising curve for Corylus/Myrica and the continuous presence of Ulmus and Alnus, and where Rumex and Filipendula disappear.

The chief characteristic of S-2 is a massive peak for Betula which reaches 77%T.L.P. Other tree pollens, especially Quercus, appear for the first time but only Pinus, which rises to 9%T.L.P. at 380cm is consistently present. Mainly because of the increase in Betula the pollen of trees and shrubs comprises 80%T.L.P. by the end of S-2, 60% more than at the S-1/S-2 boundary. Salix, Juniperus and Empetrum are still present but are reduced, as is Gramineae. Overall few N.A.P. taxa are represented and only Rumex and Filipendula consistently appear. There is a peak for Filicales and the first few spores for Sphagnum. This zone covers the change to completely organic deposits in the form of a sedge peat with some Sphagnum.

S-3 345cm - 295cm *Betula*-*Corylus*/*Myrica*

The upper boundary occurs where *Betula* declines and where the curves for *Quercus* and *Ulmus* begin to rise.

S-3 is characterised by a steep rise in *Corylus*/*Myrica* to a peak of 51%T.L.P. The local presence of *Corylus* is also attested by macrofossil remains in the form of hazelnuts. The rise of *Corylus*/*Myrica* corresponds with a decrease in *Betula*, the only other major pollen contributor. By the start of the zone the pollen of trees and shrubs comprised 90%T.L.P. and this is increased to a constant 95%. Within S-3 there are empirical limits for *Ulmus* and *Quercus* which appear together and *Pinus* remains constant throughout at between 3% and 5%T.L.P. Both *Juniperus* and *Empetrum* disappear as do many of the herb taxa found in earlier zones and Gramineae is reduced to less than 1%T.L.P. at 310cm. Again the sum of spores and aquatics is low with Filicales reduced but *Pteridium* appears for the first time. The zone covers two sedimentary units, a *Sphagnum*-sedge peat which gradually changes into a highly organic gelatinous dystrophic mud with well humified plant remains.

S-4 295cm - 243cm *Quercus* - *Corylus*/*Myrica* - *Betula* - *Ulmus*

The upper boundary is taken where there is the first decline in *Ulmus* and *Corylus*/*Myrica* with increasing *Alnus* and Gramineae. At this point both *Calluna* and *Plantago lanceolata* become consistently present and there is a general decrease in A.P. and shrubs to 90%T.L.P.

Within S-4 there is a general expansion of the principal deciduous trees, *Quercus*, which reaches up to 22%T.L.P., *Ulmus*, to 9%T.L.P., and *Alnus*, which shows an isolated peak followed by a much more gradual rise to 14%T.L.P. later in the zone. *Pinus* contributes its highest early frequencies in the profile but then decreases as do *Betula* and

Corylus/Myrica. There are the first few grains of *Tilia* and *Fraxinus* and occasional occurrences of *Ilex*, *Hedera* and *Viscum*. After a brief break *Salix* becomes consistently present again. The zone is dominated by A.P. and shrubs at 95%T.L.P. with only low Gramineae counts and sporadic records of *Calluna* and *Pteridium*. Although the spore counts are also low there is a greater variety represented with *Sphagnum*, *Polypodium* and *Lycopodium clavatum*.

There is an isolated peak for Gramineae at 260cm but there is no change in any of the other N.A.P. curves. The only arboreal taxa affected are *Betula* and *Corylus/Myrica* with a slight depression in *Pinus*. There is no change in the sediment at this level or indeed anywhere in the zone. The appearance of a large diameter grain of Gramineae (48µ) classified as *Cereal* type at 250cm is a further isolated occurrence (Table 5·4). Because it was folded closer specification proved difficult and it may be that it was an example of a large diameter grain which is not of a *Cereal* type (Beug, 1961).

S-5 243cm - 201cm

The upper boundary is taken where both *Quercus* and *Corylus/Myrica* decline and A.P. plus shrubs is reduced to 80%T.L.P. At this point there is an increase in Gramineae and continuous curves for *Calluna*, *Plantago lanceolata*, *Rumex* and *Pteridium* start.

This is the earliest zone in which relatively detailed changes in the pollen curves take place with the expansion of several N.A.P. taxa. Although there are few clearly definable patterns of change there are very noticeable alterations in the frequencies of certain taxa.

At the onset of S-5 there is a stepped decline in *Ulmus*, a brief fall at 242cm from 7 to 5%T.L.P. followed by a recovery to 6%T.L.P.

Table 5·4 Cereal pollen types from Stormont A

Depth (cm)	Grain Dia-meter (μ)	Pore Size (μ)	Preservation	Sculpturing (Beug)	Species Interpretation
48	46	–	Good	*Avena* type	*Avena* sp.
	42+	10	Crumpled	*Avena* type	*Avena* sp.
	44	–	Crumpled	–	–
	47	11	Good	*Avena* type	*Avena* sp.
	46	–	Crumpled	–	–
50	50	–	Folded	–	–
	46	–	Crumpled	–	–
	54	–	Broken	*Triticum*	*Triticum* sp.?
52	48	12	Good	*Avena* type	*Avena* sp.?
	40+	–	Crumpled	–	–
54	40	8	Folded	–	–
	42	–	Crumpled	–	–
	46	–	Crumpled	–	–
	40	–	Crumpled	–	–
56	44	–	Crumpled	–	–
	48	–	Crumpled	–	–
58	42	–	Folded	–	–
	40	9	Good	*Hordeum* type	*Hordeum* sp.
60	42	–	Broken	–	–
	40	–	Broken	–	–
	42	–	Crumpled	–	–
	42	–	Crumpled	–	–
	40+	–	Corroded/ Broken	–	–
	43	9	Good	*Hordeum* type	*Hordeum* sp.
64	42	9	Good	*Hordeum* type	*Hordeum* sp.
	46	10	Folded	–	–
	44	12	Good	*Avena* type	*Avena* sp.
66	43	10	Folded	*Hordeum* type	*Hordeum* sp.
	40	–	Crumpled	–	–
	42	11	Concealed	–	–
	45	11	Good	*Avena* type	*Avena* sp.
	40	–	Degraded	–	–
	50	–	Folded	–	–

continued.......

Table 5·4 (continued)

Depth (cm)	Grain Diameter (μ)	Pore Size (μ)	Preservation	Sculpturing (Beug)	Species Interpretation
68	42	10	Good	*Hordeum* type	*Hordeum* sp.
	40	–	Broken	–	–
70	42	8	Crumpled	–	–
	41	10	Broken	–	–
	40	10	Broken	–	–
	46	–	Broken	–	–
72	54	11	Good	*Triticum*	*Triticum* sp.?
	44	–	Folded	–	–
	40	10	Degraded	–	–
	46	–	Degraded	–	–
74	45	–	Folded	–	–
	45	8	Folded	*Avena* type	*Avena* sp.
76	40	–	Concealed	–	–
	43	9	Good	*Hordeum* type	*Hordeum* sp.
	41	11	Good	*Hordeum* type	*Hordeum* sp.
	45	13	Good	Hordeum type	*Triticum monococcum*?
	46	–	Folded	–	–
78	48	10	Folded	–	–
	46	–	Broken	–	–
	47	11	Folded	*Hordeum* type	*Hordeum* sp.?
	42	8	Concealed	–	–
	45	9	Good	*Hordeum* type	*Hordeum* sp.
	44	–	Folded	–	–
	46	10	Folded	–	–
80	40	10	Folded	–	–
	40	–	Concealed	–	–
82	42	10	Good	*Hordeum* type	*Hordeum* sp.
	44	10	Good	*Hordeum* type	*Hordeum* sp.
	43	9	Good	*Hordeum* type	*Hordeum* sp.
84	41	–	Degraded	–	–
	44	–	Concealed	–	–
88	41	11	Folded	*Hordeum* type	*Hordeum* sp.?
90	40	9	Degraded	–	–
	40	8	Good	*Hordeum* type	*Hordeum* sp.

continued........

Table 5·4 (continued)

Depth (cm)	Grain Dia-meter (μ)	Pore Size (μ)	Preservation	Sculpturing (Beug)	Species Interpretation
	42	–	Crumpled	–	–
	40	–	Crumpled	–	–
	48	–	Crumpled	–	–
	42	–	Folded	–	–
92	45	10	Good	*Hordeum* type	*Hordeum* sp.
	46	9	Folded	*Hordeum* type	*Hordeum* sp.
	47	10	Folded	*Hordeum* type	*Hordeum* sp.
94	40	–	Crumpled	–	–
	40	–	Concealed	–	–
	48	10	Good	Prolate form	*Secale cereale*
96	40	10	Good	*Hordeum* type	*Hordeum* sp.
	45	8	Folded	Prolate form	*Secale cereale*
	43	–	Broken	*Hordeum* type	*Hordeum* sp.?
98	46	11	Good	*Hordeum* type	*Hordeum* sp.?
100	44	10	Broken	–	–
102	40	10	Broken	–	–
104	40	12	Broken	–	–
	40	10	Broken	–	–
106	40	–	Folded	–	–
	48	13	Folded	–	–
	47	13	Broken	*Triticum* type	*Triticum* sp.
108	40	8	Good	*Hordeum* type	*Hordeum* sp.
110	50	–	Folded	Prolate form	*Secale cereale*
	42	10	Good	Prolate form	*Secale cereale*
	45	9	Good	Prolate form	*Secale cereale*
	47	10	Folded	Prolate form	*Secale cereale*
112	40	–	Concealed	–	–
132	45+	8	Broken	*Triticum* type	*Triticum* sp.?
134	40	9	Good	*Hordeum* type	*Hordeum* sp.
146	47	10	Folded	*Triticum* type	*Triticum* sp.?
186	45	11	Folded	*Avena* type	*Avena* sp.?
190	42	10	Good	*Hordeum* type	*Hordeum* sp.

continued.........

Table 5·4 (continued)

Depth (cm)	Grain Dia- meter (μ)	Pore Size (μ)	Preservation	Sculpturing (Beug)	Species Interpretation
192	40	8	Good	Hordeum type	Hordeum sp.
220	47	11	Folded	Hordeum type	Hordeum sp.?
228	45	10	Broken	Hordeum type	Hordeum sp.
250	48	-	Folded	-	-

The above represent all measureable Cereal type grains identified but species identification was only attempted where it was possible to obtain measurements and an indication of surface sculpturing (see Appendix V for further discussion).

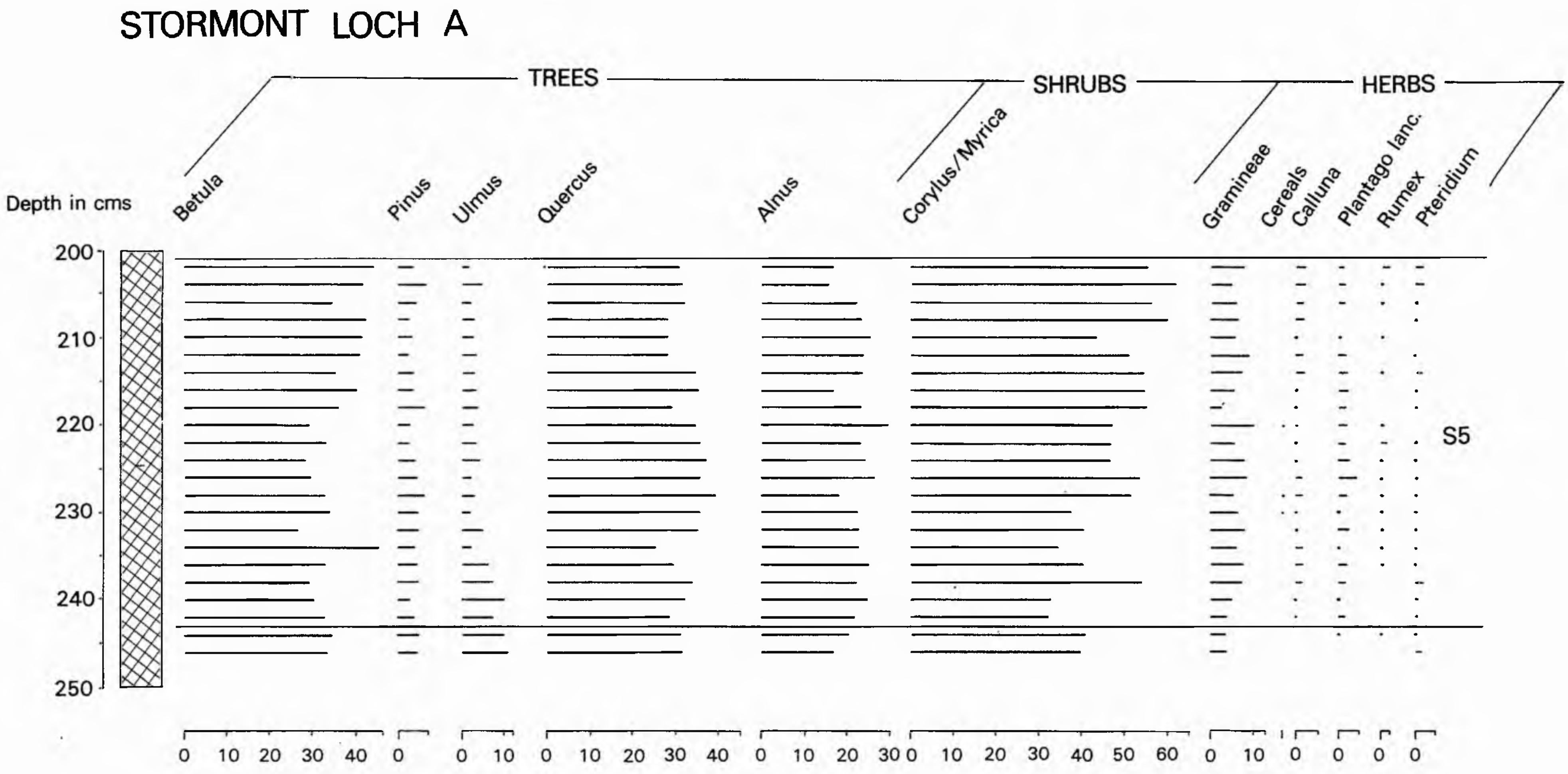
and then a gradual reduction to between 1 and 2%T.L.P., a figure which it then retains throughout the zone, only occasionally rising to 3%T.L.P. At the first decline there is a decrease in Corylus/Myrica which later peaks as the gradual decline in Ulmus takes place before falling again. During the same period Betula decreases and Alnus increases overall. Over both steps in the Ulmus curve Gramineae gradually rises to 4-5%T.L.P. and at the first step both Calluna and Plantago lanceolata appear. After the initial reduction in A.P. to below 60%T.L.P. there is a recovery but in the later part of S-5 A.P. stays at around this level. The reduction in A.P. and shrub pollen to 90%T.L.P. is offset by increases in Corylus/Myrica in the latter half of the zone and returns to 95%T.L.P.

Following the early changes in the main pollen taxa the remainder of S-5 is characterised by a slow readjustment to new relative proportions. Ulmus never recovers its former frequencies but Quercus returns to the levels of the previous zone, S-4, before a slow reduction towards the boundary with S-6. Alnus remains consistently higher in S-5 then in S-4 though its frequencies are somewhat erratic and it too is gradually reduced. After their initial decreases and variable frequencies both Betula and Corylus/Myrica increase in the latter part of the zone with Corylus/Myrica reaching levels it attained prior to the maximum for Quercus in S-4. Within the arboreal and shrub taxa the most noticeable feature of the zone is the reduction of Ulmus with rather erratic changes in most other species before a later stabilisation and consistency in the upper levels.

There is a consistent curve for Gramineae which, between 240cm and 220cm, remains at around 4%T.L.P. Between 220cm and 202cm there is a more pronounced peak isolated by a reduction to less than 2% at 218cm. and a later reduction at 202cm. Cereal type pollen grains are represented at 230cm, 228cm and 220cm and on the basis of the work by Beug (1961 - and see Appendix V) these are identified as indeterminable, Hordeum type and Triticum type (?) respectively (Table 5•4). Although continuous, Calluna rarely rises above 1%T.L.P. as does Pteridium. There is a correspondence between the higher values for Plantago lanceolata and the appearance of Rumex but despite its almost constant presence Plantago lanceolata only shows a small peak at 226cm prior to the main Gramineae peak. Other N.A.P. taxa appear in S-5 such as Plantago media/major, Artemisia, Ranunculaceae, Potentilla, Leguminosae, Caryophyllaceae and Centaurea cyanus, but they only occur spasmodically. Overall the Pastoral:Arable ratio calculated as by Roberts, Turner and Ward, 1973, exceeds 75 per cent with only one level, at 208cm, dipping below this to 50 per cent, a figure calculated on a very low pollen sum.

Because of the low N.A.P. count consideration of the diagram for selected taxa recalculated on an A.P. sum (Fig. 5•6) only serves to emphasise slightly the changes outlined above. The double decline in Ulmus is clear as is the corresponding increase in the relative proportions of Corylus/Myrica, Betula and Alnus. The recalculated diagram makes the relationship between the expansion of herb taxa and the secondary reduction in Ulmus more noticeable but does not provide any more discernible patterns in the N.A.P. curves.

Whilst there is still a continuous low presence for Filicales, both Polypodium and Sphagnum occur more consistently and Lycopodium clavatum, Typha latifolia and Myriophyllum spicatum also appear occasionally throughout. The entire zone falls within the gelatinous mud but in the upper part pollen shows more variability in the state of preservation with evidence of Corroded grains.



All species expressed as % A.P.

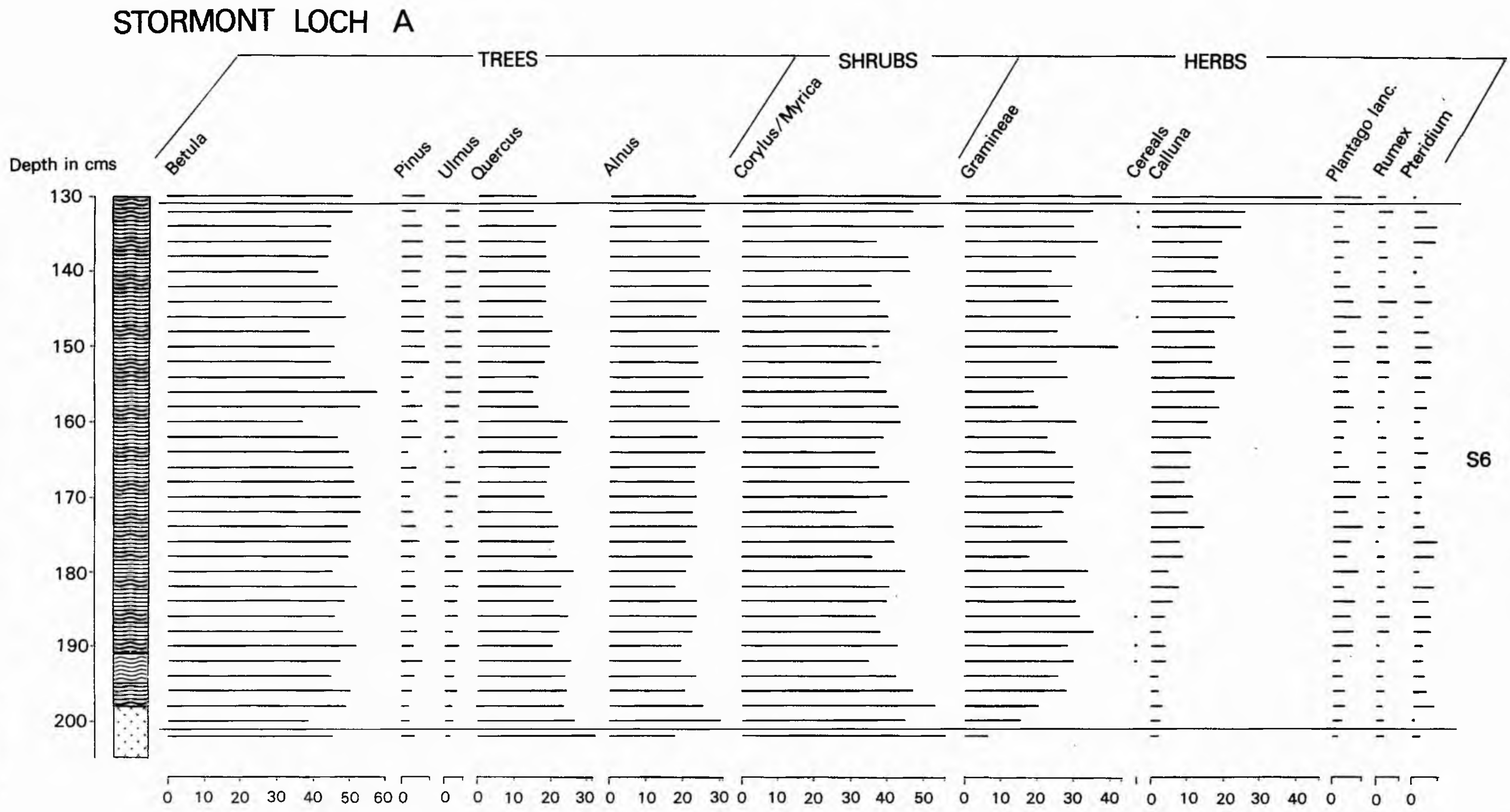
Fig.5.6 Stormont Loch A, S5. selected taxa expressed as a percentage of the A.P. sum

S-6 201cm - 131cm

The upper boundary occurs where there is a decrease in Quercus and Alnus and a reduction in the sum of A.P. and shrubs to 60%T.L.P. At this point there are rises for both Gramineae and Calluna.

S-6 is a stratigraphically long zone of remarkable consistency with only gradual changes taking place in pollen content and few noticeable peaks. The zone opens with a reduction in Quercus and Corylus/Myrica and a general reduction in the contribution of A.P. from 60 to 50%T.L.P. Once reduced most arboreal taxa remain relatively constant although as the zone progresses Quercus is gradually reduced, especially as a component of the A.P. sum (Fig. 5·7). The curves for Quercus and Alnus tend to change together with peaks corresponding to low N.A.P. levels. Although only appearing at low frequencies both Pinus and Ulmus recover, reaching up to 4%T.L.P., and also tend to show a similar pattern of change. Fraxinus appears more regularly than in S-5 and Fagus, after two isolated occurrences at 194cm and 196cm, reappears at 142cm. Values for Corylus/Myrica are more irregular than any of the tree pollen curves and by 138cm are restored to the percentages reached at the end of S-5.

Despite the consistency seen in the A.P. record there are noticeable and significant changes in the N.A.P. curves. The opening of S-6 is marked by a steep rise in Gramineae to 18%T.L.P. (40%A.P.), the expansion of Calluna and, to a lesser extent, Plantago lanceolata and Pteridium. In S-6 the main change is the increasing contribution of Calluna which, by the end of the zone, comprises percentages equivalent to those for Gramineae. Within the N.A.P. component as a whole it is possible to discern four peaks, especially from the composite curve for Group A herbs (open ground species grouped according to Sims (1973)) and in the individual curves for Pteridium, Plantago lanceolata, Rumex and Ranunculaceae.



All species expressed as % A.P.

Fig.5.7 Stormont Loch A, S6, selected taxa expressed as a percentage of the A.P. sum

These peaks are:

i) From 200cm to 192cm. With a reduction in *Quercus* and *Corylus/Myrica* and then *Alnus* there are peaks for *Calluna*, *Plantago lanceolata* and *Pteridium* followed by a reduction in N.A.P.

ii) From 192cm to 160cm. Although most of the arboreal pollens are only slightly and irregularly reduced there are high values for the Group A herbs and *Calluna* increases. The principal taxon affected is *Plantago lanceolata* which appears at up to 3%T.L.P., with only a short drop in frequencies at 182cm. The increase in *Plantago lanceolata* is accompanied by an increase in *Pteridium* and, in the earlier levels, by *Rumex* and Ranunculaceae. This period sees the highest values for these herbs in S-6 and again the pattern is emphasised in the diagram based on an A.P. sum.

iii) Between 160cm and 140cm there is a further double peak for *Plantago lanceolata* but little response from other N.A.P. taxa except *Pteridium*. This peak is associated with low but consistent *Quercus* values and lower *Corylus/Myrica*.

iv) Between 140cm and 132cm. After a depression of all N.A.P. with high *Corylus/Myrica* there is a final low peak for *Plantago lanceolata* and *Pteridium* associated with the appearance of *Cereal* type pollen in successive levels (assigned to both *Triticum* and *Triticum/Hordeum* types) and increasing *Calluna*.

It is only in the last two N.A.P. peaks that the Pastoral:Arable ratio falls below 75 per cent, except for a single low value at 190cm.

Although the overall frequencies for spores and aquatics increase in S-6 this is largely due to higher values for *Sphagnum*, corresponding to the change from gel mud to a *Sphagnum* peat with sedge remains, and the more continuous presence of Filicales. The stratigraphical change is marked by bands of *Sphagnum* peat of varying humification between 198cm and 191cm. S-6 also has more regular frequencies for *Myriophyllum spicatum*, *Potamogeton* and *Typha latifolia*. With the change in sediment there is a general increase in pollen deterioration, especially in the Degraded and Crumpled categories, with the highest values between 194cm and 190cm in association with the banded peat. After this point percentages for damaged pollen remain fairly constant at between 30 and 40%T.L.P.

S-7 131cm – 97cm

The upper boundary is defined by an increase in *Pinus*, Cyperaceae and Compositae tub. and by a decrease in all the other major A.P. taxa, *Corylus*/*Myrica* and *Calluna*.

Zone S-7 shows some interesting features in the pollen record with, at its opening, a reduction in A.P. to 30%T.L.P. due to decreases in *Quercus*, *Ulmus* and *Alnus*. There is also a corresponding decrease in *Corylus*/*Myrica*. Although *Betula* shows some reduction as a percentage of the T.L.P. sum in the latter part of the zone it never falls below 40% of the A.P. sum (Fig. 5·8). There is a more consistent curve for *Fraxinus* but at 110cm *Ulmus* disappears, only to appear later at 1%T.L.P. or less.

In the N.A.P. curves the most noticeable change is the increase in *Calluna* to levels higher than for Gramineae and its initial increase is not matched by any change in the Gramineae curve. The early peak for *Calluna* corresponds with peaks for *Plantago lanceolata*, *Pteridium* and, to a lesser extent, Ranunculaceae and *Rumex*, but there is then a general reduction in all N.A.P., except Gramineae, as seen in the composite Group A herb curve, allowing a brief increase in all A.P. taxa. After this reduction there is a general increase in all N.A.P. from 118cm to the end of the zone with high values for *Calluna* and

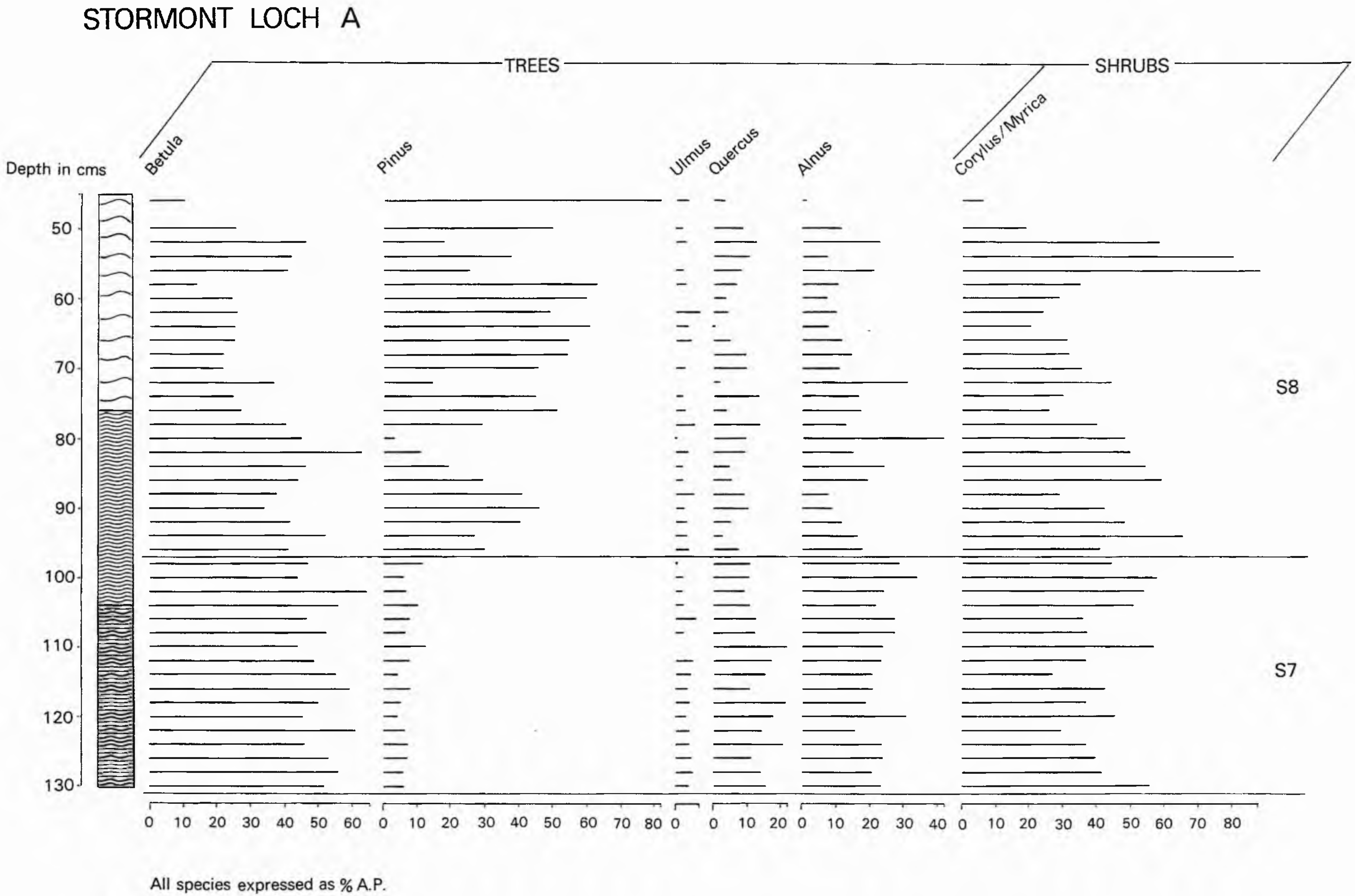
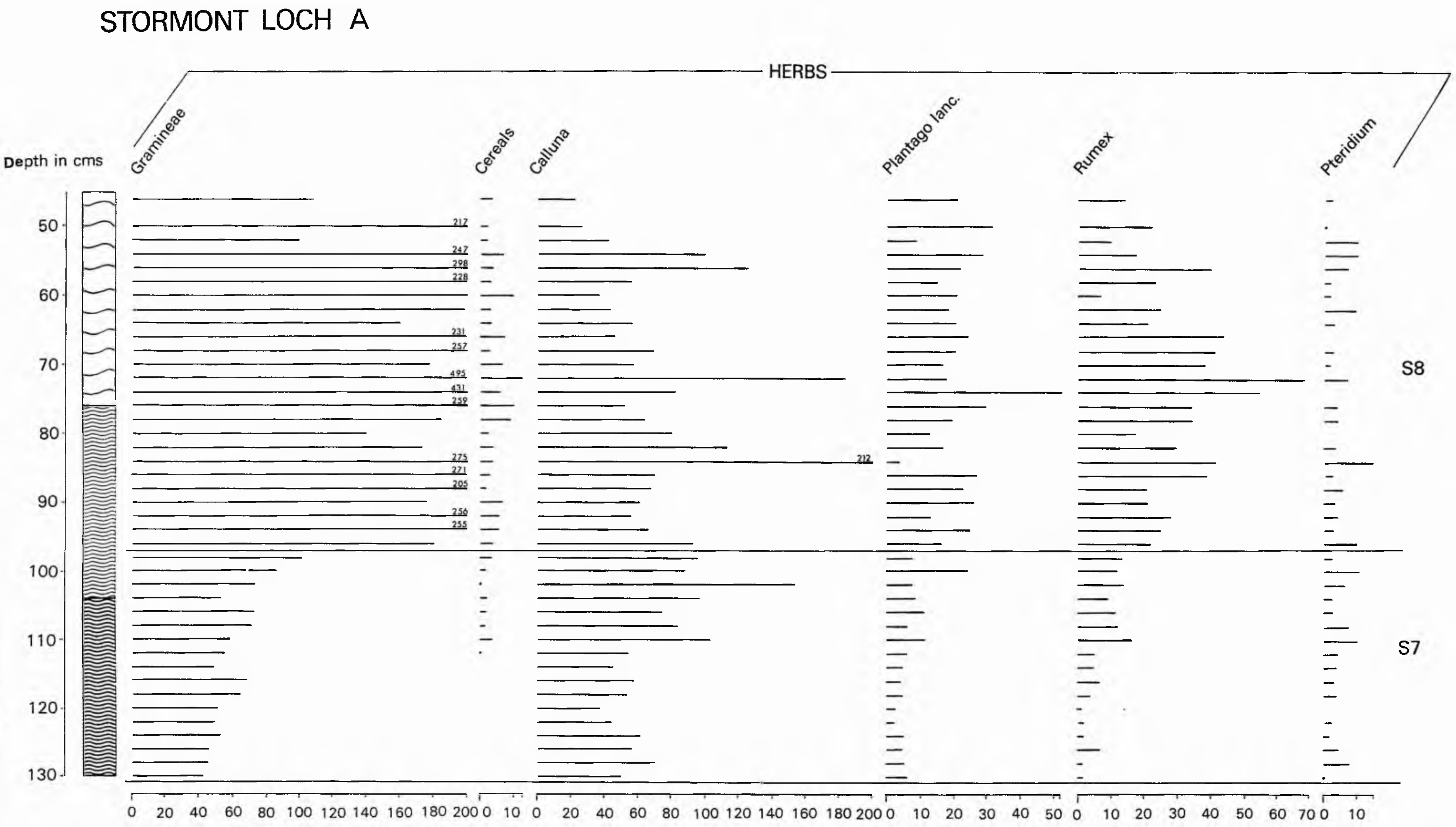


Fig.5.8a Stormont Loch A, S7 and S8, selected taxa expressed as a percentage of the A.P. sum, trees and shrubs



All species expressed as %A.P.

Fig.5.8b Stormont Loch A, S7 and S8, selected taxa expressed as a percentage of the A.P. sum, herbs and Plantago lanceolata and a continuous presence for Rumex at frequencies above 2%T.L.P. There appear to be two overall N.A.P. peaks within the zone, first at 110cm and later at 100cm but values generally remain high throughout. At 110cm the curve for Cereal type pollen becomes continuous for the first time and at this level all the grains encountered are referable to Secale type. Apart from one level the Pastoral:Arable ratio remains at similar levels to those in the later part of S-6.

Within S-6 there is a change to a less well humified Sphagnum peat but this only slightly reduces the frequencies of Sphagnum spores encountered and towards the end of the zone there is an increase in Myriophyllum spicatum and Equisetum. There is very little difference in the state of preservation between S-7 and S-6 apart from two higher peaks for Degraded pollen.

S-8 97cm - 46cm

The upper boundary does not coincide with the top of the deposit but represents the highest possible sampling point due to the poorly humified character of the peat and the high water content.

The boundary between S-7 and S-8 is marked by two major changes in the pollen record, the expansion of Pinus and the reduction in values of Calluna, with a corresponding increase in Gramineae and Cyperaceae. The A.P. sum is dominated by Pinus although in the earlier part of S-8 Betula comprises a proportion of the A.P. sum equivalent to that found in S-7. Although highly irregular there are four peaks in the Pinus curve and in the depressions between them Quercus, Betula and Alnus show smaller peaks with the latter appearing at up to 10%T.L.P. in individual levels. Corylus/Myrica shows a pattern similar to Betula with its highest values at 56cm where it comprises 80%A.P. Fagus appears more regularly as does Hedera and for the first time Salix appears only spasmodically.

Within the N.A.P. curves it is again difficult to pick out noticeable patterns, as may be seen from the Group A herb curve, but there is a change to high Gramineae frequencies, up to 495%A.P., at the expense of Calluna, and Cyperaceae also becomes important. A greater variety of herbaceous taxa are well represented for the first time since the Late Devensian with in particular Compositae tub., Cruciferae, Leguminosae, Potentilla type and Rubiaceae all appearing at over 1%T.L.P. Plantago lanceolata is also well represented and there are high consistent values for Rumex. The curve for Cereal type pollen remains continuous at up to 12%A.P., comprising mainly Hordeum type but with some Triticum/Avena type assigned to Avena. There is a distinct change in the Pastoral: Arable ratio which is much lower than in previous zones, averaging only around 50 per cent.

During S-8 the peat becomes much less humified with occasional Phragmites roots and a very high water content. This change is reflected in the high values for Equisetum and the more consistent curves for Menyanthes and Typha latifolia. The zone also has the highest values for Damaged pollen with an increase in all categories, especially in Corroded grains.

c) Statistical zonation of the profile

The results of the statistical zonation of the profile using SPLTINF and SPLTLSQ are presented in Table 5•5. This gives the analyses up to the seventh division, dividing the data into eight groups, equivalent to the number of local pollen assemblage zones identified. In the first analysis to be carried out twenty-one taxa were included, all of which contributed at least 2%T.L.P., and in a second analysis several of the herb taxa were grouped into combined values for pastoral

Table 5•5 Statistical zonation of the Flandrian Stormont Profile

Division	SPLTINF	Residual Variability %	SPLTLSQ	Residual Variability %
1	(46 – 130cm) (132 – 410cm)	60•71	(46 – 128cm) (130 – 410cm)	57•09
2	(46 – 130cm) (132 – 330cm) (340 – 410cm)	43•19	(46 – 128cm) (130 – 330cm) (340 – 410cm)	43•28
3	(46 – 130cm) (132 – 200cm) (202 – 330cm) (340 – 410cm)	32•53	(46 – 128cm) (130 – 330cm) (340 – 380cm) (390 – 410cm)	32•94
4	(46 – 86cm) (88 – 130cm) (132 – 200cm) (202 – 330cm) (340 – 410cm)	24•44	(46 – 86cm) (88 – 128cm) (130 – 330cm) (340 – 380cm) (390 – 410cm)	24•44
5	(46 – 86cm) (88 – 130cm) (132 – 200cm) (202 – 330cm) (340 – 380cm) (390 – 410cm)	19•38	(46 – 86cm) (88 – 128cm) (130 – 198cm) (200 – 330cm) (340 – 380cm) (390 – 410cm)	16•42
6	(46 – 86cm) (88 – 130cm) (132 – 200cm) (202 – 266cm) (270 – 330cm) (340 – 380cm) (390 – 410cm)	16•42	(46 – 86cm) (88 – 128cm) (130 – 198cm) (200 – 290cm) (300 – 330cm) (340 – 380cm) (390 – 410cm)	12•20
7	(46 – 86cm) (88 – 130cm) (132 – 200cm) (202 – 238cm) (240 – 266cm) (270 – 330cm) (340 – 380cm) (390 – 410cm)	15•50	(46 – 86cm) (88 – 128cm) (130 – 198cm) (200 – 254cm) (258 – 290cm) (300 – 330cm) (340 – 380cm) (390 – 410cm)	11.18

herbs and arable herbs (sensu Roberts et al., 1973; Godwin, 1968). The results from both analyses were exactly the same and the use of fewer taxa made computation quicker and simpler.

Both techniques agree on the location of the first division at or near to the S-6/S-7 boundary which marks the appearance of Calluna with a decline in A.P. SPLTLSQ places the boundary one level above that of SPLTINF and the subjective boundary and although this leaves less residual variability the subjective location is preferred as it marks the point where Calluna rises steeply. SPLTLSQ and SPLTINF also agree on the location of the second division at the S-2/S-3 boundary although both place it above the subjective line. Again the subjective division is retained as it not only marks the increase in Corylus/Myrica but also defines the empirical limits for Ulmus and Alnus, features that are numerically insignificant. Either boundary would however be suitable for there are several changes in the composition of the assemblages spread over a number of levels as it is a period of considerable ecological change. By the third division there is disagreement between the two methods with SPLTINF locating a division at the S-5/S-6 boundary and SPLTLSQ at S-1/S-2. Both divisions agree with those defined subjectively and both are located by the other method at later stages, except that SPLTLSQ places the S-5/S-6 boundary one level higher. The uppermost boundary between S-7 and S-8 is the fourth division of each method and by this stage both leave the same residual variability, 24•44%, despite the differences in the groupings defined.

By the sixth division there is considerable divergence between the two sets of results for although the SPLTLSQ division agrees with the S-3/S-4 boundary, SPLTINF places a division in the middle of S-4 where Betula is reduced and there is a second Alnus rise. Despite the variability in the alder curve this division is not considered and S-4 is left as a complete zone which has, as an integral part, the double rise in alder. It is only by the seventh division that SPLTINF locates a boundary near the S-4/S-5 boundary which was defined subjectively on the decrease in *Ulmus* and the appearance of herbs such as *Plantago lanceolata*. Ecologically this zone boundary is considered important as it is very similar to the change in pollen frequencies associated with the Elm Decline. Statistically the actual changes in the individual pollen frequencies are small and are not instrumental in providing a significant numerical change in the data. To try and account for changes which are considered ecologically significant it is possible to weight taxa and use a modified SPLTLSQ option. This was applied here weighting the values of *Ulmus* by x5 and had the effect of locating a boundary corresponding to the postulated Elm Decline at the seventh division, reducing further the overall residual variability, but had little effect on the groupings within the rest of the data. Weighting of individual values is however dangerous as it adds an element of subjectivity into a technique which is primarily objective and defeats the object of comparing subjective and objective results. It is also difficult to define an accurate weighting for it would be necessary to use correction factors calculated for the structure of the vegetation at the time, information usually based on an interpretation of the pollen evidence as a whole. Here the rather arbitrary value of x5 was used to try to overemphasise the change but still only produced a division at a late stage in the analysis. Rather than introduce an element of subjectivity into the statistical analysis it is better to allow the divisions to stand on the basis of the unaltered raw data. The statistical zonation then remains as an objective guide useful for comparison with subjective zonation.

d) Flandrian vegetation history - pollen assemblage zones S-1 to S-4

The overlap between the two sample cores can be seen in the bottom two samples of S-1 from Stormont A which record rising Gramineae and falling Artemisia, features found in SG-7. Because of the wider sampling interval used for this part of the Stormont A profile it is less easy to pick out the sequence of change in the communities surrounding the loch but a pattern emerges comparable to that found at the transition between the Late Devensian and Flandrian at most sites in Britain (Godwin, 1975b) and northern Europe (Mangerud et al., 1974). The sequence of successive peaks for Artemisia, Rumex, Empetrum and Juniperus may be found spanning the end of Zone III of the Late Devensian and the III/IV transition of the Early Flandrian in both eastern Scotland (Vasari and Vasari, 1968) and northwest Scotland (Pennington et al., 1972) although the frequencies of individual taxa vary.

The lowest two levels would, on the criteria adopted by Vasari and Vasari (1968) from Godwin (1956), be assigned to Zone III. The dominant communities were still those characteristic of an open landscape with some degree of soil instability but an amelioration in climate is indicated by a decrease in Artemisia and a corresponding increase in Gramineae and Rumex suggesting a more continuous vegetation cover. The presence of Salix with the increase in Gramineae probably indicates an expansion of a tall herb nodum dominated by Deschampsia caespitosa or Salix equivalent to the community which developed in SG-1 in the early part of the interstadial, and, as in SG-1 Rumex, Ranunculaceae and Thalictrum are also present. The disappearance of the characteristic taxa of this community at the S-1/S-2 transition is due largely to the expansion of Betula which increases rapidly above 400cm. Between the period of open grassland and the establishment of birch woodland communities transitional between the two vegetation forms are indicated with, at first the expansion of dwarf-shrub ericaceous heath dominated by *Empetrum*. This phase is poorly represented at Stormont with only a low peak for *Empetrum*, and levels do not reach those found earlier during the Alleröd. This may however be due to the sampling interval not picking up the major peak although values for *Empetrum* are generally much lower at sites south of the main Grampian watershed than to the north (Walker, 1975a) and to the west (Brown, 1971) because of both climatic and edaphic limitations (Gunson, 1975).

With the predominantly open nature of the vegetation during S-1 there would have been little change in the pollen catchment area to that of the Late Devensian and much of the *Pinus* pollen may again be due to long distance transport. Stabilisation of soils around the loch was taking place as evidenced not only by the changing pollen record but also by the change to a predominantly organic and terrestrial deposit. The increasing organic content of the basal silty clay was presumably representative of increased local productivity but in the pollen assemblage the expansion of aquatic taxa characteristic of this period (Gray and Lowe, 1977) is only seen in the presence of *Potamogeton* with occasional grains of *Myriophyllum spicatum* and, possibly, *Equisetum*. The apparent lack of aquatic taxa at Stormont compared with other sites from varying environments throughout the southern Grampians (e.g. Blackness, Roineach Mhor, Tynaspirit 2, Amulree, Corrydon) is perhaps surprising considering the high base status of the exposed gravels following the breakdown of soil organic matter during the Stadial but may be due to the water level at the time for the stratigraphy shows a gradual change to sedge peat without any reedswamp stage and with therefore only a short period of shallow water. The improved climatic conditions are also indicated by the consistent presence of *Filipendula* at low levels suggesting its presence at the loch margins but not at the sampling site.

The transitional III/IV period has been well dated in Scotland, and in particular in northeast Scotland. At Loch of Park the boundary between decreasing Rumex and increasing Empetrum has been dated to 10280±220b.p. (HEL-416, Vasari, 1977) and at Loch Kinord where Artemisia frequencies are generally higher, being nearer to the southern Cairngorms and central Grampians, the boundary between decreasing Artemisia and increasing Empetrum gave a date of 10010±220b.p. (HEL-420, Vasari, 1977). The main Empetrum expansion at Abernethy occurred at 10230±220b.p. (HEL-422, Vasari, 1977) and in western Scotland the main III/IV transition has been dated to 10010±220b.p. at Drymen (HEL-162, Vasari, 1977), 10254±220b.p. at Lochan Coir a'Ghobhainn (Q-955, H.J.B. Birks, 1973a) and c.10000b.p. for western Britain in general (Pennington, 1977b). All these dates fall close to the date of 10250b.p. suggested by Godwin (Godwin and Willis, 1959; Godwin, 1975b) for the Lateglacial/Postglacial boundary. Vasari (1977) has estimated that the period of transition, marked in particular by the expansion of Empetrum and later by Juniperus, lasted about 200 years. This is confirmed as accurately as is possible by radiocarbon-dating as is the apparent synchroneity of the change in vegetation communities in response to improving climatic conditions at this time (Smith and Pilcher, 1973). Although the overall pollen evidence clearly indicates improving climate it does little to indicate the nature and rate of climatic change and recent work on coleoptera has suggested that this improvement was more rapid than is implied from the pattern of vegetation development (Coope, 1977). From beetle evidence in Staffordshire (Osborne, 1976) a rapid rise in temperature at c.10000b.p. has been suggested based on the disappearance of cold temperature stenotherms and similar results have been obtained from southwest

Scotland where there was a change "from arctic severity ...... to a climate as warm or maybe rather warmer than that of the present day" (Bishop and Coope, 1977, p.86) within, at most, 500 years of the Late Devensian/Flandrian boundary. From the dated coleoptera evidence so far published (Coope, 1977) there is no indication of a marked change prior to c.10000b.p. and the period of the III/IV transition as marked and dated by the brief expansion of Empetrum and the reduction of open ground taxa must still have taken place within relatively cold climatic conditions and therefore not necessarily reflected a sharp rise in temperature.

The dominance of Betula in the ensuing zone, S-2, is again a feature common to most sites throughout Britain for it was the first tree species to establish itself after the disappearance of Devensian ice. The expansion of Betula is usually attributed to Betula pubescens ssp. odorata which can still be found in remnants throughout southern Scotland today (McVean and Ratcliffe, 1962). At Stormont the rise in birch pollen is first accompanied by a peak in Juniperus emphasising the similarity in the pattern of change between the early Flandrian and the earlier interstadial. In the Flandrian the expansion of Juniperus heath was merely transitional between open grassland with areas of Empetrum heath and birch woodland, whereas in the Allerӧd conditions never suited the complete development of closed birch woodland. In the absence of dates showing the duration of the juniper phase it is difficult to compare it with the period of juniper dominance during the Allerӧd but it seems that climatic conditions in the Early Flandrian were far more suitable for birch development than in the interstadial as seen in the steep, continued rise in the birch curve unlike the irregular frequencies characteristic of the earlier amelioration. H.J.B. Birks (1977) has described the principal community form of the period of birch dominance prior to the immigration of Corylus as an open-canopy woodland with Populus tremula and Sorbus aucuparia but at Stormont by the end of S-2 the woodland must have become almost completely closed, for at the sampling site, 55 metres from the present basin edge and possibly only 35 metres at this time, Betula pollen comprises 80%T.L.P. Even accounting for a closer woodland edge because of lower water levels the reduction in taxa characteristic of SG-7 and S-1 shows how areas of open ground had been reduced, for, apart from Gramineae, only occasional grains of Rumex, Compositae tub., Succisa and Filipendula are present by the end of S-1 and Juniperus disappears. The absence of pollen of either Sorbus/Prunus type or Populus gives little indication of the woodland form although the high values for Filicales suggest a fern-dominated ground flora of low species diversity as also indicated in eastern Scotland at Airds Moss and St. Fergus Moss (Durno, 1959).

The peak in values of Pinus at the beginning of the zone is difficult to interpret for pine is not thought to have entered eastern Scotland until much later (H.H. Birks, 1970; O'Sullivan, 1975). With increasing values for arboreal pollen this cannot be solely attributed to long distance transport within an open environment, although in comparison with the stadial record there is little difference in the maximum frequencies recorded of Pinus and the birch woodland was by no means closed at this time.

The dominance of the pollen spectra by Betula and the identification and definition of a Betula assemblage zone is found throughout southern and eastern Scotland. S-2 may be compared with FII in southwest Scotland (Moar, 1969c) and zone IV at Loch of Park, Loch Kinord (Vasari and Vasari, 1968) and in central Perthshire (Donner, 1962). At higher altitudes in the Grampians where there is a greater local presence and persistence of Juniperus no separate Betula zone can be defined

(Lowe and Walker, 1977; Walker, 1977), and further to the north and west the percentages of *Juniperus*, the generally lower values for *Betula* and the rapid immigration of *Corylus* again precludes any definition of an assemblage zone solely dominated by *Betula* (Moar, 1969a; H.H. Birks, 1970, 1972b; Pennington et al., 1972; Walker, 1972a). Nevertheless at Stormont there is clearly a period of birch dominance between the decline in juniper and the appearance and expansion of hazel.

Because it is often difficult to separate the rational limits for *Betula* and *Juniperus* and because at many sites hazel becomes established very soon after birch there are relatively few dates for the expansion of birch. At Din Moss the early post-glacial maximum for *Juniperus* has been dated to 10337±200b.p. (Q-1078, Switsur and West, 1973; Hibbert and Switsur, 1976). This early date is not characteristic of sites further north. At Loch Kinord the boundary between the peaks for *Betula* and *Juniperus* occurred at 9820±250b.p. (HEL-421, Vasari, 1977) and at Kingshouse 2 the same phenomenon occurred at 9910±200b.p. (BIRM-724, Walker and Lowe, 1977), slightly preceding events on Skye (e.g. Loch Cuithir at 9660±250b.p. (HEL-503, Vasari, 1977; Lochan Coir a'Ghobhainn at 9420±150b.p. (Q-957) and at Loch Cill Chroisd at 9655±150b.p. (Q-956, H.J.B. Birks, 1973a)) and in northwest Scotland. In the latter area at Loch Sionascaig the *Juniperus* maximum, which defines its own assemblage zone, has been dated to 9474±160b.p. (SRR-15, Pennington et al., 1972). Since from the summary of H.J.B. Birks (1977) the Strathmore area falls at a later period between the regions of 'predominant oak forest with birch' and 'predominant pine forest with some birch and oak' it would be expected to show an expansion in birch values at about 9800b.p. In the former area the expansion of hazel is placed at a similar time. If the inferred date is indeed true then the peat which separates birch and hazel peaks at Stormont must have accumulated in 200 years given the early appearance of hazel in the south (see below), at a rate of 20cm per 100 years, over twice the rate of any published figures (Walker, 1970). This seems unlikely and it would appear that the immigration of hazel was more delayed in Strathmore.

The boundary between S-2 and S-3 is marked by the sharp rise in Corylus/Myrica values, most of which is attributed to Corylus avellana pollen. At Stormont there is no difference between the rational and empirical limits for Corylus/Myrica as there is no significant presence prior to this point unlike at Abernethy to the north (H.H. Birks, 1970; Vasari, 1977). The percentages of Corylus/Myrica pollen at Stormont confirm the view of Walker (1974) that significantly higher hazel values are recorded south of the main Grampian watershed than to the north. The expansion of hazel is indicative of the relatively unleached nature of the soils and it must have been growing ubiquitously on both the outwash gravel and the till. It is difficult to ascertain from the pollen record whether there was any difference in the communities growing on the different parent materials so it would appear that all of Strathmore would have been covered by a closed birch-hazel forest with hazel as perhaps the most important canopy species (Jonassen, 1950). The effect of the immigration of hazel in changing the character of the woodland community is further seen in the reduction of Filicales spores so characteristic of the earlier phase of birch woodland. It is difficult to compare present birch-hazel communities with those of the Early Flandrian as there are so few herb and shrub species indicated in the fossil record but even in modern assemblages understorey components are poorly represented (H.J.B. Birks, 1973a), due in many cases to the lack of understorey development.

A Betula-Corylus/Myrica assemblage zone can be found at almost every published site in Scotland that dates back to this period, even those from the Outer Isles (Moar, 1969b). Although there are several very early dates for the expansion of Corylus on Skye indicative of a possible refugia off the western mainland of Scotland during the Late Devensian (H.J.B. Birks, 1977; H.H. Birks and Matthewes, 1978), there is still a north-south gradient to the dates for the Scottish mainland. At Din Moss in the south Corylus appears at 9275±170b.p. (Q-1076, Switsur and West, 1974) and expands at 8940±170b.p. (Q-1074), 300 years before its expansion at Abernethy (H.H. Birks, 1970; H.H. Birks and Mathewes, 1978). There are also dates from this period closer to Stormont. At Tynaspirit 2 Corylus rises at 9260±100b.p. (HV-4984), at Amulree 2 at 9115±120b.p. (HV-5642) and at Mollands at 9365±120b.p. (HV-5645, Lowe and Walker, 1977). These are however all from sites with relatively low counts for Corylus/Myrica and are also all from the western area of the Grampians. At Carey in the valley of the Earn there is a very sharp rise in Corylus/Myrica indicated in the buried peat which postdates the initiation of peat growth at 9640±140b.p. (I-2769, Callow and Hassall, 1970) and has now been dated to 8740±55b.p. (SRR-1392, P. Gotts pers. comm.). From the evidence of all these dates and the relatively rapid rate of immigration for hazel throughout the British Isles it could have been present in Strathmore by at least 9200b.p. and have become a significant element of the woodland by at the latest 8700b.p.

Corylus has always been considered more indicative of increasing temperature than Betula, apparently having a distribution which is limited by sensitivity to spring frosts (Godwin, 1956a). Its expansion in the early Flandrian has therefore been considered to be a response to improving climate although its subsequent success has also been attributed to the activity of early Mesolithic communities (Smith, 1970). If the rapid rise in temperature during the first 500 years of the

Flandrian postulated by paleoentomologists is correct (Osborne, 1972; Ashworth, 1972; Bishop and Coope, 1977) then thermal conditions would have been suitable for the establishment of hazel in Strathmore over 500 years before it did appear. Thus its expansion and successful development in this part of eastern Scotland must have been controlled by the rate of immigration from glacial refugia, either to the south or west.

In the Stormont A profile the rise in hazel is accompanied by a stratigraphical change to a sedge peat with Sphagnum and Sphagnum spores are also recovered at this point but after the peak for Corylus/Myrica there is a further change to a pollen-rich dystrophic gel mud (dy) with few recognisable remains. This suggests a rising water level in the loch probably due to overall increased plant productivity blocking the small outlets of the loch to the south and leading to the slow accumulation of plant debris with associated low nutrient levels. From the transect of borings (Fig. 5·3) it would also appear that the loch margin would still have been perhaps only 35m from the sampling site, at the break of slope 20m from the present edge.

At the same time as the change in stratigraphy both Ulmus and Quercus appear continuously for the first time. Values for Ulmus in particular are higher than those found to the north and in the area of 'pine forest with birch and oak' (H.J.B. Birks, 1977), again suggesting greater affinity to the southern 'predominant oak forest with birch'. To the north, as at Abernethy (H.H. Birks, 1970) the empirical limits for Ulmus and Quercus often occur at the same time as the expansion of Corylus yet here they do not appear until after the main peak for Corylus/Myrica pollen. The coincidence of these features is also found at Loch Mahaick, Lochan nan Cat and Loch Creagh (Donner, 1962) but in these sites, with the exception of Loch Creagh, there is still a later joint rise in Ulmus and Quercus. The apparent absence of Quercus and Ulmus during the peak for Corylus/Myrica at Stormont may point to an early date for the immigration of hazel into Strathmore or may be due to the exclusion of the pollen of these species as they became established due to the success of hazel immediately around the site. The eventual initial percentages for Ulmus and Quercus although high in a Scottish context are only representative of the first spread of the major elements of mixed deciduous forest and are overshadowed by the pollen production of the birch-hazel woodland. Empirical limits for Quercus and Ulmus have as yet rarely been dated in Scotland, except where they coincide with the Corylus expansion, but by c.8500b.p. mixed oak forest dominated by oak and elm was thought to be established in southern Scotland (H.J.B. Birks, 1977).

Throughout S-3 Pinus frequencies remain relatively constant at less than 5%T.L.P. and it is again difficult to estimate the origin of this pollen. In southern Scotland there is no marked presence of Pinus until c.8000b.p. (H.H. Birks, 1972a, 1975) and it only gradually spread into Speyside and northern Scotland between c.8000b.p. and 6600b.p. (O'Sullivan, 1975). Yet, in northern England high localised frequencies for Pinus occur within the Boreal (Pennington, 1970; Bartley, Chambers and Hart-Jones, 1976) and it is suggested that, on the basis of the analyis of several sites, the long distance element of Pinus pollen during this period of closed woodland must have been small, implying a local presence.

Thus, by the end of S-3, a closed birch-hazel woodland was established in Strathmore growing both on the outwash gravels on the northern fringe of the strath and on the till closer to the floodplain of the Isla. The first elements of the later mixed deciduous forest, oak and elm, were both present but only slowly establishing themselves, and it seems possible that there were also isolated areas dominated by pine.

The most significant change between S-3 and S-4 is the increase in values for Quercus which represents its establishment as one of the principal components of the local woodland communities. The increase in oak was largely at the expense of birch and there was no change in the closed nature of the cover. It is difficult from the pollen evidence to discern the variety of community forms this change would have produced. Even if the lake margin, and hence the woodland margin, was closer to the site as indicated by the sub-peat surface there would have been sufficient distance away from the edge to pick up a general picture of the surrounding vegetation rather than one solely dominated by local growth around the lake edge. (This is assuming a decline in pollen frequencies to a constant proportion at greater than 30m as demonstrated on Bankhead Moss and in Nidderdale (Tinsley and Smith, 1974)). This is not to underestimate the consistent contribution of fringing vegetation to the record but given the size of the basin the sampling site should have a preponderance of canopy transported pollen or rain out (Tauber, 1967). Pollen would however be derived both from the gravels to the north and west and from the till to the south and east. Up to this period it has been suggested that birch and hazel were probably ubiquitous forming the woodland throughout Strathmore on both types of parent material. With the rise in Quercus it is the Betula curve which suffers, not Corylus/Myrica. The consistency of the Corylus/Myrica curve argues for its presence as the principal species on the basin edge benefitting from the increased availability of light, and as such it was not replaced by oak. Whether oak was successfully competing with birch on both the gravel and till areas is not clear but it seems more likely that oak woodland would have developed on the till due to the better soil structure and less freely drained nature where it would have shaded out birch and hazel. If this is true then it follows that before this period birch was probably more successful on the till than hazel. Oak would still have grown on the gravel areas but perhaps not achieving the same dominance. Palynological and pedological evidence from a comparable site at Dalladies showed no podsolisation before c.5000b.p. with a persistence of brown forest soils under mixed deciduous woodland. The difference then between the two parent materials in terms of their vegetation cover would perhaps have been in the degree of oak cover rather than in any fundamental difference in community composition and structure.

The expansion of oak had little effect on the local status of elm which remained at consistent levels. Elm, Ulmus glabra, must have formed a secondary element within the mixed oak woodland but was probably restricted by edaphic constraints, especially its preference for richer mull soils. Around Stormont it would have been most successful on those areas now covered by brown earth soils of the Balrownie Association which developed on till but with little leaching elm would also have been found on the outwash, presumably as a less important element of the community. Strathmore was within the northern limit of oak woodland in eastern Scotland at this time for percentages of Quercus and Ulmus are considerably lower in northeast Scotland (Vasari and Vasari, 1968) and on Speyside (O'Sullivan, 1975). Being near the limit of oak woodland because of climatic restrictions elm would therefore be expected to be restricted to the most suitable soil conditions (there is for instance no evidence of elm in the buried soil at Dalladies on similar outwash gravels).

It is still uncertain as to whether Quercus petraea or Quercus robur was the main species of oak in this part of Scotland. At present Quercus petraea is commonly found in surviving woodland fragments in southern Scotland (H.J.B. Birks, 1977) but Quercus robur is better suited to conditions at the northern limits of oak (Jones, 1959). H.J.B. Birks suggests that within the woodland, especially in southern Scotland, *Ilex aquifolium*, *Hedera helix*, *Sorbus aucuparia*, *Viburnum opulus* and *Lonicera periclymenum* would have formed the understorey with ferns also common. In this northeastern form of oak woodland *Hedera* would, on the evidence of other pollen sites (Moore, 1978), be unlikely to be represented and this is indeed the case, but so too are all the other species mentioned by Birks with the exception of *Ilex*. Absence cannot be necessarily be inferred on this negative evidence for the effect of the dense woodland cover and the fringing vegetation could be to prevent the dissemination of understorey pollen. On the basis of the positive pollen evidence it would be necessary to infer no understorey within the woodland, so analogy with known expected forms has to be used.

The increase of *Pinus* at the onset of S-4 reflects the attempted local immigration of pine but its success must have been limited to very localised stands on poorer soils for it never successfully competed with oak which expanded at the same time. This is the reverse of the case on Speyside and Deeside where *Pinus* woodland became established and oak was never able to compete (H.H. Birks, 1970; Vasari and Vasari, 1968). The coincidence of oak and pine expansion in Strathmore allows for more precise dating by comparison with other sites for the rise in *Pinus* percentages has attracted much attention in northern Scotland. The main expansion for oak in southern and western Scotland has been dated at two sites, Din Moss and Drimnagall, to 7670±150b.p. (Q-1072, Switsur and West, 1973) and 7985±150b.p. (Q-1319, Rymer, 1977) respectively. The principal rise in *Pinus* on Speyside has been dated to 6633±57b.p. (unattributed, O'Sullivan, 1975) at Loch Pityoulish, 6803±120b.p. (Q-1271, H.H. Birks and Mathewes, 1978) at Abernethy and 6620±100b.p. (Q-1288, Switsur and West, 1973) at Morrone in Aberdeenshire. It seems increasingly obvious that pine was present in eastern Scotland before these dates and that its main expansion and successful competition for dominance in the north occurred, perhaps along a west-east gradient (H.J.B. Birks, 1977; Godwin, 1977), within a few hundred years. Being marginal between the areas of pine and oak dominance the synchroneity of the expansion of oak and pine at Stormont points to a date between the empirical limit for oak in the south and the period of pine expansion in the north, probably c.7200b.p., but the date could lie anywhere between 7400b.p. and 7000b.p. There are no figures for the rate of oak immigration into Scotland and in the absence of an understanding of the areas from which pine and oak migrated (there would for instance on the evidence from Drimnagall be some grounds for a west-east gradient for the spread of oak as well as for pine) any clearer dating without specific radiocarbon dates is impossible.

The final element of mixed oak woodland to reach Strathmore, Alnus, appears in S-4. The arrival and establishment of Alnus, probably Alnus glutinosa, has recently been the subject of debate due to new radiocarbon dates from Speyside (O'Sullivan, 1975). At Stormont the most noticeable feature of the appearance of Alnus pollen is that, after sporadic occurrences in S-3, there is a peak early in S-4 followed by a reduction and then a subsequent more gradual rise in frequencies. A double peak for Alnus frequencies has been found elsewhere, especially in eastern Scotland at Lochan nan Cat (Donner, 1962) and in the south at Din Moss (Switsur and West, 1973). At most other sites there is either a sharp increase in Alnus with the empirical and rational limits coincidental as at Loch of Park (Vasari and Vasari, 1968), or the frequencies are too irregular, as at Loch Mahaick (Donner, 1962), or too low as at Loch Kinord (Vasari and Vasari, 1968) and the Speyside sites (O'Sullivan, 1975) making definition of the empirical limit difficult.

The nature of the second *Alnus* rise at Stormont corresponds to the criteria for the Mitchell Boreal/Atlantic Transition (Smith and Pilcher, 1973; O'Sullivan, 1975) with a reduction in *Pinus* but at Stormont both *Betula* and *Corylus*/*Myrica* also suffered. The ecological niche of *Alnus* seems therefore to have been not only within the fringing vegetation where there may have been a higher water table but also within the mixed deciduous forest as a whole. Within the forest it may have survived better on the heavier, wetter soils nearer to the floodplain of the Isla for it has been suggested that where there is a reduction in *Betula* this represents a change in the vegetation of wetter hollows and valleys as water tables rose (Walker, 1966).

The reasons for a double peak in alder pollen at Stormont may lie in the postulated period of falling water levels which O'Sullivan proposed for the eastern Highlands at the time of the pine expansion on Speyside. This change in the water table and in lake levels is found in the stratigraphical record at Abernethy Forest (H.H. Birks, 1970) and Loch Kinord (Vasari and Vasari, 1968) and would correspond to the period of dryness which Godwin (1975b) has suggested for the end of the Boreal period prior to the wetter Atlantic. Stratigraphically in Scotland the only evidence for this change is found at shallow marginal sites but at Stormont there is apparent stratigraphical continuity. Despite the lack of any change in lithostratigraphy it may still be postulated that *Alnus*, having first appeared immediately prior to the rise in *Quercus*, initially established itself in the wetter marginal areas of the loch. With increasing dryness as water levels fell the areas of *Alnus* were recolonised by birch, a slight opening of the canopy accompanying this change allowing in more pine pollen. With a return to wetter conditions these areas of birch would have become waterlogged and more suitable for *Alnus* which, with damper conditions in general would have been able to spread more widely as part of the general woodland.

If the period of pine expansion dated by O'Sullivan on Speyside occurred between c.7000b.p. and 6600b.p., and the period of relative dryness was synchronous throughout Britain then these dates mark the period between the two Alnus peaks at Stormont. This dating and the hypothesis put forward to explain the changes at Stormont agree with the two dates for the Alnus rises at Din Moss, 7360±140b.p. (Q-1071) and 6778±100b.p. (Q-1068, Switsur and West, 1973) respectively. Given the gradient of northwest diachroneity of the Alnus rise outlined by Smith and Pilcher (1973), the dates of 5860±100b.p. (UB-851) at Loch Garten and 5548±50b.p. (unattributed, O'Sullivan, 1975) at Loch Pityoulish on the clearest Alnus rise, based on low counts, are not unacceptable assuming alder would find difficulty in establishing itself towards its northern limit.

There is an absence of any noticeable change in the stratigraphical record not only at the proposed period of changing water levels but throughout S-4 as a whole. The dystrophic gel mud which spans the whole zone is usually indicative of low nutrient status and slow accumulation which accounts for the lack of any sign of a lowered level away from the immediate lake margin. Even assuming a relatively late date of 8500b.p. for the change to a gel mud at 326cm based on the post-Corylus appearance of Quercus and Ulmus and an early date of 6600b.p. for the second Alnus rise, material only accumulated at a rate of 30cm per 1000 years. This agrees well with some of the estimated accumulation rates based on Walker's synthesis (1970) but is in all probability a maximum rate of accumulation.

The development of a relatively stable Atlantic forest cover in Strathmore had therefore taken place by c.6500b.p. with the eventual establishment of Alnus. The local forest communities were very much transitional between the southern oak dominated woodland and the northern pine dominated woodland for while oak was the dominant tree with birch, elm, alder and hazel there was little evidence of the southern form of understorey and each tree of those present contributed a more equal proportion of the pollen sum. The absence of *Tilia* is not surprising considering its absence further south and further confirms the idea of a northward limit for lime in the Lake District (Pennington, 1970). To further emphasise the transitional nature of the woodland mosaic in Strathmore at this time the tree pollen sequence at the end of S-4 corresponds better with Group A of Moore's scheme (1977) which covers southern and southwest Scotland rather than Group B which is based on Donner's sites in western Perthshire but still shows affinities to the lowland Aberdeenshire sites in Group F due to the greater importance of birch.

It would appear that before the end of S-4 vegetation change around Stormont Loch had been predominantly natural as a response to climatic change and plant immigration and competition but there is one brief phase within the zone which requires further explanation. The sharp rise in Gramineae at the expense of birch and hazel at 260cm after which hazel continues to fall and *Pteridium* appears more regularly may be explained in one of two ways. It could represent a local hydroseral change with *Phragmites* dominated reedswamp extending over a nearby drier site as a successional stage following the deposition of the mud. This would explain why only the Gramineae curve is affected and why birch and hazel, the littoral arboreal species, would be reduced by increased pollen filtration, but this does not explain the presence of *Pteridium*. There is also no immediate return of hazel values with the decrease of Gramineae after 260cm and no evidence in the transect for such a stratigraphical change. Overall the pollen changes are very slight with only a brief reduction in A.P. and shrub pollen to 90%T.L.P. However such changes have elsewhere been accounted for by the interference of early human communities, usually Mesolithic groups, moving seasonally through the area following the main river network. Small openings in the woodland canopy have been found in East Anglia (Sims, 1973) and North Yorkshire (Simmons, 1969a) and their significance has been summarised for Britain as a whole by Simmons (1969b, 1975). The changes at Stormont could have resulted from nothing more than an opening of a lakeside clearing, possibly by fire, which was later abandoned but the subsequent change with an increase in birch over hazel suggests that the latter may have been reduced in extent. Rather than suggesting increases in hazel due to the activity of pre-Neolithic communities it would appear that the locally abundant hazel was removed with birch colonising any open areas made available. The pollen evidence for such a process is however limited and there is no direct evidence for the existence of Mesolithic communities in this part of Strathmore.

e) Flandrian vegetation history – pollen assemblage zones S-5 to S-8

The impact of early man on the forest communities surrounding Stormont Loch is first clearly seen in S-5 where, at the opening of the zone, there is a stepped decline for *Ulmus* associated with reductions in *Quercus*, *Betula* and *Corylus*/*Myrica*, an increase in *Alnus* and Gramineae and the continuous presence of *Plantago lanceolata*, *Calluna* and *Pteridium*. This is the first significant drop in elm pollen and is assumed to be comparable to the Elm Decline which has now been recognised throughout Northwest Europe (Pennington, 1973; Smith and Pilcher, 1973). At most sites there is some variability in the pattern of change in other pollen curves at this time and the details of the changes at Stormont are considered here. The reduction in elm pollen is twofold with an original decrease of only 2%T.L.P., followed by a brief recovery and then a more gradual drop to 2%T.L.P. or less. At the first reduction oak and hazel are affected and at the later reduction birch also declines. Plantago lanceolata appears at the first change in the elm curve and then remains present at low values as does Pteridium, which appeared first in S-4, while Gramineae increases slowly. It would appear that this pattern is comparable to that found in the Lake District by Oldfield (1963) and Oldfield and Statham (1963), in Northern Ireland by Morrison (1959) and in Denmark by Iversen (1941, 1960) and Troels-Smith (1960). It is however in contrast to the single decline in elm registered at most Scottish sites which have significant levels of elm, such as Bloak Moss (Turner, 1970), Kennox Moss, Flanders Moss (Turner, 1965) and Din Moss (Switsur and West, 1976), and at many other British sites (Sims, 1973). It is possible at Stormont to distinguish a 'Primary Elm Decline' (sensu Oldfield, 1963) which is separated from a later more general reduction in elm by a brief phase of regeneration but there is a fundamental difference between the Stormont pattern and the pattern elsewhere, for, at the first decline in elm there is usually a reciprocal rise in Pinus, which is absent here, and no increase in weed species. At Stormont Plantago lanceolata appears at the first decline. There is also no pattern of clearance, utilisation and regeneration referable to the characteristic landnam process suggested by Iversen (1941), or more recently by Smith (1975), associated with either decline.

In determining the processes, anthropogenic or climatic, which caused the changes in the pollen curves it may be necessary to consider the reduction in elm frequencies as an event separate from the other changes. Radiocarbon-dating of the Elm Decline in Britain (Smith and Pilcher, 1973) suggests that the event was broadly synchronous occurring at around 3100-3000b.c. and recent work in northern Scotland by Pennington using absolute pollen analysis has established the presence of 'a numerically significant fall in the absolute pollen deposition of Ulmus ...... just before 3000b.c.' (1973, p.96). The eventual reduction of Ulmus pollen to very low values argues for a reduction of the area of till covered by elm and would, if the removal of elm was directly related to the activities of early man, imply clearance taking place throughout the area with both till soils and soils based on the outwash gravels affected. The eventual regeneration of oak in S-5, when it reaches higher levels than those found in S-4, would confirm that elm had largely disappeared from the mixed oak woodland on the till allowing further oak expansion. In view of what is known about the capabilities of early prehistoric communities and with the juxtaposition of soils which, although under similar basic vegetation types, had very different potential for cultivation, it seems unlikely that general clearance irrespective of parent material would have taken place. If however elm was severely reduced throughout the area due either to a change in certain climatic parameters (Iversen, 1941), disease (Watts, 1961; Pennington, 1975) or lopping for fodder (Heybrock, 1963) clearance of other trees for agriculture need only have taken place on the soils derived from fluvio-glacial material thus affecting birch and oak values. On these areas when pressure of land use was relaxed or clearings abandoned secondary woodland dominated by hazel would have developed as seen in the later increase in Corylus/Myrica pollen in S-5. Such a hypothesis would explain the pattern of changes in S-5, except perhaps for the double elm decline, and account for why the highest N.A.P. values which occur between 230cm and 218cm are coincident with a period of higher Quercus frequencies indicative of oak regeneration. It is difficult to explain a double decline in elm by either climatic change or disease but if elm was being utilised at the time for fodder then communities whose main settlements and agricultural activity was centred on the gravels could have been responsible for reducing elm wherever it was growing, and the double decline could reflect variations in the demand for fodder. With such a small increase in frequencies between the two declines it could also be a statistical artefact of the counting but with the close sampling interval such a change is thought to be genuine and a feature not picked up at other Scottish sites where wider spaced samples were taken. On the pollen evidence alone it is difficult to provide a definitive explanation of the pollen changes at the opening of S-5, especially the fluctuations in elm, but a summary of the postulated events and throughout the rest of the zone is presented in Table 5•6.

Although the overall sequence of events presented in Table 5•6 is quite clearly indicated there are aspects of the character of the clearances which cannot be elucidated. It has been common, following Iversen (1941), to assume that the earliest forest clearings, following any Mesolithic influences, were on a small scale, probably due to the operation of a slash and burn economy or a form of shifting cultivation with only brief phases of cereal cultivation at any one site and a dominance of pastoralism. Recent work has however suggested that such early clearings may have been more extensive and longer lasting. The duration of early clearances has now been dated not to only 50 years as suggested by Iversen (1956) but to 230 years (Sims, 1973) or possibly 600 years (Pilcher et al., 1971; Pennington, 1975; Smith, 1975).

The effect of the pollen production of the littoral vegetation at Stormont has been to present a pollen assemblage reflecting the area as a whole which does not register small amplitude changes. As such the changes representing the detailed processes involved in the Elm

Table 5·6 Sequence of postulated events in S-5

S-5

200cm

Period of lower activity with increased development of secondary woodland dominated by hazel. Some areas opened up earlier in the zone remained open under a grassland cover, possibly due to light grazing.

210cm

220cm

Main period of agricultural activity with some evidence of cereal cultivation, or barley, and highest plantain values.

Oak regeneration on areas of till formerly covered by elm.

230cm

Continued reduction of elm and clearance of oak and birch. from areas of outwash gravels leading to an expansion of grassland.

240cm

Slight regeneration of elm.

Primary Elm Decline with the establishment of the earliest clearances by removal of birch and oak from the outwash.

S-4

Decline are not seen and there is little evidence of the character and extent of land utilisation. In the overall increase of birch and hazel there is evidence for the substitution of primary oak woodland by secondary woodland, the regeneration in individual clearings only being seen in a general pattern with a mosaic of clearings and abandoned clearings (Turner, 1964). The ratio of A.P. to N.A.P. never reaches the values of S-4 so it must be assumed that there was either continuous utilisation or that once some areas were cleared regeneration could not take place. Of these two possibilities the former seems the more likely because of the indication of secondary woodland and the lack of expansion of Calluna which would have spread if soil structure or base status had been sufficiently altered to prevent any regeneration of trees or shrubs. The change in woodland form, despite the absence of Calluna, does however probably mark the initiation of podsolisation on the coarser soils of the outwash with the substitution of shallower rooting species for primary woodland in which oak was an important component, leading to a loss of base status as hypothesised by Dimbleby (1965). The small reduction in A.P. in S-5, only at most 10%T.L.P., need not merely reflect the clearance of small scattered areas for if the lakeside itself remained under closed woodland such a reduction could reflect quite large clearings at a distance from the site as seen at Bankhead Moss (albeit for a smaller and more enclosed basin). There is some evidence for the existence of cereal cultivation with isolated occurrences of Cereal type pollen, referable to Triticum/Hordeum type but the Pastoral:Arable ratio remains high suggesting that pastoralism was most important, and the effects of grazing may have been to help keep some of the clearings open. The specification of the cereals to Triticum/Hordeum type, to Hordeum species rather than Triticum monococcum, appears to agree well with the general findings for Britain as a whole where barley, especially the six-rowed polystichum forms have been the commonest identified form for the period from the Neolithic right through to Viking times (Godwin, 1975b).

The coincidence of the Elm Decline with the earliest phase of land clearance allows approximate dating of this part of the diagram. Some dates from the Elm Decline in Scotland (e.g. Switsur and West, 1973) depart from the synchroneity recognised by Smith and Pilcher (1973) and Pennington (1973), but these are based on very low counts for elm pollen which make definition of the event difficult, and those based on higher counts, as at Din Moss (Switsur and West, 1976), agree well with the date of c.3100b.c. At Stormont this date does have significance for the interpretation of the rest of the diagram for if the suggested date for the opening of S-4 is correct then the accumulation of sediment in that zone took place at a rate of only 14cm per 1000 years, a very low figure. If this rate is extraploated for S-5, which covers the same sedimentary unit, then the end of S-5 occurred at c.0b.c./a.d. or 2000b.p. This very slow accumulation rate could account for the absence of detailed changes in the pollen diagram within S-5 but also implies a long period of human activity, even if only at a low level at times, from the Neolithic into the Iron Age.

The coincidence of the Elm Decline and clearance also implies that it must have been Neolithic communities which were responsible for the earliest forest modification in this part of Strathmore. There is however no corroborative archaeological evidence for their presence although a parallel may be drawn perhaps with the evidence from the Dalladies excavation further to the northeast, where there was considerable Neolithic clearance associated with the construction of a long barrow on a similar geomorphological site. The comments of Romans and Robertson on the buried soil profile at Dalladies and its interpretations may well be valid for the south of Strathmore,

> " ...... in north-east Scotland about 5000 years ago brown forest soils under a mixed deciduous forest (within which oak was an important constituent) had developed on free-draining moraines, fluvio-glacial outwash sands and gravels around the margins of the main mass of the Grampian Highlands ...... These soils proved attractive to an immigrant population with agricultural experience" (1975, p.38).

The spore record at Stormont shows a gradual increase in Sphagnum throughout S-5 representative of the local expansion of Sphagnum prior to the development of Sphagnum peat in S-6. Typha latifolia is also better represented suggesting areas of shallower water and the presence of grains of Potentilla type is considered indicative of Potentilla palustris. The occurrence of occasional grains of Cannabis/Humulus pollen, representative probably of Humulus lupulus, is interesting as it is not common in Scottish sites, apart perhaps at Loch Dungeon (H.H. Birks, 1972a) where it is ascribed to an understorey component of alder fenwoodland. Thus at the time of earliest human influence this part of the loch was becoming shallower with Sphagnum expanding within the basin. There may also have been some expansion of alder fen but the rise in alder pollen at periods of early clearance has been explained elsewhere by increased openness allowing greater pollen contribution from wetter alder-dominated communities (Oldfield, 1963).

Interpretation of the sequence of vegetation change in the ensuing zone, S-6, is again complicated by the effect of littoral pollen production and by the general homogeneity of the pollen assemblage. The opening of S-6 is marked by woodland clearance with reduced Quercus, Alnus, Corylus/Myrica and Ulmus and higher frequencies for Gramineae, Calluna, Plantago lanceolata, Ranunculaceae and Pteridium. The initial reduction in woodland is relatively sudden with very little change in arboreal pollen frequencies after this and only a gradual increase in Calluna. Although it is the continuity of assemblage that is characteristic of S-6 it is still possible to identify four phases of vegetation change as detailed in Table 5•7.

In the first phase clearance was largely of oak, alder and hazel to the benefit of Plantago lanceolata, Pteridium and Calluna. Clearance was concentrated still on the areas of outwash with the removal of both primary and secondary woodland. On the basis of the high Pastoral:Arable ratio and the restricted variety of weeds represented clearance appears to have been predominantly for pastoral purposes. The reopening of areas under secondary hazel woodland increased the extent of podsolisation for in S-6 there is a continuous rise in the contribution of the pollen of Calluna which spread over some of the cleared areas. The end of this first clearance phase is marked by a reduction in the contribution of weed species rather than by any general woodland regeneration and probably represents a relaxation of pressure on the land, rather than abandonment, with only slight birch recolonisation.

The second phase of activity was the most important within S-6 and covers a large part of the zone. The pollen changes reflect relatively complex local vegetation changes but again the detail is not clear. It was a period of increased agricultural activity rather than more extensive clearance with higher values for Plantago lanceolata, Ranunculaceae and Pteridium, and evidence of cereal cultivation with the presence of Triticum/Hordeum type and Triticum type (?) pollen grains and more consistent records for Caryophyllaceae, Polygonum aviculare, Chenopodiaceae and Leguminosae. The earlier part of this phase was the main period for which there is evidence of cereals as seen in the lower Pastoral:Arable ratio but, throughout this phase, the ratio never falls

Table 5·7 Sequence of postulated events in S-6

S-7

130cm

Some clearance of hazel and birch for cultivation followed by regeneration of hazel and a further extension of heath.

140cm

Period of mixed agricultural activity with more evidence of cereal cultivation, followed, as the pressure on land was reduced, by the regeneration of hazel woodland with
150cm some heath development.

160cm

170cm

Increased utilisation of previously cleared land for both arable and pastoral purposes. With a decline in utilisation there is no regeneration but a spread of heather.

180cm

190cm

Clearance of primary woodland on fluvio-glacial areas and the secondary woodland that developed during the previous zone for mainly pastoral agriculture.

200cm

S-5

below 75 per cent again apparently indicating the importance of pastoralism. As in the earlier zone the identifiable *Cereal* type pollen grains are mostly assigned to *Triticum*/*Hordeum* type, and to *Hordeum* spp., but with the occurrence of a *Triticum* type grain the occasional presence of *Triticum monococcum* cannot be ruled out as it is usually found in association with emmer or *Triticum dicoccum* (Helbaek, 1973). Areas under grassland were reduced with the expansion of heather especially as the level of land utilisation was reduced. There is no indication of any woodland regeneration as the weed species decline and the areas utilised must have remained open under heath rather than secondary woodland.

The two phases identified towards the end of the zone were probably briefer than those discussed above and show lower figures for the Pastoral:Arable ratio with, in the third phase, the first appearance of Cruciferae and the more consistent appearance of *Artemisia*. This third phase is also marked by a regeneration of hazel after the period of utilisation prior to its later reduction in the fourth phase when cereal pollen grains reappear, both *Triticum*/*Hordeum* type and *Triticum* type. The latter is probably *Triticum dicoccum* which, after a reduction in its use in the Bronze Age, was more widely grown in the Iron Age and cultivated in Scotland until the early Christian period (Godwin, 1975b). The distinction between the last two phases of utilisation is made largely on the reduction of weed species rather than any increase in arboreal pollen and at the end of S-6 there is only an increase in hazel representing some extension of hazel-dominated light woodland over the cleared areas. The fact that hazel was able to regenerate at this time unlike previous periods of reduced activity either indicates some improvement of the soil during the later phases of use due to better management or a much greater degree of abandonment.

The evidence for zone S-6 as a whole is therefore of an original period of woodland clearance followed by periods of both pastoral and arable activity but which saw a continuation of podsolisation allowing heather to spread on areas which had been cleared on the outwash gravels, perhaps for a second time. Although oak is continually reduced this is taken to represent further removal of remaining areas of primary woodland on the outwash, and possibly marginal areas of till which had lighter soils, with no real evidence for a significant change in the character of the oak woodland on the till to the south. The levels with higher weed species are assumed to represent periods of increased human activity, the intervening levels representing reduced local population pressure and less management of the land for agricultural purposes with the possibility of some more extensive abandonment towards the end of the zone. On abandonment there is however a degree of stability within the secondary communities implicit in the uniformity of the pollen record. On cleared areas where the deterioration of soils and the spread of heather may have reached levels preventing the regeneration of woodland such an apparently straightforward relationship between the pollen evidence and behaviour of prehistoric communities may be too simple. It could quite easily be argued on the evidence that there are not four separate phases but that what is represented is continuous land utilisation but at different distances from the sampling site, the increased variety in weed species representing the closest activity. With the consistent presence of the local fringing woodland to the loch such a hypothesis is considered less tenable because pollen from the distances suggested would only contribute relatively small amounts to the pollen sum and hence not have the influence seen within the zone overall.

Dating of this particular zone and the events outlined above is virtually impossible but from extrapolation it has been suggested that it opened at the latest at c.2000b.p. Stratigraphically there is a change to *Sphagnum* peat at the onset of S-6 and between 198cm and and 191cm there are bands of alternately well humified and poorly humified *Sphagnum*. The band of well humified dark brown *Sphagnum* peat between 198cm and 195cm in particular appears to represent a retardation layer similar to those found in the raised bogs at Tregaron (Turner, 1965) and hence reflects a period of slowed growth in the mire. It would however be wrong to look directly to raised bogs for analogies with the stratigraphy found here and also to expect any correlation of date between apparently similar stratigraphies, as in the idea of recurrence surfaces (Godwin, 1954, 1975b), for at Stormont such changes are almost certainly controlled by local hydrological conditions. Using the growth rates established at Tregaron for *Sphagnum* peats the well humified band may well have taken up to 150 years to form, whereas, in the fresher peat above, accumulation would have been more rapid. Rates of accumulation for *Sphagnum* peat in the later part of the Flandrian vary between 18cm and 96cm per 1000 years (Walker, 1970) but there are no comparable figures for small inland basins. Only the most rapid rate would account for the depth of peat above the postulated opening of S-6, even accounting for the obviously high rate of accumulation of the very poorly humified surface peats. The nearest Scottish sites for which rates have been measured are at Flanders Moss and Bloak Moss (Turner, 1975) which grew at 68cm and 60cm per 1000 years respectively, but both these are extensive peat areas. If however these rates are applied to this profile the top of the well humified band would be dated to c.2800 - 3200b.p. (a date which is incidentally comparable to the most prominent recurrence surface in Flanders Moss). Without radiocarbon-dating this ambiguity cannot be satisfactorily resolved but it seems likely that the opening of S-6 took place earlier than previously postulated by extrapolation of accumulation rates.

As with S-6 the opening to S-7 is marked by a sudden reduction in the pollen of trees and shrubs. Almost all tree species are affected with the removal of oak, alder, hazel, birch and also the final remnants of elm unless the contribution of elm pollen is by this time all due to long distance transport. The opening is also marked by a recovery of Plantago lanceolata and Pteridium to levels found earlier in S-6, but by far the most noticeable increase is in heather. The sharp rise in Calluna pollen must represent clearance around the loch margins with a form of land utilisation not unlike that practised in the later part of S-6 allowing further spread of heather which, once established near to the sampling site, would contribute significantly to the pollen sum. Some clearance of the fringing woodland is also indicated by the reduction of those species such as birch, alder and hazel which were consistent throughout most of the preceding zone and thought to make up the woodland of the loch shore. After the initial clearance there was some regeneration of almost all species but this was brief and followed by more severe clearance. In S-7 all the land around the loch must have been affected for oak values in particular are reduced almost by half indicating the removal of woodland to the south on the heavier soils and there is a noticeable increase in the amount and variety of herb species represented. After 110cm Cereal type pollen remains consistently present through to the uppermost samples and there are much higher frequencies for Rumex. Continued clearance of woodland took place throughout the zone and the use of outwash areas for agriculture continued to assist the spread of heather and the development of the humus-iron podsols which are characteristic of the area today. It is during this zone that values for Calluna reach the highest encountered in the diagram indicating the local presence of heath up to the shores of the loch.

Initially cereal cultivation in S-7 was of Secale cereale, or rye, as indicated by the presence of its distinctive prolate pollen grains. Pollen records of the wind-disseminated Secale occur as early as the late Iron Age and finds of actual grain are often associated with Roman sites but usually Secale pollen first appears significantly in England in Anglo-Saxon times (Godwin, 1967, 1968, 1975b; Sims, 1973). In East Anglia it is often found with Cannabis/Humulus type pollen representative of hemp growing and grains of Cannabis/Humulus type are encountered at Stormont but they may be Humulus derived from alder fen rather than Cannabis. After the appearance of Secale most of the later identifications of Cereal type pollen are of the Triticum/Hordeum type and assigned to Hordeum species. The appearance of the pollen of Secale in Scottish pollen diagrams has not been dated but in early historical records there is good evidence for an increase in arable cultivation in the twelfth and thirteenth centuries with a "steady process of winning new arable from waste" (Barrow, 1962, p.127) which could explain the continuous reduction in woodland and extension of cultivation. Because of the varying humification of the upper part of the profile the time span of S-7 is difficult to establish but the association of higher values for Plantago lanceolata and Rumex with the increased Cereal curve echoes further the comments of Barrow that there was a considerable pastoral influence during the Medieval expansion of agriculture.

With the final zone, S-8, there is the almost complete removal of oak and alder and a further reduction in birch and hazel such that they were probably only left in open canopy copses in areas peripheral to the loch. This continued woodland removal allowed the expansion of grassland, especially on the areas of till, and further cultivation of cereals, both Hordeum spp. and Avena spp., as also registered in the increased variety of weed species represented. There are higher values for Cruciferae and Leguminosae and also the first noticeable curve for Compositae tub., most of which are assigned to Anthemis type (Moore and Webb, 1978), which includes both Matricaria and Chrysanthemum species, the latter incorporating Chrysanthemum segetum or geld which was such a problem in Medieval agriculture and which is frequently commented upon in the tacks of the abbey at Coupar Angus. This further increase in cultivation with, in particular, the increased presence of weed species could therefore be taken to correspond to the development of monastic agriculture following the foundation of the abbey at Coupar Angus in 1164 although the nearest abbey lands to Stormont lay to the southeast at Coupar Grange (ref. 229427).

From the documentary evidence the effect of the monastery on agriculture was not only to improve agriculture but to extend the land under the plough by clearing those wetter, heavier areas not previously cultivated. With the dispersal of the monastic lands in the sixteenth century the level of land management fell but evidence of this is not readily apparent in the diagram except perhaps for the peak in Compositae tub. at 74cm which follows high values for Cereal type pollen.

A further noticeable feature of S-8 is the appearance of Pinus which becomes the dominant tree pollen. Pine was widely planted in the eighteenth century and its rise often defines a clearly identifiable horizon in Scottish pollen diagrams (Durno, 1959). In the parish of Blairgowrie there is documentary evidence for the planting of pine in 1775 following the division of the commonty in the previous year (O.S.A.S. XVII, 1796) such that 900 acres were under fir and later larch, but there is no comment on the presence of pine prior to this. The variability in the pine curve suggests that there was more than one phase of planting and this was known to occur during the nineteenth century. There is no other documentary source which discusses the existence of pine before the eighteenth century in the area and any woodland existing was either in the form of small copses around lakes and rivers or coppiced oak which was planted for the collection of its bark for use in tanning (Lindsay, 1974, 1975). Nevertheless the source of the pine pollen is local for the frequencies cannot be ascribed to long distance transport.

The rise in pine pollen therefore presents a problem of interpretation for on the available documentary evidence it can only be dated to after 1775, unless unrecorded planting took place elsewhere around Blairgowrie, and hence this would date the S-7/S-8 boundary. If this is so then the expansion of cultivation indicated at the same time would have been due to the period of agricultural improvement which was affecting most of Strathmore between the middle of the eighteenth century and the first few decades of the nineteenth century, " ...... a fortunate epoch for Scotland in general" (O.S.A.S. I, 1791, p.509). Thus the effect of the monastic agriculturalists and the spread of settlement in the early Medieval period would probably be marked in the diagram by the pollen changes within S-7 and not separated as postulated above. Because of the extremely poorly humified nature of the peat at the top of the profile the accumulation of 90cm of peat in 200 years is not unlikely but still much higher than most published growth rates. There must therefore remain some doubt concerning the dating of the features in S-7 and S-8 for extremely variable growth rates are not impossible given fluctuations in the local hydrology consequent upon the expansion of agriculture around the lake margins.

The present composition of the vegetation at the site, with the exception of the presence of Salix, is already indicated in the pollen and spore record of S-8 with high values for Equisetum and Sphagnum, both of which are present today, and by the continuous curve for

Potentilla type pollen and isolated peaks for Rubiaceae represented today by Potentilla palustris and Galium palustre respectively. The absence of Salix in the pollen record need not reflect its absence locally for Salix pollen is not transported very far, as seen at Bankhead, but it was represented throughout most of the earlier zones. The local presence of open water to the east persisted throughout S-8 to the present as seen in the high values for Gramineae which include Phragmites communis and in the presence of Menyanthes, Typha latifolia and Myriophyllum spicatum.

iii) Soil pollen analysis - Stormont B

a) Introduction to use of soil pollen analysis

Pollen analysis of mor humus layers in soils has been carried out by several authors, such as Iversen (1969) who analysed a deep hydromor in Denmark and O'Sullivan (1973b) who examined a series of podsol profiles in Abernethy Forest, Inverness-shire. As the layers within the Ao or L, F and H horizons represent successional decay (Kendrick, 1957) it may be assumed that pollen deposited on the surface of the litter will be subjected to the same process and incorporated in the soil in a successional manner. Mixing of the pollen in these layers is thought to be restricted to the L and upper part of the F horizon and as material is quickly removed through these layers into the lower F and eventually the H horizon there is only a limited amount of destruction by soil fauna or fungi, or by oxidation during times of desiccation. Thus once pollen arrives in the amorphous H horizon it will be within a stratified deposit and may remain there for several thousand years in the most suitable conditions (Iversen, 1969). It has been suggested by Iversen that in mor soils it is also possible to use the pollen assemblage found in the upper part of the A_2 horizon to provide reliable information on earlier local vegetation communities, a view also expressed by O'Sullivan (1973), but he discounted the use of pollen in lower horizons due to the problems of stratification and differential preservation (Havinga, 1963, 1964).

The pollen analysis of mineral soils has however been carried out extensively by Dimbleby (1957, 1961a, b, 1962) who has argued that providing the soil profile is not taken to be equivalent to the stratigraphic record encountered in bogs, it is possible to use the soil pollen to understand the relationship between vegetation change and soil development in the profile under analysis. In acid mineral soils there is a broad stratification within the pollen record with the youngest pollen overrepresented in the uppermost horizons and the oldest pollen best represented in the lowest horizons, the rest of the profile showing a mix of pollen of varying age generally become older and less abundant with depth.

As the purpose here is to provide information on the relationship between vegetation change and soil development by comparison with the longer bog profiles the soil profiles analysed for pollen are assumed to show a stratigraphic record as postulated by Dimbleby (1961a). It should be possible to correlate directly the pollen record in the mor humus with the upper part of the bog profile, especially where there is a well developed H horizon, for their genesis is theoretically similar. Direct correlation of the lower soil horizons with the bog profile is not possible because of the difference in genesis but where comparison is made it should be possible to look for comparable elements in the two records to establish more clearly the different components of the soil pollen record.

b) Location and description

The location of the soil profile which was sampled for pollen analysis is marked on Fig. 5·2. The site chosen was situated away from the immediate edge of the mire where the surface becomes more level. The site is nevertheless one of the nearest points to the main Stormont A profile and lies within *Pinus sylvestris* woodland in which *Fagus sylvatica*, *Betula pubescens* and *Quercus robur* are also present. The ground vegetation cover is principally ericaceous with *Calluna vulgaris*, *Erica tetralix* and *Vaccinium myrtillus* but *Deschampsia flexuosa* is locally important.

The area of Stormont Loch and Hare Myre has been mapped as part of the Corby Series of the Corby Association (Fig. 4•4) characterised by freely drained iron podsols developed on fluvioglacial gravel of Highland origin (Laing, 1976) and the sampled profile falls into this category. The full profile description is presented in Table 5•8 and the description of the equivalent Corby Series soil profile described by Laing, also from around Stormont Loch is presented in Table 5•9. Selected physical and chemical properties of the latter profile are included in Table 5•10. There are no figures for the distribution of iron down the profile but despite its low clay content there is evidence of clay movement and overall base saturation is low. The two profiles are similar except for the deeper H horizon in Stormont B which exceeds any depth encountered by Laing and for the slightly thicker A_2 horizon which, visually, shows a much higher humic content, and is described as an A_2h horizon.

c) Sampling and pollen assemblage zones

Samples for pollen analysis were taken at 2cm intervals down the entire profile and laboratory analysis followed that outlined in Appendix II, but the lowest samples from the B_2 horizon were found to be totally devoid of pollen. As with all the soil pollen sites local pollen assemblage zones were defined irrespective of horizon boundaries on the same criteria as those used for the longer pollen diagrams and

Table 5·8

Stormont B soil profile description

Grid reference: No. 185422

Aspect: North West

Altitude: c.60m

Vegetation: Open canopy *Pinus sylvestris* with *Betula pubescens*, *Fagus sylvatica* and *Quercus robur* locally present. *Calluna vulgaris*, *Erica tetralix*, *Vaccinium myrtillus*, *Deschampsia flexuosa*.

Drainage: Free

L/F	0 - 8cm	Very dusky red 2.5YR2.5/2 partially decomposed organic material with roots, sharp change into,
H	8 - 17cm	Very dark reddish brown 5YR2.5/1 well decomposed humus which merges into,
A_2h	17 - 31cm	Dark reddish brown 5YR3/2 humic sandy loam with moderate organic matter and some bleaching. Sharp change into,
B_2	31 - 42cm	Dark reddish brown 5YR3/4 coarse sandy loam, with stones up to 5cm across, which is very slightly cemented. Gradual change into,
B_3	42cm +	Brown 7.5YR4/2 more cemented, slightly indurated coarse sandy loam.

Table 5·9

Corby Series profile description at Stormont (after Laing, 1976)

Grid reference: not given

Slope: 2^{o}

Aspect: North

Altitude: 175' (63m)

Vegetation: Scots pine woodland - open canopy - *Calluna vulgaris*, *Vaccinium myrtillus*, *Deschampsia flexuosa*, *Pleurozium schreberi*, *Hylocomium splendens*.

Drainage: Free

L and F	9 - 0cm	Dark reddish brown (5YR3/2 - 3/3) mixed plant litter and partly decomposed organic matter; many fibrous roots.
H		Trace of well decomposed dark reddish brown (5YR2/2) humus. Sharp change into,
A_2	0 - 10cm	Dark grey (10YR4/1) fine sandy loam; loose fine crumb, friable, many rounded pebbles, moderate to low organic matter, bleached sand grains, many fibrous roots, no mottles. Sharp change to,
B_2	10 - 20cm	Brown (7.5YR5/4) coarse sandy loam; coarse sub-angular blocky, friable, moderate organic matter, stones few becoming many towards the base of the horizon, high proportion of Highland origin, no mottles. Sharp undulating change to,
C	20 - 71cm+	Yellowish brown (10YR5/4) coarse sandy gravel; single grain, gravel varying in size and many of Highland origin.

Table 5•10 Physical and chemical properties of Corby Series Profile (after Laing, 1976)

	Loss on ignition %	% Sand	% Silt	% Clay	Exchangeable cations					Saturation %	pH	%C	%N	Total P_2O_5
					Ca	Mg	Na	K	H					
L/F/H	79•80	n.d.	n.d.	n.d.	9•64	6•75	1•87	1•53	103•9	16•0	3•50	46•77	1•4	100
A_2	23•55	66•6	6•4	9•3	–	0•64	0•27	0•21	45•09	2•4	3•40	13•20	0•542	88
B_2	16•40	68•7	7•6	11•4	–	0•15	0•11	0•08	31•23	1•1	3•79	7•23	0•386	119
C	7•76	86•6	2•1	11•4	–	0•04	0•04	0•06	11•42	1•2	3•91			88
C	5•24	87•8	1•4	8•2	–	0•04	0•04	0•04	7•39	1•6	3•82			72
C	3•29	93•1	2•1	4•8	–	0•02	0•04	–	3•31	1•8	4•32			71

at Stormont B the zone boundaries are included on the pollen diagram in Fig. 5•9a and b. Four local pollen assemblage zones were defined for the Stormont B profile (depths are taken from the surface).

SB-1 Base to 17cm *Betula* - *Corylus*/*Myrica* - *Alnus* - *Quercus*

The upper boundary is taken where there is a reduction in all arboreal pollens except *Pinus*, which increases, as do Gramineae and *Calluna*.

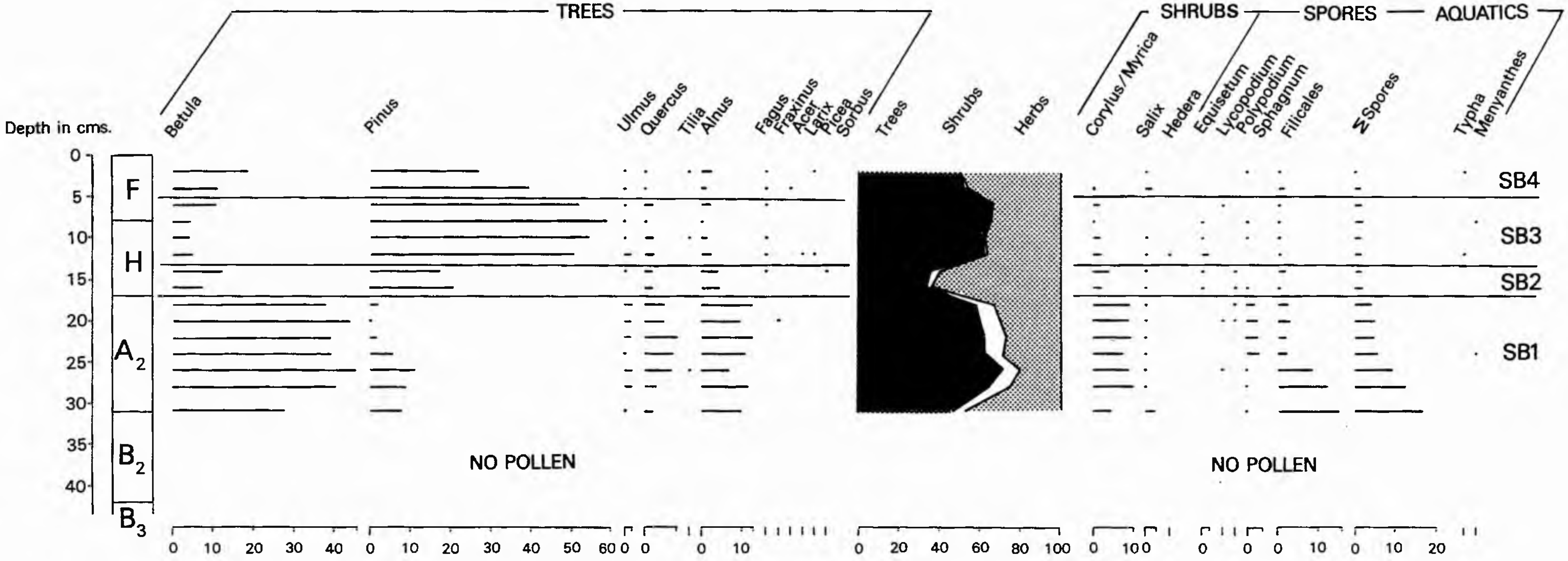
This zone lies entirely within the A_2h horizon, for no pollen was preserved in the lower horizons, and is dominated by *Betula* at over 40%T.L.P. Arboreal pollen and shrubs comprise up to 70%T.L.P. with *Alnus*, *Corylus*/*Myrica* and *Quercus* all represented. Apart from the lowest sample Gramineae and *Calluna* are equally represented at between 10-15%T.L.P. There are variable frequencies for *Plantago lanceolata*, *Rumex*, *Urtica*, Ranunculaceae, Compositae lig., Umbelliferae and *Centaurea cyanus*. Pollen preservation is poor with high frequencies for Corroded and Degraded pollen towards the base where the levels of Indeterminable pollen exceed 10%T.L.P. and the Filicales curve peaks.

SB-2 17 - 13cm *Pinus* - *Calluna* - Gramineae

The upper boundary lies where *Pinus* increases and *Betula* and *Calluna* decrease.

This zone covers the lower part of the H horizon and has increased values for *Pinus* with peaks for *Calluna* and Gramineae and the lowest A.P. plus shrubs frequencies in the profile. There are fewer herb taxa represented but *Plantago lanceolata* and Leguminosae show higher values. Although the number of Degraded grains remains high there are virtually no Corroded grains.

STORMONT LOCH B



All species expressed as % T.L.P.

Fig.5.9a Stormont Loch B soil pollen diagram, trees, shrubs, spores and aquatics

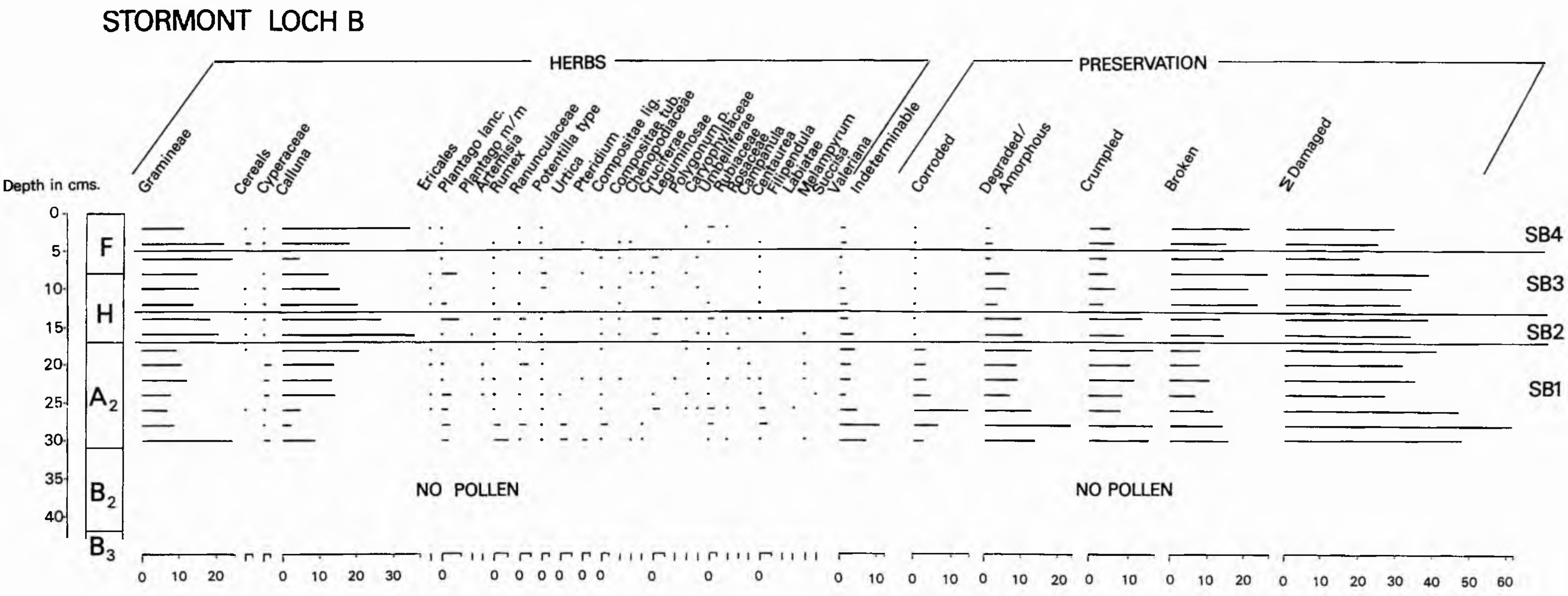


Fig.5.9b Stormont Loch B soil pollen diagram, herbs and preservation (expressed as a percentage of the T.L.P. sum)

SB-3 13 - 5cm *Pinus*

The upper boundary is where *Pinus* decreases and *Calluna* increases.

SB-3 spans the upper part of the H horizon and the lowest part of the F horizon. It is dominated by *Pinus* pollen at up to 60%T.L.P. with very low values for other trees and shrubs and with lowered frequencies of Gramineae and *Calluna*.

SB-4 5cm - top of profile *Calluna* - *Pinus*

The uppermost part of the soil has increasing *Calluna* and decreasing *Pinus* with greater representation of *Betula* and *Alnus*. There is a noticeable reduction in the number of N.A.P. species represented and amounts of Corroded and Degraded pollen are very low.

d) Comparison of soil profile and Stormont A

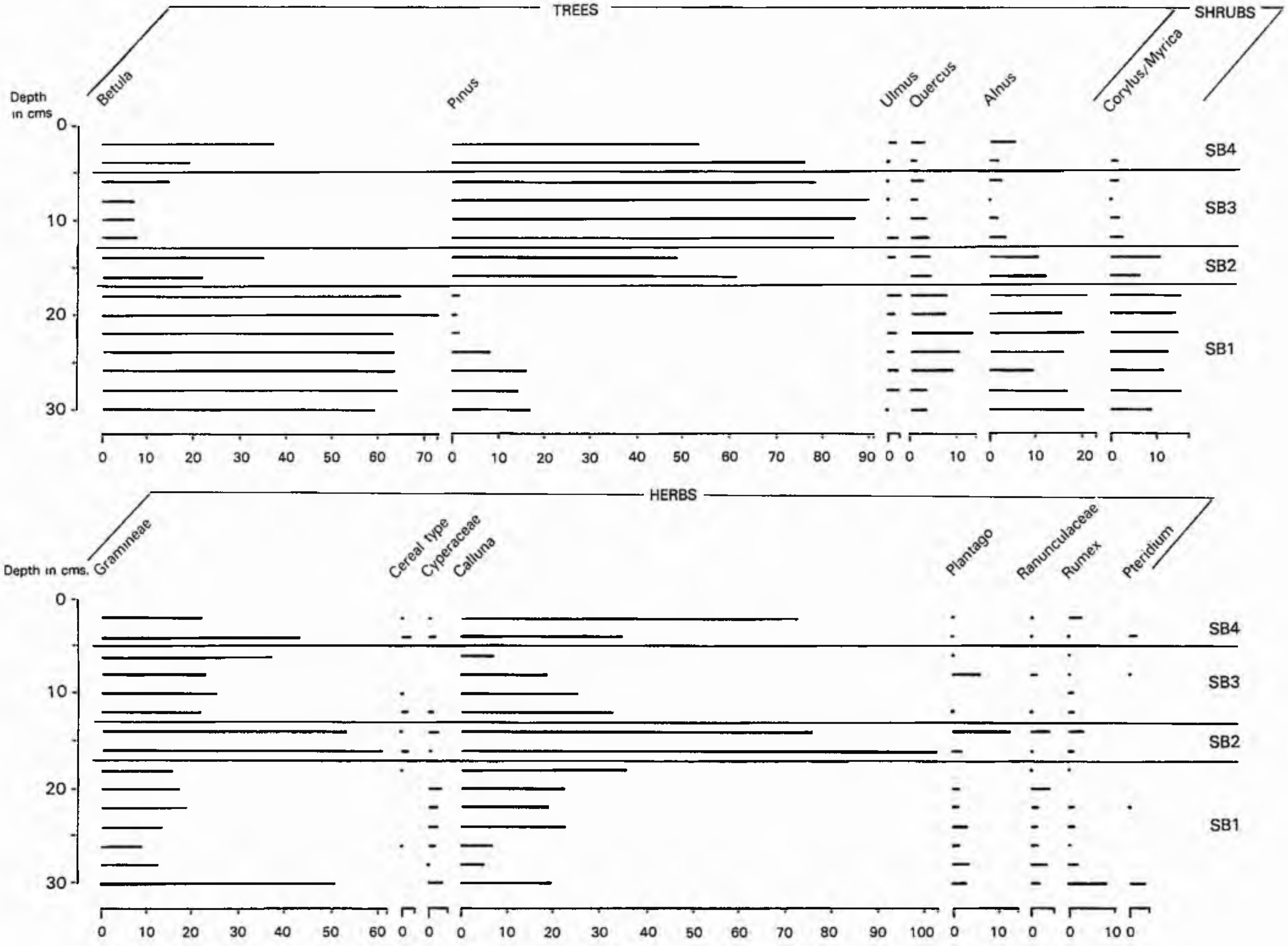
Comparison of the two diagrams can only be made with regard to the limitations discussed above and hence direct comparison is only possible between the Stormont A diagram and zones SB-2 to SB-4 which are from the mor humus. Furthermore it must be noted that whereas the soil profile shows a record which continues to the present day the uppermost part of the bog record is missing. Because of the different pollen source areas which will contribute to the different collecting environments it would be impossible to use a T.L.P. sum for comparison, particularly with respect to the importance of local pollen in the soil record. Thus only tree and shrub pollen was used, expressed as a percentage of the arboreal pollen sum, as it may be expected that any littoral tree or shrub species would show higher values in the soil than the bog and that if a species was only present as part of the regional pollen contribution the percentages would be similar or perhaps higher in the bog due to the lower local pollen production. Despite these differences any significant change in the relative contribution of tree and shrub species should be mirrored at both sites.

Using the A.P. sum (Fig. 5·10) the main point of comparison appears to be the topmost sample of the Stormont A profile which has Pinus at up to 80%A.P., and the peak for Pinus in the soil at 8cm where it reaches 90%A.P. In both diagrams this point is also marked by very low frequencies for Betula. If this assumption is correct then the main drop in Pinus pollen seen in the soil at 18–20cm is probably equivalent to the depression in Pinus frequencies at 80cm. At this point both diagrams show high Betula and Alnus values. This second point of comparison is however more dubious for the low Pinus counts occur at the H/A_2 boundary and as O'Sullivan has commented,

> "Radical changes in pollen assemblage often coincide with soil-stratigraphic changes. In such cases it is not possible to interpret diagrams in terms of their representing the pollen content of a continuously accumulating deposit" (1973, p.269).

The presence of Pinus pollen below this level in higher frequencies than at the break does compare well with the bog profile even if the detail shown in the latter is somewhat evened out and suggests that here there may be evidence of continuity either side of a major soil-stratigraphic boundary with the low values for Pinus in the top of the A_2h horizon equivalent to those either at 70cm or 80cm in Stormont A. The fact that Pinus pollen occurs throughout the soil also suggests that much of the pollen was produced and deposited during S–8, the most recent zone in the bog. The basal assemblages found in Stormont B compare with the base of S–8 and the uppermost samples of S–7 with the Pinus pollen probably representing the youngest component of the soil pollen assemblage and that of the other main tree species representing slightly older components, although almost certainly not

STORMONT B



All are expressed as % A.P.

Fig.5.10 Stormont Loch B, selected taxa expressed as a percentage of the A.P. sum from any zone earlier than S-7. It is also quite possible though that Pinus pollen is overrepresented in this part of the soil record as in levels with difficult identification the readily recognisable fragments of Pinus are more likely to be accurately identified than most other species.

Given the broad comparability established above two points of interest emerge. If the argument concerning the likely contributors of littoral and extra-local or regional pollen is applied then it would appear that Pinus and Betula grew around the soil site on the fringes of the loch for percentages in Stormont B are consistently ten per cent higher than in A. Alnus values are usually higher in A by a similar margin indicating a more extra-local origin. With the effect of having the soil site actually within woodland as is indicated throughout most of the diagram it would be unlikely that any regional contributors would have the same representation at both sites when calculated on an A.P. sum due to the influence of local species. The principal difference between the two diagrams appears to be the Corylus/Myrica curve but this is partly distorted by the use of the A.P. sum for the number of grains considered in the sum varies to quite an extent between sites A and B and Corylus/Myrica is not included. Thus with a much lower sum for Stormont A values expressed as a percentage of the A.P. sum are increased. Despite this the results do show that the contribution of Corylus/Myrica is largely extra-local and regional.

It is difficult to compare the Gramineae and Calluna records because of their different local presence at the sites but there is a noticeable difference in the remaining N.A.P. represented, especially Cereal type pollen, Plantago lanceolata, Rumex and Pteridium, which are not only more continuously present but also higher in the Stormont A profile. This is due to the filtration effect of the woodland and the contribution of other local taxa, especially <u>Calluna</u>, at the soil site, but also confirms that their presence in the bog profile reflects their occurrence at some distance from the sampling site, probably to the south. The difference in the records does therefore add weight to the interpretations of land use change based on the presence and absence of such taxa that have been made in the discussion of the Stormont A profile.

e) <u>Soil development and vegetation history</u>

On the basis of the evidence from the Stormont A analysis it was argued that the lochside vegetation nearest the sampling point was probably not cleared until at least zone S-7 and that the complete removal of birch and the subsequent planting of pine only took place in S-8. This would have meant that the soil profile under the lochside woodland would have retained the characteristics of the earlier soil form which disappeared from areas further away from the loch as they were cleared in much earlier periods. Hence until clearance the soil would have been of an acid brown earth type, perhaps slightly podsolic owing to the long period of time it had remained under the relatively open canopy woodland. On clearance and especially under pine this soil would have changed to a podsol comparable to those which developed elsewhere on the coarse sands and gravels of the outwash and which are defined within the Corby Series, although given the time under the pine cover it is unlikely that the soil would have become quite as podsolic. This seems to be the pattern which can be interpreted from the soil pollen record and from the character of the soil profile. The presence of an A_2h horizon which shows less bleaching than the normal Corby A_2 and the lack of any significant induration of the B_3 horizon (Romans, 1962) all point to a lesser degree of podsolisation than found elsewhere on the same parent material. The pollen record also seems to accord with the postulated vegetation changes and their timing.

The pollen in SB-1 in the A_2h horizon shows greater diversity of species than in the rest of the diagram and with lower frequencies for Calluna represents to a large extent the more varied vegetation communities that surrounded the loch prior to increased acidification. The dominance of Betula indicates that birch was the principal fringing tree species but with the local presence of Alnus and Quercus. Allowing for the possible underrepresentation of Quercus in mineral soil it may have formed a more important position in the woodland community (Havinga, 1964), but counts of up to 10%T.L.P. do argue for an adequate representation when compared to the probable equivalent period in the bog and the values for oak represented there. Overall the presence of a birch woodland with Alnus, Quercus and Corylus locally present agrees well with the record from S-7, some of the variety in the N.A.P. record reflecting cultivation taking place away from the lochside. The higher frequencies for Plantago lanceolata, Rumex and Urtica are also found in S-7 but the first two species are also found throughout S-8. The origin of the Pinus pollen has already been discussed and is thought to be a younger element in the pollen record.

The change at the A_2h/H boundary probably records the physical removal of birch for the planting of pine which may have produced some disturbance as suggested by O'Sullivan (1973b) but there is no visual evidence for any significant disruption of the profile at the sampling site. The general clearance indicated in the soil profile at the SB-1/SB-2 boundary is also seen at the S-7/S-8 boundary in the bog for all trees and Corylus are reduced. Below this boundary in the soil there is also evidence for increased wetness with higher values for Sphagnum spores. Thus waterlogging may have assisted in the formation of the acid mor layer and the subsequent increased podsolisation although the cause of such an event is not readily apparent in either record. Despite the increased openness at the site which allowed peaks for Plantago lanceolata, Rumex, Ranunculaceae and Leguminosae there is a decline in the species diversity due to the development of the mor. The pattern of change here would differ from that experienced at most sites on the outwash for an acid tolerant vegetation was planted on the site and it was never cultivated yet, on such a parent material, the end result in terms of the soil profile was eventually very similar.

The growth of pine and the extension of the ericaceous understorey dominated by Calluna vulgaris is seen in SB-2 and SB-3. The full variety of the local community is probably not represented for Vaccinium myrtillus which is common today does not appear in the pollen record. At the base of the L/F horizon there is an increase in Gramineae but this may only be due to the immediate presence of Deschampsia flexuosa taking over aged Calluna stands rather than a general increase in grassland for there is no reduction in A.P. values. The ageing and opening of the pine woodland is indicated in SB-4, a process which starts at the SB-3/SB-4 boundary and which is continuing today. With the reduction in pine other species were able to regenerate, especially birch, and it seems that the pine was not physically felled. The paucity of the rest of the flora on the acid mor soil is most noticeable in the severely reduced N.A.P. variety, especially as Calluna becomes locally more important towards the top.

The Stormont A record shows several peaks for pine pollen but the single peak in the soil pollen record implies that only one local stand of pine was probably present during the development of the mor horizon and the remnants of this stand are still present today. The podsol profile which has developed is therefore a recent phenomenon, due as much to the pine as to the removal of the original birch cover and any physical disruption of the profile although some podsolisation may have been taking place prior to the clearance of the birch. The accumulation of the mor must therefore have taken place within the last two or more centuries since planting began. The introduction of pine at this particular site may however have happened after this date. Dating of the base of mor profiles at Abernethy Forest has produced dates going back to 1500b.p. (O'Sullivan, 1973) but at non-dated profiles shallower accumulation may have begun as recently as 1840A.D.

Allowing for the comparability of the two diagrams the soil pollen diagram appears to confirm that the S-7/S-8 boundary could have occurred at c.1775A.D. and that the importance for instance of Compositae tub. and increased Cereal type pollen in the bog profile was due to the late eighteenth century agricultural developments rather than Medieval innovation. Thus the reintroduction of cereal cultivation in the middle of S-7 may instead be indicative of the monastic influence rather than any earlier settlement expansion, or of a composite of the two occurrences. Whatever the true pattern it confirms that accumulation rates in the upper part of the bog were extremely variable.

CHAPTER SIX

THE AREA NORTH OF THE BOUNDARY FAULT I. THE FOREST OF ALYTH

On the northern fringe of the Boundary Fault the Forest of Alyth covers a broad, slightly undulating plateau rising from 200 metres in the south to over 500 metres in the north. It is composed of metamorphic altered grits but in the south there are bands of andesitic lavas, slates, phyllites and Old Red Sandstone associated with the fault which provides a series of ridges marking the northern edge of Strathmore. At present, land use within the Forest of Alyth is predominantly moorland providing rough grazing but cultivation and improved grassland impinges on the southern, eastern and western margins at altitudes of up to 300 metres.

There are several areas of peat deposits on the plateau, mostly now fragmentary, in channels or basins formed sub-glacially or as ice marginal features during the expansion and contraction of the main Devensian ice sheet. In the higher northern part there is however a much larger expanse of peat to the south of Corb Farm (NO165508) at Dun Moss. The range of possible sites was therefore relatively wide so the final choice of sampling sites was made considering several criteria relevant to the aims of the study:

1. The need for at least one site which would provide the principal pollen record and show a long and preferably complete Flandrian record.

2. The proximity of another separate peat site to provide a comparative record, especially for the Late Flandrian to help monitor the location and extent of clearance.

3. There should be archaeological remains close to the sites, preferably of a habitativerather than funerary nature implying the earlier presence of agriculture in close proximity to the peat deposits.

4. At present there should be some evidence of variation in land use between moorland and improved land as this difference may also have been important in the prehistoric period and aid interpretation of the pollen record.

An area on the southern fringe of the Forest of Alyth at an altitude of c.230cm was eventually chosen (Fig. 6·1) as it fulfilled most of the criteria outlined above, at least on the basis of a preliminary survey. The main site lies to the south of Heatheryhaugh Farm (NO183519), an eroding basin peat lying in a meltwater channel. The second site at White Hillocks (NO188515), a circular depression at the foot of the ridge which marks the southern edge of the plateau, lies about 750 metres southwest of Heatheryhaugh. Between the two sites there are two enclosures and close to White Hillocks there are two well preserved hut circles. On the ridge to the southeast there are two stone circles and to the north and east lie further hut circles with small cairns (clearance cairns?). At present both sites are within rather acidic moorland dominated by Calluna vulgaris, but there is a patch of improved pasture lying between them and to the south the higher ridge is under pasture with cultivation taking place around the Mains of Creuchies up to an altitude of 250 metres. To the west of the area there are scattered fragments of Pinus sylvestris woodland and recent afforestation has taken place on moorland showing evidence of ridge and furrow (NO1850).

Discussion of the vegetation history of this part of the Forest of Alyth starts with a consideration of the results from the site at Heatheryhaugh. Comparison is then made with the second site at White Hillocks and finally the analysis of soil pollen from two profiles adjacent to Heatheryhaugh and a further profile in the northern part of the Forest near Rannagulzion Farm (NO169548) is used to help elucidate the relationship between vegetational history and soil development.

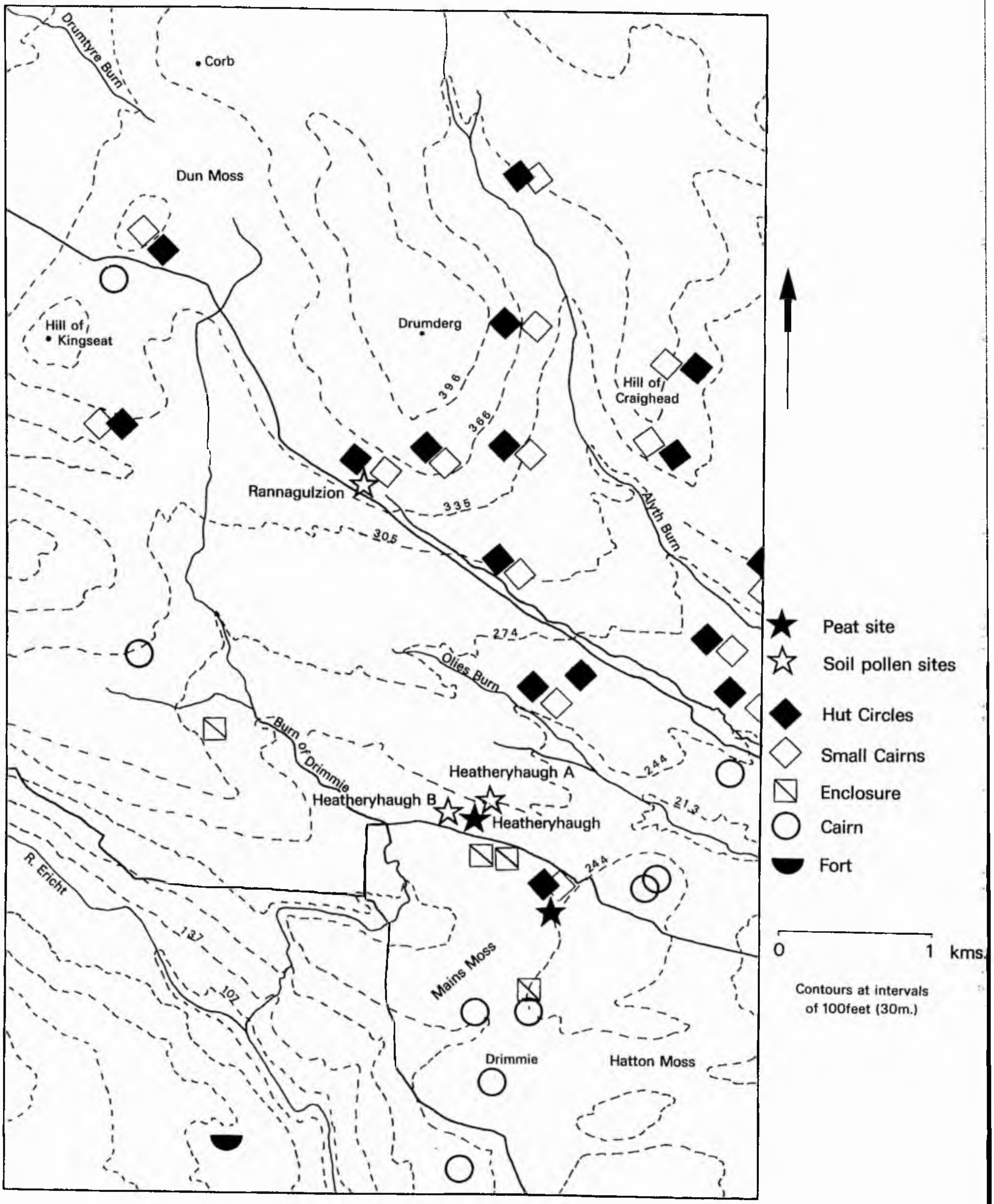


Fig.6.1 Location of pollen sites in the Forest of Alyth

i) Heatheryhaugh

a) Stratigraphy and sampling

Peat once probably filled a large part of the channel which now only holds a small remnant of raised bog which has been cut back and subsequently severely eroded (Fig. 6•2). A series of borings was made across the central dome of the bog (Fig. 6•3) which revealed a slightly asymmetrical sub-peat surface with its deepest section containing almost six metres of peat towards the western margin. Samples were taken from a core in the deepest part, marked 3 on Fig. 6•2, using a Hiller borer. The use of the Hiller, especially in the wood peat, only allowed uncontaminated sampling of sufficient material at a relatively wide sampling interval of five centimetres. Apart from the use of the Hiller the possible main drawback of the site lay in the fact that the peat in the deepest part appeared to have stopped growing and there was no guarantee that cessation of growth had not taken place at a relatively early period due to improved drainage following peat cutting.

The stratigraphy at the sampling point was as follows:

0 - 10cm	Poorly humified *Sphagnum* peat with *Calluna* twigs.
10 - 63cm	Light brown moderately humified *Sphagnum* peat with occasional remains of *Eriophorum*.
63 - 71cm	Well humified dark brown *Sphagnum* band.
71 - 93cm	Light brown moderately humified *Sphagnum* peat.
93 - 114cm	Dark brown moderately humified *Sphagnum* peat with recognisable sedge remains.
114 - 120cm	Well humified, very dark brown *Sphagnum* band.
120 - 141cm	Reddish brown moderately humified *Sphagnum*-*Eriophorum* peat.
141 - 148cm	Well humified dark brown *Sphagnum* peat with stems of *Calluna*.

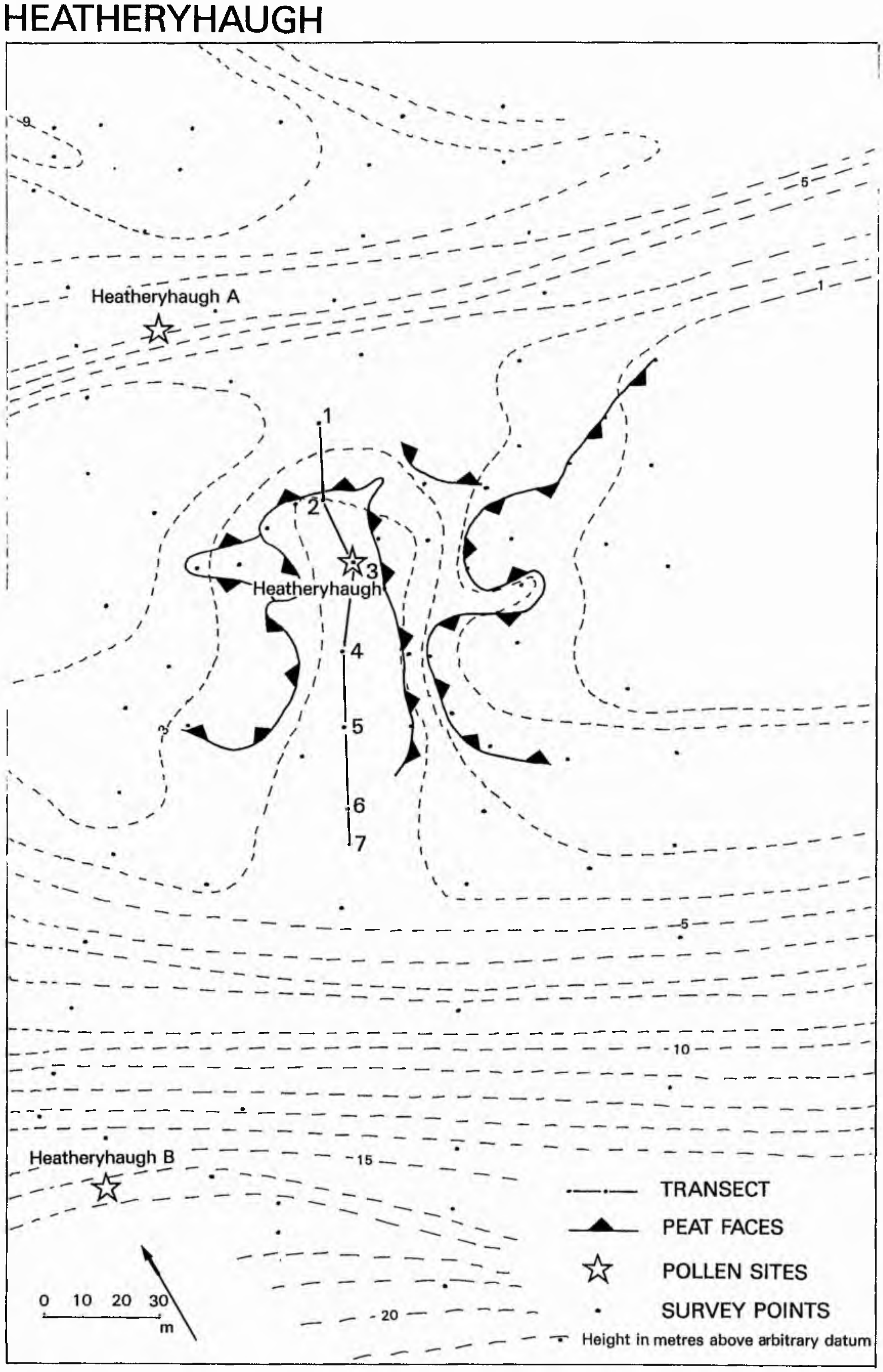


Fig.6.2 Site map for Heatheryhaugh

HEATHERYHAUGH TRANSECT

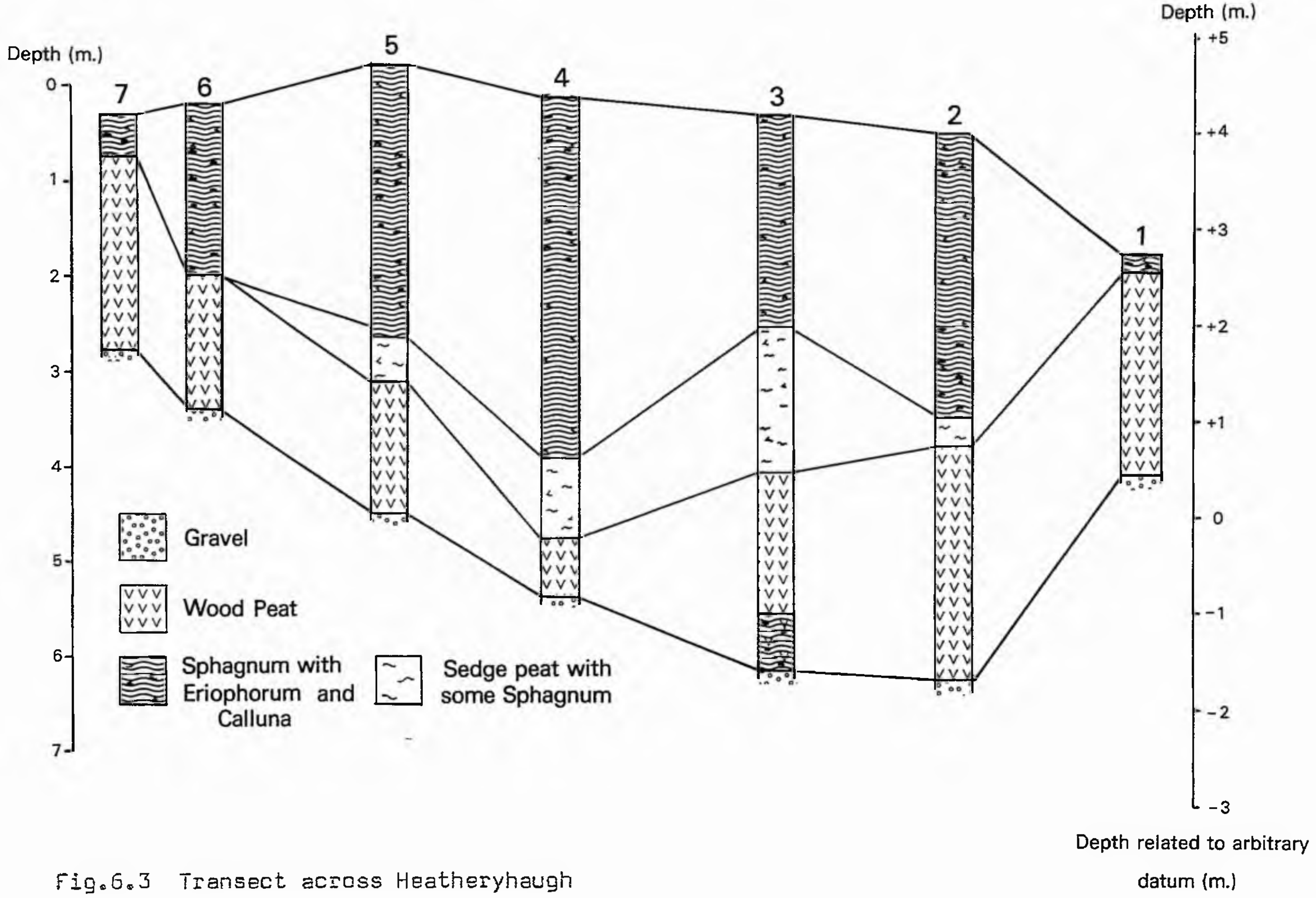


Fig.6.3 Transect across Heatheryhaugh

148 - 153cm	Light brown less well humified *Sphagnum*-*Eriophorum* peat.
153 - 172cm	Moderately humified *Sphagnum*-*Eriophorum* peat.
172 - 173cm	Well humified dark brown *Sphagnum* peat.
173 - 240cm	Reddish brown, moderately humified *Sphagnum*-*Eriophorum* peat with *Calluna* stems, especially between 216 - 220cm.
240 - 358cm	Sedge peat with occasional *Sphagnum* lenses and *Calluna* stems.
358 - 405cm	Sedge peat with *Eriophorum* remains.
405 - 520cm	Wood peat with increased density of wood remains after 500cm.
520 - 580cm	Moderately humified *Sphagnum* peat with wood remains.
580 - 600cm+	Grey gravel becoming coarser and reddish with depth.

Preparation of the samples followed procedures outlined in Appendix II. For most of the core a count of 500T.L.P. was used, except towards the base where pollen was sparse and a count of only 300T.L.P. could be used. No local species were excluded from the pollen sum despite the presence of *Calluna*, sedges and grasses in the stratigraphy. The exclusion of these would have removed up to 80 per cent of the pollen counted in parts of the diagram and, as they are all not only found in the bog vegetation but also on the slopes surrounding the bog, changes in their pollen representation may well be of wider significance. The pollen diagram for Heatheryhaugh is presented in Figs. 6•4a and b. No details of pollen preservation were taken at this site.

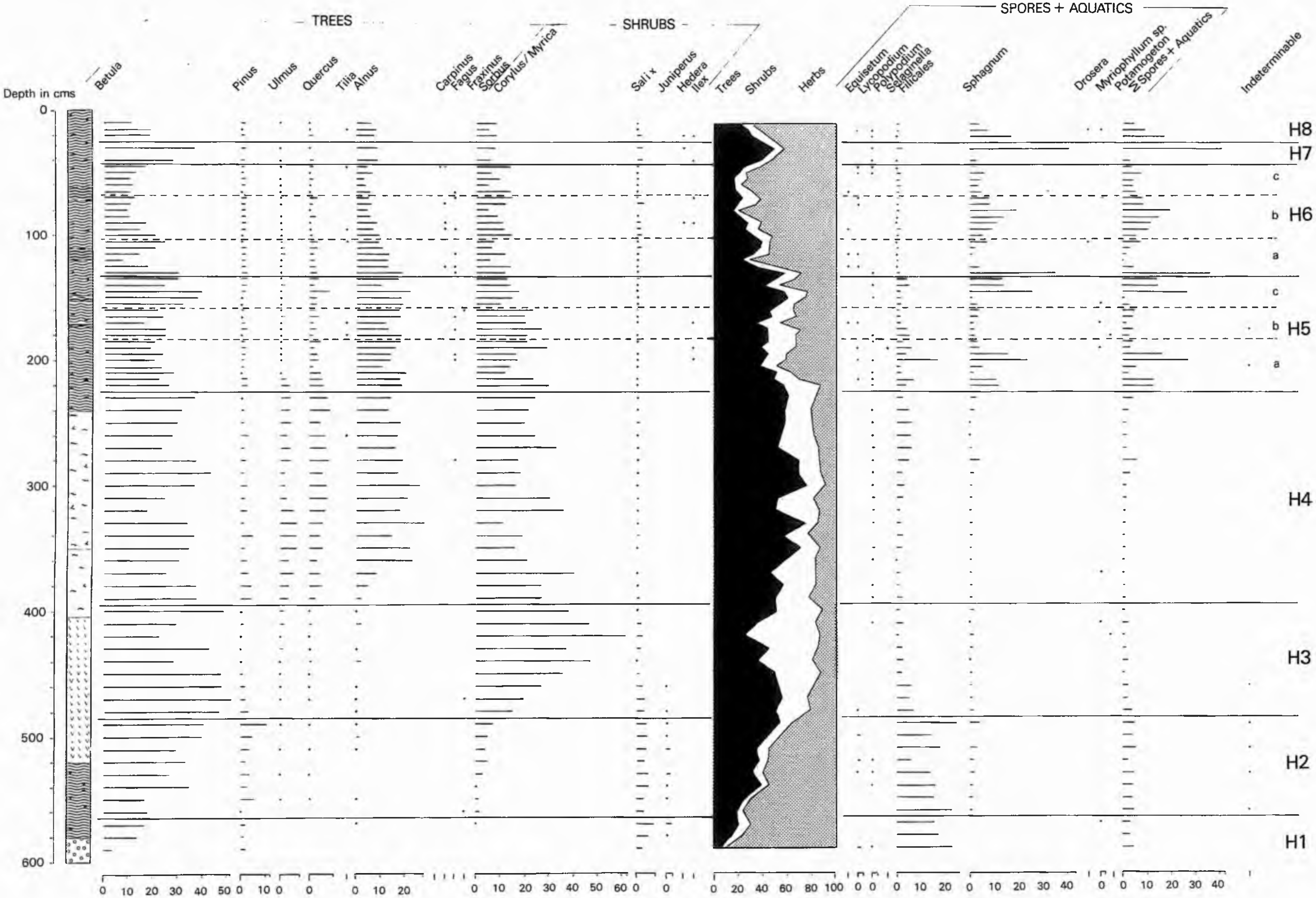
b) Pollen assemblage zones

Eight local pollen assemblage zones were defined at Heatheryhaugh prefixed by H-, and their composition is discussed below:

H1 590 - 565cm Cyperaceae - Gramineae - Compositae lig.

The upper boundary occurs where there is a decrease in *Salix* and

HEATHERYHAUGH



All are expressed as %T.L.P.

Fig.6.4a Pollen diagram from Heatheryhaugh, trees, shrubs, spores and aquatics

HEATHERYHAUGH

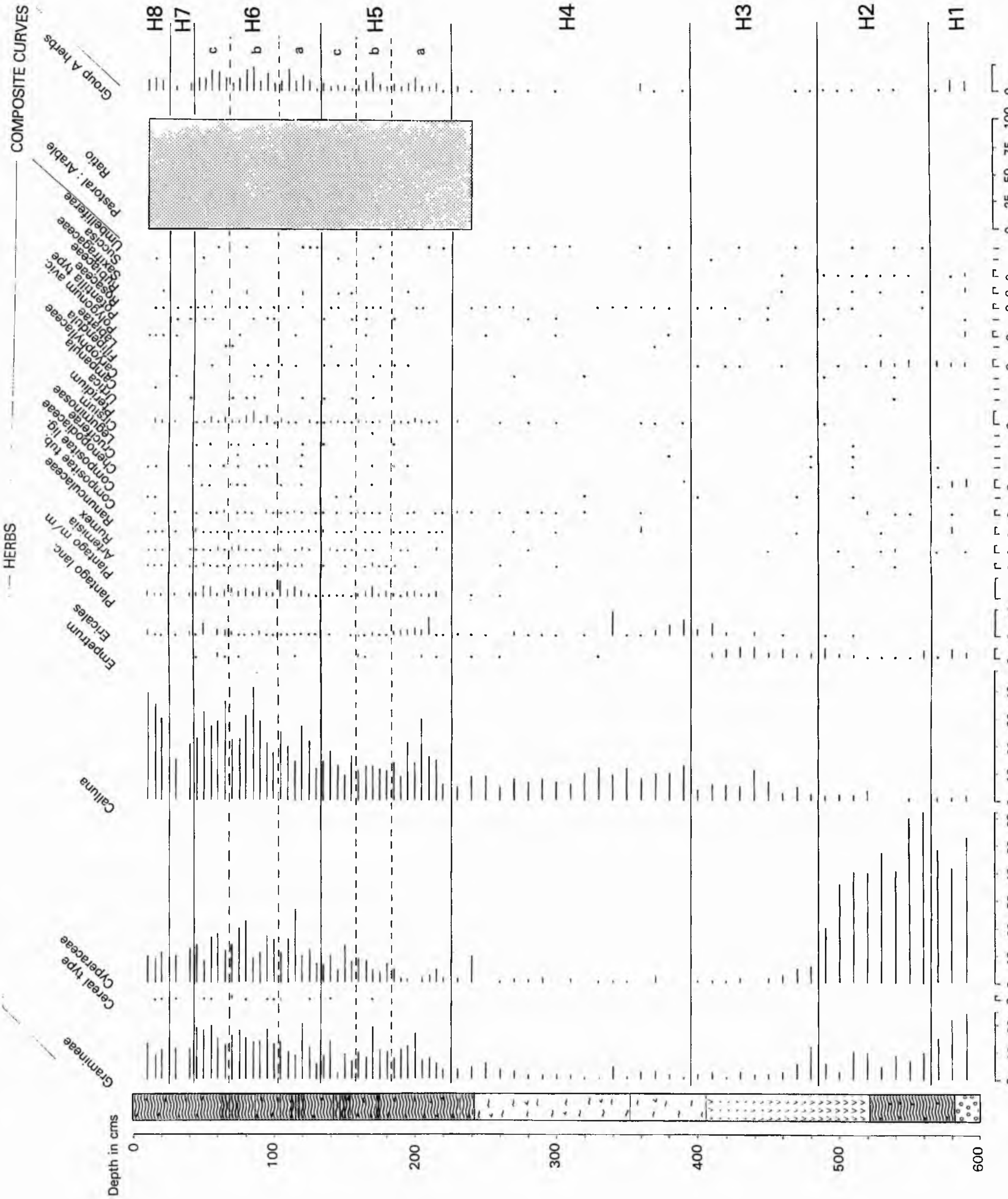


Fig.6.4b Pollen diagram from Heathreyhaugh, herbs

Gramineae and the curve for Compositae lig. ceases.

This zone covers the change from the basal grey gravel to *Sphagnum* peat with wood remains. Counts for N.A.P., mainly Gramineae and Cyperaceae, are very high with Compositae lig. and *Filipendula* represented at over 2%T.L.P. and occasional grains of *Artemisia* and *Rumex*. There is a peak for *Empetrum* near the base and both *Salix* and *Juniperus* are present, the former at over 6%T.L.P. *Betula* rises gradually to 25%T.L.P. and *Pinus* is the only other tree species present. There is a peak for Filicales spores in the sample from the gravel but they are almost equally well represented in the peat.

H2 565 - 485cm *Betula* - Cyperaceae

The upper boundary is marked by a drop in Cyperaceae and rising values for *Corylus*/*Myrica*.

H2 shows a further increase in *Betula* to over 40%T.L.P. and *Pinus* frequencies reach 8%T.L.P., higher than in any other zone, until by the boundary with H3 the pollen of trees and shrubs comprises over 50%T.L.P. *Salix* is consistently present, although at lower levels than in the previous zone, and there are occasional grains of *Juniperus* and *Sorbus*. Cyperaceae values are reduced from the very high frequencies found at the H1/H2 boundary but there are continuous curves for *Calluna* and *Empetrum*. As in H1 Filicales spores contribute between 10 and 20%T.L.P. and there is an early peak for *Sphagnum* which is coincident with the development of *Sphagnum* peat although the highest values occur after the change to wood peat.

H3 485 - 395cm *Betula* - *Corylus*/*Myrica*

The upper boundary lies where there are reduced values for *Corylus*/*Myrica* and empirical limits for *Quercus*, *Ulmus* and *Alnus*.

Within this zone the pollen of trees and shrubs rises to over 80%T.L.P. consisting entirely of Betula and Corylus/Myrica, the latter reaching 61%T.L.P. Both Gramineae and Cyperaceae are severely reduced but Calluna and Empetrum are better represented and Empetrum in particular shows a consistent curve throughout. Relative to earlier zones the variety of herbaceous taxa present is low and counts for spores are similarly reduced. The uppermost sample at 400cm lies within Sphagnum-Eriophorum peat whereas the rest of the zone is within wood peat.

H4 395 - 225cm Betula - Corylus/Myrica - Alnus

At the upper boundary Betula and Ulmus are reduced and Gramineae and Calluna increases.

This zone is dominated by A.P. and shrub pollen at up to 90%T.L.P. with not only Betula and Corylus/Myrica, which tend to show highly variable individual frequencies, but also Quercus, Ulmus, Alnus and, to a lesser extent, Pinus. At 320cm values for Ulmus are noticeably reduced but they almost regain former levels by the end of the zone. Most N.A.P. are still low but Calluna remains consistently at between 10 and 15%T.L.P. and there are occasional grains of Rumex, Plantago sp. and Pteridium. Values for Filicales increase and there is a peak for Sphagnum at 280cm. H4 lies mainly within the sedge peat but there is a change to Sphagnum-Eriophorum peat at 240cm.

H5 225 - 132·5cm

The upper boundary is taken where Gramineae and Calluna are reduced and there are peaks for Betula, Alnus and Corylus/Myrica immediately prior to a severe reduction in all three species.

The zone may be divided into three sub-zones or zonules:

a) 225 - 182·5cm At the opening there is a reduction in Ulmus and *Betula* followed later by *Alnus*, *Quercus* and *Corylus/Myrica*, so that the pollen of trees and shrubs is reduced by 35 per cent. At the decline in *Ulmus*, *Plantago lanceolata* and *Pteridium* appear and the minimum for tree pollen is marked by peaks for Gramineae and *Calluna*, although between 216 and 220cm remains of the latter occur abundantly in the peat stratigraphy. Following the lower tree pollen counts *Alnus*, and also *Quercus*, values recover and there is a sharp rise in *Corylus/Myrica*. By the end of the sub-zone Gramineae and *Calluna* are both reduced as are all the other herb taxa. Counts of *Sphagnum* are particularly high throughout and there are Filicales peaks which bracket the increases in Gramineae and *Calluna*. At 190cm there is a single tetrad of *Selaginella selaginoides*.

b) 182 - 157cm. There is a further reduction in *Alnus* and *Quercus* followed by a drop in *Betula* and *Corylus/Myrica* with the appearance of grains of *Tilia* and *Fraxinus*, the latter of which was occasionally found H5a), and 170cm marks the lowest A.P. count in H5, only 30%T.L.P. At the lowest values for A.P. and shrub pollen there are peaks for Gramineae and *Plantago lanceolata* but no change in the *Calluna* curve. A wider range of weed taxa is present with not only Ranunculaceae and *Rumex* but also Compositae lig., *Cirsium* and Chenopodiaceae, and there is a single unidentifiable *Cereal* type grain (Table 6·1), but the Pastoral: Arable ratio remains high throughout. Values for spores are much lower than in the earlier sub-zone. After the high levels for N.A.P. all the main tree species recover to levels found earlier and *Corylus/Myrica* shows a slight rise.

c) 157·5 - 132·5cm. Initially there are peaks for *Betula* and *Alnus* with lower *Corylus/Myrica* and very low Gramineae, but by 140cm all the tree species are again reduced and there are peaks for Gramineae and *Calluna*. There is however very little change in other N.A.P. as

Table 6·1

Cereal pollen types from Heatheryhaugh

Depth (cm)	Diameter (µ)	Pore Size (µ)	Preservation	Sculpturing (Beug)	Species Interpretation
5	41	10	Folded	–	–
	41	11	Good	*Hordeum* type	*Hordeum* sp.
	41	10	Good	*Hordeum* type	*Hordeum* sp.
15	40	8	Degraded	–	–
20	46	9	Folded	–	–
50	40	8	Folded	–	–
	58	13	Good	*Triticum* type	*Triticum* sp.
70	40	10	Degraded	–	–
	43	12	Good	*Hordeum* type	*Triticum monococcum*?
	44	8	Good	*Hordeum* type	*Hordeum* sp.
95	40	–	Folded	–	–
100	50	–	Degraded	–	–
125	47	9	Good	*Hordeum* type	*Hordeum* sp.
140	45	–	Folded	–	–
170	50	–	Folded	–	–

seen in the composite curve for Group A herbs which barely changes, even when expressed as a percentage of the A.P. sum (Fig. 6•5a,b). Once again spore counts, especially *Sphagnum*, reach very high levels. At the boundary with H6 there is a recovery in *Betula*, *Quercus* and *Alnus*.

All H5 lies within *Sphagnum*-*Eriophorum* peat and there are bands of very well humified peat between 172 - 173cm, 141 - 148cm and 114 - 120cm.

H6 132•5 - 42•5cm

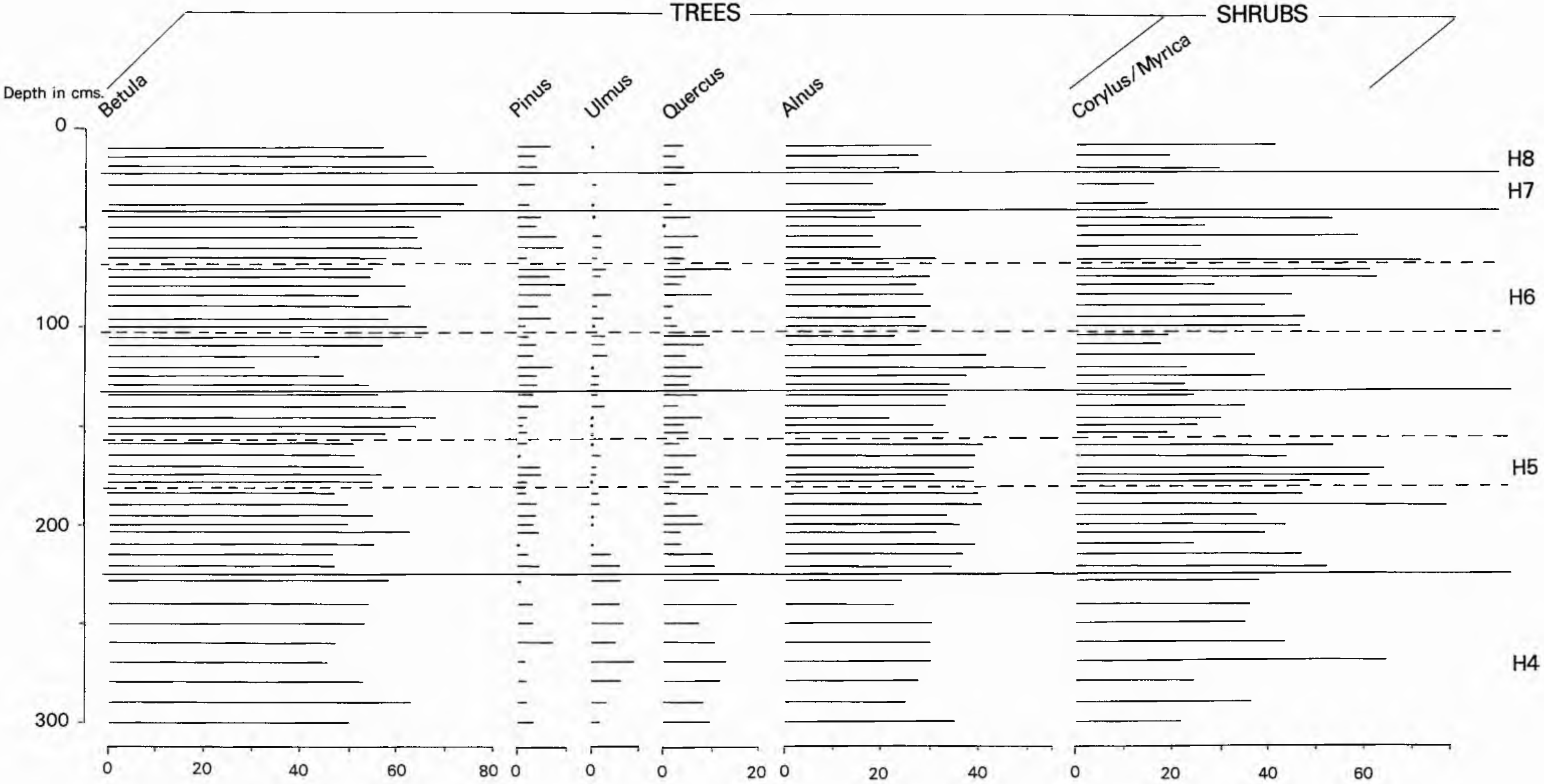
The upper boundary is marked by increases in *Betula* and *Alnus* and reduced frequencies of Gramineae and *Calluna*.

As with the previous zone it is possible to divide H6 into three sub-zones:

a) 132•5 - 102•5cm. There is a reduction in A.P. and shrub pollen to only 30%T.L.P. with *Betula*, *Quercus*, *Alnus* and *Corylus*/*Myrica* all affected. The drop in *Betula* values to less than 9%T.L.P. is however the most severe. At the minimum for *Betula* there are peaks for Gramineae and *Calluna* with a later peak for Cyperaceae and the highest frequencies encountered in the diagram for *Plantago lanceolata* when expressed as a percentage of the T.L.P. sum. *Cereal* type pollen is present, referable to *Hordeum* type (Table 6•1), and *Artemisia*, Ranunculaceae and *Pteridium* occur at more than 1%T.L.P. All these changes in N.A.P. are emphasised when expressed as a percentage of the A.P. sum (Fig. 6•5). The end of the sub-zone is marked by a rise in *Betula* and some increase in *Quercus* but there is little change in the other woody taxa. Spore counts are low with much lower Filicales frequencies than in previous zones.

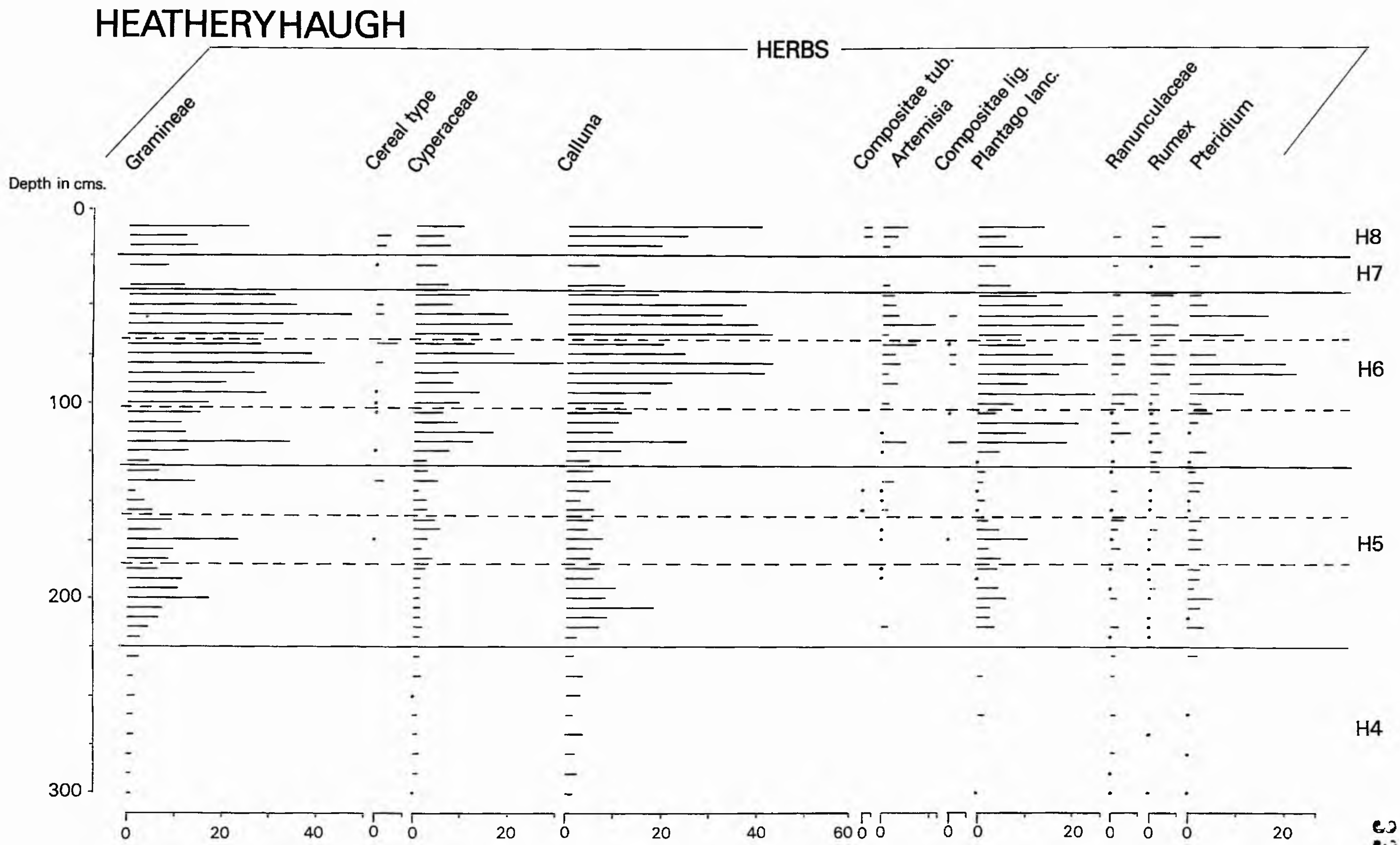
b) 102•5 - 67•5cm. This sub-zone opens with further reductions in *Betula*, *Alnus* and *Corylus*/*Myrica*, and *Quercus* falls below 1%T.L.P.

HEATHERYHAUGH



All are expressed as A.P.

Fig.6.5a Heatheryhaugh, selected taxa expressed as a percentage of the A.P. sum, trees and shrubs



All are expressed as % A.P.

Fig.6.5b Heatheryhaugh, selected taxa expressed as a percentage of the A.P. sum, herbs for the first time. There is a major peak for Calluna and Gramineae remains high throughout. Although Cereal type pollen is found in several samples it was not identifiable to species level, except at 70cm where they were of Hordeum type (Table 6•1). Plantago lanceolata stays at around 2%T.L.P., but Pteridium rises to over 4%T.L.P. and several species such as Plantago media/major, Ranunculaceae and Artemisia occur at greater than 1%T.L.P. There is little change in most tree and shrub pollens at the boundary with the next sub-zone except for a recovery in Corylus/Myrica and a much smaller recovery in Quercus. Sphagnum spores again reach very high levels.

c) 67•5 – 42•5cm. Corylus/Myrica is reduced and Betula and Alnus remain low with only occasional grains of Quercus represented. This sub-zone records the lowest A.P. plus shrubs count evident in the diagram except for the topmost samples in H8. There are few distinct peaks for N.A.P. although Plantago lanceolata occurs at up to 4%T.L.P. Cereal type pollen is present at 50cm and 55cm and is of Triticum type (Table 6•1).

H7 42•5 – 25cm

The upper boundary is taken where Calluna increases and Betula values decline.

The main feature of H7 is the rise in Betula to over 30%T.L.P. with a lesser rise in Alnus. Both Gramineae and Calluna are low relative to earlier zones and there is less variety in the N.A.P. count. Plantago lanceolata is still present, but, as the Group A herb curve shows, herb pollen is generally low. This zone does however have the highest Sphagnum values encountered at Heatheryhaugh.

H8 25cm – top of diagram

Betula values are reduced to less than 10%T.L.P. and all other tree and herb taxa show a decline. Calluna dominates the N.A.P. at up to 48%T.L.P. with only a slight increase in Gramineae and other herbs, and records of Hordeum type cereal pollen. Values for Sphagnum gradually decline towards the surface.

All the last three zones occur within predominantly Sphagnum peat of varying humification and there are two bands of well humified peat between 114 - 120cm and 63 - 71cm.

c) Statistical zonation of the profile

Statistical analysis for the determination of assemblage zones using SPLTINF and SPLTLSQ methods (Gordon and Birks, 1972) was carried out for those taxa which contributed at least 2%T.L.P. to the pollen sum. The results of this analysis up to the seventh division providing eight groups are presented in Table 6•2. There is more disagreement between the groupings established by the two methods at Heatheryhaugh than for Stormont but this is to be expected as visual examination of the data shows less apparent similarity between contiguous levels.

The first division is made either between 480 and 490cm or between 490 and 500cm, equivalent in the latter case to the H2/H3 boundary. This marks the major change in the diagram from high Gramineae and Cyperaceae to the dominance of Betula and Corylus/Myrica. The second boundary is positioned between 125 and 130cm, a level higher than the change between H5 and H6. At this point in the diagram there is again a significant change with a sharp drop in the pollen of trees and shrubs as Gramineae, Cyperaceae and Calluna increase. There is very little difference in pollen content between 130 and 135 cm but rather than place the boundary after these levels it is placed between them thus dividing two zones which have different pollen sequences within them. The third division between 360 and 370cm is based principally on the

Table 6·2 Statistical zonation of the Heatheryhaugh profile

Division	SPLTINF	Residual Vari- ability (%)	SPLTLSQ	Residual Vari- ability (%)
1	(5 - 480) (490 - 590)	66·09	(5 - 490) (500 - 590)	65·29
2	(5 - 125) (130 - 480) (490 - 590)	41·66	(5 - 125) (130 - 490) (500 - 590)	39·78
3	(5 - 125) (130 - 360) (370 - 480) (490 - 590)	32·01	(5 - 125) (130 - 360) (370 - 490) (500 - 590)	30·57
4	(5 - 125) (130 - 215) (220 - 360) (370 - 480) (490 - 590)	26·48	(5 - 125) (130 - 360) (370 - 450) (460 - 490) (500 - 590)	26·67
5	(5 - 125) (130 - 215) (220 - 360) (370 - 480) (490 - 540) (550 - 590)	24·07	(5 - 125) (130 - 215) (220 - 360) (370 - 450) (460 - 490) (500 - 590)	23·99
6	(5 - 125) (130 - 215) (220 - 360) (370 - 450) (460 - 480) (490 - 540) (550 - 590)	21·84	(5 - 125) (130 - 215) (220 - 360) (370 - 450) (460 - 490) (500 - 540) (550 - 590)	21·35
7	(5 - 125) (130 - 215) (220 - 360) (370 - 390) (400 - 450) (460 - 480) (490 - 540) (550 - 590)	20·62	(5 - 15) (20 - 125) (130 - 215) (220 - 360) (370 - 450) (460 - 490) (500 - 540) (550 - 590)	19·73

drop in Corylus/Myrica and rise in Alnus but the lower subjective boundary between H3 and H4 is retained as it marks the empirical limit for Alnus as well as for Quercus and Ulmus, and occurs within part of the diagram where values for Betula and Corylus/Myrica tend to vary considerably.

The next three divisions are common to both techniques but are not necessarily made in the same order. The statistical boundary between H4 and H5 is again placed one level higher than the subjective division but the subjective boundary is retained as it marks the first reduction in A.P., particularly Betula. The division at 450/460cm which is produced statistically has no subjective parallel. It is made largely on the basis of complementary changes between Betula and Corylus/Myrica, a change which had already begun at the H2/H3 boundary, at the statistical division between 480 and 500cm, hence a further boundary was not felt useful at this point. The change indicated between 540 and 550cm is determined mainly by changes in Betula and Cyperaceae but the subjective boundary between H1 and H2 is retained as it occurs where Gramineae values become consistent and where the Betula curve levels off.

The remaining two divisions defined statistically are unique to each approach. SPLTLSQ produces a division between 15 and 20cm, again a level above the subjective H7/H8 boundary but the subjective boundary is retained as it marks the point from which Calluna values consistently rise. The division between 390 and 400cm defined by SPLTINF agrees with the H3/H4 boundary but is not found at any further division by the SPLTLSQ method. The differences in the boundaries defined by the two approaches are not seen in the amount of residual variability left in the data for although SPLTINF is less efficient at classifying the data the variation in the figures at each level of division is never more than 2 per cent and usually less than 1 per cent. By the sixth division neither approach is able to explain as much variability in the data as at Stormont.

d) Vegetation history

The earliest polleniferous deposits represented at Heatheryhaugh in zone H1 contain an assemblage dominated by N.A.P. indicative of an open treeless landscape. Gramineae and Cyperaceae are the main contributors but there are several taxa indicative of open and disturbed ground such as Compositae lig., Artemisia, Rumex, Ranunculaceae, Umbelliferae and Saxifragaceae. With the change in stratigraphy from coarse gravel to peat there is a gradual rise in Betula and shrub pollen and a concomitant reduction in Gramineae. Unlike in the Late Devensian/ Flandrian transition deposits at Stormont the basal N.A.P.-dominated assemblages do not show high values for herb taxa other than for grasses and sedges and it would appear that the open landscape was already under an almost continuous grassland cover by the time sediment accumulation began with only slight evidence for broken ground and a continuation of solifluction. The presence of Filipendula at higher values than other herb taxa also suggests that temperatures were rising as it is a characteristic component of the warmer phase of the interstadial and the Late Devensian/Flandrian transition at Stormont.

With the increase in birch there are also peaks for Juniperus and Empetrum but there is no pattern of successive peaks for shrub species often found at Early Flandrian sites. This lack of any straightforward succession of shrubs may be explained by the wide sampling interval which is not fine enough to pick up relatively short term environmental changes, as emphasised in the Late Devensian record at Stormont, for the same problem is encountered at the Late Devensian/Flandrian transition in Strathmore. At the higher site of Heatheryhaugh this may only partly be the answer, for H1 and H2 which cover the period of birch expansion show the continued presence of shrubs as well as taxa characteristic of open ground and this may be a function of the slower response of the higher area to improving climate. H1 shows only a slight rise in Betula, no sudden expansion of birch woodland, but this was not due to any extensive local development of either Empetrum heath or the Juniperus thickets characteristic of the previous interstadial. The 'prolongation' effects suggested by Pennington (1977a) for the Late Devensian can probably be observed here at Heatheryhaugh in this later period where they would have been exacerbated by the exposure of the plateau area tending to suppress the development of birch woodland. The presence of Pinus at up to 2%T.L.P. is not enough to indicate local presence and is low even in a Late Devensian context. During H1 therefore there would have been a slowly changing pattern of communities with grassland and pockets of dwarf shrub heath. The high frequencies for Cyperaceae, which at Stormont were assigned to either a sparse vegetation cover comparable to present vegetation on summit areas or possibly a sub-Alpine grassland (H.J.B. Birks, 1973a), may here be due as much to the local presence of sedges in the stratigraphy. This further seems likely as the herb taxa characteristic of the grassland phase at Stormont are not well represented at Heatheryhaugh.

Although Salix frequencies are higher than any other shrub species this could also be due to the local presence of willow on the bog surface as small wood fragments are found in the peat. The peak for Salix in H1 at 6%T.L.P. is sufficient to indicate scattered local presence (see Chapter 4). The high frequencies for Filicales are interesting in this context for in view of the proposed open nature of the local vegetation cover during H1 they would be unlikely to be derived from outside the bog. In a part of the diagram where pollen is sparse such spores may be overrepresented but still require a source and this could probably be from within the developing Salix fen which often includes Thelypteris palustris. Such a community implies a relatively stable surface and a slow rate of peat development.

H1 does not correlate directly with any assemblage zone found at Stormont Loch for it reflects a period of delayed birch development after the disappearance of those herb species such as Rumex, Artemisia, and Thalictrum which were important constituents of the stadial landscape. The presence of Compositae lig. as an important constituent of the herb flora in the lowest samples of H1 suggest comparisons with Corrydon where it persists well into a Betula assemblage zone. This, and the persistence of other open ground species in the Early Flandrian at Corrydon suggest similarities between the Forest of Alyth and the area to the north in Glenshee rather than to the south in Strathmore. The period covered by H1 is clearly the III/IV transition (sensu Godwin/Jessen) but the low dwarf-shrub frequencies make more exact dating difficult. Nevertheless with rising birch and the absence of curves for Rumex and Artemisia it would appear that sedimentation began prior to 10000b.p. but probably not before 10200b.p.

The general slow expansion of birch continued in H2 but even by the end of this zone A.P. only comprises 50%T.L.P. indicating open canopy birch woodland with at most a cover of 35 to 40 per cent (H.J.B. Birks, 1973a). The empirical limit for Corylus/Myrica occurs before the main peak for Betula unlike Stormont where the rational and empirical limits occur simultaneously. This could either reflect the delayed expansion of hazel at the higher site after its immigration into Strathmore or be due to the higher site, with its more open vegetation cover, showing a greater representation for long distance transport which during this period of hazel immigration would obviously have comprised a lot of Corylus/Myrica pollen. Although hazel eventually expanded rapidly at Heatheryhaugh the former hypothesis seems the more likely for it has already been argued that exposure may have been an important restricting factor on early woodland development on the Forest of Alyth with the woodland fringe only slowly encroaching over the plateau surface. The effects of exposure with the cooler temperatures at this altitude could account for its delayed expansion despite its presence in Strathmore. The possible effect of long distance transport from newly colonised areas must not however be underestimated with the existence of a very open birch woodland.

H2 shows the highest Pinus frequencies in the diagram with a peak at the transition between H2 and H3. Values for Pinus are similar to those in S2 at Stormont, also a Betula assemblage zone, and they were assigned there to long distance transport by means of a comparison with the representation of Pinus pollen during the Loch Lomond Stadial. Because of the continuous presence of Pinus throughout S2 and S3 comment was made on the possible local presence of Pinus within the Boreal as postulated for northern England by Bartley et al. (1976) and Pennington (1970). In view of the low Pinus frequencies in H1 it is difficult to use the argument of long distance transport for H2 shows a generally thicker woodland cover. Some of the pollen may therefore have been locally derived from pockets of pine woodland in the southern Grampians which may have existed up to 2000 years before its general expansion in Scotland. Why such areas were not more extensive remains difficult to understand although they may have been restricted by unsuccessful competition with hazel which had begun to expand by the beginning of H3.

With the continued delay in the spread of woodland, areas of open ground dominated by grasses and sedges, with the occasional presence of

Artemisia, *Rumex* and Ranunculaceae, remained into the Boreal with patches of juniper and *Empetrum* heath. The continued high values for Cyperaceae reflect both local bog presence and probably its presence in open ground communities. It could be argued that all Cyperaceae pollen was locally produced on the bog, and that, accounting for this in the pollen sum a more closed woodland could be interpreted, similar to that found at Stormont. The persistence of *Juniperus*, *Empetrum*, Gramineae, *Artemisia*, Ranunculaceae and *Filipendula* militates against this view however as they would be unlikely to be present under an almost closed woodland canopy, although *Filipendula* could probably have been found as a component of the *Salix* fen. When values for Cyperaceae fall at the H2/H3 boundary the percentage of A.P. is still low relative to Stormont.

The local development of wood peat which is the dominant peat type after 520cm is reflected in the consistent values for *Salix* as well as increasing *Betula* but the presence of *Sphagnum* spores shows that the water table within the fen was still high with waterlogging and increasing acidity, features which had already in this early part of the Flandrian probably determined the later succession to raised bog (Walker, 1970). It is difficult to reconcile the increasing proportion of *Sphagnum* with the continued levels for Filicales unless the latter all now derived from the local woodland. The corresponding increases for these spores must represent either differences within the expanding bog itself or, at least in part, the development of a fern understorey within the birch woodland as occurred in Strathmore.

Both *Empetrum* and *Calluna* rise towards the end of H2 and in the latter case this marks the start of a continuous curve throughout the Flandrian. *Calluna* was probably already present on drier areas of the bog surface although it may also have been a component of the woodland, especially on shallower soils. The rise in *Empetrum* is an unusual feature but it does persist throughout the *Betula* - *Corylus/Myrica* assemblage zone, at Corrydon until the expansion of *Pinus*.

The *Betula* assemblage zone H2, is characteristic of Zone IV and found throughout Scotland (e.g. Donner, 1962; Vasari, 1968; Moar, 1969c). At this altitude there is insufficient *Juniperus* to be able to define a *Betula* - *Juniperus* assemblage zone as found elsewhere in the southern Grampians at Tynaspirit 2, Amulree 2, Cambusbeg and Corrydon (Walker and Lowe, 1977; Walker, 1977). At Stormont the principal expansion in *Betula* pollen is assumed to have taken place by c.9800b.p. and that *Corylus/Myrica* appeared by c.9200b.p. or just after. Birch may have begun to expand as early as 9800b.p. at Heatheryhaugh but its main peak may have been delayed to after 9200b.p. if the earliest presence of *Corylus/Myrica* at Heatheryhaugh occurred at the same time as at Stormont. The rising values for *Corylus/Myrica* marking the expansion of hazel after the H2/H3 boundary probably date to after 9200b.p. as indicated by the date from Carey. It may be that the early peak in *Pinus* at Stormont correlates with the rise in *Pinus* in the early part of H2 and that the higher later values at Heatheryhaugh indicate the presence of more suitable habitats for pine within the Grampians, but the contribution of *Pinus* throughout H2 makes such a correlation uncertain.

Zone H3, a *Betula* - *Corylus/Myrica* assemblage zone, which marks the further spread of woodland lies entirely within wood peat. *Corylus/Myrica* pollen eventually reaches a peak of 61%T.L.P. at 420cm, a value indicative of a canopy cover for hazel of up to 95 per cent (H.J.B. Birks, 1973a), unless *Myrica* was a significant element in the bog community and contributed to the local pollen sum. With the expansion of birch-hazel woodland all the taxa characteristic of open ground communities found during H1 and H2, including Gramineae and Cyperaceae, are severely reduced or disappear with the exception of Empetrum and Calluna. The presence of these ericaceous species is the main difference between the Betula - Corylus/Myrica assemblage zones at Stormont and Heatheryhaugh for in Strathmore there is no evidence for any understorey species in the pollen record. It appears unlikely that Empetrum formed part of the woodland community for no Betula - Corylus woodland today shows a significant presence of the shrub but Vaccinium-rich birchwood can contain Corylus to abundant status. Both Empetrum hermaphroditum and Calluna vulgaris occur in damp heather moor, the Vaccineto - Callunetum of McVean and Ratcliffe (1962), but this community is now a western, more oceanic phenomenon and thought to be a community derived from woodland or scrub. The high values for Calluna probably indicate its local presence in the bog communities and it may be that due to local site conditions as the fen woodland became more waterlogged the increasingly nutrient poor and wetter status of the bog allowed the development of pockets of species composition similar to that of damp moor today. There is no change in the basic form of the peat but there is some evidence for another change in the local site conditions with the reduction in Salix and Filicales and higher Sphagnum, further indication of the change to a more acidic, ombrotrophic bog.

As at Stormont it is not until after the main expansion of hazel that the empirical limits for Alnus and Quercus occur but at Heatheryhaugh the rational and empirical limits are simultaneous whereas at Stormont, at least for Quercus, there is some differentiation between the two. The empirical limit for Quercus probably occurred at the same time at both sites for there is an increase at Pinus at the same point in both diagrams.

As stated earlier when discussing the record at Stormont a Betula -

Corylus/Myrica assemblage zone can be found at most sites throughout Scotland (H.H. Birks, 1970) and the rest of Britain, and occurs in the Grampians at all analysed sites. At Corrydon it is zone C8 but with the higher altitude there is a noticeable reduction in the maximum values for Corylus/Myrica pollen with the pollen of open ground species persisting well into the Middle Flandrian.

The change from H3 to H4 which is defined where the pollen of Ulmus, Quercus and Alnus appear consistently is also marked by a change in the stratigraphy from wood peat to raised bog peat dominated by sedges and Sphagnum. Unlike Stormont the arrival of the remaining elements of mixed deciduous woodland did not lead to any significant change in the local woodland structure for Ulmus never exceeds 7%T.L.P. and Quercus 10%T.L.P. Areas of mixed deciduous woodland must have been very restricted on the plateau, probably to below 300 metres, the postulated limit for Quercus robur (Jones, 1959), and then mainly on richer and more sheltered sites. Elm was almost certainly restricted solely to valley of the Ericht and its slopes and to the lower, richer soils within the fault zone to the south of Heatheryhaugh although there may have been small pockets of suitable enriched soils within the birch-hazel woodland where exposure was reduced. Birch remained the dominant feature of the woodland with hazel and the zone with its oscillating curves for these species appears to demonstrate one of the characteristic features of birch woodland, that of its inability to regenerate directly, due probably to root competition. This tends to lead to an even-aged stand, or one with trees of two distinct ages, which eventually becomes moribund, allowing a pioneer species, in this case mainly hazel but also alder, to establish itself within the "familiar mosaic pattern of birch regeneration" (McVean and Ratcliffe, 1962). The importance of birch and the inability of pine to establish itself confirms the earlier findings of Durno (1959) that pine forest only became dominant on Speyside and in the Northern Grampians.

Within the birch-hazel woodland alder was a more important element than either oak or elm but not just as a result of the greater availability of wet sites around the peat-filled hollows. There is no stratigraphic evidence for any alder fenwood in the basin and although alder may have been well represented around the bog margins the continuous high values suggest a more widespread presence probably due to the more variable canopy cover of the woodland at this altitude. The curve for Alnus shows a double peak in H3 similar to that found at Stormont but again there is no evidence in the peat stratigraphy for increased dryness so the pattern is difficult to interpret. It would appear that the arrival and establishment of alder took place at a similar time on the Forest of Alyth to Strathmore, the greater availability of suitable habitats allowing more rapid consolidation than was possible for oak and elm. Furthermore the second rise in alder is comparable to the Boreal-Atlantic Transition of Mitchell (Smith and Pilcher, 1973) with decreasing Pinus and, as at Stormont, reduced Betula and Corylus/Myrica. Assuming the comparisons with Stormont are valid this would place the second Alnus rise at Heatheryhaugh at c.6600b.p. and imply that peat accumulated at a rate of 100cm/1000 years in the first half of H4, a rate which appears high compared to other sites (Walker, 1970). The apparent rapid accumulation may be due to incorrect estimation of the dates, particularly the opening of H4 which could be earlier than postulated and hence not delayed, or may be due to a genuine phase of rapid peat accumulation. It is noticeable that as there are no remains of Calluna in this part of the stratigraphy this could also be taken as an indication of increased wetness and rapid peat growth. The occurrence of wetter conditions at this time is however unlikely considering the period of dryness used to explain the double rise in Alnus at Stormont and on Speyside (O'Sullivan, 1975). Thus either the earlier dates are wrong or the double rise at Heatheryhaugh is not comparable with Stormont and hence of a different date. The trough between the two peaks at Heatheryhaugh is not as pronounced as at Stormont and it may be that a genuine disappearance in alder is restricted to lake-marginal sites, the apparent changes at Heatheryhaugh being due to the variable nature of the woodland structure as previously suggested.

With the immigration and establishment of alder by c.6500b.p. at the latest this part of the Forest of Alyth was covered by an Atlantic forest of relative stability as was Strathmore. The variability between birch, hazel and alder did not represent any inherent instability rather the dynamic nature of the community with regard to its dominant species. In its lower representation of mixed oak forest species the Forest of Alyth compares well with the lowland Aberdeenshire sites of Moore's Group F (1977) which are defined by higher birch and lower oak than groups to the south but still shows similarities with Donner's sites from western Perthshire, classified as Group B, with low Pinus. Thus during the Atlantic the boundary between mixed oak woodland and birch-hazel woodland probably lay within the Boundary Fault area with some extension of mixed oak woodland into the lower ends of the glens but the distinction between the two main woodland types was by no means clear cut for both were composed of the same principal species but in different relative amounts, especially of oak.

The apparent stability in the woodland of the Forest of Alyth is disturbed at two points within H4. Between 310 and 300cm there is a reduction in Ulmus frequencies from 6%T.L.P. to 2%T.L.P. which leads to a period of low sustained percentages until there is a recovery to between 4 and 5%T.L.P. at 280cm. This is thought to represent a local change in the woodland due possibly to the earlier expansion of elm onto sites which either became too leached or too exposed for continued regeneration rather than to correlate with the Elm Decline. Similar reduced frequencies are often found at sites where values for Ulmus are generally low as for instance at Loch Clair where reduced frequencies occur at 3400b.c. (Pennington et al., 1972) at Din Moss (Hibbert and Switsur, 1976) and at Thorpe Bulmer (Bartley et al., 1976). There is no other evidence for any woodland clearance associated with the reduction in elm and the only other species affected is hazel allowing greater representation of birch and alder. Had elm been reduced due to climatic change then some change might also be expected in oak which was probably growing close to its climatic limit (H.J.B. Birks, 1977) but this does not happen. Furthermore if the date of c.6500b.p. is correct as a latest date for the second alder rise then, assuming synchroneity of the Elm Decline, only 20cm of peat would have accumulated in 1600 years.

At 260cm there is a decrease in Ulmus and Quercus with rising values for Gramineae and the appearance of occasional grains of Plantago lanceolata, Plantago media/major, Ranunculaceae and Pteridium. This change only lasts for two levels but after this the curve for Gramineae remains higher than before although A.P. and shrub pollen return to the levels found earlier in H4. The effect of these changes on the general forest cover is masked by the oscillating nature of the main curves, especially Betula and Corylus/Myrica, but whatever the exact nature of the alteration the effects were only temporary. As the later decline in Ulmus which marks the H4/H5 boundary is taken to be equivalent to the Elm Decline these changes in the vegetation cover are presumed to be pre-Neolithic and, as at Stormont, could have been due to the activities of Mesolithic communities, possibly firing the forest to drive game, but in view of the fact that only oak and elm were really affected this seems unlikely, especially as the birch-hazel woodland would probably have been more attractive to a hunter-gatherer community (Smith, 1970). In other areas of the British Isles, particularly in the South West, natural fires are recorded in upland areas throughout the Atlantic (Simmons, 1964, Brown, 1977), and such fires, usually initiated by lightning, could have accounted for the changes recorded at Heatheryhaugh. There is no evidence of charcoal in the peat stratigraphy and with the selective change in tree pollen curves rather than a general reduction these changes remain enigmatic with the possibility always remaining that at this site the Elm Decline was not the severe change seen at Stormont and that there was a complete recovery in the woodland following it.

By the end of H4 the pollen record at Heatheryhaugh shows the structure of woodland on the southern fringe of the Grampians at c.5000 b.p. On the plateau surface of the Forest of Alyth the dominant community was a relatively dense birch-hazel woodland, probably largely composed of uniform stands due to the nature of its development with alder interspersed and on the wetter margins of the peat. The status and location of oak and elm is more difficult to infer. They would both have been found within the woodland but usually only on more sheltered and base-rich areas but the importance of these two species would have increased with distance away from the site to the south into the fault zone and to the west towards the valley of the Ericht.

The break between H4 and H5 occurs immediately before the main drop in *Ulmus* pollen, taken to record the Elm Decline, and marks the first noticeable phase of woodland clearance at this site. Within H5 the three sub-zones which have been defined each show separate phases of clearance of differing intensity. At the opening of H5a there is a clear reduction in all woody taxa and particularly Ulmus which drops from 3 to 1%T.L.P. Betula, Ulmus and Corylus/Myrica were first affected with a later fall in Quercus and Alnus. In sites such as Heatheryhaugh where Ulmus frequencies are never high the definition of a clear Elm Decline is uncertain but here, using the arguments for the dating of H4 outlined earlier, this fall in Ulmus pollen after which values rarely reach 1%T.L.P. is taken as the Elm Decline and therefore considered to date to c.3100b.c. Unlike Stormont there is no stepped decline in frequencies but this may be due to the wider sampling interval and the less stable nature of the curves in the pre-clearance period.

At the lowest values for A.P. and shrub pollen in H5a there are peaks for Gramineae and Calluna, and Plantago lanceolata, Rumex and Pteridium all occur throughout the sub-zone. It would appear that around Heatheryhaugh there was a close relationship between clearance and the fall in elm frequencies although more general woodland clearance was taking place. Clearance may have been taking place at more than one location for both mixed oak forest elements were affected and the local birch and hazel. The overall reduction in the pollen of woody taxa of 30 per cent clearly reflects local clearance but as oak and elm were thought not to be important around the site woodland either to the south or west must have been affected as well. The reduction in tree pollen may be overemphasised by the high Calluna counts, most of which probably derived from the bog as seen in the presence of Calluna stems in the stratigraphy. The low values for herb taxa suggest only pastoral agriculture for there is no evidence of any cereal cultivation but most of this pollen would only have derived from the local clearance. The temporary nature of the clearance is seen with the regeneration of hazel and alder and to a lesser extent oak. Despite the fact that values for tree pollen in general never again reach the levels found in H4 there is little evidence for any widespread expansion of secondary woodland and one of the main characteristics of the changes was the creation of areas which remained open, either due to suppression by increased exposure or continued light grazing pressure. The absence of any direct evidence for secondary woodland is however complicated by the nature of the original woodland cover dominated as it was by birch, alder and hazel which in Strathmore formed the secondary woodland. At Heatheryhaugh the reduced pressure of land clearance allowed in particular hazel and alder to recover. The pattern of change in H5a closely resembles that of a 'landnam' with a series of small clearings but there is no evidence for cultivation as is usually found (Smith, 1975). The extended pattern of clearance, utilisation and regeneration reflects a more complex sequence of activity than is perhaps usually considered as a landnam probably covering a period of a few hundred years considering the amount of peat that accumulated, increasingly a characteristic feature of early land clearance.

The second phase of clearance in H5b similarly shows reduced frequencies for Quercus, Alnus and Betula but there is little change in Corylus/Myrica and indeed at one level values for hazel rise. At the lowest values for these reduced species there is a noticeable peak for Gramineae with Plantago lanceolata, a Cereal type grain and an increased variety of other herb species such as Artemisia, Rumex, Pteridium, Compositae lig., Cirsium, Chenopodiaceae, Cruciferae, Caryophyllaceae and Umbelliferae. Clearance at this time was probably restricted to new areas not those previously cleared and recolonised by hazel, again probably nearer the southern margins as seen in the lower oak values, but with birch and alder both affected it is impossible to define the area or areas affected more closely. The higher values for Plantago lanceolata, over 10%A.P., again imply pastoral activity but with a Cereal type pollen and the suite of herbaceous taxa represented some cultivation must have been taking place. Despite the presence of weeds associated with arable activity there is very little change in the Pastoral:Arable ratio compared with surrounding zones. The failure of Calluna to increase may have been due to its reduced local presence on the bog but could also reflect a more organised and better managed form of land utilisation which did not lead to any deterioration in the soil and spread of heather, especially if areas previously opened were not reopened. Although apparently the time of greatest activity and diversity of use in H5 it could be argued that H5b represents clearance closest to the site thus showing up as a greater reduction in A.P. and in a wider variety of herb pollen actually reaching the bog surface. Regeneration of all the affected tree species at the end of the sub-zone took place, a further indication that land utilisation during this period did not lead to any more lasting disturbance of the local environment.

Following H5b there was a period of general woodland expansion with, in particular, birch and hazel extending over previously open areas but this was interrupted in the later part of H5c by a brief reduction in all tree and shrub species and higher values for Gramineae and Calluna. This phase did not see any noticeable increase in herb taxa except for Artemisia, and Plantago lanceolata never reaches more than 1%T.L.P. After this recession all woody taxa increased but alder was the only tree to reach comparable levels with H4 and obviously increased its local importance. The slight changes recorded in H5c, although recording some woodland clearance, only probably mark clearance taking place at some distance from the site.

The main change in the vegetation of the area around Heatheryhaugh between the beginning and end of H5 was undoubtedly the creation of clearings dominated mainly by grasses but with some heather, some of which remained open throughout the zone and never reverted to woodland. The pattern of human activity may be explained as three periods of different intensity of use although all were probably dominated by a pastoral agriculture, except for H5b which included some cultivation. This interpretation is very largely based on the severity of the changes in the pollen curves and such a straightforward relationship may be an oversimplification. Utilisation of the Forest of Alyth may have been continuous but varied spatially such that at Heatheryhaugh clearance was only recorded when it occurred within a certain distance of the site, possibly only within one kilometre. The reduced levels of woodland relative to the cover of the earlier Atlantic forest which occurred between clearance phases could have been due to continued light grazing, even of a transhumant nature, rather than abandonment and restricted regeneration due to climatic or edaphic limitations. Where local clearance was recorded as in H5a and H5b then this must have reflected some continuity of settlement in the vicinity of Heatheryhaugh.

Dating of H5 may only be done by inference but it seems to have begun at c.3100b.c. and, assuming the same rate of accumulation of peat as postulated for the latter part of H4, it could have lasted to c.1550b.c. The lower humification of the peat covering H5 may indicate a higher rate of peat accumulation which would therefore provide a shorter time span for the zone producing a terminal date of only 1800b.c. or even earlier. Between 172 and 173cm there is a distinct band of well humified Sphagnum peat which, on the earlier rate quoted would date to c.2300b.c. and therefore correlate tentatively with the recurrence surface RY5. Whatever the precise dating of H5 the phases of forest clearance probably lasted at least 300 years each and reflect human activity in the area during much of the Neolithic and early Bronze Age. Given the indications of human modification of the forest in Strathmore at this time such activity is perhaps not surprising and the more extensive nature of clearance at the higher site accords with the idea of the preference of lighter more easily cleared woodland by early communities. Furthermore the Forest of Alyth would have been closer to the altitudinal limits of woodland and an economy based largely on pastoralism would have had access to more open grazing. The absence of any Neolithic remains from the plateau is surprising considering the record from the vegetation but in view of the high density of later remains, particularly hut circles, it may be that much of the evidence for settlement was destroyed during later periods of land utilisation, especially if the same areas were being used. The later phase of H5 could then be represented by the stone circles and cairns which lie peripheral to the plateau and may date to the late third millennium or early second millennium b.c. What is more, excavation of these features could, as at Moncreiffe House and Croft Moraig, show earlier structures which could here relate to the earlier clearance phases. Although constructed within an environment in which woodland clearance was taking place there would still have been a large proportion of the plateau under woodland and the location of circles and cairns on ridge crests may have been in part a response to the need for intervisibility.

The deforestation which occurred at the opening of H6 was the most severe alteration of the local vegetation communities to take place under the influence of human groups during the prehistoric period. The reduction in Betula which had recolonised some of those areas cleared during H5 shows some reopening of secondary woodland and the lack of any reduction in Quercus suggests that much of this pollen derived from lower ground which was avoided as human communities spread onto the Forest of Alyth, and even up onto the highest areas. At the lowest levels for A.P. in the first sub-zone within H6 there are very high values for Plantago lanceolata but no expansion of other weed taxa beyond the levels encountered in H5. With the decline in herb frequencies at the end of H6a only birch regenerated with little change in hazel. Although defined as a sub-zone on the basis of the apparent pattern of clearance, utilisation and regeneration there are elements within the pollen record that argue for some continuation of utilisation throughout H6 as a whole. Late in H6a as birch regeneration was taking place there is a record for Cereal type pollen of Hordeum type (Table 6•2) and records for most herb taxa continue across the H6a/H6b boundary. Although Gramineae only increases to values similar to those in the earlier phases of H5 both Cyperaceae and Calluna reach higher figures without any noticeable change in the peat stratigraphy. During H6a the only real indications are for pastoral activity however with grazing taking place near to the site. The lower intensity of activity seen at the end of H6a may again only represent a shift in the location of agricultural activity, not the abandonment of the area as a whole.

H6b shows a very similar pattern to H6a but with higher values for Calluna and Pteridium. It was in this phase that the final elimination of oak took place in the Forest of Alyth and this, with the continued reduction of all other arboreal taxa, reflects a further expansion of the areas opened onto lower ground. There is again a little evidence for cereal cultivation with grains of Hordeum type recorded but still no expansion of arable weeds which could be taken as representative of widespread cultivation. With the reduction in the level of activity at the end of H6b continuity can be seen in the presence of herb taxa across the boundary between H6b and H6c, and there was very little regeneration of woodland. The absence of regeneration could either have been due to continued grazing pressure with human communities still using the area around Heatheryhaugh for intermittent pasture, possibly only seasonally, or to deteriorating soil conditions. It is interesting to note in this context that values for Calluna increase in H6a and in H6b reach over 40%T.L.P. The increased openness and the destruction of the former woodland ecosystem coupled with a period of grazing probably initiated the changes in soil structure which eventually produced the moorland environment of today. From the time of H6b onwards Calluna percentages never fall below 20%T.L.P. and indicate the continuous presence of areas of acid heather moorland which expanded and contracted depending on the degree of human activity.

The final period of clearance recorded in H6c took place on areas of secondary hazel woodland which had regenerated following H6b and again was largely pastoral in nature with dominantly pastoral weeds and only the occasional examples of Cereal type pollen, one of which was referable to Triticum type. The scale of human activity had by this time probably been reduced for there was no further woodland clearance and the apparent impact and extension of agriculture may be overestimated due to the spread of heather and the increase in areas under podsolised soils. The spread of acid soils would have been assisted by increased exposure consequent upon extensive deforestation allowing a greater precipitation:evaporation ratio which itself may have been exacerbated by increased precipitation.

It was with the spread of human communities throughout the Forest of Alyth during H6 that the change to predominantly acidic open heather moorland finally took place amplifying processes initiated earlier in H5. The open nature of the area did not continue to the present day for the end of this zone is marked by the regeneration of birch. The ability of birch to regenerate must indicate a significant reduction in grazing pressure and hence a decrease in the size of the local human communities of some magnitude.

From correlation with the archaeological record the period covered by H6, especially the earlier clearance phases, is probably represented by the extensive spreads of hut circles and possible field systems. It has been argued that these remains could reflect widespread settlement over a limited period of time but the pollen evidence seems to suggest settlement over a much longer period. By extrapolation of the accumulation rates used earlier H6 would fall between c.1600b.c. or slightly earlier and c.1b.c./a.d., dates which would agree with the postulated period of settlement associated with hut circles on the basis of the available evidence from Dalnaglar and Kilphedir. The two well humified bands of Sphagnum peat noted in H6, at 114-120cm and 63-71cm, are difficult to fit within this time scale by comparison with recurrence surfaces but accumulation rates covering this period may already have been affected by peat cutting with demands for fuel outstripping the availability of wood. Even allowing for such a change in rates most of H6 would still have been assigned to the first millennium b.c. Recent work on Dartmoor has dated the settlement of hut circles between 1600-700b.c. (Wainwright, in press) and as Piggott has suggested (1971) there was considerable upland settlement in the early first millennium b.c. which then contracted as climate deteriorated. On Dartmoor the eventual abandonment of upland settlement has been assigned to the extension of peaty soils consequent upon increased precipitation. The same processes appear to be represented at Heatheryhaugh but the final date of c.2000b.p. seems a little late, although the main phase of activity was in the latter half of the second millennium b.c. and lasted well into the first millennium b.c. The abandonment of settlement on the Forest of Alyth and the relationship between it and climatic change obviously requires further examination to see whether the relatively straightforward model of soil deterioration and climatic change is the best to describe the patterns established in the archaeological and paleoenvironmental records. If the estimated dating used here is correct then the process was by no means a simple and sudden one, but a pattern of reduced intensity of land use into the first millennium b.c. would equate with increasing difficulty in utilising land at this altitude successfully.

The regeneration of birch woodland with some alder appears to have been restricted to the Forest of Alyth for the record from Strathmore at Stormont shows no evidence of a period of woodland regeneration in the Late Flandrian. Thus, with the movement of people from the uplands settlement must have continued on lower ground in Strathmore and probably also in the Highland valleys where woodland had also been cleared, but they probably did not utilise the uplands even for seasonal grazing as levels of woodland returned to those found in H5. The deterioration of soils allowed no regeneration of any mixed oak forest elements and there was no return of hazel which was once an important component of the woodland on the plateau.

The final zone, H8, shows the final transition from woodland to an open moorland dominated by Calluna which is the characteristic vegetation of the area today. This change eventually took place probably as a response to increasing demands for grazing and fuel which in turn provided the necessity for peat which heralded the extensive exploitation of peat deposits in the area and particularly around Heatheryhaugh. From the pollen evidence it is not clear when active peat growth finally ceased but it was certainly prior to the eighteenth century for there is no indication of increased values for Pinus at the top of the diagram and it may well have ceased early in the Medieval period given the suggested dates for H6 and H7. Dating of these later zones is perhaps the most difficult in the diagram, as was similarly found at Stormont. Although designated a Royal Forest during the Norman period there need not have been a woodland cover and with only scattered copses remaining into this period the lower southern margins of the plateau would almost certainly have been the first to be completely cleared. In 1566 when the Forestership came under the control of the Lindsays it was designated 'where there are woods' and by this time much of the area was used for common grazing by communities living all around the fringe of the Forest. Pollen analysis of sites in the more northern areas of the Forest may show a more widespread regeneration prior to the Medieval period which then persisted later than the woodland in the south. It is unfortunate that the record at Heatheryhaugh does not record the vegetation of the Medieval period for there is documentary evidence of agriculture to the south and to the east at Tullymurdoch (NO2052) but the dominant land use around the site appears to have been grazing, probably of a transhumant nature as the name Heathery, derived from the Gaelic 'chuith airidhe', implies.

ii) White Hillocks

a) Stratigraphy and sampling

The site at White Hillocks lies to the south west of Heatheryhaugh (Fig. 6•1) at an altitude of c.229 metres in an almost completely enclosed depression immediately below the steep slope which forms the southern edge of the Forest of Alyth plateau (Fig. 6•6). The surface of the peat has been cut over but a position for sampling was chosen near the centre of the bog through a baulk which was assumed to represent

WHITE HILLOCKS

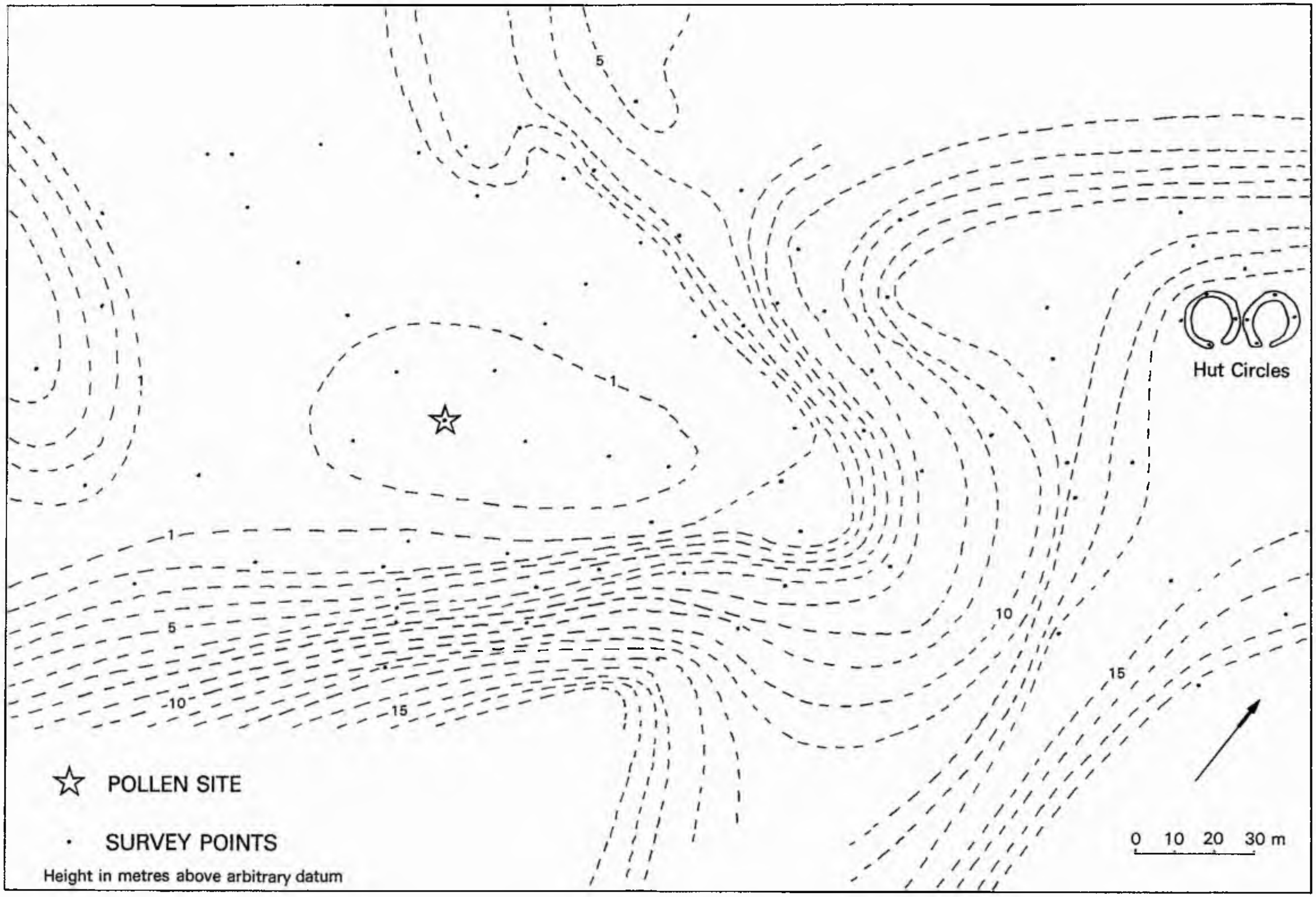


Fig.6.6 Site map for White Hillocks

the former bog surface. Coring proved difficult because, as at Heatheryhaugh, the upper raised bog peat is underlain by a wood peat which here proved impenetrable with a Russian borer and exceedingly difficult to penetrate with a Hiller borer. The nature of the large wood fragments encountered made sampling of the wood peat for pollen analysis impossible at the sampling point and sediment below this level was not reached. The upper peat which was sampled had a straightforward stratigraphy of 1·8 metres of moderately humified Sphagnum peat with Calluna and some Eriophorum remains. As at Heatheryhaugh this was largely dark reddish brown with no recognisable bands of greater humification.

Samples were taken for analysis every four centimetres down the profile and preparation followed that outlined for peats in Appendix II. A count of at least 500T.L.P. was used. Pollen preservation was however very variable and counts of between only 300 and 350T.L.P. were made between 40 and 48 centimetres and at 60 centimetres but no details of preservation were taken. As at Heatheryhaugh all land pollens were included in the pollen sum because of the importance of Calluna and Cyperaceae in the surrounding vegetation as well as on the bog surface. Counting was only carried out down to 84 centimetres as below this level no pollen was preserved. Nearer the wood peat occasional Filicales spores were encountered but no pollen. The reason for this is not readily apparent although similar problems have been encountered in the Ochil Hills (A. Caseldine pers.comm.). Here it may be due to the movement of water through the peat until the outlet to the northwest became cut off by accumulating organic matter and lateral water movement ceased.

b) Pollen assemblage zones

Only two local pollen assemblage zones were defined for White

Hillocks. They are prefixed WH- and detailed below. The pollen diagram based on the T.L.P. is given in Fig. 6•7a and b.

WH1 84 - 26cm

The upper boundary is taken where *Betula* falls and there is a rising curve for *Calluna*.

The zone shows a mixed dominance of arboreal and non-arboreal species. The A.P. is composed largely of *Betula* and *Alnus* with only low values for *Quercus* and *Pinus*. *Corylus*/*Myrica* reaches only 16%T.L.P. but varies considerably throughout. Both Gramineae and *Calluna* also vary but do not show any corresponding patterns. Similarly in the rest of the herb taxa *Plantago lanceolata*, *Rumex* and *Pteridium* are represented but only spasmodically reach above 2%T.L.P.

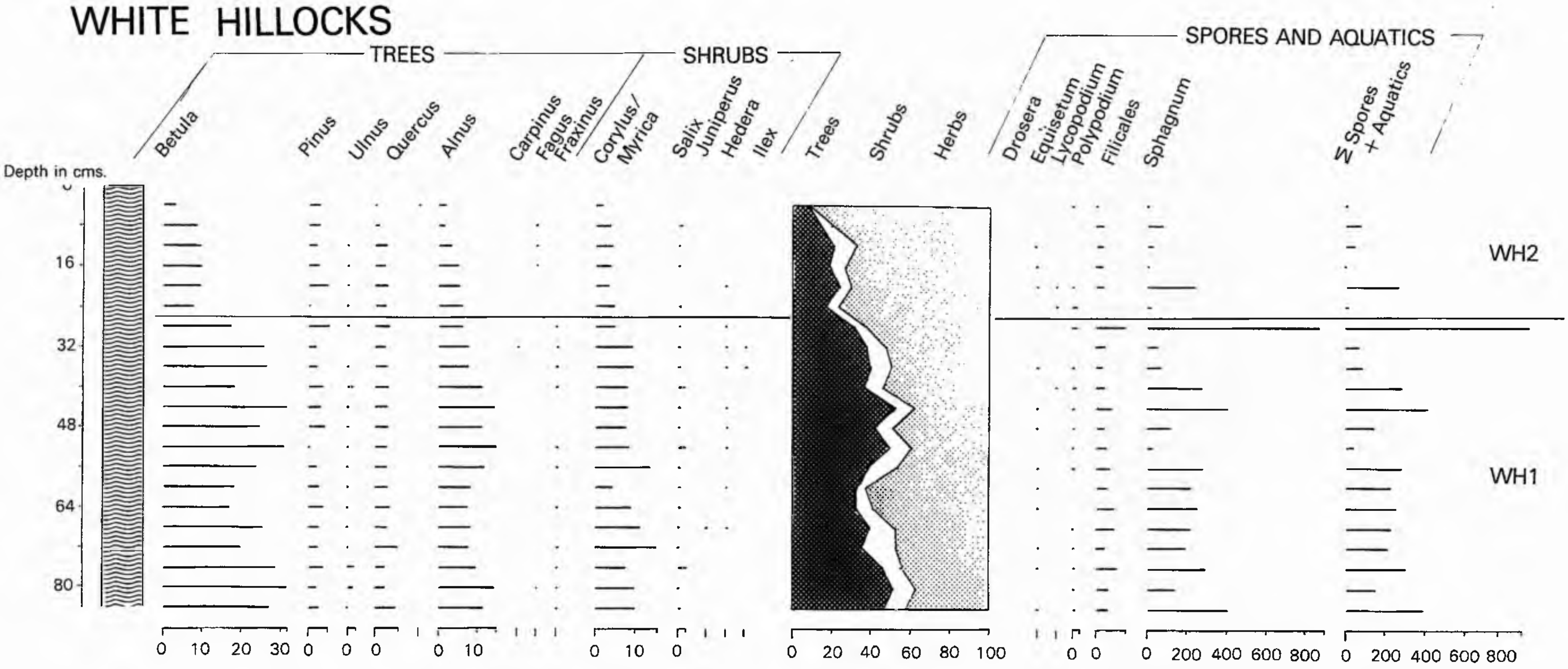
WH2 26cm - top of diagram

WH2 has very low A.P. which decreases throughout the zone until at the top only *Betula* and *Pinus* reach more than 3%T.L.P. The N.A.P. becomes increasingly dominated by *Calluna* with Gramineae only at the same levels as in WH1. *Plantago lanceolata*, *Rumex* and *Pteridium* are present and two *Cereal* type pollen grains appear, only one of which was identifiable to species level and was of *Avena* type (Table 6•3)

No statistical analyses for zonation were carried out on the data from this site due to the low number of levels.

c) Vegetation history and correlation with Heatheryhaugh

The purpose of looking at this site was twofold, to examine vegetational change in association with the nearby hut circles and enclosures, and for comparison with the record at Heatheryhaugh by matching curves, and hence allow clearer definition of the location and extent of clearance. Because of the restricted record and difficulties encountered in estimating the time period covered by the



All are expressed as % T.L.P.

Fig.6.7a Pollen diagram from White Hillocks, trees, shrubs, spores and aquatics

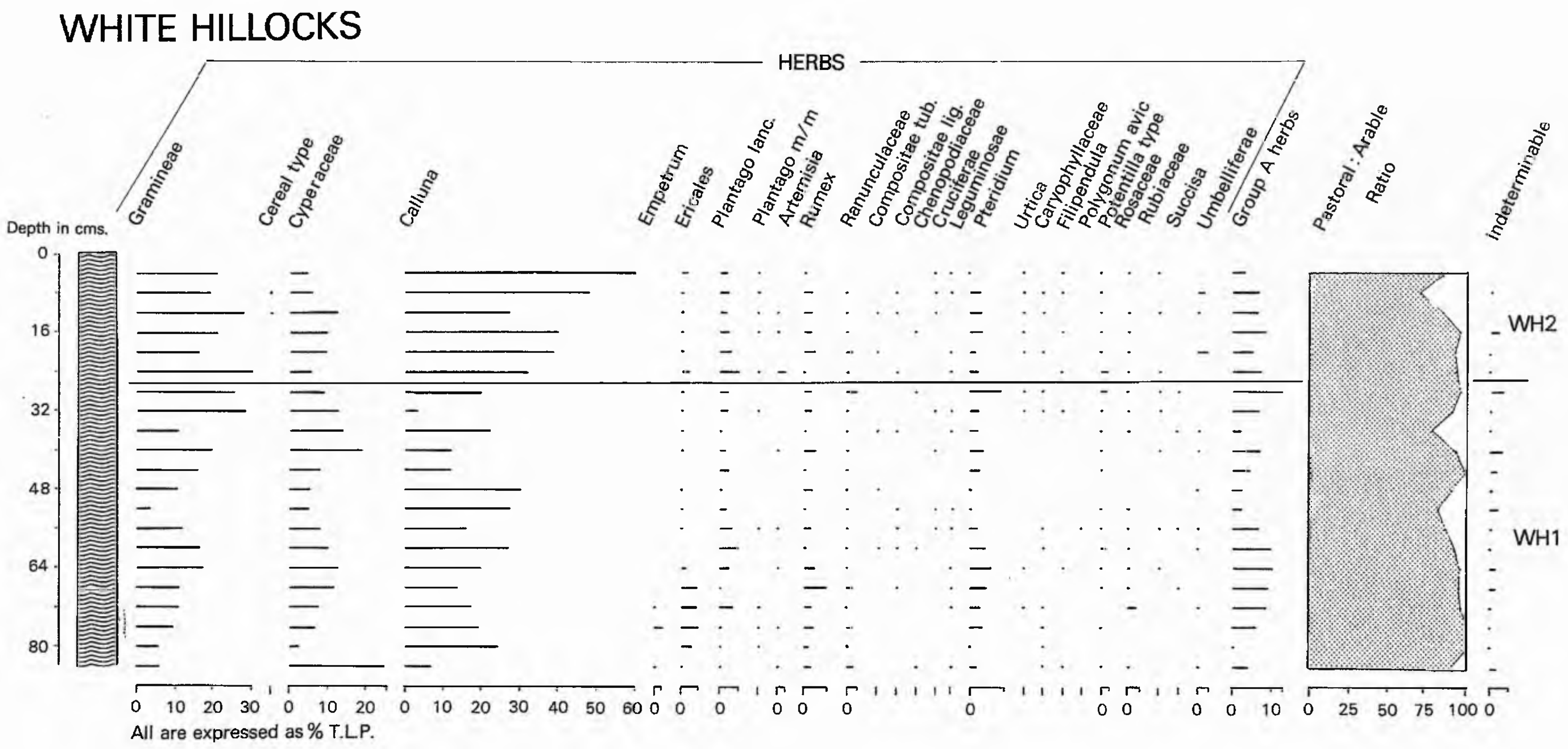


Fig.6.7b Pollen diagram from White Hillocks, herbs

Table 6·3 Cereal pollen types from White Hillocks

Depth cm.	Diameter (µ)	Pore (µ)	Preservation	Sculpturing (Beug)	Species Identification
8	42	11	Crumpled	-	-
	55	13	Good	*Avena* type	*Avena* sp.
12	42	-	Crumpled	-	-

pollen diagram from White Hillocks neither aim was fulfilled.

The lower samples in WH1 have high A.P. and shrub pollen with low Gramineae and Calluna. The pollen of woody taxa is principally of birch, alder and hazel with some oak but within the zone all these are gradually reduced. Although forest clearance was taking place during WH1 the sequence of change is not as clear as at Heatheryhaugh with a rather varied pattern expressed in the principal pollen curves. There is a clear reduction in trees and shrubs to a minimum between 60 and 64cm at which point there are the highest values for Plantago lanceolata, Rumex and Pteridium. Regeneration of birch and alder then took place before a much more marked reduction in these species at the WH1/WH2 boundary but within this phase of regeneration there is a peak for Calluna which may relate only to changes on the bog surface. The scale of change indicated in WH1 is not particularly large with a reduction of only 15 per cent in the A.P. curve as a whole and low peaks for Plantago lanceolata and Pteridium even when expressed as a percentage of the A.P. sum (Fig. 6•8). At the break between WH1 and WH2 the reduction in Betula is more severe with higher values for Plantago lanceolata, Rumex and Pteridium and a considerable expansion in Calluna which, by the end of WH2, is the most important species in the diagram.

Direct correlation with the diagram from Heatheryhaugh is difficult in particular because there are no clear reference levels which occur at both sites. The upper part of the White Hillocks diagram has no rise in Betula comparable to H7 at Heatheryhaugh which provides an easily recognisable reference point but the White Hillocks diagram obviously covers a period of human interference with the vegetation and also probably records recent vegetation development on the site as seen in the very open conditions indicated at the end of WH2 and the rising values for Pinus.

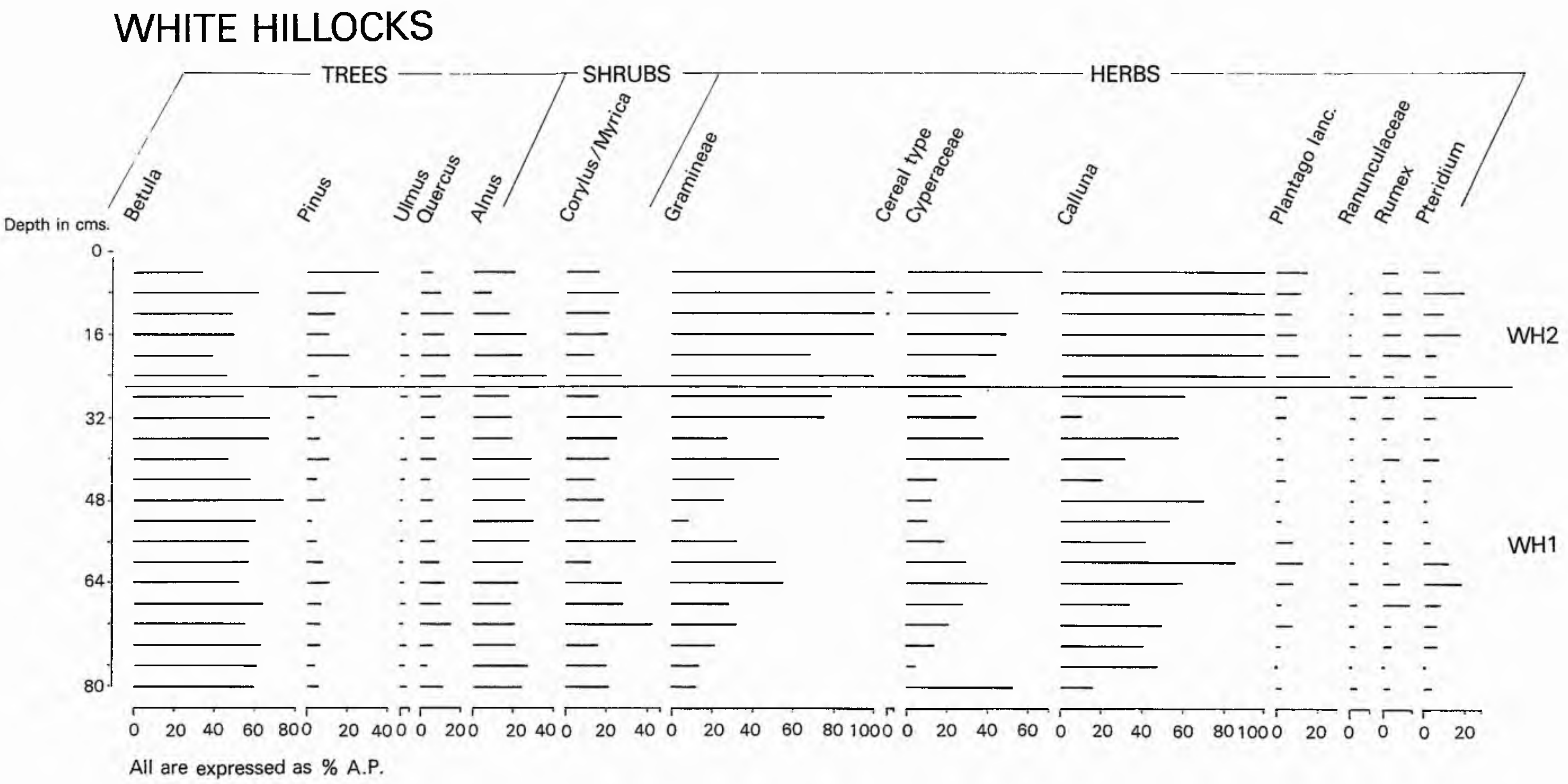


Fig.6.8 White Hillocks, selected taxa expressed as a percentage of the A.P. sum

Despite the difference in location between the two sites the values of at least 40%T.L.P. for A.P. encountered in WH1 make it unlikely that this part of the diagram postdates the H5/H6 boundary but the high N.A.P. frequencies at the end of WH2 indicate a very recent date, possibly postdating H8. The explanation for these apparent anomalies may take one of three forms. Differences in local vegetation development between the two sites could have been so pronounced as to make direct correlation of general A.P. levels impossible with a much more persistent tree cover on the steep slopes around White Hillocks influencing the local pollen sum. Thus the diagram could represent the same time period as from H6 to the present but not show the same degree of clearance as registered in H6 and also not record the rise in birch as a separate event implying a very local expansion around Heatheryhaugh. In view of the results from soil pollen analyses to be discussed later which show similarities in recent vegetation changes between northern and southern parts of the Forest of Alyth the scale of local variation implicit in this explanation is thought unlikely.

A second reason for the dissimilarities may be that the White Hillocks diagram postdates entirely that from Heatheryhaugh with the rise in birch and alder in H7 taking place at the same time as a more general rise in birch, alder, oak and hazel around White Hillocks. The changes recorded in H8 could then be explained as a more recent development following earlier cessation of peat growth. This too is thought unlikely as the more varied woodland structure in WH1 compares well with that found at Heatheryhaugh in the early part of H6 rather than in H7, and the upper samples at Heatheryhaugh cannot reflect particularly recent growth as there is no Pinus, a feature found in all the soil pollen analyses. The unlikely scale of variation between the two sites has already been commented upon.

The third explanation and the one thought the most likely, especially in view of the cut over state of the peat surface is that WH1 and the early part of WH2 do correspond to the early part of H6 but that following this there is a hiatus with the uppermost samples at White Hillocks above 8 - 12cm reflecting recent peat growth. There is some similarity in terms of the overall percentages for species between the later parts of H5 and WH1 although patterns of change in individual curves are not directly comparable. What is more the magnitude of change at the WH1/WH2 compares well with that found in the early part of H6 (H6a/H6b), a reduction in the pollen of trees and shrubs from 50%T.L.P. to 30%T.L.P. or less. There are differences between the two records as with the curve for Quercus which is consistently higher at White Hillocks and present continuously throughout WH1, but this may be expected as the site lies closer to the southern margins of the plateau. The virtual absence of Alnus and the very low frequencies for Betula and Corylus/Myrica in the topmost samples from White Hillocks do not have any corresponding record at Heatheryhaugh as expected and must therefore postdate the end of H8. Furthermore the documentary evidence which shows that deforestation was well advanced by the sixteenth century argues against White Hillocks representing a continuous record throughout the historical period.

Assuming that this final explanation is correct comparison of the general pollen record for WH1 and H6 shows little variation in the composition of woodland between the two areas except for slightly higher birch and oak at White Hillocks and higher hazel at Heatheryhaugh. The higher birch may be due to its presence on the steep slopes on the southern margin of the depression and the oak may have derived from the richer soils to the south. There is also no real difference in the non-arboreal taxa represented nor their individual percentages although the patterns of change cannot be matched and, despite the immediate presence of the hut circles at White Hillocks, which were probably constructed at some time during WH1 or very early in WH2, there is no evidence for cultivation around the site in the prehistoric period. The recent period recorded in WH2 shows the expansion of open moorland characteristic of the area today but with some evidence for continued pasture and cultivation with Cereal type pollen of Avena type. This is similar to the record found in the upper part of the soil profiles analysed and probably records quite recent cultivation around the farm at Heatheryhaugh, although cereal cultivation has now ceased so close to the site. The trend towards open moorland can be seen in the final zone at Heatheryhaugh, H8, so it seems reasonable to assume that this zone precedes the record from the upper samples of WH2.

The removal of peat at White Hillocks appears to have taken place only within the historical period with the record equivalent to H6b, H6c, H7 and H8 being removed by cutting and peat only slowly accumulating again as Sphagnum expanded over the wetter depressions that were left. By comparison with Heatheryhaugh this could have meant the removal of at least 80cm of peat.

iii) Soil pollen analyses

a) Location and Description

Three sites were used for soil pollen analysis to complement the longer peat records at Heatheryhaugh and White Hillocks. Two of these were peripheral to the bog at Heatheryhaugh (Figs. 6·1, 6·2) but the third site was taken from the northern part of the Forest of Alyth at grid reference NO172544 at an altitude of c.340m (Fig. 6·1). This third site at Rannagulzion was the only one sampled from the more northerly part of the plateau and was used to assess the comparability of later soil development there with that in the southern part.

The soil profile sampled to the west of the bog was designated Heatheryhaugh A and is a peaty gley with a thick H horizon overlying the lower gleyed horizons (Table 6•4). The soil profile on the opposite side of the bog, Heatheryhaugh B, was taken higher up the slope than A and showed no signs of gleying with an 8cm thick peaty H horizon overlying a well developed but not very bleached A_2 horizon. The soil appears podsolic but has little visual evidence of the translocation of material in the form of illuviated horizons (Table 6•5). The soil near Rannagulzion Farm was similar to that at Heatheryhaugh B but with a remnant A_1 horizon, more evidence of leaching and redeposition of iron, and a better developed acid mor surface humus clearly divided into L and H horizons (Table 6•6).

b) Sampling and pollen assemblage zones

Samples were taken at intervals down each profile the distance between each sample varying depending on the character of the horizons and the position of the horizon boundaries. The poorly humified H horizon of Heatheryhaugh A which also had a high water content made sampling difficult and the lower g_2 horizon proved devoid of pollen. No such problem was encountered at Heatheryhaugh B but the lower part of the A_2 horizon and the B_2 horizon did not contain pollen. As at Heatheryhaugh B the coarse A_2 horizon at Rannagulzion had virtually no pollen content but in the middle of the B_1 horizon it was possible to obtain a count of 300T.L.P. grains. At all the sites where possible a count of 500T.L.P. was used but in some of the lower horizons this was reduced to 400 as at 21cm in B and only 200 at 23cm and 26cm in A. The pollen diagrams for the three sites based on this pollen sum are presented in Figs. 6•9a-c, 6•10a-c and 6•11a-c.

Local pollen assemblage zones were defined for each soil profile

Table 6·4 Heatheryhaugh A soil profile description

Grid reference: NO183519

Aspect: Northeast

Altitude: c.230 metres

Vegetation: *Calluna vulgaris*, *Erica tetralix*, *Molinia caerulea*, *Nardus stricta*.

Drainage: Poor.

H	0 – 22cm	Dark reddish brown 5YR2·5/2 humic loam with deeply penetrating roots of *Molinia*, generally of a very poor humification, abrupt change to,
g_1	22 – 26cm	Grey 5Y6/1 clay loam with frequent yellowish brown 10YR5/4 mottles and few stones, abrupt boundary to,
g_2	26cm +	Light olive brown 2·5Y5/4 clay loam with coarse distinct yellowish brown 10YR5/4 mottles.

Table 6·5 Heatheryhaugh B soil profile description

Grid reference: NO184520

Aspect: Southwest

Altitude: c.235 metres

Vegetation: *Erica tetralix*, *Calluna vulgaris*, *Nardus stricta*

Drainage: Imperfect.

H	0 – 8cm	Black 7·5YR2·5/0 humus with few recognisable remains and little root penetration, distinct boundary to,
A_2	8 – 24cm	Dark brown 7·5YR3/2 loam with a high humus content and few stones, showing little sign of bleaching, diffuse boundary to,
B_2	24 – 34cm+	Yellowish brown 10YR6/6 sandy loam with numerous fine strong brown 7·5YR5/8 mottles.

Table 6·6 Rannagulzion soil profile description

Grid reference: NO176543

Aspect: Southwest

Altitude: c.340 metres

Vegetation: *Calluna vulgaris*, *Nardus stricta*.

Drainage: Free.

L	0 - 2cm	Dark reddish brown 5YR3/2 humus comprising leaves of *Calluna* showing little humification, diffuse boundary to,
H	2 - 7cm	Very dark grey 2·5YR3/0 grey humus with very little structure and no disturbance by roots, fairly distinct change to,
A_1	7 - 14cm	Dark reddish brown 5YR2·5/2 humic loam, diffuse boundary to,
A_{12}	14 - 18cm	Dark reddish grey 5YR4/2 coarse sandy loam with a high humus content and frequent stones, abrupt boundary to,
A_2	18 - 23cm	Dark reddish brown 5YR3/4 coarse sandy clay loam with frequent stones, abrupt boundary to,
B_2	23 - 33cm	Yellowish brown 10YR5/4 sandy clay loam with many rock fragments, diffuse boundary to,
B_3	33cm+	Yellowish red 5YR5/8 weakly indurated sandy clay loam showing increasing induration with depth.

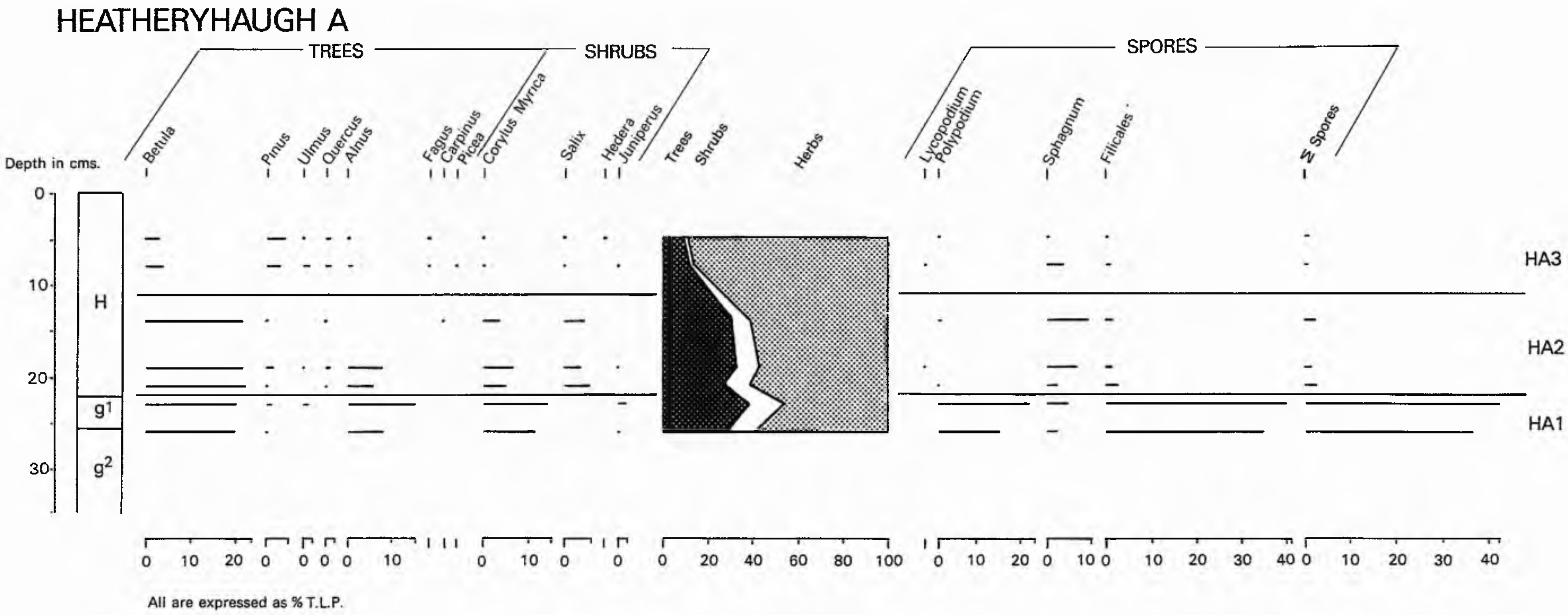
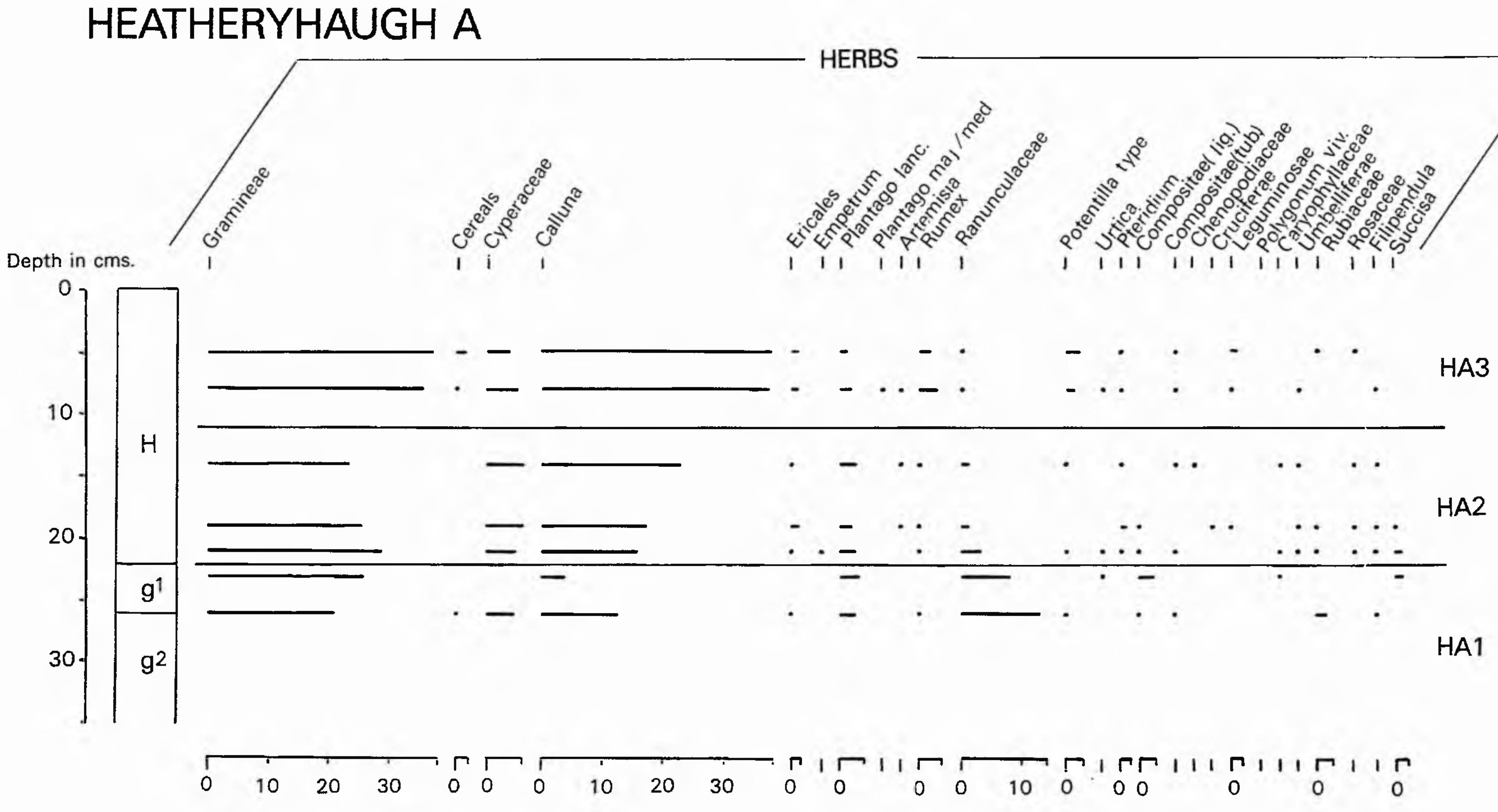


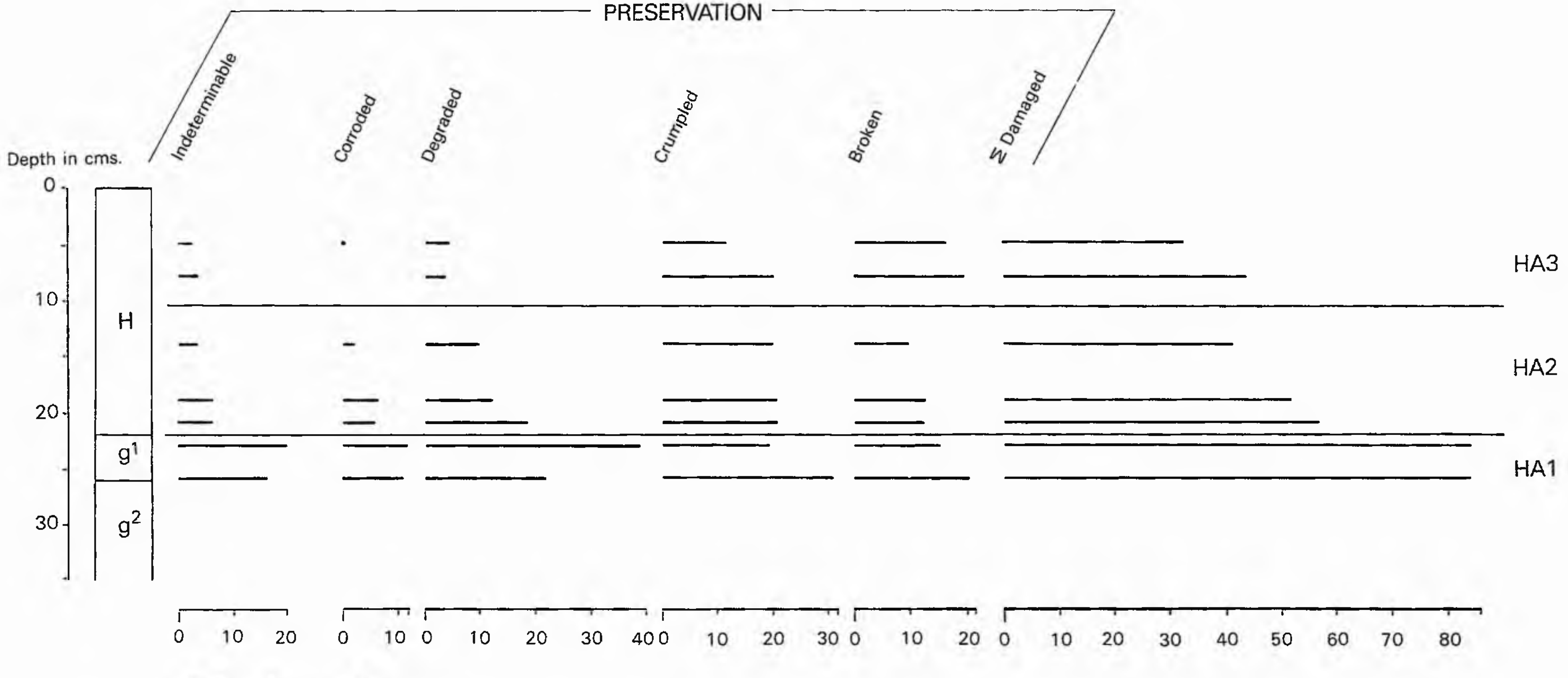
Fig.6.9a Heatheryhaugh A soil pollen diagram, trees, shrubs and spores



All are expressed as % T.L.P.

Fig.6.9b Heatheryhaugh A soil pollen diagram, herbs

HEATHERYHAUGH A



All are expressed as % T.L.P.

Fig.6.9c Heatheryhaugh A soil pollen diagram, preservation

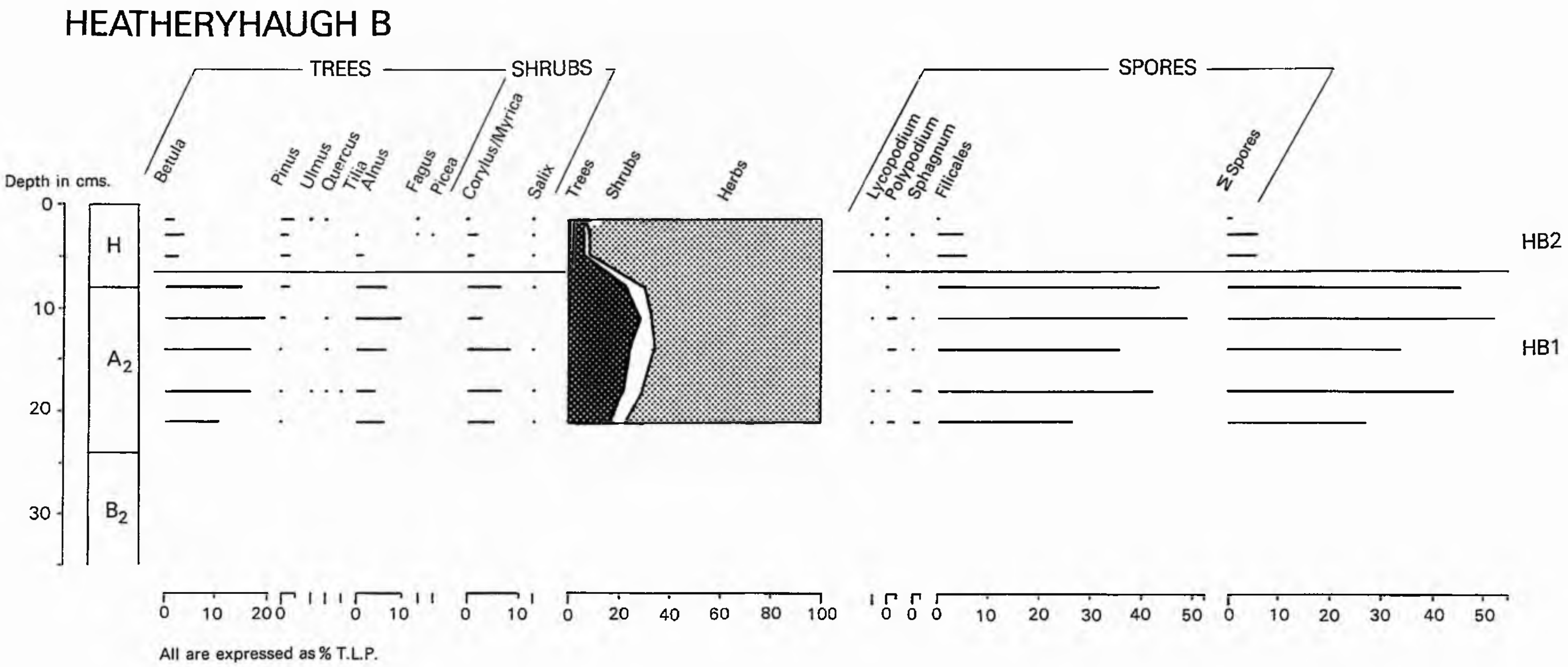


Fig.6.10a Heatheryhaugh B soil pollen diagram, trees, shrubs and spores

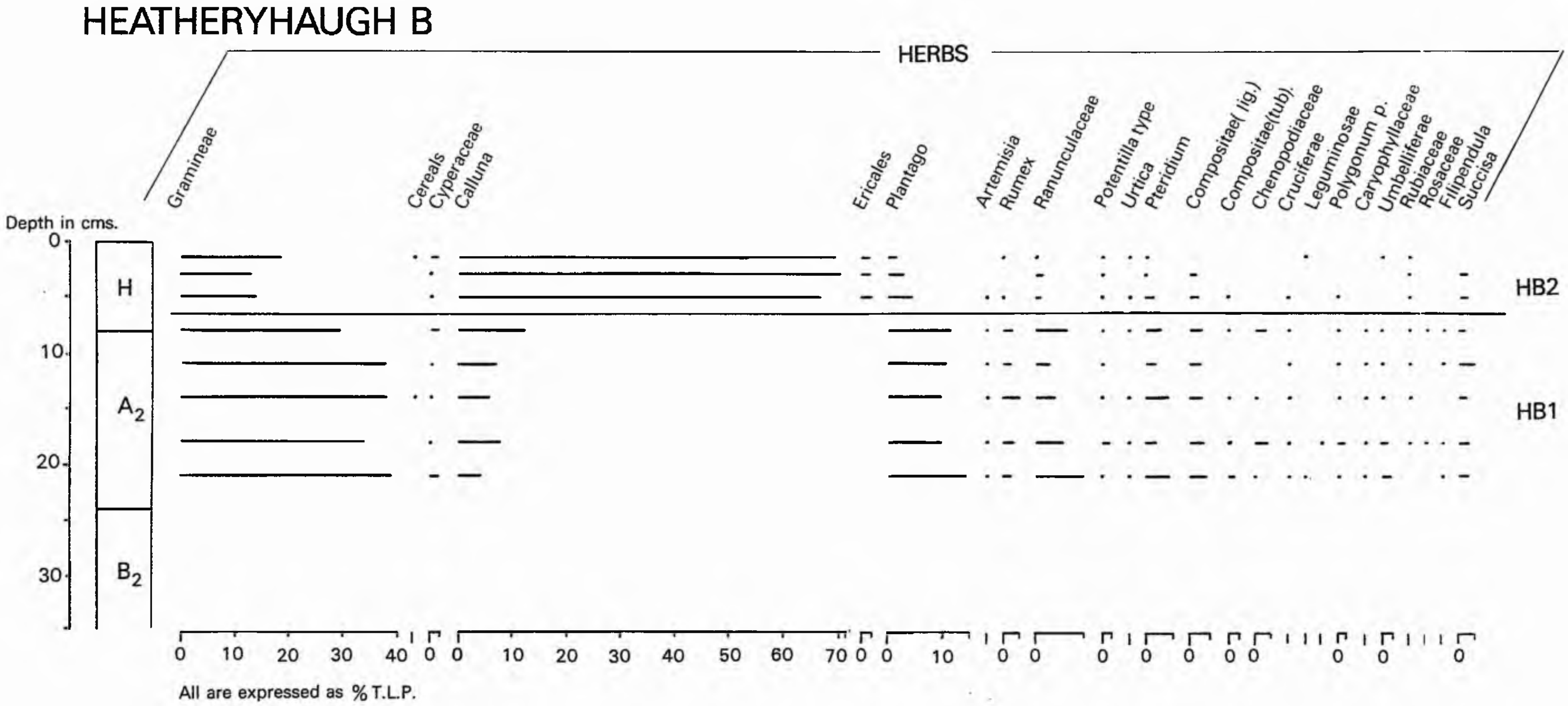
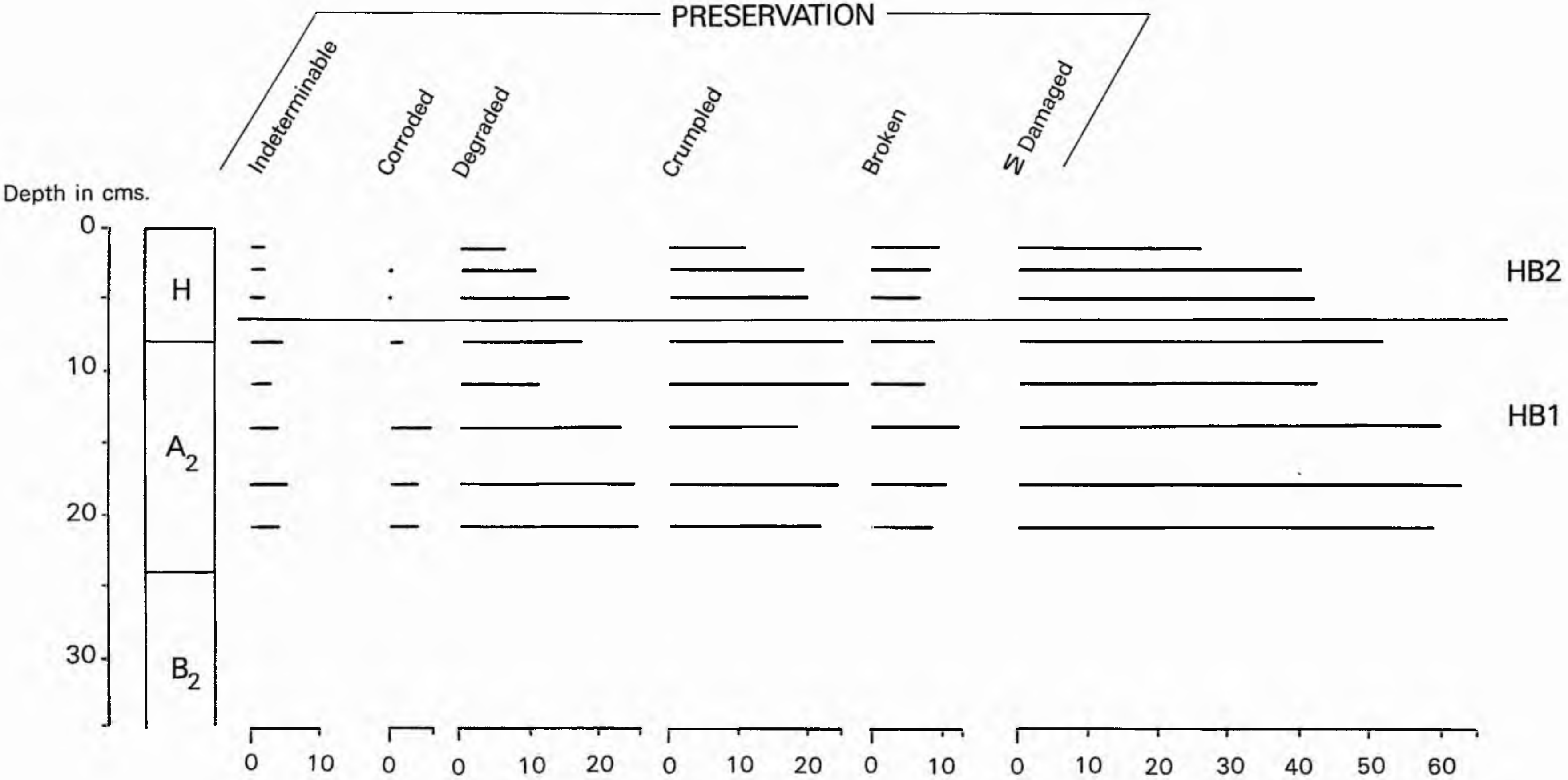


Fig.6.10b Heatheryhaugh B soil pollen diagram, herbs

HEATHERYHAUGH B



All are expressed as % T.L.P.

Fig.6.10c Heatheryhaugh B soil pollen diagram, preservation

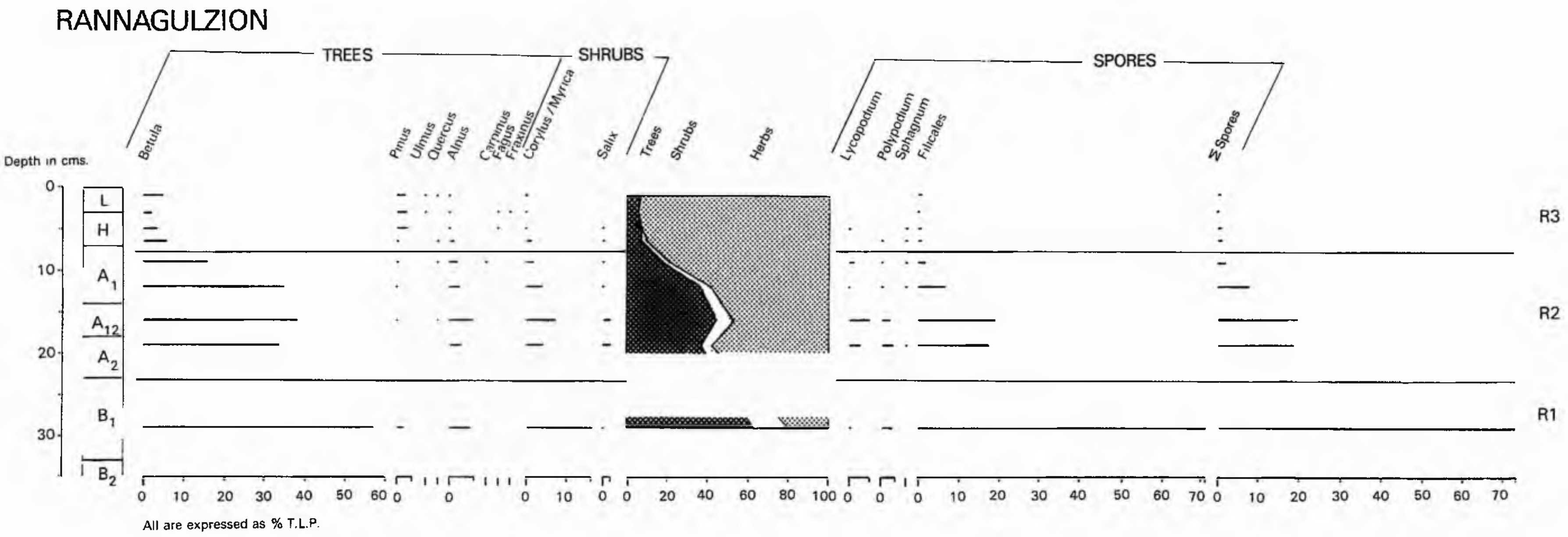
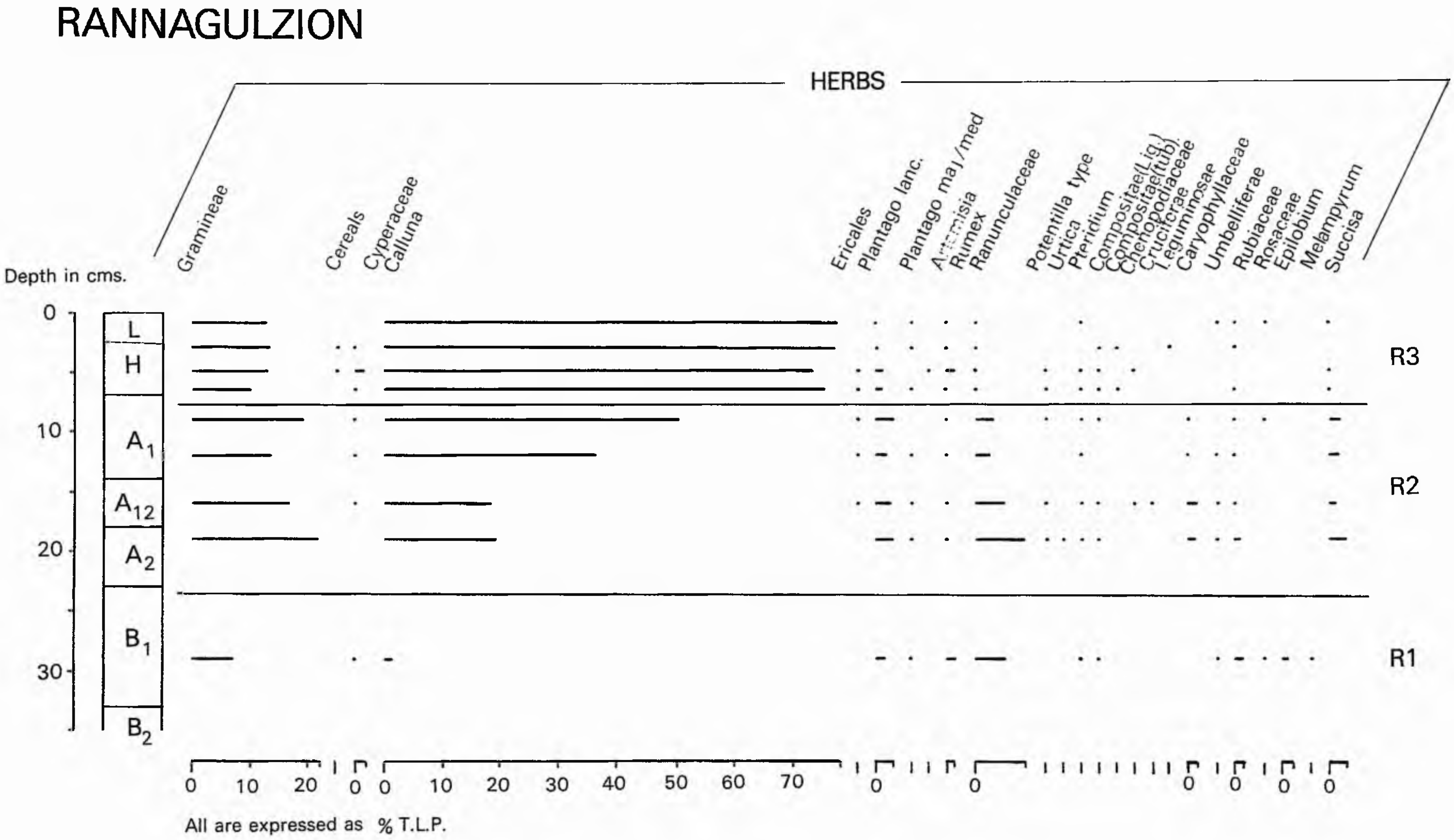


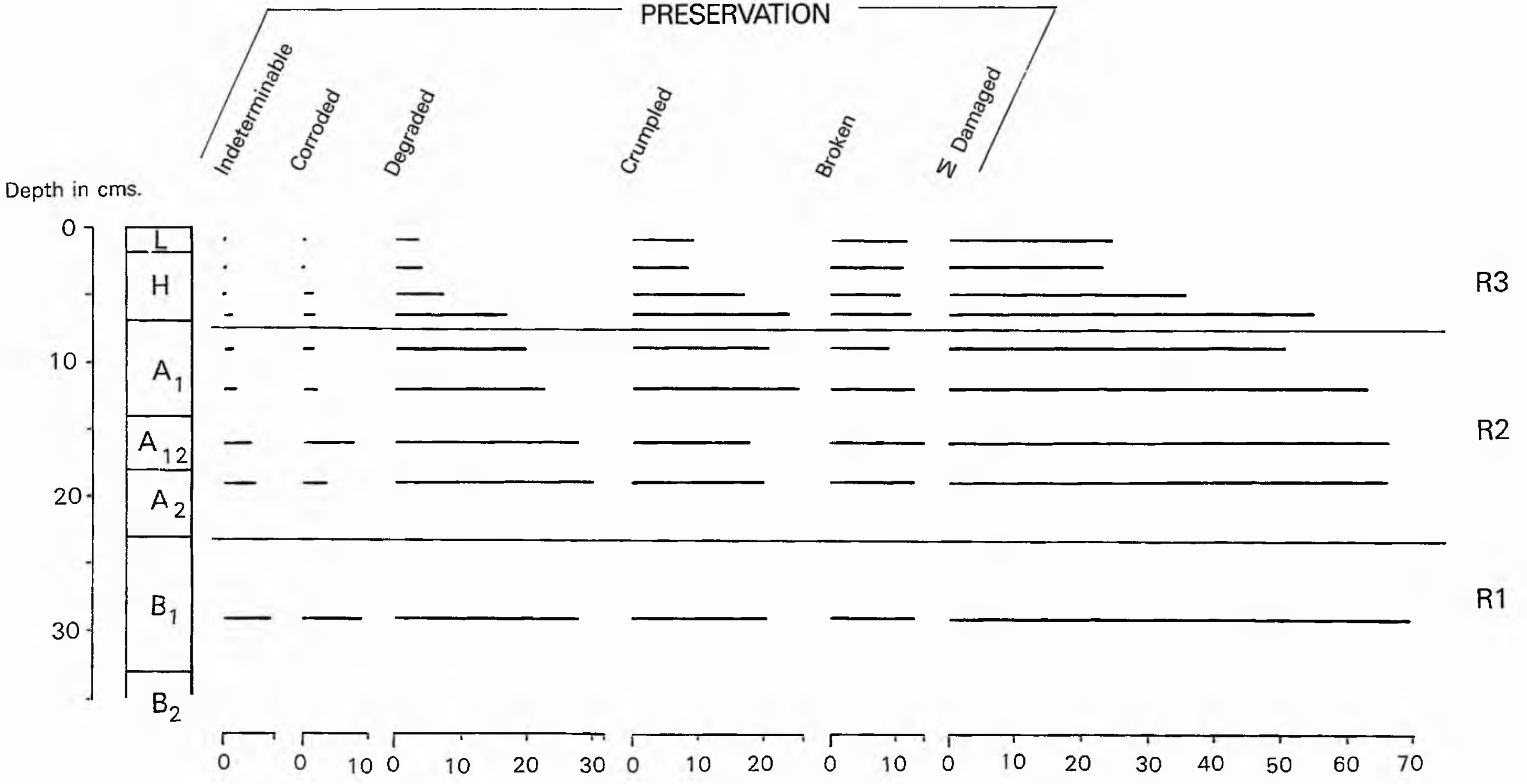
Fig.6.11a Rannagulzion soil pollen diagram, trees and spores



All are expressed as % T.L.P.

Fig.6.11b Rannagulzion soil pollen diagram, herbs

RANNAGULZION



All are expressed as % T.L.P.

Fig.6.11c Rannagulzion soil pollen diagram, preservation irrespective of soil horizons as discussed in Chapter 5. Three assemblage zones were defined for Heatheryhaugh A prefixed HA-:

HA1 Base - 22cm Betula - Alnus - Corylus/Myrica - Gramineae - Ranunculaceae

The upper boundary is marked by decreases in Alnus, Corylus/Myrica and Ranunculaceae, and by increasing Calluna.

This zone is characterised by the highest values for A.P. and shrub pollen, chiefly Betula, Alnus and Corylus/Myrica. Values for Calluna are variable but Gramineae occurs at above 20%T.L.P. and there are high values for Ranunculaceae, at up to 14%T.L.P., and Plantago lanceolata with Rubiaceae and Compositae lig. also appearing at more than 1%T.L.P. The two samples from this zone cover the g_1 horizon in which there are very high values for Damaged and Indeterminable pollen and also high frequencies for Polypodium and Filicales, with some Sphagnum.

HA2 22cm - 11cm Betula - Gramineae - Calluna - Salix

The upper boundary occurs where there is a sharp decrease in Betula and increases in Gramineae, Calluna and Pinus.

HA2 has similar percentages for Betula to HA1 but Alnus eventually disappears and there are low values of Corylus/Myrica. Salix appears at up to 6%T.L.P. The variety of N.A.P. represented remain consistent with HA1 but individual frequencies of Ranunculaceae are lower. With a slight decline in Gramineae frequencies of Calluna start to rise. This zone covers the lower part of the H horizon and has lower values for Damaged pollen with very low spore counts except for Sphagnum which slightly increases.

HA3 11cm - top Calluna - Gramineae

In this zone there is a reduction in A.P. and shrub pollen to very low levels but Pinus increases towards the top. It is largely dominated by Gramineae and Calluna with Cyperaceae but with less variety in the N.A.P. although there are peaks for Rumex and Potentilla type, and still some Plantago. Spore counts are low with reduced Sphagnum and a further reduction in the general proportion of Damaged pollen, although there is an increase in the category of Broken pollen.

Only two pollen assemblage zones were defined for Heatheryhaugh B, prefixed HB-:

HB1 Base to 6·5cm Betula - Alnus - Corylus/Myrica - Plantago - Ranunculaceae

The upper boundary is marked by a sharp increase in Calluna and a reduction in most A.P. and shrub pollen.

This zone which covers the A_2 horizon shows extreme variety, especially in the N.A.P. The pollen of trees and shrubs never rises above 33%T.L.P. and comprises mainly Betula, Alnus and Corylus/Myrica with very little Salix. Of the N.A.P. Gramineae is the main contributor but Plantago lanceolata occurs at up to 14%T.L.P., Ranunculaceae to 9%T.L.P., and Pteridium, Rumex, Compositae lig. and Succisa occur at up to 4%T.L.P. Artemisia, Potentilla type, Urtica, Chenopodiaceae, Cruciferae, Caryophyllaceae and Umbelliferae all appear at more than 1%T.L.P. Throughout the zone there are high values for Filicales with very little Sphagnum and pollen preservation only improves gradually up the profile.

HB2 6·5cm to top Calluna

HB2 is dominated by Calluna at up to 70%T.L.P. with some Ericales undiff., probably mainly Erica sp., Gramineae, Plantago lanceolata and

Ranunculaceae are present but there is a considerable reduction in the variety of N.A.P. represented. All tree and shrub pollens are reduced to low levels except for *Pinus* which increases towards the top. The zone covers the H horizon and shows reduced values for Filicales and Damaged pollen.

At Rannagulzion three assemblage zones were defined prefixed R-:

R1 Base to 23·5cm *Betula* - *Corylus*/*Myrica*

The upper boundary is taken where *Betula* and *Corylus*/*Myrica* decrease and Gramineae and *Calluna* increase.

R1 is dominated by A.P. and shrub pollen at over 80%T.L.P. but only covers one sample. In this sample *Betula* reaches 60%T.L.P. with *Alnus*, *Pinus* and *Corylus*/*Myrica* also present. The low N.A.P. count mainly consists of Gramineae with *Plantago lanceolata* and Ranunculaceae. This sample was obtained from the B_2 horizon and has high frequencies for Filicales and Damaged pollen.

R2 23·5cm to 7·5cm *Betula* - *Calluna* - Gramineae - Ranunculaceae

The upper boundary is marked by increasing *Calluna* and decreasing *Betula* and Ranunculaceae.

Although reduced, *Betula* still comprises almost 40%T.L.P. and the pollen of trees and shrubs comprises half the T.L.P. sum with *Alnus*, *Corylus*/*Myrica* and *Salix* represented. There is more variety in the N.A.P. with *Plantago lanceolata*, Ranunculaceae and Caryophyllaceae all present at more than 2%T.L.P. but *Calluna* increases throughout reaching over twice the value for Gramineae by the change to R3. R2 covers the complete A horizon and has high spore counts with *Lycopodium* well represented and continuous high frequencies for Damaged pollen, particularly in the A_{12} and A_2 horizons.

R3 7·5cm to top Calluna

Relative to the earlier zones frequencies of A.P. and shrub pollen are low with only Betula and Pinus represented. R3 is dominated by Calluna at around 80%T.L.P. but Gramineae remains consistently present at around 10%T.L.P. with low values for Plantago lanceolata. The zone covers the L and H horizons with a negligible spore content and reduced levels for Damaged pollen.

c) Soil development and vegetation history

HA1 which derives from the upper gleyed horizon shows high values for A.P. and shrub pollen of over 50%T.L.P. with Gramineae, Calluna and Ranunculaceae dominating the non-arboreal representation. Interpretation of this part of the soil profile is complicated by its gleyed nature which indicates the possibility of vertical water movement redistributing pollen. It is obviously an area of severe pollen deterioration as can be seen from the very high proportions of Damaged pollen, Filicales and Polypodium spores. The assemblage of HA1 probably represents a series of communities with the local development of birch woodland containing alder and hazel as well as areas of heather, some of which may have been on the bog surface, and open grassland with Plantago. From the sequence of vegetation change established from the bog profile the woodland appears to have been of a secondary form but it may have been similar to the herb-rich birchwood defined by McVean and Ratcliffe (1962) which includes Galium hercynicum, Ranunculus ficaria, R. repens and Thelypteris oreopteris as constants. The high values for Ranunculaceae may be partially due to preferential preservation although there is little empirical evidence to support this and could have derived from sources on the bog or in the woodland surrounding as well as in the grassland. Given the presence of over 10%T.L.P. it must have been growing on the site for there are much lower frequencies recorded in the bog profile throughout. The presence of *Polypodium* spores at high levels in low soil horizons has been used as an indicator of the presence of former woodland (Staines in press) due to its epiphytic growth form (Godwin, 1975b) but in the three sites investigated here it does not occur in zones with similar frequencies for arboreal pollen and there may not be a consistent relationship between *Polypodium* occurrence in lower soil horizons and the presence of woodland.

With the development of the H horizon there is an expansion in *Calluna* with a reduction in other non-arboreal species as well as alder and hazel, but little change in birch. The build up of the thick organic layer took place primarily due to changes in local hydrology around the bog margins and these changes are probably also indicated in HA2 by the presence of *Salix*, Cyperaceae and *Sphagnum*. The increasing wetness may have been caused by natural bog growth bringing the water table higher up the slopes but in view of the lateness of the record in comparison with the pollen record from the bog this natural explanation seems unlikely, furthermore the rise in *Salix* implies some drying out of the bog if a natural succession is postulated. The changes in local water table may have been variable over the immediate area and due to peat cutting as much as to natural bog growth or degradation or indeed also due to the removal of woodland from the margins leading to increased run off, a process which would have then continued as the woodland was further reduced.

Within the H horizon the change to HA3 occurs which marks the final expansion of *Calluna* but here, because of the wetter nature of the soil there are still high values for Gramineae, Cyperaceae and *Potentilla* type, showing how heather was locally redtricted. The rising curve for *Pinus* is characteristic of recent soil and peat profiles in the Grampians and may be used as a dating mechanism reflecting the planting of pine in the eighteenth and nineteenth centuries as occurred for instance around Stormont Loch. The presence of *Cereal* type pollen is a further feature of the upper horizon with only isolated grains in the lower horizons and probably reflects cultivation around Heatheryhaugh Farm in the last century or early part of this century.

The record from Heatheryhaugh B shows little difference in its lower pollen record from that at Heatheryhaugh A except for the lack of those taxa characteristic of poorly drained environments, particularly Cyperaceae and *Sphagnum*. Although overall values for A.P. and shrub pollen are lower the same species are represented with birch as the dominant tree (Fig. 6•12), and high Filicales but low *Polypodium*. There is much greater variety in the non-arboreal taxa found at Heatheryhaugh B with *Plantago*, *Rumex*, Ranunculaceae, Compositae lig. and *Succisa* present as well as *Pteridium*. This variety coupled with the higher values for Gramineae suggest at this site that a relatively species-rich grassland probably used as pasture existed. Present day comparisons for this proposed community are difficult to find and the former community was almost certainly largely anthropogenic in origin with its composition determined by the character of land utilisation. At present the grasslands on the more acidic rocks are either species-poor Agrosto-Festucetum with few constants or dominated by *Molinia*, especially on wetter sites.

The change from grassland to ericaceous heath occurs in the pollen record at the break between the A_2 and H horizons but on this drier site the change is a sudden one with heather becoming the dominant local species and a severe reduction in the contribution and variety of the rest of the herb flora. The expansion of heather is accompanied further by a reduction in woodland cover to the open environment characteristic of the area today although, as at Heatheryhaugh A there is a slight

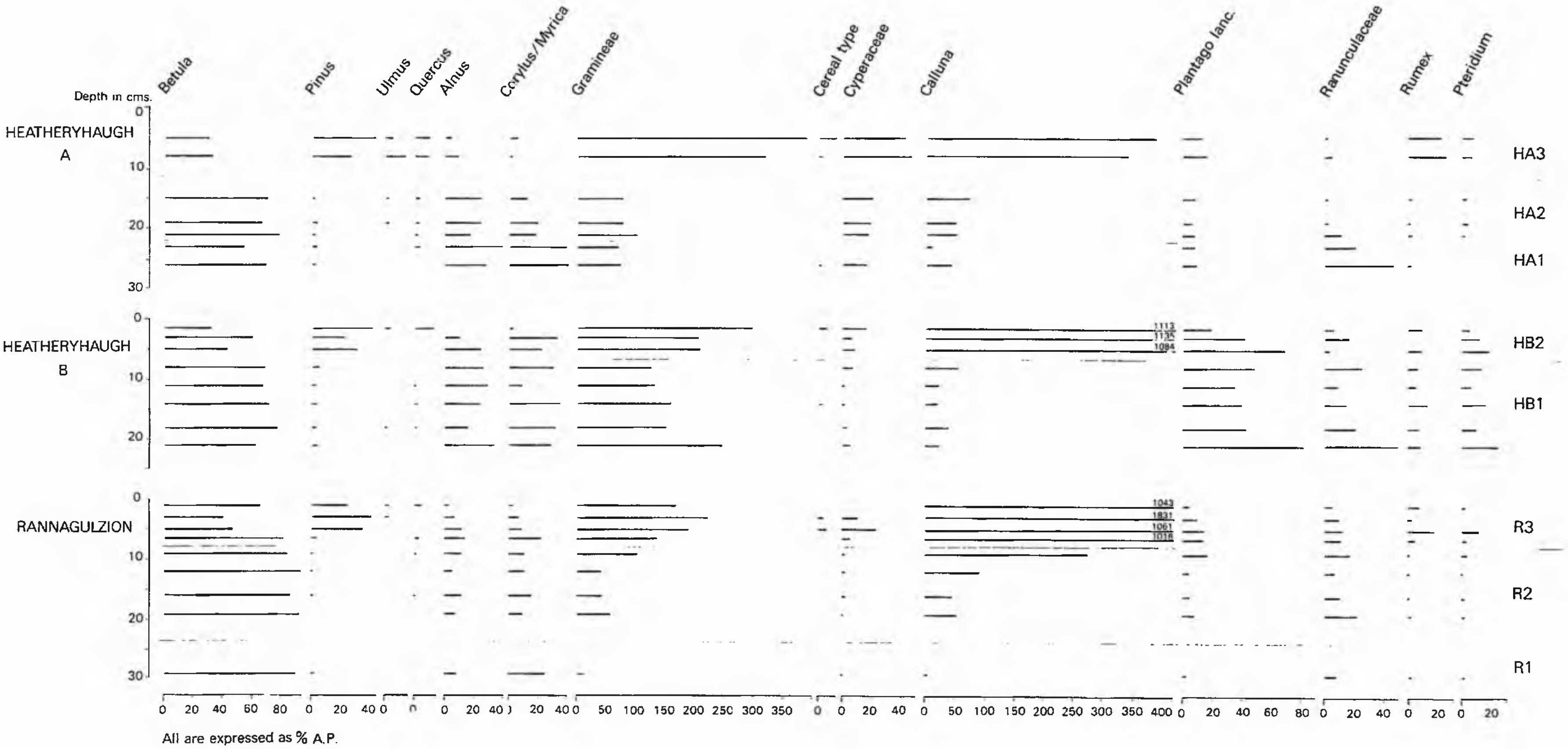


Fig.6.12 Comparison of selected taxa from Heatheryhaugh A and B and Rannagulzion, using an A.P. sum

but noticeable increase in Pinus towards the surface.

The overall similarity between the two sequences recorded in the soil profiles is striking but there are differences in the two records which are not just a function of the different drainage characteristics of the two sites. The higher frequencies for A.P. and shrub pollen in the lower levels of Heatheryhaugh A could indicate the presence of a slightly earlier record but with Heatheryhaugh B lying on the higher slopes within better drained grazing land the latter would always perhaps have been expected to be kept more open. The local development of Salix indicated in HA2 is for instance not registered at all at the other site. Apart from this there is very little difference in the relative contributions of the main woodland species at the two sites with birch as the dominant tree and alder and hazel also present. The apparent disappearance of alder prior to the reduction of hazel at Heatheryhaugh A while they both decline together at the HB1/HB2 boundary may be a reflection of a genuine local change but the apparent uniformity of the pollen record in HB1 may mask any true stratification for where such uniformity exists, particularly within the A horizon it may be due to mixing consequent upon ploughing or the activity of soil fauna. In this case there is no evidence either in the pollen record or the physical structure of the soil for cultivation so faunal mixing, probably by earthworms, could account for the homogeneity of HB1 and therefore indicate a higher base status to that of today. This would not be out of line with the variety of species recorded in HB1 and the herb-rich birch woodland which was mentioned earlier as a possible local community and which is now found on brown mineral soils with a mull humus. Even the species-poor Agrosto-Festucetum grassland can occur on brown podsolic soils with a moder humus.

At both sites the change to a dominantly ericaceous community takes place relatively suddenly in the soil record and at a time of deforestation with all tree species reduced to very low levels. The change at Heatheryhaugh B is coincident with the stratigraphic change from A_2 to H horizons but the occurrence of a similar change within the H horizon at Heatheryhaugh A shows the change to be genuine and to have occurred as a more gradual process than apparent at the other site. The record at Heatheryhaugh A is complicated by the possible local source of heather pollen from the bog surface but at Heatheryhaugh B there is clearly a close relationship between the removal of woodland and podsolisation.

Romans (1970) has argued that relatively recent destruction of the birchwoods of the south-facing Grampian valleys for charcoal used in iron smelting allowed re-podsolisation of surface soil horizons under Calluna heath implying a change from brown podsolic soils which had developed under birch-rowan woodland at the time of the post-glacial climatic optimum. On the basis of the evidence from around Heatheryhaugh there are grounds for arguing for re-podsolisation but there was far less persistence of birch woodland throughout the Late Flandrian than Romans appears to suggest, at least on the plateau area, and earlier podsolisation may have owed as much to anthropogenic removal of the woodland as to natural pedogenic change.

Comparison of the soil pollen records with the pollen record from the bog at Heatheryhaugh highlights the loss of material from the bog surface and also confirms the inability of such a deposit to record the Late Flandrian period. Both soil pollen records date back to the assemblage zone H7 dominated by Betula but show little evidence of any earlier zones with, in particular, very low Quercus. The higher frequencies for Betula on the bog may also indicate an origin in the latter part of H7 for most of the pollen in the lower soil horizons for it seems unlikely that, without evidence in the peat stratigraphy for birch, values should be higher on the bog than on the margins. The grassland and its associated species seen in the soil pollen record hardly appear in the peat profile with very low frequencies for example for Ranunculaceae throughout H7 and H8 and little indication of the variety of taxa seen in H81. This emphasises the local nature of the soil pollen record and shows the drawbacks inherent in using bog profiles to monitor local communities especially where they are dominated by non-arboreal species.

The evidence from the soil pollen shows that there was little variation in communities around Heatheryhaugh between the maximum for birch in H7 and the present dominance of open moorland with the expansion of the latter occurring as the final remnants of woodland were removed. There is no evidence for cultivation of the local soils in this period except for the presence of Cereal type pollen in the higher soil horizons which may have derived from closer to Heatheryhaugh Farm or from the south. This does not mean that the soils have never been cultivated for the presence of a pollen record only dating back to H7 could be a function of the earlier physical disruption of the soil by ploughing. The final change to heather moor and the development of an H horizon with subsequent increased acidification almost certainly took place as a result of deforestation coupled with grazing, probably of a transhumant form, of a relatively poorly managed form allowing the apread and dominance of heather. Thus the regeneration of woodland in H7 seems even more likely to have been due to a significant reduction of grazing pressure allowing birch to regenerate on a soil which was still not heavily podsolised. The podsolised nature of the present soil under the form of management now practised may perhaps be taken therefore as a measure of earlier successful management preventing extensive heather development, for comparison of figures for Calluna in the peat record for H7 and H8 with the values in the lower soil horizons suggests that much of this pollen must have been produced locally on the bog. The relatively gradual change in soil composition that has taken place on the Forest of Alyth contrasts with the relatively rapid development of a humus iron podsol in the last two hundred years under coniferous woodland around Stormont Loch.

Dating of the changes in the soil profiles by comparison with the peat record is made uncertain by the difficulties encountered with dating zones H7 and H8. The soil pollen zones HA3 and HB2 clearly include recent pollens as seen in the rising curve for Pinus but allowing for the fact that no soil horizon would contain pollen of a single age they also contain older pollen, probably including Calluna and Gramineae pollen of several ages. Comparison of these zones with the uppermost samples for White Hillocks also shows the recent components, not only the Pinus curve but also the occurrence of occasional Cereal type pollen. Although the uppermost levels of all these diagrams can be reasonably dated, the destruction of the woodland, the development of the H horizon and the previous regeneration of birch remain difficult to date accurately. O'Sullivan (1973b) has demonstrated how lower organic soil horizons can show pollen assemblages up to 1200 years older than the uppermost layers. From the peat evidence alone it was suggested that final woodland clearance took place at the latest in the Medieval period but if this is the case and the change to the development of a thick H horizon is coincident with woodland clearance then at Heatheryhaugh B 20cm of humus has accumulated in almost 1000 years. In the absence of more detailed pollen changes which can provide correlations between the different records closer dating remains uncertain.

The analysis of the site at Rannagulzion towards the northern margins of the Forest of Alyth away from Heatheryhaugh shows a very similar picture of vegetation change coupled with increased podsolisation of soils. The uppermost Calluna assemblage zone R3 has the rising Pinus and presence of occasional Cereal type pollen grains characteristic of the other two soil profiles and below this there is also evidence for an earlier phase of birch woodland but with less grassland and lower frequencies for non-arboreal pollen in general. At Rannagulzion the development of the H horizon postdates the expansion of Calluna which is present at higher levels throughout the diagram when expressed as a percentage of the T.L.P. sum, except for the sample from the B_2 horizon. This suggests that heather was more important locally during the period covered by H7, probably due to the slightly higher altitude but the final change to an acid mor only took place with the final removal of birch and complete deforestation of the northern part of the plateau. Not only was heather more important during H7 but there was also a greater development of birch woodland for in the A_1 and A_2 horizons A.P. comprises up to 50%T.L.P. emphasising the greater degree of abandonment experienced in the more northerly area. The pollen assemblage recovered from the B_1 horizon (R1) while similar in many respects to that of the A horizons (R2) does have an even greater proportion of Betula and Corylus/Myrica with A.P. comprising 80%T.L.P. and very low Calluna. Figures such as this are not registered at Heatheryhaugh after H4 and appear comparable in the absence of oak and elm to the later phase of H3 but the presence of Alnus makes this unlikely. Minerogenic soil horizons can contain pollen of considerable age as discovered in Britain (Dimbleby, 1962; Keef et al., 1965) and on the continent (e.g. Iversen, 1969; Andersen, 1979) but the interpretation of this part of the pollen record as a discrete assemblage, considering the likelihood of differential preservation and the similarity in species content to the assemblages in the lower humic/minerogenic horizons, may perhaps be unwise. It should therefore be considered as representative of an earlier period of vegetation development showing perhaps more extensive birch woodland but the dating of this may only be early H7. Whatever the origin of this particular assemblage the rest of the record from Rannagulzion does show a significantly higher proportion of birch pollen and A.P. in general throughout while the general vegetational sequence shows the same shift from regenerated birch woodland to open heather moorland established for the historical period in the southern part of the Forest of Alyth. The present status of soils is largely a factor of the destruction of this woodland cover during the Medieval period with the subsequent continuous pressure of grazing. Yet this clearance was merely the last in a series of clearance phases which probably began as early as the third millennium b.c.

CHAPTER SEVEN

THE AREA NORTH OF THE BOUNDARY FAULT II

STRATHARDLE - GLENSHEE WATERSHED

South of Kirkmichael the isolated hill mass dominated by Knock of Balmyle (445m, NO115562) and Hill of Cally (349m, NO128533) divides the lower part of Glenshee from Strathardle. Although not as high as the northern edge of the Forest of Alyth, much of the area is higher than that already sampled at Heatheryhaugh and Stormont Loch. Geologically the part south of Craigton (NO134577) comprises the same altered grits as the Forest of Alyth and to the north of this there are mica schists. The boundary between the two strata is formed by the 'green beds' which are metamorphic and there is also a thin band trending west to east across the Knock of Balmyle. Further to the north immediately to the east of Kirkmichael there is an extensive outcrop of limestones and calcareous schists. Loch Mharaich which was used as the sampling site lies in a col on the eastern side of the hills facing Glenshee at an altitude of c.350m within a Forestry Commission plantation which now covers much of the area northeast of the Knock of Balmyle (Fig. 7•1). Below Loch Mharaich between 290m and 310m there is an extensive spread of hut circles and small cairns excavated by Thorneycroft in 1932 (NO125575). There are also hut circles and small cairns around Hill of Cally and similar features on the western slopes of Strathardle near Muir of Merklands (NO104567). Afforestation around Loch Mharaich and the physical disturbance of the soils around the site have precluded the analysis of soil profiles close to the site so there is only discussion of the long profile from the loch, the only true full lake sediment examined in the thesis.

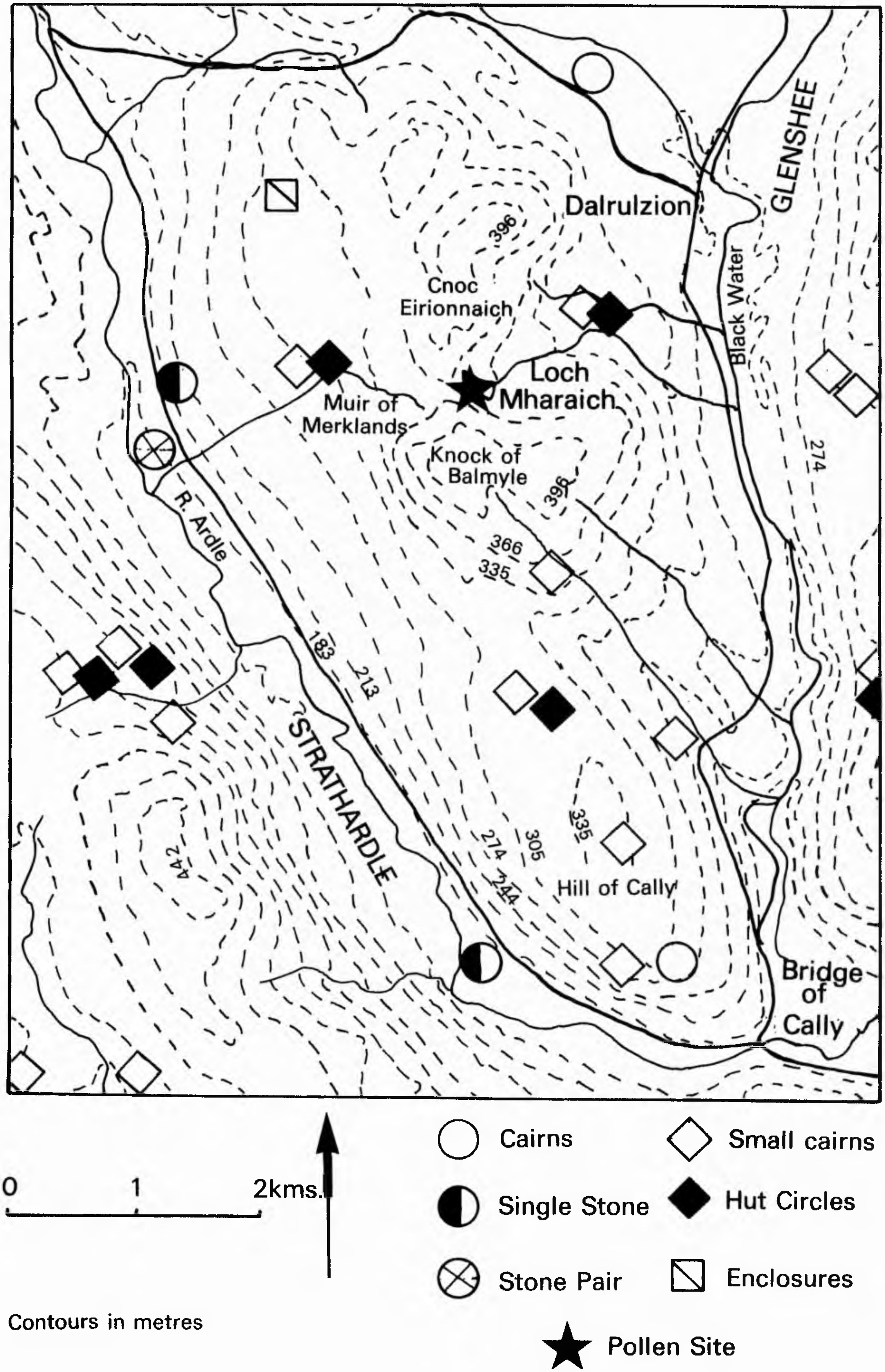


Fig.7.1 Location of pollen site at Loch Mharaich

i) Loch Mharaich

a) Stratigraphy and sampling

The small loch is very shallow and rock floored but towards the northwestern end there is a small basin which reaches a depth of over five metres and it was from this basin that a sample was obtained by means of a Mackereth corer. There is some evidence from the south-eastern end of the loch for artificial damming but any modification of the loch has not been recent for Roys map of 1755 shows the same extent of water as is found today and from the sediment record it is clear that there has been open water over the site for at least 5000 years. Although a core of only three metres was recovered the Mackereth did not penetrate the full depth of sediment and some of the unconsolidated sediment at the sediment-water interface was lost on collection. Once extruded the core showed little variation comprising a dark brown well consolidated silty mud with some large Betula twigs between 246cm and 247cm. Between 167cm and 191cm there was some distortion due to slightly higher water content but the difference between this part of the core and the rest was slight.

Samples were taken at intervals of four centimetres with extra samples at two centimetre intervals at the top and bottom. Preparation of the material followed the methods used before and outlined in Appendix II. The addition of known assays of exotic pollen, Ambrosia, to the sediment also allowed the determination of pollen concentration values (Appendix II). A count of 500T.L.P. was used with no land pollens excluded from the sum and the implications of this for the concentration values are discussed in the appendix. No data on pollen preservation was taken from this site.

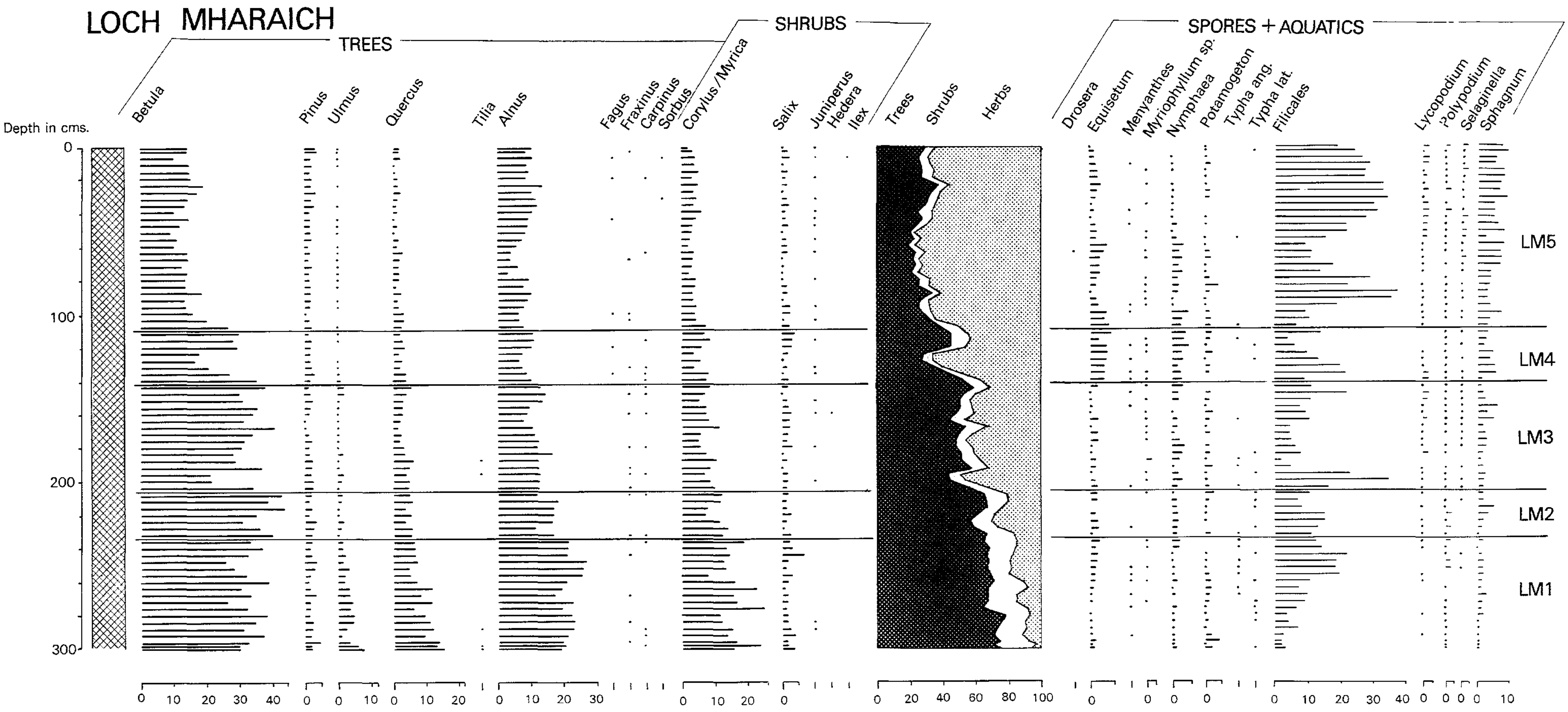
b) Pollen assemblage zones

The local pollen assemblage zones are prefixed LM- and their composition is discussed below. They were defined in terms of their relative pollen counts and comments on the pollen concentration values will be made within these zones. The relative pollen diagram is presented in Fig. 7·2a and b, and the pollen concentration diagram in Fig. 7·3a and b.

LM1 300cm - 233cm

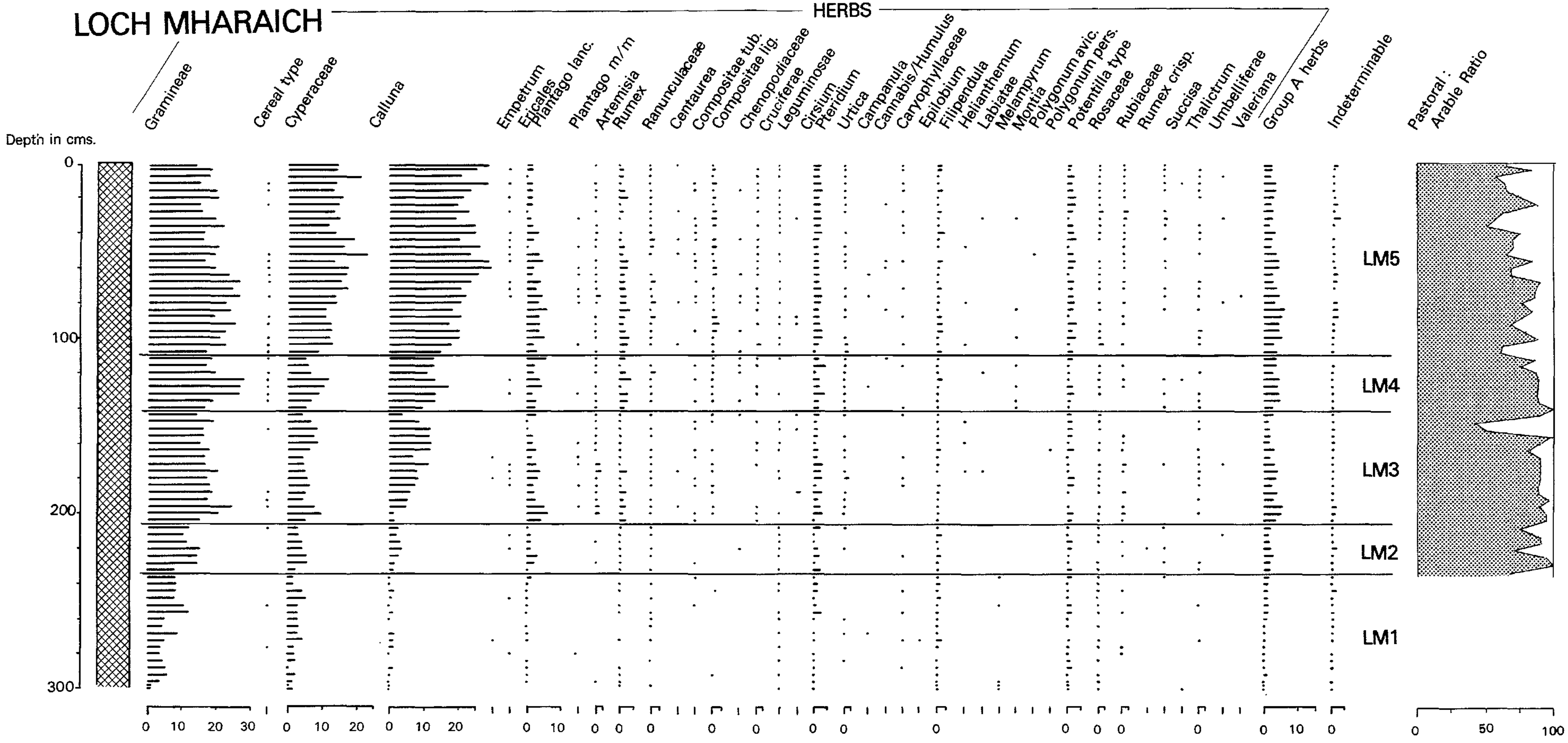
The upper boundary is taken where there is a reduction in *Ulmus* to less than 1%T.L.P., *Alnus* drops below 20%T.L.P. and *Corylus/Myrica* values are also reduced. At this point there is the start of a continuous curve for *Calluna* and the continuous presence of *Rumex*.

LM1 is characterised by decreasing values for *Ulmus*. At the base the pollen of trees and shrubs comprises 95%T.L.P. but there is then a reduction in *Ulmus* and a slight decrease in *Quercus*, increasing *Pinus* and a slow rise in *Alnus* with peaks for *Corylus/Myrica* and *Betula* and the appearance of *Fraxinus*. With the change in tree pollens there is a rise in Gramineae but only spasmodic occurrences of *Plantago lanceolata*, *Rumex*, Ranunculaceae and *Pteridium*. In the lowest samples *Melampyrum* also occurs and *Potentilla* type and *Filipendula* appear throughout the zone. After the peak for *Corylus/Myrica* which follows the initial decrease in *Ulmus* and *Quercus* there is a recovery in *Ulmus* to 5%T.L.P. with a recovery also in *Quercus*, *Betula* and *Alnus*. This precedes a second decrease in *Quercus* and *Betula* with a rise in *Corylus/Myrica* but there is little change in herb pollen except for an increase in Gramineae and *Calluna*. At this point there is a single *Cereal* type pollen grain which was not identifiable to species level (Table 7·1). Although there is some recovery in *Quercus* it then declines further as does



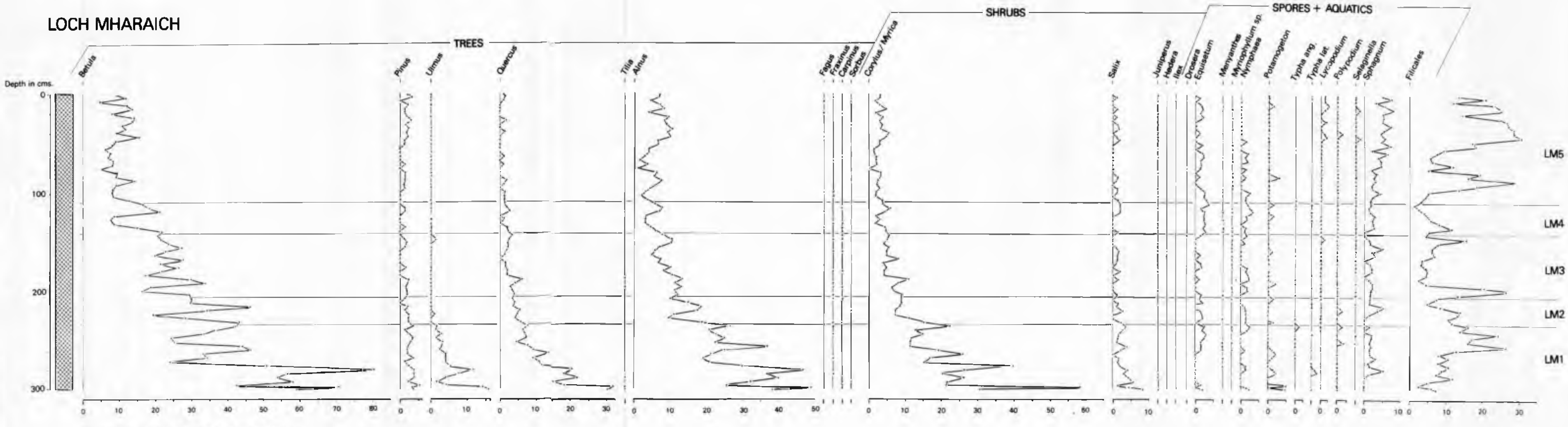
All are expressed as % T.L.P.

Fig.7.2a Loch Mharaich relative pollen pollen diagram, trees, shrubs, spores and aquatics



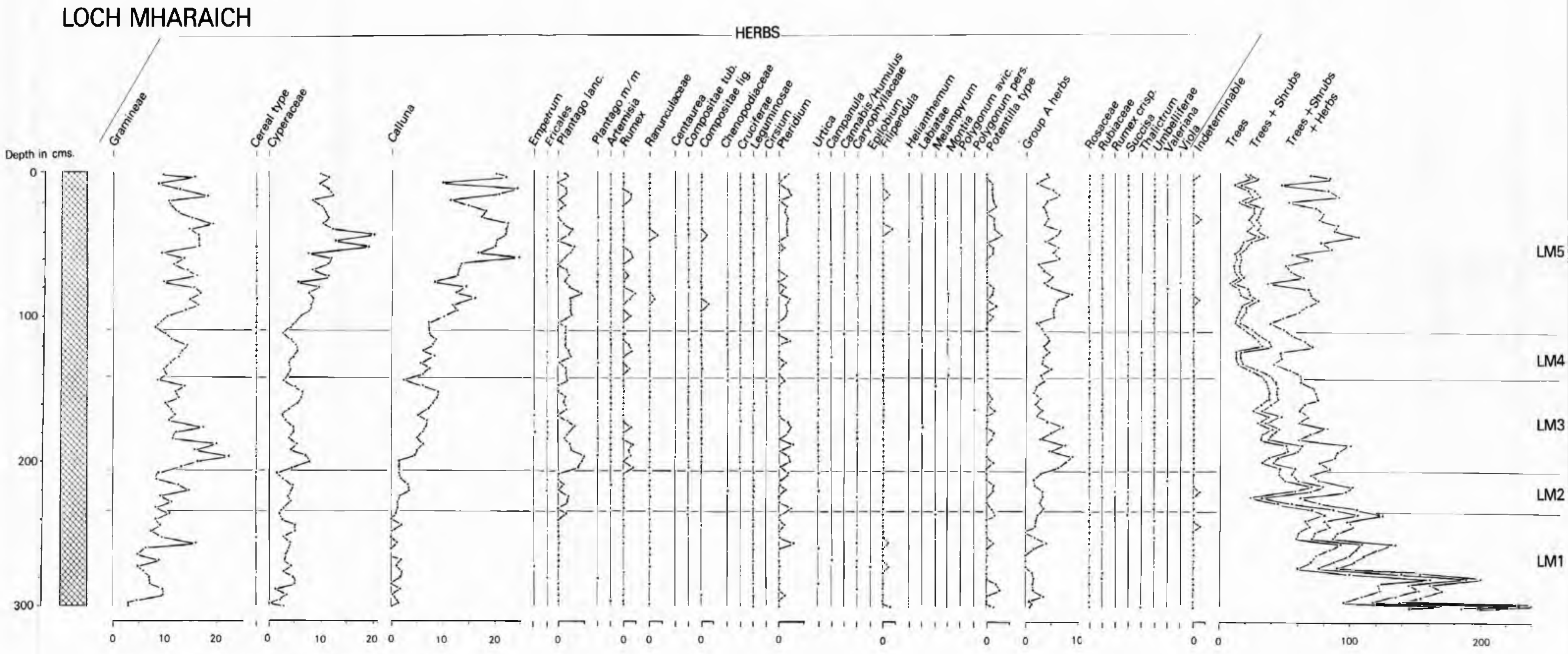
All are expressed as %T.L.P.

Fig.7.2b Loch Mharaich relative pollen diagram, herbs



All are expressed as concentration in no. of grains $\times 10^3$ per c.c.

Fig.7.3a Loch Mharaich pollen concentration diagram, trees, shrubs, spores and aquatics



All are expressed as a concentration in no. of grains $\times 10^3$ per c.c.

Fig.7.3b Loch Mharaich pollen concentration diagram, herbs

Table 7·1 Cereal pollen types from Loch Mharaich

Depth (cm)	Grain Dia-meter (μ)	Pore Size (μ)	Preservation	Sculpturing (Beug)	Species Interpretation
12	–	–	Broken	–	–
16	44	10	Crumpled	–	–
	42	9	Crumpled	–	–
	45	10	Good	*Hordeum* type	*Hordeum* sp.
24	45	10	Good	*Hordeum* type	*Hordeum* sp.
52	42	12	Crumpled	–	–
	43	–	Crumpled	–	–
56	45	–	Concealed	–	–
60	46	11	Good	*Hordeum* type	*Hordeum* ?
	40	8	Degraded	–	–
64	49	10	Folded	–	–
68	47	10	Good	*Hordeum* type	*Hordeum* sp.
76	42	13	Good	*Avena* type	*Avena* sp.
88	42	10	Crumpled	–	–
	40	10	Folded	*Hordeum* type	*Hordeum* sp.
92	49	11	Broken	–	–
	43	10	Broken	–	–
100	40+	–	Broken	–	–
104	42	13	Concealed	–	–
108	47	11	Good	*Hordeum* type	*Hordeum* sp.
	50	11	Good	*Hordeum* type	*Hordeum* sp.
112	42	10	Folded	–	–
120	50	10	Good	*Hordeum* type	*Hordeum* sp.
124	48	14	Good	*Hordeum* type	*Triticum monococcum*
	40	10	Folded	–	–
128	43	–	Corroded	–	–
132	–	–	Broken	–	–
136	45	–	Concealed	–	–
152	41	10	Folded	–	–
	40	11	Good	*Hordeum* type	*Hordeum* sp.

continued.........

Table 7·1 (continued)

Depth (cm)	Grain Dia-meter (μ)	Pore Size (μ)	Preservation	Sculpturing (Beug)	Species Interpretation
188	41	10	Folded	–	–
192	45	13	Degraded	–	–
196	40	–	Broken	–	–
208	45	9	Folded	–	–
252	45	12	Good	*Hordeum type*	*Triticum monococcum*
276	42	12	Folded	–	–

Ulmus. There are reductions in Betula and Corylus/Myrica but Alnus increases as do Gramineae and Calluna but other herb species only occasionally appear. By the end of the zone both Ulmus and Quercus are low but Betula and Corylus/Myrica recover. Highest values for Filicales and Polypodium are found towards the end of the zone but Sphagnum appears throughout. There are two peaks for Potamogeton at 296cm and 264cm and Equisetum increases towards the LM/LM2 boundary. Menyanthes, Myriophyllum spicatum, Nymphaea, Typha angustifolium and T. latifolia all also occur throughout the zone.

LM2 233 - 205cm

The upper boundary is taken where Alnus and Corylus/Myrica decline and where Gramineae, Plantago lanceolata and Rumex rise.

Within LM2 Ulmus is reduced to below 1%T.L.P. and there is a further slow decrease in Quercus. There is a dip in Betula values at 224cm which corresponds to peaks in Gramineae, Calluna, Plantago lanceolata and Pteridium, and Betula then recovers to the highest levels found in the diagram. There are peaks for Filicales, Polypodium and Sphagnum. Values for aquatics are generally low but Myriophyllum spicatum is found throughout and Equisetum occurs at more than 2%T.L.P.

LM3 205 - 141cm

The upper boundary is defined where the pollen of trees and shrubs falls below 70%T.L.P. with reductions in Betula and Alnus and increasing Gramineae, Calluna, Plantago lanceolata and Rumex.

At the opening of LM3 both Betula and Corylus/Myrica decrease and there is a drop of 20 per cent in the A.P. count although there is little change in Quercus and Alnus. At the early minimum for Betula there is a peak for Gramineae which is more clearly seen in the diagram based on an A.P. sum (Fig. 7·4) and there are also peaks for

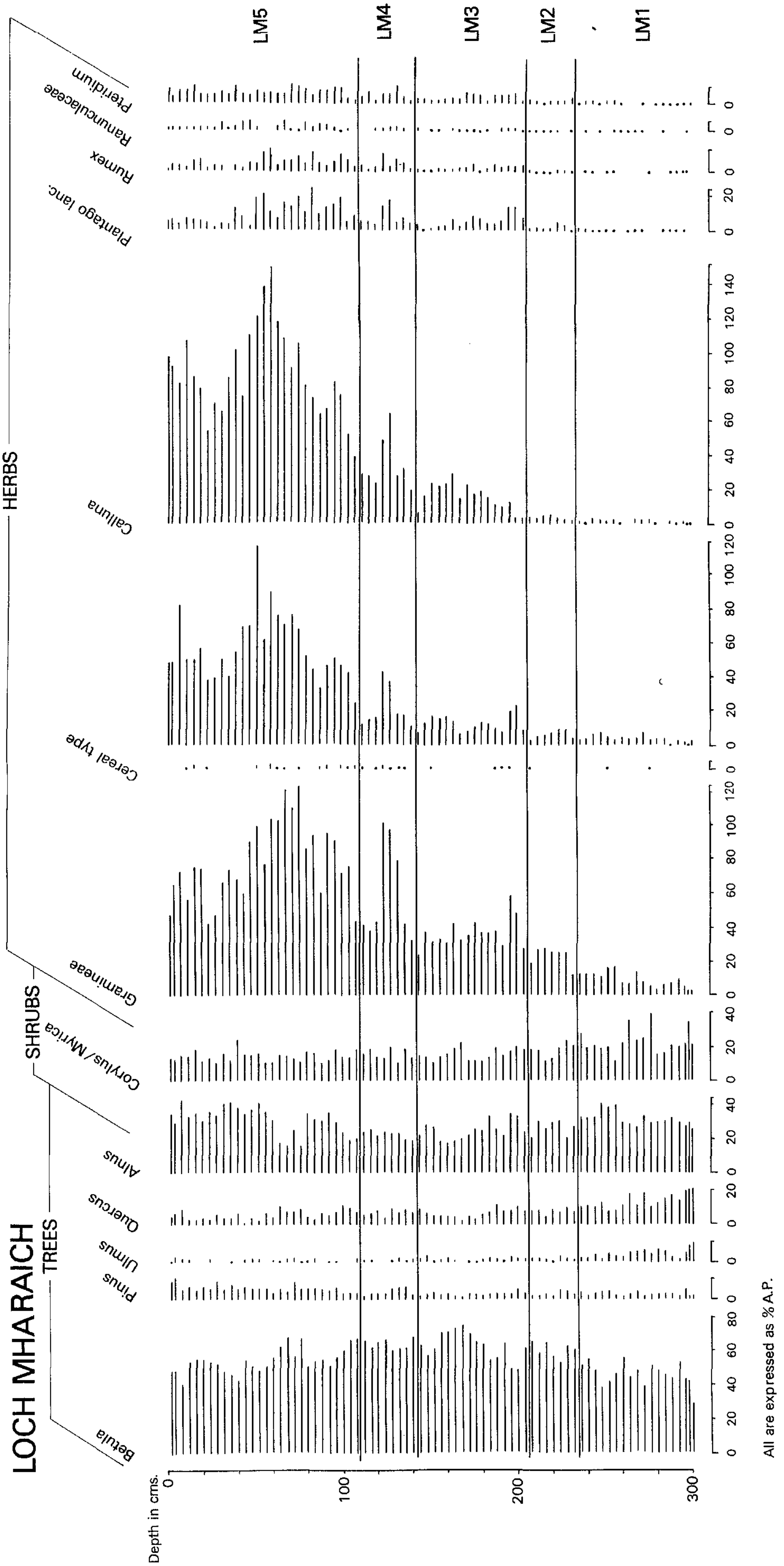
LOCH MHARAICH
TREES
SHRUBS
HERBS
Betula
Pinus
Ulmus
Quercus
Alnus
Corylus/Myrica
Gramineae
Cereal type
Calluna
Plantago lanc.
Rumex
Ranunculaceae
Pteridium
LM5
LM4
LM3
LM2
LM1
Depth in cms.
0
100
200
300
0 20 40 60 80
0
0
0 20
0 20 40
0 20 40
0 20 40 60 80 100 120
0
0 20 40 60 80 100 120
0 20 40 60 80 100 120 140
0 20
0
0
0
All are expressed as % A.P.

Fig.7.4 Loch Mharaich, selected taxa expressed as a percentage of the A.P. sum

Plantago lanceolata and Cyperaceae. Artemisia, Compositae lig. and Pteridium start consistent curves and Cereal type pollen also occurs, albeit of indeterminable species. This phase of increased herb frequencies is followed by a recovery in Betula and Corylus/Myrica and a reduction in N.A.P. except for increasing Calluna. After 192cm there is a further reduction in all A.P. frequencies except Quercus and a second peak in Plantago lanceolata with increased Calluna but little change in Gramineae. The response of other herbaceous taxa is seen best in the small peak for Group A herbs. In the rest of the zone there is a general decline in the contribution of N.A.P. with the exception of Calluna which increases and the presence of an isolated Cereal type grain. Betula increases but is then reduced as values first for Corylus/Myrica and then Alnus increase but the changes in the frequencies for these species are less well marked when expressed as a percentage of the A.P. sum (Fig. 7•4). The end of LM3 is marked by peaks for Betula and Alnus, and, to a lesser extent, Quercus with reduced frequencies of Gramineae and Calluna but overall levels for A.P. do not reach those of earlier zones.

Filicales peaks at the beginning and towards the end of LM3, reaching especially high levels at 200cm. Lycopodium is more consistently present in the later part of the zone where there are also higher values for Sphagnum. There are low peaks for Equisetum, Nymphaea and Potamogeton.

LM4 141 - 110cm

The upper boundary is defined by decreasing Betula, Corylus/Myrica and Alnus and by rises in Gramineae, Calluna, Cyperaceae and Rumex.

LM4 opens with a sharp reduction in Betula and Alnus and the steepest drop in A.P. noted in the diagram. There is a slight decrease in Quercus and later Corylus/Myrica but from the A.P. diagram it is clear that there was little change in the relative contribution of the main arboreal taxa. At the minimum for A.P. there are high peaks for Gramineae, *Calluna*, *Plantago lanceolata*, *Rumex* and *Pteridium*, and *Cereal* type pollen is present including *Hordeum* sp. (Table 7·1). Chenopodiaceae and *Urtica* are also more noticeably present and there is a single record of *Montia* sp. By the end of the zone there is a recovery of *Betula*, *Alnus* and *Corylus/Myrica* but only the latter reaches levels found at the onset of LM4. Although high at the opening of the zone Filicales declines throughout recovering only slightly at the LM4/LM5 boundary but *Sphagnum* remains consistently present. There are also much higher consistent frequencies of *Equisetum*, *Nymphaea* and *Potamogeton*.

LM5 110cm - top of diagram

Initially there is a further decrease in *Betula*, *Alnus* and *Corylus/Myrica* and A.P. fall below 30%T.L.P. *Quercus* is not affected but later falls below 2%T.L.P. and then rarely exceeds this figure for the rest of the diagram. With this decrease in woody taxa there is an increase in Gramineae, Cyperaceae and *Calluna*, and high consistent curves for *Plantago lanceolata*, *Rumex*, *Pteridium* and Compositae lig. with with Ranunculaceae, *Urtica* and *Cereal* type pollen occurring more regularly. This is the first of three periods of increased herbaceous representation in LM5 and is separated from the second phase by a slight increase in *Betula* and *Alnus* around 88cm, but there is little change in most N.A.P. taxa at this time. The second phase of high counts occurs with the lowest *Alnus* frequencies and shows initially continuous frequencies for *Cereal* type pollen with high *Calluna*, Gramineae, *Plantago lanceolata* and *Rumex*. *Artemisia*, Compositae lig. and Cruciferae are also present. It is at this point that *Quercus* is first reduced to less than 1%T.L.P. The recovery in A.P. is gradual but especially seen in increasing values for Alnus and later Betula with a slight increase in Corylus/Myrica. The maximum for A.P. is reached at 24cm when the pollen of trees and shrubs comprises over 40%T.L.P. and there is a reduction in Gramineae, Calluna, Plantago lanceolata and Rumex. After this peak in the pollen of woody taxa both Betula and Alnus are reduced but the increase in N.A.P. is mainly in Calluna, and Plantago lanceolata and Rumex frequencies remain rather irregular. Values for Pteridium are regular throughout the whole zone. The higher counts for Pinus which appear towards the end of the zone are not so apparent when seen as percentages of the A.P. sum (Fig. 7·4).

There are two main peaks for Filicales in LM5 at 88cm and between 40cm and 20cm and in the latter broad peak Lycopodium spores are also better represented. LM5 also has an almost consistent curve for Selaginella selaginoides. Sphagnum is better represented after 72cm and reaches over 10%T.L.P. Equisetum, which is high at the LM4/LM5 boundary, is reduced at 88cm but shows two peaks at 60cm and 24cm. The first two peaks occur simultaneously with peaks for Myriophyllum spicatum and Potamogeton.

c) Pollen concentration values

Without a series of radiocarbon dates it is not possible to calibrate the pollen concentration values to produce rates of pollen influx and hence all the results are expressed as the number of grains per c.c. of sediment. As there is no indication of a change in stratigraphy throughout the core it could be argued that sediment accumulation has been constant and larger lakes with non-cultivated catchments have shown linear time-depth scales covering the last 9500 years (Pennington, 1973). Even where there is evidence for cultivation and accelerated sediment accumulation within catchments this may only lead to a steepening of the still linear curve from the point of change in the vegetation communities recorded. In a site such as Loch Mharaich where there is only limited evidence for local cultivation and where the record covers only the period immediately post-dating the earliest appearance of human communities a relatively uniform accumulation rate may therefore perhaps be expected.

Assuming this and dating the base at c.3100b.c. and the top between 1700 - 1900a.d. (see ensuing discussion) to allow for the loss of recent sediment during sampling, sediment accumulation would have taken place at c. 6cm per 100 years. This would mean an A.P. influx at the base of c.8700 grains/c.c.^{2}/yr. and an influx rate for Ulmus of c.900 grains/c.c.^{2}/yr. These figures when compared to those derived by Pennington (1973) for lakes in North West England and Northern Scotland would fall midway between those found in large lakes such as Lake Windermere, and those for small lakes such as Blea Tarn, and the values for Ulmus would be equivalent to those found at Loch Clair in Northern Scotland. Considering the altitude and small catchment of Loch Mharaich such comparisons appear plausible and may act as a guide when examining the results from the loch against other available data.

In general the pollen concentration values found at Loch Mharaich are somewhat erratic but they do follow the trends established in the relative pollen curves and are not dissimilar to results found elsewhere:

LM1 - There is a reduction in overall pollen concentration from between 200-250x10^3 grains/c.c. at the base to only 130x10^3 grains c.c. at 296cm, but values recover to 200x10^3 grains/c.c. at 280cm. This recovery is most noticeable in Betula, Corylus/Myrica, Alnus and Ulmus with less change in Quercus and no alteration in the concentration of Pinus pollen. After an initial rise to between 10-15x10^3 grains/c.c. the concentration of N.A.P. remains relatively stable before rising again at 260cm. Between 280cm and 260cm there is however a severe reduction in total pollen concentration, which at 270cm falls to 10×10^3 grains/c.c.

LM2 - The changes in relative pollen counts at the LM1/LM2 boundary are foreshadowed by a drop in total pollen concentration at 238cm with all A.P. particularly affected. Both *Ulmus* and *Quercus* which were reduced gradually in LM1 are further reduced. Gramineae, although more important proportionally in the pollen count only reaches concentrations found in the earlier zone and the same is true of other N.A.P. At the end of LM2 the recovery of A.P. frequencies is expressed also as a rise in concentration, in particular in *Betula* and *Alnus*, but there is no change in *Corylus/Myrica*.

LM3 - By the opening of LM3 total pollen concentration becomes relatively stable and throughout the zone only varies between 60 and 80×10^3 grains/c.c. although the concentration of A.P. tends to oscillate. After a small early reduction in A.P. concentration there are higher values at 192cm but again not in *Corylus/Myrica*, mainly in *Quercus* and *Betula*. In this early part of the zone *Calluna* and Gramineae increase and there are also higher concentrations for *Plantago lanceolata* and *Rumex*. After 188cm total concentration only varies between 60 and 75×10^3 grains/c.c. with further varying curves for most A.P. but *Alnus* gradually increases its concentration and *Calluna* is higher than Gramineae.

LM4 - There is a severe drop in the concentration of *Betula* and in A.P. as a whole but there are rises in Gramineae, *Calluna*, *Plantago lanceolata* and *Rumex*. LM4 has continuous low pollen concentration values but by the end there is some evidence for a slight recovery in *Betula* and *Alnus*.

LM5 - The opening of LM5 is marked by a further general decrease in the concentrations of A.P., especially *Betula* and *Alnus*, and by increasing Gramineae, *Calluna* and Cyperaceae so that overall pollen concentration once again reaches more than 100×10^3 grains/c.c. There are also higher values for other N.A.P. such as Plantago lanceolata, Rumex and Pteridium but not to levels found earlier. After 50cm there is a recovery in the concentrations of Betula, Alnus and, to a lesser extent, Corylus/Myrica, but this has no effect on Calluna or Gramineae and is not reflected in any increase in total pollen concentration which remains variable. There is some increase in the concentration of Pinus in the uppermost samples but values are still relatively low.

d) Statistical zonation

As the methods devised by Gordon and Birks (1972) for the statistical zonation of pollen diagrams utilise percentage counts numerical analysis was only carried out on the relative pollen counts using 13 taxa which comprise at least 2%T.L.P. (Table 7·2). Although the initial divisions made by the two techniques employed differ both appear at later stages of division in each method and both occur one level above the boundary defined subjectively. SPLTINF locates the LM2/LM3 boundary and SPLTLSQ the LM3/LM4 boundary. The difference in location of the subjective boundaries is largely due to the boundaries involving changes in several taxa and the non-statistical divisions using rather specific changes in fewer taxa which tend to tie down the boundary to a single representative position. The LM2/LM3 boundary for instance is positioned where both Plantago lanceolata and Rumex increase from values of less than one per cent to two per cent or more, changes which would not be the main determinants of a purely objective approach. The second division using SPLTINF occurs one level above the LM4/LM5 boundary and the equivalent of a later SPLTLSQ boundary is a further level away but here again the division is based on changes

Table 7•2 Statistical zonation of the relative pollen data from Loch Mharaich

Division	SPLTINF	Residual variability (%)	SPLTLSQ	Residual variability (%)
1	(2 - 200) (204 - 300)	41•26	(2 - 136) (140 - 300)	36•25
2	(2 - 104) (108 - 200) (204 - 300)	25•45	(2 - 136) (140 - 228) (230 - 300)	23•92
3	(2 - 104) (108 - 200) (204 - 256) (260 - 300)	20•26	(2 - 100) (104 - 136) (140 - 228) (232 - 300)	18•03
4	(2 - 104) (108 - 136) (140 - 200) (204 - 256) (260 - 300)	18•44	(2 - 100) (104 - 136) (140 - 200) (204 - 228) (232 - 300)	15•97

in several taxa and the subjective boundary is made where Betula and Alnus values first fall although this postdates variations in some N.A.P. taxa. The second SPLTLSQ division occurs in the middle of LM2 because of the criteria used for defining assemblage zones subjectively, which was to encompass a phase of vegetation modification due to human activity, hence the lowest A.P. and highest N.A.P. values would occur in the middle of a zone. If the changes in pollen representation are severe, as in this case, then statistically great variability would be recognised and a boundary established. To overcome this it would be necessary to weight N.A.P. values so that such criteria could be incorporated in a statistical approach. A boundary is also established by SPLTINF at this level, for the same reasons.

The only boundary not confirmed by SPLTLSQ at a later stage of division is the LM2/LM3 boundary and similarly SPLTINF does not confirm any boundary comparable to LM1/LM2. It is difficult to see why they are not located but the main reason probably lies in the position of earlier boundaries which would place these levels within relatively homogeneous units, especially when compared with the amount of variability encountered elsewhere.

e) Vegetation history

The high pollen concentration and dominance of tree pollen at the base of the diagram reflects the character of the local Atlantic woodland on the slopes surrounding lower Glenshee. There is very little herbaceous pollen recorded except for Cyperaceae which probably originated from marginal communities around Loch Mharaich, emphasising the closed nature of the forest cover at over 300 metres and probably over the hill mass as a whole. The woodland was dominated by Betula, Alnus and Quercus but with much less hazel than at Heatheryhaugh. Not only are values for oak higher than on the Forest of Alyth but so too are those for elm indicating a greater local presence on the more sheltered valley sides. Because of its location in the lee of the main watershed pollen accumulating in the loch probably derived both locally from the small catchment and, because of its small diameter and position, by transport from lower ground as seen in more extreme examples in the Jotunheim in S. Norway (Pennington, 1973). Thus it seems likely that the mixed oak forest elements derived principally from the lower slopes, especially on soils developed on the limestone and calcareous schists to the north and on fluvioglacial and glacial deposits incorporating these rock types. It is therefore suggested that in the immediate vicinity of the loch Betula and Alnus would have been the dominant trees with the scattered presence of Quercus. The forest is only truly represented in the basal sample and the very low frequencies for herb and shrub pollen preclude the identification of other local species. Although the pollen of Melampyrum does occur this may have derived from fen vegetation rather than have been associated with earlier land clearance (Pilcher, 1973; Godwin, 1975b).

Despite the increase in pollen concentration between 300cm and 298cm this point marks a clear decline in frequencies of elm and some decline in oak in the relative diagram. It may be that this decline began earlier but is not recorded in the sampled core. Only oak and elm were reduced but there is an immediate rise in Corylus/Myrica and Pinus and more gradual increases in Betula and Alnus with a rise in Gramineae and the appearance of occasional grains of Calluna, Plantago lanceolata, Rumex and Pteridium. Despite the slight nature of the changes when expressed in percentage terms there is eventually a drop in pollen concentration by a half. Clearance was therefore taking place but not around the site and presumably, in the absence of any indicators of arable activity, for pastoral purposes. The reduction in all taxa in terms of concentration, but only of oak and elm in terms of relative representation, suggests that considerable forest reduction was probably taking place on the lower valley sides particularly on soils under oak and elm. After this opening of the forest regeneration of all arboreal taxa took place but neither elm nor oak regained their former status in the woodland and birch and alder were the trees which took over much of the cleared areas for, unlike Heatheryhaugh, the expansion of hazel was limited to colonisation immediately upon abandonment and it was not able to prevent the establishment of other woody species.

The character of this period of forest clearance at Loch Mharaich is dissimilar to that found at the other two sites but would nevertheless appear to reflect a significant sharp decline in elm pollen and is tentatively correlated with the Elm Decline and therefore dated to c.3100b.c. (Smith and Pilcher, 1975). It is only at this site that elm recovers at all after its initial decline, a decline which, when expressed in terms of the percentage reduction of the concentration of elm pollen is more extreme than that found either in North West England or in Northern Scotland (Pennington, 1973). Variability between sites as to whether they record a recovery in elm is not unusual. At Williamson's Moss, Eskmeals, Witherslack Hall, Ellerside Moss, Thrang Moss, Nichol's Moss and Haweswater in the Lake District (Oldfield, 1962; Pennington, 1975) elm recovers after the initial decline but rarely to the levels previously attained and then there is a further gradual reduction as occurs here. In Northern Ireland where general forest regeneration, including elm, occurred after most early Neolithic clearance phases associated with the Elm Decline there is also a later more gradual decline (Smith, 1975).

The ability of elm to regenerate in this upland environment while there is no indication of regeneration in Strathmore may be explained by either of two hypotheses. Despite the severe drop in pollen concentration the later recovery and regeneration of forest implies that the area of southern Glenshee was still peripheral to the main concentration of early Neolithic activity as registered at Heatheryhaugh. The transitory nature of the change in the woodland communities may therefore have been insufficient to provide the radical changes seen on the Forest of Alyth, and thus allow elm to regenerate. An alternative hypothesis may be that on soils with a higher base status than found elsewhere, those derived from calcareous parent materials, there was insufficient loss of base status to prevent the regeneration of elm and that the recovery in elm values is indicative of clearance and abandonment on such areas.

After 280cm there is evidence of further forest clearance in another reduction by half in the total concentration values with birch, oak and alder affected to the immediate benefit of hazel which spread onto recently opened areas. This period of clearance again seems to have been at some distance from the loch on the lower slopes and further removal of primary forest is indicated. There is very little evidence for the form of agricultural activity for which the woodland was removed although a Cereal type pollen grain of uncertain species occurred at 276cm. All the woodland species affected recovered slightly following this phase which appeared to last a similar length of time to the earliest clearance and there are few grounds, except the change in elm frequencies, for suggesting any difference in the form of land utilisation between the two clearance phases, the slightly higher N.A.P. frequencies in the second phase reflecting only either the clearance of a larger area or of land nearer the loch.

In the later part of LM1 there was some further reduction in the forest cover, especially in birch, oak and hazel, and alder extended as a pioneer species in cleared and abandoned areas but any more specific pattern is difficult to discern. Towards the end of the zone there are higher frequencies for Gramineae and Pteridium but few other herbs are recorded either consistently or at levels greater than 1%T.L.P. Some further clearance of areas of primary forest dominated by both birch and mixed oak wood species may have been taking place but the changes in Betula could reflect removal of secondary woodland, as could the changes in Corylus/Myrica. The gradual reduction in elm and oak points to either continuous clearance and utilisation of areas of former mixed oak forest preventing regeneration, with perhaps some use of elm for fodder, or to a slow deterioration in soil conditions leading to the disappearance of elm and reduced oak representation. Either explanation could be used to interpret the evidence but human communities, however small, must have been present for much of the period to the south of the area as evidenced at Heatheryhaugh, and, as at other sites, land did remain open once cleared. The end of LM1 marks the point at which elm was almost completely removed from the area but there was a brief recovery in secondary woodland prior to later woodland clearance in LM2.

Assuming a constant accumulation rate LM1 would have terminated at c.2000b.c. and would therefore cover the Neolithic period. As at Heatheryhaugh and Stormont the vegetation record shows the presence of human communities in the area almost continuously through this period especially on the lower valley side slopes and the fringe of the plateau areas. There are no archaeological records from the Neolithic in lower Glenshee and free-standing stone monuments which may have early construction phases predating 2000b.c. (cf. Croft Moraig) only occur in Strathardle and higher up Glenshee.

The character of the sediment throughout the diagram shows that there has always been open water and lacustrine deposition but due to the size of the basin the pollen record from the lake deposit also reflects those communities occurring along the lake margins. The presence of _Salix_, _Equisetum_, _Filipendula_ and _Potentilla_ type pollen probably indicates areas of _Salix_ fen persisting throughout LM1 and areas of shallow water were colonised by _Potamogeton_ and _Nymphaea_. There is some evidence for a change in hydroseral succession by the end of the zone with reduced _Potamogeton_ and _Nymphaea_ and higher _Salix_ and _Equisetum_ reflecting an expansion of the fen. _Sphagnum_ also occurred in the local hydrosere and probably expanded as a result of the spread of fen taking over after the development of _Salix_ for throughout the diagram the highest values for _Salix_ are found with low _Sphagnum_ counts and after these peaks _Sphagnum_ often rises until, in the later zones, _Salix_ values are generally lower and _Sphagnum_ higher.

Clearance of woodland at the opening of LM2 was mainly of birch, alder and hazel but only in the case of alder did this lead to any reduction of its percentage contribution below that already experienced in LM1. Clearance in terms of reduced pollen concentration was not so noticeable as before and although there were the first appreciable peaks for _Plantago lanceolata_ and _Calluna_ their concentrations are not significantly higher to those found earlier in LM1. This pattern reflects clearance taking place much closer to Loch Mharaich thus allowing an increase in the variety of N.A.P. represented in the pollen record, rather than any more widespread forest reduction, but the small drop in oak may reflect some increased attack on woodland on the lower slopes. Although there is an increase in the number of herbaceous taxa recorded there is no evidence for cultivation associated with the clearance. At Heatheryhaugh interpretation of the expansion of Calluna during periods of land clearance was complicated by its local presence in the peat stratigraphy but this is not the case here. Calluna may have been present on some of the drier areas of fen onto which Sphagnum had spread but from the way in which the curve for Calluna follows the peaks of other non-arboreal taxa it seems likely that it expanded as a response to clearance. The early presence of Calluna emphasises the acidity of the parent materials in the immediate vicinity of Loch Mharaich which, coupled with the altitude, would have encouraged podsolisation when the woodland canopy was removed, particularly on the thinner soils of the upper slopes.

Regeneration of secondary woodland dominated by birch, alder and hazel is clearly seen at the end of LM2 with their recovery in both percentage values and pollen concentration such that the assemblage found at the end of LM1 is closely reproduced at the end of LM2. This regeneration marks the abandonment of cleared areas but soil deterioration was still limited in extent and most tree species were able to regenerate around the site. Nevertheless some reduction in base status may be inferred from the lesser role of hazel as a coloniser at the end of LM2. Although Salix is low Sphagnum values increase and areas of shallow water are indicated by the presence of Nymphaea.

Dating of LM2 on the basis of constant sediment accumulation would place the LM2/LM3 boundary at c.1600b.c., a period for the zone of 400 years, not a brief forest recession. There is little direct archaeological evidence for this period close to the site as commented earlier. It may be that woodland clearance reflected the expansion of human communities already established along the Highland edge rather than any new immigration and that Glenshee and Strathardle were still areas of settlement peripheral to the main concentrations of human activity.

This may also explain why forest regeneration was relatively successful at the end of LM2.

A more significant change in the local vegetation communities occurred with the opening of LM3 but this change is barely reflected by any change in pollen concentration. Areas dominated by birch and alder were cleared allowing the local expansion of herbaceous species and from the drop in A.P. it seems likely that this clearance took place much closer to the site and probably around the loch margins. This interpretation is made on the basis of the higher frequencies for Gramineae and Plantago lanceolata and on the appearance at higher levels of a wider variety of herbs such as Artemisia, Rumex, Compositae tub., Compositae lig., Cruciferae and Urtica as well as further Cereal type pollen. The contribution of N.A.P. was sufficient to balance the loss of A.P. in terms of total pollen concentration probably emphasising the local nature of the changes. In the earliest period of clearance in LM3 although pastoralism is still indicated as the dominant land use by the herbs present in the pollen record the appearance of cereals and herbs such as Compositae lig. and Cruciferae suggest that cultivation may have been taking place close to the loch. As in earlier zones Calluna also expanded with the clearance episode and the same process of localised podsolisation as postulated earlier may account for this.

The recovery in Betula which occurs after this phase in both relative counts and in concentration values did not herald any general regeneration in the woodland cover and hazel was still unable to take advantage of newly abandoned areas. There was obviously some reduction in the scale of local land utilisation and the absence of Cereal type pollen and reduced herb frequencies indicate a significant decline in, if not a cessation of, cultivation near Loch Mharaich. Those clearings which were not recolonised by birch either remained under heather or grassland but the presence of weeds such as Plantago lanceolata and Pteridium indicates some possible continuity in grazing preventing any more complete woodland regeneration taking place.

The reduced frequencies for A.P. and shrub pollen between 192cm and 168cm are not of the same scale as in the earlier part of LM3 and affect Quercus and Corylus/Myrica with a later drop in Alnus rather than Betula. The lack of any significant expansion of herbs during this period points to clearance taking place on the lowermost slopes or valley floor away from the loch, those areas in which oak had persisted throughout LM1 and LM2. Around Loch Mharaich there was continuous slow recolonisation by birch and also a slow increase in Calluna at the expense of grassland with reduced values for Rumex and falling Plantago lanceolata. There is no obvious recovery of woodland at the end of this phase around 168cm although there is a small peak for Corylus/Myrica as the change in community structure had been a gradual one and superimposed on this pattern is a decline in Alnus. It is difficult to interpret the change in Alnus frequencies by means of association with a pattern of clearance although it may have unsuccessfully competed with regenerating birch and hazel. Comparison with the relative counts for Salix shows high Salix values at the time of lowest alder frequencies. This is not due to any increase in the concentration of Salix pollen but may be due to changes taking place on the loch margin with a reduction in alder as a component of the fen communities. In such a shallow basin as this with several small embayments there would always have been a mosaic of local hydroseral communities with the shallowness making it more sensitive to changes in water levels. The pollen record from the lake sediment shows that there was no single straightforward hydroseral sequence during the later Flandrian so the input of the local hydroseral communities would have varied considerably over time reflecting purely local changes within the contrasting environments around the loch. Peat development around the margins of Loch Mharaich can be seen today with different thicknesses of deposits in the small embayments, areas which would have changed in character considerably if lake levels varied.

By the end of LM3 alder had regained its position in the local woodland and possibly within any marginal fen woodland and there was relative stability within the remaining woodland with a period of considerably reduced grassland and heath, as seen in the very low frequencies for herb pollen. There was no recovery of woodland as a whole although both oak and elm managed some slight expansion. Nevertheless frequencies of A.P. and shrub pollen of up to 70%T.L.P. show that although the landscape overall may have suffered considerable deforestation and change in its species composition, with overall pollen concentration values indicating a drop of over two-thirds in the amount of pollen represented when compared to the period preceding the appearance of human communities, woodland remained on the slopes around Loch Mharaich. There had been local clearance which encouraged the development of secondary woodland but much of the upper part of the catchment must have remained under primary woodland dominated by birch. As at Heatheryhaugh the similarity in species composition between primary and secondary woodland makes accurate definition of such changes difficult.

The boundary between LM3 and LM4 can probably be dated to c.600b.c. if the same procedure outlined above is adopted and indicates that between the middle of the second and the middle of the first millennium b.c. human pressure on the watershed was relatively low. It would however have been during the first millennium b.c. that the groups of hut circles around Dalrulzion immediately below Mharaich would probably have been constructed and first used and by analogy with Dalnaglar and Kilphedir it appears unlikely that the main occupation phase would have been as early as the middle of the second millennium b.c., the opening of LM3. The pattern of the pollen evidence could be accounted for by a spread up the hillside in LM2 subsequently followed by a movement to lower ground in LM3 with some continuation in the use of the higher land for grazing but there is no hard archaeological evidence to support such a view. Such a movement would not be unusual if the effect of the suggested deterioration in climate between 1000 and 500b.c. or even earlier (Burgess, 1974), was to lead to an acceleration in the accumulation of surface organic horizons (Piggott, 1972; Godwin, 1975b). This would account for the gradual reduction in grassland seen throughout LM3 but there is no widespread expansion in Calluna as might be expected were such a process taking place. Any depression in the altitude of land used for agriculture at this time due to climate may therefore have merely been temporary for it is noticeable that archaeologically most of the hut circles which are such a common feature of the area and which spread up to over 350 metres date to after the middle of the first millennium b.c. and, at present, there is very little evidence to place them before this date.

The next phase of forest clearance which is marked by the opening of LM4 was more severe than that found in LM3 with a reduction in the pollen of all arboreal and shrub taxa to low levels and a significant drop in the concentration of such pollen as well. Land was not only cleared within the secondary woodland of the lower slopes and around the loch but also on the higher slopes within primary woodland. The persistence of Cereal type pollen, mainly Hordeum sp. where identifiable, shows that cultivation was again taking place locally and there was also a marked expansion of grassland with the highest percentage contribution for Gramineae and increased values for Plantago lanceolata, Rumex and Pteridium. Calluna also increased its relative contribution but with no change in pollen concentration it seems unlikely that there was any widespread expansion of heath. The presence of pollen of Montia type is of interest for grains of Montia fontana have been taken to be indicative of clearance and settlement from Neolithic to Roman times (Godwin, 1975b). Following land utilisation all woody taxa recover to levels found at the opening of LM4 but unlike the LM3/LM4 boundary there is some evidence for continuity of land use between LM4 and LM5 with the presence of Cereal type pollen and Plantago lanceolata across the boundary despite lowered frequencies for Gramineae.

The end of LM4 may be approximately dated to c.200b.c. implying expansion of cultivation and presumably settlement up the valley side in the latter half of the first millennium b.c. From the pottery evidence from Dalnaglar this dating would seem more appropriate as a reflection of activity around Dalrulzion. If so it shows that land utilisation associated with the hut circles was probably by no means a single short phase of agriculture, for here a period of four hundred years is suggested, but was a more discrete event than at Heatheryhaugh. The dating of LM4 to between 600b.c. and 200b.c. would place it before the 'extensive clearances' of Turner (1965) dated in Wales to between 250a.d. and 450a.d. which were thought to be associated with the construction of similar hut circles. The 'extensive clearances' identified in southern Ayrshire, also by Turner (1975), at Bloak Moss appear to occur even later but here two dates 800 years apart are very close stratigraphically and the clearances could be slightly earlier. Bearing in mind the variety of forms and periods covered by 'hut circles' such comparisons may be invidious but the expansion indicated around

Loch Mharaich could for instance reflect the "brief floruit of the isolated upland farmstead type of settlement" following earlier abandonment of 'montane' systems at the end of the second millennium b.c. (Fowler, 1978, p.3). Whatever the possible analogies from the rest of Britain correlation of the sequence of vegetation changes found in LM4 and their suggested dating of c.600 to c.200b.c. with the construction of the hut circles around Dalrulzion seems feasible and indicates that the spread of human activity up the slopes of the Glenshee – Strathardle watershed was by no means the first utilisation of the land for agriculture but was perhaps the most extensive and was not apparently hindered by any widespread inherent deficiencies in the status of soil, for utilisation may have continued for up to 400 years. Indeed in the period between c.1500 and c.200b.c. this area tended to reflect the variations in population pressure for the Highland edge as a whole as land was either brought under use or abandoned.

During LM4 there was an increase in local aquatic taxa, especially Equisetum and Nymphaea and as in LM1 the rise in Equisetum is followed by a rise in Salix. Frequencies for Sphagnum spores are relatively high but only at 10%T.L.P. not the extremely high counts found in peat deposits. The origin of the Filicales spores which show an early peak in the zone is uncertain. There appears to be some correlation throughout the diagram between the curves for Filicales and Betula, the lowest Betula percentages at around 200cm and 130cm are followed by very low Filicales counts so it could be argued that the spores derived from the fern-dominated understorey of birch woodland, the sort of community already proposed around Heatheryhaugh. During counting it was however noticeable that the fern spores were often less well preserved than the pollen which would be unusual assuming a common origin. The highest Filicales counts also occur usually where there is evidence for woodland clearance, for instance as at 200cm and 138cm. If there was increased removal of the soil cover with these clearances many of the spores could have derived from soil profiles and not therefore be related directly to contemporary vegetation communities. High Filicales counts are characteristic of lower horizons of the soil profiles sampled on the Forest of Alyth and with a less acidic soil or the removal of lower horizons there would be an increase in the relative proportion of Filicales spores represented in the sediment record at times of increased erosion. Such a hypothesis would have implications for the rate of accumulation of sediment but in the absence of more detail about the state of preservation of both pollen and spores this is difficult to prove.

At first the removal of birch, hazel and alder in LM5 led to a reduction in total pollen concentration but clearance was never as severe as experienced on the Forest of Alyth and values for A.P. do not fall below 20%T.L.P. The virtually continuous presence of cereals and high values for Plantago lanceolata, Rumex and Pteridium which are found up to 60cm show that utilisation of the slopes around the loch continued after the first millennium b.c. but perhaps never to the intensity encountered earlier and the continued presence of birch and alder shows that deforestation was never complete. As land utilisation continued throughout the earlier part of LM5 there must have been a gradual deterioration in soil conditions for Calluna rises to a peak at 60cm after which all grassland and cultivation indicators decrease. This change in the fortunes of Calluna is particularly well illustrated in the concentration diagram. All the hill mass between Strathardle and Glenshee lies below the normal lower level for blanket peat in the Southern Grampians which has been placed by Romans (1970) at c.450 metres so the rise in Calluna must reflect the expansion of heath communities on increasingly podsolised soils rather than any local development of blanket bog.

Land utilisation during LM5 obviously continued for a considerable length of time as seen in the reduced arboreal frequencies but from 60cm there is a recovery in birch and alder and the latter becomes the dominant arboreal species. It is also at this point that frequencies for oak eventually fall below 1%T.L.P. for the first time. This final period of regeneration was only partial and was restricted probably by the use of the area for grazing, albeit now at a reduced level and possibly of a transhumant form. The regeneration of woodland is picked up in the concentration diagram for total pollen concentration increases from 50×10^3 grains/c.c. to over 100×10^3 grains/c.c. at 44cm of which a third is A.P. This woodland then persisted to the end of the period covered by the diagram with only a slight reduction in alder and birch and no return of grassland. The reappearance of occasional pollen grains of Cereal type in the upper levels is not accompanied by the return of arable weeds and probably only indicates cultivation at some distance from the site.

In the uppermost samples Pinus pollen reaches 4%T.L.P. but there is no significant increase in the concentration of Pinus. The rise in relative counts is much more noticeable in the soil profiles from the Forest of Alyth and in several pollen diagrams from the Grampians so it seems unlikely that this is the same phenomenon. Sediment was lost during sampling but this was mainly the unconsolidated material at the sediment-water interface and only a short time period may be concerned. From the pollen evidence it would therefore appear that the record probably ends just as pine was being planted in the seventeenth and eighteenth centuries, enabling some pine representation but no great increase in the amount of pine pollen in the regional rain. The high values for Calluna throughout LM5 and the pattern of vegetational change prior to this zone all argue for a continuation of the pollen record throughout the historical period.

The whole of LM5 would therefore span the period from c.200b.c. to possibly as late as the middle of the eighteenth century with initially an increase in settlement activity and then a long period of fairly uniform land use dominated by grazing during which the upper slopes became increasingly podsolised as did the area of the Forest of Alyth further to the east. Settlement during this period almost certainly contracted onto lower ground leaving the area around the loch under rough grazing with occasional clumps of birch and alder and the higher hut circles would have gone out of use but there is archaeological evidence for re-use of circles at various dates at the end of the prehistoric and into the historic period. The pollen evidence from Loch Mharaich shows that unlike on the Forest of Alyth woodland remained throughout the later Flandrian and that a discrete phase of regeneration was therefore far less noticeable here than in the later zones at Heatheryhaugh. This difference, considering the pressure on woodland which is indicated in the documentary evidence must reflect the concentration of human communities with far greater pressure being exerted around the Forest of Alyth. The land around Loch Mharaich was for a time administered by Coupar Abbey within the Persey estates and management by the monks may well have contributed to the continued survival of the woodland.

Possible correlations between the overall sequences established for Loch Mharaich and Heatheryhaugh will be considered later in Chapter 9 but around Loch Mharaich it is clear that podsolisation became most widespread in LM5 preceding any recovery in woodland and that the development of such soils was not a process of repodsolisation which occurred as birch woodland was removed for smelting as suggested by Romans (1970). The main difficulty in interpreting pollen evidence from such a site as Loch Mharaich remains the one of locating the source area for the pollen for despite the catchment origin of much of the pollen the small size of the basin allows a relatively high proportion of airborne pollen which may have derived from the lower valley side slopes.

CHAPTER EIGHT

EVIDENCE FROM ARCHAEOLOGICAL SITES

During the period of research no archaeological excavation took place within the area covered by this study but two sites were excavated in peripheral areas from which material has been analysed for its pollen content. The lack of excavation data from the study area precludes direct comparison of the site data with the more general vegetation history established in the previous chapters but the sites which were analysed both shed light on local environmental conditions in closely defined areas at certain periods during the later Flandrian. The first site at Moncreiffe House near Bridge of Earn(Fig. 8·1) was excavated as part of a rescue dig due to the construction of the M90 motorway and provided evidence of use stretching from pre-Beaker times in the early third millennium b.c. to the first millennium a.d. Although originally thought only to be a stone circle four phases of construction were identified including a henge monument. The site is located on fluvio-glacial sands on the northern edge of Strathearn in a somewhat analagous location to the fluvio-glacial sands and gravels found in Strathmore within which Stormont Loch is situated. The second site at Queen's View, Loch Tummel (Fig. 8·1), a ring fort or protected homestead, probably of the first millennium a.d., was excavated as part of a Forestry Commission sponsored dig. Ring forts are a form of monument specific to western Perthshire but the environmental data are representative of a period for which evidence is generally rather unclear and the steep slopes around Loch Tummel represent a relatively severe environment in contrast to most of the sites investigated in eastern Perthshire. Both sites were excavated by Dr. Margaret Stewart of Perth and the site diagrams are presented with her permission.

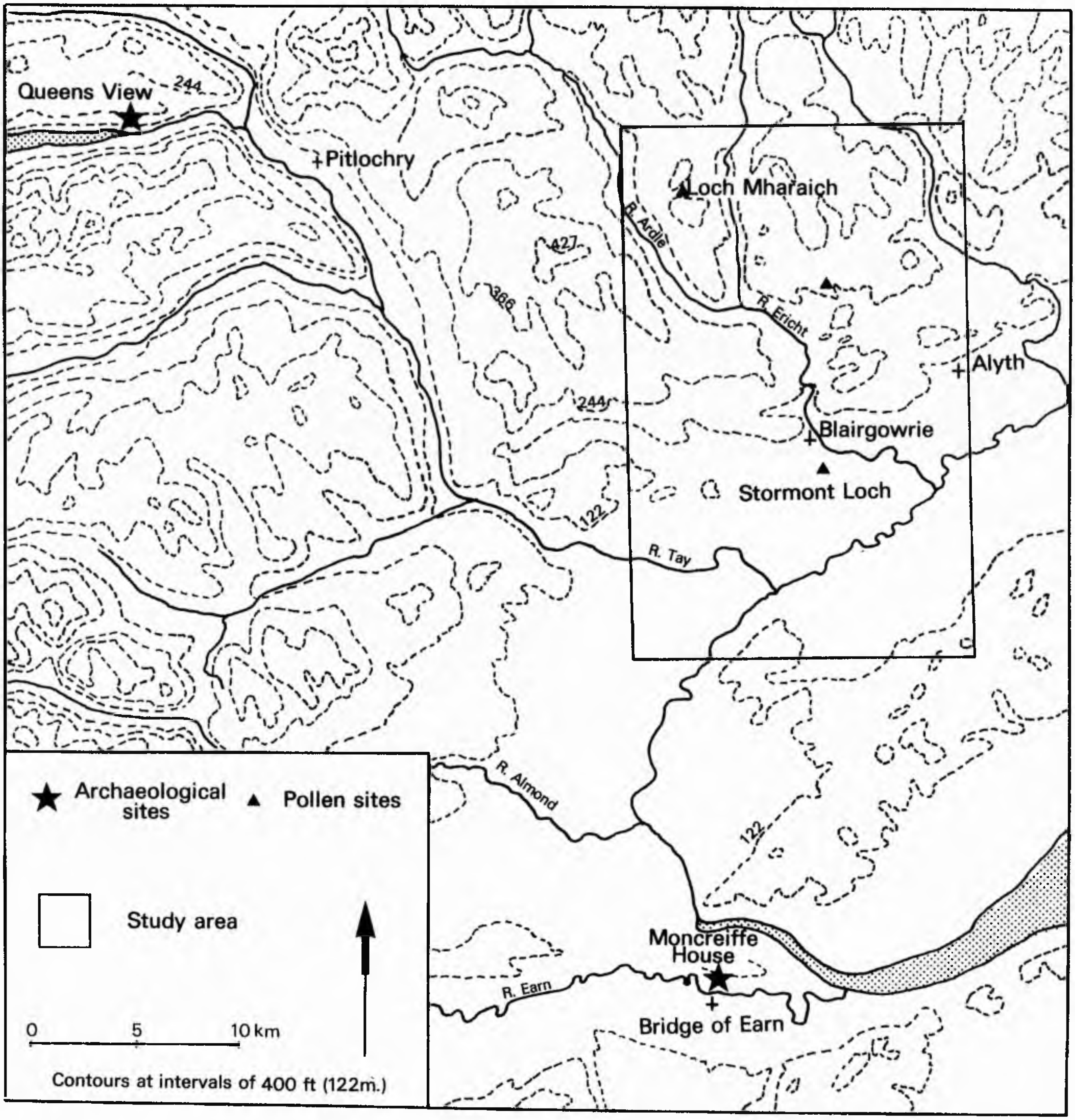


Fig.8.1 Location map of archaeological sites

i) Analysis of archaeological site material

The analysis of sedimentary material from archaeological sites can take several forms and pollen analysis is but one technique that has so far been applied to gain an understanding of the character of the environment of such sites (Dimbleby, 1967; Limbrey, 1975; Evans, 1977). In acidic environments where fossil mollusca do not survive it is the main form of microfossil evidence that is available although it is often supplemented by morphological and chemical analysis of sediments and it is a combined approach which usually provides the most thorough understanding of former environments. Archaeological sites of certain kinds can seal former soil profiles and it is buried palaesols which provide the most useful kind of evidence for former patterns of land utilisation (e.g. Dimbleby, 1962, 1965; Dimbleby and Bradley, 1975; Romans and Robertson, 1975) for not only can the vegetation record of the site and its immediate history be determined but chemical and morphological analyses of the soil horizons show the character and trend of pedological changes associated with the activities of early human communities. The discovery of complete palaeosols is however not a common feature of archaeological excavations and the available sediments for palaeoenvironmental reconstruction are often of a more fragmentary nature.

In the absence of a continuous type of record it is necessary to adopt a 'spot sample' approach where suitable deposits around the site are analysed and the results structured within a suggested chronological framework. Available deposits suitable for spot sampling fall broadly into two categories, those that are 'in situ' and those that are derived:

1. 'In situ' deposits - these may be the truncated or compressed remnants of soils but whose deformation precludes the identification

of a recognisable soil profile. Such deposits may be found under walls, banks, cairns or collapsed structures, the sort of sites where palaeosols may also be found, but they are often very thin. There is no problem in understanding the derivation of the material as it is 'in situ' although in such cases it may be possible to misinterpret an horizon as being 'in situ' when in fact it is a thin humic layer which may have been affected by inwashing on a disturbed site. Interpretation of the pollen assemblage from such horizons is difficult as is the interpretation of the results from truncated profiles.

2. Derived deposits - these are perhaps the most common type of deposits found on archaeological sites and for their accurate use it is necessary to understand the precise derivation of the sediment and the mode of deposition. Such deposits occur in post holes, socket holes, pits and in a more complicated form in ditches. Of crucial importance is often the rate of inwashing, whether for instance timber in post holes decayed slowly or was removed allowing rapid infill, or whether in ditches there was gradual siltation and slumping after abandonment. Thus the interpretation of the pollen evidence from these deposits relies on a clear understanding of the origin and mode of deposition as well as the relationship to the sequence on the site as a whole.

The value and reliability of the evidence from archaeological sites can be considered to decrease therefore from buried palaeosols, through 'in situ' deposits to 'derived' deposits because of the increasing interpretative problems but in many cases only 'derived' deposits are available for analysis and these have to be used. With all deposits from archaeological sites there are however several factors which need to be borne in mind when interpreting contained pollen assemblages.

Because most material, even on very acidic sites, although with the exception of waterlogged sites, is both humic and minerogenic pollen preservation can be poor with high levels for Indeterminable pollen and the likelihood of differential pollen preservation (Havinga, 1964). The interpretation of any pollen assemblage from such an environment cannot therefore be to any high level of resolution and only gross changes in assemblages or dominant assemblage features should be considered.

Interpretation of the derivation of material relies heavily on a clear understanding of the relative chronology of the site as understood after excavation as well as on the overall dating of the site as a whole. With the recognition of multi-phase uses in some monuments it is often impossible to identify precisely which phase deposits may originate from. This is especially true of post hole evidence if the patterns of excavated post holes do not readily allow the identification of coherent structures. A further feature of the chronological or sequential problems is the time period usually covered by deposits on archaeological sites. Buried soils or earlier surfaces can give a picture of the environment preceding and possibly contemporaneous with monument construction. Infill of pits, holes and ditches and overlying soils may allow the reconstruction of the environment on abandonment or some time after abandonment but there are few sorts of deposits which allow the determination of the landscape contemporaneous with site utilisation. Later infills may have some proportion of surface material which accumulated during utilisation but this is not always the case and unless surfaces are sealed by later phases within continuous use of the site it is unlikely that a record of activity will be preserved.

A final crucial problem which makes the interpretation of particular pollen assemblages from sites difficult is the nature of the site itself. Soil pollen records tend to represent very local environments with a low extra-local and regional pollen component. Where sites are open and perhaps not in constant use weeds characteristic of open ground are liable to be found. Interpretation of the pollen assemblage on the basis of weed species alone and especially the assumption of a particular form of agriculture in the near vicinity may therefore prove erroneous as the unique character of the site may be the overriding influence in the pollen record. A particular example of this may be found with ditch infill where, as a ditch goes out of use, it provides a very distinctive local environment which may not be evident on the pollen evidence alone unless certain grains are accurately defined to species level.

Interpretation of pollen assemblages from archaeological sites should therefore be treated with due regard to the problems outlined above. Both sites analysed here fall into the category of predominantly 'derived' deposits and hence the degree of resolution of the available data is low relative to what could have been obtained had better evidence been available.

ii) Moncreiffe House

a) Site and archaeological background

The site near Moncreiffe House is situated on a fluvio-glacial terrace above the present flood plain of the River Earn at an altitude of c.30m (NO132194). This terrace provides a pocket of sandy and coarse sandy soils between the steep slopes of Moncreiffe Hill and the gleys developed on the carse clays of the Earn valley. Three soil series have been identified in this small area (Fig. 8·2). The site itself stands on freely drained podsols of the Inchewan Series, part of the Boyndie Association developed on fine fluvio-glacial sands of

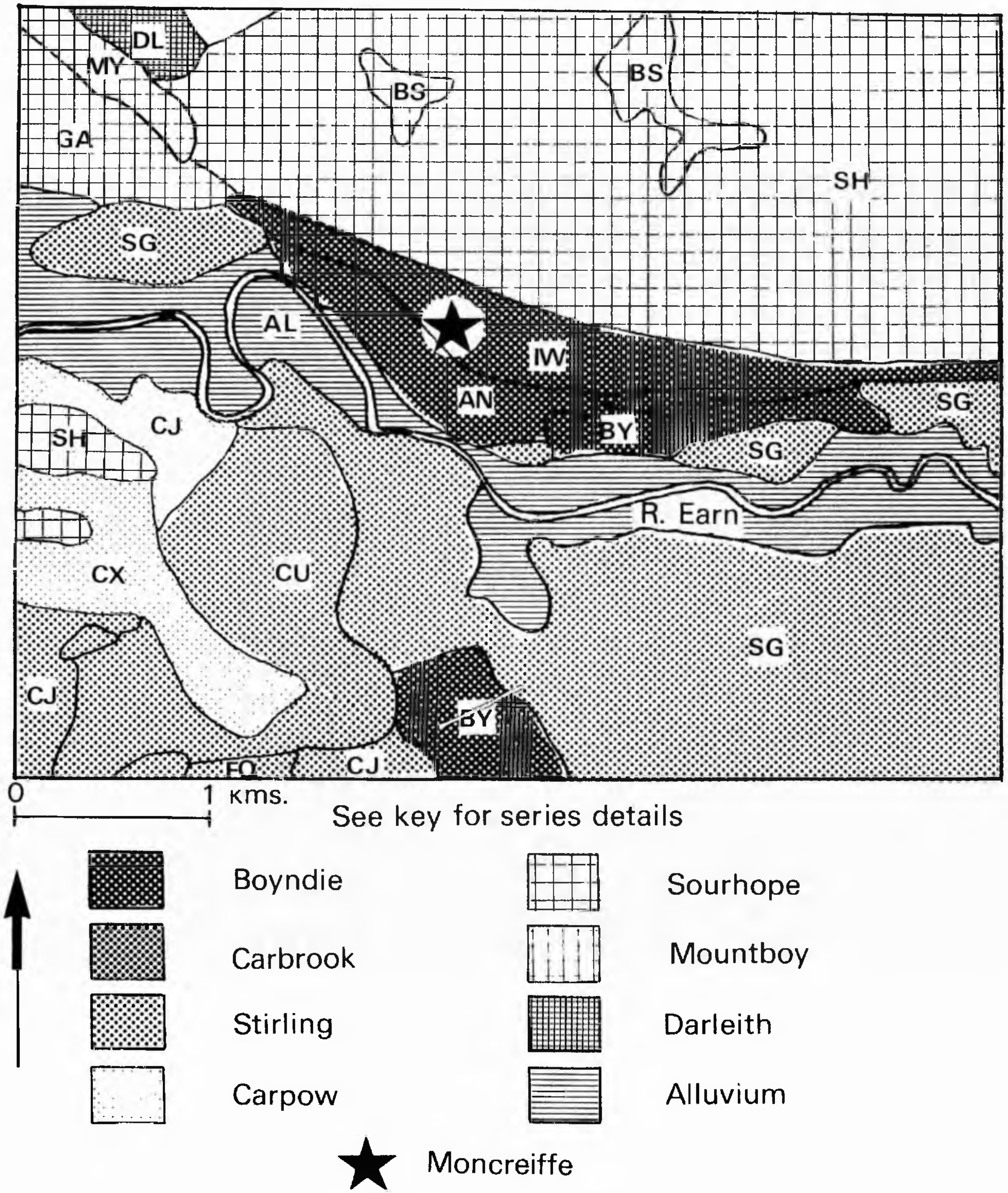


Fig.8.2 Location of the archaeological site at Moncreiffe House

Key for Fig. 8·2

Association	Series	Profile	Parent Material
Boyndie	BY Boyndie	Freely drained podsol	Medium and coarse fluvio-glacial sand of Highland rocks.
	AN Anniston	Imperfectly drained podsol	Medium and coarse fluvio-glacial sand of Highland rocks.
	IW Inchewan	Freely drained podsol	Fine fluvio-glacial sand of Highland rocks.
Carbrook	HV Harviestoun	Imperfectly drained podsol	Terrace and raised beach estuarine silts and clays of high raised beach.
Stirling	SG Stirling	Poorly drained non-calcareous gley	Estuarine silts and clays.
	CU Cauldside	Imperfectly drained podsol	Estuarine silts and clays.
	FQ Fordel	Poorly drained non-calcareous gley	Estuarine fine sands and silts.
Carpow	CX Carpow	Freely drained brown forest soil	Upper terrace coarse sands and gravels.
	CJ Carey	Imperfectly drained brown forest soil	Upper terrace fine sands and silts.
Sourhope	SH Sourhope	Freely drained brown forest soil	Drifts from intermediate lavas of O.R.S. age.
	BS Bellshill	Freely drained brown forest soil	Drifts from intermediate lavas of O.R.S. age.
Mountboy	MY Mountboy	Imperfectly drained brown forest soil	Till from O.R.S. lavas and sediments.
	GA Garvock	Freely drained brown forest soil	Till from O.R.S. lavas and sediments.
Darleith	DL Darleith	Freely drained brown forest soil	Basic lavas and basic intrusive rocks.

Highland origin, but to the south and west there are small patches of Anniston and Boyndie Series soils which are also part of the Boyndie Association but are derived from medium to coarse sand (Laing, 1976). Thus geomorphologically and edaphically there are similarities between this area and the outwash sands in Strathmore although the parent material here is finer and at present the soils are capable of cultivation despite being podsolic.

Archaeological interpretation of the excavated site is based on the preliminary findings of Dr. Stewart as no full report is yet available. Originally a stone circle was the only visible feature lying tangential to the driveway to Moncreiffe House and it was this, under the threat of the new road, which provided the focus for the excavation. On excavation however the monument proved more complex with at least four constructional phases spanning the period between c.2500b.c. and c.400a.d. The initial structure in Phase I (Fig. 8·3a) comprised a henge of timber construction surrounded by a ditch of which only the ditch and the sockets for the timbers remained. It is possible that the henge was constructed in two phases but the archaeological evidence for this is, as yet, inconclusive. The coarse ditch infill included Beaker pottery and on the basis of this and the general character of the henge a date of between c.2500 - 1800b.c. has been proposed. On the outer margin of the ditch a series of small stake holes were discovered which were contemporary with the henge and probably represented a fence of hurdle construction.

In Phase II (Fig. 8·3a) there was a small central burial cairn surrounded by four to five stone monoliths which was probably constructed between 1600 and 1400b.c. This is the first use of stone at Moncreiffe and provided the basis for a later feature, the recumbent stone circle of Phase III which was the main extant monument (Fig. 8·3b),

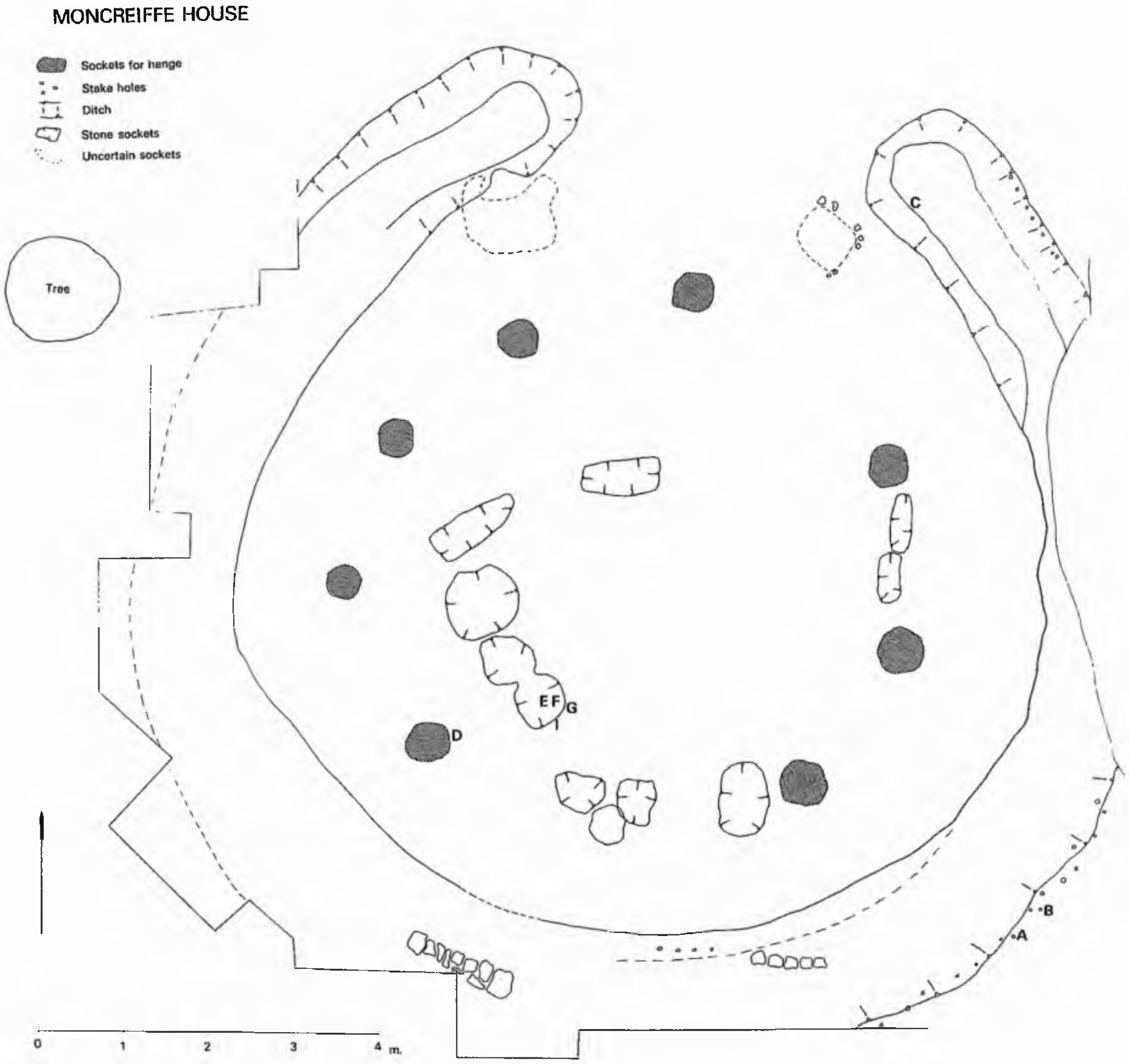


Fig.8.3a Excavation diagram from Moncreiffe House, Phases I and II

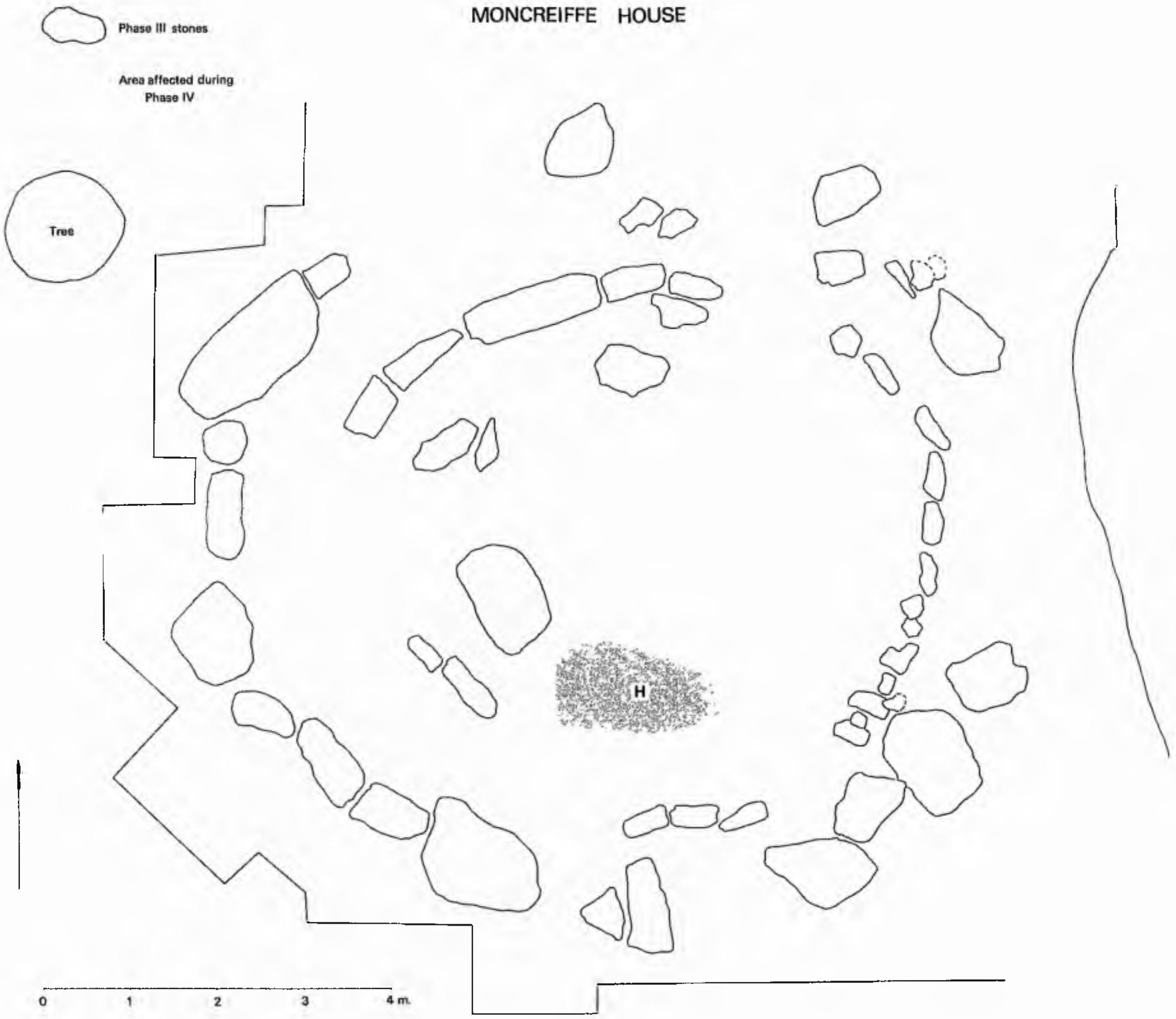


Fig.8.3b Excavation diagram from Moncreiffe House, Phases III and IV

itself probably built around 1200b.c. This later stone feature had a central cairn with a spread of quartz pebbles, and stones from Phase II were utilised to provide the circle severely destroying the evidence for Phase II. In the final phase, Phase IV, the burials and central cairn of III were disturbed and the southern part of the circle was used for smelting as seen in the existence of a clay-lined pit (Fig. 8•3b, detailed site diagrams of this phase were not available). A partial shelter was constructed around the pit using some of the stones from II and III and stake holes were also discovered from this period, estimated as occurring between 500b.c. and 500a.d. A cremation was found in association with one of the fallen stones but the archaeological provenance and hence the date of this is uncertain. It may have been a token burial related to either Phase II or III but it may be a later intrusion for, by chance, outside the ditch a cinerary urn was also discovered on the extension of a section into a neighbouring field.

Thus the site at Moncreiffe is essentially a complex one and as yet, apart from the evidence of the Beaker pottery and the general character of the monuments, only tentatively dated. The sequence established above is however accepted as the basis for the interpretation of the pollen evidence.

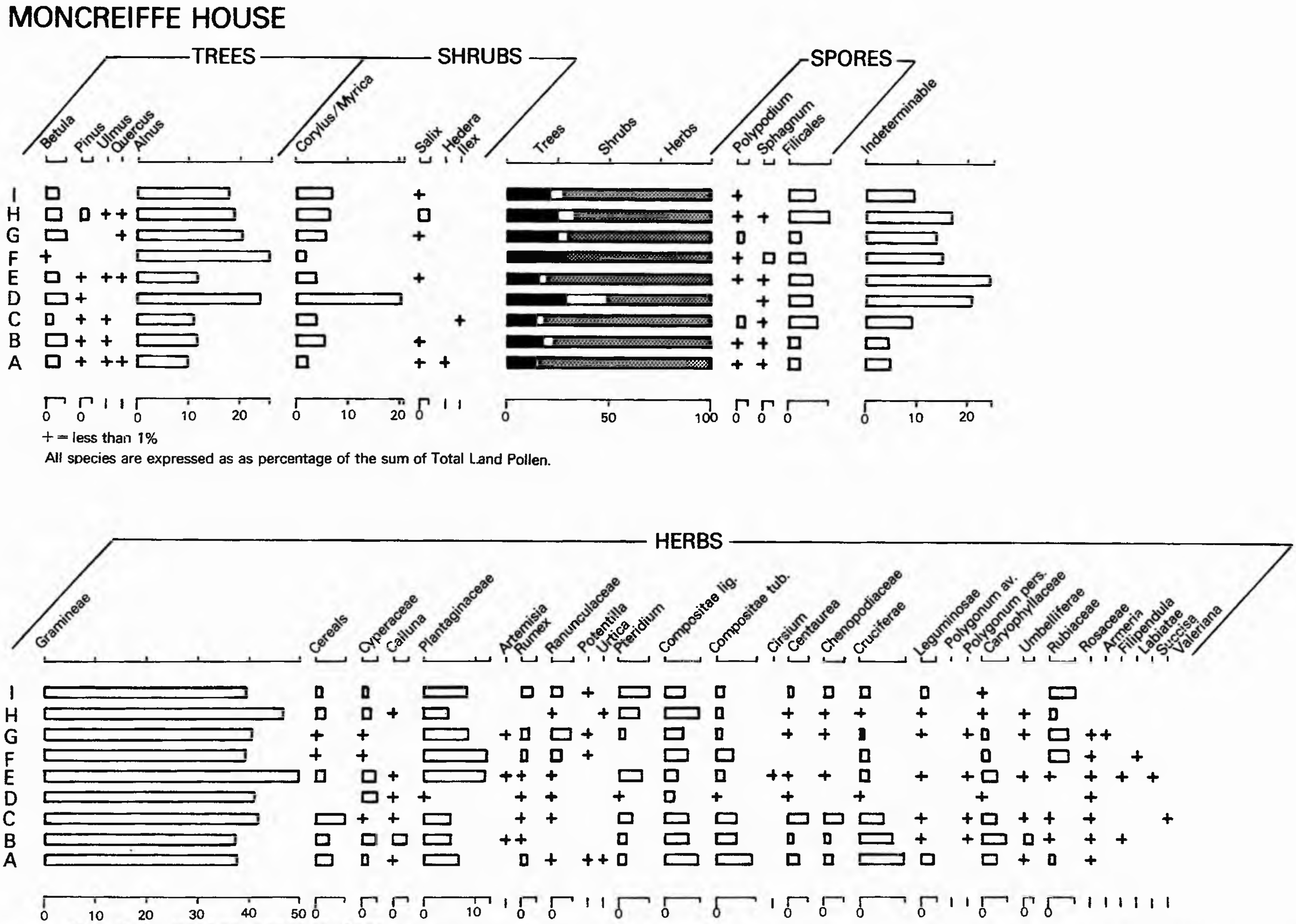
b) Sampling and the derivation of the material

Nowhere on the site produced any convincing evidence of a buried soil profile so a spot sample approach was adopted taking samples from recognised stratigraphical positions and relating them to the overall archaeological sequence taking into account its assumed derivation. Sampling on the southern edge of the feature was complicated by the disturbance caused by the construction of the driveway to Moncreiffe House.

Discussion of the samples analysed follows their assumed chronological order based on the stratigraphical evidence and this same sequence is followed for the presentation of the pollen diagram (Fig. 8·4). On the site diagrams (Fig. 8·3a and b) the position of each sample is denoted by the same sample letters.

Samples A and B were taken from the remaining lower parts of two adjacent stake holes outside the ditch in the south east quadrant of the site. Only the lowest tapering sections were encountered on excavation and these were sampled as a homogeneous deposit. From the excavation evidence it is difficult to establish whether the stakes were removed or decayed 'in situ'. There is no evidence for enlargement of the holes as may be expected on removal (Limbrey, 1975) but with only the lower part remaining this cannot be conclusively proved. The infill may therefore either represent the inwashing of soil immediately upon removal of the stakes or the more gradual infill associated with the decay of the wooden stakes. The samples must therefore date at the earliest to the abandonment of the outer fence which may or may not pre-date the abandonment of the henge. Because of the size of the holes infill would have been relatively rapid as soon as a void became available.

Sample C was taken from a small patch of silty material found within the generally coarse infill overlying a few centimetres of primary stony infill in the base of the ditch. This silty layer only occurred by the eastern ditch terminal and was not present on any drawn sections from other parts of the ditch. It formed a discrete band and although not on the floor of the ditch it probably represents siltation which took place after the initial slumping of coarser material from the ditch sides. Thus the silt must have been deposited at a period when the ditch was still open i.e. before it was filled in prior to the



+ = less than 1%

All species are expressed as as percentage of the sum of Total Land Pollen.

Fig.8.4 Pollen samples from Moncreiffe House construction of Phase II. Thus the layer probably dates to immediately after the henge went out of use. It seems likely therefore that it may be contemporary with A and B assuming contemporaneity between fence and henge disuse.

Sample D was obtained from one of the sockets used for the main timbers of the henge and was the only socket infill to provide a countable pollen assemblage. The socket infill showed little variation in its composition and samples were only taken from the basal layers. The derivation of D is somewhat analagous to that of the stake holes although on a larger scale, the date of infill depending on the removal or decay of the timber. Here again there is no physical evidence for disturbance of the socket and decay may be assumed. If this is so then it would appear likely that inwash would postdate henge abandonment by a longer time period than experienced for A, B and C and hence the pollen assemblage would be representative of local environmental conditions after abandonment i.e. after c.1800b.c. and before c.1600b.c.

E, F and G relate to the later use of the site as a stone monument. E and F were taken from the infill of sockets used for the free-standing stones and in this case there is good evidence that at least one of the sockets, E, was opened as a result of the physical removal of the stone for the later recumbent stone circle. The socket from which F was taken lay next to a fallen stone and in this case it would appear that infilling only took place after the stone fell, presumably upon the destruction of the circle. Material for G was taken from beneath the fallen stone and in theory it could be assumed that inwash into F would have derived mainly from the local surface which was sealed by the fallen stone. Both socket samples were taken from the lowest material within the homogeneous infill. The socket from which E was obtained was probably infilled before the construction of the main recumbent stone circle as the stone was reused within the circle and therefore should date to the end of Phase II.

The only sample relating to Phase IV was obtained from the lowest portions of the stake holes found around the clay-lined pit, sample H. As with A and B there is no evidence for stake removal but here the portion of the stake hole discovered on excavation was very small and once excavation was completed they were soon lost by erosion of the sandy parent material. The same interpretation for the origin of the infill is advanced for H as for A and B with rapid inwash consequent upon either removal or decay and thus reflects surface conditions on the final abandonment of the site, possibly as late as c.400a.d. The final sample, I, was taken from a cremation associated with the stone socket from which F was taken. The relation of this to the general sequence on the site is uncertain as discussed earlier. Whatever the date of the cremation it should provide environmental evidence of either local conditions or the surface on which the cremation took place.

The possibility of contamination in such deposits is obviously high, especially when they are not immediately sealed or when they are only covered by a coarse sandy matrix. This was tested by taking samples from the parent material around the stake holes and sockets and, where possible, above them. A set of samples was also taken above the outer side of the ditch in the south west of the site to test for pollen being transported through the later overburden. In all cases these showed no pollen preserved or, at most, only traces of Indeterminable pollen. The absence of <u>Tilia</u> and <u>Fagus</u> grains (see surface sample, Table 8·1) being washed down suggests that contamination has not recently occurred. The variety in the pollen assemblages discovered and especially the change in species content between samples also argues against contamination unless it perhaps took place in the prehistoric period.

c) Preparation and analysis

The samples were prepared for pollen analysis using the same technique by which all other soil profile analyses were processed (Appendix II). Pollen preservation in all the samples was poor with high counts for Indeterminable pollen, up to 23·8%T.L.P. in E (Fig. 8·4). These high percentages must be borne in mind when interpreting the assemblages but where there are fundamental differences between samples in their species composition the high Indeterminable count is not considered to have been a primary contributory cause. The T.L.P. count varied from 163 in F and 183 in I to 479 in A but for all samples except F and I at least 350T.L.P. grains were counted. The results of the analyses are presented in Fig. 8·4 and Table 8·1. It is emphasised that the samples may not necessarily be in chronological order but that they are grouped according to their location on the site which is assumed to reflect age.

d) Pollen assemblages

Henge stake holes (A and B) - Both have very similar pollen assemblages with high values for N.A.P. of 76·7% and 83·7% respectively. Although this comprises mainly Gramineae pollen many weed taxa are well represented in both, especially Plantaginaceae, Cruciferae, Compositae lig. (mainly *Taraxacum* sp.), Compositae tub., Chenopodiaceae and *Centaurea cyanus*. *Cereal* type pollen is also represented at values of up to 3%T.L.P. but the grains were too poorly preserved to allow any species identification. The A.P. component is low consisting mainly of *Alnus*. *Betula* is also present.

Ditch infill (C) - This produced a pollen assemblage very similar to that discovered in the stake holes with a higher value for *Cereal* type pollen of 5·4%T.L.P., and consistent values over 4%T.L.P. for Cruciferae, Compositae lig., Compositae tub. and *Centaurea cyanus*.

Table 8·1 Surface sample from Moncreiffe House

Arboreal Pollen		Non-Arboreal Pollen	
Betula	1·5	Gramineae	24·8
Pinus	4·6	*Cereal* type	2·0
Ulmus	1·5	Cyperaceae	1·0
Quercus	+	*Calluna*	1·0
Tilia	22·8	*Centaurea*	+
Alnus	+	Caryophyllaceae	+
Fagus	30·9	Chenopodiaceae	+
Acer	+	Cruciferae	+
Picea	+	*Plantago lanceolata*	+
A.P.	63·8	Ranunculaceae	+
		Rosaceae	+
Shrub Pollen		Rubiaceae	+
Corylus/Myrica	1·0	*Rumex*	1·5
Salix	+	*Urtica*	+
Shrubs	1·5	*Valeriana*	+
		N.A.P.	34·7
Spores			
Polypodium	+		
Pteridium	1·0		
Filicales	+		
Spores	1·5		

Values for A.P. are also similar and dominated by Alnus.

Timber socket infill (D) - Despite being dominated again by Gramineae most of the herb taxa found in A, B and C are either absent or present only at very low percentages. There are high values for Alnus (24·3%T.L.P.) and Corylus/Myrica (20·3%T.L.P.) and A.P. plus shrub pollen comprises over 50%T.L.P.

Stone socket infill and sealed surface (E, F and G) - The assemblages of these three samples are similar to each other except that E has lower values of Alnus and higher Gramineae. Overall Gramineae is the dominant pollen type but the rest of the N.A.P. varies from that previously recorded. Plantaginaceae frequencies are higher, between 8·6% and 12%T.L.P., Rubiaceae appears at up to 3·7%T.L.P. and only Compositae tub. and Compositae lig. occur at more than 1%T.L.P. Cereal type pollen grains are recorded but only at 1%T.L.P. or less.

Stake hole of the clay-lined pit (H) - This produced a similar assemblage to that of E, F and G except that Plantaginaceae percentages are slightly lower and Compositae lig. higher. Salix appears at more than 1%T.L P. and a further noticeable difference is the appearance of Pteridium at 4%T.L.P., a species only occasionally found in the earlier samples.

Cremation (I) - Again the assemblage is similar to that of E, F, G and H but Plantaginaceae reaches 9%T.L.P. and percentages for Chenopodiaceae, Cruciferae and Centaurea cyanus are slightly increased. Both Rubiaceae and Pteridium remain at around 5%T.L.P.

Surface samples (Table 8·1) - A surface sample of litter was taken three metres to the west of the site and shows A.P. dominant with Fagus, the principal tree species along the driveway, at 38%T.L.P. and Tilia, which is found around the house, at 23%T.L.P. Despite the proximity of the site to cereal cultivation herbaceous pollen is low, except for

Gramineae at 24·8%T.L.P.

e) Environmental history of the site

On the evidence of their pollen assemblages it would appear that the material in the stake holes around the ditch and the silt in the ditch derived from the same source and probably at the same time. It is also noticeable that the character of pollen preservation, as seen in the relative proportions of grains in the different categories of deterioration, is similar in all the samples (Appendix IV). Thus the material in these deposits either derived from the surface around the ditch during the period of henge use and was washed in when the stake holes went out of use but when the ditch was still open, or represented inwashing immediately after the whole structure went out of use with siltation of the ditch and infilling of the stake holes occurring simultaneously. There was no time for a soil to form in the ditch before the infill of the coarse matrix and no signs of a continuous slow infill in the form of tip lines or a stratified accumulation. Either the ditch was infilled on abandonment or there was no break between the final use of the site as a henge and the first use of stone in Phase II. The presence of Beaker sherds within the coarse ditch infill is probably also indicative of physical infilling of the ditch on abandonment with only slight slumping and siltation taking place earlier. Whatever the relationship between the samples the pollen assemblage recorded in the deposits suggests that cereal cultivation was taking place in the immediate vicinity of the henge towards the end of the period of its use as seen in the presence of Cereal type pollen and several weed taxa usually associated with arable agriculture such as *Centaurea cyanus*, Chenopodiceae, Cruciferae, Compositae tub. and Caryophyllaceae. Cultivation must have been taking place very close to the henge and from the low A.P. count it seems likely that much of the terrace was open. This area must have provided some of the only cultivable land in this part of the northern edge of Strathearn and had obviously been cleared, if not by the builders of the henge then by earlier communities.

The low number of tree species represented further indicates the complete clearance of the area for alder would probably have been important on the margins of the flood plain and on the waterlogged carse areas and with birch and hazel it would have formed the woodland on the slopes behind Moncreiffe. The absence of any significant record for oak may be due to the problem of the preservation of Quercus pollen in soils (Havinga, 1964), but in view of the wide variety of other species represented this is not thought likely. The absence of elm is not surprising considering the low percentages of elm pollen recorded at the other sites investigated in this study in deposits postdating c.3100b.c. Thus, the absence of the main mixed oakwood species, in particular Quercus, not only confirms the apparent age of the henge, but also shows that most of the primary oak woodland which would probably have developed within such an area had already been removed.

The evidence from these samples at Moncreiffe thus confirms that arable cultivation was almost certainly taking place on lighter soils before c.2000-1800b.c. and also shows that the sandy fluvio-glacial deposits in Strathearn and possibly in Strathmore may have formed a focus for lowland land utilisation during this period.

The infill in the timber socket of the henge (D) clearly postdates the utilisation of the feature and from the pollen evidence probably represents gradual infilling with the timber decaying 'in situ' for there is a considerable difference between its pollen assemblage and those of the ditch and stake holes. This difference also tends to confirm that the infilling of the ditch probably took place as the henge was abandoned allowing a period of disuse before the construction of the first stone monument. The pollen record from the socket shows a much more wooded landscape with a secondary woodland dominated by alder and hazel and areas of grassland lacking the variety of herb species present earlier. The terrace was by no means completely reforested but any human pressure on the land was considerably reduced and not concerned with arable agriculture.

The assemblage found in D is not only useful in establishing the likelihood of a hiatus between the henge and the later stone monuments but also in indicating the status of the soil at this time. Although previously cultivated there is no evidence that this form of agriculture had seriously depleted the soil in any way. Woodland regeneration was able to take place with hazel expanding and there is no record of heather spreading over the site. In this response to human interference Moncreiffe again shows similarities with the more general record from Stormont where hazel also benefitted from the extension of cleared land on the outwash gravels. Podsolisation may have started this early preventing the regeneration of oak woodland but probably not to any significant extent as seen in the rest of the plant record.

The interpretation of E, F and G as contemporaneous deposits is thought valid despite differences in the detail of their pollen assemblages because of the general similarity of the main N.A.P. taxa represented, the difference from the earlier assemblages and the origin of the material. There is much less evidence for cereal cultivation, although _Cereal_ type pollen is present as are some arable weeds, and there was more woodland than before, mainly of alder. The dominance of pastoral weeds such as _Plantago_ implies that grazing was of prime importance but probably within a system of mixed land use. This interpretation may be an example of the misleading impression given by local pollen from the immediate vicinity of the site, where the open ground would probably have been dominated by grasses and plantains, especially if it was lightly grazed. By this time, the middle of the second millennium b.c., either there was less demand for arable land in Strathearn or agricultural practices had changed for there was certainly less cereal cultivation close to the site and it is unlikely that the area of carse clays to the south would have been available for cultivation. The slight difference between E and the other two samples, F and G, may reflect a temporal difference with E showing higher Gramineae, Cereal type pollen and Pteridium and less Ranunculaceae, Rumex and Rubiaceae, but could also reflect a difference in the soil horizon from which the material originally derived. There is a greater ratio of Crumpled:Degraded pollen in E and this may be a sign of derivation from a horizon with a higher humic and lower minerogenic component (Appendix IV). In the parent soil this would make E representative of a higher soil horizon and hence dominantly showing a later pollen assemblage which, on the evidence of the changes in pollen content, would indicate some clearance of alder and the initial spread of Pteridium. Assuming that all these samples relate to the period between phases II and III then they show the surrounding environment between c.1400 and c.1200b.c. with clearance of the secondary woodland of alder and hazel having taken place before c.1400b.c.

From the pollen assemblage found in I there is little reason to suspect that it is a later intrusion into the site. The only noticeable difference between it and E, F and G is the higher count for Pteridium. This may have derived from the surface on which the cremation took place which, on the rest of the evidence must have been very close to the site, or just emphasises the trend observed earlier in E and shows the material to have derived from the very surface of the soil.

Archaeologically the assemblage found in the stake holes from around the clay-lined pit (H) could postdate the youngest of the other samples by as long as 1600 years but there is very little difference in the pollen spectrum found in H to those found in E, F and G. The assemblage shows a dominantly open vegetation cover of grasses with Plantago, Pteridium and Compositae lig. and again some Cereal type pollen. The A.P. and shrub pollen content is almost identical to that of G except for the presence of Pinus and Salix at over 1%T.L.P. In such a low count these differences may not be significant but in view of the poor dispersal of Salix the appearance of such frequencies may reflect the increasing local presence of willow, perhaps as scrub colonising open ground marginal to the wetter areas to the south. The overall species similarity between H and the other samples makes the disparity in timing between the abandonment of the circle and the use of the pit seem unlikely. As several of the stones were apparently used to assist in the construction of the shelter with which the stake holes were associated it may be that the deposits sampled from the stone sockets date to the later phase and could be as late as c.400a.d. rather than before c.1200b.c. Without sounder archaeological evidence either explanation could be correct. The absence of Calluna and the present use of the area for cultivation shows that the soils derived from the finer sands of this part of Strathearn, although eventually podsolised, were always of a better structure than those derived from the coarser sands and gravels to the north which were more freely draining, and did not deteriorate to the point whereby acid heath took over.

The pollen evidence from the samples taken from Moncreiffe House, despite the difficulties encountered in analysis and interpretation, do show differences in the local environment associated with the different constructional phases. The indication of cereal cultivation at an early stage, probably in the third millennium b.c., is of interest and has implications for the interpretation of the small scale changes in vegetation found at an equivalent period at Stormont. The development of secondary woodland with alder and hazel following cultivation is also indicated at Stormont although the absence of any regeneration of oak is perhaps surprising. The rather uncertain nature of the later record, especially the dating of the deposits, makes correlation with other records difficult but does seem to show some shift of emphasis and, if anything, a lessening of the pressure on the local environment, as well as highlighting the difference in soil conditions between the fluvio-glacial sands of Strathearn and the coarser sands and gravels of Strathmore.

iii) Queen's View - Loch Tummel

a) Site and archaeological background

The ring fort at Queen's View, lies at an altitude of c.340 metres (NO863662) on a small bench within the generally steep slopes of the northern side of Loch Tummel (Fig. 8·5). There is no published information relating to the soils around the loch but from a brief survey those on the bench appear thicker than those on the steeper slopes, where in places only thin skeletal soils appear, due probably to a combination of hillwash and possibly the presence of thicker pockets of till. At present much of the area lies within coniferous woodland planted by the Forestry Commission and the soils appear dominantly podsolic.

The ring fort is circular in form, up to 30 metres across, and built of dry stone walling three to four metres thick with some individual blocks up to two metres across. The walls are faced on both sides and there is a narrow entrance facing west. Ring forts show a

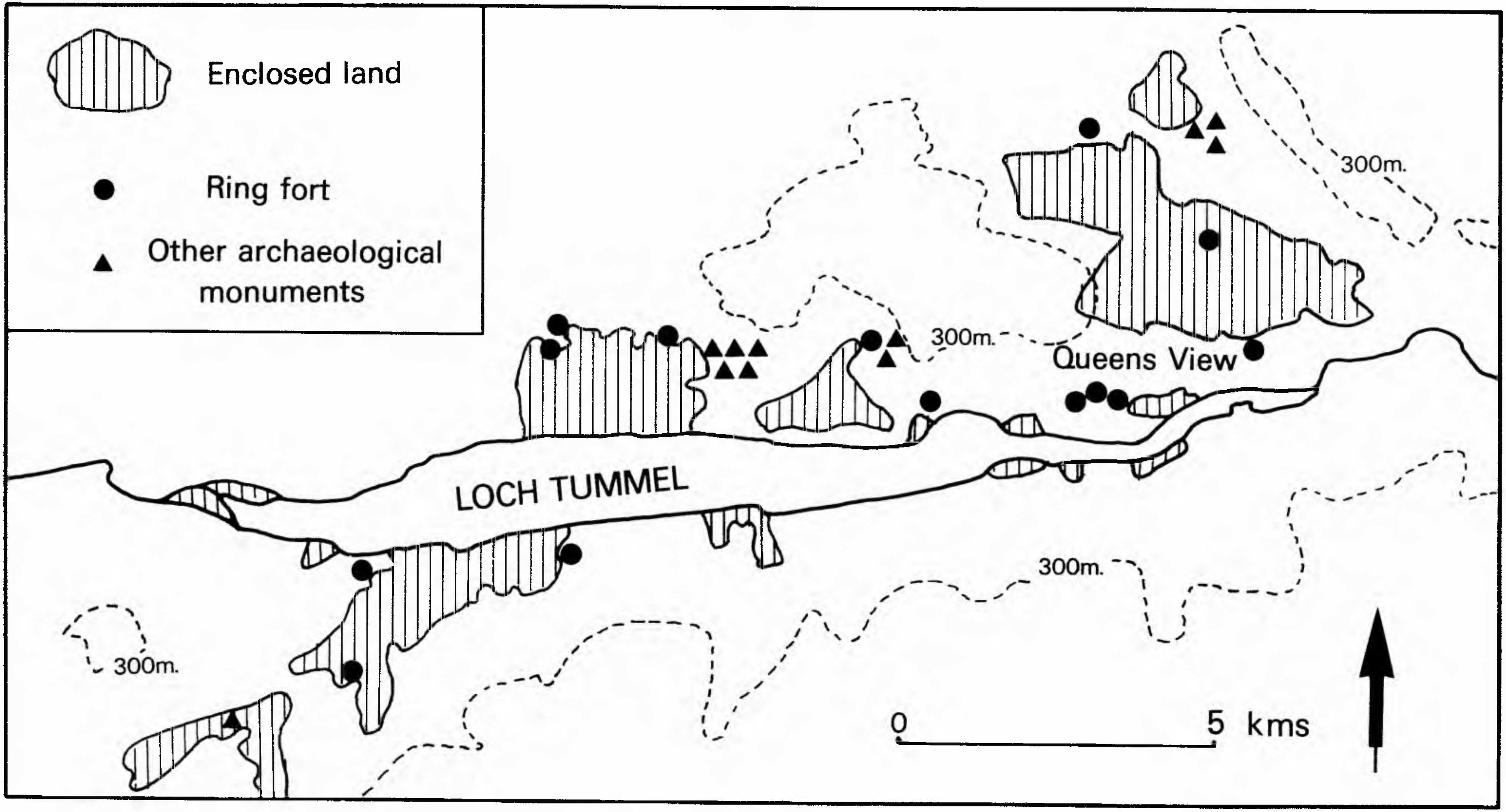


Fig.8.5 Location of the archaeological site at Queen's View

limited distribution in Perthshire, especially in the straths of Tummel and Garry, and also in Glen Lyon, Strath Tay and as far west as Rannoch. The designation ring fort is perhaps unfortunate and was coined in the early part of this century due to their size and apparent defensive functions. More recently the term 'protected homestead' has been suggested (Stewart, 1969) and on the latest 1:50000 Second Series Ordnance Survey maps they are called 'homesteads'. There has been some discussion over their function following the hypothesis put forward by Stewart (1969) that they were located along the arable/pastoral margin so as to exploit both areas but with a pastoral bias. Stevenson (1975) has suggested that the distribution of ring forts owes much to preferential survival for they are commonly found either just above or just inside the head dyke, the limit of cultivation. He argues that they may also have been located on low ground but that the original distribution has been masked as it probably formed the basis for the later Medieval settlement pattern as seen for instance in the use of 'dun' in placenames. Thus the ring forts which have survived may have been peripheral to the main pattern and represent less successful settlements. Dating of ring forts is difficult for although they may have originated in the late Iron Age there have been only three excavations and in these the main evidence was sometimes of later occupation. Litigan near Keltneyburn (NO765498) provided carbonised wood dated to the tenth century a.d. and forts were almost certainly still in use this late but as yet there is no conclusive proof of the general date of their construction.

At Queen's View excavation took place only in the central part of the fort and in the first season from which these samples were obtained only the northern half of this area was investigated. The excavation provided evidence of a paved entrance and a series of post holes but they were insufficient to allow the reconstruction of the internal structure of the fort. Iron slag found within the northern part is probably evidence of later occupation and there were no finds which could be associated with any earlier occupation. Thus the complete chronology and sequence of occupation remains unknown. Against the outer wall the remains of a 'kiln' were found with charred grain although the detailed structure and function of this feature were not clarified by excavation.

Although ring forts are not found further to the east they represent settlement during a period for which evidence is slight. The topography in the west is steeper and there would have been less land available for settlement in Strath Tummel. The nearest topographical analogy would be the hill mass between Strathardle and Glenshee in which Loch Mharaich is found and indeed the altitude of the fort and the loch are similar.

b) Sampling and the derivation of the material

As excavation only took place in the central area of the fort and in limited areas outside the walls with no detailed examination of the wall itself it was not possible to establish whether any continuous palaeosol existed beneath the wall, and with no structures or banks either inside or outside the fort there were no other locations where surfaces could have been sealed. Nevertheless traces of a thin humic horizon could be seen beneath the wall blocks at several locations and these were sampled at two places in the north-west quadrant (Fig. 8·6). At the first of these sampling locations less than two centimetres of humic material was found overlying a thin, coarse gravelly parent material immediately overlying bedrock and this provided two samples, A and B, the former coming from the lower position. The construction of the wall at this point comprised smaller stones than

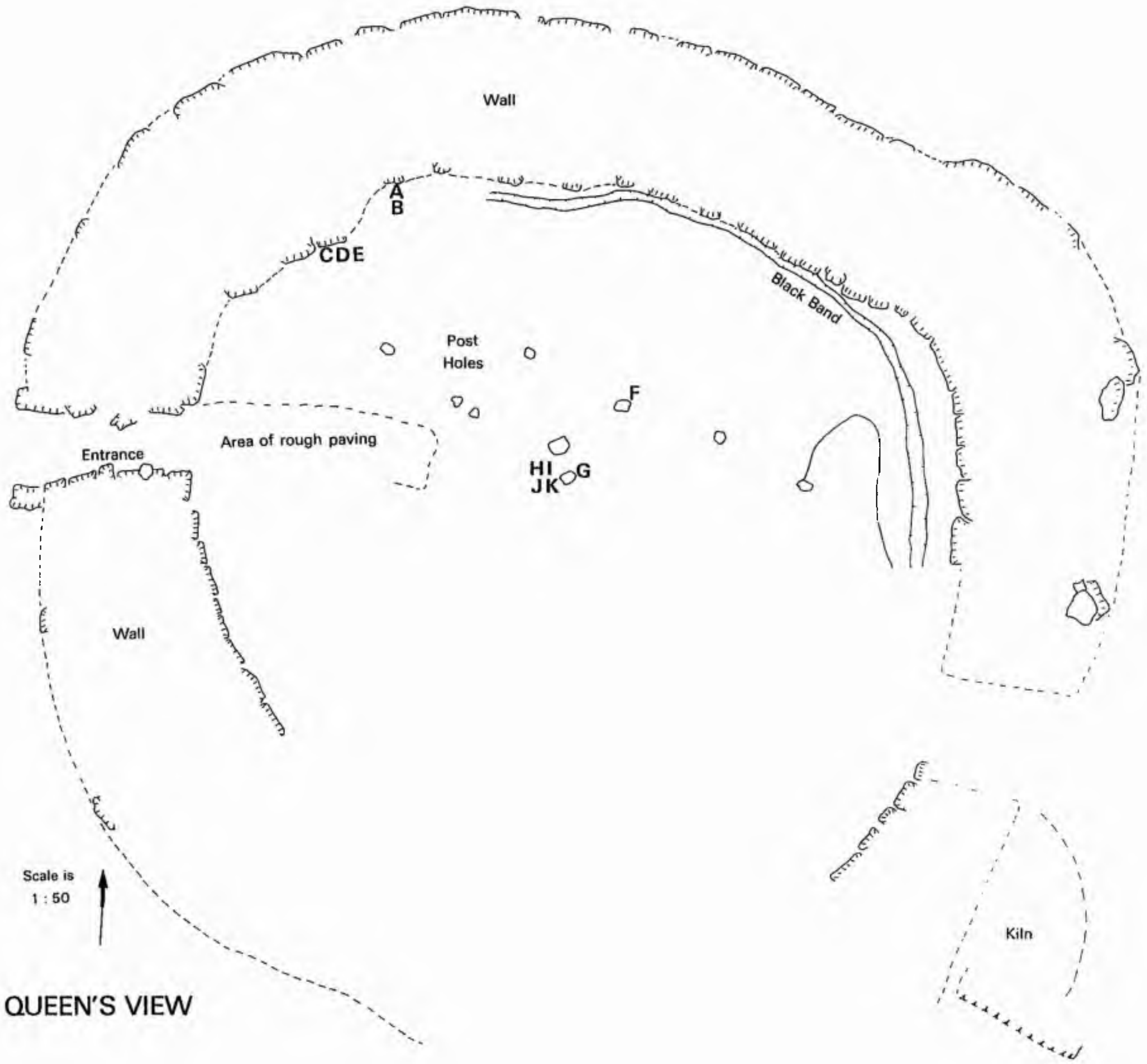


Fig.8.6 Excavation diagram from Queen's View

generally found and there is some possibility that there may have been a later fall of stone sealing the humic surface but as the line of the wall is consistent this is considered unlikely. Samples C to E were taken from approximately one metre to the west of the earlier samples from a similar but slightly thicker deposit with C deriving from the lowest level. Although thin such a deposit may represent the old land surface which was compressed by the weight of the blocks but as it was not continuous throughout the site it may only represent surface material disturbed during the construction of the fort when the surface soil was largely removed. As such the pollen assemblage should still be representative of conditions immediately prior to the building of the fort although possibly derived from several sources and therefore difficult to interpret.

Samples F and G were taken from the infill of two small post holes within the fort. Both holes had a homogeneous dark infill and the samples were obtained from the lowest part of the holes. In the absence of archaeological evidence for more than one constructional phase it may be assumed that infill took place on abandonment of the site. There were no marks of former timbers and no packing stones left in these post holes so it seems likely that the timber was removed and infilling would have been relatively rapid.

By the post hole from which G was taken a series of samples was taken through the overlying thin soil which, at this point, was only ten centimetres thick and comprised a uniform coarse sandy loam with a large proportion of Pteridium rhizomes. The lowest sample was H and the rest were collected at three centimetre intervals up to the surface. The soil at this point appeared representative of the cover in general over the site but in many places the soil was disturbed by stones associated with a later clearance cairn in the southern part of the fort and it is unlikely that soil development took place continuously from fort abandonment to the present day.

Samples from the kiln were taken from all recognisable horizons (Fig. 8·7) but pollen was only preserved below the carbonised grain and in adjacent pockets (M on the diagram includes both M and N) above the grain. The structure of this feature was not clear on excavation although it was partly stone built and had a channel leading away from it. It may have been constructed at the end of a ditch around the fort but this was not proved on excavation and it may be that the lowest horizon from L was obtained represents the parent material at this point, or a truncated lower soil horizon. The derivation of the clay is uncertain but the sand must have come from outside the immediate site and been physically put over the carbonised grain for it does contain pockets of material similar to that from which M was taken. Above the sand there was a very coarse cover of large stones and interstitial peaty material.

c) Preparation and analysis

Samples from Queen's View were analysed using the same techniques as for Moncreiffe House (Appendix II). Overall pollen preservation was good with the exception of the samples from the post holes but no details of pollen preservation were taken. Although identification was easier than for the material from Moncreiffe House the considerable number of Crumpled grains made species identification difficult and no Cereal species were identified. A count of 500T.L.P. was made in all cases except for the post holes where only 224 (F) and 247 (G) T.L.P. grains were counted. The presentation of the data is again made in apparent chronological order with the oldest samples at the base although A–B and C–E are probably contemporary (Fig. 8·8). The samples from the kiln are separated from the rest of the data as their age and

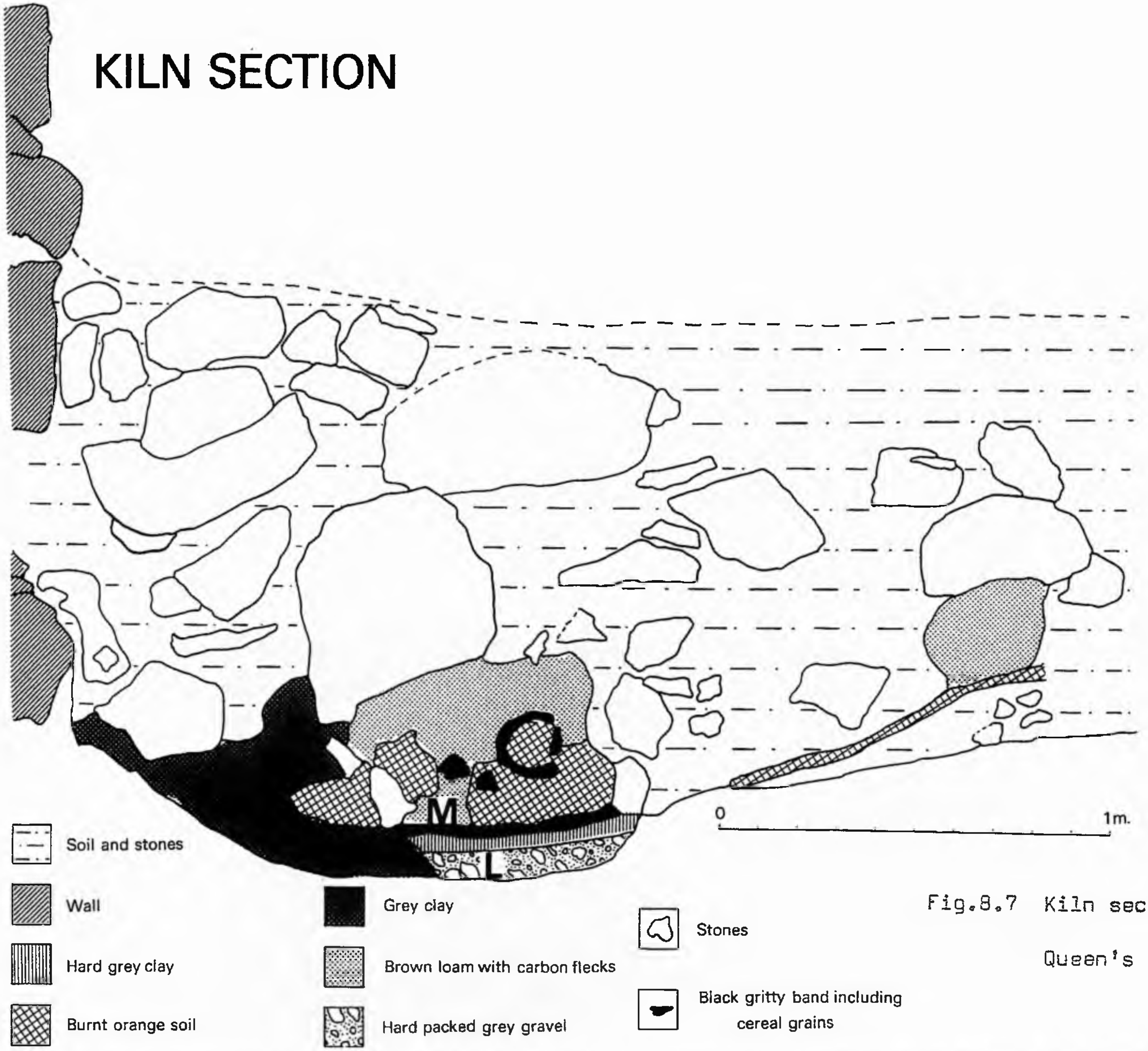
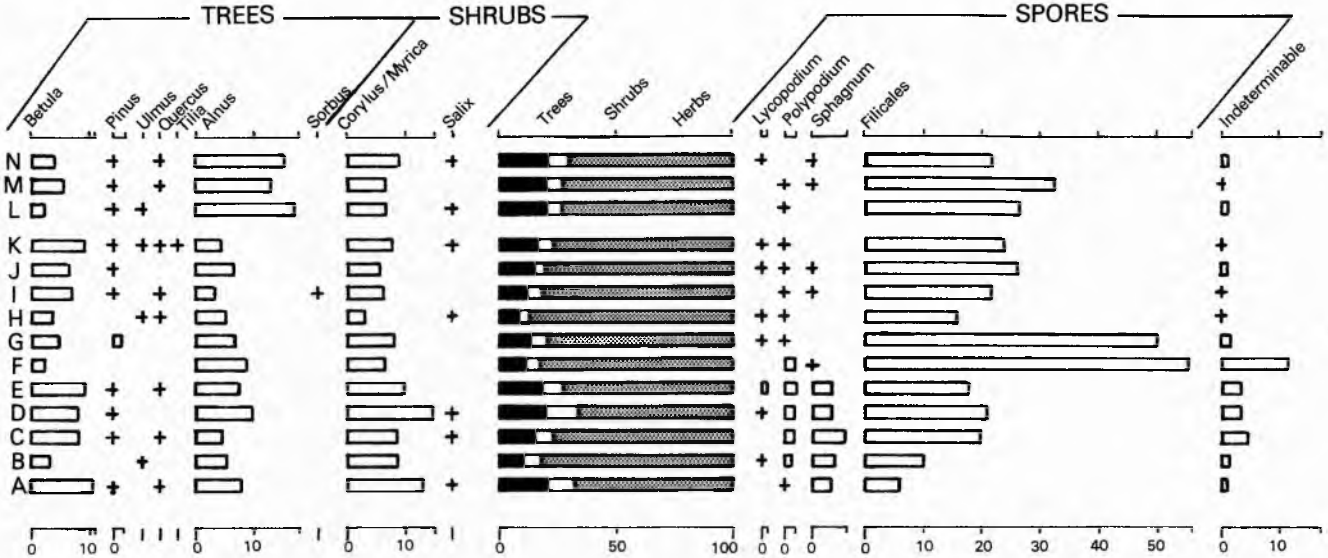


Fig.8.7 Kiln section at Queen's View

QUEEN'S VIEW



+ = less than 1%
All species are expressed as a percentage of the sum of Total Land Pollen

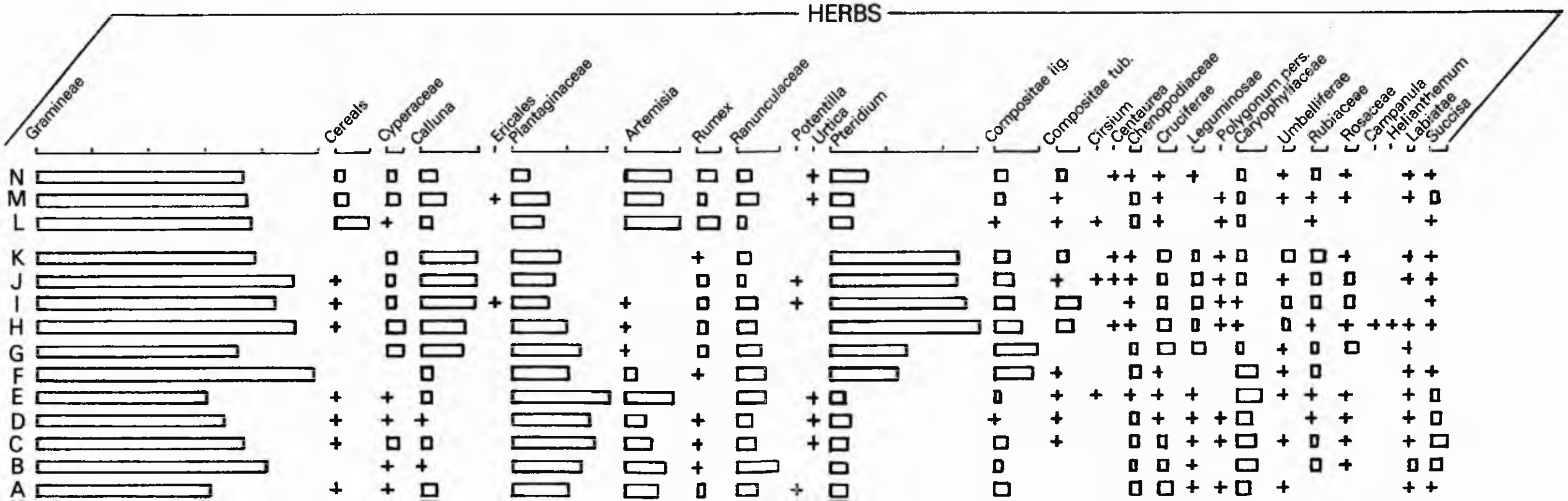


Fig.8.8 Pollen samples from Queen's View origin are uncertain.

d) Pollen assemblages

Samples from below the wall (A – E) – A and B are characterised by low values for A.P., 19·9% and 9·2% respectively, chiefly consisting of *Betula* and *Alnus* which, with *Corylus/Myrica* at 13%T.L.P. and 8·6%T.L.P., all show a reduction between the lower and upper sample. The N.A.P. count is dominated by Gramineae which rises from 30% to 40%T.L.P. with high counts also for Plantaginaceae, *Artemisia*, Ranunculaceae and Caryophyllaceae. There is also an increase in Filicales, and *Sphagnum* is present in both at up to 3·8%T.L.P. C, D and E show similar values for A.P. and shrub pollen although *Betula* is never found at less than 8%T.L.P. The percentages of Gramineae decrease from 37% to 30%T.L.P. rather than increasing but the same herb assemblage is found except for higher values of Plantaginaceae. In all samples except B *Cereal* type pollen occurs but never at more than 1%T.L.P.

Post hole infill (F and G) – Both show somewhat similar pollen assemblages dominated by N.A.P., especially Gramineae. The remainder of the N.A.P. count varies little from that discussed above except that *Pteridium* is considerably higher, up to 13%T.L.P., and so too are the values for Compositae lig. They have high values for Filicales (55·4% and 49·5%T.L.P.) but this may be due to differential preservation as pollen preservation in these samples was very poor.

Overlying soil (H, I, J and K) – The lowest sample, H, which was taken from the soil/parent material interface shows an absence of any pollen assemblage comparable to that discovered below the wall. They show that despite an increase in *Betula* up the profile A.P. remains at 15%T.L.P. or less with lower values for *Corylus/Myrica* than in any other sample. In contrast to A–E *Artemisia* occurs only spasmodically and apart from Gramineae the main N.A.P. are Plantaginaceae, Ranunculaceae and Compositae lig. with very high values for Pteridium of up to 26% T.L.P. The local presence of Pteridium is also indicated by the presence of remains of root systems in the soil. Calluna is a further important element in the N.A.P. sum.

Kiln (L, M and N) - Both M and N are dominated by Gramineae with Artemisia, Rumex, Ranunculaceae, Plantaginaceae, Calluna and Pteridium comprising the majority of the N.A.P. sum. Unlike other samples the A.P. count is dominated by Alnus rather than Betula. In both M and N Cereal type pollen occurs at 2•2% and 1•8%T.L.P. and in the lowermost sample a percentage of 5•9 was obtained. With the exception of this L shows an assemblage very like that of M and N.

e) Environmental history of the site

The samples taken from Queen's View give an indication of the local environment both before construction and after abandonment but do not represent what was happening during occupation of the site. The evidence from the material sealed under the wall shows a relatively open environment with only light birch-hazel woodland which also contained some alder. The topmost sample, B, shows a reduction in values for Betula and could imply clearance but the same pattern was not found from the other samples under the wall despite the similarity in the pollen assemblages of all the samples below the wall. The openness of the hillside as seen in the low percentages for A.P. and shrubs indicates that considerable woodland clearance had already taken place before the utilisation of the site for the fort and the overall frequencies for A.P. and shrub pollen compare well with those found in LM5 at Loch Mharaich. The presence of Cereal type pollen must be indicative of cultivation taking place but not necessarily close to the fort for there are very low values for arable weeds, especially when compared to those found at Moncreiffe, and the topography of the area would have precluded arable agriculture except on the bench itself.

Several weed taxa occur in the pollen record, Plantaginaceae, Ranunculaceae, Compositae lig., Chenopodiaceae, Cruciferae, Caryophyllaceae and in particular Artemisia, and they may indeed represent the character of the local agriculture but several of these families include plants that are characteristic of disturbed ground and it may be that the disturbance due to the construction of the fort and the confinement of the human community on a small site produced a local environment in which such weeds flourished. Rather than being a compressed soil the material below the wall may be the thin remnants of a humic horizon considerably disturbed by the building of the fort, thus reflecting this period of disturbance rather than a sequence of events leading up to fort construction. The presence of Sphagnum spores shows that there were local waterlogged areas again reflecting a much disturbed and occasionally extensively wet surface. The low values for Calluna indicate that at this time there was no widespread development of heather and the pollen probably derived from the steeper slopes. The evidence from the samples below the wall is therefore taken largely as being representative of the immediate environment during the period of disturbance associated with the construction of the fort and they do not provide much evidence of the earlier environment.

The assemblages found in the post hole infill could only reflect conditions within the fort as they went out of use but need not represent conditions on total abandonment for there is no discernible pattern within the post holes and a single construction seems very unlikely. There is very little evidence of any major change in the local environment although there is no Cereal type pollen recorded and there are higher values for Pteridium and Compositae lig. Most of the weed taxa could have spread onto the surface of the fort upon abandonment or represent the trampled area immediately around the fort, especially the Compositae and Plantaginaceae. Higher Pteridium and Calluna values are also characteristic of the overlying soil and hence of the later period following abandonment. The post holes therefore could date from the complete abandonment of the area but considering the poor preservation of pollen all the pollen in the post holes could have derived from the overburden and not represent contemporary vegetation at all. Whatever the origin of the material there is no evidence for a period of significant woodland regeneration after the fort was left.

As stated in the earlier discussion it seems unlikely that the overlying soil profile shows a continuous record from abandonment to the present but there is some increase in birch and hazel up to profile, although insufficient to indicate a widespread expansion of birch woodland as found at Heatheryhaugh and, to a much lesser extent, at Loch Mharaich. The most noticeable difference between the assemblage from the soil and the stratigraphically earlier samples are the higher frequencies for Calluna and Pteridium. The former, with the increased representation of sedges, probably reflects the expansion of acidic heath communities over the hillside in general within scattered birch-hazel-alder copses, and the latter, as seen in the rhizomes in the soil profile, spread over the fort and the adjacent areas with thicker soils and higher base status. There is a noticeable lack of Artemisia in the soil record which probably indicates that any disturbance after the final use of the fort was only of a limited scale.

Because of the difficulty in understanding the structure of the kiln and hence the derivation of the material found within it, interpretation of the assemblages is questionable. There are differences between the kiln record and all the other samples although within the kiln itself there is very little variability. There are high values for *Cereal* type pollen but few arable weeds are represented and *Artemisia*, *Pteridium* and Plantaginaceae are present. In the A.P. record all three samples show much higher *Alnus* frequencies than in any other samples. From all this evidence it seems unlikely that the material could have derived locally from around the fort. The origins of the pollen assemblages found in the kiln may be explained in two ways. Either the soil had been brought in from a lower site where cereal cultivation was taking place and where alder was the dominant tree, or, when the grain was brought to the fort to be processed it may have also needed to be threshed and have attached to it pollen from a different environment (Robinson and Hubbard, 1977). Neither explanation fully deals with all the data, but in view of the other pollen evidence from the fort it seems unlikely that the high frequencies for *Cereal* type pollen and *Alnus* could relate to the environment in the immediate vicinity.

As with Moncreiffe House the nature of the available material and difficulties associated with the archaeological interpretation of the features makes certain elements of the pollen record appear rather enigmatic and more than one hypothesis may be invoked to explain the evidence. Comparison with the more general record to the east and north is only possible in very general terms and one of the major drawbacks remains the impossibility of returning to the site after excavation to look for further evidence to answer the questions thrown up by the analysis.

CHAPTER NINE

CONCLUSION

Because of the complexity of the patterns of changes found in the vegetation record during the later Flandrian in the three areas studied it is not possible to adopt a single method for summarising the results from all the sites. For the period preceding the advent of human communities on a scale sufficient to alter significantly the local vegetation, such that a consistent trace can be found in the pollen record, a series of regional pollen assemblage zones are proposed but for the later period only a descriptive summary of the various sequences indicating possible correlations is produced.

The regional pollen assemblage zones are based almost entirely on the sites studied here due to the paucity of other analysed sites. This means that the sample is of necessity small but where records exist encompassing complete sequences such a basis is valid. The aim behind producing such zones is largely that outlined by H.J.B. Birks (1973a),

> "Although the zones are highly discontinuous laterally, they can be recognised over a geographical and stratigraphic interval of sufficient magnitude to make them useful for purposes of biostratigraphic comparisons between sites." (p.280)

Thus the final zonation provides a background of the sequence of principal characteristic pollen assemblages to be found in the region against which other analyses may be evaluated. In Chapter One brief mention was made of the problems involved in defining the area to be termed the region, and these problems have to be faced. In the Late Devensian the sequence found in Strathmore shows significant differences from sites analysed further to the west and can more easily be correlated with sites to the east and north although there are still points of divergence. While there is similarity between Strathmore and Corrydon in the Grampians there are still parts of the record which differ considerably, especially during the Loch Lomond Stadial. Whether the records should be treated completely differently or as variants of a regional pattern remains open to question but here the latter is accepted and a regional sequence across the Highland Edge attempted. Correlations with sites further to the east in Aberdeenshire are discussed but at the moment the differences between the two areas are considered sufficient to warrant treating them as separate regions. These differences are moreover particularly noticeable later during the Flandrian. Within eastern Perthshire therefore the differences between the sites examined are treated only as differences of gradient within a fundamentally uniform sequence. Examination of sites to the east and west, such as those in the glens of Angus or western Perthshire, show distinct differences, and during the Flandrian reflect the development of different woodland communities.

In the Early and Middle Flandrian (Fl I and Fl II) the area within which general regional uniformity may be traced was probably greater, especially during Fl I, but with the establishment of the main woodland communities certain fundamental regional characteristics emerged and discernible boundaries can be established. This is especially true of the relative importance of birch and pine which appeared to change to the north and south of the Dee valley (Durno, 1959). Nevertheless the transitional nature of the main woodland types found in eastern Perthshire makes the exact extent of the influence of various woodland communities difficult to ascertain (H.J.B. Birks, 1977, Moore, 1977). For the purposes of this summary the regional characteristics are based solely on the area studied and possible correlations with adjacent areas only considered when discussing the probable spatial extent of any zone. There is of course no reason why the spatial extent of the zones should not have varied between the Late Devensian and the Flandrian as well as within the Flandrian, especially in view of the importance of the immigration and establishment of new species not perhaps found locally for over 100,000 years.

The sequence of regional pollen assemblage zones is outlined below and summarised in Fig. 9·1 where estimated dates are assigned to the zones:

Gramineae - *Rumex*

Type locality and pollen characteristics - Zone SG1 at Stormont Loch. The zone is characterised by the dominance of Gramineae with high frequencies for *Rumex*. *Artemisia* and *Thalictrum* are present as is *Salix* but the latter in particular only occurs at low frequencies.

Environment - Although presumably not recording the earliest vegetation communities which developed following deglaciation this zone represents the development of open grassland with a gradual reduction in the incidence of soil instability and the earliest origins of dwarf-shrub heath.

Extent and dating - High values for *Rumex* are characteristic of many sites in the Grampians but within the Highlands there are lower frequencies for Gramineae, and herb or spore taxa indicative of broken ground are better represented. This is the case at Corrydon where Compositae values are higher in a similar zone (Walker, 1977). To the east the record from Loch of Park (Vasari, 1977) has a comparable zone, as probably does Tirinie (Lowe and Walker, 1977) to the west. In its principal pollen characteristics this regional assemblage zone is very similar to the Gramineae - *Rumex* p.a.z. found in northern and western Britain as defined by Pennington (1977b) with the exception of the lower *Salix* values. Where a Gramineae - *Rumex* zone is preceded by

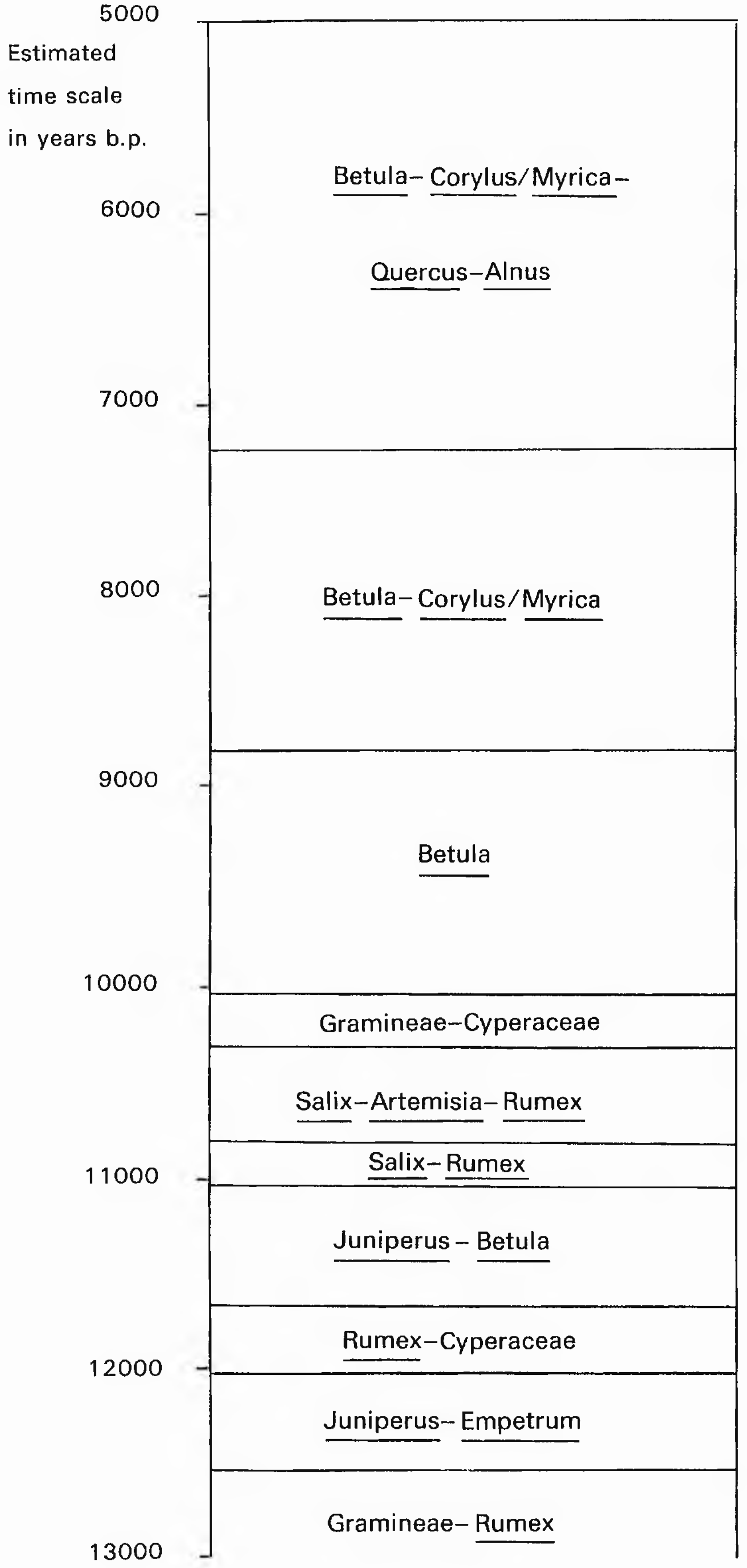


Fig.9.1 Summary diagram of regional pollen assemblage zones

other zones they are usually dominated either by Salix herbacea and Oxyria (Pennington et al., 1972), Salix herbacea and Cyperaceae (Pennington, 1977), Lycopodium and Cyperaceae (H.J.B. Birks, 1973a) or secondary pollen (Crabtree, 1973). The appearance of a zone dominated by Gramineae and Rumex is therefore widespread in northern and western Britain but the taxa found associated with these dominants vary, in some cases to the significant suppression of Gramineae values. In most areas the development of a Gramineae - Rumex assemblage zone has been dated to before 13000b.p. although initial dates have yet to be established and it probably terminated by 12500b.p. at the latest. It is believed to represent the Oldest Dryas or Middle Weichselian of Mangerud et al. (1974), the earliest phase of the Lateglacial Interstadial (Gray and Lowe, 1977).

Juniperus - Empetrum

Type locality and pollen characteristics - Zone SG2 at Stormont Loch. The zone shows successive peaks for Empetrum and Juniperus with some increase in Betula but all the principal herb taxa are represented, in particular Artemisia, Rumex and Thalictrum.

Environment - Elements of dwarf-shrub heath dominated by Empetrum and juniper form a significant part of the landscape but there is still a persistence of grassland and the indication of pockets of disturbed soils.

Extent and dating - Early peaks for Juniperus and Empetrum occur to the northeast at Garrall Hill, Loch Kinord and Loch of Park (Vasari and Vasari, 1968; Vasari, 1977), and to the north at Corrydon (Walker, 1977) a similar zone has been defined, albeit with higher counts for Rumex. To the west the only comparable sequence appears to be found at Tirinie but the evidence here is slight. In central Scotland therefore this zone appears discontinuous although at Corstorphine

(Newey, 1970) a similar assemblage may be inferred. Despite being absent at sites along the western margins of the Grampians a zone characterised by the increasing importance of dwarf-shrub taxa can be found in northwest Scotland (Pennington, 1977b) and northern England (Bartley, 1962), thus the appearance of the zone is not dictated by the eastern location of the area. It appears to date to between 12500 and 12000b.p. and as such may be tentatively correlated with the Bölling of northwest Europe but has no comparable sub-division within the Lateglacial Interstadial.

Rumex - Cyperaceae

Type locality and pollen characteristics - Zone SG3 at Stormont Loch. It is dominated by high counts for N.A.P., especially *Rumex*, Cyperaceae and Gramineae with the persistence of *Artemisia* and *Thalictrum*.

Environment - This zone registers a change to open grassland or broken ground communities with the loss of dwarf-shrub heath, especially that under juniper.

Extent and dating - A *Rumex* - Cyperaceae zone may be inferred from the diagram for Loch of Park (Vasari, 1977) and a zone with high *Rumex* counts also appears at Corrydon (Walker, 1977) but is absent from all other sites within the Grampians or along its southern fringes. Zones with high *Rumex* frequencies, but usually also with a significant proportion of *Artemisia*, appear throughout northwest Scotland, and in northwest England high *Rumex* counts also occur, usually in association with *Betula* (Pennington, 1977b), except at higher sites such as Sty Head Tarn (Pennington, 1970). The extent of this zone is therefore difficult to define, it may be found at sites both within the eastern Grampians and in the surrounding lowlands but is absent from equivalent areas to the west. Some altitudinal variation is apparent both in the Grampians and in the Lake District but its variable presence and absence remains difficult to understand. In eastern Perthshire the Rumex - Cyperaceae zone is correlated with the Older Dryas and dated to between 12000 and 11800b.p. It has no equivalent in the Lateglacial Interstadial.

Juniperus - Betula

Type locality and pollen characteristics - Zone SG4 at Stormont Loch. This has peaks for Betula and Juniperus, particularly the latter which is the dominant pollen type. Values for herb taxa are low and Filipendula is present.

Environment - This marks the expansion of woody taxa, especially thickets of juniper, with birch copses occurring in the straths and into the heads of the glens. Grassland still formed an important part of the landscape but was not disturbed by any soil instability.

Extent and dating - Zones dominated by Betula and Juniperus are found throughout the Grampians but usually with other taxa also important such as Salix and Rumex. The highest values for juniper tend to occur at those sites at the outlet of the glens or on lower ground but the pattern in eastern Perthshire is more readily compared to lowland Aberdeenshire and the Dee valley. Constraints on the extent of this zone appear to be both altitudinal and latitudinal with lower counts for woody taxa to the north and west and the persistence of herbaceous taxa at higher altitudes. At all sites where a Betula - Juniperus zone has been dated it occurs after 11800b.p. and usually terminates between 11300 and 11000b.p. In Perthshire a dating of 11800 to 11000 is considered likely and as such this would correlate with the Allerød or the later phase of the Lateglacial Interstadial.

Salix - Rumex

Type locality and pollen characteristics - Zone SG5 at Stormont

Loch. This has high Rumex values with only low Juniperus, increasing Salix and the presence of Thalictrum, Caryophyllaceae and Selaginella selaginoides.

Environment - Open communities dominated by Salix and Rumex were widespread with the presence of soil instability allowing the development of a variety of herbaceous taxa.

Extent and dating - The extent of this zone is uncertain. At Corrydon there is no directly comparable zone but high Salix values do occur elsewhere in the Grampians as at Amulree and Tirinie (Lowe and Walker, 1977). At this point in the stratigraphy it is perhaps the low values for Artemisia that are the significant feature rather than the presence of a distinctive pollen assemblage for it is a zone which appears transitional between full interstadial and full stadial assemblages. High Salix values can be traced in the Grampians but are highly discontinuous and limited in their spatial extent. The importance of Salix and the persistence of Betula may be an altitudinal feature but interpretation in terms of temperature distribution may not be as important as variability in amounts of precipitation. The Salix - Rumex zone postdates 11000b.p. but its termination is undated, although it may have occurred before 10800b.p. and probably before 10700b.p., in the earliest phase of the Loch Lomond Stadial.

Salix - Artemisia - Rumex

Type locality and pollen characteristics - Zone SG6 at Stormont Loch. It has high consistent values for Salix, Artemisia, Rumex and Cyperaceae with the presence of Caryophyllaceae, Thalictrum and a variety of herbaceous taxa. It may be sub-divided by different but consistent values for Thalictrum.

Environment - The pollen assemblage suggests a landscape of highly discontinuous vegetation communities with little complete cover and a wide variety of taxa present, equivalent perhaps to freshly deglaciated terrain at present.

Extent and dating - Assemblage zones incorporating *Artemisia* are found throughout the British Isles, especially with *Rumex*, but the importance of *Salix* is restricted to the eastern and southeastern Grampians. Within this area there is also variability in the values of *Artemisia* although figures do not usually equal those found in the Cairngorms area (Birks and Mathewes, 1978). This particular assemblage zone is therefore very restricted spatially to the southeast Grampians and the significant parameters behind this are as yet not fully understood. The effect of the higher *Salix* values may be due to essentially local site characteristics and this could have produced lower *Artemisia* counts than elsewhere, but even accounting for this, some local variability in vegetation communities must have occurred and therefore requires explanation. This zone covers part of the Loch Lomond Stadial but is not found within sediments that contain much dateable material. From its stratigraphical position and pollen assemblage it does, by analogy with similar deposits elsewhere, seem to date to between 10700 and 10300b.p., and represents the most severe phase of the Loch Lomond Stadial.

Gramineae - Cyperaceae

Type locality and pollen characteristics - There is no single zone which can be cited as an example of this regional assemblage but both SG7 and S1 at Stormont Loch and H1 at Heatheryhaugh are dominated by Gramineae and Cyperaceae, although the other accompanying important pollen types vary. At the lower site *Rumex* remains at high levels whereas on the Forest of Alyth Compositae (mainly Compositae lig.) are important. These differences are seen as variations of the same basic regional pollen assemblage zone which is dominated by Gramineae and Cyperaceae.

Environment - The landscape indicated is very open with grassland, involving a high proportion of Rumex on lower ground, and with the continuation of disturbed soils on higher ground. Within this zone elements of dwarf-shrub heath begin to develop, especially Empetrum.

Extent and dating - This zone is similar to the III/IV transition as defined by Vasari and Vasari (1968) and probably marks the transition between the end of the Late Devensian and the beginning of the Flandrian. As such it would be dated to between 10300 and 10000b.p. There are equivalent zones in the Grampians such as the Gramineae - Cyperaceae zone at Blackness (Lowe and Walker, 1977) but it does not occur in western Scotland. In northern Britain however peaks for Gramineae and Cyperaceae appear earlier (e.g. before 10400b.p. at Blelham Bog) and Juniperus usually occurs within an assemblage zone dominated by Gramineae or Gramineae and Cyperaceae as at Blea Tarn (Pennington, 1977b).

Betula

Type locality and pollen characteristics - Zone S2 at Stormont Loch and H2 at Heatheryhaugh. It shows increasing values for Betula until it becomes the dominant pollen type, possibly reaching up to 80%T.L.P. Juniperus and Empetrum are usually also present.

Environment - This shows the spread of birch woodland with some earlier local development of Empetrum heath and juniper thickets but by its termination birch woodland, probably with a fern-dominated understory, was widespread although with many openings occupied by dwarf shrubs or grassland.

Extent and dating - The presence of a Betula assemblage zone is characteristic of southern and eastern Scotland (Donner, 1962; Vasari and Vasari, 1968; Moar, 1969a) but to the west its extent is limited by the rapid immigration of hazel and it is only found locally. To the north and at higher sites it is restricted by the continued presence of juniper and the slower consolidation of birch and although occurring in northern Britain it is mainly restricted to the low-lying areas of Wales (Seddon, 1962), northwest England (Smith, 1958; Oldfield, 1960), the Lake District (Pennington, 1970) and northern Yorkshire (Bartley, 1962). The development of an assemblage dominated solely by Betula appears therefore to be restricted in extent by both immigration rates and climatic factors related to latitude and altitude which allowed shrubby taxa to persist. This pattern can be traced within the study area for Betula quickly becomes dominant ousting juniper and Empetrum in Strathmore whereas north of the Boundary Fault its development was much slower. Thus the inception of the assemblage zone was probably diachronous within Scotland although clearly early Flandrian (Fl I) in date. In eastern Perthshire the zone as a whole is likely to have covered the period from 10000b.p. to soon after 9000b.p., or possibly 8700b.p. at sites along the edge of the Grampians.

Betula - Corylus/Myrica

Type locality and pollen characteristics - Zone S3 at Stormont Loch and H3 at Heatheryhaugh. It is dominated by the pollen of Betula and Corylus/Myrica with the latter as the major contributor, possibly comprising up to 60%T.L.P. Values for N.A.P. are very low. The empirical limits for Quercus and Ulmus usually occur within this zone.

Environment - The immigration of hazel allowed the development of a birch-hazel woodland with hazel eventually becoming co-dominant. The relative importance of the two species varied between Strathmore and the Forest of Alyth, hazel becoming more important in the latter area. There was also some variability over time due to the pattern of regeneration within the woodland.

Extent and dating - A Betula - Corylus/Myrica assemblage zone is the most common Flandrian zone found throughout Scotland from the southwest (Moar, 1969c; H.H. Birks, 1972a) to northern Scotland (Pennington et al., 1972; H.H. Birks, 1970; Moar, 1969c) and the Outer Isles (Moar, 1969b; Vasari and Vasari, 1968; H.J.B. Birks, 1972a), although the relative contribution of shrub and tree species does vary between these areas. In England the immigration of Pinus usually precludes the definition of a zone based solely on Betula and Corylus/Myrica as at Red Moss (Hibbert, Switsur and West, 1971). This assemblage is therefore particularly Scottish but may, perhaps, be found in Wales (Godwin, 1955) and Cheshire (H.J.B. Birks, 1965) as well as occasionally in northern England (Smith, 1958; Oldfield, 1960; Bartley, 1966). Both zone boundaries are diachronous across the country due to the pattern of hazel immigration and the later immigration of elements of mixed oak forest but in eastern Perthshire they would appear to date from 8800/8700b.p. to 7200b.p.

Betula - Corylus/Myrica - Quercus - Alnus

Type locality and pollen characteristics - Because of the variability in the records from the sites studied there is no single zone which directly represents this particular regional pollen assemblage zone but both S4 at Stormont Loch and H4 at Heatheryhaugh have Betula, Corylus/Myrica, Quercus and Alnus as their dominant taxa, albeit in varying proportions, as does the lowest sample from Loch Mharaich. At both Stormont Loch and Heatheryhaugh Betula and Corylus/Myrica are the main contributors but values for Quercus are highest at the lower site. Although Alnus is considered a diagnostic element of this zone its rational limit usually postdates the opening of the zone and a distinction can be drawn between sites where the rational limit is coincident with the rational limits for Quercus and Ulmus, and those where it occurs within the zone although there is usually a low curve for Alnus from the opening of the zone. Ulmus pollen achieves its highest values in this zone and the contribution from N.A.P. is very low, less than 20%T.L.P., and in some cases as low as 5%T.L.P.

Environment - This zone marks the development of closed deciduous woodland largely dominated by birch and hazel, especially on the Forest of Alyth. The diagram from Stormont Loch indicates a considerable presence of oak in Strathmore and it was also present along the valley floors and lower valley-side slopes north of the Boundary Fault. Elm was locally present, particularly in Strathmore, and the evidence from Loch Mharaich shows that it was well represented in higher areas, probably on soils derived from more calcareous parent materials. Alder was a widespread component of the woodland in all areas and especially important in wetter habitats. There is some evidence that towards the end of the zone there may have been isolated brief reductions in the woodland cover due to the activity of early human communities.

Extent and dating - In a wider context this zone is probably of an extremely limited spatial extent for the main elements appear transitional between the pine-dominated areas to the north of the Dee Valley (Durno, 1959; H.J.B. Birks, 1977) and the areas of southern Scotland where Quercus was more important and birch less frequent. The importance and indeed the dominance of birch appears to be characteristic of eastern Scotland as far north and east as the Aberdeenshire coast (Vasari and Vasari, 1968) and particularly characteristic of the fringes of the southern and eastern Grampians. To the west higher pine frequencies of Moore's Group B sites (1977) provide significantly different assemblages. There is a danger in basing the regional assemblage on two sites in that the local woodland around the sites may not be fully representative of the spectrum of woodland communities in the region but using two different types of sites partially overcomes this, although the contribution of trees restricted to dry land habitats may be underestimated. The Betula - Corylus/Myrica - Quercus - Alnus assemblage zone probably lasted from the expansion of Quercus at 7200b.p. to 5100/5000b.p. and reflects a long period of relatively stable vegetation communities.

In the absence of an independent time scale it is not possible to directly correlate the patterns of human activity after c.5000b.p. as ascertained from the three different areas. Attempts at providing a summary of these events may take one of two forms. Similarities in the pollen sequences, not so much in the character of the assemblages themselves but in the changes between assemblages, can be looked for and correlated. This would for instance produce similar periods where A.P. is reduced by a significant amount over very few levels. Alternatively, an estimated time scale can be used as a general framework within which to discuss trends and possible links. Neither approach is without flaws, the former would seem possinle when examining the records from Stormont Loch and Heatheryhaugh, for following the Elm Decline and initial woodland clearances there are 'steps' or significant changes in pollen assemblages in both records but the overall sequences are too complex for any such approach, as is the sequence at Loch Mharaich. The inadequacies of the estimated time scales proposed in the text have been discussed earlier but they are accepted as a basis for comparison and summarised in Fig. 9·2 with diagonal lines representing particularly uncertain zone boundaries. More detailed outlines of the sequences of vegetational changes in the three areas are presented in Tables 9·1, 9·2 and 9·3. From examination of the possible correlations indicated in Fig. 9·2 it is possible to divide the period following 5100/5000b.p. into four phases

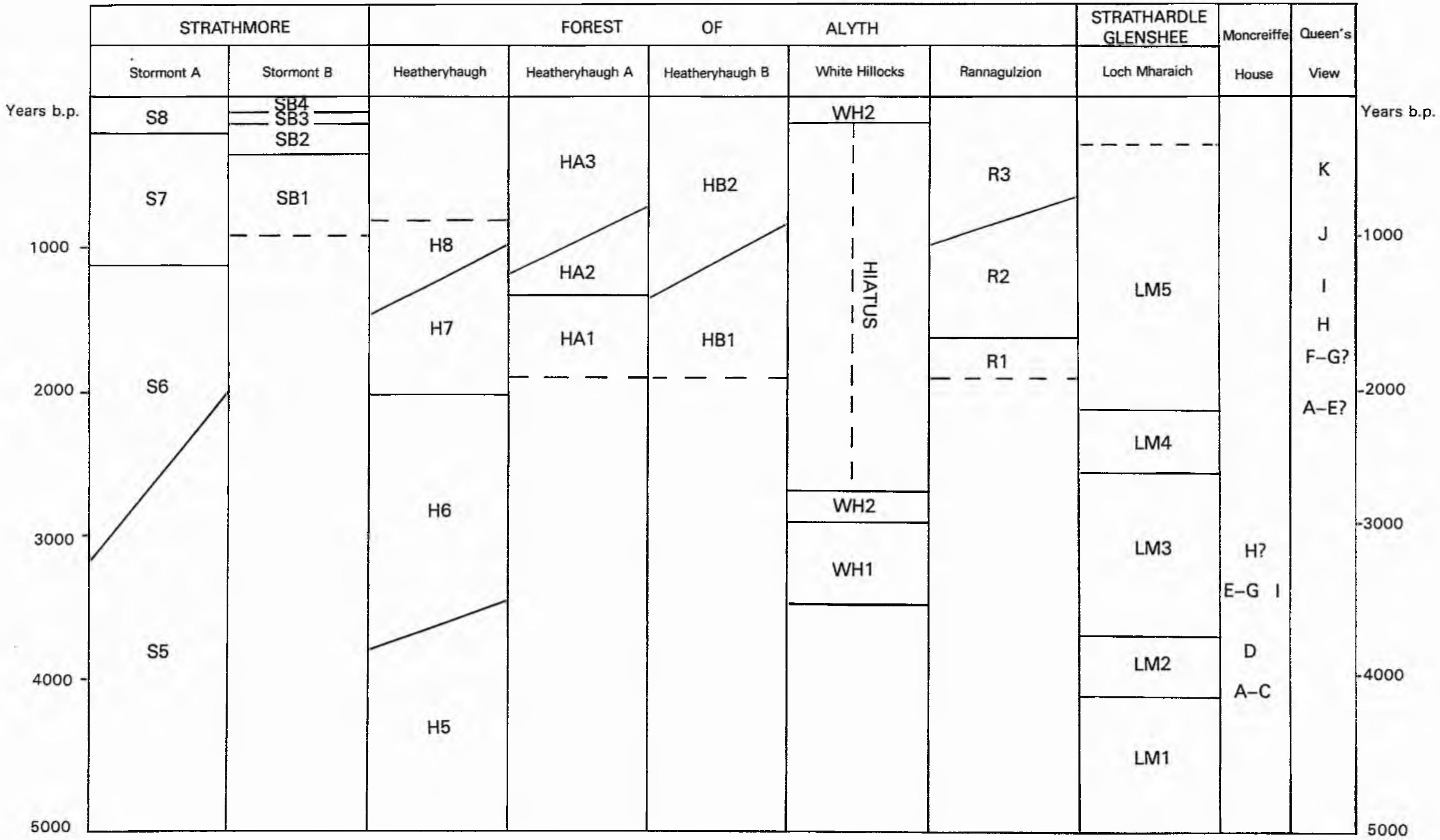


Fig.9.2 Suggested correlation of local pollen assemblage zones after c.5000b.p.

Table 9·1 Summary of events in vegetation history of Strathmore after c.5000b.p.

Years b.p.	STRATHMORE
5000 4000	Removal of elm from all habitats as scattered clearance took place on areas of outwash principally affecting birch and oak. Evidence for greatest intensity of land use during the later part of this millennium although still probably only in the form of small clearings for mainly pastoral purposes but with some cereal cultivation. Regeneration of oak on areas of till once covered by elm. Some reduction in local pressure on land to very low levels allowing development of secondary woodland dominated by hazel but with the continuous presence of open grassland, possibly under light grazing. Some very local deterioration in soils may have taken place allowing the development of more shallow rooting species.
3000 2000	Clearance of primary woodland dominated by oak and alder and secondary woodland under hazel on the outwash and marginal areas of the till providing larger clearings mainly for pastoral purposes. Clearance of hazel allowed some podsolisation and the local expansion of heather. Some slight birch regeneration as pressure eased. Period of increased land utilisation on the outwash and marginal till areas for both grazing and cereal cultivation, probably for a reasonable length of time. As land use declined there was further expansion of heather and some slight woodland regeneration. Further utilisation at a lesser intensity but including cereals. Slight woodland regeneration of hazel but the continued presence of open areas under grassland and heather.
1000	Clearance of all tree species growing both on outwash and till. Clearance of lake margins allowed local podsolisation and heather development. Utilisation for grazing and then after a brief phase of woodland regeneration there was widespread cereal cultivation including rye, as woodland was further reduced, probably due to the expansion of settlement in the 12th and 13th centuries and to the foundation of the Cistercian abbey at Coupar Angus.
0	Virtual complete woodland removal with only scattered remnants of birch and hazel. Planting of pine on the heavily podsolised soils on the outwash and continued cereal cultivation on the till.

Table 9•2 Summary of events in the vegetation history of the Forest of Alyth after c.5000b.p.

Years b.p.	FOREST OF ALYTH
5000 4000	Clearance of all tree species from several locations with both mixed oak and birch-hazel woodland affected. Reduction of elm frequencies in particular. Probable use for pastoralism and some local heather expansion. Regeneration of hazel and alder and to a lesser extent oak. Further clearance of new areas under oak, alder and birch with some local cultivation. Regeneration of all tree species except elm, especially birch and hazel, halted by a brief clearance before further regeneration and the increasing importance of alder.
3000	Relatively severe woodland removal, especially of birch, both primary and secondary woodland growing locally but only slight alteration of remaining oak woodland on lower ground. Land used mainly for grazing and with reduced intensity of use some birch regeneration as well as the further spread of heather. Further clearance including oak as clearance extended onto lower ground, probably for mixed agriculture. Another reduction in land use but still some continuity of use for grazing and heather was able to extend further. Removal of secondary woodland dominated by hazel but still only light local use of the land as soil deterioration and the development of communities dominated by *Calluna* took place.
2000	Regeneration of woodland dominated by birch and alder, particularly in the northern part of the area due to the widespread abandonment of the area by human communities.
1000 0	Removal, eventually completely, of the regenerated woodland which allowed repodsolisation and podsolisation of soils eventually leading to the *Callunetum* found today. Use of the Forest as common land for grazing from shielings but some cultivation around the fringes below c.300m.

Table 9·3 Summary of events in vegetation history of the Strathardle-Glenshee watershed after c.5000b.p.

years b.p.	STRATHARDLE - GLENSHEE WATERSHED
5000	Clearance of areas dominated by oak and elm as well as birch and alder on lower valley-side slopes for pastoral purposes with some slight recolonisation of hazel and the more gradual recovery of all tree species, including elm. Further clearance of birch, alder and oak on lower slopes for similar utilisation allowing the immediate spread of hazel followed by slight woodland recovery and a later clearance of birch, oak and hazel for mainly pastoral purposes. Recovery of all woodland species except elm mainly as secondary birch and alder woodland with some areas remaining open.
4000	Clearance of birch, alder and hazel higher up the slopes for pastoral use allowing some local heather development. Regeneration of all woodland species to similar local level of woodland cover to that preceding the clearance.
3000	Clearance of birch and alder, probably as high as 350m for both cultivation and pastoral use allowing further spread of heather. Some recovery of birch but continuation of areas of grassland. Clearance of oak and hazel on lower slopes for predominantly pastoral agriculture but gradual slow recovery of birch on higher slopes and expansion of heather at expense of grassland. Period of relative stability in the vegetation with considerable local woodland, and some recovery of oak.
	Relatively severe local clearance of both primary and secondary woodland, including that on the highest slopes, for the local cultivation of barley and grazing. Recovery of secondary woodland to earlier levels of cover but continuity of use at lower altitudes.
2000	Removal of birch, alder and hazel for principally pastoral use but this caused further podsolisation of soils and the development of the <u>Callunetum</u>. At lower altitudes remnants of oak woodland were finally removed.
1000	There is evidence of some continuous use of land for agriculture but local woodland survived and both birch and alder recovered slightly.
0	

for discussion, 5100/5000 - 3800/3600b.p., 3800/3600 - 2200/2000b.p., 2200/2000 to 1000/800b.p. and 1000/800b.p. to the present.

5100/5000 - 3800/3600b.p. - In all areas the opening of this period was marked by the removal of elm. In Strathmore this was probably selective and associated with the clearance of small areas on the outwash where birch and oak were removed. Here it would appear that elm was being used as fodder by pastoralist groups utilising the lighter soils and only exploiting the soils derived from till for its elm, as discussed earlier when examining the diagram from Stormont Loch. With the removal of elm, oak was able to expand further on the heavier till soils. The main phase of activity in Strathmore postdated the earliest clearances and may have included some cereal cultivation. Whether clearance was of a scale comparable to that at Dalladies further to the north or around Moncreiffe House to the south appears unlikely from the pollen evidence but openings remained in the local vegetation cover for a considerable length of time, certainly for longer than the period under discussion in this section.

On the Forest of Alyth the reduced frequencies for elm occurred in association with more general woodland clearance probably at several locations but again for principally pastoral agriculture. This clearance may have allowed some local expansion of heather, but as Calluna stems were also present in the peat stratigraphy this may be a change within the bog community. The effect of local pollen production by Calluna on Bankhead Moss showed how the presence of ericaceous species can dominate local assemblages. The initial clearance at c.5000b.p. was merely the first of a series of three phases of clearance taking in new areas for agriculture with clearance around Heatheryhaugh taking place in particular at some time around the middle of the third millennium b.c. Towards the end of the millennium land utilisation was reduced in intensity and alder increased its local status.

On the Strathardle - Glenshee watershed at the time of the Elm Decline there is evidence for clearance taking place on the lower slopes possibly including the physical removal of elm growing locally, the earliest clearance of most woodland species allowing the expansion of hazel. In contrast to the other areas elm regeneration took place after the earliest clearances, although as later woodland removal took place elm was gradually reduced and virtually eliminated. The initial regeneration of elm may have been due to the presence of more base-rich soils which were not significantly altered during this period but probably also reflects the fact that this area was on the fringes of human settlement and not affected to the same degree as those areas to the east and south. During this period of elm reduction further clearances did take place on the watershed and land utilisation did spread further upslope with the removal of birch and hazel, although hazel was never as important here as on the Forest of Alyth. On the available pollen evidence clearance of land appeared to have been chiefly for grazing animals and, as to the east, pressure on land appeared to decline towards the end of the millennium allowing alder to become more important. However, towards 2000b.c. there was a phase of land clearance on higher slopes near Loch Mharaich which caused the first noticeable expansion of heather but this was short-lived and woodland regeneration then took place to the levels found earlier.

Thus in the two higher areas there is some indication of reduced local land use following a series of clearances during the third millennium b.c. allowing woodland regeneration but with areas remaining open both as grassland and, particularly around Loch Mharaich, under heather. On the Forest of Alyth there would appear to have been a degree of land management which prevented soil deterioration, at least during the middle of the period. All the clearances appeared to be principally for a form of economy based on pastoralism with only slight indications of cereal growing. Assuming that woodland was still present near the pollen site the lack of evidence for cultivation could still be a function of pollen filtration or weakness of dispersal as demonstrated at Bankhead Moss. In Strathmore there is no indication of any reduced pressure on land but clearance was not as severe as that inside the Highland Edge and land utilisation at low levels of intensity continued into the second millennium b.c., any reduction in intensity allowing the spread of hazel rather than alder. Although in Strathmore the utilisation of elm could be interpreted as for fodder the records from the northern areas appear to show its removal as part of more general land clearance as well.

The existence of a series of clearances related to the spread of human communities during the Neolithic and early Bronze Age is not supported by the archaeological record. The clearances were probably restricted to the Forest of Alyth, the lower slopes of the main valleys of Strathardle and Glenshee and, perhaps at a less intensive level, the outwash spread on the northern margins of Strathmore. It may be that much of the archaeological evidence for these events has disappeared due to later land utilisation for in all these areas there was a considerable period of agricultural activity following these initial clearances.

<u>3800/3600 - 2200/2000b.p.</u> - On both the Forest of Alyth and the Strathardle/Glenshee area there was a significant reduction in the local woodland cover between c.3800 and 3600b.p. On the Forest of Alyth this first affected birch and hazel, while oak (probably by now

restricted mainly to low ground) was only affected as clearance expanded onto such areas in a second phase. At first, clearance took place due to the further development of pastoral agriculture but with the removal of oak there is evidence for cereal cultivation. On the watershed the first clearance took place on the higher slopes with immediate evidence for cultivation and then spread onto lower ground with the removal of oak and hazel. In both areas these clearances caused some local podsolisation and the expansion of heather.

On the Forest of Alyth although the intensity of land use varied there is evidence for some continuity of utilisation, probably in the form of grazing, and only slight woodland regeneration occurred between the phases of more intensive land utilisation. In Strathardle and Glenshee the earlier clearance of woodland on the higher slopes allowed the gradual regeneration of birch but again there is evidence of continuity of use and by the first half of the first millennium b.c. there appeared to be some stability in the vegetation cover even allowing partial regeneration of oak and elm in selected locations. Throughout this period woodland was more widespread in this area than on the Forest of Alyth again perhaps emphasising the peripheral nature of the area as regards human settlement at this time. Whereas on the Forest of Alyth towards the end of the first millennium there is only slight evidence for further removal of secondary woodland dominated by hazel there was another severe local phase of woodland clearance on the watershed area affecting both primary and secondary woodland with the cultivation of barley as well as the extension of grassland for grazing.

In both areas the earlier clearances may perhaps be linked with the human communities who constructed the stone monuments now found both on the Forest of Alyth and in the valleys. The immigration of these communities must have caused a significant modification of the landscape, especially on the Forest of Alyth. The continuity of land use indicated in both areas during the second millennium b.c. and the early first millennium b.c. strongly suggests that there was some continuity between the communities which constructed those early stone monuments such as circles, cairns and standing stones, and those which were associated with the hut circles, small cairns and possible field systems. The areal spread of these latter features and the pollen evidence indicates a fairly extensive period of land utilisation within the limits of the environment and the relatively later dates so far obtained from such monuments may well be dating the final phase of utilisation of multi-phase features. In both areas there is evidence for cereal cultivation taking place but within a mainly pastoral economy. Soil deterioration became more noticeable as utilisation continued. On the Forest of Alyth by the end of the first millennium b.c. there would have been considerable areas under heather with the soils showing podsolised profiles and this soil deterioration may have accounted for the gradual reduction in land use throughout this period, the earlier spread onto lower ground having taken place as much due to pressure of numbers as to the inhospitable nature of the environment. How much these later changes were assisted by deteriorating climate is difficult to judge although it is perhaps significant that woodland was still able to regenerate after this period on the higher parts of the Forest of Alyth.

Despite experiencing similar clearance of woodland the Strathardle - Glenshee area always retained a higher woodland cover than the Forest of Alyth, probably due to the greater difficulty encountered in utilising the slightly higher and steeper slopes on which the expansion of heather can be traced accompanying earlier clearances. The rather late local woodland clearance in the latter half of the first millennium b.c. around Loch Mharaich may well reflect activity associated with the use of the hut circles now found between Loch Mharaich and Dalrulzion, and the clarity with which the clearance and utilisation is indicated in the pollen record probably signifies the local nature of environmental change. Nevertheless with the abandonment of these hut circles woodland was able to recover and this recovery coupled with the probable late date for this expansion up the hillside probably belies the apparent role of climatic deterioration in this area although this clearance phase could have been a response to the movement of communities off the more exposed Forest of Alyth.

There is therefore some general agreement for this period between the environmental record and the archaeological record north of the Boundary Fault as both suggest some continuity of settlement and land utilisation from 3800/3600 to 2200/2000b.p. with perhaps a lessening of intensity towards the end of this period, but in the absence of excavation such an interpretation of the field archaeological features may be stretching the evidence. Throughout the area to the north of the Boundary Fault there were significant changes in the landscape during this period with the removal of woodland and the spread of _Calluna_- dominated communities but in the more northern areas woodland was able to regenerate and always formed a more significant element of the landscape.

In Strathmore during this period there was probably a similar phase of relatively severe local woodland clearance on the outwash sands and gravels but the inception of this period is difficult to date. However in the light of the evidence, both palynological and archaeological, from the areas to the north it is tempting to push this particular phase into the later first millennium b.c. as a response to the movement of communities off the Forest of Alyth, especially as in Strathmore this clearance was the first of a series which increased in intensity into the first millennium a.d. Here on the outwash, clearance of hazel woodland, at first for pastoralism, but later for cultivation as well, also allowed the spread of heather as soils became podsolised.

<u>2200/2000 - 1000/800b.p.</u> - North of the Boundary Fault there was only light utilisation of land for primarily pastoral purposes with some further woodland clearance in the Strathardle - Glenshee area, in particular affecting any remaining oak woodland. Clearance allowed further heather expansion but also, as land use was reduced, birch and alder were able to consolidate their position in the remaining woodland cover. On the Forest of Alyth the regeneration of birch and alder woodland, particularly in the north, suggests reduced pressure on land and indicates a considerable reduction in the human population exploiting the area. Archaeologically the evidence for this period is also limited. The place name evidence and the location of Pictish monuments within the upland area indicates settlement on the valley floors and thus probably agrees with the pollen evidence in suggesting utilisation of the higher land only for grazing, possibly only on a transhumant basis.

In Strathmore woodland clearance and land utilisation appears to have been more extensive and despite some reduction in pressure on land allowing hazel regeneration towards the end of the first millennium a.d. the presence of communities using the outwash soils for cultivation as well as grazing is indicated. It still seems unlikely that there was much reduction of the woodland which dominated the areas of till but there must have been pressure on these areas as clearance and cultivation of the outwash was allowing the spread of heather. Some marginal areas of till must have been affected but the degree and scale of use is difficult to estimate.

1000/800b.p. to the present - The final removal of woodland from the Forest of Alyth appears to have taken place within the last 800/1000 years although from the soil pollen record the age of deforestation is difficult to determine. Nevertheless this final elimination of the woodland cover caused the development of the acidic mor horizon now such a noticeable element of the podsols of the area and also saw the final spread of the Callunetum which dominates much of the landscape today. For much of this period the land was used for common grazing from shielings and even when designated a Royal Forest it is questionable whether much woodland remained. Podsolisation of soils had taken place during earlier periods of woodland clearance but the pollen record in these soils only records the later changes and soils may have been improved during the extension of birch-alder woodland, the final clearance causing repodsolisation. Further to the north and west on the Strathardle-Glenshee watershed the final elimination of the woodland must have taken place much later. It is not recorded in the pollen record at Loch Mharaich, and woodlands were managed as part of the Persey lands near Bridge of Cally during the period of monastic control.

In Strathmore widespread woodland clearance probably took place eventually on both the till and outwash areas with the expansion of settlement in the twelfth and thirteenth centuries and the founding of the abbey by the Cistercians at Coupar Angus. There was cereal cultivation taking place, at first including rye and later including both oats and barley, as indicated in both the pollen and documentary records. Final removal of oak and alder leaving only scattered woodland remnants probably took place with the agricultural improvements of the eighteenth century and around Stormont Loch the substitution of fringing deciduous woodland by pine took place. This planting of pine which occurred throughout the region is recorded in all the soil pollen profiles, as is the possible expansion of cereal cultivation up to 270-300 metres on the fringes of the Forest of Alyth in the last two centuries.

The application of pollen analysis has therefore provided results which give a preliminary basis for further more detailed studies. The results from the area to the north of the Boundary Fault show a particularly interesting sequence of clearance episodes which require accurate dating and closer definition as well as the support of excavation-based archaeological evidence to establish their age and duration. In Strathmore there is obviously a need for a site less affected by the pollen production of local communities than Stormont Loch. Most of the available lochs have ineffective or complex catchments but the existence of significant breaks in the Late Flandrian pollen record provides hope for successful comparison with any future sites investigated locally. In the analysis of earlier periods there is a need for sites in the valley floors to help ascertain the pattern of woodland communities and going further back in the pollen record a site mid-way between Corrydon and Stormont Loch would shed light on the possible existence of a recognisable gradient in the vegetation communities which developed in the area during the Late Devensian.

It was argued earlier that the area under study could be treated as a regional unit assuming general similarity in the vegetation record, albeit with differences in the timing of the response of vegetation to environmental change and with variations in the degree to which certain types of vegetation communities could establish themselves. Throughout the period under investigation this part of eastern Perthshire has exhibited a record of vegetation changes showing differences to that of neighbouring areas, although the dominant characteristics of the vegetation communities have consistently been more comparable to those found to the east of Perthshire rather than to the west, south or north. During the Late Devensian the closest affinities are to be found with the site at Corrydon and sites to the north and east in the Dee valley and the Aberdeenshire lowlands. During the Early Flandrian, the period when there was perhaps the greatest uniformity in the response of vegetation to climatic change within the country as a whole, the patterns of change seen in Eastern Perthshire similarly reflect change on a much wider scale, but as the Flandrian progressed and forest communities developed the area showed distinctive community characteristics. Eastern Perthshire has remained very much a transitional zone between southern and northern Scotland not fitting clearly into the patterns established by either Birks (1977) or Moore (1977). During the Middle Flandrian the importance of birch clearly mirrored findings elsewhere in the Eastern Grampians and Eastern Lowlands of Aberdeenshire, and the absence of pine and presence of oak showed the influence of more southern woodland elements. Once prehistoric communities entered the area then any regional pattern is difficult to discern and it is not possible at present without the existence of well dated profiles to establish regional trends. Nevertheless in the period preceding the presence of man in noticeable numbers the transect across the Highland Edge does appear to provide a picture of vegetational and environmental change which is explicable within a general regional context, even if the area as a whole may well have been transitional between dominant vegetation types when viewed on a national scale.

The limitations of pollen analysis remain and are acute when interpreting early patterns of land clearance. The fragmentary nature of the deposits will always pose a problem but the analysis of the pollen profiles from soils offers useful corroborative evidence against which peat records can be evaluated. The difficulties inherent in interpreting location, scale and process from the pollen evidence have still to be overcome, especially when using peat records, and hence detail of events is lacking. In the light of the results from the surface pollen work undertaken on Bankhead Moss it could be argued that the extent of human interference with the vegetation of eastern Perthshire has been consistently underestimated but the direct application of such studies to fossil data cannot yet be successfully made. The caution advocated by Deevey (1966) would therefore still seem justified although it should be remembered that without the application of pollen analysis in such areas the pattern of vegetation change in eastern Perthshire over the last 14000 years would have been lost rather than elusive.

Appendix I Species composition of transects across Bankhead Moss

Results are based on observations of the presence of species in quadrats one metre by one metre from within which samples for pollen analysis were taken. In the woodland the quadrat size was increased to five metres by five metres.

Transect A

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Betula pubescens					x			x	x		x	x	x	x	x	x	x	x	x												
Calluna vulgaris	x	x	x	x	x	x	x	x	x																						
Erica tetralix				x		x	x			x																					
Bellis perennis																					x										
Cirsium arvense																						x		x							
Galium saxatile															x			x			x										
Myosotis arvensis																															x
Potentilla erecta																					x	x	x	x	x	x	x	x			
Rumex acetosa																								x	x						
Senecio jacobea																							x								
Stachys palustris																											x	x			
Stellaria graminea																					x	x	x	x	x	x				x	x
Taraxacum officinale																								x							
Veronica chamaedrys																							x								

continued.....

Transect A (continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Gramineae																x	x			x	x	x	x	x	x	x	x	x	x	x	x
Eriophorum vaginatum	x	x	x	x	x	x	x	x	x																						
Juncus spp.				x																								x		x	x
Dryopteris austriaca														x	x	x	x	x	x												
Equisetum palustre																															x
Sphagnum spp.	x	x	x	x	x	x	x	x																						x	x
Moss spp.	x	x		x	x	x		x	x		x	x	x	x																	
Bare earth	x						x		x		x	x	x	x	x	x	x		x	x											

Transect B

	2	3	4	5	6	7	8	9	10	11
Betula pubescens					x	x	x	x	x	
Calluna vulgaris	x	x	x	x						
Erica tetralix		x		x						
Chenopodium album										
Cirsium arvense										x
Epilobium palustre										
Filipendula ulmaria										x
Heracleum sphondylium										x
Rumex acetosa										x
Senecio jacobea										x
Urtica dioica										x
Gramineae										x
Eriophorum vaginatum	x	x	x							
Juncus spp.										x
Dryopteris austriaca					x	x	x	x	x	
Sphagnum spp.	x	x	x	x						
Moss spp.			x	x	x	x				
Bare earth	x		x	x	x	x	x	x	x	

12	13
×	
×	×
×	
×	
×	×
×	×
×	

Transect C

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Betula pubescens								x	x	x	x	x													
Salix sp.															x										
Calluna vulgaris	x	x	x	x	x	x	x																		
Erica tetralix		x	x	x		x																			
Centaurea nigra																						x			
Chenopodium album													x	x		x						x		x	
Cirsium arvense														x	x						x				
Cirsium palustre													x	x					x			x	x	x	x
Epilobium palustre														x				x							
Filipendula ulmaria															x	x	x	x	x	x					
Galium aparine																x	x	x							
Heracleum sphondylium																						x	x	x	
Lathyrus pratense																					x		x	x	x
Rosaceae sp.													x												
Rumex acetosa													x	x						x					
Senecio jacobea														x											
Stachys palustris																		x	x						
Trifolium repens																				x					
Urtica dioica																x	x				x		x		
Vicia cracca																						x			x

continued......

Transect C (continued)

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Gramineae												x	x	x	x	x	x	x	x	x	x	x	x	x	x
Eriophorum vaginatum	x		x	x	x	x	x																		
Juncus spp.												x	x	x							x				
Dryopteris austriaca									x	x															
Sphagnum spp.	x	x	x	x	x																				
Moss spp.						x	x						x	x	x	x	x	x	x						
Bare earth	x		x					x	x	x	x														

APPENDIX II

Pollen preparation procedures

Relative pollen preparation

As far as possible a standard preparation procedure was used for all analyses. The standard procedure adopted followed that developed originally by Faegri and Iversen (1975) although a NaOH pre-treatment rather than a KOH pretreatment was used. For peats and mainly organic sediments only acetolysis was used and for minerogenic sediments additional treatment by HCl and HF was necessary. The general procedure therefore at all sites was:

1. Deflocculation and maceration by boiling in 10%NaOH for at least 15 minutes followed by centrifuging.

2. Washing twice in distilled water, first with a few drops of NaOH, followed by centrifuging.

3. Dehydration in glacial acetic acid followed by centrifuging.

4. Boiling for four to five minutes in an acetolysis mixture of acetic anhydride and H_2SO_4 to remove cellulose, firstly bringing up the water bath to boiling point with the mix immersed, followed by centrifuging.

5. Washing in glacial acetic acid followed by centrifuging.

6. Washing twice in distilled water, once with a little teepol, followed by centrifuging.

7. In minerogenic sediments in order to remove silica the material was boiled in 30-40%HF for up to 30 minutes, centrifuged and then washed twice prior to the acetolysis treatment (steps 3-5). As a precaution the material was also heated in 10%HCl for one to two minutes before the use of HF to remove any free $CaCO_3$. Despite the comments of Moore and Webb (1978) the brief heating did not lead to any apparent exine corrosion.

Mounting procedures varied, for at the first site analysed, Heatheryhaugh, mounting was carried out in Glycerine jelly and the mountant stained as outlined below:

8. Safranin was added at the second of the later washes in distilled water and after mixing and centrifuging a few drops of hot Glycerine jelly added before putting into a labelled phial.

For all subsequent samples mounting was made in silicon oil of a viscosity of 12,500 centistokes using the following procedure:

9. Washing in 95% alcohol followed by centrifuging.
10. Washing in 99% alcohol, followed by centrifuging.
11. Washing with tertiary butyl alcohol followed by centrifuging.
12. Addition of c.1ml. of tertiary butyl alcohol, stirring and then transfer into a labelled phial containing silicon oil.
13. Evaporation in a fume cupboard.

In certain cases where sediment varied in form and where measurements were being made the full procedure including treatment in both HCl and HF was used for all samples irrespective of their composition to provide comparability in treatment between levels. This practice was followed on Bankhead Moss for both moss and soil samples, and at Stormont Loch.

Preparation for pollen concentration measurements

To provide data on pollen concentration values at Loch Mharaich additional steps were taken. Several techniques are now available which can be used to provide pollen concentration figures either by volumetric methods (Dimbleby, 1961a; Davis and Deevey, 1964; Davis, 1965, 1966), weighing methods (Jørgensen, 1967) or exotic marker grain methods (Benninghof, 1962; Bonny, 1972), and several of these have recently been compared by Peck (1974). The procedure eventually adopted was of the latter form by the addition of exotic pollen grains and was based on Bonny (1972) and Edwards (pers.comm.). The procedure involved the preparation of a known assay of exotic pollen which could be added to a known volume of sediment. The calibration of the assay of pollen by the use of a haemocytometer caused many problems and several assays were prepared before one which had acceptable confidence limits was obtained. The difficulty was in devising a method of extracting at least 40 samples from the main suspension which would provide reproducible counts in the haemocytometer of sufficient accuracy. Using a round-bottomed flask and magnetic stirrer the vortex set up by the stirrer obviously affected the settling of the assay prior to collection by pipette. Eventually stirring for one minute after an initial stir of at least 15 minutes followed by a settling time of 45 seconds prior to collection was used, and this provided the set of readings given in Table II.1 which gave an acceptable measure of the assay. The whole procedure proved time consuming in the preparation stage, although not in the extraction stage, and the time spent in preparing the assay meant that it was only available for use on the Loch Mharaich samples, the last site examined, and not in any of the soil samples. The use of silicon oil for mounting the soil samples which, because of the difficulties encountered in pollen identification, was preferred as a mounting medium, precluded the use of methods of concentration determination using known volumes of the mountant (Dimbleby, 1961a). The use of tablets of known assays of pollen or spores (Stockmarr, 1972) now makes the preparation of an assay unnecessary.

The assay of <u>Ambrosia</u> pollen was made in distilled water and prepared in a 500ml round-bottomed flask. Forty samples were taken from this by pipette using the procedure outlined above and counted in a haemocytometer (Table II·1). Calculation of the total assay within the 95% confidence limits was made using the formula given in Bonny (1972):

Table II·1 Haemocytometer readings for the assay of *Ambrosia* pollen

368	385	381	363
370	364	346	389
330	365	370	377
321	319	387	346
320	317	348	382
331	326	355	366
316	359	360	377
339	379	328	328
357	381	366	338
344	359	332	326

$\bar{x}$ = 352·88

s^2 = 502·01

s = 22·41

χ^2 = 55·48

Haemocytometer volume = 3·16µl

$$\bar{x}\left(\frac{1000}{c}\right) \pm t\sqrt{\frac{\bar{x}}{n}}\left(\frac{1000}{c}\right) \qquad \text{II·1}$$

where $\bar{x}$ = mean of the counts; c = volume of the haemocytometer chamber in μl.; t = Student's t for n - 1 degrees of freedom; and n = number of counts. For the assay this produced the following calculations:

$$352{\cdot}88\left(\frac{1000}{3{\cdot}16}\right) \pm 2{\cdot}02\sqrt{\frac{352{\cdot}88}{40}}\left(\frac{1000}{3{\cdot}16}\right) \qquad \text{II·2}$$

where $\bar{x}$ = 352·88 grains

c = 3·16u1

n = 40

t = 2·02 (39d.f.)

<u>Number of grains = 111,672 per c.c.</u>

The number of grains in each haemocytometer reading is higher than that used by Bonny (1972) but falls well within the suggested upper limit for accurate haemocytometer readings and to produce 95% confidence limits more samples than necessary were in fact collected and counted but in the absence of a good estimate of the final concentration this was considered a necessary precaution.

The assay was added to a known volume of sediment, displaced volumetrically, before maceration so that any variation in losses during extraction of the pollen in the different preparations could be accounted for. Rather than add 1c.c. of assay to 1c.c. of sediment 0·6c.c. of assay was added to 0·6c.c. of sediment as this provided enough material for the preparation procedures adopted, thus approximately 67003 grains were added on each occasion. In calculation of the results every sample was recalculated to provide values expressed as the number of grains per c.c. of sediment. Bonny (1972) advocated the use of a count of 1000 grains including both exotic and fossil pollen as an aid to calculation and as a means of narrowing the confidence intervals for the calculation of the final pollen concentration values. At Loch Mharaich a count of at least 500 T.L.P. was used which meant usually an overall count of less than 1000 grains but rarely less than 700. The total number of grains counted varies of course depending on the concentration in the sediment which will itself vary but the lower counts do not seriously affect the accuracy of the results (Faegri and Iversen, 1975).

Appendix III Distribution of diameters (μ) of Gramineae for the three transects across Bankhead Moss

Transect A:

	n	Σ	x̄	12/13	14/15	16/17	18/19	20/21	22/23	24/25	26/27	28/29	30/31	32/33	34/35	36/37	38/39
1	59	1459	24•73			1	6	5	9	15	10	3	7	2	1		
2	41	1063	25•93				1	7	2	7	10	5	4	5			
3	68	1742	25•62				2	8	15	14	8	8	4	7	1	1	
4	76	1931	25•41			1	1	9	19	13	12	6	8	6		1	
5	40	976	24•40				3	8	6	12	4		2	5			
6	46	1179	25•63				1	10	7	9	5	5	2	3	2	2	
7	77	1933	25•10			1	2	6	20	16	13	9	6	4			
8	46	1174	25•52			1	1	4	11	6	7	6	8	2			
9	47	1193	25•38		1		1	6	5	15	7	2	3	6		1	
10	63	1717	27•25					7	6	9	12	9	10	6	2	2	
11	33	903	27•37					2	4	6	7	3	3	6	1	1	
12	41	1107	27•00					4	6	7	6	3	7	8			
13	49	1312	26•78					3	5	13	9	5	10	2	2		
14	60	1688	28•13					2	3	14	11	6	10	8	5	1	
15	60	1699	28•32				1		5	13	9	8	9	8	5	2	
16	58	1563	26•95					3	6	11	11	12	9	5	1		
17	50	1356	27•12				1	3	6	8	13	3	9	3	3	1	
18	43	1084	25•21					5	9	10	12	2	2	3			
19	94	2586	27•51				2	7	8	16	19	11	14	10	4	3	
20	142	3840	27•04					6	16	42	19	16	27	6	10		
21	275	7207	26•21				3	23	32	81	57	17	33	18	9	1	1

(continued)

Transect A (continued)

	n	Σ	$\bar{x}$	12/13	14/15	16/17	18/19	20/21	22/23	24/25	26/27	28/29	30/31	32/33	34/35	36/37	38/39
22	287	7270	25•33		1	2	7	37	51	85	32	17	31	7	13	4	
23	229	5836	25•49				5	26	33	70	37	15	14	20	6	2	1
24	165	4272	25•89			1	1	21	18	46	30	15	19	9	2	2	1
25	248	6012	24•24			2	16	51	51	51	26	18	20	8	4	1	
26	233	5654	24•27		1	1	8	44	53	61	26	11	16	5	6	1	
27	376	9407	25•02			1	16	40	65	112	66	21	40	9	5	1	
28	205	5420	26•44				5	21	21	50	34	16	34	10	8	6	
29	182	4615	25•36				3	20	29	48	40	8	24	6	2	2	
30	132	3392	25•70				2	15	22	31	32	5	14	4	5	2	
31	171	4442	25•98				4	12	17	56	38	11	20	8	4	1	
Transect B:																	
2	65	1573	24•20			2	3	14	13	12	8	5	3	3	1	1	
3	81	2134	26•35				3	9	12	15	10	10	12	4	5	1	
4	84	2224	26•48				1	5	15	18	14	8	13	8	2		
5	50	1315	26•30				2	3	5	13	9	6	8	2	2		
6	41	1030	25•12				1	5	13	5	7	3	4	1	2		
7	57	1554	27•26					2	7	12	12	7	7	6	3	1	
8	59	1546	26•20				1	3	12	13	14	5	3	4	3	1	
9	66	1714	25•97		1	2	3	5	6	18	8	5	9	4	4	1	
10	42	1213	28•88				1	4	4	10	2		4	4	6	7	
11	153	3950	25•82				6	9	31	36	25	19	8	13	2	4	
12	202	5465	27•05				2	10	13	51	43	17	47	17	1	1	
13	194	5187	26•74				8	13	27	37	28	27	19	24	7	4	

Transect C:

	n	Σ	$\bar{x}$	12/13	14/25	16/17	18/29	20/21	22/23	24/25	26/27	28/29	30/31	32/33	34/35	36/37	38/39
2	61	1540	25•25				3	7	12	15	7	6	7	3	1		
3	66	1634	24•76				3	8	10	15	14	7	7	2			
4	54	1308	24•22				2	11	14	11	7	2	5	2			
5	60	1486	24•77				1	10	11	16	9	7	3	3			
6	51	1269	24•88				1	9	10	10	10	7	1	2	1		
7	43	1109	25•79				1	4	9	15	2	3	2	5	1	1	
8	59	1591	26•97				1	5	10	11	7	3	11	6	2	2	1
9	39	994	25•49				1	8	2	10	7	1	8	1	1		
10	62	1675	27•02				4	4	2	19	4	5	13	4	7		
11	51	1407	27•59			1		4	4	4	11	8	9	7	1	2	
12	43	1178	27•40				2		2	11	6	9	7	3	2	1	
13	159	4282	26•93			1	3	13	16	36	23	22	18	11	12	2	2
14	234	5953	25•44	1	1	1	9	23	31	73	29	23	23	16	3	1	
15	215	5430	25•26				8	31	26	63	33	24	18	6	4	2	
16	41	1129	27•54					2	5	7	9	3	5	8	1	1	
17	95	2421	25•48				3	13	15	27	11	8	8	4	5	1	
18	52	1405	27•02					5	3	10	10	7	10	7			
19	89	2299	25•83				1	9	8	27	20	10	11	1	1		1
20	130	3559	27•38		1			14	11	24	24	12	27	11	4	2	
21	321	7861	24•56				7	52	71	100	38	13	23	11	5		

(continued).........

Transect C (continued)

	n	Σ	$\bar{x}$	12/13	14/15	16/17	18/19	20/21	22/23	24/25	26/27	28/29	30/31	32/33	34/35	36/37	38/39
22	256	7018	27•41				2	21	25	50	38	20	53	32	8	7	
23	321	9234	28•77		1	2	4	16	23	33	44	35	75	41	29	18	
24	257	7217	28•08	1		3	7	20	12	36	35	21	49	34	27	12	
25	251	6667	26•65			2	17	23	23	47	35	35	20	24	16	7	2
26	307	7780	25•34		1	2	17	45	38	73	45	28	25	15	11	5	2

APPENDIX IV

Pollen preservation

Previous work and the aims of the analysis

Work on pollen preservation has tended to be either based on experimental data (Havinga, 1964, 1971) or on observations from fossil data (Cushing, 1964, 1967; Elsik, 1966, 1971; Havinga, 1968, 1971; H.J.B. Birks, 1970, 1973a). A summary of even earlier work may be found in Havinga (1964). Using these sources and his own experimental work he suggested a general scale for the relative susceptibility of pollen to various deterioration phenomena (Havinga, 1967, 1971). Although there are several ways in which pollen may be damaged or destroyed Havinga emphasised the importance of oxidation which may occur naturally immediately upon deposition and be a precursor of later destruction by microorganisms, "the more readily the pollen is oxidised, the more rapidly it is destroyed by subsequent attack by microorganisms" (p.628, 1964). It is perhaps possible to identify three fundamental causes of pollen deterioration, chemical oxidation, microbial, fungal or faunal destruction and mechanical breakdown caused by the movement of grains or pressure upon them. Thus the character of pollen preservation will vary depending on the dominant destructive element and this in turn will depend on the sediment type. Preservation also varies however among pollen types, the susceptibility to destruction probably depending upon sporopollenin content (Havinga, 1964). The form of pollen preservation in any fossil context will therefore vary "among pollen types and sediment types" (Cushing, 1967, p.98).

The aims of the analysis carried out here were to further investigate briefly both the character of pollen preservation in the different deposits examined and to see whether, on the basis of an examination of fossil material, it is possible to determine the dominant factors behind the patterns of preservation encountered, i.e. whether sediment type or pollen type is most important. In studies of Late Devensian deposits for example, high counts of deteriorated pollen are often considered indicative of inwashing with the likely presence of reworked pollen (Gray and Lowe, 1977) but it may be that these counts are due more to the greater representation of taxa susceptible to deterioration in those levels. A further aim was to examine the variation in pollen preservation within soil profiles to see whether patterns emerged which could be of value in the interpretation of the original soil pollen assemblages and in the interpretation of sediments from archaeological sites as an aid to understanding the origin of 'derived' deposits or the more detailed character of 'in situ' deposits. Within the context of the thesis this work is but a subsidiary element and is limited in scope. This limitation meant that only a selection of sites was investigated and as such the results are but an indication of possible trends but where pollen data are being collected omission of details on pollen preservation could lead to the absence of important indicators as to the origin and character of the pollen assemblage. In order to fully explore the aims set out here a much more detailed and exhaustive sampling programme would have to be used involving both fossil material and experimental work, especially if the processes behind pollen deterioration are to be considered.

Data collection

A system for the identification of different forms of pollen deterioration was adopted based on that of Cushing (1964, 1967) and H.J.B. Birks (1973a). All land pollens were included in the counts of Damaged pollen but spores and aquatics were excluded, rather for ease of analysis than for any other reasons, for in some of the soils extremely high counts of Filicales were made. Unless otherwise stated the values for Damaged pollen are expressed as a percentage of the T.L.P. sum as are values for individual forms of preservation although in the later discussion the latter values are considered within the sum of Damaged pollen. Counts for Indeterminable pollen are included within the T.L.P. sum and include pollen that was too badly damaged, concealed or unsuitably orientated making identification impossible. Four categories of pollen damage were identified:

i) Corroded - grains which were pitted or etched, probably due to microbial activity (Elsik, 1971; Havinga, 1971). Examples of Corroded grains are presented in Havinga (1971). In all sediments except those from Moncreiffe House few Corroded grains were encountered.

ii) Degraded - "those (grains) whose structural and sculptural features cannot be resolved" (H.J.B. Birks, 1973a, p.243). As such this includes the thinning of pollen grains observed by Havinga (1964) and is probably a function of some fusing of structural elements in the pollen wall. Although authors have commented on the high proportion of Degraded pollen in silts (Cushing, 1967) and of thinning in podsolised soils (Havinga, 1971) the factors influencing this form of destruction have not been clearly isolated.

iii) Crumpled - in previous studies only badly folded, twisted, wrinkled or collapsed pollen grains have been included in this category (e.g. H.J.B. Birks, 1973a, and the 'ad indeterminable plicatum' class of Fredskild, 1967). As creasing of pollen grains, even if only along one or two axes, presumably weakens the pollen wall then such a process may well make those grains more susceptible to later deterioration. Because of this all grains exhibiting such creasing were placed in this category. This accounts for apparently high counts of

Damaged pollen in some sediments but is considered a necessary step in order to understand in particular the likelihood of certain taxa being damaged.

iv) Broken - those grains which were fragmented or which had cracks in their exine. Both Broken and Crumpled grains are probably found due to physical disturbance of the grains, in some cases no doubt due to microfaunal activity such as ingestion by earthworms.

These four categories are not mutually exclusive and pollen grains were often found exhibiting two or even three forms of damage. In such cases the principal form of damage was adopted. The groups do not form a progression such that one type of damage leads to another but in soils for instance it could often be observed that where degradation and thinning was the major cause of destruction these grains were also very likely to be crumpled or broken, possibly as a result of the weakening of the exine.

Because of the time involved in collecting additional information on pollen preservation, details down to species level were taken only at a representative sample of the sites studied; at Stormont Loch from both cores, the samples from the archaeological site at Moncreiffe House, and from all the soil profiles, although in these only counts under the general groupings were made, not down to species level. Generalised results from all these sites appear in the full pollen diagrams and, in some cases, have already been commented upon.

Analysis

Preservation in the sediments from Stormont Loch: The Late Devensian core at Stormont Loch presented an excellent example of alternating sediments of varying character, both mainly organic and mainly inorganic. No attempt was made to separate the pollen into 'secondary' eroded pollen and 'inwashed' contemporary pollen

(H.J.B. Birks, 1970) but the characteristics of pollen preservation within each different sedimentary unit were examined. From the pollen diagram (Fig. 5•4) there are peaks for Damaged pollen which appear to correspond to periods of inwashing and the dominance of silts but with the high degree of pollen deterioration and the variability in the importance of different taxa between the units such a distribution may be overemphasised by the presence of those pollens susceptible to deterioration.

By separating the sediments into predominantly organic (organic mud, sedge peat and gyttja) and predominantly inorganic (silts, clays and silty clays) and then further subdividing the latter group into coarse and fine it is possible to observe a slight progressive change in the relative importance of degradation as against crumpling and breakage from organic sediments with lower values for degradation to inorganic sediments with higher values (Fig. IV•1a). The distinction is a fine one for in all cases crumpling and breakage are the main forms of destruction but there is very little difference in the number of grains damaged between on the one hand coarse, inorganic sediments and on the other hand organic sediments (Fig. IV•1b). (Except in Fig. IV•1b the results of the preservation analyses are presented as grouped frequency graphs using the sum of Damaged pollen i.e. Total Damaged Pollen = 100%, such that above Corroded is given the percentage of Corroded grains, above Degraded the percentage of Corroded + Degraded, above Crumpled the percentage of Corroded + Degraded + Crumpled. The value of Broken pollen is the difference between the percentage above Crumpled and 100%.)

From this preliminary analysis the observation by Cushing (1964) of the importance of degradation in silts is confirmed but the consistent high values for crumpling, using the criteria adopted here, show that

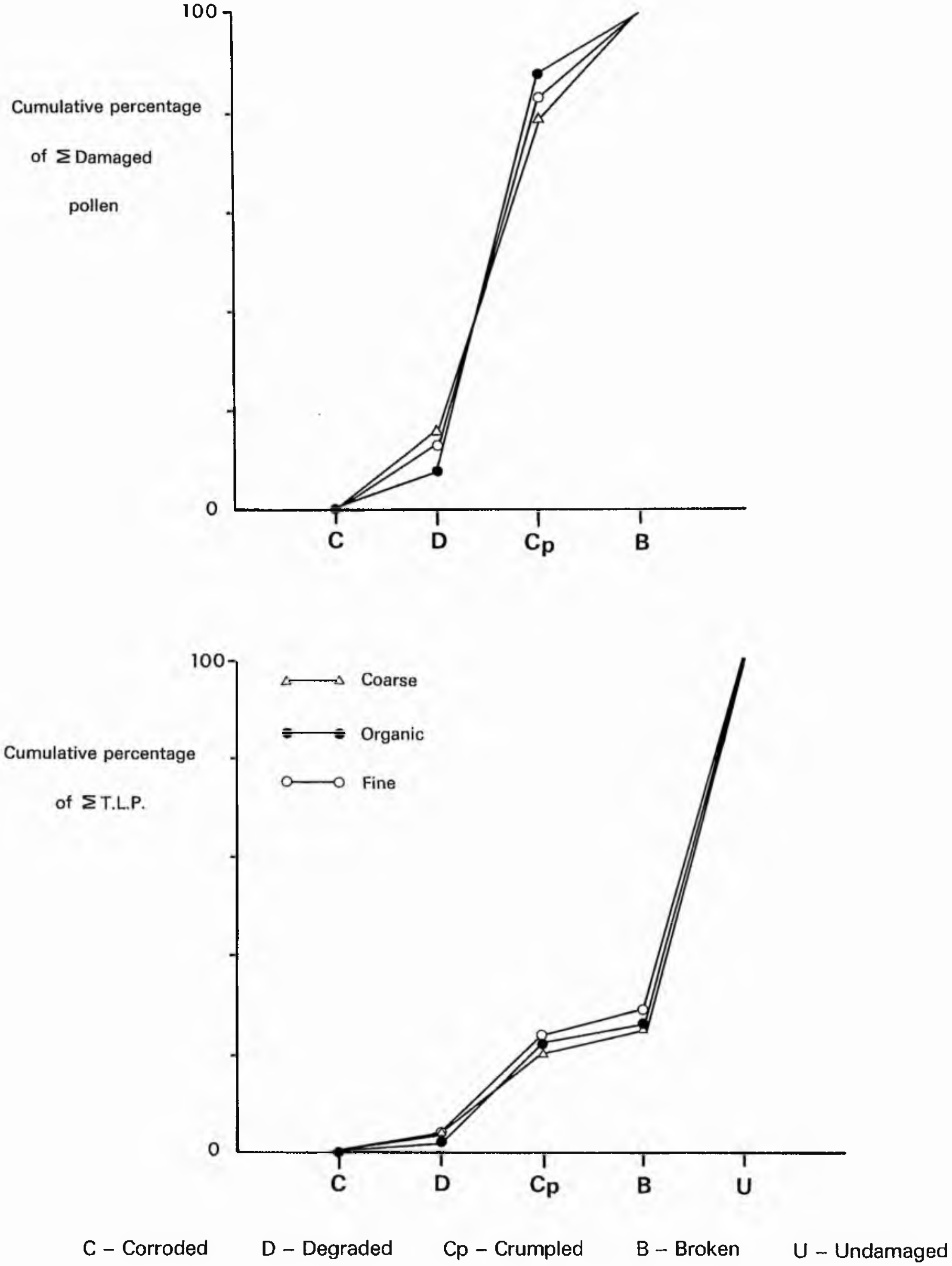


Fig.IV.1 Cumulative frequencies of pollen preservation categories for different Late Devensian sediments at Stormont Loch susceptibility to mechanical breakdown is still high and where species are prone to folding because of their form or size relatively high counts of Damaged pollen would ensue.

Using the same data from the Late Devensian profile an analysis was made of all the Damaged grains of the principal taxa using the same cumulative frequency method, with the total number of Damaged grains of each taxa as the sum, and the results are presented in Fig. IV•2. This shows that there is a clear differentiation between different groups of pollen grains which appear susceptible to different forms of deterioration, despite the very low counts for Corroded pollen. Three groups can be identified:

i) Those showing a high occurrence of Degradation - _Artemisia_ and _Salix_.

ii) Those showing a high occurrence of Breakage - _Pinus_.

iii) Those showing a higher occurrence of Crumpling, either -

  a) With a relatively high proportion of Degradation - _Thalictrum_, _Juniperus_, _Betula_ and Caryophyllaceae.

  b) With a relatively low proportion of Degradation - Gramineae, Cyperaceae, _Empetrum_ and _Rumex_.

There is of course a dangerous circular argument in using observational data because here it could be argued that the only reason for the separation of _Artemisia_ and _Salix_ is that they are important in silts in which particular forms of deterioration are usually found, but this is not the case for instance for _Thalictrum_ (although here the sample is small) or for Gramineae which occurs throughout but with high levels in the silts and yet shows a different pattern of deterioration. The differences that can be observed between taxa in such sediments could therefore, if particular pollen grains are more susceptible to damage, lead to an overrepresentation of Damaged pollen in some levels. If

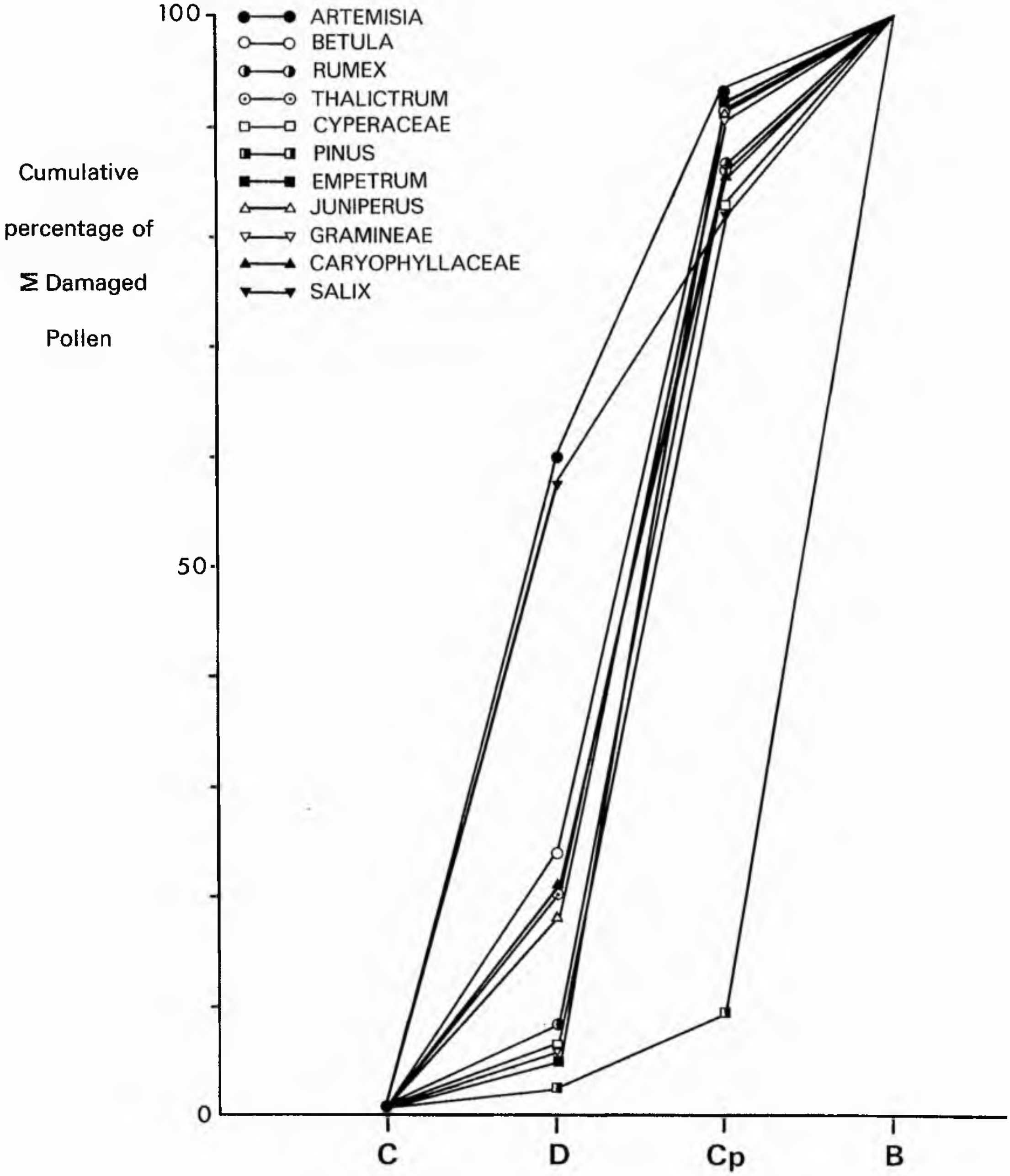


Fig. IV.2 Cumulative frequencies of pollen preservation categories for different pollen taxa from the Late Devensian at Stormont Loch the criteria for identifying Crumpled grains used here are accepted, then, where high counts for Gramineae occur, high levels for Damaged pollen could also be found, even if the main sedimentary unit was organic and indicative of stable local environmental conditions.

The results from the Flandrian core are summarised in Fig. IV·3 using a sample of the data collected (every third level), and from the diagram it is possible to observe a difference between the state of preservation in the upper *Sphagnum*-sedge peat and the lower gel mud. In the upper peat over half the Damaged pollen is Crumpled and Broken and values for Degraded pollen rarely fall below 25 per cent (Total Damaged Pollen), results similar to those quoted by Cushing (1967). Although the pattern of pollen deterioration is relatively uniform within the peat there are three levels which show different patterns. At each of these levels, 80cm, 120cm and 160cm, there are peaks for Corroded pollen at the expense of the Crumpled category. From the preservation of the pollen it could be argued that there is evidence for some inwashing at these levels, either with the presence of mineral particles causing a different pattern of pollen deterioration or with the inclusion of secondary pollen. There is some support for such explanations in the pollen record. At 80cm there are isolated peaks for *Alnus* and *Pinus* within a period of low A.P. values and also higher values for *Menyanthes* and *Myriophyllum* which could be indicative of higher local water levels. At 120cm there are peaks for *Alnus* and *Corylus*/*Myrica* but they are not so noticeable as at 80cm, and at 160cm. there is very little difference between the pollen assemblage and surrounding levels although *Betula* values are low. Taken together then the pollen preservation results and the assemblage characteristics may be used to indicate possible changes in the character of sedimentation which are not readily observable on visual inspection of the core but it would need some

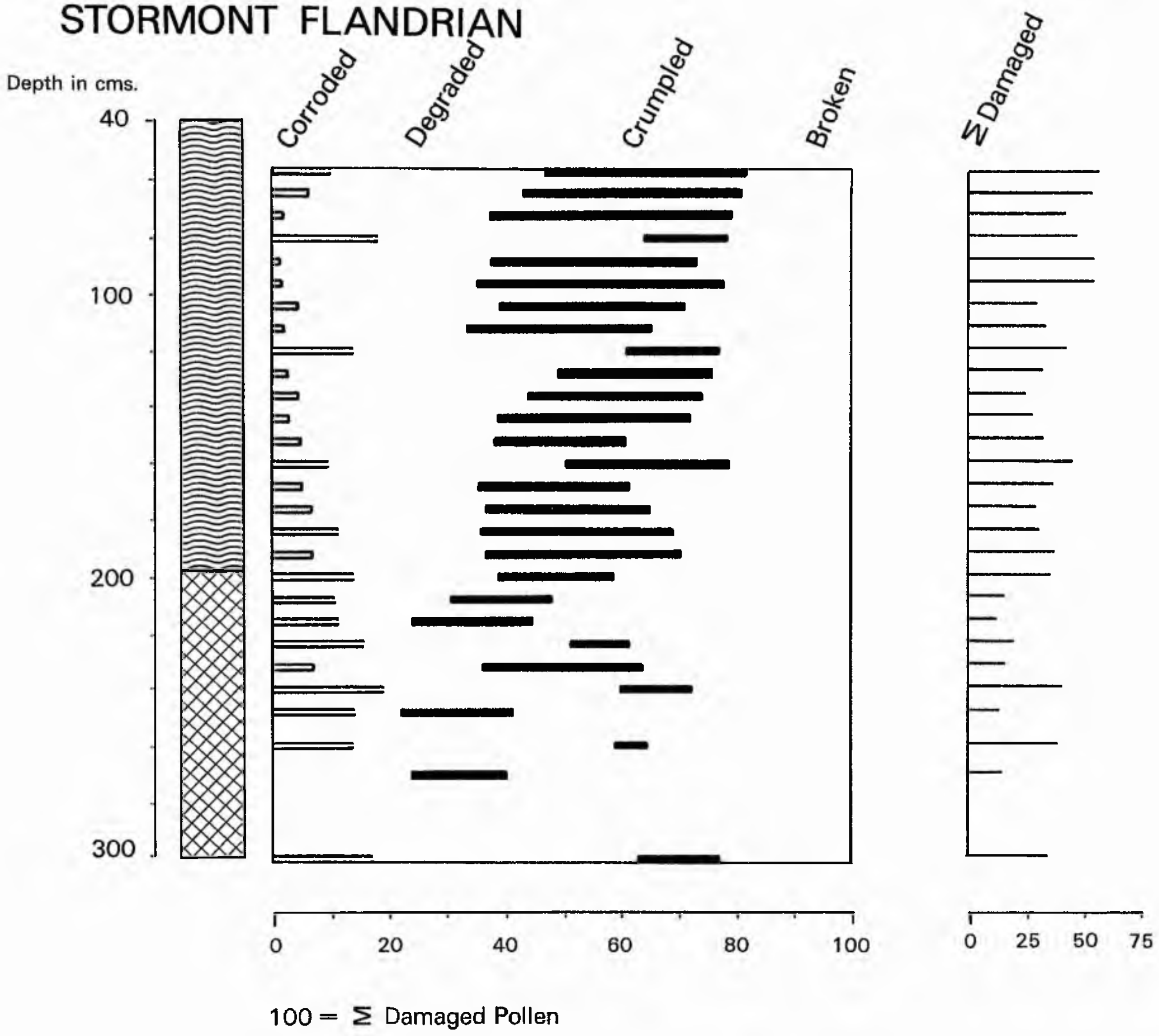


Fig.IV.3 Pollen preservation from selected levels for Stormont Loch A, the Flandrian pollen diagram further chemical analysis of the sediment to check these results. If the more severe deterioration were due instead to a slowing of the accumulation rate then increased oxidation would have been responsible for the loss of pollen but not have caused any distinctive change in pollen representation except in those species particularly susceptible to deterioration.

Within the gel mud there is a greater variety in the pattern of pollen preservation but some of this may be due to the lower overall frequencies for Damaged pollen (Fig. IV•3). There are however much higher frequencies for Corroded pollen and less evidence for mechanical breakdown. The increase in corrosion is perhaps not surprising in view of the slow accumulation rate but the variability in preservation within this unit is more difficult to understand. Of particular interest is the state of preservation at 270cm where there is a complete absence of Corroded pollen with Crumpled and Broken pollen comprising over 75% of the Total Damaged Pollen count. This level corresponds to the decline in <u>Alnus</u> frequencies following the first <u>Alnus</u> peak. It is not clear from earlier work whether the lowering of water levels and presumably increased oxidation which would have taken place could lead to such a pattern of deterioration. Increased microfaunal activity in a drier sediment could lead to greater physical movement of pollen grains but would also have been indicated by an increase in corrosion. The evidence from this level cannot therefore be fully explained but it is interesting to note that there is a significant difference in preservation at a level where, on pollen evidence alone, some change in the nature of sedimentation was suspected. A shorter sampling interval and detailed preservation data as well as chemical analysis of oxidisable carbon may provide more accurate evidence for the possible changes inferred here.

At least some of the variability in the pattern of pollen preservation within the gel mud may be due to species content. Fig. IV·4 shows the character of preservation of the principal species found in the Flandrian core and some differences do occur. As in the Late Devensian samples Pinus has a very distinctive pattern due to the high number of Broken grains, the preservation 'signatures' are indeed virtually identical. Quercus may also be separated from the main group in having a higher proportion of Broken grains and this could account for the higher proportion of Broken pollen in the upper level of the gel mud where it is the major contributor to the A.P. sum. Apart from these distinctions it is not possible to define any clear groupings for although separated into distinct categories according to the proportion of Degraded pollen these are not supported by correspondingly similar counts for either Crumpled or Broken pollen.

Preservation in the soil profiles and archaeological site material: Although data on the preservation of individual taxa were not collected from the soil profiles general counts within the major categories were made. The distribution of the different proportions of pollen in these categories down each profile and within each horizon is presented in Fig. IV·5. There is a difference, seen most clearly in Stormont B, between the mainly organic L and H horizons and the lower mixed but dominantly inorganic A and B horizons with highest counts for Broken pollen in the former and for Corroded and Degraded pollen in the latter. This distinction is graphically illustrated in Fig. IV·6 where the observations for each horizon are summarised in a cumulative frequency graph. If Corrosion phenomena, the pitting and etching of the exine, are largely microbial in origin then it seems surprising that they should increase down profile, and especially increase with depth in the H horizon as seen at Heatheryhaugh A. The higher levels for

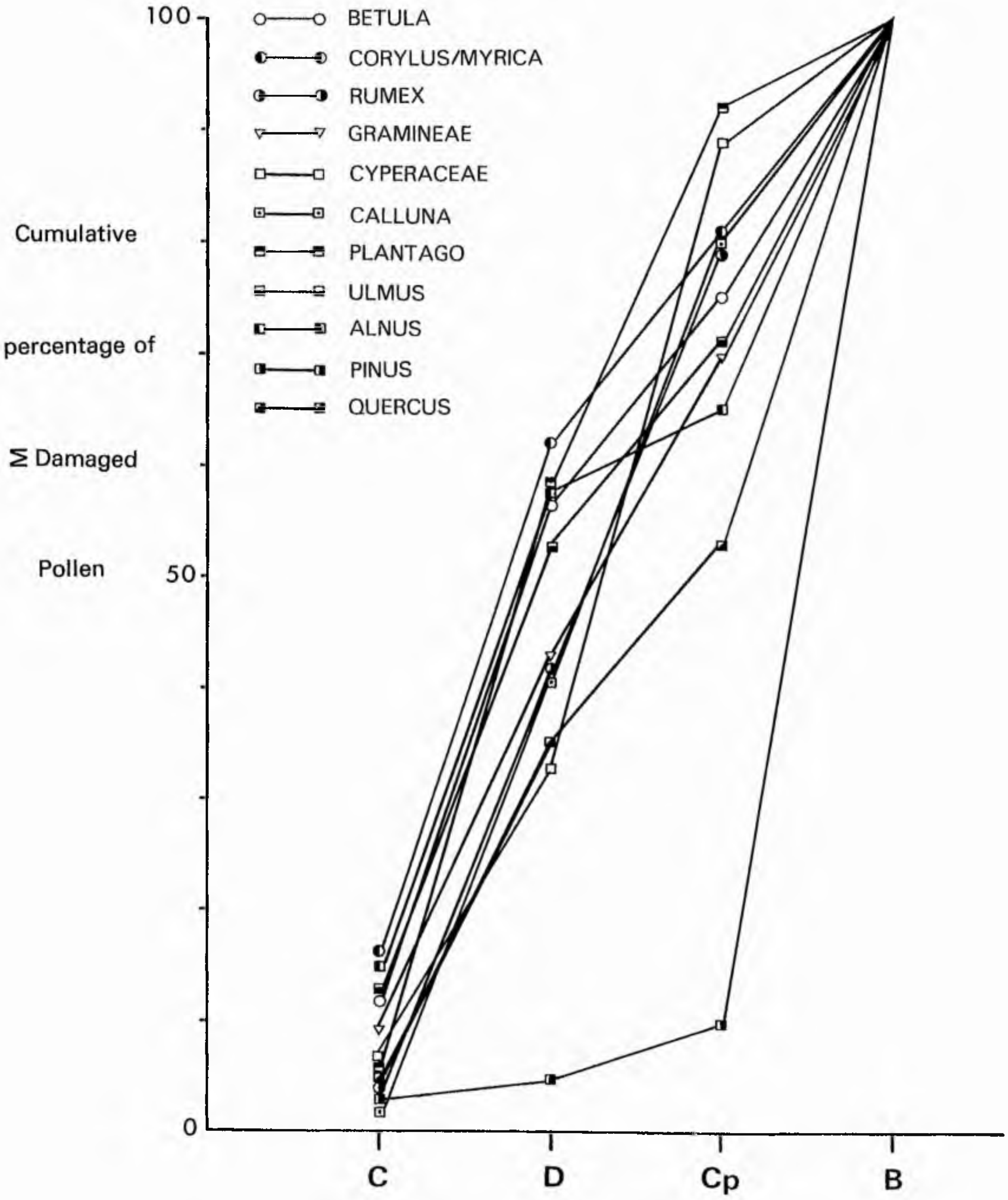


Fig.IV.4 Cumulative frequencies of pollen preservation categories for different pollen taxa from Stormont Loch A

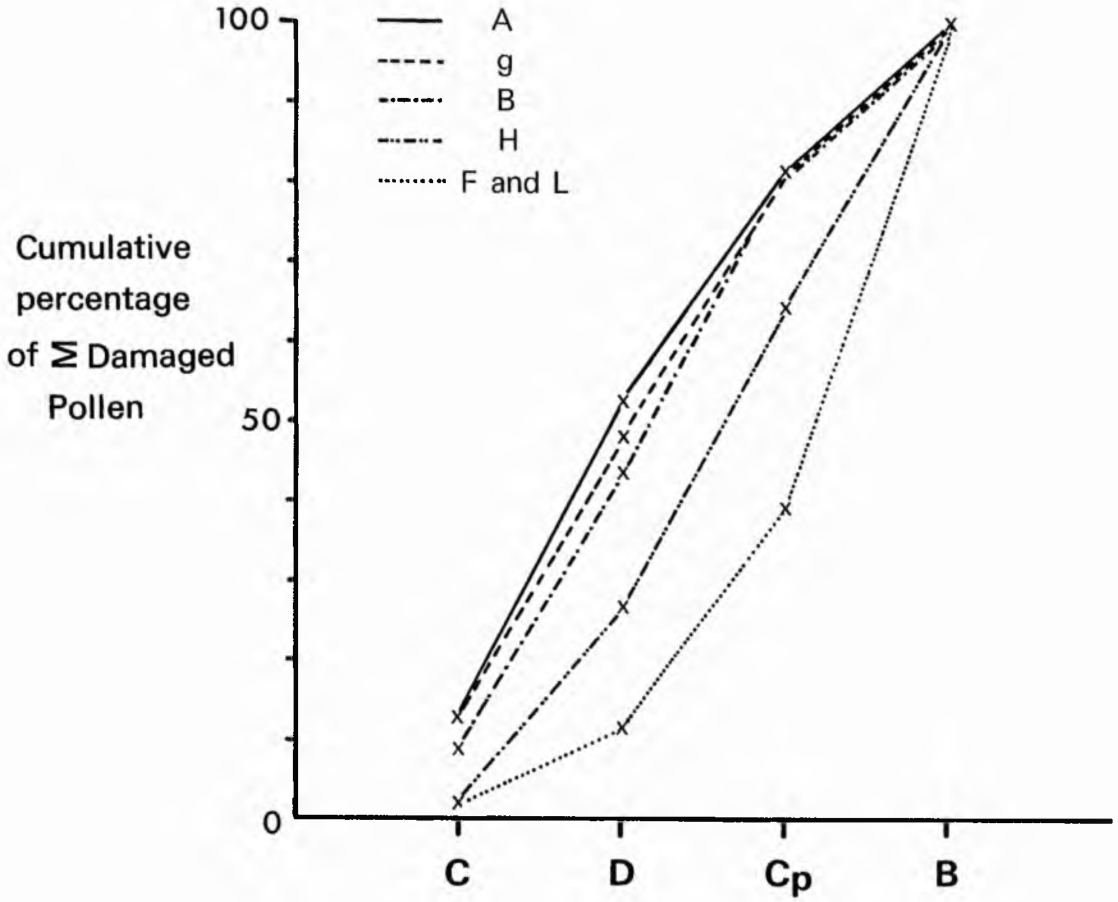


Fig.IV.5 Cumulative frequencies of pollen preservation categories for different soil horizons

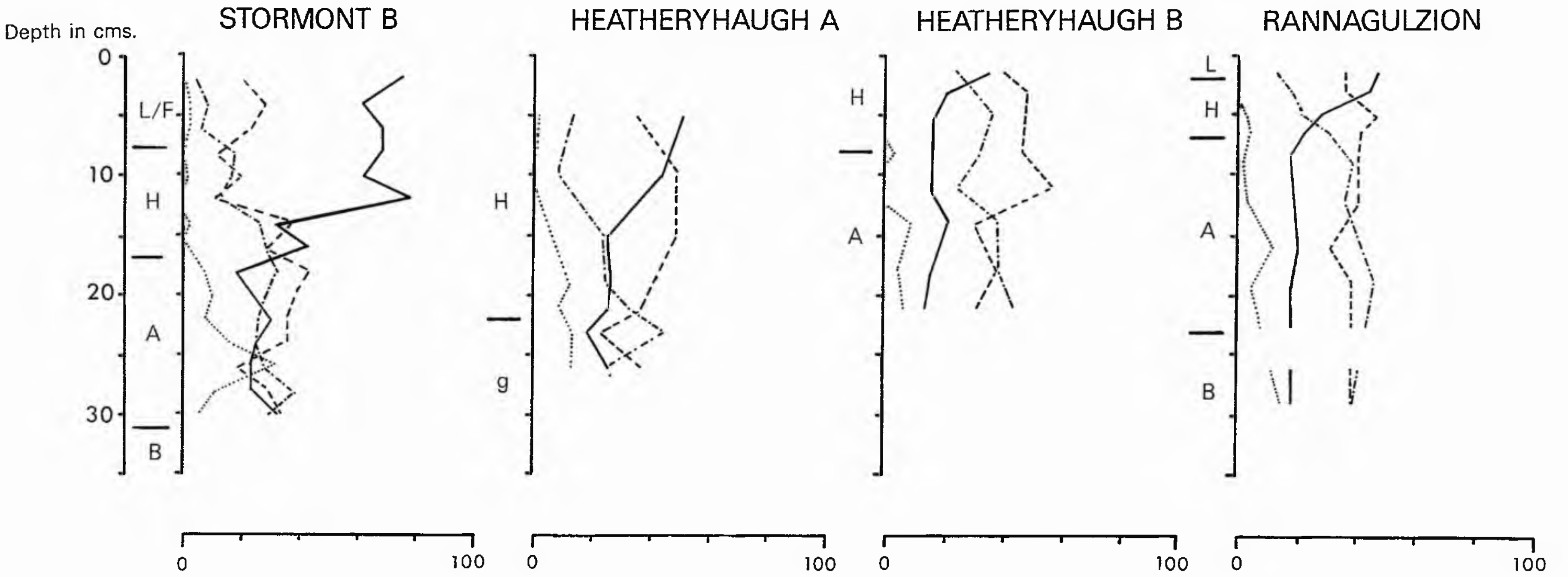


Fig.IV.6 Comparison of percentages in different preservation categories in soils (expressed as a percentage
—— B ---- Cp -·-·- D ·········· C
of Damaged pollen)

Corroded pollen may therefore lend support to the view that at least part of the pollen spectra in the A and B horizons derived from a period preceding the full development of a podsol profile when the soil was more biologically active. Assuming this it may be possible to try and differentiate those elements of the pollen assemblage which are older and represent the earlier vegetation cover developed on the brown earth or acid brown earth, although due to differential decay such an explanation may be too straightforward (Havinga, 1974). Under acid humus horizons pollen would take a long time to move into the lower horizons and with a very high incidence of breakage in these horizons severe preferential losses could occur. This could particularly affect _Quercus_ as broken fragments would be difficult to identify unlike fragments of _Pinus_ but, given the presence of acidic surface horizons _Quercus_ would be unlikely to be present. At both Stormont B and Rannagulzion there are peaks for Corroded pollen above the lowest levels from which pollen was recovered and may indicate former levels of higher activity but again corroborative chemical evidence would be of value.

The high counts for Broken pollen grains in the uppermost levels may reflect physical breakage due to movement and microfaunal activity in these relatively active layers or be due to oxidation leading to splitting of the grains. Whatever the processes breakage is obviously a significant effect on pollen distribution in the upper horizons and radical changes in vegetation communities based on the analysis of acid mor and the pollen changes found within when based on changes in taxa particularly susceptible to breakage may be an oversimplification (O'Sullivan, 1973b). In soils which have a complex history and in particular which have only recently changed from a brown forest soil the occurrence of higher counts for certain taxa, especially _Pinus_ and _Quercus_, in the A horizon probably relate to the character of the vegetation during the transitional phase. This probably accounts for the pattern found at Stormont and supports the supposition that the two peaks for Pinus represent two genuine periods of the growth of pine on the site, the change to a podsol taking place during the first period.

The pattern of Degraded grains within the soil profiles follows that of Corroded grains in increasing down the profile and values are usually higher in the A and B horizons than in the H horizons except for occasional levels at Stormont and Heatheryhaugh B. Havinga (1971) has shown thinning to be a common phenomenon in both podsolised sandy soils and Carex peat so it seems unlikely that any more significant difference between the horizons should have appeared. In view of the suggested origin of Corroded pollen the implications of the distribution of Degraded pollen are open to debate. While it is still uncertain as to the process or processes responsible for thinning their importance as an indicator of pollen movement through soils cannot be ascertained. Havinga (1971) appears to imply that thinning will increase over time and as such a slow increase down profile would be expected.

From this brief analysis of the distribution of deteriorated pollen within these soil profiles the possibility of identifying pollen 'signatures', patterns of deterioration characteristic of soil horizons appears possible. With the problems associated with interpreting how pollen is incorporated into the soil profile (Dimbleby, 1961a; Munaut, 1967; Guillet, 1972; Havinga, 1974) and the probable variety of age of any single assemblage encountered within a soil horizon such a proposal may be rather premature but the possibility of achieving a worthwhile result from more detailed work appears high.

Even if it is not possible to ascertain the origin of the pollen assemblages in terms of original soil horizons when examining sediments from archaeological sites it should be possible to use similarity of preservation patterns as evidence for similarity of origin when looking at derived deposits. Furthermore, high levels of Broken pollen could be used as an indicator of the presence of upper humic horizons in 'in situ' deposits.

At Moncreiffe similarity of deterioration 'signatures' may be used to argue for a similar source for A, B and C as suggested in Chapter 8 (Fig. IV·7) but the variability of the samples E, F and H (no details of pollen preservation were taken from G) is too great to use the same argument. It is also interesting to note that deposits from similar structural features can have very different 'signatures'. The stake hole deposit in H varies considerably from A and B. The high levels for Corroded pollen make direct comparison with any of the results from the soil analyses unwise, however, and the general poor preservation of such deposits may make close determination of sources difficult. For more worthwhile comparison it would be necessary to examine in some detail the distribution of various forms of deterioration in present soils by the site. The variation in patterns of preservation within the samples is also seen in the character of preservation of the different taxa (Fig. IV·8).

Conclusions

From this brief examination of the data collected from the different sediments investigated the following points can be made in summary:

i) Pollen preservation does vary both with sediment type and the susceptibility of different pollen types but it is still possible to determine some consistent patterns.

ii) There is a difference between dominantly organic and dominantly inorganic sediments in that the latter usually have higher levels for Degraded pollen although both have a majority of Crumpled grains.

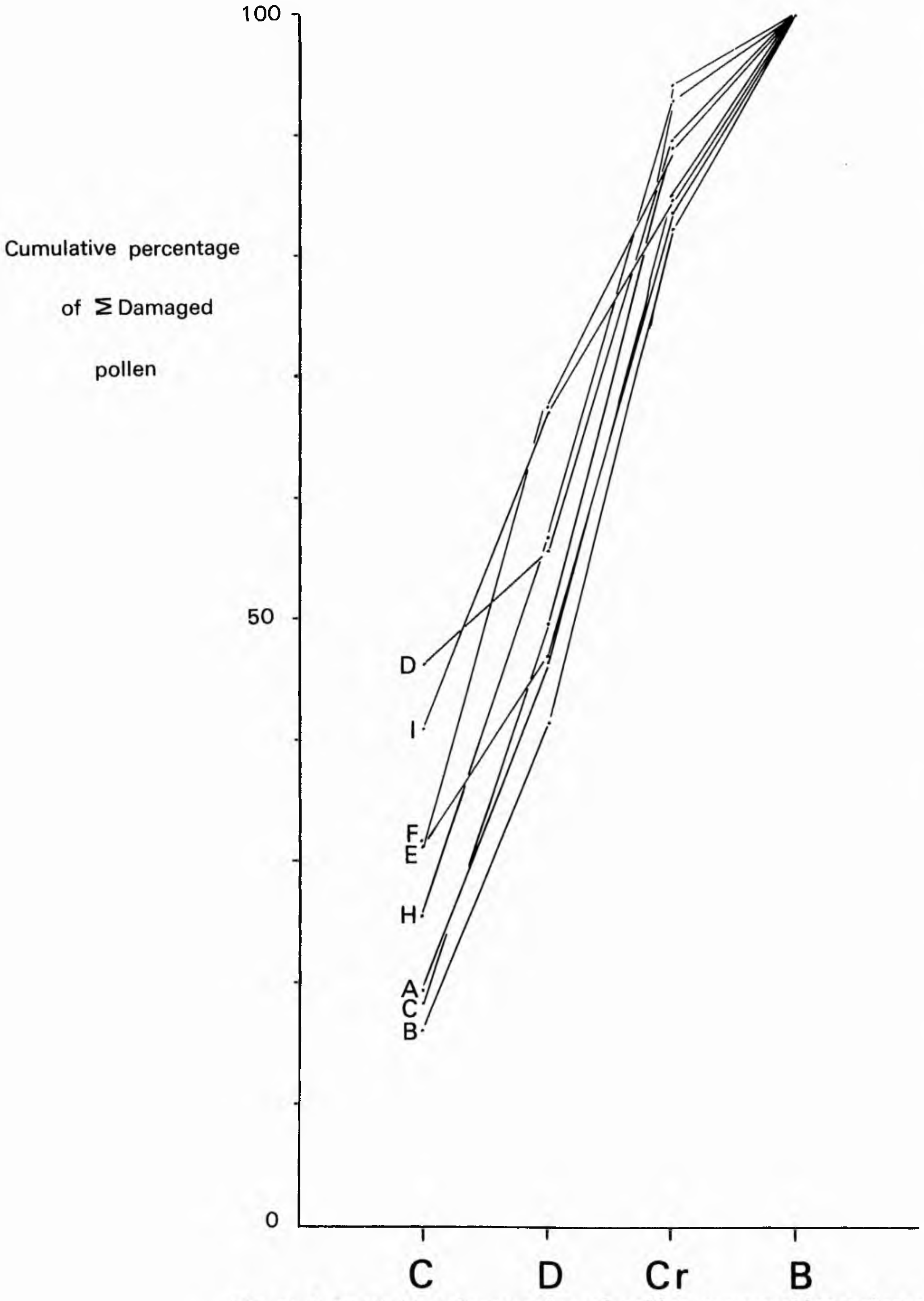


Fig.IV.7 Cumulative frequencies of pollen preservation categories for the samples from Moncreiffe House

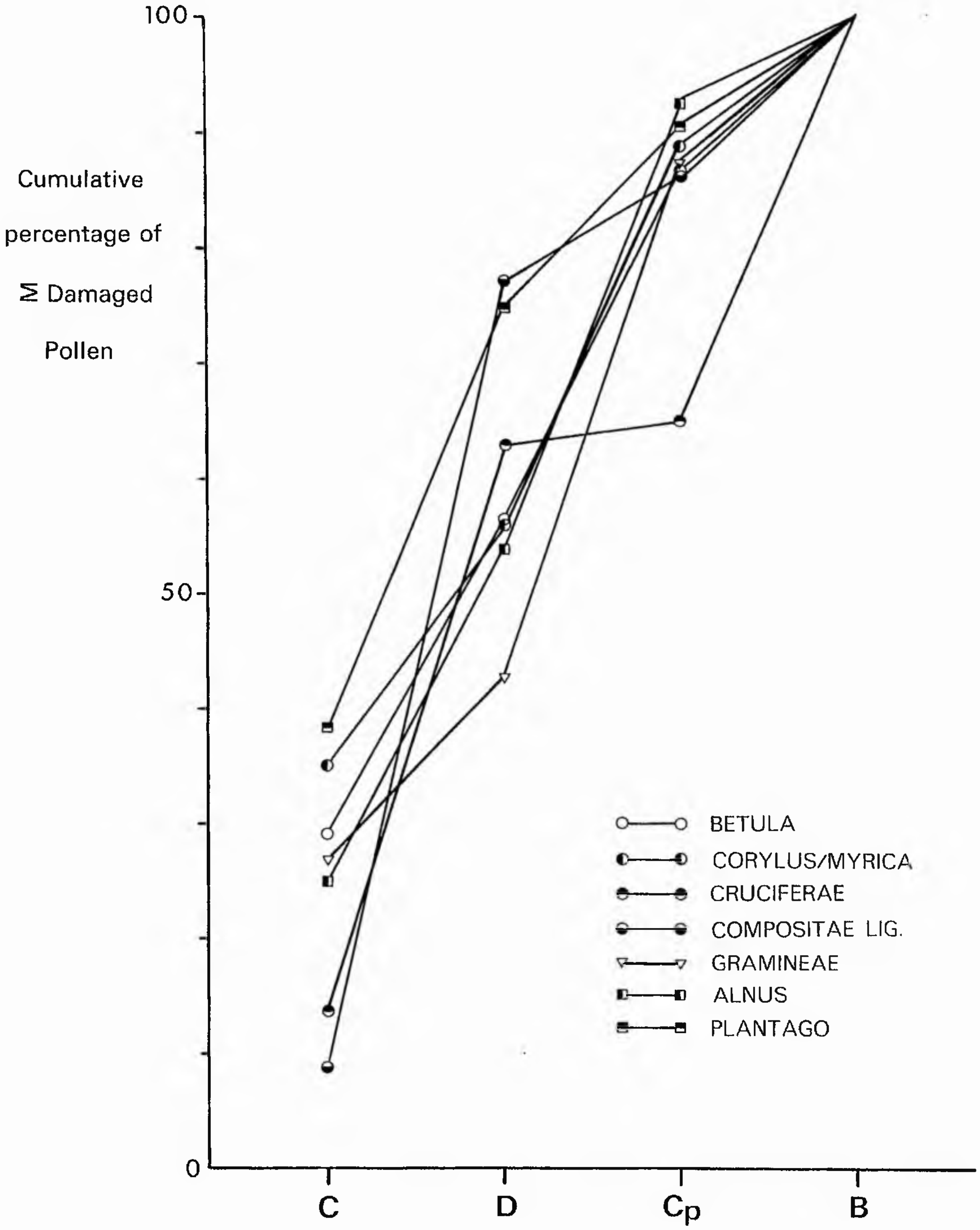


Fig. IV.8 Cumulative frequencies of pollen preservation categories for selected taxa from Moncreiffe House

iii) There is a similar but more noticeable difference between humic horizons and minerogenic horizons within podsol soil profiles with higher values for Broken pollen in the former and higher levels for Corroded pollen in the latter. Values for Broken pollen are particularly high in the uppermost levels of humic horizons (especially L and F horizons) but in the soils examined values for Broken grains may have been exaggerated by the presence of Pinus.

iv) Although it is possible to demonstrate a difference in the character of pollen preservation between different pollen types in certain sediments this is not always the case (Fig. IV 9a, b and c), except in the case of Pinus as seen in Fig. IV•9a. Certain taxa can however show a remarkable similarity in their pattern of preservation in radically different sediments as in the case of Gramineae (Fig. IV•9c). (in the diagram F refers to Stormont A (Flandrian), G refers to Stormont G (Late Devensian) and M refers to Moncreiffe House.)

v) To provide better evidence for the suggestions made above would require a very detailed and exhaustive study of pollen preservation patterns in both sediments and soils. In the latter case the state of pollen preservation may lead to a clearer understanding of the derivation of pollen assemblages within the different soil horizons investigated.

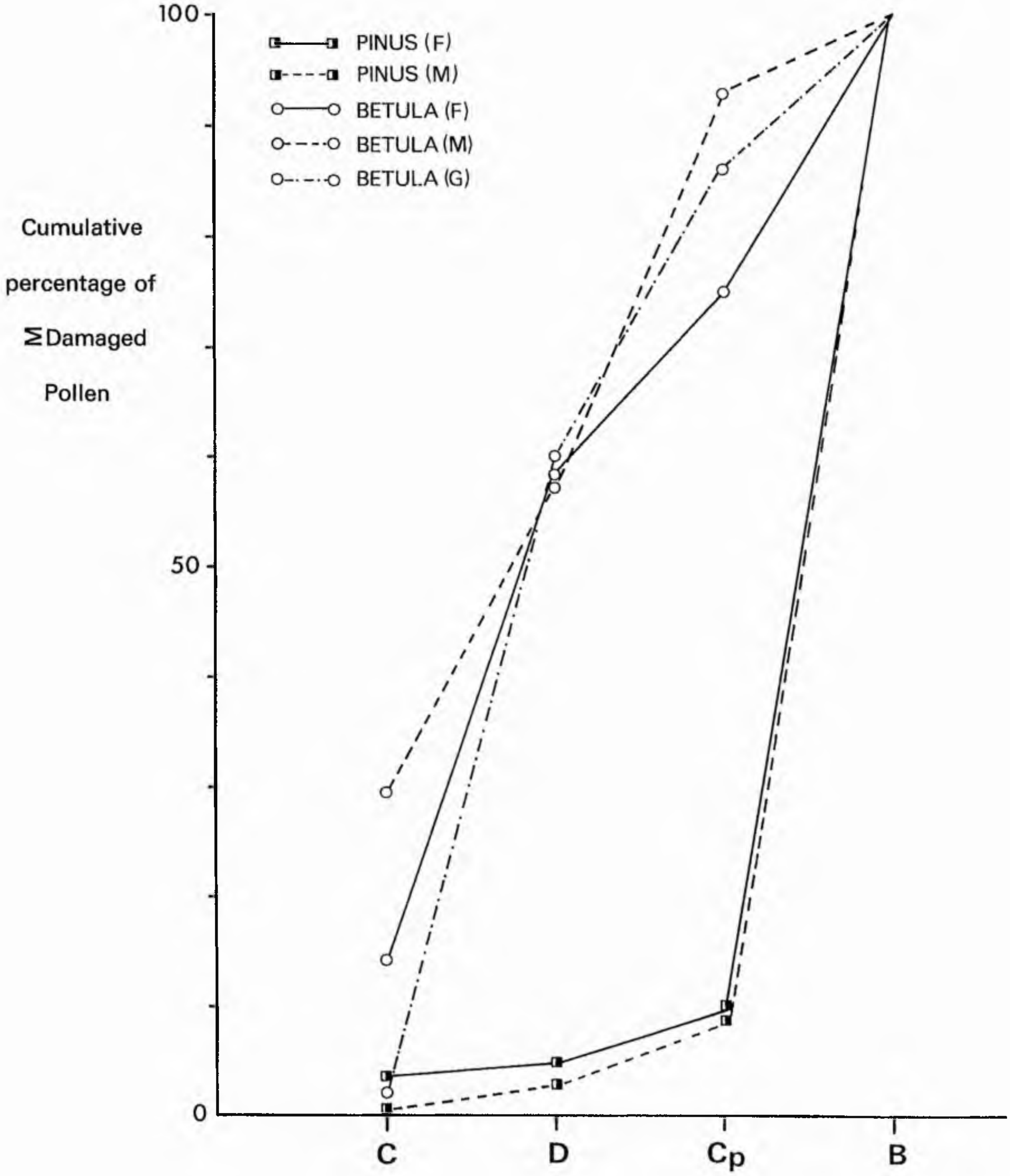


Fig.IV.9a Cumulative frequencies of pollen preservation categories for selected taxa from Stormont Loch and Moncreiffe House, Pinus and Betula

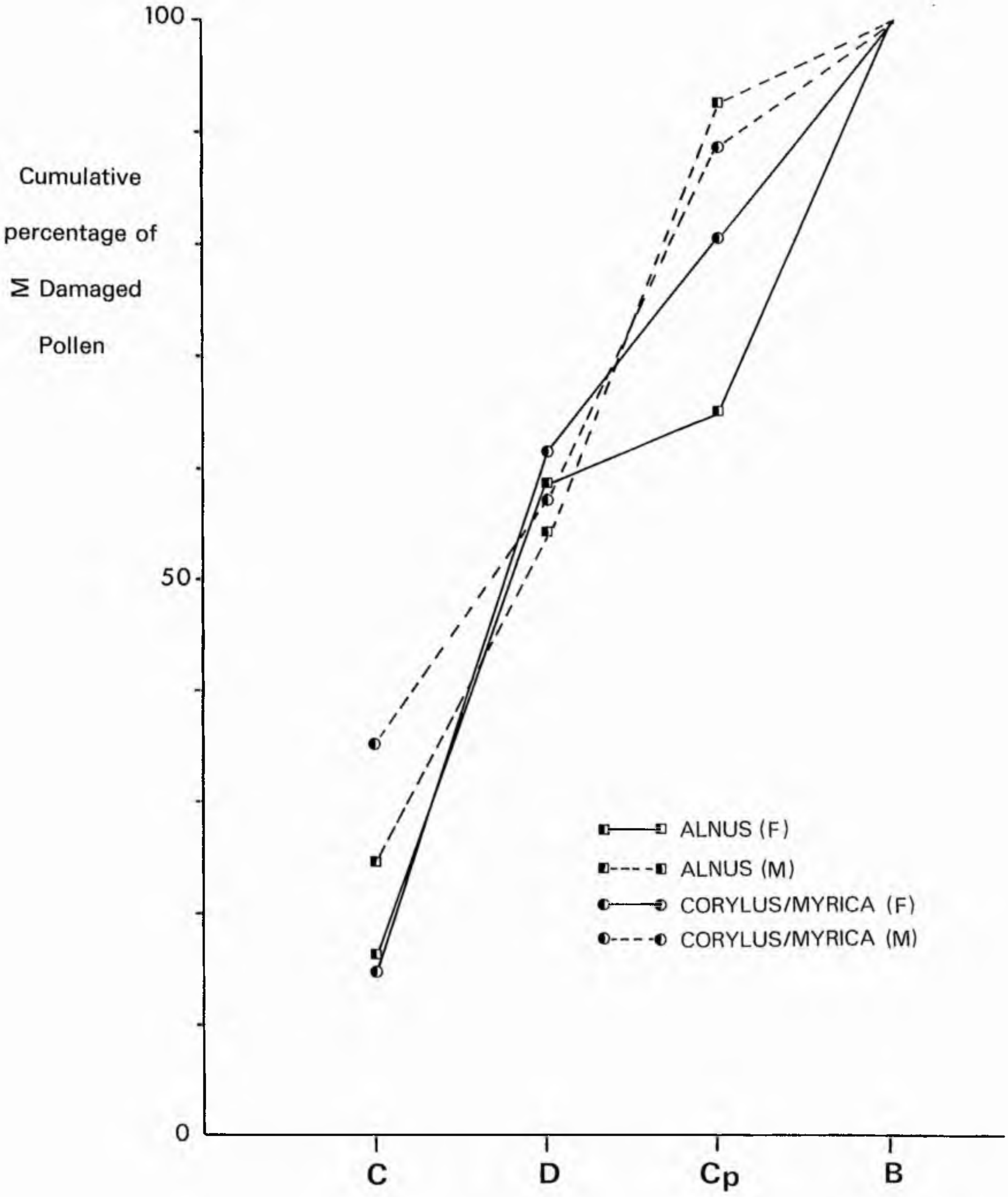


Fig.IV.9b Cumulative frequencies of pollen preservation categories for selected taxa from Stormont Loch and Moncreiffe House, Alnus and Corylus/Myrica

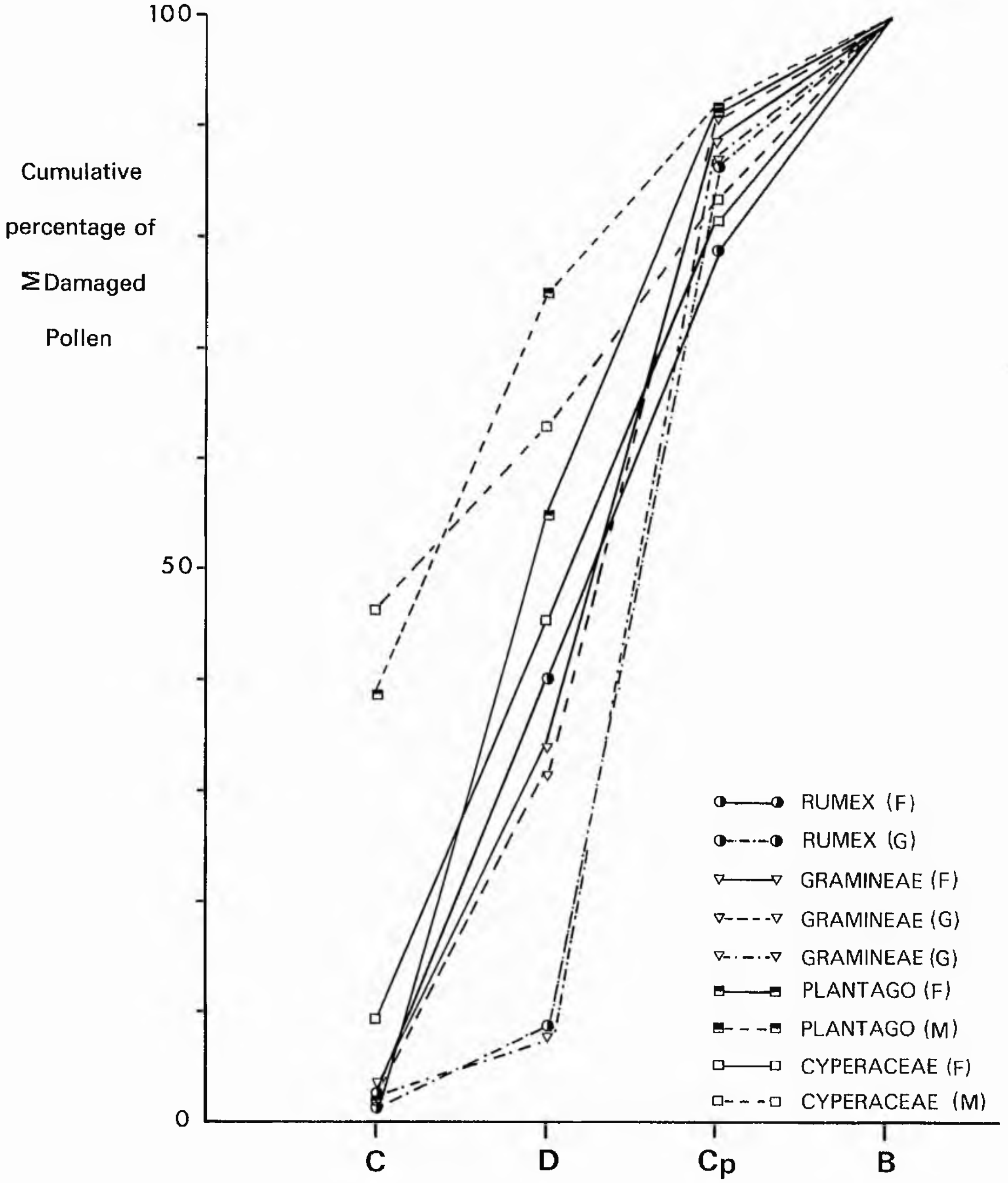


Fig.IV.9c Cumulative frequencies of pollen preservation categories for selected taxa from Stormont Loch and Moncreiffe House, Rumex, Gramineae, Plantago and Cyperaceae

APPENDIX V

Pollen identification

The notes below relate to the identification of selected pollen types only and not all species or families encountered are covered although a large majority are mentioned and all problems discussed.

PTERIDOPHYTA

Filicales: All monolete spores were grouped under the general heading of Filicales. Occasionally the presence of the perine allowed identification down to species level but the variability of perine preservation did not allow the consistent separation of individual species. Spores of *Polypodium* were however separated.

Lycopodium: Identification of *Lycopodium* spores to species level was made for *Lycopodium selago* and *L. clavatum* using criteria outlined by H.J.B. Birks (1973a) and reference material.

GYMNOSPERMAE

Juniperus communis: In the deposits from the Late Devensian at Stormont Loch high counts of this pollen grain were made and most of them were split.

ANGIOSPERMAE

Betulaceae: Although it is possible to separate *Betula nana* from tree birches on the basis of grain diameter and pore depth (H.J.B. Birks, 1968) no separation was made using this method because of the variable preservation of the pollen and the inability to measure to a greater precision than 1·1μ on the graticule (except at x1000+ magnification). In order to determine which species of birch was dominant the grain diameters of all complete *Betula* grains were measured and presented for each level as a mean value. These were further generalised to three level running means to show the trend in changes in diameter size and hence presumably the change in populations. The use of frequency histograms showing the existence of one or two populations of grain diameters (Johansen, 1975) was not adopted because of the differences in the number of measurable *Betula* grains within zones.

Caryophyllaceae: In the absence of sufficient reference material definition of the Caryophyllaceae to species level was based largely on Chanda (1962) and H.J.B. Birks (1973a). Different species or types were identified and commented upon where apposite but in the pollen diagrams they are all grouped within a single curve.

Compositae: Division of the Compositae generally followed the distinctions made by Faegri and Iversen (1975) with, where possible, the use of Stix (1960) and available reference material. In the pollen diagrams the main division made was between Compositae tubiflorae and Compositae liguliflorae.

Under Compositae lig. many grains were considered comparable to *Taraxacum* sp. using reference material but with a variety of species showing similar features such an identification may be uncertain.

Under Compositae tub. grains of *Achillea* type were identified (H.J.B. Birks, 1973a) a group which includes both *Chrysanthemum* sp. and *Matricaria* sp., and which compares with the *Anthemis* type of Moore and Webb (1978).

Where indicated *Centaurea cyanus* was identified but otherwise *Centaurea* is referable to *Centaurea nigra* type which includes both *Centaurea nigra* and *C. nemoralis*.

Corylaceae: Following most authors no distinction was made between *Corylus* and *Myrica* despite the possible use of the pore characteristics to differentiate the two (Praglowski, 1962; Erdtman, Praglowski and Nilsson, 1963). Pollen preservation and the general uncertainty over the differentiation therefore precluded separation.

Crassulaceae: Determination of Sedum type pollen was made using reference material and the Faegri and Iversen (1975) key. More recent identifications were confirmed using phase contrast (Moore and Webb, 1978).

Empetraceae: Size determinations were made on Empetrum grains at several levels from Stormont Loch but because of the overlap in size ranges and the low number of measureable grains no further differentiation was possible (Oldfield, 1959; H.J.B. Birks, 1973a). General separation of the Ericaceae followed Oldfield (1959) but only Calluna was consistently separated.

Gramineae: Apart from the work on Gramineae grains undertaken on Bankhead Moss no attempt was made to differentiate between species. Interpretation of Cereal species was however made using a combination of the key developed by Faegri and Iversen (1975), the work of Beug (1961) and of Anderson and Bartelsen (1972). Work by Grohne (1957) indicated the existence of thickenings in the exine which were either dot-shaped or irregular, the latter grouping corresponding to the reticulate pattern observed by Faegri and Iversen (1975). Rowley (1960) showed these differences in more detail but it was Beug (1961) who tried to make a clearer specification using phase contrast.

Beug defined three groups which could be separated on phase contrast of the surface sculpturing:

Punktlumpen - Avena type which includes most Avena sp. although A. strigosa, A. nuda and A. brevis may occur under Triticum type.

Punktgruppen - Triticum type which includes all Triticum sp. except T. monococcum and possibly the Avena sp. mentioned above.

Isolated dots – *Hordeum* type which includes all *Hordeum* sp., *Triticum monococcum*, *Secale cereale* and the pollen of several wild grass species e.g. *Agropyron* sp., *Bromus* sp. and *Glyceria* sp.

Such a breakdown using surface sculpturing roughly equates with the areolate (*Avena* type and *Triticum* type) / psilate (*Hordeum* type) division of Faegri and Iversen (1975) although they include the possibility of *Triticum* occurring within a psilate grouping.

Andersen and Bartelsen (1972) using SEM techniques found that the Punktlumpen – Punktgruppen distinction could not be substantiated but suggest that it is still possible to separate *Avena sativa* from *Triticum* sp. by their annulus size rather than surface sculpturing.

Using all this work a system of *Cereal* type pollen identification was adopted which utilised both surface sculpturing under phase contrast and size characteristics. Where necessary the measurements of all fossil grains were converted to silicon oil equivalents by use of a correction factor (Faegri and Iversen, 1975). The measurements to be found in Beug (1961) were made on grains embedded in Glycerine Gelatine as probably were those he quotes from Rohde (1959) so converted values for these were also used. The general differentiation made between surface sculpturing by Beug (1961) under phase contrast was accepted but final species identifications were only made using both measurements and sculpturing. Table V·1 shows the procedure adopted.

Leguminosae: Identification of species was only made using both a pollen key and reference material. Usually it was only possible to define three groups, *Ononis* type, *Vicia* type and *Trifolium* type (Faegri and Iversen, 1975) and unless stated most grains under the general curve derived from the second of these types. In later material occasional grains of *Ulex* type were separated (Moore and Webb, 1978).

Plantaginaceae: Determination of *Plantago lanceolata* was made using the number of pores and form of the verrucae (Andersen, 1961; Bassett and Crompton, 1967; Faegri and Iversen, 1975). In most of the soils the poor preservation of the exine and crumpled nature of the grains often meant that separation of *Plantago lanceolata* and *Plantago media/major* was not possible and a single curve for Plantaginaceae used.

Polygonaceae: No distinction was made between *Oxyria digyna* and other *Rumex* species in the pollen diagram but on the basis of surface sculpturing occasional possible identifications were made. Without reference material these were not confirmed.

Separation was made between *Polygonum aviculare*, *P. persicaria* and *P. viviparum/bistorta* type (Faegri and Iversen, 1975; Moore and Webb, 1978).

Potamogeton: This includes both *Potamogeton* sect., Eupotamogeton and *P.* sect Coleogeton (Faegri and Iversen, 1975) although most grains were less than 20µ and probably *P.* sect Eupotamogeton (Moore and Webb, 1978).

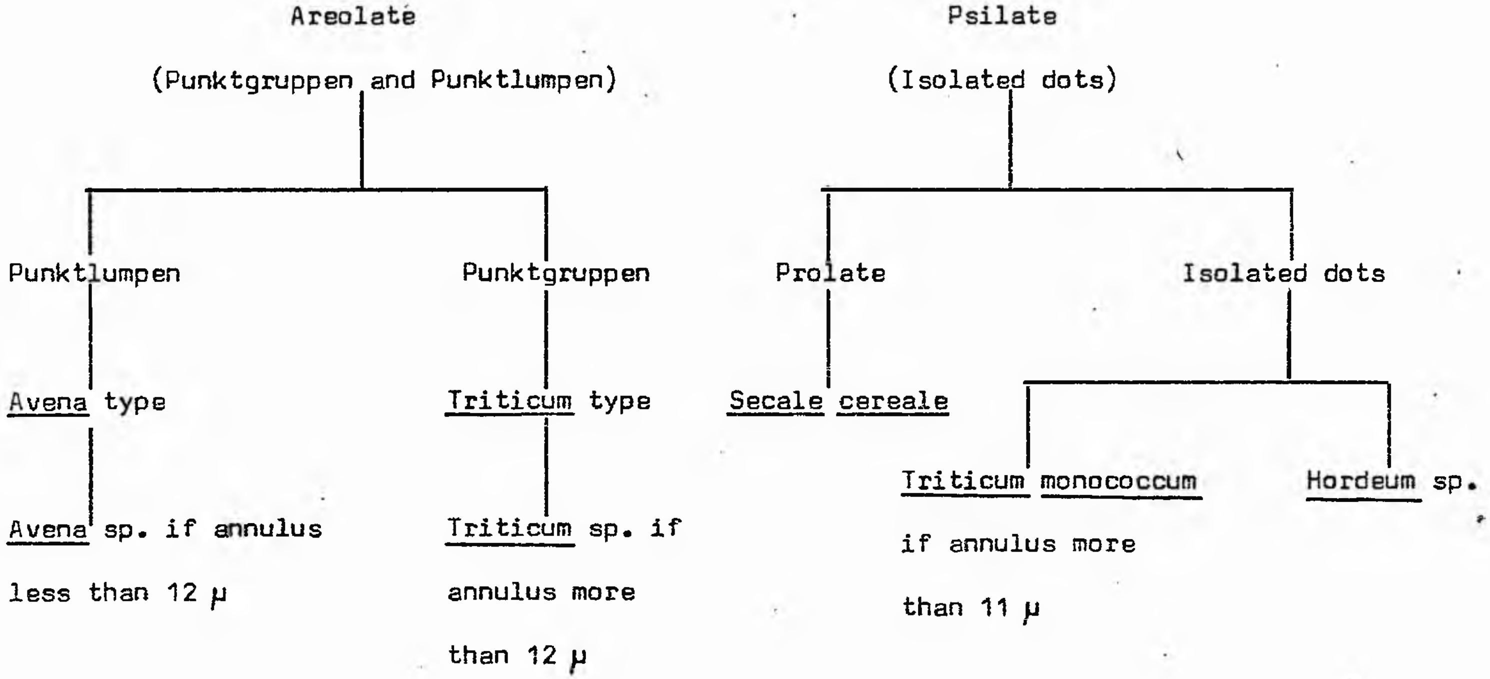
Ranunculaceae: Separation of *Caltha* was made (Faegri and Iversen, 1975; Moore and Webb, 1978) although few grains were encountered but some difficulty was found in separating *Ranunculus acris* type from *R. trichophyllous* type (Andersen, 1961), especially in the soils where most were probably examples of the former.

Rosaceae: Within the Rosaceae curves were isolated for *Filipendula*, *Sorbus* and *Potentilla* type. All other species were grouped under a general Rosaceae heading (Reitsma, 1966; Faegri and Iversen, 1975). *Potentilla* type includes both *Potentilla erecta* and *P. palustris* and in Late Devensian sediments could also include examples of *Sibbaldia procumbens* or *Fragaria vesca* (H.J.B. Birks, 1973a).

Saxifragaceae: Although only a single curve for Saxifragaceae was used

Table V·1

Cereal type pollen identification procedure



species identification was made using Faegri and Iversen (1975), H.J.B. Birks (1973a) and in later examples Moore and Webb (1978).

Scrophulariaceae: Melampyrum was separated using both Faegri and Iversen (1975) and reference material.

Sparganiaceae: The definition of grains of Sparganium was made using reference material and Beug (1961) but in view of the comments made by H.J.B. Birks (1973a) such an identification could refer to Typha sp.

REFERENCES

ADAMS, I.H., 1973: 'The legal geography of Scotland's common lands.' Revue de l'Institut de Sociologie, Univ. of Brussels, 2, 259-332.

ADAMS, I.H., 1976: 'Agarian landscape terms: a glossary for historical geography.' Inst. Brit. Geogr. Spec. Pub., No. 9.

AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE, 1961: 'Code of Stratigraphic Nomenclature.' Bull. Am. Ass. Petrol. Geol., 45, 645-655.

ANDERSEN, S.Th., 1961: 'Vegetation and its environment in Denmark in the Early Weichselian Glacial.' Danm. Geol. Unders., Ser. II, 75, 175pp.

ANDERSEN, S.Th., 1967: 'Tree-pollen rain in a mixed deciduous forest in south Jutland (Denmark).' Rev. Palaeobot. Palynol., 3, 267-275.

ANDERSEN, S. Th., 1970: 'The relative pollen productivity and pollen representation of north European trees, and correction factors for tree pollen spectra.' Danm. Geol. Unders., Ser.II, 96, 99pp.

ANDERSEN, S. Th., 1973: 'The differential pollen productivity of trees and its significance for the interpretation of a pollen diagram from a forested region', in H.J.B. Birks and R.G. West (eds.), Quaternary Plant Ecology, 109-116. Oxford.

ANDERSEN, S. Th., 1979: 'Brown earth and podzol: soil genesis illuminated by microfossil analysis.' Boreas, 8, 59-73.

ANDERSEN, S. Th. and BERTELSEN, F., 1972: 'Scanning electron microscope studies of pollen of cereals and other grasses.' Grana, 12, 79-86.

ANDERSON, M.L., 1967: A History of Scottish Forestry, Vols. 1 and 2. Edinburgh.

ASHWORTH, A.C., 1972: 'A Late-glacial insect fauna from Red Moss, Lancashire, England.' Entomol. Scand., 3, 211-224.

ATHERDEN, M.A., 1976: 'The impact of late prehistoric cultures on the vegetation of the North Yorkshire Moors.' Trans. Inst. Brit. Geogr., N.S.1, 284-300.

BARBER, K.E., 1976: 'History of Vegetation', in P. Chapman (ed.), Methods in Plant Ecology, 5-22. Oxford.

BARROW, G.V.S., 1962: 'Rural settlement in Central and Eastern Scotland.' Scott. Studs. 6, 123-144.

BARTLEY, D.D., 1962: 'The stratigraphy and pollen analysis of lake deposits near Tadcaster, Yorkshire.' New Phytol., 61, 277-287.

BARTLEY, D.D., 1966: 'Pollen analysis of some lake deposits near Bamburgh in Northumberland.' New Phytol., 65, 141-156.

BARTLEY, D.D., CHAMBERS, C. and HART-JONES, B., 1976: 'The Vegetation history of parts of south and east Durham.' New Phytol., 77, 437-468.

BASSETT, I.J. and CROMPTON, C.W., 1968: 'Pollen morphology and chromosome numbers of the family Plantaginaceae in North America.' Can. J. Bot., 46, 349-361.

BASSETT, I.J. and TERASMAE, J., 1962: 'Ragweeds, Ambrosia species, in Canada and their history in Postglacial time.' Can. J. Bot., 40, 141-150.

BAXTER, M.S., ERGIN, M. and WALTON, A., 1969: 'Glasgow University Radiocarbon Measurements 1.' Radiocarbon, 11, 43-52.

BECKETT, S.C. and HIBBERT, F.A., 1976: 'An absolute pollen diagram from the Abbot's Way.' Somerset Levels Papers, 2, 24-28.

BELL, J.N.L. and TALLIS, J.H., 1973: 'Biological Flora of the British Isles: Empetrum nigrum L.' Jour. Ecol., 61, 289-307.

BENNINGHOF, W.S., 1962: 'Calculation of pollen and spore density in sediments by addition of exotic pollen in known quantities.' Pollen Spores, 4, 332-333.

BERGLUND, B.E., 1973: 'Pollen dispersal and deposition in an area of Southeastern Sweden - some preliminary results', in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 117-130. Oxford.

BEUG, H.J., 1961: Leitfaden der Pollenbestimmung. Stuttgart.

BIBBY, J.S. and MACKNEY, D., 1969: 'Land Use Capability Classification.' Soil Surv. Gt. Brit. Tech. Monograph No. 1.

BIRKS, H.H., 1970: 'Studies in the vegetational history of Scotland. I. A pollen diagram from Abernethy Forest, Inverness-shire.' Jour. Ecol., 58, 327-346.

BIRKS, H.H., 1972a: 'Studies in the vegetational history of Scotland. II. Two pollen diagrams from the Galloway Hills, Kirkcudbrightshire.' Jour. Ecol., 60, 182-217.

BIRKS, H.H., 1972b: 'Studies in the vegetational history of Scotland. III. A radiocarbon-dated pollen diagram from Loch Maree, Ross and Cromarty.' New Phytol., 71, 731-754.

BIRKS, H.H., 1975: 'Studies in the vegetational history of Scotland. IV. Pine stumps in Scottish blanket peats.' Phil. Trans. R. Soc. Lond., B270, 181-226.

BIRKS, H.H. and MATHEWES, R.W., 1978: 'Studies in the vegetational history of Scotland.V. Late Devensian and Early Flandrian pollen and macrofossil stratigraphy at Abernethy Forest, Inverness-shire.' New Phytol. 80, 455-484.

BIRKS, H.J.B., 1965: 'Late-glacial deposits at Bagmere, Cheshire and Chat Moss, Lancashire.' New Phytol., 64, 270-285.

BIRKS, H.J.B., 1968: 'The identification of Betula nana pollen.' New Phytol. 67, 309-314.

BIRKS, H.J.B., 1970: 'Inwashed pollen spectra at Loch Fada, Isle of Skye.' New Phytol., 69, 807-820.

BIRKS, H.J.B., 1973a: Past and Present Vegetation of the Isle of Skye, a Palaeoecological Study. London.

BIRKS, H.J.B., 1973b: 'Pollen representation studies in Arctic and Alpine environments', in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 143-168. Oxford.

BIRKS, H.J.B., 1977: 'The Flandrian Forest History of Scotland: a Preliminary Synthesis', in F.W. Shotton (ed.) British Quaternary Studies, Recent Advances, 119-136. Oxford.

BIRKS, H.J.B., DEACON, J. and PEGLAR, S., 1975: 'Pollen maps for the British Isles 5000 years ago.' Proc. R. Soc. Lond., B189, 87-105.

BIRKS, H.J.B., WEBB, T. III and BERTI, A., 1975: 'Numerical analysis of pollen samples from Central Canada: A comparison of methods.' Rev. Palaeobot. Palynol., 20, 133-169.

BISHOP, W.W. and COOPE, G.R., 1977: 'Stratigraphical and Faunal Evidence for Lateglacial and Early Flandrian Environments in South-West Scotland, in J.M. Gray and J.J. Lowe (eds.) Studies in the Scottish Lateglacial Environment, 61-88. Oxford.

BLACKBURN, K.B., 1946: 'On a peat from the island of Barra, Outer Hebrides. Data for the study of Post-glacial history X.' New Phytol., 45, 44-49.

BONNY, A.P., 1972: 'A method for determining absolute pollen frequencies in lake sediments.' New Phytol., 71, 393-405.

BONNY, A.P., 1976: 'Recruitment of pollen to the seston and sediment of some Lake District lakes.' Jour. Ecol., 64, 859-888.

BREMNER, A., 1942: 'The origin of the Scottish river system.' Scott. Geogr. Mag., 58, 15-20, 54-59, 99-103.

BROOKS, C.L., 1972: 'Pollen analysis and the Main Buried Beach in the western part of the Forth Valley', Trans. Inst. Brit. Geogr., 55, 161-170.

BROWN, A.P., 1971: 'The Empetrum pollen record as a climatic indicator in the Late Weichselian and Early Flandrian of the British Isles.' New Phytol., 70, 841-849.

BROWN, A.P., 1977: 'Late Devensian and Flandrian vegetational history of Bodmin Moor, Cornwall.' Phil. Trans. R. Soc. Lond., B 276, 251-320.

BUCKLEY, J.D., 1973: 'Isotopes Radiocarbon Measurements X.' Radiocarbon, 15, 280-298.

BUCKLEY, J.D. and WILLIS, E.H., 1972: 'Isotopes Radiocarbon Measurements IX.' Radiocarbon, 14, 114-139.

BURGESS, C., 1974: 'The Bronze Age', in C. Renfrew (ed.) British Prehistory: a new outline, 165-232. London.

BURGESS, J.A., 1975: 'Bankhead Moss, Fife: The Survival of a Raised Bog Flora in the Midst of Intensive Agriculture.' Trans. Bot. Soc. Edinb., 42, 191-199.

BURL, H.A.W., 1972: 'Stone Circles and Ring-Cairns.' Scott. Arch. Forum, 4, 31-47.

BURL, H.A.W., 1976: The Stone Circles of the British Isles. London.

BURROWS, C.J., 1974: 'Plant macrofossils from Late Devensian deposits at Nant Ffrancon, Caernarvonshire.' New Phytol., 73, 1003-1033.

CALLOW, W.J. and HASSALL, G.I., 1970: 'National Physical Laboratory Radiocarbon Measurements VII.' Radiocarbon, 12, 181-186.

CALLOW, W.J., BAKER, M.J. and PRITCHARD, D.M., 1963: 'National Physical Laboratory Radiocarbon Measurements I.' *Radiocarbon*, 5, 34-38.

CAMPBELL, D., 1888: *The Book of Garth and Fortingall*. Perth.

CASE, H.J., DIMBLEBY, G.W., MITCHELL, G.F., MORRISON, M.E.S. and PROUDFOOT, V.B., 1969: 'Land use in Goodland Townland, Co. Antrim from Neolithic times until today.' *J.R. Soc. Antiq. Irel.*, 99, 38-53.

CASELDINE, C.J., 1973: 'A study of the Flandrian vegetation history of the Glen Clova area of the Eastern Grampians.' *Unpub. M.A. Thesis*, Univ. of St. Andrews.

CASELDINE, C.J. and WHITTINGTON, G., 1975-76: 'Pollen analysis of material from the Stones of Stenness, Orkney', in J.N.G. Ritchie, 'The Stones of Stenness, Orkney.' *Proc. Soc. Ant. Scot.*, 107, 37-40.

CHALMERS, G., 1807: *Caledonia*. Edinburgh.

CHANDA, S., 1962: 'On the pollen morphology of some Scandinavian Caryophyllaceae.' *Grana palynol.*, 3, 67-89.

COLES, F.R., 1908: 'Stone Circles Surveyed in Perthshire, North East Section.' *Proc. Soc. Ant. Scot.*, 42, 95-162.

COLES, F.R., 1909: 'Stone Circles Surveyed in Perthshire, South East District.' *Proc. Soc. Ant. Scot.*, 43, 93-130.

COLES, J.M., 1962: 'Scottish Late Bronze Age Metalwork.' *Proc. Soc. Ant. Scot.*, 97, 16-134.

COLES, J.M., 1971: 'The early settlement of Scotland: excavations at Morton, Fife.' *Proc. Prehist. Soc.*, 37, 284-366.

COLES, J.M. and SIMPSON, D.D.A., 1965: 'The excavation of a Neolithic round barrow at Pitnacree, Perthshire, Scotland.' *Proc. Prehist. Soc.*, 31, 34-57.

COOPE, G.R., 1970: 'Climatic interpretations of Late Weichselian Coleoptera from the British Isles.' *Rev. Geogr. Geol. Dynam.*, 12, 149-155.

COOPE, G.R., 1975: 'Climatic fluctuations in northwest Europe since the last Interglacial, indicated by fossil assemblages of Coleoptera', in H.E. Wright and F. Moseley (eds.) Ice Ages: Ancient and Modern, 153-168, Liverpool.

COOPE, G.R., 1977: 'Fossil coleopteran assemblages as sensitive indicators of climatic changes during the Devensian (Last) cold stage.' Phil. Trans. R. Soc. Lond., B280, 313-340.

COOPE, G.R. and BROPHY, J.A., 1972: 'Late Glacial environmental changes indicated by a coleopteran succession from North Wales.' Boreas, 1, 97-142.

COTTAM, M.B., 1974: 'The Historical Geography of Strathmore up to the late 11th century A.D.' Unpub. Ph.D. Thesis, University of Dundee.

COTTAM, M.B. and SMALL, A., 1974: 'The Distribution of Settlement in Southern Pictland.' Med. Arch., 18, 43-65.

COUTTS, H., 1971: Tayside Before History. Dundee.

CRABTREE, K., 1975: 'A review of methodological advances in pollen analysis', in R. Peel, M. Chisholm and P. Haggett (eds.) Processes in Physical and Human Geography. Bristol Essays, 266-283. Bristol.

CROWDER, A.A. and CUDDY, D.G., 1973: 'Pollen in a small river basin: Wilton Creek, Ontario', in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 61-78, Oxford.

CURTIS, J.T., 1959: The Vegetation of Wisconsin. Univ. Wisconsin Press, Madison.

CUSHING, E.J., 1964: 'Redeposited pollen in Late-Wisconsin pollen spectra from east-central Minnesota.' Am. J. Sci., 262, 1075-1088.

CUSHING, E.J., 1967: 'Evidence for differential pollen preservation in Late Quaternary sediments in Minnesota.' Rev. Palaeobotan. Palynol., 4, 87-101.

DAVIDSON, D.A., JONES, R.L. and RENFREW, C., 1976: 'Palaeoenvironmental reconstruction and evaluation: a case study from Orkney.' Trans. Inst. Brit. Geogr., N.S.1., 346-361.

DAVIS, M.B., 1963: 'On the theory of pollen analysis.' Am. J. Sci., 261, 897-912.

DAVIS, M.B., 1965: 'A method for determination of absolute pollen frequency', in B.G. Kummel and D.M. Raup (eds.) Handbook of Palaeontological Techniques, 674-676. San Francisco.

DAVIS, M.B., 1966: 'Determination of absolute pollen frequency.' Ecology, 47, 310-311.

DAVIS, M.B. and DEEVEY, E.S., 1964: 'Pollen accumulation rates: estimates from late-glacial sediment of Rogers Lake.' Science, 145, 1293-1295.

DAVIS, M.B. and GOODLET, J.C., 1960: 'Comparison of the present vegetation with pollen spectra in surface samples from Brownington Pond, Vermont.' Ecology, 41, 346-357.

DEEVEY, E.S., 1965: 'Pleistocene non-marine environments', in H.E. Wright and D.G. Frey (eds.) The Quaternary of the United States, 643-654. Princeton.

DIMBLEBY, G.W., 1957: 'Pollen analysis of terrestrial soils.' New Phytol., 56, 12-28.

DIMBLEBY, G.W., 1961a: 'Soil pollen analysis.' J. Soil Sci., 12, 1-11.

DIMBLEBY, G.W., 1961b: 'Transported material in the soil profile.' J. Soil Sci., 12, 12-22.

DIMBLEBY, G.W., 1962: 'The Development of British Heathlands and their Soils.' Oxford Forestry Memoir, 23, Clarendon Press, Oxford.

DIMBLEBY, G.W., 1965: 'Pollen analysis', in P.A.M. Keef, J.J. Wymer and G.W. Dimbleby 'A Mesolithic site on Iping Common, Sussex, England.' Proc. Prehist. Soc., 31, 85-92.

DIMBLEBY, G.W., 1978: Plants and Archaeology. London, 2nd. edition.

DIMBLEBY, G.W. and BRADLEY, R., 1975: 'Evidence of pedogenesis from a Neolithic site at Rackham, Sussex.' J. Arch. Sci., 2, 179-186.

DIMBLEBY, G.W. and EVANS, J.G., 1974: 'Pollen and land-snail analysis of calcareous soils.' J. Arch. Sci., 1, 117-133.

DODGSHON, R.A., 1973: 'The nature and development of infield-outfield in Scotland.' Trans. Inst. Brit. Geogr., 59, 1-23.

DODGSHON, R.A., 1975a: 'Towards an understanding and definition of runrig: the evidence for Roxburghshire and Berwickshire.' Trans. Inst. Brit. Geogr., 64, 15-33.

DODGSHON, R.A., 1975b: 'Scandinavian Solskifte and the sun-wise division of land in eastern Scotland.' Scott. Studs., 19, 1-14.

DONNER, J.J., 1957: 'The geology and vegetation of Late-Glacial retreat stages in Scotland.' Trans. R. Soc. Edinb., 63, 221-264.

DONNER, J.J., 1958: 'Loch Mahaick, a late-glacial site in Perthshire.' New Phytol., 57, 183-186.

DONNER, J.J., 1962: 'On the Post-glacial history of the Grampian Highlands of Scotland.' Soc. Sci. Fenn. Comm. Biol., 24, 1-29.

DONNER, J.J., 1970: 'Land/sea level changes in Scotland', in D. Walker and R.G. West (eds.) Studies in the Vegetational History of the British Isles. Essays in honour of Harry Godwin. 23-29. Cambridge.

DURNO, S.E., 1956: 'Pollen analysis of peat deposits in Scotland.' Scott. Geogr. Mag., 72, 177-187.

DURNO, S.E., 1959: 'Pollen analysis of peat deposits in the Eastern Grampians.' Scott. Geogr. Mag., 75, 102-111.

DURNO, S.E., 1961-62: 'Pollen analysis of peat', in M.E.C. Stewart 'The excavation of two circular enclosures at Dalnaglar, Perthshire.' Proc. Soc. Ant. Scot., 95, 154-158.

DURNO, S.E., 1965: 'Pollen analytical evidence of 'Landnam' from two Scottish sites.' Trans. Bot. Soc. Edinburgh., 40, 13-19.

DURNO, S.E., 1967: 'Scottish woodland history since Boreal time as revealed by pollen analysis of peat.' Unpub. Ph.D. Thesis, University of Aberdeen.

DURNO, S.E. and MCVEAN, D.N., 1959: 'Forest History of the Beinn Eighe Nature Reserve.' New Phytol., 58, 228-236.

EBDON, D., 1977: Statistics in Geography, A Practical Approach. Oxford.

EDWARDS, K.J., 1974: 'A Half-Century of Pollen Analytical Research in Scotland.' Trans. Bot. Soc. Edinb., 42, 211-222.

EDWARDS, K.J., 1977: 'Environmental Impact in the Prehistoric Period' Scott. Arch. Forum, 9, 27-42.

ELSIK, W.C., 1966: 'Biologic degradation of fossil pollen grains and spores.' *Micropalaeontol.*, 12, 515-518.

ELSIK, W.C., 1971: 'Microbial degradation of sporopollenin', in J. Brooks, P.R. Grant, M.D. Muir, P. van Gijzel and G. Shaw (eds.) *Sporopollenin*.

ERDTMAN, G., 1923: 'Iakttagelser från en mikropaleontologisk undersokning at nordskotska, Hebridiska, och Shetländska torvmarker.' *Geol. För. Stockh. Förh.*, 45, 538-545.

ERDTMAN, G., 1924: 'Studies in the micropalaeontology of Post-glacial deposits in Northern Scotland and the Scotch Isles, with especial reference to the history of the woodlands.' *J. Linn. Soc. (Bot.)*, 46, 449-504.

ERDTMAN, G., 1928: 'Studies in the postarctic history of the forests of North-Western Europe. I. Investigations in the British Isles.' *Geol. För. Stockh. Förh.*, 50, 123-192.

ERDTMAN, G., BERGLUND, B.E. and PRAGLOWSKI, J.R., 1961: *An Introduction to a Scandinavian Pollen Flora*. Stockholm.

ERGIN, M., HARKNESS, D.D. and WALTON, A., 1972: 'Glasgow University Radiocarbon Measurements V.' *Radiocarbon*, 14, 321-325.

EVANS, J.G., 1975: *The Environment of Early Man in the British Isles*, London.

EZEKIEL, M. and FOX, K.A., 1959: *Methods of Correlation and Regression Analysis*. New York.

FAEGRI, K. and IVERSEN, J., 1964: *Textbook of Pollen Analysis*. 2nd edition, Copenhagen.

FAEGRI, K. and IVERSEN, J., 1975: *Textbook of Pollen Analysis*. 3rd edition, Copenhagen.

FAIRHURST, H. and TAYLOR, D.B., 1970-71: 'A Hut Circle Settlement at Kilphedir, Sutherland.' *Proc. Soc. Ant. Scot.*, 103, 65-99.

FEDROVA, R.V., 1956: 'Dissemination of cereal pollen by air.' *Akademiya Nauk. S.S.S.R. Doklady*, 897-898. (In Russian)

FIRBAS, F., 1949: *Waldgeschichte Mitteleuropas, I: Allgemeine Waldgeschichte*. Jena.

FITZPATRICK, E.A., 1956: 'An indurated soil horizon formed by perma frost.' *J. Soil Sci.*, 7, 248-254.

FLEET, H., 1938: 'Erosion surfaces in the Grampian Highlands of Scotland.' *Rapport de la Commission pour la Cartographie des Surfaces d'Aplainissement*. *Union Geographique Internationale, Paris*, 91-94.

FLEMING, A. and COLLIS, J., 1973: 'A Late Prehistoric Reave System near Cholwich Town, Dartmoor.' *Proc. Dev. Assoc. Sci.*, 31, 1-21.

FLENLEY, J.R. and PEARSON, M.C., 1967: 'Pollen analysis of a peat form from the island of Canna (Inner Hebrides).' *New Phytol.*, 66, 299-306.

FORSYTH, R., 1806: *Beauties of Scotland*. Vol. IV. Edinburgh.

FOX, C., 1932: *The Personality of Britain*. Nat. Museum of Wales.

FRANKLIN, T.B., 1952: *A History of Scottish Farming*. Edinburgh.

FRASER, G.K., 1943: 'Peat Deposits of Scotland. Part I General Account.' *Wartime Pamphlet No. 36. D.S.I.R.*, Geological Survey of Great Britain; Scotland.

FRASER, G.K. and GODWIN, H., 1955: 'Two Scottish pollen diagrams: Carnwath Moss, Lanarkshire and Strichen Moss, Aberdeenshire. Data for the study of Post-glacial vegetation history XVII.' *New Phytol.*, 54, 216-221.

FREDSKILD, B., 1967: 'Palaeobotanical investigations at Semermuit, Jakobshavn, West Greenland.' *Meddr. Grønland*, 178, 54pp.

GEIKIE, A., 1865: *The Scenery of Scotland*. Edinburgh.

GEIKIE, J., 1865-66: 'On the buried forests and peat mosses of Scotland and the changes of climate which they indicate.' *Trans. R. Soc. Edinb.*, 24, 363-384.

GEIKIE, J., 1880: 'Discovery of an Ancient Canoe in the Old Alluviun of the Tay at Perth.' *The Scottish Naturalist*, V, 1-7.

GEIKIE, J., 1894: *The Great Ice Age*. London.

GLENTWORTH, R. and MUIR, J.W., 1963: 'The soils of the country around Aberdeen, Inverurie and Fraserburgh (sheets 77, 76, 87/97).' *Mem. Soil Surv. Scot*. Edinburgh.

GODDARD, A., 1971: 'Studies of the vegetational changes associated with the initiation of blanket peat accumulation in North East Ireland.' *Unpub. Ph.D. Thesis*, Queen's University of Belfast.

GODWIN, H., 1940: 'Pollen Analysis and the Forest History of England and Wales.' *New Phytol.*, 39, 370-400.

GODWIN, H., 1955: 'Vegetational history at Cwm Idwal: A Welsh plant refugia.' *Svensk. bot. Tidskr.*, 49, 35-43.

GODWIN, H., 1956a: *The History of the British Flora. A Factual Basis for Phytogeography.* Cambridge.

GODWIN, H., 1956b: 'Pollen analyses', in V.G. Childe 'Maes Howe'. *Proc. Soc. Antiq. Scot.*, 88, 169-172.

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

GODWIN, H., 1967: 'Pollen-analytic evidence for the cultivation of Cannabis in England.' *Rev. Palaeobotan. Palynol.*, 4, 71-80.

GODWIN, H., 1968: 'Studies of the post-glacial history of British vegetation; XV. Organic deposits of Old Buckenham Mere, Norfolk.' *New Phytol.*, 67, 95-107.

GODWIN, H., 1975a: 'History of the natural forests of Britain: establishment dominance and destruction.' *Phil. Trans. Roy. Soc.*, B271, 47-67.

GODWIN, H., 1975b: *The History of the British Flora. A Factual Basis for Phytogeography.* 2nd edition, Cambridge.

GODWIN, H. and WILLIS, E.H., 1959: 'Radiocarbon dating of the Late-glacial Period in Britain.' *Proc. Roy. Soc.*, B150, 199-215.

GODWIN, H. and WILLIS, E.H., 1960: 'Cambridge University Natural Radiocarbon Measurements II.' *Radiocarbon*, 2, 62-72.

GODWIN, H. and WILLIS, E.H., 1961: 'Cambridge University Natural Radiocarbon Measurements III.' *Radiocarbon*, 3, 60-76.

GODWIN, H., WALKER, D. and WILLIS, E.H., 1957: 'Radiocarbon dating and post-glacial vegetational history: Scaleby Moss.' *Proc. Roy. Soc.*, B147, 352-366.

GORDON, A.D. and BIRKS, H.J.B., 1972: 'Numerical methods in Quaternary palaeoecology. I. Zonation of pollen diagrams.' *New Phytol.*, 71, 961-979.

GORDON, A.D. and HENDERSON, J.T., 1977: 'An algorithm for Euclidean Sum of Squares classification.' Biometrics, 33, 355-362.

GRAY, J.M. and LOWE, J.J. (eds.), 1977: Studies in the Scottish Lateglacial Environment. Oxford.

GREGORY, S., 1955: 'Some aspects of the variability of annual rainfall for the standard period 1901-1930.' Quart. J. Roy. Met. Soc., 81, 257-262.

GROHNE, U., 1957: 'Die Bedeutung des Phasenkontrastverfahrens für die Pollenanalyse, dargelegt am Beispiel der Gramineapollen von Getreidetyp.' Photogr. Forsch., 7, 237-248.

GUNSON, A.R., 1975: 'The vegetation history of north east Scotland', in A.M.D. Gemmell (ed.) Quaternary Studies in North East Scotland, 61-72, Aberdeen.

GUILLET, B., 1972: 'Relation entre l'histoire de la végétation et la podzolization dans les Vosges.' Diss. Nancy C.N.R.S., 7640, 112pp.

HAFSTEN, U., 1965: 'Vegetation history and land occupation in Valldalen in the sub-alpine region of Central South Norway.' Univ. Bergen Årbok. Mat. Naturvit. Ser. 3, 26pp.

HAMILTON, H., 1963: An Economic History of Scotland in the Eighteenth Century. Oxford.

HANDLEY, J.E., 1953: Scottish Farming in the Eighteenth Century. London.

HARKNESS, D.D. and WILSON, H.W., 1973: 'Scottish Universities Research and Reactor Centre Radiocarbon Measurements I.' Radiocarbon, 15, 554-565.

HARKNESS, D.D. and WILSON, H.W., 1974: 'Scottish Universities Research and Reactor Centre Radiocarbon Measurements II.' Radiocarbon, 16, 238-251.

HAVINGA, A.J., 1963: 'A palynological investigation of soil profiles developed in cover sand.' Mededel. Lanbouwhogeschol. Wageningen, 63, 1-93.

HAVINGA, A.J., 1964: 'Investigation into the differential corrosion susceptibility of pollen and spores.' Pollen Spores, 4, 621-635.

HAVINGA, A.J., 1967: 'Palynology and pollen preservation.' Rev. Palaeobotan. Palynol., 2, 81-98.

HAVINGA, A.J., 1968: 'Some remarks on the interpretation of a pollen diagram of a podzol profile.' Acta. Bot. Neerl., 17, 1-4.

HAVINGA, A.J., 1971: 'An experimental investigation into the decay of pollen and spores in various soil types', in J. Brooks, P.R. Grant, M.D. Muir, P. van Gijzel and G. Shaw (eds.) Sporopollenin, London.

HAVINGA, A.J., 1974: 'Problems in the interpretation of pollen diagrams of mineral soils.' Geol. en. Mijnb., 53, 449-453.

HAWKINS, D.M. and MERRIAM, D.F., 1973: 'Optimal zonation of digitized sequential data.' Math. Geol., 5, 389-395.

HAWKSWORTH, D.L., 1969: 'Studies on the peat deposits of the island of Foula, Shetland.' Trans. Bot. Soc. Edinb., 40, 576-591.

HAWORTH, E.Y., 1976: 'Two Late-glacial (Late Devensian) diatom assemblage profiles from Northern Scotland.' New Phytol., 77, 225-254.

HEIM, J., 1962: Recherches sur les relations entre la végétation actuelle et le spectre pollinique récent dans les Ardennes, Belges.' Bull. Soc. r. Bot. Belg., 96, 5-92.

HELBAEK, H., 1953: 'Early crops in southern England.' Proc. Prehist. Soc., 18, 194-233.

HENDERSON, I., 1967: The Picts. London.

HENSHALL, A.S., 1972: Chambered Tombs of Scotland, Vols. I and II. Edinburgh.

HENSHALL, A.S., 1974: 'Scottish chambered tombs and long mounds', in C. Renfrew (ed.) British Prehistory, a new Outline, 137-164. London.

HENSHALL, A.S. and STEWART, M.E.C., 1954-56: 'Excavations at Clach na Tiompan, West Glen Almond, Perthshire.' Proc. Soc. Ant. Scot., 88, 112-124.

HEYBROCK, 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. and SWITSUR, V.R., 1976: 'Radiocarbon Dating of Flandrian Pollen Zones in Wales and Northern England.' New Phytol., 77, 793-807.*

HIBBERT, F.A., SWITSUR, V.R. and WEST, R.G., 1971: 'Radiocarbon dating of Flandrian pollen zones at Red Moss, Lancashire.' Proc. Roy. Soc., B177, 161-176.

---

* Note the title error; Din Moss, which is discussed in this paper is in Roxburghshire, Scotland.

HICKS, S., 1974: 'A method of using modern pollen rain values to provide a time-scale for pollen diagrams from peat deposits.' *Mem. Soc. Fauna Flora Fenn.*, 49, 21-33.

HONOURS CLASS IN BOTANY, UNIVERSITY OF ST. ANDREWS, 1971: *A Survey of Bankhead Moss*, Unpublished.

HUME BROWN, P., 1891: *Early Travellers in Scotland*. Edinburgh.

HUTCHESON, A., 1886: 'Notice of the discovery of a stratum containing worked flints at Broughty Ferry.' *Proc. Soc. Ant. Scot.*, 20, 166-169.

IVERSEN, J., 1941: 'Landnam i Danmarks Stenalder.' *Danm. Geol. Unders.*, Ser. II, 66, 68pp.

IVERSEN, J., 1947: 'Plantevaekst, dyreliv og klima i det senglaciale Danmark.' *Geol. För. Stockh. Förh.*, 69, 67-78.

IVERSEN, J., 1954: 'The Late-glacial flora of Denmark and its relation to climate and soil.' *Danm. Geol. Unders.*, Ser. II, 80, 87-119.

IVERSEN, J., 1956: 'Forest clearance in the Stone Age.' *Scient. Am.*, 194, 36-41.

IVERSEN, J., 1958: 'The bearing of glacial and interglacial epochs on the formation and extinction of plant taxa systematics of today.' *Proc. Sympos. Univ. Uppsala 1957. Upsala Univ. Årsskr.*, 6, 210-215.

IVERSEN, J., 1960: 'Problems of the early Post-glacial forest development in Denmark.' *Danm. Geol. Unders.*, Ser. II, 4, 1-32.

IVERSEN, J., 1969: 'Retrogressive development of a forest ecosystem demonstrated by pollen diagrams from fossil mor.' *Oikos*, 12, 35-49.

JACKSON, A., 1971: 'Pictish social structure and symbol-stones', *Scott. Studs.*, 15, 121-140.

JANSSEN, C.R., 1959: '*Alnus* as a disturbing factor in pollen diagrams.' *Acta. bot. neerl.*, 8, 55-58.

JANSSEN, C.R., 1966: 'Recent pollen spectra from the deciduous and coniferous-deciduous forests of north western Minnesota: a study in pollen dispersal.' *Ecology*, 47, 804-825.

JANSSEN, C.R., 1967a: 'A comparison between the recent regional pollen rain and the subrecent vegetation in four major vegetation types in Minnesota, U.S.A.' Rev. Palaeobotan. Palynol., 2, 331-342.

JANSSEN, C.R., 1967b: 'Stevens Pond: a Postglacial pollen diagram from a small Typha swamp in north western Minnesota, interpreted from surface samples and pollen indicators.' Ecological Monographs, 37, 145-172.

JANSSEN, C.R., 1970: 'Problems in the recognition of plant communities in pollen diagrams.' Vegetatio, 20, 187-198.

JANSSEN, C.R., 1972: 'The palaeoecology of plant communities in the Dommee Valley, North Brabant, the Netherlands.' J. Ecol., 60, 411-437.

JANSSEN, C.R., 1973: 'Local and regional pollen deposition ', in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 31-42. Oxford.

JENSEN, I. and BLØGH, H., 1942: 'Indflydels paa Krydsringsfaren has vindbestøvende kulturplanter (On conditions influencing the danger of crossing in the case of wind pollinating cultivated plants).' Tidsskr. For Plant., 46, 238-266.

JESSEN, K., 1949: 'Studies in the late-Quaternary deposits and floral history of Ireland.' Proc. R. Ir. Acad., B52, 85-290.

JOHANSEN, J., 1975: 'Pollen diagrams from the Shetland and Faroe Islands.' New Phytol., 75, 369-387.

JONASSEN, H., 1950: 'Recent pollen sedimentation and Jutland Heath diagrams.' Dansk. Botan. Arkiv., 13, 1-68.

JONES, E.W., 1959: 'Biological Flora of the British Isles. Quercus L.' J. Ecol., 47, 169-222.

JONES, S.J. (ed.), 1968: Dundee and District. British Association for the Advancement of Science. Dundee.

JØRGENSEN, S., 1967: 'A method of absolute pollen counting.' New Phytol., 66, 489-493.

KEEF, P.A.M., WYMER, J.J. and DIMBLEBY, G.W., 1965: 'A Mesolithic site on Iping Common, Sussex, England.' Proc. Prehist. Soc., 31, 85-92.

KENDRICK, W.D., 1959: 'The time factor in the decomposition of coniferous leaf litter.' *Can. J. Bot.*, 37, 907–912.

KUOX, E., 1954: 'Pollen analysis of a peat at Kingsteps Quarry, Nairn.' *Trans. Bot. Soc. Edinb.*, 36, 224–229.

LAING, D., 1976: 'The soils of the country around Perth, Arbroath and Dundee.' *Mem. Soil Survey of Great Britain* (Sheets 48 and 49), Edinburgh.

LAMB, H.H., 1966: *The Changing Climate*. London.

LEWIS, F.J., 1905: 'The Plant Remains in the Scottish Peat Mosses. Part I. The Scottish Southern Uplands.' *Trans. R. Soc. Edinb.*, 41, 699–723.

LEWIS, F.J., 1906: 'The Plant Remains in the Scottish Peat Mosses. Part II. The Scottish Highlands.' *Trans. R. Soc. Edinb.*, 45, 335–360.

LEWIS, F.J., 1907: 'The Plant Remains in the Scottish Peat Mosses. Part III. The Scottish Highlands and the Shetland Islands.' *Trans. R. Soc. Edinb.*, 46, 33–70.

LEWIS, F.J., 1911: 'The Plant Remains in the Scottish Peat Mosses. Part IV. The Scottish Highlands and Shetland with an Appendix on the Icelandic Peat Deposits.' *Trans. R. Soc. Edinb.*, 47, 793–833.

LICHTI-FEDEROVITCH, S. and RITCHIE, J.C., 1965: 'Contemporary pollen spectra in central Canada. 2. The forest-grassland transition in Manitoba.' *Pollen Spores*, 7, 63–87.

LICHTI-FEDEROVITCH, S. and RITCHIE, J.C., 1968: 'Recent pollen assemblages from the western Interior of Canada.' *Rev. Palaeobotan. Palynol.*, 7, 297–344.

LIMBREY, S., 1975: *Soil Science and Archaeology*. London.

LINDSAY, J.M., 1974: 'The Use of woodland in Argyllshire and Perthshire between 1650 and 1850.' *Unpub. Ph.D. Thesis*, University of Edinburgh.

LINDSAY, J.M., 1975: 'The History of Oak Coppice in Scotland.' *Scott. Forestry*, 29, 87–93.

LINTON, D.L., 1951: 'Problems of Scottish Scenery.' *Scott. Geog. Mag.*, 67, 65–85.

LOWE, J.J. and WALKER, M.J.C., 1977: 'The reconstruction of the Lateglacial Environment in the Southern and Eastern Grampian Highlands', in J.M. Gray and J.J. Lowe (eds.) *Studies in the Scottish Lateglacial Environment*, 101-118, Oxford.

LÜDI, W., 1947: 'Der Pollengehalt von Oberflächenproben am Katzensee bei Zürich.' *Ber. geobot. Inst. Rübel Zürich*, 1946, 82-92.

MACGREGOR, M. and MACGREGOR, A.G., 1948: *The Midland Valley of Scotland*. *British Regional Geology*, Edinburgh.

MAHER, L.H., Jr., 1963: 'Pollen analyses of surface materials from the southern San Juan Mountains, Colorado.' *Bull. Geol. Soc. Am.*, 74, 1485-1504.

MANGERUD, J., ANDERSEN, S.Th., BERGLUND, B.E. and DONNER, J.J., 1974: 'Quaternary stratigraphy of Norden, a proposal for terminology and classification.' *Boreas*, 3, 109-126.

MATTHEWSON, A., 1879: 'Notes on Stone Circles and an Ancient Kitchen Midden near Dundee.' *Proc. Soc. Ant. Scot.*, 13, 303-307.

McANDREWS, J.H., 1966: 'Postglacial history of prairie, savanna and forest in northwestern Minnesota.' *Torrey Bot. Club Mem.*, 22, 72pp.

McANDREWS, J.H., 1967: 'The pollen record for Late presettlement and postsettlement vegetation changes in eastern Minnesota (U.S.A.).' *Rev. Palaeobotan. Palynol.*, 2, 21-32.

McVEAN, D.N., 1956: 'Ecology of *Alnus glutinosa* (L.) Gaertn. VI. Post-glacial history.' *J. Ecol.*, 44, 331-333.

McVEAN, D.N., 1963: 'The ecology of Scots Pine in the Scottish Highlands.' *J. Ecol.*, 51, 671-686.

McVEAN, D.N. and RATCLIFFE, D.A., 1962: *Plant Communities of the Scottish Highlands*. (Monograph of the Nature Conservancy, No. 1.) London.

MEIKLE, J., 1925: *Places and Place-Names Round Alyth*. Alyth.

MERCER, J., 1967: 'Stone tools from a washing-limit deposit of the Highest Post-Glacial Transgression, Lealt Bay, Isle of Jura.' *Proc. Soc. Antiq. Scot.*, 100, 1-46.

MERCER, J., 1970: 'The microlithic succession in N. Jura, Argyll, W. Scotland.' Quaternaria, 13, 177-185.

MITCHELL, G.F., 1948: 'Late-glacial deposits in Berwickshire.' New Phytol., 47, 262-264.

MITCHELL, G.F., 1952: 'Late-glacial deposits at Garscadden Mains, near Glasgow.' New Phytol., 50, 277-286.

MOAR, N.T., 1969a: 'Two pollen diagrams from the Mainland, Orkney Islands.' New Phytol., 68, 201-208.

MOAR, N.T., 1969b: 'A radiocarbon-dated pollen diagram from north-west Scotland.' New Phytol., 68, 209-214.

MOAR, N.T., 1969c: 'Late Weichselian and Flandrian pollen diagrams from South-west Scotland.' New Phytol., 68, 433-467.

MOIR, D.G., 1973: The Early Maps of Scotland to 1850. Vol. I. Edinburgh.

MOORE, P.D., 1968: 'Human influence on the vegetational history of north Cardiganshire.' Nature, 217, 1006-1009.

MOORE, P.D., 1972: 'The initiation of peat formation and the development of peat deposits in Mid-Wales.' Proc. Fourth Int. Peat Congress, Helsinki, 1, 89-100.

MOORE, P.D., 1973: 'The influence of prehistoric cultures upon the initiation and spread of blanket bog in upland Wales.' Nature, 241, 350-353.

MOORE, P.D., 1977: 'Stratigraphy and pollen analysis of Claish Moss, North-West Scotland: Significance for the origin of surface-pools and forest history.' J. Ecol., 65, 375-397.

MOORE, P.D. and WEBB, J.A., 1978: An Illustrated guide to pollen analysis. London.

MORRISON, M.E.S., 1959: 'Evidence and interpretation of 'Landnam' in the north-east of Ireland.' Bot. Notiser, 112, 185-204.

MULLENDERS, W., 1962: 'Les relations entre la végétation et les spectres polliniques en forêt du Mont-Dieu (départment des Ardennes, France).' Bull. Soc. r. Bot. Belg., 94, 131-138.

MUNAUT, A.V., 1967: 'Rocherches paleo-écologiques en Basse et Moyenne Belgique.' Acta. Geogr. Lovan., 6, 191pp.

MURRAY, Hon. Mrs., 1799: A Companion and Useful Guide to the Beauties of Scotland. Edinburgh.

NEW STATISTICAL ACCOUNT OF SCOTLAND, 1845: Blairgowrie, Vol. X, 896-933.

NEWEY, W.W., 1966: 'Pollen analyses of sub-carse peats of the Forth Valley.' Trans. Inst. Porit. Geogr., 39, 53-59.

NEWEY, W.W., 1967: 'Pollen analyses from south-east Scotland.' Trans. Bot. Soc. Edinb., 40, 424-434.

NEWEY, W.W., 1970: 'Pollen analysis of Late-Weichselian deposits at Corstorphine, Edinburgh.' New Phytol., 69, 1167-1177.

NICHOLS, H., 1967: 'Vegetational change, shoreline displacement and the human factor in the Late Quaternary history of south-west Scotland.' Trans. R. Soc. Edinb., 67, 145-187.

NICOLAISEN, W.H.F., 1975: 'Placenames', in P. McNeil and R. Nicholson (eds.) An Historical Atlas of Scotland c.400-c.1600. St. Andrews.

OGDEN, E.C., RAYNOR, G.S. and HAYES, J.V., 1971: 'Travels of airborne pollen.' Progr. rep. 11. N.Y. State mus. sci. serv. Mimeographed.

OGDEN, J.G., III, 1969: 'Correlation of contemporary and Late-Pleistocene pollen records in the reconstruction of Post-Glacial environments in north-eastern North America.' Mitt. Internat. Verein. Limnol., 17, 64-77.

OGILVIE, A.G., 1928: 'Central Scotland', in A.G. Ogilvie (ed.) Great Britain: Essays in Regional Geography, 420-465.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1791-1799: 'Caputh'. Vol. IX, 485-509.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1791-1799: 'Clunie'. Vol. IX, 225-276.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1792: 'Rattray'. Vol. IV, 148-151.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1793: 'Alyth'. Vol. VI, 397-406.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1793: 'Glenisla'. Vol. VI, 390-396.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1796: 'Blairgowrie'. Vol. XVII, 191-208.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1796: 'Coupar Angus'. Vol. XVII, 1-12.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1796: 'Kinloch'. *Vol. XVII,* 468-481.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1796: 'Lethendy'. *Vol. XVII,* 521-529.

OLD STATISTICAL ACCOUNT OF SCOTLAND, 1797: 'Bendothy'. Vol. *XIX,* 334-371.

OLDFIELD, F., 1959: 'The pollen morphology of some of the West European Ericales.' *Pollen Spores,* 1, 19-48.

OLDFIELD, F., 1960: 'Studies in the Post-glacial history of British Vegetation: Lowland Lonsdale.' *New Phytol,* 59, 192-217.

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., 1970: 'Some aspects of scale and complexity in pollen analytically based palaeoecology.' *Pollen Spores,* 12, 163-171.

OLDFIELD, F. and STATHAM, D.C., 1963: 'Pollen analytical data from Urswick Tarn and Ellerside Moss, North Lancashire.' *New Phytol.*, 62, 53-66.

OSBORNE, P.J., 1972: 'Insect faunas of Late Devensian and Flandrian age from Church Stretton, Shropshire.' *Phil. Trans. R. Soc.*, B263, 327-367.

O'SULLIVAN, P.E., 1973a: 'Contemporary pollen studies in a native Scots pine ecosystem.' *Oikos,* 24, 143-150.

O'SULLIVAN, P.E., 1973b: 'Pollen analysis of Mor humus layers from a native Scots pine ecosystem, interpreted with surface samples.' *Oikos,* 24, 259-272.

O'SULLIVAN, P.E., 1974a: 'Two Flandrian pollen diagrams from the east central Highlands of Scotland.' *Pollen Spores,* 16, 33-57.

O'SULLIVAN, P.E., 1974b: 'Radiocarbon-dating and prehistoric forest clearance on Speyside (East-Central Highlands of Scotland). *Proc. Prehist. Soc.*, 40, 206-208.

O'SULLIVAN, P.E., 1975: 'Early and Middle Flandrian pollen zonation in the Eastern Highlands of Scotland.' *Boreas,* 4, 197-207.

O'SULLIVAN, P.E. and RILEY, D.H., 1974: 'Multivariate numerical analysis of surface pollen spectra from a native Scots Pine forest.' Pollen Spores, 16, 239-264.

O'SULLIVAN, P.E., OLDFIELD, F. and BATTARBEE, R.W., 1973: 'Preliminary studies of Lough Neagh sediments. I. Stratigraphy, chronology and pollen analysis', in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 267-278. Oxford.

PARRY, M.L., 1975: 'Secular climatic change and marginal agriculture.' Trans. Inst. Brit. Geogr., 64, 1-14.

PATERSON, I.B., 1974: 'The supposed Perth Readvance in the Perth District.' Scott. Jour. Geol., 10, 53-66.

PEACH, B.N. and HORNE, 1930: Chapters on the geology of Scotland. Edinburgh.

PEARS, N.V., 1968: 'Post-glacial tree-lines of the Cairngorm Mountains, Scotland.' Trans. Bot. Soc. Edinb., 40, 361-394.

PEARS, N.V., 1969: 'Post-glacial tree-lines of the Cairngorm Mountains, Scotland: some modifications based on radiocarbon dating.' Trans. Bot. Soc. Edinb., 40, 536-544.

PEARS, N.V., 1975: 'Radiocarbon dating of peat macrofossils in the Cairngorm Mountains, Scotland.' Trans. Bot. Soc. Edinb., 42, 255-260.

PECK, R.M., 1973: 'Pollen budget studies in a small Yorkshire catchment.' in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 43-60. Oxford.

PECK, R.M., 1974: 'A comparison of four absolute pollen preparation techniques.' New Phytol., 73, 567-587.

PENNINGTON, W., 1970: 'Vegetation history in the north-west of England: a regional synthesis', in D. Walker and R.G. West (eds.) Studies in the Vegetational History of the British Isles. 41-79. Cambridge.

PENNINGTON, W., 1973: 'Absolute pollen frequencies in the sediments of lakes of different morphometry', in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 79-104. Oxford.

PENNINGTON, W., 1975a: 'The effect of Neolithic man on the environment in north-west England: the use of absolute pollen diagrams', in J.G. Evans, S. Limbrey and H. Cleere (eds.) The effect of man on the landscape: the Highland Zone.' *C.B.A. Research Report 11*, 74-86.

PENNINGTON, W., 1975b: 'An application of principal components analysis to the zonation of two Late-Devensian profiles: Section II: Interpretation of the numerical analyses in terms of Late-Devensian (Late-Weichselian) environmental history.' *New Phytol*., 75, 441-453.

PENNINGTON, W., 1977a: 'Lake Sediments and the Lateglacial Environment in Northern Scotland', in J.M. Gray and J.J. Lowe (eds.) *Studies in the Scottish Lateglacial Environment*, 119-141. Oxford.

PENNINGTON, W., 1977b: 'The Late Devensian flora and vegetation of Britain.' *Phil. Trans. R. Soc*., B280, 247-271.

PENNINGTON, W. and BONNY, A.P., 1970: 'Absolute pollen diagram from the British Late-glacial.' *Nature*, 226, 871-873.

PENNINGTON, W., HAWORTH, E.Y., BONNY, A.P. and LISHMAN, J.P., 1972: 'Lake sediments in Northern Scotland.' *Phil. Trans. R. Soc*., B264, 191-294.

PENNINGTON, W. and LISHMAN, J.P., 1971: 'Iodine in lake sediments in northern England and Scotland.' *Biol. Rev*., 46, 279-313.

PENNINGTON, W. and SACKIN, M.J., 1975: 'An application of principal components analysis to the zonation of two late-Devensian profiles: Section I: Numerical analysis.' *New Phytol*., 75, 419-441.

PERSSON, Å., 1964: 'The vegetation at the margin of the retreating glacier Skaftafellsjökull, southeastern Iceland.' *Bot. Notiser*, 117, 323-375.

PIGGOTT, S., 1971-1972: 'Excavation of the Dalladies long barrow, Fettercairn, Kincardineshire.' *Proc. Soc. Ant. Scot*., 104, 23-47.

PIGGOTT, S., 1972: 'A note on climatic deterioration in the first millennium B.C. in Britain.' *Scott. Arch. Forum*, 4, 109-113.

PIGGOTT, S., 1973: 'The Dalladies Long barrow.' *Antiquity*, 47, 96-100.

PIGGOTT, S. and SIMPSON, D.D.A., 1971: 'Excavation of a Stone Circle at Croft Moraig, Perthshire, Scotland.' Proc. Prehist. Soc., 37, 1-15.

PILCHER, J.R., 1973: 'Pollen analysis and radiocarbon dating of a peat on Slieve Gullion, Co. Tyrone, Northern Ireland.' New Phytol., 72, 681-689.

PILCHER, J.R., 1974: 'Botanical report on Dun Mor Vaul', in E.W. Mackie, Dun Mor Vaul, An Iron Age Broch on Tiree, 204-209. Glasgow.

PILCHER, J.R., SMITH, A.G., PEARSON, G.W. and CROWDER, A., 1971: 'Land Clearance in the Irish Neolithic: New Evidence and Interpretation.' Science, 172, 560-562.

POTTER, L.D. and ROWLEY, J.S., 1960: 'Pollen rain and vegetation, San Augustin Plains, New Mexico.' Botan. Gaz., 122, 1-25.

POTZGER and COURTEMANCHE, A., 1956: 'A series of bogs across Quebec from the St. Lawrence valley to James Bay.' Can. J. Bot., 34, 473-500 .

PRAGLOWSKI, J.R., 1962: 'Notes on the pollen morphology of Swedish trees and shrubs.' Grana, 3, 45-65.

RAISTRICK, A., 1939: 'Report upon earth sample from Fendoch', in I.A. Richmond and J. McIntyre, 'The Agricolan Fort at Fendoch', Proc. Soc. Antiq. Scot., 73, 154-156.

RAMSAY, J.H., 1915: Bamff Charters and Papers. Oxford.

RAND, W.M., 1971: 'Objective criteria for evaluating clustering methods.' J. Am. Statist. Assoc., 66, 846-850.

READ, H.H. and MacGREGOR, A.G., 1948: The Grampian Highlands. British Regional Geology, Edinburgh.

REITSMA, Tj., 1966: 'Pollen morphology of some European Rosaceae.' Acta. bot. neerl., 15, 290-307.

RENNIE, REV. R., 1807: Essays on the natural history and origin of Peat Moss. Edinburgh.

RITCHIE, J.N.G. and MACLAREN, A., 1972: 'Ring-Cairns and Related Monuments in Scotland.' Scott. Arch. Forum, 4, 1-17.

RITCHIE, A., RITCHIE, G., WHITTINGTON, G. and SOULSBY, J., 1974: 'A Prehistoric field-boundary from the Black Crofts, North Connel, Argyll.' Glasg. Arch. Forum, 3, 66-70.

RITCHIE, J.C. and LICHTI-FEDEROVITCH, S., 1967: 'Pollen dispersal phenomena in arctic and sub-arctic Canada.' *Rev. Palaeobotan. Palynol.*, 3, 255-266.

ROBERTS, B.K., TURNER, J. and WARD, P.F., 1973: 'Recent forest history and land use in Weardale, Northern England.' in H.J.B. Birks and R.G. West (eds.) *Quaternary Plant Ecology*, 207-222. Oxford.

ROBERTSON, J., 1799: *General View of the Agriculture in the County of Perth*. Edinburgh.

ROBINSON, M. and HUBBARD, R.N.L.B., 1977: 'The transport of pollen in the bracts of hulled cereals.' *J. Arch. Sci.*, 4, 197-199.

ROGERS, C., 1879: *Rental Book of the Cistercian Abbey of Coupar Angus. Vols. I and II*. Grampian Club.

ROHDE, E., 1959: *Überprüfung und Ausbau der Getreide-Pollenanalyse*. Göttingen.

ROMANS, J.C.C., 1962: 'The origin of the indurated B_3 horizon of podzolic soils in north-east Scotland.' *J. Soil Sci.*, 13, 141-147.

ROMANS, J.C.C., DURNO, S.E. and ROBERTSON, L., 1973: 'A fossil brown forest soil from Angus.' *J. Soil Sci.*, 24, 125-128.

ROMANS, J.C.C. and ROBERTSON, L., 1975: 'Soils and archaeology in Scotland.' in J.G. Evans, S. Limbrey and H. Cleere (eds.) The effect of man on the landscape: the Highland Zone. *C.B.A. Research Report*, 11, 37-39.

ROWLEY, J.R., 1960: 'The exine structure of "cereal" and "wild" type grass pollen.' *Grana*, 2, 9-15.

RYMER, L., 1977: 'A late-glacial and early post-glacial pollen diagram from Drimnagall, North Knapdale, Argyllshire.' *New Phytol.*, 79, 211-221.

SALMI, M., 1962: 'Investigations on the distribution of pollens in an extensive raised bog.' *Bull. Comm. geol. Finl.*, 204, 28pp.

SAMUELSSON, G., 1910: 'Scottish Peat Mosses. A contribution to the knowledge of the late-quaternary vegetation and climate of North-Western Europe.' *Bull. Geol. Inst. Uppsala*, 10, 197-260.

SANGSTER, A.G. and DALE, H.M., 1961: 'A preliminary study of differential pollen grain preservation.' *Can. J. Bot.*, 39, 35-43.

SHOTTON, F.W. and WILLIAMS, R.E.G., 1971: 'Birmingham University Radiocarbon Dates V.' Radiocarbon, 13, 141-156.

SHOTTON, F.W. and WILLIAMS, R.E.G., 1973: 'Birmingham University Radiocarbon Dates VII.' Radiocarbon, 15, 451-468.

SIMMONS, I.G., 1964: 'Pollen diagrams from Dartmoor.' New Phytol., 63, 165-180.

SIMMONS, I.G., 1969: 'Pollen diagrams from the North York Moors.' New Phytol., 68, 807-827.

SIMMONS, I.G., 1975: 'Towards an ecology of Mesolithic man in the uplands of England and Wales.' J. Arch. Sci., 2, 1-15.

SIMPSON, J.B., 1933: 'The Late Glacial readvance moraines of the Highland Border west of the river Tay.' Trans. R. Soc. Edinb., 57, 633-645.

SIMS, R.E., 1973: 'The anthropogenic factor in East Anglian vegetational history: an approach using A.P.F. techniques', in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 223-236. Oxford.

SISSONS, J.B., 1963: 'The Perth readvance in central Scotland I.' Scott. Geogr. Mag., 79, 151-163.

SISSONS, J.B., 1967: The Evolution of Scotland's Scenery. Edinburgh.

SISSONS, J.B., 1974a: 'A lateglacial ice-cap in the central Grampians, Scotland.' Trans. Inst. Brit. Geogr., 62, 95-114.

SISSONS, J.B., 1974b: 'The Quaternary in Scotland: a review.' Scott. Jour. Geol., 10, 34-37.

SISSONS, J.B., 1976: The Geomorphology of the British Isles: Scotland. London.

SISSONS, J.B., LOWE, J.J., THOMPSON, K.S.R. and WALKER, M.J.C., 1973: 'Loch Lomond Readvance in the Grampian Highlands of Scotland.' Nature, 244, 75-77.

SISSONS, J.B. and WALKER, M.J.C., 1974: 'Lateglacial sites in the Central Grampian Highlands.' Nature, 249, 822-824.

SMITH, A.G., 1958: 'Two lacustrine deposits in the south of the English Lake District.' New Phytol., 57, 363-386.

SMITH, A.G., 1975: 'Neolithic and Bronze Age landscape changes in northern Ireland', in J.G. Evans, S. Limbrey and H. Cleere (eds.) The effect of man on the landscape: the Highland Zone. C.B.A. Research Report, 11, 64-74.

SMITH, A.G. and PILCHER, J.R., 1973: 'Radiocarbon dating and vegetational history of the British Isles.' New Phytol., 72, 903-914.

SMOUT, T.C., 1969: A History of the Scottish People, 1560-1830. London.

STEVENSON, J.B., 1975: 'Survival and Discovery', in J.G. Evans, S. Limbrey and H. Cleere (eds.) The effect of man on the landscape: the Highland Zone, C.B.A. Research Report, 11, 104-108.

STEWART, M.E.C., 1959: 'Strathtay in the 2nd Millennium B.C.' Proc. Soc. Ant. Scot., 92, 71-84.

STEWART, M.E.C., 1961-1962: 'The Excavation of two Circular Enclosures at Dalnaglar, Perthshire.' Proc. Soc. Ant. Scot., 95, 134-158.

STEWART, M.E.C., 1966c: 'Excavation of a Circle of Standing Stones at Sandy Road, Scone, Perthshire.' Trans. & Proc. Perth. Soc. Nat. Sci., 11, 7-23.

STEWART, M.E.C., 1966b: 'Excavation of a setting of Standing Stones at Lundin Farm, near Aberfeldy, Perthshire.' Proc. Soc. Ant. Scot., 98, 126-149.

STEWART, M.E.C., 1969: 'The ring-forts of Central Scotland.' Trans. Proc. Perth. Soc. Nat. Sci., 12, 21-32.

STEWART, M.E.C., 1974: 'Moncreiffe Stone Circle.' D. and E., 86, 86-87.

STIX, E., 1960: 'Pollenmorphologische Untersuchungen an Compositen.' Grana, 2, 41-114.

ST. JOSEPH, J.K., 1973: 'Air Reconnaissance in Britain 1969-1972.' J. Rom. Stud., 63, 214-246.

STOCKMARR, J., 1972: 'Tablets with spores used in absolute pollen analysis.' Pollen Spores, 13, 615-621.

STUART, J., 1866: 'Notice of excavations in cairns, stone-circles and etc. On Balnabroch and at West Persie.' Proc. Soc. Ant. Scot., 6, 402-410.

SWITSUR, V.R. and WEST, R.G., 1972: 'University of Cambridge Natural Radiocarbon Measurements X.' Radiocarbon, 14, 289-246.

SWITSUR, V.R. and WEST, R.G., 1973a: 'University of Cambridge Natural Radiocarbon Measurements XI.' Radiocarbon, 15, 156-164.

SWITSUR, V.R. and WEST, R.G., 1973b: 'University of Cambridge Natural Radiocarbon Measurements XII.' Radiocarbon, 15, 534-544.

SWITSUR, V.R., and WEST, R.G., 1975: 'University of Cambridge Natural Radiocarbon Measurements XIV.' Radiocarbon, 17, 301-312.

SYMON, J.A., 1959: Scottish Farming Past and Present. Edinburgh.

TALLANTIRE, P.A., 1974: 'The Palaeohistory of the grey alder (Alnus incana (L.) Moench.) and black alder (A. glutinosa (L.) Gaertn.) in Fennoscandia.' New Phytol., 73, 529-546.

TAMPIERI, F., MANDRIOLI, P. and PUPPI, G.L., 1977: 'Medium range transport of airborne pollen.' Agric. Met., 18, 9-20.

TANSLEY, A.G., 1939: The British Isles and their Vegetation. Cambridge.

TAUBER, H., 1965: 'Differential pollen dispersion and the interpretation of pollen diagrams.' Danm. Geol. Unders., Ser. II, 89, 1-69.

TAUBER, H., 1967: 'Investigations of the mode of pollen transfer in forested areas.' Rev. Palaeobotan. Palynol., 3, 277-286.

TAYLOR, D.B., 1968: 'Prehistoric, Roman and Pictish Settlement', in S.J. Jones (ed.) Dundee and District, 127-143. Dundee.

TAYLOR, J.A. and SMITH, R.T., 1972: 'Climatic peat - a misnomer.' Proc. 4th Int. Peat Congr., Finland, 1, 471-484.

TAYLOR, P.J., 1975: 'Distance Decay in Spatial Interactions.' Concepts and Techniques in Modern Geography, No. 2, 35pp.

THOMAS, C., 1963: 'The interpretation of Pictish symbols.' Archaeol. J., 120, 31-97.

THORNEYCROFT, W., 1932: 'Observations on hut-circles near the eastern border of Perthshire, North of Blairgowrie.' Proc. Soc. Ant. Scot., 67, 187-208.

TINSLEY, H.M. and SMITH, R.T., 1974: 'Surface pollen studies across a woodland/heath transition and their application to the interpretation of pollen diagrams.' New Phytol., 73, 547-565.

TROELS-SMITH, J., 1960: 'Ivy, Mistletoe and Elm: Climatic indicator - fodder plants.' *Dank. Geol. Unders.*, Ser. IV, 4, 32pp.

TSUKADA, M., 1958: 'Untersuchungen über das Verhältnis Zwischen der Pollengehalt der Oberflächenproben und der Vegetation des Hochlandes Shiga.' *Osaka City Univ., Inst. Polytechn., J.*, Ser. D., 9, 217-234.

TURNER, J., 1964: 'Surface sample analysis from Ayrshire, Scotland.' *Pollen Spores*, 6, 583-592.

TURNER, J., 1965: 'A contribution to the history of forest clearance.' *Proc. R. Soc.*, B161, 343-354.

TURNER, J., 1970: 'Post-Neolithic disturbance of British vegetation', in D. Walker and R.G. West (eds.) *Studies in the Vegetational History of the British Isles. Essays in Honour of Harry Godwin*, 97-116. Cambridge.

TURNER, J., 1975: 'The evidence for land use by prehistoric farming communities; the use of three-dimensional poden diagrams', in J.G. Evans, S. Limbrey and H. Cleere (eds.) The effect of man on the landscape: the Highland Zone, *C.B.A. Research Report*, 11, 86-95.

TYLDESLEY, J.B., 1973a: 'Long-range transmission of tree pollen to Shetland. I. Sampling and trajectories.' *New Phytol*, 72, 175-181.

TYLDESLEY, J.B., 1973b: 'Long-range transmission of tree-pollen to Shetland. II. Calculation of pollen deposition.' *New Phytol.*, 72, 183-190.

TYLDESLEY, J.B., 1973c: 'Long-range transmission of tree pollen to Shetland. III. Frequencies over the past hundred years.' *New Phytol.*, 72, 691-697.

VASARI, Y., 1977: 'Radiocarbon Dating of the Lateglacial and Early Flandrian Vegetational Succession in the Scottish Highlands and the Isle of Skye', in J.M. Gray and J.J. Lowe (eds.) *Studies in the Scottish Lateglacial Environment*, 143-162. Oxford.

VASARI, Y. and VASARI, A., 1968: 'Late- and Post-glacial macrophytic vegetation in the lochs of Northern Scotland.' *Acta. Bot. Fenn.*, 80, 1-117.

VON POST, L., 1916: 'Om skogstädpollen i sydsvenska torfmosslagerfjöldjer.' *Geol. För. Förh*, 38, 384-394.

VUORELA, I., 1970: 'The indicators of farming in pollen diagrams from southern Finland.' *Acta. Bot. Fenn.*, 2, 248-273.

VUORELA, I., 1973: 'Relative pollen rain round cultivated fields.' *Acta. Bot. Fenn.*, 102, 1-27.

VUORELA, I., 1975: 'Pollen analysis as a means of tracing settlement history in S.W. Finland.' *Acta. Bot. Fenn.*, 104, 1-48.

WAINWRIGHT, F.T. (ed.), 1955: *The Problem of the Picts*. London.

WAINWRIGHT, F.T., 1963: *The Souterrains of Southern Pictland*. London.

WALKER, D., 1966: 'The late Quaternary history of the Cumberland lowlands.' *Phil. Trans. R. Soc.*, B251, 1-210.

WALKER, D., 1970: 'Direction and rate in some British post-glacial hydroseres', in D. Walker and R.G. West (eds.) *Studies in the Vegetational History of the British Isles. Essays in Honour of Harry Godwin*, 117-139. Cambridge.

WALKER, D., 1972: 'Quantification in historical plant ecology.' *Proc. Ecol. Soc. Aust.*, 6, 91-104.

WALKER, F., 1961: *Tayside Geology*. Dundee.

WALKER, M.J.C ., 1974: 'Lateglacial and Early Postglacial Environments in Part of the Grampian Highlands of Scotland.' *Unpub. Ph.D. Thesis*, University of Edinburgh.

WALKER, M.J.C., 1975a: 'Late Glacial and Early Postglacial environmental history of the central Grampian Highlands, Scotland.' *Jour. of Biogeog.*, 2, 265-284.

WALKER, M.J.C ., 1975b: 'Two Lateglacial pollen diagrams from the eastern Grampian Highlands of Scotland.' *Pollen Spores*, 17, 67-92.

WALKER, M.J.C., 1977: 'Corrydon: a lateglacial profile from Glenshee, South East Grampian Highlands, Scotland.' *Pollen Spores*, 19, 391-406.

WALKER, M.J.C. and LOWE, J.J., 1977: 'Postglacial environmental history of Rannoch Moor, Scotland. I. Three pollen diagrams from the Kingshouse area.' *Jour. of Biogeog.*, 4, 333-351.

WATTS, W.A., 1961: 'Post-Atlantic forests in Ireland.' Proc. Linn. Soc. Lond., 172, 33-38.

WATTS, W.A., 1963: 'Late-glacial pollen zones in western Ireland.' Ir. Geogr., 4, 367-376.

WEBB, T.,III, 1974: 'Corresponding patterns of pollen and vegetation in Lower Michigan: a comparison of quantitative data.' Ecology, 55, 17-28.

WELIN, E., ENGSTRAND, L. and VACZY,S., 1972: 'Institute of Geological Sciences Radiocarbon Dates II.' Radiocarbon, 14, 140-144.

WEST, R.G., 1970: 'Pollen zones in the Pleistocene of Great Britain and their correlation.' New Phytol., 69, 1179-1183.

WEST, R.G., 1973: 'Introduction', in H.J.B. Birks and R.G. West (eds.) Quaternary Plant Ecology, 1-3. Oxford.

WHITTINGTON, G., 1973: 'Scottish Field Systems', in A.R.H. Baker and R.A. Butlin (eds.) Studies of Field Systems in the British Isles, 530-579.

WHITTINGTON, G., 1974-1975: 'Placenames and the settlement pattern of dark-age Scotland.' Proc. Soc. Ant. Scot., 106, 99-110.

WHITTINGTON, G., CASELDINE, C.J. and BOGDAN, N.Q., 1976: 'A discovery of Medieval Plough-Marks in St. Andrews.' Scott. Studies, 20, 109-116.

WHITTINGTON, G. and SOULSBY, J.A., 1968: 'A preliminary report on an investigation into pit placenames.' Scott. Geogr. Mag., 84, 117-125.

WRIGHT, H.E., 1967: 'The use of surface samples in Quaternary pollen analysis.' Rev. Palaeobotan. Palynol., 2, 321-330.

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