A PALAEOECOLOGICAL STUDY OF CORS GYFELOG AND TRE'R GOF: LOWLAND MIRES IN NORTH WEST WALES.

By

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I certify:

(i) That the greater portion of the work submitted in the above thesis has been done subsequent to my registration for the degree of Ph.D.

(ii) That the above thesis is my own account of my own research.

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To the Marys:

My mother, Mary Warbis (Carpenter),

and in memory of

my grandmother, Mary Carpenter (Gillespie).

ABSTRACT

This study investigates post-Glacial development of Cors Gyfelog and Tre'r Gof - lowland mires in north west Wales - and the vegetational history of the region over the same period. Using existing hydroseral theories, possible future successions are predicted, their desirablility from conservation viewpoints, and whether management might be considered necessary.

Peat stratigraphy records vegetational changes at the two sites, supported by pollen analysis, which also reveals regional developments. Additionally, correlations are attempted between variations in peat chemistry and mineral content, and mire vegetational changes shown by the other techniques.

Results from Cors Gyfelog indicate central parts of the mire were of early post-Glacial lacustrine origin, but terrestrialisation followed quickly. The wetland area expanded during the Atlantic period. Pollen and biostratigraphy indicate fluctuations between poor-fen and alder carr until the sub-Atlantic, when there was reedswamp and incipient valley bog, before general succession to sedge fen. Latterly, probably following minor drainage attempts, conditions have become drier, and large areas are now dominated by *Molinia* or *Salix*.

Tre'r Gof history spans the post-Glacial. Until *c.*4000 B.P., conditions were lacustrine, with calcareous waters deriving from shelly Irish Sea till. Surrounding wet meadow succeeded to carr. With terrestrialisation, the mire became rich fen. Southern parts of the mire have recently been affected by drainage, leaving drier grassland areas and small patches of carr, although with some very wet patches.

Whilst research on British mires suggests that eventual domination by *Sphagnum* mosses is normal, this does not appear to be happening here. Drainage attempts, however, could raise surface vegetation above the water table, away from nutrient-rich waters, and allow ombrotrophic *Sphagnum* growth. Alternatively, carr may spread and dominate, particularly at Cors Gyfelog. It is suggested that neither would be desirable, so frequent monitoring should be conducted, unwanted carr removed, and water levels manipulated to prevent excessive drying.

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INTRODUCTION

Natural habitats of all kinds are disappearing all over the world. Wildlife destruction by man has been occurring ever since he first began to understand how to manipulate nature to benefit his own purposes, but now the population of the world is greater than ever before, and the technology exists for man to control the surface of the planet on a scale which has never been possible in the past.

In developed countries, large percentages of the population have become so removed from contact with the natural world that they hardly realise that wildernesses still exist, and even fewer recognise the rôle of nature in understanding the history of or present-day setting for the human race. Many city dwellers in Britain never step outside their concrete jungles, and many more think that fields and hedges constitute "natural countryside". On the other hand, as wildlife destruction has continued, leaving only small areas of natural, or even semi-natural land in most of the more developed countries, some sections of the community have became aware of the irreplacability of destroyed ecosystems, and have suggested that there is a need and a duty to preserve and carefully manage those that are left.

Wetlands have long been targets for destruction, mainly by way of drainage for agriculture. Only recently have they become recognised as important areas for scientific study, as well as having cultural, educational, leisure and commercial value (Ratcliffe & Hattey, 1982). Conservation has, since the 1960s, been discussed on an international scale. Projects, such as the 1970 UNESCO (United Nations Educational and Cultural Organisation) Man and the Biosphere (MAB) scheme have been launched in an effort to preserve natural areas throughout the world (Usher 1986), aided by the publication of the World Conservation Strategy (International Union for the Conservation of Nature and Natural Resources (IUCN), (1980). Regarding wetlands, the Ramsar Convention of 1971 urged governments to encourage wetland conservation. Through UNESCO, twenty-nine countries had signed the convention by 1980 (Etherington, 1983), and, by April 1982, the total was thirty-three. The Council of Europe in 1976 brought matters down to a continental level with the European Wetlands Campaign (Ratcliffe & Hattey op. cit.).

In the United Kingdom at that time, a degree of protection was afforded to some major wildlife habitats by way of such systems as National Nature Reserves and National Parks, but such protection was not nearly enough to stem the tide of destruction which had been taking place, especially since the end of the Second World War, to further the interests of agriculture, forestry, water and mineral extraction and, of course, urban expansion.

In the second half of the 1970s, there was a major campaign in Britain, with the Nature Conservancy Council (NCC) taking a leading rôle, to educate the public in matters of conservation, to promote liaison between competing land users, and to define, pinpoint and survey wildlife habitats. The Nature Conservation Review (NCR) (Ratcliffe, 1977) was a major publication in which many ecosystems were defined, the British Isles divided into regions, and a grading system used to identify the most important remaining examples of the defined ecosystems in each region. Under this system, Grade 2 indicated that the site in question was a major representative of a certain habitat type, Grade 1 signified national importance, and Grade 1* referred to habitats of international importance. However, such status gave no legal protection, nor at that time did the system of Sites of Special Scientific Interest (SSSI). In Wales, for instance, several wetland sites graded under the NCR system were damaged after the publication of the Review, and in north Wales at least, an acquisition policy was established for NCR wetlands (Ratcliffe & Hattey, op. cit.).

At the same time, the NCC began to pursue what they considered to be their other task regarding wetlands in Wales - to find and assess further sites of value. The Council estimated that between 1910 and 1978, more than 36% of Welsh wetlands had been destroyed, and the real total was feared to be much higher, because of the loss of sites which had never even been identified. It was in this context that the Wales Wetland Survey (WWS) was initiated in 1977. Because of limitations in the survey budget, it was decided to concentrate on lowland wetlands, the limit being 800 ft (243m) O.D. The survey adopted a two-tier approach, firstly roughly assessing all identifiable lowland wetland areas (over 700) for type, hydrological status and degree of damage. In the following two years, 177 of these sites were surveyed in detail using a classification system which was to provide the framework for subsequent surveys. In North Wales, 83 sites were intensively studied as part of the WWS, 41 by the NCC Wales Field Unit (WFU) in 1983, and further sites in Anglesey by the North Wales Naturalists Trust also in 1983. Some of the latter two surveys included mires not pinpointed by the WWS. Some sites remain unsurveyed.

From the detailed surveys, the WWS grouped mires into 11 categories, and subsequently into six larger ones (Table 1). This afforded the same degree of precision as the NCR classifications, except on floristic, rather than hydromorphic grounds. NCR criteria such as typicalness, naturalness, recorded history and intrinsic appeal were all used as components of a scoring system for each mire. Depending on how rare or otherwise the floristic type as a whole was considered to be, a certain number of sites in each selection area were recommended within each group for designation (or renotification) as SSSIs under the new Wildlife and the Countryside Act (1981) (W & C Act). In the West Gwynedd selection area, for example, Types A,B,C and E were considered to be non-rare (sic.) but threatened, and the guidelines were that more than one, but no more than five

WWS Site Classification		WWS Site Evaluation	
Type I	Oligotrophic sites with Sphagnum lawns	Type B	Acid topogenous mires
Type II	Ombrotrophic mires	Type A	Ombrotrophic mires
Type III	Raised mires	Type A	Ombrotrophic mires
Type IV	Molinia -Juncus and poor fen	Type C	Northern mesotrophic mires
Type V	Wet heaths/acid mires with Molinia-Juncus	Type B	Acid topogenous mires
Type VI	Base-rich fens with Molinia development	Type D	Rich Fens
Type VII	Fen meadow with Molinia-Juncus and poor fen	Type C	Northern mesotrophic mires
TypeVIII	Fen meadow and tall fen	Type E	Southern mesotrophic mires
Type IX	Base rich fens	Type D	Rich Fens
Type X	Phraqmites australis reed beds	Type E	Southern mesotrophic mires
Type XI	Glyreria maxima reedswamp	Type F	Glyceria maxima reedswamp

Table 1. Mire Classifications

(Wales Wetlands Survey
After Ratcliffe & Hattey, 1982,
NCC Wales Field Unit, 1984).

sites should be recommended for SSSI designation, whereas Type D was considered to be both rare and threatened, and thus all viable examples should be selected (Ratcliffe & Hattey, op. cit., NCC (WFU), 1984). In fact, some sites previously notified as SSSIs which had been damaged prior to the introduction of the W & C Act were actually recommended for denotification under the survey.

Under the terms of the W & C Act, owners of land designated or redesignated as SSSIs must be notified of its status. Having been so notified, the landowners are then precluded from carrying out operations detrimental to the wildlife value of the site, but are eligible to be compensated for loss of earnings which would have been received had the land been agriculturally improved.

A major feature of the selection of wetlands for SSSI status, however, is that criteria are based upon extant vegetation, relating to one small moment in time, i.e. now, whereas the mires which have been surveyed may have histories which span the whole of the post-glacial period, and may be in a state of succession, not prevailing climax. Perhaps history should be taken into consideration when wetlands are evaluated, and questions asked along the following lines:

Is the mire very old?
Were the conditions which led to peat initiation natural or (albeit inadvertently) man-made?
Has succession been wholly natural or affected by

man?

How long has the mire been at its current stage of development?

Are successional changes likely to occur? If so, can the next vegetational stage be predicted?

How long is it likely to be before change occurs?

Will succession make the mire more or less valuable in conservation terms?

If succession is undesirable, can it be prevented by management? Can succession be reversed?

The concept of hydroseral succession is a feature of standard textbook ecology. Whilst Clements (1916) is accredited with the formulation of the first modern-style hydrosere theory, the concepts of Tansley (1939) are most often quoted. According to Tansley, submerged soils at the margins of lakes or rivers are colonised by hydrophytes, and subsequently by bulrushes and other aquatic macrophytes. Products of decay accumulate, and the submerged "soil" surface rises above the water, allowing water and marsh plants to get a foothold. Shrubs and trees which are tolerant of saturated soils eventually establish, and form carr woodland. From time to time, the raising of the surface by organic deposition will be assisted by mineral inwashes during flooding episodes. Sooner or later the soil will be sufficiently above the water table to dry out, allowing colonisation by trees of dry land, and climax woodland will ultimately follow. Tansley also acknowledged that, in conditions of oceanic climate, succession could be deflected towards bog.

The theory of hydroseral succession was initially based upon the observation of zonation on aquatic fringes, and incorporated the intrusion of allogenic materials, i.e. mineral inwashes, as precipitating factors. Walker (1970) sought to investigate whether peat stratigraphical changes might confirm vertically what was observed spatially. In particular, he sought answers to the following questions:

> "1. To what extent does the commonly observed zonation: submerged macrophytes, floating-leaved macrophytes, reedswamp, fen, fen carr, and its variants, parallel an autogenic succession?
> 2. To what degree, at which points, and under which conditions, may such a succession be deflected?
> 3. At what rates do hydroseres progress?
> 4. To what terminal vegetation types have hydroseres led and how stable have these proved under Post-glacial environmental conditions?"
>
> (p.119)

Walker relied on the published work of other palaeoecologists and palaeohydrologists for his study. The records were, as much as possible, from topogeneous (drainage-fed) mires, and he purposely took no account of basin rock or soil types, nor of geographical location. He concentrated on sites which indicated sedentary, rather than sedimentary, deposits, which he placed into three categories:

a. Small inland basins (Maximum flooded diameter <0.5km)

b. Large inland basins (Maximum flooded diameter >0.5km)

c. Areas of impeded drainage in coastal or estuarine locations

He defined twelve vegetational units (Table 2), and constructed a series of arrow diagrams to show the frequency

2.	Microorganisms in open water
3.	Totally submerged (or only flowers emerged) macrophytes (e.g. Myriophyllum spp., Littorella uniflora, Potamogeton spp.).
4.	Floating-leaved macrophytes, usually with some intervening open water (e.g. Nymphaea alba, Potamogeton natans).
5.	Reedswamp, rooted in the substratum and standing in in more-or-less perennial water, with aerial shoots and leaves (e.g. Phragmites communis, Schoenoplectus lacustris, Carex rostrata).
6.	Sedge tussock, rooted in the substratum and standing in more or less perennial water (e.g. Carex paniculata, C. acutiformis).
7.	Fen, dominated by grasses (e.g. Phragmites communis, Molinia caerulea) or sedges (e.g. Carex flava, C. nigra) with a variety of acid-intolerant herbs (e.g. Comarum palustre, Filipendula ulmaria, Valeriana dioica), all rooting in organic deposits which are waterlogged for the greater part of the year.
8.	Swamp carr formed by trees (e.g. Salix atrocinerea, Alnus glutinosa) growing on unstable sedge tussocks with some fen herbs, the intervening pools often harbouring thin reedswamp or floating-leaved macrophytes.
9.	Fen carr, dominated by trees (e.g. Alnus glutinosa, Frangula alnus, Betula pubescens, Fraxinus excelsior) with an undergrowth rich in fen herbs and ferns (e.g. Thelypteris palustris), all rooting in a physically stable peat mass.
10.	Aquatic Sphagna, floating very closely below or on the water surface (e.g. S. subsecundum, S.cymbifolium).
11.	Bog, usually distinguished by a variety of Sphagnum species (notably S. palustre and S.imbricatum) and acid-intolerant phanerogams (e.g. Oxycoccus quadripatelus, Erica tetralix, Myrica gale, Eriophorum spp.) growing in an organic substratum.
12.	Marsh, composed of "fen" species (e.g. Filipendula ulmaria, Eleocharis palustris) growing on water-logged mineral soil.

Table 2. Stages of Hydroseral Succession. (After Walker, 1970).

of successional routes for the three categories, separately and combined. Using records from available pollen diagrams, he calculated the duration of different successional stages at the sample mires, and also estimated peat accumulation rates. Dating was based partly on the comparison of tree pollen spectra with standard zonations (Sensu. Godwin 1956) and, in some cases, directly from radiocarbon dates. His conclusions include the following:

> Change has predominated over stability in the Post-glacial period.
>
> Autogenic change is predominantly progressive.
>
> Successional paths are very varied. Predictions can only be made on the basis of probability.
>
> Succession cannot begin until the body of water is sufficiently shallow to support floating-leaved macrophytes.
>
> Reedswamp forms a pivot between essentially aquatic and terrestrial ecosystems.
>
> Many transitions are gradual. Rapid ones are often the product of allogenic factors.
>
> Different successional stages tend to have predictable timespans.
>
> Once a hydrosere is initiated to the floating-leaved macrophyte stage, conversion to fen may be less than 1000 years, rarely more than 2000 years. Succession from macrophytes to bog may be equally rapid but, if fen intervenes, more like 2500-4000 years.

The modal rate of peat accumulation is 21-60cm/ 1000yr-1.

Data indicate that Sphagnum can intervene at any of several stages of succession and, having done so, will drive subsequent succession towards bog.

Sphagnum bog, rather than climax forest, appears to be the ultimate stage in the succession of wetlands in the United Kingdom.

Aims

Walker suggested that, although individual paths may be different, a wetland free from external influences is likely to follow a successional path leading from the wetter to the drier, but always with the possibility of the intervention of Sphagnum and the onset of raised mire conditions. The aim of this thesis is apply Walker's theories to two contrasting SSSI wetland sites in north west Wales. The mires are both within the area served by the NCC's Bangor station, from whence has come supervision by way of assistance in site selection, access to documentation, and funds for fieldwork.

As discussed below, this study falls into the category of "descriptive palaeoecology" (Birks & Birks, 1980), and uses multiple working hypotheses. Walker, for example, referred to the selection of mires free from external influences. It is felt that, in the absence of visible evidence of peat extraction or other destruction or modification, ascertaining whether there have been past external influences is actually part of the operation. It must also be accepted that very few wetlands exist in the United Kingdom, let alone north west Wales, which do not show some sign of human influence, especially by way of drainage. On this basis, the interpretation of Walker's thesis may need to be modified somewhat to include the assumption that if succession has obviously been diverted, and its causes and course are detectable by palaeoecological methods, then the supposition will be made that succession recommences from the stage reached after the disruption.

Investigation of past events relating to the two selected mires, Cors Gyfelog in the Lleyn Peninsula and Tre'r Gof in Anglesey (Figure 1), will enable parallels or otherwise to be drawn with the developmental histories of other wetlands in Wales. It is hoped that data obtained will also aid predictions regarding future vegetational developments on the two mires under study, and allow discussions regarding whether they are likely to retain SSSI status in the long term, i.e. whether they are likely to become more or less important for conservation purposes. If deterioration is likely, management proposals may be necessary.

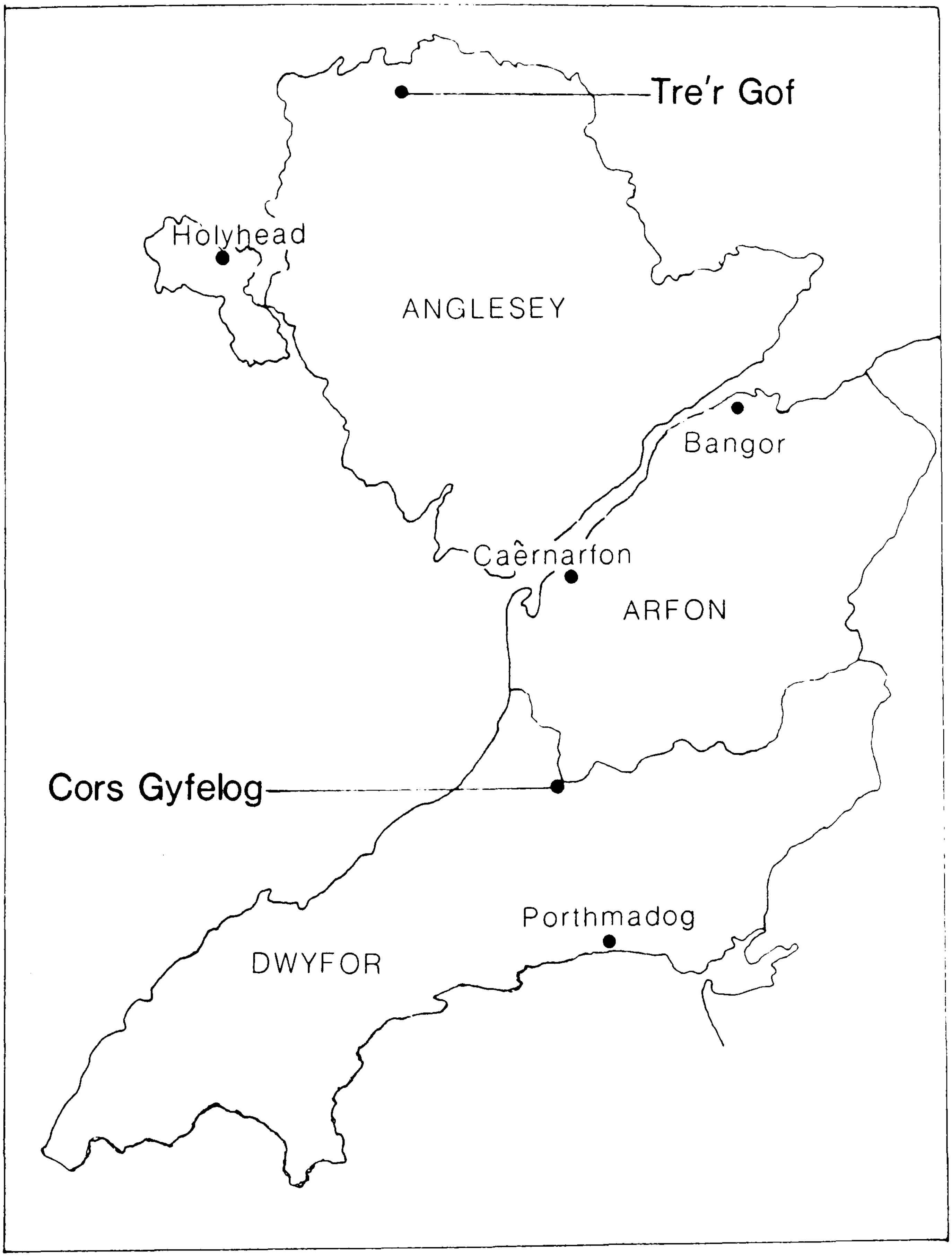


Figure 1 North Wales showing the locations of Cors Gyfelog and Tre'r Gof

Methodology

Introduction

Palaeoecological studies may be undertaken to provide information in a number of fields, including historical biogeography, cultural landscape ecology, palaeobotany, vegetational history and palaeoclimatology. It is not always easy to define into which of these sub-disciplines a study actually falls. Although the main strand of this thesis is directed towards tracing the vegetational development of the two mires under study, to undertake such an exercise without taking into consideration natural and cultural events affecting the whole of both catchments, influencing in turn the hydrological balance of the mires, would be foolhardy. The study therefore includes elements of several sub-disciplines, but the methological considerations which underlie palaeoecological investigations are generally applicable to all the pollen-based studies.

Approaches

Palaeoecology, which may be defines as the study and understanding of relationships between past organisms and the environment in which they lived, may be contrasted with ecology, which is the study and understanding of complex relationships between living organisms and their present environment. There are major differences in approach between the two disciplines. Ecologists, for instance, can select which organisms they wish to study, can operate within well-defined boundaries of space and time, can plan and repeat observations, and can use a wide range of sampling strategies. Palaeoecologists, on the other hand, have to rely on preserved material, they have to accept evidence from wherever it can be found, and then attempt to say what it represents and to explain its origin. A palaeoecological observation, although comparable with other observations, is not repeatable, and the sampling strategies of a palaeoecologist are limited.

Heck and McCoy (1979), made a comment regarding historical biogeography which is also applicable to palaeoecology, namely "It is often difficult, if not impossible in some instances, to present valid and accurate palaeoecological interpretations as realistic, falsifiable hypotheses". Their approach, largely followed in this thesis, is to accumulate all available data without any _a priori_ assumptions, and then to select from multiple causal explanations which one is most consistent with the available evidence. This is analogous to the "multiple working hypothesis" approach of Chamberlain (1965, 1980), and, it is argued, results in an eventual explanation much closer to the truth than would result if only one explanation was considered, and then developed into a hypothesis and later a theory.

Assumptions

Fossil plant and animal remains have formed the cornerstone of Quaternary environmental reconstructions. Uniformitarian principles ("The present is the key to the past") have generally been followed. Whether approaches in such investigations are quantitative, hypothesis-testing, or descriptive and narrative, certain assumptions have to be made regarding the material under investigation, and about modern ecological knowledge.

Lowe and Walker (1984) list such assumptions as follows:-

1. That we fully understand and can isolate environmental parameters governing present-day plant and animal distributions.
2. That present distributions are in equilibrium with controlling variables.
3. That former plant and animal distributions were in equilibrium with their environmental controls.
4. That former plant and animal distributions have analogues in modern flora and fauna.
5. That ecological affinities of plants and animals have not changed through time.
6. That a fossil assemblage is representative of the death assemblage and has not been biased by differential destruction of its original parts or contamination by older or younger material.

7. That the origin of the fossil assemblage (taphonomy) can be established.

8. That the fossil remains can be identified to a sufficiently low taxonomic level to enable uniformitarian principles to be applied.

The authors suggest that the number of above assumptions which can be satisfied depends upon the type of evidence, but rarely can all be met at once. The assumptions inherent in this thesis are generally in line with those of Lowe and Walker, but with the following exceptions:-

1. Uniformitarian principles tend to assume gradual vegetational development and succession. Modern trends are towards greater appreciation of catastrophic events as agents of change. Recent episodes, such as the 1987 hurricane in south-east England, and several freak storms in various parts of the world in 1988, may well mark the boundaries of pollen zones in future palaeoecological studies. Comparable events may have precipitated past vegetational change.

2. The author is aware that some researchers have expressed doubts as to whether some Late-Glacial assemblages have modern analogues. It is, however, felt that this in itself does not prevent the recognition in a pollen diagram of spectra which can be assumed to represent Late-Glacial vegetation.

3. Mid-Flandrian vegetational communities can be recognised in pollen diagrams. This does not, however,

necessarily mean that pollen spectra from modern, anthropogenically-manipulated vegetation directly compare with those representing the earlier, more natural assemblages.

Pollen Analysis

Pollen analysis remains the most widely adopted and successful technique of Quaternary vegetational reconstruction. It was developed in Scandinavia at the turn of the century, and spread to other European countries after the First World War. The main approach to pollen analysis is still descriptive and inductive, which may be a consequence of its European origin, although much pollen work is now carried out in the United States. There have indeed been attempts to introduce more quantitative and deductive approaches to pollen analysis since the 1960s, for example by Birks (Birks & Birks, 1980 Birks, Birks, Kaland & Moe, 1988), but with only a limited amount of success. The general desire by palaeoecologists to continue using techniques which in many fields would be considered characteristic of an immature science is, however, by no means due to inertia but, as mentioned above, greatly influenced by the nature of the material with which palaeoecologists are forced to work.

In pollen analysis, certain basic principles are assumed (Birks & Birks, (Op. cit.), several of which modify the general palaeoecological assumptions listed above:-

1. Pollen and spores are produced in abundance.

2. Very few grains fulfil their natural function, the rest fall to the ground.

3. They decay unless conditions are anoxic.

4. Before reaching the ground, grains are mixed by atmospheric turbulence, resulting in a uniform pollen rain.

5.Proportions of pollen types depend on the number of parent plants, and pollen rain is therefore a function of vegetational composition at that time.

6. Pollen grains are identifiable to various taxonomic levels.

7. If a sample is taken from peat or mud of a known age, the spectrum shows the vegetation at a particular point in time.

8. If pollen spectra are obtained from several levels through the sediment, they provide a picture of the vegetation and its development at that place through the length of time represented by the sediments.

9. If cores are taken from several sites, changes can be compared.

Most of the above assumptions have been accepted for this thesis, but certain comments are considered necessary (points are numbered as above):-

1. Although pollen and spores are produced in abundance, different plants have various pollen production

strategies. Most of the recorded pollen is likely to be wind-blown (anemophilous). Because wind-pollination is a chancy strategy, pollen from plants relying on this method of fertilisation is produced in large amounts. Grains tend to be light and smooth (or, in the case of conifers, to have bladders), and thus have the potential to be carried long distances. Zoophilous pollen (carried by animals) or entomophilous grains (carried by insects) are generally produced in smaller quantities than anemophilous pollen, and the grains are relatively lumpy, heavy and sticky, although there is much specific variation. Tilia cordata (lime) and Calluna vulgaris (ling), and both insect pollinated, but both produce grains in large numbers. Other plants, such as cereals, are self-pollinating (autogamous), requiring a smaller investment in pollen. The ultimate degree on self-pollination is cleistogamy (as in Viola species), where pollen does not leave the flower.

3. Pollen is best preserved in waterlogged or acidic conditions, but can be found in other situations. The author wishes to suggest, however, and discusses in the various pollen interpretational sections, that preferential destruction of grains occurs where conditions for preservation are not wholly favourable, and that some taxa are easier to recognise in a damaged condition than are others.

4. The pollen rain principle is rather generalised, and is largely dependent upon the location from where pollen is extracted. Tauber (1967) proposed a general model of

forest pollen dispersal which suggests that grains originating in the trunk space of a forest tend to be trapped there and form only a minor part of the generally circulating pollen. Much depends, however, on the relative importance of regional and local pollen elements. Jacobson & Bradshaw (1980) suggest that the relative proportions of local and extra-local grains in a sample depend on the size of the site from which it was extracted. The character of the site, however, is also important. As an example, a sample taken from the middle of a lake 1km in diameter is likely to contain mainly regional pollen, because no plants will have been growing within 0.5km of the sampling point. At the other extreme, pollen taken from a small terrestrial mire (for example an infilled pond) in the middle of a forest is likely to contain little in the way of "general" pollen rain, but to have a large local component, both from the surrounding trees and from the mire plants themselves. Pollen taken from the centre of a large terrestrial mire (e.g. Cors Gyfelog) would be likely to contain both regional and extra-local elements, but a profile taken from the edge of the same mire would be likely to contain much extra-local and local pollen, but have a relatively minor regional component.

5. Researchers such as Pohl (1937) suggest that, in the production of a pollen diagram, certain multiplication factors may be employed to account for differential arboreal pollen production.

6. Problems associated with the identification of pollen to different taxonomic levels are discussed in the section relating to pollen diagram construction in Chapter Two.

7. There is a possibility that older or younger sediments may have been mixed into the deposit by, say, burrowing animals, or that grains may have moved vertically or laterally after deposition.

9. Comparison of changes in pollen spectra in profiles taken from several locations is employed extensively in this thesis, partly in an attempt to compare overall vegetational changes in north Wales, but particularly in trying to distinguish ultra-local events from general changes.

Other techniques

Assumptions made in palaeoecology and pollen analysis may appear very crude to those whose science allows a greater degree of exactitude. It is, however, normal for several techniques to be used simultaneously in palaeoenvironmental reconstruction, partly because data obtained by using one technique may be inconclusive, and partly to enable the construction of a fuller picture. This, as seen in the discussion chapter of this thesis, may not only assist the formulation of explanations relating to the actual problem under consideration, but also may also allow comments to be made in connection with other lines of palaeoecological research, although without the obligation to take such discussion any further.

Dating Techniques

Dating techniques are central to palaeoecological reconstruction. Early dating was on a relative basis, and essentially showed an order of events in a particular location. A combination of techniques, especially pollen analysis and biostratigraphy, showed some features, such as the elm decline and the grenzhorizont, to be of widespread occurrence, and as such were originally considered to be synchronous. More recently, the wide application of 14C dating techniques has allowed the absolute dating of profiles, and has shown that events previously thought to be synchronous are not necessarily so. Even 14C dating cannot completely be relied upon, however. Apart from the practical problems of avoiding natural or accidental contamination of samples, phenomena known as Suess' wiggles can cause dating ambiguities of up to 200 years, and are most marked in samples more than 2000 years old. Dendrochronological calibration tables are available, but tend to be used with only a limited degree of confidence. dates are calculated only within confidence limits, with the inherent implication that the true date may be outside these limits. It is certainly to obtain a sequence of dates for a profile, rather than just a single one.

Chemical Analysis

Although several studies which include peat chemical analysis have been carried out over the past twenty-five years (e.g. Chapman, 1964 Green & Pearson, 1977), it is the current work of Ross which is likely to provide the guidelines and the assumptions upon which future peat chemical research will be based. Ross (Pers. comm.) proposes that the total inorganic chemical content of plant litter and the peat formed from it depend upon the type of species colonising a wetland habitat, which themselves are controlled by pH and nutrient conditions. Plants rooted in sub-peat mineral substrates bring up elements and introduce them into peat layers during decay. As an extension of this, Ross proposes that different peat types can be characterised on the basis of their total inorganic chemistry.

Previous whole profile chemical analyses have tended to be from peats at the oligotrophic end of the spectrum. Although Ross has studied oligotrophic peat from the Isle of Islay, she has also used rich fen data from the Somerset levels (Heathwaite & Ross, 1987), and some of the author's own data from Cors Gyfelog, in an attempt to distinguish between the chemical spectra of peat types of different trophic richness. Her initial conclusions appear to be that overall concentrations of elements tend to rise with trophic status, that nitrogen levels tend to relate to the percentage of organic matter in a sample, and stay relatively constant whatever the trophic status, and that sodium appears to be related to environmental inputs, whilst calcium, potassium, phosphorus and magnesium levels are thought to be connected with mineral weathering.

The chemical work in this thesis was undertaken under the guidance (but not the supervision) of Ross, and was at least in part intended to test whether her ideas could be of general application. Whereas Ross's work has tended to be concerned only with surface peat studies, this thesis looks further into the question of whether successional changes in mesotrophic and eutrophic mires are accompanied by changes in peat chemical spectra.

CHAPTER TWO

METHODS

Cores were taken from a total of four locations, two at each mire, and subjected to laboratory pollen and chemical analyses. Whilst it was also originally hoped to carry out macrofossil analyses, this idea was abandoned for several reasons. Firstly, full macrofossil analysis is very time consuming and it was realised that it would not be possible to undertake all three analyses at both sites in the allotted period. An alternative would have been to include macrofossil analysis, but to concentrate on one site only. However, large amounts of material are necessary for macrofossil analysis, and water tables on both mires are too high to allow digging for the removal of material in monolith boxes. Additionally, the peats are too unconsolidated for the use of a large capacity piston corer (cf. Walker, 1982a). The only other possibility was to remove a series of cores from each location with a smaller borer. It was already realised that multi-coring would have to be used to provide enough material for pollen and chemical analyses, loss on ignition and 14C dating and it was felt that there were limits to the amount of disturbance that could be made at any one point without causing lasting damage. Certainly, in the case of Tre'r Gof, the NCC were anxious to keep disturbance and trampling to a minimum and it is unlikely that permission would have been granted for such extractions.

Nomenclature

The coring locations and extracted profiles were given code letters as follows:

Location	Code	Profile	Code	Site Description
Cors Gyfelog	GYF	Central	GYFC	Valley mire
Cors Gyfelog	GYF	Peripheral	GYFP	Valley mire
Tre'r Gof	TRG	Main	TRGM	Basin mire
Tre'r Gof	TRG	Subsidiary	TRGS	Basin mire

Field Stratigraphy

Stratigraphical profiles were drawn up for both mires. Sampling was carried out with a standard Jowsey corer. At each site, two transects were made at right angles to each other, with additional smaller transects at TRG (See Figure 5, Chapter 3, and Figure 12, Chapter 4). Surface levelling was carried out at all profiling points, using an automatic level.

Field Sampling for Laboratory Analysis

Samples for laboratory analysis were taken using a modified Jowsey borer of 7cm diameter, as opposed to the standard 5cm. The borer was copied by the Keele University workshop from one designed and used at UC, Cardiff. Profile TRGS was originally taken for exploratory purposes only, and a standard Jowsey sampler used. Only later was it decided to analyse the material and construct a "skeleton" pollen diagram. The standard procedure of extracting cores from alternating holes at each location was adhered to, each 50cm sample then being transferred to a length of plastic guttering and enclosed in polythene tubing for transport. Whilst awaiting laboratory sampling, cores were stored at Keele University in a cool, dark (but not refrigerated) place.

Laboratory Sampling

All stored cores were carefully cleaned prior to subsampling. In the case of TRGS, subsamples of 0.5cm3 were removed at 32cm intervals without further cutting of the core. Material for pollen and chemical analyses, and loss on ignition tests from the other three locations was cut horizontally into 0.5cm slices, those for each centimetre being designated + or - for speed in labelling and ease in subsequent recognition (e.g. GYFC196+, GYFC196-). From one set of cores at each location, subsamples of 0.5cm3 were taken from every slice and stored in corked, labelled storage tubes, so although pollen analysis was normally carried out at 4cm intervals, material was available for closer sampling if necessary. The remaining cleaned material was oven dried at 50oC and stored in labelled polythene bags for the other analyses.

Separate cores were used for 14C dating, four from each of the GYF profiles, and two from TRGM. The GYF cores, after cleaning, were cut into 1cm slices. When pollen analysis had pinpointed horizons for which dates were required, slices for each core at those levels were combined to give corresponding samples weighing approximately 100g, each covering 2cm depth. The samples were stored in double polythene bags, which were enclosed in jiffy bags for postage to the dating laboratories. As the TRGM profile was approximately twice the length of either of those from GYF, it was decided that 4cm lengths from two cores at this site would cover a time span roughly equivalent to 2cm at GYF. Otherwise, preparation was carried out in the same way as for GYF.

Pollen Extraction

The established preparation technique (Faegri and Iversen, 1975) was used. This involved deflocculation in 10% sodium (or potassium) hydroxide solution, sieving, acetylation in a 9:1 acetic anhydride/sulphuric acid mixture (Erdtman, 1943), followed by dehydration in alcohol and finally mounting in silicone fluid of 2000cs, as recommended by Andersen (1960). Mineral matter, if present, was removed where possible by decanting samples between beakers after sieving. Otherwise, treatment with hot hydrofluoric acid (40%) was necessary. The whole procedure essentially followed Barber (1976), but without the solution of carbonates. In addition, two tablets of <u>Lycopodium</u> spores (obtained from Lund University, Sweden) were added to each 0.5cm3 sample for the determination of pollen deposition rates.

Samples from the two GYF sites were stained with liquid safranin, added after acetylation (Cambridge School of identification of problem grains from unstained type-slides more difficult, but facilitated the observation of features in badly corroded grains, which were frequently found in the GYF samples. In many GYF sample preparations, flocculation of pellets was also a major problem. This may have been the result of insufficient dehydration, insufficient rinsing with distilled water following KOH treatment, the addition of Lycopodium spores (Francis & Hall, 1985), or even because of staining. Whatever the reason, staining did help to show up grains in detritus clumps, because pollen grain coats stain a different colour from all other material in a slide, including fungal spores.

Material from Tre'r Gof was always less of a problem. Pollen was more abundant and in better condition, and so staining was not considered necessary. Simultaneously, additional washes with water and alcohol were made when preparing TRG samples, and clumping occurred much less frequently.

In all cases, the larger particles which were retained during the sieving procedure were stored in petri dishes for subsequent scanning.

Samples were counted using either Olympus BHB or Nikon Optiphot X/Y series microscopes at x600 magnification. Both types of microscope were fitted with x15 wide field eyepiece objectives and x40 Apochromat objectives with correction oculars. Both were also equipped with x100 objectives, allowing x1500 magnification for the identification of problem grains.

A total of approximately 500 land plant pollen grains was counted at each horizon if possible. As indicated before, some samples, mostly from Cors Gyfelog, were very badly preserved, and on a number of occasions a smaller sum had to be settled for. Spores of Pteridophytes, *Sphagnum* and *Lycopodium*, and aquatic pollen types such as *Typha*, *Nymphaea* and *Potamogeton* were recorded, but not included in the pollen sum (see below).

Construction of Pollen Diagrams

The sediment stratigraphy from the coring point is shown on the left hand side of each pollen diagram. The symbols (Figure 2) broadly (but not exactly) follow Troels-Smith (1955). The same symbolism has been used for the basin stratigraphy diagrams. Pollen totals for terrestrial higher plants have been shown as percentages of total land pollen (TLP), without the application of any correction factors. Percentages are shown on the diagrams as proportional bars, rounded up or down to the nearest 1%. Occurrences of less than 0.5% are shown as circles in the diagrams, but are referred to as 0% in discussion sections. From left to right the sequence is as follows:

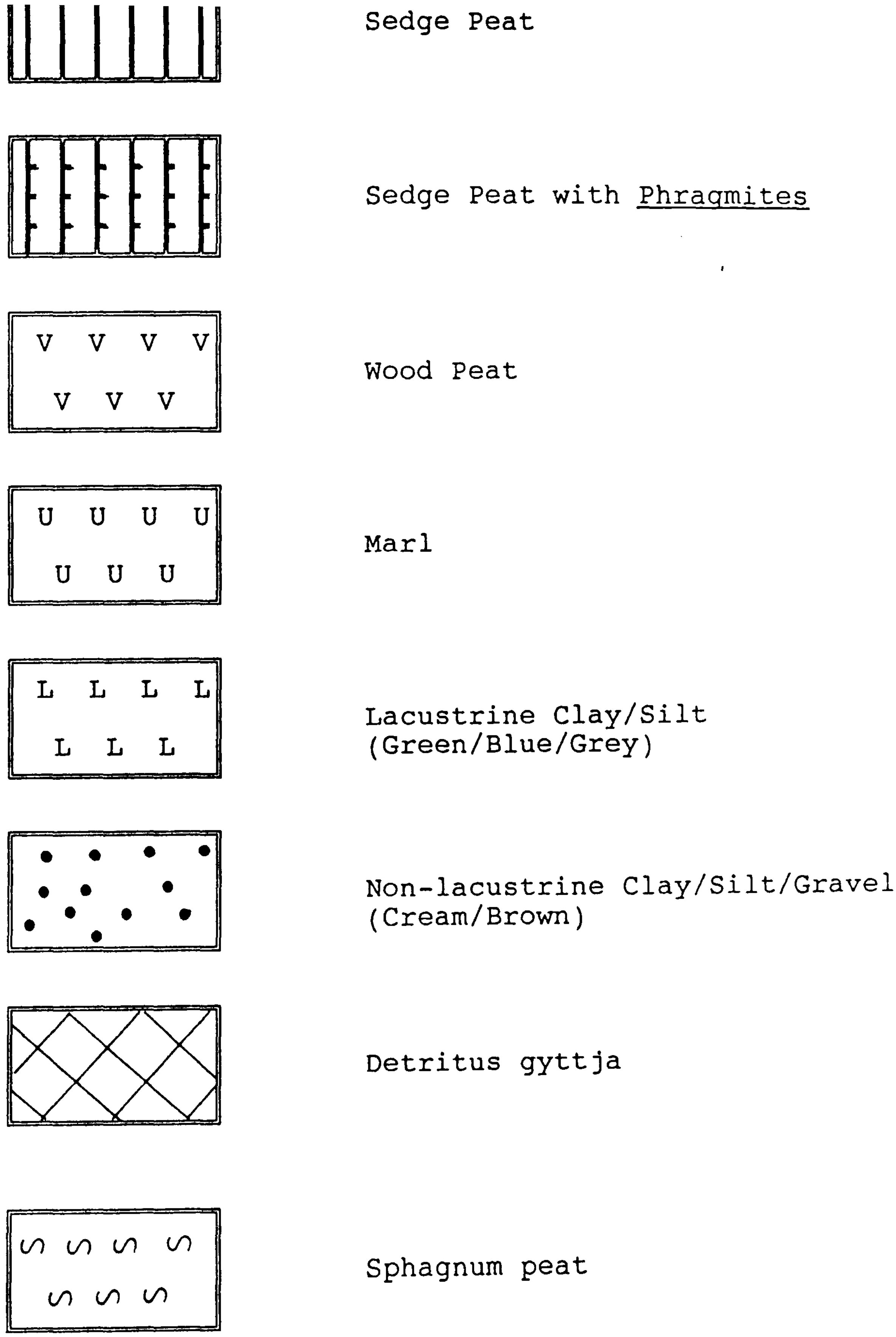


Figure 2. Stratigraphical Symbols
(After Troels-Smith, 1955)

1. Trees. The order of taxa is conventional (cf. Godwin, 1975)

2. Shrubs. Including non-canopy trees such as Salix and Corylus and woody plants such as Hedera and Lonicera.

1. and 2. together constitute the arboreal pollen (AP)

3. Non-arboreal pollen (NAP), i.e. herbs. An attempt has been made to designate NAP taxa to different ecological types, e.g. Umbelliferae (woodland margin), Artemisia (ruderal/arable), Cerealia (arable), Gramineae (pasture), Cyperaceae (mire) (cf. Behre, 1981).

There are, of course, a number of problems associated with trying to group in this way, for instance:

a. Difficulty in splitting taxa, e.g. does Gramineae (pasture) include Phragmites (aquatic margin)?

b. Some taxa contain species with more than one affinity. Rumex acetosa and R. acetosella for instance, were not separated satisfactorily. Even if they had been, the latter aggregate includes species of various ecological affinities.

total, but the Cors Gyfelog peat contains a considerable amount of alder wood. As the species was obviously growing on the mire, should the pollen have been included with trees, which essentially reflect regional events, or with the mire taxa?

Taxa included in the pollen diagram but excluded from the pollen sum, are shown in brackets. They are:

1. Aquatic and marginal aquatic taxa.
2. Moss (Sphagnum) and fern spores.
3. Exotic Lycopodium marker spores.

In order that no non-pollen sum taxon exceeds 100% of the pollen sum, non-pollen sum percentages have been calculated thus:

$$\% \text{ Non-pollen sum taxon} = \frac{\text{Non-pollen sum taxon} \times 100}{\text{pollen} + \text{Non-pollen sum taxon}}$$

(Birks & Birks, 1980)

On the right-hand side of the diagrams are:

1. Tree/shrub/herb ratio (TSH)
2. Radiocarbon dates
3. Pollen zones (phases)

In accordance with convention, the pollen diagrams have been divided into zones for interpretation and discussion purposes. Zonations, based on changes in pollen assemblages, have been made by eye, rather than by computer. The reason for this is that, as there are two diagrams from each mire, attempts have been made to pinpoint diagram similarities and variations and to create common zones for each site. The author felt that hand drawing of pollen diagrams resulted in familiarity with patterns and changes in each diagram, and allowed the detection of features which could be missed by a computer, even if some of the less prominent taxa were weighted.

Radiocarbon dating

Material from both GYF profiles and TRGM was sent for 14C dating. A different laboratory was used for each of the three cores. Five samples from GYFC went to the NERC laboratory at East Kilbride. Although the terms of the CASE studentship included the use of NERC dating facilities, there were in practice various administrative problems. Firstly because of an ever-increasing workload, East Kilbride turnover was taking, at the time of writing, eight months. Before permission for submission of material could be obtained, application had to be made to the NERC council, together with supporting evidence, e.g. a detailed pollen diagram. However, the council only meet twice a year, and not always at regular intervals. So, whilst an application was made, sanctioned, and results obtained in good time in respect of GYFC, the council would not pass the application for TRGM dates on the evidence of a skeleton diagram only. By the time a full diagram was available (mid-January 1988), and thus no hope of an application being sanctioned and processed during the period of the studentship.

Fortunately, sufficient funds were available to allow three TRGM samples to be sent to the Centre for Isotopic Research, Groningen. It is worth noting that not only are the facilities at this laboratory relatively inexpensive and have quite a short turnover time, but also that smaller samples can be dealt with than at either East Kilbride or Cardiff (see below).

The remaining samples, i.e. five from GYFP, went to Dr. P.Q. Dresser at UC, Cardiff. These dates were sponsored by the Gwynedd Archaeological Trust Ltd. (GAT) to help clarify dating of a profile at nearby Cefn Graeanog. Radiocarbon dates for Cefn Graeanog had shown abnormalities and an inversion, and therefore GAT, by obtaining the GYFP dates, hoped to be able to strengthen their own records.

Samples sent for dating coincided where possible with major vegetational events as recorded in the pollen and/or chemical diagrams, e.g. Alnus rational limit, first Plantago record, AP decline/NAP rise, Nitrogen peaks or troughs etc.. In the occasional case where such an event coincided with the end of a core, e.g. at 50, 100, 150cm etc., samples were taken from slightly higher up or lower down so that the possibility of contamination by modern material was reduced.

In each case, it was suggested that the fine particulate fraction (250 m) was dated (Dresser, 1985). As mentioned above, for each GYF sample, material from four cores was recombined to give 2cm sections in an effort to achieve the suggested minimum weight of 100g required by East Kilbride and Cardiff, which was also the estimated maximum sample length which could be used without covering too wide a time span to yield sensible results. As it was, East Kilbride were unable to obtain enough material from the 250 m fraction, and defined instead a maximum limit of 500 m. With TRGM, weight was much less of a problem, because Groningen's minimum requirement was only 40g, and 100g of material, giving the same temporal resolution as the GYF samples, was obtainable from the deeper basin at Tre'r Gof using half as many cores but sample lengths twice as long as for GYF.

Loss on Ignition

At 2cm or 4cm intervals, oven dried samples covering 0.5cm depth were ground and used for the determination of loss on ignition. All the material at these levels which remained after pollen and chemical analyses was used, usually giving a dry weight of <u>circa.</u> 1g. The samples were weighed and put in a furnace at 900 for two hours before being cooled in a desiccator and reweighed. For calculation purposes, known crucible weights were subtracted from the total weights both before and after ashing. Calculations were made as follows:

Loss on ignition (LOI) $= \frac{\text{Dry wt.} - \text{Ash wt.} \times 100}{\text{Dry wt.}}$

Results were then plotted graphically.

Chemical Analysis

All chemical analyses were carried out in the Geography Department of the University of Bristol under the direction of Dr.S.M. Ross. For TRGM and GYFP, material was taken from the same cores as were the pollen samples. In the case of GYFC, a separate, but parallel, set of cores was used.

Material from previously oven-dried 0.5cm slices was ground and passed through a 0.5mm sieve. Sub-samples of 0.15g were then extracted and subjected to acid digestion using a modified microkjeldahl technique with concentrated H_2SO_4 and H_2O_2 (Allen et al, 1974, Ross & Heathwaite, 1984). To the sample in each digestion tube was added 2ml H_2SO_4, the tube heated over a bunsen burner and 3ml of H_2O_2, 1ml at a time, introduced. Following the subsidence of the initial vigorous exothermic reaction, sample tubes were placed in digestion blocks at 340 F (Mark 7). Further additions of 1ml H_2O_2 were made as the initial ones were used up in the digestion process. The blocks were left on overnight in the fume cupboard, and digestion was normally complete by the next morning.

Each of the two digestion blocks was able to hold twelve tubes, giving a total of twenty-four samples per batch, of digestion (when the residue in each tube had turned a milky white without any yellow tinges), the samples were cooled in the fume cupboard until no more fumes were given off. They were then passed through Whatman 42 filter paper into volumetric flasks and made up to 50ml with distilled water before being transferred to glass bottles for storage.

Subsequent analyses were for the determination of total N, P, K+, Na+, Ca++ and Mg++. N and P in solution were determined using automated versions of the colorimetric techniques of Crooke & Simpson (1971) for ammonium ions, and Murphy & Riley (1962) for phosphate (Ross & Heathwaite op. cit.).

For K+ and Na+, flame emission photometry was employed, and for Ca++ and Mg++, atomic absorption spectrophotometry using a Pye Unicam SP9 spectrophotometer. For all Mg++ samples, and Ca++ from GYFP and TRGM, an acetylene flame was used. To each sample 1% La_2O_3 was added to suppress interference. Ca++ samples from GYFC were analysed using a hotter and more sensitive nitrous oxide flame, with 0.1% HCl as a suppressor.

In all cases, analyses were carried out against standard solutions which included H_2SO_4 and, in the cases of Mg++ and Ca++, suppressors, in the same proportions as the sample solutions. In accordance with Berglund (1986), calculations were made in g/kg dry weight. Graphs were plotted in a smoothed form, by taking running averages of results, i.e. the top three levels, then the second, third and fourth, the reduce the possibility of chance high or low individual readings and emphasise trends.

It was felt necessary to ascertain how large sampling intervals could be before information regarding peaks and trends was lost. To this end, contiguous 0.5cm levels from the first profile, GYFC, were analysed. From the sample graphs produced (Figure 3), it was decided that little information was lost if analyses were at 2cm intervals, but that at 4cm individual peaks and troughs were either missed, or they began to merge. For subsequent discussion relating to GYFC, therefore, the 2cm interval has been used, and the TRGM profile was subsequently sampled at that interval. Chemical analysis at GYFP, however, was only intended as a back-up for the results obtained from GYFC, and so, except in levels considered crucial, 4cm intervals were deemed satisfactory.

Pairs of results were subjected to Spearman's Rank tests. This was essentially to try and ascertain if any, or all, curves showed similar trends. If all the curves tended to rise or fall at the same time for instance, it could help, in conjunction with pollen evidence, to establish whether the mires had undergone major trophic changes, in accordance with the suggestion by Ross that the richer the wetland, the higher the overall nutrient levels. If, as actually happened, curves for some pairs of elements were found to be directly correlated, others inversely so, and yet others

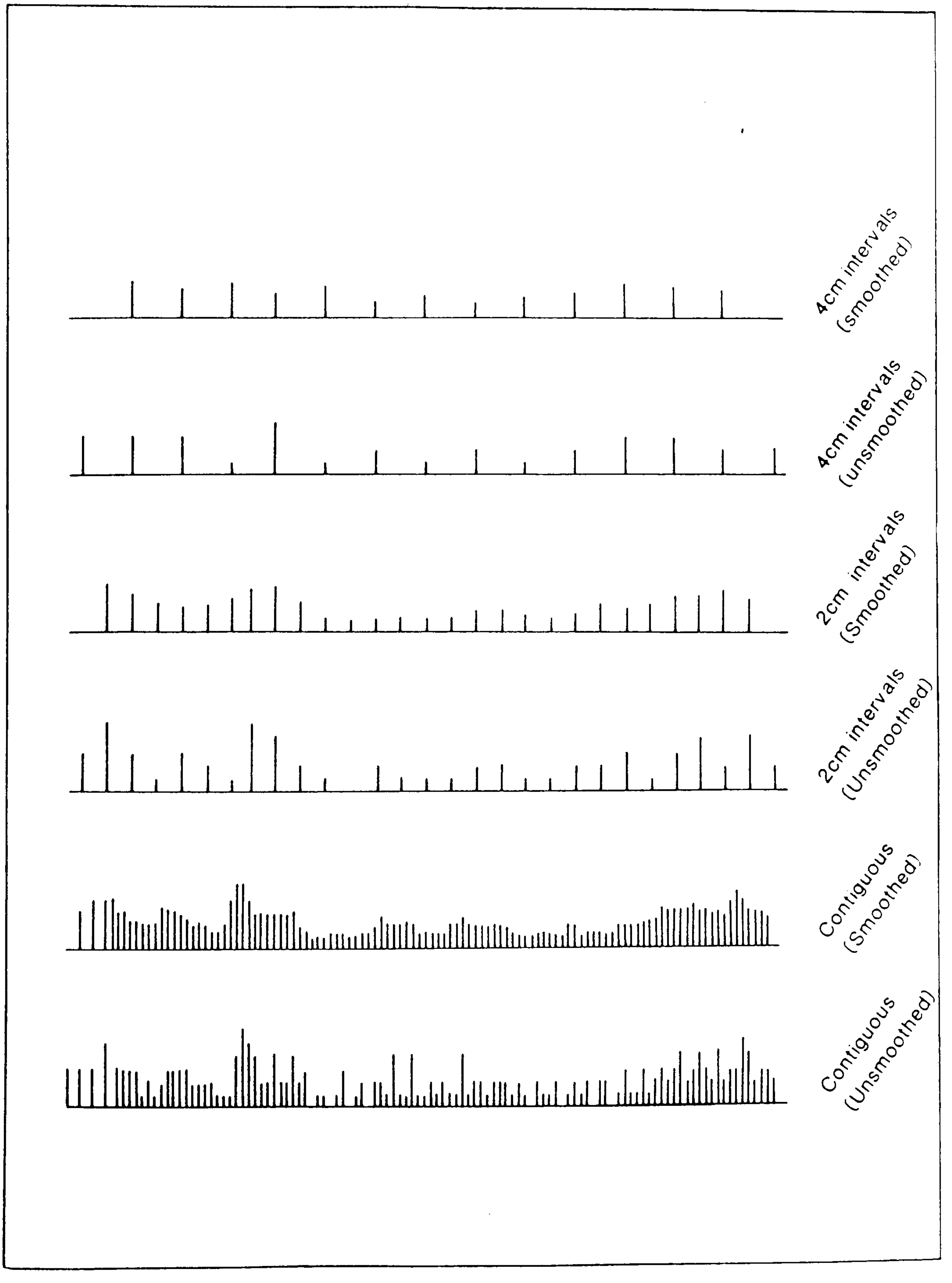


Figure 3 Sample chemical analysis graphs

unrelated, the logical conclusion was that changes in different nutrient concentrations were due to a series of factors. Ideas regarding these factors were then discussed in interpretation sections.

Although for graphical purposes, 2cm sampling intervals had been considered necessary, it was ascertained that correlation coefficients (Rs) were not very different at 2 or 4cm intervals, and so the latter was used in the majority of cases. Statistical tables, e.g. in Matthews (1981), show that, for sample sizes of 50 and 60 (within which both GYF profiles fall), Rs values of 0.279 and 0.255 respectively represent correlation at the 95% confidence level, and the corresponding values for correlation at 99.9% are 0.456 and 0.418. For samples of >200, as at TRG, the 95% level is about 0.15, and the 99.9% level about 30%. Whilst accepting these statistical values, it was also considered practical to value correlations in terms of magnitudes of the coefficients. On this basis it was considered that, whatever the sample size, with Rs between 0.00 and 0.25, the relationship was not significant, between 0.25 and 0.50, there was a direct or inverse relationship, but not a particularly strong one, 0.50 to 0.75 suggested a marked relationship, and above 0.75, the curves were considered to be virtually identical or mirror images.

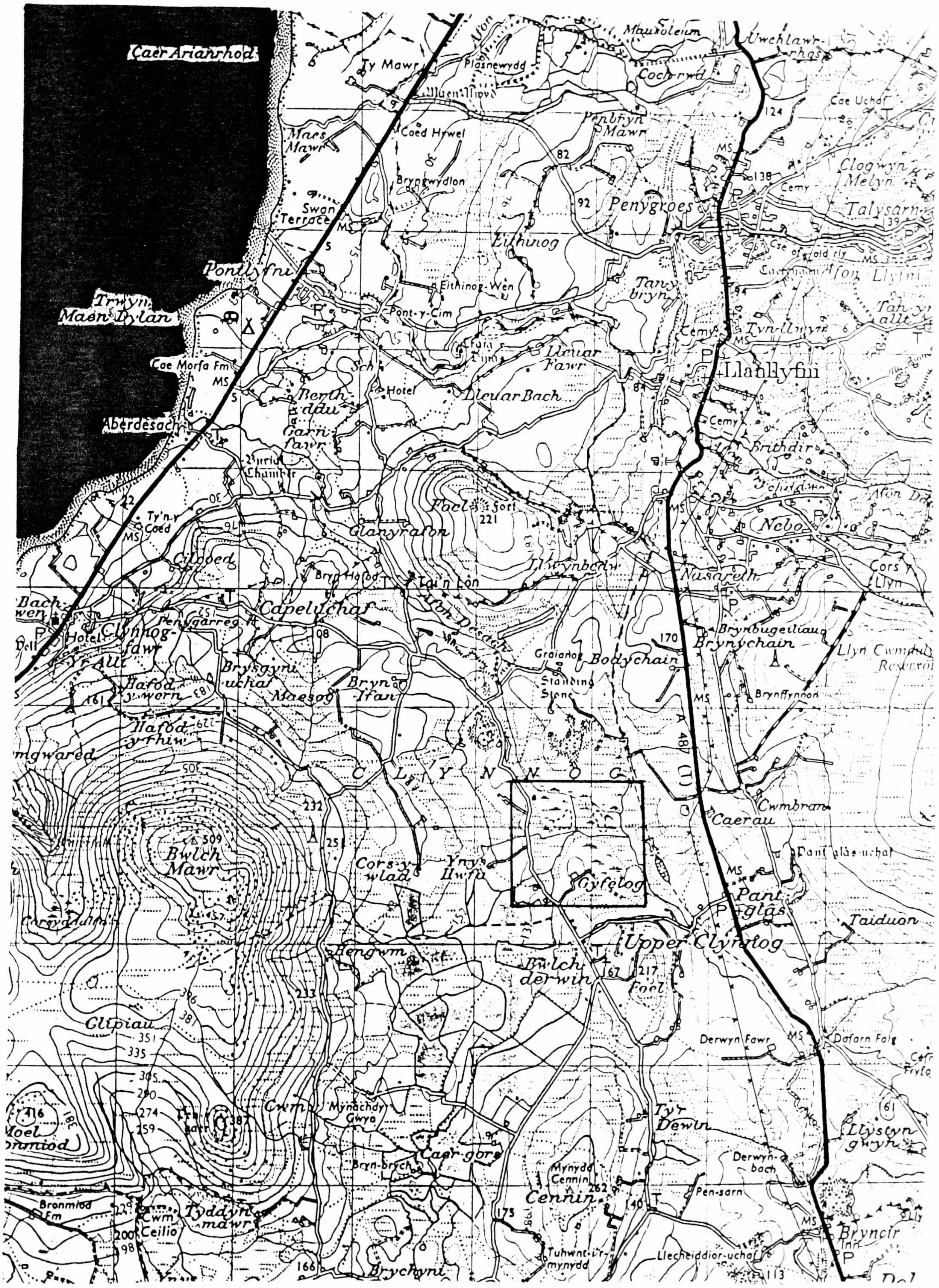


Figure 4 Cors Gyfelog - Local topography

CHAPTER THREE

CORS GYFELOG

Cors Gyfelog (Figure 1 & Plate 1), is situated in the northern part of the Lleyn peninsula (Figure 4). It is grouped into WWS Evaluation Type C (Northern Mesotrophic Mire), having been categorised as Type IV (Molinia-Juncus wet meadow with poor fen) in the initial survey. It is 68.2ha in size (WFU, 1984), and is the second largest site of its type in the North Wales Region of the WWS.

Subsequent to the publication of the Nature Conservation Review (Ratcliffe, 1977), Cors Gyfelog was awarded Grade 2 status, and declared a SSSI in 1981. The WFU evaluated it as one of the "best five" examples of its type in West Gwynedd.

The SSSI schedule for Cors Gyfelog (NCC) refers to:

> "... large areas of bogmoss (Sphagnum spp.) with bog asphodel (Narthecium ossifragum and cranberry (Vaccinium oxycoccus) interspersed with open pools ... (with) ...marsh St. John's wort (Hypericum eloides), bog sedge (Carex limosa) and bladderwort (Utricularia sp.). .... patches of sallow carr (Salix cinerea). Herbs which occur commonly .... include meadowsweet (Filipendula ulmaria), gipsywort (Lycopus europaeus), common valerian (Valeriana officinialis), wild angelica (Angelica sylvestris) and marsh violet (Viola palustris) .... more restricted species include globeflower (Trollius europaeus) and marsh helliborine (Epipactis palustris). There are swamp communities with bottle sedge (Carex rostrata), and marsh cinquefoil (Potentilla palustris) and bogbean (Menyanthes trifoliata). Slender sedge (C. lasiocarpa) is dominant in places and there are

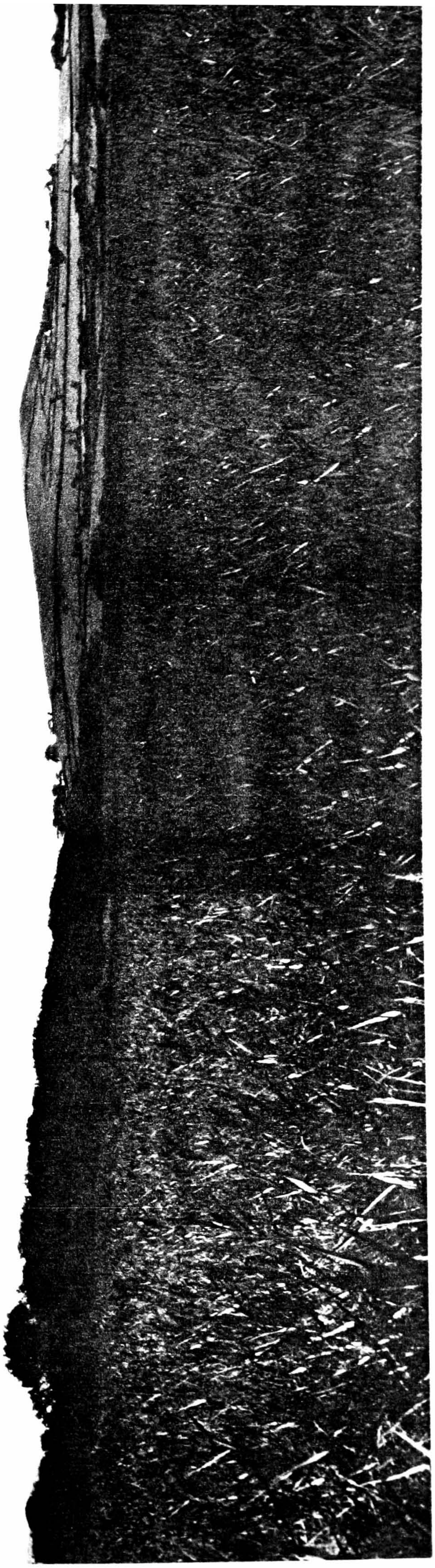


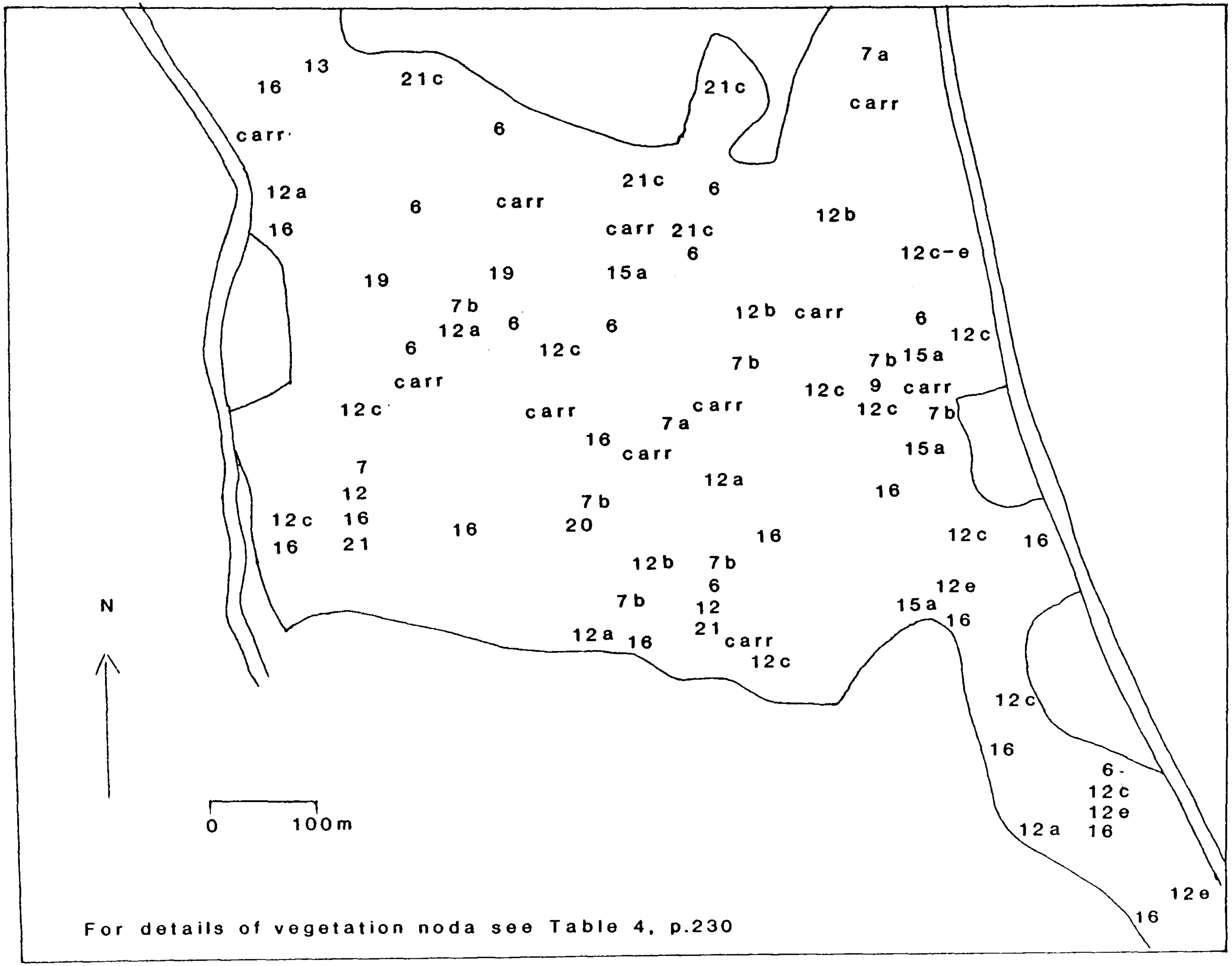
Plate 1 Cors Gyfelog

occasional tussocks of panicled sedge (C. paniculata) and royal fern (Osmunda regalis)."

Some attempts at drainage are evident although, according to the SSSI schedule, the wetland has been little damaged by this activity. In the north west is evidence of former peat extraction, and modern vegetation there tends to be more acidic in character than over most of the mire. In their survey, the WFU recorded 17 different vegetational noda (excluding Salix carr) at Cors Gyfelog (figure 5, and Table 4, Chapter 5), a total of five more than at any other site of any type in the North Wales Region. The average number for Type C sites in North Wales is 5-6. However, although this diversity indicates a very complicated mosaic of surface vegetation at Cors Gyfelog, it is also a reflection of the fact that the WFU surveyed this mire more intensively than it did most of the others. Some of the recorded noda in fact occupy very small areas, and could quite easily have been overlooked in a less stringent survey. Nevertheless, the attention paid to Cors Gyfelog by the WFU reflects the value put on it by the NCC.

Conway (In press), describing the soils of the area in the context of archaeological excavations at Cefn Graeanog a little way to the north of the mire, far less sympathetically refers to Cors Gyfelog as:

> "Poorly drained land forming the watershed between the Afon Desach, draining the northern area into Caernarfon Bay and the Afon Dwyfach, draining south into Cardigan Bay."



For details of vegetation noda see Table 4, p.230

Figure 5 Cors Gyfelog - Vegetation

and

Infilled by a coarse, fibrous acid deep peat".

Geology

Roberts (1979) assumes the valley to be underlain by Lower Ordovician slates and shales, flanked on the west by a series of small acid igneous intrusions, mainly microgranites and granodiorites, and on the east by Caradocian volcanics, interbedded with sediments. Most of the valley is now covered with glacial or fluvioglacial deposits, although there is an element of controversy about their origin. Whittow & Ball (1970) suggested that there were two ice advances, both of which involved Northern (Irish Sea) and Snowdonian ice. In the first (Criccieth) advance, Irish Sea ice reached northern Lleyn, and forced the Snowdonian ice down valleys such as the one in which Cors Gyfelog is found. In the second (Arfon) advance, Snowdonian ice dominated in Lleyn, the Irish Sea flows having been unable to penetrate further than the north coast. On this basis, only till derived from acidic Snowdonian rocks should be present in the valley, but Synge (1964) claims to have found Northern till in the area. Whilst Conway (op. cit.) accepts the limited presence of Northern deposits, all the soils he describes for the area derive from acid igneous parent material, varying with topography and drainage. He refers to the main local topographic features as kame deposits, mounds of gravel and lenses of sand, with low lying areas of silt and clay between the hummocks, and boggy depressions as described earlier.

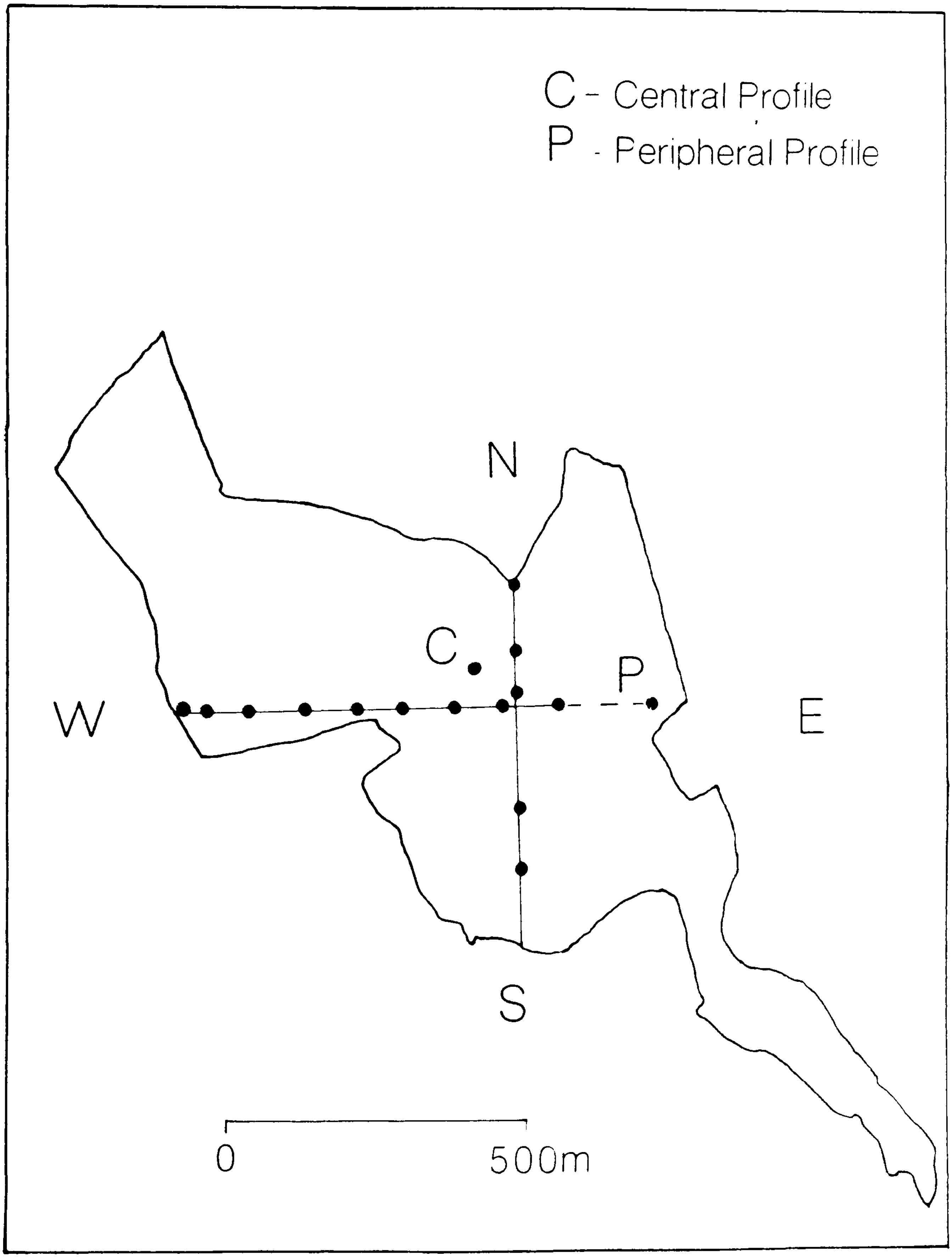


Figure 6 Cors Gyfelog - Transects

Today, sand and gravel deposits direstly to the north of Cors Gyfelog are being exploited commercially.

Peat Stratigraphy and Topography

Profiling was accomplished by way of two transects, one in an east-west direction along O.S. Grid Ref. SH348000, and the other along SH246050, running north-south (Figure 6). Levelling showed the highest points to be in the north and west, dipping progressively towards the south and east (Figures 7 & 8). The most westerly coring point (8a) was almost 3m higher than E-W point 1. Point 0 on the east-west transect is the estimated location of GYFP, and may be 10-20cm lower again (It should be explained that, following the extraction of cores for laboratory analysis from the GYFP site, further access permission for purposes such as levelling was not forthcoming from the owners of that section of the mire, hence the need to estimate the exact location of point 0.). The north-south transect showed a fall of only 1.17m, but the most southerly core was in fact taken some way from the edge of the site, and the eventual fall may have been greater. It was intended that coring points should be 100m apart but, in a few cases, intervening borings were also taken, or distances varied to avoid being too close to rivers, drains, etc..

The East-West Transect

The basin appears to divide naturally into two, the west side (Points 4-8a), and the east side (Points 0-4) (Figure 7). The dividing line appears to be close to the present course of the Afon Desach. Near to the western half of the transect is a reclaimed area, now improved grassland. Some of the bordering areas of the current mire appear disturbed. At the western end the top 25cm of deposits are a mixture of herbaceous peat and silty or gravelly material, which may indicate partial drainage. Underlying this, from point 7 westwards, the peat is mostly composed of wood, sometimes in combination with herbaceous material, leading to the conclusion that this side of the mire has been carr or wet woodland for most of its post-glacial history. From the stratigraphy alone, it cannot be deduced whether peat initiation began at the same time as it did further east, but because the base of the peat is substantially higher in the west, and because the line of wood peat, if projected eastwards, coincides with the upper layers of carr on that side, the suggestion is that peat formation began in the east much earlier than it did in the west.

The area between points 4-7 is quite complicated. Below the surface silt is a wide herbaceous band which connects with that in the eastern side, overlying the wood peat mentioned above. Below this is evidence of a wetter era, with fen deposits and a rather ill-defined and sometimes quite deep band of grey-brown clay. The most concentrated clay mass

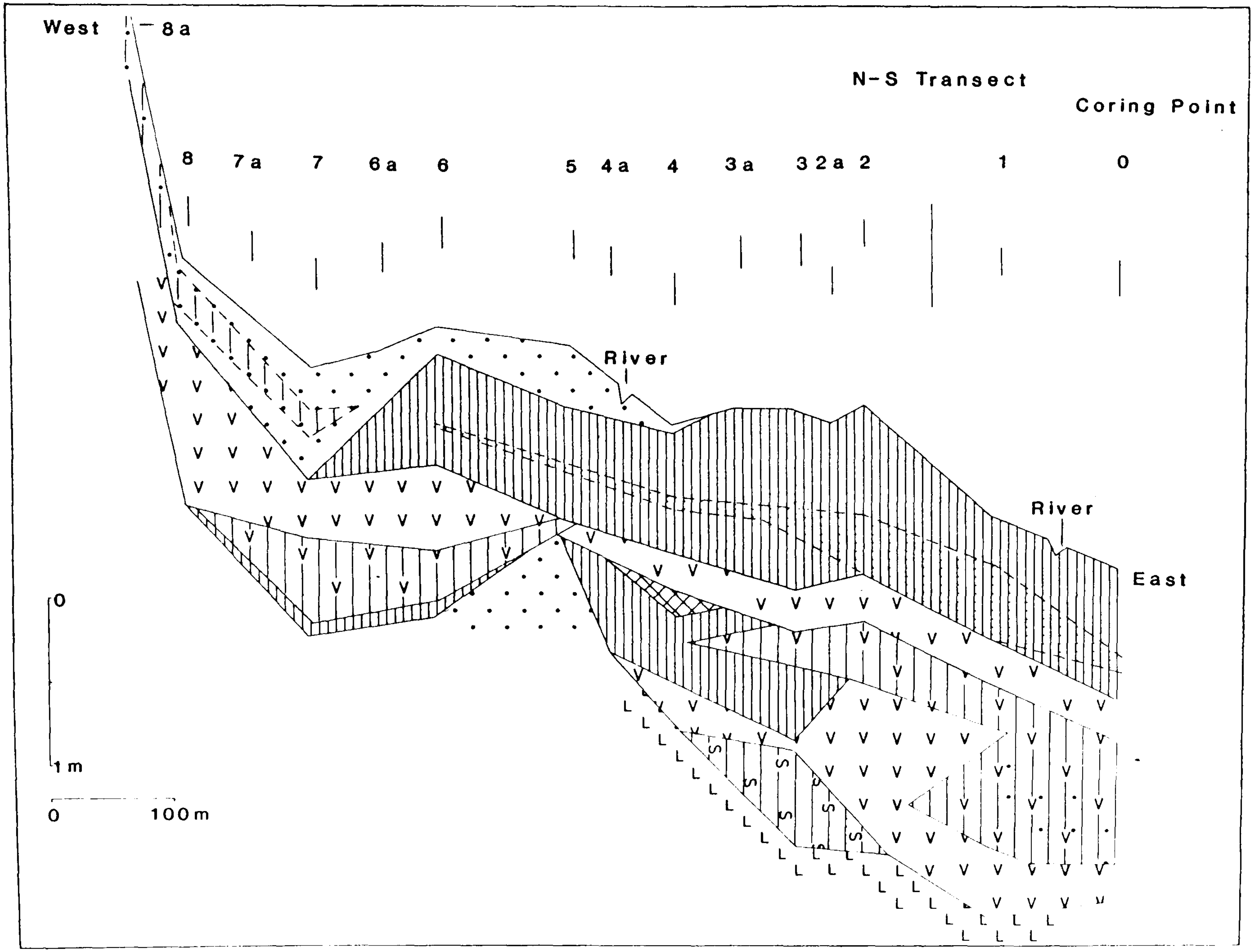


Figure 7 Cors Gyfelog - East-West Stratigraphy

actually spreads out in alternating tongues (not shown in the simplified diagram), possibly representing meanderings of the Afon Desach. At the base of point 6 there is a hint of green in the clay, a possible indication of longer-term standing water.

The eastern stratigraphy is somewhat different. Profiles 1-3 all include basal green-grey clay, assumed to be lacustrine in origin, whilst at point 4, green tinges under grey clay probably represent the western margins of the lake. There is evidence of very wet conditions following terrestrialisation, with Sphagnum, Phragmites, and detrital remains under points 2,3 and 4. Point 1 shows rapid transition from lake to carr, whilst point 0 was never lake at all. The basal deposit at point 0 was wood, and it appears that carr eventually encroached on to the mire as far west as point 3. Occasional silt bands found at points 0 (See Peripheral Pollen Diagram, Figure 11) and 1 apparently coincide with pollen and stratigraphical evidence of at least temporary opening up of the carr. The upper peat is mainly sedge-dominated, with few wood remains, but there are bands in which Phragmites remains are common, suggesting that a period of very wet or reedswamp conditions followed the demise of the carr. Microscopic inspection has shown a few Sphagnum remains just above the Phragmites bands. Pollen analysis suggests that grass, presumably Molinia, becomes more dominant in the top 10cm.

The North-South Transect

This transect (Figure 8) can roughly be divided into three, the area north of the Afon Dwyfach, a section between the river and a drainage ditch, and the area south of the ditch.

Only two profiles, at points 4 and 5, were extracted from the southern section. Of these No. 5, the most southerly, was still some way from the edge of the mire. This profile revealed several small bands with varying proportions of Sphagnum, herb and wood peat. The diagram shows a simplified stratigraphy, and suggests a definite successional sequence. The basal grey clay has been taken to suggest deposition at the edge of a lake, the body of which is assumed to have extended to the south. Terrestrialisation brought succession to carr, perhaps swamp, rather than fen carr, before regression to herb and Sphagnum dominated vegetation. The core recovered from point 4 was shorter than that at point 5, with no suggestion of lake clay. It would appear that point 4 is above a ridge which separates two different basins. Apart from the absence of lacustrine sediments, the basal sequence suggests similarity to point 5. In both cases, wood peat overlies the Sphagnum/herb peat. A line of the wood peat can be projected through to the northern section, indicating that at this stage, peat may have overtopped the central ridge and the mire became a single entity rather than a series of shallow basins. Above the lower wood peat band at points 4 and 5 is a section of

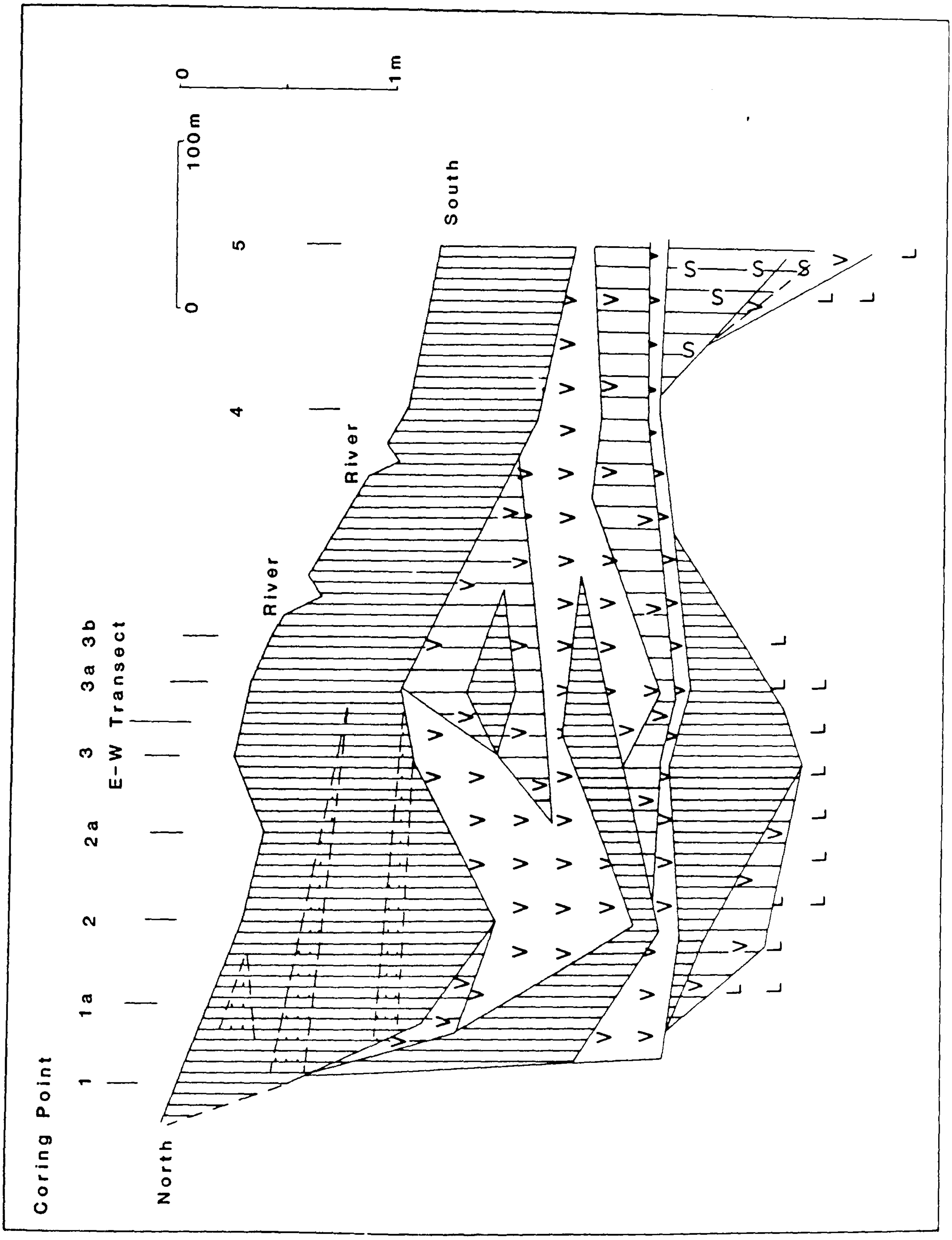


Figure 8   Cors Gyfelog - North-South Stratigraphy

mixed wood/herb peat, topped by another wood-dominated layer before a thick surface section of herb peat.

The river and the drain (shown in the diagram as nicks on the surface only) are both deep and wide, and were not crossable with the coring and levelling equipment, and so the diagrammatic representation of the central stratigraphy is speculation only, but points 3 (north of the river) and 4 (south of the drain) were levelled against each other, and so there is no reason to think that sequences which apparently correspond in the north and south sections do not continue through the middle.

North of the river, the transect completes the picture of the eastern half of the east-west traverse. Core 3a was taken as near to the river as was thought possible without picking up river deposits. The base of the profile consisted of the grey clay taken to represent marginal lake deposits, whereas at points 2 and 3, green lake clay was clearly visible. At point 2, light flecks in the clay may indicate marl. Points 1 and 1a were definitely outside the boundary of the former lake.

In this part, the succession from lake deposits to herb or herb/wood peat is similar to that in the south although there are fewer Sphagnum and Phragmites remains in the early terrestrial deposits of the northern section than there are in the south. If the deposit at point 2 was indeed marl, presence of calcium at this end of the mire would undoubtedly mitigate against the development of local bog vegetation.

As discussed above, succession to carr marks the emergence of the single mire. Regression to either fen or fen carr follows, before succession to carr again. At some points there are further reversions to either fen or open carr before the universal onset of fen peat in the upper section. During this phase, as in the N-S transect, there are indications that fen temporarily gave way to reedswamp.

To summarise, the overall stratigraphy at Cors Gyfelog suggests succession from a series of shallow lakes, each passing through reedswamp and sometimes Sphagnum lawn phases to fen before the development of carr and the amalgamation of the various basins into one mire. There are subsequent "flips" from carr to fen which appear to be associated with inwashes of mineral material, followed, except in the top 70-80cm, by succession back to carr. The upper section is mostly sedge-dominated, but there appear to have been phases of incipient reedswamp and valley bog. The most recent trend seems to be towards Molinia-dominated vegetation.

Cors Gyfelog Centre (GYFC)

Pollen Analysis

Cores for pollen analysis were extracted from a point some 30m west of the north-south transect line, and 50m north of the east-west transect. The stratigraphy is as follows:

0-10cm	Unconsolidated fibrous material.
10-30cm	Brown fibrous herb peat
30-60cm	Brown well decomposed herb peat. Occasional <u>Menyanthes</u> seeds and <u>Phragmites</u> remains.
60-75cm	Brown fibrous herb peat. Some <u>Phragmites</u> remains.
75-80cm	Brown, mainly fine, herb peat.
80-120cm	Brown herb and wood peat.
120-150cm	Brown wood peat (alder), including large chunks.
150-170cm	Brown wood and herb peat.
170-200cm	Brown wood peat.
200-230cm	Brown wood and herb peat. Dark band 210cm, dark flecks 215-225cm.
230-240cm	Transition to green-grey silt.

The resulting pollen diagram (Figure 9) was zoned in the following manner:

0-10cm	Unconsolidated - not sampled
10-20cm	Zone J
20-55cm	I
55-80cm	H
80-100cm	G
100-130cm	F
130-145cm	E
145-170cm	D
170-198cm	C
198-222cm	B
222-240cm	A

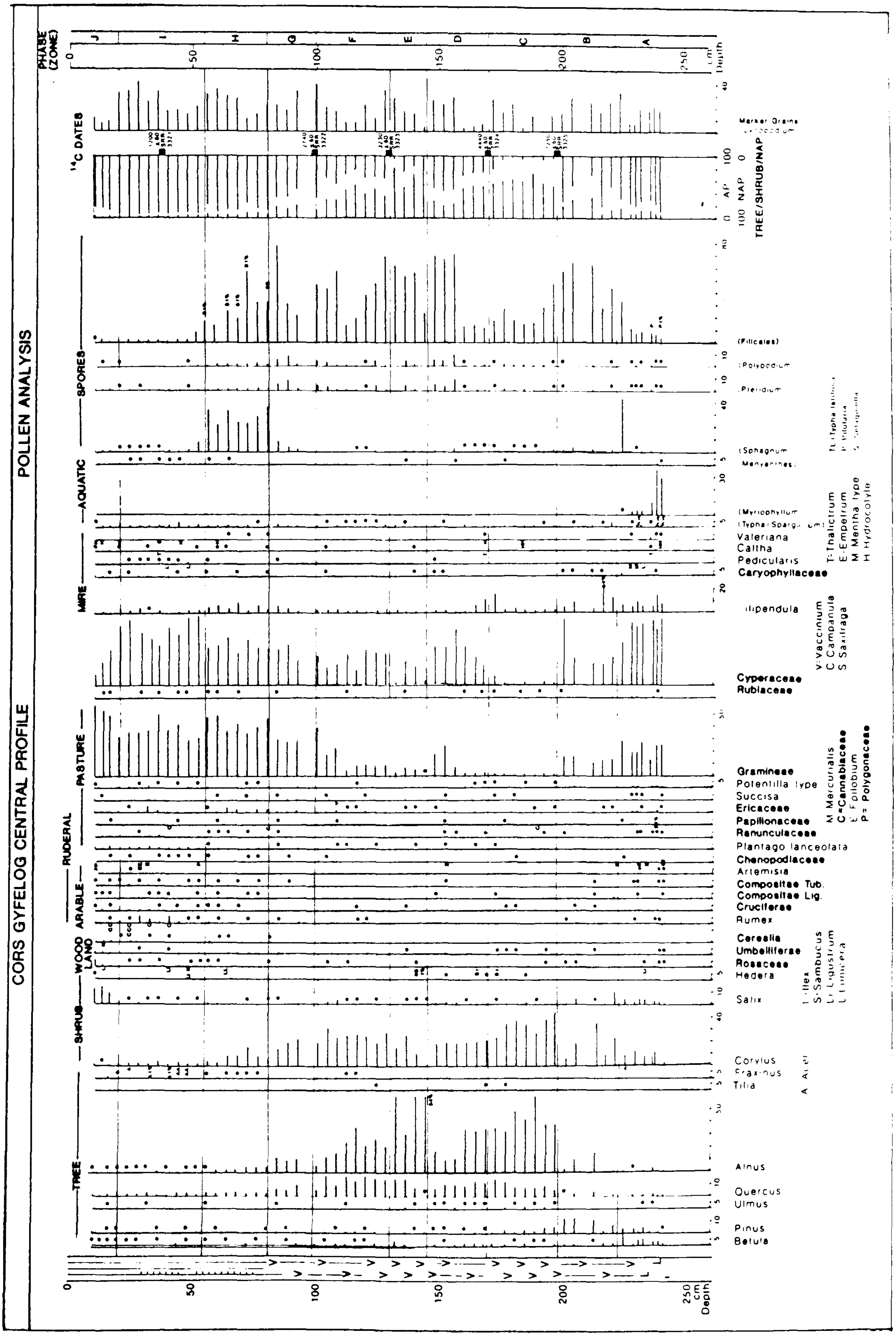


Figure 9 Cors Gyfelog Central Profile - Pollen Analysis

Zone A (222-240cm)

Main Features

AP makes up a relatively small proportion, no more than 30%, of TLP. Of this, tree pollen ranges between 3-15%, and shrub pollen 3-14%. Betula pollen represents 5-10% of TLP which, although a relatively low total, is higher than in any other zone. Salix representation of 2-5% is also high for this taxon and Pinus pollen reaches similar levels. Corylus totals, averaging 10%, are higher than for the other arboreal taxa, but low in comparison with levels reached later in the profile. Quercus, Ulmus and Alnus pollen grains are present, but in very low frequencies.

NAP is dominated by Gramineae and Cyperaceae. Gramineae levels, about 25% of TLP, are moderately high in relation to the rest of the profile, whilst Cyperaceae values (up to 55%) are very high. Other herbaceous taxa are well represented, including arable/ruderal types such as Rumex (up to 2%), both Compositae, Artemisia and Epilobium. Of the types tentatively designated as pasture (or grassland) indicators, Ranunculaceae, Succisa, Potentilla-type and Rubiaceae grains are also well in evidence, but Ericaceae levels (0-2%) are quite low.

In the "mire" section, the high Cyperaceae totals are accompanied by strong Filipendula representation, plus records of Valeriana (cf. V. officianalis, marsh valerian), Thalictrum, Caltha, Hydrocotyle, Mentha-type (cf. M. aquatica, water mint) and possibly Empetrum.

Several of the aforementioned herbaceous taxa occur only in this basal zone, whilst most of the others are not found in any number again until much higher up. Of the aquatic types, a very striking feature is the very high incidence of Myriophyllum pollen, entirely M. alterniflorum, reaching 36% of the TLP & Myriophyllum sum (see Chapter Two for calculation of percentages for aquatic pollen and spores). Only two other grains of this taxon are found in the rest of the profile. The only occurrences of Pilularia (pillwort) and Typha latifolia are also at the base. There are also Menyanthes records at two levels, and relatively high Typha/Sparganium values. Of the spores, Sphagnum totals are generally low, apart from the very high total of 44% at 224cm. Representation of both Pteridium and Polypodium is minimal, no more than 1%, whilst Filicales spores average about 10%, but range between 3-33%, the higher totals being at the top of the zone. The proportion of exotic Lycopodium spores is low-medium.

Interpretation

The low AP:NAP ratio suggests that the landscape in the vicinity of the young mire was dominated by open grassland. The presence of ruderal pollen in quantity may indicate that colonisation of bare terrain was still occurring following glacial retreat. Evidence by way of Betula, Corylus, Salix and Pinus pollen, suggests that pioneer woodland was present and spreading, perhaps colonising the margins of the mire.

There are grounds for believing that the area of Cors Gyfelog expanded following peat initiation (See peat stratigraphy and GYFP pollen analysis sections), so this central coring point may once have been on the periphery of the mire.

The material from which pollen was extracted in this basal zone was mainly inorganic, green-grey silt, indicative of lacustrine conditions. The shallowness of the silt layer, which gives way to autochthonous terrestrial peat (rather than allochthonous detrital deposits), suggests that the lake phase of the mire did not last for very long. The abundance of *Myriophyllum alterniflorum* pollen, which, according to Godwin (1955), is a constant feature of British early post-glacial lake deposits, suggests that the water was not deep. Handa & Moore (1976) suggest that both *Myriophyllum* and *Typha latifolia* indicate calcareous water supply, and Iversen (1954) suggests that the latter is moderately thermophilous. Whilst this part of the mire was certainly lacustrine at the time, pollen from the mire taxa suggest that there were also substantial areas of sedge fen, with quite a rich herb flora, in the locality.

On the basis of traditional interpretation, the *Alnus* pollen curve would be taken to suggest that large-scale alder migration had not yet occurred, but that trees were present, perhaps by way of small patches of carr (but see Bennett (1988)). Pollen representation even at these low levels suggests that alder establishment was early in relation to much of the British Isles (extrapolation of a curve based on

14C dates implies that basal sediments may have been deposited about 10000 years BP), but Chambers & Price (1985) have found this to be a feature of several pollen diagrams from North West Wales.

Filicales spore records may relate to wetland species such as Thelypteris (marsh fern) or Dryopteris sp. (buckler ferns), which could have been growing in the open with sedges, or in association with any incipient carr. The low Polypodium totals, however, suggest that trees on which they would be epiphytic were not common. The occurrence of a single very high Sphagnum spore count amongst generally low totals may represent a very short lived phase of Sphagnum colonisation following terrestrialisation (see stratigraphical section), or perhaps just chance over-representation from a single plant. Lycopodium spore values suggest that pollen influx was quite high at this stage, which in turn implies that sediment was accumulating at a relatively slow rate, which would be expected in deposits containing a high proportion of mineral matter.

Zone B (198-222cm)

Main Features

In this zone, AP rises markedly, and reaches 60% in the middle. Not only does the overall frequency of AP differ from the previous phase, but also the proportions of pollen from the various arboreal taxa. Betula pollen declines to 0-2%, at which levels it remains for most of the remainder of the profile. Pinus pollen, on the other hand, reaching 12%, is represented at higher levels than in any other zone. No Ulmus grains are recorded but Quercus and Alnus levels (Abs.-4% and 1-16% respectively), although far short of their respective peaks, show definite increases over Zone A totals. The single Acer record is assumed to relate to A. campestre (field maple). Curves for both Salix and Corylus are somewhat erratic, but whilst Corylus levels, reaching 31%, show an overall increase, Salix pollen declines after an initially high value of 10%.

Levels of most of the herbaceous species decline, and some taxa found in the previous zone are no longer present. Gramineae values are still moderately high (11-16%), although lower than in the basal zone, and Ericaceae records cease in the top half of the phase. Cyperaceae levels fall to an average of 20%, although there is an erratic record of 54% at the top. Filipendula totals, however, are higher than before, generally 3-12%, but rise to 54% at one level. A more continuous Caryophyllaceae curve is also seen, and pollen is taken to represent Lychnis flos-cuculi (ragged robin).

Of the aquatic pollen, two final Myriophyllum grains are recorded, but there are no records of Typha latifolia or Menyanthes. After an intiial record of 4%, the Typha/Sparganium curve falls to 1%, the lowest levels in the profile. Sphagnum spore values reach 5%, and the overall levels for the zone are only exceeded in one other part of the profile. *Pteridium* spore values remain more or less at Zone A levels, but the *Polypodium* total rises as high as 10%, and the Filicales curve expands to very high levels of up to 64%. *Lycopodium* values are relatively high.

Interpretation

The increasing AP:NAP ratio clearly shows that woodland was expanding in the valley. Pioneer birch woodland was, however, being succeeded by Boreal pine forests and, to a lesser degree, oakwoods. The absence of ruderal pollen suggests more complete vegetation cover, as does the sparcity of Ericaceae pollen and *Pteridium* spores.

Both pollen and stratigraphy suggest that carr was expanding on the mire. The peat in this zone is a mixture of wood (probably alder) and herbs, which, considered along with the relative proportions of *Alnus* and Cyperaceae pollen, indicate quite an open canopy. Meadowsweet and ferns (both terrestrial and epiphytic) were apparently thriving in the community. Willow could have been restricted to the mire, and even hazel may have been in competition with other trees for marginal sites. Hazel macrofossils have often been found in peat, so not only may the species have been present as a co-dominant of pioneer woodland, or in pure stands, but it could also have been represented on "drier" carr. Today, however, hazel tends to be considered as an oakwood understorey tree.

Although the overall trend appears to have been towards fen and carr, there are suggestions that some *Sphagnum* lawn and reedswamp persisted in the locality for a while. Increased *Lycopodium* frequencies imply that, with the transition from mineral to organic sediments, deposition rates were higher than in Zone A.

Zone C (170-198cm)

Main Features

AP averages over 90% of TLP. Of this, 50-70% relates to trees, and the rest is mostly of *Corylus*. *Betula* levels remain low, and the *Pinus* curve decreases markedly, to about 5% at the base before falling to 1-3%. Proportions of pollen from trees associated with mixed oakwoods, however, increase. *Quercus* totals are between 5-13%, the higher values being towards the top of the zone, and *Ulmus* representation, although only reaching 2%, is high in relation to the rest of the profile. The *Alnus* curve shows a considerable rise. Values range from 34-61% of TLP, and are rarely exceeded elsewhere in the profile. *Corylus* levels, mainly over 30%, are also very high. *Salix* values of 2% are generally low, but pollen of several other arboreal taxa, namely *Tilia*, *Sambucus*, *Hedera* and *Ilex*, appear for the first time in the diagram.

Herbaceous pollen values are correspondingly very low, and few taxa represented. Even Gramineae totals do not exceed 2%, and Cyperaceae values are only slightly higher, although a count of 7% is recorded just below the Zone C/D boundary. The *Filipendula* curve is also at lower levels than before although, like Cyperaceae, increases just below the upper boundary, at which stage pollen from one or two herbaceous taxa, such as *Plantago*, are recorded. On the basis of the foregoing, there is possible justification for a further zonal division within this phase.

Frequencies of both Ericaceae and *Pteriduim* are very low, as are *Sphagnum* spore records, but *Polypodium* levels are at their highest in the profile, whereas Filicales representation declines to about 15%. *Lycopodium* values are generally low.

Interpretation

The high AP levels show that local woodland cover was by this time virtually complete, as was succession to mixed oak woodland. The presence of lime, holly and ivy indicate that warm conditions prevailed (Iversen, 1944). The pollen spectra are suggestive of Godwin's Zone VIIa, but 14C Dating of peat at the base of the phase (7250 70 BP [SRR-3325]) may define the Boreal/Atlantic chronozone.

In conjunction with high *Alnus* pollen totals, abundant wood remains in the peat leave little doubt that alder carr dominated the local vegetation at this time. Although the Atlantic period was supposedly wetter that the preceding Boreal, pollen and stratigraphical evidence from the lower part of the phase suggests that mire conditions were still relatively dry, perhaps enough to allow competition to continue between hazel and alder for parts of the mire, with the virtual exclusion of willow. The LOI curve (Figure 9), however, indicates mineral inwashes throughout the zone. It is possible that central water levels did not rise sufficiently in the earlier part of the phase to drown out the carr. It is likely that the forested catchment absorbed some of the run-off, whilst more water was removed via the river system. Lower Cyperaceae and Filipendula pollen values, and Filicales spore totals may be due to reduced production under the closed carr canopy, although the same conditions were apparently beneficial to the epiphytic polypoidy ferns.

Generally lower Lycopodium frequencies in this phase imply a reduction in peat growth rates, which may be related to the closing of the carr canopy, and the presence of greater proportions of woody material in the peat, but may equally reflect the increased mineral content of the sediment.

Changes in pollen composition towards the top of the zone may indicate that poor-fen was becoming re-established on parts of the mire, as wet conditions persisted. Although 14C dating (see below) suggests that these changes coincide with the onset of the Sub-Boreal period, Smith et. al., (1981), point out that British evidence of increasing continentality at the beginning of the Sub-Boreal period is scanty. At the C/D boundary, the peat becomes more organic for a short while, possibly because of a period of rapid peat growth following the opening up of the carr. As always, when discussing events connected with the Atlantic/Sub-Boreal transition period, the question must be raised regarding the possible influence of human agency in events. Chambers (In press) refers to circumstantial evidence for Mesolithic activity in the area, although there seem to be no signs of any effect on the local forest. On the other hand, if the 14C Dating of the upper boundary is correct (4440 60 BP[SRR-3324]) , the first signs of change at c.175cm may mark the arrival of Neolithic peoples in the area, around 5000 BP. There is certainly ample evidence of Neolithic settlement in the Lleyn Peninsula (Savory, 1965, 1980). It is indeed noticable that a *Plantago* pollen grain was recorded at 172cm, but no *Ulmus* pollen.

Zone D (145-170cm)

Main Features

There is a significant decline in the proportion of AP in this Zone, to about 44%. *Alnus* levels decrease significantly from c.30% in the bottom half of the phase to 8-17% at the top. *Corylus* values of about 20% also show a reduction from Zone C. Of the other tree pollen, *Betula* totals decrease from about 2% to <1% towards the top, whilst *Pinus* pollen never exceeds 1%. *Quercus* levels are similar to those of the previous phase, at 6-12%, but with the lower totals towards the close of the zone. *Ulmus* representation is weaker than before, with only one record of >0.5%, but

Salix levels of about 2% are a little higher. No *Tilia* grains are recorded, and only one *Hedera*.

Pollen totals of certain herbaceous taxa are stronger than before, and others which have been absent from Zone C reappear. Gramineae values reach 24% towards the upper boundary, whilst Cyperaceae levels rise from 16% at the beginning of the zone to 46%, before declining again slightly to 30%. Ericaceae pollen is found again more or less continuously, and *Pteridium* spore totals rise to about 11%. There are further records of *Plantago*.

Filipendula values, which rose suddenly at the end of Zone C, decline again, but there are records of other wetland taxa, notably *Thalictrum*, *Pedicularis*, Caryophyllaceae and *Valeriana*. There is a slight increase in *Sphagnum* spore representation. Filicales totals, which rise from 13-70% coincide with decreasing *Polypodium* values. Aquatic pollen taxa are represented by a low and erratic *Typha*/*Sparganium* curve, and by a single *Menyanthes* grain. In the top half of the phase, *Lycopodium* totals increase markedly.

Interpretation

In this zone, there was a definite return to fen conditions, as shown by the Cyperaceae pollen totals and the variety of mire herb taxa. The reduction in levels of *Corylus* pollen may indicate that hazel was retreating to the margins of the mire as conditions became less favourable for competition with alder, and the subsequent decrease in Alnus pollen totals suggests that eventually alder, too, was unable to thrive. As the canopy opened, fern spore production would have increased, but fewer trees would mean less substrate for epiphytes. It is possible, however, that willows were able to take some advantage of the gaps left by the demise of the alder and hazel trees.

From the pollen diagram, it had been decided to place the zonal boundary at the point where the Cyperaceae pollen curve began to rise markedly, and where there was a marked decline in the incidence of marker spores, and it was from this point that samples were sent for 14C Dating. The resulting date, however, appeared to be too young to be associated with the Atlantic/Sub-Boreal transition. The possibility of sample contamination cannot be ruled out with certainty, but, for reasons stated in the interpretation section relating to Zone C, there are logical grounds for assuming that the date is correct, and that the beginning of Zone D, as defined above, was already 500 years or so into the Sub-Boreal period.

Although Ulmus pollen totals are never high in the GYF pollen diagrams, there are sufficiently noticeable reductions in GYFC Zone D values to suggest that there was an elm decline in the area. Additionally, the slight but progressive reduction in Quercus levels, and the decline in Corylus pollen (although it has been suggested that hazel grew in close proximity to alder in the vicinity of the mire, it was almost certainly also present in the oakwood understorey too), combined with increases in the pollen of Gramineae and pastoral and ruderal taxa, leads to the conclusion that some local woodland clearance was occurring. The reappearance of Ericaceae pollen and the increase in Pteridium spores may indicate that some of the clearance was in upland areas.

With the suggestion of human manipulation of the vegetation in the catchment, evidence from the LOI curve of further inwashes of mineral material can as readily be put down to run-off following local clearance as it can to climatic influences. The rise in exotic Lycopodium spores values at the top of the zone may be related to increased peat growth rates with the re-establishment of fen, but it is notable that mineral influxes cease at the same time as Lycopodium values rise.

Zone E (130-145cm)

Main Features

This zone is delimited by a temporary reversal in the decline of AP, which is largely attributable to a rise in Alnus pollen values, which range between 30-94%, and include two totals of 60%. The very high Alnus representation at 144cm renders other pollen proportions valueless at this level, and is itself probably a chance over-representation. Trends can, however, still be established for the rest of the zone.

Of the tree pollen, Pinus levels continue to decline, and very little Ulmus pollen is recorded. Betula pollen is absent from the base of the zone, but totals rise to 3% at the top, whilst Salix levels fall again to <1%. Quercus representation (14%), appears as strong as in any other phase, but the Corylus curve is somewhat variable. There are no Tilia records, but there are individual occurrences of Hedera and Sambucus.

Most of the herbaceous taxa revert to levels similar to those in Zone C. In particular, the Plantago curve becomes broken and Ericaceae values decline. Pteridium totals are lower than in Zone D, but still higher than in the three earlier phases. Gramineae representation falls, but levels are above those of Zone C. Despite presumed suppression by Alnus pollen, Cyperaceae levels (19%) remain relatively high. Polypodium spore totals rise slightly, and Filicales levels remain above 50%. Lycopodium spore values increase.

Interpretation

In this zone, there appears to have been a reversal of the trends which characterised Zone D. With regard to the mire, pollen totals suggest major alder recolonisation, and the peat mainly consists of chunks of alderwood, but despite this, there is evidence that tree cover was not as complete as it had been previously. Cyperaceae and Filicales levels are relatively high, suggesting strong sedge and fern growth in the understorey, and one or two other mire taxa, such as Caltha (marsh marigold), still appear in the pollen record. Fluctuating levels of Corylus pollen may suggest that hazel was not able to colonise the mire when, as must be assumed, conditions again became drier.

High levels of Quercus pollen suggest that any cleared tracts were reverting to forest, although it would appear that there was proportionately less elm in these woods. The continuation of relatively high frequencies of Pteridium spores, however, suggest that some open land still remained. The rise in Betula values at the close of the zone could relate to colonisation by birch of these areas.

Culturally, interpolation between 14C Dates suggests the age of the lower boundary to be about 3700 BP, which would equate roughly to the beginning of the Bronze Age. Grimes (1965) suggests that the most concentrated Bronze Age activity in the area would have occurred at this time, but pollen evidence suggests otherwise. The LOI curve, too shows a decrease in the proportion of mineral material in the peat which would suggest either dry conditions (substantiated by pollen evidence), or greater catchment stability (which is likely to have followed forest regeneration), or both. It is notable that Lycopodium spore values continue to rise in the absence of inorganic matter.

Zone F (100-130cm)

Main Features

Another decline in the AP:NAP ratio occurs, again largely reflecting the behaviour of the Alnus curve. Values of 12-

35% are about half as high as those in the preceeding phase. Betula levels fall again to 1%, but Pinus values are higher than for some time, reaching 2%. There are only single records for Ulmus, Lonicera and Tilia, the latter being the final appearance of that taxa in the profile.

Quercus values are high (9-16%), whilst Corylus levels of 19-31% are higher than at any stage since Zone C. Salix representation is sporadic, but there is a peak of 4% at the close of the zone. Mid-way through the phase, the first Fraxinus grains appear, and at subsequent levels are recorded in values of 1%.

Umbelliferae pollen values (assumed to represent woodland [edge] types) are low, but grains are now present in more or less every sample level. Of the potential indicators of human activity, there are two Rumex records, the first ones since the base of the profile. There are also odd records of other open country types such as Compositae Tub., Papilionaceae, Succisa, Potentilla-type and Rubiaceae. The Plantago curve remains weak until the top level of the phase, when a count of 1% is recorded. The Ericaceae curve strengthens and becomes more continuous than before, rising to 2%, but Pteridium levels are generally low, except for two 5% records. For most of the zone, the Gramineae curve is slightly higher than before (4-9%), but it rises significantly at the top, with values of 22% and 17%. Cyperaceae levels are generally higher than in Zone E, but still below the Zone D peaks. *Filipendula* values (1-3%) are low, but there are a few pollen records of other mire taxa.

Sphagnum spore levels are very low, and are absent altogether at the close of the zone. *Polypodium* frequencies of 2-8% are quite high, but the lower totals are those at the top. Filicales representation varies (14-70%), with the lowest levels in the middle, a pattern also seen in the *Lycopodium* curve, although less extreme in character.

Interpretation

Several possible interpretations can be put on pollen diagram features in this zone. On a regional scale, the overall extent of woodland cover appears to have changed little since Zone D, intervening AP fluctuations being largely due to changes in the status of alder on the mire. However, pollen records suggest alterations in woodland composition, with the replacement of lime, and largely of elm, by ash. It is suggested that ash was able to colonise abandoned clearings, and thus is taken as an indicator of secondary woodland (Tinsley *et. al.*, 1981).

On the other hand, sustained higher Gramineae values (even before the marked rise at the top of the zone) suggest that there were areas of open vegetation. Increasing Ericaceae totals may indicate that unforested areas were largely on hillslopes. Although the frequency of *Plantago* pollen only rises in the upper levels, the appearance of *Rumex* grains suggests continued settlement in the area. Although, as mentioned in Chapter Two, Rumex has been included, for the sake of convenience, in the arable/ruderal section of the pollen diagram, different Rumex species have various affinities, including as indicators of pastoral activity (Behre, 1981). Without further differentiation, and in the absence of any records of cereal pollen, it cannot be suggested that the grains found in this zone indicate any change from pastoral farming.

From the dated boundaries (3230 60 [SRR-3323] and 2740 60 [SRR-3322]) it may be suggested that this phase marks the Middle Bronze Age (Savory *op. cit.*), and the latter part of the Sub-Boreal period, during which time the climate may well have been becoming cooler and wetter. A slight dip in the LOI curve at the base possibly indicates a wet phase, which could have precipitated the change to more open fen conditions. The Alnus pollen curve, and the mirror-image Filicales curve suggest that the only time when there may have been some semblance of a closed carr canopy was in the middle of the zone. The increase in Corylus pollen may suggest peripheral colonisation, but it seems unlikely that conditions would have been suitable for any great degree of penetration. It is interesting to note that, despite mire conditions getting wetter at this stage, Sphagnum representation petered out, suggesting that there was at least a neutral water source.

Changes in the pollen spectra at the top of the zone by way of increases in the proportions of Gramineae pollen, as well as maximum diversity in herbaceous records, certainly suggest a renewed burst of clearance activity.

Zone G (80-100cm)

Main Features

Worsening of the AP:NAP ratio which began at the top of Zone F is accentuated in this phase. The maximum AP total is only 45%, of which tree pollen makes up less than half. Curves for both <u>Betula</u> and <u>Pinus</u> never exceed 1%, and the maximun <u>Quercus</u> frequency is only 9%, whereas it had never been lower than 10% in the previous zone. It must be pointed out that the quality of pollen in this phase was very poor, hence the absence of a sample at 96cm. The two samples on either side of this were also abandoned well before full counts had been made. Because of this, it is suggested that values recorded for taxa of more minor occurrence, or subject to preferential destruction, are not necessarily accurate. However, it may be suggested that the single <u>Ulmus</u> record does reflect a real decline, but <u>Fraxinus</u> pollen may be under-represented. <u>Corylus</u> percentages of 14-22% are only slightly lower than previously, but <u>Alnus</u> levels of 5-11% are much reduced, and <u>Salix</u> frequencies are also lower.

Despite the foregoing comments regarding pollen quality, there are increasingly common and more varied records of herbaceous taxa, notably Umbelliferae, *Plantago*, and *Rumex*, all reaching 2% levels, the beginnings of continuous curves for Compositae Tub. and Ranunculaceae, and increases in the frequency of *Succisa*, Rubiaceae and Papilionaceae records. Both Gramineae (28-39%) and Cyperaceae (20-33%) totals are markedly higher, as are those for *Filipendula* (1-6%) and *Pteridium* spores (2-9%). Ericaceae levels remain much as before.

On the mire, the *Sphagnum* curve recommences and levels rise significantly to 9%. There is a slight increase in the frequency of *Typha*/*Sparganium* pollen. The Filicales curve is variable at 22-77%, with the highest levels at the top and bottom. The *Lycopodium* curve is generally high.

Interpretation

The marked reduction in the AP:NAP ratio at the base of Zone G leads to the conclusion that a major and rapid phase of woodland clearance was taking place at this time. The date of the boundary (2740 60 BP [SRR-3322]) suggests that the zone marks the final stages of the Bronze Age, and the latter part of the Sub-Boreal period, during which time climatic deterioration may have been occurring.

Despite the suggestion of deforestation, the LOI curve only gives slight indication of increased run-off, and the *Corylus* pollen curve remains high. It is possible that stands of hazel on the mire margin were being selectively preserved for coppicing purposes, and sediment from the catchment was being trapped by the roots of the trees instead of being washed into the mire. Coppicing of hazel, in the Bronze Age and earlier, has certainly been recorded in other parts of the country (Smith et. al., op. cit., Tinsley et. al., op. cit.).

Reductions in *Alnus* pollen totals, coupled with increases in the incidence of Cyperaceae and *Filipendula* pollen, and Filicales spores, suggests further carr decline and sedge fen expansion. Occasional *Phragmites* remains were found in the peat relating to this zone, pollen from which would be included in the Gramineae curve. The presence of reeds suggests a trend of reverse succession towards reedswamp on the mire, which could reflect wetter climatic conditions, or be the result of increased run-off and a raised water table following deforestation. The increase in the incidence of *Sphagnum* spores, however, may indicate ombrotrophic influences, and strengthen the suggestion of climatic deterioration, as would higher *Lycopodium* values, implying fast rates of peat growth.

Zone H (55-80cm)

Main Features

At the base of the zone, with an interpolated date of about 2500 BP, there is another step-wise decline in the AP:NAP ratio. Maximum AP is always less than 25%, usually only 15%, and no tree pollen total exceeds 10%. Of the individual taxa, Quercus values are 3%, and Alnus totals only marginally higher. Betula, Pinus and Salix levels do not exceed 1%, and there is just a single Ulmus record. The Corylus curve now also joins the downward trend, with values of 3-15%.

Pollen of herbaceous taxa are by now frequent enough to allow more clear divisions into different ecological affinities. Undifferentiated Rosaceae-type pollen are recorded more frequently than before, and Umbelliferae totals are as high as 2%. Both these types have been taken to represent woodland edge (or, more recently, hedgerow) species, which would have been able to flower more freely with the opening up of the landscape.

Of the types designated as arable, or arable/ruderal, the most marked feature is the beginning of a broken Cerealia curve. At the same time, Rumex (1-2%), Cruciferae, Chenopodiaceae and Compositae Lig. values all increase, and Compositae Lig. pollen reappears. On the pastoral, or pastoral/ruderal, side, Gramineae representation continues to rise (34-48%), as do Ericaceae values, although Pteridium spore counts do not follow the same trend. The Plantago curve becomes more consolidated, and several other taxa continue to increase in frequency.

Of the mire types, Cyperaceae percentages rise only slightly to 27-39%, whereas Filipendula totals (2-9%) increase markedly. Pollen from other wetland herbs, namely

Valeriana, *Caltha*, Caryophyllaceae, *Pedicularis* and *Hydrocotyle*, are now also found. Records of taxa relating to aquatic margins also become more common, with the beginning of a broken *Menyanthes* curve, and an increase in *Typha*/*Sparganium* values.

There is a marked escalation in the frequency of *Sphagnum* spores, which reach totals of 21-37%. Of the ferns, *Polypodium* values fall to their lowest levels since before the rise of the *Alnus* curve. Filicales totals are still quite high (14-58%), but tend to decline towards the close of the zone. *Lycopodium* totals are quite high.

Interpretation

A further AP decline suggests that more forest clearance was taking place. Interpolated dating suggests that the base of the zone (*c.* 2400 BP) marks the beginning of the Iron Age, and the end of the phase is estimated at between 1400-1500 BP. It thus includes the Roman period, and the beginning of the Celtic phase. The climatic implication of the lower boundary is that it marks the Sub-Boreal/Sub-Atlantic transition.

Although oakwoods had been severely depleted by this time, the re-emergence of the *Fraxinus* curve may suggest some secondary woodland regeneration. If the suggestion that hazel was coppiced locally is correct, then the reduction in the incidence of *Corylus* pollen in this phase could either indicate the maintenance of a smaller coppicing area than previously, or that, with improved metallurgical technology, trees were being over-exploited and flowering less freely. Increasing Gramineae, Cerealia and ruderal herb pollen totals, the latter including both "arable weeds" and "pastoral weeds", suggest that the farming community was quite active. Low Cerealia pollen values make it difficult to establish the extent to which arable agriculture was being carried out, but the form of the curve may indicate that the practice was more widespread in and after, rather than before, Roman times. The strengthening of the Ericales curve, however, may point to impoverishment on higher land, a trend which is likely to have been accentuated if the climate was becoming more oceanic.

Although there had been indications of increasing wetness on the mire for some time, higher aquatic pollen totals in this zone suggest that further regression to reedswamp was occurring, a supposition supported by more Phragmites macrofossil remains in the peat. If reedswamp, as well as sedge fen, was widespread on the mire at this time, the inclusion of Phragmites grains in the Gramineae pollen total helps to explain why the reduction in the Alnus curve in this zone has been matched only partly by greater Cyperaceae representation (which had been the normal trend in the past), but also now by increased Gramineae levels. It is probable that substantial proportions of the increased Gramineae frequencies could be attributed to pastoral activities in the catchment. The high Sphagnum spore totals, which cover the entire phase, further suggest that there was some ombrotrophic mire growth, although totals of taxa normally associated with poor-fen are sufficiently high to indicate that minerotrophic conditions were still widespread. The continuation of high exotic spore counts adds to the general picture of rapid peat growth.

Zone I (20-55cm)

Main Features

AP is generally less than 10% in this zone, and tree pollen never exceeds 6%. Of the latter, Quercus totals of 1-3% are only slightly lower than those of Zone H, but there is only one record of Ulmus, and the Fraxinus curve does not extend into this phase. At 44cm, however, the lowest of a series of Acer records is found. Both Alnus (Abs.-1%) and Corylus (1-4%) levels are very low, whilst Betula and Salix curves, although never exceeding 1%, are more continuous than before. There are single records of Lonicera and Ilex.

Of the woodland edge taxa, frequencies of both Rosaceae (Undiff.) and Umbelliferae (Abs.-1%) increase. There are more records of arable taxa, representing both cultivated and ruderal types, including several more Cerealia (Undiff.) grains, and examples of Cannabiaceae. The Rumex curve continues to rise, and reaches a peak of 6%. There are general trends of increasing frequency and diversity in the pollen curves of other arable taxa.

In the pastoral section, Plantago records are as high as 3%, whilst both Potentilla-type and Ranunculaceae curves become more or less continuous and reach 2%. Other records are for Papilionaceae, Succisa and Rubiaceae. The Ericaceae curve is slightly weaker than in Zone H, but reaches a peak of 5%. Pteridium values of 0-2% are lower than of late, but still higher than pre-cultivation values. Gramineae levels (28-49%) are on average slightly lower than in Zone H, whilst Cyperaceae totals (29-57%) are higher than at any stage since the pre-Alnus period. Filipendula values decline a little in the middle of the zone, but overall totals, especially towards the top, are quite high (Abs.-6%). Other recorded mire taxa are Caryophyllaceae and Pedicularis, both with continuous curves and, more sporadically, Empetrum (which may be a mis-identification), Thalictrum, Hydrocotyle and Caltha. There are also a number of records for Menyanthes, not only by way of pollen, but also in the form of seed evidence. Typha/Sparganium levels (1-4%) show little in the way of change.

The incidence of Sphagnum spores is much reduced from the high totals latterly recorded. Following a basal record of 8%, subsequent values do not rise above 2%. Polypodium spores are only found in the bottom part of the zone, and Filicales totals are very low. Lycopodium representation varies between medium in the bottom half of the zone and high in the upper part.

Interpretation

Samples from a horizon above the zonal boundary give a 14C date of 1200 BP 60 (SRR-3321), which leads to the supposition that Zone I covers most of the post-Roman period. The pollen record suggests that the catchment area was by now generally open, and dominated by grazing land, although with a limited amount of arable agriculture in the form of cereals and hemp (Cannabiaceae). Woodland was probably confined to small areas, and no doubt much fragmented. Even the once extensive stands of hazel coppice seem to have gone.

Although the climate would by this time have been generally cool and wet, several oscillations have been recorded in the Sub-Atlantic period, and may well have influenced mire development. The reduction in *Sphagnum* pollen, for instance, suggests that the incipient succession to valley bog recorded in Zone H had somehow been averted in favour of sedge poor-fen development (as shown by the curves for Cyperaceae and mire herbs). It may also be implied from the reduction in Gramineae values that the *Phragmites* reedswamp had largely disappeared, althouth the *Menyanthes* records suggest the retention of small semi-open water patches. If there was a phase of drier climatic conditions, then the *Sphagnum* growth rate would slow down, compaction could bring the surface back into contact with the water table, and plants would again be in receipt of mineral-rich waters. At the same time, the former reedswamp areas would succeed to sedge fen. The *Lycopodium* curve suggests that the rate of peat growth slowed down in the first part of the phase, but subsequently increased again. Decreasing peat compaction towards the surface may, however, result in spore frequencies similar to those encountered in periods of rapid peat deposition.

There are no signs of the re-establishment of alder carr, although the slightly stronger Salix curve may indicate that conditions in places were conducive to the development of wet woodland. It may be that stocks of alder had by this time become so depleted that there was no suitable seed source. From the cessation of Polypodium records, it may be inferred that the epiphytic ferns disappeared along with the alder. Very low Filicales spore values point to the demise of the marsh ferns, which may indicate that they, too, grew best in the proximity of alder. On the other hand, it may simply be that the marsh ferns were drowned out in the reedswamp phase.

Zone J (10-20cm)

Main Features

Most of the trends of the previous zone are continued, but there are also some marked changes in this phase. Firstly, there is a revival in the proportion of AP, which reaches 20% of TLP in the top level. The rise can be directly attributed to substantially higher levels of Salix pollen than at any other stage in the diagram, with percentage frequencies of up to 14%. There is also re-establishment of the Pinus curve, albeit at low levels. Other tree and shrub taxa essentially follow recent trends, although the *Acer* curve which began in Zone I disappears.

There is a continuation of strength and diversity in relation to woodland edge, arable and pastoral taxa, although there are no records of Cannabiaceae above 16cm.

A major reversal occurs, however, in the relative proportions of Gramineae and Cyperaceae pollen, values of the former rising to levels of 48-56%, whilst those of the latter fall from 50% at the top of Zone I to 29% at the base of this phase, and subsequently to 9%. Other mire taxa still show reasonably high levels of diversity but, of the aquatic types, *Menyanthes* pollen no longer occurs, and *Typha*/*Sparganium* levels are slightly lower than before. *Lycopodium* spore frequencies decrease markedly.

Interpretation

The re-establishment of the *Pinus* curve probably reflects latter-day conifer cultivation. There are small plantations of young trees close to the mire, and, although the plants are almost certainly too immature to have produced the pollen recorded in the diagram, there could be a history of small-scale conifer cultivation locally.

In the light of decreasing levels of peat compaction towards the mire surface, it is difficult to suggest a date for the beginning of this zone, but the phase may well entirely reflect changes which have taken place within the last two hundred years. Thus, the final record of Cannabiaceae pollen may mark the end of local hemp cultivation (cf. French & Moore, 1986).

The major changes which delimit the zone, however, relate to events on the mire itself. The high *Salix* pollen totals are almost certainly related to the sizeable area of willow carr now to be found in the centre of the mire, and the reversal in the Gramineae:Cyperaceae pollen ratio is likely to reflect the fact that much of Cors Gyfelog now supports *Molinia*-based communities (Figure 4). The much-reduced exotic spore count may reflect a considerable slowing-down in peat growth rates but, as in the basal zones, may be related to mineral inwashes (see Chemical Analysis section). Although the modern status of the mire is largely a topic for later discussion (See Chapters Five and Six), the implications are that Cors Gyfelog is now considerably drier than it was even two hundred years ago, and that drying has occurred quite rapidly. The presence of drains on the mire has already been noted, and the correlation between the drainage system and "dry" mire communities seems quite obvious.

Chemical Analysis

Curves for each analysed element and for LOI (Figure 10), are described below. The zonations referred to are the same as those used for the pollen diagram.

Nitrogen

Concentrations at the base of Zone A are low in comparison to the rest of the profile (13.1 g/kg smoothed, 12.0 raw), but rise to a peak of 20.9 just before the upper boundary. Levels fall again to c.18 for most of Zone B, and to a minimum of 13.7 just below the B/C boundary. Zone C values are on the whole lower than those for B (15-16), but there is a peak at the close with levels similar to those of the Zone A peak (Max. 20.5). In Zone D, concentrations are roughly the same as those of Zone C, but with a slight peak (18.3) in the middle of the phase.

Levels increase considerably in Zone E, to a maximum of 30.5, and higher values are maintained throughout the remainder of the profile, although subject to fluctuations. Concentrations on the E/F boundary are lower than at the Zone E peak (Min.21.9), but still exceed those of Zones A-D. Values increase again in Zone F, and peak at 30.1 just before the close. A decline sets in during Zone G, however, and there is a minimum level of 20.6 in the middle of the phase before another increase in H, with a peak of 30.9 at the H/I border. From then on, there is a trend towards lower values

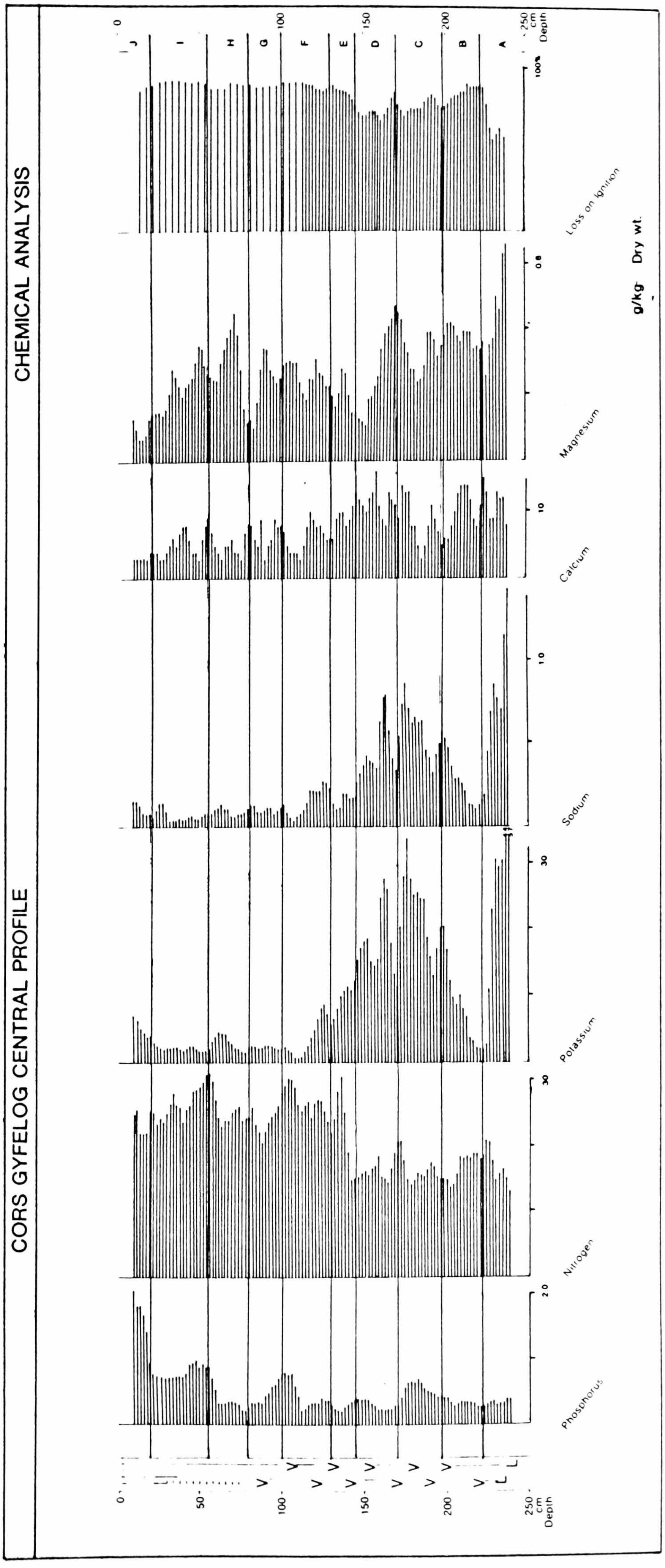


Figure 10 Cors Gyfelog Central Profile - Chemical Analysis

with minima in the region of 23 in Zone I and 21.9 in Zone J, but with minor peaks in both phases, including at the top of the latter.

Phosphorus

Concentrations in Phases A and B are similar (0.26-0.41 g/kg), before a peak in the middle of C of 0.66. Levels are lower again at the closing boundary, and for the bottom half of D (Min. 0.22, smoothed, 0.17 raw). Values similar to those in A and B are found by way of small peaks on the D/E (Max. 0.40) and E/F boundaries (0.39). There is a major peak at the top of Zone F of 0.79 before a return during G and most of H to values similar to those of A,B, D/E and E/F. There is then another large peak on the H/I border (Max. 0.97, smoothed, 1.12 raw), after which concentrations drop only marginally. Levels much higher than at any previous stage are seen at the base of Zone J, and values continue to rise during that phase to a maximum of 2.04 (2.25, raw).

Sodium

The highest levels in the profile (1.44 g/kg, smoothed, 2.00, raw) occur at the base, but values fall during Zone A to very low concentrations (c. 0.1), before reviving and reaching a peak of 0.57 at the top of Zone B. Despite fluctuations, the overall pattern in Zone C is of increasing concentrations culminating in a peak of 0.86 just below the upper boundary. Following a temporary decline on the boundary itself, high levels are again achieved in the lower part of Zone D (Max. 0.79), but from there a decline sets in, and concentrations are considerably lower for the remainder of the profile.

There is a minor peak of 0.27 on the E/F border, but a fall to very low levels (Min. 0.04) towards the top of Zone F. Values in G and H are generally low, but fluctuate at between 0.08 and 0.14, and even lower for most of Zone I (< 0.10), but concentrations in Zone J are similar to those of G and H (Max. 0.15).

Potassium

As with sodium, levels of potassium are very high at the base of the profile (Max. 56.8 g/kg, smoothed, 65.0, raw), and fall to a minimum (2.1) on the A/B boundary, but rise to a peak of 20.6 at the top of Zone B. After fluctuations, a higher peak of 33.5 is reached near the top of Zone C. Values decline somewhat on the C/D boundary, but then peak again at 24.9 in D before a general decline sets in.

There is a slight revival towards the top of Zone D (Max. 18.2), and another at the base of Zone F, (8.5) but values fall to very low levels half way through that phase (Min. 0.8). Zone G concentrations are a little higher (Max. 2.6), but still much below those for the lower part of the profile. There is a minor peak towards the top of H (Max. 4.5), then a reversion to values similar to those of G in Zone I before a more marked peak of 6.7 at the top of Zone J.

Calcium

The calcium curve is very erratic, but there are, nonetheless, certain visible trends in the smoothed data. On an overall basis, it would appear that concentrations fall with decreasing depth. Levels in Zones A and B are generally high (5-15 g/kg), but with troughs in the middle of A, on the A/B boundary, and on the B/C border. Despite fluctuations, concentrations tend to increase until halfway through Zone D, and reach a maximum of 16, before a decline sets in leading to a trough (Min. 6) on the E/F boundary. Values in the lower half of F are slightly higher (Max. 10), but fall again in the top section (Min. 3). Zone G levels show an increase, but the curve is very erratic. Concentrations are very low again at the base of H, but there is a peak of 10 at the close. Following another decline, there is a small peak (8) in the middle of Zone I, but from thereon, levels are low, between 3 and 5.

Magnesium

Magnesium levels are at their highest at the base of the profile (Max. 0.66 g/kg, smoothed, 0.92 raw), and then fall to more or less stable, but still quite high, concentrations throughout Zone B and the lower part of Zone C (0.3-0.4). There is a trough in the middle of C, (Min. 0.24) but a peak at the C/D boundary (0.47).

During Zone D, there is a general decrease in values resulting in a more marked trough than before (Min. 0.11), but levels increase erratically through E, F and the lower half of G to 0.34. Concentrations are not, however, as high as in the basal zones. Following the peak in Zone G, there is a major decline at the top of the phase (Min. 0.10), before a maximum in Zone H of 0.45, a minor trough, then another peak at the base of Zone I (0.35), followed by a punctuated decline to 0.07 before a slight revival to 0.13 at the top of J.

Loss on Ignition

Levels are low for much of Zone A, but rise to a peak on the upper boundary. Overall Zone B values are higher than those of A, but fall to a trough on the B/C boundary. A slight revival follows, but there is then another series of low values in Zone C which, apart from a peak on the upper boundary, continue for most of Zone D.

Concentrations in Zone E and later are higher than any recorded since the A/B boundary, although values are slightly lower at the base of F, in G, at the base and the close of I, and again in J.

Comparison of Curves

Spearman's Rank Correlation Coefficient tests (see Chapters One & Two) show that the highest positive correlation is between the K+ and Na+ curves (Rs=0.87, n=55). The curves for N and LOI are also similar (Rs=0.74, n=90), there is a strong correlation between P and Ca++ (Rs=0.53, n=55), and to a lesser extent between P and N (Rs= 0.32, n=55), P and Mg++ (Rs=0.31, n=55), and Ca++ and Mg++ (Rs=0.31, n=55). Ca++ is more strongly related to the monovalent cations than is Mg++ (e.g. Ca++:Na+ Rs=0.43, n=55, Mg++:K+ Rs=0.29, n=55).

There are particularly strong negative relationships between the monovalent cations and LOI (e.g. Na+:LOI Rs=-0.84, n=90), and slightly less marked ones between the monovalent cations and N (K+:N Rs=-0.62, n=55, Na+:N Rs=-0.68, n=55). Weaker negative relationships are found between the curves for the divalent cations and N (Ca++:N Rs=-0.22, n=55, Mg++:N Rs=-0.31, n=55). The relationship between Mg++ and N would be considered significant at the 95% confidence level (critical value about 26%, n=55), but not at the 99.9% level (Matthews, 1981), as would the negative relationships between Ca++ and LOI (Rs=-0.29, n=90), and Mg++ and LOI (Rs=-0.22, n=90), (critical value 0.21, n=90), and the positive relationship between P and LOI (Rs=0.22, n=90). There appear to be no relationships between the curves for P and LOI (Rs=0.22, n=90), or P and the monovalent cations (P:Na+ Rs=-0.14, n=55, P:K+ Rs=0.20, n=55).

To summarise, the most obvious positive relationships are those between the curves for K+ and Na+, and between the N and LOI curves. Ca++ and Mg++ have a positive, but weaker correlation to each other, whilst Ca++ also appears to have a positive relationship with P and the monovalent cations. There are also relatively weak correlations between Mg++ and P, and Mg++ and the monovalent cations. There are a few curves which show little or no correlation. All four cation curves show negative relationships with N and LOI, strongest in the cases of Na+ and K+.

Interpretation

High basal values for sodium and potassium in Zone A reflect the strong mineral element in the bottom sediments. Low LOI and nitrogen values confirm the predominance of mineral, rather than organic, material. The relatively low calcium concentrations in this zone suggest that the silt was not derived from basic parent material. With the presumed infilling of the shallow lake (see stratigraphy section), and colonisation by land plants, sodium and potassium totals decline, but nitrogen and LOI values rise. The increase in calcium concentrations on the A/B boundary may be due to locking up of the element in plant tissue, especially wood (Ross, Pers. comm.).

Table 3, modified from Allen et. al. (1974), shows chemical characteristics of some selected plants, but the results relate to certain tissue only, and so are of relatively little value in making comparisons with whole plant material in peat deposits.

Plant	g/kg Dry weight					
	N	P	Ca	Mg	Na	K
[a] Carex nigra	16	1.3	4.5	1.7	1.2	16
[a] Glyceria maxima	18	2.3	7.1	2.1	0.4	16
[a] Molinia caerulea	19	1.2	1.4	1.1	0.3	13
[a] Phragmites communis	30	2.0	5.0	1.8	0.4	16
[b] Alnus glutinosa	28	1.7	10.0	2.7	0.1	13
[b] Betula spp.	20	1.9	6.9	2.7	0.1	10
[b] Corylus avellana	23	1.7	6.9	2.7	0.1	10
[b] Salix spp.	24	2.3	7.4	2.3	0.4	16
[b] Filipendula ulmaria	26	2.2	8.5	5.9	0.1	15
[c] Sphagnum spp.	10.5	0.9	3.0	1.0	0.4	3.5

[a] Aerial growth
[b] Leaves
[c] Whole plant

Table 3 Chemical characteristics of selected plants

Modified from Allen et. al. (1974)

Influxes of mineral material are implied in Zone B by declines in values for nitrogen and LOI, and increases in those for sodium and potassium. High magnesium levels at the base of Zone A are probably associated with the mineral content of the sediment, but also coincide with a peak in Filipendula pollen values (Figure 9). Table 3 suggests that magnesium concentration is higher in meadowsweet leaves than in other major peat forming plants but, turning the argument round, meadowsweet thrives in waterlogged mineral soils, and may have been well represented in this period because of the mineral substrate. Other Filipendula pollen peaks, (in Zones B, the top of Zone C, and in Zone H), however, do not coincide with low LOI values, but there are magnesium peaks in each case. Phosphorus concentrations also tend to be slightly higher in meadowsweet (and in Phragmites) than in most other mire plants, but the curve does not appear to respond in the same way as that for magnesium, except perhaps at the top of Zone C.

In the lower part of Zone C, there is a slight reversal in concentrations of nitrogen and LOI, which rise, on the one hand, and sodium and potassium, which fall, on the other. The curve for calcium declines slightly later than do those for the monovalent cations, by which time the latter are rising to a peak again, and nitrogen and LOI falling.

The relationship between nitrogen concentrations and LOI values has already been noted, as has the inverse relationship between nitrogen and LOI on the one hand, and the monovalent cations on the other. It is possible that when there is a closed carr canopy, vegetational turnover is relatively slow, and much of the peat mass is made up of wood deposited periodically in large chunks. This situation may be conducive to the accumulation of mineral matter, partly because peat build-up may be slow, with any one point representing a long timespan, and perhaps also because of trapping of sediment by tree roots. It is notable that, as nitrogen and LOI levels rise at the top of Zone C, so does the Cyperaceae curve in the pollen diagram.

It is unfortunate that "interference" to the nitrogen curve by influxes of mineral material makes it difficult to establish relationships between nitrogen levels and peat types. In theory (Table 3 and Ross, Pers. comm.), apart from when Phragmites is present, nitrogen concentrations should be greatest in the lower two-thirds of the profile which are largely wood-dominated but, because of repeated influxes of mineral material in Zones A-D, the opposite is found in practice. When LOI values remain high and relatively steady, from Zone E upwards, nitrogen values rise markedly (whilst carr still dominates), but fall from Zone G onwards when the peat is sedge- (and much later Molinia-) dominated, except for a period of very high values between 40-60cm, which largely coincides with discoveries of Phragmites macrofossils in the peat.

A presumed transition to more open carr in Zone D is accompanied by mineral inwashes as shown by sodium and potassium peaks, together with low LOI values. The cations peak twice in Zone D, but the upper peak is less marked than the lower. Values for calcium, although fluctuating, are generally high until the middle of Zone F, when the carr begins to phase out, vindicating the suggestion that the element accumulates in woody tissue.

Phosphorus levels are generally low from Zone D to the upper part of F, but concentations seem to be slightly higher when the canopy is more open and percentages of Gramineae pollen, which may include Phragmites, rise.

The pollen diagram suggests more open carr in Zone F. LOI, sodium and potassium curves all suggest a minor mineral inwash event at the opening of the phase, after which monovalent cation curves fall to very low levels. Table 3 suggests that potassium concentrations vary only marginally in different plants, except for particularly low levels in Sphagnum tissue. Sodium concentrations, on the other hand, should be highest in sedge-dominated peat, and the curve, after falling to a minimum in Zone F, does revive slightly in Zones G and H as mixed alder and sedge peat gives way to sedge deposits. A return to lower values in Zone I may reflect the presence of Phragmites material. In theory, with increasing domination by Molinia, sodium concentrations should be low at the top of the profile, but towards the close of Zone I, LOI values begin to fall again, and those for the monovalent cations rise, suggesting renewed mineral inwashing, probably due to modern agricultural practices.

Although much less marked than at the periphery, the inorganic content of the peat at the top makes further interpretation of the curve impossible in terms of plant material.

The erratic calcium curve dips markedly at about 115cm, roughly coinciding with the reappearance of herbs in the peat, and again at 80cm when wood disappears altogether. Very low concentrations at the top of Zone I and in Zone J again probably reflect Molinia invasion. Obviously, the progressive decline in calcium levels during the upper part of the profile raises questions regarding the future trophic status of the mire. These are discussed more fully in Chapter Six.

The 14C date of the base of Zone G, 2740 60 BP (SRR-3322), suggests the beginning of the Sub-Atlantic period. There is surprisingly little evidence of mineral input (low sodium, potassium, high LOI) even though pollen records suggest that major deforestation was taking place in the catchment at this time. Simultaneous evidence of valley bog development leads to the suggestion that ombrogenous, rather than anthropogenic, influences were mainly responsible for the implied sequence of retrogressive succession on the mire. In either situation, however, evidence of mineral input would be expected because of instability on the newly-denuded valley slopes. It is possible that if, as previously suggested, stands of hazel were being selectively maintained on the mire margins for coppice, their roots could have had a buffering effect on material coming down from the catchment, just as alder on the carr could have concentrated particles in earlier times. It may also be that conditions were just so wet that inorganic matter reaching the mire was flushed straight through in the river system.

In Zone I, with the assumed re-establishment of sedge fen, phosphorus levels are higher than at any previous stage. Whilst this may be partly attributable to the presence of Phragmites, the further increases in Zone J point, as with the sodium and potassium curves, to input from agricultural run-off. and the possibility of seepage into the upper parts of the profile.

Cors Gyfelog Periphery (GYFP)

Pollen Analysis

Material for this profile was extracted from the eastern side of the mire (Figure 6), in line with the East-West transect (Figure 7). Cores were taken before levelling had been carried out but unfortunately, because of a dispute between the owners of this particular part of the mire and the NCC regarding drainage restrictions following SSSI renotification, permission for further access was not granted. The location and surface level of the coring point has therefore been estimated in Figures 6 and 7 to enable as full a section as possible to be shown.

The stratigraphy is as follows:

0-50cm	Brown fibrous peat. Roots to 18cm, dark brown band 13-14cm.
50-75cm	Dark brown fibrous peat with *Phragmites* remains.
75-100cm	Dark brown peat with herb, alder, *Phragmites* and possibly charcoal remains.
100-160cm	Brown alder peat with occasional herbs. Mineral material 143-145cm.
160-180cm	Brown peat with wood and herbs. Possible mineral bands at 162cm and 180cm.
180-200cm	Wood peat.

Zones for the pollen diagram (Figure 11) have been defined mainly by the comparison of peripheral dates and events with those of the central core. Some divisions however, in particular the sub-phases in Zone I, are based on characteristics individual to the peripheral pollen diagram.

Zonations are as follows:

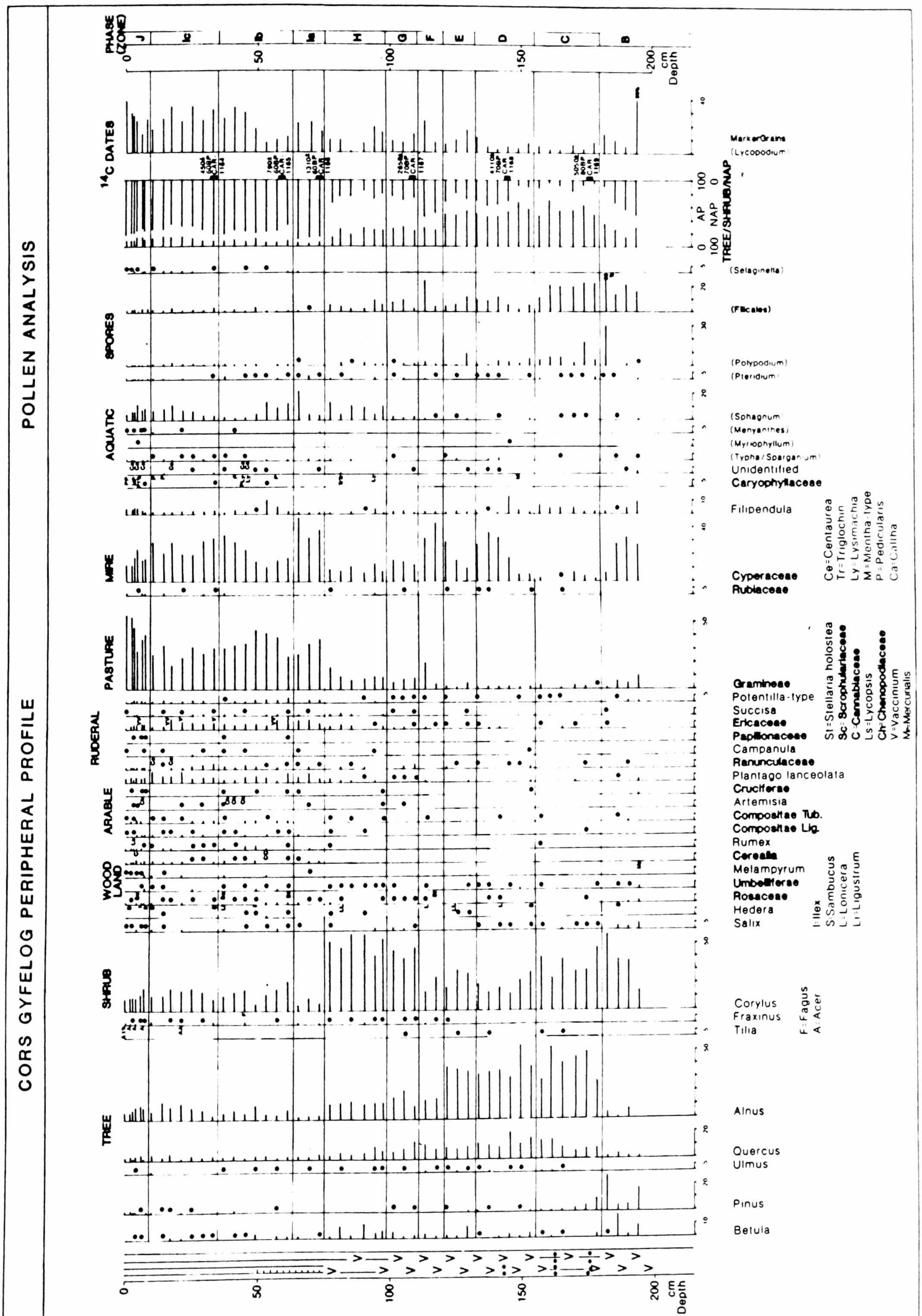


Figure 11 Cors Gyfelog Peripheral Profile - Pollen Analysis

0-9cm	Zone J
9-35cm	Ic
35-63cm	Ib
63-75cm	Ia
75-98cm	H
98-110cm	G
110-120cm	F
120-132cm	E
132-155cm	D
155-180cm	C
180-200cm	B

The profile is only 200cm deep, as opposed to 240cm in the central core, and basal deposits are of wood rather than mineral material. These factors, combined with the presence of relatively large proportions of AP at the base of the GYFP pollen diagram imply that peat initiation began substantially later at the periphery than in the centre. There is no suggestion of a pollen zone analogous with GYFC Zone A, and the basal GYFP zone has therefore been named B on the basis of certain similarities with GYFC Phase B.

Zone B (180-200cm)

Main Features

At the base of the zone, 48% of TLP is AP, whilst by the top the total has risen to 91%, of which 35% is tree pollen. The main tree taxa are Betula (0-17%) and Pinus (5-27%), although both curves fluctuate considerably. There are no Ulmus records, and Quercus values are very low (2-4%) as are those of Alnus (Abs.-7%). Corylus totals rise steadily from 15-56%, whilst Salix counts fall to zero after a high basal record of 5%. There is one Sambucus record.

Taxa associated with woodland fringes decline as the zone progresses. Records for both Rosaceae (undiff.) and Umbelliferae cease after opening values of 2%. There is a single *Mercurialis* grain. The only ruderal/arable pollen observed are a few Compositae Tub. grains, and one Cruciferae. Grassland taxa frequencies decline as AP values rise. Gramineae concentrations fall from 10% to 1%, and *Plantago* from 2% to zero. *Potentilla*-type grains are also found only in the lower samples and there are just single Ericaceae, *Succisa* and Ranunculaceae records. *Pteridium* spore values are also minimal.

The only records of mire pollen taxa are Cyperaceae, which decrease from 32% to 6%, and *Filipendula*, with values which fall from 8-0%. *Typha*/*Sparganium* totals are very low, as are *Sphagnum* spore percentages. *Polypodium* representation is sporadic, but totals reach 30% at the close of the phase. Filicales frequencies are quite high in relation to the rest of the profile, at between 14-39%. Apart from the extremely high level of *Lycopodium* spores (99%) in the basal sample, totals are generally low.

Interpretation

Certain pollen diagram features are common to Zones B in both Cors Gyfelog profiles, but the closing date at GYFP (5050 80 [CAR-1169]) is much later than the corresponding one for GYFC (7250 70 [SRR-3325]). This would suggest that on the basis of age, GYFP Zone B is actually equivalent to the opening part of GYFC Zone C, but in this case the common phase name has been based on similarities in pollen spectra.

Extrapolation of ^{14}C dates points to peat initiation in this part of the mire about 6000 years ago, presumably in the wet Atlantic climate, although the similarities to GYFC Zone B may indicate that the basal phase at GYFP covers a longer time period in which local conditions were sometimes favourable for peat formation, and sometimes not. Low Lycopodium frequencies suggest that peat growth rates were very slow.

High Betula and Pinus values combined with low Quercus totals and the absence of Ulmus pollen, for instance, are more suggestive of the Boreal than the Atlantic, and Alnus values are surprisingly low considering that the central diagram (Figure 8) indicates that alder was well established in the area over 7000 years ago. Whilst it could be argued that the pollen diagram shows a very localised picture in which hazel growing at the margins of the original mire area was replaced by sedges and willows as the climate became wetter, and eventually by alderwoods as peat built up, it is interesting to note that Corylus totals rise from relatively low values at the base of the zone. This suggests that hazel, too, was in the process of establishment, even though central diagram evidence suggests much earlier colonisation.

Despite the fact that Gramineae values are relatively low and pollen from open country herbs is in decline, NAP spectra from this phase appear more characteristic of GYFC Zone B than of Zone C at the central site.

Zone C (155-180cm)

Main Features

AP percentages rise to their highest levels in the profile (84-96%), and include tree pollen of 47-71%. The composition of the tree pollen is considerably different from that of Zone B, with marked declines in the frequencies of both Betula and Pinus, but with simultaneous increases in Quercus and Alnus percentages (7-15% and 27-53% respectively). Ulmus pollen appears at the top of the phase and two records of 1% mark the highest levels in the profile. Two Tilia grains are recorded.

Of the shrubs, Corylus values (24-47%) are similar to those of the basal zone. Salix totals (Abs.-1%) are low, but the curve is semi-continuous.

Pollen records for woodland herbs are few, and there are only occasional appearances of arable/ruderal or pastoral types. These do, however, include single Rumex and Compositae Tub. grains, and a sample with Plantago at 1%. Gramineae levels (Abs.-3%) are very low, as are those of Ericaceae and Pteridium. Cyperaceae values (Abs.-7%) are the lowest in the profile but Filipendula levels (2-7%) are quite high. Very few Typha/Sparganium grains or Sphagnum spores are present, but fern spores, both Polypodium (3-18%) and

Filicales (12-23%) are found in quantity. *Lycopodium* spore levels are again low.

Interpretation

Declining *Betula* and *Pinus* curves, coupled with rising *Quercus* and *Alnus* values and the appearance of *Ulmus* pollen, all indicate the expansion of mixed oak woodland at the expense of the remnants of Boreal forest, whilst low NAP values suggest that little open land remained in the vicinity by this time.

The peat, which appears to contain more herbaceous material than in the previous zone, suggests that the carr on the mire was relatively open, and possibly relates to the replacement by alder carr of former fringing communities of hazel, birch, willow and sedge. There is evidence from the LOI curve (Figure 12) that mineral inwashes dominated this phase, whereas it would be expected that if tree cover in the catchment was more or less complete, movements of mineral matter would be minimal. There are no suggestions from the pollen diagram (such as the appearance of ruderal pollen) that inwashes derived from local felling. As with the equivalent GYFC phase, low exotic spore records may reflect inputs of inorganic material.

Explanations for the inflows may centre around local river activity, either by way of flooding events, or because of changes in watercourses due to meandering. This latter explanation is quite plausible, especially as some of the cores taken at this sampling point show silt/clay bands of up to 5cm thick, which are hardly likely to be related to single events. As suggested in respect of the central profile, once mineral material had reached the mire, it may have accumulated around tree roots. Conditions in the open carr seem to have been particularly favourable for the growth of ferns, both ground species and epiphytes, and also for meadowsweet.

The placing of the upper zonal boundary at 155cm coincides with the beginning of an upward trend in Cyperaceae pollen levels which, by intrapolation of ^{14}C dates, equates approximately with comparable events in the main profile.

Zone D (132-155cm)

Main Features

AP ranges between 61-90%, with the lowest values in the top half of the zone. Although tree pollen totals are slightly lower than before (46-68%), the main AP decline is by way of shrub pollen, essentially that of Corylus, levels of which range from 40% in the opening part of the phase to 13% in the closing half.

Of the trees, Betula values (Abs.-3%) approximate to those of Zone C, but Pinus representation (Abs.-1%) continues to decline. Ulmus records are lower than before, and the curve is only semi-continuous. Quercus frequencies of 9-20% are the highest in the profile, although the higher counts tend to be in the bottom half of the zone. There is an Alnus peak of 54%, but overall levels of 30-40% are marginally lower than before. There is one record of Tilia. Of the remaining shrubs, Salix grains, when present, never exceed 0.5%. There are single records of Sambucus and Lonicera.

Gramineae (1-2%), Ericaceae (Abs.-1%) and Pteridium values remain very low, and a Plantago record of 1% is similar to the previous phase, but curves for other herbaceous taxa show signs of increasing strength. Of woodland edge taxa, there are a couple of records for Rosaceae (undiff.), and Umbelliferae values of up to 1%. In the arable/ruderal section, there are single Cruciferae and Compositae Tub. records, whilst in the pasture section, curves for Ranunculaceae, Potentilla-type and Rubiaceae are all stronger, and there is a single Campanula grain.

The Cyperaceae curve rises markedly to a peak of 36%, and Filipendula values reach 13%, but decline markedly at the top. There is a single Mentha-type grain, but few Sphagnum spores. In the aquatic section, there are occasional Typha/Sparganium records, and one Myriophyllum. Of the spores, Polypodium values of 1-7% are lower than before, especially at the close of the phase, as are Filicales levels (3-21%). Lycopodium totals are generally very low, but increase temporarily at the top.

Interpretation

On the basis of interpolated dating, this zone is estimated to have lasted for approximately 900 years, from about 4500 BP to c.3600 BP, which more or less parallels GYFC Zone D. As with that zone, it is difficult to accurately define exact boundaries. In both cases, however, AP declines significantly, and there is the suggestion that hazel was occupying a more limited range than before. Other arboreal pollen features in common are low levels of Betula and Pinus, an apparent Ulmus decline and the presence of occasional Tilia grains. In particular, both Quercus curves are strong at the base of the zone but weaken in the upper half, although the incidence of taxa which may be associated with human activity (e.g. ruderal, grassland and heathland types) is more marked at the centre than at the periphery.

In both diagrams the phase is characterised by considerable increases in the proportions of Cyperaceae pollen, possibly distorting the curves for woodland taxa, and probably indicating wet conditions, which would endorse the suggestion from the central diagram that hazel was being pushed back beyond the mire margins. The decline of Alnus pollen at the centre but not at the periphery may merely suggest that the wet conditions were affecting hazel more severely than alder. The fact that the peripheral peat appears to be still mainly composed of alder is taken to be a less reliable reflection of the open-ness or otherwise of the canopy than is the pollen record. It was quite often found that, when describing a series of cores from a multi-profiling location such as GYFP and GYFC, proportions of wood and herbs and the stratigraphical boundaries of profiles taken even from within a couple of metres of each other did not match at all well.

Again the LOI curves for both profiles suggest inflows of mineral material, which may possibly have resulted from clearance activity, but could be logically explained by flooding episodes. Low Lycopodium counts again reflect the inorganic element in the peat.

Zone E (120-132cm)

Main Features

The opening AP value of 83% shows a marked increase over the closing Zone D total. Levels decline again to 67% at the top, although tree pollen values of 48-54% remain marginally higher than before. There is a particularly high Betula total of 9% at 129cm before a fall to 2%, still quite strong in relation to much of the profile. Pinus, Ulmus and Tilia values are much as before, but Quercus percentages (8-10%) equate to the least of the Zone D values. The first Fraxinus grains are recorded.

Alnus totals (35-38%) are a little higher than before, as are the opening records for Corylus (28%,30%) before they decline at the close to 17%. There are no records of Salix, but occasional Lonicera and Hedera grains.

Most of the NAP is of Cyperaceae (10-29%), frequencies of which rise again at the close of the zone after a temporary fall from Zone D values. One Umbelliferae grain represents the sum of woodland edge pollen, there are no records of arable/ruderal taxa, and levels of grassland types are either much the same as, or slightly lower than, Zone D values. A Gramineae record of 5% at 129cm, however, represents the highest recorded count since Zone B. The same sample includes a Succisa grain and a Plantago record of 1% (which is rounded-down from 1.2%, unlike the previous two phases where Plantago percentages of 1% have been rounded-up ones, from 0.6% in both cases). Filipendula values (1-3%) are quite low, as are Typha/Sparganium and Sphagnum totals. Frequencies of both Filicales and Polypodium decline through the phase, the latter to only 1%. Lycopodium spores return to low levels after having attained quite high values over the opening boundary.

Interpretation

As with the central profile, there are suggestions that tracts of cleared forest were regenerating during this phase, which is estimated to cover the early Bronze Age over a period of 400-500 years up to about 3200 BP. The upper boundary is thought to coincide with the GYFC dated horizon of 3230 ± 60 [SRR-3323]. Central pollen records point to the re-establishment of oakwoods over much of the area, whilst lower Quercus values in GYFP suggest that this was not necessarily the case locally. Both profiles, however, suggest that elm was of less importance in the forest than previously. The very high basal Betula record here coupled with the resurgence of Corylus, and the apparent decline of grassland taxa after the base suggest a "landnam" phase (cf. Iversen, 1941) in which birch colonised an abandoned area, and was eventually replaced by hazel and ash, but full succession to oak was not completed.

On the mire, weaker Cyperaceae and slightly stronger Alnus values may indicate that dry conditions returned until the upper boundary, when a further increase in Cyperaceae levels suggests reversion to open carr. As at GYFC, the LOI curve shows no indication of mineral inwashes in this zone, and exotic spore values rise somewhat.

Zone F (110-120cm)

Main Features

This short zone, comprising only two samples, precedes the ^{14}C dated boundary of 2650 ± 70 BP [CAR-1167] for the base of the suceeding phase, and thus covers roughly the same timespan as the corresponding zone in GYFC (dated upper boundary 2740 ± 60 [SRR-3322]). It is delimited at the base by a sharp decrease in Alnus values, which ranged from 35-38% in Zone E, but fall to 14-15%, and are the major reason for the lower AP totals of 43-50%.

Levels of Quercus pollen increase slightly to 11% in the upper level, at which stage Betula frequencies rise from 1%

to 3%, which are still within the general percentage range of the later part of the previous phase, as are the *Ulmus* values of 0-1% (rounded-up). *Corylus* records of 14% and 25% are not dissimilar to those of the two preceding zones. There are further records of *Fraxinus*, which reaches 1% at 113cm, and a single *Lonicera* grain, but no *Pinus*, *Salix* or *Tilia*.

In the woodland edge section, there are single grains of Rosaceae (undiff.), Umbelliferae and *Stellaria holostea*, but the sole representative of the arable/ruderal section is one Compositae Tub. The *Plantago* record of 1% at 113cm marks the beginning of a continuous curve, and coincides with an increase in Gramineae values from 4% to 20%. The Ericaceae curve is by now continuous and the *Pteridium* curve nearly so, both with levels slightly higher than before.

Cyperaceae representation reaches at 43% before declining to a still-high total of 32% at 113cm, whilst *Filipendula* levels of 2% remain on the low side. There are no *Typha*/*Sparganium* records, and *Sphagnum* values do not exceed 1%, but nonetheless, the spores mark the beginning of a continuous sequence. *Polypodium* totals (2-4%) remain low, but a Filicales record of 24% at 113cm coincides with a small peak in *Lycopodium* values.

Interpretation

As with the corresponding GYFC zone, on the one hand, major fluctuations in AP since Zone D seem to have been related more to events on the mire than in the catchment, allowing the suggestion that forest cover in the Middle Bronze Age was still extensive. On the other hand, however, pollen evidence points to increasing human impact resulting in nearby areas of secondary woodland, moorland and grassland.

The late Sub-Boreal climatic deterioration implied in the GYFC pollen diagram is substantiated in this profile by the reversal of Alnus and Cyperaceae pollen levels, and the beginning of a curve for Sphagnum. As in the central profile, there is no real evidence from the LOI curve of increased run-off, but higher Lycopodium frequencies at the upper boundary suggest an increase in peat growth rates.

Zone G (98-110cm)
Main Features

AP totals of 70-75% are much higher in this phase than in Zone F, although the main increase is by way of shrubs (40-48%) rather than trees (25-30%). Betula values rise from 2% at the base to 5% at the top, and Salix pollen (0-2%) is present again for the first time since Zone D. Quercus levels decline from 13% as the zone opens to 6% at the close. Pinus pollen appears only sporadically, there is a single record for Ulmus and one final Tilia. Fraxinus is present at low levels in a broken curve. There is a minor Alnus peak of 21%, but values are generally much lower than in Zones C-E. Corylus levels, on the other hand, rise markedly to 39-48%, higher than at almost any other stage.

Woodland edge taxa are represented by Rosaceae (undiff.), with values of <0.5% at each level, and one Umbelliferae grain. The only arable/ruderal record is a single Artemisia, the first occurrence of the taxon at this site. Of the grassland types, Plantago grains are by now present in nearly every sample, Ericaceae and Pteridium curves become slightly stronger than before, and a broken curve begins for Succisa. Gramineae levels of 5-8% are lower than the Zone F peak, and Cyperaceae frequencies of 13-16% are also less than those of the previous zone, but Filipendula values of 1-3% are more or less unchanged. Very little aquatic fringe pollen is recorded (one Typha/Sparganium grain), but Sphagnum levels (2-3%) continue to rise. Percentages of both Polypodium (0-2%) and Filicales (3-10%) are low, whilst Lycopodium values are quite high.

Interpretation

This zone is essentially dominated by Corylus pollen, adding weight to the suggestion from GYFC that hazel coppicing was practiced in the locality by Late Bronze Age peoples. As stated above, high Corylus levels make it difficult to interpret the behaviour of other curves. Despite the decline in Quercus pollen values, for instance, there may still have been considerable areas of oakwood, although GYFC Quercus levels suggest that deforestation activities were accelerating, as do increasing pollen records for pastoral taxa. The occurrence of small Betula and Salix peaks despite Corylus "interference" makes it seem likely that some local woodland regeneration was taking place after clearance activities.

Although Gramineae levels are lower than the peak at the top of Zone F, they are still higher than at any other stage since the base. In the central diagram, Gramineae increases markedly, and the GYFP curve would be expected to behave likewise if it were not being artificially depressed by high Corylus levels. The same is likely to be true of the Cyperaceae curve, and perhaps even that for Alnus, although stratigraphical evidence from all over the mire suggests that by this stage carr was giving way to sedge fen. Although Typha/Sparganium values do not yet give any indication of reedswamp development, strengthening of the Sphagnum curve suggests that climatic conditions were deteriorating. The high Lycopodium values over the lower boundary could represent a short period of rapid peat growth, perhaps of a more ombrotrophic nature than before.

Zone H (75-98cm)

Main Features

AP (67-85%) remains high in this zone, again mainly due to shrub (essentially Corylus) values of 44-57%. The boundary between this and the following phase has been ^{14}C dated at 1310 ± 60 BP [CAR-1166], representing the point at which Corylus levels finally decline. Tree pollen percentages range from 14-28%, values at the top being noticeably lower than those of the previous two phases.

The basal *Betula* value of 6% represents the continuation of a small peak which began in Zone G. The curve then fluctuates, but two further peaks, of 11% and 10% respectively, can be seen within the phase. A relatively high *Quercus* record of 10% immediately follows the first *Betula* peak, but later values do not exceed 5%. *Salix* pollen is only found at two levels, the earlier record of 2% coinciding with the *Quercus* peak. Curves for *Ulmus* and *Fraxinus* are much as before, and there are occasional records of *Sambucus* and *Hedera*, but none of *Pinus*. *Alnus* values of 11-13% are perhaps slightly lower than in the previous two zones, but *Corylus* totals of 41-57% are even higher than in Zone G.

The curve for Rosaceae (undiff.) is more broken than before, but individual values are a little higher, reaching 1% by the close. Umbelliferae grains are present at every level. There are more arable/ruderal taxa than before, namely a further *Artemisia* record, several representatives of both Compositae types, and single grains of Cruciferae and *Rumex*. The pastoral section includes stronger *Plantago* (Abs.-3%), *Succisa* (Abs.-2%) and Ericaceae (Abs.-3%) curves, but slightly weaker ones for Ranunculaceae and *Potentilla*. There are also records of *Campanula* and Rubiaceae. Gramineae levels (6-16%) rise only slightly, but the highest value occurs at the top of the phase.

On the mire, Cyperaceae representation, at 6-13%, is a little lower than in Zone G, _Filipendula_ values of Abs.-4% are more or less the same, and there are occasional records of _Triglochin_ and _Lysimachia_. _Typha_/_Sparganium_ occurrences are still very irregular, but the _Sphagnum_ curve rises markedly, with values of between 5% and 14%. Totals for both _Polypodium_ (0-3%) and Filicales (3-10%) are rather low, whilst _Lycopodium_ levels are high at both zonal boundaries but fall in the middle.

Interpretation

Like Zone H in GYFC, the base of this phase is assumed to coincide with the Sub-Boreal/Sub-Atlantic transition at about 2400 BP, and the beginning of the Iron Age. As with Zone G, _Corylus_ dominates the pollen diagram, perhaps even more than before, and the evaluation of local vegetational changes continues to be difficult. As the _Corylus_ curve holds reasonably steady, however, the AP decline in the upper part of the phase is assumed to be real, suggesting quite major deforestation. Amongst the several cores taken at this location for analysis and dating, there are various field note entries relating to dark bands at about 80cm which may be of charcoal and be related to felling activities. The three _Betula_ peaks could well represent minor phases of regeneration. Whereas the central diagram suggests that hazel coppices were either being destroyed or over-exploited by this time, peripheral records indicate that there were still important local stands.

Slowly strengthening curves for herbaceous taxa provide further evidence of agricultural activity locally and, although there is no Cerealia pollen in this zone to parallel GYFC, nonetheless there are several new records of taxa associated with arable farming, and stronger curves relating to grassland and moorland even though the Gramineae curve is still suppressed by Corylus.

There is nothing in the pollen record to suggest that the balance between alder carr and sedge fen changed markedly at this stage. There is also no indication from Typha/ Sparganium pollen of incipient reedswamp development, but there are occasional Phragmites remains in the peat, and the high Sphagnum spore totals point towards a very wet climate with further succession towards valley bog, although Lycopodium spore counts are not as high as would be expected under such a regime.

Zone I

Introduction

For much of the GYFP profile, evidence from pollen records and ^{14}C dating has suggested that rates of peat deposition have been slower than at GYFC, and zones have been correspondingly shorter. The base of GYFP Zone I, at 75cm depth however, has been allocated a date of 1310 ± 60 BP

[CAR-1166], which is roughly equivalent to the estimated date for GYFC Zone I, (interpolated from 1200 ± 60 BP [SRR-3321]) &at only 55cm depth. It would appear, therefore, that at this stage, GYFP peat deposition rates suddenly increased (or that the general environment was by this time wet enough to arrest peat decomposition at the periphery). Unlike Zone I at GYFC, the parallel phase at the periphery is divisible into three, horizons of which have all been dated. Rather than diverging from the original aim of matching zones in the two profiles by giving them the same letter name, it has been decided to divide GYFP Zone I into three subzones, entitled Ia, Ib and Ic respectively.

Zone Ia (63-75cm)

Main Features

Following a major decline in Corylus values, AP totals do not exceed 14% of TLP, and the relative proprtions of tree and shrub pollen are more or less equal. Values for most of the individual tree and shrub taxa decrease: Quercus gradually to 2%, Alnus more suddenly to 2-3%, and Betula to Abs.-1%. There are no Pinus records, and only one each of Ulmus and Salix. Fraxinus, with values of 1% in two of the three samples covered by the phase, fares a little better. As mentioned above, however, the most dramatic decline is in the Corylus curve, which falls from about 50% to 4-9%.

Of the woodland edge types, there are several records of Rosaceae (undiff.) and one of Melampyrum, but none for

Umbelliferae. In the arable/ruderal section, both Compositae types undergo a temporary decline, there being just one record in the Tub. section. Rumex is recorded at one level, but with an increased value of 1%. There are further single Artemisia and Cruciferae grains. The most notable feature in this section, however, is the beginning of a curve for Cerealia, with values of 0-1%.

There are further increases in the frequencies of grassland pollen taxa. Gramineae levels rise markedly to 26-38%, the highest total being in the bottom sample, Plantago values reach 3-7%, and Ericaceae 4-7%. Curves for Ranunculaceae, Potentilla-type and Pteridium are also stronger, that for Succisa is almost continuous, and there is a further Campanula record. Selaginella spores are recorded for the first time at the top of the zone.

On the mire, Cyperaceae levels of 32-47% are the highest in the profile, but Filipendula totals (1%) stay low. Typha/Sparganium pollen is recorded from two of the three samples, with values of 1% and 2% respectively, and one sample contains Menyanthes at 1%. Opening Sphagnum totals of 4% and 5% are lower than most of the Zone H values, but the record of 22% in the top level is the highest in the profile. There are only occasional Polypodium and Filicales spores, but Lycopodium counts are rather high.

Interpretation

Radiocarbon dating indicates that this phase covers a period of about 500 years, from 1310 ± 60 BP [CAR-1166] to some time before 790 ± 60 BP [CAR-1165]. The pollen diagram suggests that the local landscape was virtually as open as today. Gramineae and Cyperaceae pollen values increase greatly as those for Corylus decline, but AP curves do not, confirming suggestions that major deforestation had taken place locally at some stage between the Late Bronze Age and the end of the Roman periode, but that its effects were masked by Corylus over-representation in this profile. Chambers (In press) refers to evidence indicating several local clearance phases, e.g. after c.3100 BP, c.2300 BP and c.1950 BP, the latter having the most major impact on the landscape. The two Cors Gyfelog profiles more or less back Chambers' interpretation, but pollen from GYFC in particular suggests that the phase of human activity which had the greatest permanent effect on the landscape was at the end of the Bronze Age, rather than in the Iron Age or the Roman period. There does not seem to be any evidence from the two GYF pollen diagrams to confirm Chambers' suggestion of a reduction in human activity and the development of hazel and birch scrub between c.1540 BP and c.1225 BP. Instead, there is the suggestion that stands of hazel were preserved at the expense of other trees but destroyed before 1310 BP.

Although the pollen record indicates the local importance of pastoral agriculture, the establishment of a cereal pollen curve in this zone confirms that arable activities were also taking place.

High Cyperaceae pollen values and stratigraphical evidence such as *Phragmites* remains leave no doubt that the mire by this time was both open and wet. The GYFC *Sphagnum* curve suggests a return to minerotrophic conditions throughout Zones I and J. The peripheral *Sphagnum* curve declines temporarily in this phase, perhaps indicating some climatic amelioration, but the continuation of relatively high levels of *Sphagnum* in the remaining zones suggests that rapid peat growth in the first part of the Sub-Atlantic has left this part of the mire on a threshold between ombrotrophy and minerotrophy. High values of exotic *Lycopodium* spores confirm speculations regarding faster rates of peat growth in Zone I at GYFP than at GYFC, although less compact peat towards the surface could also result in fewer pollen grains per unit volume.

Zone Ib (35-63cm)

Main Features

AP (19-33%) increases slightly over Zone Ia, with higher values for both trees and scrub. Most of the scrub pollen is accounted for by increased *Corylus* levels (5-21%, average 14%), and much of the tree pollen relates to slightly raised *Alnus* values (3-9%). *Polypodium* (Abs.-2%) and Filicales (1-4%) totals increase at the same time. The *Betula* curve is essentially low and irregular, but there is a record of 3% at

49+cm. *Quercus* values (1-3%) are the lowest in the profile, and there are only odd appearances of *Pinus*, *Ulmus*, *Fraxinus* and *Salix*. There are single occurrences of *Acer* and *Fagus*, the latter being the only example of the taxon found at Cors Gyfelog. There are also *Hedera* grains at four levels and single ones for *Lonicera* and *Ligustrum*.

There are more records of woodland edge pollen types, Rosaceae (undiff.) and Umbelliferae occurring almost continuously. Scrophulariaceae (*cf. Digitalis purpurea*), *Melampyrum* and *Stellaria holostea* grains are also present. Cerealia pollen is absent for part of the lower part of the zone, but reaches 2% in the top half. There are also two records of Cannabiaceae. The *Rumex* curve peaks at 3%, there are three records each of Chenopodiaceae and Cruciferae, continuous curves for both Compositae types, and one *Artemisia* grain.

Gramineae levels rise to 44% after a slight decline over the lower boundary, whilst *Plantago* frequencies (1-7%) are similar to those in Zone Ia. Curves for Ranunculaceae (0-3%), *Potentilla*-type (0-4%) and *Succisa* (Abs.-1%) strengthen, a broken Rubiaceae curve begins at the top of the phase, and there are also records of *Campanula*, *Vaccinium* and Papilionaceae. *Selaginella* spores occur in three samples. Ericaceae levels reach 9% at the base but then decline to 3-4%, which is lower than in the previous zone, although still above the average for the profile. *Pteridium* values (Abs.-3%) are more or less the same as before.

Cyperaceae percentages fall markedly to 11-17% in the lower part of the phase, but rise to 34% by the top, whilst Filipendula levels reach 11% early in the zone, but then fall to ≤3%. There are single records of other taxa associated with the mire, namely Caltha, Caryophyllaceae, Lysimachia, and Pedicularis at three levels. Typha/Sparganium grains occur in four samples, but never exceed 1%, and a single Menyanthes grain is recorded. The Sphagnum curve peaks at 14% in the bottom half but falls to 3% in the top levels. Lycopodium levels decline somewhat as the phase opens, but rise considerably in the latter samples.

Interpretation

Radiocarbon dating suggests that this phase lasted for about 350 years from 790 ± 60 BP [CAR-1165] to before 450 ± 60 BP [CAR-1164], and thus covers the Mediaeval period. Raised Corylus values may indicate that some tracts of land were abandoned at the beginning of this phase, but are perhaps more likely to relate to renewed coppicing activities. Certainly, there is no evidence from the Quercus curve that any succession to forest was taking place.

Excavations of a mediaeval farmhouse at Cefn Graeanog, near the northern end of Cors Gyfelog (Kelly, 1982) have shown that the property was deserted about 1300 AD, which would coincide with the middle of Zone Ib. At this stage, the pollen diagram shows high values for Gramineae, Cerealia, Rumex and Plantago . Gramineae and ruderal values subsequently decline, Betula rises to 3% and Corylus levels increase slightly, which may suggest some reversion to scrub. Cereal pollen is still recorded in the upper part of the zone, although at somewhat reduced values. Chambers (In press) refers to evidence of hemp cultivation after c.745 BP, and pollen diagram evidence in the form of two Cannabiaceae grains at 53+cm would confirm this observation.

Several strands of evidence point to drier mire conditions during this period, namely increased Cyperaceae levels in the upper part of the zone and fewer remains of Phragmites in the peat. A Filipendula peak at 57+cm and 53+cm, records of a variety of poor-fen taxa, and subsequently reduced Sphagnum frequencies may represent reversion from predominantly ombrotrophic to more minerotrophic influences locally. A marked decline in the LOI curve would substantiate this assumption, but not neccessarily tie up with the idea of minor scrub redevelopment. Reduced Lycopodium values in the lower part of the phase are in accordance with the aforementioned assumptions. Higher totals in the upper samples may reflect decreasing peat compaction. The opening part of the zone probably coincides with the early mediaeval warm epoch (Lamb, 1982) in which a temporary reversal of "Atlantic" features might be expected.

Zone Ic (9-35cm)

Main Features

Although NAP values rise over the Ib/Ic boundary to 82%, they decline again to 67% in the middle before a partial recovery at the top of the zone. Tree pollen totals (9-16%) are higher than at any time since the end of Zone H, but shrub percentages (9-17%) are about the same as in Zone Ib. Betula values do not exceed 1%, but Quercus levels (1-5%) are very slightly higher than before, and Fraxinus pollen occurs more frequently than in the previous two sub-zones. Acer pollen is recorded from two levels, and Ulmus from the upper boundary at 1%. A very notable feature is the recommencement of a curve for Pinus, albeit in frequencies of less than 1%. Alnus levels are very low (3%) at the base, but recover for the rest of the phase, and reach 13%, only a little lower than Zone H. Shrub pollen is almost entirely of Corylus (9-17%), but Salix occurs intermittently, with values of up to 1%, and there are odd records of Sambucus and Hedera.

Pollen from woodland edge taxa is perhaps slightly lower than in Zone Ib, whilst arable/ruderal totals stay largely the same. Apart from two records of ≤0.5%, Cerealia values of 1-2% are higher and more constant than before. Of the pastoral types, Gramineae values (17-33%) are slightly reduced, but other grassland taxa are well represented. Plantago levels (1-8%) are the highest in the profile, and there are strong curves for Ranunculaceae (Abs.-4%), Succisa

(0-1%), Potentilla-type (Abs.-2%) and Ericaceae (2-8%), as well as several records for Campanula, Centaurea and Vaccinium. Pteridium levels do not exceed 1%, but the Selaginella curve is almost continuous, with a maximum value of 2%.

Cyperaceae levels (20-32%) are about the same as in the upper part of Sub-zone Ib, as are those of Filipendula (2-3%). There are also records of Pedicularis in two samples, and one grain each of Caltha and Caryophyllaceae. Typha/Sparganium grains are recorded in all samples, and totals reach 2% at 14+cm. There are also two records of Menyanthes, including one of 1% at 10cm. The Sphagnum curve rises again and peaks at 12%. Lycopodium spores continue at high levels (17-34%) throughout the zone.

Interpretation

The AP/NAP ratio gives no real indication of increases in the area under cultivation, but the re-establishment of a curve for Pinus suggests intentional pine planting. The Pinus curve does not begin again at GYFC until Zone J which means that, unless the upper boundaries of Zone I are not synchronous, tree planting activities were very localised. A similar conclusion may be reached regarding the possible continuation of coppicing activities because Corylus values remain higher at the periphery than in the central diagram.

Higher *Alnus* representation may suggest further drying-out in the eastern part of the mire, and lower Gramineae totals may in part be due to loss of reedswamp. On the other hand, despite a further decline in LOI values, higher *Sphagnum* levels suggest a return to the valley bog threshold. It is assumed that much of this phase relates to the "Little Ice Age" (Lamb *op. cit.*) so, although water levels may have been relatively low, conditions above the water table could have been conducive to raised mire development. Despite high LOI levels, exotic spores are still recorded in considerable frequencies, endorsing suggestions of wet conditions, although decreased degrees of peat compaction would be expected by this stage.

Zone J (0-9cm)
Main Features

AP totals decline again to 19-27%, and there are gradual decreases in both tree and shrub levels. The curve for *Pinus* becomes stronger (0-2%), records for *Fraxinus* (0-1%) and *Acer* (Abs.-1%) are more consolidated than at any other stage, and *Salix* pollen occurs more regularly than for some time. Levels of *Quercus* (1-4%), *Alnus* (4-10%) and *Corylus* (9-17%) all decline. There are only two records of *Betula*, one each of *Ulmus* and *Sambucus*, and two of *Ilex*.

Woodland edge taxa are present in more or less the same proportions as before, whilst records of arable/ruderal types are more varied and frequent. Pastoral taxa are also very well represented, especially Gramineae (29-55%), increasing levels of which define this surface phase.

Cyperaceae values (12-23%) are somewhat lower than before, but *Filipendula* percentages (2-5%) a little higher. Other mire taxa are *Mentha*-type, *Caltha*, Caryophyllaceae and *Pedicularis*. Of the aquatic taxa, there is one record of *Myriophyllum*, and also a curve for *Menyanthes*, but with values of ≤0.5%. *Typha*/*Sparganium* (Abs.-1%) and *Sphagnum* (5-12%) levels are similar to Zone Ic, but the lowest *Sphagnum* totals are those towards the surface. *Lycopodium* values (14-38%) remain high.

Interpretation

As with GYFC, the reversed Gramineae/Cyperaceae ratio is thought to be associated with the development of *Molinia*-based communities on the mire. The strengthening *Salix* curve only marginally reflects the growth of willow carr, especially when compared to the high values for the taxon recorded at the centre. The variety of pollen types relating to mire taxa, however, accurately depict species growing in the modern poor-fen. The LOI curve suggests that increasing amounts of mineral matter are being washed into the mire from the surrounding grassland, or blown in from the nearby sand and gravel quarry. The continuing *Sphagnum* curve suggests that there is still a degree of ombrotrophic influence, although there are no visible indications of incipient *Sphagnum* lawn on the eastern side of the mire.

Chemical Analysis (Figure 12)

As before, zonations used in the discussion of chemical analyses are the same as for the pollen diagram. Where possible, results are compared with those from the central profile.

Nitrogen

Nitrogen concentrations at the base of Zone B are relatively low (Max [smoothed] 14.2 g/kg) and fall to the minimum for the profile (7.1) over the B/C boundary. In Zone C, levels recover somewhat, and peak just below the close of the phase at 18.2 before declining again in Zone D to a low value of 12.7 at 143+cm. The pattern closely approximates to that seen at GYFC, but whereas the division between mainly low values in the bottom part of the profile and high ones in the upper half occurs in Zone E at GYFC, at GYFP the first major peak is just below the D/E boundary. Values continue to rise over Zone E and reach 23.6 in the bottom sample of Zone F before declining during Zone G to a trough of 15.8 in the lower part of Zone H, at which stage, despite a similarity in the overall pattern, there is a minor peak at GYFC not recorded in the GYFP graph. The highest levels in the profile (26.7) occur in Zone Ia, whilst the same peak appears on the H/I border at GYFC. Values are lower in Ib and Ic, but a slight peak in the middle of the latter Sub-Zone may equal one in the upper part of GYFC I. Levels at both profiles decline in the late stages of Zone I and in Zone J,

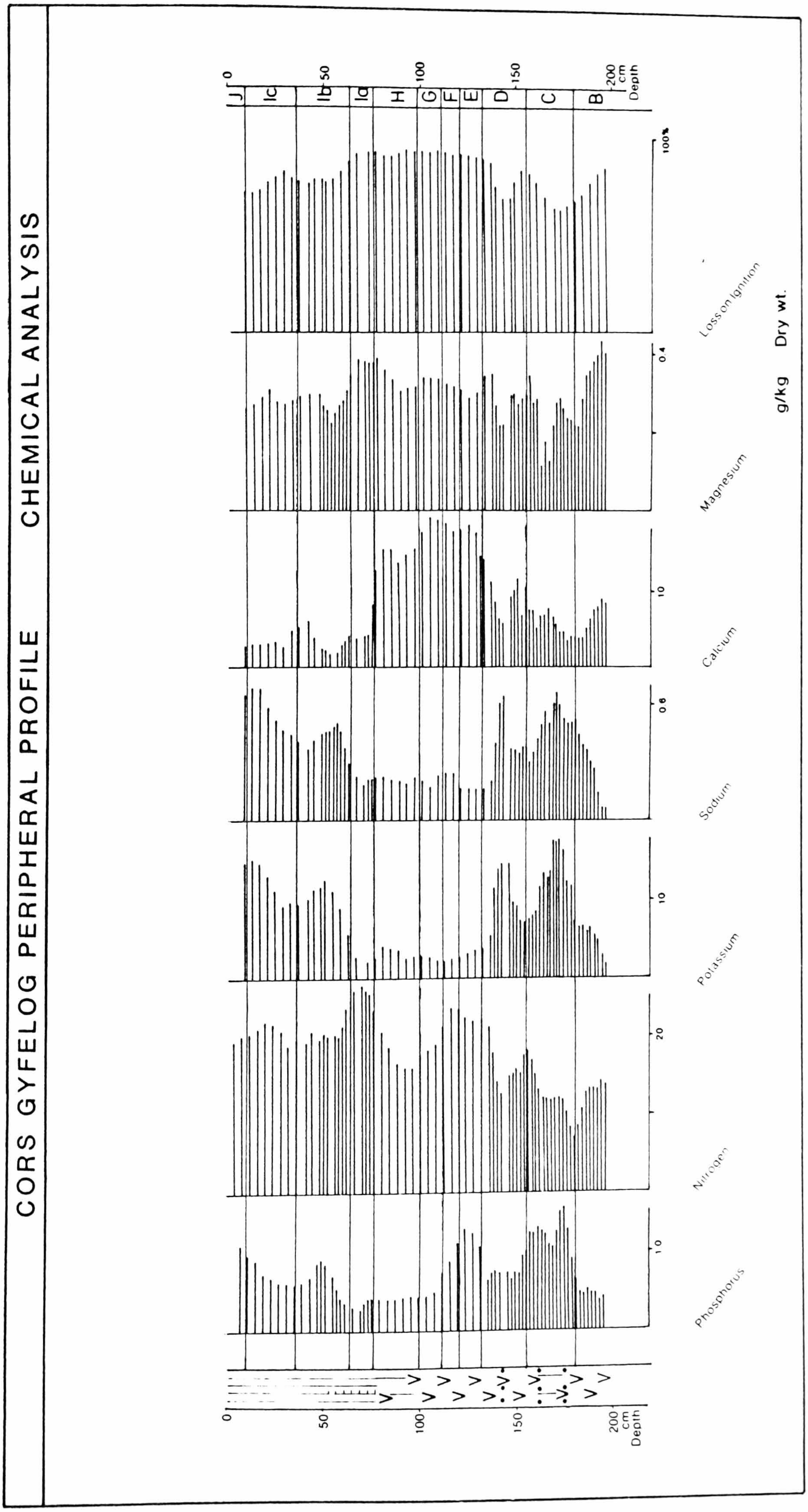


Figure 12 Cors Gyfelog Peripheral Profile - Chemical Analysis

but at GYFP there is no equivalent of the final upturn at GYFC. Average concentrations of nitrogen at GYFP (7.1-26.7 g/kg) appear to be about 5 g/kg lower than at GYFC (13.1-30.7g/kg).

Phosphorus

Zone B values of (0.39-0.91 g/kg [smoothed]) are rather low, but a major peak, with levels as high as 1.58, spans Zone C, and is roughly equivalent to, but with higher values than, one at GYFC. Zone D values are lower, but still higher than those of Zone B. There is another peak (Max. 1.30) in Zone E, which may equate to small maxima on the D/E and E/F boundaries of GYFC, or a larger peak on the border of Zones F and G. Values are low again (0.41-0.50) in Zones G and H, as they are at GYFC, and even lower in Sub-Zone Ia (0.28-0.36), but there is a peak in Zone Ib (Max 0.92), which is probably equivalent to one on the GYFC H/I border, and another in Zone J (Max. 1.09), again also visible in the GYFC profile. Apart from the surface peak at GYFC, phosphorus levels in the peripheral profile (0.31-1.58) are generally higher than those at the centre (0.21-2.04).

Potassium

The basal concentration is very low (1.9g/kg [smoothed]), but values rise during Zone B and peak at 17.8 in C, before declining on the C/D boundary but rising again to a smaller maximum of 14.7 in Zone D. The same overall pattern is also seen at GYFC, but the highest concentrations are greater at the centre than the periphery, and there is also GYFC evidence of other, smaller peaks not picked up in the GYFP analysis. Values are low in Zones E,F and G, and there is no equivalent at GYFP of the small maximum on the GYFC E/F boundary, but a minor peak in Zone H (Max. 4.1) is also seen in the central profile. A major surface rise begins in Zone Ib, which is also visible at GYFC, but at much lower concentrations (GYFC Max. 6.7, GYFP Max. 15.1).

Sodium

As with potassium, the basal level is very low (0.066g/kg [smoothed]), but values rise during Zone B. A small peak of 0.53 on the B/C boundary and further ones in Zones C and D (Maximum values 0.67 & 0.66 respectively) equal those of GYFC, but at slightly lower values. Concentrations in both profiles are low in Zone E, but both have a minor peak in Zone F. Values decline again in Zones G, H and I, and it is difficult to see whether there are any small fluctuations like those at the centre. As with the potassium curve, there are major peaks in Zones Ib (Max. 0.51) and J (Max.0. 69), more minor versions of which can be seen in the central profile.

Calcium

Values at the base of Zone B (c. 8g/kg [smoothed]) are slightly lower than in the corresponding GYFC phase, but higher than those at the top of the profile. At the end of the phase they fall to 3.7, the same stage as which values fall at GYFC, before rising gradually over Zone C to reach a peak of 11.3 at the beginning of Zone D, which is also more or less what happens in the centre. There is then a trough in Zone D (Min. 5.6) before a major peak (Max. 19.3) which spans E, F and G before declining gradually in H. Values during this period are much higher than any at the centre, and there is no real correspondence between the two curves. Concentrations are much lower during the three Sub-Zones I, but a small peak (Max. 5.7) in Ib may equate to one in GYFC I. There is no surface upturn in either profile.

Magnesium

A basal peak in Zone B (Max. 0.43g/kg [smoothed]) is the highest in the profile, but values decline markedly at the B/C boundary (Min. 0.22), and then again in the middle of Zone C (Min. 0.12), at which stage GYFC levels are also low. A peak at the top of Zone C (Max. 0.35) followed by a marked decline (Min. 0.22) in Zone D also corresponds to the central pattern. A further maximum at the top of Zone D (0.34) may relate to the GYFC Zone E peak, and a gradual build-up in concentration levels to a maximum of 0.34 in Zone G may equal a series of peaks in Zones E, F and G in the central profile. A slight decline (Min. 0.30) in the lower part of Zone H may parallel a low point on the G/H boundary of GYFC and a further small peak in Sub-Zone Ic may equal one above the middle of GYFC Zone I. Values in both profiles then decline, except for the final upturn at GYFC which is not repeated at the periphery. In general, magnesium levels for the two profiles are similar, although the GYFC curve is perhaps a little more prone to fluctuations than GYFP.

Loss on Ignition

Values at the base of Zone B are quite high (Max. 84.46% [smoothed]) but immediately start to decline, and reach a low point of 62.87% in the bottom half of Zone C, before peaking again over the top boundary of that phase (Max. 82.63%). The pattern is the same at that at GYFC, except at the latter there is an intervening peak in the lower part of Zone C which has no equivalent at the periphery. A trough in Zone D (Min 68.26%) can also be related to GYFC, but without a minor peak seen in the latter. Losses are at their highest over the top of Zone D, through E, F and G and into the beginning of H (Max. 93.22%). The same pattern is seen at GYFC, as is a slight decline higher up in Zone H. Both profiles return to higher values in I, and a small peak in GYFP Ic (82.80%) may equate to the stage at GYFC where values are highest. In general, GYFP losses throughout the three Sub-Zones I are lower than their equivalents at GYFC, but both profiles show a further decline in Zone J.

Comparison of Curves

Again, Spearman's Rank Correlation Coefficient Tests show that the strongest positive correlation is between the two monovalent cations (K^+:Na+ R_s=0.88, n=51 in all cases), and there is a definite relationship between N and LOI (R_s=0.46). Unlike GYFC, the curves for P and K^+ (R_s=0.55) and P and Na^+ (R_s=0.41) also show similarities, but those for P and Ca^{++} (R_s=-0.08) and P and N (R_s=-0.16) show no affinity at all, whilst there is a very strong negative relationship between P and Mg^{++} (R_s=-0.80 compared with 0.31 in GYFC). The relationship between Ca^{++} and Mg^{++} appears weaker at GYFP than GYFC (R_s=0.14 c/w 0.31), and there are strong negative correlations between the monovalent and divalent cations (Mg^{++}:K^+, R_s=-0.40. Ca^{++}:Na^+, R_s=-0.57. Ca^{++},K^+, R_s=-0.47) as opposed to quite marked positive relationships at GYFC. On the other hand, both divalent cations show strong positive correlations with LOI (Ca^{++}:LOI, R_s=0.54. Mg^{++}:LOI, Rs=0.46), whilst at GYFC the relationships are negative.

At GYFP there is an overall similarity between the curves for Mg^{++} and N (R_s=0.29), whilst a negative relationship between the two at GYFC is nearly as marked. A non-relationship between Na^+ and N at GYFP (R_s=-0.16) is turned into a strong negative correlation at GYFC, a positive GYFC P:Mg^{++} relationship into a very strong negative one at GYFP (R_s=-0.80), and a weak P:LOI GYFC correlation into a strong GYFP negative relationship (R_s=-0.53). The negative relationships between monovalent cations and LOI, however, are as strong at GYFP (K^+:LOI, R_s=-0.81. Na^+:LOI, R_s=-0.74) as at GYFC.

The comparison of chemical curves between the two GYF profiles creates many problems. The only clear messages to come out of both analyses are that K^+ and Na^+ levels are strongly related to each other, but both are negatively related to LOI, whilst there is correspondence between N and LOI. It appears that sodium and potassium are washed in to the mire as particulate matter, and that nitrogen levels equate to the ratio of organic and mineral material present at any one time. Despite apparent coincidences in peaks and troughs for the other elements when the two profiles are compared, the degree of overall synchroneity is apparently not sufficient to produce similar relationships when subjected to statistical testing.

Interpretation

Nitrogen levels in Zone B relate to a period when the mire was extending during the Atlantic period over former areas of scrub woodland, probably hazel and birch, at GYFP. Falling curves for nitrogen and LOI over the phase, in combination with rising sodium and potassium values suggest the receipt of mineral material from outside. Decreasing calcium and magnesium levels may relate to the build-up of peat and loss of contact by plant roots with the underlying mineral substrate. As in the central profile, there may be a relationship between high basal magnesium levels and peaks in the <u>Filipendula</u> pollen curve (Figure 11). Further magnesium maxima in the upper parts of Zones C and D also coincide with high *Filipendula* levels, but another magnesium peak in Sub-Zone la predates one for *Filipendula*.

The continuation of high concentrations of sodium and potassium in Zone C, matched by low levels of LOI, nitrogen and calcium suggests phases of mineral inwash as alderwoods became established. Phosphorus peaks in Zones C and E may be related to alder colonisation. Certainly levels are lower in Zones B and D when Cyperaceae pollen diagram values are high. Further evidence of mineral inwashes in Zone D mean that, as with the central profile, attempts to associate chemical curves with vegetational types are rather pointless before Zone E.

In Zones E-Ia, LOI values are relatively high and stable. As at GYFC, nitrogen concentrations rise as soon as the mineral influence is lost (at the top of Zone D), as do those for calcium, whilst sodium and potassium levels are very low. Nitrogen values start to decrease in Zone G, and calcium concentrations in Zone H, both events roughly coinciding with the final opening up of the carr canopy. Above 75cm, calcium concentrations are always low, but the nitrogen curve recovers in Zone Ia, coinciding with discoveries of *Phragmites* remains in the peat. These observations strengthen suggestions made in connection with GYFC that high calcium values relate to woody vegetation, and that nitrogen concentrations primarily reflect the ratio of organic to mineral matter, but in the event of this being stable, high concentrations appear to be associated with wood or Phragmites peat.

GYFP pollen diagram evidence suggests that by Sub-Zone Ia, the carr had finally disappeared, and the mire was drying out after a phase of reedswamp conditions. Despite the deforestation which had been taking place over the previous zones, there had been very little mineral inwash, perhaps because of buffering by hazel coppice which is thought to have been growing on the mire margin, or perhaps because by this time peat was growing above the level of the river flood plain. By this phase, pollen evidence implies that even the coppice had gone, but Sphagnum spore totals suggest that the mire may well have been on the verge of ombrotrophy.

At the beginning of Sub-Zone Ib, LOI and nitrogen values decline, whilst those for phosphorus, sodium and potassium rise markedly, suggesting the mire to be in receipt of mineral material again. This trend more or less continues and accentuates through to the surface. It would appear that for most of the past eight hundred years, the eastern part of the mire has constantly been in receipt of allochthonous mineral material. An alternative suggestion, however, is that all this material is very modern, having been washed in as a result of twentieth century farming activities, and is gradually being dispersed into deeper peat. It is notable that indicators of inwash are much less marked in the central profile than at the periphery, and that a much shorter timespan appears to be involved.

Plate 2 Tre'r Gof

CHAPTER FOUR

TRE'R GOF

The WWS schedule describes Tre'r Gof (Plate 2) as a rich fen (Evaluation Type D, Classification Type IX), of 4.5ha in extent. It was declared a SSSI in 1980, the total designated area, including surrounding fen meadow, totalling 10ha. The NCC SSSI schedule reads as follows:

> "... a small base-rich fen.... remote from other similar fens in the east of the island, but contains the same dominant species, notably blunt flowered rush (Juncus subnodulosus), fen sedge (Cladium mariscus), common reed (Phragmites communis) and, locally, black bog rush (Schoenus nigricans).
>
> There is a clear hydroseral development, Around the periphery is a herb rich Juncus meadow with such species as meadowsweet (Filipendula ulmaria), zigzag clover (Trifolium medium) and northern marsh orchid (Dactylorchis purpurella). Within this site is a stand of vigorous, flowering Cladium and intermixed with this the very common marsh fern (Thelypteris palustris) is abundant. Centrally Phragmites grows with patches of willow carr (Salix cinerea). On the edge of a small pool, greater reedmace (Typha latifolia) grows, with thread leaved water crowfoot (Ranunculus trichophyllus) on the bare mud."

Geology

The mire is situated to the south of Wylfa Head and Porth y Wylfa in northern Anglesey (Figures 1 & 13). It lies immediately to the east of Wylfa Nuclear Power Station.

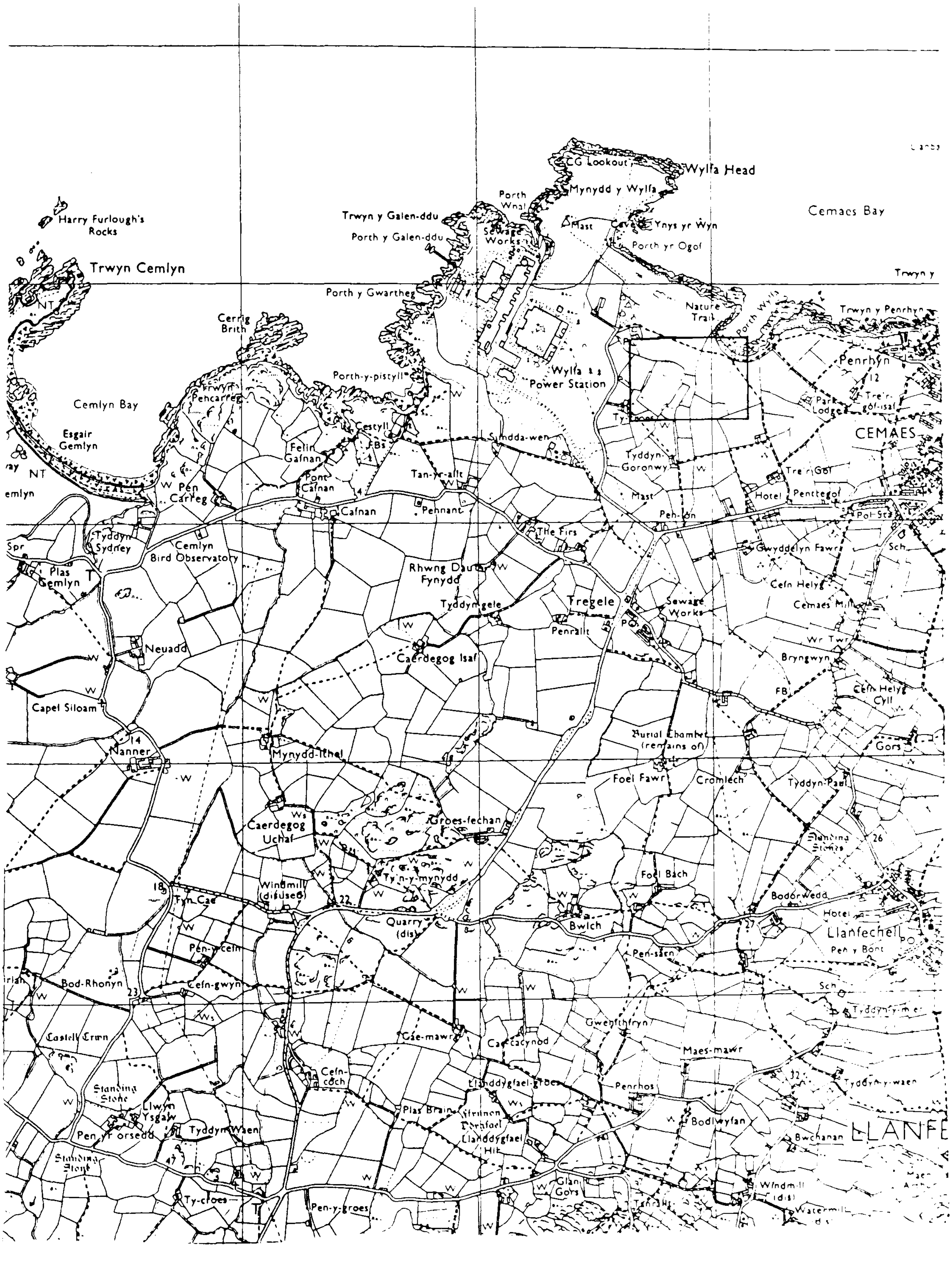


Figure 13 Tre'r Gof - Local topography

Geologically, the Wylfa area is on the boundary of the Gwna and Fydlyn, and New Harbour groups of rocks (Greenly 1919, Challinor & Bates, 1973). Harris (1986) submitted a report on the surface geology of the area to a company who were under contract to the Central Electricity Generating Board (CEGB) to investigate which of two sites would be most suitable for the construction of a new nuclear reactor to replace the current Magnox station, which is nearing the end of its working life. (In Spring 1988, the government officially announced its plans to build the new station on the "southern" site, rather than on the "northern" one where Tre'r Gof is situated, but at the time of writing, there was almost certain to be a public enquiry before any plans could be implemented).

Harris refers to the proximity of the boundary between the Gwna and Fydlyn groups to the SSSI. Challinor & Bates (op. cit.) describe the Gwna group as a very varied group within the Mona Complex, whilst the Fydlyn Group, which only outcrop in the region of Carmel Head further to the west, is described as highly acid, massive, and weathering white. Harris refers to finds of Fydlyn beds near the mire as deeply weathered low grade metavolcanic rocks. He also describes the presence of the Wylfa fault zone running beneath, and parallel to, the SSSI which, one assumes, renders the northern site unsuitable for a nuclear reactor.

The rich-fen status of Tre'r Gof implies a supply of calcium rich water. An obvious conclusion from the description

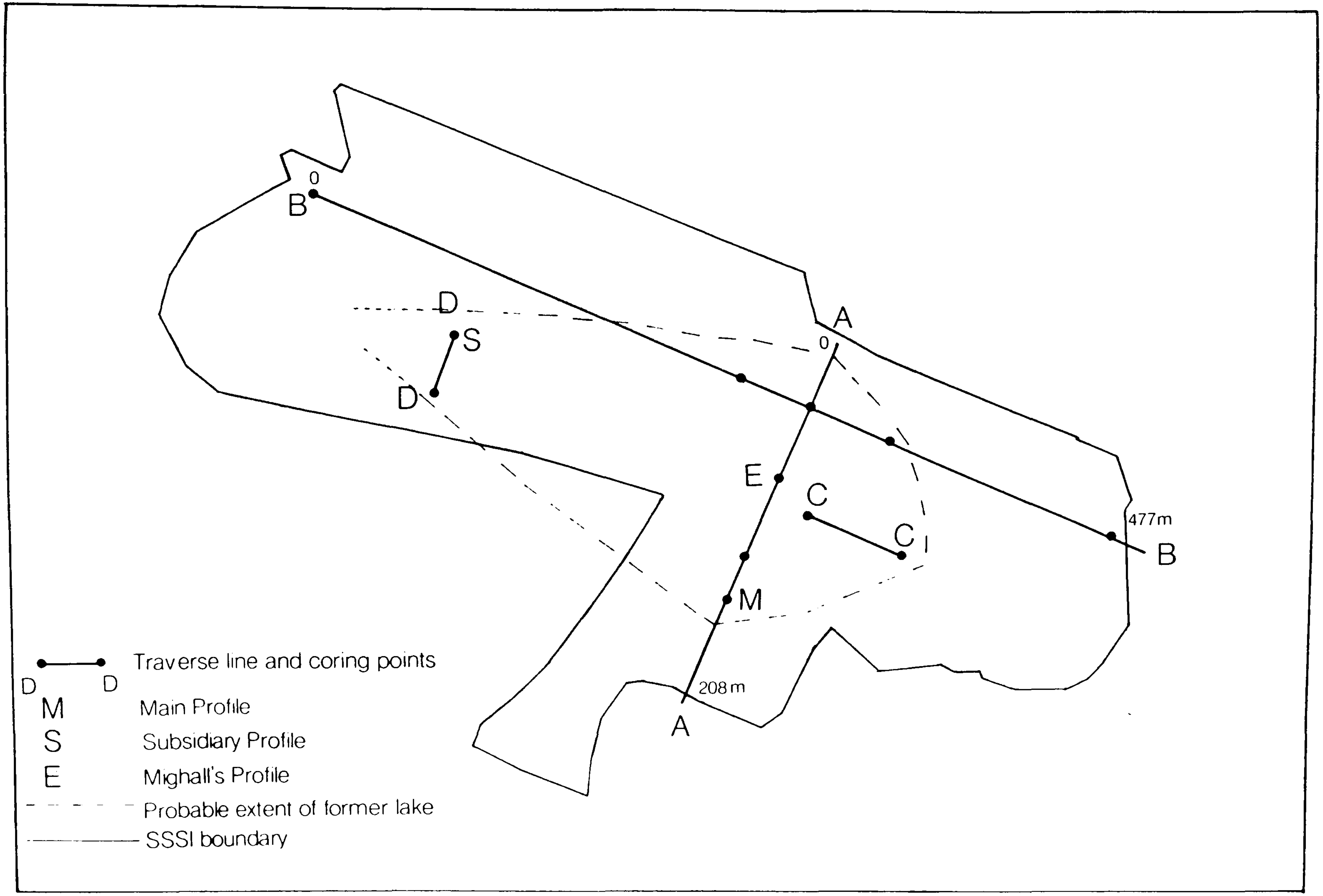


Figure 14 Tre'r Gof - Transects

above is that calcium sources for the mire are not erosion products of the Fydlyn beds. There appears instead to be a readily available supply of calcium from the glacial deposits which surround the SSSI. Two glacial stages have been recorded for Anglesey, the locally-derived Main Anglesey Advance, and the Liverpool Bay Phase. Whilst the two types of till could represent different events, Harris (op. cit.) favours an explanation that advancing ice from the north picked up loose sediments from the Irish Sea and Liverpool Bay which were then carried on the base of the glacier. Included in this load were many minute shell fragments, and thus the load was highly calcareous. When the ice reached Anglesey, the basal Liverpool Bay material lodged against the coast, whilst the clean ice above it continued to move over the island and subsequently picked up fresh local material. Liverpool Bay deposits are mainly found on the east coast of Anglesey, although a few tongues protrude inland along valleys.

Whilst Tre'r Gof is on the north coast, rather than the east, Harris (op. cit.) describes one of the major till types surrounding the mire as a "matrix supported black silty clay diamict containing subrounded to rounded erratic pebbles". It is rich in shell fragments and "reacts vigorously with dilute HCl, indicating a highly calcareous matrix".

Not only was this till, described by Harris as being of Irish Sea origin, deposited at Porth y Wylfa, but it was also

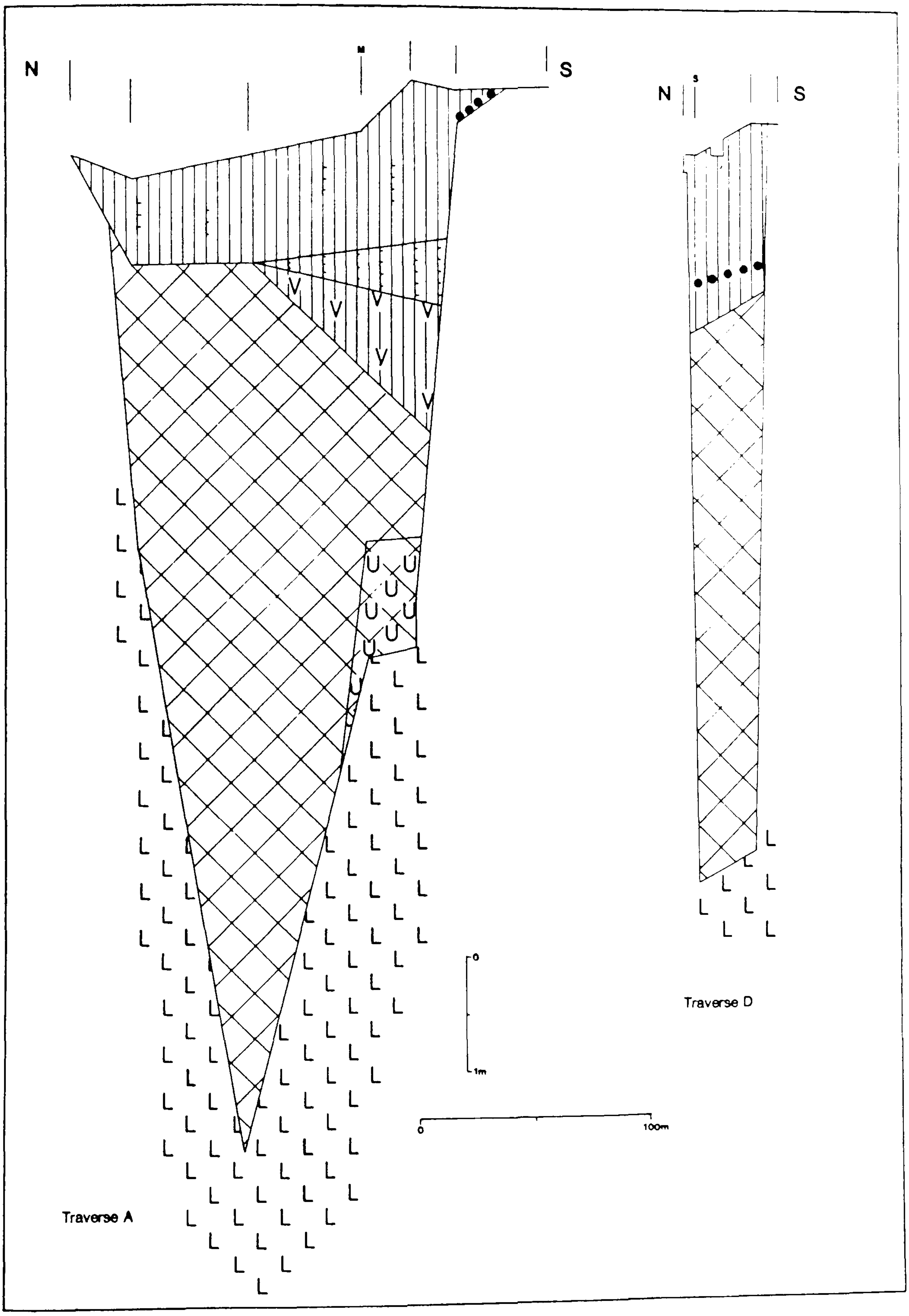


Figure 15 Tre'r Gof - Stratigraphy, Transects A & D

carried inland along the fault zone, and deposited to the south of the mire as drumlinoid hills.

Stratigraphy

Basin stratigraphy was investigated mainly by borings along two transects (A and B, Figure 14). Subsidiary transects (C and D) further elucidate the picture. Stratigraphical details are presented in Figures 15 & 16. Harris (op. cit.) suggests that the origin of Tre'r Gof lies in the underlying Wylfa fault which was instrumental in directing Devensian Ice. As the climate ameliorated, the fault became host to melting ice, forming a kettlehole surrounded by till, but with no outlet for water because of the deposition of Irish Sea till between the basin and the sea.

A trial boring penetrated to over 10 metres, and the deepest sediments were found to be blue-grey laminated silt overlying gravel. In subsequent borings, further records of lacustrine silts showed that the former lake occupied only the area which is now the centre of the mire (Figure 12). These mineral deposits, assumed to mark the end of the Late-Devensian Glacial Stage, were not investigated in detail by the author, but it was noted that in places the silt is several metres thick, and the blue-grey silt underlies green-grey silt, whilst where the mineral bands are narrower, only the green-grey silt is present. The borings confirm that the original lake basin was essentially elongated along a WNW-ESE axis, substantiating the hypothesis of development

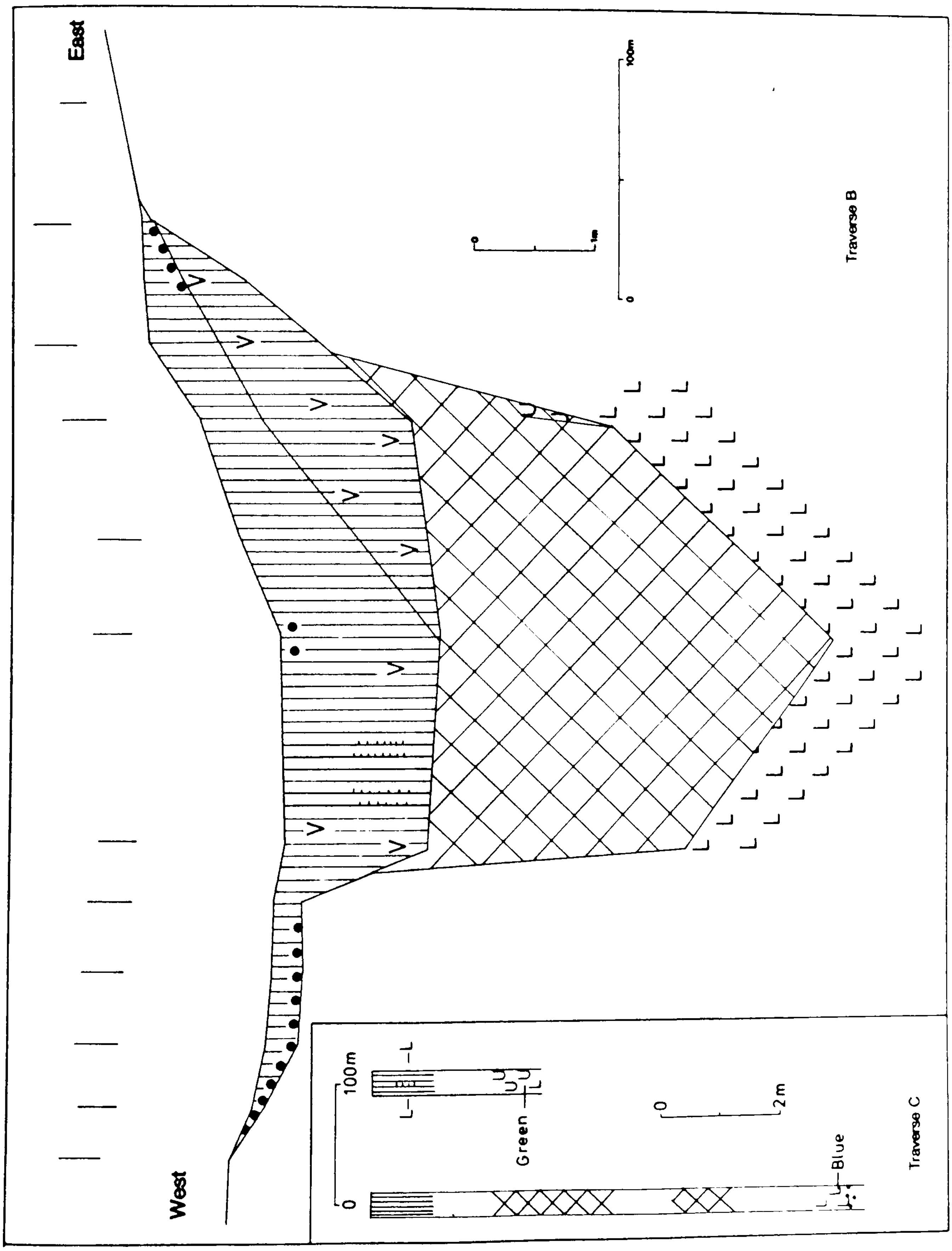


Figure 16 Tre'r Gof - Stratigraphy, Transects B & C

over a fault line. Indeed, Transect D (Figure 15) shows the basin to be very narrow at the WNW end of the mire, whilst Transects A (Figure 15) and C (Figure 16) show it to be broader towards the east and south, although still with very steep sides, especially at the northern edge. Note that for ease of reference, transects in Figures 15 and 16 are depicted as running from north to south and west to east rather than between interquartile points.

Another feature evident from the stratigraphy is that the current extent of the peat is twice that size of the original lake, encompassing the NCC's "wet meadow" (Figure 16). Much of the peripheral peat is very shallow, and presumably recent, but is nevertheless accumulating.

In the main basin, organic gyttja overlying the silt indicates that inwashes of mineral material were replaced by a mixture of allochthonous material derived from dead vegetation in the surrounding catchment and autochthonous matter from aquatic plants. In the south eastern quarter of the former lake are calcareous marl deposits - essentially calcium carbonate flecks intermixed with gyttja. These deposits appear to be most common where the sides of the basin shelve slightly. They may represent material washed out of the till, material which has precipitated out in deep water conditions where calcium levels are high, but nitrogen and phosphorous concentrations low (Birks & Birks, 1980), or deposition by shallow water plants and animals. Of these possibilities, the final one is perhaps the most likely. If

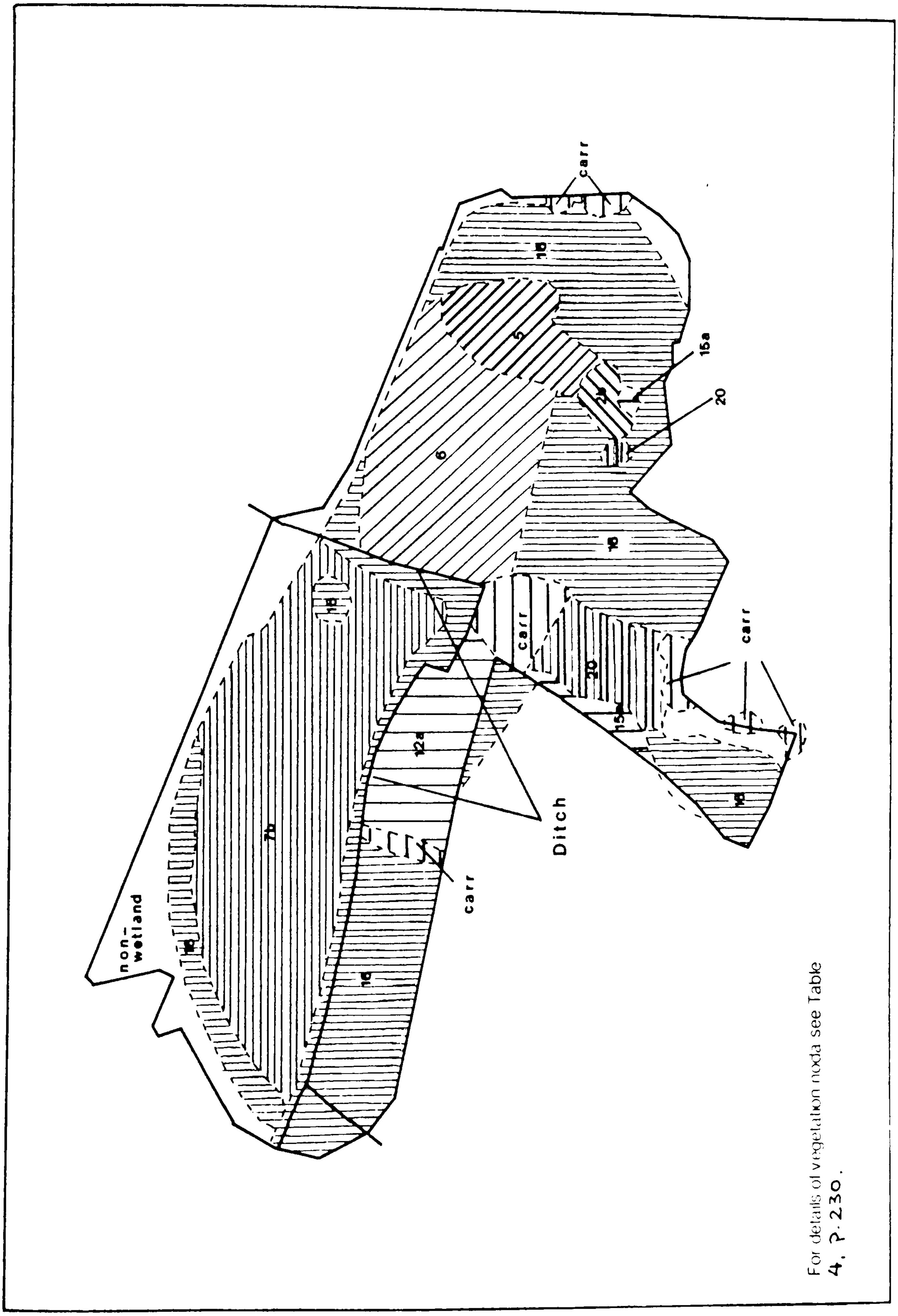


Figure 17 Tre'r Gof - Vegetation

either of the first two explanations were true, then the marl deposits would surely be more general. Additionally, chemical analysis (Figure 20) suggests that levels of nitrogen and phosphorous were no lower at the time of marl accumulation than at other stage in the history of the mire. The major argument against deposition by shallow-water organisms is that substantial deposits of gyttja overlie the marl, indicating continuing lacustrine conditions rather than subsequent terrestrialisation. However, with rising Post-glacial lake levels, the possibility of the drowning out of shallow-water communities cannot be ruled out. It would appear that, when terrestrialisation did finally take place, these parts of the mire were amongst the first to become land, and that areas overlying former marl deposits tend to be higher than non-marl areas.

Higher up in the profiles, the detritus mud becomes coarser, indicating progressive shallowing of the basin, and there is an eventual transition into terrestrial sedge peat, with abundant Phragmites remains. On the southern and eastern sides there are also sporadic post-terrestrialisation wood remains, suggesting a period of carr on that part of the mire, albeit very open.

Tre'r Gof Main Profile

Pollen Analysis

Material for pollen analysis was extracted from Point M on

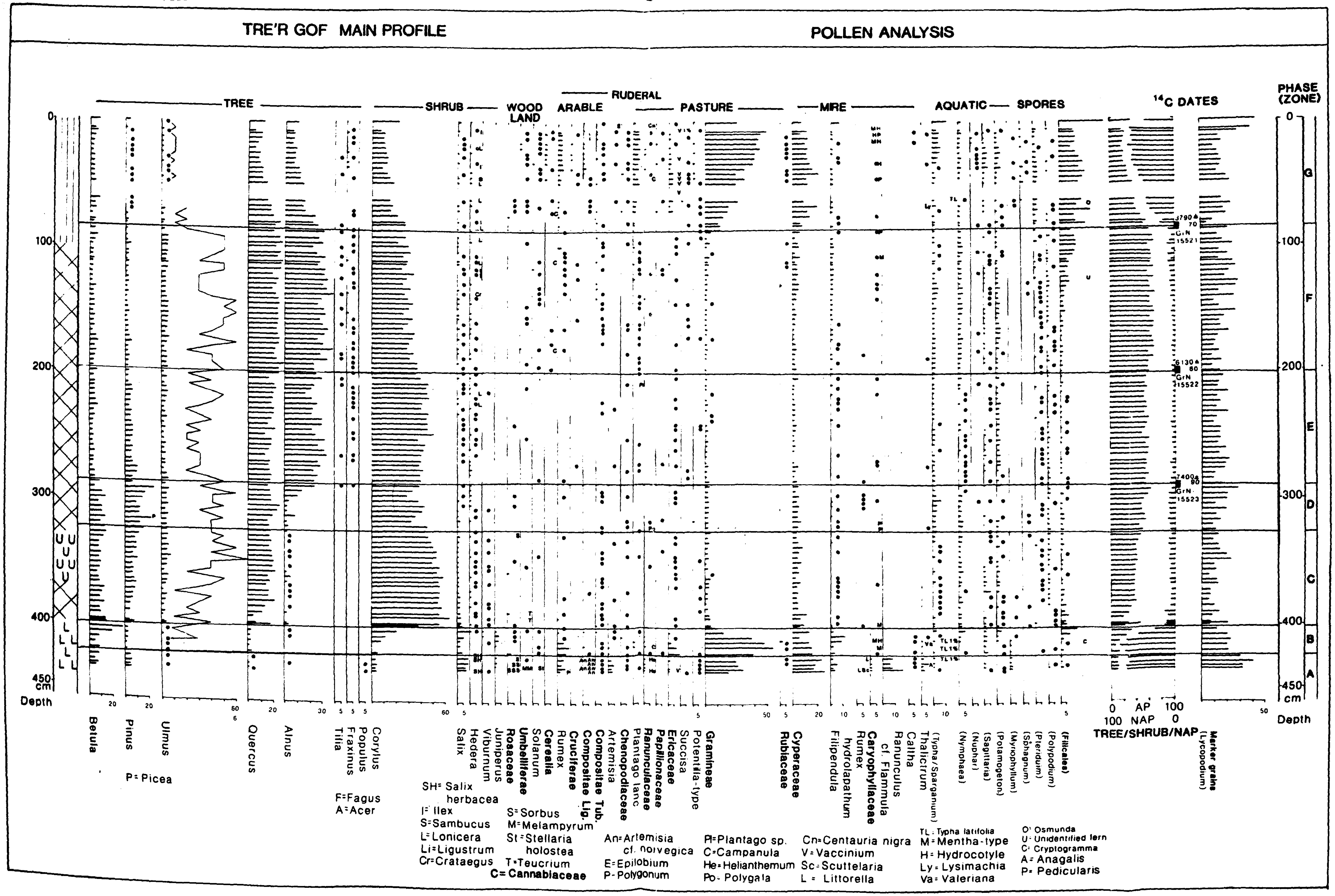


Figure 18 Tre'r Gof Main Profile - Pollen Analysis

traverse A (Figure 14). The stratigraphy at this point was as follows:

0-50cm	Brown fibrous herb peat.
50-100cm	Brown herb peat. Occasional _Phragmites_ remains, _Menyanthes_ seeds, wood.
100-150cm	Coarse detritus gyttja. Occasional _Phragmites_ remains.
200-330cm	Detritus gyttja.
330-370cm	Marl in detritus gyttja.
370-400cm	Detritus gyttja.
400-435cm	Green-grey lacustrine silt.

After construction of the pollen diagram (Figure 18), the following zonations were made:

0-85cm	Zone G
85-202cm	F
202-290cm	E
290-327cm	D
327-402cm	C
402-425cm	B
425-435cm	A

Zone A (425-435cm)

Main Features

AP levels, at about 25% of TLP, are low. Of this total, shrub pollen percentages are generally marginally higher than those for trees. Much of the tree pollen is of _Betula_, with values of 5-8%, and _Pinus_, with levels of _c._5%. Of the other trees, there are a few records for _Populus_, the only grains of that taxon found in the profile, but only occasional _Quercus_, _Ulmus_ or _Alnus_. Most of the shrub pollen belongs to _Salix_ (7-9%), continuous representation of that taxa being higher than in any other phase, and there are a few grains of _Salix herbacea_, the dwarf willow. _Corylus_ values of about 5% are very low relative to later zones. Other shrub records are of Juniperus (1-2%) and Sorbus (0-1%). Gramineae pollen accounts for 20-30% of TLP, and Cyperaceae for another 20-30%. There are particularly high frequencies of Rumex (3-8%) and Artemisia (4-6%). Filipendula counts of 2-5% are also relatively strong, and there are various records of ruderal-type taxa. There are, however, several taxa which only appear in this phase, such as Artemisia cf. norvegica, Helianthumum, and Ranunculus cf. flammula. Pollen totals of the latter range between 7-15%, and seeds are also common in the silt. Although Thalictrum is not restricted to this zone, values of 2-6% are very high, as are those for Caryophyllaceae (1%).

Of the aquatic taxa, Typha/Sparganium levels (0-1%) are rather low, but there are some records of Typha latifolia and of Myriophyllum (1-2%), generally M. alterniflorum, but also a few of M. spicatum. Potamogeton sp. and grains tentatively identified as Sagittaria sagittifolia (arrowhead) are present at ≤1%. Spore totals (Filicales and Polypodium) are very low, but exotic Lycopodium values are particularly high.

Interpretation

This phase is characterised by two main features, firstly the high NAP:AP ratio, and secondly the presence, often in quantity, of tree and shrub pollen relating to taxa characteristic of cold climatic conditions, i.e. Populus cf. tremula, Juniperus communis and Salix herbacea, whilst pollen associated with temperate woodland is largely absent. Several of the herbaceous taxa in this zone may relate to tundra species rather than their temperate counterparts. Thalictrum grains, for example, may have derived from T. alpinum (Alpine meadow rue) rather than T. flavum (Common meadow rue). Helianthemum pollen may be of H. chamaecistus (Common rockrose), which is still common on limestone grassland, or H. canum (Hoary rockrose), which is now only very locally distributed on rocky limestone pastures. The grains referred to as Ranunculus cf. flammula may indeed be such, but could also be Ranunculus (Batrachian) spp.. Both, however, reflect shallow-water habitats, and both have been found in Late-glacial deposits (Godwin, 1975). Similarly, whilst both rockroses indicate limestone grassland, the presence of Helianthemum pollen is especially characteristic of the Late-glacial (e.g. Moore, 1972), as is the pollen of Thalictrum cf. alpinum and Artemisia cf. norvegica (Scottish wormwood), whilst Artemisia vulgaris (Mugwort), which is also present, is associated with both Late-glacial and early Flandrian periods.

The pollen record, therefore, suggests that the basal deposits are of Late-glacial origin, and that the regional vegetation was tundra or, perhaps more correctly, park tundra. It could be described as a Rumex-grass-willow-Artemisia association (cf. Godwin, 1975) with scattered aspen and rowan trees, and juniper bushes. There would also have been small areas of pioneer birch and hazelwood, either separately or in association, and occasional pine. The very high Lycopodium spore totals may suggest fast rates of sediment deposition, but could also imply low pollen deposition rates, which would imply that the landscape included unvegetated, or partly vegetated tracts, which were probably in the process of being colonised by ruderal herbs.

The silt substrate clearly shows that lacustrine conditions prevailed in the basin during this phase, and the presence of pollen of various marginal aquatic taxa suggests that at least some of the water was shallow enough for macrophyte growth, whilst mire pollen types may indicate that there were boggy fringes to the early lake, or surrounding areas of wet meadow.

Zone B (402-425cm)

Main Features

In the early part of the zone, AP percentages fall even lower than in Zone A, and account for only 15% of TLP at 416cm, before they rise rapidly and reach 64% by the close. At each sampling level, tree and shrub pollen each account for roughly half of the AP total. Of the individual taxa, Betula levels rise progressively through the phase, and reach 27% of TLP at the top, the highest total recorded in the profile, whilst Pinus totals (2-3%) do not exceed those of Zone A. There are no further records of Populus, but slightly stronger Quercus (≤3%) and Ulmus (≤1%) counts. Only two Alnus grains are recorded. Of the shrubs, Corylus values are still low for most of the phase, but rise to 20% by the close. Salix values, except for one record of 11% at the top, are generally lower than in Zone A, although still higher than for much of the remainder of the profile. One or two of the Rosaceae (undiff.) grains at the base of the zone may relate to Sorbus. Values for Juniperus stay more or less the same as in Zone A, and there are records of Viburnum in most samples, albeit at low frequencies (0-1%).

Gramineae values (35-55%) are very high, and there are records of several other herbaceous taxa, namely a few grains of types possibly associated with woodland fringes, and in the arable/ruderal section, high Rumex values (0-9% at the base of the phase but largely disappearing at the top), a relatively strong Compositae Lig. curve (0-1%) and single Compositae Tub. grains. There are further records of Artemisia cf. vulgaris, but none of A. cf. norvegica. Apart from Gramineae, pastoral taxa include continuous curves for Plantago (0-1%) and Rubiaceae (0-2%). Ericaceae values of 2-9% are the highest in the profile, but, like Rumex, frequencies decline towards the close of the phase. Thalictrum, perhaps still T. alpinum, proportions reach only 1% before records cease.

Cyperaceae values of up to 15% are high, but lower than in Zone A, whilst Filipendula totals of 3-12% are the highest in the core. There are also records of other mire taxa, namely

Caltha, Mentha-type, Hydrocotyle and Valeriana. Of the aquatics, Typha/Sparganium levels (Abs.-2%) are roughly the same as before, and there are still some records of T. latifolia. Myriophyllum values do not exceed 1% before fading out towards the close of the phase. Potamogeton representation (0-3%) is not particularly strong, but frequencies are greater than before, and Sagittaria values (1-3%) are high. Nymphaea grains are recorded for the first time at 420cm, and reach 4% at 404cm.

Of the spores, there are odd records of Pteridium and Polypodium, and Filicales values reach 12% by the close, whilst Lycopodium levels decline.

Interpretation

The increase in Gramineae values coupled with the decline in AP percentages may suggest that conditions became colder for a while than they were in Zone A. The pollen record may also be interpreted as depicting the decline and disappearance of tundra taxa but predating large scale pollen production by temperate woodland species, although Betula and Corylus curves do suggest that pioneer woodland was expanding (but see Bennett, 1988). Viburnum grains may represent either V. opulus (guelder rose) or V. lantana (wayfaring tree). Wayfaring tree is, in modern times, restricted to calcareous soils in the south and east of Britain. Whilst soils derived from Liverpool Bay till were probably quite able to support wayfaring tree. Janssen (1970) suggests that early Post-glacial soils were largely undifferentiated anyway), uncertainly regarding former distribution of the species leads to the alternative suggestion that the Viburnum grains actually relate to guelder rose, which often grows in wet woodland, and may have been part of a community colonising the wet meadow area referred to in Zone A.

The expansion in the Gramineae curve may itself be taken to indicate an ameliorating climate, by suggesting general expansion in vegetation cover. High Ericaceae pollen values may indicate that heather was colonising higher land which had previously been unvegetated. Decreased proportions of marker grains imply either that sediment deposition rates had slowed down, or that pollen deposition rates were increasing. The latter explanation would be quite likely if the regional vegetation cover was more complete than in Zone A.

Stratigraphy, both at the profiling point and elsewhere, indicates that lacustrine conditions continued to prevail in the main part of the basin, but pollen evidence points to further establishment of fringing aquatic and wet meadow/mire communities. Although Cyperaceae pollen declines somewhat, records suggest that sedges may have been replaced to an extent by meadowsweet, and there are implications that other plants, such as marsh marigold, water mint, marsh valerian and marsh ferns were forming a rich wet meadow community in the vicinity of the lake. At the same time, water lillies had become established as members of the aquatic ecosystem, although the water milfoils were apparently finding conditions less favourable.

Zone C (327-402cm)

Main Features

For most of this zone, AP makes up over 90% of TLP, and includes tree pollen totals which generally exceed 30%, and which reach 46% by the close. Betula values of 6-15% are lower than in the previous phase, but the curve is still relatively strong, whilst Pinus levels (5-10%) rise. The highest Pinus totals tend to coincide with the lowest Betula values. Ulmus frequencies rise progressively from 1% to 7%, the latter being the highest total in the profile, whilst Quercus values average 15-20% after rapid expansion at the opening of the zone. Alnus totals (Abs.-8%) are still very low, but records are continuous, indicating that alder has passed its empirical limit in the locality (Smith & Pilcher, 1973, but see Bennett, op. cit.).

The Corylus curve rises markedly at the lower boundary, and values of 50-60% are found throughout the phase, but there are no further records of Juniperus. Salix totals (1-3%) are much lower than previously, but there are several Viburnum records, all of ≤0.5%. There is a continuous curve for Hedera, with values of 1% or less.

Pollen records for herbaceous taxa are much lower than previously. Gramineae frequencies do not exceed 5%, and other grassland or ruderal types decline generally, both in frequency and variety. The Ericaceae curve becomes less continuous, and counts never exceed 1% during this phase.

Cyperaceae values (3-12%, average 5%) also decline, as do Filipendula totals (≤1%, sporadic). There are few records of other mire species. Of the aquatic taxa, only Nymphaea frequencies (0-3%) are higher than before, whilst Typha/Sparganium values fall to less than 1%. There are no T. latifolia records, and only two for Myriophyllum. Totals for both Potamogeton and Sagittaria are generally medium to low, but variable. A more detailed diagram of the aquatic pollen curves from both TRG sites is shown in Figure 19. Exotic Lycopodium counts are low, but rise slightly in the upper part of the phase.

Interpretation

The lower boundary of the zone is defined by a marked decline in NAP, coupled with the rapid expansion of the curves for Quercus and Corylus, the latter coinciding with the cessation of Juniperus records (cf. Moore, 1972). Events suggest that the beginning of the phase might mark the onset of the Pre-Boreal period, as defined by Godwin (1975). According to Godwin's generalised model for the United Kingdom, the taxa which would be expected to be involved in AP expansion are Betula and Pinus, but at Tre'r Gof, the most marked increases are in the Corylus and Pinus curves. Since Godwin, other researchers have found varying patterns of woodland

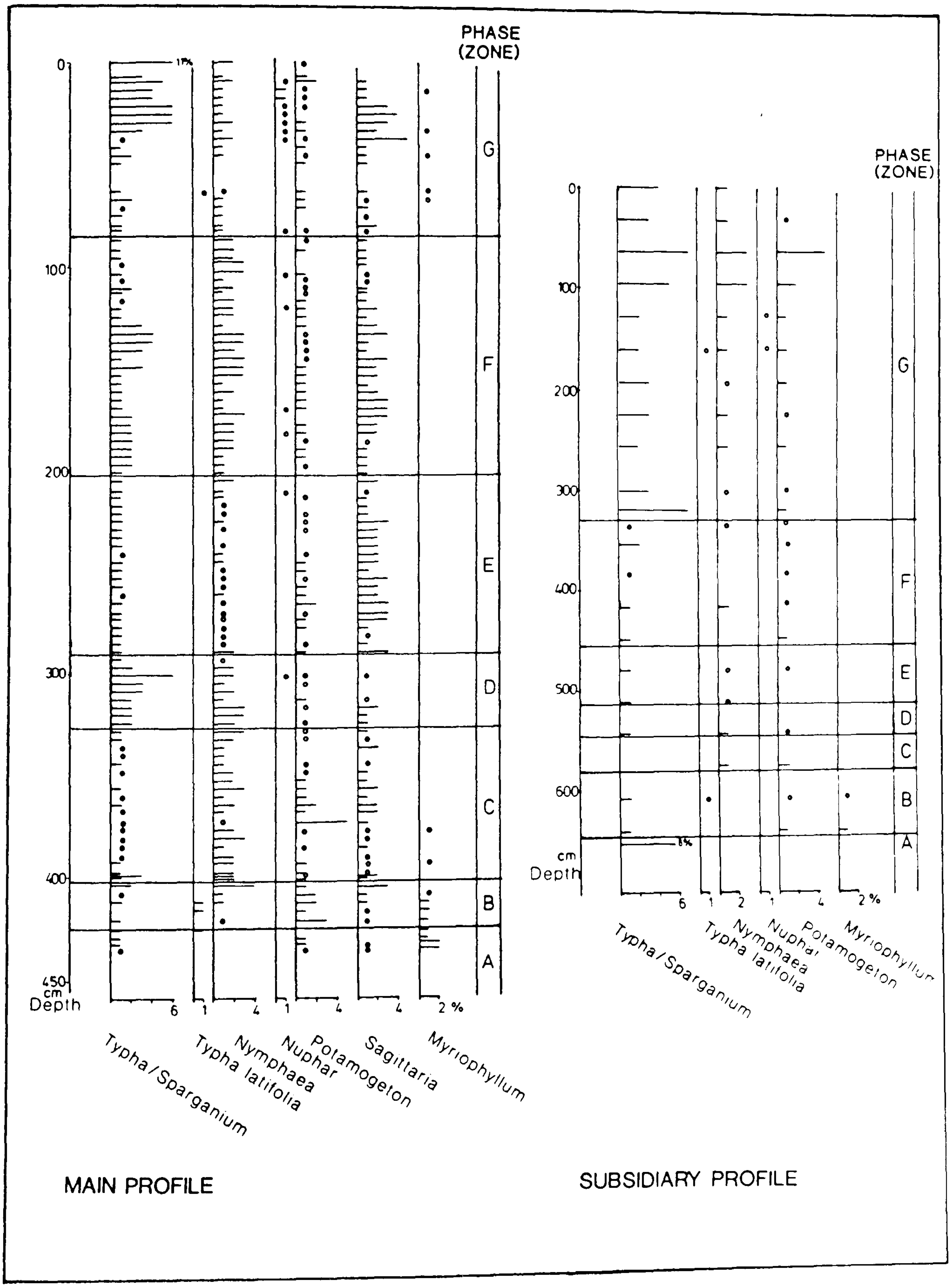


Figure 19 Tre'r Gof Aquatic Taxa - Expanded Pollen Diagram

development in different parts of the Britain, such as the expansion of birch and hazel together (Birks, 1973). On the basis of theories proposing glacial refugia in parts of Britain for certain species (Chambers & Price, 1985, Deacon, 1974), such variations are not surprising. Alternatively, rising Betula values in Zone B may mark the beginning of the Pre-Boreal, rather than the NAP decline at the base of this zone, in which case the opening of this phase could be taken to represent the Boreal itself, at about 9500 BP, which would correlate with Godwin's hazel-birch-pine picture for the British Isles.

Such a dramatic reversal of the AP:NAP ratio makes it difficult to assess the effects of the rising Quercus and Corylus curves on pollen proportions for other taxa, and to interpret what the curves mean in real terms. High rates of pollen influx as suggested by low Lycopodium values might diminish the compensatory effect of Quercus and Corylus on the other curves (but see below), but the decrease in Gramineae values is so marked that an interpretation of woodland expansion at the expense of grassland can hardly be avoided. Greater problems occur in the interpretation of the Betula, Pinus and Salix curves. Even though Betula frequencies are lower than in Zone B and fluctuate, the area covered by birch may well still have been expanding, or colonisation of new areas may have been simultaneously compensated for by succession to oak, elm, or even hazel in more established woods. There is a definite increase in Pinus representation, but pine colonisation may have been more extensive than the curve suggests. On the other hand, pine is a particularly prolific producer of pollen (Pohl, 1937), and so it would be expected that extensive local pine forests would result in very high pollen totals for that taxon. Pinus pollen values may, however, reflect long-distance transport, whereas totals for other taxa are assumed to relate to more local events. It is also suggested that pine forests were never as extensive in Wales as in many other parts of Britain (Godwin, 1975).

The Salix decline, too, may be more apparent than real, or willow distribution may have become more restricted, probably to lake margins, as the general woodland area increased. If Ericaceae pollen, as proposed, relates to the presence of heather on higher ground, then lower values in Zone C suggest that non-wooded upland areas were by this time very limited. The pollen could, however, have derived from different habitats, such as local rocky outcrops on the coast.

The Cyperaceae curve is assumed to reflect events occurring very close to the lake. Again, there is a possibility that the decline of Cyperaceae values in this phase may not be a true one, but it seems likely that expanding woodland was encroaching upon the wet meadow/mire area fringing the lake and either reducing the area covered by sedges, meadowsweet and other wetland plants, or hindering herbaceous pollen production and/or dispersal. The same explanation may account for the decline in Filicales spore levels, although there is also the possibility that some of the ferns were growing in association with the woodland rather than in the wet meadow, but now suffering the effects of a closing canopy on spore production.

Very low Typha/Sparganium values coupled with increasing Nymphaea representation suggests the lake was deepening as post-glacial water levels rose. Although it is not possible to accurately ascertain where previous water levels were in relation to the top of the modern basin, it is quite likely that in early post-glacial times they were much lower. The best clue may be given by the slight shelf where the marl deposits were accumulating (Figures 15 & 16). This may define the area occupied by the early fringing reedswamp, which, as water levels rose, could have been drowned out and succeeded by plants such as the pondweeds, whilst the more central parts of the lake were becoming deep enough for substantial colonisation by water-lilies. Lycopodium values may suggest that sediment deposition rates were low at the base of the zone but rose somewhat in the upper part, or as mentioned above, they may be related to the establishment of local woodland.

Zone D (290-327cm)

Main Features

AP totals continue to reach 90% or more of TLP, but a larger proportion than before (44-62%) is tree pollen. The highest AP values are at the top of the phase. Betula frequencies of 7-13% generally exceed those of Zone C, and Pinus values of 9-23% are the highest in the profile. Ulmus totals (3-

6%) are similar to before, as are _Quercus_ values, which are mostly 15-18% but peak at 25% in the middle of the zone. _Alnus_ values are still low but start to rise markedly at the top. The overall rise in tree pollen is compensated for by a fall in _Corylus_ levels to 29-45%, with a more erratic curve than before for that taxon. _Salix_ values continue to decline, no count exceeding 2%. _Hedera_ frequencies of 1% or less are the same as before, and there are single records of _Viburnum_ and _Sorbus_.

Again, pollen records for herbs are minimal. Gramineae levels are about the same as, or perhaps slightly lower than, Zone C values. There are occasional grains of Umbelliferae, _Rumex_, Compositae Tub. and Chenopodiaceae and of a few pastoral taxa. Ericaceae pollen appears only occasionally, as do _Pteridium_ spores.

Mire records are also very limited. Cyperaceae values (_c._5%) are a little lower than before, and _Filipendula_ values do not exceed 1%, but there are four records of _Rumex hydrolapathum_ (water dock). Of the aquatic types, _Typha_/_Sparganium_ frequencies recover to 2-6%, whilst _Potamogeton_ and _Sagittaria_ records are slightly weaker, but _Nymphaea_ (2-3%) levels are stable. There are very occasional records of _Sphagnum_ spores, as there have been before. Values for both Filicales and _Polypodium_ remain very low, but the _Lycopodium_ total rises a little.

Interpretation

The peak in Pinus pollen, which largely defines the zone, suggests that it relates to part of the Boreal period. This is confirmed by ^{14}C dating of the upper boundary at 7400 ± 90 BP [GrN-15523]. The extent of woodland was apparently still increasing, but the pollen record suggests that at this stage, it was pine and birch forests which were expanding at the expense of hazelwoods, whilst the proportion of mixed oak woodland remained more or less as in the previous phase. There are also signs of the impending immigration (the "rational" limit of Smith & Pilcher, op.cit.) or expansion (cf. Bennett op. cit.) of alder. The Picea grain recorded at 321+cm is almost certainly exotic, the nearest known sprucewoods at the time being on the north-west European mainland.

Godwin (1975) suggests that the Boreal period was very dry, resulting in lowered lake levels, drying out of bogs and their colonisation by trees. A further decline in mire taxa in the pollen diagram may indicate continued tree invasion of the fringing wet meadow, but there is certainly evidence that lacustrine conditions still prevailed in the basin. Firstly, the peat at the coring point consists of organic detritus gyttja, and secondly, there are quite a number of pollen records of aquatic taxa in this zone. The evidence regarding changing lake levels is, however, slightly confusing. Increased Typha/Sparganium pollen records (Figure 17) suggest that water levels fell, allowing recolonisation by reedswamp, possibly along the shelf where the marl had been deposited before. If that were so, however, further records of marl deposits would be expected, but there is no evidence to support this. On the other hand, renewed gyttja deposits suggest that lake levels rose in this zone, and high Nymphaea values indicate that there were areas of deepish water (≤2.5m, Walker, 1982a) suitable for water-lily growth. A compromise hypothesis would be that, although water levels fell, there was still open water deep enough for water-lilies, whilst the shelving areas had become shallow enough again for reedswamp, perhaps without marl-depositing organisms. Lycopodium frequencies may imply slightly higher peat deposition rates than Zone C.

Pollen records of the thermophilous Rumex hydrolapathum, which could have grown either in the wet meadow or the reedswamp, suggest, along with Hedera, that climatic conditions were by this time quite mild (Iversen, 1944).

Zone E (202-290cm)

Main Features

Throughout the zone, AP makes up more than 90% of TLP. The ratio of tree to shrub pollen is generally about 60:40, although towards the top there is a tendency for the gap to close. Betula values, ≤5%, show a marked decline, although they recover a little towards the close of the phase. Pinus levels (4-10%) are also lower than before, as are those of Ulmus, which fluctuate between 2% and 5%, the first evidence of decline coming at the base of the phase. Opening Quercus totals (c.15%) show a slight fall from those of Zone D, but recover again to reach c.20% by the close. Alnus values are much higher than before (16-33%), and somewhat erratic, but peak between 240cm and 260cm. There are occasional Tilia records, and more or less continuous ones for Fraxinus, but at levels of less than 0.5%. Corylus values recover gradually to reach 50% again, whilst the Hedera curve remains unchanged. A few grains of Lonicera are recorded, and one last Viburnum. Salix values fall yet again, and are often less than 1%.

There are single appearances of pollen associated with woodland edge taxa, i.e. Solanum and Umbelliferae, and some ruderal taxa, for instance one Rumex (undiff.) grain, three Plantago lanceolata, and two Plantago (undiff.). Most of these come from the lower half of the zone. Gramineae values remain very low, however, not exceeding 3%, and there are only occasional Ericaceae records. Cyperaceae levels are also very low (0-4%), and Filipendula representation is sporadic. Of other taxa possibly associated with the mire, there are occasional Caryophyllaceae records, two Rumex hydrolapathum grains, and one Thalictrum. With regard to the lake, Typha/Sparganium values of 0-1% are less than in Zone D, as are those of Nymphaea (0-2%), but there is a single Nuphar record. Sagittaria frequencies are much as before, but Potamogeton totals increase slightly.

Pteridium, *Polypodium* and Filicales values remain very low, but *Lycopodium* counts are slightly lower than those at the close of Zone D.

Interpretation

The base of the zone was defined in terms of the major expansion of *Alnus* pollen levels, coupled with the appearance of *Tilia* and *Fraxinus* grains, and simultaneous declines in *Betula*, *Pinus* and *Ulmus* values. Dating of both boundaries shows that the phase covers the period between 7400 ± 90 BP [GrN-15523] and 6130 ± 80 BP [GrN-15522], coinciding with the first half of the Atlantic period. The date of the *Alnus* rational limit equates well with that of Chambers (In press) for the northern arm of Cors Gyfelog. The implications of this are discussed more fully in Chapter Five.

Reductions in tree pollen proportions are likely to have been in response to the *Alnus* expansion, but it is interesting to note that the *Betula* curve strengthens again at 231+cm, and is followed by the curves for *Corylus*, *Quercus* and *Ulmus*. This, together with records of pollen which may refer to woodland edge and ruderal taxa, invokes the suggestion that small scale clearance may have been taking place locally followed by woodland regeneration.

Whilst the presence of *Tilia* pollen, in the small numbers which are characteristic of north west Wales, suggests the continuation of a warm climate, Fraxinus pollen may indicate secondary woodland, although the first records predate the Plantago grains found in this phase. On the other hand, it would hardly be surprising to find early colonisation by ash in an area where soils were developing over basic till.

The climate in Anglesey during this part of the Atlantic is assumed to have been wet, which helps explain changes in the wetland and aquatic pollen spectra. Very little terrestrial wetland pollen was recorded in this zone, and aquatic representation also declined. In previous zones, it was suggested that forests were encroaching on the area surrounding the lake which had formerly supported wet meadow vegetation. It might be envisaged that, if the climate became wetter, conditions could become unsuitable for encroaching "dry" forests, and wet meadow would return. However,it is likely that these areas would also be quite suitable for colonisation by alder, which had not been present in earlier times. If water levels rose in the lake, the reedswamp could have been flooded out and lake fringes with water depths of less than 1m colonised by Potamogeton (cf. Walker, 1982a, b). The decline in Nymphaea pollen totals may suggest that much of the centre of the lake was by this time too deep for the white water-lily. It is interesting to note the first pollen records of Nuphar, the yellow water-lily, which can grow in deeper water than can Nymphaea (Fitter et.al., 1974). It is unfortunate that, because of uncertainties regarding lacustrine sediment origins (allochthonous/autochthonous), variations in

Lycopodium spore totals cannot be used to imply that changes in gyttja deposition rates result from vegetational disruptions following lake level fluctuations.

Zone F (85-202cm)

Main Features

AP values still normally account for over 90% of TLP, but levels in the top third of the zone decline slightly. In general. tree pollen totals are double those of shrub pollen *Betula* representation (2-7%) is more or less the same as in Zone E, but there are three troughs, around 200cm, 170cm and 130cm respectively, followed by recovery in each case. *Pinus* levels (1-5%) are much lower, but the *Ulmus* curve (2-6%) is stronger than before, except between 120cm and 140cm where there is a cluster of lower values. *Quercus* frequencies (19%-28%) are the highest in the profile, as are those for *Alnus* (22-38%), but both curves are subject to slight fluctuations, *Alnus* more so than *Quercus*. There are a series of records for *Tilia*, mostly single ones, and the *Fraxinus* curve continues as in Zone E. *Corylus* values (21-37%) show a marked and progressive decline, but *Hedera* totals are much as before, and there are odd records of *Lonicera*, *Ilex* and *Crataegus*. The *Salix* curve, although with values not exceeding 1%, appears to have strengthened slightly.

There are several records of Umbelliferae and *Solanum* in the woodland edge section. In the arable division, grains which were originally identified as Cerealia occur at three levels, the first shortly after the lower boundary, and the other two also towards the base. The sample slides from which the pollen counts were made were not retained, but when dating indicated that the deposits were older than was originally thought, further slides were prepared and scanned, but failed to reveal any cereal-type pollen. There are also two possible records of Cannabiaceae grains. Other arable or arable/ruderal pollen types seen in this phase include Rumex, with a broken curve of single records that spans the zone, and one total of 3% towards the top, Compositae Tub., with a curve of 0-1% from about a third of the way up the zone, and odd records of Chenopodiaceae and Cruciferae. In the pastoral section, Gramineae frequencies (1-4%) remain very low, but increase slightly towards the close of the phase. There are continuous Plantago records of 0-1%, and occasional Succisa, Potentilla-type and Rubiaceae grains. Ericaceae records are sporadic, as are those for Pteridium spores.

Cyperaceae values (1-6%) are still very low at the base of the zone, but increase from about half way up, at which stage a broken Caryophyllaceae curve begins. Filipendula levels (0-2%) are slightly higher than before, especially towards the top. There are odd records of Rumex hydrolapathum, Thalictrum, Mentha-type and Pedicularis. Typha/Sparganium values (0-4%) show an increase, especially in the upper two thirds of the phase, and the same trend is followed by Nymphaea (1-3%). There are several more single grains of Nuphar, whilst Sagittaria and Potamogeton frequencies are similar to those of Zone E. There are a couple of records of *Sphagnum* spores, whilst Filicales totals increase progressively in the latter two-thirds of the phase, as do those for *Lycopodium*.

Interpretation

This phase spans the period between 6130 ± 80 BP [GrN-15522] and 3790 ± 70 BP [GrN-15521], and thus covers the second half of the Atlantic period and the first half of the Sub-Boreal. The continuation of high AP totals suggests that forest cover was still almost complete in the area. In particular, *Ulmus* records indicate that elm had to a large extent successfully re-established after what may have been a small clearance phase in the previous zone. Further *Tilia* grains indicate contined warmth, as does the appearance of *Ilex* pollen. Although there are no signs of major deforestation in this zone, during which later Mesolithic and Neolithic cultures may have been present, there are several strands of evidence to suggest repeated phases of small-scale human activity. Firstly, apart from being an indicator of warmth, the presence of holly may also suggest the establishment of secondary woodland, as may hawthorn and honeysuckle, implied by *Crataegus* and *Lonicera* records. Secondly, fluctuations in the *Betula*, *Quercus* and *Salix* curves may reflect phases of woodland recolonisation after a succession of clearance episodes.

The decline in *Corylus* frequencies may suggest that hazel was being selectively felled, but the progressive reduction in the pollen curve gives no particular indication that hazel was being set aside for coppice in the way implied at Cors Gyfelog. On the other hand, rising Alnus totals could indicate that the range of alder was expanding in wet climatic conditions, and there is a possibility that alder, and perhaps willow, may have been replacing hazel in damper areas.

Thirdly, although NAP values begin to increase only in the upper part of the zone, and even then very slowly, taxa indicative of cultivation, such as Rumex and Plantago are present throughout, suggesting acts of clearance. If the identifications of Cerealia grains were correct, the implication would be of a phase of very early sedentary activity. The grains coincide with a marked, but temporary, dip in LOI values (Figure 20), which may be a reflection of run-off from a localised area of clearance. The grains were identified by size (>40μ), but Molloy & O'Connell (1987), suggest that the annulus:total diameter ratio is the main criterion which should be used to separate cereal pollen from large grains of wild grasses. The pollen may actually have been that of Glyceria, which, in the light of the probable reedswamp development discussed below, would be quite possible. There have, however, been archaeological finds of Mesolithic artifacts only a few miles south of Tre'r Gof which correspond to others in western Scotland and on the east coast of Ireland (Livens, 1972) and there are records of early Neolithic activity in Ireland (Edwards, 1985) which open up interesting questions about prehistoric links across the Irish Sea. These will be discussed further in Chapter Five.

Cannabiaceae records in this zone must relate to the native hop (Humulus lupulus) which grows wild in moist and fen woodlands, rather than to the introduced hemp (Cannabis sativa) of late Saxon and Norman times.

The peat profile suggests that terrestrialisation of the lake began during this phase, evidence for which is further substaniated by pollen records, namely increasing Cyperaceae and Filipendula pollen concentrations, and a greater variety of mire taxa, such as Mentha-type and Pedicularis. There is even the possibility that Rubiaceae records refer to Galium palustre (marsh bedstraw) rather than dryland species. Increased Filicales totals may well relate to Thelypteris, and rising Gramineae values are likely to include Phragmites. Peat from several profiles suggests at least some encroachment of carr on to the periphery of the newly developing fen. Whether the ferns grew under the canopy or in the open is uncertain. Although increased Lycopodium spore counts precede records of fen peat, it seems likely that they relate to the raising of peat deposition rates as terrestrialisation began on a major scale.

Slowly increasing NAP values can be interpreted as relating to woodland destruction, (and must be in the final zone) but it is the Cyperaceae and, outside the pollen sum, Typha/Sparganium pollen curves, rather than that for

Gramineae, which show the first signs of upturn in this phase. This suggests that the terrestrialisation of the lake, and contemporary inward expansion of reedswamp and mire vegetation from the periphery can be picked out in the pollen diagram as events preceeding major woodland clearance.

At the same time as pollen evidence from terrestrial and reedswamp taxa points to infilling of the lake, continuing pollen records for fully aquatic taxa such as *Nymphaea*, *Nuphar*, *Sagittaria* and *Potamogeton* imply that substantial areas of open water still remained at this stage.

Zone G (0-85cm)

Main Features

In this zone, the proportion of AP falls progressively to as little as 29%, of which about half is tree pollen. *Betula* values range between 2% and 8%, the highest totals being at 63cm, and again at the surface. *Pinus* representation does not exceed 3%, and is generally less than 1%. *Ulmus* frequencies fall markedly, the highest records of 2% being attained just above the base. Values for *Quercus*, *Alnus* and *Corylus* all range between 10% and 25%, and in all three cases a marked decline in values which occurs in the lower part of the zone is followed by a slower fall at the top. Of the other trees, there are three records of *Tilia*, three of *Fagus*, two of *Acer*, and a semi-continuous *Fraxinus* curve of 1% or less. *Salix* values (Abs.-2%) are similar to those in Zone F, as are those for *Hedera*. There are four observations of Lonicera, two of Ilex, one of Sambucus and one of Ligustrum.

Of the woodland edge taxa, there are by this stage semi-continuous curves for Umbelliferae and Solanum, and occasional Rosaceae (undiff.) records. In the arable/ruderal section, there are frequent counts of ≤1% for Cerealia, plus one Cannabiaceae grain. Rumex values reach 4%, and as the zone progresses, continuous curves develop for Compositae Tub., Compositae Lig., Cruciferae and Chenopodiaceae. There are also four records of Artemisia and one at the surface of Epilobium.

Gramineae levels rise progressively from 10% to 50%, although in the top sample they fall to 25%. Values for Plantago reach 6%, and there is a Ranunculaceae curve with totals of ≤1%, as well as frequencies of 1% or less for Papilionaceae (Vicia- and Trifolium-types combined). There is a Campanula grain at 40cm, and a Centaurea nigra-type at the surface. Ericaceae values of 0-5% are the highest seen since the base of the profile. There are also occasional records for Vaccinium. Pteridium spores reach the much-increased total of 3%.

In the mire section, Cyperaceae values range between 6-21%, but average 10-15%, which is very high in relation to the rest of the profile. Apart from a surface total of 6%, Filipendula levels are usually 1% or less. There are odd records for Caltha, Mentha-type, Hydrocotyle, Pedicularis, Lysimachia and Thalictrum grains. Typha/Sparganium frequencies of about 5% are high in relation to the other zones, and a peak of 11% at the surface is unrivalled elsewhere in the core. Nymphaea representation (0-3%) is slightly lower than before, but Nuphar records are more frequent, especially from 40cm upwards. Curves for both Potamogeton and Sagittaria are more or less continuous, and reach relatively high totals of 5%. There are also records for Myriophyllum at six levels.

Sphagnum spores, previously of only occasional occurrence, are recorded in much of the zone, and reach 3%. Of the ferns, Polypodium frequencies (Abs.-1%) are still negligible, but Filicales values (9-24%, with a surface total of 35%) are very high. Lycopodium spore totals are generally equal to or lower than those in Zone F, except for in the top 10cm, where they rise markedly.

Interpretation

There are very dramatic changes in the pollen spectra in this surface phase. The basal ^{14}C date of 3790 ± 70 [GrN-15521] suggests that the zone covers the second half of the Sub-Boreal period and the whole of the Sub-Atlantic, essentially from the Bronze Age onwards. Of the arboreal taxa, only Betula and Salix values compare with previous zones. Records for the other main tree and shrub taxa all decline sharply at the base. It is possible that, with the terrestrialisation of the lake, arboreal pollen influx was being masked by the proportion of grains originating from the mire, but evidence by way of general increases in the proportions of pollen from Gramineae and herbaceous taxa, combined with reduced LOI levels for most of the zone, make it seem likely that major and permanent deforestation was taking place.

The pollen diagram suggests that there may have been several clearance phases. The first, at the base of the zone, probably relates to Bronze Age activities, and a rise in Gramineae values to 24% at 63+cm may herald the Iron Age. High Betula values in the lower part of the phase suggest that a certain amount of regeneration followed both these phases. Archaeological evidence suggests Bronze Age activity in northern Anglesey (Savory, 1965) after a quiet Neolithic period (Grimes, 1965, Savory, 1980), followed by another quiet phase until the middle part of the Iron Age (Hogg, 1965). The Romans certainly reached Anglesey, and built a fort at Caergybi (Holyhead), as well as mining copper from Parys Mountain which was subsequently smelted in native furnaces scattered over the island. Smelting had probably been taking place on the island since the Bronze Age (Richmond, 1965), and the retention of trees for this activity could explain why, after the major Bronze Age forest clearances, AP levels remained reasonably stable for some time. The next Gramineae rise, to 38% at 33+cm probably post-dates the Romans, and increasing herbaceous pollen totals thereafter probably relate to the gradual expansion of land under cultivation as the demand for smelting timber declined, and Anglesey developed its reputation as the granary of Wales.

Peat deposition during this phase was apparently very slow at TRGM compared with TRGS and with a core taken from 75m along Traverse A and analysed by Mighall (Pers. comm.). The accumulation of 85cm of peat in 3790 years works out at 22cm $1000yr^{-1}$, which is only just within the modal range suggested by Walker (1970). Despite an apparent slowing down in peat accumulation rates compared with Zones E and F (^{14}C dates suggest Zone E rates of c. 75cm $1000yr^{-1}$ and Zone F rates of ≥50cm $1000yr^{-1}$), *Lycopodium* spore values are only slightly lower than the highest levels in Zone F which, like Cors Gyfelog, may be due to decreasing surface compaction. An overall impression is that, especially with so few ^{14}C dates for comparison, marker spores have limited value in ascertaining deposition rates at a site such as this.

During the zone, high levels of Cyperaceae pollen, the implied variety of other mire taxa, particularly high values for *Typha*/*Sparganium*, and the probability of *Phragmites* pollen in the Gramineae totals, indicate further succession from lake to reedswamp and then to rich fen. Continued occurrences of pollen associated with aquatic taxa suggest that some areas of open water persisted as terrestrialisation progressed, and small pools are still to be found on the mire today.

Pollen in the top 10cm shows somewhat of a reversal of the AP:NAP ratio, with decreasing Gramineae values and higher ones for Betula, Salix, Corylus and Pinus, as well as for some taxa characteristic of rich fens, such as Filipendula, and Filicales (cf. Thelypteris). It must be stated that surface pollen quality proved to be rather poor (hence reluctance to define a further zone), but the possibility of very recent changes on the mire and in the immediate locality must be considered. With regard to the catchment, whilst the mire is generally surrounded by grazing land, there is an area of planted, mainly deciduous, woodland adjacent to the mire on the north-west side, and a larger one a little further to the west between the mire and the power station, with a high proportion of coniferous trees. Whilst the woods may be the source of some of the tree pollen, it is likely that much of it has derived from the area of carr close to the coring point, as well as from scattered trees fringing the fen meadow south of the ditch (Figure 17).

Pollen evidence suggests that meadowsweet is more prolific on the mire today than at any other post-terrestrialisation stage. Previous peaks in Filipendula pollen are associated with Late-glacial and early Post-glacial stages when the substrate was mainly mineral, and several nutrients, especially magnesium, were in plentiful supply (Figure 20). Although more a topic for the Chemical Analysis section, it is interestinmg to note that levels of certain nutrients are higher in the surface peat than in the mire peat lower down in the zone. The possibility of a relationship between the apparent recent increase in the richness of the vegetation and modern agricultural activity must be seriously considered.

Chemical Analysis

Zonations used in the diagram (Figure 20) and the discussion of results are the same as those for the main pollen diagram (Figure 18).

Nitrogen

Concentrations in Zone A are very low (2.7-4.1 [all g/kg, smoothed]), but start to rise a little above the A/B boundary and reach 12.6 by the close of Zone B. This rising trend continues into Zone C until a peak is reached at 377+cm with a maximum smoothed value of 30.1, after which levels subside a little, but increase again towards the top of the phase to 26.0. Concentrations gradually decline over Zones D and E until a low point of 14.8 is reached at 255+cm. They then rise very slightly but fall again to 15.3 just before the close. Values in Zone F are generally higher than in Zone E. There are peaks of 19.8 at 199+cm, 20.2 from 173+-177+cm, 22.1 at 135+cm, and 22.4 at 101+cm and 103+cm. Levels decline again in Zone G to a minimum value of 13.2 at 43+cm, but then rise to 18.9 at 25+cm and 18.3 at 9+cm before falling again to 13.8 at 3+cm.

Phosphorus

After a high basal reading of 0.71 g/kg (smoothed), values fall progressively to 0.34 at 417+cm in Zone B before rising

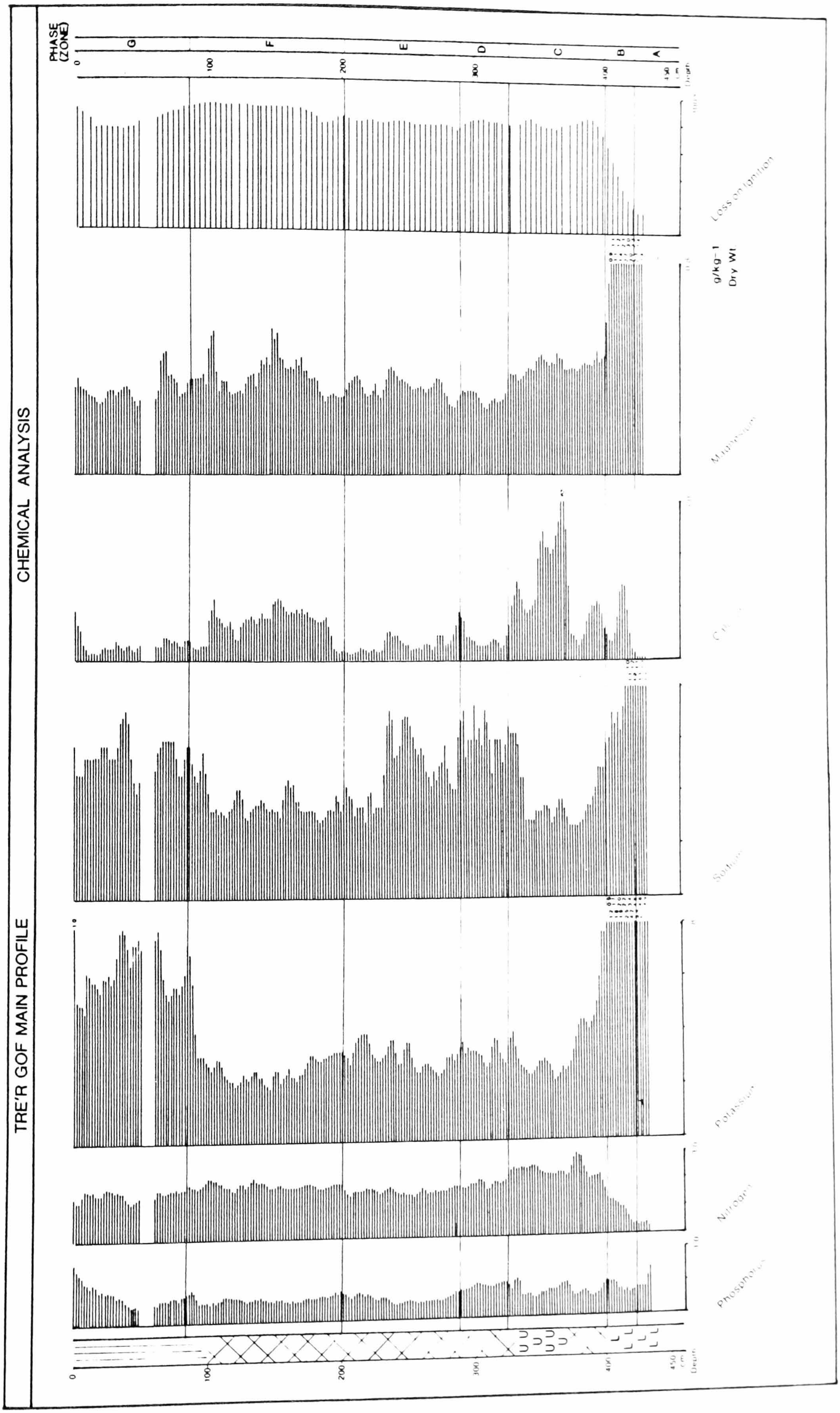


Figure 20 Tre'r Gof Main Profile - Chemical Analysis

to a maximum of 0.52 over the B/C boundary, and then falling to minimum of 0.32 at several levels in Zone C. At 369+cm there is a peak of 0.52, but values decline again to 0.31 before another maximum of 0.58 just before the upper boundary. There is then a gradual decline over Zone D which continues into Zone E, and concentrations fall as low as 0.23 (241+cm), but then slowly recover, and rise to 0.44 over the E/F boundary. Levels in Zone F are generally a little higher than in Zone E, except at around 100cm where they fall below 0.30. They soon recover, however, to 0.48 at 87+cn, before declining to 0.22 at 43+cm, but then rise steadily to a surface value of 0.86.

Potassium

From a basal concentration of 60.3 (g/kg smoothed [66.3 raw]) values decline progressively over Zones A, B and the opening part of C until they reach a minimum level of 2.2 at 361+cm. There is then a small peak (Max. 3.0 at 253+cm), and a larger one over the upper boundary (4.0 at 229+cm). Zone D concentrations are generally higher than those of Zone C, with peaks at 315+cm (3.8) and just below the D/E boundary (3.7). Levels in the opening part of Zone E are lower (Min. 2.4 at 273+cm) but there is a small peak of 2.9 at 263-265+cm. As the phase progresses, there are a series of more marked peaks, 3.8 at 249-251+cm and at 237-239+cm, and 4.0 at 217-219+cm. Concentrations decline in the first half of Zone F, to a minimum of 2.0 at 147+cm. They stay relatively low until about 120cm before rising, slowly at first to 3.2

between 93-97+cm, and then very markedly to 7.3 on the F/G boundary.

Zone G values are all higher than at any stage since the beginning of Zone C, but there are a series of fluctuations. After the peak on the boundary, concentrations decline to 5.3 at 71+cm, rise to 7.9 at 63+cm, fall to 6.6 at 41+cm, then rise again to 8.0 at 35+cm before declining to 4.8 at 7+cm with small intervening peaks at 25+cm and 9+cm. Finally, there is a very high surface value of 10.7, smoothed (raw 12.0).

Sodium

Like those of potassium, basal concentrations of sodium are very high (Max. 1.18 g/kg, smoothed [1.33 raw]), but decline over Zones A and B until minimum values of 0.27 are recorded at 375-381+cm in Zone C. There are then a couple of minor peaks (0.43 at 357+cm and 0.37 at 351+cm before a more major one at the close of the phase (0.65 at 327+cm). Values in Zone D are somewhat erratic, but generally high, with maxima of 0.71 at 309+cm, 0.73 at 301+cm and 0.71 at 293+cm. The latter immediately precedes a marked decline at the beginning of Zone E, with minimum values of 0.41 at 285-287+cm and 0.42 at 269+cm punctuated by a peak of 0.58 at 279+cm. Concentrations again rise in the middle of the phase, and can be broken up into two definite maxima, 0.69 at 249-251+cm and 0.71 at 237+cm. Levels decline markedly in the top part of Zone E (Min. 0.29), and stay low through much of Zone F, with only minor peaks of 0.43 at 165+cm, and 0.41 at 123-125+cm. At the top of the phase, however, concentrations rise again, firstly to 0.56 at 97+cm, and then to 0.58 at 85-87+cm.

Values decline to 0.47 after the beginning of Zone G, but peak at 0.60 between 67+cm and 75+cm before falling to 0.40 at 47+cm and then rising to 0.71 at 39+cm. There is then a general decline to 0.47 at 3-7+cm, but values rise to 0.58 at 21-25+cm and finally to 0.58 (smoothed [0.67 raw]).

Calcium

Zone A values are low (1.3-2.5 g/kg, smoothed), but there is a peak in Zone B of 28.2 before levels decline on the upper boundary to 7.2. A further maximum of 22.1 occurs in the bottom part of Zone C followed by a fall in values to 5.7 at 381+cm before concentrations rise to the highest levels in the profile (62.3 at 369+cm) but decline again for the rest of the phase, although there are lesser peaks at 353+cm (48.5) and 333+cm (29.2). Zone D concentrations are low, generally between 5.0-8.0 g/kg, but rise over the upper border to 16.9. Values in Zone E fall even lower (Min. 2.4), although there is a minor peak of 10.9 at 237+cm. Concentrations recover again for much of Zone F, the maxima being 23.0 at 153+cm and 22.6 at 105+cm, although average levels are lower than 20. There is a further marked decline from 99+cm upwards, after which concentrations rarely exceed 8.0 (the exception being 8.4 at 67+cm), and are often considerably lower, until the top 5cm, when there is a recovery, and a final peak of 18.0.

Magnesium

Zone A and B values are very high (basal reading 3.42 g/kg, smoothed [4.20 raw]), but decline sharply at the top of the latter phase to levels more normal for the profile (e.g. 403+cm, 0.45). Concentrations then slowly decrease until the middle of Zone C when, after a "low" of 0.39 at 373+cm, there is a minor peak of 0.45 at 365+cm, and another of the same value at 353+cm. Concentrations then fall, but stabilise at 0.38 at the top of the phase before a sharp decline to 0.24 in Zone D. There is a small peak of 0.31 at the top of the phase, a further trough of 0.25 (285-287+cm) at the base of Zone E, followed by a trend of recovery with maxima of 0.35 at 273-275+cm, 0.40 at 239+cm, and 0.36 at 211-213+cm. Values rise through Zone F to 0.54 at 153+cm, then fall to concentrations similar to those of Zone E, and rise to 0.53 at 105+cm before reverting to pre-peak levels again. There is a slight declining trend over Zone G, but values then rise to 0.45 at 69+cm, 0.33 at 39+cm and 0.31 from 25-29+cm before upturning in the top 10cm to reach a surface value of 0.47 (smoothed, 0.67 raw).

Loss on Ignition

Zone A values are very low (15%), but levels increase over Zone B and peak at 84% (387+cm) in Zone C. There is a slight dip in the middle of the phase to 77% (at 353+cm) before a return to 84% at 343+cm. Above this, values are slightly lower (Ave. 80%) until three samples between 299-307+cm where they rise to 82%. Residues of these samples were seen to be dark grey rather than the normal creamy colour. Basal Zone E values are a little lower than those of Zone D (75-78%), but rise slowly and reach 82% at the upper boundary. There is a definite dip in lower Zone F levels, to 78% at 189+cm, but a quick recovery and then a slow rise to 92% at 101+cm. Thereafter, losses decline gradually to a minimum of 73% (31-39+cm) before upturning in the top few centimetres to 88%.

Comparison of Curves

As at Cors Gyfelog, the strongest positive relationship between two curves is for those of the monovalent cations (K^+:Na^+, R_s=0.75 n=214). There are also marked relationships between the divalent cations (Ca^{++}:Mg^{++}, R_s=0.45 n=214), and between Nitrogen and LOI (R_s=0.51 n=105). Unlike the Cors Gyfelog analyses, the inverse relationship between LOI and the monovalent cations is quite low (R_s=-0.25 in both cases. n=105), although statistically that would still suggest a relationship at the 99.9% confidence level. Tests also imply a correlation between phosphorus and the monovalent cations (e.g. P:K^+, R_s=0.36 n=215).

Weaker relationships are suggested between magnesium and potassium (Mg^{++}:K^+, R_s=0.14 n=215), phosphorus and nitrogen

($P:N$, $R_s=0.12$ n=215), and inversely between nitrogen and potassium ($N:K^+$, $R_s=-0.15$ n=215), but there appear to be no relationahips at all between the curves for magnesium and nitrogen ($Mg^{++}:N$, $R_s=0.05$ n=215), magnesium and LOI (Mg^{++}:LOI, $R_s=-0.03$ n=105), or magnesium and phosphorus ($Mg^{-++}:P$, R^s=-0.02 n=215), or between calcium and phosphorus ($Ca^{++}:P$, $R_s=-0.03$ n=215) or phosphorus and LOI (P:LOI $R_s=0.06$ n=105).

It would appear, therefore, that the curves fall into three main pairs: sodium and potassium, nitrogen and Loss on Ignition, and calcium and magnesium, with a lesser relationship between phosphorus and the monovalent cations. These pairings more or less agree with those seen in the Cors Gyfelog chemical profiles, and strengthen the hypotheses that in the first instance, nitrogen concentrations relate to the proportion of organic matter in a sample, and sodium and potassium to mineral content.

Interpretation

Phosphorus, and all the cations except calcium are present in very high concentrations in Zone A, where deposits are predominantly of mineral material. As organic matter begins to accumulate, values for all the above elements except magnesium fall to minima Zone C and maintain low concentrations over the phase in which marl deposits are found in the peat.

The calcium pattern is quite different. Values are very low in Zone A, suggesting that the basal silt deposits were not derived from calcareous sources. Peaks in Zone B and the lower part of Zone C probably relate to the receipt of sediment of a more organic nature following the development of vegetation on the fringing parts of the lake. Certainly the large peak in upper Zone C is related to the marl phase in the peat, which, as mentioned above, is thought to represent deposits from shallow water plants. The two earlier peaks may be scaled-down versions of the same phenomenon, although there is no evidence of marl to coincide with them. Whether or not this was the case, the suggestion remains that water reaching the lake was more base-rich than in Zone A.

Magnesium values decline considerably after the two "mineral" zones, but do not reach minimum levels until Zone D, perhaps suggesting that the waters supplying calcium to the mire at this stage were also relatively magnesium-rich. As at Cors Gyfelog, there are suggestions of correlations between magnesium peaks and high Filipendula values in the pollen diagram (Figure 18). However, it is assumed that attempts to relate element levels and vegetation types during the lacustrine phase at Tre'r Gof are likely to be only marginally successful because much of the gyttja may be allochthonous in origin. LOI levels are never particularly high in the first five phases, presumably because mineral material was continuously being washed in to the lake along with organic detritus.

Nitrogen and LOI curves show basically the opposite pattern to phosphorus and the monovalent cations over the first three phases, rising from minima in Zone A to peaks in Zone C as the deposits become more organic. They dip slightly during the marl phase. In Zone D, low calcium and magnesium values suggest drying-up of basic water supplies, whilst increases in phosphorus, sodium and potassium levels may imply somewhat of a return to mineral influences.

Nitrogen concentrations vary relatively little between Zone D and the top of Zone F, presumably reflecting steady inwashes of local organic material throughout the period in which the catchment was well wooded.

In Zone E, covering the first part of the Atlantic period, cation input levels fluctuate, perhaps because of wetter conditions, but appear not to change too markedly from those of Zone D. The slight decline in the LOI curve suggests increased inwash but there may have been considerable buffering by surrounding forests. The pattern of the phosphorus curve appears to have become detached by this time from those of the monovalent cations, levels remaining low from the beginning of Zone E to the end of Zone F.

In Zone F, concentrations of calcium and magnesium rise, apparently at the expense of sodium and potassium, but LOI levels increase at the same time, suggesting decreased mineral input. These events may be related to drier climatic conditions, especially in the upper part of the phase which covers the first part of the Sub-Boreal period, but are probably more likely to relate to the build up of in situ vegetation as terrestrialisation begins. At the top of the phase, a small nitrogen peak immediately preceeds the first records of terrestrial peat, but levels, along with those for LOI and magnesium, fall throughout Zone G, whilst those for sodium, potassium and phosphorus rise markedly. Calcium concentrations are very low until the surface.

The behaviour of the curves in Zone G may relate to destabilisation of soils in the catchment during the deforestation which characterises this phase. Of particular note, however, is the fact that the major increases in sodium and potassium levels take place below the F/G boundary, at about 100cm depth, and thus apparently relate to events which occurred some 4000 years ago (F/G boundary at 85cm ^{14}C dated 3790 ± 70 BP [GrN-15521]). This period seemingly represents a potted version of Cors Gyfelog Zones D-J but, although there are marked inwashes in GYF Zones C and D (ending about 3500 years ago) and again towards the surface, especially at GYFP from Zone Ib (1310 ± 60 BP [CAR-1166]) onwards, there is an intervening period of up to 2500 years in which sodium and potassium levels are very low. At TRG, on the other hand, whilst there are certainly samples in Zone G in which concentrations fall, levels are never as low as those in Zones C-F. Phosphorous values follow roughly the same pattern at Cors Gyfelog, although there are some low Zone G readings at Tre'r Gof. Comparison of these characteristics suggests, even more strongly than on the evidence of Cors Gyfelog alone, that mineral materials relating to modern agricultural practices permeate downwards into the peat and distort the upper chemistry, the point at which certain curves rise appearing to be more a function of depth than of age. With Nitrogen and LOI values inversely related to those of the monovalent cations and, similarly to pollen analysis, over-representation in one or more curves possibly suppressing others, the value of chemical analyses of many later peat deposits may be called into question.

Concentrations at the surface, however, may be reasonably reliable indicators of current events. Whilst very high sodium, potassium and phosphorus levels confirm the continued receipt of material containing these elements, calcium values are like those in Zone F, much higher than for most of Zone G or at the surface in the GYF profiles, and more as would be expected in rich-fen rather than mesotrophic conditions.

Tre'r Gof Subsidiary Profile

Pollen Analysis

Material for analysis was extracted from point S on Traverse D (Figure 14). The stratigraphy is as follows:

0-60cm	Dark brown fibrous herb peat. Silt band 10-20cm.
60-150cm	Brown herb peat, probably <u>Carex</u>. Occasional seeds. Light band at 108cm.
150-608cm	Brown detritus gyttja. Slightly darker 525-575cm, greenish tinges 575-608cm.
608-625cm	Greenish silt.
625-630cm	As above but lighter.
630+cm	Green-grey silt. Depth of base not ascertained.

Pollen spectra in the resulting "skeleton" diagram (Figure 21) were zoned to correspond with TRGM phases:

0-330cm	Zone G
330-460cm	F
460-520cm	E
520-550cm	D
550-580cm	C
580-645cm	B
645+cm	A

Zone A (645+cm)

Main Features

This zone is based upon a sample count of 117 grains at 650-cm. AP makes up 30% of the total, which includes <u>Betula</u> at 15%, <u>Pinus</u> at 1% and <u>Populus</u> at 2%, the latter being the only record for that taxon in the profile. Pollen of <u>Juniperus</u> is present at 8%, and <u>Corylus</u> and <u>Salix</u> at 2% each.

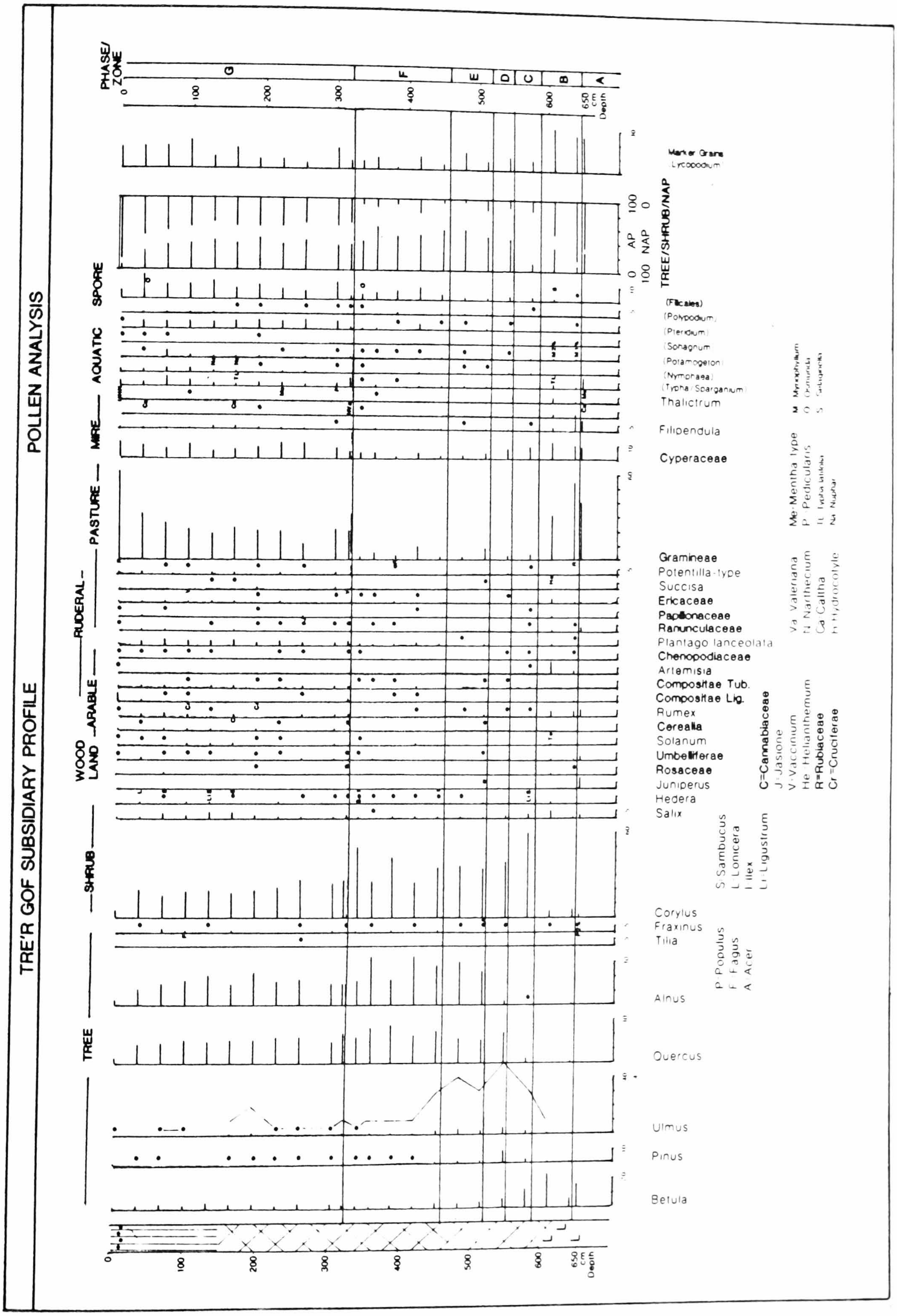


Figure 21 Tre'r Gof Subsidiary Profile - Pollen Analysis

Umbelliferae at 3% represent woodland edge taxa, and a Rumex record of 5% the arable/ruderal section. The Gramineae total of 40% is very high. Other grassland pollen counted are Ericaceae at 1% and Ranunculaceae at 3%. There is quite wide range of mire taxa, with Cyperaceae at 9%, very prominent Filipendula at 8% and Mentha-type, Thalictrum and Caltha all at 1%. The only aquatic fringe representative is Typha/Sparganium at 8%. Lycopodium values are high.

Interpretation

Although the pollen was in good condition in this sample, it was very sparse, hence the early abandonment of the count. It is accepted that this means possible distortion of pollen values, but it is felt that enough information has been gained to justify the zonal separation of this sample from the one 10cm above it.

The phase was actually delimited by the presence of Populus pollen. There are no records of Salix herbacea, Artemisia cf. norvegica or Ranunculus cf. flammula to support the comparison with TRGM Zone A, although the Thalictrum grain may relate to T. alpinum. High Juniperus frequencies at TRGM were considered to be a feature of Zone B, rather than Zone A, but the total in this sample may be an over-representation.

The Umbelliferae record is much higher than at TRGS than TRGM, and may relate to aquatic or reedswamp species rather than woodland edge types in this case. Rumex counts from the two cores are quite comparable and, although Artemisia records are lacking, the TRGS pollen spectrum suggests a park tundra landscape including unvegetated areas (and thus low pollen deposition rates, as implied by high Lycopodium levels) much as postulated for the main profile.

The very high Typha/Sparganium record may relate to small-sample bias, or it may be a real indication of a local area of reedswamp, especially as the Cyperaceae total is quite a bit lower here than at TRGM, although Filipendula values are high at both sites.

Zone B (580-645cm)

Main Features

This phase includes two samples, at 608+ and 640+cm respectively. As in Zone A, pollen was sparse and reduced counts were made, of 153 and 272 land pollen grains. Although the Betula total at 640+cm falls to 6%, the record of 14% at 608+cm is the highest in the profile. Values for Pinus, Quercus and Alnus do not exceed 1%, but there are records of Ulmus and Fraxinus in the upper sample. Corylus levels (5-6%) remain low but there is a high Salix count of 5% at 608+cm, and also a Hedera record of 2%.

Rosaceae (undiff.) values of 0-1% may relate to Sorbus. Other possible woodland edge taxa are Umbelliferae and Solanum cf. dulcamara, both recorded at 1%. Arable/ruderal taxa are represented by high levels of Rumex (4%) and Artemisia (2-8%), plus Compositae Lig. (Abs.-1%) and a single Chenopodiaceae grain. Gramineae levels decline from a peak of 54% at 640+cm to a still high total of 32% at 608+cm. A variety of other grassland taxa are also recorded, namely Plantago (0-1%), Ericaceae (1-3%), Ranunculaceae (0-1%), two grains of Teucrium and one each of Papilionaceae, Helianthemum and Rubiaceae, as well as single spores of Selaginella and Pteridium.

Cyperaceae levels (10-12%) are higher than Zone A, whilst the first Filipendula one (9%) is the same, but the upper one (2%) much lower. Other possible mire taxa are Caryophyllaceae (1-2%) and Thalictrum (1-6%). Of the aquatics, Typha/Sparganium values (1-4%) are quite high, and a T. latifolia grain is also recorded at 608+cm. Myriophyllum records of 1-2% are the only ones in the profile, whilst Potamogeton at 1% is about average.

There are no records of Polypodium, and Filicales values (0-2%) are low, but Lycopodium levels high.

Interpretation

As at TRGM, high Betula and Salix, and rising Corylus values suggest the spread of pioneer woodland. Sorbus pollen implies that rowan was present locally, and Quercus, Ulmus, Alnus and Fraxinus grains in small numbers suggest occasional mixed oak woodland in the area (but see Bennett, 1988). In the case of ash, the pollen record is a very early one, but as has been previously mentioned, basic till in the locality would favour colonisation by that species. The high Hedera count may be chance over-representation.

Umbelliferae and Solanum grains may relate to herb flora on the margins of pioneer woodland, or they may represent the colonisation of bare land, as may the plentiful representatives of arable/ruderal taxa. The Gramineae peak in the lower part of the phase is similar to that in the main profile, and again leads to interpretation either in terms of renewed cold conditions, or of general grassland expansion, whilst the high Ericaceae record at 608+cm may imply colonisation of poorer land.

Mire and aquatic pollen taxa suggest that the balance between reedswamp and fen on the fringes of this part of the lake may have changed somewhat in favour of the latter. As previously suggested, the presence of Myriophyllum and Typha latifolia pollen grains are characteristic of early post-glacial lake deposits.

Zone C (550-580cm)

Main Features

This phase consists of one sample, at 576+cm, with AP of 84%. The Betula total of 12% is high, but lower than the Zone B maximum. Pinus and Quercus values both rise slightly, to 3%

in both cases, as does the Ulmus count, the latter being a particularly significant increase. Alnus frequencies are still very low (<0.5%) but the Corylus total of 60% is the highest in the profile. Salix is still quite well represented at 3%, but at a lower level than previously. There are also single records for Sambucus and Ligustrum.

The phase includes the first record of Polypodium (<0.5%) and a Filicales total of 3%. There are no other grains of taxa which may be associated with woodland, and few ruderal representatives. Levels of Rumex and Artemisia fall markedly to below 0.5%, and there is just a single Chenopodiaceae grain, but a relatively high Compositae Tub. record of 1%. The Gramineae total declines to 4%, there are no Plantago records, and only single grains of Ranunculaceae, Potentilla-type and Papilionaceae.

On and around the lake, the Cyperaceae record of 9% is much the same as before, but the single Filipendula grain represents a big decline. There are no records of Typha/Sparganium, but Potamogeton and Nymphea both feature at 1%, the latter being the first record for the taxon. As at TRGM, Lycopodium values are much lower than previously.

Interpretation

This phase was delimited on the basis of the expanding Corylus curve. Most of the changes in tree and shrub pollen correspond to those at TRGM, the major difference being the more marked increase in _Quercus_ in the main profile. Similarly, at both locations, the incidence of herb pollen is greatly reduced.

The TRGS Cyperaceae total is higher than the TRGM average for this zone, but well within the total range, whilst _Filipendula_ frequencies decline markedly at both. Low counts (or absences) of _Typha_/_Sparganium_ pollen also seem to be a common feature, as do rising _Nymphaea_ levels. As at the main site, therefore, the picture would appear to be one of woodland encroaching into the wet meadow surrounding the lake, at the same time as rising water levels in the kettlehole were drowning out fringing reedswamp.

Zone D (520-550cm)

Main Features

This zone is based on a single sample at 544+cm. In it, the AP level is 87%, of which the relatively high but falling _Betula_ total is 6%. _Pinus_ (9%) and _Ulmus_ (5%) frequencies are the highest in the profile, a continuous curve begins for _Fraxinus_, and there is a major rise in _Quercus_ representation, to 21%. _Corylus_ pollen is present at 40%, which is a little lower than before, as is the _Salix_ total of 2%. Apart from _Polypodium_ and Filicales levels which are similar to those in Zone C, there are no records of herb-level woodland taxa. As in the previous zone, totals for arable/ruderal and grassland types are very low. A Cyperaceae count of 7% is slightly lower than that of Zone C, but the Filipendula curve (1%) is a little stronger. Typha/Sparganium pollen reappears at a frequency of 1%, whilst the Potamogeton total falls to <0.5%, but Nymphaea stays the same as before (1%). Lycopodium values remain low.

Interpretation

Pollen proportions of the major arboreal taxa are largely as in TRGM Zone D. There are some differences, such as falling Betula values at TRGS but rising frequencies at TRGM, and the establishment of the TRGS Fraxinus curve, but the overall picture is the same, especially regarding the peak in Pinus pollen and the expansion of the TRGS Quercus curve. Like TRGM, TRGS mire pollen suggests further encroachment by forest on to the wet meadow, and the probable partial re-establishment of fringing reedswamp with lowered Boreal lake levels.

Zone E (460-520cm)

Main Features

Samples at 480+cm and 512+cm provide the material for this zone. In it, AP values range between 85% and 95%, but due to a big rise in Alnus levels to 23-30%, proportions of pollen for the other arboreal taxa tend to decline somewhat, Betula to 3-4%, Pinus to 2%, Ulmus to 3-4%, Quercus to 16-17%, Corylus to 35-37% and Salix to 1%. On the other hand, there is the beginning of a continuous curve for Hedera, and single records for Juniperus and Acer.

Polypodium and Filicales values remain much as before. There is one Umbelliferae grain at 512+cm and, at the same level, Rumex values increase to 1%, there is a single Compositae Tub. record, one of a Cerealia-type grain, Plantago at 1%, a temporary rise in Gramineae to 8%, and a Succisa grain. Pollen values at 480+cm are more like those of the previous zone.

Cyperaceae levels of 2-4% are very low, as are those of Filipendula (0-1%), Potamogeton and Nymphaea (both <0.5%), whilst Typha/Sparganium levels of 1% are much as before. The greater of the two Lycopodium totals, at 480+cm, is relatively high.

Interpretation

The overall picture obtained from the pollen diagrams, especially in the context of the immigration (or expansion) of alder, is very similar at both TRG locations. Of particular importance, however, is the suggestion of possible human activity locally, as shown by the short-term increase at 512+cm in proportions of grassland and ruderal taxa, and especially by the possible Cerealia record. This event also coincides with the first decline in Ulmus values in the profile, from 5% at 544+cm to 3% at 512+cm, before a revival to 4% at 480+cm. Not only is this decline detectable in the TRGM pollen diagram, but also in one by Mighall (Pers. comm.) which, like TRGS, has a very short-term Gramineae peak.

In common with TRGM, evidence implies that alder may have colonised the meadow fringing the lake, which had become damper with the onset of the Atlantic period. The _Typha_/_Sparganium_ curve suggests that increasing lake levels had less effect on reedswamp here than in the area of the main profile, although the water-lily population seems to have suffered.

Zone F (330-460cm)

Main Features

Five samples were analysed in this zone. In the phase, AP ranges from 81% to 95%, and includes _Betula_ at 1-3%, _Pinus_ at 0-1% and _Ulmus_ at 0-3%, all apparently in decline. The _Quercus_ (18-26%) and _Alnus_ (17-33%) curves include the highest values for those taxa in the profile, although both are somewhat erratic, as are _Corylus_, frequencies which range between 25% and 50%. The _Fraxinus_ curve, at 0-1% is stronger than before, and counts for _Hedera_ continue, but at <0.5%. There are occasional records of _Sambucus_ and _Ilex_. _Salix_ values of 0-1% are low.

The curve for _Polypodium_ is broken, but includes one record at 2%, whilst Filicales values of 4-9% are quite high. Of the woodland edge taxa, continuous records for Umbelliferae begin at 355+cm, and Solanum pollen appears in two samples, with values of ≤1% . Only one Rumex grain is found in the phase, but a Compositae Tub. curve begins at 416+cm, and there are also occasional records of Compositae Lig. and Chenopodiaceae. Of the pastoral taxa, Gramineae values generally range between 2-5%, but there is one count of 9% at 416+cm, at which level Pteridium values rise from their zonal norm of 0-1% to 4%, Plantago from 1% to 2%, and Ericaceae records become continuous at 0-1%. There are also occasional Ranunculaceae, Potentilla-type, Rubiaceae and Papilionaceae grains.

Of the mire taxa, Cyperaceae values of 1-4% are the lowest in the profile, and the Filipendula curve (Abs.-1%) is less continuous than before, but there are single records of Caryophyllaceae and Thalictrum. Typha/Sparganium values range between 1% and 2%, which is slightly higher than in Zone E, whilst Potamogeton (0-1%) and Nymphaea (2 records of <0.5% and 1%) levels are low. Lycopodium frequencies are much as before.

Interpretation

At at TRGM, the pollen record gives the impression of a high level of forest cover in the area, but fluctuations in the arboreal curves, together with strengthening representation of herbaceous taxa suggests some minor clearance events. The most obvious of these is at 416+cm, and may well mark a further phase of Neolithic activity in the area. Apart from the features mentioned above, it is particularly noticeable that the Ulmus curve declines markedly at this level, and never recovers. As in the main profile, the presence of Ilex grains suggest continuing warmth but, probably more than ash at this site, possibly points to the establishment of secondary forest.

It is thought that Polypodium records relate to ferns epiphytic on alder, and Filicales to terrestrial ferns under the local woodland canopy. Unlike Cors Gyfelog, where alder was growing in situ, the wet woodland here is assumed to have been growing some way away from either coring point. Fern spore totals are correspondingly lower here than at GYF, and it is not really possible at TRG to ascertain whether Polypodium values tend to increase when Alnus values are high, and Filicales to decrease if the canopy closes, features which seem to be implicit in the Cors Gyfelog diagrams. Further complication occurs because marsh ferns (Thelypteris) are common on the mire today, and even when lacustrine conditions prevailed, they could have been growing in the open as part of the wet meadow community.

The pollen record suggests, however, that there was very little wet meadow at the western end of the mire during this period. In the corresponding TRGM phase, there is pollen and peat evidence of lake terrestrialisation early in the Sub-Boreal, but none really here, except for the appearance of grains assumed to represent ragged robin and meadow rue, and a very slight suggestion of strengthening reedswamp at the expense of deeper water.

Zone G (0-330cm)

Main Features

At the beginning of this phase, AP declines sharply from 92% to 67%, and thereafter progressively to 48% at 32+cm before falling again to 14% at the surface. Betula values range from 1% at 0cm to 4% in the middle of the zone, but are normally 2-3%, which is slightly higher than in Zone F. Pinus levels range from Abs. to 1%, the peak being at the surface. The highest Ulmus value (2%) is found at 192+cm, but otherwise the range is from Abs. to 1%. Quercus totals are a little lower than before, fluctuating between 13-19%, the higher values generally being found towards the base of the zone. There is a marked decline to 3% at 0cm. The surface Alnus value is similarly low after totals of 11-22% in the remainder of the phase, also with fluctuations and lower percentages than in Zone F. A record of Tilia at 256+cm is the only one in this profile, as is one for Fagus at 96+cm. The Fraxinus curve is a little more erratic than before, ranging from Abs. to 2%, whilst that for Corylus has a similar overall pattern to those for Quercus and Alnus. Values of 16-27% are somewhat lower than before, but there is a marked decline to 5% at the surface. The Salix curve revives somewhat, and ranges from 1-4%, the highest totals being in, and upwards from, the middle of the phase. A sometimes broken curve for Hedera continues and includes several values of 1%. There are occasional records of Sambucus (three grains), Lonicera (one grain) and Ligustrum (one grain).

There are quite a few records of woodland edge taxa. Curves for Umbelliferae and Solanum are nearly continuous with maxima of 1%, whilst Rosaceae (undiff.) grains, also with a maximum of 1%, are found at three levels. The Polypodium curve continues more or less continuously, with values of 0-1%, the higher ones tending to be towards, but not at, the surface. Arable/ruderal records increase markedly. There are almost continuous curves for Cerealia (often with values of 1%), Rumex (≤2%), Chenopodiaceae (≤0.5%) and Compositae Tub. (0-1%), plus a more broken one for Compositae Lig., but with a surface value of 6%, two records for Cruciferae, one at the top for Artemisia, and one at 160+cm for Cannabiaceae.

Of the grassland taxa, Gramineae frequencies jump from 2-20% over the zonal boundary, and then largely mirror Quercus values, rising to 31% at 32+cm, and to 60% at the surface. Increases are stemmed slightly at 256+cm and 128+cm. Plantago totals range from 1-4%. Values rise from 1% at the top of Zone F to 3% at the base of this one, and then decline slightly before peaking at 160+cm and 64+cm. The minimum level of 1% is found at 0cm. Curves for Ranunculaceae, Potentilla-type and Papilionaceae are semi-continuous, with values of up to 1%, and there are several records of Succisa, reaching the same maximum. There are single grains of Jasione and Rubiaceae. Pteridium levels range from 0-7%, but are mostly 5-6%, which is a big increase over previous values. Ericaceae grains are present in totals of ≤1% for most of the phase, and there are two records of *Vaccinium*.

Cyperaceae levels range from 5-11%, values rise shortly after the beginning of the zone, fall in the middle, and rise again at the top. The *Filipendula* curve becomes a little more consolidated, and reaches 2% in the middle of the phase. There are single records of Caryophyllaceae, *Thalictrum*, *Valeriana*, *Narthecium*, *Pedicularis*, and *Mentha*-type, two of *Caltha*, and a *Hydrocotyle* of 1% at the surface. Filicales values range between 3-16%. The *Typha*/*Sparganium* curve rises to 7% at the opening of the phase, and thereafter fluctuates between 2% and 7%. There is a single *T. latifolia* at 160+cm, and *Sphagnum* spores at four levels. *Potamogeton* frequencies (Abs.-5%) are high (particularly at 96+cm and 64+cm), as are those for *Nymphaea* (Abs.-3%), especially from 96+cm to the surface. There are records of *Nuphar* at 160+cm and 128+cm. *Lycopodium* levels fluctuate, but counts are generally high from 96+cm upwards.

Interpretation

On the basis of the rising NAP values which define the base of the zone, it is assumed to cover a similar time period to the corresponding one at TRGM, but the length of the profile at this location implies that deposition rates over the past 4000 years have been very high (≥80cm $1000yr^{-1}$). Closer sampling intervals in this zone would actually allow the study of human effects on the local vegetation in much more detail than at the main site, although it seems doubtful whether any extra information would be gained in respect of mire development.

The main Gramineae and main AP curves suggest that there may have been several different phases of woodland destruction. The first one occurs at the base of the zone, but the pollen spectra at 256+cm implies that some regeneration had taken place before renewed deforestation episodes at 224+cm and 160+cm. Especially in the top half of the zone, it is possible that Gramineae pollen totals may include Phragmites grains, although the curve actually dips slightly at 128cm before rising progressively in the uppermost four samples. Pollen records for arable/pastoral and ruderal taxa strengthen and diversify largely as would be expected in a recent deposit.

Unlike TRGM however, where once the Gramineae curve starts to rise, the AP:NAP ratio reverses more or less progressively thereafter, AP curves stay relatively stable until the top of the zone, perhaps reflecting the survival of some local stands of trees.

Sedge peat deposits are not found until halfway through the zone at TRGS, whereas at TRGM they coincide with the beginning of the phase, indicating that terrestrialisation occurred here considerably later than at TRGM. Throughout the zone, however, mire and aquatic fringe pollen totals are high which, in conjunction with the recording of a diversity of mire taxa, portrays the succession to reedswamp and fen which was simultaneously occurring on nearby parts of the fen.

CHAPTER FIVE

SYNTHESIS

The Regional Picture

Although the primary aim of this thesis is to trace hydroseral succession at Cors Gyfelog and Tre'r Gof, it is also fitting to use pollen diagram data to add to existing information regarding post-glacial vegetational history in Wales, especially the north western part of the country. Suitable starting points are the expansion of pollen curves for _Quercus_, and the beginning of continuous _Ulmus_ records. These events occur on the B/C boundary at GYFC, ^{14}C dated at 7250 ± 70 BP [SRR-3325], and on the same boundary at TRGM. The latter is certainly earlier than 7400 BP, the date of the D/E boundary [GrN-15523]. Extrapolation of ^{14}C dates suggests that peat deposition rates in the early organic sediments at TRG may have been very high, making the gap between immigration (or, _sensu._ Bennett (1988), expansion) dates at the two sites very small. Unfortunately, increasing proportions of mineral matter at the base of the TRGM peat rendered it impractical to attempt dating of the expansion of the curves for _Quercus_ and _Ulmus_. The available dates may be compared with those of Chambers (In press) for the northern extension of Cors Gyfelog near the Cefn Graeanog archaeological complex. Chambers extrapolated a date of 7225 ± 85 BP and estimated that peat initiation at his site began about 7400 BP, by which time Quercus pollen values were already quite high, and Ulmus records increasing. This could suggest that oak and elm became established earlier on land north of the mire than elsewhere in the locality, but in reality, not least because of poor quality pollen in Zone B at GYFC, it seems more likely that events were more or less simultaneous, probably between 7200-7500 BP. The Lleyn dates are slightly later than those for Nant Ffrancon (8120 BP) and Tregaron (Quercus 8150, Ulmus 9550) (Hibbert & Switsur 1976). Huntley and Birks (1983), with a very limited database, postulated that oak and elm immigration into Anglesey may have been slightly earlier than into Lleyn, which seems to be vindicated by the TRG evidence.

At Graeanog and GYFC, the Alnus rational limit occurs at roughly the same time as the Quercus/Ulmus pollen expansion. In the TRG pollen diagrams, however, Alnus certainly postdates the other two taxa, but the ^{14}C date mentioned above (7400 ± 90 BP) confirms that large-scale invasion (or expansion) occurred at about the same time in Anglesey as in Lleyn. This observation may provide information regarding supposed glacial refugia for alder in North Wales (Chambers & Price 1985). If, as postulated, a refuge was somewhere in the Ardudwy region, it would be expected that alder would reach northern Anglesey later than the Lleyn, but this appears to be not the case. Another species for which a Welsh glacial refugia is postulated is hazel. At Cors Gyfelog, on the basis of extrapolated dating, the Corylus rational limit could have been passed at or before 9500 BP, similar to Tregaron (9747 ± 220 BP) (Deacon, 1974), and before Nant Ffrancon (9098 ± 180) (Hibbert & Switsur, op.cit.). At TRG, it occurs on the B/C boundary, some time before 7400 BP, but probably nowhere near as early as in Lleyn, which suggests a spread from central Wales, as proposed by Deacon (op.cit.) and Moore (1972). Although of interest, debate regarding Alnus and Corylus immigration dates at Cors Gyfelog and Tre'r Gof in relation to glacial refugia is not central to this thesis, and will, therefore, be taken no further.

Although early organic deposition at TRG may have been quite rapid, it would appear that the two basal mineral zones cover a much longer period than do those at GYFC, as shown by the presence of such taxa as Artemisia cf. norvegica, Juniperus and Populus at the former location. Moore (1972) has shown that some cold phase pollen taxa can be found well into the Flandrian, but the behaviour of the NAP curve at TRGM, reaching higher levels in Zone B than Zone A, before an overall decline, suggests that TRGM Zone B does not post-date GYFC Zone A, and that TRGM Zone A represents an earlier phase not recorded in GYF deposits.

The pollen record suggests differences in early regional woodland composition between the northern Lleyn and northern Anglesey. At Cors Gyfelog, birchwoods appear to have been succeeded by pinewoods in Zone B, and pinewoods by mixed oakwoods in Zone C. Apart from possible GYFP evidence of a oakwoods in Zone C. Apart from possible GYFP evidence of a birch community fringing the mire, and the implication of birch in the recolonisation of cleared land, neither it nor pine appear to be of regional importance after the establishment of oakwoods. At Tre'r Gof, Betula pollen levels remain relatively high until the Alnus rise at the top of Zone D, whilst Pinus values, although falling from a maximum at the D/E boundary (roughly the equivalent of GYFC B/C), are still reasonably strong in Zone E, well after the establishment of oakwoods.

There is the possibility at Gors Gyfelog that regional woodland pollen totals may be distorted by local over-representation, especially by Alnus and Cyperaceae pollen. The amount of local dominance may be seen from the percentages of individual taxa from the two sites. Whilst Betula, Pinus, Ulmus, Quercus and Corylus percentages are all higher at TRG than GYF, those for Cyperaceae and, except in the most modern sediments, Alnus, are lower. High pollen values for the latter two taxa coincide with stratigraphical evidence of local presence in both GYF profiles. In a national context, however, both areas are characterised by relatively low Pinus and Tilia frequencies, and by high Alnus and Corylus totals, which appear to be normal for Western Wales (Moore, 1972, Godwin,1975).

At Tre'r Gof, forest pollen makes up a considerable proportion of TLP until the top zone, but dating at TRGM

(Zone F/G boundary 3790 ± 70 BP [GrN-15521]) has shown peat deposition rates in this final phase to be very slow, and the zone to cover a much longer timespan than was originally envisaged. Dating has been very important here in explaining what originally appeared to be a major discrepancy in establishing the order of terrestrialisation events on the mire. Because the ratio of terrestrial to limnic peat at TRGS is much greater than at TRGM, the initial impression was that fen vegetation began to develop at the deep site (TRGS) earlier than at the markedly shallower TRGM location, where early terrestrialisation would have seemed more likely. There was no possibility of an explanation in terms of one profile being in a central location and the other in a peripheral one, because both were peripheral to the original lake (Figure 14). One justifiable proposal appeared to be the possibility of more rapid accumulation of lacustrine deposits in the "bottleneck" at the western end of the kettlehole than in the broader area of the main part of the lake.

Dating, however, has allowed construction of what is thought to be a more true picture which appears to be that, as would have been expected, land plants colonised TRGM first, but subsequent deposition rates were much slower there than at TRGS. Although there is no date for terrestrialisation at TRGS, evidence for this event post-dating the equivalent at TRGM rests on the fact that reversal of the AP:NAP ratio at TRGS occurs simultaneously with evidence of fen and reedswamp peat, whereas at TRGM similar peat and a slowly rising

Cyperaceae pollen curve can definitely be pinpointed whilst Gramineae values are still very low. The only other pollen diagram from an Anglesey rich fen, Cors Goch (Seddon, 1957 in Newson & Gilman, 1981), shows a slow and progressive AP decline beginning in Zone VIIa., and latterly more marked, but in which major deforestation and terrestrialisation do not entirely coincide.

Archaeological records (Savory, 1980 and Grimes, 1965) show considerable evidence of Neolithic activity in eastern Anglesey, but much less on the north of the island. Records of later prehistory are less frequent, but there is a hillfort, Dinas Gynfor, with an enclosed area of over 15 acres, only a few miles to the east of the mire (RCAHM, 1937). TRG pollen evidence (Figures 18 & 21 and Mighall, Pers.Comm.) suggests that major deforestation began in the Bronze Age, but as with Seddon's diagram, there is the suggestion of some very early Neolithic, or perhaps even Mesolithic, clearance, although apparently of a much more temporary nature than that on the east of the island.

Mesolithic Bann Flakes have been found at several locations in Anglesey (and at at least one site in Lleyn) (Livens 1972), similar to finds made on the eastern side of Ireland. Edwards (1985) refers to several Irish cereal pollen records from before 5500 bp, all of which predate the elm decline. Edwards not only suggests that the grains could represent pioneer Neolithic arable activity, but also mentions the possibility of farming by Mesolithic people who had acquired agricultural knowledge. It is interesting to speculate on the possibility of early Irish connections with north Wales. According to Synge (1985), the final land bridge between Ireland and Lleyn was severed about 12000 years ago, but Dennell (1983) refers to extensive evidence indicating that Mesolithic peoples possessed considerable seafaring prowess, so visits would not be out of the question at all. Dennell also suggests that the sheep and cereals characteristic of Neolithic farming may have been imported by native Mesolithic sailors, along with new technologies discovered abroad, rather than these being the product of a new wave of colonisation. He suggests that "Neolithic land-based agriculturalists who spent their lives tending sheep and growing cereals would have had as little reason to take up seafaring as the Swiss Navy had to invent battleships." (p.185)

At first sight, AP:NAP ratios for the Cors Gyfelog profiles look much more erratic than do those for Anglesey. If, however, the proportions of the GYF curves which are directly attributable to _in situ_ alder and sedge vegetation were to be discounted, then the curves would have a much smoother appearance. In the pollen diagrams for both sites there are suggestions of landnam phases (cf Iversen, 1941), namely declines in _Quercus_ pollen levels, followed by short term _Betula_, and sometimes _Corylus_, increases before restoration of _Quercus_ values.

The pollen diagram from Cefn Graeanog (Chambers, In press) shows the same overall AP curve pattern as those for GYFC and GYFP (allowing for later peat initiation at GYFP), and includes evidence of similar major events, such as mineral inwashes. The suggestion from these diagrams, as discussed earlier, is that forest degradation began in Neolithic times, and became more intense in the Bronze and Iron Ages. Much the same conclusion is reached in many other studies of vegetational history from north and central Wales e.g. Cefn Gwernffrwd (Chambers, 1982), Moel y Gerddi (Chambers & Price, 1985, 1988), Western Rhinogau (Walker & Taylor, 1976), Ardudwy (Moore, 1973), North Cardiganshire (Moore, 1968, Smith & Taylor, 1969), Elan Valley and Llyn Gynon (Moore & Chater, 1969), Llanllwch (Thomas, 1965), Llyn Padarn (Elner & Happey-Wood, 1980), Melynllyn (Walker, 1978), Llyn Llydaw and Cwm Cywion (Ince, 1983), Llyn Dwythwch and Nant Ffrancon (Seddon, 1962).

Archaeological records suggest that there was much human activity in the Lleyn Peninsula during Neolithic times, but less in mid-Wales and northern Anglesey (Savory, 1965,1980). In the studies mentioned above and others, mid-Welsh pollen diagrams tend to have relatively minor declines in AP frequencies in relation to events which can be attributed to Neolithic activities, the more major ones relating to Bronze, or sometimes Iron, Age activities. Evidence from Lleyn or Snowdonian diagrams, on the other hand, suggests that Neolithic clearances in the north were often more severe, and more permanent.

Welsh Wetland Development

Tre'r Gof and Cors Gyfelog not only provide examples of mires formed under different water regimes, but also of two contrasting types of wetland succession. Tre'r Gof, in a basin, has been a lake for a sizeable proportion of its post-glacial history, and fen for about four thousand years, whilst Cors Gyfelog, which is actually in the peculiar situation of being a watershed but also in a stream catchment has, after only a very brief lacustrine spell, undergone succession and retrogression between reedswamp, carr and fen. In Walker's (1970) terms, the Tre'r Gof succession route has been:

Open water (1) > Micro-organisms in open water (2)
> Floating Aquatics (3) > Rooting Aquatics (4)
> Reedswamp (5) > Fen (7)

probably with some Carr (9) with the fen on the south side and now incipient again.

At least limited areas of each type still survive on Tre'r Gof today. In stratigraphical terms, succession has been:

Lake clay > (Marl) > Organic gyttja >
Phragmites peat > Fen peat > (Wood peat).

Other palaeoecological studies of Welsh wetlands with predominantly lacustrine histories are of little relevance to the discussion of Tre'r Gof succession. Evans & Walker, (1977), and Walker (1978) both discuss extant upland oligotrophic tarns, whilst Ince (1983) has looked at Llyn Llydaw, an infilled Snowdonian rock basin, with successional complications caused by periodic mineral inwashes, resulting in an Open water > Fen > (Carr > Fen) > Incipient bog history. Moore and Beckett (1971) studied Llyn, further south in the Wye valley, with two shallow basins showing Lake clay > Reedswamp > Fen > Carr > Molinia > Bog succession, but with surface levels damaged by peat extraction, and the modern stage probably representing secondary colonisation. The main basin has also developed a schwingmoor, so the whole picture is rather more complicated than necessary to compare with the apparently simple Tre'r Gof history.

The major factor which differentiates Tre'r Gof from any of the aforementioned is, however, its receipt of base-rich waters. Cors Erddreiniog (CE) and Cors Goch (CG), two calcareous mires in eastern Anglesey, have been studied in respect of stratigraphy, hydrology and chemical status, and reports prepared (Newson and Gilman (1981), Gilman & Newson, (1979, 1982), and Meade (1981)). Both are much larger than Tre'r Gof (CE 200ha, CG 39 ha, NCC[WFU] (1984)), and both have NCR Grade 1 as well as SSSI status. Part of CE is a NNR, but other areas of the SSSI were badly damaged by drainage in the mid-sixties, and the NCC have continued to contest further threats.

Whereas the calcium supply for TRG is all assumed to derive from till (Harris, 1986), the eastern mires receive run-off from Carboniferous limestone. The successional paths of both are similar to that of TRG, although neither support any carr, and both include small areas of open water showing succession through Nymphaea and Nuphar (which appear to the author as being characteristic of eutrophic and mesotrophic water bodies although Walker (1982b) suggests that Nymphaea is also found in nutrient poor reedswamps) and Schoenoplectus. CG includes higher, more acidic, areas (with identical stratigraphy to the richer parts) (Newson and Gilman, 1981) supporting Sphagnum species, whilst the CE vegetation becomes less rich with distance from eastern base-rich springs (SSSI schedule).

Although all three mires are classified as WWS Type D, vegetation noda and their proportions vary between them (Table 4), presumably through differences in water levels and regimes, and degrees of disturbance. The only noda which occur in all three are Type 5, which is characteristic of highly calcareous mires, and Type 6, which is found in topogeneous eutrophic situations (Ratcliffe, 1983). The two combined account for 28% of CE vegetation, and 40% of CG but only 18% of TRG. Nodum 10 (eutrophic with former rich fen relicts) covers a further 50% of CE, presumably representing deterioration following drainage, and the remainder is made

Cors Gyfelog		Tre'r Gof		Cors Erddreiniog		Cors Goch	
Nodum	%	Nodum	%	Nodum	%	Nodum	%
6	15	2	1	5	21	4	5
7a	3	5	8	6	7	5	30
7b	10	6	10	10	50	6	10
12	26	7b	20	12	22	7a	45
13	2	12	8			10	5
14	1	16	35			15a	5
16	10	20	5				
19	5	Carr	8				
20	5	Other	5				
21b	1						
21c	5						
Carr	15						
Other	2						
Total	100	Total	100	Total	100	Total	100

Key:

Nodum	Association
4	Cladium mariscus-Rubus fruticosus
5	Schoenus nigricans-Juncus subnodulosus
6	Calliergon cuspidatum-Carex diandra
7	Potentilla palustris-Carex rostrata a. Lemna minor variant b. Typical variant
10	Molinia caerulea-Myrica gale
12	Wet meadow complex (a-e)
13	Iris pseudacorus-Mentha aquatica
14	Carex paniculata-Rubus fruticosus
15a	Phalaris-Phragmites-Epilobium hirsutum-Filipendula (Typical subassociation)
16	Fen meadow community
19	Vaccinium oxycoccus-Sphagnum recurvum
20	Carex rostrata-Sphagnum recurvum
21	Erica tetralix-Sphagnum magellanicum b. Sphagnum papillosum-Erica tetralix c. Trichophorum cespitosum-Eriophorum angustifolium

Table 4. Distribution of vegetation in selected north Welsh mires and key to WWS noda

After Ratcliffe & Hattey, 1982, WFU, 1984 up of mixed Type 12 communities. Much of CG is transitional between reedswamp and poor fen, as is 20% of TRG, which also has fen and wet meadow for 43% of its area, and carr for 8%.

Despite evidence from archaeological and pollen records that eastern Angelsey has been longer and more intensely settled than the north since Neolithic times, hydroseral succession at CE and CG seems to have reached roughly the same stage as at Tre'r Gof, that is, essentially to fen. The major exceptions are the Sphagnum-based noda (albeit with different species) found at TRG and CG, and the carr at TRG. These may merely reflect different responses to the raising of vegetation levels near to or above the water table at the same stage of succession. The suggestion that local disturbance has little effect on the successional pattern of a lake, as opposed to a terrestrial wetland, is hard to justify. It is difficult to pick up changes in the former, such as the difference between floating leaved or aquatic macrophyte communities, in pollen or sediment columns, because several different phases of the hydrosere are likely to be present in a small area at any one time.

Although there are both similarities and differences in the types and proportions of the different vegetation noda within the three rich fens, several noda from the Anglesey mires are also common to mesotrophic Cors Gyfelog. The division into different mire types is arbitrary and presumably, if succession results in the loss, gain or change in proportion of certain noda, individual mires may be reclassified in the future. Cors Gyfelog lacks any representation of Nodum 5, which presumably puts mires in the rich fen group, but 15% of its surface bears Type 6 vegetation (topogeneous, eutrophic conditions) (Figure 5), another 38% supports fen communities, and 18% poorer fen, and almost all of the groups are common to TRG (Table 4). Both also have areas of carr, but, unlike Tre'r Gof, Cors Gyfelog has tracts of acidic, possibly onbrogenous vegetation (11%). Figure 5 shows that the acidic noda are mostly situated on the western side of the mire, in the area disturbed by past peat digging. Acidiphilous communities often seem to develop on mires recovering from peat extraction (cf. Green & Pearson, 1968, Moore & Beckett, 1971, Giller & Wheeler, 1988).

Whilst the analytical chapters looked at vertical changes in the chemical profiles, differences in nutrient levels between mires of contrasting histories and ostensibly different modern status must also be considered, although straightforward comparisons of overall levels between Cors Gyfelog and Tre'r Gof are of little value because of different origins of the peat (i.e. organic material from Cors Gyfelog is likely to be predominantly autochthonous, whilst that from Tre'r Gof may be more allochthonous), and inwashed mineral matter. More valuable is the discussion of comparable horizons in the peat profiles, the most obvious ones being the fen deposits following terrestrialisation at Tre'r Gof, and after the last Cors Gyfelog woody phase. In both cases there are indications of reedswamp development before succession to fen. To this end, averages have been calculated for chemical analyses in levels from 0-100cm at TRG, and from 0-80cm in the GYFC and GYFP profiles. Coring points for both TRGM and GYFC are in areas of Type 6 vegetation, whilst GYFP is in a Type 12 region.

Levels of sodium and potassium are higher at GYFP and TRG than at GYFC, which seems to confirm that the cations seep into the mires from adjacent catchments, although transport by rain is also implicated in the case of sodium (Green & Pearson, 1977). Magnesium may enter by seepage too, but there are no surface increases to substantiate this claim. However, as mentioned in Chapters Three and Four, the question arises regarding sodium and potassium as to whether high surface values have been the historical norm, suggesting that the cations slowly infiltrate the peat from above, or whether they are a modern phenomenon, reflecting a concerted period of runoff associated with modern agricultural practice, and giving the same effect as the peaks recorded lower down in the GYF profiles.

Ross (Pers. Comm.) suggests that nitrogen and phosphorus levels are likely to be the best indicators of vegetational status on the mires, and thus it would be expected that the upper levels of GYFC and TRG would show similar nitrogen and phosphorus levels, as both support similar vegetation. In fact, phosphorus concentrations rise at the surface in all three profiles (probably due to agricultural input), but values in both GYF profiles are higher than that for Tre'r Gof, as also are their nitrogen levels. The GYFP totals fall between those of GYFC and TRG, so it cannot be inferred that levels are higher or lower in Molinia-dominated fen than in the eutrophic Type 6 areas. The higher GYF levels may reflect a longer period of vegetation growth *in situ*, rather than derivation from secondary sources (i.e. gyttja), as must have happened at Tre'r Gof. It may even be that there is a greater tendency for plants to retain nitrogen and phosphorus in potentially less rich feeding situations as at Cors Gyfelog. On an overall basis, except for during periods of heavy mineral inwash, nitrogen records at GYF do appear to reflect major vegetational changes, but the TRG picture, not surprisingly, appears much less eventful. In retrospect, had the long time period covered by the fen peat been known before the various analyses had been carried out, the author would almost certainly have decided to at least halve the upper sampling intervals (but see comments in Chapter Two regarding ^{14}C dating).

Calcium values are historically higher at Tre'r Gof than at Cors Gyfelog, although not always greatly so. If totals for the complete profiles are averaged, the results are: TRG 12.4 g/kg, GYFC 7.6 g/kg, GYFP 7.5 g/kg, but these figures cover some large variations. The highest TRG readings, for instance, reach 66 g/kg in the "marl phase", three times as great as any GYF reading, and there is another phase of high concentrations just prior to terrestrialisation, but in the top reedswamp/fen zones, averages are (g/kg): TRG 7, GYFC 5, GYFP 4. These figures lead to speculation that levels at TRG are falling, although, as discussed in the analysis section, there is a marked rise to 22.0 g/kg (raw) at the surface, which may truly reflect the difference between the two mires. The question does arise, however, as to why the locality of GYFC can support eutrophic vegetation similar to that of TRG whilst, with only slightly lower base levels, GYFP supports a poorer Molinia association. The logical assumption is that the water table is lower to the east of Cors Gyfelog, possibly through drainage.

All three sets of values are well above the oligotrophic threshold suggested by Chapman (1964) of 250mg% (2.5 g/kg). Previous peat chemistry studies (Green & Pearson, 1977, Chapman, op. cit., Tallis, 1973) show major changes in calcium values relating to such major events as minerotrophic/ombrotrophic changes, as in blanket mire or schwingmoor development, rather than in a mesotrophic/ eutrophic divide. In some of their profiles calcium concentrations appear to decline with time, as may partly be the case in GYFC, but the marked and sustained peak in the middle levels of GYFP appears to vindicate the suggestion by Ross (Pers. Comm.) that calcium values may be higher in wood peat than in sedge-dominated deposits.

Analyses of calcium, magnesium, sodium, and potassium have been carried out on surface peat at CE and CG (Meade, 1981), and cross-relationships established between levels of cations, soil (sic.) water content and vegetation associations. Calcium concentrations sometimes exceed 150 µg/ml (g/kg) at both sites, although values of <100 are more the norm. It would appear that whilst levels correlate to vegetational types, they also reflect the proportion of mineral matter in the peat which, where the mires adjoin limestone slopes, is considerable. Maximum magnesium concentrations exceed 10g/kg, although 2-4 is more common. Compared with TRG surface levels of 0.24-0.66 (raw), these are again very high, although comparable with the TRG basal mineral samples.

Sodium values average between 24-32 g/kg, compared with TRG surface concentrations of c.0.5, and potassium levels reach 18 g/kg, compared with 5-10 at the TRG surface. The monovalent cation results from CG and CE are certainly much higher than those from TRG. Allen et.al. (1974, 1986) and Berglund, 1986 quote typical concentration rates of elements in plant material and soil. Values at CE and CG tend to be on the high side of those suggested as typical, and sometimes, (as in the case of sodium) well outside the suggested range for either soil or plant material, whereas TRG and GYF concentrations appear to be on the low side.

It must be pointed out that different methods were used for cation extraction at CE and CG than at TRG and GYF, which may render the successful comparison of results impossible. In the author's own experience, for example, it has been observed that sodium and potassium readings increase dramatically if "fast" filter papers are used in sample preparation, rather than the "slow", type used for the GYF and TRG samples. A conclusion to be drawn from the above discussion is that there is a need for the standardisation of analytical methods in palaeoecology, as proposed by Berglund (Op. cit.). It is also unfortunate that no whole profile analyses were carried out at CE and CG which would have at least allowed the comparison of overall curve shapes with those from the genetically similar Tre'r Gof. Such research was not possible during the current studentship but, in the opinion of the author, should be considered in the future as part of an exercise to ascertain whether peat profiles from vegetationally similar hydroseres produce comparable chemical spectra.

Within the immediate study area, i.e. West Gwynedd, there are a number of mesotrophic lowland wetlands (NCC Types C & E, Table 1), of which some are valley mires, and thus historically comparable to Cors Gyfelog, but there are no available palaeoecological studies, and so a wider area has to be cited in this discussion. There are also a small number of ombrotrophic (Type A) mires in the locality, which may or may not represent former mesotrophic wetlands which are now developing into raised bogs. Two of these were originally considered for study in this thesis to complete a eutrophic-mesotrophic-oligotrophic suite, but both had to be discounted. At Cors Graeanog, a NCR Grade 2 site and SSSI, efforts to retrieve a core were unsuccessful because, following peat cutting, sediments were very shallow and unconsolidated. Again there is the speculation that peat extraction itself may have precipitated the growth of ombrotrophic vegetation. A second site, Rhosgyll Fawr, quite close to Cors Gyfelog, was ruled out on NCC advice because of recent heavy disturbance.

Chambers' (In press) Cefn Graeanog work (there is no connection between Cors Graeanog and Cefn Graeanog which are several miles away from each other) north of Cors Gyfelog confirms the patterns of succession seen in the more central areas of the mire, i.e. carr development interrupted by mineral inwashes causing reversion to fen, succession back to carr, a wet phase and finally modern sedge/Molinia peat.

Work from other valley mires comes from further afield. The definition of valley mire is sometimes a loose one, and it must be accepted that different settlement histories may have distorted succession patterns in other areas of Wales. Rhosgoch Common, Radnor (Bartley, 1960) has a variety of wetland communities, including a central raised mire surrounded by carr, and fen swamp communities in the lower part of the valley. Apart from the raised mire section, mesotrophic conditions are indicated. Stratigraphy shows an open water > fen > bog succession, which Walker (1970) calculates to have taken 3000 years, the open water > fen stage having been completed in less than 500 years. Llanllwch, Carmarthen, was once drained by the River Towy, but in post-glacial times, only by two small streams. Thomas (1965) also showed an open water > fen transition time of less than 500 years, and succession through carr to Molinia and to bog a further 2000 years. A very late AP decline here suggests that vegetation changes were climatically, rather than anthropogenically, induced. Turner's (1964) work at Tregaron deals only with the period since the raised mire developed, but Hibbert & Switsur (op.cit.) suggest that open water > fen again took less than 500 years, and the transition to raised mire another 3000.

Walker (1970) used non-riverine basin systems as two of his three categories for the discussion of succession rates (the other category being estuarine wetlands). It is difficult to ascertain what Walker means by non-riverine, but the following definitions would appear to include valley mires. In respect of small basins, he says "They draw their water from small catchments and drain through single, sometimes intermittent, overflow channels" and of large basins "Their catchments are often relatively large; water enters them by one or many, often well-defined, streams and usually leaves by a single perennially flowing river" (p.120).

Rates of succession in the wetlands referred to above are within Walker's estimations. Other mire systems, however, have taken considerably longer to develop into bogs. Moel y Gerddi (Chambers and Price, 1985, 1988) is an upland valley mire in which only as _Alnus_ pollen levels declined (3715 ± 70 BP) did _Sphagnum_-dominated valley bog develop. There is no stratigraphical evidence that the mire was originally lacustrine, but fen > bog transition certainly took over 5000 years. Interestingly, the pollen diagram shows a temporary _Alnus_ decline at about 6435 ± 85 BP, and lasting for about 500 years. Stratigraphy shows the event to postdate a mineral inwash. This date compares reasonably well with Hibbert & Switsur's (op.cit.) date for raised mire initiation at Tregaron (6530 ± 110 BP). The Moel y Gerddi alder sequence looks similar to those at Cefn Graeanog (although the decline occurred somewhat later [after 5595 ± 70 BP]), and at Cors Gyfelog (earlier than 4440 ± 60 BP) where in both cases a Cyperaceae rise coincides with the *Alnus* decline.

At Cefn Gwernffrwd (Chambers, 1982), which is a basin mire with a long history of carr domination, the transition to *Sphagnum* bog was more recent than 2580 ± 60 BP, at more or less the same time as the Cors Gyfelog reedswamp/valley bog phase, and over 7000 years after the infilling of the shallow postglacial lake.

Gwarllyn (Moore, 1972), an upland valley bog close to Tregaron, shows a succession from open water to bog, then to carr and back to bog. Moore's horizons are not dated, but the stratigraphical column suggests that the reversion from carr to bog occurred at the Zone VI/VIIa boundary, i.e. the Boreal/Atlantic transition as defined by the rise in the *Alnus* pollen curve, which synchronises the carr-bog transition with raised mire initiation at Tregaron.

The suggestion of bog initiation after the onset of wet climatic periods is standard textbook material e.g. Godwin (1956). Of the examples mentioned above, only Llanllwch (Thomas, op. cit.) seems to become ombrotrophic in stages rather than as a clearly defined event. The first reversion (brushwood - *Molinia*), however, coincides with the onset of the Atlantic period, and the dark brown Calluna/ Sphagnum/ Eriophorum peat gives way to light brown Sphagnum-dominated peat just before the Zone VIIb/VIII boundary, i.e. at the Sub-Boreal/Sub-Atlantic transition.

Records from Welsh wetlands suggest, then, that with some mires, e.g. Tregaron, Rhosgoch Common, the balance between minerotrophic and ombrotrophic conditions was tipped at the beginning of the first major post-glacial wet period, whilst in other cases, e.g. Moel y Gerddi, the response was reversion from carr to fen. The same happened at Cors Gyfelog, and Cefn Graeanog, but at a later date. At Moel y Gerddi and Gwernffrwd, Sphagnum initiation was at the beginning of the Sub-Atlantic, at which time the Cors Gyfelog and Cefn Graeanog pollen diagrams also suggest incipient succession to valley bog, which was apparently subsequently deferred.

The suggestion to emerge from the foregoing discussion is that, although Walker's estimations of open water > bog transition times are vindicated in some of the examples cited above, most of the major transitions can be traced to allogenic factors, mainly climatic change. Open water > reedswamp > fen > carr certainly appears to have been a preferred succession before the Atlantic, but there seem to be profound variations in Atlantic and post-Atlantic mire vegetational types. Walker certainly suggested that many successional routes may be taken, and his observations in this matter cannot be refuted. It is felt, however, that the influence of local rocks and soils is of primary importance when considering mire vegetation changes in the Atlantic and later. Although peat chemistry data are not available from most of the Welsh wetlands, a tentative suggestion may be made that those which developed Sphagnum lawns in the Atlantic period may have already been in receipt of base-poor waters, whilst richer ones, such as Cors Gyfelog, were able to survive the wet phase and revert to carr again when conditions allowed. If, as suggested by data from GYFC, and earlier work (e.g. Green & Pearson 1977), the influence of groundwater calcium decreases as peat builds up, it is not surprising that further mires developed Sphagnum nuclei and eventually became ombrotrophic when wet conditions returned in the Sub-Atlantic.

Cors Gyfelog, however, is likely to have had a continuous throughflow of water which is assumed to have come from a reasonably base-rich source. In contrast to Snowdonia and central Wales, there are thought to be occasional pockets of calcareous till in the Lleyn Peninsula (Synge, 1964), and it appears at least one of Cors Gyfelog's rivers rises in or flows through such an area. Further calcareous till deposits in eastern Anglesey (Harris, 1986), as well as limestone bedrock, have apparently protected the island's rich fens from large scale Sphagnum invasion. Not surprisingly, most of the mesotrophic mires and almost all of the rich fens in the NCC's North Wales region are concentrated in these two areas (WFU, 1984).

Another factor which may be particularly important in discussions regarding open water > bog transitions is original lake depth. Quite a few of the post-glacial lakes mentioned in this chapter appear to have become terrestrialised at about the same time, probably because their initial depths were similar. Is is likely, therefore, that they would have reached comparable stages of development when the climate became wetter in the Atlantic period. There are, of course, others which either silted up much later (such as the Anglesey fens) or are still open water (such as the Snowdonia tarns), but these probably originated in deeper basins. Even in relatively closed situations like basin mires, it seems difficult to separate major vegetational changes from allogenic factors. In the lacustrine phase of development, for instance, it can be imagined that much accumulating gyttja would actually be of external origin, especially if the basin was steep-sided.

In the Anglesey fens there are no obvious signs that human agency has affected mire development. Certainly in the case of TRG, it appears that the open water > fen transition took place before major deforestation and that fen vegetation has dominated for the past four thousand years. In Zone D of the Cors Gyfelog profiles, however, the temporary reversion from carr to fen does not appear to relate to a climatic event, and can be explained in anthropogenic terms when considered in the light of other pollen and chemical evidence. Human activity may, however, actually have "benefitted" Cors Gyfelog in the context of its modern status. If the carr had not been temporarily swamped, there is the possibility that, by the beginning of the Sub-Atlantic period, peat levels would have risen far enough above the water table to have allowed a much greater degree of ombrotrophic development than actually happened.

CHAPTER SIX

CONCLUSIONS

Much of the preceding body of work has been concerned with vegetational history, partly relating to the mires themselves, and partly in connection with the regional setting in which they, and other wetlands, developed. In this last chapter, it is intended to apply some of the information obtained to points raised in Chapter One regarding past developmental sequences and their implications for the future.

Cors Gyfelog

Extrapolation of ^{14}C dates suggests that lacustrine sediments began to accumulate in the eastern part of Cors Gyfelog at least 10000 years ago, and that terrestrialisation probably took place about 9500 BP. Small lakes are thought to have originally occupied several shallow depressions, but accumulating peat overtopped these, and the mire became one entity, probably at the same time as the wetland expanded into the surrounding valley during the wet Atlantic period, estimated on the basis of GYFP ^{14}C dates to have been between 6000 and 7000 years BP.

Walker (1970) proposed that, in the absence of external influences, succession tends to be from the wet to the dry.

This is applicable to Cors Gyfelog inasmuch as fen and carr development followed a brief lacustrine phase in central parts of the mire, but not in respect of the later sequence of fen <> carr transitions, and the reedswamp phase which is thought to have preceded the mosaic of poor-fen and carr communities found on the mire today. Pollen and chemical data suggest, however, that phases of retrogressive succession can generally be traced to allogenic events, whether "natural" (e.g. climatic) or otherwise (i.e. anthropogenic).

With central deposits probably dating back 9500 years or more, and terrestrialisation complete well before the earliest ^{14}C date of 7250 ± 70 BP [SRR-3325], it is obvious that Walker's open water > fen > bog succession time of 2500-4000 years has already been exceeded. The central profile pollen diagram (Figure 9) suggests that there was a temporary phase of valley bog as the climate became wetter with the onset of the Sub-Atlantic period. Whilst the peripheral pollen diagram (Figure 11) implies the continuous presence of *Sphagnum* over the past 2700 years or more, results of the WFU survey suggest that much of the acidophilous vegetation on the mire belongs to a *Vaccinium oxycoccus*-*Sphagnum recurvum* association found on the western side (Nodum 19, Figure 5), which is thought to represent recolonisation of old peat workings.

In the previous chapter it was suggested that the rivers flowing through the Cors Gyfelog valley prevented succession to bog under Atlantic and Sub-Atlantic regimes, but in each case there appear to have been definite responses to the wet conditions. Pollen and stratigraphical evidence imply that the most recent major phase of retrogressive succession was towards reedswamp during Sub-Boreal/Sub-Atlantic climatic deterioration, at the same time as Sphagnum spores appear in the pollen diagrams. During this period, the mire is thought to have been at a "lower" successional stage than at any other period since terrestrialisation. It seems logical to re-commence calculations relating to the duration of seral stages from this time. This, in Walker's terms, means that in the absence of allogenic influences, the mire could develop into bog within the next 1500 years.

As suggested above, however, Cors Gyfelog is thought to have almost invariably been in receipt of allogenic material either via its rivers or from catchment seepage and is likely to continue to be so in the largely treeless modern valley. To counteract this, however, questions regarding the effects of drainage have to be introduced. The SSSI schedule refers to the site as being "little damaged by drainage", but there are various man-made channels on Cors Gyfelog of unknown age. Marked increases in Gramineae pollen values in the uppermost samples of both profiles are thought to be related to drainage attempts, which appear to have lowered water levels on the eastern side sufficiently for the large-scale invasion by Molinia of areas which had probably previously been sedge-dominated for most of the last three thousand years, rather than to any recent enlargement or intensification of local grazing areas. *Molinia* is particularly characteristic of "dry" wetlands (Wheeler, 1980, Meade, 1981, Ratcliffe & Hattey, 1982), as is *Salix* carr which currently occupies 15% of Cors Gyfelog (Figure 5) and which, according to central pollen diagram evidence, is relatively newly established.

Alternative explanations for these events could be lowering of the water table in connection, for instance, with sand and gravel quarrying operations at Graeanog Crossing, directly to the north of the mire. A band of ombrogenous (Nodum 21c) vegetation which runs along the northern fringe of Cors Gyfelog and adjoins the sand and gravel workings may be related to drainage disruption connected with the latter. In some parts of the mire, peat may currently be growing fast enough to accumulate above the water-table. The uppermost GYFC ^{14}C date suggests recent peat accumulation of 30-35cm/1000yr, whilst the top two dates from GYFP suggest >70cm/1000yr, the latter being above Walker's modal rate of 21-60cm/1000yr. GFYP accumulation rates slow down somewhat with depth and presumably, increasing compaction, but rates towards the surface are still much higher than directly comparable ones in the GYFC profile (and much higher than TRGM rates of 22cm/1000yr over the past 4000 years).

There are several points regarding the future at Cors Gyfelog which should be considered. Firstly, 15% of the surface of the mire is now *Salix* carr, and, as mentioned above, at least some of this colonisation appears to be quite recent. It seems logical to suppose that the current carr islands have the potential to spread and amalgamate. Whilst carr represents an important stage in the development of a mire, much of that on Cors Gyfelog borders eutrophic Nodum 6 vegetation, which is assumed to be of much higher conservation priority to the NCC. Active management may be necessary to prevent the spread of carr to these adjacent areas.

If, as suspected, large areas of wet meadow in the eastern and southern parts of the mire arose as a result of relatively recent drainage activities, they too may be subject to invasion by carr, whereas if water levels rose, or were induced to do so, Nodum 7b or even Nodum 6 communities could become established (or, more probably, re-established) over a much wider area than at present.

Predictions regarding the future development of Cors Gyfelog would obviously benefit from detailed hydrological studies like those carried out at Cors Erddreiniog and Cors Goch, and from further topographical investigation. All over the mire, and especially in areas dominated by "drier" communities, such as wet meadow and carr, it is important to watch for Sphagnum invasion. According to Giller & Wheeler (1988), Sphagnum colonies are more likely to become established where peat is buoyant and moves vertically with water level changes, than in more solid deposits where periodic indundation may drown them out. However, if the slope is minimal, once peat levels permanently rise above the water-table, Sphagnum can colonise mires of any trophic status, even in areas of low rainfall (Birks & Birks, 1980). It is assumed by the author that partial drainage would result in the same net effect on extant mire vegetation as would natural peat accumulation above the water table.

In summary, the modern vegetation of Cors Gyfelog is very diverse, and may well be more varied than at almost any other stage in the history of the mire. There are, however, indications that its recent development has been greatly affected by human activity.

Tre'r Gof

The history of Tre'r Gof is markedly different from that of Cors Gyfelog. The rich fen of today represents the infilling of a kettlehole lake fed by run-off from shelly till. Fen vegetation has prevailed for about 4000 years. Overall succession appears to have been from wet to dry, but there are some indications of water level fluctuations in the former lake which are assumed to relate to changes in climate.

The modern SSSI encompasses terrestrial deposits which overlie the former lake basin, and also fringing fen meadow, in which barely formed peat rests on top of till. Vegetation associations over the central deposits, especially on the eastern side where the former basin was relatively wide, are those which are most characteristic of rich fen. Ditches, up to 2m wide and about 70cm deep run roughly parallel to, but slightly west of, Traverse A, and parallel to, but some way south of, Traverse B. The ages of the ditches are unknown, and they are largely choked with tall vegetation.

Whilst much of the drier fen meadow is outside the old lake boundary where the terrain begins to slope upwards, some areas, such as the Nodum 12a patch to the south of the ditch (Figure 17), and the Nodum 16 band which flanks it, are largely within the deep peat area, but appear to have been affected by drainage. Most of the fen meadow areas are grazed, sometimes heavily so.

On the other hand, a large percentage of the area to the north of the drain which now supports Nodum 7b vegetation is outside the former lake margin. Pollen studies suggest that there may have been a damp fringe to the lake for much of its history, but very shallow peat deposits in the north-western quarter of the SSSI imply that only occasionally have conditions been wet enough there for peat accumulation. Levelling shows the surface of the south side of the fen to be higher than the north side, and the east higher than the west, so the north western area is now one of the lowest on the mire, and thus in net receipt of water. This quarter is isolated from the rest of the fen by the ditches, so it is now probably a hydrologically separate entity. Much of its water supply may originate from a spring on the northern border of the section.

In the east, flanked by grazed fen meadow vegetation, are the rich fen areas which overlie the main part of the old lake. Much of the mire directly east of the north-south ditch bears Type 6 flora which, like the Type 7b association mentioned above, is also found in central parts of Cors Gyfelog. The two noda apparently often grade into each other (Ratcliffe 1983). The area is generally damp, and is bordered to the east by Nodum 5 vegetation, which is probably fed from the same water source. The latter community, which is essentially a stand of Cladium mariscus, is characteristic of highly calcareous mires. It actually overlies the parts of the lake basin where marl was recorded in the stratigraphy. Run-off is assumed to come from the calcareous black silty clay till described by Harris (1986) to the north and east of the fen.

The TRGM calcium curve (Figure 20) shows that the highest concentrations are in Zones B,C and F, which may coincide with drier post-glacial climatic phases, whereas lower values appear to be associated with the Atlantic and Sub-Atlantic periods. Apart from Zone B when the lake was still in receipt of glacial melt-out material, high calcium values more or less correspond with phases in which Loss on Ignition is also relatively high. It is possible that in dry periods, a large proportion of run-off comes from very local sources, in this case the calcareous till, but from a much wider radius in wet phases.

Of particular importance is the fact that both calcium and Loss on Ignition levels rise in the uppermost part of Zone G, possibly suggesting that the conditions which have encouraged the establishment of Cladium mariscus colonies are relatively recent. Such a conclusion perhaps seems out of place in the context of today's climate which is by no means dry, and in a deforested landscape where run-off would be expected to increase. The LOI curve suggests that, since deforestation began and until recently, this had indeed been the case, although as commented in Chapters Three and Four, it is felt that caution must be exercised in the interpretation of LOI curves in the upper part of profiles because of the probability of downwash from agricultural activities. In support of the theory that Cladium establishment is recent, however, is the absence of remains of the plant in the peat at any of the traverse coring points. It is possible that the ditch has channelled away more general run-off and left this part of the fen in receipt of a particularly concentrated source of calcium-rich water.

Alternatively, if the main ditch is subject to choking by vegetation, drainage of rich till-derived water may be at least periodically impeded and flooding occur further back in the system. Daniels (1978) associates Glyceria communities with nutrient-rich areas on mineral ground. The part of the fen classified by the NCC as Type 2b is dominated by Typha latifolia with subordinate Glyceria fluitans and Eleocharis palustris. Although no borings were made in that part of the mire, evidence from Traverses A and C (Figure 14) suggests that it is outside the former lake area. A small natural channel originating in the south-east corner of the fen flows through the Nodum 2b area before reaching the main ditch. The vegetational unit may represent the part of the channel flood plain which runs over mineral soil.

The area of the mire in which the interpretation and evaluation of present-day communities in the context of their vegetational history and modern topographical setting causes the most problems is the Salix carr to the south of the ditch, and the adjoining Nodum 20 vegetation. The carr might have been expected to occupy a dry part of the mire, but the individual unpublished WWS survey report for the site refers to:

> "Salix cinerea carr with tall Juncus subnodulosus, Phragmites, Eupatorium. Raft-like. Open areas".

The Type 20 vegetation is described as:

> "Juncus articulatus/acutiflorus - Agrostis - Carex rostrata. Sparse Phragmites. Some Cladium. Ungrazed. Quite wet."

Ratcliffe (1983) describes the association as being "very wet, often floating". No borings were made in either of these areas, but projection of the proposed former lake margin between points on Traverse A and Traverse D suggests that the carr almost certainly overlies deep peat, but the Type 20 vegetation may not.

The raft-like attributes of the carr may reflect schwingmoor-type development, although there are no indications from TRG pollen analyses or ^{14}C dates that raft vegetation was of general occurrence on the mire. Alternatively, both communities may be associated with former peat cutting. Giller & Wheeler (1988), investigating Broadland mires, refer to Sphagnum invasion in mobile carr communities overlying nineteenth century peat cuttings. Similarly Green & Pearson (1968) cite Sphagnum recurvum as a colonist of old peat workings, although the species is not actually mentioned in the above WWS description of the Nodum 20 community at Tre'r Gof. It may be that these areas are mobile enough to allow Sphagnum invasion in the future. Giller & Wheeler (op. cit.) suggest two types of vegetational development which may follow Sphagnum invasion. In the first scenario, once an ombrotrophic nucleus is formed, the lawn will continue to spread (cf. Walker (1970)). In the second, when the peat builds up and becomes consolidated, vertical motion ceases, Sphagnum is drowned out during flooding episodes, and fen vegetation returns. For the present, it is felt that more study, of both modern and fossil plant communities, is required for this part of the fen.

Overall, indicators of incipient acidification at Tre'r Gof are minimal, and will probably stay so as long as the peat surface stays in contact with the water table. As with Cors

Gyfelog, however, it is felt that the construction of a drainage channel has affected the modern vegetational pattern, and that water-level monitoring may be advantageous in drier areas of the mire.

At first sight, Cors Gyfelog and Tre'r Gof do not appear conducive to comparative study. They are hydromorphically different, one being in a valley and the other in a basin. One has supported terrestrial vegetation for most of its existence and the other for less than half. One receives mesotrophic water from two rivers and the other eutrophic water by catchment seepage, a minor channel and a spring. Yet both have been subject to human interference, one more noticeably than the other in the past, but both recently as a result of drainage activities. Parts of one, and possibly both, have been exploited for peat. Both are scheduled for conservation but in vegetational terms, they are classed separately. However, despite all the developmental differences which stratigraphical, pollen and chemical analyses have revealed, about 85% of the area of each mire bears vegetional communities which are also found on the other (Table 4), although in varying proportions. The major differences between them are that about 10% of the surface area of Tre'r Gof supports vegetation limited to calcareous mires, and about 20% of Cors Gyfelog is acidic, although often because of human interference.

In the first chapter, a question was raised relating to the desirability or otherwise of the vegetational communities which are likely to succeed the present ones. Without management, succession will occur and, unless major climatic events intervene, is likely to be towards carr or bog, or both in turn. The immediate question which the NCC have to consider is whether the development of carr and bog is desirable, both in general terms, and specifically in relation to these two mires. The answer from conservationists to the first part of the question would probably be in the affirmative, but not as the universal mire vegetation of the United Kingdom. Despite the overall loss of wetlands, there is still great variety in Britain, representing a series of responses to a multitude of influential factors. As stated above, there are many similarities between present-day vegetation at Cors Gyfelog and Tre'r Gof, but also many differences, and each mire contains a mosaic of communities. If either suffered large-scale Sphagnum invasion then its vegetation would probably become more uniform, as it would under total carr cover. Confining carr is a relatively straightforward matter, although carr can itself succeed to bog. Both Walker (1970) and Tansley (1939) envisage bog as the climax vegetation in British mires. In this corner of north west Wales, geology and glacial influence have been particularly favourable to the avoidance of bog formation. Consequently, long-term management to maintain mesotrophic and eutrophic wetlands in this part of the United Kingdom would appear to be particularly important.

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