PALAEOECOLOGICAL STUDIES OF SELECTED MIRES IN THE CRAVEN DISTRICT OF WEST YORKSHIRE WITH SPECIAL REFERENCE TO THE LATE DEVENSIAN PERIOD AND THE *ULMUS* DECLINE

Submitted in accordance with the requirements for
the degree of Doctor of Philosophy

by

Emel Oybak

Department of Pure and Applied Biology
The University of Leeds

March 1993

PALAEOECOLOGICAL STUDIES OF SELECTED MIRES IN THE CRAVEN DISTRICT OF WEST YORKSHIRE WITH SPECIAL REFERENCE TO THE LATE DEVENSIAN PERIOD AND THE *ULMUS* DECLINE

Submitted in accordance with the requirements for
the degree of Doctor of Philosophy

by

Emel Oybak

Department of Pure and Applied Biology
The University of Leeds

March 1993

CONTENTS

Summary

(1) Percentage and absolute pollen diagrams are presented for a lowland site, Sniddle Moss, and two upland sites, Thieves' Moss and Sunset Hole, in the Ingleborough Region, the Craven District, north-west Yorkshire.

(2) The analysis of the earliest sediments of Sniddle Moss and Thieves' Moss suggests the existence of a Lateglacial sequence. A reconstruction of the regional vegetational succession mainly based on the Sniddle Moss 4 data reveals that at first a very open vegetation and a species-rich calcareous grassland were formed. The spread of juniper scrub preceded the expansion of tree birches. It is tentatively inferred that the early part of the Lateglacial is interrupted by a phase of deteriorating climate and that the relative warmth of the Lateglacial Interstadial gives way to a further and more prolonged deterioration. The climatic deterioration of the Younger Dryas Period is clearly registered by the decline of thermophilous taxa and the local severity of conditions demonstrated by the increased abundance of chianophilous taxa and other montane herbs in the profile of both Sniddle Moss (4) and Thieves' Moss (2).

(3) The ensuing amelioration in climate at the beginning of the Flandrian (early and middle) is traced.

(4) It is suggested that the woodland vegetation was being managed by the local Mesolithic and early Neolithic population prior to the first classical elm decline of the Atlantic/Sub-Boreal transition (c. 5000 BP).

(5) Pollen analysis involving continuous sampling across the elm decline at Sniddle Moss (9) and Sunset Hole permitted a detailed reconstruction of the vegetational changes and the observation of the nature of the elm curve. A chronology for Sniddle Moss (9) is provided by radiocarbon dating. The initial recovery of elms is dated to 4710±45 BP and the second elm decline to about 4520 BP. The possible factors contributing to the first classical elm decline and the changes in the elm curve immediately following the first decline are considered.

Figures Page

Plates

Tables

Tables and diagrams enclosed in pocket

Acknowledgments

I am indebted to Dr D. D. Bartley, who is the supervisor of this study, for his sustained interest, advice and unlimited patience, and for his untiring help in field work.

My thanks are due to Mr Paul Field for his invaluable assistance in the field and in running the "Tilia Software Package"; to Professor C. D. Pigott and M. E. Pigott for bringing the Sniddle Moss site to my attention and access to the preliminary lihtological and pollen analytical data; to Mr Tom Blockeel and Dr J. H. Dickson for their help in identifying the mosses from Sniddle Moss; to Mr Albert Henderson for his encouragement during the study of the fossil oospores of Characeae from the study sites; to J. A. Moore and D. M. John of the British Museum (Natural History) for useful discussions and giving of their advice concerning Characeae oospores; to Mr Adrian Hick for his invaluable assistance in the SEM; to Cem Saraç who drew Figure 5.2.1.; to the Natural Environment Research Council, Dr D. D. Harkness for the determination of the radiocarbon ages; to Mr Peter Haw who allowed access to his land (Crummack Farm); to my parents and friends for their psychological support throughout, and to the University of Hacettepe (Ankara, Turkey) for its sponsorship.

INGLEBOROUGH

1. INTRODUCTION

The Ingleborough Region, in which the study areas lie, forms the western margin of the Craven District (Figure 1.1.). It displays strongly contrasting scenery with a wide variety of geological formations and structures due to the various geological events, which have shaped the landscape over the years. The area to the north-east dominated by the peaks of Whernside (NGR SD 7381), Pen-y-ghent (NGR SD 8373), and Ingleborough (NGR SD 7474) shows an abundant limestone cliff scenery. The limestone country is cut off abruptly by the dislocation of the Craven Faults running north-west to south-east. South of the faults lies the western part of the Craven Lowlands which is mainly undulating pastoral country shrouded in thick glacial deposits, with the very minimum of rock features.

The sites selected for this study, with the exception of Sniddle Moss, lie on the Ingleborough Massif within the limestone upland. The Ingleborough Massif is situated in the Yorkshire Dales National Park (NGR SD 77). It spreads over an area of about 65 km^2. Above the plateau, Ingleborough hill rises to 723 m (MSL), extending south-west and overlooking the lowlands - e.g. Sniddle Moss - on Newby Moor near Clapham in the south of the Ingleborough Region (Plate 1.1.).

Previous palaeobotanical investigations undertaken in Upland Craven (Pigott & Pigott, 1959 and 1963), in the lowlands (Jones, 1977; Bartley et al., 1990) and on the Ingleborough Massif (Gosden, 1965; Swales, 1987) have provided data relating to the vegetational history of parts of the Craven District, which has encompassed mainly Flandrian events. It is particularly noticeable in most of the diagrams from the region that there is a lack of clear lithological evidence for deposits of Devensian

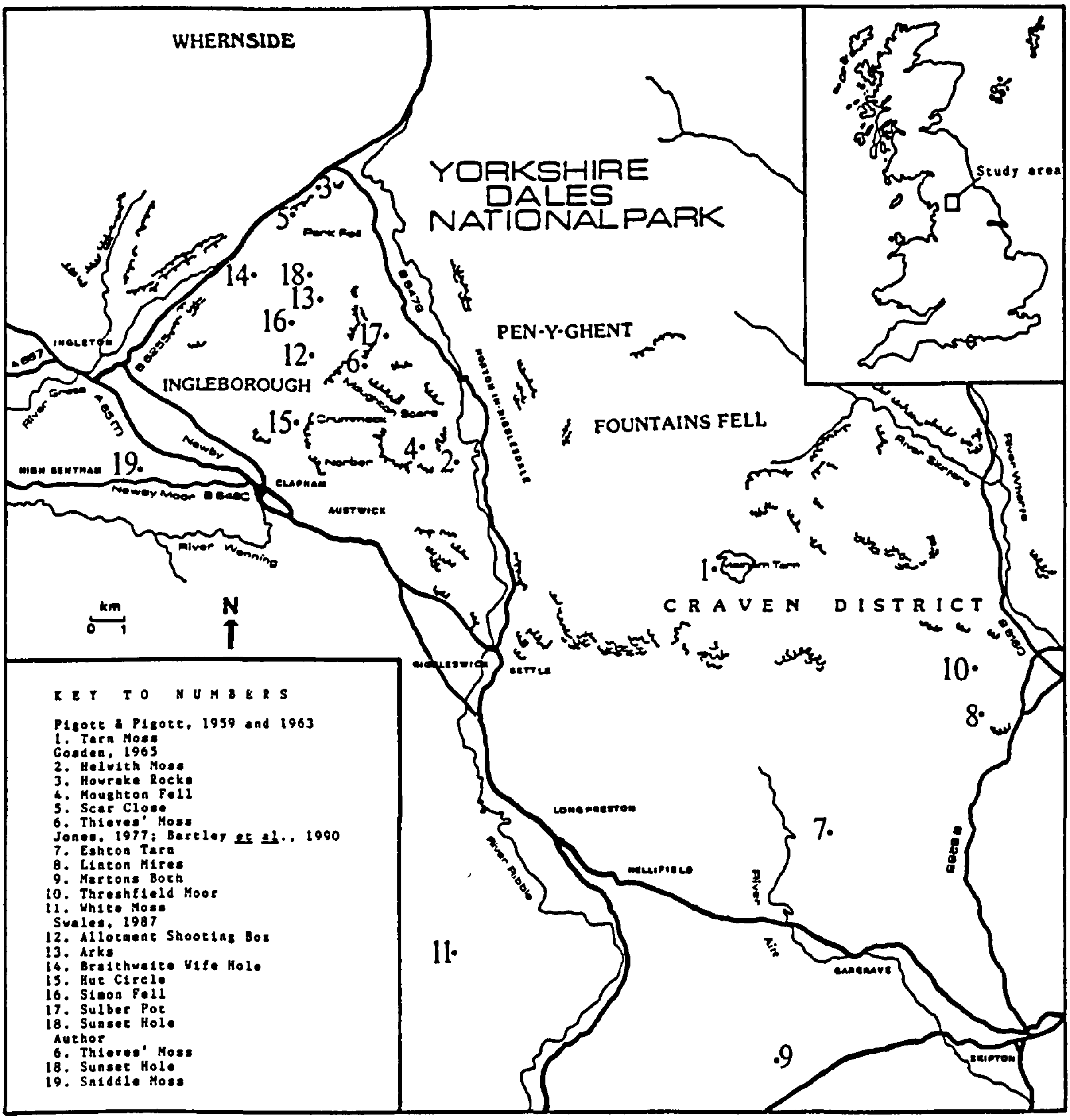


Figure 1.1. Map of the Craven District showing the location of the study sites.

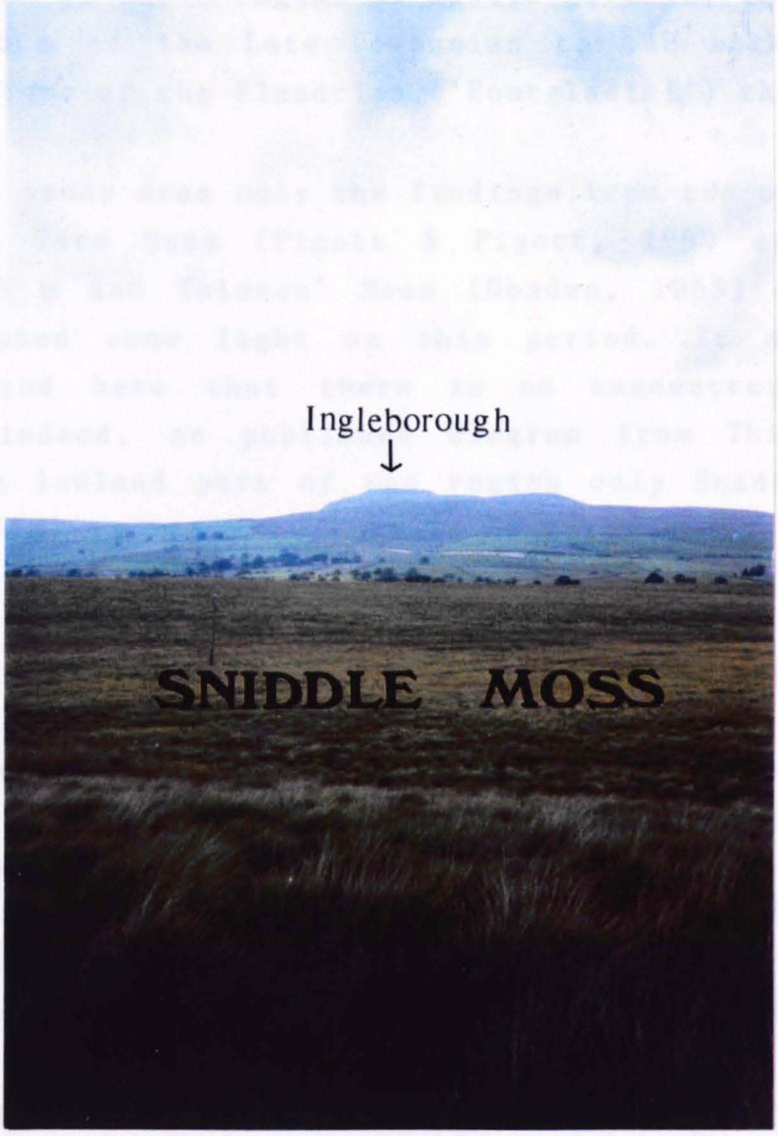


Plate 1.1. Ingleborough overlooking SNIDDLE MOSS, viewed from the south.

Lateglacial age (usually abbreviated to 'Lateglacial').

In spite of its brief duration (from c. 13,000 to 10,000 BP) the Lateglacial was an important transitional period from the climatic regime of arctic severity that prevailed for much of the Late Devensian to the markedly warmer conditions of the Flandrian ('Postglacial') that followed.

In the study area only the findings from two upland sites, Malham Tarn Moss (Pigott & Pigott, 1959 and 1963) at c. 400 m and Thieves' Moss (Gosden, 1965) at c. 348 m have shed some light on this period. It must however be noted here that there is no concentration diagram and, indeed, no published diagram from Thieves' Moss. In the lowland part of the region only Sniddle Moss (at c. 160 m) is known to contain deposits of the Lateglacial Period. The data from a large number of Lateglacial sites collectively suggest local differentiation in Lateglacial vegetation patterns due to variations in plant response to climatic change at different altitudes, and also to such microscale factors as edaphic conditions, exposure, aspect and so on (Pennington, 1977). One of the main aims of this study is therefore to look at Lateglacial deposits of a valley bog at low altitude, Sniddle Moss in an area of glacial drift and a raised bog, Thieves' Moss on limestone at high altitude (c. 8 km from Sniddle Moss):

(a) in order to provide some complementary and comparative data for the region and

(b) to assess basically how short-lived climatic fluctuations and environmental changes of this interesting period (the Lateglacial) shaped the vegetation succession of the Ingleborough Region.

The other aim is to look at Ulmus (elm) decline. Recent changes in elm populations brought about by Dutch Elm Disease have raised questions about the nature of the Neolithic Elm Decline, particularly its possible association with human interference in the forest. It was therefore decided to study the elm decline in detail through close contiguous samples and radiocarbon dating - again at low altitude and at higher altitude sites.

Because the elm decline is too close to the eroded surface of 'Thieves' Moss, one other upland site on the Ingleborough Massif, Sunset Hole at 393 m has been selected. The sediments containing the desired periods of this site and Sniddle Moss have been examined in detail for this purpose.

2. THE PHYSICAL BACKGROUND

2.1. Geology

The geology of the Ingleborough Region constitutes a very small part of a very complicated picture. Over most of the area the rocks showing great contrasts are very nearly horizontal and the significant breaks in the landform pattern are produced by major faults. The Carboniferous Limestone dominates the Region, along with Millstone Grit, and with some Coal Measures (Figure 2.1.1.).

The account of the geology of the area can be given in three main sections, in time sequence, dealing with the contribution of pre-glacial, glacial and post-glacial periods to the present landscape.

2.1.1. The Pre-glacial Period

The main structural elements belonging to the Pre-Glacial Period are the Askrigg Block lying to the north and the Bowland Block which occupies much of the southern part of the Ingleborough Region. The South Craven Fault is usually taken as a boundary between these two blocks which constituted two entirely different depositional environments during the Carboniferous Period.

As defined in Figure 2.1.1. the Ingleton Group sediments (sandstones, siltstones and conglomorates) are the oldest rocks which were folded in pre-Ashgill times associated with tectonism (early Arenig Age). The deformed Group forms part of a belt of magnetic basement rocks, the Furness-Ingleborough-Norfolk Ridge (Wills, 1978). In the Ingleborough Region it can be seen in two localities in the north of the North Craven Fault - the Chapel-le-Dale inlier, near Ingleton and the Horton-in-Ribblesdale inlier on the east, though there is no exposure

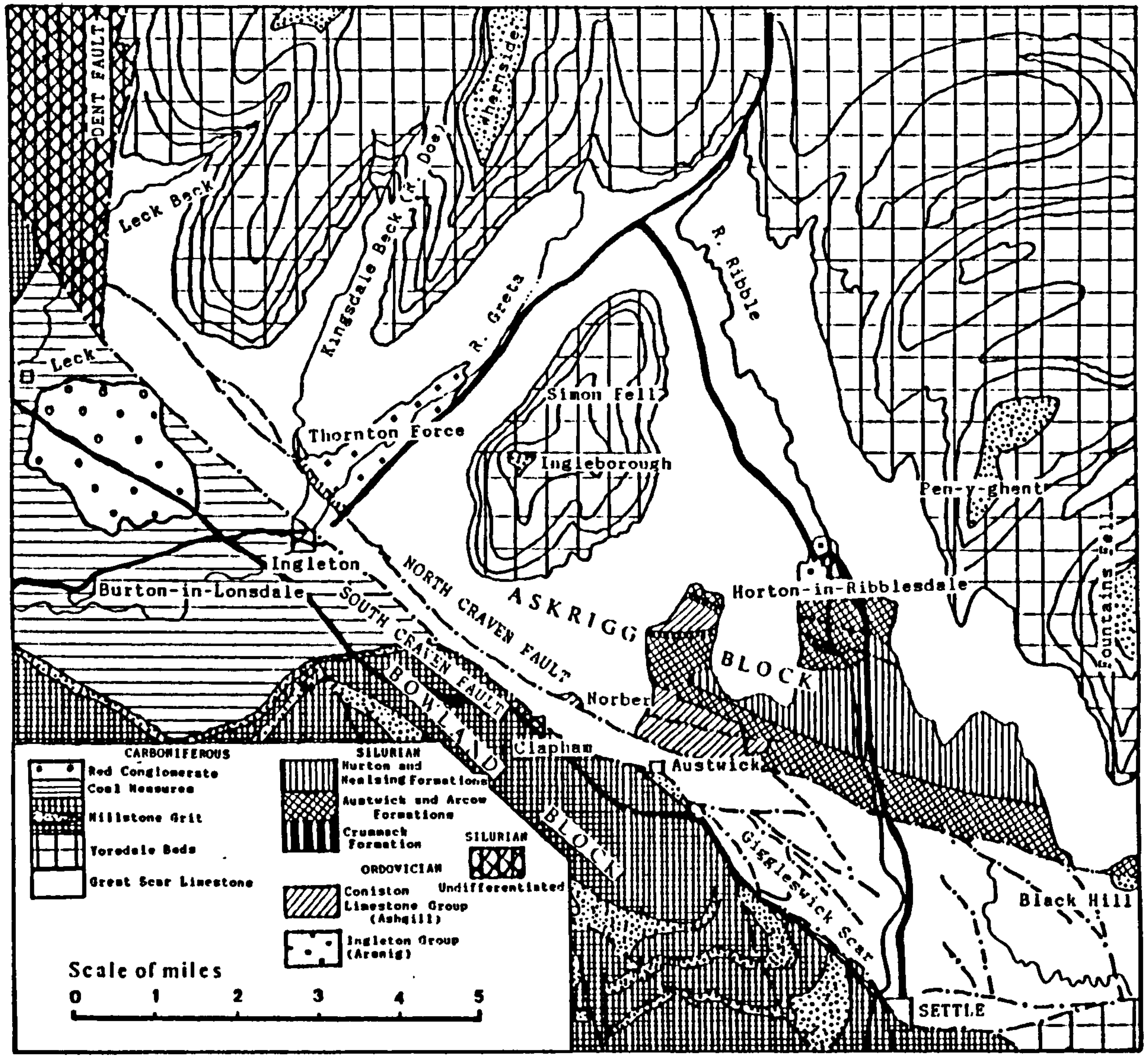


Figure 2.1.1. Geological sketch map of the district around Ingleborough (modified from Dunham *et al*., 1953).

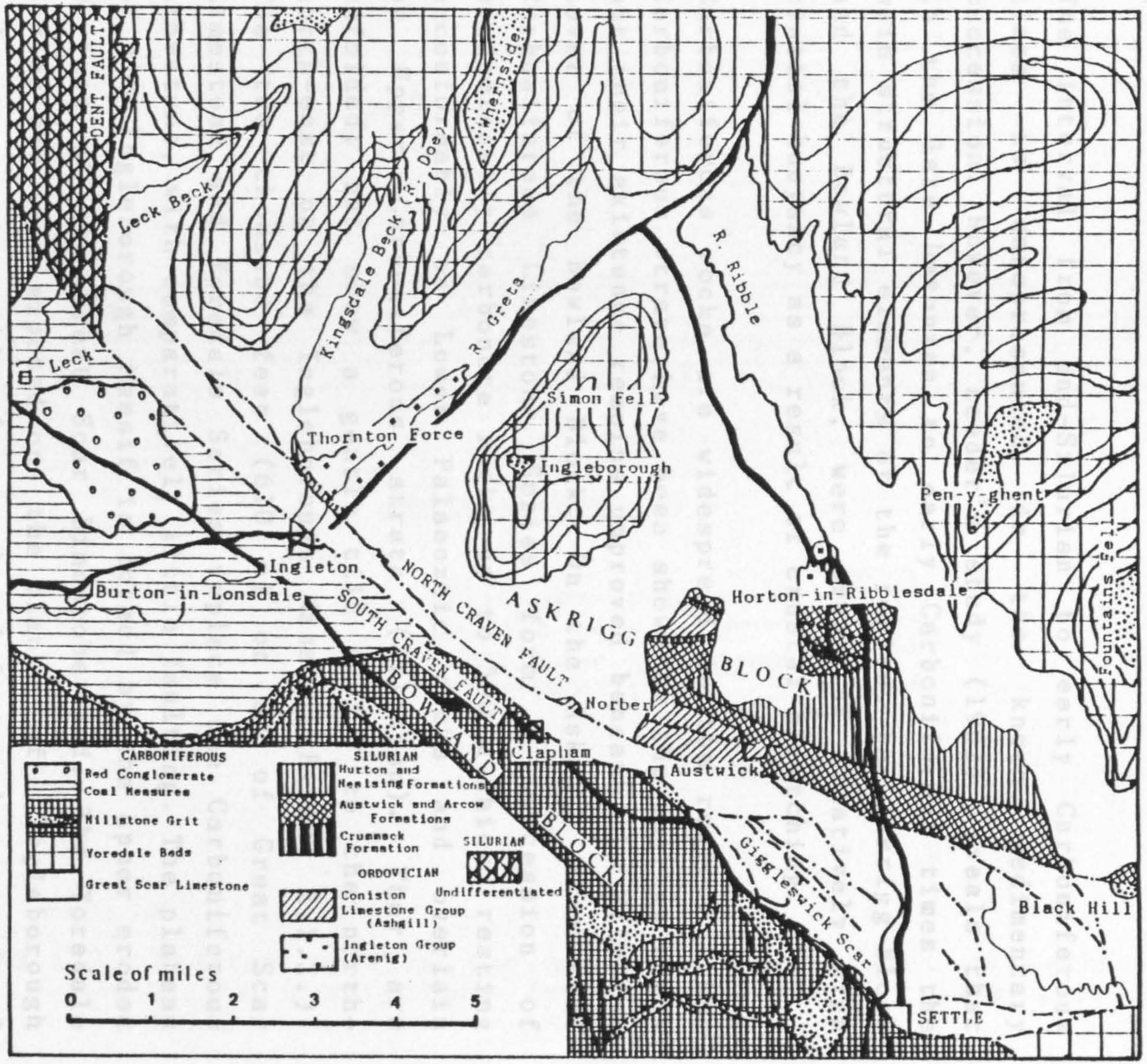


Figure 2.1.1. Geological sketch map of the district around Ingleborough (modified from Dunham et al., 1953).

known within the study area.

The Ingleton Group is overlain by Lower Palaeozoic strata. Both Ordovician and Silurian rocks are found and crop out in a series of inliers (the Craven Inliers), along its southern margin. The Silurian formations, particularly, cover considerable areas - mainly Silurian grit and sandstones.

The interval from end-Silurian to early Carboniferous times is unrepresented in the known sedimentary succession. However, Leeder's study (1982) reveals that in the late Devonian to early Carboniferous times the main structural elements of the region, the Askrigg Block and the Bowland Block, were areas of relatively high crustal buoyancy as a result of crustal stretching.

Carboniferous rocks are widespread in the region. Lower Carboniferous strata have been shown on the Askrigg Block but their existence remains unproved beneath the Silesian cover of the Bowland Block. On the Askrigg Block the Carboniferous Limestone Series form a succession of predominantly carbonate rocks up to 500 m thick, resting unconformably on Lower Palaeozoic rocks and overlain by Upper Carboniferous strata (Silesian). They are unfolded; but show a gentle tilt ($3-5^{o}$) to the north-north-east on the Ingleborough Massif (Figure 2.1.2.). The two thousand feet (610 m) or so of Great Scar Limestone and Yoredale Series replace the Carboniferous Limestone, with comparatively little faulting. The plateau of the Ingleborough Massif is formed by the upper eroded surface of the Great Scar Limestone bed. The Yoredale Series are well exposed on the flanks of Ingleborough and are responsible for a broad-featured country of step-topography in the north of the region.

The main outcrops of Upper Carboniferous strata are mainly Millstone Grit Series and some Coal Measures on the Bowland Block. On the Ingleborough Massif lying on the

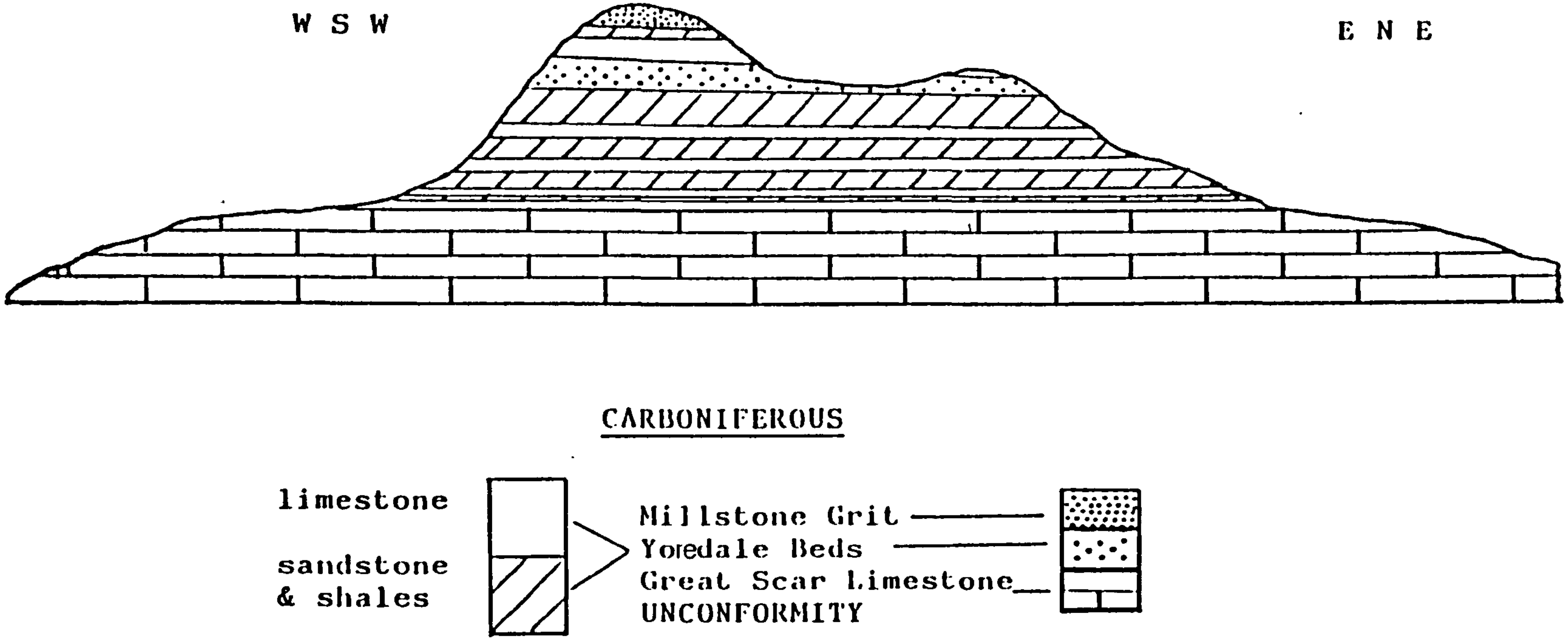


Figure 2.1.2. Diagram showing the geological succession of Carboniferous strata forming the Ingleborough Massif (taken from Swales, 1987).

Askrigg Block, Millstone Grit Series form a small outlier which caps the Yoredale Beds of Ingleborough. The Westphalian strata dominate the western end of the region.

There is no direct evidence about the geological history of the area during Mesozoic and Tertiary times. If the formations of Mesozoic Period ever occurred they have been removed by denudation and during the Tertiary Period the region seems to have experienced prolonged erosion. The summit of Ingleborough and surrounding hills represent an ancient erosion surface at 610 m. The Glacial and Recent deposits are thus the only records of deposition within the area since the Permo-Triassic Period.

2.1.2. The Glacial Period

Pleistocene deposits show that the Ingleborough Region was occupied by ice-sheets on several occasions during the Quaternary but only the effects of the Last Glaciation can be recognised in the area. Pre-Devensian deposits seem to be very limited in extent, since the last glaciation destroyed almost all records of earlier Pleistocene events and their deposits. In Victoria Cave near Settle the Ipswichian interglacial sediments containing mammalian faunas dated at about 114,000 to 135,000 BP are the only older deposits known in the area (Arthurton *et al*., 1988).

Ice entered the area from the north and modified the local landscapes considerably. Its deposits ('drift') cover much of the area, and they take several forms, of which the chief is the general irregular blanket of boulder clay (till), erratics and drumlins.

Almost everywhere the deposits of boulder clay consist of unstratified clay soil mixed with boulders and pebbles of different sizes. Much of the debris is of local composition derived largely from Carboniferous limestones and sandstones with some Lower Palaeozoic clasts from the Craven Inliers. It is spread generally over the region but thickest in the lowlands where it may be more than 20 m thick. It is however patchy over much of the uplands and absent above about 490 m O.D. The broad swathes of head above this height suggest that the upward limit of the boulder clay approximates to the margin of the ice-sheet against the Pennine flanks (Arthurton et al., 1988).

A sheet of boulder clay, which is commonly more than 10 m thick, occupies much of the River Wenning catchment area on Newby Moor in the south-west of the region. This sheet thins out against the limestone escarpment of Clapham and Austwick.

Boulders which were brought from a distance and carried in or on the ice are called **erratics**. These blocks of limestone and sandstone are common on some of the Ingleborough platforms (e.g. Clapham Moor). On the west side of Crummack Dale, north of Austwick, nearly all the large erratic boulders of green slates and grits (Norber erratics; Kendal & Wroot, 1924) carried by the ice out of Crummackdale and Ribblesdale are now found on a limestone pedestal of about ten inches in height. This is a measure of the amount of limestone removed since the retreat of the ice, by the solvent action of the rain (Raistrick & Illingworth, 1959). This subaerial dissolution of limestone is, in fact, an important erosive process in Postglacial times.

The drumlins are stream lined low hills with an oval outline deposited beneath moving ice. They are formed mainly of till, although some contain lenses of gravel or a rock core. The remarkable drumlin fields occupy chiefly the lowlands of the region, and they trend generally N-S (Figure 2.1.3.). The direction of their long axis reflects local direction of glacier movement. Their orientation (Figure 2.1.4.) mapped by Raistrick

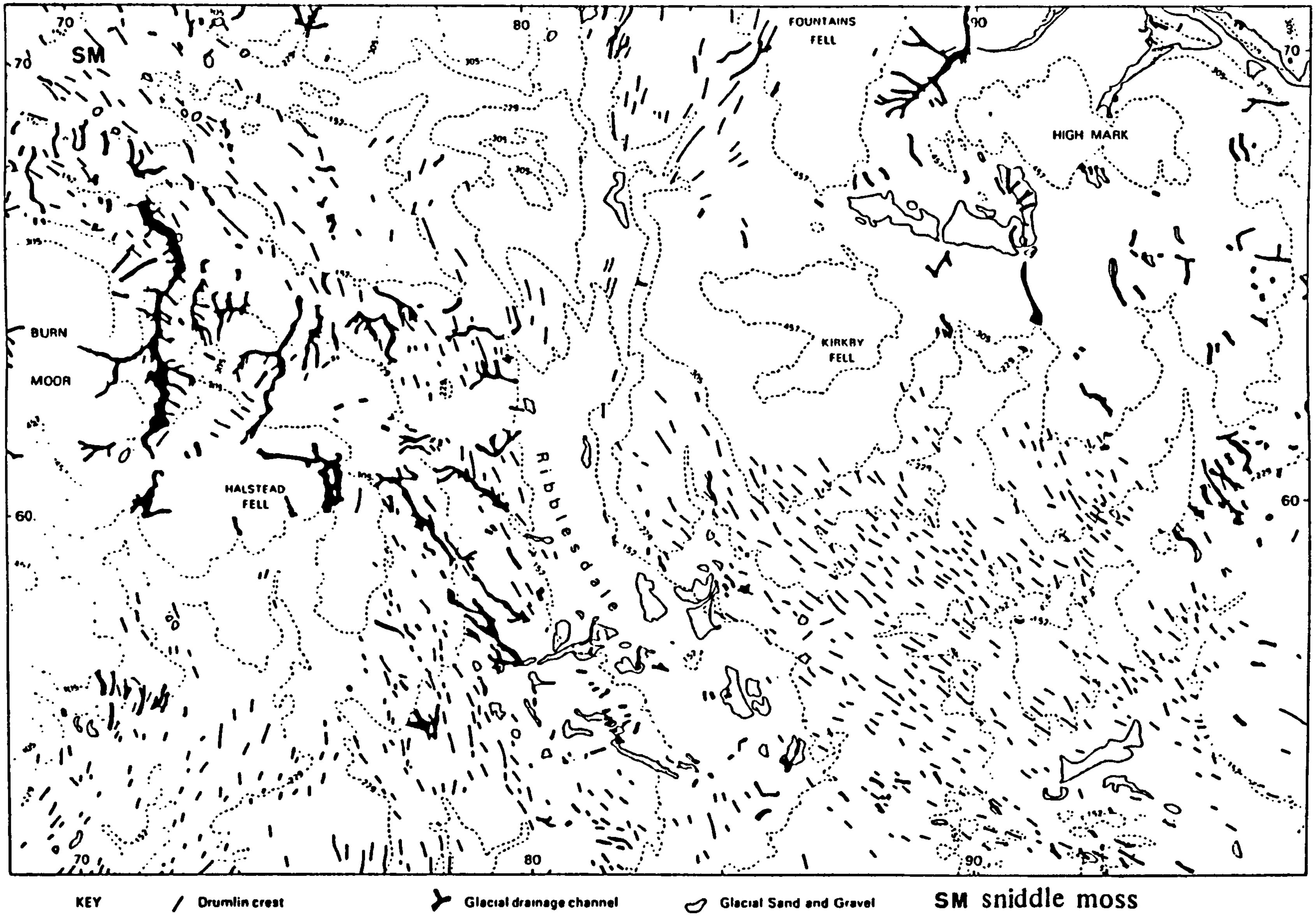


Figure 2.1.3. Glacial features of the Settle District (Source: Arthurton et al., 1988).

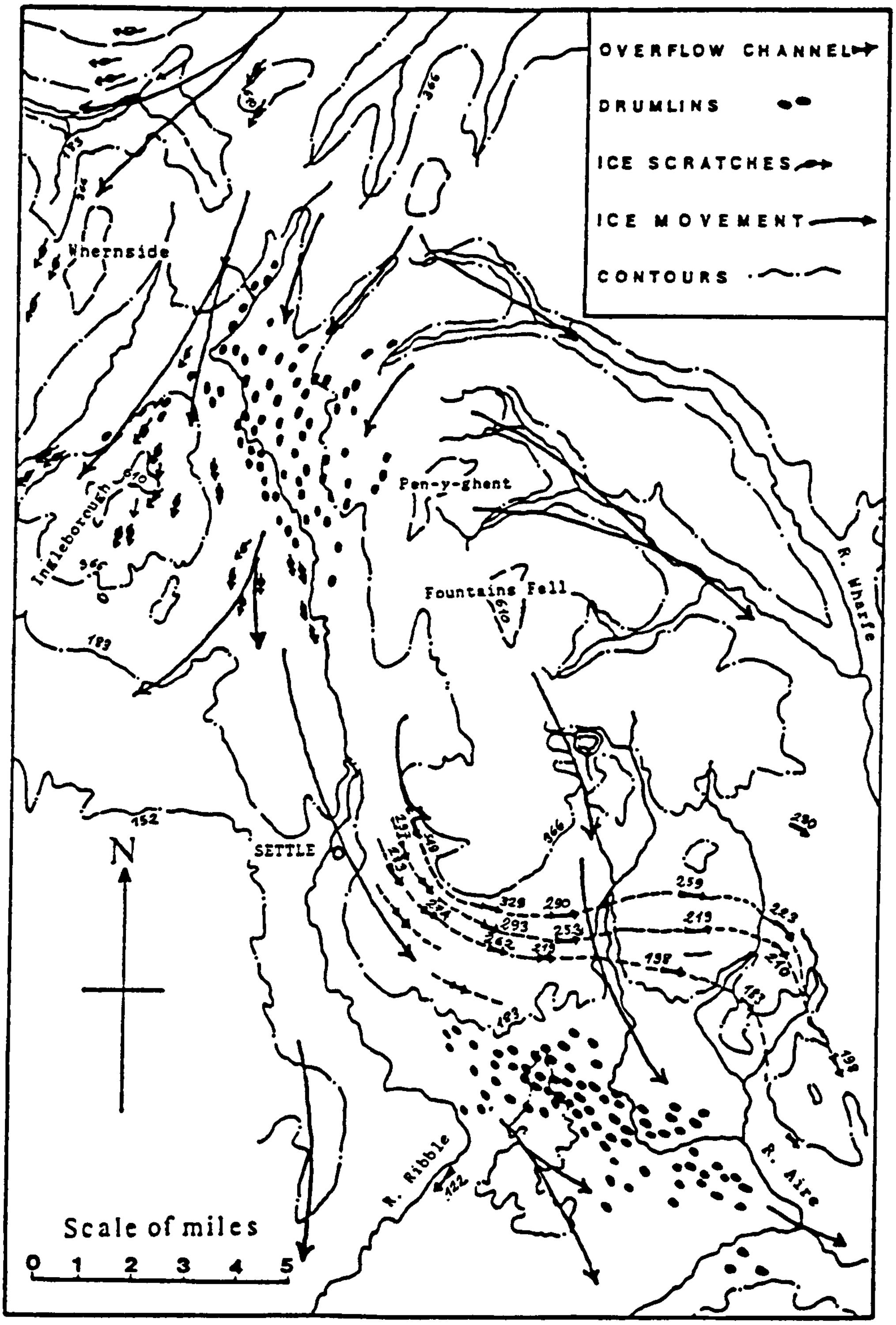


Figure 2.1.4. Drumlins in the Ribble-Aire Valleys (Source: Raistrick, 1930).

(1930) suggests that ice funnelled into the region from the north and north-west and then moved down in a southerly direction.

Landforms of glacial erosion are less apparent in the Ingleborough Region. The solid rocks on the flanks of some of the drumlins however seem to have been shaped by moving ice.

The withdrawal of glacier-ice at about 13,000 BP was followed by a gradual climatic amelioration towards the close of the Devensian, and periglacial conditions prevailed with widespread fluvial activity and solifluction. Meltwater from the decaying ice-sheet collected in subglacial streams and these incised channels, extending over several kilometres, in the underlying boulder clay and bedrock. Examples of glacial drainage channels, which generally trend subparallel to the direction of ice-movement are seen near Burn Moor south of the River Wenning (Figure 2.1.3.). Their floors are mainly covered by peat; but there are also channels modified either by the deposition of alluvium or glacial gravel or by erosion. Sand and gravel deposits are associated with the channel systems and their landforms are eskers and kames which consist largely of sand with a veneer of clayey sand and gravel or stony clay. Mounds of sand and gravel (NGR SD 728700) lie to the north-east of Newby. Three kame-like mounds (NGR SD 706688; 710685 and 710684) are found on Newby Moor.

Deposits of head formed by solifluction under periglacial conditions are common in the upland limestone outcrops, whereas aprons of scree are present below the limestone scars and cliff, for example those in the valley of Clapham Beck (NGR SD 763697), north of Austwick.

2.1.3. The Postglacial Period and the Present Landscape

In the Ingleborough Region the short record of Postglacial time may be found in some deposits such as peats, alluvium and calcareous tufa.

A blanket of peat resting on head or boulder clay occurs on the gentler slopes and plateaux of the Ingleborough Massif. On low ground peat is also present in poorly drained hollows and mosses as at Sniddle Moss (NGR SD 707695).

In the catchment of the River Wenning south of Clapham the alluvium forming the present-day flood plain is the most extensive of the post-glacial deposits within the drumlin fields. In some areas peat is associated with the alluvium as at Austwick Moss (NGR SD 761666).

It is largely believed that much of the characteristic limestone pavement of Craven was developed in the post-glacial period.

2.2. Climate

There is no meteorological station within the study area, but meteorological data have been produced by Manley (1957) and Lockwood (1967) for several places in the Craven District. Their results reveal that climatic variables change with increasing altitude in the region.

Manley (1957) described the climate of the uplands around Malham Tarn at 395 m as windy, humid and cloudy. As can be seen from Table 2.2.1. the uplands are cooler than the lowlands throughout the year.

On the main limestone plateau the mean annual temperature range is 11.6°C, being 2.3°C lower than that for the lowlands. There are, however, temperature inversions in West Yorkshire. The minimum night temperatures of the lowlands are often as low, or lower than, the Craven Uplands.

Air frost in Upland Craven could be expected on about 90 days a year, whereas in the lowlands this is 70 days of the year.

Winds are predominantly westerly and south-westerly. Average windspeed for the uplands around Malham Tarn which is 16 km from the Ingleborough Massif is 1.5 times higher than that for Lowland Craven. According to Manley (1957) under such conditions local shelter in the area assumes a greater importance for the vegetation.

The effect of altitude can also be seen in differences in precipitation. The rainfall is more pronounced in Upland Craven than in the lowlands, being at a minimum in April-June (Figure 2.2.1. and Table 2.2.2.).

Table 2.2.1. Daily mean temperatures around Malham Tarn (taken from Jones, 1977).

		JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Yearly mean
Daily mean temp.	Malham	1.5	1.7	3.4	5.4	8.4	11.6	13.5	13.1	10.8	7.6	4.1	2.2	(1921-50) 7°C
	Lowlands	4	4	6	8	11	14	16	16	13	10	6	4	(1916-50) 9.3°C
Mean daily max. temp.	Malham	3.7	3.8	6.5	9.4	13	15.3	17.2	16.5	12.9	10	6.3	4.2	10.1°C
	Lowlands	7	7	9	12	16	19	21	20	17	13	9	7	13°C
Mean daily min. temp.	Malham	-0.7	-0.5	0.3	2.1	4.4	7.4	9.8	9.6	7.6	5.1	1.9	0.2	3.9°C
	Lowlands	2	1	2	3	7	10	12	11	9	7	3	2	5.8°C

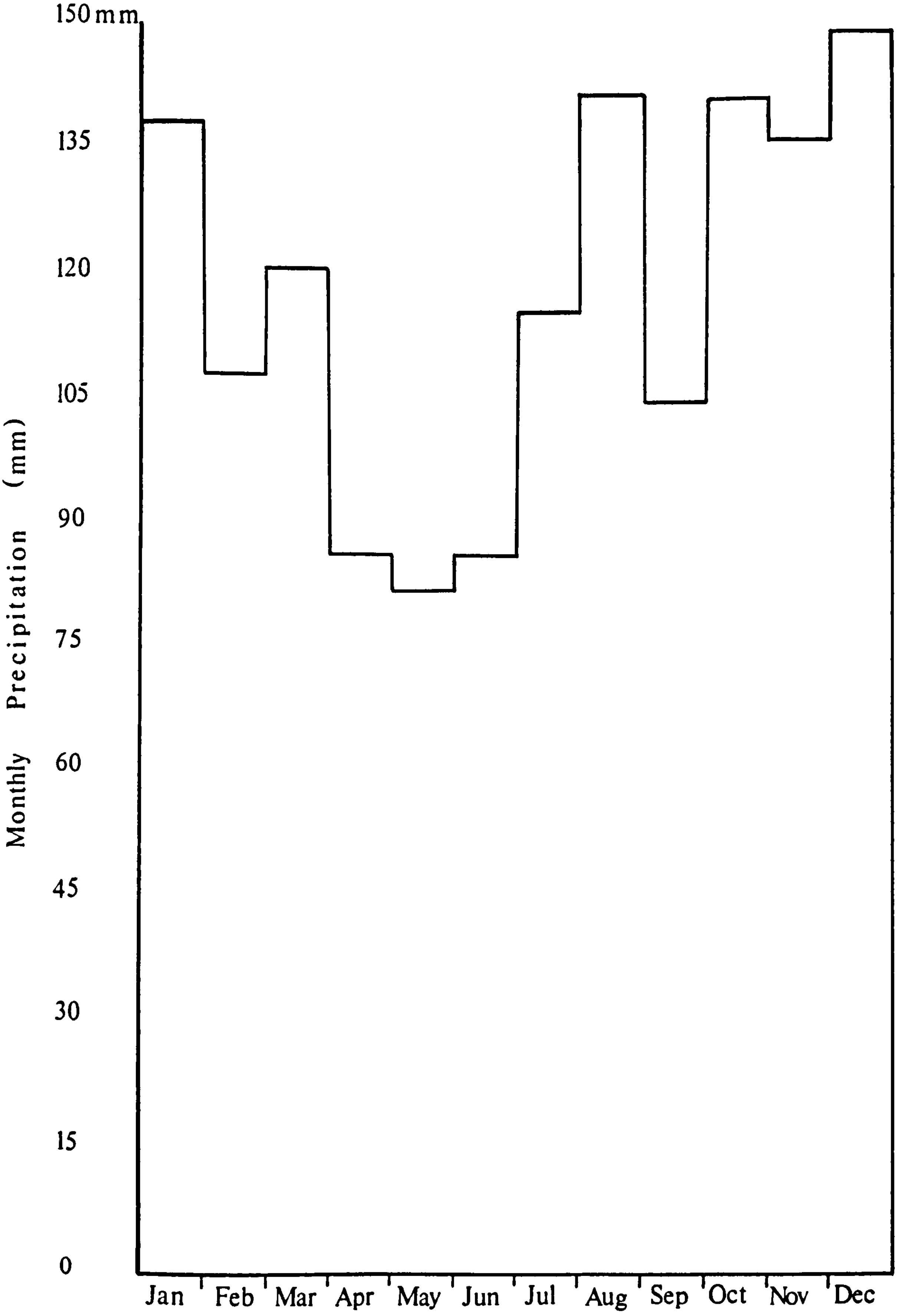


Figure 2.2.1. Mean Monthly Precipitation, Malham (1881-1915) (taken from Jones, 1977).

Table 2.2.2. Average annual precipitation for the Craven area (after Gosden, 1965).

STATION	NGR	ALTITUDE	ANNUAL PRECIPITATION
Malham Tarn	SD 893672	395	1.53 m
Ribblehead	SD 766789	312	2.00 m
Settle (Great Bridge)	SD 702589	252	1.85 m

The average annual rainfall on the limestone uplands falls in measurable amounts on 220 days. In Lowland Craven it shows a considerable decrease from west to east (Table 2.2.3.): - (after Jones, 1977)

Slaidburn	SE 715549	192	1.57 m
Threshfield	SD 995638	180	1.23 m
Gargrave	SE 939549	140	1.15 m
Skipton (Town Hall)	SE 991518	112	0.89 m

The areas in the extreme west and at high altitudes therefore could be more liable to intense soil leaching and less potential evaporation.

Atmospheric pollution is a further climatic factor in Craven. Bullock (1971) points out the effect of such pollution and says that it lowers the pH of rain and increases weathering potential.

2.3. Soil

Crompton (1961) in a general account of the soils of Yorkshire includes the soils of the Craven District in two basic types, mountain limestone soils and moorland soils. More detailed descriptions of soils in the Malham Tarn area were made by Barratt (1960), Wood (1963), Syers (1964) and Bullock (1964 and 1971). Bullock (1971) also gave information relevant to a further 300 km^2 of the Craven District.

The soils of the Ingleborough Region are mainly developed in drift derived from the underlying rocks (local Silurian shales, Carboniferous Limestone, Yoredale sandstones, shales and limestones and Millstone Grit), and only thin soils on Millstone Grit, and on scree slopes on limestone are likely to be residual.

Soil types play an important part in determining the scenery of the Region. The Great Scar Limestone, which outcrops over so wide an area to the north and the Millstone Grit of the south have each given rise to a distinctive soil range.

The major soil groups of the Ingleborough Massif are rendzinas (calcareous soils), brown earths, podzolized soils, gley soils and organic soils. Transitional forms also occur, such as brown rendzinas and eutrophic brown earths which are intermediate between rendzinas and mesotrophic brown earths. The distribution of the various soil types in the area is very complex due to variations in depth and nature of the drift, slope and aspect, though their morphological grouping is clear. In general, rendzinas and brown earths are found in thin drift, over pavement clints or on stable limestone screes and ledges, all of which receive bases from above compensating for those lost by leaching. Podzolized soils and gley soils are the most widespread in areas of thick drift where acid peat surfaces are waterlogged. Even on shallow soils over limestone there may be extensive acidification of the surface because the high precipitation/ evapotranspiration ratio ensures intense leaching, with lost material not replenished by weathering.

From the slopes of the Ingleborough Massif to the valleys of Newby Moor on the Millstone Grit the drift becomes deeper and heavier. Thick deposits of clay and clay loam are common here. Most is poorly drained and strongly acid with a variable thickness of peat.

At all sites under investigation the main soil types largely belong to the acid members of the groups - peat and peaty gleyed podzols, except at Thieves' Moss which is surrounded by limestone pavements and grassland on the rendzina soils.

2.4. Vegetation

No complete study of the vegetation of the Ingleborough Region has been made but a very general account has been given by Raistrick and Illingworth (1959), and a detailed vegetation survey of the Ingleborough Massif has been carried out by Bartley and Clark (1979).

A strong contrast between the limestone platform and the Millstone Grit, which are brought into a sharp juxtaposition by the faults of Craven, can also be seen in the plant life. The limestone supports a very large number of plants associated with a whole complex of soils. The richness of the flora distinguishes the scenery of the limestone platform from that of the neighbouring Millstone Grit. Conversely, the latter favours the complete dominance of a limited number of species forming the moorland associations.

THE LIMESTONE PLATFORM

On the limestone trees are rare but they form small patches on some pavements. This is attributed to the destruction of the former forest cover by man, leaving woodlands only in certain places, e.g. those in Colt Park Wood (NGR SD 775775). Fraxinus excelsior is the most dominant tree, associated with other trees and shrubs such as Sorbus aucuparia and Prunus padus. Larch has been introduced in considerable numbers. There is a rare type of natural juniper scrub on Moughton (NGR SD 790710), Ingleborough.

The greater part of the limestone is covered by grassland. Festuca ovina and other small herbs - Helianthemum and Thymus drucei become predominant due to intensive grazing, mainly by sheep. Galium sterneri and Carex caryophyllea are also characteristic species of the grassland.

The pavements of the Ingleborough Massif bear a rich assemblage of species. Upon the soil-less surface of clints only crustose lichens and mosses grow. Within the shaded and sheltered fissures having a good soil development there are, however, quite a number of species. In the deeper grykes characteristic plants of limestone woods may be found - *Actaea spicata*, *Allium ursinum* *Phyllitis scolopendrium*, *Asplenium* spp., *Mercurialis perennis*, *Polystichium aculeatum* and *Sanicula europaeus*. Shallow grykes support *Sesleria albicans*, *Convallaria majalis*, *Trollius europaeus*, *Geranium sanguineum* and *G. lucidum*.

Much of the lower slopes of Ingleborough, Pen-y-ghent and Whernside are masked by a blanket of non-calcareous glacial drift. Over considerable areas the typical limestone vegetation is interrupted by the occurrence of plants characteristic of the acid moorlands. This is particularly noticeable on Ingleborough. On the deep drift soils the main cover-formers are *Nardus stricta*, *Juncus squarrosus*, *Molinia caerulea* and *Polytrichum commune*. On the wetter parts *Nardus stricta* and *Juncus squarrosus* communities are replaced by *Molinia* grassland. In drier and shallower areas *Calluna vulgaris* and *Empetrum nigrum*-dominated heaths may be found, but heaths are not common on Ingleborough. *Calluna* along with *Eriophorum angustifolium* tend to be removed by grazing.

Blanket bog communities also occur on the higher slopes of Ingleborough. Deep peat deposits are particularly dominated by *Eriophorum* communities.

On the summits of the hills of the Ingleborough Region a few species of the Lateglacial flora may be found. For example, on Ingleberough and Pen-y-ghent *Saxifraga oppositifolia* has survived. Again, on Ingleborough *Poa alpina*, *Saxifraga aizoides* and *Draba incana* grow.

THE MILLSTONE GRIT

As mentioned already, a journey down to the Millstone Grit would show the poverty of the moorland flora and the dominance established by the more successful species where there exists a covering of glacial drift of non-calcareous origin.

Calluna vulgaris occurs as a dominant species of the heath on flat or gently sloping ground. The members of the associated flora, such as *Erica cinerea*, *Ulex gallii*, *Vaccinium myrtillus* and *V. vitis-idaea* form extensive patches.

Relatively steeper slopes are covered by a *Nardus* grassland with *Deschampsia flexuosa* and *Festuca ovina* and many of the moorland plants. In the flatter and wetter areas *Nardus* grassland gives way to *Molinia caerulea*-dominated grassland, often on a peaty substrate.

On deep peat with thick textured glacial drift the heath and grassland communities grade into the characteristic cotton-grass moors of the Millstone Grit, known locally as mosses - *Eriophorum vaginatum* and the associated flora, *Eriophorum angustifolium*, *Erica tetralix*, *Drosera rotundifolia* and *Sphagnum* may be found on the wetter ground, *Calluna*, *Empetrum nigrum* and *Vaccinium myrtillus* on the drier ground.

The pattern of vegetation types in the whole region is controlled by soil and climate but this pattern almost entirely represents secondary communities. It is obvious that man's influence has to a large extent overridden that of climate and soil. Deterioration of soils, caused by forest clearance over a long period, together with different grazing regimes would account for the present distribution of the heath and grassland types.

3. THE HISTORICAL BACKGROUND

The Archaeology of the Ingleborough Region

During the cold phases of the glacial period at least the North of England would have been an unattractive place for Palaeolithic man. After the retreat of the ice-sheet in the Lateglacial Period there is, however, the first evidence of human penetration into the Craven District. Victoria Cave near Settle (1, SD 838650) is a major site which has yielded Magdalenian bone implements of the upper Palaeolithic phase (c. 10,000 BC) (Longworth, 1965).

As the climate improved during the post-glacial period the warmer conditions began to favour the development of vegetation. These changes in climate and vegetation produced some changes in the animal population and forced men to find new ways to supplement their diet. New tools and new forms of weapons were developed by Mesolithic hunter-gatherers (Tardenoiseans). The frequent discoveries of their characteristic implements - microlithic flints - suggest the greater intensity of Mesolithic settlement in the Craven District (c. 10,250-5650 BP). On the scars of Ingleborough, particularly near Dowlas Moss some microliths have been seen (Swales, 1987). At Stump Cross (7, SD 088635), near Grassington, on an eastward extension of the Great Scar Limestone many implements have been found under the blanket peat bog which may have been deposited in the Boreal-Atlantic transition (Zone VII a) or possibly later (Zone VII b) according to Godwin's zonation. Malham Moor was also visited by Mesolithic hunters - probably seasonally (Raistrick & Holmes, 1962). Other finds in this region include a stag-antler harpoon from Victoria Cave, Settle.

The transition from nomadic hunting communities to permanent groups of Neolithic farmers was a slow process but it was a tremendous step forward in man's fight against nature.

The first farmers from the Continent began to reach Britain during the mid 4th millennium BC (Megaw & Simpson, 1979). Remains of Neolithic settlements in Northern England indicate that new types of stone and bone implements gradually came into use. New forms of pottery and burial customs appeared alongside simple and old traditions. Evidence of land clearance is provided by the appearance of cereal pollen along with the increase in herb pollen and the refinement of hand-axe shapes in flint and stone.

No satisfactory evidence of settlements of this phase have yet been found in the Craven District. Only some caves and rock shelters yielded evidence of occupation. A highly decorated type of pottery assigned to the Late Neolithic Peterborough Culture of the north has been identified in inhabited caves, Swell's and Kinsey Caves, near Settle and on the verges of the plateau in Elbolton Cave near Linton (Longworth, 1965). However, Gilks (1973) says that judging by the fabric of some fragments, the pottery should be compared with the characteristic wares of the Midlands and southern England. Other notable finds come from a number of caves around Settle, such as Jubilee, Lesser and Raven Scar. These are mostly burials whose construction is similar to megalithic tombs found in northern England (Gilks, 1973 and 1981). Giants' Graves on Pen-y-ghent (NGR SD 857746) (Bennett, 1936) and the Bordley Circle on Malham Moor (Raistrick & Holmes, 1962) are examples of such tombs.

On the Ingleborough Massif there are three major records of Neolithic Age finds: -
(a) At Foxholes (NGR SD 75667147) (Ordnance Survey Antiquity Number/OSAN SD 77 SE 5), a rock shelter near Clapdale on the southern edge of the Massif yielded human remains, bones of red deer, wild ox, wolf and boar,

traces of fire-places, charred bones, flint and chert flakes, a hammer stone and sherds of rough pottery.

(b) A gryke on Over Pasture, about 0.7 km west of South House Farm (NGR SD 787741) revealed a burial and polished stone axe (OSAN SD 77 NE 11; Gilks & Lord, 1985). The latter belongs to the Group VI Cumbrian axe type and seems to be associated with the Late Neolithic and Early Bronze Age pottery types, All-Over-Cord, early style Comb Decorated Beakers and Grooved Ware, covered the period between c. 4050-3650 BP.

(c) A cairn resembling the megalithic tombs in plan (NGR SD 75677836) is thought to belong to Late Neolithic times.

In the early Bronze Age (c. 2000 BC) new immigrants of the Beaker Culture from the Continent introduced new tastes in pottery and brought the custom of single burial to Britain. They seem to have lived side by side with the indigenous people or in mixed societies (Megaw & Simpson 1979). The south-eastern economy was probably based on arable farming whereas in the north-west, stock-raising was important. The major crops were <u>Hordeum</u> spp. (barley), <u>Triticum</u> <u>monococcum</u> (einkorn wheat) and <u>T</u>. <u>dicoccum</u> (emmer wheat). Pigs, cattle, sheep and horse were domesticated animals during the Late Neolithic-Early Bronze Age. Later in the Bronze Age cattle and particularly sheep became the most abundant ungulates.

The evidence from pottery and cairns suggests a prolonged late Neolithic and early Bronze Age overlap in the Pennines, though Beaker barrows on the chalk soils of the Wolds and limestone hills indicate the use of the Pennine passes, as at Lea Green near Grassington (Longworth, 1965). It appears that the western uplands were scarcely affected by the Beaker phase.

In the Craven area, once again many of the archaeological finds including occupation and burial debris come from the limestone caves. These span the Late Neolithic Period through to Early Bronze Age, e.g. Raven Scar Cave (NGR SD 730757) near Settle (Gilks, 1973 and 1981).

The identification of Bronze Age above-ground settlement sites presents difficulties. Some of the huts and farm patterns on Malham Moor may, however, date from this period (Raistrick & Holmes, 1962).

The Bronze Age occupation on the Ingleborough Massif is authenticated by a few records of finds: -
(a) Several metallic objects in typical Bronze Age fashion - a looped spearhead (OSAN SD 77 SW 10) found near Scale Mire Farm (NGR SD 721705).
(b) A flanged axe (OSAN SD 77 NW 2), a pin and a diamond-shaped plate dated to 700 BC (2650 BP) at Ingleton (King, 1970).
(c) A cairn called "Apron Full of Stones", near the head of Kingsdale (NGR SD 709787), revealing an empty grave, a cremation burial, a pit and several flints (King, 1978 a).

After 700 BC in Britain the majority of artefacts were still of bronze, but some were already of iron. Thus, the introduction of metal, such as copper and bronze, for tools along with long-distance trade in Bronze Age times was to form the basis of the iron-using culture of the Iron Age.

On the limestone uplands of the Craven District the Iron Age occupation is represented by numerous archaeological remains - hut circles, settlements, field systems, burials, iron artefacts and fragments of early Native and Later Romano-British pottery. It was shown through radiocarbon dating that these elements belong to the last stage of a long period of occupation.

According to Raistrick and Holmes (1962) old traditions and constructions continued with slow and slight changes over a long time. Megaw and Simpson (1979) also point out the existence of more continuity between the Bronze Age and Iron Age, particularly with respect to the hillforts. In northern Britain pastoralism, with a great proportion of cattle and flocks of sheep, retained a dominant role in the economy (Cunliffe, 1978; Megaw & Simpson, 1979). The Iron Age infiltration and later occupation of the Craven area was continuous, probably from the 2nd century BC until the end of the Roman invasion in the early 5th century AD. The chief resistance to Roman occupation centred on a hill tribe, the Brigantes of the North of England. In general, the most abundant archaeological remains found in the Ingleborough Region belong to Iron Age/Romano-British Period. A hillfort dated 300 BC-100 AD according to Longworth (1965) (King, 1970; OSAN SD77 SW1) on the summit of Ingleborough Hill is one of the major Iron Age sites. Many examples of small farmsteads, surrounded by drystone walls, can be seen near Ribblehead (NGR SD 7778). Some of them show drove-ways with steep banks on either side. It is clear that the construction of such settlements started in the beginning of the 2nd century and continued in the 4th century (King, 1969). Similar cultivation sites have been recorded from Malham Moor and Grassington (Raistrick, 1936 and 1939; Raistrick & Holmes, 1962).

In Penigent Gill the settlements excavated by Bennett (1938) yielded bones and teeth of horse, ox and sheep, pottery pieces of c. 200 BC - 200 AD, a piece of Roman ware of a much later date, pot boilers, fragments of querns, rubbing stones. Caves around Settle revealed Iron Age brooches and domestic items. A remarkable suite of Romano-British objects of the second century was also reported from several caves, such as Victoria, Attermire and Sewell's Cave.

In the Dark Ages, all the Dales saw the gradual penetration of Anglian and later Danish settlers from the east. On Malham Moor the period is represented by the isolated 'Priest's House' which is thought to have been the house of an Anglian priest or hermit of 7th century date, and by two coins of the ninth century from Prior Rakes, coins of King Eanred (807-841 AD) (Raistrick & Holmes, 1962). At a site consisting of the three buildings at Ribblehead (NGR SD 766784) on the limestone pavement a long iron spearhead, knives and three bronze coins of around the mid-9th century were identified (King, 1978b). These are accompanied by a knife and four coins of the 9th century in Scandinavian fashion which suggest the occupation of Ribblehead during the second half of 9th century by Scandinavian settlers (OSAN SD 77, NE 12).

In the tenth and eleventh centuries the uplands were inhabited by Norsemen. The evidence is provided by their typical farmsteads scattered over Malham Moor. Norse settlement in the Pennines can be also be traced in place-names and much of the local Dales dialect (Raistrick & Holmes, 1962).

In the twelfth century the land was given over to the monasteries of Fountains and Bolton under whom the Norse settlers continued sheep-farming. The monasteries then developed a new system of sheep-ranching in the uplands, which continued until the time of Dissolution of the monasteries in 1535. Several medieval farmsteads can be seen on the Ingleborough Massif (OSAN SD 77 NE 6, SD 77 NW 6; SD 77, SW 5, 9).

This sequence of archaeological sites covering a long period of time may suggest an almost continuous occupation of the limestone plateaux of Craven from the Mesolithic Period onwards (Figure 3.1.). Areas of Upland Craven which are free from boulder clay seem rich in archaeological remains. The nature of the soil and vegetation cover should ensure the use of such areas as permanent sheep run for many centuries. Today the Ingleborough Region and the Craven Area as a whole is still grazed, mainly by sheep. Many small settlements

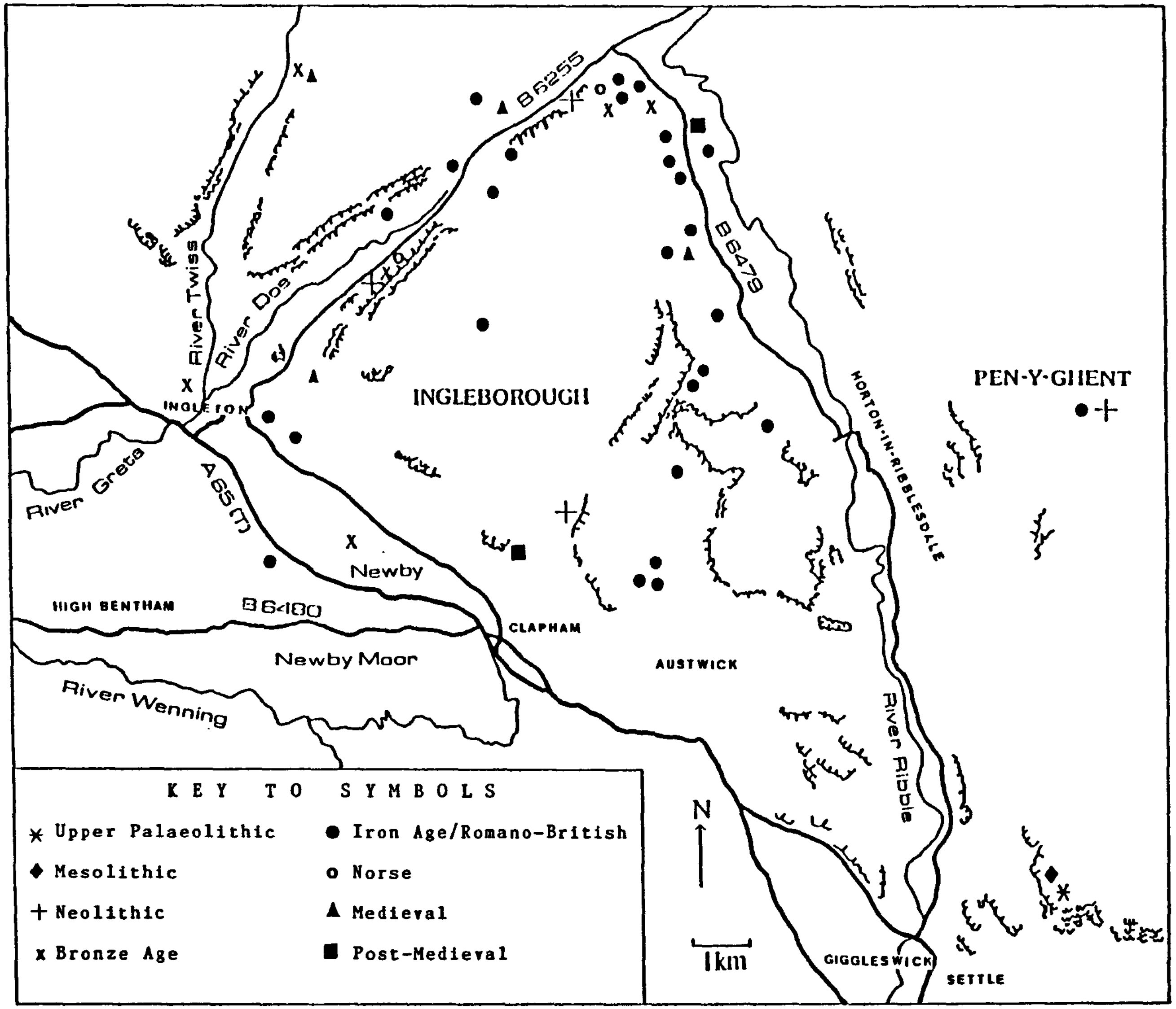


Figure 3.1. Map showing the position and age of some archaeological remains in the Ingleborough Region.

are located in the river valleys which are used as pastoral and arable fields.

4. MATERIALS AND METHODS

4.1. Collection and storage of samples

Peat samples for analyses were collected by a "Russian" type sampler (50 cm long). A "Hiller" type borer was also employed to extract extremely stiff Lateglacial deposits of Thieves' Moss (sampling point 1).

The depth and stratigraphy of the deposit of Sniddle Moss were established at thirteen sampling points across the deposit (see Figure 5.2.1.). The stratigraphy of the deposits selected in the limestone upland was given by earlier workers - Thieves' Moss by Gosden (1965) (see Figure 6.2.1.) and Sunset Hole by Swales (1987). Coring points from each site, which were believed to contain a sequence of the desired periods, were chosen and their samples were examined for detailed pollen analyses along with macrofossil analyses. Keys to symbols used in this study for the lithology of both Thieves' Moss and Sunset Hole are different from those presented by Gosden and Swales.

Each core as it was taken was described in the field and collected in plastic drain-pipes. It was then labelled, including an indication of the site, boring location and depth in the stratigraphic sequence, before being wrapped and sealed in clean polythene to prevent drying. All peat samples were stored at $2^{o}C$ to inhibit the development of microbial activity.

4.2. Macrofossil analyses

In the laboratory, subsamples from Sniddle Moss were taken mainly at intervals of 10 cm (SM9) or at closer intervals (SM4), taking into consideration the marked changes in physical properties which had been recorded in the field. Each subsample was treated with about 10%

nitric acid overnight and then strained through two sieves with meshes 425 and 250 µm. For Thieves' Moss and Sunset Hole, only the small amounts of sediment left after pollen preparation were analysed. The washed samples were placed on a Petri dish in small proportions in water in order to separate macroscopic plant remains. Vegetative remains, such as buds, fruits and seeds, were examined under a low power binocular microscope (x10 and x30) whilst mosses, Juncus seeds, cuticles of monocots and sectioned wood samples were studied using a high power microscope (x100 and x400).

4.2.1. Determination of macrofossils

The determination of macrofossils was based on comparisons with some vegetative parts of plants in reference collections and identification manuals (Beijerinck, 1947; Dixon, 1954; Jessen, 1955; Körber-Grohne, 1964; Katz et al., 1965; Smith, 1978; Bergrren, 1969 and 1981; Schweingruber, 1990). The identification of Betula female catkin scales was mainly made from the illustrations in Godwin (1975).

An achene of Cirsium ? heterophyllum/palustre from SM8 (254-256 cm) is thought to belong to either C. ? heterophyllum or C. ? palustre. The same also applies to fruits of Glyceria fluitans/declinata at SM5, leaf remains of Drepanocladus fluitans/exannulatus at SM4, and of Orthotrichum sp./Ulota sp. at SM9. Bryum sp./Mnium sp. from SM10 (208-210 cm) refers to leaf remains resembling Bryum sp. or Mnium sp. But, in the case of other samples from Sniddle Moss and from Thieves' Moss 3 it was possible to separate the leaves of Bryum sp. from Mnium sp. Carex flava-type nuts were referred to those which are trigonous, dark brown and broadly obovate with sharp angles, whilst C. rostrata-type nuts were referred to those which are trigonous, broadly obovate with almost flat and verrucose faces and with a curved stylar base and often a twisted base and a twisted beak.

Large numbers of Characeae oospores were found in the deposits of Sniddle Moss and Thieves' Moss during the examination of macrofossils. An account of both LM and SEM studies of these oospore types is given in Appendix 10.

Nomenclature of vascular plants follows Clapham, Tutin and Moore (1989) and of mosses follows Smith (1978).

4.2.2. Presentation of macrofossils

The macrofossils from Sniddle Moss (SM4 and SM9) and Thieves' Moss (TM1, TM2 and TM3) are plotted against a stratigraphic column. The taxa from SM4 and SM9 and Thieves' Moss have been arranged according to their occurrence in the stratigraphic sequence and the basis of their known ecology. Those from other sampling points of the Sniddle Moss site, which have not been recorded from SM4 and SM9, are in alphabetical order. The assemblages have been zoned in the same manner as pollen diagrams, excluding subzones.

4.3. Microfossil analyses

4.3.1. Preparation of samples for pollen counts

1 cm^3 samples were first measured using a syringe after cleaning of the sediment surface to avoid contamination. In order to determine the concentration of pollen in the sediment, tablets of Lycopodium clavatum were then added to all samples according to the method described by Stockmarr (1971).

Peat samples were treated with KOH solution (5 % w/v) and some of those from Sniddle Moss were then subjected to Erdtman's acetolysis to remove large amounts of plant debris. The samples which were calcareous were treated with 5% HCl and the pollen was separated from the mineral material by bromoform-acetone flotation.

Two slides were prepared for each level (mounted in glycerine-jelly).

4.3.2. Counting procedure

In most cases a minimum sum of 500 pollen grains was counted per level, 250 from each of the duplicate slides. The pollen content of some samples was low and pollen was counted from traverses covering the whole slide and extra slides. Even then some samples - chiefly those from several layers of the lake clays of Sniddle Moss and Thieves' Moss - yielded less than 100 grains.

Pollen and spores were identified using the reference collection in the Department. The pollen and spore types used are defined in Faegri and Iversen (1989) and Moore, Webb and Collinson (1991), except for Humulus lupulus-type. Its identification has been made from the reference slides and the descriptions in Punt and Malotaux (1984). Microscopic algae were also counted during the analyses. Routine (pollen) counting was carried out at a magnification of x400, with x1000 used for more detailed examinations and critical determination.

4.3.3. Radiocarbon dates

Subsamples from a number of levels of the study sites have been taken for radiocarbon dating. Lateglacial deposits of Sniddle Moss and Thieves' Moss were carbonate-rich and not suitable for dating. The main criteria in the selection of horizons for radiocarbon dates are as follows:

(a) horizons from peats showing no evidence of contamination by calcium carbonate and modern roots
(b) the detailed pattern of the Ulmus (elm) decline which is well defined at Sniddle Moss and at Sunset Hole by

sampling through and above the elm decline at 1 cm intervals.

(c) important vegetational changes indicated in the pollen diagrams

(d) marked changes in the nature of the peat for calculating of rates of peat growth.

All the samples were sent to the NERC Radiocarbon Laboratory at East Kilbride to be dated by Accelerator Mass Spectrometry at the University of Arizona. Radiocarbon dates for Sniddle Moss and Thieves' Moss have been obtained (for a list of these dates see Appendix 1). An estimated time scale for Sniddle Moss 9 is presented in Appendix 2. All radiocarbon dates are expressed in conventional radiocarbon years BP (before 1950, according to Stuiver and Polach, 1977). Unfortunately, the dates for Sunset Hole are not available now.

4.3.4. Calculations and construction of the pollen diagrams

The pollen data were handled by the **Tilia Software Package**, designed and written by Eric Grimm of the Illinois State Museum, USA. The calculation sum chosen consisted of total land pollen (TLP) excluding Lycopodium clavatum spores. Pollen of aquatic plants, spores, algae and indeterminable pollen (most are corroded) were excluded from the pollen sum. The frequencies of these were calculated separately.

Both percentage and concentration diagrams have been produced for the profiles of all selected sites. An influx diagram has been constructed only for the Sniddle Moss site (sampling point 9). Since the concentration diagram produced for SM9 is similar to the influx diagram, it has not been included. A lithostratigraphical column following radiocarbon dates has been placed at the beginning of each diagram. The tree pollen curves followed by those for shrub pollen first have been presented in order to facilitate comparisons with published and unpublished diagrams. Herbaceous pollen curves are presented next. In the percentage diagrams, a summary diagram showing the proportions of tree, shrub and herb pollen follows the curves for aquatics and algae. Some selected pollen and spore types which occur rarely are listed separately. In the concentration and influx diagrams only selected taxa have been plotted, followed by indeterminables, total aquatic pollen and total land pollen.

4.4.4. Zonation of the pollen diagrams

The pollen diagrams have been divided into local pollen assemblage zones (LPAZ) by noting major changes in the individual pollen curves in the percentage diagram. Each zone boundary has been drawn where significant changes were present in the values of major taxa. Boundary lines were placed through the first level in which the changes seem to have occurred. The subdivision was based on the inherent features of the diagrams. The dotted lines in zones SM9-III (Sniddle Moss) and SH-IV (Sunset Hole) do not represent subzone boundaries. They have been used to define the main stages related to changes in the elm curve, along with other important elements of these zones. The screen type dashed lines in the Sniddle Moss diagrams (SM4 and SM4a) represent the assumed hiatuses.

In each pollen diagram the zones and subzones are prefixed by the site and the number of sampling point and are numbered from the base to the top of the sequence.

5. SNIDDLE MOSS (NGR SD 707695)

5.1. Description of site

Sniddle Moss (54 07' N, 2 27' W) situated at an altitude of c. 160 m is c. 4 km to the west of Clapham. The area is bounded to the north by a trunk road, A65(T) (Clapham to Ingleborough), to the south by the B 6480, Clapham to High Bentham Road, and to the west by a few farms (see Figure 1.1.).

The moss is almost oval in shape. It is surrounded by drumlins and drift material giving an undulating relief. At the northern end there is a permanent stream running off the Moss. The present vegetation of the site consists chiefly of low hummocks of *Sphagna*; namely *Sphagnum magellanicum* and *S. papillosum* with *Aulacomnium palustre*, *Polytrichum commune*, *Calliergon cuspidatum*, *C. stramineum*, *Carex* species - *C. curta*, *C. nigra*, *C. panicea* and *C. rostrata* - and some *Eriophorum angustifolium*. There are also smaller amounts of *Filipendula ulmaria*, *Galium palustre* *Juncus effusus*, *J. bulbosus*, *Polygala serpyllifolia*, *Potentilla palustris*, *Viola palustris* and *Rhytidiadelphus squarrosus* in wetter areas of the bog surface. In the pools *Equisetum palustre*, *Hydrocotyle vulgaris*, *Menyanthes trifoliata* and *Potamogeton polygonifolius* can be found. On the drier parts *Calluna vulgaris* and *Erica tetralix* become common.

5.2. Stratigraphy

A series of borings showed that the deposits occupy a basin which in the region of the section is some 8 m deep near the middle and about 116 m across (Figure 5.2.1.).

According to preliminary work by Margaret Pigott with an undergraduate in 1980, there is a basic sequence of

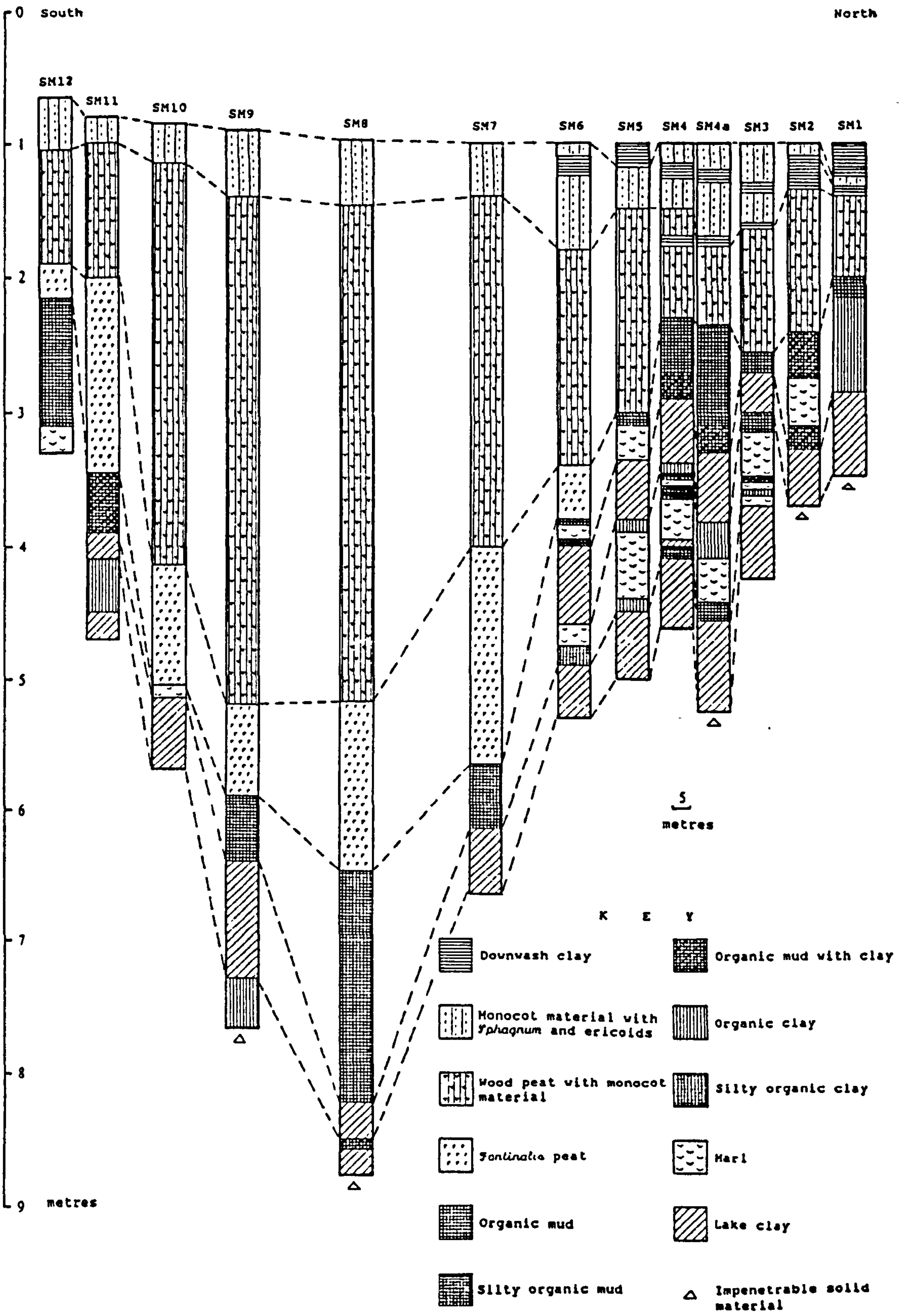


Figure 5.2.1. Stratigraphy across Sniddle Moss (SM4a is closer to SM4 than it is shown in the figure. Only the upper parts of coring points have been correlated since the lower parts show great variation and it is difficult to correlate).

two lake clays separated by organic mud on each side of the section of the Moss. The present study, however, suggests rather irregular preservation of these earlier (Lateglacial) sediments since they appear to be only very well developed on the northern side. In addition, various layers of organic mud with marl and organic clay between these two lake clays are not easy to correlate from one core to the next. The lower lake clay, which is predominantly grey in colour, presumably represents the lake deposits from the closing stages of the last major glaciation. The upper clay (fine-blue) with no banding may indicate rapid deposition under uniform conditions, possibly into quite deep water. The main Postglacial deposits, above the upper clay, extend almost continuously over the bed of the lake.

In most places the upper clay passes up into a mud of increasing organic content, which is about 1.70 m thick in the middle of the lake. This organic mud is overlain by a very thick fen-carr peat. The lower part of the peat has a zone of aquatic mosses, chiefly dominated by <u>Fontinalis antipyretica</u> on the southern side. The upper part contains wood with monocot material. This is usually superseded by a layer with some <u>Sphagna</u> and ericoid remains.

A typical Lateglacial sequence seen at SM4 yielded the following:

cm
130-168 - organic mud
168-192 - organic mud with clay
192-238 - lake clay
238-244 - organic clay
244-248 - silty organic mud
248-253 - marl
253-264 - silty organic mud
264-296 - marl
296-300 - clay

300-313 - silty organic mud
313-367 - lake clay

A description of the profile at SM9 will serve to illustrate the nature of the various layers of the Flandrian:

cm	
0-50	- monocot material with Sphagnum and ericoid remains
50-429	- wood peat with monocot material; charcoal at 126-128 cm
429-500	- Fontinalis peat
500-548	- organic mud

In some cases (mainly on the northern side of the section) bands of clay interrupt the Postglacial deposits, probably as a result of periods of increased erosion, the possible consequence of forest clearances.

The whole area is now very peaty in nature.

5.3. Macroscopic fossils

The results of the examination of the macrofossils from SM4 and SM9 are plotted in Tables 5.3.1. and 5.3.2. In addition, finds of macroscopic plant remains from other sampling points, which have not been found in the profiles of SM4 and SM9 are listed in Table 5.3.3. Some of these finds can be related to the phases of local vegetational history defined for profiles SM4 and SM9.

5.4. Microscopic fossils and local pollen assemblage zones

The pollen diagram 'Sniddle Moss 4' seems to provide a record of the vegetational history during the Lateglacial and the early stages of the Flandrian Period in the area (Diagrams 5.4.1., 5.4.2., 5.4.3., 5.4.4., 5.4.5. and Appendix 3). It is believed that there is an hiatus (between 79-90 cm where there is a tree trunk) in the sequence of SM4 and much of the recent vegetational record is not well-presented in the diagram. Consequently, additional cores - SM4a, a parallel core to SM4, and SM9 in the centre of the basin - which are believed to contain sequences of the desired periods have been examined (Diagrams 5.4.6., 5.4.7., 5.4.8., 5.4.9., 5.4.10., 5.4.11. and Appendix 4 and 5). Local pollen assemblage zones are defined for each profile as follows:

SM4

SM4-I Pinus-Gramineae LPAZ

(366-314 cm)

Zone SM4-I represents a section of the profile of very low pollen concentration. Pinus and Gramineae are significant contributors to total land pollen in the percentage diagram whereas in the concentration diagram both have low values. The same also applies to almost all taxa in the pollen record. Total land pollen concentrations increase towards the top.

The terminal boundary: Salix and Rumex/Oxyria pollen percentages rise, the curve for Pinus declines.

SM4-II Gramineae-Cyperaceae-Salix-Rumex/Oxyria LPAZ

(314-306 cm)

This zone is characterized by an increase in total pollen concentrations. A striking feature of the zone is the persistence and further development of herbaceous taxa, chiefly Gramineae, Cyperaceae and Rumex/Oxyria. A rise in the Salix and Potamogeton curves also marks this zone.

The terminal boundary: Juniperus pollen percentages increase and those for Salix and Rumex/Oxyria fall.

SM4-III (306-274 cm)

The fluctuating values for juniper provide a basis for division of this zone (subzones -IIIa, -IIIb and -IIIc). Subzone SM-IIIb has lower pollen concentrations than either the underlying or overlying subzones.

SM4-IIIa Gramineae-Juniperus-Cyperaceae LPAZ

(306-302 cm)

The increased percentage and concentration values of Juniperus and Betula pollen characterize this subzone. The contribution of shrub pollen is higher than in the preceding zone due largely to an initial increase in juniper, but herbaceous pollen is still dominant.

The terminal boundary: Juniperus pollen declines.

SM4-IIIb Gramineae-Cyperaceae LPAZ

(302-294 cm)

There is a decrease in pollen concentrations. Gramineae dominates this subzone, regularly contributing 34.5-35.6% of TLP. Cyperaceae reaches its maximum value of c.22%. After its initial fall at 302 cm juniper pollen shows a further decline in mid-zone and then increases abruptly towards the top. Birch pollen also fluctuates. Other herbaceous taxa characteristic of disturbed ground (such as Artemisia, Helianthemum and Rumex/Oxyria) assume an importance. Thalictrum is well-represented in this subzone, though at low values.

The terminal boundary: Juniperus pollen increases considerably.

SM4-IIIc Gramineae-Cyperaceae-Juniperus LPAZ

(294-274 cm)

This subzone is characterized by increased pollen concentrations, by a rise in *Juniperus* (up to 41.2%), and by higher values of thermophilous taxa including *Filipendula*. *Betula* pollen presents fluctuating values by mid-zone and then increases suddenly, before decreasing steeply towards the end of the subzone. *Hippophaë* becomes significant. *Rumex*/*Oxyria* and *Artemisia* have lower values in this subzone than in the preceding subzone. The shrub pollen contributes its maximum value of 43% of TLP, for the first time.

The terminal boundary: A rise in the *Betula* curve defines the terminal boundary.

SM4-IV (274-238 cm)

The zone is divided into four subzones, on the basis of the *Betula*, *Juniperus* and *Filipendula* curves.

SM4-IVa *Betula*-Gramineae-Cyperaceae-*Filipendula* **LPAZ**

(274-264 cm)

Subzone SM4-IVa is distinguished by its high *Betula* and *Filipendula* pollen values and by decreased pollen values for *Juniperus*. *Hippophaë* is well-represented, though at low values. Tree pollen comprises up to 46% of TLP, but very high values of NAP are maintained (up to 68%).

The terminal boundary: *Betula* pollen declines.

SM4-IVb Cyperaceae-Gramineae-*Betula* **LPAZ**

(264-256 cm)

The reduced values of *Betula* and *Filipendula* pollen and the increased values for Cyperaceae and Gramineae mark this subzone.

The terminal boundary: *Betula*, *Juniperus* and *Filipendula* increase.

SM4-IVc Betula-Gramineae-Cyperaceae-Juniperus LPAZ

(256-248 cm)

Total land pollen concentrations of this subzone are lower than in the preceding subzones of SM4-IV. Betula and Juniperus pollen first shows a slight rise. The former increases abruptly at the end of the subzone, while the latter peaks towards the top, before declining. Gramineae pollen is still important. Cyperaceae pollen values fall.

The terminal boundary: Juniperus pollen decreases.

SM4-IVd Betula-Gramineae-Cyperaceae-Filipendula LPAZ

(248-238 cm)

There is an increase in total land pollen concentrations. Gramineae pollen is the main contributor of this subzone. Although Betula displays fluctuations, it has high values, between 20% and 29.2% of TLP. Juniperus pollen remains in low quantities, before showing a slight increase at the top. After an initial rise, Filipendula pollen declines. Rumex/Oxyria pollen is well-represented.

The terminal boundary: Gramineae and Cyperaceae pollen rises, Betula, Juniperus and Filipendula pollen values decline.

SM4-V Gramineae-Cyperaceae-(Betula)-Artemisia LPAZ

(238-190 cm)

Low pollen concentrations are characteristic of this zone. There are reductions in Betula, Juniperus, Hippophaë and Filipendula as Gramineae, Cyperaceae, Artemisia, Ranunculaceae and other herbs become significant. Selaginella assumes an importance in the beginning, before declining gradually.

The terminal boundary: The Juniperus curve rises.

SM4-VI Gramineae-Juniperus-Cyperaceae

(190-180 cm)

This zone records a rise in pollen concentrations of almost all taxa with the exceptions of Artemisia. NAP is still the main contributor to the total land pollen. Juniperus and Filipendula have higher pollen values than in the preceding zone. Hippophaë completely disappears as Quercus first appears. Algae decline.

The terminal boundary: Betula pollen rises and the curve for Juniperus declines.

SM4-VII Betula-Gramineae **LPAZ**

(180-170 cm)

Betula pollen dominates this zone. Juniperus becomes less significant. Ulmus and Corylus pollen first occurs in this zone.

The terminal boundary: Corylus pollen shows an increase and Betula pollen falls.

SM4-VIII (170-92 cm) (Corylus Phase)

This succeeding zone is divided into two subzones, primarily on the basis of changes in the pollen curve of Corylus. There is a rise in concentration of indeterminables.

SM4-VIIIa Corylus-Betula **LPAZ**

(170-128 cm)

Corylus pollen accounts for 45-61% of TLP. Betula has lower percentages than zone SM4-VII. Juniperus pollen declines and disappears completely towards the top. Ulmus forms a continuous curve and it is better represented than Quercus. NAP is considerably lower than tree and shrub pollen for the first time.

The terminal boundary: *Corylus* pollen values decrease.

SM4-VIIIb *Corylus*-Cyperaceae

(128-92 cm)

The most striking feature of this subzone is the decline in pollen concentrations. *Corylus* pollen is still dominant, but it has lower values than those in the previous subzone as does *Betula*. Both percentages and concentrations of *Pinus* increase towards the top. *Alnus* pollen first appears in the subzone. Filicales spores peak irregularly.

The terminal boundary: It is difficult to define the terminal boundary precisely because there is a tree trunk belonging to *Salix* sp. from 90 to 79 cm.

SM4-IX (78-16 cm)

Zone SM-IX is characterized by major changes in the pollen record. There is a rise in the values of pollen-concentration.

A subdivision of this zone into two phases can be made - subzone SM4-IXa and SM4-IXb.

SM4-IXa Cyperaceae-*Betula*-*Alnus* **LPAZ**

(78-24 cm)

NAP is over 60% of TLP with Cyperaceae the dominant type. *Betula* and *Alnus* are the chief contributors to total tree pollen. Ericales and *Sphagnum* become significant. Pollen of cultural indicators (e.g. Cerealia-type and *Plantago lanceolata*-type) is well-represented.

The terminal boundary: NAP shows a further rise and AP values decline.

SM4-IXb Cyperaceae-Gramineae-Alnus **LPAZ**

(26-16 cm)

Cyperaceae and Gramineae have high pollen values as non-herbaceous pollen falls.

The terminal boundary: AP presents a further reduction.

SM4-X Cyperaceae-Gramineae **LPAZ**

At 16 cm, the beginning of zone SM4-X there are substantial and abrupt falls in values of tree and shrub pollen and total dominance of Gramineae and Cyperaceae pollen on both percentage and concentration diagrams.

Deposits above 12 cm could not be analysed palynologically due to the presence of large amounts of modern plant fragments.

SM4a

SM4a-I Corylus-Cyperaceae **LPAZ**

(116-100 cm)

This zone is marked by low total land pollen concentrations. Corylus, Cyperaceae, Pinus and Filicales are important components of the assemblage.

The terminal boundary: Pinus pollen increases.

SM4a-II Pinus-Corylus-Cyperaceae **LPAZ**

(100-90 cm)

Total land pollen concentrations are still low. Pinus is the most abundant pollen type, rising up to c.47% but decreasing to 21% by the end of the zone.

The terminal boundary: Pinus and non-herbaceous pollen declines.

SM4a-III Cyperaceae-Corylus-Gramineae-Ericales-Betula LPAZ

(90-68 cm)

There is a sharp increase in total pollen concentrations. The herbaceous values are high, over 50% of TLP, with Cyperaceae, Gramineae and Ericales the most important contributors. Corylus, Betula, Alnus and Quercus remain relatively stable throughout the zone while Pinus and Ulmus pollen shows very low values. Sphagnum is more abundant than in SM4a-II.

SM9 (Figures 5.4.1. and 5.4.2.)

SM9-I Corylus-Betula-Pinus-Quercus LPAZ

(502-430 cm)

Non-herbaceous pollen dominates this zone with Corylus, Betula, Pinus and Quercus the main types. Alnus pollen first appears in this zone.

The terminal boundary: Alnus pollen rises.

SM9-II Alnus-Corylus-Quercus LPAZ

(430-118 cm)

In this zone the sedimentation rate increases from 7.3 yr cm^{-1} to 4.5 yr cm^{-1} and it decreases towards the top. There is also a rise in total pollen influx values due largely to the presence of high pollen producers such as alder. Alnus pollen is the major tree pollen, but exhibits fluctuations throughout. Corylus and Quercus pollen also comprises considerable percentages of TLP. Pinus and Salix are present throughout, but at low values. Betula values decline dramatically, showing a peak at 334 cm. Ulmus pollen percentages are up to 7.7%. Tilia and Fraxinus appear sporadically. Gramineae is not well-represented while Cyperaceae fluctuates. Pteridium becomes significant from 190 cm.

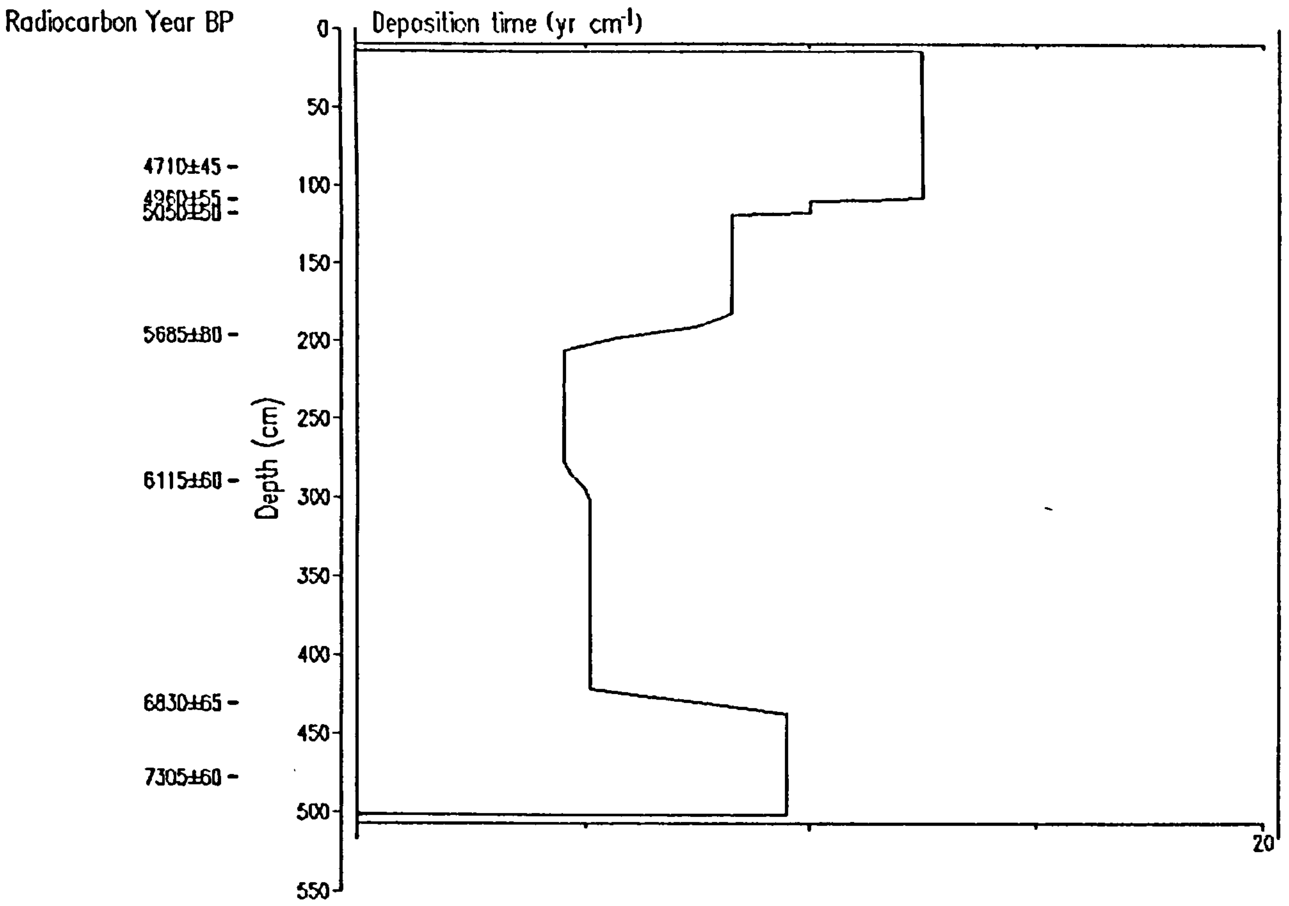


Figure 5.4.1. Deposition time (yr cm^{-1}) for Sniddle Moss 9 (between 14-502 cm). Also shown are radiocarbon dates.

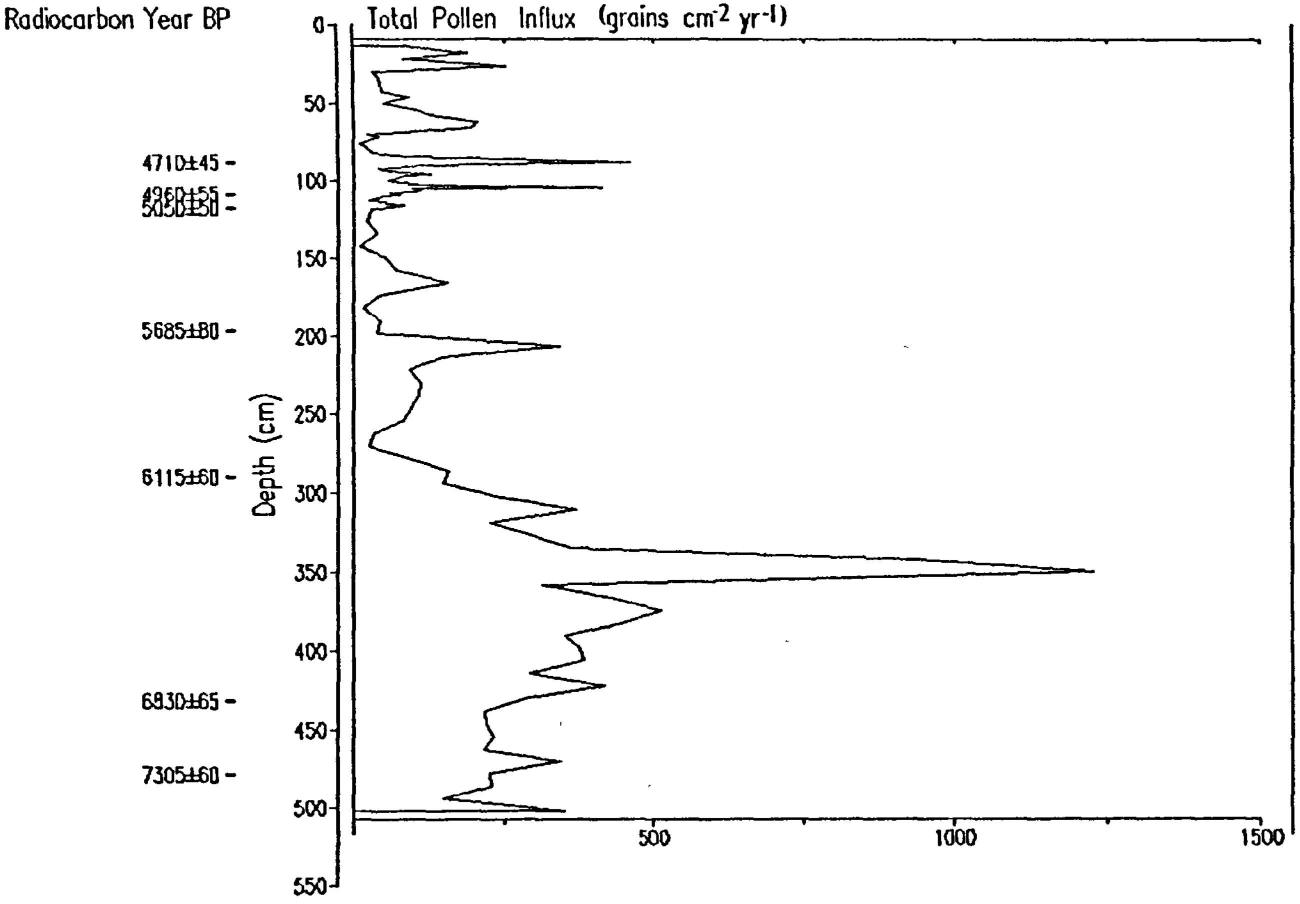


Figure 5.4.2. Total pollen influx (grains cm^{-2} yr^{-1}) and radiocarbon years for Sniddle Moss 9 (between 14-502 cm).

The terminal boundary: The first classical elm decline is recognized.

SM9-III Alnus-Cyperaceae **LPAZ**

(118-26 cm)

As mentioned in Chapter 4., the dotted lines in this zone (Diagrams 5.4.10. and 5.4.11) define the main phases related to changes in the elm curve.

Five main phases have been distinguished:

Phase 1. A first elm decline (118-108 cm)

The first classical Ulmus decline is dated to 5050±50 BP at 118 cm where elm pollen falls to 1.6% of TLP, but there is no change in its concentration and influx values. At this level, though there is a fall in deposition time from 8.2 to 9.2 (yr cm^{-1}), total pollen influx rate (grains cm^{-2} yr^{-1}) shows a rise. Arboreal pollen is still dominant. At the onset of this phase Alnus, Corylus and Quercus percentages fall temporarily because of high percentages of Cyperaceae pollen. Corylus influx values particularly display a definite rise. Betula is less significant. Tilia and Fraxinus pollen rises up to 1%. Salix pollen increases towards the top. Filipendula pollen peaks immediately after the elm decline, up to 7.8% at 116 cm - before declining gradually. Plantago lanceolata pollen appears at 114 cm for the first time, though intermittently and at low values (0.2-0.4%). Cerealia-type pollen also first occurs at 114 cm. Pteridium spores are present frequently and reach a peak of 1.8% at 111 cm.

Phase 2. (107-90 cm)

This phase is characterized by the absence of elm pollen at 107 cm and low and fluctuating values at other levels. There are also marked variations in pollen percentages and influx values of major taxa, including Alnus, Corylus, Quercus, Betula and Cyperaceae. The last-mentioned taxon rises sharply towards the end. Filipendula peaks at 105 cm (4.7%) and then declines abruptly. Melampyrum appears at 106 cm at a value of 2.8% and reaches 12.5% at 105 cm, before disappearing. Cerealia-type pollen occurs intermittently.

Phase 3. A partial recovery of elm (88-76 cm)

Ulmus pollen recovers at 88 cm, rising from 0.2% at 90 cm to values over 0.9%, with a maximum of 2% at 82 cm. In the beginning, total pollen influx values rise abruptly and fall by the middle of this phase. As Cyperaceae declines steeply, Alnus and Corylus pollen shows a temporary increase. Towards the top, Cyperaceae rises and Alnus and Corylus correspondingly decrease. Plantago spp. pollen occurs very rarely. Cerealia-type pollen disappears. Pteridium assumes some importance.

Phase 4. A secondary fall in elm (74-70 cm)

Ulmus pollen falls to 0.4% at 74 cm where there is an increase in total pollen influx values. It has lower values than in the preceding phase.

NAP becomes significant due largely to the percentage contribution of Cyperaceae, though lower than total non-herbaceous pollen.

Phase 5. A renewed recovery of elm (66-26 cm)

This phase is distinguished by the recovery of elm pollen, but its percentages and influx values are lower than those in SM9-II and higher than those in the third phase.

Alnus pollen fluctuates greatly as does Cyperaceae pollen. Quercus becomes more significant than Corylus towards the top. Betula is better represented than in phase 3 and 4. *Fraxinus* rises up to c. 2% while *Tilia* is present sporadically, reaching 1.4% of TLP. Cerealia-type pollen reappears at 46 cm. *Plantago lanceolata* occurs again at 42 cm. *Pteridium* peaks up to c. 6% at 38 cm.

The terminal boundary: Non-herbaceous pollen declines.

SM9-IV Cyperaceae-*Betula*-Gramineae **LPAZ**

(26-14 cm)

After a further decline at the onset of this zone, total land pollen influx values rise and fluctuate throughout. NAP increases up to c. 73% of TLP and non-herbaceous pollen correspondingly falls. *Betula*, Gramineae, Ericales and *Sphagnum*, in particular, become abundant.

Deposits above 14 cm were not available for pollen analyses because for the reason mentioned previously for the uppermost layers of SM4.

5.5. A tentative correlation of the local pollen assemblage zones for the three cores from Sniddle Moss

As seen in Figure 5.5.1., SM4 and the studied sequence of SM4a have comparable assemblages, except for SM4a-II. The differences in the pollen record between the two sites are slight. In SM4-VIIIb Pinus pollen rises up to 15.5%, whereas in SM4a-I it varies from 14.3% to 28.7% of TLP. However, both zones represent similar concentrations for Pinus up to $9.1x10^3$ grains cm^{-3} at SM4 and up to $7.2x10^3$ grains cm^{-3} at SM4a. In addition, Corylus has higher values in SM4-VIIIb than in SM4a-I. Quercus pollen never exceeds 5% of TLP in SM4-VIIIb, whilst in SM4a-I it is slightly higher than in SM4-VIIIb, but not over 10% of TLP. The following zone, presenting high Pinus pollen values at SM4a is considered not to have an equivalent at SM4 . At first glance, fluctuations in Pinus pollen concentrations, rising up to c. $18x10^3$ grains cm^{-3} in subzone SM4-VIIIa might question this assumption. A closer look however suggests that these fluctuations show a good coincidence with TLP concentrations, possibly indicating sedimentological rather than floristic changes. The persistence of Juniperus and the absence of Alnus pollen in subzone SM4-VIIIa may show that it is earlier than any part of SM4a. In SM4a-II, Pinus pollen reaches about 47% of TLP and $25x10^3$ grains cm^{-3}, while Corylus falls to a minimum value of 15.4%. The maximum Pinus pollen marks the Late-Boreal Period of the Flandrian (before c. 7000 BP).

The base of the studied sequence of SM9 shows a section between 430-502 cm with Corylus, Betula and Pinus pollen predominant. The initial rise of Alnus pollen dated to 7305±60 BP and Quercus pollen up to 17.4% evidence that SM9-I corresponds to the beginning of the Atlantic Period.

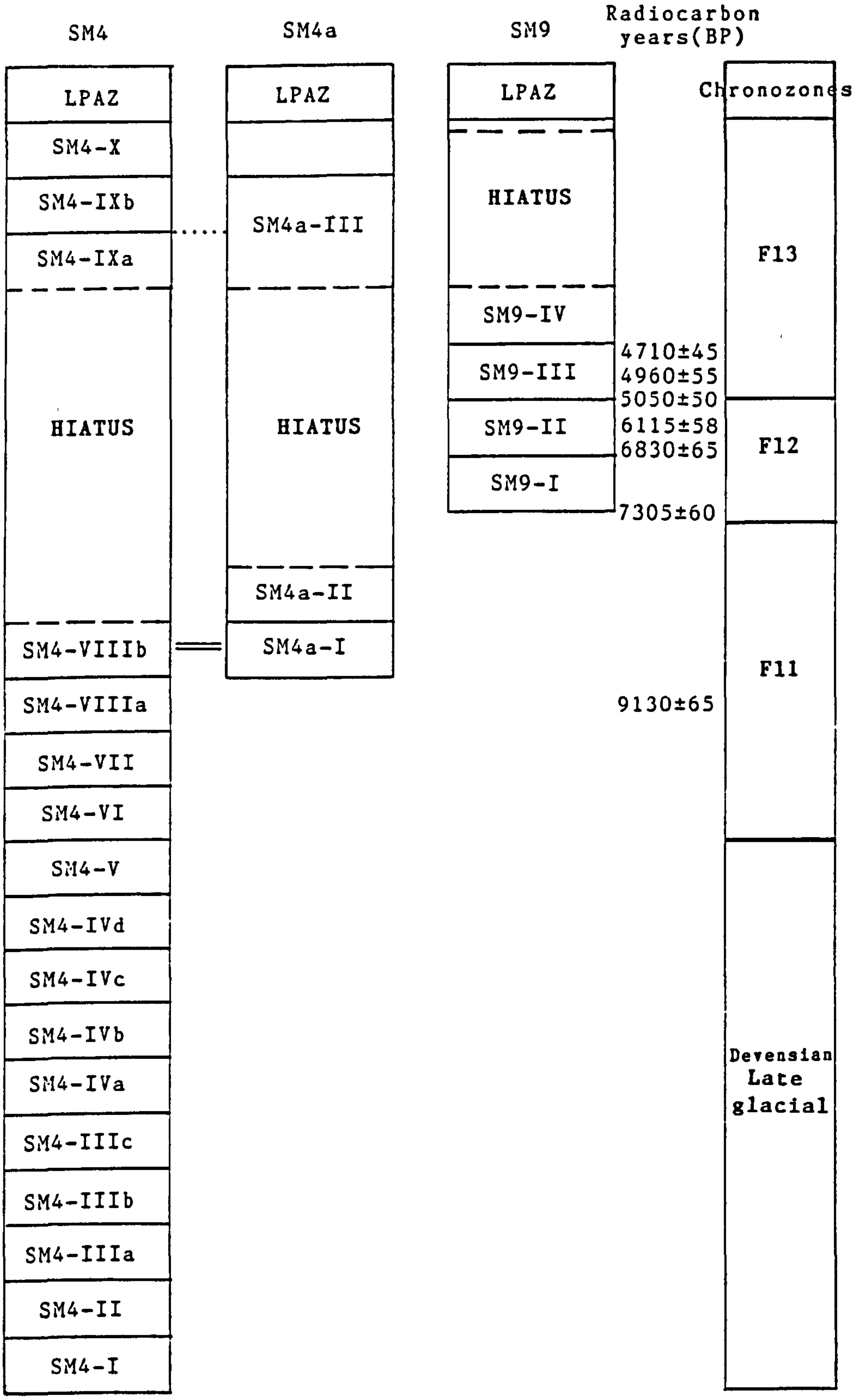


Figure 5.5.1. A tentative correlation of the local pollen assemblage zones from Sniddle Moss and the (supposed) equivalent Flandrian chronozones. (....) similarity; (----) the assumed hiatus boundary; (=) direct comparison

A considerable part of SM9-II is characterized by high Alnus pollen quantities (the Atlantic Period), with a range of dates between about 6830 BP and 5000 BP, which do not appear at the two other sites. SM9 also records the first classical elm decline at 118 cm dated to 5050±50 BP (the Atlantic/Sub-Boreal transition).

When using the estimated time scale based on the peat growth rate for SM9-IV (12 yr cm^{-1}), the age of the peat at 14 cm would be c. 3770 BP. A hiatus in peat growth appears to have occurred so that the record in the profile of SM9 is likely to be missing from the beginning of the Sub-Boreal Period onwards (Figure 5.2.2.). However, to-day there are no signs of erosion and the peat seems to be actively growing. Since there are no radiocarbon dates from the deposits above 78 cm at SM4 and the observed sequence of SM4a above 90 cm, it is difficult to make a direct comparison between the three profiles. But it is obvious that there is an increase in NAP with corresponding peaks in sedge, grass and ericaceous pollen and Sphagnum spores in all sequences. Equally, there is a fall in values of the formerly important tree species, with the exception of Betula in SM9-III reaching over 25% of TLP. The sudden changes in the pollen curves in SM4-IX and SM4a-III support the possibility of gaps in the sequences of SM4 and SM4a and suggest that the upper samples of these two sites are post-Ulmus decline and, consequently younger than 5000 BP. Both may correspond to a period of forest clearance activities in more intense form, culminating in more open landscape near Sniddle Moss and in the Craven District as a whole. SM4-X clearly represents the open habitat which exists at the present day. A feature common to the upper parts of the three profiles is that there is a rise in the concentrations of indeterminable pollen, probably due to poor pollen preservation.

Recent works based on multiple core approaches have shown spatial variability in past vegetation and pollen

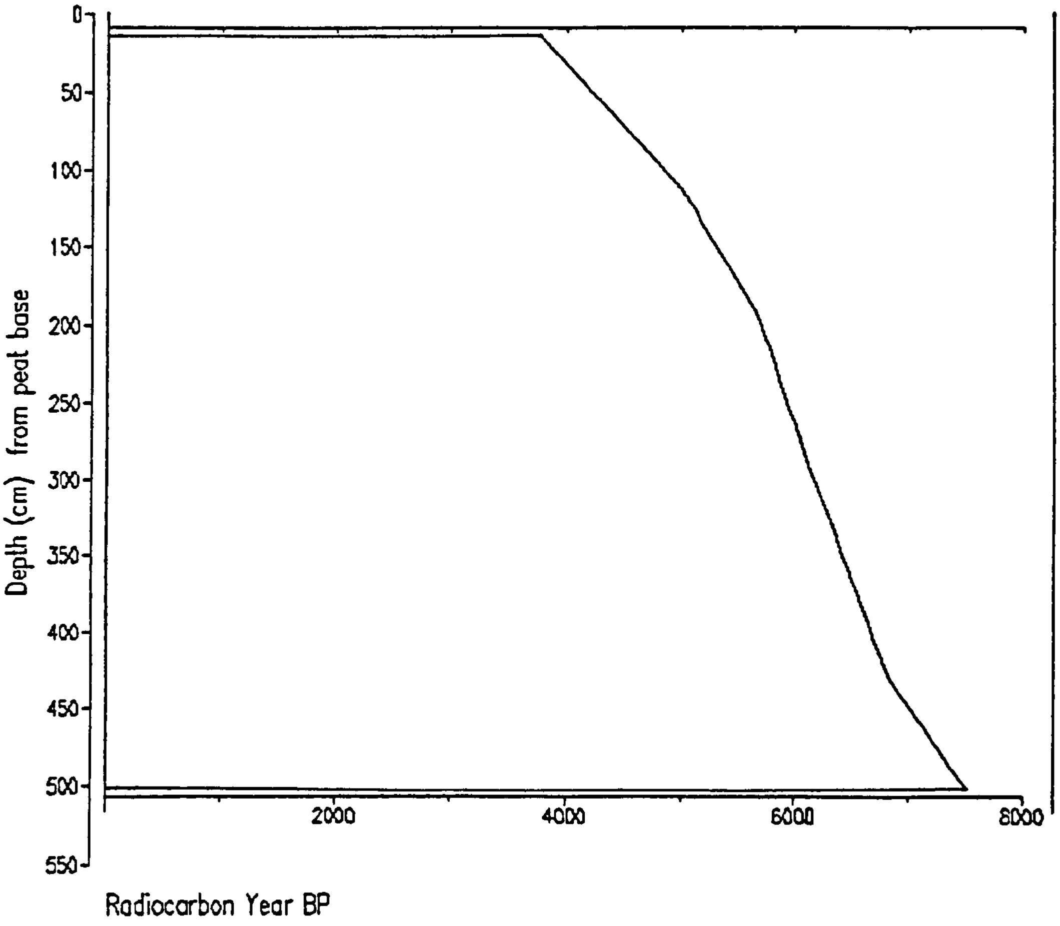


Figure 5.5.2. Graph of peat growth rates for the Sniddle Moss 9 diagram (between 14-502 cm).

dispersion pathways in a single basin (e.g. Edwards & Thompson, 1984; Whittington et al., 1991a). A synthesis of the pollen histories of the studied Flandrian sequences of Sniddle Moss profiles also reveals local variations in the sediment record and pollen catchment area processes. Although SM4a is adjacent to SM4, it displays a marked difference - zone SM4a-II whose correspondence is not identified in the profile of SM4 - possibly related to variations in peat growth affected by the micro-topography of the mire surface (cf. Turner et al., 1989). The pollen record of the Atlantic Period, in particular, seems to be missing at SM4 and SM4a near the margin of the basin. The phenomenon of the occurrence of hiatuses in the deposits of the Atlantic Period is widespread in northern Europe (Rybnicek & Rybnickova, 1987; Bartley & Morgan, 1990). The preservation of such deposits at SM9 suggest that erosion was not so severe in the centre of the mire during the Atlantic Period.

5.6. A reconstruction of the local vegetational succession at Sniddle Moss

Four main phases of the hydroseral succession may be distinguished for the Sniddle Moss site as follows:

1. A lake with fringing swamp phase,
2. A rich (eutrophic) fen/swamp phase,
3. A mesotrophic fen/swamp carr phase,
4. A bog-heathland phase.

1. A lake with fringing swamp phase

SM4 zones from SM4-I to SM4-V
SM9 the upper lake clay (642-548 cm)

The local deposition of a grey clay (SM4) indicates that there was a lake, on the spot, which originated in a deep basin after the retreat stages of a glaciation. Abundant desmids, in particular, imply meso- to eutrophic conditions (cf. Coesel, 1979a and b). Frequent moss fragments in the basal clay suggest that immature and base-rich soil profiles were colonized by bryophytes, amongst which *Homalothecium sericeum* and *H. nitens* were present. It appears that erosion was severe and minerogenic material along with moss fragments washed into the lake from the unstable slopes surrounding it. Macrophyte vegetation in the immediate area must have been very sparse, with grasses and other herbs of open areas (such as Chenopodiaceae, *Helianthemum*, *Rumex/Oxyria Geranium*, *Saxifraga granulata*-type and *S. oppositifolia*-type), and receiving *Pinus* pollen through long-distance transport. The regular occurrence of *Artemisia* pollen completes the well known palynological reflection of the vegetation of the early Lateglacial period (cf. Iversen, 1954). Scattered grains of *Filipendula* and *Ilex* must have been secondary pollen from the older deposits over which the ice had passed.

Organic material then began to accumulate in the lake, suggesting a distinct change in environmental conditions. This was accompanied by a gradual diversification in the flora. *Potamogeton* (a maximum of 20% of TLP) and algae(*) (including Characeae) in abundance imply a rich aquatic vegetation with *Myriophyllum alterniflorum* and *Typha angustifolia/Sparganium*. The rise in Cyperaceae pollen and *Equisetum* spores may point to the beginning of the hydroseral invasion of the open water by the lake-side vegetation. *Galium*-type, Ranunculaceae and *Thalictrum* were also present in this sedge-dominated stand. Away from the lake itself, the ground seems to have remained sparsely vegetated. *Sphagna* (spores) tolerant of basic conditions may have occurred sporadically on damper parts of the locality. *Salix*

(*) *Pediastrum* and *Tetraedron* were also recorded but they have not been plotted in pollen diagrams due to their scarcity.

(probably dwarf willow) may have become important in the pioneer shrub-heath vegetation. A fruit of *Betula* sp. found at 302 cm indicates the local presence of the taxon at this time. Unfortunately, specific identification is very difficult because of its poor preservation.

The clay (300-296 cm) overlying the organic mud in the profile of SM4 does not show any marked change in the local plant life. There is no strong evidence pointing to the presence of retrogressive environmental factors such as any climatic deterioration (see also discussion).

The lithology of local pollen assemblage zones SM4-III and SM4-IV is chiefly a highly calcareous organic mud or marl which is often considered to be suggestive of more stable conditions in and around the lake. The macroscopic finds of *Cratoneuron commutatum* show that this calcicole species was present at this time. The occurrence of *Drepanocladus revolvens*, *Hylocomium splendens* and *Racomitrium* sp. was also ascertained. The pollen spectra illustrate that on damper parts of the site, sedges and willow carr may have expanded along with tall herbs such as *Filipendula* cf. *ulmaria*, *Caltha palustris* and *Urtica* with *Equisetum*. On drier parts a mosaic of species of base-rich areas was widespread including *Centaurea nigra*-type, *Epilobium*, *Helianthemum*, *Plantago major*/*P. media*, *Succisa* and other herbs. Female catkin scales of *Betula pubescens* at 278 cm confirm its local occurrence.

The composition of the local flora and vegetation gradually began to change. The dominance of Gramineae and *Rumex*/*Oxyria* is coupled with the deposition of mineral-rich sediments in the lake, predominantly silty organic mud with clay, which are suggestive of erosion.

In zone SM4-V and in the profile of SM9 (642-548 cm) a clay was deposited as a result of solifluction and slopewash from the surrounding land under severe climatic conditions. The onset of climatic deterioration is most likely to have led to the drastic decline of thermophilous species. Aquatic vegetation became rare, with *Menyanthes trifoliata*, *Myriophyllum alterniflorum*, *Potamogeton*-type and *P. natans*, but algae were of importance in the lake.

The sporadic occurrence of aquatic pollen during this last stage of the Lateglacial is regarded as the result of the freezing of the lake for long periods of time under extreme climatic conditions (Gray & Lowe, 1977). At almost all sampling points near the edges of the former lake *Calliergon giganteum*, *Drepanocladus exannulatus*, *D.* ? *fluitans* and *Scorpidium scorpioides* leaves first appear in the upper clay. It might be inferred that the margins of the lake were dominated by these aquatic brown mosses. Dickson (1973) records these above-mentioned taxa among the most frequently encountered species from Lateglacial sites (Godwin zones II and III) in Britain. A similar assemblage of species in Lateglacial/early Holocene deposits were also shown from other parts of Europe and North America (Vitt & Kuhry, 1992). Sedges with frequent Ranunculaceae (including *Ranunculus* Sect. *Batrachium*) and some *Salix* persisted around the lake at this time. On the ground grasses expanded more widely with a variety of taxa of open areas such as *Armeria*, *Artemisia*, *Rumex*/*Oxyria* and *Selaginella*.

2. A rich (eutrophic) fen/swamp phase

SM4 zones from SM4-VI to SM4-VIII (and SM4a; zones SM4a-I and -II)
SM9 organic mud (548-500 cm) and zone SM9-I

The deposits of this phase consisting largely of organic material are made up of fragments of a fen/swamp vegetation. The diminution of the mineral content suggests reduced erosion, probably reflecting the development of a more closed vegetation on the surrounding slopes with the onset of climatic amelioration. In this phase aquatic vegetation became rich with *Menyanthes trifoliata*, *Myriophyllum alterniflorum*, *M. spicatum*, *M. verticillatum*, *Nymphaea alba*, *Typha angustifolia*/*Sparganium*, *T. latifolia*, *Sparganium minimum*, *Potamogeton*-type, *P. natans*, *P. praelongus* and *P.* cf. *zizii*, pointing to an increased productivity in the lake. The margins of the lake supported a sedge-dominated community, including *Cladium mariscus*, Ranunculaceae and *Thalictrum minus* along with willow carr. *Caltha palustris*, *Filipendula*, *Potentilla palustris*, *Sanguisorba officinalis* and *Solanum dulcamara* may have been part of a tall herb community in damp grassland. It appears that *Betula* spp. (*B. pendula* and *B. pubescens*) and *Populus tremula* were the principal trees on the spot. Thus *Antitrichia curtipendula*, *Eurhynchium praelongum* and *Hypnum cupressiforme* agg. could have grown on the tree bases. *Amblystegium* ? *riparium*, *A. varium* and *Sphagna* (*S.* Sect. *Acutifolia* and *S.* Sect. *Cuspidata*) may have been present in damp habitats.

This phase also saw the spread of *Fontinalis antipyretica*. The stratigraphic section reveals that this aquatic species did not colonize the northern side of the lake. Only occasional leaves were recorded from SM4 and the adjacent sampling points. *Calliergon giganteum* existed in the aquatic bryoflora. *Alisma plantago-aquatica*, *Ceratophyllum demersum*, *Hippuris vulgaris*, *Nuphar*, *Potamogeton perfoliatus*, *P. pusillus* and *P. obtusifolius* joined the rich-aquatic vegetation. Algae disappeared or decreased in numbers, probably as a result of a decrease in water level through strong evaporation under warm and dry climatic conditions in the early Flandrian Period (the Boreal Period).

3. A mesotrophic fen/swamp carr phase

SM4 zones SM4-VIII and SM4-IX (and SM4a; zone SM4a-III)
SM9 zones SM9-II and SM9-III

This phase is characterized by a decline in the eutrophic aquatic plant taxa and a rise in pollen and macrofossils of monocots. There can be no doubt that the lake was gradually filled with vegetation. The appearance of *Carex diandra*, *C. echinata*, *C.* Sect. *Extensae*, *C. flava*-type, *C.* Sect. *Paniculata*, *C. vesicaria* and *Eriophorum* supports the idea that marginal communities spread towards the middle of the lake (terrestrialization) and the accumulation of organic deposits (peat formation) took place. This may have eventually resulted in the establishment of *Alnus glutinosa* and *Salix* sp., and the expansion of fen and fen carr species, such as *Angelica sylvestris*, *Caltha palustris*, *Cicuta virosa*, *Eupatorium cannabinum*, *Filipendula ulmaria*, *Frangula alnus*, *Galium palustre*, *Lycopus europaeus*, *Ranunculus* Sect. *Ranunculus*, *R. repens*, *Rumex hydrolapathum*, *Solanum dulcamara* and *Viola palustris*. *Betula* and *Populus* were still important in the tree layer. A broken nut shell belonging to *Corylus avellana* recovered at 139-141 cm (SM11) indicates the local presence of this taxon. Frequent occurrence of *Hedera* pollen suggests that this woody climber was either climbing in the wood or creeping along the ground. Woodland herbs *Ajuga reptans*, ?*Fragaria vesca*, *Stachys sylvatica* and *Rubus idaeus* would have played some role in the plant community. *Cirsium heterophyllum*/*palustre*, *Melampyrum*, *Lotus*, *Pteridium*, *Rumex crispus*, *Taraxacum officinale* and *Urtica dioica* may have occupied open parts of the local woodland. *Botrychium lunaria*-type, *Cryptogramma*, *Dryopteris*-type, *Polypodium* and the other representatives of Filicales may have occupied the field layer of the woodland. The shade-tolerant components of the moss flora survived, whereas *Fontinalis antipyretica* completely disappeared. *Calliergon giganteum* was replaced by *C. cuspidatum* in this phase. *Bryum* sp., *Bryum* sp./*Mnium* sp., *Dicranella schreberana*, *Neckera complanata*, *N. pumila*, *Dicranum scoparium*, *D. fuscescens*, *Plagiomnium affine*, *Thuidium tamariscinum* and *Zygodon viridissimus* were also found, probably growing on the tree trunks and bases.

4. A bog-heathland phase

SM4 zones SM4-IX and SM4-X
SM9 zone SM9-IV

Towards the top of the profile the occurrence of *Sphagnum papillosum* in combination with high Ericales pollen values, macroscopic remains of *Erica tetralix* and *Calluna vulgaris* and the presence of *Aulacomnium palustre*, *Glyceria fluitans*, *Juncus bulbosus*, *Montia fontana*, *Potentilla erecta* and *Ranunculus* Sect. *Flammula* illustrate oligotrophic conditions and a bog-heathland development on the site. The disappearance of aquatic species other than *Potamogeton*-type and *Menyanthes trifoliata* is likely to be due in part to the increasing acidification of the site. This last phase of hydroseral succession coincides with massive deforestation in the surrounding area reflected in the deposition of bands of clay.

6. THIEVES' MOSS (NGR SD 771736)

6.1. Description of site

Thieves' Moss (54 09' N, 2 20' W) lies at about 348 m on the north-west of Moughton Scars above Crummack Dale, on the Great Scar Limestone of the Ingleborough Massif (see Figure 1.1.).

The main basin is in an oval depression on the plateau and it is bounded to the north by a semicircle of limestone cliffs which are about 15 m high. On the southern side this limestone is well exposed, and it forms limestone pavements (Plate 6.1.1.). To-day, there are two springs collecting into a stream which crosses the bog and disappears into the limestone. The present vegetation is dominated by tussocks of *Eriophorum vaginatum* with *Calluna vulgaris*, *Erica tetralix* and many lichens in drier areas. *Eriophorum angustifolium*, *Festuca rubra*, *Juncus effusus*, *Carex echinata*, *C. panicea*, *Sphagnum papillosum*, *Aulacomnium palustre* and *Polytrichum commune* are present on damper parts of the bog.

6.2. Stratigraphy

A detailed section of Thieves' Moss constructed by Gosden (1965) shows an asymmetrical development of earlier sediments in the main basin (Figure 6.2.1.). Gosden attributed this to differences in the depth of the rock strata of each side. The two lake clays are separated by a layer of organic mud on the gentler southern slope. The upper clay is overlain by a shell marl which does not reach the extreme south of the Moss. The marl is, in turn, superseded by swamp vegetation, *Hypnum* peat, *Sphagnum* peat and mixed peat.

Plate 6.1.1. The basin of Thieves' Moss, viewed from the west showing the three coring sites.

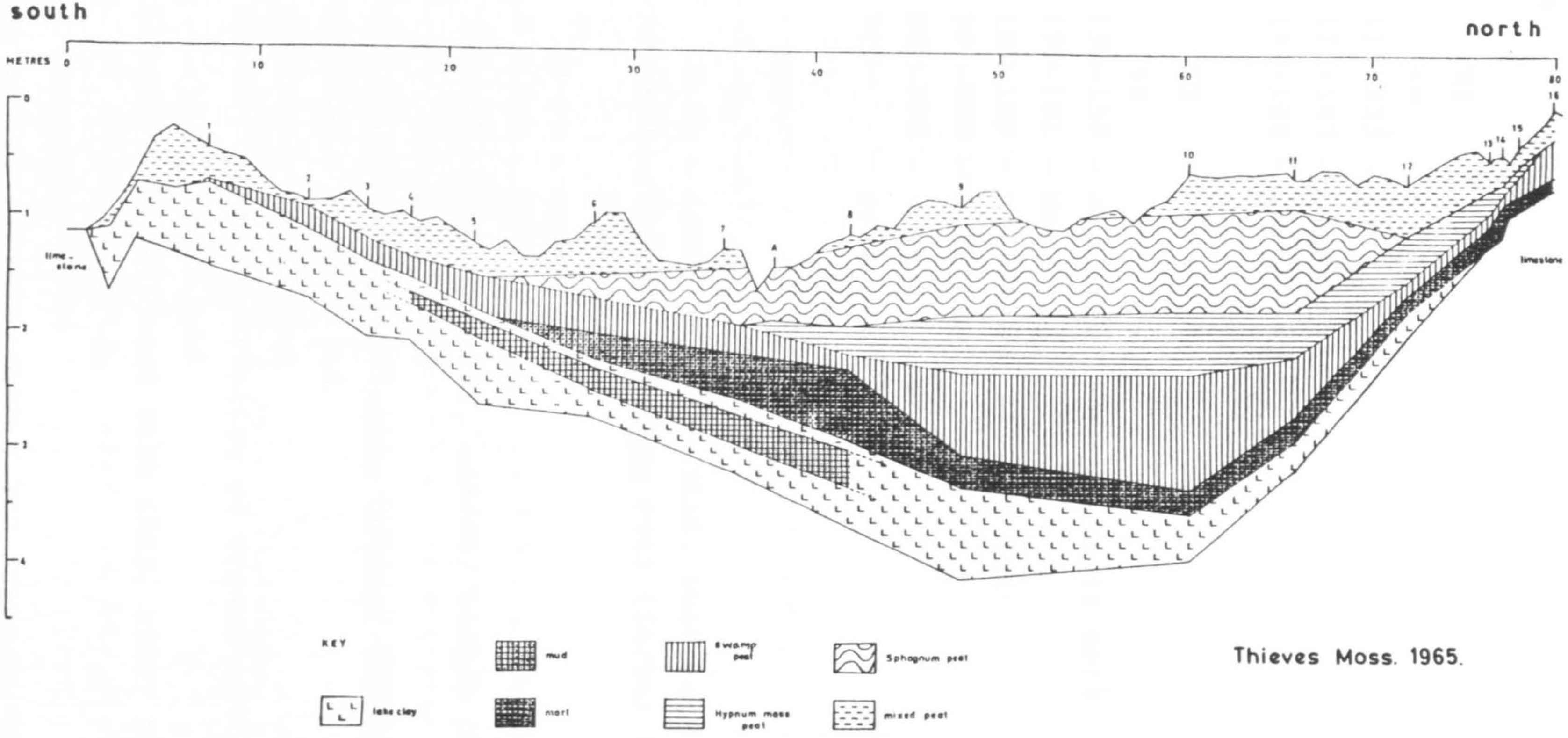


Figure 6.2.1. A section of Thieves' Moss (taken from Gosden, 1965).

Three cores extracted for the present study yielded the following:

TM1
cm
118-125 - lake clay
125-143 - organic mud
143-168 - lake clay

TM2
cm
138-150 - a gradual transition to marl
150-182 - marl
182-186 - dark-brown organic mud
186-200 - lake clay
200-215 - organic clay
215- no penetration

TM3
cm
0-26 - dark, very humified, amorphous peat
26-79 - lighter *Sphagnum* peat (darker between 71-79 cm)
79-83 - wood peat
83-93 - fibrous peat
93-175 - light, brown, coarse, swampy fibrous peat
175-185 - wood peat (mossy between 183-185 cm)
185-220 - organic mud
220-250 - shell marl
250-277 - the alternation of organic mud and shell marl
277-295 - organic mud with clay, silty from 281-291 cm

The surface relief of this raised bog suggests that there has been erosion, leaving older peat deposits exposed at the surface. The centre has been dissected considerably.

6.3. Macroscopic fossils

The macrofossil assemblages from three sampling points are shown in Table 6.3.1.

6.4. Microscopic fossils and local pollen assemblage zones

Microscopic fossils are presented in Diagrams 6.4.1., 6.4.2., 6.4.3., 6.4.4., 6.4.5., 6.4.6. and Appendix 6, 7 and 8. Local pollen assemblage zones are given below:

TM1

Samples from TM1 contained pollen grains of deciduous trees (principally Corylus) which are sometimes in considerable quantities. Since their presence must be the result of contamination, the values of these tree pollen grains are not included in the description of LPAZ. This means also that the pollen spectra cannot be regarded as completely reliable.

TM1-I Pinus-Betula-Gramineae LPAZ

(151-149 cm)

Total land pollen concentration is low. In the percentage diagram Pinus, Betula and Gramineae are the main contributors, but they present low concentration values, as do other taxa. Artemisia and Rumex/Oxyria pollen is well-represented.

The terminal boundary: Betula pollen increases.

TM1-II (149-120 cm)

This zone is divided into subzones, on the basis of the Betula and Juniperus curves.

TM1-IIa Betula-Gramineae-Cyperaceae **LPAZ**

(149-145 cm)

Total land pollen concentrations are higher than in the preceding zone. Betula pollen is the dominant type. Gramineae and Cyperaceae assume an importance. Artemisia and Rumex/Oxyria pollen falls, whereas Filipendula pollen rises. Hippophaë appears at the top for the first time.

The terminal boundary: Juniperus pollen rises and Betula pollen shows a further increase.

TM1-IIb Betula-Juniperus-Gramineae-Cyperaceae **LPAZ**

(145-134 cm)

Juniperus has higher pollen values than in the preceding subzone, reaching its maximum value of c.18% before falling at the top. Hippophaë is well-represented, comprising up to 1.5% of TLP.

The terminal boundary: Juniperus pollen declines.

TM1-IIc Betula-Cyperaceae-Gramineae **LPAZ**

(134-124 cm)

This subzone is characterized by high Betula pollen values, and by lower values of Juniperus pollen than in the preceding subzone.

The terminal boundary: Betula pollen falls.

TM1-IId Betula-Gramineae-Cyperaceae **LPAZ**

(124-120 cm)

Total land pollen concentrations exhibit an initial decrease, before rising at the top of this subzone. Betula has lower values than in subzone TM1-IIc. There is an increase in the abundance of herbaceous taxa such as Artemisia, Rumex/Oxyria and Thalictrum. Selaginella becomes significant.

TM2

TM2-I Betula-Gramineae-Cyperaceae **LPAZ**

(214-206 cm)

Zone TM2-I is marked by high NAP values, up to c.58% of TLP. Betula is the main tree pollen type. Hippophaë forms a continuous curve, with values of 0.4-1.1%. Thalictrum pollen is well-represented, reaching a maximum value of 7%.

The terminal boundary: Juniperus pollen declines.

TM2-II (206-182 cm)

Two subzones are defined, with respect to the Betula curve.

TM2-IIa Betula-Cyperaceae-Gramineae-Artemisia **LPAZ**

(206-188 cm)

Almost all taxa have lower pollen concentrations than in zone TM2-I, with the exception of Artemisia. In the percentage diagram, Betula is still the dominant type. The contribution of herbaceous pollen continues to rise, with Cyperaceae, Gramineae and Artemisia predominant. Hippophaë pollen occurs sporadically. Caryophyllaceae and Selaginella become significant, though at low values.

The terminal boundary: Betula pollen falls.

TM2-IIb Gramineae-Cyperaceae-Betula-Rumex/Oxyria **LPAZ**

(188-182 cm)

NAP shows a further rise and becomes more important than in the preceding subzone while Betula declines. Rumex/Oxyria and Ranunculaceae pollen increases before falling at the top of the subzone where Filipendula peaks and Empetrum rises slightly.

The terminal boundary: Betula pollen increases.

TM2-III (182-142 cm)

This zone is divided into two subzones on the basis of the Juniperus curve.

TM2-IIIa Betula-Juniperus **LPAZ**

(182-162 cm)

There is a rise in total pollen concentrations. Betula and Juniperus pollen dominates this zone as NAP exhibits a gradual fall throughout. Filipendula is well-represented

The terminal boundary: Juniperus pollen decreases.

TM2-IIIb Betula-Gramineae **LPAZ**

(164-142 cm)

NAP falls to 11.6% of TLP for the first time. Corylus and Quercus first appear in this subzone. Betula pollen is the main type (up to c.73%) though it decreases towards the top, whilst Corylus values progressively rise. Juniperus pollen declines by mid-zone and disappears completely.

The terminal boundary: Corylus pollen rises.

TM2-IV Corylus-Betula **LPAZ** (Corylus Phase)

(142-126 cm)

Total pollen concentrations of this zone are higher than in the preceding subzone. The expansion of Corylus which began in the underlying zone continues and reaches 58% of TLP. Betula declines steeply towards the top.

TM3

TM3-I Corylus-Betula **LPAZ** (Corylus Phase)

(218-182 cm)

Corylus is the dominant type though it decreases towards the top of the zone. Filicales peaks at the end.

The terminal boundary: Pinus pollen rises.

TM3-II (182-50 cm)

This zone is divided into two subzones, mainly on the basis of *Pinus* pollen values.

TM3-IIa *Corylus*-*Pinus*-Cyperaceae **LPAZ**

(182-106 cm)

This subzone is characterized by a fall in total pollen concentrations. *Corylus* percentages decline, whilst *Pinus* rises. After an initial increase Cyperaceae pollen exhibits fluctuations as does *Equisetum*.

The terminal boundary: *Pinus* pollen shows a further rise.

TM3-IIb *Pinus*-*Corylus* **LPAZ**

(106-50 cm)

There is a considerable decrease in total land pollen concentrations. *Pinus* is the major tree pollen. Cyperaceae peaks nearly in the mid-zone, while Ericales and *Sphagnum* become significant towards the end of this zone. Filicales spores assume an importance.

The terminal boundary: *Pinus* pollen declines.

TM3-III (50-2 cm)

This zone is characterized by an increase in total land pollen concentrations. Two subzones are defined, on the basis of the Ericales curve.

TM3-IIIa *Corylus*-Ericales **LPAZ**

(50-6 cm)

Pinus pollen shows an abrupt decline. *Corylus* pollen values rise, reaching a maximum value of c. 69% of TLP, but then its values fall towards the top of the zone as do those of non-herbaceous taxa, e.g. *Alnus*, *Ulmus* and *Quercus*. Ericales becomes more significant, almost throughout, while Gramineae and Cyperaceae start to increase towards the end.

The terminal boundary: Ericales pollen rises.

TM3-IIIb Ericales-Corylus **LPAZ**

(6-2 cm)

A further rise in total land pollen concentrations and Ericales values marks this subzone. Corylus pollen is still the dominant non-herbaceous type, whereas NAP increases considerably, contributing up to c. 54% of TLP.

6.5. A tentative correlation of the local pollen assemblage zones for the three cores from Thieves' Moss

It is suggested that the three cores from Thieves' Moss provide almost a continuous pollen record from the Lateglacial Period to the beginning of the Flandrian 2 (Figure 6.5.1.). Even though the profile of TM1 suffers from contamination, it appears that its uppermost (sub)zone TM1-IId has similar features with the lowermost zones of TM2, TM2-I and TM2-IIa. It is, however, difficult to make a direct comparison between TM1-IId and either of TM2-I and TM2-IIa because TM1-IId presents a mixture of pollen characters of the main types from each zone. The possible problems arising from contamination at TM1 and the absence of radiocarbon dates also influence confident correlation. But, it appears that TM1-IId has some features of the Younger Dryas Period more similar to those in TM2-IIa than in TM2-I - lower Juniperus pollen quantities and more significant Pinus, Caryophyllaceae and Selaginella.

Another correlation has been made between TM2-IV and TM3-I. There seem to be similar patterns in the pollen curves of the zones, but higher pollen values of the major tree taxa - particularly Betula, Quercus and Ulmus - at TM3 than those at TM2 make a direct comparison difficult. Gradually increasing values of Quercus and Ulmus in TM2-IV may indicate the beginning of the

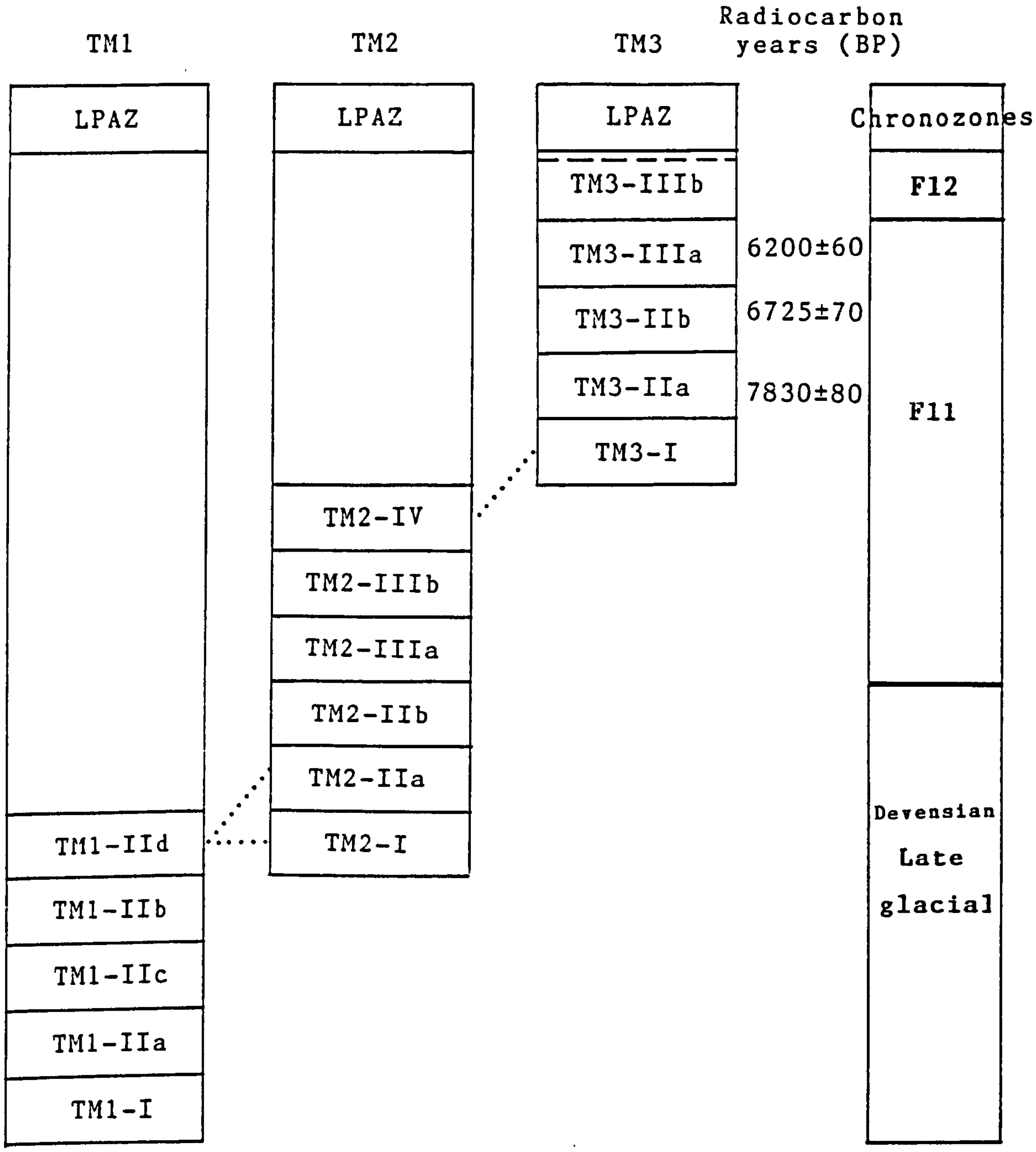


Figure 6.5.1. A tentative correlation of the local pollen assemblage zones from Thieves' Moss and the (supposed) equivalent Flandrian chronozones. (......) similarity; (------) end of deposition

establishment of these thermophilous taxa in the area in the early stages of Flandrian 1. TM3-I might, on the other hand, reflect a further expansion of deciduous trees, corresponding to a later stage of Fl1.

6.6. A reconstruction of the local vegetational succession at Thieves' Moss

Four main phases of development can be distinguished for the Thieves' Moss site:

1. A lake with fringing swamp,
2. A fen/swamp phase,
3. A raised *Sphagnum* bog phase,
4. A heathland phase.

1. A lake with fringing swamp

Zones from TM1-I to TM2-IV (and TM3-I)

It appears that a lake occupied the site in the early stages of development, probably at the close of the Late-Devensian Glaciation. There is no organic matter preservation in the profile of sampling point TM1 below 151 cm. However, towards the upper part of the basal clay organic content gradually increases. In this phase a community of aquatic plants inhabited the lake, including microscopic algae, *Myriophyllum alterniflorum*, *M. spicatum*, *Nymphaea*, *Potamogeton*-type, *Typha angustifolia*/*Sparganium* and *T. latifolia*-type. The edge of the basin was probably occupied by a sedge stand with *Salix*, *Filipendula*, Ranunculaceae, *Thalictrum*, *Galium*-type and *Urtica*. If abundant leaves of *Sphagnum* are not contamination it might be inferred that it was present on damper parts of the spot, but contamination is more likely. The dry ground supported characteristic taxa of the Lateglacial such as *Empetrum*, *Artemisia*, *Saussurea*-type, *Helianthemum*, *Rumex*/*Oxyria* and *Saxifraga* spp. The local vegetation seems to have been 'open' in nature at this time.

As a more dense vegetation cover developed in the surrounding area with the onset of a further climatic improvement, an organic material (organic mud) accumulated in the Thieves' Moss lake. The earliest colonizers of the locality still played an important role, e.g. *Filipendula* and *Thalictrum*. Characeae oospores appear at this time. *Calliergon giganteum* may have been present in the moss layer of the swamp.

The following layer, lake clay, may indicate temporary retardation of the hydroseral development under cooler climatic conditions. The main components of the vegetation remained but thermophilous taxa retreated. Grasses, *Artemisia*, Caryophyllaceae, *Rumex*/*Oxyria*, *Selaginella* and *Racomitrium* sp. became important. A nut of *Carex* ? *lepidocarpa* was recorded. The finds of moss fragments in the profile of TM2 may show that unstable slopes around the lake were invaded by mosses.

A return to warmer climatic conditions resulted in organic material (organic mud and marl) deposition and expansion of the thermophilous taxa on the site. A seed of *Arenaria norvegica* recovered at 186 cm (TM2) is of special interest. To-day two subspecies found in the British Isles are rare and local plants of base-rich soils, *A. norvegica* ssp. *anglica* being endemic to the limestone of upper Ribblesdale (Clapham, Tutin & Moore, 1989). The local occurrence of *Betula* was ascertained by the finds of female catkin scales and fruits at several levels of TM3. *Sphagna* (*Sphagnum* Sect. *Acutifolia* and *S*. Sect. *Cuspidata*) were represented by occasional leaves and spores. Their peat-forming function was probably not very important at this time. The presence of *Polytrichum* sp. was also recorded.

2. A fen/swamp phase

Zone TM3-II (185-79 cm)

In the second phase the mire saw a lowering of the ground watertable as a result of terrestralization. High percentages of Cyperaceae pollen and Equisetum spores in the pollen spectrum and co-occurrence of macrofossil finds of Carex sp., C. flava-type, C. Sect. Paniculatae and Phragmites coincide with telmatic peat accumulation. This was accompanied by the spread of birch (including Betula pubescens) and the gradual establishment of Alnus glutinosa on the mire surface. The members of the aquatic community declined (except Potamogeton), but brown mosses of wet areas (Calliergon giganteum, Drepanocladus revolvens, Homalothecium cf. nitens and Scorpidium scorpioides) could find suitable places, possibly by the shallower water. Bryum sp. and representatives of Brachytheciaceae probably took some part in the local woodland.

3. A raised Sphagnum bog phase

Zones TM3-II and TM3-III

The third phase was characterized by a rise in spores and branch leaves of Sphagna, in combination with a gradual rise in ericaceous pollen. As can be seen from the section of the site (Figure 6.2.1.) a raised bog developed on the surface. It is likely that a considerable increase of precipitation and humidity with the onset of the Atlantic Period introduced suitable conditions for the expansion of Sphagna (which occurred regularly in earlier phases). The surface of the mire rose considerably, due to the intensive growth of the deposit. Thus the vegetation was isolated from mineral soil water, which caused a lower nutrient status in the mire (acidification) and the disappearance of aquatic mosses of rich-fens.

4. A heathland phase

Zone TM3-III (26-0 cm)

The surface of the deposit reveals the development of a heathland with abundant Ericales. Sphagna maintain themselves, but in lower quantities. It might be inferred that a decrease in precipitation at the end of the Atlantic Period resulted in a drier bog surface which stimulated the spread of low heath shrubs (predominantly *Calluna vulgaris*). *Juncus* sp. also entered the community.

As mentioned before, the profile and the studied pollen sequence show that erosion of parts of the upper peat layer have taken place.

7. SUNSET HOLE (NGR SD 745759)

7.1. Description of site

The sampling site is approximately 0.3 km east of Sunset Hole (54 11' N, 2 23' W) at an altitude of about 393 m (see Figure 1.1.). It is an eroded raised bog lying on a drift-covered shelf on the lower slopes of the Ingleborough Hill. The southern end of the site overlooks the limestone pavements. A stream runs west-east through the bog. The present vegetation consists of *Sphagnum* on wetter parts, *Eriophorum vaginatum*, *Erica tetralix* *Trichophorum cespitosum* and *Vaccinium myrtillus* on dry parts and *Deschampsia flexuosa* in the very dry areas of the site. The peat surface has been dissected by erosion channels.

7.2. Stratigraphy

The stratigraphy, taken from a monolith, is as follows:

cm
0-30 - fine, highly humified *Eriophorum vaginatum*-*Calluna*-*Sphagnum* peat
30-50 - fibrous, lighter, humified *Eriophorum*-*Calluna*-*Sphagnum* peat with *Hypnum cupressiforme* agg.
50-210 - *Eriophorum vaginatum* peat with remains of *Sphagnum*, *Calluna* and *Aulacomnium palustre*, abundant charcoal from 145 to 160 cm. Wood remains appear at 95 cm
210-275 - wood peat with fruits of *Betula* sp.
275-278 - fine, silty material
278- solid material

7.3. Macroscopic fossils

The macroscopic fossils from one sampling point at Sunset Hole have already been presented above, in connection with the changes in the stratigraphic sequence.

7.4. Microscopic fossils and local pollen assemblage zones

The pollen assemblages are shown in Diagrams 7.4.1., 7.4.2., 7.4.3. and 7.4.4., while some rare pollen and spore types are given in Appendix 9. Local pollen assemblage zones are as follows:

SH-I (277-250 cm)

The Pinus curve provides a basis for division of this zone - subzones SH-Ia and SH-Ib.

SH-Ia Corylus-Pinus **LPAZ**

(277-260 cm)

Corylus and Pinus are the main types in this subzone. Alnus, Tilia and Fraxinus are present at low values. High quantities of Filicales spores occur.

The terminal boundary: Pinus pollen falls

SH-Ib Corylus-Betula **LPAZ**

(260-250 cm)

A further rise in Corylus and abrupt decline in Pinus mark this zone. Betula pollen has higher values than in the preceding subzone. Alnus pollen increases steeply.

The terminal boundary: Alnus pollen rises.

SH-II Alnus-Corylus **LPAZ**

(250-210 cm)

Alnus pollen assumes a great importance, reaching over

50% of TLP. Corylus pollen is still significant, but it has lower values than in SH-I.

The terminal boundary: Alnus pollen falls.

SH-III Alnus-Corylus-Betula **LPAZ**

(210-149.5 cm)

Alnus pollen has lower values than in the preceding zone. Betula becomes important. Corylus pollen remains almost constant. Ulmus pollen rises up to 5% of TLP. Tilia is more frequent. Melampyrum, Filipendula and Ericales become significant towards the middle of the zone where Fraxinus pollen reappears. As Ericales declines, Gramineae, Cyperaceae and Sphagnum become important. Towards the top of this zone, Plantago spp. pollen first occurs.

The terminal boundary: The first elm decline is defined.

SH-IV Corylus-Ericales **LPAZ**

(149.5-10 cm)

The dotted lines in this zone (Diagrams 7.4.3 and 7.4.4.) mark some important changes observed in the elm curve and allow one to define five main phases.

Phase 1. A first elm decline (149.5-144 cm)

The first classical Ulmus decline is defined at 149.5 cm where elm pollen is at c. 0.8%. There is a rise in TLP concentrations at the elm decline level. Corylus is the dominant type. Tilia pollen is frequent. Gramineae peaks in the middle while Cyperaceae and Ericales show slight rise. Sphagnum spores are still abundant. Plantago spp. pollen is significant, though at low values.

Phase 2. (143-137 cm)

Elm pollen falls considerably in this phase and it is absent at 140 cm. Corylus and Gramineae peak in the middle as Ericales falls. The last taxon along with Sphagnum rises towards the top.

Phase 3. A partial recovery of elm (136-131 cm)

Elm pollen rises from 0.4% at 137 cm to 1.2% at 136 cm. Corylus has lower percentage values than in the previous phase. Alnus and Betula pollen falls as Ericales increases considerably.

Phase 4. (130-120 cm)

Elm pollen shows a further rise in much of this phase. Corylus becomes important again. Alnus and Betula pollen values increase as Ericales declines.

Phase 5. (118.5-10 cm)

Elm pollen rises considerably in the beginning and then it fluctuates. Gramineae, Cyperaceae and Ericales pollen also fluctuates; the last two taxa assume greater importance. Corylus is predominant, along with Alnus. Fraxinus pollen rises up to 3%. Tilia pollen occurs regularly. Non-arboreal pollen increases towards the top.

The terminal boundary: Ericales pollen rises.

SH-V Ericales-Corylus **LPAZ**

(10-5 cm)

There is a marked rise in total land pollen concentrations. Ericales pollen dominates this zone. Arboreal pollen is less significant.

7.5. A reconstruction of the local vegetational succession at Sunset Hole

The stratigraphy and pollen spectra suggest two main phases of development:

1. A fen-carr phase,
2. An *Eriophorum*-*Calluna*-*Sphagnum* bog phase.

1. A fen-carr phase

Zones SH-I and SH-II

High *Corylus* and *Pinus* pollen percentages of zone SH-I may indicate that peat accumulation started in the early stages of the Flandrian Period. Swales (1987) reports an ancient radiocarbon date, 9400±100 BP, for the basal peat of Sunset Hole. She adds that the true age should lie between 8730 and 7450 BP, considering the conventional values for the age of the rational rise in the *Corylus* curve obtained from several sites in north-west England. The presence of *Betula* fruits and *Salix* wood fragments in the wood peat together with pollen counts show that two taxa were growing on the spot. *Corylus* may have been present locally or near the sampling site. The pollen spectra suggest that there were openings in the local woodland or scrub with Cyperaceae, Gramineae, *Filipendula*, *Melampyrum*, *Urtica*, Chenopodiaceae, *Lycopodium*, *Pteridium* and other light-demanding taxa. High percentages of Filicales spores indicate the importance of ferns as an undergrowth in the carr.

Halfway through the wood peat in the profile (zone SH-II) it appears that *Alnus glutinosa* spread into the area under wetter conditions. At this time a more closed tree canopy (including *Betula*) was established in the locality.

2. An *Eriophorum*-*Calluna*-*Sphagnum* bog phase

Zones SH-III, SH-IV and SH-V

The upper boundary of the wood peat coincides with a reduction in total land pollen concentrations and the beginning of the deposition of *Eriophorum vaginatum* peat, along with *Calluna*, *Sphagnum* and *Aulacomnium palustre* remains. An increased accumulation of organic matter from the *Eriophorum*-dominated vegetation may have resulted in faster rates of sedimentation leading to the dilution of pollen grains in the deposit. This was accompanied by a decline in tree pollen and a rise in herbaceous pollen. Almost complementary swings in the Ericales (*Calluna*) and Cyperaceae and Gramineae curves which are repeated several times throughout zones SH-III and -IV could be explained by local changes on the bog surface (Conway, 1954).

The first peak in Ericales pollen is coupled with an increase in *Filipendula* and *Melampyrum* pollen and the appearance of open ground taxa such as *Artemisia*, *Geranium*, *Plantago* sp., *Teucrium*, *Trifolium montanum*-type, *Vicia*-type and *V. cracca*-type, pointing to the expansion of a heath and an opening up of the carr in the immediate area.

Aquatic pollen is not very well presented but scattered grains of *Hydrocotyle*, *Myriophyllum spicatum* and *Potamogeton*-type show that shallow pools of the site supported these taxa very occasionally.

Wood remains disappear above 95 cm, suggesting the removal of the remaining elements of local carr, probably due, in part, to an increased acidity on the site.

Higher up the profile *Hypnum cupressiforme* agg. in abundance between 30-50 cm indicates its association with ericaceous plants at this time. From 50 cm to the top, *Eriophorum vaginatum* is still the principal component of the deposit and Cyperaceae pollen rises considerably. However, there is an increase in remains of *Calluna* and *Sphagnum*. It can be inferred that they became more important in the bog development.

8. A RECONSTRUCTION OF THE REGIONAL VEGETATIONAL SUCCESSION AND ENVIRONMENT

8.1. Lateglacial

The lowermost parts of the section from Sniddle Moss 4 and Thieves' Moss 2, and the upper part of the observed sequence of Thieves' Moss 1 appear to provide some data on flora and vegetation during the Lateglacial Period. It is believed that the Thieves' Moss 1 pollen diagram should be viewed with caution because as mentioned elsewhere, the samples from this site suffer from contamination. Therefore, the interpretation and reconstruction of the regional vegetational development and environment during the supposed early stages of the Lateglacial Period are chiefly based on the Sniddle Moss 4 data. The studied sequence of Thieves' Moss 2 is taken into consideration for the assumed later stages of this period and it is tentatively correlated with SM4 (Figure 8.1.1.). Five main phases of the regional vegetational succession are distinguished and the inferred vegetation is summarized in Table 8.1.1.

PHASE 1. Very open vegetation

Since much of the basal clay of Thieves' Moss 1 lacks any organic material (between 168 and 152 cm) it is assumed that it may reflect a cold period prior to establishment of a vegetation cover after deglaciation. In zones Sniddle Moss SM4-I and Thieves' Moss TM1-I macro- and microfossils are found. Both have pollen at low densities and seem to record the deposition of clays in a very open, sparsely vegetated environment. They may therefore be of a later age than the sterile sediments of TM1. The presence of pollen of the oceanic Armeria maritima at SM4 indicates that the mean January temperature was not below $-8^{o}C$ (Iversen, 1954). In damper areas mosses become dominant while in drier areas

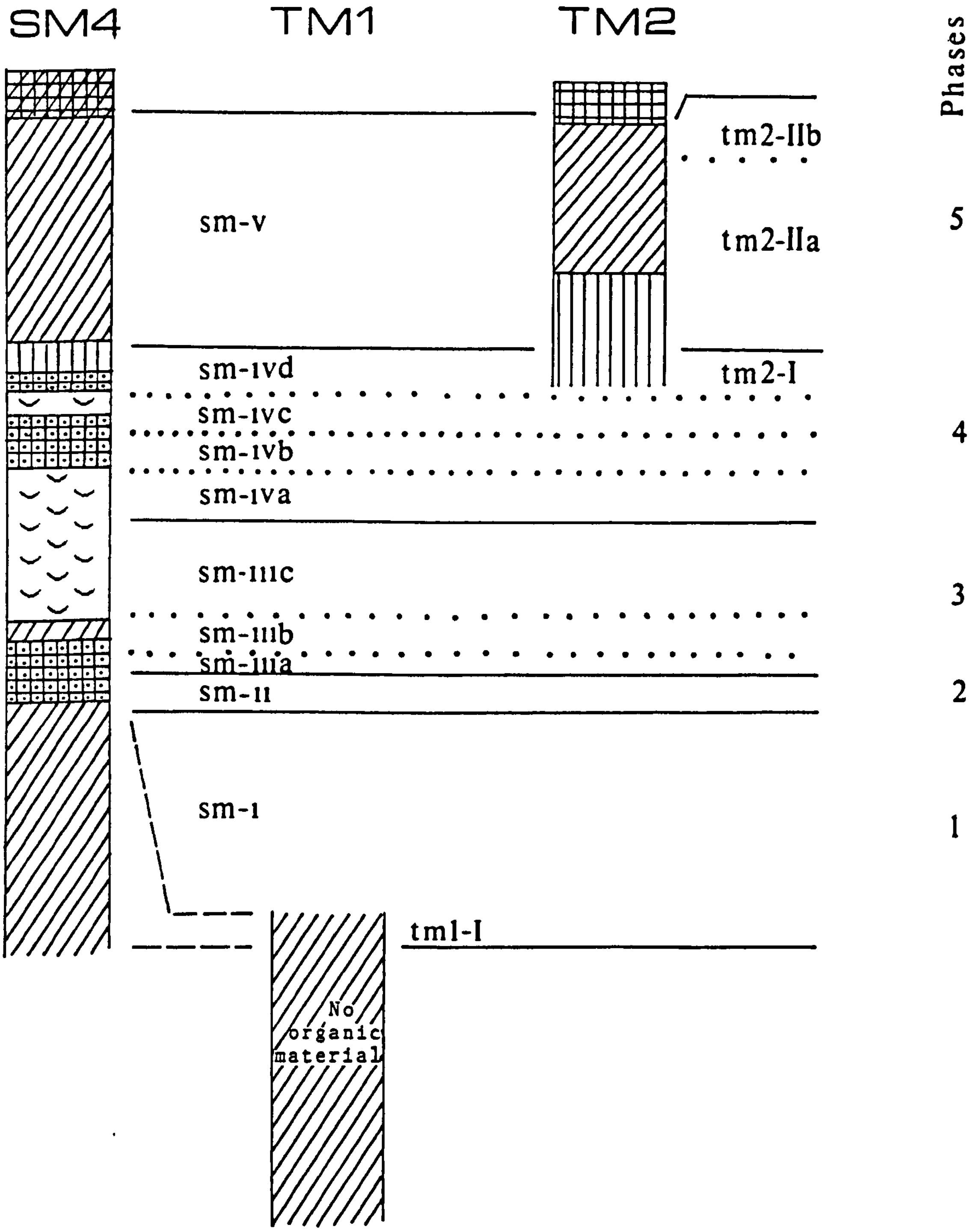


Figure 8.1.1. Comparability of the local pollen assemblage zones and sediment stratigraphies for Sniddle Moss 4 and Thieves' Moss 1 and 2.

Table 8.1.1. Vegetational reconstruction of the Lateglacial Period for the Ingleborough Region on the observed pollen stratigraphy of Sniddle Moss (and Thieves' Moss).

SNIDDLE MOSS LPAZ	THIEVES' MOSS LPAZ	PHASES		INFERRED VEGETATION
SM4-V	TM2-IIb TM2-IIa	5		Open grassland with abundant heliophytes
SM4-IV	TM2-I	4	BETULA	Open woodland with tall herbs and increasing disturbed-soil species
				Open woodland with tall herbs
				Open woodland
				(Open) birch woodland
SM4-III		3	JUNIPERUS	Partially closed grassland
				Open grassland
				Open grassland with juniper and birch
SM4-II		2		Open grassland (herb rich grassland)
SM4-I		1		Very open vegetation
	TM1 (168-152cm)			No organic material

heliophytes began to assume importance. At this time, deglaciated raw soils were rich in lime and slope instability was common.

Very high percentages of particular taxa (e.g. Pinus and Gramineae) are certainly the result of statistical artefacts due to very low pollen deposition as seen in the concentration diagram. Pennington (1970) stresses the fact that Pinus pollen has been shown to be over-represented in many deposits of periods where local pollen was sparse. Bartley (1967) reports the presence of Pinus pollen grains from the surface samples of Arctic Quebec, in an area some 885 km north of the forest. Where local pollen production is low, as on ridge tops, the proportion of coniferous pollen rises up to 16.6% of total pollen. The low concentration values for Pinus in zones SM4-I and TM1-I, in particular, indicate that this profilic pollen producer cannot have been contributing materially to the regional vegetation and its grains were merely the product of long-distance transport. Both tree and dwarf birch (the majority of Betula pollen grains belong to tree birches) may have been present, but very sparse, probably in sheltered localities. Juniperus and Empetrum pollen can imply areas of a pioneer shrub-heath, perhaps including dwarf birch and dwarf willow. The pollen of Ephedra types (E. distachya and E. ? fragilis)is likely to have been derived from long-distance dispersal from the south, as shown by Birks (1973) at the present day.

PHASE 2. Open grassland (a transitional phase)

In the beginning of SM4-II a rise in total pollen concentration values and organic content of the lake sediment suggest an increase in biomass and productivity of the ecosystem which resulted in soil humus accumulation. The vegetation represented by this zone with grasses, sedges, Salix (probably dwarf willow) and Rumex/Oxyria pollen prominent was evidently open. Dwarf willow in combination with Saxifraga types points to a light but never heavy snow cover during the winter (Kolstrup, 1980). This may mean that the climate was a limiting factor in this early phase of the regional vegetational succession. However, an increase in the productivity of aquatic vegetation with Potamogeton might indicate that the climate was not severely limiting. The pollen spectra, in fact, seem to represent a transitional phase in vegetation development and soil maturation, involving a gradual establishment of juniper-dominated scrub.

PHASE 3. Interrupted Juniperus phase

The beginning of this succeeding phase (SM4-IIIa) records an initial development of juniper, along with a rise in birch. But herbaceous taxa, predominantly grasses, appear to have retained their importance. Salix and Rumex/Oxyria were present, though there is a marked decline in the latter. It is probable that the initial development of juniper was interrupted by a climatic recession during subzone SM4-IIIb. A drop in juniper pollen is accompanied by a clay band along with increases in open- and disturbed-ground taxa including Rumex/Oxyria, Artemisia, Helianthemum and Thalictrum. The reduction in total land pollen concentration values is marked, due probably to a combination of reduced local pollen production and increased sedimentation rate. It is difficult to explain the rise in Betula pollen at the time of the Juniperus minimum. Betula nana perhaps comprises a reasonable proportion of birch pollen. But this question will remain uncertain unless dwarf birch pollen could be separated quantitatively.

Pollen changes do not indicate major changes in vegetation (both local and regional) but the presence of clay and of taxa of open-ground suggest a change in vegetation which allowed the erosion of mineral soils, i.e. a more open vegetation with perhaps less scrub and grass.

Although the succeeding subzone SM4-IIIc also has abundant grass pollen, its contrasting pollen flora and sediment type with those of subzone SM4-IIIb provide strong evidence for ecological changes. After a temporary decline, juniper is likely to have colonized the landscape. Hippophaë and Empetrum also played a role in the scrub, the latter being less significant. As the abundance of shrubs intolerant of shade demonstrates an open landscape with some trees, so the presence of many light-demanding herbs shows that the shrubs did not form a complete cover. It seems that the climate during this subzone became more favourable for thermophilous juniper and Hippophaë than in SM4-IIIa and SM4-IIIb. According to Iversen (1954) these typical heliophytes of pioneer woodlands demand a minimum July temperature above 10°C. A rise in juniper and Hippophaë also indicate the presence of the tree-line and the expansion of woodlands in the following phase when tree birches spread over much of the region.

PHASE 4. Betula phase

Zone SM4-IV throughout demonstrates great fluctuations in the birch curve along with the curves for other major taxa. Pennington (1986) notices the close relationship between the success of tree birches and the fluctuating temperatures of the north-European Lateglacial. Tree birch is generally considered to be sensitive to high winds and low average temperatures. Sniddle Moss at low altitude is an exposed site. In the light of these views, it can be postulated that strong variations particularly in tree birch values mirror the response of birch woods to changes in temperature. Fluctuations in major taxa frequencies in SM4-IV make interpretation difficult. However, the subzones of this zone chiefly based on birch pollen values may allow one to draw a general picture of the vegetation succession in the area during the birch woodland phase.

It appears that a woodland dominated by tree *Betula* (most *Betula* pollen are tree birch and the macroscopic find of *B. pubescens* at 278 cm at SM4 makes its presence certain) developed in the beginning of this phase (SM4-IVa). The frequent statoblasts of *Cristatella mucedo* recovered support this context as *C. mucedo* is absent north of the timberline in Europe (Van Geel *et al.*, 1980). Juniper could have been suppressed due to the fact that it became shaded out as tree density increased. At the same time *Filipendula* assumed an importance in the tall herb communities. This suggests a mean July temperature of not less than 8-9°C (Kolstrup, 1979).

The following subzone SM4-IVb suggests that warmth-demanding birch and *Filipendula* became less important and open-ground herbs showed an expansion. This change in the vegetation cover is, in fact, not very significantly reflected in the pollen record and the sedimentological change from marl to silty organic mud does not help very much, though it might indicate lower temperatures.

In subzone SM4-IVc birch and juniper appear to have behaved in the way that Pennington (1975) suggested "... an interplay between birch and juniper within a fluctuating environment ..." (p. 163). It is likely that a temporary decline of birch trees in the previous subzone introduced conditions in favour of juniper. Thus, juniper could have penetrated into the open parts of the woodland. But it would not have been able to flower freely as tree birches spread widely at the end of this subzone. *Filipendula*, on the other hand, became abundant in damper areas.

It is thought that zone TM2-I has, in general, similar pollen features to much of subzone SM4-IVd. Both can be interpreted as reflecting a transitional phase in which warmth-demanding species began to decline as the climate became more severe. This was coupled with an increase in minerogenic material content. Open communities became established gradually with an abundance of grasses, sedges, *Rumex*/*Oxyria* and *Artemisia*. At Thieves' Moss the *Thalictrum* representation is higher than at Sniddle Moss, while Caryophyllaceae appears to have expanded earlier at Sniddle Moss than at Thieves' Moss.

PHASE 5. Open grassland with abundant heliophytes

A fall in total land pollen concentration values in zone SM4-V and subzones TM2-IIa and -IIb suggests a sparse vegetation cover, although the lower concentration values may, in part, have resulted from rapid sediment accumulation rates due to extensive inwashing of minerogenic material. The significant reduction in the thermophilous taxa (*Betula*, *Juniperus*, *Hippophaë* and *Filipendula*) and further dominance of herb communities, including cold-tolerant species such as *Armeria* and *Selaginella*, support the picture of the onset of climatic deterioration.

The birch woods of the preceding phase may have contracted considerably. However, some patches of birch woodland may have survived in favoured localities, but they were apparently of a more open nature. A reduced frequency of *Filipendula* and *Hippophaë* may indicate summer temperature maxima somewhat below 10°C. An increase in *Artemisia* pollen at both sites is noteworthy. This increase appears to be a real rise since the concentrations of this genus are higher in this phase than in the preceding phase (4), in spite of low local pollen deposition during the cold period. Iversen (1954) says that species of *Artemisia* are usually associated with dry and frost-disturbed soils. It is less sensitive to winter temperatures but it does not tolerate much snow cover. Manley (1959), however, writes of the local re-establishment of small glaciers, which must have required precipitation as snow, on Whernside and Ingleborough in the last episode of the Lateglacial climatic oscillation. An increase in pollen deposition of Artemisia in the lowlands is not so surprising but in the Thieves' Moss area which is closer to the re-established small glaciers of the Lateglacial Period a rise in Artemisia pollen is particularly interesting. This might be attributed to variations in snow cover, even within very restricted area, probably related to topography. Pennington (1980) considers the present distribution of Artemisia in continental West Greenland. She says "The parts of the mosaic where Artemisia borealis grows today in Region 1 are relatively snow-free because situated either on south-facing slopes or on ridges ..." (p. 197). In the Thieves' Moss area on well-drained scree slopes facing south Artemisia may have assumed some importance whereas the Ingleborough glaciers were probably in the Arks above Sunset Hole, facing north.

Local differences in vegetation pattern between the study areas during this cold phase appear to have been slight and quantitative rather than qualitative. Both supported a mosaic of vegetation types rich in species. In the Sniddle Moss area Ranunculaceae along with Salix may have been more significant than in the Thieves' Moss area. Thalictrum was still more important at Thieves' Moss than at Sniddle Moss. These small differences can be attributed to variations in local environmental conditions, competition and timing of population change.

8.2. Flandrian (Postglacial)

As explained in the Introduction palaeobotanical investigations already carried out in the region have provided data mainly on Flandrian events. Recent pollen diagrams with associated radiocarbon dates from lowland Craven particularly reveal variations in the vegetation. Bartley _et al_. (1990) compare the vegetation sequences from various localities in Craven in detail and discuss the varying roles of climate, soil and human interference. Swales (1987) gives some information about the vegetational history of the Ingleborough Massif in conjunction with archaeological evidence and radiocarbon dates, Hence, a general picture of the Flandrian vegetation development of the region is available. In this study, the Flandrian pollen sequences of Sniddle Moss and Thieves' Moss and the Sunset Hole pollen diagram are used to add some complementary and comparative data to this picture. A brief account of the regional vegetational succession with special reference to the patterns of the _Ulmus_ decline is presented below. Tentative correlations of the Flandrian local pollen assemblage zones from the study sites are summarized in Figure 8.2.1. Sites frequently referred to in the text are listed in Table 8.2.1.

Flandrian 1

The changes in the pollen curves show that the opening of the Flandrian Period (c. 10,000 BP) corresponds to the zones SM4-VI and TM2-IIIa. These curves demonstrate that a more continuous vegetation cover consisting mainly of juniper and grasses re-developed in the region. The Sniddle Moss 4 pollen spectra show that the age of the juniper maximum dated to 12,020±90 BP at 181 cm (Appendix 1) is too old because of the hard-water effect and it is discounted. The continuing high values of total herbaceous pollen in both zones mentioned above support

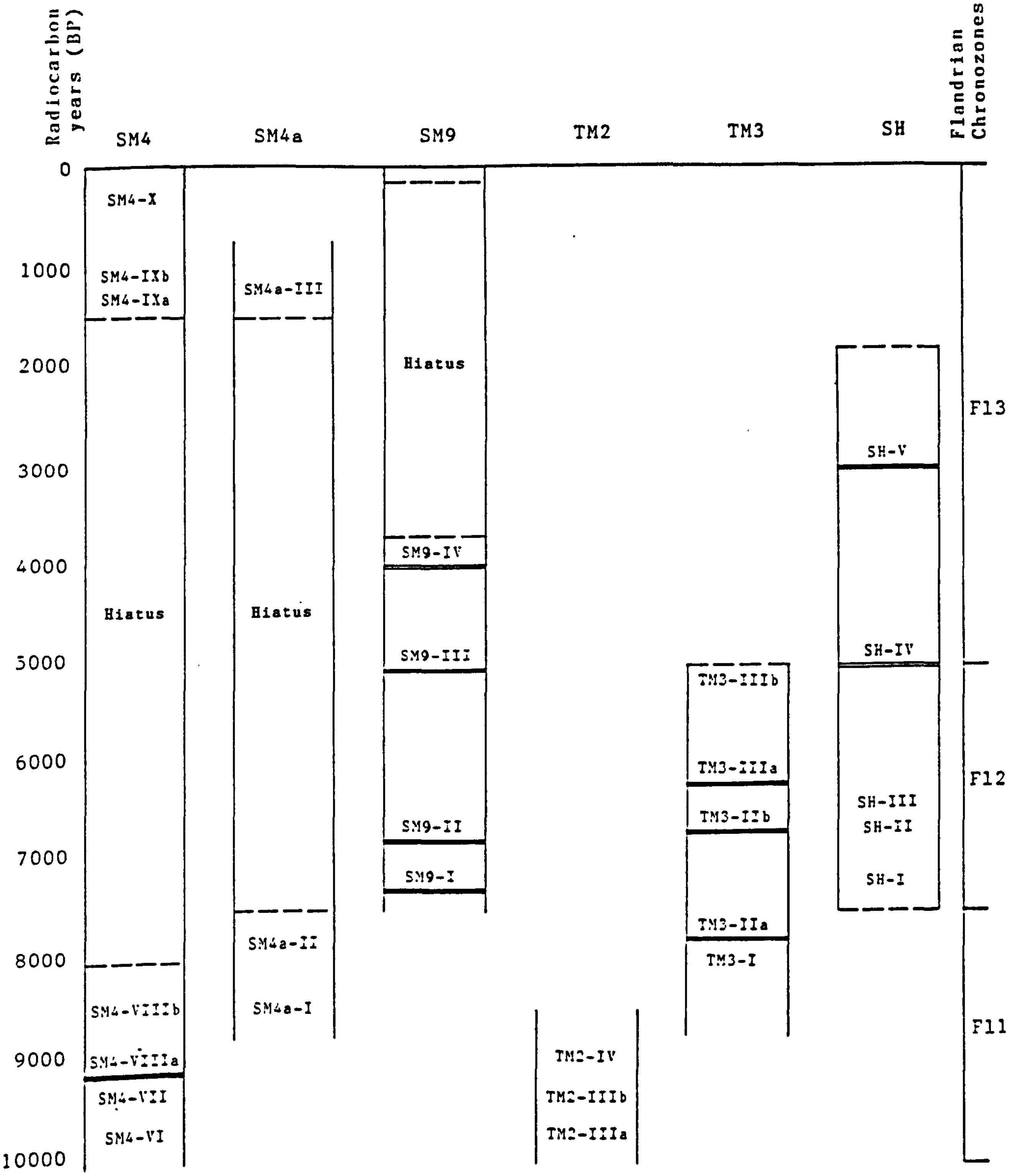


Figure 8.2.1. A tentative correlation of the Flandrian local pollen assemblage zones of the study sites and the (supposed) equivalent Flandrian Chronozones. SM, Sniddle Moss; TM, Thieves' Moss; SH, Sunset Hole. (----) Beginning or end of deposition; (═══) proposed boundary; (━━━) radiocarbon-dated boundary.

Table 8.2.1. Sites frequently referred to in the text.

SITE	ALTITUDE (MSL)	AUTHOR and DATE
Helwith Moss (Ingleborough)	244 m	Gosden 1963
Allotment Shooting Box (Ingleborough)	434 m	Swales 1987
Arks (Ingleborough)	533 m	Swales 1987
Braithwaite Wife Hole (Ingleborough)	354 m	Swales 1987
Simon Fell (Ingleborough)	617 m	Swales 1987
Tarn Moss (Malham, Craven)	381 m	Pigott & Pigott 1959 and 1963
Eshton Tarn (Lowland Craven)	144 m	Jones 1977; Bartley _et al_. 1990
Linton Mires (Lowland Craven)	190 m	Jones 1977; Bartley _et al_. 1990
Threshfield Moor (Lowland Craven)	282 m	Jones 1977; Bartley _et al_. 1990
White Moss (Lowland Craven)	190 m	Jones 1977; Bartley _et al_. 1990

the idea that the previous vegetation was only partially replaced by pioneer woodland (open woodland). Many taxa common during the preceding zones declined or disappeared (e.g. *Artemisia* and *Hippophaë*). However, some of the members of the Lateglacial herbaceous flora such as *Helianthemum*, *Saxifraga* types and *Thalictrum* persisted into these zones. *Saxifraga oppositifolia* and *S. aizoides* are still growing on the limestone cliffs of Ingleborough (Bartley & Clark, 1979). Pennington (1964) also reports the persistence of several Lateglacial herbs from the Postglacial layers of Red Tarn in Langdale in the Lake District. She concludes that this was the result of the continuing active solifluction, keeping the forest open. The organic sediments of zone SM4-VI contain clay and this implies the presence of erosion and inwashing of minerogenic material. The range of species growing around the study sites is similar to those indicated by other site localities, e.g. Arks II on Ingleborough, Malham Tarn Moss, Linton Mires and Threshfield Moor in the Craven area. Clearly, there are also variations in the earliest Flandrian vegetation pattern. For example, grasses appear to have expanded more widely at Sniddle Moss in the boulder clay than at Thieves' Moss on the limestone.

In the succeeding zones SM4-VII and TM2-IIIb tree birches spread and replaced the juniper-dominated scrub. At this time both sites saw the arrival and early expansion of *Corylus*, as in much of the Craven area. Hazel may have formed scrub or woodland in areas that *Betula* did not colonize since it is intolerant of heavy shade and does not flower effectively when light penetration is impaired (Rackham, 1980). As at the Arks on the north-north-west side of the Ingleborough Massif, at Thieves' Moss juniper declines and disappears completely before *Corylus* rises considerably in the following zone TM2-IV, whereas at Sniddle Moss it persists into the *Corylus*-dominated subzone SM4-VIIIa. The coverage of birch woodland at Thieves' Moss (birch pollen rises up to 80% of TLP) seems to have been more dense than at Sniddle Moss, so juniper scrub in the Thieves' Moss area may have thinned out more rapidly due to dense shade cast by birch woods. It is of special interest that scattered juniper bushes can be found today on Moughton, about 1.5 km south-east of Thieves' Moss.

According to Bartley _et al_. (1990) _Pinus_ migrated into the region and formed local stands in various parts of Craven, especially on the well-drained limestone soils, at least as early as 9430 BP. The very early establishment of the _Pinus_ before the _Corylus_ phase has also been identified at Helwith Moss situated on the eastern side of the Ingleborough Massif. Bartley _et al_. make the point that the early appearance of pine occurred in climatically and edaphically favourable sites. In addition to these variables competition from birch woods may also have been an important factor in the expansion of _Pinus_. For instance, in the Thieves' Moss area, only c. 4.5 km from Helwith Moss, _Pinus_ pollen reaches only up to 20% (TM2-IIIb). It appears that _Pinus_ was unable to penetrate into early Postglacial _Betula_ woodland forming a sufficiently closed forest at Thieves' Moss.

At Sniddle Moss the last appearance of juniper is dated at 9130±65 BP. This compares with the dates for the final disappearance of juniper from the Arks (9240±90 BP) on the Ingleborough Massif and Din Moss (9270±170 BP) lying close to the Northumberland-Roxburghshire (Hibbert & Switsur, 1976). The _Corylus_ expansion associated with the fall in juniper is also synchronous at both Sniddle Moss and Din Moss and the rational limit of _Corylus_ has been dated to 9120±170 BP at the latter site. As at Thieves' Moss, at the Arks juniper declines before _Corylus_ increases. This trend suggests that hazel expanded later in the upland areas than in the lowlands of the Ingleborough Region.

In zones SM4-VIII, TM2-IV and TM3-I _Corylus_ becomes a relatively important element of the woodland in the Boreal

Period. Although the percentages of Betula pollen decrease at both sites, the concentrations do not, suggesting that the fall in pollen percentage is an artefact of the percentage method due to the massive expansion of Corylus pollen. Rackham (1980) says that Corylus pollen dominance is likely to have emanated from Corylus canopy woodland in the early Flandrian period. Thus in the region birch and hazel may have been segregated, probably in relation to the nutrient status of the soils. The thermophilous Quercus and Ulmus could have gained a foothold in suitable localities under warmer climatic conditions, with Ulmus establishing itself more widely at first, possibly in better drained parts of the landscape, e.g. at Eshton Tarn. Subzone SM4-VIIIb and zones SM4a-I and TM3-I record the arrival and sporadic occurrence of Alnus. It must have begun to colonize wetter places. The first appearance of alder at values of at least 1% is dated to 7830±80 BP at Thieves' Moss 3 (TM-IIa). This date conforms well with the beginning of a continuous curve for Alnus at an estimated date of c. 8000 BP at Crose Mere, Shropshire (Beales, 1980) and White Moss, Craven.

In subzones SM4-VIIIb and TM3-IIa fluctuations in the major taxa curves coincide with sedimentological and consequent hydrological changes in the study site localities. Additionally, there appear to have been changes in the woodland cover. This is seen particularly well in TM3-IIa with a number of conspicuous oscillations in Pinus and Corylus pollen. These oscillations may point to an interplay between pine and hazel in the forest.

With the beginning of subzones SM4a-II and TM3-IIb Pinus assumes importance, after the rise in Corylus, following the characteristic pattern of the Boreal Period in the north and the west of England (Beales, 1980). Huntley and Birks (1983) point out that values of pine pollen > 25% probably reflect local presence of small areas of pine in a forested landscape. Therefore, at both

Sniddle Moss and Thieves' Moss pine pollen rising up to 50% would imply the spread of local stands of pine. The major expansion of pine took place at 6725±70 BP at Thieves' Moss. Other evidence from limestone areas in the region also shows that pine was abundant on limestone soils, e.g. at Tarn Moss (Malham), Linton Mires and Threshfield Moor. According to Bennett (1984) such soils may be too extreme for most deciduous species, but *Pinus sylvestris* which is tolerant of such extreme conditions, would be favoured. Though Sniddle Moss lies on poorly-drained soil, high pollen values of pine may indicate that *Pinus* was established, perhaps on the slopes of Newby. It is probable that soils around the Sniddle Moss area became so dry that it was less favourable to other trees and pine was able to colonize *Corylus*-dominated woodland.

Flandrian 2

In the Atlantic Period the behaviour of *Pinus* and *Alnus* in the study areas varies according to soil type as described for the lowlands of Craven by Bartley *et al.* (1990). At Thieves' Moss on drier (limestone) soil pine declined by 6200±60 BP and it was (first) replaced by *Corylus* (TM3-III) with a slight increase in *Alnus*, whereas at Sniddle Moss on heavier soil it disappeared earlier, at 6830±65 BP and *Alnus* rises to 20% (SM9-II) and then to 40% or more with the increasing wetness of the Atlantic Period. The beginning of a continuous curve for *Alnus* is dated to 7305±60 BP at Sniddle Moss 9 (SM9-I). At Thieves' Moss it dates from 7830±80 BP, and it seems that alder grew very sparsely in the Thieves' Moss area, for a long time before its main rise associated with the increase in *Corylus* at c. 6200 BP. Well-drained soils around Thieves' Moss are unlikely to have become wet enough for *Alnus* and there was a long delay before it increased to significant amounts. At Sniddle Moss in the boulder clay the major expansion of *Alnus*, on the other hand, occurred rapidly. Though radiocarbon dates are not available for the Sunset Hole pollen diagram now, it may be deduced that the pattern recognized at Sniddle Moss 9 also applies to the Sunset Hole site lying on a drift-covered shelf on the lower slopes of the Ingleborough Hill. The fall in pine pollen in SH-Ib is accompanied by an initial rise in Alnus and a slight increase in Corylus. Unlike the Thieves' Moss 3 pollen diagram, hazel never reaches more than 45% of TLP before an abrupt rise in Alnus pollen with the beginning of zone SH-II.

Despite the differences in the local pollen spectra, taking the Ingleborough Region along with Craven as a whole, in the Atlantic Period a mixed woodland has been detected; oak/hazel with some elm on drier ground and alder with birch and willow in damper places. Tilia pollen appears in the pollen diagrams in small amounts. Greig (1982) points out that lime may have been much more important in the forests of the past. He says that values of up to 30% corrected Tilia are considered small. "Corrected" pollen values for Tilia are less than 30% in the Ingleborough Region (e.g. about 13% at Sunset Hole and 18% at Sniddle Moss) and in lowland Craven (e.g. about 13% at White Moss), suggesting that lime was a minor component of the mixed woodland.

This period was also marked by the initiation of bog and heath development in upland areas (e.g. Thieves' Moss and Tarn Moss). Before the onset of the following chronozone, Flandrian 3, the forest seems to have been more or less stable. There is however some evidence of the activity of Mesolithic or early Neolithic people in parts of the region. This will be taken up later in the main discussion.

Flandrian 3 (Vegetational history in relation to human interference)

The beginning of Flandrian 3 is conventionally defined by the elm decline at about 5000 BP. In this study, the elm decline could be traced only at Sniddle Moss 9 and Sunset Hole and it is dated at the former site. At Thieves' Moss the elm decline is very close to the top of the sediments and there is the possibility of erosion and peat cutting. The date of 5050±50 from Sniddle Moss 9 is in good agreement with the dates obtained for the first fall in elm pollen from other sites in the region - Arks I (5030±50 BP), Allotment Shooting Box (5160±60 BP), Eshton Tarn (5010±110) and White Moss (5058±100 BP). The pollen diagrams presenting the elm decline from the site localities will be considered in relation to changes in vegetation after the first classical elm decline.

(a) From c. 5000-4000 BP

At Arks I zone AI3 (5030±50 - 3960±50 BP) and at Allotment Shooting Box zone ASB2 (5160±60 - 4440±60 BP) are characterized by a permanent decline in elm pollen associated with increased representation of Corylus and indicator species (Plantago lanceolata, Rumex acetosa/acetosella-type and Urtica) indicating pastoral farming. At both sites at the elm decline level, there is a rise in total pollen influx and concentration values. In zone Arks I3 major changes in the composition of the woodland are recorded. These changes include a temporary reduction in birch and oak trees. At Allotment Shooting Box the elm decline coincides with a decrease in arboreal pollen percentages. The succeeding zone ASB3 of the Allotment Shooting Box site marks a regeneration phase with a sharp rise in non-herbaceous taxa percentages (up to 70% of TLP) and a reduced number of clearance indicators. Swales (1987) regards the increase in elm pollen dated to 4440±60 BP as a slight recovery of Ulmus which lasted c. 790 years. The end of zone ASB3 (3650±60 BP) shows a renewed fall in elm pollen.

Bartley et al. (1990) recognize a series of clearance phases in the Eshton Tarn zone ET5b, between the elm decline (5010±10 BP) and the upper boundary of the zone (3600±100 BP). Plantago lanceolata pollen appears immediately after the elm decline and cereal pollen first occurs in considerable amounts at an estimated date of 4500 BP. The same authors describe only low-level interference in the woodland around White Moss , with high values of non-herbaceous pollen (about 80% of TLP), occasional grains of Plantago lanceolata and an interrupted curve for cereal-type pollen (until c. 1470 BP). At Eshton Tarn in the limestone area Corylus appears to be the dominant pollen type whereas at White Moss in the boulder clay Alnus assumes greater importance and Betula is more significant.

The descriptions of vegetational phases whose boundaries are defined in respect of Ulmus pollen representation for Sniddle Moss (zone SM9-III) and Sunset Hole (zone SH-IV) have been given in Chapters 5 and 7. Here, these descriptions for each study site are interpreted and then a brief comparison between the two sites is presented. It should be emphasized that a proper comparison can be given when radiocarbon dates are available for the Sunset Hole site.

SNIDDLE MOSS (Diagrams 5.4.10. and 5.4.11.)

Phase 1. A first elm decline (From 118 cm to 108 cm)

The start of this phase is marked by the first classical elm decline (dated to 5050±50 BP) at which there is a rise in total pollen concentration and influx values. Since total non-herbaceous pollen values (both relative and absolute) are still higher than herbaceous pollen values, it may be inferred that openings were of limited extent around Sniddle Moss. Both Alnus and Quercus seem to have been the main elements of the local forest. However, increased representation of *Corylus* reflects higher pollen production, probably due to a (slightly) more open woodland structure. *Tilia* and *Fraxinus* may also have benefited from such small-scale clearances, possibly on the southern pavements of the Ingleborough Massif. The first occurrence of Cerealia-type and *Plantago lanceolata* pollen is roughly dated to 5010 BP. These types along with abundant *Pteridium* may point to both arable and pastoral agriculture. A rise in the frequency of Cyperaceae, *Filipendula* and *Salix* may merely indicate a wetter mire surface.

Phase 2. (From 107 cm to 90 cm)

Ulmus trees seem to have declined considerably by about 4935 BP (estimated) at 107 cm where elm pollen is absent. Great fluctuations in total pollen influx values might be the result of sedimentological changes rather than instability in vegetation in this early period of forest clearance. Abundant birch suggests that this light-demanding species became important in damper areas. However, it should be stated here that high percentages of *Betula* pollen at 102 cm (47%) and at 104 cm (c. 73%) are probably due to birch catkins, which also account for an increase in total pollen influx values. The occurrence of Cerealia-type pollen and other cultural indicators such as *Plantago lanceolata*, *Succisa* and *Pteridium* and weeds including *Artemisia* and *Cirsium*-type might be taken as indicative of increased farming practice. On the mire *Filipendula* appears to have been replaced by *Melampyrum*. Godwin (1975) cites that high *Melampyrum* pollen frequencies are associated with disturbance of the vegetation by fire (Mamakowa, 1968). Since there is no charcoal at or around the *Melampyrum* maximum levels, as mentioned previously it is probable that it was only an element of a mesotrophic fen-carr community.

Phase 3. A partial recovery of elm (From 88 cm to 76 cm)

A partial recovery of the elm pollen commencing at 88 cm is dated to 4710±45 BP. At 86 cm total pollen influx values decline, but elm pollen exhibits a rise, suggesting a real increase and regeneration of elm trees at c. 4670 BP. However, during this phase elm pollen never fully recovers nor regains its former proportions. An increase in pollen of non-herbaceous taxa and the disappearance of Cerealia-type and *Plantago lanceolata* pollen can be interpreted as the abandonment of agricultural areas. But frequent *Pteridium* spores may signify that pastoral farming continued or at least that there were openings in the woodland cover, as indicated by the presence of weeds (e.g. *Cirsium*-type and Cruciferae).

Phase 4. A secondary fall in elm (From 74 cm to 70 cm)

A secondary elm decline at about 4520 BP, in which other trees also diminish, can be regarded as a clearance phase. There is, in fact, nothing to suggest that this represents a further forest clearance because there is no increase in cultural indicators and weed species. The rise of Cyperaceae and corresponding drop in alder pollen may have been caused by changes in mire hydrology. This may also be affecting the percentage values of *Ulmus*.

Phase 5. A renewed recovery of elm (From 66 cm to 26 cm)

A renewed recovery of elm pollen is dated to about 4420 BP at 66 cm. *Ulmus* never again attains its former values but it appears to show a better recovery than that in phase 3, but only for one sample. This is paralleled by a rise in non-herbaceous taxa pointing to forest regeneration. The decline in farming (until almost mid-phase) might have promoted the expansion of trees such as birch which regenerates and flowers quickly. Alder would have colonized damper ground. On drier places, hazel may have played a role and then it was replaced by oak, perhaps as deterioration in soil fertility increased in the Sniddle Moss area. Elm along with ash and lime probably took some part on base-rich soils upon the limestone pavements. The absence of most cultural indicators supports the idea that agricultural land was abandoned. However, towards the top, a gradual decline in non-herbaceous taxa and reappearance of Plantago lanceolata and Cerealia-type pollen and frequent Pteridium spores may demonstrate that forest destruction started again, at about 4200 BP.

SUNSET HOLE (Diagrams 7.4.3. and 7.4.4.)

Phase 1. A first elm decline (From 149.5 cm to 144 cm)

The first classical elm decline is recognized at 149.5 cm. Since the elm decline is apparently a synchronous event for various parts of the Craven District, it is thought that it may also date from about 5000 BP at the Sunset Hole site. Other associated changes include a rise in Corylus. Hazel may have spread into areas previously occupied by Ulmus. Ilex pollen appears at 147 cm. Woodland of open structure may have facilitated the establishment and flowering of Ilex. The occurrence of Cerealia-type pollen in combination with other disturbance-indicator species such as Plantago spp., Urtica, Rumex/Oxyria and Pteridium suggests clearance for pastoral and arable agriculture close to the Sunset Hole site. There is abundant charcoal in the peat around the level of the elm decline. Though Ericales (Calluna) shows a slight increase at this time, its rise might be taken as an indication of its response to fire (Odgaard, 1992).

Phase 2. (From 143 cm to 137 cm)

This phase records a further fall in elm pollen and its absence at 140 cm accompanied by a further rise in Corylus pollen reaching 50% of TLP. It is likely that hazel became the dominant species in the woodland. Cultural indicators show the continuation of pastoral farming.

Phase 3. A partial recovery of elm (From 136 cm to 131 cm)

A partial recovery of elm pollen coincides with a rise in total land pollen concentrations due to either decreased sedimentation rates or increased pollen production. The Ulmus curve shows a slight recovery and it might be postulated that elm trees may have started to occupy their former places with Corylus gradually being shaded out by elm trees on the better quality soils. It is also noteworthy that species associated with various aspects of man's farming activities become sparse. All these may suggest a regeneration phase. A fall in both birch and alder pollen matched by abundant Ericales pollen might be explained by a change to more heathy, and presumably drier, conditions on slopes as well as on the bog surface.

Phase 4. (From 130 cm to 120 cm) and **Phase** 5. (From 118.5 cm to 60 cm)

These following phases record low values of cultural indicators and weeds reflecting decreased farming activity and allowing the forest to recover. During much of phase 4 Ulmus pollen shows a further rise. At this time elm trees may have expanded in the hazel-dominated woodland. Again, during phase 4 increased representation of birch and alder could be connected with wetter conditions in the vicinity of the Sunset Hole site. In the beginning of phase 5 a considerable rise in elm (up to 5% of TLP) represents a real increase in elm pollen reaching the bog. Although there is little evidence of forest clearance in the Sunset Hole area, a conspicuous rise in ash pollen along with the presence of Tilia and Ilex pollen in phase 5 may suggest their expansion onto limestone pavements.

A brief comparison between Sniddle Moss and Sunset Hole:

(a) The general pattern of elm pollen changes in phases 1, 2 and 3 seems to be the same at both sites.

(b) The decline of elm in phase 4 at Sniddle Moss may be correlated with minimum values of Ulmus pollen at 132 cm in SH3 (Sunset Hole - phase 3) and at 122 cm in SH4 (phase 4).

(c) SH5 shows fluctuating values of elm pollen, which are not as high as at pre-elm decline times, but much higher than in phase 5 at Sniddle Moss.

(d) Betula and Salix are temporarily very conspicuous at Sniddle Moss. It is probable that both taxa assumed some importance on the damper soils in the Sniddle Moss area. At Sunset Hole Salix, in particular, is not very conspicuous. This would be attributed to lack of suitable soils in the Sunset Hole area.

(e) At Sniddle Moss Fraxinus becomes important after the elm decline whereas at Sunset Hole it is present before the elm decline. Later, in phase 5 ash is better represented at Sunset Hole than at Sniddle Moss. There is no doubt that ash was more successful on limestone pavements in the uplands than in the boulder clay in the lowlands.

(f) The very conspicuous spread of heath at Sunset Hole could be local and it may partly reflect the elm decline because of acidification of soils. Unlike Sunset Hole, the Sniddle Moss site shows little spread of heath. This may go with the much slighter evidence for forest clearance in that area.

(g) Melampyrum is more abundant at Sunset Hole than at Sniddle Moss, suggesting an open woodland in the vicinity of Sunset Hole.

(h) *Polypodium* is more important at Sniddle Moss than at Sunset Hole. This may point to denser forest in the lowlands. To-day *Polypodium* grows on the ground and on the branches of oak trees in the damp woods of the Ingleton Gorges, a short distance from Sniddle Moss (Bartley, personal communication).

(b) From c. 4000 BP - present day

The growth rate of the uppermost zone of Sniddle Moss 9 (SM9-IV) has been used to estimate the range of the age for the peat from 26 cm to 14 cm, this being between c. 3920 BP and 3770 BP (see Figure 5.5.2.). Zone SM9-IV reveals that on the sampling site and its immediate surrounding birch carr took over from the alder carr with conditions becoming more acid. Birch along with *Sphagnum* may have colonized the wetter ground while Ericales (*Calluna*) would have spread over drier areas. Other trees may have retreated due partly to increased acidification of soils around the Sniddle Moss site. There are signs of continuous pastoral farming with *Plantago lanceolata*, *Rumex*/*Oxyria*, *Rumex acetosa*-type, *Succisa* and *Pteridium*, and of a little arable activity. Weeds include *Artemisia*, Chenopodiaceae, Cruciferae and *Vicia cracca*-type.

A comparison of the pollen curves in the upper part of the Sunset Hole pollen diagram produced for this study with those in the earlier dated pollen diagram given by Swales (1987) suggests that the sediments from 60 cm to 30 cm may correspond to a period between c. 3850 BP and 2970 BP. During this stage it is probable that in the locality of Sunset Hole, as acid heath/bog development spread over wider areas including the upper slopes to the north, the remaining trees were reduced gradually. The significant pollen of clearance indicator species *Plantago*, *Rumex*/*Oxyria*, *Urtica* and *Pteridium* demonstrates that pastoral agriculture was practised.

The pollen spectra of SM9-IV and of Sunset Hole (zone SH-IV) presented by a section of the profile between 60 cm to 30 cm may be correlated with Arks I (AI4) and Simon Fell I (SFI3). The lower boundary of AI4 at 3960±50 BP and of SFI3 at 3810±50 BP is defined as the beginning of more intensive clearance phase with pastoral-based economy (Early Bronze Age). In the pollen diagrams from the Massif (Arks, Simon Fell and Sunset Hole) both Corylus and Fraxinus pollen, in particular, are more abundant than in the Sniddle Moss 9 (zone SM9-IV) pollen diagram. It is likely that hazel and ash were completely restricted to the limestone pavements and colonized cleared areas. Thus, the Sniddle Moss site and its immediate surrounding on deteriorating soils may have been receiving hazel and ash pollen mainly from upland vegetation, only a few kilometres away.

At Braithwaite Wife Hole and Allotment Shooting Box a more extensive Early Bronze Age clearance phase commenced later, at c. 3680 BP and 3650±60 BP respectively. At Arks (AI5) large-scale clearances with pastoralism and cereal cultivation continued during the mid-Bronze Age (c. 3400±50 BP). The Simon Fell (SFI5) area also saw massive clearance (pastoral) until c. 1400 BP (Anglo-Saxon times) corresponding to the end of peat growth.

Swales (1987) says that the surface of the Sunset Hole site seems to have stopped growing and erosion is underway. She gives an estimated date of c. 1820 BP for the surface samples of Sunset Hole using the growth rate of peat and she concludes that the pollen record appears to be missing from the beginning of Romano-British times to the present day. As in other areas of the Ingleborough Massif in the Sunset Hole area heath and bog development became more widespread from Early Bronze Age onwards. The pollen spectra of zone SH-V indicate that opened areas were still under grazing pressure with typical species of grassland such as Plantago spp., Urtica and Pteridium, but Rumex/Oxyria disappeared.

Pigott and Pigott (1959 and 1963) interpreted the great rise of herb pollen in the upper part of the Malham Tarn Moss diagrams as being in early zone VIII (Godwin's zonation) and contemporary with the Iron Age. Abundant Plantago lanceolata, Artemisia and Rumex pollen along with the occurrence of cereal pollen has been assigned to the increase of agriculture. Continuous rise in the ratio of herb to tree pollen throughout the uppermost layers has been taken as indicative of the progressive destruction of woodland associated with the Norse settlements and historic periods.

According to Bartley et al. (1990) there appear to have been changes in agricultural practice around Eshton Tarn in lowland Craven at about 3800 BP. The first major increase in Plantago lanceolata and Gramineae pollen dated to 3600±100 BP (Early Bronze Age) may compare with more intensive clearance phases started around or after 4000 BP on the Ingleborough Massif. At White Moss in the boulder clay, some 18 km from Eshton Tarn, the beginning of the major agricultural activity is dated to 1470±100 BP, approximately 2000 years later than at Eshton Tarn.

In zone SM4-IX of the Sniddle Moss 4 pollen diagram reduced tree pollen values coincide with bands of clay and a sharp increase in pollen of herbaceous taxa probably reflecting extensive forest clearance, consequent erosion of mineral soils and flooding of the mire surface. This resulted in reduced pollen production from trees both allowing the grassland pollen to reach the Sniddle Moss site in greater amounts and to have a greater representation. Trees probably occupied a very minor part of the landscape at this time. The nature of the pollen curves for the main taxa in zone SM4-IX resembles that of the upper zones of White Moss (WMI-6 and WMI-7) representing a period from Anglo-Saxon times onwards. In both pollen diagrams there is a major rise in cereal-type and Plantago lanceolata pollen. In zone SM4-IX these two cultural types show almost a gradual increase. If it is supposed that SM4-IX also dates from Anglo-Saxon times, on the basis of the similarities with the White Moss zones, it seems that a part of the vegetational record from about 3770 BP (Early Bronze Age) to around 1500 BP is missing in the observed sequence of Sniddle Moss. If this assumption is correct, it may be deduced that, as at White Moss, at Sniddle Moss intensive farming activity took place later than in limestone areas. This assumption also supports the contention of Bartley _et al_. (1990) that on the unattractive heavy soils of Craven, agriculture remained at a low level until at least the Anglo-Saxon Period, whereas on the fertile limestone soils extensive agriculture started earlier, in the Bronze Age.

The uppermost zone SM4-X exhibits the removal of most remaining woodland in the majority of localities: tree and shrub cover must by now have been reduced more consistently, leaving a quite open environment with areas of acid grassland and heath, which are similar to those of to-day.

9. DISCUSSION

9.1. Lateglacial

In the previous chapter some regional aspects of the Lateglacial vegetation and environment with regard to the Sniddle Moss 4 (and Thieves' Moss 2) data, have been presented. In this chapter, these data are tentatively correlated and compared with other Lateglacial sequences, and some of these correlations are discussed. Sites referred to in the text are located on Figure 9.1.1. The proposed climatostratigraphic correlation of the pollen sequence at Sniddle Moss 4 (and Thieves' Moss) with the scheme of Lowe and Gray (1980) is illustrated in Table 9.1.1.

There is general agreement that within NW Europe the Late Devensian glaciation was followed by a marked climatic improvement at about or sometime before 13,000 BP (Mangerud *et al*., 1974; Coope, 1977; Lowe & Gray, 1980). According to Atkinson *et al*. (1987) coleopteran evidence suggests that from 14,500 BP until just before 13,000 BP the British climate was characterized by very cold winter months and the first warming took place at about 13,000 BP. Therefore, the lowest polleniferous sediments of the study sites (zones SM4-I and TM1-I) reflecting a very open landscape (Phase 1) may coincide with a date of around 13,000 BP. The climatostratigraphic scheme proposed by Lowe and Gray (1980) places the main interstadial episode of the Lateglacial between 13,000 and 12,000 BP. The succeeding phases 2 and 3 might be equated with this unit.

Phase 2 characterized by the Gramineae-Cyperaceae-*Salix*-*Rumex*/*Oxyria* local pollen assemblage zone at Sniddle Moss shows affinities with the features of the first pollen assemblage zones defined for a number of Lateglacial sites in northern Britain and Ireland. *Salix*

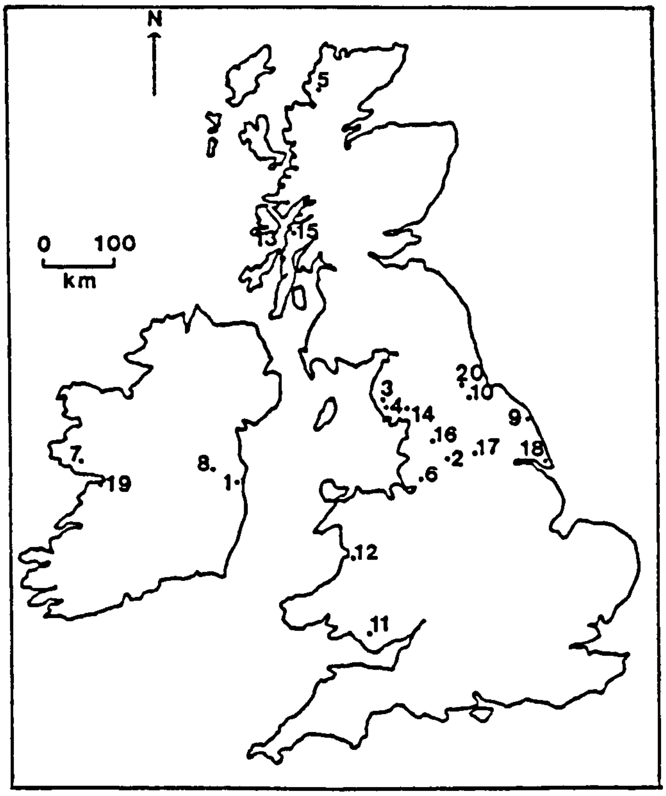


Figure 9.1.1. Locations of Lateglacial sites in Britain and Ireland referred to in the text.

1. Ballybetagh
2. Bingley Bog
3. Blea Tarn
4. Blelham Bog
5. Cam Loch
6. Chat Moss
7. Conneḿara
8. Dunshaughlin
9. Gransmoor
10. Kildale
11. Llanilid
12. Llyn Gwernan
13. Loch an t'Suidhe
14. Low Wray Bay
15. Pulpit Hill
16. Sniddle Moss (and Thieves' Moss)
17. Tadcaster
18. The Bog
19. The Burren
20. The Lower Tees Basin

Table 9.1.1. The proposed climatostratigraphic correlation of the pollen sequence at Sniddle Moss 4 (and Thieves' Moss) with the scheme of Lowe and Gray (1980).

SNIDDLE MOSS LPAZ		THIEVES' MOSS LPAZ		Vegetational Phases	LOWE & GRAY (1980) FLANDRIAN INTERSTADIAL	RADIOCARBON YEARS (BP)
						10,000
					Transition	
						10,500
		TM2-IIb	Gramineae-Cyperaceae-*Betula*-*Rumex*/*Oxyria*		Younger Dryas Stadial	
SM4-V	Gramineae-Cyperaceae-(*Betula*)-*Artemisia*			5		
		TM2-IIa	*Betula*-Cyperaceae-Gramineae-*Artemisia*			
						11,000
SM4-IVd	*Betula*-Gramineae-Cyperaceae-*Filipendula*	TM2-I	*Betula*-Gramineae-Cyperaceae			
SM4-IVc	*Betula*-Gramineae-Cyperaceae-(*Juniperus*)				Transition	
SM4-IVb	Cyperaceae-Gramineae-*Betula*			4		
SM4-IVa	*Betula*-Gramineae-Cyperaceae-*Filipendula*					
						12,000
SM4-IIIc	Gramineae-Cyperaceae-*Juniperus*					
SM4-IIIb	Gramineae-Cyperaceae			3		
SM4-IIIa	Gramineae-*Juniperus*-Cyperaceae				Lateglacial Interstadial	
SM4-II	Gramineae-Cyperaceae-*Salix*-*Rumex*/*Oxyria*			2		
SM4-I	*Pinus*-Gramineae	TM1-I	*Pinus*-*Betula*-Gramineae	1		
						13,000
		TM1 (168-152 cm)	No organic matter		Transition	
						14,000
					LATE DEVENSIAN	

(herbacea), particularly, appears to have been an important element of the earliest vegetation in the Lake District, e.g. at Blelham Bog and Low Wray Bay, Windermere and at Blea Tarn, Longdale (Pennington, 1977) and in eastern Ireland, e.g. Ballybetagh and Dunshaughlin (Watts, 1977). Pennington (1975) also records significant Salix pollen values from the supposed equivalent zone of Cam Loch in Sutherland, north-west Scotland. At Sniddle Moss Salix pollen never exceeds 15% of total land pollen but at Pennington's sites it has higher values than at Sniddle Moss, especially at Blea Tarn reaching over 40% (Pennington, 1970). The variability of Salix values may only represent a difference in the location of boring sites relative to the nearest willow communities because its pollen is poorly dispersed. Alternatively, it may present a pattern related to specific environmental parameters, such as snowfall. Since Pennington's sites are located further west, higher Salix (herbacea) pollen values at her sites might be attributed to more snow cover in the extreme west than in the study area.

The early expansion of Juniperus before the Betula phase in the early parts of the interstadial has been widely recognized at western sites in Britain (Pennington, 1977). At Sniddle Moss, juniper exhibits almost a two-forked curve before the tree birch peak (SM4-IVa) which resembles that found at Blea Tarn, at an altitude of 187 m, among the mountains of the central Lake District. At both sites, after an initial rise juniper temporarily declines. Pennington (1970) deduces from her pollen diagram that the first juniper phase precedes a more chianophilous vegetation with Betula nana and Lycopodium selago. Geochemical analyses at Blea Tarn are in agreement with the palynological data and suggest a renewed frost-disturbance of the soils (Pennington and Lishman, 1971). This first climatic oscillation of the Lateglacial appears to be synchronous over Europe and it dates from an age in the range of c. 12,500 to 12,000 BP, e.g. in Scandinavia (Björck et al., 1988), in Switzerland (Lotter et al., 1992), in Ireland and Britain (Watts, 1980; Atkinson et al., 1987). The juniper decline which has been dated to 12,120±130 BP at Llyn Gwernan, west Wales (Lowe & Lowe, 1989) and to 12,255±70 BP at Llanilid, south Wales (Walker & Harkness, 1990) is compared with this widespread event. The Sniddle Moss subzone SM4-IIIb might be also correlated with the same period.

In earlier papers the pollen record equated with the interstadial phase after a brief phase of deteriorating climate is often compared with the Alleröd Chronozone of Mangerud et al., (1974) characterized by a cooling trend. However, in recent works a relatively warm period following the first climatic cooling in the early part of the Lateglacial has been identified, e.g. those from north-west Scotland, at Loch an t'Suidhe on the Isle of Mull (Lowe & Walker, 1986) and at Pulpit Hill near Oban (Tipping, 1991). At the first site, the later (warm) episode of the interstadial is marked by a rise in *Empetrum* whereas at Tipping's site open grassland with a slight rise in juniper and *Empetrum* is described. Subzone SM4-IIIc at Sniddle Moss with high juniper and significant *Hippophaë rhamnoides* pollen appears to fit into the pattern observed at the sites quoted above. High *Hippophaë* values are generally characteristic of the inferred climatic recession episode of the Lateglacial interstadial (the Older Dryas equivalent) in the north-east of England, as at Kildale, the Cleveland Dales (zone KA-3) (Jones, 1977) and at The Bog, Ross (subzone RB-1b) (Beckett, 1981). According to Beckett, during the early climatic deterioration of the interstadial phase in eastern England the temperature drop was less marked and less pronounced oceanic conditions may have been major factors, allowing the spread of *Hippophaë*. Pennington (1975) points to the presence of more oceanic climate with warmer winters and greater precipitation in western Britain during the earlier stages of the Lateglacial. A delay in the establishment of *Hippophaë* in the region of Sniddle Moss may be explained by the persistence of oceanity, probably until the later interstadial phase. Hippophaë may have expanded, perhaps with a decrease in precipitation.

As mentioned previously, the Sniddle Moss zone SM4-IV demonstrates fluctuations in the major taxa curves during the birch phase. At many sites in Britain and Ireland, strong fluctuations in the pollen record are accompanied by signs of climatic deterioration and the increased deposition of mineral material (Pennington, 1977; Watts, 1980). Both conventional radiocarbon age determinations and recently published accelerator dates support the idea that a fall in temperatures and climatic deterioration began at about 12,000 BP. Even though much of the lithostratigraphic section of Sniddle Moss corresponding to zone SM4-IV does not provide any significant evidence of erosion, great fluctuations in pollen values seem to be consistent with the general climatic trend. This may permit the correlation of zone SM4-IV with the transition unit of the climatostratigraphic scheme of Lowe and Gray (1980), spanning from c. 12,000 to 11,000 BP.

The beginning of the Sniddle Moss subzone SM4-IVa records an abrupt rise of birch pollen. There are a number of sites showing high values of birch in the southern part of the north of England and in the north-east, e.g. at Tadcaster - 50% (Bartley, 1962), The Bog, Ross - 75% (Beckett, 1981) and at Bingley Bog in the Aire Valley of Pennines - 70% (Keen et al., 1988). Further north in Cleveland (Jones, 1977) and the lower Tees Basin (Bellamy et al., 1966) birch wood was less established. Again, in Lancashire-Cheshire, e.g. at Chat Moss (Birks, 1965) where Betula values are less than 20%, birch woods were poorly developed. Bartley and Morgan (1990) discuss the Lateglacial distribution of Betula and note that birch became established in areas of high relief, perhaps on sunny south-facing slopes but on exposed lowlands it was not so successful. The lower percentages of Betula pollen (up to 44% of TLP) at Sniddle Moss in an area of relatively low relief accord with this contention.

Subzone SM4-IVb is marked by a decline in birch along with other warmth-demanding taxa. The fall in birch pollen values has been dated to 11,344±90 BP in the Windermere profile (Pennington, 1977). More recent works reveal evidence for a pre-Younger Dryas climatic oscillation. Isotopic traces in ice cores from Greenland and in lake profiles from Switzerland and faunal records from North-Atlantic deep-sea cores (Broecker _et_ _al_., 1988) led to the proposal of a possible cold event prior to the onset of the Younger Dryas Stadial. Lotter _et_ _al_., (1992) stress that in many profiles, small or very short oscillations in the pollen curves may often be missed. They compare the Swiss oxygen isotope profiles and notice a second climatic oscillation (before the Younger Dryas biozone c. 10,700-10,000 BP). Walker and Harkness (1990) report a date of c. 11,400 BP for the _Betula_ decline at Llanilid. They correlate this date with an age of 11,500 BP estimated by Broecker _et_ _al_. and the date from Windermere. In the 8th International Palynological Congress (1992) several authors also presented data supportive of a pre-Younger Dryas climatic oscillation; Levesque _et_ _al_. from a number of sites in Canada, O'Connell _et_ _al_. from the southern parts of the Burren and Connemara in western Ireland and Walker _et_ _al_. from Gransmoor, East Yorkshire, Britain. Again, though evidence from Sniddle Moss 4 is not very strong, subzone SM4-IVb might be tentatively compared with the same episode.

Much of subzones SM4-IVc and -IVd with increased thermophilous species percentages and total land pollen concentration values may coincide with the Llanilid zone L-6 (Walker & Harkness, 1990) reflecting a short-lived recovery of _Betula_ dated to c. 11,300 BP and the second _Betula_ peak associated with fauna-rich in southern species at Gransmoor (Walker _et_ _al_.). The authors interpret these changes as showing a rise in temperatures immediately before the Younger Dryas. Atkinson et al. (1987) also record a brief period of warming around 11,300 BP.

The most prominent period of climatic cooling of the Lateglacial is considered to be the Younger Dryas Stadial. The dates assigned to the beginning of this episode from various parts of Europe are in broad agreement with the age of about 11,000 BP (Mangerud et al., 1974; Lowe & Gray, 1980). There is clear evidence for renewed mountain glaciation in Ireland (Watts, 1977 and 1980) and in northwest England (Manley, 1959) and in Scotland where there was major glacier growth during the Loch Lomond Stadial (Sissons, 1974 and 1976). Zone SM4-V and the correlated subzones of Thieves' Moss 2 (TM2-IIa and -IIb) with low pollen density and extremely minerogenic sediments seem to corroborate this event. The end of the Lateglacial Period is usually dated at 10,000 BP.

9.2. Flandrian (Postglacial)

Pre-elm decline disturbance

Previously, it was thought that Mesolithic peoples lived within the framework of their environment without changing it significantly. However, this view has been contested and there is a growing body of evidence for the possibility of human interference in the early Flandrian vegetation (both the Boreal and Atlantic periods) of Britain and Ireland. For example, Smith (1970) suggests that expansion of hazel may be connected with Mesolithic activity. Smith and Goddard (1991) attribute the decline of the pine pollen curve at the Boreal-Atlantic transition to intentional burning by man. A further hypothesis involves association between the rise in Alnus pollen and charcoal which has been taken as evidence for vegetational disturbance by Mesolithic peoples (Smith, 1984; Smith & Cloutman, 1988). The possible anthropogenic changes visible in pre-elm decline deposits of Britain and Ireland also include the appearance of cereals (from about 6500 BP) and increases in representation of agriculturally significant weed taxa such as Plantago lanceolata, Pteridium, Rumex, Urtica and Compositae Tubuliflorae (Edwards & Hirons, 1984 and Peglar, 1993).

Occupation sites dating to the Mesolithic Period (c. 10,250-5650 BP) are well known in parts of the Craven District (see Chapter 3). It has been shown that there is palaeoecological evidence of possible Mesolithic activity in the region. Bartley et al. (1990) recognize a few indications of instability in vegetation of lowland Craven in both Boreal and Atlantic times. Wide fluctuations in the major taxa such as hazel, pine and alder associated with the increase in mineral input in the early Flandrian sediments of Eshton Tarn and Linton Mires have been ascribed to human interference. At Threshfield Moor at an altitude of c. 282 m the early initiation of heathland development and frequent occurrence of *Sphagnum* spores after the first pine maximum at early stages have been interpreted as the acidification of the thin drift soils, probably following disturbance in the woodland.

In the early Flandrian subzones of the study sites Sniddle Moss SM4-VIIIb and Thieves' Moss TM3-IIa, dated to c. 8000-6725 BP, fluctuations in the major curves coincide with sedimentological and consequent hydroseral changes (telmatic peat accumulation) (see Chapters 5 and 6). As explained elsewhere, TM3-IIa also appears to reflect changes in the hazel-pine dominated forest but there is no significant evidence of human interference with the vegetation, accompanying these changes. However, as at Threshfield Moor, towards the top of the succeeding subzone of Thieves' Moss TM3-IIb (c. 6725-6200 BP) increased representation of Ericales and *Sphagnum* follows the pine dominance. This is coupled with a peak of *Rumex/ Oxyria* and abundant Cruciferae pollen, suggesting disturbance by man. Similarly, the lower part of the Sunset Hole zone SH-III with frequent *Eriophorum* remains, *Sphagnum*, *Melampyrum* and later Ericales shows the acidification of the soil on the site, probably towards the close of the Atlantic Period. The pollen data from Thieves' Moss and Sunset Hole site localities appear to agree with Swales's (1987) suggestion that small-scale clearance of the forest in parts of the Ingleborough Massif started below the Atlantic/Sub-Boreal transition (at about 5700 BP) due to activities of late Mesolithic or early Neolithic people. The course of natural acidification of upland soils is related to changes in vegetation from mixed woodland to heath and bog development (Pennington, 1991). It might be postulated that man's activity accelerated the soil deterioration (podsolization) in areas of glacial drift on the Massif, which probably began with the major climatic shift to the more oceanic regime of the Atlantic Period.

At Sniddle Moss (SM9) after c. 6830 BP the curves for the main components of the vegetation (chiefly Alnus and Cyperaceae) exhibit great fluctuations, perhaps due partly to local changes and variation in sedimentation. There are signs of mesotrophic conditions on the mire (see Chapter 5), but up to the level 126-128 cm where charcoal is found the pollen spectra demonstrate no evidence for human interference. Open ground taxa appear only occasionally with the exception of Pteridium spores which become abundant after about 5685 BP. Charcoal has been recovered from the sediments at both Sniddle Moss and Sunset Hole. At Sniddle Moss it occurs some way below the elm decline (126-128 cm) and at Sunset Hole it occurs at 145-160 cm which lies across the elm decline. It remains debatable whether fire was directly used in clearance. However, it is thought that in Northern England Mesolithic people were deliberately managing the woodland by using fire (e.g. Simmons, 1969 and 1975; Mellars 1976; Jacobi et al., 1976; Simmons et al., 1981; Simmons & Innes, 1987). Mesolithic horizons containing flints are often associated with charcoal deposits, as at Stump Cross near Grassington, in the Craven District (Walker, 1956). Charcoal layers are also found in other site localities of Craven, for example at Malham Tarn Moss (Pigott & Pigott, 1959 and 1963) and Great Close Pasture (Smith, 1986) where again there is abundance of mesolithic artefacts. The charcoal, if anthropogenic in origin, may merely derive from local domestic fire settings (Edwards, 1988) or it may represent the reduced screening effect of woodland close to the sampling site (Hirons & Edwards, 1990). No mesolithic remains are known from the immediate vicinity of either Sniddle Moss or Sunset Hole. Therefore, the find of charcoal from the study sites might be consistent with the second hypothesis put forward by Hirons and Edwards. Another aspect of the charcoal is that in the Craven District its abundance seems to be reduced after about 5000 BP, suggesting a decline in the incidence of fires. This pattern is similar to that found in the North York Moors

(Simmons & Innes, 1981) and in Scotland (Edwards & McIntosh, 1988; Edwards, 1990; Hirons & Edwards, 1990). A fire-decreased model may reflect a change of woodland management at the Mesolithic-Neolithic transition, as deduced by Simmons and Innes. Apart from man-fire relationship, it is feasible to state that pre-elm decline deposits of Craven also feature the establishment of grazing land. At Tarn Moss a rise in herb pollen associated with _Plantago lanceolata_, _Urtica dioica_ and Chenopodiaceae has been correlated with the activity of man. At Eshton Tarn in lowland Craven immediately below the elm decline increased representation of Gramineae pollen and the appearance of _Plantago lanceolata_, _Rumex acetosella_ and _Succisa_ have been interpreted as indicating human interference. Coming to the Ingleborough Region, the mid-Flandrian pollen zones of Arks I, Allotment Shooting Box, Sunset Hole and Thieves' Moss on the Massif and of Sniddle Moss on Newby Moor also demonstrates the occurrence of cultural indicators (such as _Pteridium_ and _Rumex_ spp.) along with other ruderals including Chenopodiaceae, Cruciferae and _Cirsium_-type, suggesting pastoral economy.

In earlier studies the elm decline has been defined as the first horizon in pollen profiles marking the activities of agriculturalists. However, taken together, the palynological data from the Craven District seem to support the idea of supposed Mesolithic disturbance and early Neolithic agriculture prior to the elm decline.

The elm decline

Before commencing a discussion of the elm decline it might be worthwhile to summarize some of the important features of this event and subsequent changes in the elm pollen curves in the Craven District:

(a) The first classical elm decline of c. 5000-5100 BP appears to be synchronous in the region.

(b) In the concentration and influx pollen diagrams produced for the study sites and other sites on the Massif at elm-decline times there is a rise in the values of total pollen concentration and influx which shows that the elm decline is a real phenomenon and it is not a statistical response to the increased frequencies of other pollen types.

(c) The elm pollen formerly rising up to 20% at sites on well-drained limestone soils and to 10% in areas of glacial drift falls to less than 1% of TLP at the first elm decline in almost all localities. In other words, the first elm decline shows a consistent pattern from site to site on different soils.

(d) It displays a dramatic effect over an extensive area because elm trees do not seem to regain completely their former habitats, even on limestone.

(e) The elm decline itself is usually accompanied by palynological indications of human activity and forest clearance.

(f) At Sniddle Moss 9 two periods of recovery, roughly dated to c. 4700 BP and 4420 BP respectively, are defined and the latter comparing with a similar recovery dated to c. 4440 BP at Allotment Shooting Box.

(g) At Sniddle Moss 9 a second elm decline is recognized at an estimated date of 4520 BP which is earlier than the dates from Allotment Shooting Box (c. 3650 BP) and Arks I (c. 3960 BP).

Much attention has been given to the first classical elm decline at about 5000 BP and it is widely reported from north-west Europe (Huntley & Birks, 1983). Four main hypotheses have been put forward to explain it: changes in climate, soil deterioration, anthropogenic effects on the vegetation and disease. The idea of marked climatic change was originally proposed by Iversen in the early 1940's (Troels-Smith, 1960) on the basis of the decreasing values of thermophilous types such as Hedera, Tilia and Ulmus pollen in Danish pollen diagrams. However, this explanation has received much less support as there is a lack of evidence from other sources (Ten-Hove, 1968; Godwin, 1975). In more recent works, absolute changes in the behaviour of pollen curves around elm-decline times show that there is a reduction in pollen concentration and influx values (e.g. Smith & Cloutman, 1988; Hirons & Edwards, 1990; Whittington et al., 1991b). Hirons and Edwards (1990) suggest that a general pattern of reduced pollen production might indicate the influence of widespread climatic change. A climatic deterioration is not made likely by the associated increase of warmth-demanding trees like Fraxinus and Tilia along with the occurrence of Hedera and Ilex pollen at and around the time of the elm decline in parts of Craven. In addition, the absolute pollen diagrams from the Ingleborough Region displaying an increase in total pollen concentration and influx values also argue against the suggestion of Hirons and Edwards (1990).

Another factor besides climatic conditions is that of soil deterioration. Elm demands a nutrient-rich soil and podsolization could slowly impede its ability to grow on poor soils. Sturludottir and Turner (1985) suggest that the cumulative effect of centuries of Mesolithic activity resulted in soil depletion, leading to a decline in elm populations. A gradual fall in frequency may be expected on poor, badly-drained soils with the onset of waterlogged conditions and soil leaching for whatever reason, as at Sniddle Moss and White Moss. However, since the elm decline is consistent on both poor and base-rich soils of the Craven District, this interpretation may also be discounted.

The coincidence of the first clear indications of agricultural activity by Neolithic peoples with the elm decline has led to the proposal of an anthropogenic cause

(Troels-Smith, 1960; Iversen, 1973). Troels-Smith suggested that Neolithic man was selectively using elm as fodder for livestock. Such method of managing woodlands still persists in several parts of Europe and Asia (Hybroek, 1963). The associated changes in the pollen assemblages of Craven at elm-decline times and the existence of evidence for Neolithic settlement in the region seem to accord with an anthropogenic-explanation. But the idea of selective utilization of elm is not entirely supported because the pollen of other trees of contrasting ecological requirements (e.g. *Pinus*, *Quercus*, *Betula* and *Alnus*) also declines. This is particularly conspicuous in limestone areas, e.g. at Eshton Tarn and Tarn Moss. The fact that remains of Neolithic age come mainly from the limestone caves and rock shelters of the uplands reflects marked differences in prehistoric activity between the uplands and the lowlands. Thus the synchroneity of the elm decline all over the region reduces the probability of a solely human cause to explain the biotic crisis. Disease might be the most likely primary cause, with early human interference providing conditions which encouraged its spread, as suggested by Rackham (1980, 1986 and 1988), Groenman-van Waateringe (1983) and Peglar (1993). The disease hypothesis was initially put forward by Iversen in 1955 (Troels-Smith, 1960). What pathogen could have been involved is unfortunately unknown. The current elm disease (Dutch elm disease) is caused by the fungus, *Ceratocystis ulmi* which is transmitted by bark beetle *Scolytus* spp. Hybroek (1963) once rejected a disease-induced elm decline in Neolithic times but the recent outbreak of Dutch elm disease has renewed interest in this as a possibility. Perry and Moore (1987) have shown similarities between current changes in elm-containing woodlands and the Neolithic elm-decline. Also, Moore (1984) has recorded the discovery of the beetle, *Scolytus scolytus* in Neolithic deposits on Hampstead Heath, as a clue to pre-historical decline of elms.

At elm-decline times, the death of elm trees in areas decimated by elm disease may have created additional space in the forest of Craven which was already undergoing some changes through the activity of Mesolithic and early Neolithic people. This would have allowed the increased response of the light-demanding trees such as Corylus and Fraxinus, resulting in the frequently observed rises in their pollen. The more open canopy and continued farming would also have encouraged open ground taxa (e.g. Plantago lanceolata, Pteridium and Urtica). Elm trees damaged by man for pollarding or ring-barking, as today, would be more subject to fatal pathogen attack than undamaged trees (Huntley & Birks, 1983). Thus the spread of the disease may have been accelerated by the arrival of new people (Neolithic people) who brought new ideas to the Craven District.

In many pollen diagrams elm pollen shows a recovery after the first decline. Huntley and Birks (1983) have drawn attention to a marked geographic variation in pattern of elm regeneration across north-west Europe. The recovery phenomenon is particularly strong in Ireland (e.g. O'Connell, 1980; Hirons & Edwards, 1986) and at Black Loch, Fife, Scotland (Whittington et al., 1991b). In England elm populations, on the other hand, never regained their former status after 5000 BP, probably as a result of soil acidity, competition, human activity and decimation of populations to values too low for any subsequent recovery (Birks, 1990).

Elm trees never fully recovered in the Craven District, but the increased elm pollen values after the first decline at Sniddle Moss, Sunset Hole and Allotment Shooting Box are noteworthy. The work by Rackham (1980) demonstrated that some modern elms are resistant to Dutch elm disease. Thus it does not seem unreasonable to suppose that elm populations recovered, at least partially, after the devastation of pathogenic attack. Estimated time of expansion from minimum to higher values after the first decline of elm for the Sniddle Moss site is approximately 350 radiocarbon years. Watts (1982) suggests that the lag between the first decline and the recovery reflects the time required for individuals that survived the epidemic due to natural immunity, isolation or reduced pathogenic virulence or for injured trees to recover. There is no doubt that local factors such as soil conditions and ecological competition also played an important role during the time of the recovery of elms in Craven.

The pollen evidence from the study site localities shows that the nature of the elm regeneration varied from site to site. Elm trees seem to have made a better recovery on limestone soils near Sunset Hole than in areas of poor soil (Sniddle Moss). Similarly, at the recovery time, elm pollen is better represented at Eshton Tarn than at White Moss.

As already interpreted in the context of the elm recovery within the study areas, Sniddle Moss and Sunset Hole (Chapter 8), the changes in the pollen curves suggest a reduction of farming. It may be the case that the abandonment of agricultural areas helped elm to recover on poor soils as well as on the better soils. However, incomplete recovery of elm populations, even on limestone soils, raises the question of causation. Here, on the basis of the evidence available the possibility of competition from other trees - particularly <u>Corylus</u> which appears to have formed dense areas of shrub on the limestone pavements - might be counted.

Several authors (e.g. Hirons & Edwards, 1986; Whittington <u>et al</u>., 1991b; Edwards & McDonald, 1991) consider the second elm decline which succeeded the recovery of elm. The second elm decline is what Hirons and Edwards (1986) refer to as the possible synchronous event which occurred between 4470 BP and 3945 BP in Britain and Ireland. Several explanations analogous to the debate surrounding the cause of the first elm decline have been presented; for example, disease (Bennett, 1983), human impact (Garbett, 1981; Whittington et al., 1991b) and a combination of continuous low levels of the disease and continued human activity (Peglar, 1993).

During the secondary elm decline of c. 4520-4470 BP in phase 4 of Sniddle Moss there is no clear evidence of possible clearance. Therefore, the idea of a renewed activity of the pathogen might be tentatively considered. Estimated dates of 4520-4470 BP from Sniddle Moss 9 may compare with the dates of 4470-3945 BP cited by Hirons and Edwards (1986). However, the second elm decline may demand explanations specific to each locality and it is very early to assert a case for its synchroneity.

The Neolithic Clearances (From 5000 BP - c. 4000 BP)

In the immediate post-elm period Neolithic woodland destruction phases for farming purposes, as originally described by Iversen (1956 and 1973), appear in most of the pollen diagrams from Craven. In the Sniddle Moss 9 pollen diagram clearance phases appear as episodes of about 500-600 years duration. This correlates with the estimated longevity of the same phase, between 585 and 720 years, for the Ingleborough Massif (Swales, 1987). Another coincidence is that in both the uplands and the lowlands of the Ingleborough Region Neolithic forest clearance was taking place some 700 years after the establishment of the first agriculture. Iversen (1956 and 1973) suggests the cutting down of the forest and subsequent burning. As already pointed out elsewhere, however, no significant quantities of charcoal have been recorded from post-elm decline deposits of the Craven District. It might be suggested that man-induced clearance was chiefly affected by felling rather than burning. Polished hand-axes dating from Neolithic times recovered on Over Pasture on the Ingleborough Massif (Gilks & Lord, 1985) and by Great Close and Fountain Fell (Pigott &

Pigott, 1959 and 1963) may also point to the involvement of felling.

The pollen data from the Ingleborough Region seem to indicate the episodes of clearances taking place in the context of a pastoral economy, with little crop growing, deduced from frequent occurrence of pastoral indicators. The date of about 5010 BP for the first appearance of cereal-type pollen in the pollen record of Sniddle Moss 9 suggests that in the Ingleborough Region, though on a minor scale, cereal cultivation may have started earlier than in lowland Craven where cereal-type pollen first appears at an estimated date of 4500 BP (at Eshton Tarn).

Another aspect of the episodes as recognized in the pollen profiles of the Ingleborough Region is that long-term Neolithic disturbance was followed by a short forest-regeneration phase. The longevity of this phase (some 220 years) revealed at Sniddle Moss also accords with the duration of about 200-550 years on the Massif (Swales, 1987).

The beginning of major episodes of forest clearance started at approximately 3840-4200 BP in the Craven District. This suggests that the later Neolithic or early Bronze Age was a time of major human impact on the vegetation. The archaeological evidence points to late Neolithic and early Bronze Age overlap in the region (see Chapter 3). It might be tentatively inferred that an increase in local population resulted in more intensive woodland destruction, especially on high-quality limestone soils.

From c. 4000 BP - present day

As mentioned elsewhere, it appears that intensive farming continued on the fertile limestone soils of Craven while the majority of sites (including Sniddle Moss) in the boulder clay saw more intensive clearance later (from

Anglo-Saxon Period).

10. CONCLUSION

The importance of the results of this study lies in two main areas of interest:

(a) By means of both percentage and concentration diagrams it has been possible to describe the Devensian Lateglacial vegetational history of the area around Sniddle Moss.

(b) Relative and absolute pollen diagrams produced for the study sites (Sniddle Moss/radiocarbon-dated and Sunset Hole) are the only pollen sequences from the Craven District which show the elm decline and the associated events in detail.

A reconstruction of the principal Lateglacial vegetational changes for the Ingleborough Region based mainly on Sniddle Moss 4 data is shown in Table 8.1.1. In general terms, the pattern of these vegetational changes is similar to that observed at other Lateglacial sites in western England, notably the spread of the juniper-scrub followed by the expansion of birch trees during the Interstadial. There are, however, several features of the data from SM4 and TM1 to which attention should be directed in further studies of Lateglacial history in the Craven District.

(1) There is very little pollen-stratigraphic evidence (from SM4) for the occurrence of phases of retrogressive vegetation development prior to the Younger Dryas Period.

(2) There are great fluctuations in the pollen curves in the SM4 Lateglacial pollen diagram, particularly in phase 4, which may be due partly to the influence of local site factors.

(3) Contamination in the profile of TM1 makes the interpretation of the TM1 data and the inference of the early and middle Lateglacial vegetation in the immediate vicinity of the site very difficult.

The existence of short-lived climatic oscillations during the Interstadial remains an enigmatic aspect of

Lateglacial pollen-sequences. Such events may be recorded at Sniddle Moss (and Thieves' Moss) but as mentioned above, evidence is slight and not conclusive. More detailed analyses at closer sampling intervals involving geochemical data might be useful to establish the occurrence of such climatic episodes. These may also help to understand the extent of site-specific influences. It is hoped that further sampling of Thieves' Moss (1) may produce contamination-free material.

As explained in the discussion, there is a growing body of evidence for the possibility of human interference in the pre-Ulmus decline forests in parts of Britain and Ireland. The present study shows no significant evidence in support of human interference with the early Flandrian vegetation. It is however possible to relate the changes in forest composition of the early Flandrian to changes in climatic conditions (dryness, wetness, etc.) and soils. At the beginning of the Flandrian at Sniddle Moss on the wet peaty soils in the lowland grasses expanded widely and then juniper established itself in this grassy vegetation. On the other hand, on drier limestone soils in the uplands, as at Thieves' Moss, grasses were not important and birch and juniper almost equally invaded a more open vegetation. In the lowland, grass and juniper-dominated vegetation remained important up to about 9130 BP but it was invaded by birch and hazel, the latter eventually becoming dominant with some pine. In the upland birch shaded out juniper and, perhaps for a relatively short time, must have formed almost pure woodland. This was then replaced by hazel which became the dominant tree on the drier soils as in the lowland. In the late Boreal Period pine colonized both the uplands and the lowlands. Alder may have been present in the Thieves' Moss area as early as 7830 BP. In the Sniddle Moss area in the boulder clay alder appears to have expanded quickly, in response to a rise in water table, possibly initiated by a climatic change, and it replaced the pine woodland. At Thieves' Moss on the well-drained limestone soils pine was first replaced by hazel.

It is only towards the close of the Atlantic Period (at about 5700-6000 BP) there are signs of possible human interference, but the effect of late Mesolithic or early Neolithic people seems to have been minimal.

The elm decline is shown to be a recurrent rather than a unique feature and five main phases are distinguished in respect of elm pollen representation at Sniddle Moss (9) and Sunset Hole. The pattern of elm pollen changes during phases 1, 2 and 3, in general, appears to be the same at both sites. The recovery of elm was not complete in the study area but was slightly more comprehensive near Sunset Hole on the Massif than at Sniddle Moss in the lowland. A shift towards increased Corylus and more frequent Fraxinus in the Sunset Hole area and more frequent Betula, Salix and Polypodium in the Sniddle Moss area was evident at and around the time of the elm decline. These between-site differences are related to soil differences and differences in prehistoric land-use.

When radiocarbon dates are obtained for the Sunset Hole site, the detailed picture of the elm decline events may be interpreted more properly and comparisons and correlations between the two sites may be made more efficiently.

APPENDIX 1

Radiocarbon dated levels

SITE	DEPTH (cm)	DATE (BP)	LAB. NUMBER
SM4	169-169.5	9130±65	AA - 9401
"	181-181.5	12020±90	AA - 9402
SM9	88-88.5	4710±45	AA - 9394
"	108.5-109	4960±55	AA - 9395
"	117.5-118	5050±50	AA - 9396
"	196-196.5	5685±80	AA - 9397
"	289.5-290	6115±60	AA - 9398
"	431-431.5	6830±65	AA - 9399
"	478-478.5	7305±60	AA - 9400
TM3	51-51.5	6200±60	AA - 9403
"	107.5-108	6725±70	AA - 9404
"	156.5-157	7830±80	AA - 9405

APPENDIX 2

Estimated time scale for Sniddle Moss 9

DEPTH (cm)	DATE (BP)	DEPTH (cm)	DATE (BP)
14	3770	103	4885
18	3820	104	4900
22	3870	105	4910
26	3920	106	4920
30	3970	107	4935
34	4020	110	4970
38	4070	111	4980
42	4120	112	4990
46	4170	113	5000
50	4220	114	5010
54	4270	115	5020
58	4320	116	5030
62	4370	119	5060
66	4420	126	5110
70	4470	134	5180
72	4500	142	5250
74	4520	150	5310
76	4550	158	5380
78	4570	166	5450
80	4600	174	5510
82	4620	182	5580
84	4650	190	5645
86	4670	198	5700
90	4720	206	5735
92	4750	214	5770
94	4770	222	5800
96	4800	230	5845
97	4810	238	5880
98	4820	246	5915
99	4835	254	5950
100	4850	262	5990
101	4860	270	6025
102	4870	278	6060

APPENDIX 2 (Cont.)

DEPTH (cm)	DATE (BP)
286	6100
294	6135
302	6180
310	6220
318	6260
334	6340
342	6380
350	6420
358	6460
366	6500
374	6545
382	6585
390	6625
398	6670
406	6710
414	6750
422	6790
430	6830
438	6900
446	6980
454	7060
462	7135
470	7210
486	7360
494	7440
502	7515

APPENDIX 3

Selected rare pollen and spore types* from SNIDDLE MOSS 4

TAXON	DEPTH (cm)
Trees and shrubs	
Tilia	28, 32, 40, 42, 46, 58
Fagus	24, 118, 170
Fraxinus	16, 20, 22, 24
? *Populus tremula*-type	94, 116
Ilex	54, 318, 354
Herbs	
Cornus sanguinea	110
C. suecica	234
Epilobium-type	136, 202, 270, 278, 296
Geranium	78, 316
Humulus lupulus-type	54
Leguminosae undiff.	214, 222
Lotus-type	12, 28, 194, 280, 282, 296, 330
Onobrychis-type	252, 286, 294
Lycopus subtype	106, 128
Melampyrum	42
Mercurialis	62, 210, 218
Solanum dulcamara	186
Spergularia-type	174, 222
Urtica	272, 312
Valeriana	46, 226, 230, 256, 258, 278, 280
Viburnum	178, 180
Pteridophytes	
Botrychium lunaria-type	256, 290
Cryptogramma	290, 292

---

*less than 1% of total land pollen

APPENDIX 4

Selected pollen and spore types* from SNIDDLE MOSS 4a

TAXON	DEPTH (cm)
Trees	
Tilia	70, 88, 94
Fagus	108
Fraxinus	72, 74, 76, 94, 98, 102, 106, 108, 110, 114
Shrubs	
Hedera	68, 76, 80, 82, 84, 86, 90, 92, 96, 100, 102, 104, 106, 108, 110, 112, 114, 116
Ilex	76
Herbs	
Cerealia-type	68, 70, 76, 78, 80, 82, 86, 88, 90
Cladium mariscus	92, 94, 96, 100, 102, 104, 112, 114
Compositae Tubuliflorae undiff.	76, 80, 82, 86
Artemisia	88, 90, 92, 98, 108, 114
Centaurea nigra-type	88
Cirsium-type	76, 82, 88
Achillea-type	70, 78, 82, 110
Solidago-type	74, 80, 82, 86, 90, 92, 102, 104, 108, 114, 116
Compositae Liguliflorae undiff.	70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 96, 104, 110

APPENDIX 4 (Cont.)

TAXON	DEPTH (cm)
Caltha-type	70, 76, 82, 84, 86, 88, 96, 102, 108
Caryophyllaceae	68, 70, 76, 82, 86, 88, 90, 116
Chenopodiaceae	68, 98
Cruciferae	70, 80, 84, 86, 88
Leguminosae undiff.	70
Mercurialis	74, 78, 94, 96
Scabiosa	84
Plantago	88, 102, 106, 110
P. coronopus	76, 80, 90
P. lanceolata	68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92
P. major/*P. media*	74, 78, 80, 82, 86, 92, 112
Polygonum amphibium	84
Potentilla-type	68, 70, 72, 76, 82, 84, 86, 88, 90, 94, 110
Ranunculaceae	68, 70, 72, 74, 76, 78, 80, 82, 84, 86, 88, 90, 92, 96, 98, 102, 104, 106, 110
Galium-type	70, 72, 74, 76, 78, 80, 82, 84, 86, 90, 94, 108, 114
Rumex/*Oxyria*	68, 72, 74, 76, 78, 80, 102, 114
R. acetosa-type	68, 70, 72, 82
Sanguisorba officinalis	106, 114
Succisa	70, 72, 74, 76, 84, 86, 92, 94, 96, 102, 106, 110

APPENDIX 4 (Cont.)

TAXON	DEPTH (cm)
Umbelliferae	68, 92, 100, 104, 108, 114
Valeriana	78
Aquatics	
Myriophyllum verticillatum	114
Nymphaea	110, 114
Potamogeton	68, 70, 72, 76, 78, 84, 86, 88, 90, 92, 94, 96, 98, 108, 112, 114
Typha angustifolia/*Sparganium*	84, 92, 102, 110, 112, 114
T. latifolia-type	96
Pteridophytes	
Equisetum	68, 78, 80, 82, 90, 92, 94, 96, 98, 100, 102, 104, 106
Polypodium	68, 70, 72, 76, 78, 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116
Dryopteris-type	94, 100, 106, 108, 112, 114, 116

---

* less than 2% of total land pollen

APPENDIX 5

Selected rare pollen and spore types* from SNIDDLE MOSS 9

TAXON	DEPTH (cm)
Trees	
Fagus	101
? *Populus tremula*-type	406
Herbs	
Cladium mariscus	438
Centaurea nigra-type	18, 438
Vicia cracca-type	14
Humulus lupulus-type	30
Potentilla-type	100
Sanguisorba minor	206
S. officinalis	198, 278
Thalictrum	462
Epilobium-type	100, 158
Geranium	30, 206, 270
Mercurialis	46, 118
Viburnum	470, 494
Aquatics	
Myriophyllum spicatum	398
Pteridophytes	
Lycopodium	30

---

* less than 1% of total land pollen

APPENDIX 6

Selected rare pollen and spore types* from THIEVES' MOSS 1

TAXON	DEPTH (cm)
Herbs	
Epilobium-type	122
Plantago coronopus	132
P. maritima	132, 136
Polygonum aviculare-type	145
Succisa	124, 138
Valeriana	145
Vallerianella	134
Viburnum	120, 124
Viola palustris-type	130
Aquatics	
Myriophyllum verticillatum	120
Typha latifolia-type	149
Pteridophytes	
Cryptogramma	124
Equisetum	126, 130, 134
Polypodium	134

---

* less than 1% of total land pollen

APPENDIX 7

Selected rare pollen and spore types* from THIEVES' MOSS 2

TAXON	DEPTH (cm)
Herbs	
Cornus suecica	142, 194
Epilobium-type	186, 196
Leguminosae undiff.	196
Mercurialis	208
Rumex aquaticus-type	202
Urtica	126, 130
Valeriana	142
Viburnum	130, 146, 154, 162
Pteridophytes	
Polypodium	126, 178, 186

---

* less than 0.5% of total land pollen

APPENDIX 8

Selected rare pollen and spore types* from THIEVES' MOSS 3

TAXON	DEPTH (cm)
Herbs	
Compositae Tubuliflorae undiff.	114
Cirsium-type	98
Compositae Liguliflorae undiff.	2, 18
Armeria	70, 106
Epilobium-type	154, 202
Leguminosae undiff.	174
Trifolium	2
Vicia cracca-type	130
Potentilla-type	202
Linum catharticum-type	2
Humulus lupulus-type	14
Geranium	78
Thalictrum	198
Urtica	102
Valeriana	62
Viburnum	202, 210
Aquatics	
Myriophyllum verticillatum	198
Nuphar	210
Pteridophytes	
Lycopodium	74
L. annotinum	154

---

* less than 0.5% of total land pollen

APPENDIX 9

Selected rare pollen and spore types* from SUNSET HOLE

TAXON	DEPTH (cm)
Trees	
Carpinus	131, 155
Shrubs	
Ilex	70, 93.5, 147
Herbs	
Achillea-type	144
Solidago-type	146, 153, 155, 163.5, 190
Compositae Liguliflorae undiff.	64, 250
Leguminosae undiff.	122, 160, 180, 230, 277
Trifolium montanum-type	157, 180
Vicia-type	49.5, 180
V. cracca-type	49.5, 180
Caltha-type	141
Galium-type	20, 118.5, 260
Humulus lupulus-type	142, 143
Droseraceae	138, 140, 141, 158
Geranium	128, 230
Mentha-type	270
Mercurialis	25, 40, 45, 49.5, 120, 149.5
Lonicera	180
Prunella-type	145
Succisa	62, 82, 103
Teucrium	180
Valeriana	230, 250, 270
Viburnum	151, 277
Viola palustris-type	106.5

APPENDIX 9 (Cont.)

TAXON	DEPTH (cm)
Aquatics	
Hydrocotyle	99
Myriophyllum spicatum	20
Potamogeton	49.5, 70, 99, 136, 146
Pteridophytes	
Equisetum	78, 115, 135, 151, 152, 153, 154
Lycopodium	277
Dryopteris-type	82, 88, 90, 103, 118.5, 156, 161.5, 180, 190, 199

---

* less than 2% of total land pollen

APPENDIX 10

Characeae oospores

The oospores of Characeae were abundant in the Lateglacial and early Flandrian deposits of both Sniddle Moss and Thieves' Moss. Consequently, an attempt has been made to make specific identifications by using the light microscope (LM) and the scanning electron microscope (SEM).

Nomenclature follows Groves and Bullock-Webster (1920 and 1924).

LM study

Some important characters of the fossil oospores were firstly used to distinguish the two genera, _Nitella_ and _Chara_. The oospores of _Nitella_ recovered from Sniddle Moss (_Nitella_-type A) and Thieves' Moss (_Nitella_-type C) were compared with the modern oospores of British _Nitella_ species of G. R. Bullock-Webster's specimens at the herbarium of Leeds University. Type A fitted into _Nitella flexilis_ while type C was determined as _N. opaca_ (Tables 1 and 4).

It is assumed that there may have been at least two species of _Chara_ growing in the former lake in the area of Sniddle Moss since two morphologically distinct types (type B1 and B2) have been recovered (Tables 2 and 3). _Chara_ oospores found in the profile of Thieves' Moss were named as type D (Table 5). Although herbarium samples of various species of _Chara_ have been examined to compare with those from Sniddle Moss and Thieves' Moss it seems difficult to be certain about the determination under the LM because the oospores of available material show great similarity to one another.

SEM study

Recent works show that the SEM investigation appears to improve knowledge of the nature of the oospore wall (e.g. Cáceres, 1975; Frame, 1977; Leitch, 1986; John & Moore, 1987; John _et al_., 1990; Leitch _et al_., 1990). It also provides taxonomically more important characters of both modern and fossil representatives of the group (Characeae). Therefore, in this study the scanning electron microscope was employed to understand the exact structure of the wall of oospores found. The SEM technique applied is as follows:

After washing in distilled water, selected fossil oospores were mounted on aluminium stubs with double-sided tape and coated with a gold layer of 50 nm using a POLARON sputter coater. Photographs were taken using a CAM SCAN SERIES 3 scanning electron microscope.

Notes on Characeae oospores recovered

Sniddle Moss

(1) Type A (Table 1; Plate I, Figs 1 and 2)
Nitella flexilis

The SEM study by Frame (1977) demonstrate that in various forms of modern _Nitella flexilis_ there are highly variable oospore wall patterns, either smooth, pitted, finely spongy or scabrous. The comparison between his study (see Frame, 1977; p. 47; Plate III, Figs, 19 and 20) and the SEM photographs of the oospore wall of type A with spongy pattern allowed for intraspecific determination and suggested that it is _Nitella flexilis_ var. _flexilis_ f. _flexilis_.

(2) Type B1 (Table 2; Plate II, Figs 1 and 2)
Chara sp. (_C_. ? _aspera_)

The SEM photographs of this type were compared with those of modern _Chara_ oospores in John _et al_. (1990). In general, the oospore wall of *Chara* shows a conservative nature and this makes further determination difficult. Consequently, the grouping of the *Chara* taxa based on the morphology of the outer fossa wall given by John *et al*. (1990) has been considered and type B1 has been placed in group (I)-B. The group includes *Chara aspera*, *C. baltica*, *C. capensis* and *C. strigosa* characterized by either relatively smooth or roughened (due to the presence of numerous small pits, pores and depressions) oospore wall in the fossa region and low, fused, nodulated elements on the surface of the ribbon-like structure. Detailed examination suggests that the fossil type has some features more similar to *Chara aspera* than other species in the group - the fossa wall has pores varying in size; larger ones range from 0.05-1 µm in diam.

(3) Type B2 (Table 3; Plate III, Figs 1 and 2)
Chara sp.

This type has been placed in group (I)-A-iii (John *et al*., 1990) whose members (*Chara corallina*, *C. desmacantha* and *C. rusbyana*) have pusticular projections and low domes with or without an opening on the fossa wall. It resembles *Chara rusbyana* (see John *et al*., 1990; Fig. 51) and the fossil oospores recovered by John Foster from deposits about 25,000 years old found near Hatfield (Hertfordshire) (D. M. John & J. A. Moore, personal communication). *Chara rusbyana* is unknown in Britain and mainland Europe.

Thieves' Moss

(4) Type C (Table 4; Plate IV, Figs 1 and 2)
Nitella opaca

The taxonomic position of modern *Nitella opaca* and its relationship with *N. flexilis* are still controversial since they display a range of morphological characters that could fall within both taxa (Moore, 1986). When only oospore features are taken into consideration, *Nitella opaca* has smaller oospores than *N. flexilis*

(Groves & Bullock-Webster, 1920). In this study, it was possible to distinguish Nitella oospores (type C) recovered from Thieves' Moss from those (type A) found in the profile of Sniddle Moss under the binocular microscope - type C being smaller and more compressed than type A. The oospore wall of type C (Nitella opaca) also displays a different character under the SEM - there are very small granules and pits giving a roughened surface.

(5) Type D (Table 5; Plate V, Figs 1 and 2)
Chara vulgaris

The specific determination of this type is based on the comparison with the outer wall structure of Chara vulgaris specimens seen with the SEM (see John et al., 1990; Figs 60-62) - granules or papillae in the fossa region, their number being five along a 10 μm width across the fossa; low, fused nodular elements on the surface of the ribbon-like structure.

Palaeoecological significance of fossil Characeae at the study sites

Sniddle Moss

Characeae oospores appear to be more abundant in the uppermost part of the lower lake clay than in overlying and underlying sediments. The types recovered may have been the pioneering elements in the newly created lake of the Sniddle Moss site in the beginning of the Lateglacial Period. Later, they may have been replaced by aquatic angiosperms as climate showed further improvement. However, the presence of their oospores in the upper Lateglacial and early Flandrian sediments suggests that these types may have continued to assume some importance in the aquatic vegetation.

Nitella flexilis tolerates a wide range of pH levels while *Chara aspera* demands a pH range of c. 6 to 9 (Moore, 1986). *Nitella flexilis* oospores were found together with *Chara*-type B1 (*C.* ? *aspera*) at various depths of the Sniddle Moss lake. This may indicate that the pH level of the lake was not below 6.

Chara-type B2 which is thought to resemble *C. rusbyana* would be regarded as an extinct type in Britain. It may have been highly sensitive to local and environmental changes.

Thieves' Moss

Since only a part of contamination-free Lateglacial sediments could be extracted from the sampling point TM2, it is now impossible to draw a complete picture of the (Lateglacial) aquatic vegetational history, including charophytes. It is however noteworthy that in minerogenic sediments (the upper lake clay) *Nitella opaca* is the dominant type whereas *Chara vulgaris* oospores become abundant in the organic mud of the early Flandrian Period. A similar pattern has been reported by several authors (e.g. Vasari & Vasari, 1968; Berglund & Digerfeldt, 1970; Birks & Mathewes, 1978) worked on the Lateglacial sites, though there is no specific determination for *Chara* in these papers.

Nitella opaca grows in diverse habitats under a wide range of conditions. Langangen (1974) says that this species shows optimal development in (*Lobelia*) lakes, characterized by low production and dense charophytes, in Norway. During the Younger Dryas Period, a decline in vigorous aquatic angiosperms may have created conditions favourable for *Nitella opaca*. Thus it may have flourished the former lake of the Thieves' Moss site, even it may have formed almost a pure charophyte community. With the climatic improvement, *Chara vulgaris* seems to have replaced *Nitella opaca*. Either competition or nutrient status of the lake, or both, would have been of great importance in the expansion of Chara vulgaris.

Conclusion

Ecological information available appears to be of little help in the palaeoecological interpretation of some Characeae oospore types found in deposits of Sniddle Moss and Thieves' Moss. Further ecological studies of this group, possibly involving detailed analysis of chemistry and other features of lakes, are essential. These might help palaeoecologists to draw more definite conclusions. This study presents a limited palaeoecological interpretation but it may be a part of an index for fossil Characeae oospores in Quaternary deposits.

References (for Appendix 10)

Berglund B. E. & Digerfeldt G. (1970) "A palaeoecological study of the Late-Glacial lake at Torreberga Scania, South Sweden", Oikos, 21, 98-128.

Birks H. H. & Mathewes R. W. (1978) "Studies in the vegetational history of Scotland", New Phytologist, 80, 455-484.

Cáceres E. J. (1975) "Novedades Carologicas Argentinas I. Una Nueva Especie de Nitella y tres Adiciones al Genero Para La Flora Argentina", Kurtziana, 8, 105-125.

Frame P. (1977) "Fine Structural Studies of Oospore Ornamentation and Bulbil Development in Charophytes", PhD Thesis, University of Toronto.

Groves J. & Bullock-Webster G. R. (1920) "The British Charophyta Volume I Nitelleae", Ray Society, London.

Groves J. & Bullock-Webster G. R. (1924) "The British Charophyta Volume II Chareae", Ray Society, London.

John D. M. & Moore J. A. (1987) "An SEM study of the oospore of some Nitella species (Charales, Chlorophyta) with descriptions of wall ornamentation and an assessment its taxonomic importance", Phycologia, 26/3, 334-355.

John D. M., Moore J. A. & Green D. R. (1990) "Preliminary observations on the structure and ornamentation of the oosporangial wall in Chara (Charales, Chlorophyta)", British Phycological Journal, 25, 1-24.

Langangen A. (1974) "Ecology and distribution of Norwegian charophytes", Norwegian Journal of Botany, 21, 31-52.

Leitch A. R. (1986) "Studies on Living and Fossil Charophyte Oosporangia", PhD Thesis, University of Bristol.

Leitch A. R., John D. M. & Moore J. A. (1990) "The oosporangium of the Characeae (Chlorophyta, Charales)", (In "Progress in Phycological Research", Vol. 7, ed. by F. E. Round & D. J. Chapman), pp. 213-268. Biopress Ltd.

Moore J. A. (1986) "Charophytes of Great Britain and Ireland", Botanical Society of the British Isles, London, No 5.

Vasari Y. & Vasari A. (1968) "Late- and post-glacial macrophytic vegetation in the lochs of northern Scotland", Acta Botanica Fennica, 80, 4-120.

Table 1. Some characters of *Nitella* (type A) oospore from Sniddle Moss under the LM and SEM and their comparison with the records of earlier workers on *Nitella flexilis*.

Some characters	Groves & Bullock-Webster (1920) *Nitella flexilis*	Frame (1977) *Nitella flexilis*	*Nitella* (type A) LM (µm)	SEM
LPA (Length of the polar axis)	500-575 µm		520-640	
LED (Largest equatorial diameter)	425-500 µm		450-520	
Shape			Subprolate	
AND (Anisopolar distance: distance from the apical pole to the largest equatorial diameter)			300	
ANI (Anisopolar index: AND/LPAx100)			53 (Ellipsoidal)	
The maximum width of the segmented basal pore			80-140	
The number of convolutions of the fossules (in lateral view)			6-7	
The number of convolutions of the spirals (in lateral view)	5-7		6-7	
Ornamentation on the fossa wall		Highly variable: smooth, pitted, finely spongy or scabrous	verrucate-reticulate	spongy with mesh size c. 1.2 µm

Table 2. Some characters of *Chara* (type B1) oospore from Sniddle Moss under the LM and SEM and their comparison with the records of earlier workers on *Chara aspera*.

Some characters	Groves & Bullock-Webster (1924) *Chara aspera*	John *et al.* (1990) *Chara aspera*	*Chara* (type B1) LM (µm)	SEM
LPA	400-600 µm		664-840	633*
LED	250-375 µm		430-550	
Shape			Perprolate	
AND			300-400	333
ANI			44 (Ellipsoidal)	
The height of the basal claw			40-100	
The maximum width of the pore			100-160	
The number of convol. of the fossules			12-13	
The number of the spirals	12-14		12-14	
Ornamentation on the fossa wall		roughened	roughened (pits and pores)	
Surface of the ribbon		low, fused nodulated elements	low, fused, nodulated elements	
The width of the ribbon		c. 20 µm	c. 30	

* excluding basal cage

Table 3. Some characters of *Chara* (type B2) oospore from Sniddle Moss under the LM and SEM.

Some characters	LM (μm)	SEM (μm)
LPA	620-700	770*
LED	320-390	
Shape	Prolate	
AND	300-360	
ANI	50 (Ellipsoidal)	
The height of the basal claw	20-50	60
The maximum width of the pore	100-120	
The number of convol. of the fossules	12-14	
The number of the spirals	13	
Ornamentation on the fossa wall	Foveolate	Low pustular elevations with pores

* including basal claws

Table 4. Some characters of *Nitella* (type C) oospore recovered from Thieves' Moss under the LM and SEM and their comparison with the records of Groves & Bullock-Webster (1917) on *Nitella opaca*.

Some characters	Groves & Bullock-Webster (1920) *Nitella opaca*	*Nitella* (type C) (Thieves' Moss)	
		LM (µm)	SEM (µm)
LPA	375-425 µm	420	302
LED	350-400 µm	360	258
Shape	Spheroidal/broader than long	Subprolate	
AND		200	162
ANI		48 (Ellipsoidal)	
The numb. of convol. of the fossules		6	
The numb. of convol. of the spirals		7	
Ornamentation on the fossa wall			roughened

Table 5. Some characters of *Chara* (type D) oospore from Thieves' Moss under the LM and SEM and their comparison with the records of earlier workers on *Chara vulgaris*.

Some characters	Groves & Bullock-Webster (1924) *Chara vulgaris*	John *et al.* (1990) *Chara vulgaris*	*Chara* (type D) LM (μm)	SEM
LPA	425-675* μm		630-740*	567
LED	225-400 μm		370-550	367
Shape			Prolate	
AND			300-400	300-400
ANI			48 (Ellipsoidal)	
The height of the basal claw			50-70	
The maximum width of the pore			70	
The number of convol. of the fossules			11-14	
The number of the spirals	12-15		11-14	
Ornamentation on the fossa wall		roughened/granulate		granules/ papillae
Surface of the ribbon		low, fused, nodulated elements		low, fused nodulated elements

* excluding basal cage

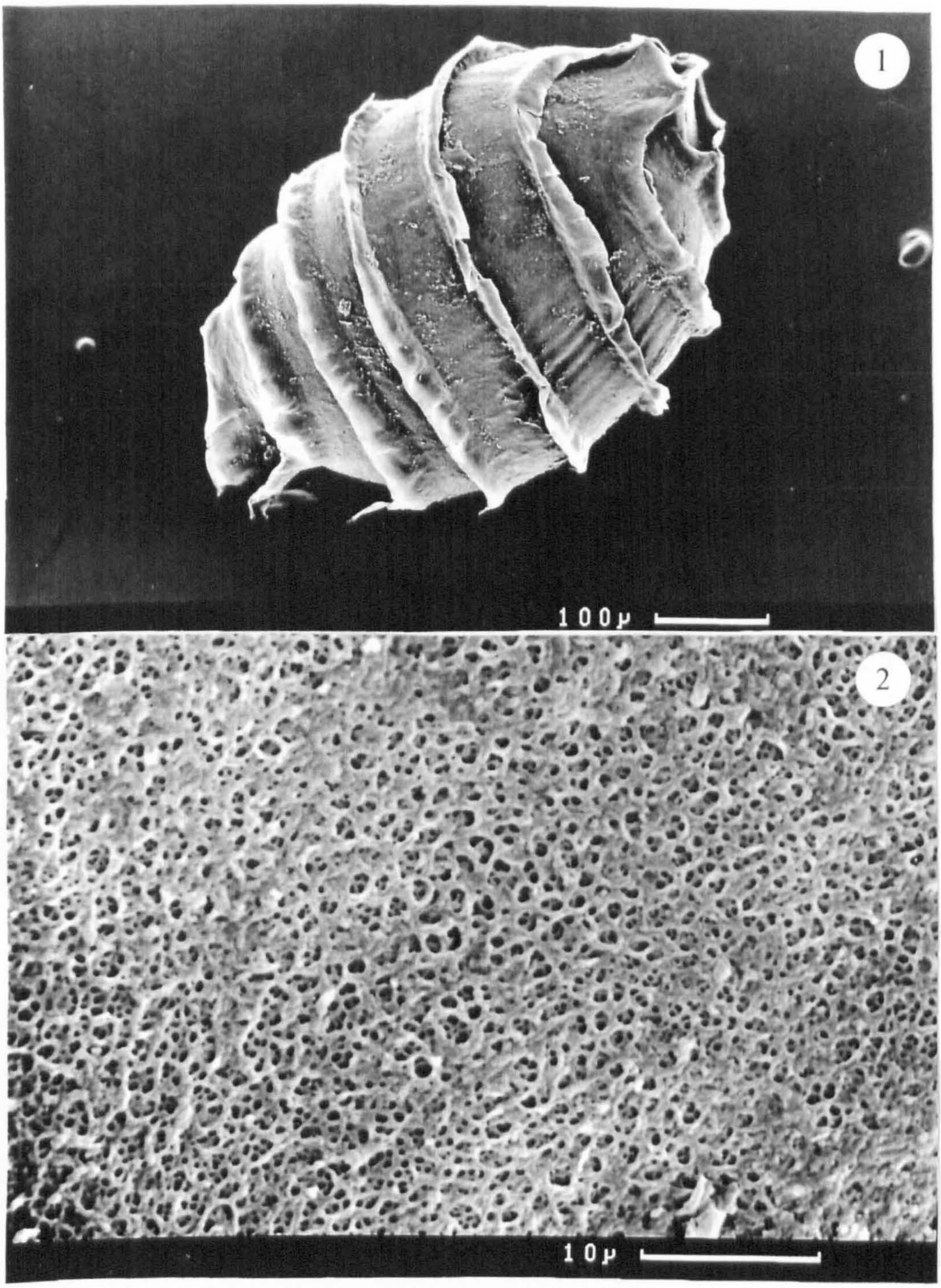


Plate I. Figs 1-2. SEM of *Nitella* (type A) (*Nitella flexilis*) oospore from Sniddle Moss (SM9 458-460 cm - peat). Fig. 1. Oospore in lateral view. Fig. 2. Fossa wall showing spongy ornamentation.

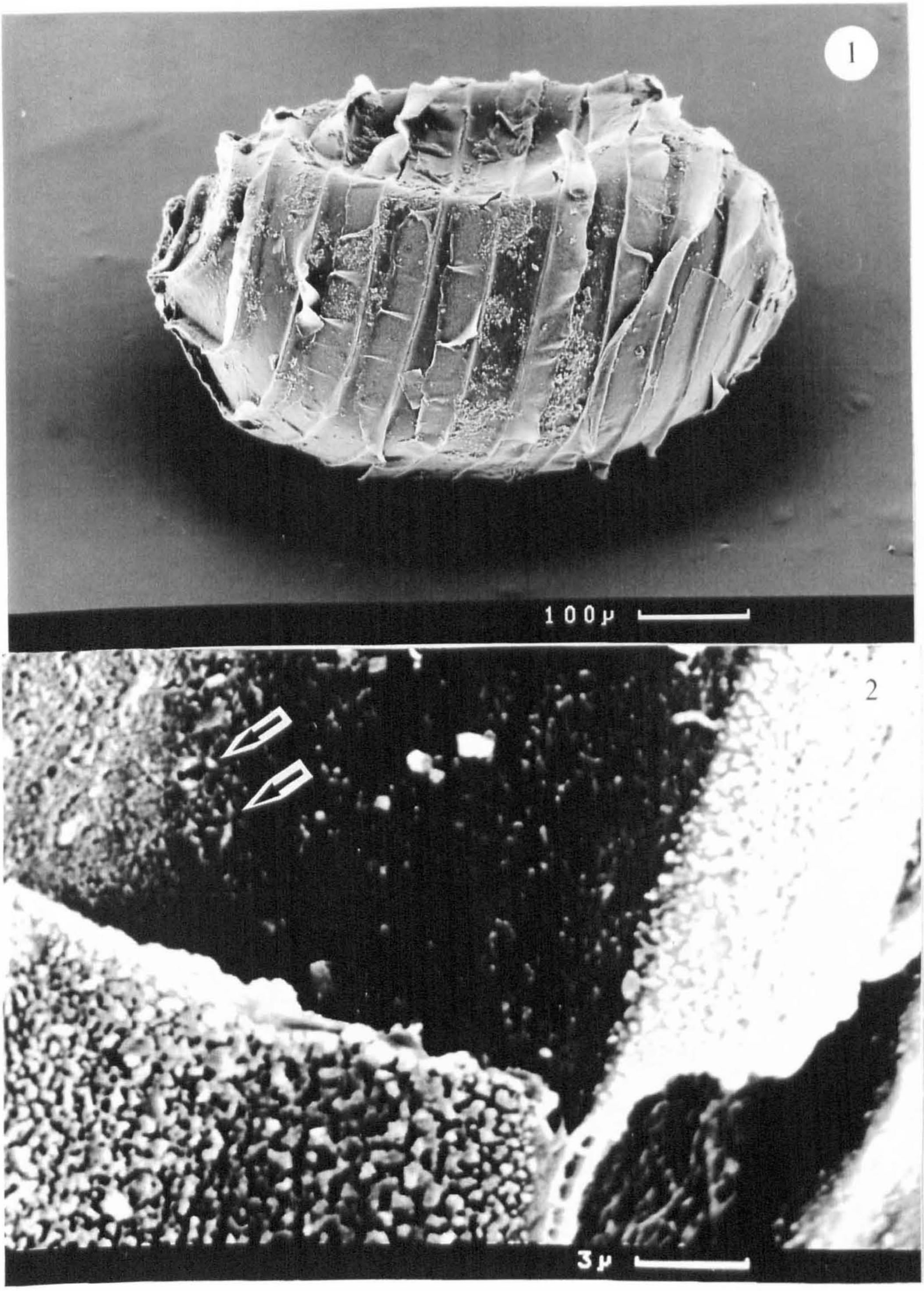


Plate II. Figs 1-2. SEM of *Chara* (type B1) (*Chara ? aspera*) oospore from Sniddle Moss (SM6 217-219 cm - marl). Fig.1. Oospore with some debris in lateral view. Fig.2. Surface of the fossa wall covered by numerous pits, pores (arrowed) and depressions and broken ribbon shrouding the fossa wall; note the difference in the nature of its surface compared to the adjacent wall area (fossa).

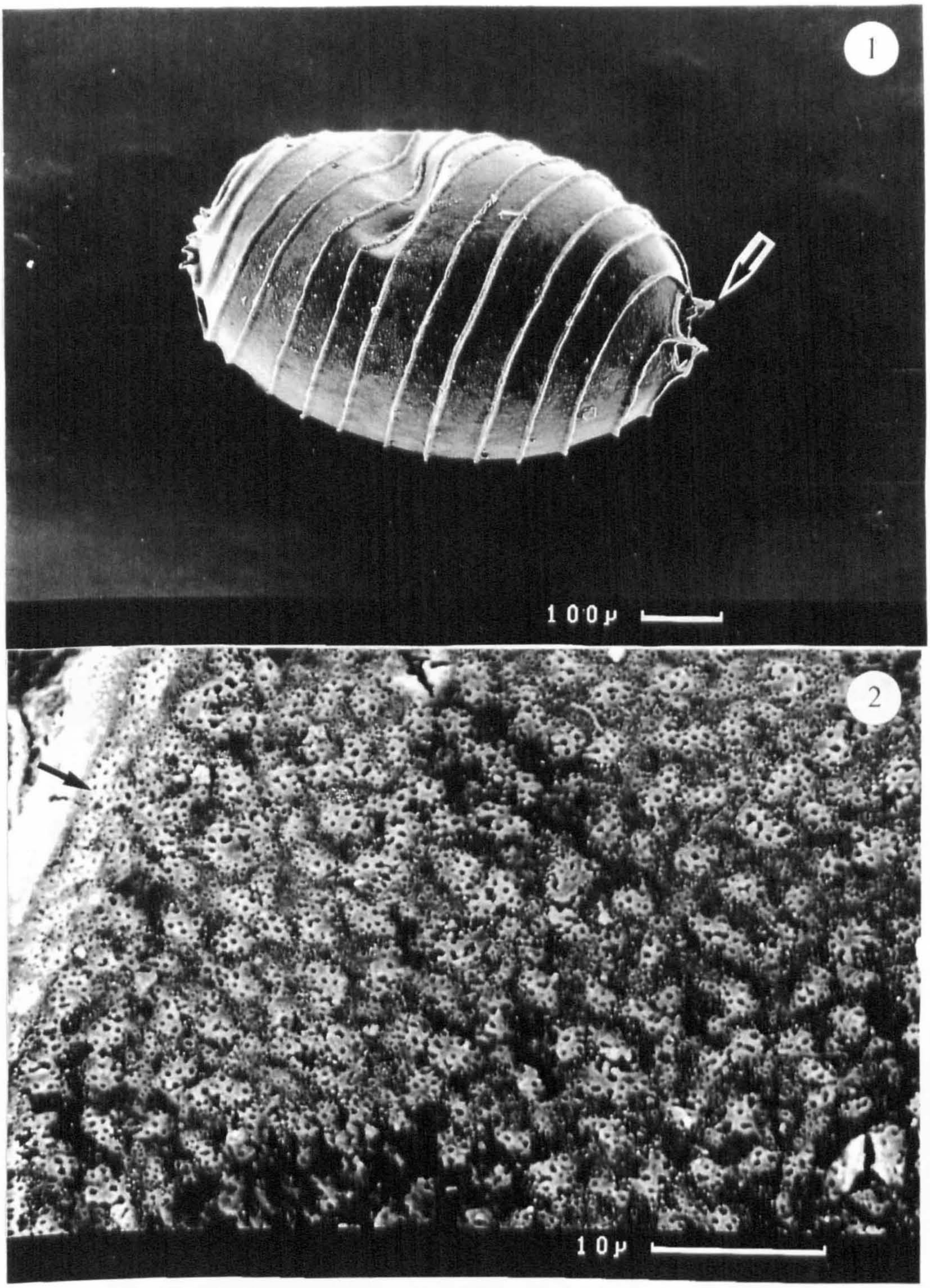


Plate III. Figs 1-2. SEM of Chara (type B2) oospore from Sniddle Moss (SM3 226-228 cm - marl). Fig.1. Oospore with basal claws (arrowed) in lateral view. Fig.2. Oospore wall showing low pustular elevations with perforations extending towards the lower part of the ridge (arrowed).

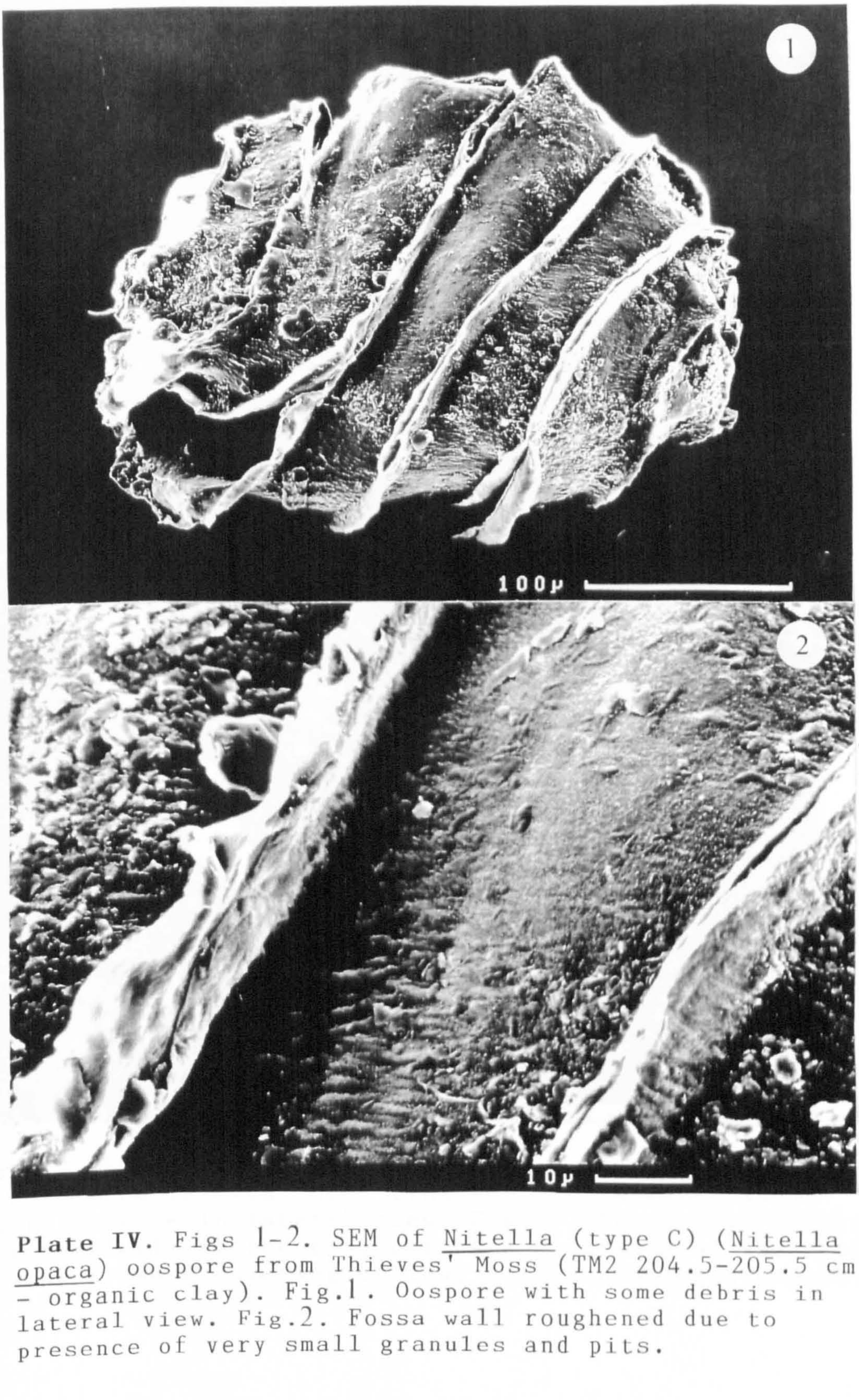


Plate IV. Figs 1-2. SEM of *Nitella* (type C) (*Nitella opaca*) oospore from Thieves' Moss (TM2 204.5-205.5 cm - organic clay). Fig.1. Oospore with some debris in lateral view. Fig.2. Fossa wall roughened due to presence of very small granules and pits.

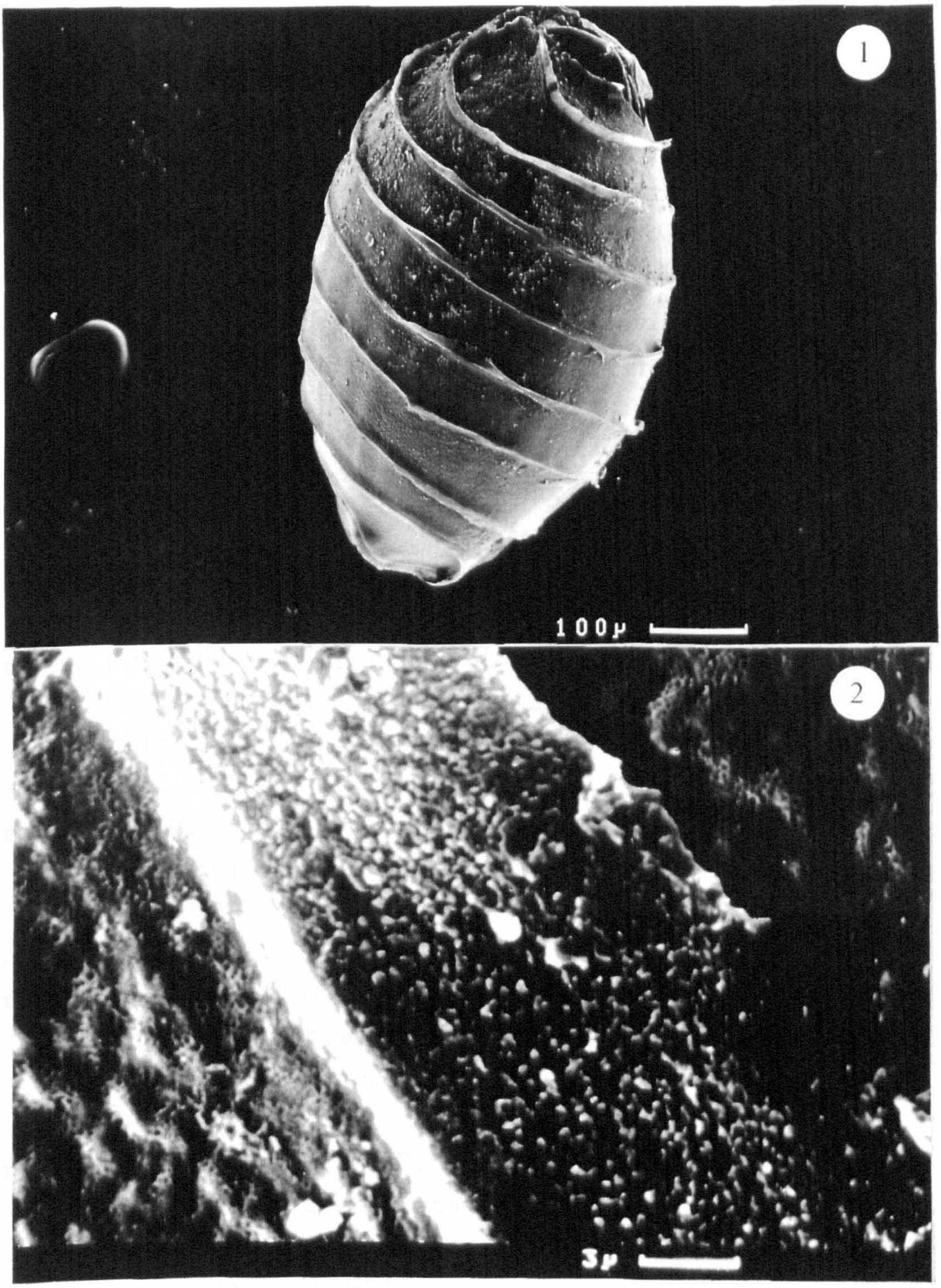


Plate V. Figs 1-2 . SEM of Chara (type D) (Chara vulgaris) oospore from Thieves' Moss (TM2 184 cm - organic mud). Fig.1. Oospore in lateral view. Fig.2 . Fossa wall covered by irregularly shaped projections and surface of the ribbon showing a dense covering of low, fused nodular elements.

References

Arthurton R. S., Johnson E. W. & Mundy D. J. C. (1988) "Geology of the country around Settle", BGS (British Geological Survey), London.

Atkinson T. C., Briffa K. R. & Coope G. R. (1987) "Seasonal temperatures in Britain during the past 22,000 years, reconstructed using beetle remains", Nature, **325**, 587-592.

Barratt B.C. (1960) "An investigation of the morphology and development of some grassland humus forms", PhD Thesis, University School of Agriculture, King's College, University of Durham.

Bartley D. D. (1962) "The stratigraphy and pollen analysis of lake deposits near Tadcaster, Yorkshire", New Phytologist, **61**, 277-287.

Bartley D. D. (1967) "Pollen analysis of surface samples of vegetation from Arctic Quebec", Pollen et Spores, **9**, 101-105.

Bartley D. D. & Clark S. C. (1979) "A vegetation survey of the Ingleborough", S.S.S.I., University of Leeds Industrial Services Ltd. (ULIS), Leeds.

Bartley D. D., Jones I. P. & Smith R. T. (1990) "Studies in the Flandrian vegetational history of the Craven District of Yorkshire: The lowlands", Journal of Ecology, **78**, 611-632.

Bartley D. D. & Morgan A. V. (1990) "The palynological record of the King's Pool, Stafford, England", New Phytologist, **116**, 177-194.

Beales P. W. (1980) "The Late Devensian and Flandrian vegetational history of Crose Mere, Shropshire", New Phytologist, 85, 133-161.

Beckett S. C. (1981) "Pollen diagrams from Holderness, North Humberside", Journal of Biogeography, 8, 177-198.

Beijerinck W. (1947) "Zadenatlas Der Nederlandsche Flora", H. Veenman & Zonen, Wageningen.

Bellamy D. J., Bradshaw M. E., Millington G. R. & Simmons I. G. (1966) "Two Quaternary deposits in the Lower Tees Basin", New Phytologist, 65, 429-442.

Bennett W. (1936) "Giants' Graves, Pen-y-Ghent", The Yorkshire Archaeological Journal, 33, 318-319.

Bennett W. (1938) "Iron Age Settlements in Penigent Gill", The Yorkshire Archaeological Journal, 34, 413-419.

Bennett K. D. (1983) "Devensian Late-glacial and Flandrian vegetational history at Hockham Mere, Norfolk, England", New Phytologist, 95, 457-487.

Bennett K. D. (1984) "The Post-glacial history of Pinus sylvestris in the British Isles", Quaternary Science Reviews, 3, 133-155.

Berggren G. (1969) "Atlas of Seeds, Part 2, Cyperaceae", Swedish Natural Science Research Council.

Berggren G. (1981) "Atlas of Seeds, Part 3, Salicaceae-Cruciferae" Swedish Museum of Natural History.

Birks H. J. B. (1965) "Late-glacial deposits at Bagmere, Cheshire and Chat Moss, Lancashire", New Phytologist, 64, 270-281.

Birks H. J. B. (1973) "Past and Present Vegetation of the Isle of Skye : A Palaeoecological Study", Cambridge University Press, Cambridge.

Birks H. J. B. (1990) "Late-Quaternary biotic changes in terrestrial and lacustrine environments, with particular reference to north-west Europe", (In "Handbook of Holocene Palaeoecology and Palaeohydrology", ed. by B. E. Berglund) pp. 3-65. John Wiley & Sons Ltd.

Björck S., Berglund B. E. & Digerfeldt G. (1988) "New aspects on the deglaciation chronology of south Sweden", Geographica Polonica, 55, 37-49.

Broecker W. S., Andree M., Bonani G., Wolfli W., Oeschger H. & Klas M. (1988) "Can the Greenland climatic jumps be identified in records from ocean and land ?", Quaternary Research, 30, 1-6.

Bullock P. (1964) "A study of the origin and development of soils over Carboniferous Limestone in the Malham District of Yorkshire", MSc Thesis, University of Leeds.

Bullock P. (1971) "The soils of the Malham Tarn Area", Field Studies, 3, 381-408.

Clapham A. R., Tutin T. G. & Moore D. M. (1989) "Flora of the British Isles", 3rd ed., Cambridge University Press, London.

Coesel P. F. M. (1979a) "Desmids of the broads area of N. W. Overjissel (The Netherlands) I", Acta Botanica Neerlandica, 28, 257-279.

Coesel P. F. M. (1979b) "Desmids of the broads area of N. W. Overjissel (The Netherlands) II", Acta Botanica Neerlandica, 28, 385-423.

Conway V. M. (1954) "Stratigraphy and pollen analysis of Southern Pennine blanket peats", Journal of Ecology, **42**, 117-147.

Coope G. R. (1977) "Fossil coleopteran assemblages as sensitive indicators of climatic changes during the Devensian (Last) cold stage", Philosophical Transactions of the Royal Society of London B, **280**, 313-340.

Crompton A. (1961) "A brief account of the soils of Yorkshire", Journal of Yorkshire Grassland Society, **3**, 27-35.

Cunliffe B. (1978) "Iron Age communities in Britain", Routledge & Kegan Paul, London & Boston.

Dickson J. H. (1973) "Bryophytes of the Pleistocene. The British record and its chronological and ecological implications", Cambridge University Press, London.

Dixon H. N. (1954) "The Students Handbook of British Mosses", Sumfield & Day Ltd.

Dunham K. C., Hemingway J. E. , Versey H. C. & Wilcockson W. H. (1953) "A guide to the geology of the district round Ingleborough", Proceedings of the Yorkshire Geological Society , **29**, 77-115.

Edwards K. J. (1988) "The hunter-gatherer/agricultural transition and the pollen record in the British Isles", (In "The Cultural Landscape - Past, Present and Future", ed. by H. H. Birks, H. J. B. Birks, P. E. Kaland & D. Moe) pp. 255-266. Cambridge University Press.

Edwards K. J. (1990) "Fire and Scottish Mesolithic: evidence from microscopic charcoal", (In

"Contributions to the Mesolithic in Europe", ed. by P. M. Vermeersch & P. Van Peer) pp. 71-79. Leuven University Press, Leuven.

Edwards K. J. & Hirons K. R. (1984) "Cereal pollen grains in pre-elm decline deposits: Implications for the earliest agriculture in Britain and Ireland", Journal of Archaeological Science, 11, 71-80.

Edwards K. J. & MacDonald G. M. (1991) "Holocene palynology: II human influence and vegetation change", Progress in Physical Geography, 15, 364-391.

Edwards K. J. & McIntosh C. J. (1988) "Improving the detection rate of cereal-type pollen grains in Ulmus decline and earlier deposits from Scotland", Pollen et Spores, 30, 179-188.

Edwards K. J. & Thompson R. (1984) "Magnetic palynological and radiocarbon correlation and dating comparisons in long cores from a Northern Irish lake", Catena, 11, 83-89.

Faegri K. & Iversen J. (1989) "Textbook of Pollen Analysis", (IV Edition by K. Faegri, P. E. Kaland & K. Krzywinski), John Wiley & Sons.

Garbett G. G. (1981) "The elm decline: the depletion of a source", New Phytologist, 88, 573-585.

Gilks J. A. (1973) "The Neolithic and early Bronze Age pottery from Elbolton Cave, Wharfedale", The Yorkshire Archaeological Journal, 45, 41-54.

Gilks J. A. (1981) "Ingleton, Ravenscar Cave, SD 730757" in "Yorkshire Archaeological Register: 1981", The Yorkshire Archaeological Journal, 54, 171-172.

Gilks J. A. & Lord T. (1985) "A late Neolithic crevice burial from Selside, Ribblesdale, North Yorkshire", The Yorkshire Archaeological Journal, 57, 1-5.

Godwin, H. (1975) "History of the British Flora", Cambridge University Press.

Gosden, M. S. (1965) "An investigation into the origin and nature of some organic deposits of the Ingleborough Region", PhD Thesis, University of Leeds.

Gray J. M. & Lowe J. J. (1977) "The Scottish Late Glacial environment: a synthesis" (In "Studies in the Scottish Lateglacial environment", ed. by J. M. Gray & J. J. Lowe) pp. 163-181. Pergamon Press, Oxford.

Greig J. (1982) "Past and present lime woods of Europe", (In "Archaeological Aspects of Woodland Ecology", ed. by M. Bell & S. Limbrey) pp. 23-55. Symposia of the Association for Environmental Archaeology No.2 BAR International Series 146.

Groenman-van Waateringe W. (1983) "The early agricultural utilization of the Irish landscape: the last word on the elm decline ?", British Archaeological Report British Series, 116, 217-232.

Hibbert F. A. & Switsur V. R. (1976) "Radiocarbon dating of Flandrian pollen zones in Wales and Northern England", New Phytologist, 77, 793-807.

Hirons K. R. & Edwards K. J. (1986) "Events at and around the first and second Ulmus declines: Palaeoecological investigations in Co. Tyrone, Northern Ireland", New Phytologist, 104, 131-153.

Hirons K. R. & Edwards K. J. (1990) "Pollen and related studies at Kinloch, Isle of Rhum, Scotland, with particular reference to possible early human impacts on vegetation", New Phytologist, 116, 715-727.

Huntley B. & Birks H. J. B. (1983) "An Atlas of Past and Present Pollen Maps for Europe: 0-13000 years ago", Cambridge University Press, Cambridge.

Hybroek, H. M. (1963) "Diseases and lopping for fodder as possible causes of a prehistoric decline of Ulmus", Acta Botanica Neerlandica, 12, 1-11.

Iversen J. (1954) "The Late-glacial flora of Denmark and its relation to climate and soil", Danmarks Geologiske Undersøgelse, II, 80, 87-119.

Iversen, J. (1956) "Forest clearance in the Stone Age", Scientific American, 194, 36-41.

Iversen, J. (1973) "The development of Denmark's nature since the last-glacial", Danmarks Geologiske Undersøgelse, V, 7-C, 126 pp., Copenhagen.

Jacobi R. M., Tallis J. H. & Mellars P. A. (1976) "The southern Pennine Mesolithic and the ecological record", Journal of Archaeological Science, 3, 307-320.

Jessen K. (1955) "Key to subfossil Potamogeton", Botanisk Tiddskriff, 52, 1-6.

Jones I. P. (1977) "Studies in the Flandrian vegetational history of the Craven District of Yorkshire", PhD Thesis, University of Leeds.

Jones R. L. (1977) "Late Devensian deposits from Kildale, Northeast Yorkshire", Proceedings of the Yorkshire Geological Society, 41, 185-188.

Katz N. Ja., Katz S. V. & Kipiani M. G. (1965) "Atlas and Keys of fruits and seeds occuring in the Quaternary Deposits of the USSR", Moscow.

Keen D. H., Jones R. L., Evans R. A. & Robinson J. E. (1988) "Faunal and floral assemblages from Bingley Bog, West Yorkshire, and their significance for Late Devensian and early Flandrian environmental changes", Proceedings of the Yorkshire Geological Society, 47, 125-138.

Kendall P. F. & Wroot H. E. (1924) "The Geology of Yorkshire", Vienna.

King A. (1969) "A study of early settlement in Upper Ribblesdale and adjacent uplands", MA Dissertation, University of Liverpool.

King A. (1970) "Early Pennine settlement", Dalesman, Clapham.

King A. (1978a) "Apron Full of Stones, a prehistoric cairn, Thornton in Londsdale, North Yorkshire", The Yorkshire Archaeological Journal, 50, 25-30.

King A. (1978b) "Gauber High Pasture, Ribblehead - an interim report", (In "Viking Age York and the North" ed. by R. A. Hall) pp. 21-25. CBA Research Report, No. 27.

Kolstrup E. (1979) "Herbs as July temperature indicators for parts of the pleniglacial and Late-glacial in the Netherlands", Geologie En Mijnbouw, 58(3), 377-380.

Kolstrup E. (1980) "Climate and stratigraphy in northwestern Europe between 30,000 b.p. and 13,000 b.p., with special reference to the Netherlands", Mededelingen Rijks Geologische Dienst, 32-15, 181-253.

Körber-Grohne U. (1964) "Probleme der kustenforchung im sudlichen nordseegebiet. 7. Bestimmungsschlussel für subfossile. Juncus-Samen und Graminen-Fruchte", Hildesheim: August Lax.

Leeder M. R. (1982) "Upper Palaeozoic basins of the British Isles - Caledonide inheritance versus Hercynian plate margin processes", Journal of Geological Society, London, **139**, 479-491.

Lockwood J. G. (1967) "Climate", (In "Leeds and its region", ed. by M. W. Beresford & G. R. J. Jones) pp. 30-43. British Association for the Advancement of Science. Leeds Local Executive Committee.

Longworth I. (1965) "Yorkshire", Cory, Adams & Mackay.

Lotter A. F., Eicher U., Siegenthaler U. & Birks H. J. B. (1992) "Late-glacial climatic oscillations as recorded in Swiss lake sediments", Journal of Quaternary Science, **7(3)**, 187-204.

Lowe J. J. & Gray J. M. (1980) "The stratigraphic-subdivision of the Lateglacial of North-west Europe" (In "Studies in the Lateglacial of Northwest Europe", ed. by J. J. Lowe, J. M. Gray & E. Robinson) pp. 157-175. Pergamon Press, Oxford.

Lowe J. J. & Lowe S. (1989) "Interpretation of the pollen stratigraphy of Late Devensian Lateglacial and early Flandrian sediments at Llyn Gwernan, near Cader Idris, North Wales", New Phytologist, **113**, 391-408.

Lowe J. J. & Walker M. J. C. (1986) "Lateglacial and early Flandrian environmental history of the Isle of Mull, Inner Hebrides", Transactions of the Royal Society of Edinburgh: Earth Science, **77**, 1-20.

Mangerud J., Andersen S. Th., Berglund B. E. & Donner J. J. (1974) "Quaternary stratigraphy of Norden, a proposal for terminology and classification", Boreas, 3, 109-126.

Manley G. (1957) "The climate at Malham Tarn", Field Studies Council, Annual Report (1955-1956), 43-56.

Manley G. (1959) "The late-glacial climate of North-west England", The Liverpool and Manchester Geological Journal, 2, 188-215.

Megaw J. V. S. & Simpson D. D. A. (1979) "Introduction to British prehistory", Leicester University Press.

Mellars P. A. (1976) "Fire, ecology, animal populations and man; a study of some ecological relationships in prehistory", Proceedings of the Prehistoric Society, 42, 15-46.

Moore P. D. (1984) "Hampstead Heath clue to historical decline of elms", Nature, 312, 103.

Moore P. D., Webb J. A. & Collinson M. E. (1991) "Pollen Analysis", second edition, Blackwell Scientific Publications.

O'Connell M. (1980) "The developmental history of Scragh Bog, Co. Westmeath and the vegetational history of its hinterland", New Phytologist, 85, 301-319.

Odgaard B. V. (1992) "The fire history of Danish heathland areas as reflected by pollen and charred particles in lake sediments", The Holocene, 2, 3, 218-226.

Peglar S. M. (1993) "The mid-Holocene Ulmus decline at Diss Mere, Norfolk, UK: a year-by-year pollen stratigraphy from annual laminations", The Holocene, 3, 1, 1-13.

Pennington W. (1964) "Pollen analysis from the deposits of six upland tarns in the Lake District", Philosophical Transactions of the Royal Society London B, 248, 205-244.

Pennington W. (1970) "Vegetation history in the north-west of England: a regional synthesis", (In "Studies in the vegetational history of the British Isles", ed. by D. Walker & R. G. West) pp. 141-158. London: Cambridge University Press.

Pennington W. (1975) "A chronostratigraphic comparison of Late-Weichselian and Late-Devensian subdivisions, illustrated by two radiocarbon-dated profiles from western Britain", Boreas, 4, 157-171.

Pennington W. (1977) "The Late Devensian flora and vegetation of Britain", Philosophical Transactions of the Royal Society of London B, 280, 247-271.

Pennington W. (1980) "Modern samples from west Greenland and the interpretation of pollen data from the British Late-Glacial (LATE DEVENSIAN)", New Phytologist, 84, 171-201.

Pennington W. (1986) "Lags in adjustment of vegetation to climate caused by the pace of soil development: evidence from Britain", Vegetatio, 67, 105-118.

Pennington W. (1991) "Palaeolimnology in the English lakes - some questions and answers over fifty years", Hydrobiologia, 214, 9-24.

Pennington W. & Lishman J. P. (1971) "Iodine in lake sediments in Northern England and Scotland", Biological Reviews, 46, 279-313.

Perry I. & Moore P. D. (1987) "Dutch elm disease as an analogue of Neolithic elm decline", Nature, 326, 72-73.

Pigott M. E. & Pigott C. D. (1959) "Stratigraphy and pollen analysis of Malham Tarn and Tarn Moss", Field Studies, 1, 1-18.

Pigott C. D. & Pigott M. E. (1963) Late-glacial and Post-glacial deposits at Malham, Yorkshire", New Phytologist, 62, 317-334.

Punt W. & Malotaux M. (1984) "Cannabaceae, Moraceae and Urticaceae" (In "The Northwest European Pollen Flora IV", ed. by W. Punt & G. C. S. Clarke) pp. 23-44. Elsevier.

Rackham O. (1980) "Ancient Woodland: its history, vegetation and uses in England", Edward Arnold, London.

Rackham O. (1986) "The History of the Countryside", Dent, London.

Rackham O. (1988) "Trees and woodland in a crowded landscape - the cultural landscape of the British Isles", (In "The Cultural Landscape - Past, Present and Future", ed. by H. H. Birks, H. J. B. Birks, P. E. Kaland & D. Moe) pp. 53-77. Cambridge Univesity Press, Cambridge.

Raistrick A. (1930) "Some glacial features of the Settle District, Yorkshire", Proceedings of the University of Durham, 8, part 3, (1929-1930).

Raistrick A. (1936) "Prehistoric cultivation at Grassington, Yorkshire", The Yorkshire Archaeological Journal, 33, 166-174.

Raistrick A. (1939) "Iron-age settlements in West Yorkshire", The Yorkshire Archaeological Journal, 34, 115-150.

Raistrick A. & Holmes P. F. (1962) "Archaeology of Malham Moor", Field Studies, 1, 73-96.

Raistrick A. & Illingworth J. I. (1959) "The face of North-West Yorkshire", The Dalesman Publishing Company.

Rybnicek K. & Rybnickova E. (1987) "Palaeogeobotanical evidence of Middle Holocene stratigraphic hiatuses in Czechoslovakia and their explanation", Folia Geobotanica et Phytotaxonomica, 22, 313-327.

Schweingruber F. H. (1990) "Anatomy of European woods", Paul Haupt Berne and Stuttgart Publishers.

Simmons I. G. (1969) "Pollen diagrams from the North York Moors", New Phytologist, 68, 807-827.

Simmons I. G. (1975) "The ecological setting of Mesolithic man in the Highland Zone", (In "The Effect of Man on the Landscape: The Highland Zone", ed. by J. G. Evans, S. Limbrey & H. Cleere) pp. 57-63. CBA Research Report No. 11.

Simmons I. G. , Dimbleby G. W. & Grigson C. (1981) "The mesolithic", (In "The Environment in British Prehistory", ed. by I. G. Simmons & M. J. Tooley) pp. 82-124. Duckworth, London.

Simmons I. G. & Innes J. B. (1981) "Tree remains in a North York Moors peat profile", Nature, 294, 76-78.

Simmons I. G. & Innes J. B. (1987) "Mid-Holocene adaptations and later Mesolithic forest disturbance in northern England", Journal of Archaeological Science, 14, 385-403.

Sissons J. B. (1974) "The Quaternary in Scotland: a review", Scottish Journal of Geology, 10, 311-337.

Sissons J. B. (1976) "A remarkable protalus rampart in Wester Ross", The Scottish Geographical Magazine, 92, 182-190.

Smith A. G. (1970) "The influence of Mesolithic and Neolithic Man on British vegetation: a discussion", (In "Studies in the vegetational history of the British Isles", ed. by D. Walker & R. G. West) pp. 81-96. Cambridge University Press, Cambridge.

Smith A. G. (1984) "Newferry and the Boreal-Atlantic transition", New Phytologist, 98, 35-55.

Smith A. G. & Cloutman E. W. (1988) "Reconstruction of Holocene vegetation history in three dimensions at Waun-Fignen-Felen, an upland site in South Wales", Philosophical Transcations of the Royal Society of London B, 322, 159-219.

Smith A. G. & Goddard I. C. (1991) "A 12500 year record of vegetational history at Sluggan Bog, Co. Antrim, N. Ireland (incorporating a pollen zone scheme for the non-specialist)", New Phytologist, 118, 167-187.

Smith A. J. E. (1978) "The Moss Flora of Britain and Ireland", Cambridge University Press.

Smith R. T. (1986) "Aspects of the soil and vegetation history of the Craven District of Yorkshire", (In "Archaeology in the Pennines", ed. by T. G. Manby & P. Turnbull) pp.3-28. British Archaeological Reviews, British Series 158.

Stockmarr J. (1971) "Tablets with spores used in absolute pollen analysis", Pollen et Spores, **13**, 615-621.

Stuiver M. & Polach H. A. (1977) "Discussion: reporting of ^{14}C data", Radiocarbon, **19**, 355-363.

Sturludottir S. A. & Turner J. (1985) "The elm decline at Pawlaw Mire: an anthropogenic interpretation", New Phytologist, **99**, 323-329.

Swales S. (1987) "The Vegetational and Archaeological History of the Ingleborough Massif, North Yorkshire", PhD Thesis, University of Leeds.

Syers J. K. (1964) "A Study of soil formation on Carboniferous Limestone with particular reference to lichens as pedogenic agents", PhD Thesis, University School of Agriculture, King's College, University of Durham.

Ten Hove H. A. (1968) "The Ulmus fall at the transition Atlanticum-Subboreal in pollen diagrams", Palaeogeography, Palaeoclimatology, Palaeoecology, **5**, 359-369.

Tipping R. (1991) "The climatostratigraphic subdivision of the Devensian Lateglacial: evidence from a pollen site near Oban, western Scotland", Journal of Biogeography, **18**, 89-101.

Troels-Smith J. (1960) "Ivy, mistletoe and elm climatic indicators - fodder plants", Danmarks Geologiske Undersøgelse, **IV**, **4(4)**, 32 pp.

Turner J., Innes J. B. & Simmons I. G. (1989) "Two pollen diagrams from the same site", New Phytologist, **113**, 409-416.

Van Geel B., Bohncke S. J. P. & Dee H. (1980) "A palaeoecological study of an upper Late Glacial and Holocene sequence from 'De Borchert' the Netherlands", Review of Palaeobotany and Palynology, 31, 367-448.

Vitt D. H. & Kuhry P. (1992) "Changes in moss-dominated wetland ecosystems", (In "Bryophytes and Lichens in a changing Environment", ed. by J. Bates & A. M. Farmer) pp. 178-210. Clarendon Press, Oxford.

Walker D. (1956) "A site at Stump Cross near Grassington, Yorkshire and the age of the Pennine microlithic industry", Proceedings of the Prehistoric Society, 22, 23-28.

Walker M. J. C. & Harkness D. D. (1990) "Radiocarbon dating the Devensian Lateglacial in Britain: new evidence from Llanilid, South Wales", Journal of Quaternary Science, 5(2), 135-144.

Watts W. A. (1977) "The Late Devensian vegetation of Ireland", Philosophical Transactions of the Royal Society of London B, 280, 273-293.

Watts W. A. (1980) "Regional variation in the response of vegetation to Lateglacial climatic events in Europe", (In "Studies in the Lateglacial of Northwest Europe", ed. by J. J. Lowe , J. M. Gray & J. E. Robinson), pp. 1-22. Pergamon Press, Oxford.

Watts W. A. (1982) "Response of biotic populations to rapid environmental and climatic changes", Abstracts Seventh AMQUA Conference, 19-21.

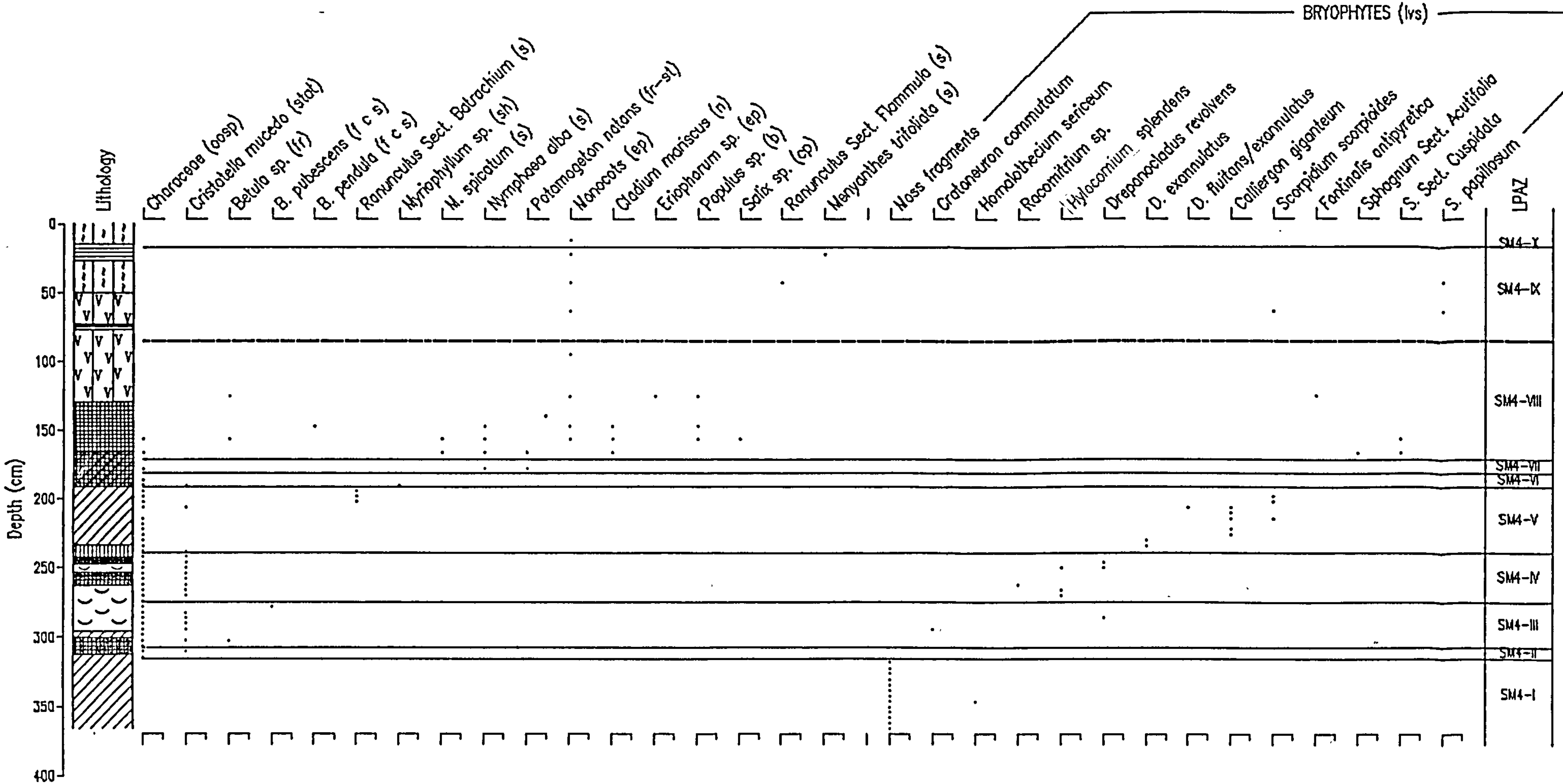
Whittington G., Edwards K. J. & Cundill P. R. (1991a) "Late- and Post-glacial vegetational changa at Black Loch, Fife, eastern Scotland - a multiple core approach", New Phytologist, 118, 147-166.

Whittington G., Edwards K. J. & Cundill P. R. (1991b) "Palaeoecological investigations of multiple elm declines at a site in north Fife, Scotland", Journal of Biogeography, **18**, 71-87.

Wills L. J. (1978) "A palaeogeographic map of the Lower Palaeozoic floor below the cover of Upper Devonian Carboniferous and later formations", Memoir Geological Society of London, **8**, 36 pp.

Wood T. G. (1963) "The Fauna of Certain Moorland Soils Developed on Limestone and Non-calcareous Drift", PhD Thesis, University of Nottingham.

Table 5 3.1. Macroscopic fossils from SNIDDLE MOSS 4

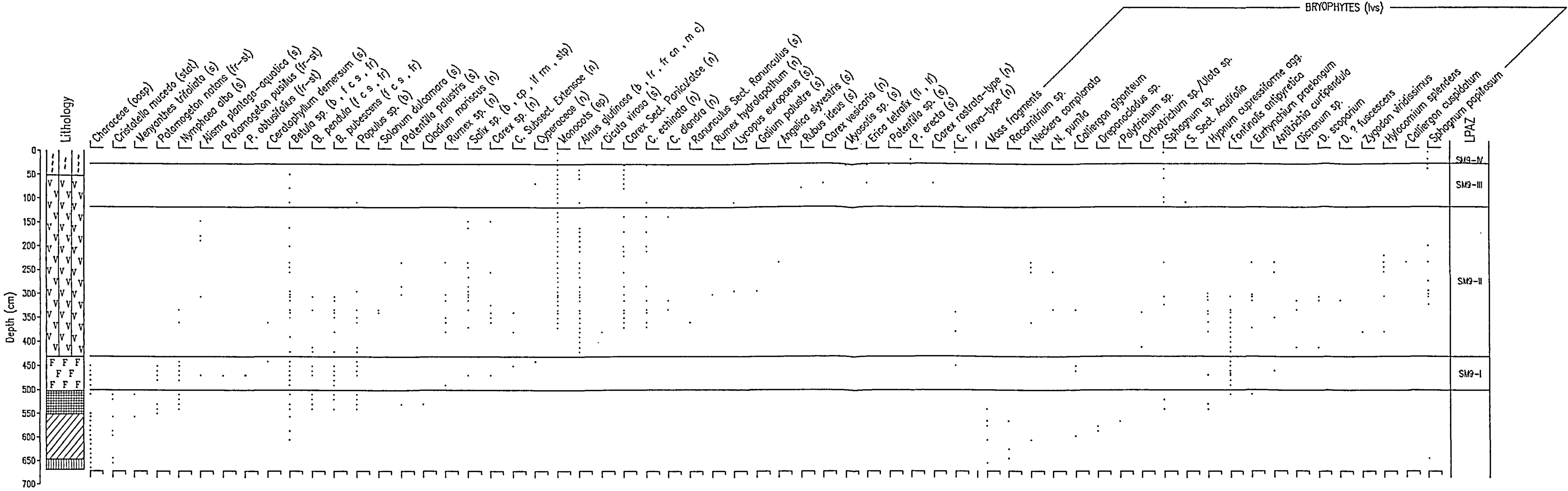


. present

Abbreviations:

b=bud
cp=capsule
ep=epidermis
f c s=female catkin scale
fr=fruit
fr-st=fruit-stone
lvs=leaves
n=nut
oosp=oospore
s=seed
sh=shoot
stat=statoblast

Table 5.3.2. Macroscopic fossils from SNIDDLE MOSS 9



. present

Abbreviations:

b=bud
cp=capsule
ep=epidermis
f c s=female catkin scale
fl=flower
fr=fruit
fr cn=fruit cone
fr-st=fruit-stone
lf=leaf
lf rm=leaf remain
lvs=leaves
m c=male catkin
n=nut
n s=nut shell
oosp=oospore
s=seed
stat=statoblast
stp=stipule

Table 5.3.3. Macroscopic fossils from other sampling points, which have not been found in the profiles of SM4 and SM9.

TAXA	REMAINS	SAMPLING NO AND DEPTH (cm)
VASCULAR PLANTS		
Ajuga reptans	s	SM12 47-50;55-57
Calluna vulgaris	fl	SM3 30-32/SM7 50-52; 60-62/ SM8 0-3/SM11 0-3
Caltha palustris	s	SM-5 32-34/SM-8 164-166; 384-386/SM10 198-200; 208-210; 218-220
Cirsium sp.	a	SM8 234-236
C. ? *heterophyllum*/*palustre*	a	SM8 254-256
Corylus avellana	n s	SM11 139-141
Eupatorium cannabinum	a	SM8 214-216; 224-226; 244-246/SM7 274-276/SM9 110-112; 120-122; 150-152
Filipendula ulmaria	s	SM3 129-131/SM5 106-108
?*Fragaria vesca*	s	SM1 102-104/SM3 95-97/SM5 142-146
Frangula alnus	s	SM7 234-236
Glyceria fluitans/*declinata*	fr	SM3 30-32/SM5 32-34
Hippuris vulgaris	s	SM7 350-352/SM8 426-428; 436-438; 466-468; 476-478/ SM10 172-174; 182-184
Juncus ? *bulbosus*	n	SM7 30-32; 40-42
Myriophyllum alterniflorum	s	SM12 200-202
Lotus sp.	s	SM12 143-145; 200-202
Potamogeton perfoliatus	fr-st	SM11 216-218/SM12 210-212
P. polygonifolius	fr-st	SM1 20-22/SM3 27-29/SM5 32-34/SM7 40-42; 60-62/SM8 54-56; 64-66 SM7 40-42; 60-62/SM10 9-11/SM11 19-21; 236-238
P. praelongus	fr-st	SM11 263-265; 293-295/SM12 170-172
P. cf. *zizii*	fr-st	SM5 207-209
Potentilla cf. *anglica*	s	SM12 0-3
Ranunculus ? *repens*	s	SM8 565-567/SM10 198-200
Rubus sp.	s	SM11 29-31; 59-61
Rumex crispus	n	SM10 192-194
Scirpus sp.	n	SM3 59-61/SM8 254-256; 364-366; 374-376
Scirpus maritimus	n	SM3 120-122;150-152;155-157
Sparganium minimum	n	SM7 410-412; 470-472
Stachys sylvatica	s	SM12 47-50
Taraxacum officinale	s	SM11 19-21
Thalictrum minus	s	SM3 110-112/SM10 218-220/SM11 199-201/SM12 210-212
Urtica dioica	s	SM11 59-61/SM12 47-50
Viola sp.	s	SM10 271-273/SM11 206-208/SM12 0-3
V. palustris	s	SM1 0-3/SM5 7-9; 32-34/SM7 30-32; 40-42; 50-52/SM8 54-56; 184-186/SM12 27-29
BRYOPHYTES		
Amblystegium ? *riparium*	lvs	SM11 253-255
A. varium	lvs	SM3 216-218; 256-258; 261-263/SM8 354-356/SM11 206-208
Aulacomnium palustre	lvs	SM3 48-50; 150-152; 198-200/SM10 9-11/SM11 0-3/SM12 47-50
A. turgidum	lvs	SM5 267-269/SM11 351-353
Bryum sp.	lvs	SM1 24-26/SM3 155-157/SM7 320-322; 330-332; 350-352/ SM8 324-326; 334-336; 344-346/SM11 348-350
Bryum sp./*Mnium* sp.	lf	SM10 208-210
Dicranella ? *schreberana*	lvs	SM1 196-198
Plagiomnium ? *affine*	lvs	SM11 226-228
Thuidium tamariscinum	lvs	SM8 304-306; 334-336; 354-356

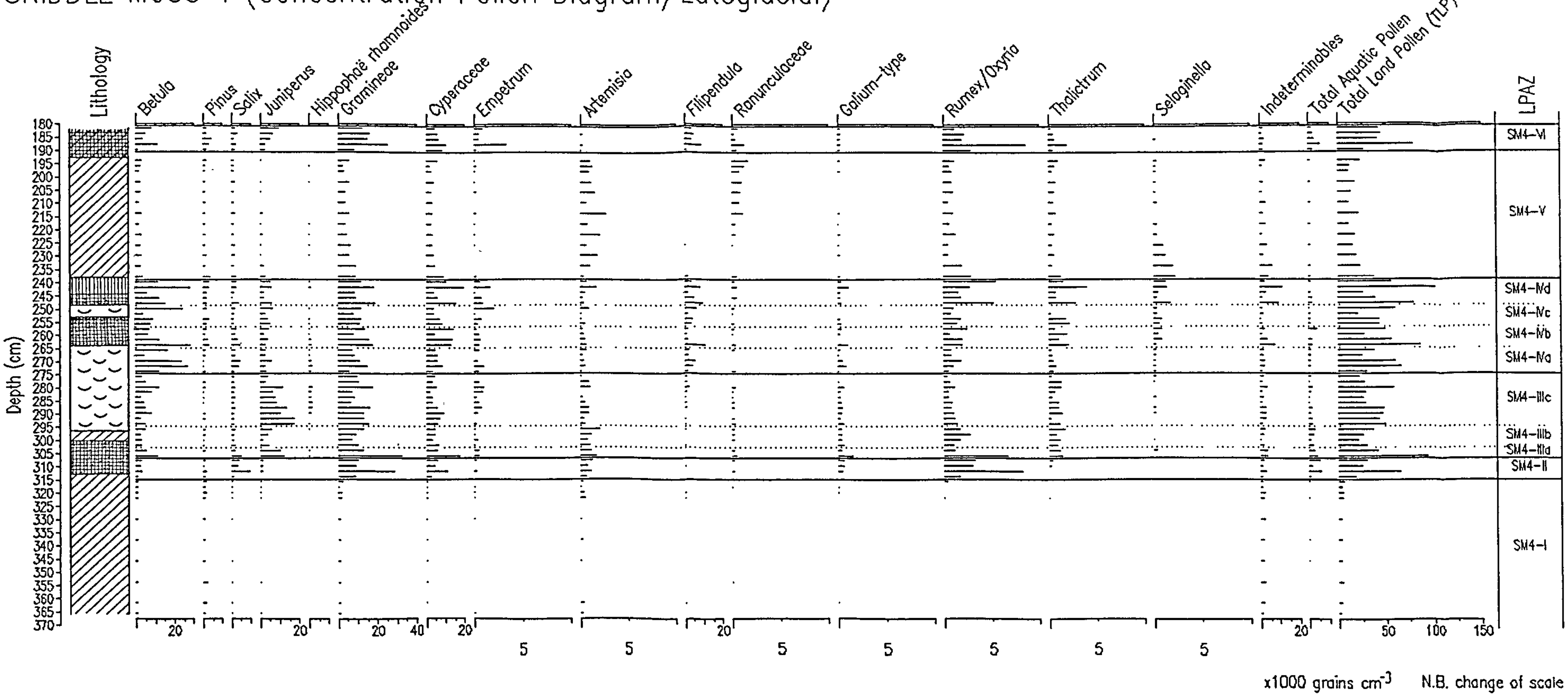
Abbreviations: a=achene, fl=flower, fr=fruit, fr-st=fruit-stone,lf=leaf, lvs=leaves, n=nut, n s=nut shell, s=seed.

SNIDDLE MOSS 4 (Percentage Pollen Diagram)

N.B. Note the change of scale for Filicales and desmids

SNIDDLE MOSS 4 (Percentage Pollen Diagram/Lateglacial)

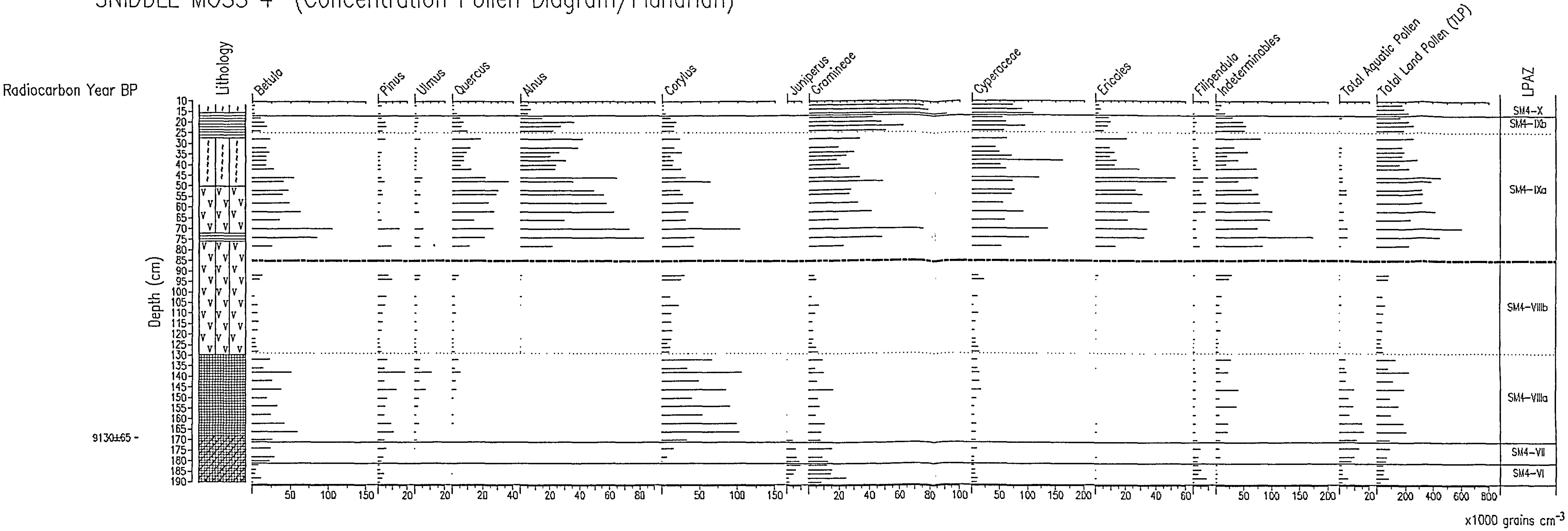
SNIDDLE MOSS 4 (Concentration Pollen Diagram/Lateglacial)



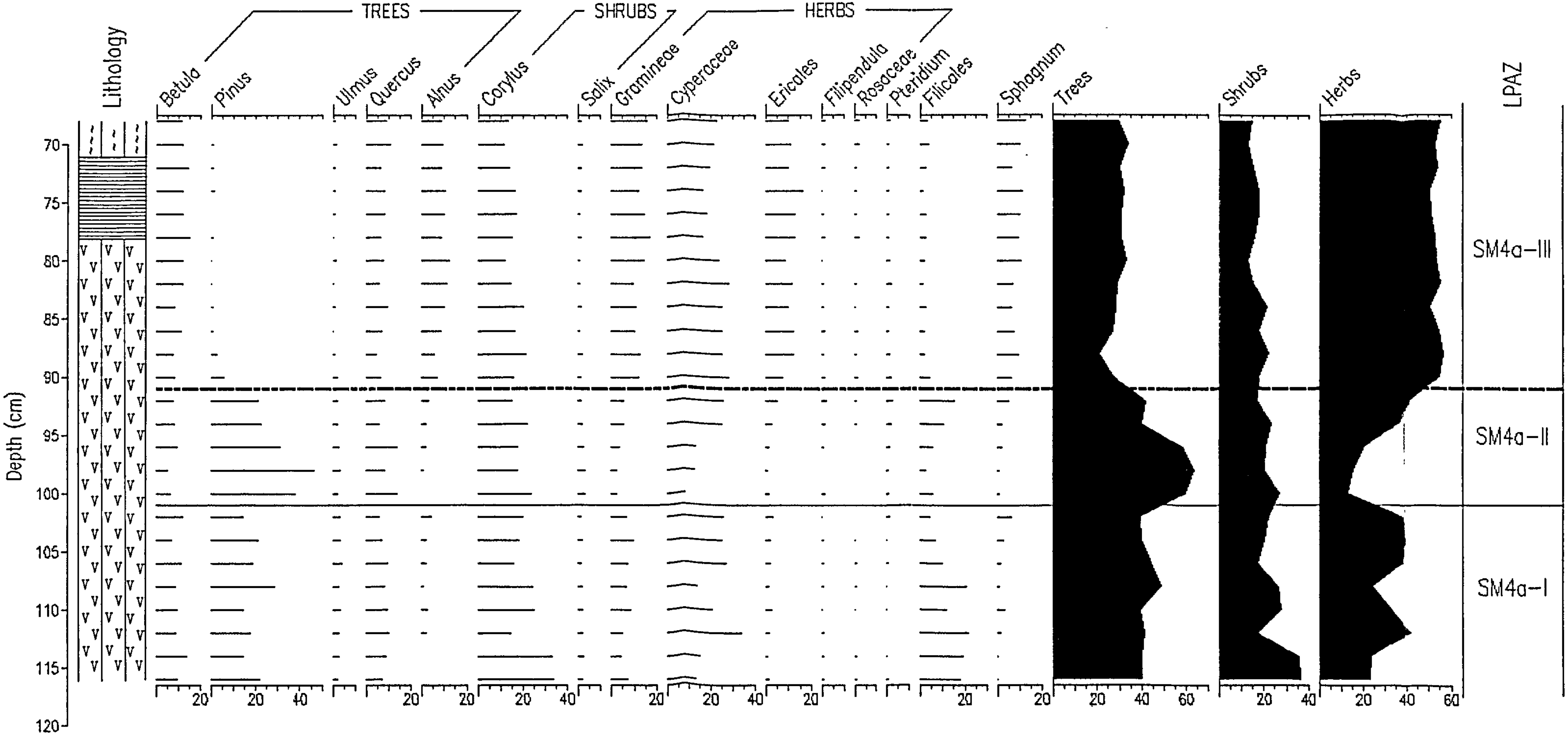
SNIDDLE MOSS 4 (Percentage Pollen Diagram/Flandrian)

N.B. Note the change of scale for Filicales and desmids

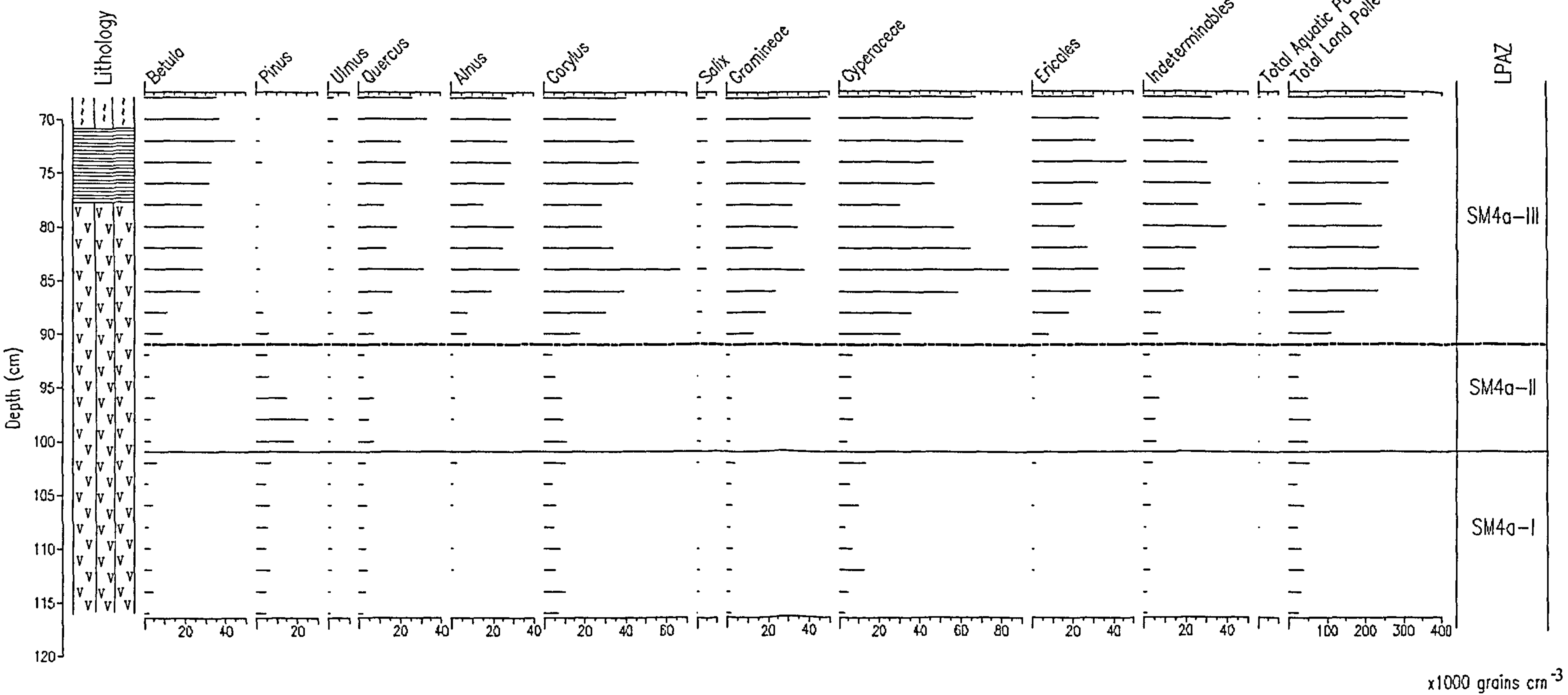
SNIDDLE MOSS 4 (Concentration Pollen Diagram/Flandrian)



SNIDDLE MOSS 4a (Percentage Pollen Diagram)



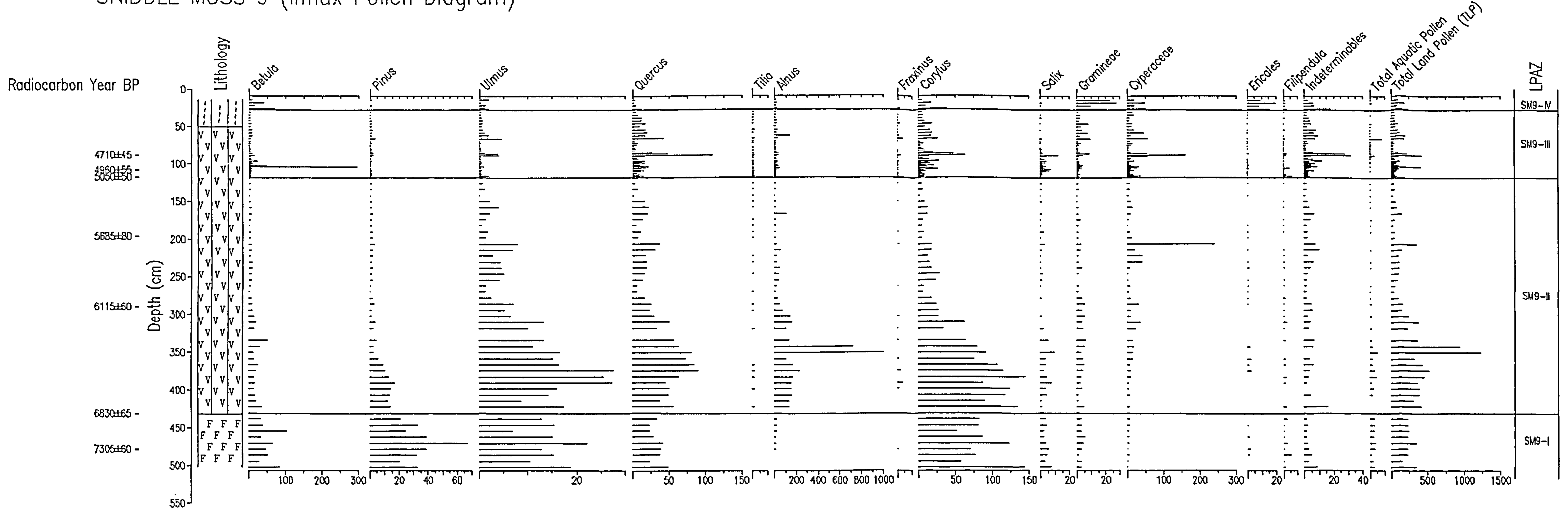
SNIDDLE MOSS 4a (Concentration Pollen Diagram)



SNIDDLE MOSS 9 (Percentage Pollen Diagram)

N.B. Note the change of scale for *Ulmus*

SNIDDLE MOSS 9 (Influx Pollen Diagram)



x100 grains cm^{-2} Year^{-1} N.B. Note the change of scale for <u>Ulmus</u>

SNIDDLE MOSS 9 (Percentage Pollen Diagram/The Ulmus Decline)

N.B. Note the change of scale for Ulmus, Tilia and Fraxinus

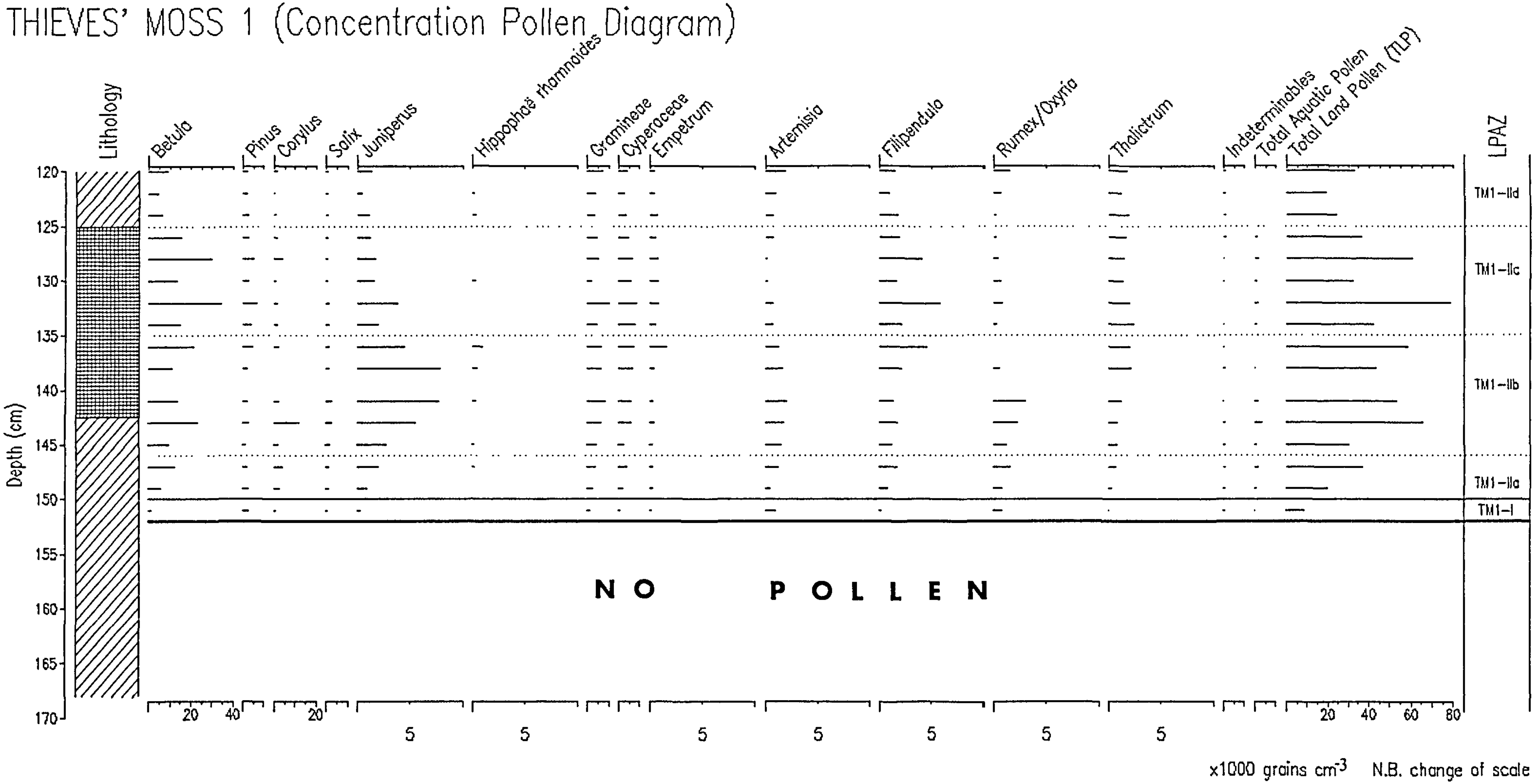
SNIDDLE MOSS 9 (Influx Pollen Diagram/The *Ulmus* Decline)

x100 grains cm^{-2} Year^{-1} N.B. change of scale

Table 6.3.1. Macroscopic fossils from THIEVES' MOSS

THIEVES' MOSS 1 (Percentage Pollen Diagram)

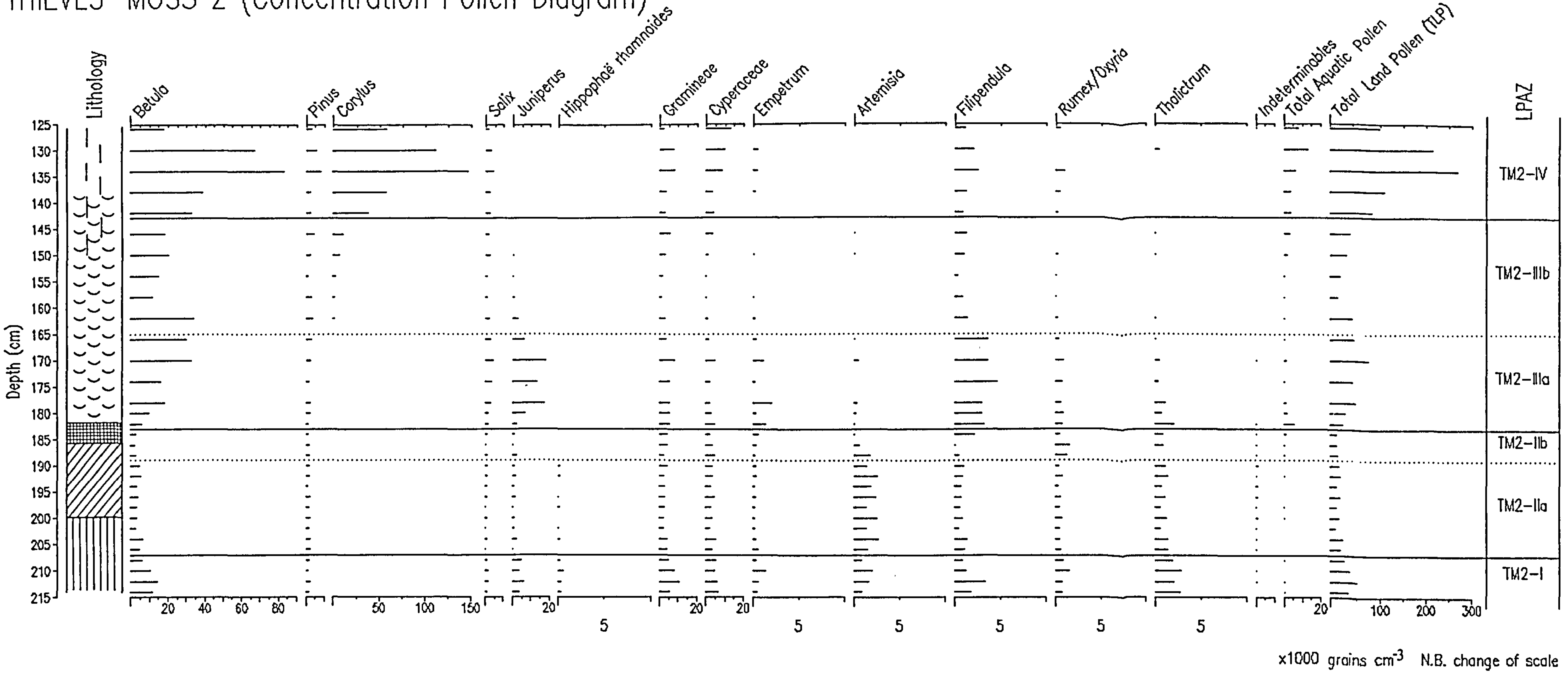
N.B. Note the change of scale for *Hippophaë* *rhamnoides* and algae


THIEVES' MOSS 1 (Concentration Pollen Diagram)

THIEVES' MOSS 2 (Percentage Pollen Diagram)

N.B. Note the change of scale for Hippophaë rhamnoides and algae

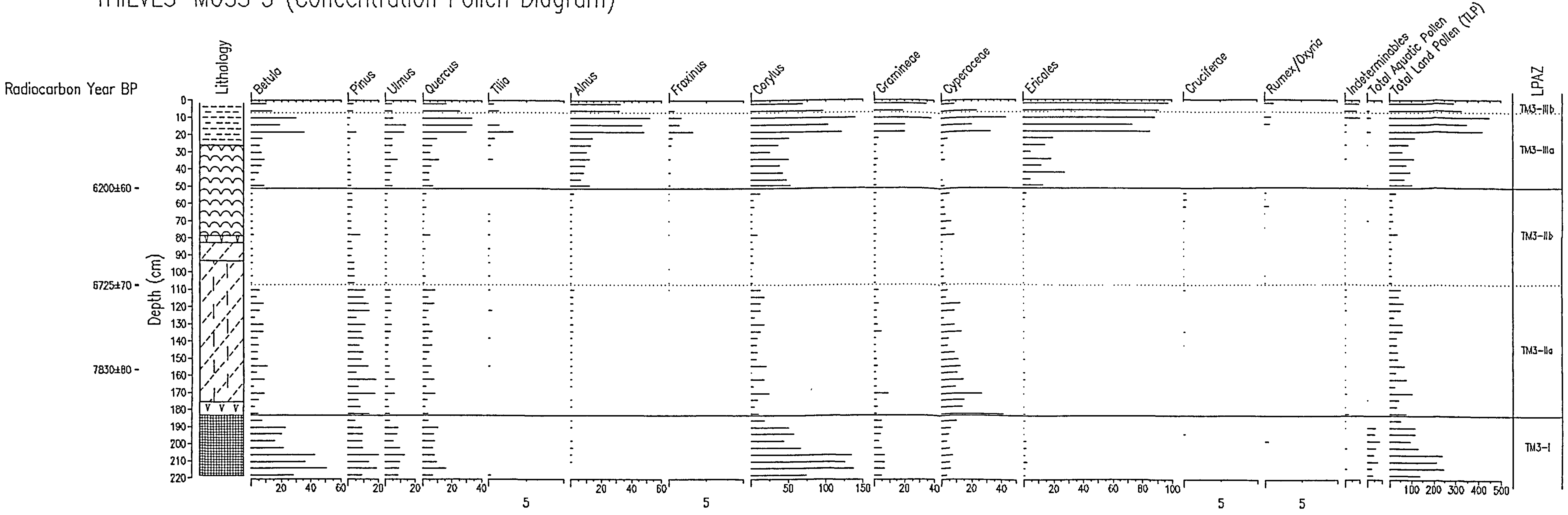
THIEVES' MOSS 2 (Concentration Pollen Diagram)



THIEVES' MOSS 3 (Percentage Pollen Diagram)

N.B. Note the change of scale for Equisetum, Sphagnum and Tetraedron

THIEVES' MOSS 3 (Concentration Pollen Diagram)



x1000 grains cm^{-3} N.B. change of scale

SUNSET HOLE (Percentage Pollen Diagram)

N.B. Note the change of scale for Ulmus

SUNSET HOLE (Concentration Pollen Diagram)

x1000 grains cm^{-3} N.B. change of scale

SUNSET HOLE (Percentage Pollen Diagram/The *Ulmus* Decline)

N.B. Note the change of scale for *Ulmus*, *Tilia* and *Fraxinus*

SUNSET HOLE (Concentration Pollen Diagram/The Ulmus Decline)