STUDIES IN THE HOLOCENE VEGETATION HISTORY OF WENSLEYDALE

by

ANNE HONEYMAN

Submitted in accordance with the requirements for the degree of Ph.D.

The University of Leeds
School of Geography

July 1985

SUMMARY

Total and arboreal pollen diagrams have been prepared for three blanket bog sites and one valley bog in the Wensleydale area of the Yorkshire Dales. Local pollen assemblage zones have been defined for each site using numerical methods, and these have been correlated to give regional pollen assemblage zones. A computer program has been developed to calculate and plot the palynological data, and an absolute chronology has been established for the pollen diagrams from a series of twenty radiocarbon dates.

Detailed humification profiles have been produced for each site to assist in the interpretation of the pollen records, and chemical analyses have also been carried out for the valley bog site.

The regional zones have been used as the basis for a discussion of the Holocene vegetation history of Wensleydale. The palynological, radiocarbon, humification, chemical and archaeological/historical evidence is drawn together to provide a comprehensive study of the vegetation changes which have occurred over the approximately 9,000 years covered by the pollen records. By adopting a holistic approach to interpretation, it has been shown that man has been an important influence on the landscape of Wensleydale throughout this entire period. Possible anthropogenic causes are put forward for a number of vegetation changes previously assumed to be of climatic origin.

ACKNOWLEDGEMENTS

I would like to thank first of all my supervisor, Dr. R. T. Smith, for all his help and advice throughout my period of research. The time and effort he has devoted to this project are much appreciated.

I am also grateful to all the friends and colleagues who assisted with the fieldwork, and to the landowners who allowed access to their property. In addition I would like to thank the NERC Radiocarbon Laboratory for providing the radiocarbon dates, and Dr. D. D. Harkness in particular for his advice and assistance on this aspect of the research. I am also much obliged to Dr. H. J. B. Birks, who provided copies of his zonation programs for my use.

Finally, I must give special thanks to my husband, John Parsons, for his endless support and encouragement as well as practical help.

This work was carried out during the tenure of a University of Leeds research studentship.

CONTENTS

CONTENTS (continued) Page

CONTENTS (continued) Page

CONTENTS (continued) Page

LIST OF FIGURES

LIST OF FIGURES (continued) Page

ABBREVIATIONS

The following abbreviations are used throughout the thesis:-

AP	Arboreal Pollen
NAP	Non-Arboreal Pollen
TP	Total Pollen
B.P.	(Years) Before Present, i.e. years before the standard radiocarbon zero year of 1950
L.P.A.Z.	Local Pollen Assemblage Zone
R.P.A.Z.	Regional Pollen Assemblage Zone

On the pollen diagrams, the names of some pollen and spore types are abbreviated as follows:-

JUNIPER	*Juniperus*
ERICA.	Ericaceae
CYPER.	Cyperaceae
GRAMIN.	Gramineae
PLANTAGO	*Plantago lanceolata*
RUMEX	*Rumex acetosella* type
CHENO.	Chenopodiaceae
ROSA.	Rosaceae
FILIP.	*Filipendula*
POTEN.	*Potentilla*
ARTEM.	*Artemisia*
UMBELL.	Umbelliferae
CARYOPH.	Caryophyllaceae
COMP. L.	Compositae Liguliflorae
COMP. T.	Compositae Tubuliflorae

ABBREVIATIONS (continued)

RANUNC.	Ranunculaceae
DIPSA.	Dipsaceae
POLYGON.	Polygonaceae
SAXIFRA.	Saxifragaceae
PRIMULA.	Primulaceae
HEDERA	*Hedera helix*
RUBIA.	Rubiaceae
LEGUM.	Leguminosae
MENYAN.	*Menyanthes trifoliata*
MYRIOPH.	*Myriophyllum alterniflorum*
POTAMO.	*Potamogeton*
PTERID.	*Pteridium aquilinum*
FILI.	Filicales

CHAPTER 1: INTRODUCTION

1.1 Aims

1.2 The study area

1.3 Previous palaeoecological studies in the Pennines

INTRODUCTION

1.1 Aims

Most of the palaeoecological research so far carried out in the Pennine area has been focussed on either the southern Pennines of Derbyshire and south Yorkshire, or the northern Pennines of Durham and Northumberland (see section 1.3). The Yorkshire Dales, in the central area of the Pennines, have received comparatively little attention. Palynological studies have covered the Nidderdale Moors (Tinsley, 1972), parts of Wharfedale (Raistrick and Blackburn, 1938; Walker, 1956) and the Craven area (Pigott and Pigott, 1959; Gosden, 1968; Jones, 1977; R. T. Smith, 1985, in press), but no work of this nature has been done in the more northerly dales, of which Wensleydale is the most extensive. This is probably due to difficulty of access from the centres of research, as Wensleydale in particular has both polliniferous peat deposits and an interesting situation and historical background to recommend it for detailed palaeoecological study. It is geologically and topographically distinct from the other dales, so that a comparison of pollen records should help to show the effects of these factors on vegetation. Also, whilst little is known of the archaeology of Wensleydale, there is evidence that the dale has been inhabited since at least Mesolithic times. The pollen records can thus be expected to reflect the extent and nature of human interference with vegetation over the millennia.

It is apparent, then, that a palynological study of Wensleydale will be valuable in completing the picture of post-glacial vegetation history in the Dales. This study therefore has the following aims:

(i) To determine the pattern of vegetation history in the area of

Wensleydale, North Yorkshire; and

(ii) To investigate the role played by prehistoric man in the vegetation changes which are detected.

The principal techniques used to achieve these objectives are pollen analysis and radiocarbon dating. However, to assist in the analysis and interpretation of the palynological data, a number of additional techniques have been introduced. These include chemical and humification analyses, and numerical methods for the zonation of the pollen diagrams. A further, subsidiary aim has therefore developed:

(iii) To assess the value of a multi-disciplinary approach to palaeo-ecology, and of the particular secondary techniques incorporated into this study.

1.2 The study area

Wensleydale is the most extensive of the river valleys of the Yorkshire Pennines, which are collectively known as the Yorkshire Dales (see fig. 1.1). Early monastic charters indicate that it was formerly called Yoredale, after the river Yore (now known as the Ure), but the name Wensleydale has been in use since at least the mid-twelfth century. This more recent appellation is taken from what was once an important market town for the area, but is now only a small village. It is here, at Wensley Bridge, that the eastern boundary of Wensleydale is often drawn. In Elizabethan times, for example, Leland wrote of Wensley that 'straite on the farther side beginnith Wensedale' (quote from Hartley and Ingilby, 1977). Any boundary on this side of the dale must be purely arbitrary, but for the purposes of this study Wensley is a suitable place for the division, as it is about here that the Ure finally emerges from the uplands (i.e. land over 300m/1000ft), and the valley becomes broader and flatter towards the Vale of York.

In the west, Wensleydale extends to the source of the river Ure on Lunds Fell, and in the north and south it is defined by the watersheds between the Ure, and the Swale and Wharfe. Figure 1.1 illustrates the location of Wensleydale in relation to the other Yorkshire Dales, while figure 1.2 shows the study area in more detail.

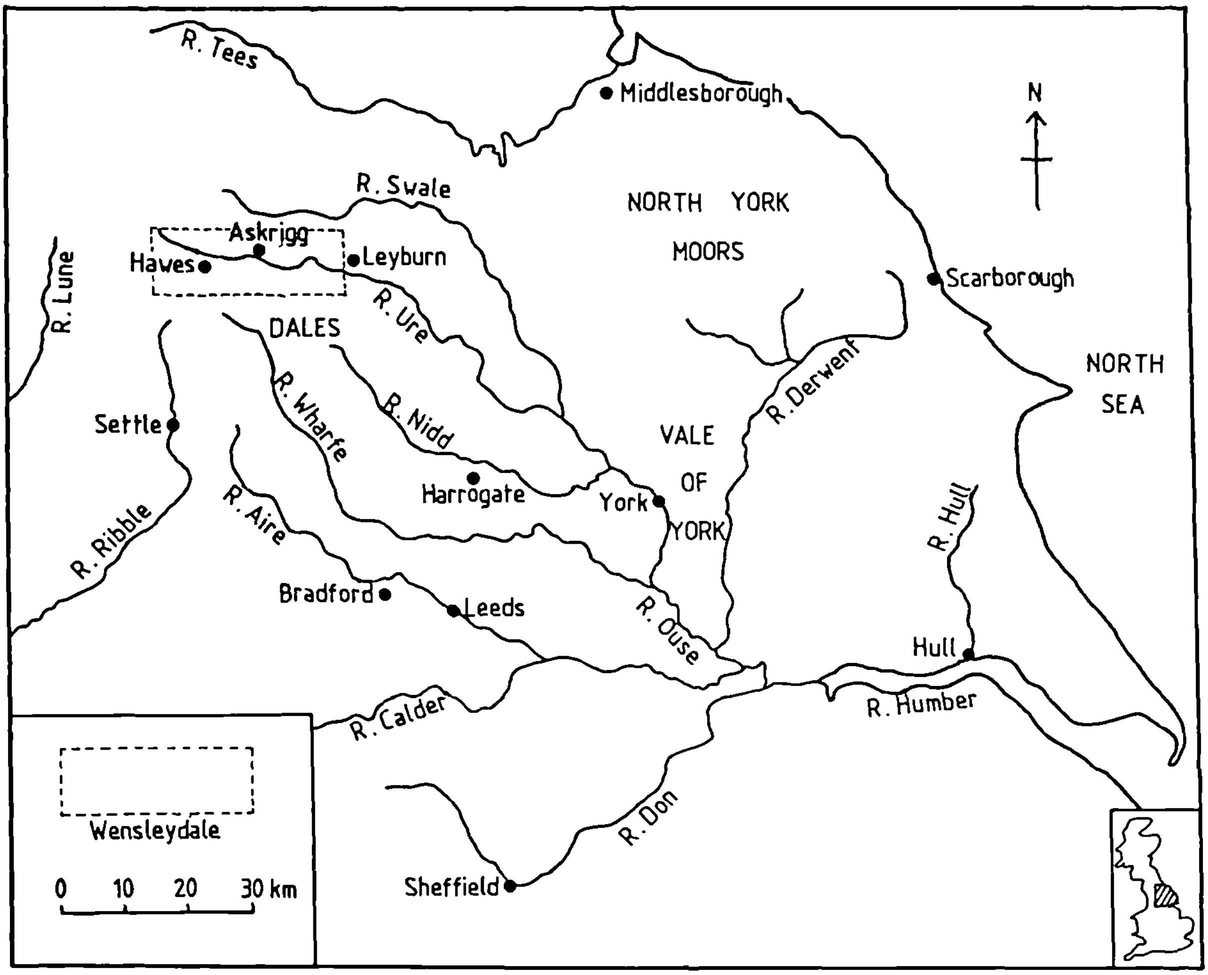


Figure 1.1: The location of Wensleydale

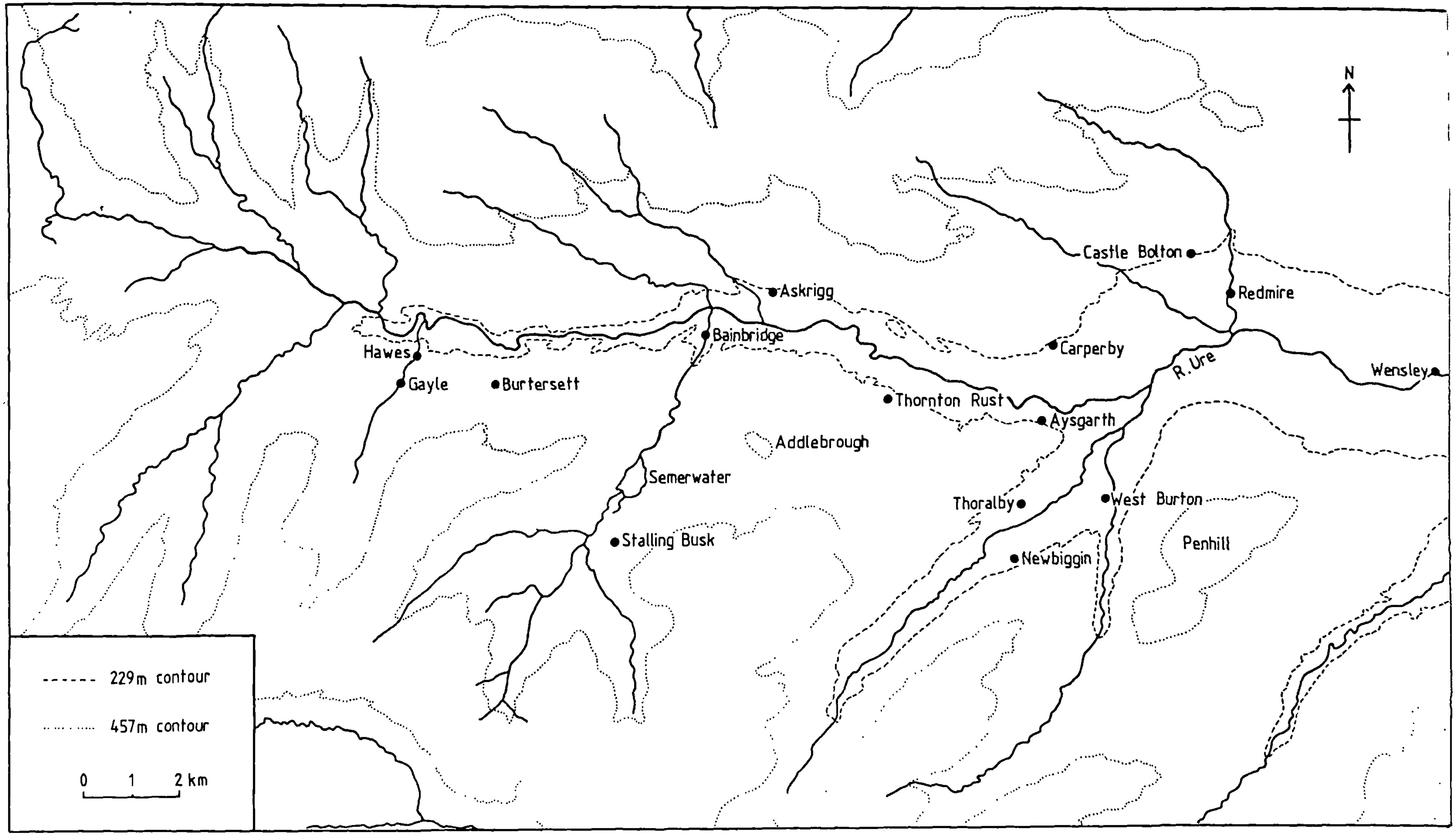


Figure 1.2: General map of the study area

1.3 Previous palaeoecological studies in the Pennines

The earliest palaeoecological studies (for example Geikie, 1877) were concerned with the easily-recognised macrofossils preserved in peat deposits. By the beginning of the twentieth century, it was already generally believed that peat moors occupied the sites of former forests. The frequent occurrence of tree remains in the basal layers of the peat supported this hypothesis, but before the development of pollen analysis and radiocarbon dating it was extremely difficult to assess the possible causes of this dramatic change in vegetation, and impossible to determine accurately the date at which it occurred.

Moss (1904) studied buried timber in peat deposits of the southern Pennines in conjunction with the present distribution of indigenous trees, arriving at a view of the vegetation history remarkably similar to current thinking on the subject. He concluded that:

> " ... the peat moors of the Pennines have originated in morasses formed probably by the destruction of primitive Pennine woods, which in their prime were not only much more extensive, but ascended to a much higher elevation, than their present meagre remains; that in age they are post-glacial, of later date than the Britons, of earlier date than the Saxons and Danes, and probably date from the Roman Conquest, and cannot be considered older than 2000 years."

Moss believed that the Saxon and Danish place-names of the Pennine slopes implied tree cover, whilst those of the summits indicated boggy conditions. Documentary evidence suggested that Britain as a whole was well-wooded in Roman times, and that the Romans, in subjugating the Pennines, destroyed much of the woodland which provided cover for the Britons. The Roman roads of the Pennines were thought to lie on subsoil rather than peat, and traces of the 'Britons' who occupied the area prior to the Roman Conquest tended to be found under the peat.

Later studies disputed the post-Roman origin of the peat. Woodhead (1929) stated that there was actually a considerable depth (55cm) of peat beneath the Roman road at Blackstone Edge in the southern Pennines, which suggested that the peat pre-dated the Roman invasion. By this time, pollen analysis had begun to be applied to the study of vegetation history, and the divisions of the Holocene established in Scandinavia by Blytt (1876) and Sernander (1908) had come into general use. Thus Woodhead, referring mainly to macrofossils but with some rudimentary pollen analysis, was able to postulate that the Pennine forest, composed mainly of birch but also including hazel, oak and alder, reached its climax in late Boreal or early Atlantic times, and then degenerated due to the increasing wetness of the climate.

These ideas were elaborated by subsequent investigations. Detailed palynological studies by Conway (1947), Bartley (1964, 1975), Tallis (1964a, 1964d, 1975), Hicks (1971), and Tallis and Switsur (1973) lead to the following general conclusions about the vegetation history of the southern Pennines.

During the Boreal period, the uplands supported a forest composed mainly of pine and hazel, with some alder/birch woodland in shallow, ill-drained depressions. Peat formation began around the time of the Boreal/Atlantic transition, or during the Atlantic period. The exact time of onset depended on altitude and local topography, giving a range of dates for peat initiation from about 7000 to 5000 B.P. The earliest dates are for the flat plateaux at the highest altitudes; subsequently peat began to form in the valley bottoms and on the gentler slopes at lower altitudes; but on exposed ridges at lower altitudes a peat cover did not develop until considerably later (Tallis, 1964d). The increased oceanicity of the Atlantic climate is generally cited as the cause of peat development. However Tallis (1975) points to widespread evidence of burning in the basal layers of peats in the southern Pennines, and postulates that Mesolithic man may have been responsible for recurrent fires which prevented tree growth before, and in the early stages of peat accumulation.

By about 6000 B.P., those parts of the area not under blanket bog supported mixed-oak forest, interspersed with patches of damp heath and alder/birch carr. Hazel, elm and lime were present in varying proportions. Pine was still present in the area, though much reduced. Whilst elm was never abundant in the southern Pennines, a significant 'elm decline' can be detected at most sites. Hicks (1971) dated this horizon to 3040 $\pm$ 140 B.C. at Totley Moss and 2820 $\pm$ 100 B.C. at Hipper Sick. The first appearance of <u>Plantago lanceolata</u> also marks this horizon. Clearance phases become increasingly frequent and extensive after this, and while some woodland regeneration occurred after each clearance, the cumulative effect was an opening up of the forest cover. Man is believed to have been responsible for forest clearances from Neolithic times onward. Particularly extensive destruction of forest was thought by Conway (1947), on the basis of the growth rates of peat, to have begun about A.D. 1100, continuing to a maximum depletion in the seventeenth century. However, Hicks (1971), with radiocarbon analyses available, attributed this clearance to the mixed farming, and felling of timber for lead-smelting, of the Roman occupation rather than the Medieval period. Following this, the degradation of the soil may well have precluded tree regeneration over large areas of the upland, allowing the development of a shallow peat cover over areas which in Atlantic times had supported mixed-oak forest. The whole of the gritstone upland of the southern Pennines was eventually cleared of forest, largely being used to provide pasturage rather than arable fields.

In the northern Pennines, the picture is similar. Numerous studies have shown that the uplands which now consist of open moorland, with a mixture of rough grassland, heath and blanket bog, were once forested. Turner and Hodgson (1979) brought together pollen data from 42 sites in the northern Pennines, and found that between 8800 and 7000 B.P., these forests were composed of hazel, pine, birch, oak and elm, the proportions of these trees varying from one site to another. In both Upper Teesdale and the Derwent area pine was particularly abundant, its distribution showing no relationship to either altitude or geology, and it was associated with low amounts of birch. Hazel and elm were more abundant at high altitudes, but elm was less frequent on the Millstone Grit of the east and north of the region. Woodland appears to have extended over the whole altitudinal range of the sites, from 200m to 750m.

The subsequent history of the vegetation parallels that of the southern Pennines. Blanket bog developed on the high plateaux, and mixed-oak forest predominated elsewhere. Chambers (1978) suggests that interference with this forest by man may have begun as early as the Mesolithic in Upper Teesdale, but Davies and Turner (1979) found no evidence of human impact on the forests of Northumberland before the Bronze Age. The elm decline is dated to 4794 ± 55 B.P. at Valley Bog in Upper Teesdale (Chambers, 1978), which is significantly later than dates obtained from nearby lowland sites.

The pattern of vegetational history in the southern and northern parts of the Pennines is thus broadly similar, and so it might be expected that the Yorkshire Dales will again show a comparable sequence. However, insufficient data is available to adequately test this hypothesis. The research which has been carried out in the Dales area will be discussed more fully in chapter 7, but it is appropriate at this point to briefly summarise the current state of our knowledge of the vegetation history of this area.

The earliest palynological study in the Dales was that of Blackburn (Raistrick and Blackburn, 1938), who investigated Linton Mires, the site of a former lake near Grassington in Wharfedale. The pollen record here suggested that the Boreal vegetation of the area was comprised predominantly of pine, birch and hazel. This was succeeded by mixed-oak forest, and then alder rapidly increased while pine decreased with the onset of the wetter Atlantic climate.

Walker (1956) studied another site near Grassington, where an organic deposit had accumulated in a frost-crack in a large erratic. The pollen record was thought to start from Godwin's (1940) Zone V, which was dominated by birch, with some hazel, willow and a little pine. The transition between Zones V and VI saw a rapid rise in hazel, together with an increase in pine and the appearance of elm and oak. An expansion of alder, accompanied by decreases in pine and birch, characterised the following Zone VIIa, and mixed-oak forest became established. The record thus corresponds to that at Linton Mires. Of particular interest at this site, however, was the occurrence of flint microliths of Mesolithic age in the lower part of Zone VIIa. This horizon was later dated to 6500 ± 310 B.P. (Godwin and Willis, 1959).

More recently, Jones (1977) investigated several sites in the 'Craven' area of the Dales. These were Threshfield Moor, Eshton Tarn, White Moss and Linton Mires, the latter being the site already mentioned above which was studied in the early days of pollen analysis by Blackburn. By the early Boreal period, Craven supported a closed woodland composed largely of birch, although pine was more important at Linton and apparently in the more calcareous districts (R. T. Smith, personal communication). Pine became dominant throughout the area by the end of the Boreal period, and persisted until about 6300-6000 B.P. despite the expansion of alder which marked the Boreal/Atlantic transition. With the decline of pine, alder became dominant over much of lowland Craven, with oak, elm and some lime. The main elm decline was dated to 5000 B.P., and this was followed by a series of clearance phases attributed to Neolithic man. At Eshton Tarn, a great expansion of agriculture occurred in the early Bronze Age, and further episodes of increased agricultural activity ascribed to the Iron Age and Romano-British period resulted temporarily in the virtual deforestation of the area. At White Moss, the only other record which covers this period, the first large-scale clearance of woodland did not occur until the late Romano-British period.

The vegetation history of the Craven area has also been studied at Malham Tarn (Pigott and Pigott, 1959) and at Scar Close near Ingleborough (Gosden, 1968). The general pattern is similar to that found by Jones (1977) and Raistrick and Blackburn (1938), with a gradual reduction of the upland forest from the Atlantic period onwards. However, Pigott and Pigott (1959) found that forest decline began in the late Neolithic or early Bronze Age at Malham, and was closely correlated with successive population increases. Gosden (1968), on the other hand, concluded that the decline of woodland and the associated spread of peat over the limestone pavement resulted from climatic deterioration during the Sub-Atlantic period. More recently, R. T. Smith (1985, in press) has found evidence of vegetation disturbance as far back as the Mesolithic period on Malham Moor.

The other part of the Yorkshire Dales for which detailed pollen analysis has been undertaken is the Nidderdale Moors (Tinsley, 1972). Again, the pine-birch-hazel woodland of the Boreal period was replaced by a mixed oak community after about 7000 B.P. Clearances by Neolithic man from about 5000 B.P. did not have any permanent impact on the vegetation in this area, the first major decline in upland woodland and expansion of heath being associated with the pastoral farming of the early Bronze Age. From this period onwards the forest retreated progressively, and there is increasing evidence of agricultural activity in the area.

Thus the vegetation history of Craven, Wharfedale and the Nidderdale Moors has been studied in some depth. But virtually nothing is known of the sequence of vegetation change in the more northerly dales, of which Wensleydale covers the greatest area. Pollen analyses of a small number of samples have been carried out at Lunds, at the head of the Ure valley (Walker, 1954) and at Semerwater (Ingram et al, 1959). Whilst these analyses were secondary to the main aims of the studies concerned, the conclusions drawn from them suggest that the vegetation history of Wensleydale merits further attention.

At Lunds, Walker (1954) examined the deposits above and below a solifluction earth. The lower deposit was thought to represent Zones

I, II and III, and pollen analysis showed that herbaceous vegetation dominated the uplands throughout this period. The tree pollen frequency was generally less than 8%, with a small peak in the middle zone. Willow was the dominant tree species, with some birch and only a few badly eroded pine pollen grains. Whilst the present study is confined to the post-glacial vegetation history of Wensleydale, it is interesting to note that in the corresponding late-glacial period of the Craven area, Jones (1977) found birch and juniper to be dominant in an open park tundra community.

The peat above the solifluction head at Lunds was of less interest to Walker, and he only noted that tree pollen was abundant, with alder, birch and hazel dominant and some oak. This was thought to indicate an Atlantic or later date for the deposit. The proportion of oak is unusually low and that of birch correspondingly high by comparison with other studies from the Dales.

At Semerwater (Ingram et al, 1959), the pollen content of a sample taken from a depth of 1025cm in a core through the lake mud was compared with three modern pollen samples. Tree pollen comprised 40% of the total in the older sample, and this was composed mainly of oak, alder and hazel, with a small amount of birch. The modern samples contained less than 30% tree pollen, the dominant tree species being the same although additional species were present. Ingram et al concluded that:

> " ... the proportions of the various pollen types in all four samples are similar, which suggests that in the past 5000 years the vegetation around Semerwater has undergone little change, other than some decrease in the number of trees."

This seems unlikely, in view of the data obtained from more recent studies elsewhere in the Dales.

The extremely limited research so far carried out in Wensleydale therefore provides only tantalizing hints about the vegetation history of the area, suggesting that the sequence may be sufficiently different from those found elsewhere in the Dales to be worthy of detailed study. Whilst most Pennine sites reveal a broadly similar pattern of vegetation change, it is the local variations caused by both physical and human factors which are of particular interest. As mentioned earlier, the distinctive physical features of Wensleydale and its long history of human occupation make it especially attractive for palaeoecological study. The physical and historical background against which the vegetation history of the area must be viewed is described in the following chapters.

CHAPTER 2: PHYSICAL BACKGROUND

2.1 Geology and topography

2.1.1 Carboniferous stratigraphy

2.1.2 Structural geology and mineralisation

2.1.3 The Quaternary period

2.2 Climate

2.2.1 Temperature

2.2.2 Precipitation

2.2.3 Wind

2.3 Soils

2.4 Vegetation

PHYSICAL BACKGROUND

2.1 Geology and topography

The solid geology of Wensleydale is composed entirely of Carboniferous strata, and it is these which are responsible for the major topographical features of the area. They were deposited in the relatively stable environment of the Askrigg Block, which was not submerged until quite late in the Lower Carboniferous period (Edwards and Trotter, 1954).

As figure 2.1 shows, the Carboniferous rocks of much of the area are now covered by Quaternary deposits. The distinctive hummocky topography of the valley floor is due to features of glacial deposition such as drumlins, while blanket peat has accumulated on the acid grits of the fell-tops and is now eroding in many places to form extensive gully systems.

2.1.1 Carboniferous stratigraphy

On the basis of lithology, the Carboniferous system is subdivided as follows :-

Upper Carboniferous	Coal Measures
	Millstone Grit Series
Lower Carboniferous	Yoredale Series
	Carboniferous Limestone Series

These divisions represent successive phases of deposition in an area which was subsiding irregularly. Four major eustatic cycles of transgression and regression have been recognised in the Lower Carboniferous

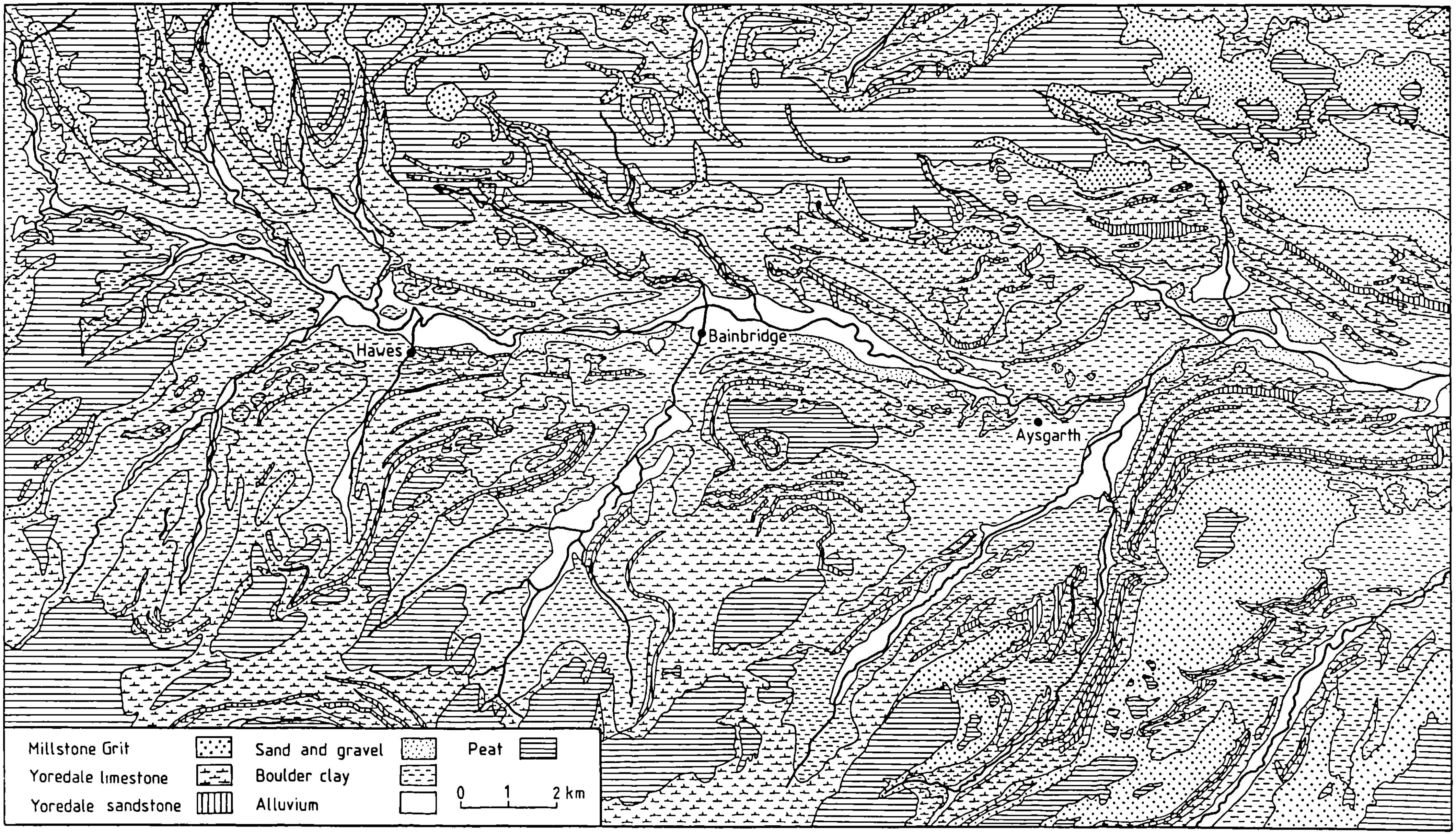


Figure 2.1: The geology of Wensleydale

(Ramsbottom, 1974), during which the Carboniferous Limestone Series was deposited. The Askrigg Block was not completely submerged until the last of these cycles, when deposition of the Great Scar limestone began. Inliers of this pure, well-bedded and massive limestone occur in Wensleydale from Hardraw to Redmire and also in Semerdale and Bishopdale.

The major cycles were followed by a period of frequent minor transgressions and regressions, in which the rhythmic deposits of the Yoredale Series were laid down. This series dominates the geology of Wensleydale, which is the type area from which Phillips (1836) took the name 'Yoredale'.

The Yoredale succession of the Askrigg Block is shown in figure 2.2. The rhythmic units consist of the following ascending sequence of phases: limestone, shale, sandstone, ganister, coal. In many cases this sequence is incomplete; the coals in particular are often absent. The named limestones (see fig. 2.2) are the most constant members of the cycles, and are quite easily correlated over wide areas.

The limestones were deposited in a shallow sea, while the clastic beds between them represent different forms of deltaic sedimentation. D. Moore (1958) regarded the fossiliferous marine shales above the limestones as pro-delta deposits, the succeeding unfossiliferous shales and sandstones as the deposits of the delta slope, and the sandy beds above these as the deposits of the areas between the distributary channels. In two cases in Wensleydale, in the Hardraw and Undersett cycles, the coarsely arenaceous deposits of large channels can be traced across the area, and these channels are up to 2km wide. The ganisters and coals are the deposits of interdistributary marshes behind the levees. The Yoredale beds were thus formed by a delta repeatedly

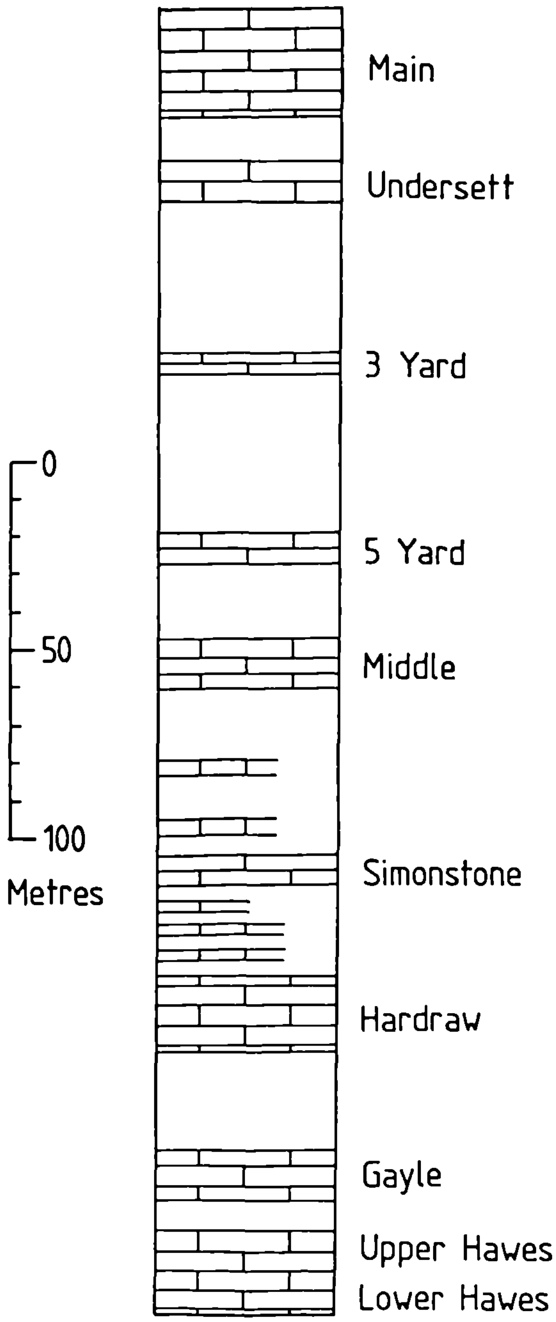


Figure 2.2: The Yoredale succession of the Askrigg Block, showing the sequence of the named limestones

advancing into an area which had, since the previous advance, been subjected to relative subsidence which allowed the deposition of the limestone - the effect either of isostatic subsidence or of eustatic marine transgression, or, most probably, of both factors (Ramsbottom, 1974).

Differential weathering of the bands of limestone, shale and sandstone gives rise to the terraced slopes of Wensleydale. The hard limestones form prominent scars, their flat tops being exposed by the weathering of the less resistant shales; the sandstones are often concealed under screes from the limestone and form a lower, less steep portion of the rise (Raistrick and Illingworth, 1949). As the Yoredale strata remain almost undisturbed, other than a slight tilt to the east, each terrace and scarp generally extends throughout the whole length of the dale. The many waterfalls of Wensleydale are also due to the differing strengths of the Yoredale rocks.

The succeeding Millstone Grit Series similarly represents the periodic incursions of deltas following marine transgressions. In this series, though, the deposits of the marine phase are shales, and these alternate with sandstones or 'grits' deposited in the deltaic distributary channels. The typical grits are coarse and often cross-bedded. Thin coal seams are also sometimes present, as in the Yoredale Series. In Wensleydale, the rocks of the Millstone Grit Series cap the higher fells.

The Coal Measures of the late Carboniferous period are not represented in this area, and subsequent geological periods up to the Quaternary have left no trace on the present landscape.

2.1.2 Structural geology and mineralisation

Wensleydale, due to its position on the stable structural unit of the Askrigg Block, has been largely unaffected by the post-Carboniferous orogenic phases. The Carboniferous strata of this area remain unfolded and almost horizontal, with only a slight dip of about 2° to the east. This easterly tilting is believed to have occurred during the Tertiary period, but it now seems that it was not due to the classic Alpine orogeny but rather to a long-continued, purely epeirogenic movement starting in the early Eocene and continuing to the present day. As the North Sea Basin progressively subsides, the positive area of the Pennines is slowly uplifted (Kent, 1974).

A number of faults occur in Wensleydale, but these are relatively infrequent and have only small throws, in contrast to those of the Craven area to the south of the Askrigg Block. The faults tend to trend approximately north-south, and have been active periodically since the Carboniferous period. Along many of them, epigenetic mineralisation has produced veins of galena, which supported a local lead mining and smelting industry until the late nineteenth century.

2.1.3 The Quaternary period

Whilst the Quaternary period covers only about the last two million years of earth history, its remarkable series of climatic fluctuations have had a profound effect on the landscape of the Dales. The cross-profile of Wensleydale and many of its surface deposits are due to the effects of a sequence of glacial episodes, which alternated with more temperate interglacial phases.

Ice spreading from a local ice cap centred over Baugh Fell and Wild Boar Fell moved eastwards down Wensleydale during the last (Devensian) glaciation. At the maximum, the glaciers of each dale spread over the intervening ridges and coalesced. Only the highest peaks of the Dales area, such as Ingleborough and Penyghent, projected as nunataks above the ice (Penny, 1974). Evidence of earlier glaciations in Wensleydale is therefore lacking, the deposits having been removed or reincorporated by the advancing Devensian ice.

Erosion of the valley sides combined with deposition in the valley bottom to produce the characteristic 'U-shaped' cross-profile in parts of upper Wensleydale. Glacial deposits of various types are abundant throughout the dale (see fig. 2.1), and are particularly important in terms of their influence on soil and vegetation development, as will be discussed later.

The stages in the retreat of the ice have been studied in some detail by Raistrick (1926). Phases of rapid retreat alternated with periods of stagnation, producing a distinctive series of deposits which is repeated several times in Wensleydale. The furthest possible extent of the Wensleydale glacier is marked by a line of morainic hillocks running approximately north to south across the valley at Rookwith, east of Thornton Steward (just outside the study area). The erratics of these deposits suggest that they represent the lateral moraine of the Vale of York glacier, and to some extent a terminal moraine of the Wensleydale glacier (Raistrick, 1926). A more typical terminal moraine crosses the Ure valley at Aysgarth. Behind this barrier the ponding of meltwater has left an extensive lake flat, whilst beyond it the escaping water resulted in the deposition of a fan of fluvio-glacial sands and gravels.

Prominent lateral moraines extend for 16km in an easterly direction from Redmire, and another at Bainbridge closes the Bain valley and impounds Semerwater. The retreat of the ice also exposed drumlins, which formed earlier beneath the moving ice (Penny, 1974). These are particularly well-developed around the Moorcock Inn at the head of the dale, but are abundant throughout upper Wensleydale. Raistrick (1926) noted the existence of over 80 large drumlins in the 19km of valley west of Aysgarth.

In addition, the retreat of the ice gave rise to an extensive system of lakes on the south side of the Ure valley (Raistrick, 1926), of which the only surviving remnant is Semerwater. Raistrick postulated that at its highest position, this lake drained across the Aysgarth Moors to Bishopdale by means of an overflow channel at 390m O.D. At this stage, the lake would have been approximately 6•5km long, 2km wide at the narrowest part, and about 150m deep at most. Similar lakes are thought to have existed in Bishopdale and Coverdale.

It is clear, then, that glacial processes have played an important part in shaping the landscape of Wensleydale. By comparison, the geological events of the post-glacial (Holocene) period have been insignificant. Blanket peat up to 3•65m thick has developed on the grit-capped fells, but this is now eroding in many places, often due to artificial drainage. The only other deposits of the Quaternary period, as shown in figure 2.1, are the fluvial sediments of the valley bottom. A covering of fertile alluvium on the broad, flat reaches of the valley floor provides good pasture land.

2.2 Climate

There are no meteorological stations within Wensleydale. Estimates of climatic statistics have therefore been based largely on generalised figures for the region provided by studies such as that of L. P. Smith (1976), taking into account the influence of local factors such as relief. Accurate rainfall measurements are available, however, from a number of rain gauges maintained by the Yorkshire Water Authority.

2.2.1 Temperature

Mean monthly air temperatures for the area as a whole range from 1° C in January to 13•5° C in July (L. P. Smith, 1976). These figures are based on an average height of about 325m. Local variations are determined by altitude, which ranges from 135m to over 700m within the study area. The decrease in mean air temperature with height varies slightly throughout the year, but is generally estimated as 0•6° C per 100m. This implies that the high fells may be over 3° C cooler than the valley bottoms at any particular time, which is important in terms of local vegetation and agricultural potential. The situation is complicated by the occurrence of temperature inversions, however. In the Craven area of the Dales, Manley (1956) suggested that the minimum night temperature of the lowlands is as low as, or lower than, that of the uplands as often as one night in three.

The incidence of frost also varies with local topography, but L. P. Smith (1976) estimates that on average the last spring frost in this area occurs in late May.

2.2.2 Precipitation

Rainfall data are collected at a number of sites in Wensleydale, and published by the Meteorological Office. Figures for 1968, a year in which a comparatively large number of rain gauge sites were in operation in this area, show a range of annual precipitation from 995mm at Bolton Hall (SD 075897, altitude 128m) to 2093mm at Top Snaizeholme (SD 830834, altitude 579m).

The influence of altitude on annual precipitation is illustrated by the following figures :-

Site	Grid Ref.	Altitude	Precipitation (1968)
Hawes	SD 874902	227m	1422mm
Burtersett	SD 891893	290m	1624mm
Mirk Pot Farm	SD 828870	312m	1782mm
Top Overley	SD 860846	567m	1847mm

There is also evidence of a 'rain shadow' effect, with rainfall decreasing from west to east for sites at a similar altitude :-

Site	Grid Ref.	Altitude	Precipitation (1968)
Hawes	SD 874902	227m	1422mm
Bainbridge	SD 934902	216m	1322mm
Carperby	SE 007898	223m	1050mm

The highest annual precipitation is therefore found at high altitudes at the western end of the dale. This has important implications for soil and vegetation. Excess rainfall is a notable feature of much of this area, producing leached soils and allowing the development of bog vegetation.

2.2.3 Wind

The prevailing direction of winds is from the west and south-west, although the local pattern may be influenced by the orientation of the valleys. On the exposed high fells, strong winds cause the occasional trees which survive to be stunted and permanently bent in the direction of the prevailing winds.

2.3 Soils

No maps or descriptions of the soils of Wensleydale have been published. The types of soils which develop on the particular parent materials of the Dales area with different rainfall and drainage conditions have, however, been studied (for example Bullock, 1971) and field observations suggest that the soils of Wensleydale conform to these general patterns.

The surface geology of Wensleydale, as described in section 2.1, consists of boulder clay and alluvial material in the valley bottom, with the limestones, shales and sandstones of the Yoredale Series forming the terraced slopes of the valley and Millstone Grit capping the fells. Because of the almost horizontal bedding of the Carboniferous strata, each type of rock tends to occur in the same topographical situation in different parts of the dale. The same zones of soils from the river up to the highest peaks therefore tend to be found throughout Wensleydale, particularly as rainfall also tends to increase with altitude, so that, for example, the soils of the highest fells are generally developed on Millstone Grit under conditions of heavy rainfall. The only factors which may alter this broad pattern are the increase in rainfall towards the west, and the effects of aspect.

In the valley bottoms, the solid geology is obscured by deposits of boulder clay, fluvio-glacial sands and gravels, and alluvium. It is these superficial deposits, together with the high water-table, which determine soil development. The boulder clay yields a variety of gleyed soils. These soils are heavy in texture, and often have a surface horizon of acid mor humus. Surface-water gleys develop on flat ground and in depressions, while the drumlin slopes drain more freely so that the brown earth profiles show less gleying. The fluvio-glacial deposits and the gravelly moraines produce much drier soils, as they allow rapid drainage of water. These soils are of little value for agriculture, however, as they are base-deficient and dry out too quickly, becoming subject to drought in summer. The best soils are those derived from alluvium and lacustrine deposits. They are rich in minerals, but their situation causes them to be poorly drained. Brown earths with gleying at depth are common, and with efficient drainage these soils provide rich meadows.

On the valley slopes limestone outcrops most frequently, giving rise to dry calcareous soils. Rendzinas of pH 7-8 are produced when the rapid leaching caused by the wet climate and rapid soil-water movement is offset by upward mixing due to soil creep and the abundant soil fauna (Eyre, 1968). These soils are light and crumbly and support good pasture, but they tend to lose fertility quite rapidly as the presence of calcium accelerates the breakdown of organic matter. This means that whilst the nutrients are quickly made available to growing plants, humus soon disappears, so that considerable amounts of manure or very long leys are necessary when the soils are cultivated (Raistrick and Illingworth, 1949).

In some cases, the limestone weathers into large fragments which cannot be disseminated and intimately incorporated into the soil. When a depth of a few centimetres of soil has been achieved, only a moderate precipitation is sufficient to leach away any calcium carbonate which dissolves from the hard limestone fragments and thus to maintain an acid soil reaction. This allows the dissociation of clay minerals, releasing ferric oxide which gives these 'terrae rossae' their red colouration. In extreme cases, true podsols can develop on limestone in this way; examples are known on the Carboniferous Limestone plateaux of the Craven area (Eyre, 1968).

The sandstones of the Yoredale Series outcrop less frequently, occurring in thin bands along the valley sides. Their soils are light, sandy, porous and deficient in bases. Podsols and peaty podsols are most common, with a surface layer of blackish acid peat underlain by an eluvial horizon of bleached sand and finally an illuvial iron-rich horizon above the rotted sandstone.

The Yoredale shales weather so rapidly that little trace of them remains today. The soils derived from the shales are heavy clays, deficient in calcium and poorly drained. However the clay does tend to become mixed with sand from the stratum above, giving a more friable, loamy soil, although still base-deficient.

Above the alternating calcareous and sandy soils of the Yoredales, the fells of Wensleydale are capped by Millstone Grit. The characteristic soils of the grit are podsols, as on the Yoredale sandstones. The annual rainfall at this altitude is somewhat heavier, though, so that leaching is intense. Occasionally the iron oxides which are leached downwards in the soil profile become concentrated into an indurated moor pan, which prevents the downward movement of water and plant roots.

Where local hydrological conditions led to waterlogging, extensive peat deposits have developed on the gritstone fells. This peat is up to 3•65m thick, and is maintained by the heavy rainfall of the area.

Thus the soils of Wensleydale are determined by lithology and drainage conditions, the same general sequence from valley bottom to fell top being discernible throughout the dale.

2.4 Vegetation

The plant communities associated with the different habitats of the Yorkshire Dales have been described in a number of studies, for example Smith and Rankin (1903), and Raistrick and Illingworth (1949). However, the actual distribution of vegetation types in Wensleydale was not mapped by these early workers. In more recent years this task has been undertaken by the Second Land Utilisation Survey, who have mapped the vegetation and land use of England and Wales at a scale of 1:63,360. Whilst the proposed publication of this material in the form of a 'Wildscape Atlas of England and Wales' has not yet proved feasible (Miss Alice M. Coleman, personal communication), the Wensleydale area was the subject of an experimental sheet printed with the aid of a grant from the West and North Ridings. Twenty major vegetation classes are recognised (Coleman, 1970), and further detail is added by means of overprinted symbols indicating different habitats. Figure 2.3 is based on a simplification of the experimental Wensleydale sheet, which was produced at a scale of 1:100,000.

One of the most extensive plant associations in Wensleydale, as shown in figure 2.3, is heather moor. This occurs particularly on the drier eastern end of the Ure-Swale interfluve, although patches are found throughout the dale above about 300m where the podsols or peats are sufficiently well-drained to preclude the growth of bog species. The dominant plant is *Calluna vulgaris*, which often occurs in almost pure stands, especially where the moors are managed for grouse by periodic burning. In drier areas *Erica cinerea*, *Vaccinium myrtillus* and *Empetrum nigrum* appear as co-dominants. On the well-drained,

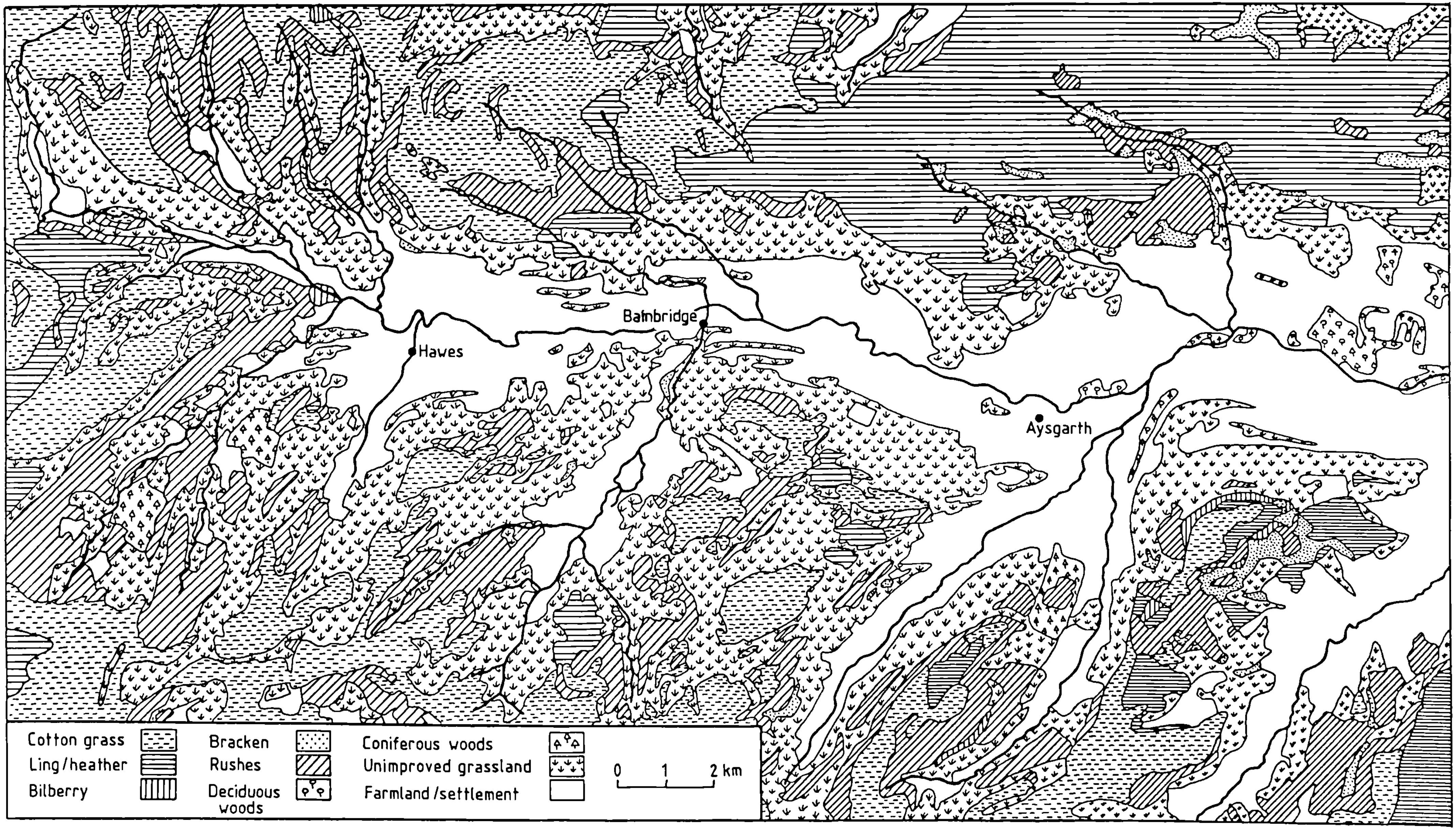


Figure 2.3: The vegetation of Wensleydale

exposed fell margins where the gritstone is close to the surface almost pure '*Vaccinium* edges' occur (Tansley, 1953), as for example on the upper slopes of Penhill. Where drainage is locally poorer, *Erica tetralix* and *Juncus squarrosus* are associated with *Calluna*.

As annual rainfall increases towards the west, and where drainage is poor, the fells of Wensleydale are occupied by cotton-grass mosses or bogs. Extensive mosses of this type occur on Abbotside Common between Wensleydale and Swaledale and on the spurs between the southern tributaries of the Ure. *Eriophorum vaginatum* is usually dominant, but wetter patches favour *Eriophorum angustifolium*. The cotton-grasses often exclude other flowering plants, but *Vaccinium myrtillus*, *Empetrum nigrum*, *Erica tetralix*, *Trichophorum cespitosum*, *Molinia caerulea*, *Juncus* spp. and *Sphagnum* spp. become locally abundant whenever ecological conditions change in their favour (Raistrick and Illingworth, 1949; Tansley, 1953). More rarely, and particularly at the higher levels, *Rubus chamaemorus* is important, as at Fleet Moss. As Tansley (1953) says of the cotton-grass moss, 'The community normally occurs on deep peat which it has itself formed.' However, large areas are now degenerating, particularly as a result of moor-gripping. This improvement in drainage tends to cause the replacement of cotton-grass by heather, as is occurring around Whirley Gill Head on Askrigg Common. Also, where streams cut back deeply into the peat, severe gullying leads to the formation of isolated peat haggs and eventually to the complete destruction of the peat. This process is becoming marked at Fleet Moss.

On the margins of the cotton-grass moss and in valley flushes, *Juncus* spp., especially *Juncus squarrosus*, become dominant. This association is often found around the heads of streams and around pools of standing water on the moors, where Sphagnum spp., Polytrichum commune and a variety of herbs tolerant of wet conditions such as Narthecium ossifragum, Erica tetralix and Drosera rotundifolia also occur.

The valley slopes below the moors and bogs of the gritstone plateaux usually support grassland of various types, the dominant species depending on the lithology and drainage conditions. The poorest pasture is found on the ill-drained, acidic soils of the upper slopes, and is dominated by Nardus stricta, which is unpalatable to sheep. Also of little value for livestock is Molinia caerulea, which predominates on still wetter acidic soils. Whilst this grass produces luxuriant growth, it starts late in the spring and then grows too rapidly for the sheep to keep pace, so that 90% is wasted (Raistrick and Illingworth, 1949).

Better pasture is provided by the Festuca-Agrostis grassland of the drier slopes. This association tends to occur on slightly acidic soils, often brown earths, and is very widespread. Its fertility varies enormously, as at one end of the habitat range it merges into the valuable Festuca ovina grassland of the limestones, while at the other end of the scale it passes into the unpalatable Nardus-Juncus squarrosus grasslands of the more acidic soils (Pearsall, 1950). Problems arise when the soil is over about 25cm in depth, as Pteridium aquilinum can then encroach upon the grassland. This process has been accelerated in recent years by the replacement of cattle by sheep on the hill grazings, as cattle eat young bracken and trample even greater quantities, and by the increased cost of the labour necessary to control the bracken by frequent mowing (R. T. Smith, 1977; Watt, 1976).

Undoubtedly the best pastures, though, are the *Festuca* grasslands of the dry calcareous habitats. Around the head of Wensleydale, the outcrops of the Hardraw, Simonstone, Middle and Undersett limestones give bright green strips of fescue-pasture along the valley sides, in which plants such as *Poterium sanguisorba*, *Viola lutea*, *Lotus corniculatus*, *Luzula campestris*, *Sesleria caerulea* and *Anthoxanthum odoratum* also occur (Raistrick and Illingworth, 1949; Smith and Rankin, 1903). The relationship between vegetation and geology is not always simple, however, as variations in soil characteristics with depth (due to liming, for example) can lead to a mixture of 'acidic' and 'calcareous' species which root at different levels.

Woodland is uncommon in Wensleydale, and mostly consists of small coniferous plantations on poor acidic soils towards the dale head, for example in Widdale. Perhaps more representative of the 'natural' woodlands of the area are the lowland oak woods, the gill woods, and the scar woods of the limestone outcrops. The former type of woodland is absent from the study area, but does occur on the deep, somewhat acid and damp soils of lower Wensleydale, from Masham to Leyburn. Gill woods survive in some of the steep tributary valleys joining the Ure from the north, such as Bolton Gill, Whitfield Gill and Shaw Gill. *Betula pubescens* and *Sorbus aucuparia* form a thin scrub, with a ground flora of moorland species. The final type of woodland, that of the limestone scars, tends to be dominated by *Corylus avellana* and *Fraxinus excelsior* and again is often thin and scrubby. In Wensleydale below Bainbridge, the lines of the lower limestone scars are marked by narrow horizontal bands of ash (*Fraxinus excelsior*) and beech (*Fagus sylvatica*) coppice (Raistrick and Illingworth, 1949).

The remainder of Wensleydale is under improved pasture, dairying being of great importance on the lower-lying land. The upper limit of improved 'intakes' is about 365m, although many fields abutting on the moors have reverted through neglect to Nardus-dominated grass heath. The valley pastures are mainly of Agrostis, usually with little admixture of better grasses. In lowland Wensleydale, up to Leyburn, a greater abundance of Lolium perenne provides more valuable fodder for livestock.

The field boundaries of Wensleydale are usually dry stone walls, but solitary trees and shrubs of oak, elm, sycamore, hazel and hawthorn are quite common. Hedges are not often found within the study area, but become increasingly frequent from West Witton eastwards.

CHAPTER 3: HISTORICAL BACKGROUND

3.1 The Palaeolithic

3.2 The Mesolithic

3.3 The Neolithic

3.4 The Bronze Age

3.5 The Iron Age

3.6 The Roman Period

3.7 The Anglo-Saxon and Scandinavian Period

3.8 The Norman Settlement and the Monastic Period

3.9 The Post-Monastic Period

HISTORICAL BACKGROUND

3.1 The Palaeolithic

This period began with the emergence of man and the manufacture of the earliest tools some 2½ to 3 million years ago, and lasted through the Pleistocene Ice Age. In Europe, a clear sequence of upper Palaeolithic industries can be traced, which are thought to have evolved from middle Palaeolithic groups. But in Britain, which was at this time merely a peripheral north-western area of the European land-mass, the severe climate strictly limited human habitation. The area was probably only periodically visited by hunting and collecting parties from Europe, and it is not possible to see a well-defined set of industrial levels comparable to the European sequence (Megaw and Simpson, 1981).

Earlier upper Palaeolithic artefacts, dated to the last inter-glacial, have been found as far north as Derbyshire, but it seems unlikely that man was able to penetrate any further north than this until after the final retreat of the ice sheets about 10,000 years ago. For this reason, Palaeolithic finds are extremely scarce in the Yorkshire Dales. However, Victoria Cave near Settle has yielded a number of tools and weapons made of bone and antler, which resemble those of the European Magdalenian tradition (later upper Palaeolithic) (King, 1970). This indicates that Palaeolithic man may possibly have reached the Wensleydale area, but it seems unlikely that he could have had any significant effect on the development of later landscapes.

3.2 The Mesolithic

It is impossible to define a precise boundary between the upper Palaeolithic and the Mesolithic. Such divisions are purely artificial constructions imposed upon what was, in effect, a continuous process of adaptation to changing environmental conditions. The Mesolithic is, in any case, a period of transition between the Palaeolithic and Neolithic ages.

The continuity and overlap in time is shown in the use of the same sites in certain areas, in the progressive decrease in the size of stone tools, in the continuous use of some technological processes (such as that of the groove and splinter method of working antler), and by the range of radiocarbon dates covering these periods. Recognisable groups of what are regarded as Mesolithic artefacts began to appear about 10,000 years ago, thus overlapping with dated sites at the end of the later upper Palaeolithic.

Mesolithic man therefore lived in the rapidly changing environment of the early post-glacial. As temperatures increased, the ice sheets melted and sea level rose. Ireland was cut off from Europe at an early stage; later the English Channel was flooded and the Straits of Dover breached. The establishment of full oceanic circulation around Britain, at the beginning of the 'Atlantic' period, accounts for the higher rainfall of this time.

As the climate ameliorated, forest spread through Britain and the easily-culled herds of reindeer which were so crucial to Palaeolithic man were replaced by more diffuse populations of forest-dwelling animals such as red deer and aurochs. Mesolithic man accordingly had to adapt his hunting methods to the pursuit of individual animals rather than herds, and began to make greater use of the bow and arrow. He became less specialised, pursuing a greater variety of animals than did his predecessors in the Ice Age. He also made use of the more varied plant diet which became available.

The earliest Mesolithic culture in Britain is the Maglemosian, named after the Danish type site of Magle Mose and classically associated with forest, marsh and reed-swamp habitats. An example of a site of this age is Star Carr, situated in the Vale of Pickering, between the North York Moors and the Yorkshire Wolds (Clark, 1954). The human occupation horizon here is dated to 9538 $\pm$ 350 B.P. The camp was constructed by the edge of a lake, and birch trees were felled to build a stable platform on the reed-swamp. The main function of the camp, judging from the bone and antler remains, appears to have been as a base for seasonal hunting (principally of red deer) in the surrounding forests, although many varieties of smaller animals and fish were probably also exploited. Most of the antler, stone and amber artefacts found at Star Carr were concerned with hunting and the preparation of animal products. They included barbed points and mattock heads made from antler, and microlithic arrowtips. Also present were a few small chipped flint axes, used for felling timber.

Most early Mesolithic sites in Britain are in river valleys or low-lying areas. However, there are sites in the Pennine uplands which yield archaeological remains of this age. Clark (1972) interpreted these as the temporary summer camps of the hunters whose winter base camps were in the swampy and forested valleys below. The remains are dominated by broad-bladed flints, axes being scarce.

Warcock Hill, Marsden, near Huddersfield, is one of a group of Mesolithic sites in the southern Pennines (Woodhead and Erdtman, 1926). The flints found here are mainly of the 'broad-bladed' type, and have strong affinities to the Star Carr assemblage, suggesting that this does represent a summer camp of hunters following the movements of the deer over wide areas in the uplands (Megaw and Simpson, 1981). Deepcar, 27km to the south-east, provides another example of the 'broad-bladed' Pennine flint industry (Radley and Mellars, 1964).

Early Mesolithic artefacts are less frequently encountered in the more northerly areas of the Pennines, but Raistrick (1933) reported finds of broad-bladed flints at two sites on the moors above Carperby and Askrigg in Wensleydale (see fig. 3.1). A large collection of flints from the Sandbeds at Otley in lower Wharfedale (Cowling, 1973) is also thought to represent this early Mesolithic industry. Mellars (1973) postulated that this site may have been occupied in winter by the nomadic hunters who spent the summer on the higher moorlands immediately to the west.

From about the beginning of the seventh millennium B.C., there was a general increase in the variety of tools and techniques used by Mesolithic man. This provides a convenient subdivision of the British Mesolithic. The flint industries of this later Mesolithic period were characterised by narrow, 'geometric' microlithic forms, which Clark (1955) believed to be related to the French Sauveterrian industries. More recently, however, it has been recognised that it is not possible to link the British later Mesolithic industries very closely to one particular continental provenance (Megaw and Simpson, 1981). They are more realistically interpreted as an adaptation to, and exploitation of

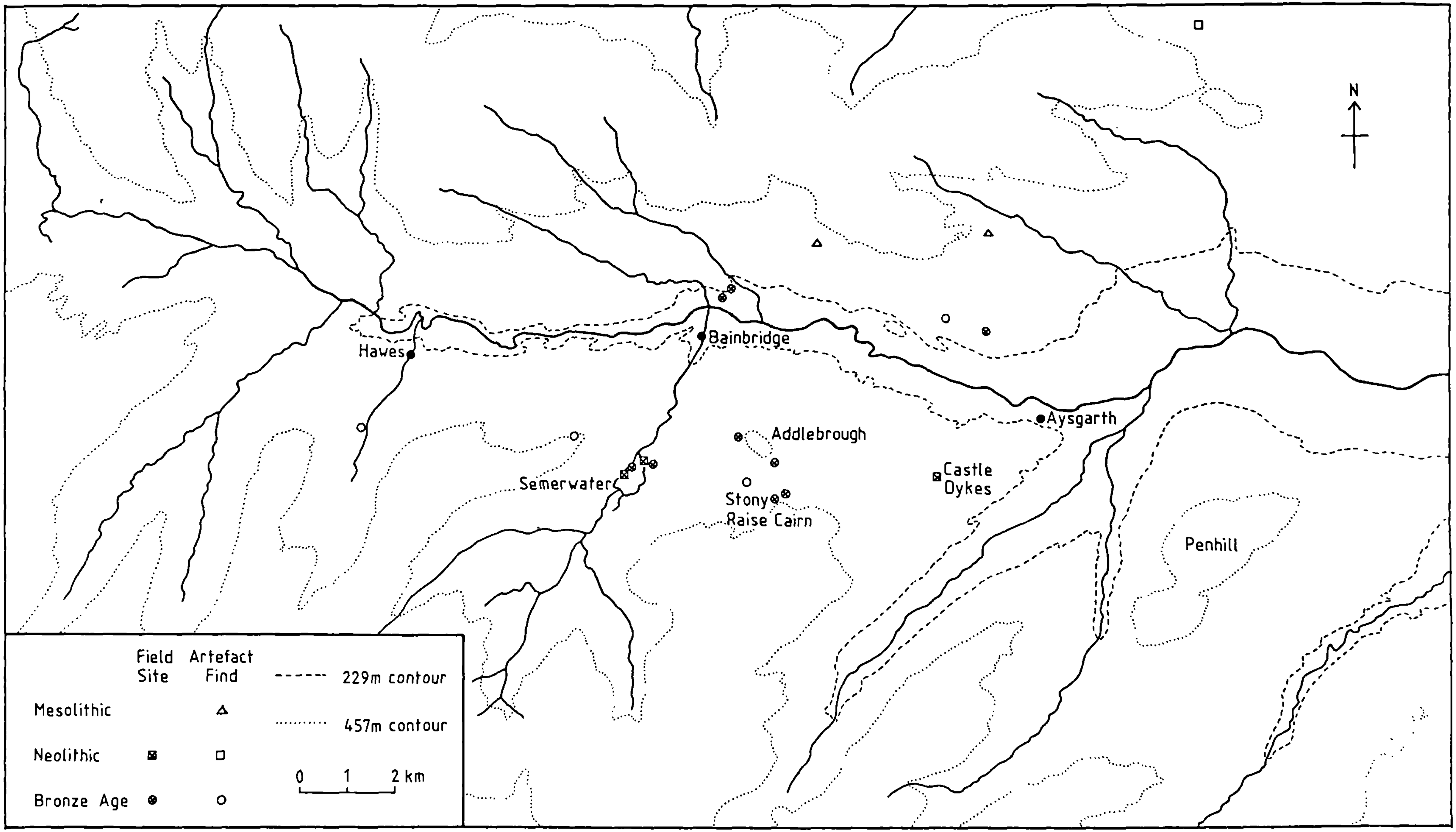


Figure 3.1: Mesolithic, Neolithic and Bronze Age sites and finds in Wensleydale

the raw materials available within a particular area.

It was during this period that Britain was finally cut off from the continent, the Channel being formed at around 8,500 B.P. The rising sea level decreased the available land surface and so increased the need for man to exploit zones further inland and to improve the efficiency of his hunting techniques. The number and density of Mesolithic sites in Britain increases from the mid-seventh millennium B.C. onwards, but this does not necessarily represent a sharp rise in population numbers (Brothwell, 1972). Vast areas of swampy ground and forested hunting territory were replaced by open sea or marshy seashore, driving Mesolithic man inland (and up into the hills) whilst at the same time destroying evidence of his former habitations.

The 'narrow-bladed' Pennine flint industry is attributed to this later Mesolithic period. Many of the flints from the Marsden area near Huddersfield belong to this category (Hallam, 1960; Woodhead and Erdtman, 1926). Unfortunately, the absence of organic remains makes accurate dating impossible. Also, the microliths are usually found beneath peat rather than stratified within it, so that it can only be said that the remains pre-date the onset of peat formation in the area (about 7,500 B.P.). In this respect, the site investigated by Walker (1956) at Stump Cross, near Grassington in the Yorkshire Dales was unusual as microliths were found within an organic deposit. Pollen analysis showed that the artefacts were associated with the first half of Zone VIIa (Atlantic), and radiocarbon dating of charcoal from the same horizon (Godwin and Willis, 1959) placed the remains in the mid-fifth millennium B.C. (6500 $\pm$ 310 B.P.). Also in the Wharfedale area, Davies (1963) studied a Mesolithic workshop site on Blubberhouses Moor which he believed to date from the same period.

So whilst remains are scarce, it is clear that man was present in the Yorkshire Dales area at various times throughout the Mesolithic. This fact must be taken into consideration in any attempts to explain the vegetation history of the area. Through the work of Simmons (1969a, 1969b, 1975), A. G. Smith (1970), and Dimbleby (1962) in particular, it has become apparent that Mesolithic man, equipped with fire and axes, had a significant effect on his environment.

Few pollen profiles of this age show signs of 'clearances'; if patches of forest were deliberately cleared, the effects were too localised and short-lived to be detected unless they occurred in close proximity to the sedimentary record. Some evidence of forest clearance has been found, but early man may have had more impact in terms of his effects on the timing, intensity and rapidity of 'natural' floristic changes. As R. T. Smith (1982) suggests, the major vegetation changes of the early Holocene should now be reconsidered from a more holistic perspective. It is unrealistic to assume that man only began to influence the environment with the coming of agriculture in the Neolithic age. The cumulative effects of small anthropogenic changes in the preceding millennia may have been equally significant, though less easily discernible.

3.3 The Neolithic

The beginning of the Neolithic period is marked by the first signs of agriculture. The division is clearer than that between the preceding two ages, as the new culture was actually introduced into Britain by immigrants, rather than evolving indigenously.

Agriculture first arose in the ninth millennium B.C. in the Near East and western Asia. In this area, the wild progenitors of the animals and plants which were to form the basis of the agricultural economy were present, while Britain and northern Europe were still largely ice-covered. As environmental conditions changed, the practice of agriculture spread in various directions. The earliest agricultural communities to settle in Britain crossed from the continental European landmass in the middle of the fourth millennium B.C. Radiocarbon dates suggest that a very wide area both in Britain and Ireland was settled at approximately the same time (Megaw and Simpson, 1981). However, there was some chronological overlap between the Mesolithic and Neolithic cultures. In parts of northern Britain, for example Jura, characteristic Mesolithic assemblages have been found which are thought to have been in use as late as the third millennium B.C.

Britain at this time was in the later part of the 'climatic optimum', with temperatures slightly higher than today. The climate was thus favourable for agriculture, but the vegetation was not. Neolithic man needed open country for the cultivation of cereals and for his sheep and cattle, but most of Britain up to about 700-875m was forested. Grassland existed only in the montane zone above this level, and in unstable habitats such as river flood plains and along the coast.

The dense mat of roots formed by grass would in any case be difficult to remove. It was therefore necessary for much forest clearance to be carried out, and it is the palynological evidence for this environmental interference that forms the bulk of our knowledge of the earliest Neolithic period. A period of adjustment and settlement, with a strong emphasis on food production, would be necessary before the Neolithic communities could devote resources to the construction of enduring monuments such as the megalithic tombs of the north and west and the causewayed enclosures of southern and eastern Britain.

Material remains of the early Neolithic in the lowland zone of Britain are referred to the Windmill Hill culture, named after the hill-top site near Avebury in Wiltshire where it was first recognised. Research in this area shows that Neolithic man had a marked preference for Chalk lands. As these areas probably supported thick oak forest in the same way as the heavier clay soils of central England (Evans, 1971), it seems that it was the properties of the soil itself that were attractive to the early agriculturalists rather than any lack of forest cover. The soil of the Chalk lands would be light and readily cultivable by implements available at this time.

The recognisable field monuments of the Windmill Hill culture include causewayed enclosures, houses, flint mines, long barrows, and long mortuary enclosures. From these structures and the artefacts found in association with them, much can be deduced about the Neolithic culture. The material from the causewayed enclosures indicates that stock-raising, with a predominance of cattle, was important. Grain impressions on pottery and carbonised remains of cereals from storage pits provide evidence of cereal production, a mixed crop of wheat and barley being grown (Helbaek, 1952). The cereals were harvested with flint knives and sickles, and ground into flour using sandstone querns. Little is known of the size and nature of the fields which were cultivated, but plough marks found beneath a long barrow in north Wiltshire (Smith and Evans, 1968) indicate the use of a traction plough. This was probably drawn by a pair of oxen, as shown in later rock carvings and models from the continent. Even in the early Neolithic, the agricultural economy of southern Britain was sufficiently developed to be able to support a group of specialised craftsmen, the flint miners, who extracted the raw materials for the essential axes and other implements.

Remains of dwellings are rare, but communities seem to have consisted of small social units based upon an isolated farmstead. A site at Haldon in Devon (Clark, 1938) reveals the foundations of a rectangular house with wall footings of stone in which were set the sockets for wooden uprights. Two posts along the axis suggest a gabled roof with an entrance at one corner of the building.

Much less is known about the early agriculturalists of northern Britain. This is partly due to a lack of research, but also because the causewayed enclosures which provide so much of the evidence in the south appear to be completely absent. The surviving monuments are almost all funerary or ritual in character, long barrows and round barrows being the most common. These are particularly concentrated on the limestones of Lincolnshire and East Yorkshire. One of the best examples is the long barrow at Willerby Wold, about 11km south of Scarborough (Manby, 1963). This is a long trapezoid mound covering a cremation burial. Nearly all the northern Neolithic barrows were excavated in the nineteenth century, with the result that little information has been gained from them. The only round barrow in Yorkshire to have been excavated by modern methods is that at Ayton Moor in North Yorkshire, overlooking the Vale of Pickering (Megaw and Simpson, 1981). This mound again covered a multiple cremation, and the associated grave goods were of early Neolithic age.

Beacon Hill, at Flamborough in East Yorkshire, is the only undoubted Neolithic settlement site in Yorkshire, and this revealed only a few hearths and pottery fragments of the early and middle Neolithic (Moor, 1963). The scarcity of settlement sites on the limestone of Yorkshire may be due to the fact that the settlements were actually in the valley bottoms rather than on the higher ground, and are now covered by layers of sediment washed down from the hills.

The later Neolithic period of Britain, from the second half of the third millennium B.C., saw the development of regional forms and styles in material equipment and monuments, largely distinct from those of the continent. A possible exception is the introduction of megalithic passage graves, which can be attributed to continental sources. Again, evidence is scarce in northern England and particularly in the Pennines, but Grant's Grave, at the head of Penyghent Gill, may be an example of a passage grave of a rather degenerate type (King, 1970). The burial on South House Moor, north-east of Simon Fell, probably also dates from this time. Here a single skeleton was placed in a limestone gryke, with a large polished Langdale stone axe head, and covered with a slab of stone (King, 1970). In Wensleydale, Mr. P. Chadwick of the North Yorkshire Archaeology Unit (personal communication) has recently suggested that Stony Raise Cairn on Greenber Edge may date from the late Neolithic. This cairn has long been attributed to the Bronze Age (see section 3.4), and is shown as such in figure 3.1, but Chadwick points out that its chambered appearance is more typical of the late Neolithic period. If the cairn does belong to this earlier culture, then the nearby enclosures may also have Neolithic rather than Bronze Age origins.

Henges and stone circles are also characteristic of this period, and are represented in northern England. The henges, which are circular areas enclosed by a bank and a ditch broken by one or more entrances, are generally found in low-lying situations and often close to water. Class I henges have a single entrance, while Class II have two or more and are generally larger. A concentration of henges of the Class II type is found around Ripon in Yorkshire. Castle Dykes, above Aysgarth in Wensleydale, is a rare example of a Class I henge on high ground (Thomas, 1976). The purpose of these monuments is uncertain, but the general absence of occupation debris and the association of burials, pits or settings of standing stones in their interiors, together with their usually indefensible positions, suggest a religious or ritual significance.

Stone circles are also poorly understood, but are again thought to be ceremonial or funerary. One concentration of these structures is found in Cumbria, where the circles tend to lie close to axe factories or to the trade routes along which the axes are thought to have been distributed.

The Yorkshire Pennines provide very few examples of Neolithic monuments, but this does not mean that the area was unoccupied at this time. The relatively hostile environment would make the establishment of an agricultural economy more difficult and thus leave fewer resources available for large construction projects which served no obvious purpose in the survival of the community. Neolithic man was certainly present in the area, as is shown by a wide scattering of artefacts such as axes and pottery fragments. Langdale axes are understandably the most common in Yorkshire, although an example from the axe factory at Tievebulliagh in Ulster has been found on Blubberhouses Moor (King, 1970). In Wensleydale, Neolithic axes and arrowheads have been found around Semerwater (see fig. 3.1). Caves near Settle and at Elbolton in Wharfedale have yielded pottery showing features of the later Neolithic Peterborough ware (Butler, 1967a).

The scarcity of Neolithic remains in the Pennines leaves considerable gaps in our knowledge of this period, which can to some extent be filled by palynological studies. It has long been recognised that Neolithic man had a significant effect on the landscape, and the few pollen diagrams from this area do show characteristic clearance phases. The clearances appear to have been small and temporary, in contrast to the larger, permanent clearances of the Chalk in southern and eastern England.

The other feature of environmental change widely believed to be attributable to Neolithic man is the marked decline in elm which occurs in pollen records throughout Britain at about 5000 B.P. This phenomenon is seen in some pollen diagrams from the Pennines, such as those from lowland Craven (Jones, 1977), and is often associated with the first appearance of cultural indicators such as cereal and weed pollen.

The effect of Neolithic man on vegetation will be discussed further in chapter 7, but for the moment it is worth acknowledging that palynological evidence may be of great value in elucidating the way of life of a culture which has left so few monumental indications of its presence in the area.

3.4 The Bronze Age

The next major economic and social change in British prehistory was again brought about by immigrants from the Continent who arrived in the early centuries of the second millennium B.C. (Megaw and Simpson, 1981). They have often been referred to as the 'Beaker people', after the characteristic drinking cup frequently found in graves of this age. Of more importance in economic terms, however, was the introduction of metalworking.

Material from sites such as henges indicates a considerable intermingling of the new culture with the old, and it has been suggested (Case, 1977) that the beaker culture was introduced not by immigrants but by trade between British communities and the makers of the Beaker pottery on the Continent. Whichever origin is accepted, there is no doubt that the new techniques and customs did not evolve indigenously in Britain. In particular, the early British beakers show strong affinities with those of the Rhine area.

Apart from the distinctive beakers, the early Bronze Age saw the replacement of the collective inhumations or cremations of earlier ages by single grave burials, often covered by round barrows. It is these structures which provide most of the material evidence of the beaker culture. Knives and axes of copper are found in the earliest graves of this period, but by about 1800 B.C. bronze was predominant.

In northern England the greatest concentration of early Bronze Age barrows is found on the Chalk wolds and limestone hills of east Yorkshire. At Kelleythorpe farm, near Driffield, for example, excavation of a round barrow revealed a crouched burial in a stone cist, accompanied by a long-necked beaker, a copper knife, an archer's wrist guard with gold rivets, and amber buttons (Longworth, 1965). Such burials are uncommon in the Pennines, and the grave goods are poor compared with those of the south of England, or even east Yorkshire. This is presumably because of the remoteness from trade routes to the Continent. Those examples of beaker burials which do exist in the Pennine area again tend to be on limestone, as at Lea Green, Grassington, in Wharfedale (Butler, 1967a).

Evidence of the agricultural economy of this time is limited to occasional clues from the few domestic sites found scattered throughout Britain. At some sites, for example Northton in the Outer Hebrides, the settlers appear to have subsisted entirely by pastoralism, hunting and gathering. This supports the contention that beaker groups were semi-nomadic, which would explain the shortage of house structures. On the other hand, at Gwithian in Cornwall grain rubbers and corn-drying racks imply a sedentary existence (Megaw and Simpson, 1981). Further indications of cereal production are provided by grain storage pits, plough marks, and grain impressions on beakers. The latter evidence suggests that barley may have replaced wheat as the principal cereal crop (Helbaek, 1952). A beaker from Dorset shows impressions of flax seeds, but whether this crop was used as a cereal or for textile manufacture is not known. With regard to domestic animals, remains of sheep, cattle, goats and pigs have all been found at various Beaker sites, and the predominance of any one species may have depended largely on local environmental conditions. In the Pennines, pastoral rather than arable farming was probably predominant, but the relatively warm and dry climate at this time may have made cereal production more feasible than today.

The Bronze Age saw a great increase in trade, as the essential metal ores were obviously not evenly distributed throughout the country. This in turn led to more rapid diffusion of ideas and technological improvements. The constant changes in tools, weapons and pottery have led to great emphasis being placed on typology in the study of the Bronze Age. However, frequent regional differences and chronological overlaps tend to confuse the issue, and for the purposes of this study only the more important trends relevant to the Pennine area will be discussed.

By the beginning of the sixteenth century B.C., the practice of placing beakers in graves had ceased in the Wessex area of southern England, although the custom persisted during that century in the north. At the same time, a new metallurgical tradition developed in response to further stimulus from continental sources. The 'Wessex culture' profited from its trade links with the Continent, and its grave goods were particularly rich, including many objects of gold and amber, and elaborate bronze daggers. The north was still relatively poor in such material goods, and the principal remains found are of the new form of pottery known as food vessels. 'Vase' food vessels are particularly concentrated on the Chalk wolds of east Yorkshire, with lesser concentrations on the limestone of the Peak District of Derbyshire and a northward distribution from Yorkshire to north-eastern England and eastern Scotland. The only object consistently associated with these 'Yorkshire vases' is an elongated leaf-shaped flint knife. Characteristic food vessels have been found near to the Pennine passes which must have been important trade routes at this time: for example at West Tanfield, Ferry Fryston, on Baildon Moor, near Grassington, and at Pule Hill near Huddersfield (Longworth, 1965).

In Yorkshire, an unusual feature of this period is the occurrence of numerous stones carved with 'cup' and 'ring' marks (Longworth, 1965). These are most common between the rivers Aire and Nidd, and are found in groups with a scatter of more isolated stones around them. Examples of such groups are found on Addingham High Moor and Ilkley Moor in the mid-Wharfedale area, and near Appletreewick to the north. That these objects are associated with the food vessel culture is shown by their presence in the same barrows, as at Howe Hill, Brotton, North Yorkshire, but their significance is unknown.

The custom of putting grave goods other than pottery into barrow burials gradually declined as the Bronze Age progressed, and cremations rather than inhumations became the convention. The ashes were placed in urns, which were sometimes inserted as secondary burials in pre-existing barrows, but more frequently were placed in flat cemeteries or within an enclosure defined by earth banks or stones. Archaeological evidence of this phase is therefore rather limited.

Again, the finds in the north are concentrated on the light, dry soils of the Wolds and the limestone hills above the Vale of Pickering. Only a few urns have been found in the Yorkshire Pennines, mainly along the trade routes. Burials at Halifax and above Todmorden mark the route through the Calder valley, those on Baildon Moor lie near the route through Airedale, and that at Tarnbury near Grassington is associated with the route through Wharfedale (Longworth, 1965). Very little can be learned of the agriculture and way of life of these Bronze Age people from such remains, although occasional grain impressions on the urns point to cereal production.

In a few cases, several small objects were placed in the urns with the cremation remains. At Blackheath Cross, near Todmorden, one urn contained a small bronze knife, a bronze awl, various beads, and a small, highly decorated pottery cup. These small cups, often termed 'pygmy cups', may have held incense. In Wensleydale, a cup of this type was found at Crake Close Farm, near Gayle (County Archaeological Record).

Some of the late urn burials were placed at the centre of ring cairns, such as that on Danby Rigg on the North York Moors. A stone circle near Yockenthwaite on the north bank of the river Wharfe is probably another such site (Longworth, 1965). Bordley Circle on Malham Moor (Raistrick, 1929), and two circles in Wensleydale, near Carperby and Redmire, may be of the same age (Raistrick, 1968).

Finds from the south of England show the continued improvement in metallurgical techniques. This has implications in terms of woodland destruction, as charcoal would be required in ever-increasing quantities for the smelting process. The addition of lead to tin-bronze from about 1000 B.C. made pouring in the casting process more manageable, and also helped in subsequent working of the metal. In the south-east this led to the first mass production of new forms of swords and other weapons. Two-piece stone moulds were largely used for casting, but by the late Bronze Age more complex techniques were available, such as the hollow casting required in the production of socketed spears needing cores.

These techniques spread to northern England by the eighth century B.C., and a few scattered examples have been found in the Pennine area. However most such finds are poorly documented, if at all. A hoard discovered at Portfield Camp, Whalley, Lancashire, included two late Bronze Age socketed axes, together with gold jewelry probably imported from Ireland. At Ingleton in the Dales, a large disc-headed pin similar to North European types of about 700 B.C. was found, whilst socketed axes have been found on Ingleborough and near Rathmell.

Whilst such stray finds show the presence of late Bronze Age man in the area, even if only passing through on the trade routes, there is no certain evidence of settlement and agriculture, and the lack of dates for sites unassociated with distinctive pottery or metalwork makes it extremely difficult to piece together the history of this culture.

Hut circles and enclosures which may date to the Bronze Age are found throughout the Yorkshire Dales. Those near Grassington (Raistrick, 1938) are associated with Bronze Age barbed and tanged arrowheads, as well as implements of iron suggesting continuity of occupation. In Wensleydale, the area around Semerwater and Addlebrough, near Bainbridge, appears to have been occupied at this time. A number of finds indicate occupation of the lake shore in both the Neolithic and the Bronze Age, the finds of the latter age being comprised mainly of barbed and tanged arrowheads (see fig. 3.1). At the nearby farm of Carpley Green, a perforated whetstone of a type often associated with undoubted Bronze Age artefacts was found (Yorkshire Archaeological Journal, 1938).

The enclosures and hut circles on the terraces of Addlebrough and Greenber Edge (Elgee and Elgee, 1933) may represent the settlement of the people who left these implements. Stony Raise Cairn, also on Greenber Edge, covered a skeleton in a cist which Elgee and Elgee (1933) believed to be indicative of a Bronze Age date. However, as mentioned in section 3.3, it has recently been suggested that the cairn dates from the late Neolithic period. It is therefore not possible to be certain of the age of these features. The enclosures may date from the Neolithic, as suggested in section 3.3, the Bronze Age, or even the Iron Age. Perhaps more probably, the sites were developed and used by more than one culture, the transitions between cultures being more gradual than is often supposed.

Radiocarbon dating has shown that some structures formerly thought to be attributable to the Iron Age, hillforts in particular, were actually first constructed in the late Bronze Age. At Castle Hill, Almondbury, near Huddersfield, the first univallate phase of a fortified settlement (following a period of open occupation) has been dated to 595 $\pm$ 180 B.C. (Varley, 1976). The increase in defended sites in the later Bronze Age of highland Britain is the first indication of the changing political, if not economic, structure which was to become established in the subsequent Iron Age.

3.5 The Iron Age

The beginning of the Iron Age is generally dated to about 600 B.C., when the first material attributable to invaders or immigrants from the Hallstatt culture of Europe occurs in Britain. But the idea of a new population at the start of the Iron Age bringing knowledge of hillforts and characteristic pottery and settlements, as well as iron technology, is hard to maintain in the light of recent evidence. Much of what has always been regarded as Iron Age was in fact already current in the Bronze Age: in particular, pottery and hillforts, the earliest of which have been shown by radiocarbon methods to be late Bronze Age in date. It has even been suggested (Champion, 1975) that the change from bronze to iron itself may have occurred as a natural progression in the development of British metallurgy. The late Bronze Age saw a great expansion in the quantity and range of metal goods produced, and it is possible that with continued expansion it would have become advantageous, or necessary, to change to the more readily available iron.

The whole concept of the series of invasions invoked to explain developments in the Iron Age must now be in doubt. But the extreme, of insular continuity of British cultures, is also inadequate in explaining the Iron Age. It seems more likely that the parallels and differences between Britain and Europe at this time are due to a more subtle combination of indigenous development and long-lasting cross-Channel contacts of a social or economic nature (Megaw and Simpson, 1981).

Part of the stimulus for change may have come from the increasing population. By the end of the Bronze Age, pollen diagrams suggest a contrast between the widely deforested Chalk-lands of the south and east, and the rest of Britain, where clearances were on a smaller scale. But population pressure was such in the early Iron Age that widespread clearance of forest for agriculture took place in many parts of England and Wales. In Derbyshire, the East Moor shows extensive clearance for pastoral use c. 400–300 B.C. (Hicks, 1972), and a similar development can be seen on the North York Moors (Atherden, 1976); in both areas cereals only began to appear some time after clearance.

Deteriorating climatic conditions could also have been a significant influence at this time, as some upland areas, such as Dartmoor (Simmons, 1969b) were abandoned. This would increase pressure on the remaining land, thus stimulating the development of improved techniques and leading to changes in social and political organisation. Hunting and gathering do not appear to have played a significant part in supplementing the diet, so the agricultural system must have been efficient. Remains of field systems and enclosures suggest an intermixture of arable and pastoral farming. The lack of evidence for an annual autumn slaughter implies the production of winter fodder for the livestock, and some of the enclosures are thought to have been used for stock control, which would be particularly important if winter-sown crops were grown (Megaw and Simpson, 1981).

Iron Age field systems are known in the Yorkshire Pennines, for example near Grassington in Wharfedale (Raistrick, 1938), but there is little evidence of the nature of farming in this area. Grain storage pits are absent, and animal bones are often not preserved in the acid soil conditions. But pollen records such as those from Nidderdale (Tinsley, 1972) indicate that cereals were grown at this time.

Over-population of favourable territory may also have been a reason for the increased aggression suggested by the many defended sites attributed to this period. As stated earlier, hillforts were first built in the late Bronze Age, but there is a great increase in the number of such sites and in their size and complexity in the Iron Age. The largest in northern England is that at Almondbury, near Huddersfield. In the Dales, there are hillforts on Ingleborough, and at Far Gregory in upper Wharfedale. Whilst the ages of these sites are unknown, they do seem to pre-date the Roman road network (King, 1970). The Ingleborough hillfort covers about 6•5ha, and contains numerous hut circles.

Another form of defended Iron Age settlement is exemplified by Staple Howe on the north edge of the Yorkshire Wolds (Brewster, 1963). Here, a large palisaded enclosure contained three circular houses and a granary.

Some other settlements, notably on the uplands, were undefended. Several sites in Wensleydale are of this type, for example the hut circles and enclosures on Penhill, on Hukermire Moss near Bainbridge, on Preston Scar between Wensley and Bolton, and near Oxclose, Carperby (Raistrick, 1939) (see fig. 3.2). Caves were also used, for example near Leyburn in Wensleydale (Raistrick, 1939).

The Iron Age is thus the first age in British prehistory for which the primary source of material is an abundance of settlement sites. The funerary traditions which provided so much of the archaeological evidence before the mid-Bronze Age had disappeared by the Iron Age, and 'hoards' were no longer deposited, indicating a changed view of the afterlife.

For much of the Iron Age most parts of Britain show no archaeol-

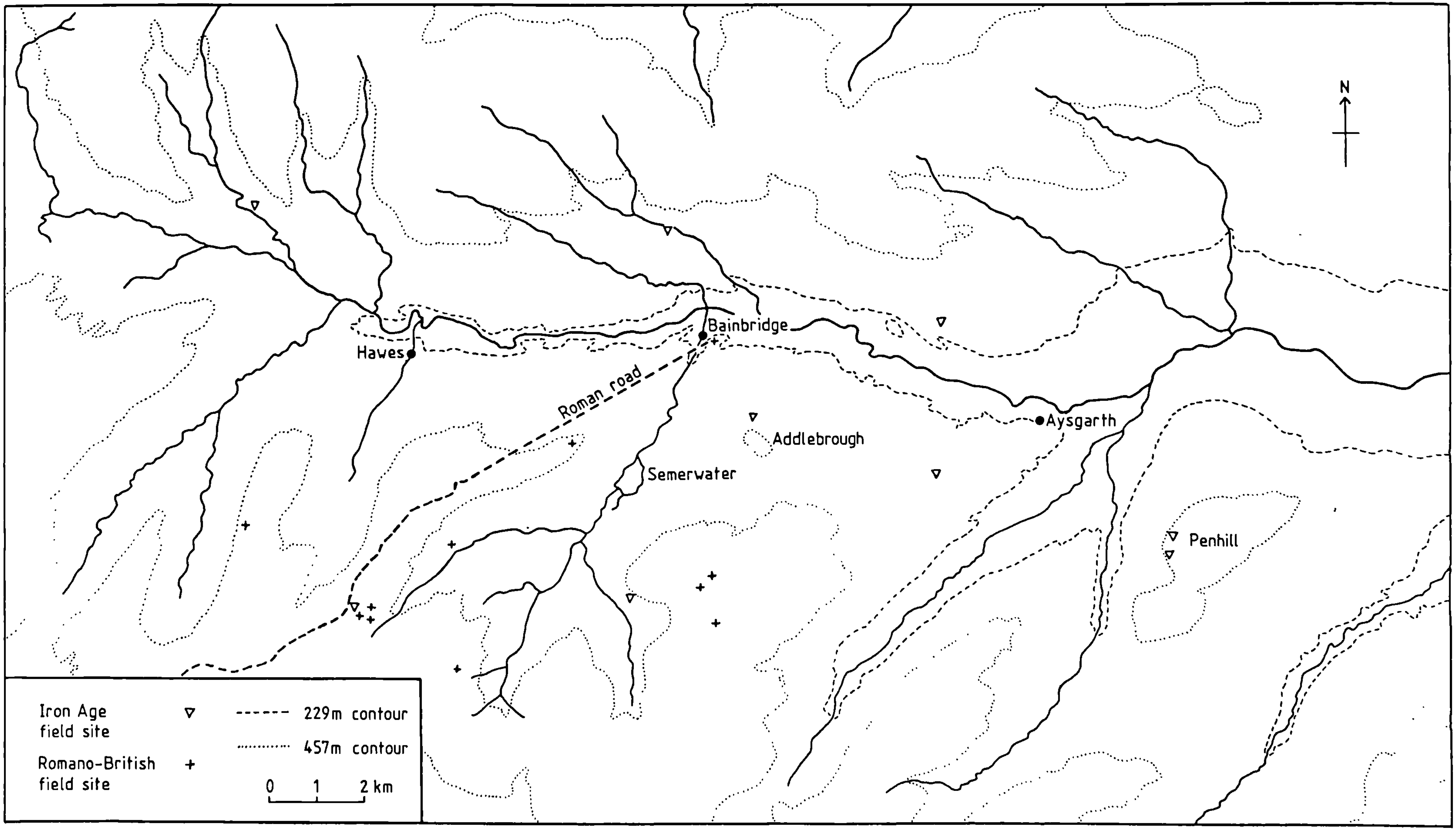


Figure 3.2: Iron Age and Romano-British sites in Wensleydale

ogical evidence of burials. However east Yorkshire does show a distinct regional burial tradition, usually named after the cemetery at Arras (Stead, 1965). Recent excavation and aerial photography has revealed extensive inhumation cemeteries, several of which, such as Danes' Graves near Driffield, include hundreds of burials. The graves were mostly under small round barrows, and some contained personal ornaments of a form which indicates that this rite was established by the fourth century B.C., and probably did not continue after the first century B.C.

No undoubted purely Iron Age burial mounds are known from the Yorkshire Pennines, but at Seatty Hill, on Malham Moor, an originally Bronze Age mound contained thirteen secondary interments dating from the Iron Age (Raistrick and Holmes, 1962). The Great Raise cairn associated with the Iron Age settlement on Hukermire Moss in Wensleydale (see fig. 3.2) represents another form of burial practised in areas with abundant stone. This cairn contained several grave hollows and the remains of more than one burial (Raistrick, 1939).

Most such burial sites provide little evidence of Iron Age technology, but a few have yielded grave goods, and these together with the plentiful remains from excavations at settlement sites give an impression of the industries and customs of the period.

Ironworking was established in Britain by at least the seventh century B.C., and the new metal supplanted bronze for most tools and weapons, though bronze continued to be used for many ornamental items. Metal objects are generally dated by their affinities to the Hallstatt and La Tène cultures of Europe. In the early Iron Age, pins of bronze or iron were used as a means of fastening clothing. Examples were found at Staple Howe, and at Castle Hill, Scarborough (Longworth, 1965).

By the fifth century B.C., brooches of early La Tène form had become common. Some of these may have been imported from the Continent, but most were probably insular products (Megaw and Simpson, 1981). A number of brooches and other personal ornaments have been found at sites in the Dales area, for example in Dowkerbottom Cave near Kilnsey in Wharfedale, near Ingleton, and at Embsay near Skipton (King, 1970).

Both swords and daggers were favoured weapons at various times in the Iron Age, and many were highly decorated, often showing a La Tène influence. Swords of this age have been found at Low Langdale near Stanwick, at Cotterdale above Hawes, and at Flasby between Skipton and Settle (Elgee and Elgee, 1933).

A great quantity and diversity of Iron Age pottery has been found, often coarse and undecorated as at Grassington in Wharfedale and on Hukermire Moss in Wensleydale (Raistrick, 1939). Other items of domestic equipment include loom weights and spindle whorls of stone and pottery, and querns, examples of which were found near Leyburn in Wensleydale (Raistrick, 1939).

Evidence of Iron Age modes of transport is also quite frequent. Many items associated with horses and horse-pulled vehicles have been found, as at Stanwick (Longworth, 1965), and some of the burials of east Yorkshire contain the remains of wooden chariots, for example at Arras and Danes' Graves.

Thus it can be seen that archaeological evidence of all aspects of the Iron Age cultures is relatively abundant. It is at this time, too, that the first documentary evidence becomes available. Even before the Roman conquest, Greek and Latin writers made some reference to the 'barbarians' of Britain. However such references are infrequent and lacking in detail, and so cannot be used as a reliable basis for the interpretation of the Iron Age. It is the great increase in the quantity and quality of documentary evidence with the coming of the Romans which marks the end of British prehistory, and the beginning of the historical period. There is no sharp division in terms of cultural development, many facets of Iron Age society surviving the Roman centuries, particularly in highland Britain, as will be discussed in the following section.

3.6 The Roman Period

The Romans first invaded Britain in A.D. 43, gaining control of England south of a frontier running from the Humber to the Welsh border. Further north, the Iron Age way of life continued with very little Roman influence. The Yorkshire Dales area formed part of the kingdom of Brigantia, a loose federation of tribes under the dominance of the Brigantes which covered the whole of northern England (Longworth, 1965). In recognition of the Roman threat, the Brigantes extended their existing forts and built new ones. The Stanwick fortification near Richmond, which was first built in the early first century A.D., was enlarged c. A.D. 50-60 (Wheeler, 1954).

While the Romans did not control the north at this time, the stability of their northern frontier was ensured by treaties with the Brigantian ruler. The Roman legions were called to Brigantia several times to quell civil wars before the strongly anti-Roman faction finally became dominant. The situation was then no longer tolerable to the Romans, and annexation of northern England became inevitable. Several forts in the Dales area provide evidence of the resistance of the Brigantes to Roman conquest. The earthworks at Stanwick were extended to enclose a further 240ha c. A.D. 72 (Wheeler, 1954), but the construction appears to have been unfinished when the Brigantes were finally defeated here in A.D. 74. Those who escaped from Stanwick may have retreated further into the Dales to the hillfort of Ingleborough and smaller strongholds such as that at Far Gregory in upper Wharfedale (King, 1970).

The Roman hold over the area was soon consolidated by the construction of a network of roads and forts. The major lines of communication running north-south on either side of the Pennines were linked by a series of east-west roads making use of the well-established routes through the Pennine passes. One such cross-route used the Wharfe-Aire gap, and a diagonal route linked Barrow-in-Lonsdale with Bainbridge in Wensleydale. The associated forts, such as those at Ilkley, Elslack and Bainbridge, consisted of earthbanks and ditches with timber buildings (Barringer, 1982).

The sudden influx of population into the area with the manning of the Roman forts is thought to have had a significant effect on agriculture. For economic and strategic reasons the Romans needed to obtain much of their food locally, and many field systems are thought to have been established at this time to meet the demand. At Lea Green, Grassington, the field systems first used in the Bronze Age appear to have been greatly expanded between the second and fourth centuries A.D. to cover c. 120ha (Raistrick, 1938). In Wensleydale, enclosures at several sites near Bainbridge may date from this period.

The diet of the Romans in their native land was based on grain and vegetable oil, whilst the British (or Celts) ate more meat. Cereal cultivation must therefore have been encouraged during the Roman occupation. In the Dales area, pastoralism was probably always dominant, and Romano-British sites provide ample evidence for the rearing of cattle, sheep, horses and pigs. However, a site near Helwith Bridge in Ribblesdale suggests increasing concentration on grain production. The 12 querns found here in varying stages of completion suggest that this was a manufacturing centre. Associated Samian ware dates the site to the second century A.D. (King, 1970).

With the expansion of agriculture in the Pennines, a concomitant increase in woodland clearance would be expected. In addition, the exploitation of mineral resources by the Romans led to further tree-felling for the production of charcoal. The Pateley Bridge-Greenhow and Reeth areas were particularly important for lead-mining, and inscribed pigs of lead dating from A.D. 79-81 onwards have been found on Heyshaw Bank near Pateley Bridge and on Greenhow Hill near Grassington (King, 1970).

So the Romans were responsible for an intensification of agriculture and industry in the Dales. However, there is no evidence that the domestic life of the natives was influenced, as it must have been in the lowland areas where large Roman settlements were established. The Celts continued to live as they had before the Roman conquest, often retreating to the higher ground to escape conscription and building simple huts which must have contrasted sharply with the Roman dwellings. Few villas are known in this area, but a second century example was found at Gargrave, between the forts of Elslack and Long Preston, and at Middleham in Wensleydale a hypocaust provides evidence of a Roman house site (Barringer, 1982).

The natives remained hostile to their Roman governors, and there is evidence of periodic rebellion in the Pennines. A revolt in A.D. 115 resulted in the burning of the fort at Ilkley, and Raistrick (1972) suggests that several old cave dwellings were used as retreats at this time. Once the wall from the Tyne to the Solway had been built by Hadrian (Emperor from A.D. 117 to 138), most of the forts were evacuated, but following another rebellion in A.D. 154 many were re-garrisoned. Some, like Bainbridge, were then held until the end of Roman rule, being rebuilt several times after further uprisings (King, 1970).

Despite such occasional attempts to defeat the Romans, the natives never did win their independence. From the end of the third century A.D., invaders from the Continent began to make raids on northern England. In A.D. 367 attacks were made by Franks and Saxons in the east and by Picts and Scots in the west. There was widespread destruction and the fort at Bainbridge was burned down. The Roman defences had been weakened by soldiers settling down to become farmers and intermarrying with the natives, and the remaining troops were needed to protect Rome itself. In A.D. 428 the Romans finally left Britain, being unable to defend their territory from the invaders any longer. What little influence they had exerted on the people of the Pennines was soon forgotten, as the latest invaders took control and began to impose their own culture on the area.

3.7 The Anglo-Saxon and Scandinavian Period

With the final withdrawal of the Roman forces in the early fifth century, Britain was left defenceless against the persistent raids of invaders from Europe. Almost 400 years of Roman rule had weakened the defensive capabilities of the Celts. The Angles and Saxons penetrated Yorkshire from the east, reaching York by about the year 500 A.D. (Raistrick, 1972). A burial at Sowerby and finds from a disturbed burial at East Witton indicate the northward expansion of the Anglian settlement through the Vale of York and into Wensleydale (Butler, 1967b). However, it is the evidence from place-names and occasional documentary sources, rather than archaeological remains, which elucidates the history of this period.

In the Yorkshire Dales, Celtic place-names appear to have survived the change of language introduced by the Anglian and Saxon settlers only when they were the names of major natural features. In Wensleydale, the river Ure has retained a name of British origin, and Penhill is also a Celtic name (A. H. Smith, 1928). This scarcity of place-name evidence does not necessarily denote a sparse British population, as there is independent proof of the survival of a British kingdom well into the seventh century in the Leeds district, where there is a similar lack of British place-names. It is more accurately regarded as an indicator of the great extent of the Anglian and Scandinavian settlements. Some British names may have survived the Anglian settlement only to be displaced in the later Scandinavian phase.

The fate of the Celtic people themselves is unknown. The best agricultural land was seized by the invaders, and some of the British may have been taken as slaves, but a few natives may have escaped to live in the uplands. Bede, in his 'History of the English Church' (Colgrave and Mynors, 1969), described how in A.D. 603 'Ethelfrid of Northumbria overran a greater area than any other kings or chiefs, exterminating or enslaving the (British) inhabitants, extorting tribute and annexing their lands for the English.'

Anglo-Saxon place-names are relatively uncommon in Wensleydale, and tend to be confined to the valley bottoms of the lower, eastern end of the dale (see fig. 3.3). Names ending in -ton (derived from the Old English 'tun', meaning an enclosure, farmstead or village) are the most frequent indicator of Anglian settlement in this particular dale. Examples are Bolton, Preston, Witton and Burton, which are found in close proximity to each other in lower Wensleydale. The element 'ley', from the Anglian 'leah', a clearing or woodland glade, is also restricted to the lower part of the dale, as at Leyburn (just to the east of the study area) and Wensley. Occasional Anglian names do remain in upper Wensleydale, but beyond Askrigg there are none which are indicative of villages.

Whilst it must always be borne in mind that settlements are often renamed by later inhabitants (A. H. Smith, 1928), in this case the distribution of Anglo-Saxon place-names is probably a true reflection of the extent of the Anglian settlement of Wensleydale. These settlers introduced the nucleated village with its associated open field system of agriculture; a system far more suited to the broad, flat lower dale than to the narrower, more hummocky reaches of the valley to the west. Lynchets indicative of former open fields can still be seen around West Witton and Castle Bolton, where their association with Anglian place-

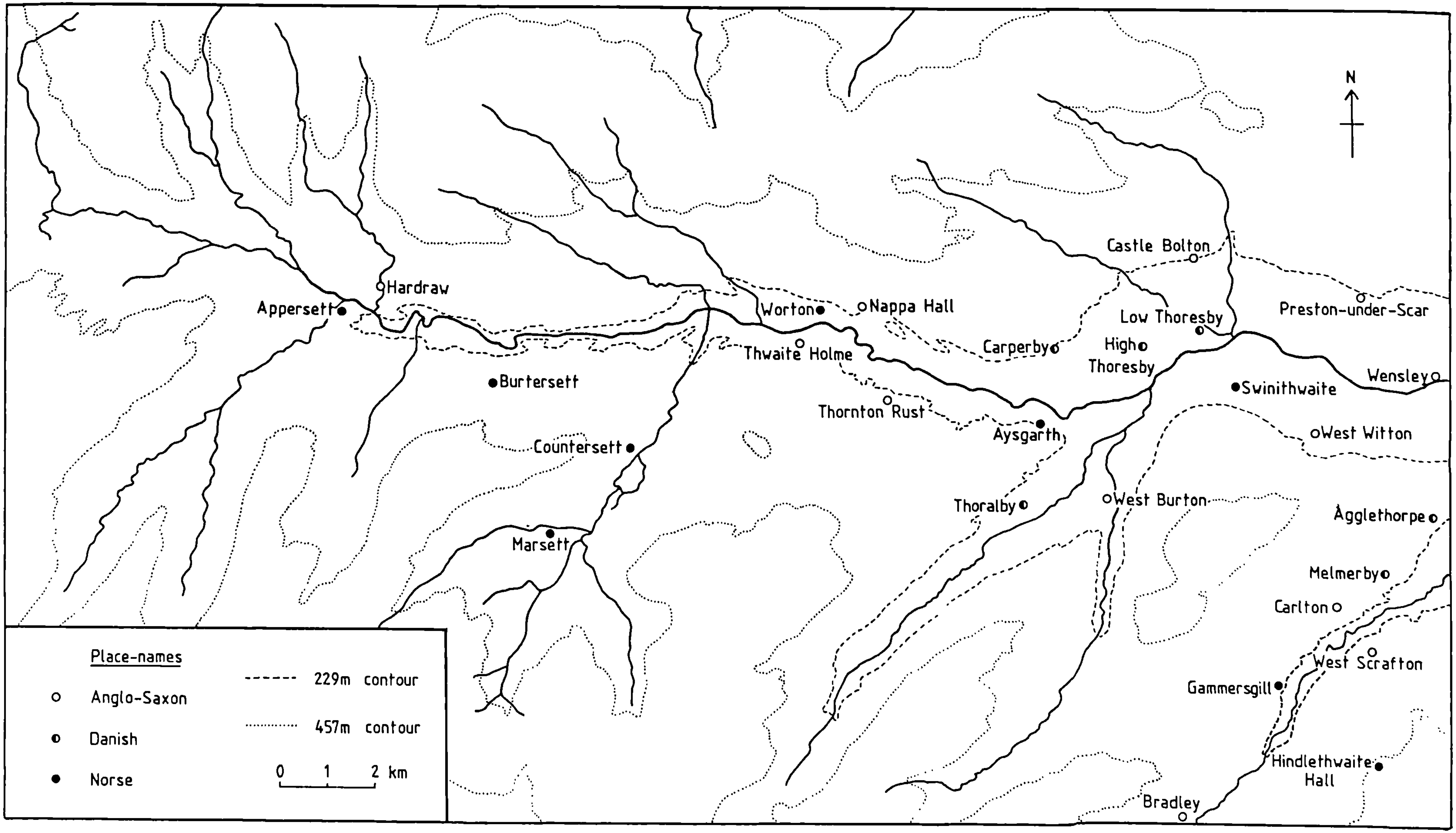


Figure 3.3: The Anglo-Saxon and Scandinavian place-names of Wensleydale

names suggests that they probably originated at this time.

The Anglo-Saxons appear to have led a settled existence in Wensleydale for several centuries, before the next series of attacks on the east coast of Britain began in 787. The Danes mounted a number of exploratory raids before a large army landed in East Anglia and York was captured in 867. Danish settlements spread towards the Dales from the east, followed by a similar incursion of Norse settlers from the west. The distribution of both groups can be traced in place-names (see fig. 3.3).

Like the Anglians before them, the Danes tended to settle on the heavier, more fertile soils of the lowlands. Characteristic Danish elements such as 'by' and 'thorpe' (meaning settlement and secondary or outlying settlement respectively) are thus restricted to lower Wensleydale, as for example at Carperby, Thoralby and Agglethorpe (see fig. 3.3) and Danby on Ure ('village of the Danes') (slightly to the east of the study area).

Place-names of Norse origin, on the other hand, are abundant throughout Wensleydale. Both the uplands and the valley bottoms have many examples of names with the elements 'thwaite', 'gill', 'fell', 'beck' and 'moss', the latter four being too widespread to show in figure 3.3. In upper Wensleydale, Appersett, Burtersett, Countersett and Marsett (see fig. 3.3) all contain the Norse 'saetr', meaning a temporary summer settlement (Barringer, 1982).

The only known archaeological evidence of this period is a Viking burial of early tenth century date in Wensley churchyard (Butler, 1967b). Elsewhere in the Dales Norse long-houses have been excavated, for example at Penyghent Gill and Ribblehead, but if these existed in Wensleydale they must have been destroyed by later land use. It is therefore difficult to assess the size of the population of Wensleydale at this time. Norse place-names may have been given to pre-existing settlements, and others may have been lost in later years. But the wide distribution of names of Norwegian origin implies a population of moderate size, exploiting the land and its resources to varying degrees throughout the whole of Wensleydale rather than being concentrated in well-defined pockets of settlement. The large number of Norse elements remaining in the language of the Dales to this day also testifies to the considerable impact of the Norwegians.

Many of the Anglo-Saxon and Scandinavian place-names in Wensleydale contain elements referring to vegetation and agriculture, and are thus of particular interest in the context of this study. However, their meanings are often ambiguous. A reference to a particular type of tree, for example, may indicate either that the tree was common in the area or that it happened to be a notable feature in that locality. Also, names may continue in use for centuries after the feature they marked has disappeared.

Despite such limitations, the place-names of this period can provide some useful information. Many names contain elements signifying clearings, which suggest that the valley was well-wooded in Anglian and Norse times. In lower Wensleydale, Brindley means 'clearing in a wood caused by fire', and Bradley means 'broad clearing'. Another Anglian name implying the presence of forest is West Witton, meaning 'farm in the wood' (A. H. Smith, 1928). Also of Anglo-Saxon origin are Nappa, meaning 'turnip field' and Hardraw, meaning 'shepherds dwelling'. Such names suggest that the dale was well-wooded, with clearings for arable farming in the lower reaches and grazing towards the head of the dale.

Norse names containing the element 'thwaite' also indicate clearings in a generally wooded area, as for example at Swinithwaite ('place cleared by burning') and Hindlethwaite ('forest clearing for hinds'). Indications of some of the trees present at this time are provided by the names Aysgarth, meaning 'open space marked by oaks', Appersett meaning 'shieling near the apple tree', and Burtersett meaning 'shieling near the alder tree' (A. H. Smith, 1928). Clearings for cultivation or permanent settlements appear to have been restricted once again to the lower dale, and place-names provide no information about the vegetation of the uplands. According to Raistrick (1976), the Norsemen were essentially pastoralists, who built their farms in the valleys but also utilised the higher ground for summer pastures. The place-names of Wensleydale support this idea of an agricultural economy based on transhumance.

The evidence from place-names therefore suggests that Wensleydale was still largely wooded at this time, with clearings for agriculture and settlement becoming more numerous towards the lower-lying lands of the east, and summer pasture available in the uplands.

3.8 The Norman Settlement and the Monastic Period

The Norman conquest of 1066 ended the period of Scandinavian dominance in the Dales. Resistance to the Normans was particularly strong in Yorkshire, and a series of uprisings led King William to take punitive action in 1069. This together with raids by Danes and Scots led to extensive devastation in the county, so that by 1086 when the Domesday Book was compiled much of the area was recorded as 'waste'.

The exact meaning of the term 'waste' in this context is uncertain, but it is generally thought to refer to holdings with no population. Waste vills were particularly frequent on the flank of the Pennines and in the northern part of the Vale of York. The largest area in the North Riding without much waste appears to have been the land lying west of the river Swale, between Richmond, Masham and Leyburn (Maxwell, 1962). Lower Wensleydale therefore seems to have been relatively undisturbed and prosperous at this time, while a drastic reduction in population occurred in the less favourable area to the west. This depopulation, however, was probably not entirely due to the devastation wrought by the invaders in the Dales. Detailed examination of the Domesday Book indicates that organised migration may have been an important factor.

Bishop (1948) suggests that between 1070 and 1086, the new Norman landowners initiated a movement of people from agriculturally poor areas to the wasted holdings of the more fertile districts. This is what appears to have happened in Wensleydale, which formed part of the Honour of Richmond granted to Count Alan by William I. The people from the less prosperous upland vills were moved to the depopulated holdings of the more favourable lowlands, and so Count Alan's land soon recovered its pre-Conquest value. In contrast, landowners whose holdings were entirely in the lowlands did not have undevastated upland vills from which to draw labour, and many of their estates on the fertile plain remained abandoned (Bishop, 1948).

The Domesday Book does not provide much information about the vegetation and agriculture of Wensleydale. This may be attributed to the fact that the area was largely devoid of population and mostly unsuited to cultivation. One notable entry, for Crooksby, mentions moors: 'morae sunt ibi' (Maxwell, 1962). All the villages up to Askrigg were in existence by 1086, but to the west of this lay the 'Forest of Wensleydale', an extremely important feature of the area throughout the middle ages.

The term 'forest' did not originally signify a large wood, but was used to denote a tract of land reserved for royal hunting and placed under the strict regulations of forest law (Victoria History, 1914). Whilst the primary meaning of the word was 'waste land', most such land tended to be covered to a greater or lesser degree with wood or undergrowth and so the word 'forest' gradually came to be applied to a large wood. The precise nature of the vegetation of the Forest of Wensleydale is therefore uncertain, but there must have been a considerable amount of true woodland to shelter the game and to have inhibited the growth of settlements before the Conquest. Bainbridge was established in the twelfth century as a centre of the forest government, and the only settlements permitted within the forest itself were the lodges of the foresters and forest servants (Hartley and Ingilby, 1977).

The impression of a largely wooded area given by the Anglian and

Scandinavian place-names of Wensleydale is thus corroborated by the documentary evidence of the Middle Ages. But despite the forest laws, the wooded area was constantly under pressure throughout this period as a result of grazing at the forest margins and the felling of timber for building.

The depopulation which followed the Norman invasion was only a temporary pause in the colonisation of Wensleydale, and under the influence of new landowners agriculture was soon re-established. Of particular significance was the growth of monastic houses.

Following the Norman Conquest, increasing numbers of monks began to come to Britain to form religious communities. In Yorkshire, the Cistercian order was especially prominent, setting up a considerable number of religious houses in isolated parts of the county by 1155. These included Fountains Abbey (1132) near Ripon, and Byland Abbey (1138) on the edge of the Hambledon Hills. In 1145 the Abbey of St. Mary was founded at Fors, near Dalegrange in upper Wensleydale, by Acaris, a close relation of the Count of Richmond (Hartley and Ingilby, 1977). Various documents indicate that the monks were given rights to use timber from the Forest of Wensleydale for building, and to dig and use lead and iron. In 1150 Fors was placed under Byland Abbey, and six years later, owing to the unsuitability of the land for agriculture, the monastery was removed to a new site near East Witton, on land given by Earl Conan. The abbey then became known as Jervaulx (Yore or Ure valley), and the monks prospered. Their land on the north side of the Ure from Askrigg up to the dale head provided pasture for large flocks of sheep, from whose milk Wensleydale cheese was first made. In recognition of its former ownership, this land is still known as

Abbotside Common. The monks of Coverham Abbey, a Premonstratensian house built near Middleham in 1202, held only a small amount of land in Wensleydale and were not significant in the development of the landscape (Hartley and Ingilby, 1977).

Another great property in the Middle Ages was the Lordship of Middleham, which included most of the south side of the valley from Middleham westwards and was held by Ribald, younger brother of Count Alan of Richmond, who built a castle at Middleham. This estate was subsequently owned by Robert Fitzralph, a nephew of William the Conqueror, who began building the present Middleham Castle in 1170. It then passed by marriage to the Nevilles of Raby before reverting to the Crown in 1471 after the death of Richard Neville, Earl of Warwick and Salisbury. Most of the remainder of Wensleydale belonged to the Scrope family, who built Bolton Castle in 1379 (Hartley and Ingilby, 1977).

Under the control of these three great 'Lords of the Manor', the population of Wensleydale increased through the Middle Ages. The land was worked by small tenant farmers who paid for their tenancies by labour or by paying small rents. Around the villages of lower Wensleydale a variety of crops were grown in open fields, whilst the higher ground provided pasture for sheep, cattle and horses. With the expansion of population, the area of arable land was increased and new settlements arose. Villages spread towards the head of the dale, Hawes being first mentioned in 1307. The Forest of Wensleydale was therefore declining, for in addition to the clearance taking place for settlement and agriculture, the continual pressure of grazing animals was preventing tree regeneration. Increasing amounts of timber were also being felled both for building purposes and for the production of charcoal for lead smelting.

This period of expansion was followed by a reduction in population, due to a combination of factors. Throughout the fourteenth century, raids by the Scots had been causing considerable losses, and the conditions of many tenancies compelled tenant farmers to follow their Lords to fight on the Borders. Then, in the mid-fourteenth century, The Black Death caused a decrease in population throughout England, and the gradually deteriorating climate may also have been making agriculture difficult in what has always been a marginal area. Many people may therefore have left the Dale at this time to farm the lowlands where, as a result of the plague, land was now available. Consequently there are several examples of deserted medieval villages in Wensleydale, of which few traces remain today. They include Ulvishowe between East Witton and Middleham, which had nine persons paying tax in 1301, Thoresby near Redmire, which had twelve taxpayers in 1377 (Hartley and Ingilby, 1977), and West Bolton and East Bolton for which documentary evidence exists up to 1334.

This setback was again only temporary, and the population of Wensleydale gradually recovered. Pastoral farming flourished, especially on the monastic lands, and the exploitation of minerals was also becoming increasingly important. But cultivation was always unreliable in this area, and a period of successive poor harvests could soon cause great distress, particularly if the population had increased in a run of good years. In 1428 the Archbishop of York was 'met at Wensley church by the abbots of Jervaulx and Coverham ... who informed him ... that the countryside was too greatly impoverished by failure of crops, murrains, etc., to bear the heavy cost' of a visitation (Barringer, 1982).

The comparative prosperity of pastoral farming is exemplified by an inventory of the goods owned by one Thomas Metcalfe in 1577. Metcalfe had a farm in Fossdale, upper Wensleydale, and left £85 worth of goods. His inventory was comprised entirely of livestock: over 130 sheep, 46 cattle and 15 horses (Barringer, 1982).

Thus by the sixteenth century had the basic settlement and land use pattern of Wensleydale been established. All of today's villages were in existence, and whilst open field cultivation persisted in the lower dale, the agricultural economy was largely based on sheep and cattle.

3.9 The Post-Monastic Period

The dissolution of the monasteries in 1539 marked the beginning of a period in which most of the great estates of the Middle Ages were broken up and agricultural and social organisation underwent considerable changes. The lands of Jervaulx Abbey passed into Crown ownership, as the Lordship of Middleham had done in the late fifteenth century, only the large estate of the Scropes remaining in the hands of local land-owners.

By a complex series of transactions much of Wensleydale finally came to be owned by the former tenant farmers. In 1628, Charles I sold the Lordship of Middleham to the citizens of London, who in turn sold it in lots to the farmers of the dale in the mid-seventeenth century.

Thus in the seventeenth century a class of yeomen gradually replaced the tenant farmers of the Middle Ages, and much of the lower ground of Wensleydale was divided into the small holdings of individual farmers. The process was not without its problems, however, as many of the dalesmen were reluctant or unable to buy their farms instead of paying the small rents which brought guaranteed possession, as had been the custom for many preceding centuries (Hartley and Ingilby, 1977).

The Forest of Wensleydale, which had been divided between Jervaulx Abbey and the Lordship of Middleham, was no longer protected and the area of woodland was rapidly diminishing. The last forest court of which there is any record was held at Middleham in 1539 (Victoria History, 1914), and there are records of actions brought against poachers of game as late as 1621 (Hartley and Ingilby, 1977). But after the mid-seventeenth century there is no further documentary evidence of deer in Wensleydale, and the Forest appears to have given place to orderly fields and common pastures.

Several documentary sources provide detailed information about the agriculture of Wensleydale in the seventeenth century. The former Lordship of Middleham was surveyed in 1605, when the Crown was contemplating its sale. By this date, most of the best land in the valley bottoms of Wensleydale and its tributary dales had been enclosed, although it was not yet totally divided up into individually held enclosures. On the lower slopes of the fell-sides, above this prime land, there were large enclosed pastures, often several hundred acres in size. These were the stinted or controlled pastures, in which the inhabitants of the villages held beastgates. Above these lay the unstinted common and wastes where theoretically farmers could graze as many stock as they wished. Generally, however, the number was limited to the amount of stock a farmer could support through the winter on the hay grown in his enclosed land in the valley bottom (Wensleydale W.E.A. History Class, 1978).

Whilst a great deal of enclosure had taken place by this time, the survey also provides clear indications of surviving open fields (Fieldhouse, 1982). At West Witton, 26 of the 46 tenants had land in the High, East and Low fields. The three fields were described as the 'common fields' and consisted of approximately 50ha of arable land. The locations of these open arable fields are marked today by lynchets, which are particularly seen to the east of the village. At Swinithwaite, a few kilometres to the west, 5 of the 9 tenants held land in the West Field, and 4 in the Low Field. Most of these small parcels were arable.

Bishopdale, a tributary dale joining the main Ure valley just above Swinithwaite, also had extensive common open fields. West Burton had four arable open fields, totalling almost 50ha, and Newbiggin had four fields totalling 40ha, of which one was a common meadow and the rest arable. At Thoralby, the East and West Cornfields were held in common by 18 of the 65 tenants, but whilst these were certainly the surviving remnants of the open arable fields they included some meadow by this date. Carlton in Coverdale also had three common fields of arable and meadow land.

Thus in 1605 there was quite clearly a residue of common open field farming in some of the townships of Wensleydale and its subsidiary dales. In fact almost all the arable farming still practised in the area was to be found in these surviving open fields (Fieldhouse, 1982). Apart from these common arable and meadow fields, the enclosed pastures of the dale bottom and lower slopes were also often shared. Communal agriculture therefore continued despite the enclosure which was transforming the landscape at this time.

The 1605 survey also provides details of the type of farming practised during the seventeenth century. As already stated, nearly all the arable land was in the remaining open fields of lower Wensleydale. Further up the dale, 187ha at Woodhall and Bainbridge were described as 'arable and meadow'. This may represent an area of 'convertible husbandry', where a small part of the meadow land was ploughed each year and sown with corn, after which it was re-seeded as grass and used as meadow until its turn to be cultivated came round again in the rotation, perhaps ten or twelve years later. Corn mills at Carlton in Coverdale, West Burton, Thoralby, Newbiggin, West Witton, Aysgarth and Bainbridge also testify to the production of grain (Wensleydale W.E.A.

History Class, 1978).

The probate inventories of a number of tenants provide further agricultural information. Those farming the upper dale beyond Aysgarth held large numbers of sheep, less than half as many cattle, and a few horses. The total value of the cattle was greater than that of the sheep, however. Only one farmer near Woodhall owned ploughing equipment, which probably reflects the convertible husbandry practised in that township. The farmers of the lower dales also had livestock, the proportion of sheep to cattle being even higher. In addition, the inventories of these farmers include corn and ploughs, though arable farming was obviously secondary to pastoralism. Wheat was grown at West Witton, and wheat and oats at Swinithwaite, probably in the open fields. Barley and rye were also grown in the lower dale. Occasional mentions of hemp and line and references to a 'lyne ing' at West Witton and 'hemp garth' at Burghill, near Bainbridge, suggest that some hemp and linseed were grown (Wensleydale W.E.A. History Class, 1978).

A comparison of inventories from 1575–1625 and 1670–1700 shows that cattle farming was more important than sheep farming in all parts of the dale and that the relative importance of cattle was becoming more marked by the end of the seventeenth century (Wensleydale W.E.A. History Class, 1978). Three possible reasons for this are put forward. After c. 1620, wool prices began to fall because of increased imports from Ireland and Spain, a depression in the domestic cloth industry which reduced demand, and a ban on the export of raw wool which was introduced for the benefit of the cloth manufacturers. Another reason may have been that the dales farmers had more labour than capital available, so that dairy farming, which was more labour-intensive and yielded quicker and more regular returns was more suited to them. In addition, the marketing of agricultural produce had improved, making it possible for farmers in the Dales to concentrate on producing butter and cheese which could be sold through market towns such as Richmond and Ripon to more and more distant markets.

In the earlier period, two-thirds of the farmers in the lower dales had grain crops. But by the later seventeenth century, far fewer farmers had any corn or ploughing equipment, only small quantities of wheat, rye, oats, barley and beans being recorded. At the same time, standards of living were improving, as shown by the decreasing proportion of the farmers' capital which was tied up in farm stock (Wensleydale W.E.A. History Class, 1978).

Enclosure and the consolidation of individual holdings continued, and by the end of the seventeenth century the last remaining open fields at Wensley and Thoralby were being eliminated (Fieldhouse, 1982).

The eighteenth century saw the continuation of these agricultural trends. Despite continuous encroachment and intaking, the area of common moorland grazing in the first half of the eighteenth century was still greater than the total area of enclosed land. But from c. 1760 the commons began to be enclosed wholesale, by agreement or Act of Parliament, and allotted to individual landowners. The cattle plagues of the mid-eighteenth century may have encouraged this practice, as disease spread more readily on the common grazing lands (Fieldhouse, 1982).

At this time also, several industries flourished briefly in Wensleydale. In 1780 Thomas Maude wrote: 'The commodities of the valley for home and foreign consumption, which last is not inconsiderable, are fat cattle, horses, wool, butter, cheese, mittens, knit stockings, calamine, lead.' (Hartley and Ingilby, 1977). But the fluctuating fortunes of the lead and textile industries did not affect the population of Wensleydale significantly. As Raistrick (1967) says, 'The very small amount of mining and the extent of the richer farming acted as a buffer against sudden variations, so that family migrations are far less a part of the Wensleydale story than in the other dales.' The growth of the cheese industry, first in almost every farmhouse, then later on a factory scale, compensated for the closing of the textile mills. At the end of the nineteenth century when the lead industry was declining, the railway from Northallerton through the length of the dale further encouraged dairying and gave an outlet for milk and other products to the great markets of the industrial towns.

Whilst it had little impact on the population of the dale, the lead industry may have been responsible for the destruction of the last vestiges of the Forest of Wensleydale. The demands of the smelting mills for charcoal in the seventeenth and early eighteenth centuries would have led to extensive felling. Since the adoption of peat as the fuel for smelting in the mid-eighteenth century (Raistrick and Jennings, 1965), the area of woodland has probably remained relatively constant.

Despite the comparative prosperity of agriculture, the population of Wensleydale has declined continuously since the mid-nineteenth century. Agricultural depression led to a reduction in the numbers of farms on the more marginal land, and it became more profitable for landlords to let shooting rights on the moors than to keep the land for pasture.

During the twentieth century upland farming has undergone further contraction, but the general pattern of dairying in the valley bottom and on the lower slopes and sheep on the high fells remains. In 1974, Leyburn Rural District Council still had over 4250ha of common land (Barringer, 1982). Some parts of the moors are now managed for grouse, while others are being drained to improve their value as pasture. Wensleydale has not been subjected to afforestation, and now has very little woodland, the nearest large plantation being at the head of Langstrothdale to the south.

CHAPTER 4: THE FIELD SITES

THE FIELD SITES

4.1 Choice of sampling sites

The primary requirement of a study of this type is for sites at which pollen has been preserved by deposition in anaerobic conditions. Whilst waterlogging and peat formation does occur locally at low altitudes in Wensleydale, particularly on boulder clay, the ground-water entering such basins is generally too calcareous to favour pollen preservation. Thus the major source of pollen records in Wensleydale is the blanket peat of the high gritstone fells. This type of peat is widespread (see fig. 2.1), and as it is up to 3•65m deep it can be expected to provide comparatively long records of post-glacial vegetational history.

There are, however, a few points which must be considered when analysing pollen records from blanket peat. The exposed, high altitude sites where this type of peat is found do tend to collect pollen from the valleys below as well as local pollen, so that it can be difficult to determine where particular plant communities grew, or where incidents such as clearance episodes occurred. In addition, it is probable that the removal of trees from such localities took place before the initiation of peat accumulation, so that the event cannot be analysed from the pollen records. A further problem in Wensleydale is that many areas of blanket bog have undergone various forms of disturbance which may cause discontinuities in the pollen records. Some, particularly those accessible to settlements or early lead-smelting mills, have been subject to peat-cutting. Others have been drained and are eroding rapidly. Suitable sites for pollen analysis are therefore not as abundant as might at first be assumed.

With these limitations in mind, together with further restrictions imposed by the need to carry the sampling equipment and cores over terrain inaccessible to vehicles, four sites were chosen to fulfill the aims of this study. Their locations are shown in figure 4.1. Initially two deep blanket peat sites were selected to provide long records of the pattern of vegetational change throughout the study area. The first was at Whirley Gill Head, on the Ure-Swale interfluve in the north-eastern part of the dale, and the second was at Fleet Moss, above Hawes in the south-western part of the dale. To provide more local detail of the effects of man on the vegetation, two further sites were chosen from areas with archaeological evidence of prehistoric settlement and agriculture. Penhill, above West Burton in the south-east, is another blanket peat site, but on the limestone terrace immediately below the sampling site there are enclosures thought to represent an Iron Age settlement. The final sampling site is Thornton Mire, a valley bog between Addlebrough and Greenber Edge, just east of Semerwater. As described in chapter 3, this part of Wensleydale has evidence of occupation by man since Mesolithic times, and the terraces on either side of Thornton Mire itself have enclosures which may represent Bronze Age or even late Neolithic settlement and field systems. The great potential of this site for producing a record of the influence of prehistoric man on the vegetation was considered to outweigh the problems posed by the poor pollen preservation in a basin receiving inputs of calcareous ground-water.

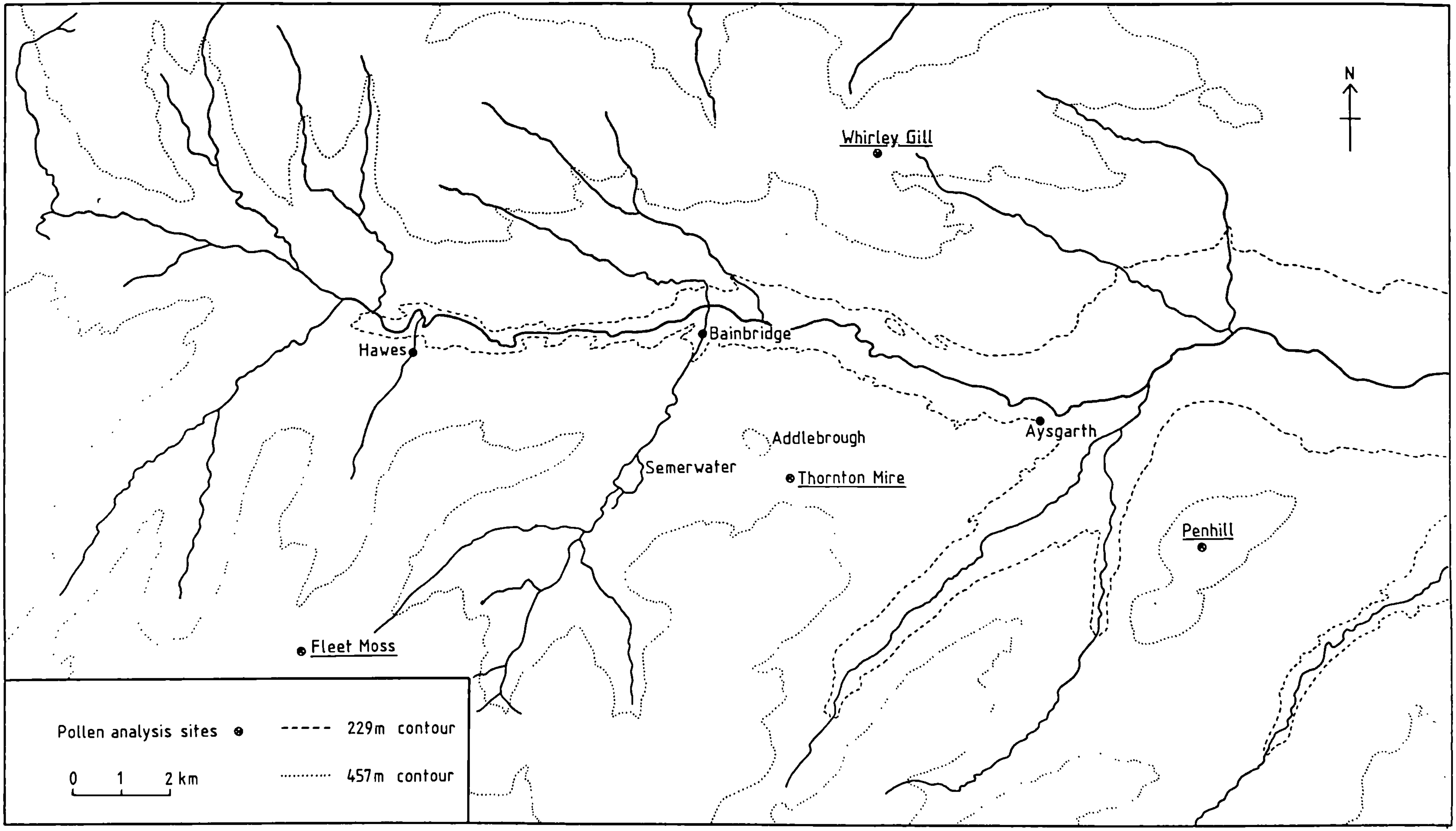


Figure 4.1: The location of the sampling sites

4.2 Description of the sampling sites

At each field site observations were made on the extent and nature of the peat deposit. This data was supplemented by a laboratory study of the stratigraphy and humification of each core. The field sampling methods are described in Appendix 1.

The composition of the blanket peats is quite uniform, and only of interest in determining what part of the pollen spectrum can be attributed to the plants of the bog itself. The stratigraphy of Thornton Mire is more variable and has in fact been studied in detail by previous researchers (Harley and Yemm, 1942). For the purposes of the thesis, it is the vegetation of the terrain around the bogs rather than that of the bogs themselves that is of prime importance, and the macroscopic analysis is only intended to indicate the depositional contexts from which the pollen records have been obtained. The stratigraphy at each site is shown at the side of the relevant pollen diagram (see chapter 6), and a key to the stratigraphic symbols used is given in figure 4.2.

The variation in the degree of humification throughout the profiles was studied in detail by means of the method developed by Bahnson (1968) (see Appendix 1). More humified layers of peat indicate slower peat growth as a result of drier conditions, and so this data is of use not only in detecting hydrological changes but also in interpreting the chronology of vegetation history, as the time span represented by a given depth of peat will vary according to the degree of humification. The humification profiles are also shown on the relevant pollen diagrams.

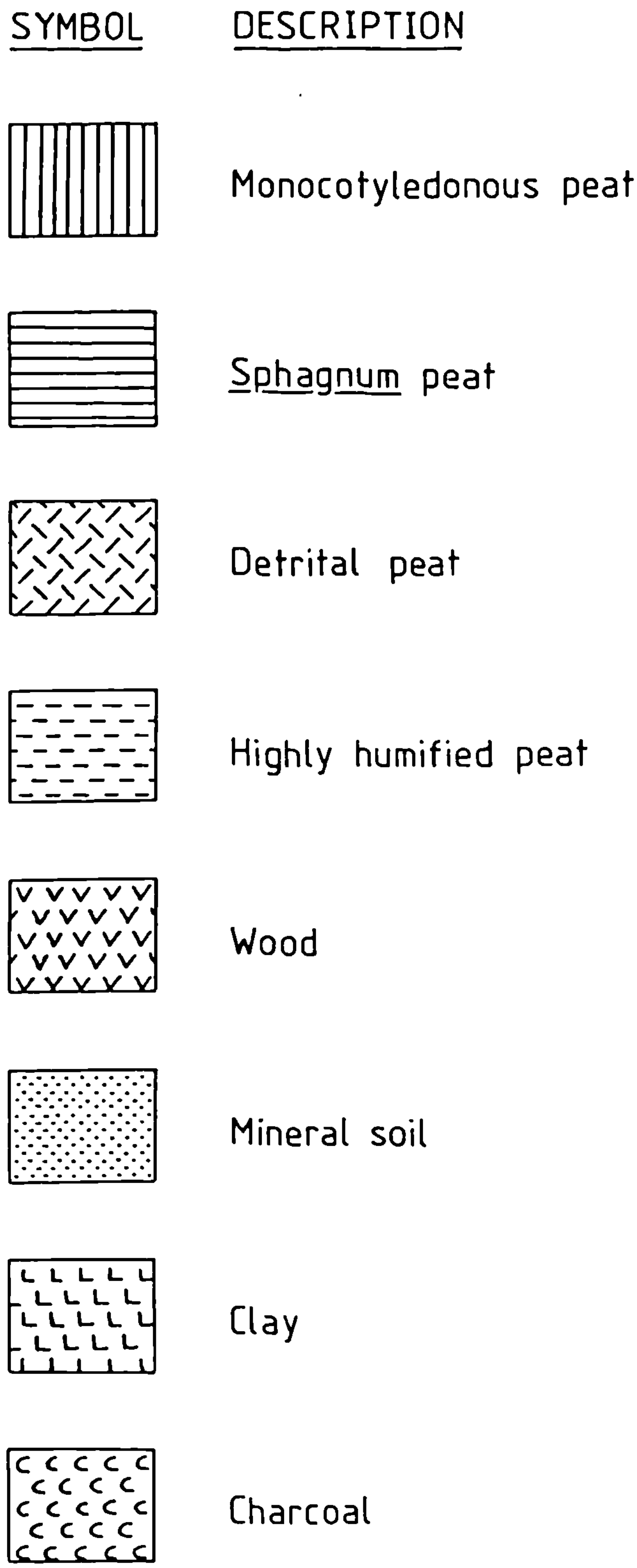


Figure 4.2: Key to stratigraphic symbols

4.2.1 Whirley Gill (SD 970940, altitude 488m)

On this part of the Ure-Swale watershed, blanket peat has smoothed the surface of the originally uneven Millstone Grit outcrop. The deepest section on the Wensleydale side is just north of Whirley Gill, where cores 3·5m long were taken for analysis (see fig. 4.3). Some gullying has occurred at this site, and the bog surface has dried out considerably. Since the samples were taken, moor-gripping has been carried out which will cause further drying and deterioration of the peat. There does not appear to have been any peat-cutting here, although a few hundred metres to the west, on The Fleak, turbary has been practised in the recent past and stacks of peat bricks can still be seen. Also on The Fleak, the peat has dried out sufficiently to become subject to wind erosion on slight slopes, and bare rock is exposed in places. Again, the sampling site has escaped such disturbance.

The peat is typical of the cotton-grass moss described in section 2.4, being composed almost entirely of _Eriophorum_ remains, with the exception of the uppermost layer. The stratigraphy of the site chosen for pollen analysis is described below:

Depth (cm)	Description
0-5	Slightly humified, springy, light yellowish-brown _Sphagnum_ peat with living _Calluna_ roots.
5-72	Fairly well-humified, dark brown _Sphagnum_ peat with some _Eriophorum_ at 36-44cm.
72-192	Increasingly well-humified, dark red-brown _Eriophorum_ peat with occasional fragments of _Calluna_ at 72-82cm, 98cm and 158cm.
192-218	Very well-humified dark brown monocotyledonous peat with occasional recognisable _Eriophorum_ fragments.
218-278	Less humified, slightly lighter _Eriophorum_ peat.

a) General view (looking east)

b) Close-up of the sampling site

Figure 4.3: The Whirley Gill pollen analysis site

278–316	Very well-humified, dark brown *Eriphorum* peat.
316–330	Well-humified, dark brown *Eriophorum* peat with fragments of compressed wood and small twigs of *Betula* type.
330–350	Less humified *Eriophorum* peat with small twigs around 344cm. Some mineral material (quartz particles from the underlying grit) at the base.

Although the tip of the peat sampler touched solid rock, the bottom 15cm penetrated by the blade but not the core chamber could not be sampled.

The stratigraphy suggests that a thin, damp woodland dominated by *Betula* existed on the site when rapid peat formation began, and was eventually overwhelmed by the bog community. A layer of less humified peat between 218cm and 278cm marks a period of increased wetness, probably in the Atlantic period, while *Calluna* fragments between 72cm and 192cm suggest that the bog was becoming drier. Another return to wet conditions locally is indicated by the predominance of *Sphagnum* in the upper layers of the profile, before the bog finally attained its present state.

The vegetation of the site is now dominated by *Calluna vulgaris*, with some *Erica tetralix* and *Vaccinium myrtillus* on the driest patches. Although the present ground surface is mainly dry, a few quite large (several metres in diameter) pools exist, with species of *Sphagnum* growing in and around them, together with *Eriophorum vaginatum*, *Polytrichum commune* and *Juncus effusus*. In the gullies there is little flow for most of the year, only small stagnant pools remaining with *Sphagnum* in the wettest parts and *Eriophorum vaginatum* elsewhere.

4.2.2 Fleet Moss (SD 860836, altitude 565m)

Fleet Moss lies on the watershed between the Ure to the north and Oughtershaw Beck to the south. As at Whirley Gill, the peat overlies Millstone Grit and is over 3·5m thick in the deepest parts. However, severe erosion has occurred at this site, and a complex network of deep gullies penetrating down to the grit has developed. The gullies are dry for much of the year, and wind erosion assists in the redistribution of the peat. Towards the northern margin of the bog, shallow, rocky streams flow down to Semerdale, but towards the south the peat haggs are separated by very flat areas of redeposited peat. Recent moor-gripping is accelerating the destruction of the bog.

Cores 3·5m long were taken for analysis from the central area of Fleet Moss, about 2m from the nearest gully. As the remaining 15cm of peat could not be sampled by coring from the surface, a pit was excavated into the side of the nearest gully to obtain a monolith of the basal sediments (see fig. 4.4). The monolith was later correlated with the cores on the basis of pollen analysis and stratigraphy, giving a total profile depth of 3·65m at this site.

The most common identifiable remains in the peat are of *Eriophorum*, but the bulk of the deposit is composed of very fine, homogeneous material in which the constituents cannot be differentiated. The stratigraphy of the pollen analysis site is as follows:

Depth (cm)	Description
0–10	Well-humified, dark yellowish brown *Eriophorum* peat with living *Calluna* roots.
10–54	Well-humified, dark brown, almost homogeneous peat with occasional recognisable *Eriophorum* remains.
54–134	Very well-humified, dark brown *Eriophorum* peat with *Calluna* at 79cm, 92–96cm and 120–134cm.

a) General view (looking east)

b) Close-up of the sampling site

<u>Figure 4.4:</u> <u>The Fleet Moss pollen analysis site</u>

134–246	Increasingly humified, dark reddish-brown, almost homogeneous clay-like peat, with few recognisable remains. Occasional *Eriophorum* and *Sphagnum* fragments throughout, plus a little *Calluna* between 160cm and 210cm.
246–282	Very well-humified, dense, clay-like peat with no recognisable remains.
282–348	As above, but with identifiable *Eriophorum* fragments between 310cm and 340cm, and *Calluna* at 284cm, 326–330cm and 343cm.
348–356	Well-humified, dark *Eriophorum/Sphagnum* peat with some wood.
356–363	Predominantly highly compressed *Betula*-type wood with some homogeneous peat and occasional *Eriophorum* and *Sphagnum* remains.
363– 368	Very compact mixture of organic and mineral material. No identifiable plant remains. Mica visible, and increasingly gritty towards the rotted bedrock. Fossil soil ?

The stratigraphy of Fleet Moss suggests a similar history to that of Whirley Gill, damp *Betula* woodland having grown on the site before the bog became established. Between 280cm and 325cm the humification profile indicates a wetter phase, although this is less marked than at Whirley Gill. Cotton-grass moss with *Sphagnum* in the wetter patches probably covered the site until recently, when the peat surface became dry enough to support the present heath vegetation and intensive erosion began.

According to Birks and Birks (1980), an annual rainfall of over 1300mm favours the extensive development of blanket bog on slopes less than 15°. Figures for Top Duerley (SD 860846, altitude 567m) and Top Snaizeholme (SD 830834, altitude 579m) suggest that the rainfall at Fleet Moss is probably 1800–2000mm per year, so the degeneration of the moss is probably due to anthropogenic factors such as drainage, burning and pollution.

The present vegetation of the site consists largely of Calluna vulgaris, Vaccinium myrtillus, Empetrum nigrum and Rubus chamaemorus. These four plants grow in varying proportions on the dry tops of the peat haggs, each becoming dominant on certain parts of the bog where ecological conditions change slightly in its favour. Erica tetralix is sometimes found in drier areas, and Eriophorum vaginatum occasionally occurs in the damper depressions in the peat surface. Most of the gullies are cut into bare rock and support no vegetation, but between some of the haggs towards the south flat expanses of fine, redeposited peat have developed and are being colonised by Eriophorum vaginatum. No other species were noted on the moss apart from a small patch of Polytrichum commune growing on the wood exposed by erosion towards the base of the peat.

4.2.3 Penhill (SE 038858, altitude 549m)

Penhill overlooks Wensleydale to the north, and its tributaries Waldendale to the west and Coverdale to the east. It rises in a series of marked terraces formed of Yoredale strata to a fairly flat summit area of Millstone Grit. As at Whirley Gill and Fleet Moss, blanket peat has covered this surface, although not to such a great depth. Of particular interest at this site is the series of enclosures, thought to date from the Iron Age, at an altitude of 457m on the limestone terrace facing towards the north-west. The builders of this complex of small hut circles and fields or stock enclosures (see fig. 4.5) must have had some impact on the local vegetation, which should be discernible in the pollen records. Little erosion of the peat has

Figure 4.5: The prehistoric enclosures on Penhill

occurred on Penhill, but peat-cutting has been practised towards the more accessible north-eastern area of the summit plateau. The moor is now used as rough grazing for sheep.

Monoliths for analysis were taken from a pit 1·75m deep excavated near the edge of the blanket peat immediately above the enclosures (see figs. 4.6 and 4.7). Whilst the deposit is slightly deeper towards the centre of the moor, proximity to the archaeological site was considered to be of greater importance than peat depth in this case. In addition, this margin is unlikely to have been subject to peat-cutting, which is more frequent towards the north-east.

The stratigraphy of the pollen analysis site is described below:

Depth (cm)	Description
0–16	Slightly humified, dark yellow-brown *Eriophorum* peat with living *Calluna* roots.
16–37	Well-humified, dark brown *Eriophorum* peat with some *Sphagnum* at 18–29cm and 31–37cm.
37–52	Less well-humified, dark red-brown *Eriophorum* peat with *Sphagnum* remains between 42cm and 45cm.
52–65	Well-humified, dark red-brown *Eriophorum* peat.
65–68	Well-humified, lighter red-brown *Sphagnum* peat.
68–102	Less well-humified, orange-brown *Sphagnum* peat. Degree of humification decreases sharply from 68cm to around 80cm, where the *Sphagnum* remains are hardly decomposed and light in colour, and then gradually increases again towards 102cm. Occasional *Calluna* remains between 97cm and 100cm.
102–154	Largely homogeneous peat with few identifiable plant remains. *Sphagnum* is most abundant throughout, with *Calluna* fragments around 105cm and *Eriophorum* 125–134cm.
154–172	Very dark, well-humified, dense, almost homogeneous peat with a few recognisable *Eriophorum* remains between 160cm and 172cm.
172–175	Mixture of very dark, well-humified organic material and grit, with no identifiable plant remains. Increasingly gritty towards the rotted bedrock at 175cm.

Figure 4.6: The Penhill pollen analysis site, looking south-east

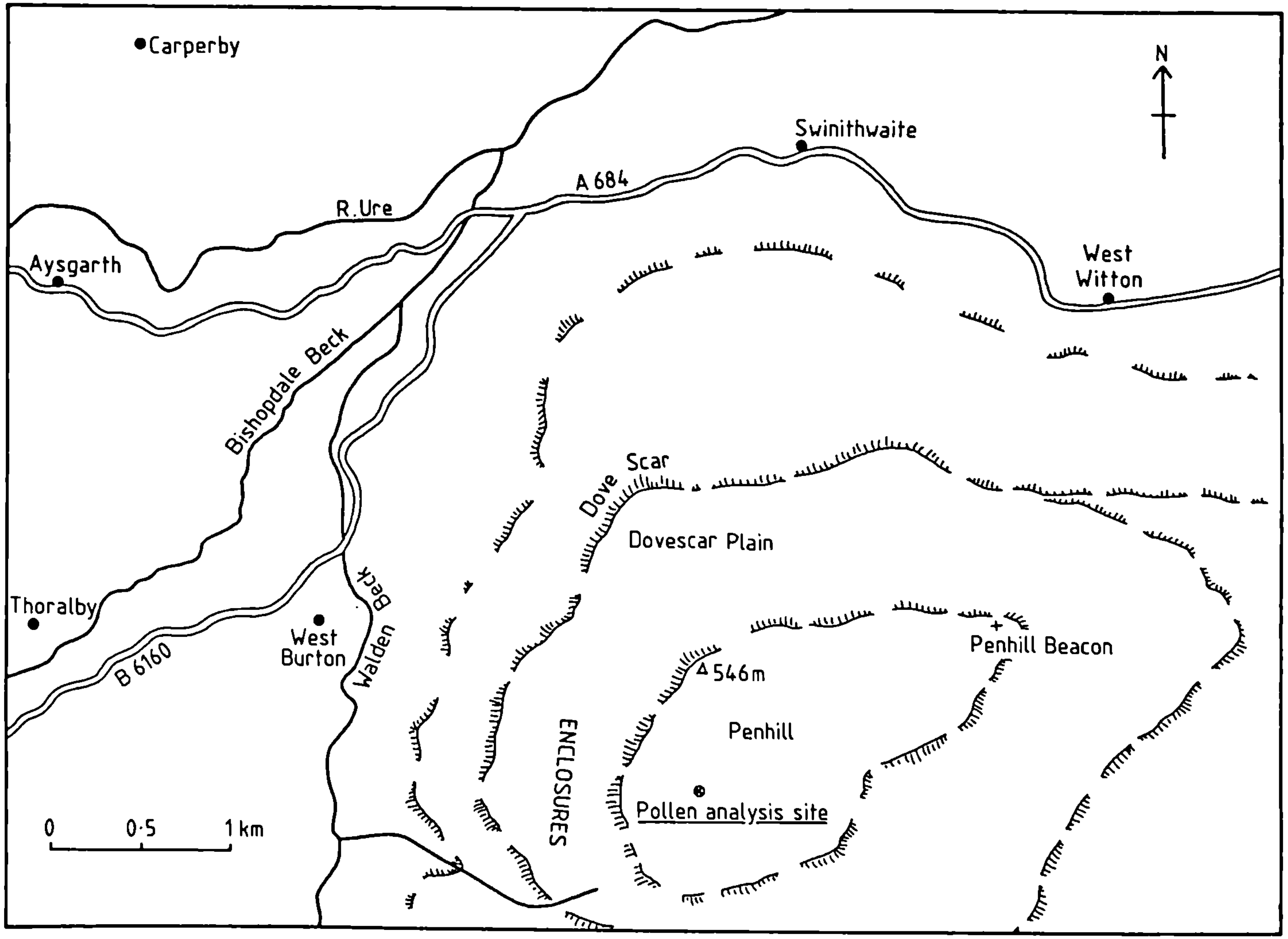


Figure 4.7: Sketch map of Penhill, showing the sampling site in relation to the prehistoric enclosures

The Penhill peat profile does not provide any evidence of former woods on the site. However, the alternative name for the summit, 'Hazely Peat Moor', implies the existence of hazel scrub at some time in the past. A period of erosion may have removed the earliest post-glacial soil or peat before the development of boggy _Sphagnum_ and _Eriophorum_ communities. The humification profile shows pronounced variations in hydrological conditions which may be due to localised anthropogenic factors, as Whirley Gill and Fleet Moss do not show corresponding patterns.

The cotton-grass moss is now giving way to drier heath vegetation. Although there is still some _Eriophorum vaginatum_, _Calluna vulgaris_ is dominant with _Empetrum nigrum_ and _Vaccinium myrtillus_ locally abundant. The latter predominates on the dry margins of the gritstone plateau, while occasional clumps of _Molinia caerulea_ grow in wetter patches.

4.2.4 Thornton Mire (SD 952872, altitude 380m)

Thornton Mire is a small valley bog, situated between Addlebrough and Stake Fell 2•5km east of Semerwater (see fig. 4.8). According to Raistrick (1926), the topography of this area was shaped in the late phases of the last glaciation. Impounded by the Wensleydale glacier, the melting ice and snow of the watershed to the south collected in Semerdale, forming a lake up to 152m deep. Thornton Mire represents an overflow channel of the highest stage of the Semerdale lake, where the summer flood water escaped eastwards across Thornton Rust Moor into Bishopdale, which also contained a great lake. A temporary readvance of ice left the channel blocked by a small lateral moraine, and this

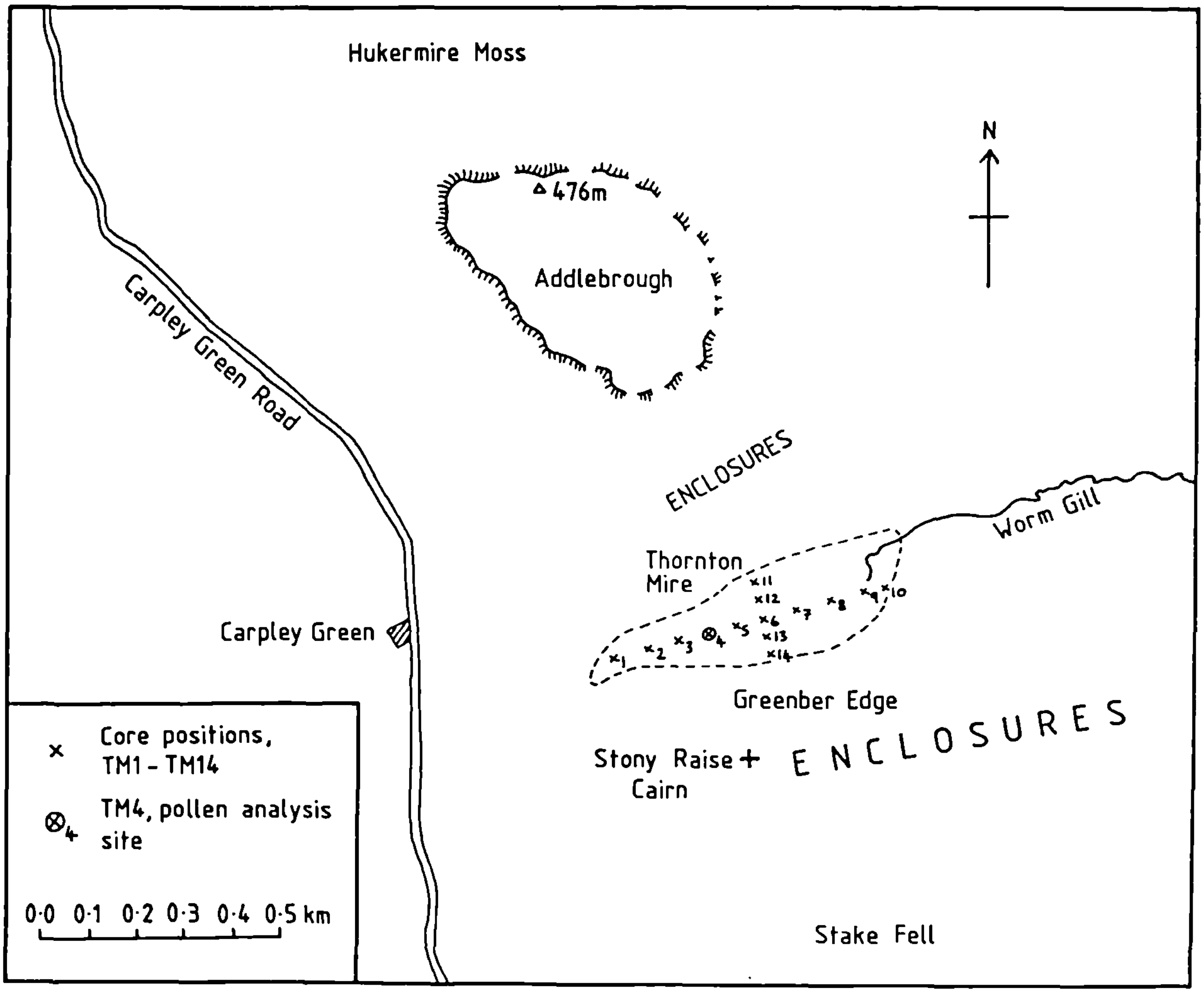


Figure 4.8: Sketch map of Thornton Mire, showing the sampling site in relation to the prehistoric enclosures and cairn

impeded drainage to some extent but was later breached. Today, almost all the water draining into Thornton Mire comes from the slopes of Stake Fell and Addlebrough; very little enters the channel from the western end. The outflow from the mire passes down Worm Gill to the east in a meandering stream usually about 2m wide.

The topographical situation of this sampling site is therefore very different to those of Whirley Gill, Fleet Moss and Penhill, and the pollen profile can also be expected to show significant variations from the general pattern of the area. Apart from providing evidence of the development of the mire itself, the pollen record should give better representation of the vegetation of the lower-lying land and therefore of agricultural activity throughout history.

The main reason for the choice of this site, though, as mentioned in section 4.1, is the existence of prehistoric enclosures on the terraces overlooking the mire to the north and south (see figs. 4.8 and 4.9). Recent investigations by the North Yorkshire County Council Archaeology Unit (P. Chadwick, personal communication) have shown that these structures are much more extensive than was previously thought, particularly on Greenber Edge, and suggest that they may date from as far back as the late Neolithic (see chapter 3). More enclosures can be seen on the west-facing slopes of Addlebrough, and others once existed on Hukermire Moss to the north of Addlebrough but have now disappeared. These two groups of structures are believed to date from the Iron Age (see section 3.5). However, archaeological evidence from nearby Semerwater and Carpley Green farm indicates that the area has in fact been occupied since the Mesolithic age. The Thornton Mire pollen record should therefore be of considerable value in assessing the

Figure 4.9: The Thornton Mire pollen analysis site: general view

effects of each successive culture on the landscape and especially in determining the particular culture responsible for the remarkable series of enclosures.

The vegetation and ecological conditions at Thornton Mire were studied by Harley and Yemm (1942), who also investigated the depth and nature of the peat. However, an independent examination of the stratigraphy was necessary for this project, in order to determine the most suitable part of the mire for pollen analysis and to provide details missing from the 1942 study. Fourteen cores were taken along two transects, and their positions are shown in figure 4.8. The stratigraphy of the mire is represented in figure 4.10.

The peat is everywhere underlain by a grey-blue clay, the depth of which is unknown as its stiffness prevented the corer from penetrating through to bedrock. Around the centre of the mire, up to 3·15m of peat has accumulated, but the thickness of the deposit decreases rapidly towards the margins. As the variable depth of peat could be due merely to differences in accumulation rates, rather than to earlier peat initiation in the centre of the mire, some preliminary pollen analyses were carried out before the site for detailed analysis was chosen.

For each core, a sample from the clay/peat transition was analysed, and the results are shown in figure 4.11. By comparison with the completed Whirley Gill and Fleet Moss profiles, it was decided that the oldest peat was in fact the deepest, from the central area of the mire. The basal peat of cores TM4, TM5, TM6, TM7, TM8, TM9, and TM13 seems to be the earliest, as the pollen spectra of these samples are typical of an early post-glacial date, dominated by pine, hazel and birch. The basal samples from the other seven cores show a much greater variety of

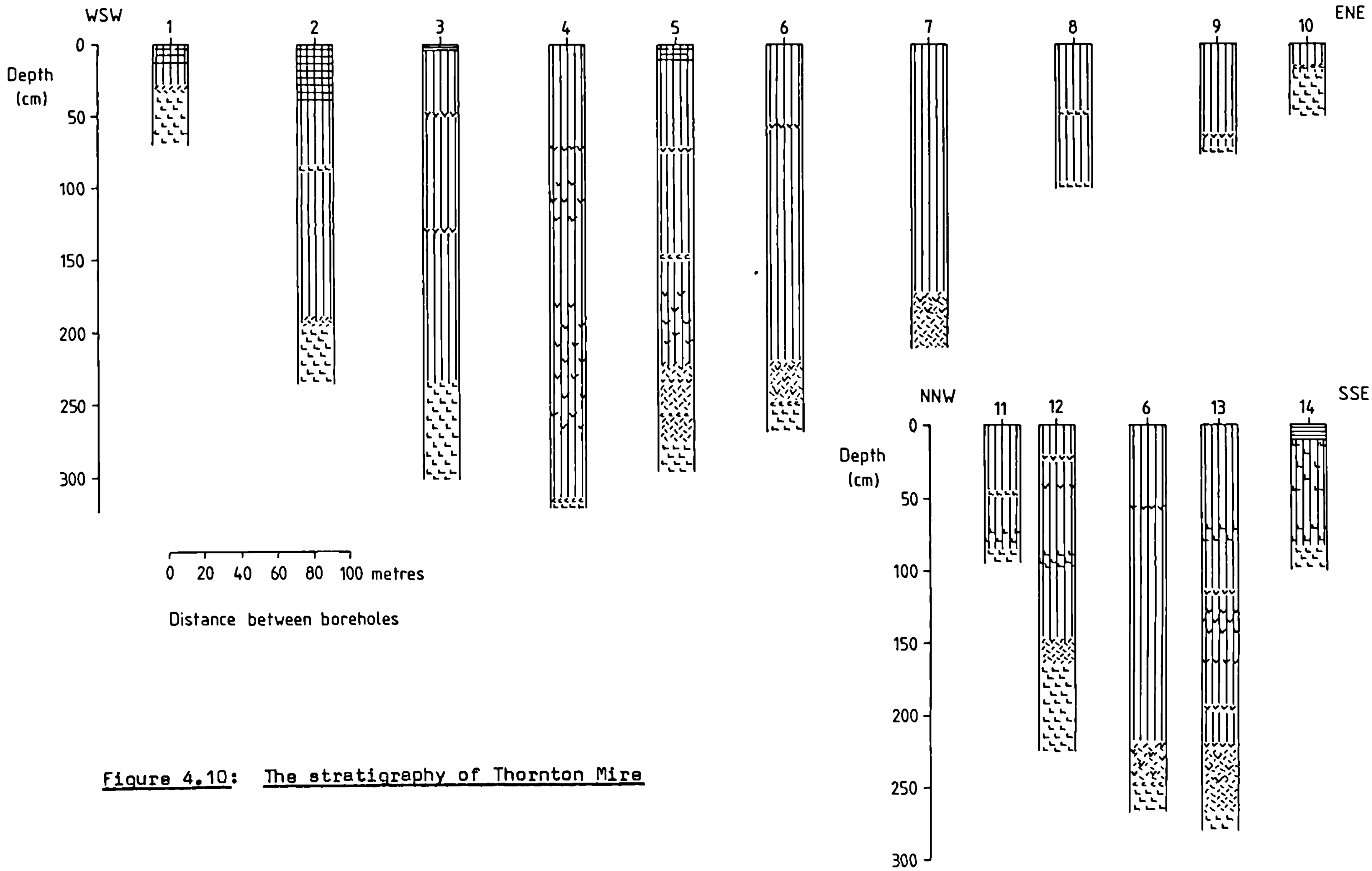


Figure 4.10: The stratigraphy of Thornton Mire

CORE NUMBER	DEPTH	POLLEN CONTENT
TM1	34cm	37% AP, mainly hazel and alder, followed by oak, then birch and occasional pine, ash and willow. Grasses dominant overall, including cereals. Other NAP types include weeds of agriculture such as Plantago lanceolata, and heaths.
TM2	205cm	Too sparse to count.
TM3	231cm	54% AP, with alder and hazel dominant, then oak, and some elm, ash, birch, pine and willow. NAP mainly grasses and sedges.
TM4	313cm	67% AP, pine, birch and hazel dominant, then willow. No other AP species found. NAP mainly sedges and grasses.
TM5	275cm	65% AP, dominated by pine and hazel, then birch, with occasional elm. Grasses and sedges most abundant of NAP types.
TM6	248cm	Too sparse for proper counting, but pine seems dominant with some birch and hazel.
TM7	210cm	94% AP, mostly hazel, then pine, with some birch and occasional elm. NAP mainly grasses and heaths.
TM8	95cm	64% AP, hazel dominant then pine and birch with occasional alder, willow and oak. NAP mostly sedge.
TM9	70cm	76% AP, dominated by birch and hazel with some pine and occasional willow. NAP mainly grasses and sedges.
TM10	20cm	98% AP, alder and hazel co-dominant, followed by birch, oak, elm and lime, and occasional pine and willow. Only NAP type found was Filipendula.
TM11	70cm	51% AP, mostly hazel and alder with some birch and oak and occasional pine. NAP dominated by grasses and Caryophyllaceae , but great variety of other species including heaths, Filipendula, Compositae, Umbelliferae and Succisa pratensis.
TM12	165cm	86 % AP, with hazel dominant but considerable quantities of oak, alder, birch and elm, and occasional pine, willow and lime. NAP mostly sedges and grasses.
TM13	267cm	89% AP, dominated by hazel and pine with some birch but no other species. NAP includes sedges, grasses, Filipendula and occasional heaths.
TM14	82cm	67% AP, mostly hazel followed by alder, birch, pine and elm. NAP nearly all sedge.

Figure 4.11: Pollen content of the Thornton Mire basal samples

pollen types, including species like lime which would not have migrated into the area until much later in the post-glacial, and others indicative of extensive clearance for agriculture. Of the earlier cores, TM6 was eliminated because of the scarcity of its pollen, and TM8 and TM9 because of their short depths. Occasional elm pollen in TM5 and TM7 suggests a slightly later origin, so these cores were also eliminated. This left only TM4 and TM13, from which TM4 was chosen because of its greater depth and its position nearer to the centre of the mire where peat-cutting is less likely to have taken place (see fig. 4.12).

The stratigraphy of core TM4 is described below:

Depth (cm)	Description
0–10	Slightly humified, light brown-yellow, fibrous *Eriophorum* peat with living *Eriophorum* roots.
10–68	Fairly well-humified, medium-brown *Eriophorum* peat with occasional *Sphagnum* remains throughout and *Calluna* fragments around 33cm.
68–90	Dark brown, quite well-humified fen peat, with *Juncus* and *Phragmites* remains and small pieces of well-preserved *Betula* wood at 70–72cm.
90–128	Wood peat composed predominantly of *Betula* remains in a matrix of well-humified, dark brown, amorphous organic material. Slightly silty in parts.
128–174	Quite well-humified, dark monocotyledonous peat, with occasional *Eriophorum* and *Juncus* remains.
174–266	Wood peat, composed of *Salix* fragments in a matrix of quite well-humified, dark *Juncus/Phragmites* peat.
266–315	Less well-humified, brown-grey *Juncus* peat with increasing amounts of clay towards the base and occasional *Equisetum* remains. Distinct charcoal layer at base of peat.
315– ?	Stiff grey-blue clay with occasional fragments of limestone and pockets of coarse, sandy material. No evidence of bedding or organic remains.

Figure 4.12: The Thornton Mire pollen analysis site: close-up of the sampling site, looking north-west

To provide additional information about the development of Thornton Mire, a series of chemical analyses was carried out. The following determinations were made for a core taken immediately adjacent to TM4 :- pH, ash weight/carbon content, exchangeable calcium/magnesium ratio, and total calcium, magnesium, iron, aluminium, sodium, potassium, manganese and silica. The methods used are given in Appendix 1, and figure 4.13 shows the chemical profiles obtained.

Whilst the chemical profiles are discussed further in chapter 7, in relation to the pollen records, it is appropriate at this point to describe the features relevant to the development and ecology of Thornton Mire. The exchangeable calcium to exchangeable magnesium ratio is often used to distinguish peats formed under minerotrophic conditions from those formed under ombrotrophic conditions (Mattson, Sandberg and Terning, 1944; Chapman, 1964b). For minerotrophic peats the ratio is usually greater than 1•0 and for ombrotrophic peats less than 1•0. Complications arise, however, as changes in vegetation and thus in peat may lag behind the change in water supply, and mineral salts within the rooting zone may be brought up and incorporated in the surface peats (Chapman, 1964b). Figure 4.13 shows that the exchangeable calcium/magnesium ratio is well above 1•0 throughout the Thornton Mire profile, but there is a steady decrease towards the surface. This indicates that the mire has developed under the influence of a groundwater regime, but the contribution of direct precipitation is gradually becoming more important. A high iron content is also indicative of minerotrophic conditions, and figure 4.13 shows a significant drop in iron values near the top of the profile, again suggesting an increasing tendency towards an ombrotrophic regime.

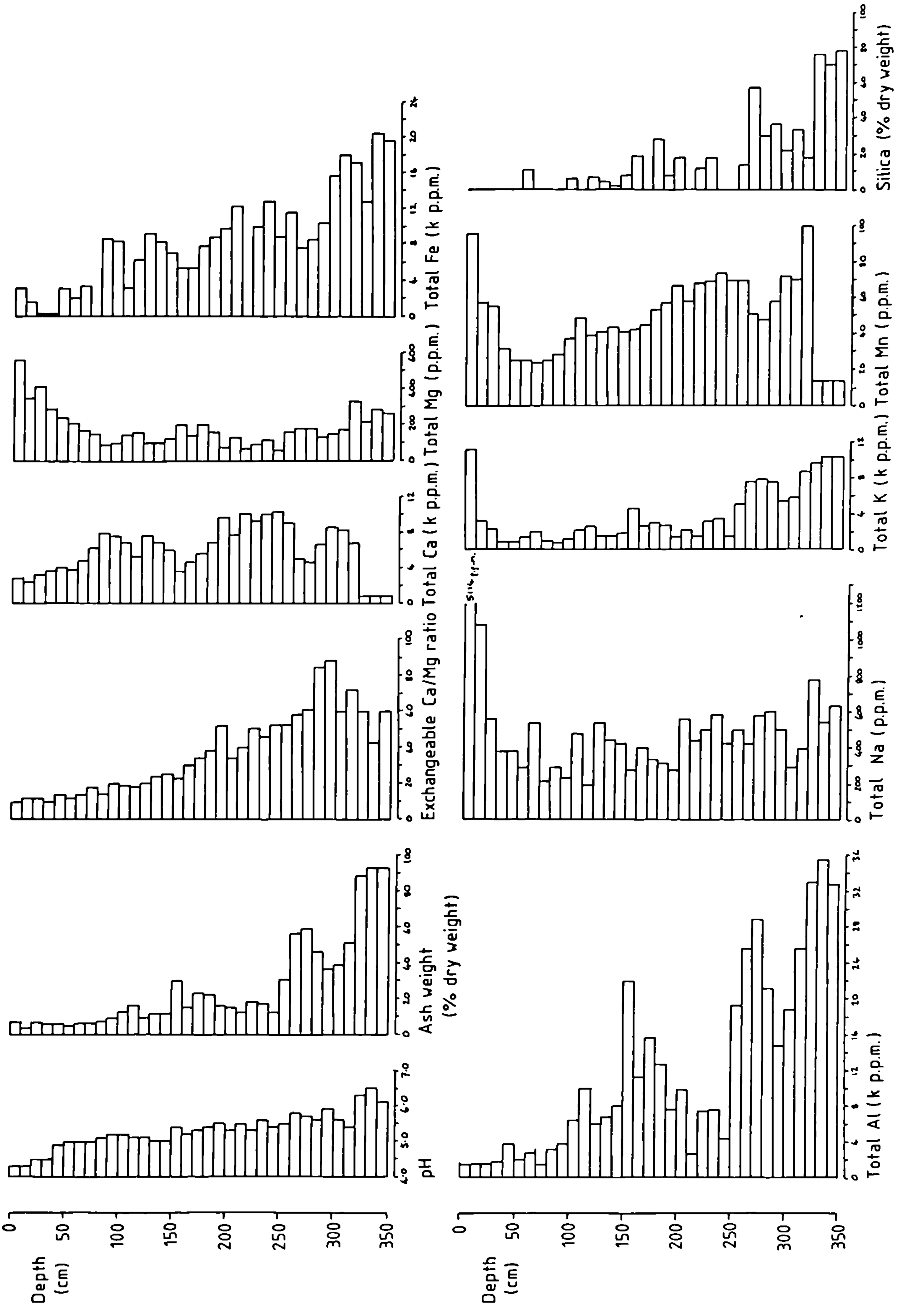


Figure 4.13: Thornton Mire chemical analysis results

It is clear, then, that Thornton Mire has developed under the influence of calcareous ground-water from the limestone of the surrounding slopes. The initial reason for its development was the existence of a slight basin covered by relatively impervious clay, which prevented the escape of water. The origin of the clay is uncertain; it may be a boulder clay deposited by retreating ice, or a limnic deposit laid down in a small late-glacial water body. A locally-derived deposit might, however, be expected to be more calcareous, and this together with the apparent absence of bedding and organic material, and the presence of quite large pieces of rotted sandstone, tends to suggest that it is a boulder clay.

The charcoal layer above the clay suggests that the burning of forest on the surrounding slopes may have caused peat initiation, by producing increased runoff which led to waterlogging in the valley bottom. Wet fen-type vegetation then developed and the mire spread outwards from the centre of the basin, being sporadically colonised by willow. According to Harley and Yemm (1942), the mire surface developed a slight west to east slope as the depth of peat increased, and this led to partial localisation of drainage. The resulting greater rate of runoff at the margins of the mire caused the centre to become less directly influenced by drainage, allowing the development of the more ombrotrophic conditions favouring _Eriophorum_ and _Sphagnum_.

The present vegetation of Thornton Mire shows a distinct zonation from the margins to the centre, the vegetation varying with local drainage conditions. Harley and Yemm studied the distribution of the chief plant communities in 1942, and the general pattern today shows little change, except perhaps for some increase in wetness in the central zone.

The drier marginal areas of the mire, particularly on the Addlebrough side, support a grassy community dominated by Nardus stricta, with Holcus lanatus, Festuca ovina, Anthoxanthum odoratum and Molinia caerulea. Eriophorum vaginatum and Juncus communis are locally abundant, and Polytrichum commune, Potentilla erecta, Galium uliginosum and Ranunculus spp. were also noted. Where more surface drainage enters the mire, Juncus swamp is dominant. This occurs most widely along the southern side of the mire, but is also present in a narrower belt on the northern side. Juncus acutiflorus is the main species, but Juncus communis occurs on the marginal slopes. The water level in this community remains above the surface throughout the year, and the associated species usually form a low layer close to the water surface, sometimes floating or submerged, beneath the dense growth of Juncus acutiflorus. Species observed in the Juncetum zone include Menyanthes trifoliata, Sphagnum spp., Equisetum palustre, Potamogeton natans, Viola palustris, Potentilla erecta, Lychnis Flos-cuculi, Rumex acetosa, Scabiosa succisa, Eriophorum vaginatum and Eriophorum angustifolium.

The next zone inwards is dominated by Sphagnum spp., and is particularly widespread at the western end of the mire. Sphagnum recurvum and Sphagnum cuspidatum are the most abundant species, and are associated with Juncus acutiflorus towards the margins of the bog and Carex rostrata further towards the centre. Other species include Eriophorum vaginatum and Eriophorum angustifolium, Polytrichum commune, Cirsium palustre, and many of those found in the Juncetum.

Most extensive of all the plant communities is that of the central zone. Harley and Yemm (1942) classed this as Callunetum, stating that Calluna vulgaris was dominant, with Eriophorum vaginatum locally co-dominant. Today, however, the centre of Thornton Mire appears to be dominated by Eriophorum spp., indicating the prevalence of wetter conditions. Large tussocks of Eriophorum vaginatum are most common, with Sphagnum spp. in the surrounding pools and Calluna vulgaris on the drier hummocks formed by the cotton grass. Eriophorum angustifolium sometimes occurs in the wet hollows, and on the southern edge of the zone a small area is dominated by this species. Associated with the Calluna are Vaccinium myrtillus, Erica tetralix, Empetrum nigrum, and occasional Deschampsia flexuosa, Polytrichum commune and Potentilla erecta.

Harley and Yemm also distinguished small areas of peat cuttings at the western and eastern ends of the mire, but these are no longer clearly discernible, blending in with the cotton grass and Sphagnum communities. They also noted five living trees on the mire, all Salix cinerea, of which only two stunted (2-3m), wind-deformed examples remain, growing close together on the Addlebrough side of the central Eriophorum zone.

The ecological setting of Thornton Mire is thus completely different to those of the other three pollen analysis sites, and therefore offers considerable interest both in terms of the development of the mire itself and in the record it provides of anthropogenic influences on the vegetation of the surrounding area.

CHAPTER 5: CONSTRUCTION, ZONATION AND DATING OF THE POLLEN DIAGRAMS

CONSTRUCTION, ZONATION AND DATING OF THE POLLEN DIAGRAMS

5.1 Construction of the pollen diagrams

For each of the sampling sites described in chapter 4, relative pollen diagrams have been constructed. The use of relative proportions of the different pollen types leads to some problems in interpreting the data, as a real change in one component will produce apparent changes in all other components. However, the cost of the closely-spaced set of radiocarbon dates required to determine absolute pollen frequencies is prohibitive. It is therefore necessary to find ways of overcoming the problems inherent in proportional representation of pollen types, and the techniques employed for this purpose are described below.

5.1.1 Laboratory techniques

The techniques used for extracting pollen from the peat samples and its subsequent microscopic analysis are described in Appendix 1. Samples were initially analysed at an interval of 5cm, but intermediate samples were later analysed for some horizons where extra detail was considered necessary.

5.1.2 Choice of total pollen count

Whilst no pollen count is absolutely reproducible from another slide of the same sample (Birks and Birks, 1980), the choice of a suitable total pollen count can reduce sampling errors. The total count should be sufficient to maintain fairly constant percentages of the pollen sum for the principal components of the pollen spectrum. An adequate estimate of this figure can be obtained by plotting the variation in the percentages of different pollen types with increasing total pollen counts. This was done for four samples from Fleet Moss, and an example is shown in figure 5.1. It is clear that a count of less than 300 may produce quite unreliable results, but the plot also shows that even up to a count of 1000 pollen grains there is still some slight variation. From this data, it was decided to use a total count of 500, as all the plots showed the different pollen types to have settled down to their final order of frequency by this point, and a larger count, up to 1000, does not seem to make a significant difference to the degree of accuracy obtained. Counting more than 1000 would be impractical. Another test, plotting the number of different pollen types found with increasing total count, revealed that for all four samples, all the species which eventually attained values of 1% or more had been found by the time 350 grains had been counted. The total number of species found will obviously increase indefinitely, but little ecological importance can be attached to occasional single grains.

A total count of 500 was therefore deemed to adequately represent the pollen spectrum, and this figure was counted for almost all the samples analysed. The only exceptions were some of the samples from Thornton Mire, where the calcareous environment had caused poor pollen preservation, and some near-surface samples which contained very little arboreal pollen. For the Thornton Mire samples a total count of at least 300 was used. Only one sample (115cm) had too little pollen to

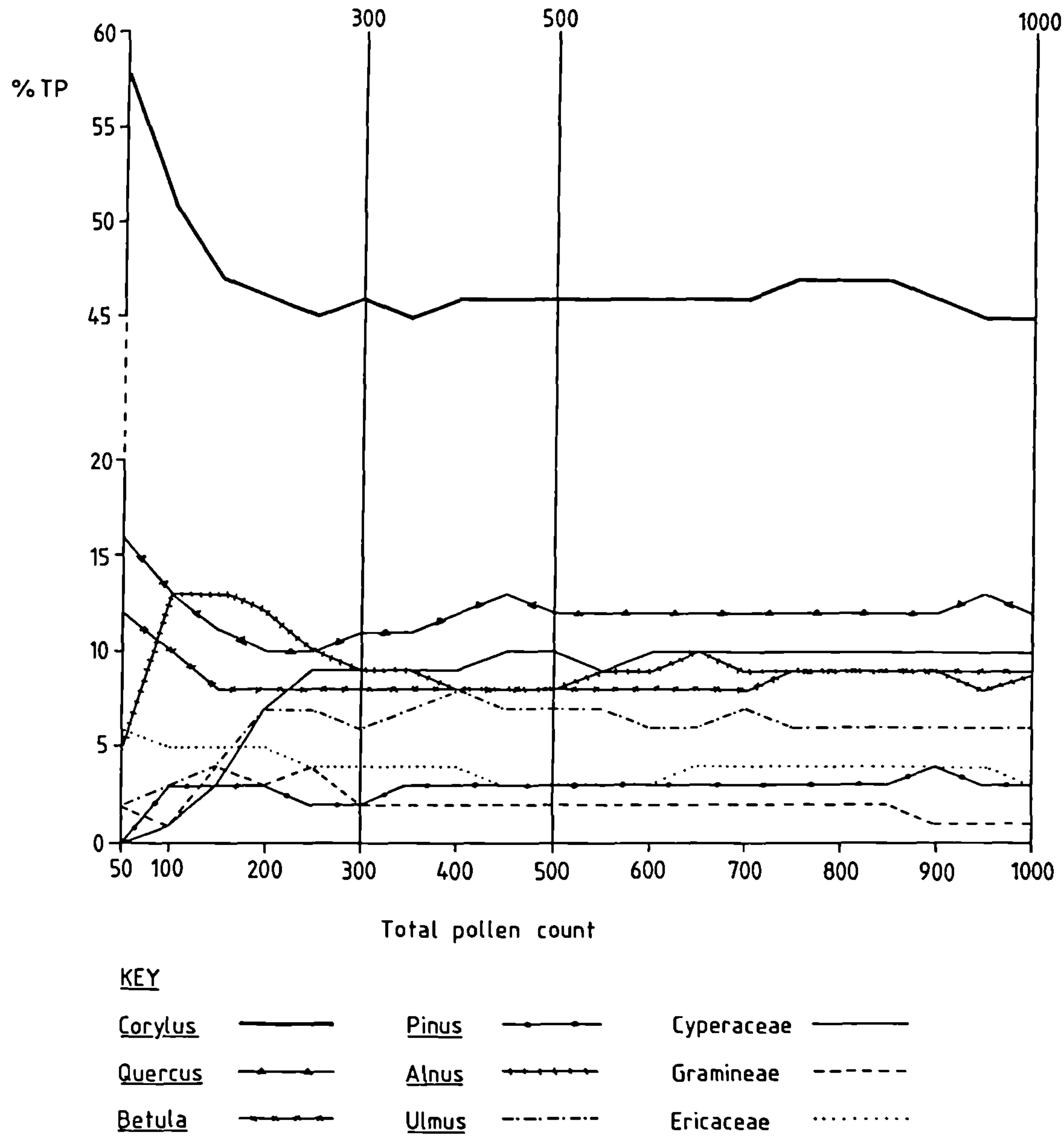


Figure 5.1: The variation in pollen proportions with total pollen count

make this total feasible, and this was omitted from the diagram. Where arboreal pollen was scarce, the count was continued until at least 100 and preferably 150 AP grains had been counted. This was necessary for the production of meaningful arboreal pollen diagrams. The actual totals counted for each sample are provided in Appendix 2.

5.1.3 Choice of pollen sum and calculation of percentages

The choice of a pollen sum to be used as the basis of representation is a critical one which may either reveal or obscure the real changes underlying the fluctuating pollen curves (Moore and Webb, 1978). Early pollen analysts tended to be interested mainly in forest history, and so their pollen sums consisted of tree pollen, and all pollen types were calculated as percentages of this arboreal pollen (AP) sum. However, as Birks and Birks (1980) point out, the modern approach to vegetational history involves a study of the herb and shrub components as well, especially in land artificially cleared of forest by man, so these pollen types should also be included in the pollen sum. For this study, therefore, the basic pollen sum is composed of all terrestrial pollen types. Only the pollen of obligate aquatic plants such as _Potamogeton_ and all spores are excluded. For these excluded species, the percentages are calculated as follows :-

$$\% = \frac{\text{count for species}}{\text{pollen sum + count for species}} \times 100$$

This is in accordance with recent practice in palynology, as it is now recognised that for the sake of both statistical validity and easier interpretation of a diagram, 'the occurrence of any pollen category should be expressed in percentages of a universe of which it forms a part' (Faegri and Iversen, 1975).

The calculations are performed by a FORTRAN computer program, POLLPLOT, written as part of this study (see manual, Appendix 4). This enables the data to be rapidly and accurately recalculated and plotted using different pollen sums, which assists in interpretation of the pollen diagrams and in comparison with other work. With such techniques it is feasible to omit any particular species from the pollen sum to assess the true nature of the variations in relative proportions - for example, the effect of excluding Cyperaceae from the sum for cotton-grass peat can be observed, or the influence of a species like *Corylus* which fluctuates rapidly over a wide range of values.

In addition to the total pollen diagrams which form the basis of this study, arboreal pollen diagrams have been plotted for each site using a pollen sum comprising all trees and shrubs. These components are not separated because the distinction between trees and shrubs is somewhat arbitrary in an upland environment (Tinsley, 1972). So-called 'shrubs' such as *Ilex* and *Salix* often form well-grown trees of equal status to *Quercus* or *Betula* in the gill woods of the Pennines.

Diagrams using a variety of other pollen sums have been produced for interpretative purposes but are not included here.

5.1.4 Production of the pollen diagrams

The pollen diagrams were plotted by the program mentioned above, POLLPLOT, using a Calcomp graph plotter. Once files of pollen counts and sample depths are available, this program runs interactively, offering a number of options concerning the species to be plotted and the scale and style of the plot. These options are described in detail in the manual provided in Appendix 4.

For this study, each pollen type is represented by a bar histogram. 'Saw-tooth' style plots are misleading as the joining of two points implies that intermediate samples would have proportions of pollen which would fall upon the line so drawn - this assumption is totally unjustified (Moore and Webb, 1978). Open rather than shaded bars are preferred as adjacent samples with the same proportions of a particular pollen type are clearly discernible. The horizontal scales of pollen percentages are consistent throughout.

The total pollen diagrams include summary plots of the variation in the percentage of arboreal pollen. All tree and shrub pollen is included in the AP sum, and these % AP diagrams are plotted in 'saw-tooth' style for contrast with the species histograms.

The 'Varia' curves are composed of pollen types which occur in less than five samples in the profile and never attain a value of 1% of total pollen. Appendix 3 shows their detailed composition.

Also included on the pollen diagrams are the stratigraphic and humification profiles, as described in chapter 4, and the radiocarbon dates, which are explained in section 5.3 below.

5.2 Zonation of the pollen diagrams

Pollen diagrams are usually divided into a series of zones, each of which is considered to have some degree of internal uniformity. As in the subdivision of history into periods, this zoning is necessarily artificial, as the changes through time occur continuously and gradually. However, the process is an essential one, as it facilitates the description and interpretation of a pollen profile and its comparison and correlation with other diagrams.

5.2.1 Definition of pollen zones

A pollen zone has been defined as ' a body of sediment with a consistent and homogeneous fossil pollen and spore content that is distinguished from adjacent sediment bodies by differences in the kind and frequencies of its contained fossil pollen and spores' (Gordon and Birks, 1972). It should therefore be a strict 'assemblage zone', erected solely on the basis of its microfossils without any attempt at regional synthesis and correlation.

The concept of pollen assemblage zones was introduced into Quaternary palaeoecology by Cushing (1967). Previously, pollen zones had been defined on various criteria, in particular as units of inferred past vegetation or inferred past climate. In Britain, most pollen diagrams have been zoned by correlation with the system established by Godwin (1940). This zonation system divided the period from the closing phases of the Devensian glaciation to the present into a series of zones labelled I-VIII. Although the zones were originally based on fluctuations in tree pollen proportions, they came to be associated intricately with the underlying climatic changes, so that Godwin's zone VIIa, for example, was identified with the Atlantic period of Blytt and Sernander and thus had immediate climatic connotations (Moore and Webb, 1978). Later the zones became associated with radio-carbon datings, despite the lack of evidence for synchroneity of the zone boundaries in different parts of the country. The pollen zone thus came to be regarded as a period of time, having a particular type of climate resulting in certain features recorded in the proportions of various tree pollen types.

It was not until man's influence on vegetation history came to be recognised, for example by the work of Turner (1962), that local zonation schemes began to replace the classic system. Whilst climatically-determined changes may have been widespread and synchronous throughout Britain, anthropogenic effects must have been more localised and asynchronous. Thus for example the VIIa/VIIb boundary, defined by the elm decline, could no longer be held to have any temporal connotations once an anthropogenic cause became accepted. Nevertheless, the majority of published British pollen diagrams have adopted the Godwin zonation system either in a pure or a modified form, resulting in an over-simplification of vegetation history:

> " In effect the zonation of pollen diagrams has become an exercise in fitting the data from the site under investigation into a pre-determined mould. Undoubtedly the significance of many local and regional variations in the general picture has been lost as a result of this concern for conformity on the part of British palynologists."
>
> Moore and Webb, 1978.

The use of strict pollen assemblage zones, applicable only to the site being studied, is the only means by which diagrams can be examined objectively. If it does prove possible to match local zones at other sites, regional pollen assemblage zones can then be defined. This scheme is much more flexible and allows for the inevitable local variations in vegetation caused by differences in topography, soil and microclimate as well as anthropogenic factors. However, it is difficult to adhere rigidly to such a system, as subconscious bias is likely to occur. Palynologists tend to zone their diagrams not only by considering the observed pollen fluctuations, but also by drawing on previous experience, and looking for important changes which have been recognised in other pollen diagrams (Birks and Birks, 1980). If this element of subjectivity is to be avoided, new ways of implementing the assemblage zone system are required: hence the introduction of numerical methods, as described below.

5.2.2 Numerical zonation methods

With the advent of the computer age, numerical methods have become an essential tool in palaeoecology. Since 1970, a variety of techniques for numerical zonation of pollen diagrams have been devised which are rapid to implement and use consistent, well-defined criteria to produce strict pollen assemblage zones. In general, the results agree broadly with a zonation done by eye, but any discrepancies are interesting because they demand explanation. The investigator may benefit by being forced to look at the main numerical changes in his diagram, and to interpret them, as well as looking for correlative features with other diagrams, such as a perhaps statistically insignificant elm decline (Birks and Birks, 1980).

One of the earliest attempts to apply numerical classification methods to pollen data was that of Dale and Walker (1970). Using the techniques of information analysis, the differences between the pollen counts of samples were expressed in terms of dissimilarity coefficients. The least different pair of samples was then fused, and the analysis repeated so that groups of samples of measured similarity were formed. However, the program did not consider stratigraphic order, so that some stratigraphically separated samples were grouped together in clusters.

Later programs imposed stratigraphic order, so that only adjacent levels could be combined. The most successful and widely-used methods are those developed by Gordon and Birks (1972, 1974). In addition to agglomerative techniques, they employed divisive methods of classification, and ordination methods such as principal components analysis. All the methods produce remarkably similar results.

For the zonation of the Wensleydale pollen diagrams, the three simplest and most exhaustively tested of these numerical methods were used: CONSLINK, SPLITINF, AND SPLITLSQ. These techniques were first described by Gordon and Birks (1972), and later applied successfully to a large number of pollen diagrams by Gordon and Birks (1974), Birks (1974), Birks and Berglund (1979), and Peglar (1979).

CONSLINK is a constrained single-link clustering method, in which stratigraphic order is imposed so that only adjacent sample levels can be grouped together. Dissimilarity coefficients are calculated between all pairs of adjacent samples as follows:

$$DC_{ij} = \sum_{k=1}^{m} \left| pk_i - pk_j \right|$$

DC_{ij} is the dissimilarity coefficient between samples i and j, and pk_i is the proportion of pollen type k in sample i when the number of different pollen types is m. The two stratigraphically adjacent samples with the lowest dissimilarity are then grouped together, and the procedure is repeated until all the samples are joined in one group. Clusters of samples of similar pollen composition, or pollen assemblage zones, are thus obtained. As only adjacent samples are compared, this technique is not very effective in parts of a sequence characterised by small fluctuations in one or two pollen types which occur in small proportions. However it is particularly effective in displaying transitional levels.

The other two methods used are divisive rather than agglomerative, splitting the pollen diagram in such a way that the total numerical information it contains is maximally reduced at each division. SPLITINF divides the data in terms of the total information content, and SPLITLSQ divides the data on the sum of least squares deviations. These methods are potentially more sensitive in detecting quantitatively small but stratigraphically consistent changes that occur over several levels, as the whole sequence is examined rather than just pairs of adjacent samples.

A copy of the FORTRAN program which implements these numerical zonations methods was obtained from Dr. H. J. B. Birks, and the results of its application to the Wensleydale data are described below.

5.2.3 Zonation of the Wensleydale pollen diagrams

For each site, the zonation program was run once using the pollen counts for all the species and once using the data for arboreal pollen types only. Twenty divisions were requested for the Whirley Gill, Fleet Moss and Thornton Mire diagrams, and ten for the shorter Penhill profile. The results provide divisions of the pollen diagrams in order of importance, i.e. the most significant variations occur between the first two samples to be split (for the divisive methods) or the last two samples to be clustered together (for the agglomerative method). The earliest divisions produced by SPLITINF and SPLITLSQ usually correspond to zone boundaries, and the later divisions, which account for a lower decrease in total variation tend to correspond to boundaries between subzones. This distinction cannot be made so readily from CONSLINK results, as only adjacent samples are compared.

Figures 5.2-5.5 show the original 'subjective' zonation, produced before running the program, in comparison with the numerical zonations. For the numerical methods, the divisions are numbered in order of their importance. The final zones and subzones decided upon are shown on the right of each diagram. In general, the boundaries selected were those chosen by a majority of the techniques at an early stage in the analysis. However, the value of the divisions in describing and interpreting the pollen diagrams was also borne in mind, so that care was taken to ensure that the spacing was not too uneven. A minimum size for a zone or subzone of three samples was decided upon, with the exception of the bottom and top zones of a profile, which are likely to be incomplete.

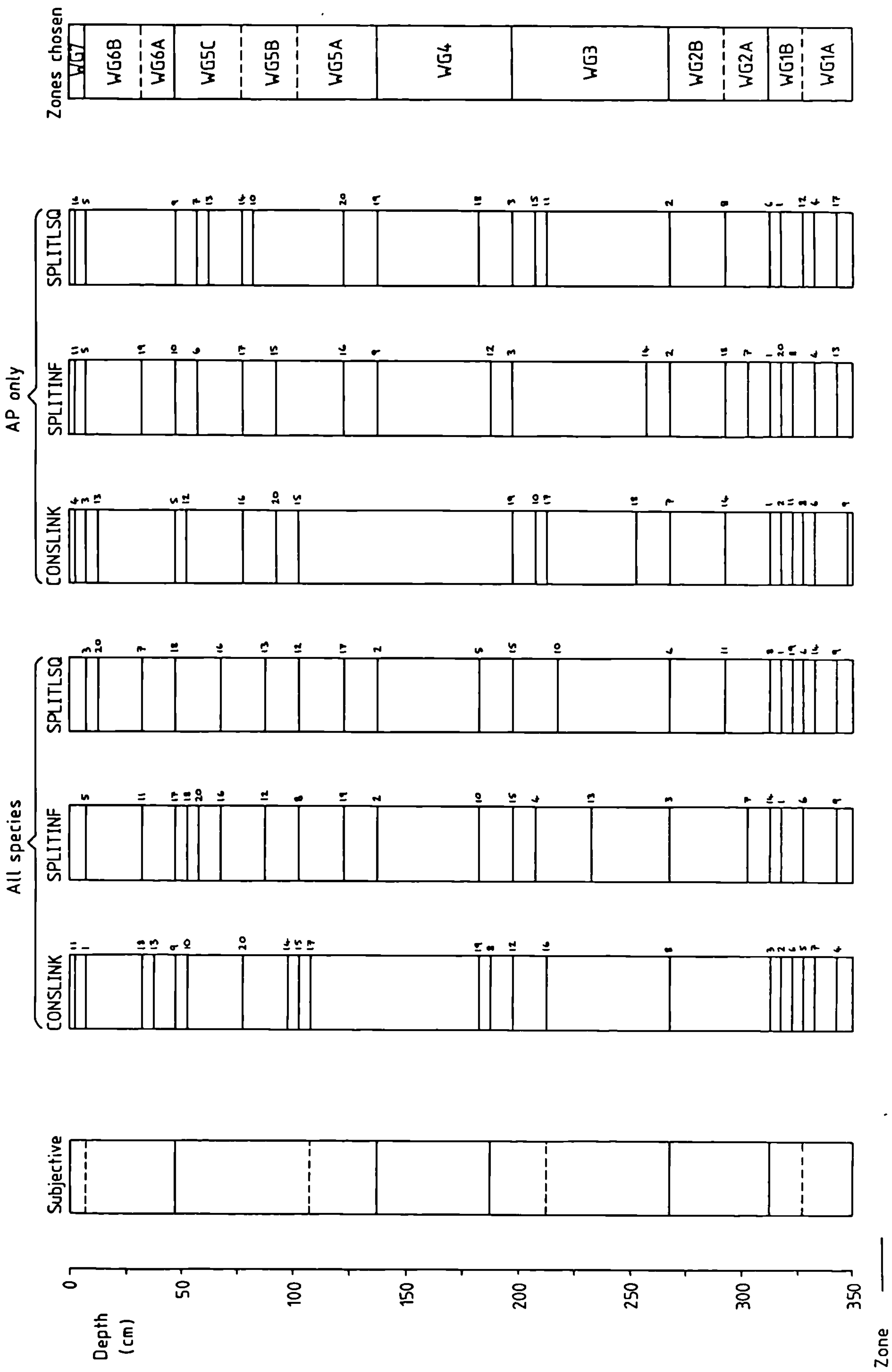


Figure 5.2: Whirley Gill zonation

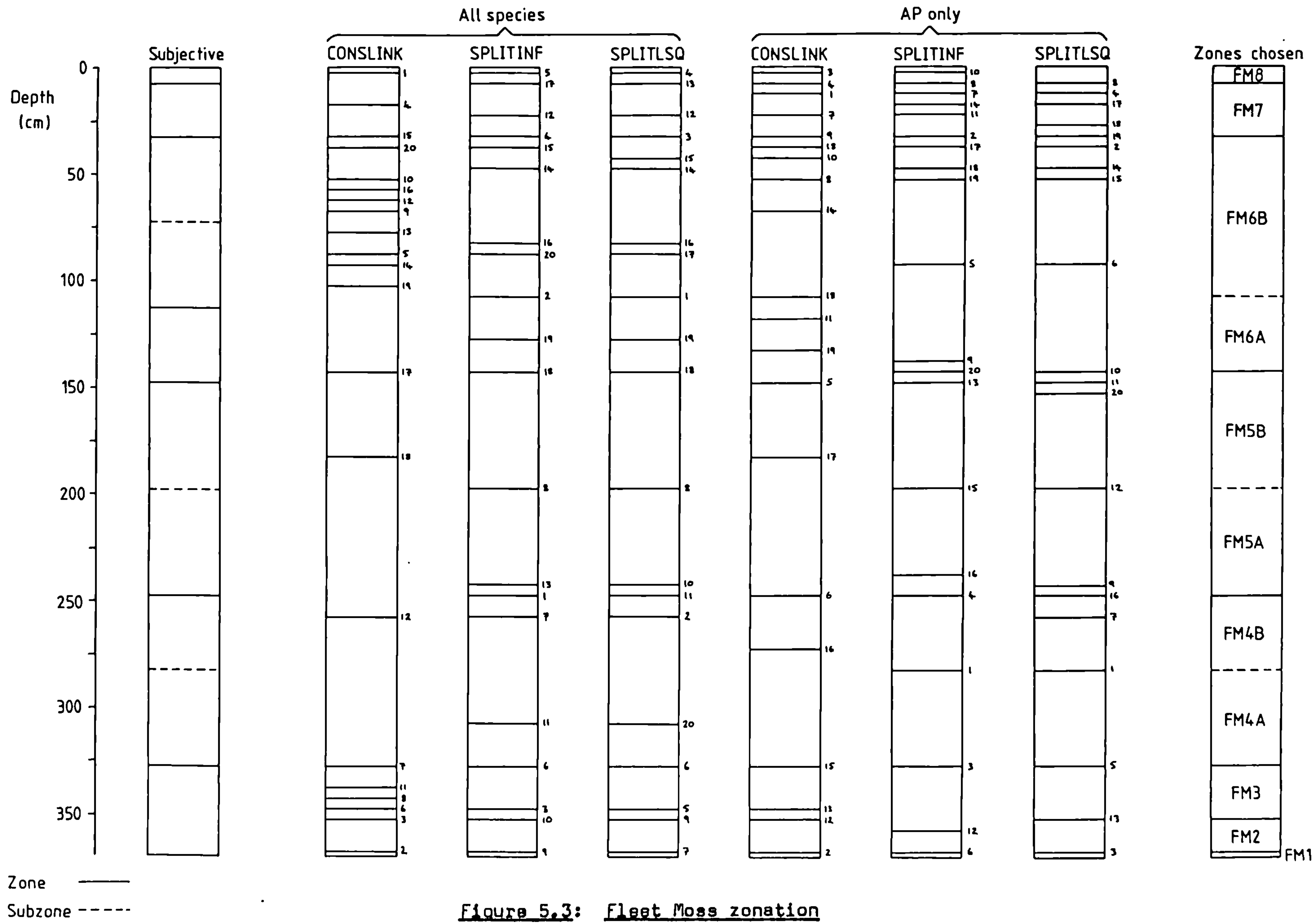


Figure 5.3: Fleet Moss zonation

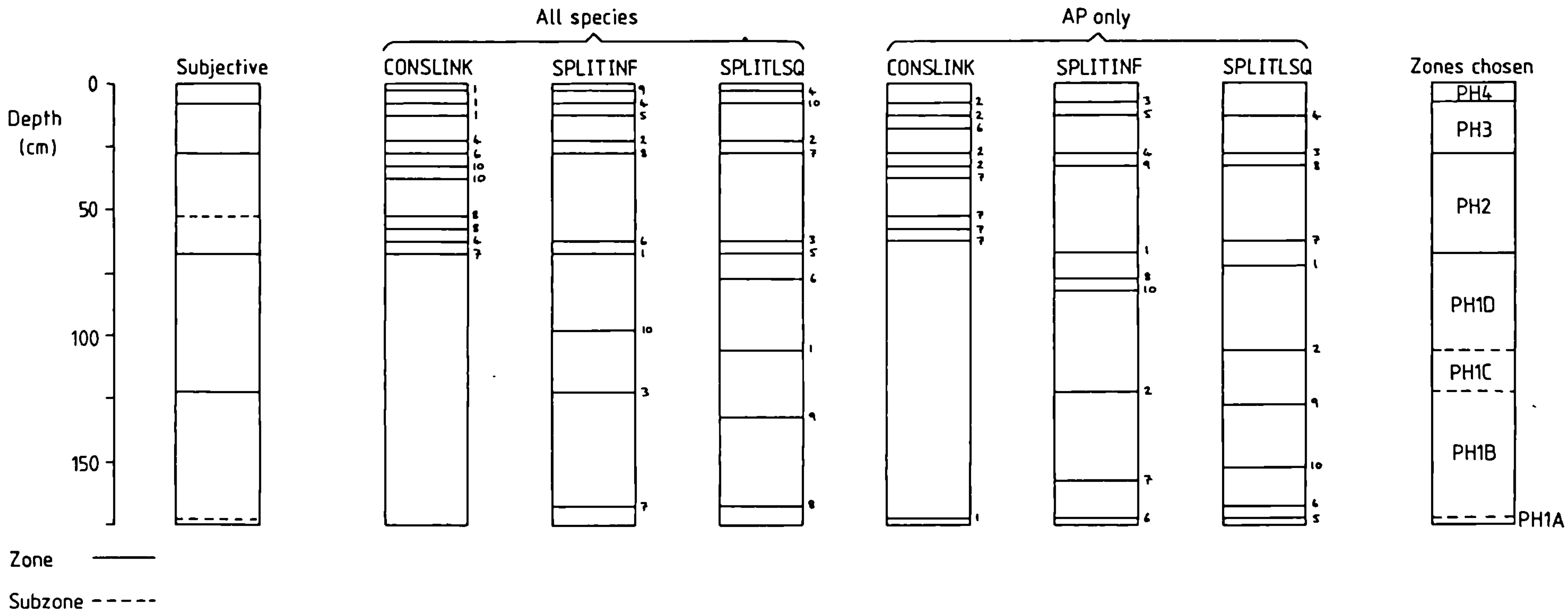


Figure 5.4: Penhill zonation

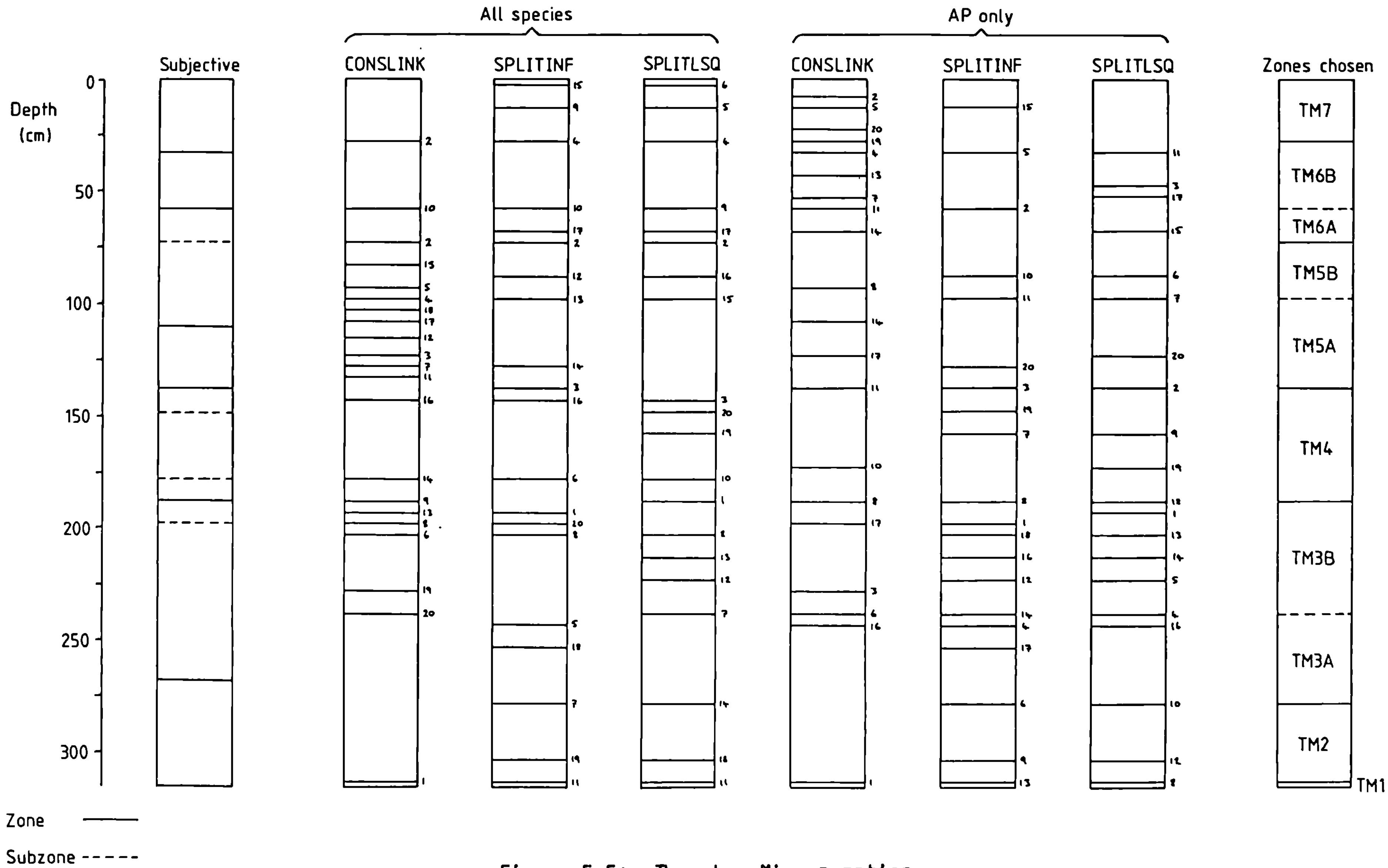


Figure 5.5: Thornton Mire zonation

5.3 Radiocarbon dating

Two series of radiocarbon age determinations, totalling 20 dates, were obtained for the Wensleydale pollen diagrams. The analyses were carried out by Dr. D. D. Harkness of the NERC Radiocarbon Laboratory, Glasgow, and funded by NERC.

The first series was submitted before the pollen analysis was complete, and consisted of seven dates. This was considered to be the absolute minimum necessary to provide an adequate chronology upon which to base the interpretation of vegetation history. As the Whirley Gill record was thought to be the longest and to show the general regional pattern of vegetation change, it was proposed to date the major features of this record and then correlate the records from the other sites with this time scale. Dates were therefore obtained in the first instance for the base of the peat at Whirley Gill, the boundary between zones WG1 and WG2, and the peak of a marked clearance episode in zone WG5B. The other dates obtained were for the base of the peat at each of the remaining three sites, and for the peak of a major clearance phase in zone TM4 which did not appear on the Whirley Gill diagram.

When funds were made available by NERC for a further series of radiocarbon assays, the policy of obtaining dates from the Whirley Gill record for features common to several sites was continued. The horizon at which elm declines and the *Plantago lanceolata* curve begins, just above the WG3/WG4 boundary, was dated, and also the zone boundaries WG2/WG3, WG4/WG5 and WG5/WG6. In addition, dates were obtained for features of the other pollen records which could not easily be dated by correlation with Whirley Gill. Unfortunately, the results of the first series of determinations were not available before the submission of the second series. However, the pollen analysis and zonation were complete. The Thornton Mire record proved to vary considerably from the general pattern, and so all the major zone boundaries for this site were dated. For Fleet Moss, the elm decline at the FM4/FM5 boundary was dated as it was thought that such a change might not be synchronous throughout Wensleydale. The other horizon dated at this site was a clearance phase just before the FM5/FM6 boundary. At Penhill, dates were obtained for the PH1B/1C and PH1D/PH2 boundaries. The L.P.A.Z.s PH1C and PH1D contain several minor clearance phases, culminating in more extensive clearance at the PH1/PH2 boundary; dating was therefore required to help establish the links between these vegetation changes and the nearby Iron Age (?) settlement.

The preparation of the samples for dating and the results obtained are described in Appendix 5. The dates are shown on the relevant pollen diagrams (see figs. 6.1-6.8) as conventional radiocarbon years B.P., to facilitate comparison with other dated records from the Pennines. However, in the interpretation of the records the possible inaccuracies inherent in radiocarbon determinations for older samples (see Appendix 5) are taken into account.

CHAPTER 6: THE POLLEN ASSEMBLAGE ZONES

6.1 Local pollen assemblage zones

6.1.1 Whirley Gill

6.1.2 Fleet Moss

6.1.3 Penhill

6.1.4 Thornton Mire

6.2 Regional pollen assemblage zones

THE POLLEN ASSEMBLAGE ZONES

6.1 Local pollen assemblage zones

6.1.1 Whirley Gill (Figures 6.1 and 6.2)

(i) WG1: *Betula*-Cyperaceae L.P.A.Z. (350–312·5cm)

This zone dates from 8950 ± 80 to 8160 ± 60 radiocarbon years B.P. The results of the numerical zonation methods show a high degree of variability within WG1: for very strict L.P.A.Z.s, it would have been necessary to divide almost every sample from the next, but this is clearly of little value in interpretation.

The zone is characterised by high values for *Betula* pollen (up to 47% TP/82% AP) and for Cyperaceae (up to 40% TP). The percentage of arboreal pollen increases from 40% TP at 350cm to over 70% TP at 315cm, and it is in this zone that *Salix* and *Pinus* attain their highest values in the profile, of 9% TP/20% AP and 7% TP/11% AP respectively. *Corylus* is infrequent in zone WG1A, but increases rapidly in WG1B to reach 39% TP/55% AP at 315cm; the AP diagram (figure 6.2) shows that this increase occurs at the expense of *Betula*. The only other tree pollen types in WG1A are *Juniperus* (2% TP/4·5% AP at 350cm), and occasional *Quercus* and *Ilex*. In WG1B there is no *Juniperus*, but continuous curves for *Quercus* and *Ulmus* are established, although neither attains 1% TP. A single grain of *Alnus* pollen occurs at 325cm.

The NAP spectrum is dominated by Cyperaceae, but Gramineae pollen is also frequent, particularly in the basal samples where it attains 18% TP. The proportion of Ericaceae increases through WG1 and reaches 24% TP at 315cm. A large number of other NAP types occur in this zone, including aquatics such as Menyanthes trifoliata which reaches a maximum of 3•3% TP at 345cm, Myriophyllum alterniflorum which constitutes 1•7% TP at 350cm and then declines and disappears, and Alisma plantago-aquatica. Filipendula ulmaria is particularly abundant at the base of WG1, where it comprises 9% TP, and then declines gradually through the zone to values of less than 1% TP in upper WG1B. Rumex acetosella type is more frequent in WG1A than in any subsequent zone, at up to 1•2% TP, and Umbelliferae pollen also achieves 1% TP at the base.

(ii) WG2: Corylus-Ericaceae-Betula L.P.A.Z. (312•5–267•5cm)

Zone WG2 covers the period from 8160 ± 60 to 6370 ± 70 radiocarbon years B.P. Corylus is overwhelmingly dominant, at 48-68% TP/62-83% AP. The next most abundant types are Ericaceae (7-16% TP) and Betula (7-13% TP/8-15% AP), but a variety of others are present in significant quantities.

As the numerical zonation results show (figure 5.2), the changes in the AP spectrum between zones WG1 and WG2 are very marked. The replacement of Betula by Corylus as the dominant type is the most obvious difference, but there are equally important changes in other arboreal species.

The proportion of arboreal pollen is high throughout this zone, at 75–85% TP, and the number of AP types is greater than in the previous zone. First Ulmus and then Quercus increase through zone WG2A (at the expense of Corylus), and both maintain values of around 6% TP/8% AP in WG2B. A continuous curve for Alnus begins in the upper part of WG2A and this species attains up to 4% TP/5•5% AP in WG2B. Pinus is still present but in reduced quantities, constituting less than 2% TP/3% AP. Salix is also much reduced, at values of less than 1% TP/AP. A few grains of _Ilex_ occur in WG2B, but _Juniperus_ is no longer found. _Tilia_ first occurs at 270cm, albeit only a single grain.

The number of NAP types is less than in WG1, and apart from Ericaceae, the most abundant are Cyperaceae and Gramineae. The proportions of these two types are noticeably higher in WG2B than in WG2A, reaching 7% TP and 5% TP respectively. _Filipendula_ occurs in all but one sample in WG2A, although never attaining 1% TP. Other types such as _Potentilla_ and Umbelliferae are represented only by occasional single grains. WG2B contains a greater variety of NAP types, including Umbelliferae, _Lotus_ type, _Potentilla_, _Hedera helix_ and _Mercurialis_. _Filipendula_, however, does not occur in this upper subzone.

From 300cm, _Pteridium_ spores are found in nearly every sample, although never attaining values of 1%.

(iii) WG3: _Corylus_-_Alnus_-_Quercus_ L.P.A.Z. (267•5–197•5cm)

The base of this zone is dated to 6370 ± 70 radiocarbon years B.P. The upper boundary is not dated, but from the date of 4790 ± 50 B.P. obtained for the 187•5cm depth it can be estimated at about 5000 years B.P. From the numerical zoning results (figure 5.2), it can be seen that WG3 is one of the most uniform zones of the pollen diagram.

Arboreal pollen is dominant throughout the zone, at 74–86% TP, but the proportion declines steadily to a minimum at 225cm and then increases again towards the upper boundary of WG3. _Corylus_ is still dominant, comprising 32-50% TP/39-60% AP, although it is less abundant than in WG2 and continues to decline slowly. _Alnus_ and _Quercus_ both increase sharply at the base of WG3 and attain values of up to 17% TP/21% AP and 18% TP/22% AP respectively. _Ulmus_ is also slightly more frequent than in the previous zone, achieving its maximum of

10% TP/12% AP.

The next most abundant pollen type is *Betula*, but this occurs in lower proportions than in earlier zones, between 3% TP/4% AP and 9% TP/11% AP. *Pinus* and *Salix* also continue to decline, being generally below 1% TP/AP. The other tree pollen types present in WG3 are *Tilia* and *Fraxinus*, both of which occur in most samples at less than 1 %TP/AP.

The NAP spectrum is dominated by Gramineae, Cyperaceae and Ericaceae, the proportions varying considerably throughout the zone. Ericaceous pollen decreases sharply at the base of WG3, but is the most abundant NAP type in the upper half of the zone. The proportion of Cyperaceae is quite steady at about 6% TP until it suddenly falls to less than 1 % TP at 205cm. Gramineae pollen increases through the lower half of the zone to peak at 240cm and 220cm and then declines again. Of the remaining NAP types, *Potentilla* is the most frequent, occurring in every sample from 255cm upwards and attaining up to 1•5% TP. Others include *Knautia*, *Artemisia*, Chenopodiaceae and *Urtica*, the variety of different types being greatest between 250cm and 230cm. *Pteridium* is also most frequently found in this part of the zone.

(iv) WG4: *Corylus*-Ericaceae-*Alnus* L.P.A.Z. (197•5–137•5cm)

The lower boundary of WG4 is estimated to date to about 5000 B.P. (*vide supra*), and the upper boundary is dated to 3930 ± 50 radiocarbon years B.P. The proportion of arboreal pollen is more variable than in previous zones, ranging from 61% to 83% TP, and shows an overall decline. However the pollen assemblage as a whole is remarkably uniform, particularly above 185cm (see figure 5.2).

Corylus remains dominant, although at slightly reduced values of 32–40% TP/47–53% AP. The zone begins with a decrease in the proportion of *Ulmus*, and a further decrease in this pollen type occurs at 185cm so that it generally only constitutes about 2% TP/3% AP. *Quercus* does not follow this pattern, but remains at similar values to those of WG3, while *Betula* shows an initial temporary increase before settling down to an average value of about 4% TP/5% AP. *Alnus* also increases sharply at the base of WG4, and whilst its maximum of 28% TP/34% AP is achieved here it continues to occur in relatively high proportions, being the second most frequent AP type throughout this zone. *Tilia* and *Fraxinus* both occur in every sample of WG4, and attain higher values than in previous zones. *Salix* and *Pinus* are also found in low proportions, and *Carpinus* occurs in several samples.

Ericaceae pollen increases considerably in this zone, reaching up to 36% TP. Gramineae increases sharply at the base of WG4 to 10% TP and then declines again. Cyperaceae is much reduced, averaging less than 2% TP. Of particular interest is the diversity of other NAP types. *Plantago lanceolata* occurs in most samples from 185cm upwards, and cereal pollen is also found, particularly in the lower part of WG4. Other cultural indicators present include *Artemisia*, *Urtica* and Chenopodiaceae. In addition, *Pteridium* occurs in most samples and reaches over 2% TP at 140cm.

(v) WG5: Ericaceae-*Corylus*-*Alnus* L.P.A.Z. (137·5–47·5cm)

This zone dates from 3930 ± 50 to 2280 ± 50 radiocarbon years B.P. Whilst tree pollen is still dominant in most samples, the values are very variable, ranging from 35% TP to 72% TP, and there is a progressive reduction in the proportion of arboreal pollen through the zone. The most marked trough in the total %AP curve occurs at 95cm, and this horizon has been dated to 3040 ± 50 radiocarbon years B.P.

WG5A begins with a sharp decline in total arboreal pollen to a minimum of 53% TP at 125cm. Ulmus, Quercus and Corylus are particularly affected, although Corylus remains the dominant AP type at 23–36% TP/ 43–52% AP. Ulmus declines to less than 1% TP/AP and Quercus to 6% TP although its proportion of the arboreal pollen increases at first. Tilia also becomes less frequent, but Betula appears largely unaffected and Alnus, Fraxinus and Carpinus tend to increase. Pinus and Salix are still present at low values, and Fagus occurs occasionally.

The WG5A reduction in arboreal pollen is accompanied by increases in Ericaceae, Cyperaceae and Gramineae. There are also peaks in the Plantago lanceolata and cereal pollen curves, and other clearance indicators such as Rumex acetosella type, Urtica, Artemisia, Chenopodiaceae and Pteridium increase.

After a temporary recovery in arboreal pollen at the end of WG5A, a very pronounced decrease occurs in WG5B. Alnus and Corylus are particularly affected this time, although Quercus and Ulmus also decline further and Tilia becomes infrequent. Corylus drops to a minimum of 14% TP but is still the most abundant tree pollen type at over 40%AP. Betula again is unaffected by the general decline and its proportion of the arboreal total increases temporarily, as do those of Fraxinus and Pinus. Fagus reaches its maximum of 1·5% AP. Ericaceae, Cyperaceae and Gramineae proportions all increase to peaks at 95–90cm, as does Plantago lanceolata which reaches its maximum in the profile of 6% TP. A greater variety of other NAP types is present than in any previous zone, and they include cereals and all the 'clearance indicators' found in WG5A.

The proportion of arboreal pollen recovers again in upper WG5B, and this trend continues in WG5C although a small trough occurs at 55cm. Most of the tree species increase from their WG5B minima, but Fagus does not occur in this zone and Tilia is rare. Corylus and Alnus remain most abundant, but the general decline in the tree types at 55cm is followed by increases in Betula and Fraxinus. Gramineae and Plantago lanceolata values are lower than in the rest of WG5, but Ericaceae and Cyperaceae remain quite high and Rumex acetosella type, Urtica, Artemisia, Chenopodiaceae and Pteridium are still present.

(vi) WG6: Ericaceae-Corylus-Cyperaceae L.P.A.Z. (47•5-7•5cm)

Zone WG6 begins at 2280 ± 50 radiocarbon years B.P. The proportion of arboreal pollen is fairly high (about 60% TP) at the base but then declines rapidly and permanently.

Corylus increases sharply at the base of WG6A at the expense of NAP types, but then drops again and averages about 18% TP in WG6B. It is the reduction in this species which is mainly responsible for the fall in total AP, as whilst the other trees also decline their proportions are relatively small in the first place. Quercus is quite stable at about 5% TP and its proportion of the total AP increases slightly in WG6B, while Ulmus declines to less than 1% AP. Alnus maintains a fairly steady 20% AP but its % TP value gradually falls. Betula and Fraxinus also decline at the beginning of WG6, and Tilia does not occur, but Fagus is more frequent than in previous zones.

Ericaceae pollen becomes the most common type, increasing gradually through WG6, and Cyperaceae and Gramineae also expand. Plantago lanceolata maintains relatively high values (1-4% TP) and pollen of agricultural weeds and other NAP types indicating open ground is abundant, the diversity increasing through the zone.

(vii) WG7: Ericaceae L.P.A.Z. (7·5–0cm)

No radiocarbon dates are available for this zone, but it marks a drastic change in vegetation, the greatest between-samples variation of the whole profile occurring at the WG6/WG7 boundary. The proportion of arboreal pollen falls steeply from 35% TP to only 10% TP at this level, Corylus, Quercus, Alnus and Betula being affected. The % AP value for Corylus also drops steeply, giving rise to increases in the relative proportions of Quercus, Ulmus, Pinus and Fraxinus although their % TP values are small. A single grain of Acer pollen occurs at 0cm.

Ericaceae pollen is overwhelmingly dominant, constituting 76% TP at 5cm. Gramineae values are also comparatively high, at 10–15% TP, but Cyperaceae decreases sharply. Cereal and weed pollen types occur, but the high Ericaceae values have a masking effect so that these other NAP types are under-represented in the pollen assemblage.

6.1.2 Fleet Moss (Figures 6.3 and 6.4)

(i) FM1: Gramineae-*Corylus*-*Pinus* L.P.A.Z. (370-367•5cm)

Whilst this zone comprises only one sample (370cm), the numerical zonation results (figure 5.3) show that the pollen assemblage is too different to permit inclusion in the subsequent zone. The dissimilarity coefficients between the 370cm and 365cm samples are the second highest in the profile. The date of 8510 ± 50 radiocarbon years B.P. obtained for the 365cm level sets an upper limit for the chronological extent of FM1, but as this assemblage is from a highly compacted mineral soil it is not possible to ascertain the total length of time represented.

The proportions of arboreal and non-arboreal pollen are approximately equal. *Corylus* is the dominant AP type, at 27% TP/55% AP, followed by *Pinus* at 15% TP/31% AP and *Betula* at 4% TP/8% AP. The other AP types present are *Ulmus* and *Salix* (both 1% TP/3% AP) and *Quercus* (less than 1% TP/AP).

Gramineae is the most abundant pollen type overall, at 34% TP, and the next most frequent NAP type is *Rumex acetosella* type, comprising 10% TP. Ericaceae and Cyperaceae pollen are also present in small quantities, and the only other type found is a single grain of Caryophyllaceae type.

(ii) FM2: *Corylus*-*Rumex*-*Betula* L.P.A.Z. (367•5-352•5cm)

The 365cm level of this zone is dated to 8510 ± 50 radiocarbon years B.P., but no date is available for its upper boundary.

Arboreal pollen is dominant, comprising 62-73% TP, with *Corylus* most abundant at over 36% TP/58% AP. *Pinus* declines sharply between FM1 and FM2, and averages about 5% TP/6% AP. *Betula*, *Ulmus* and *Quercus* all increase at the boundary, and attain values of 10% TP/14% AP, 7% TP/11% AP and 6% TP/8% AP respectively. Salix comprises 2% TP/3% AP at the beginning of FM2 but then decreases, and Ilex follows a similar pattern, achieving 1% TP/2% AP in early FM2 but being absent by the end of the zone. Alnus occurs for the first time at 350cm, at about 2% TP/3% AP.

The NAP spectrum is dominated by Rumex acetosella type, which constitutes 17–19% TP. Gramineae is much reduced, at only 4–13% TP, as is Ericaceae at less than 1% TP, but Cyperaceae pollen increases slightly and occasional grains of Umbelliferae and Ranunculaceae pollen are also present.

(iii) FM3: Corylus–Ericaceae–Betula L.P.A.Z. (352•5–327•5cm)

In terms of its arboreal pollen content, this zone is quite similar to FM2. Arboreal pollen constitutes 66–73% TP, with Corylus still dominant although slightly reduced at 31–44% TP/46–59% AP. Betula remains the next most frequent AP type, reaching values of up to 12% TP/18% AP before declining towards the top of FM3. Alnus also increases in FM3, attaining 5% TP/6% AP at 340cm. The proportions of Quercus, Ulmus and Pinus are quite variable, but generally similar to those of FM2, averaging 6% TP, 7% TP and 5% TP respectively. Salix maintains values of about 1% TP/2% AP, but Ilex is no longer present.

It is the NAP assemblage of FM3 which shows the most variation from that of FM2. Rumex drops from 19% TP at the top of FM2 to less than 1% TP at the base of FM3, and is then absent from the rest of this zone. In contrast, Ericaceae increases from less than 1% TP in FM2 to 9% TP at 350cm and continues to increase through FM3, attaining values of up to 27% TP. Gramineae also increases sharply at the FM2/FM3 boundary, reaching 19% TP before declining again to low values.

Cyperaceae pollen continues to average about 4% TP. A greater variety of other NAP types is present than in FM2, although none of them reach 1% TP. The more frequent types are _Filipendula_, _Lotus_ type, Umbelliferae and _Myriophyllum alterniflorum_. _Pteridium_ occurs for the first time at 350cm.

(iv) FM4: _Corylus_-_Alnus_-_Quercus_ L.P.A.Z. (327•5–246•25cm)

The upper boundary of this zone is dated to 4680 ± 50 radiocarbon years B.P. It is subdivided at 282•5cm, largely on the basis of changes in the AP assemblage.

The proportion of arboreal pollen increases sharply at the FM3/FM4 boundary, and remains at about 85% TP throughout FM4A before declining through FM4B to less than 70% TP. _Corylus_ is still dominant, increasing to about 55% TP/60% AP at the base of FM4 but showing a general decline towards the top of the zone. _Alnus_ increases gradually through FM4, attaining values of up to 20% TP/25% AP. _Quercus_ also reaches higher values than in previous zones, but is quite steady at about 10% TP/12% AP. _Ulmus_ and _Betula_ are both reduced, averaging about 6% TP/7% AP, and _Pinus_ declines sharply at the FM3/FM4 boundary and then declines still further to less than 1% TP in FM4B. _Salix_ is still present at low values. _Tilia_ occurs for the first time at the base of FM4A, and becomes more frequent in FM4B, and _Fraxinus_ first appears at the base of FM4B and then occurs in almost every sample. A single grain of _Fagus_ pollen also occurs in FM4B.

The NAP spectrum is dominated by Ericaceae, Cyperaceae and Gramineae, although their proportions are quite variable. Ericaceae values drop steeply at the FM3/FM4 boundary, and continue to decrease through FM4A, to a minimum of about 2% TP, before increasing again in

FM4B. Cyperaceae values show the opposite trends, a peak of 10% TP coinciding with the Ericaceae minimum. The proportion of Gramineae pollen is low at the base of FM4 but rises gradually through the zone, reaching 16% TP at 250cm, and then dropping sharply to 4% TP. A few grains of cereal-type pollen occur at 252•5cm and 247•5cm. FM4B shows a greater variety of other NAP types than any previous zone, including Rumex acetosella type, Urtica, Chenopodiaceae and Potentilla. Pteridium occurs in most FM4 samples but never attains 1% TP.

(v) FM5: Corylus-Ericaceae-Alnus L.P.A.Z. (246•25–142•5cm)

The base of this zone is dated to 4680 ± 50 radiocarbon years B.P., and marks the 'elm decline'. FM5 is subdivided at 196•25cm, where significant changes occur in both AP and NAP components, but the pollen assemblage within each subzone is quite uniform, as shown by the numerical zoning results (figure 5.3).

The decline of Ulmus to less than 1% TP at the FM4/FM5 boundary is part of an overall reduction in arboreal pollen, which reaches a minimum at 245cm of 55% TP. Betula and particularly Corylus are also reduced, although Corylus values immediately increase again above 245cm. Quercus values remain stable at around 9% TP, and Pinus at less than 1% TP, while Alnus increases to a peak of 22% TP at 235cm. Tilia is more frequent in FM5, particularly FM5A, than in any other zone, sometimes exceeding 1% AP although never attaining 1% TP. Fraxinus and Fagus are also more frequent in this zone, and single grains of Carpinus are often found, especially in FM5B.

The FM5A/FM5B boundary is marked by an apparent decline in all the major AP types, but particularly Corylus, although their % AP values are little changed. This is due mainly to a sharp increase in

Ericaceae values, from 15% TP to 47% TP. Ericaceous pollen is the most abundant NAP type, and is much more frequent in FM5 than in previous zones. Cyperaceae values are slightly lower than in FM4, averaging about 4% TP, and Gramineae pollen is also relatively infrequent in FM5A, but increases in FM5B. Plantago lanceolata first occurs at the base of FM5A, but is much more abundant in FM5B, where it shows peaks of up to 4% TP coinciding with low AP values and the occurrence of cereal pollen, a large variety of other NAP types, and Pteridium spores. The most marked peak of such clearance indicators occurs around 155cm, and this horizon has been dated to 3070 ± 50 B.P.

(vi) FM6: Ericaceae-Corylus-Alnus L.P.A.Z. (142•5–32•5cm)

This zone is marked by a relatively high degree of variability (see figure 5.3), and the gradual rise to dominance of NAP types. It is subdivided at 107•5cm, mainly because of changes in the NAP spectrum.

The proportion of arboreal pollen shows a general decrease from over 80% TP to about 30% TP, Corylus and Alnus in particular being much reduced. Betula, Ulmus and Fraxinus values are similar to those of FM5, and Quercus is only slightly reduced, but Tilia and Fagus become scarce.

Ericaceae pollen is the most abundant overall, attaining values of up to 57% TP. Cyperaceae and Gramineae values are low in FM6A, but increase gradually in FM6B, reaching peaks of 24% TP and 16% TP respectively. Plantago lanceolata is relatively infrequent in FM6A, but shows a pronounced peak in FM6B coinciding with a decline in total AP, the occurrence of cereal pollen, a peak in the Pteridium curve, and an increase in the number of other NAP types present.

(vii) FM7: Ericaceae L.P.A.Z. (32•5–7•5cm)

Zone FM7 shows considerable variability, particularly with regard to its AP assemblage. The FM6/FM7 boundary is marked by a sharp drop in the proportion of arboreal pollen, to only 15% TP, and this value continues to decrease through FM7. All the tree types decline to low % TP values, Corylus remaining the most abundant at 8% TP while Betula, Quercus and Alnus are all reduced to less than 3% TP. The % AP diagram (figure 6.4) shows that Alnus, Quercus, Betula, Pinus and Fagus all increase their proportions of the AP sum while Corylus declines. Fraxinus and Carpinus also remain relatively frequent, and Ulmus starts to increase towards the top of FM7, but Tilia is completely absent from this zone.

The differences between the AP assemblages of the 15cm and 10cm samples are the most marked in the profile, as figure 5.3 shows. However, when the total assemblages are considered, the 10cm level appears to be more similar to FM7 than to FM8, and so the boundary has been placed at 7•5cm. The main change at the top of FM7 is the rapid decline of Corylus, to only 13% AP. This minimum is accompanied by the maximum Fraxinus value for the profile, of 10% AP, and increases also in Quercus, Ulmus and Betula.

The reason for the drastic reduction in tree pollen is a great increase in Ericaceae pollen, which rises from 22% TP at 35cm to 54% TP at 30cm and averages 68% TP in FM7. This tends to swamp the contribution of other NAP types, but it appears that Cyperaceae values are lower than in FM6 and Gramineae values remain fairly high at an average of 7% TP. Plantago lanceolata is also abundant in the lower half of FM7, reaching values of over 6% TP before declining to less than 1% TP in response to the Ericaceae rise. The number of other NAP types present is generally higher than in previous zones, and they include Cerealia, Rumex acetosella type, Urtica, Chenopodiaceae and Artemisia. Pteridium, however, is less frequent than in FM6.

(viii) FM8: Ericaceae-Cyperaceae L.P.A.Z. (7·5–0cm)

The uppermost zone of the Fleet Moss profile comprises only two sample levels, but the pollen assemblage shows a considerable degree of variation, particularly with regard to the NAP types.

The proportion of arboreal pollen remains low, at about 11% TP. Corylus shows a relative increase, once more becoming the dominant AP type at 26–33% AP. In response to this, Alnus, Quercus, Fraxinus and Fagus % AP values are lower than in FM7, but Betula, Ulmus, Pinus and Salix all show increased proportions. In the surface sample, Pinus, Ulmus and Tilia values are unusually high: 9% AP, 13% AP and 2% AP respectively.

Ericaceae and Cyperaceae are overwhelmingly dominant in FM8, but at 5cm Ericaceae is most abundant at 52% TP, and Cyperaceae is quite low at 9% TP, while at 0cm the position is reversed, Cyperaceae constituting 62% TP and Ericaceae being reduced to only 15% TP. Gramineae pollen is the next most frequent, with values of 16% TP at 5cm and 4% TP at 0cm, followed by Plantago lanceolata at about 3% TP. The number of other NAP types is less than in FM7, but this is probably due largely to the swamping effect of the large quantities of Ericaceae and Cyperaceae pollen. Caryophyllaceae pollen is particularly frequent, however.

6.1.3 Penhill (figures 6.5 and 6.6)

As Ericaceae pollen is dominant throughout this profile, the L.P.A.Z.s are distinguished by the next most important pollen types.

(i) PH1: Corylus-Alnus-Quercus L.P.A.Z. (175–67·5cm)

This zone dates from 4820 ± 50 to 2410 ± 50 radiocarbon years B.P. As the results of the numerical zonation (figure 5.4) show, the pollen assemblage is remarkably uniform throughout this zone. The changes which do occur are gradual ones, so that the dissimilarity coefficients between adjacent samples are generally very low. Whilst the 175cm and 170cm samples show the highest dissimilarity in the profile in terms of their AP content, the coefficient is in fact unusually low.

Arboreal pollen is dominant overall, ranging from 40% TP to 72% TP, but shows a progressive decline in subzones PH1C and PH1D. Corylus is the most abundant AP type throughout PH1, comprising 20–43% TP/42–60% AP, and its curve tends to follow that of the total % AP values, being highest in PH1B and then decreasing at the PH1B/PH1C boundary and again at the PH1C/PH1D division. Alnus is the next most frequent, at 10–20% TP/ 15–34% AP; its values increase from the base of the profile and then show a marked trough in mid-PH1B, attaining high values again in PH1C and PH1D. Quercus values are relatively high in PH1A and PH1B, at around 9% TP/ 13% AP, but decline to about 5% TP/10% AP in PH1C and PH1D. Betula remains quite constant at around 4% TP/7% AP, but shows a slight increase at the top of PH1D. The highest value for Ulmus, of 6% TP/10% AP, occurs in PH1A, but it decreases sharply at the PH1A/PH1B boundary to less than 1% TP/AP. This is regarded as the main 'elm decline'. It then rises again gradually through PH1B, reaching 4·5% TP/7% AP before dropping again at the PH1B/PH1C boundary. This secondary elm decline is dated to 3850 ± 50 B.P. The other AP types present in PH1 are Fraxinus, at up to

1% TP/2% AP, and Salix, Pinus, Carpinus and Tilia at less than 1% TP/AP. Tilia is noticeably less frequent from the PH1B/PH1C boundary onwards.

The NAP spectrum is overwhelmingly dominated by Ericaceae pollen, at 17–55% TP. This pollen type shows a slight increase at the PH1B/PH1C boundary, and a further, greater increase at the PH1C/PH1D division, thus displaying the complementary trends to those of Corylus. Cyperaceae values are variable, ranging from less than 1% TP to 14% TP, but particularly low in PH1D. Gramineae pollen is fairly infrequent, at up to 3% TP, but is generally more abundant in PH1C and PH1D than in the earlier subzones. Plantago lanceolata shows a similar pattern, being occasionally present, at less than 1 % TP, from 170cm onwards but reaching values of 1–2% TP in PH1C and PH1D. The number of other NAP types present also increases above PH1B, the most frequent ones being Cerealia, Filipendula, Potentilla and Caryophyllaceae. Pteridium also is occasionally present in PH1B but increases considerably in PH1C and PH1D.

(ii) PH2: Cyperaceae–Corylus–Alnus L.P.A.Z. (67•5–27•5cm)

The PH1/PH2 boundary is dated to 2410 $\pm$ 50 radiocarbon years B.P., and is marked by a steep fall in the total AP curve, from 63% TP at 70cm to 24% TP at 65cm. Whilst tree pollen values recover slightly, they average only 33% TP throughout PH2.

The decline in total AP is mainly caused by sharp drops in both Corylus and Alnus, these species averaging 16% TP and 6% TP in PH2. However, as figure 6.6 shows, the proportion of the arboreal pollen represented by Corylus remains high, while that of Alnus shows a marked decline. The other AP types seem largely unaffected, their % TP values remaining similar to those of PH1, but as Alnus declines, the % AP values for Betula and Pinus increase. Fagus pollen occurs for the first time in this zone, although it never attains 1% TP.

Ericaceae pollen increases sharply at the PH1/PH2 boundary, but then drops again and averages 42% TP. Cyperaceae pollen is more abundant in PH2 than in any other zone, reaching up to 28% TP, and Gramineae, Plantago lanceolata and other NAP types are also more frequent in PH2 than in PH1. Gramineae pollen averages about 5% TP and Plantago lanceolata attains values of up to 5% TP, its main peak at 60cm coinciding with the minimum total AP value and the occurrence of a relatively high number of other NAP types, including Cerealia. The maximum value for Pteridium also occurs at this level.

(iii) PH3: Cyperaceae–Gramineae–Corylus L.P.A.Z. (27•5–7•5cm)

The PH2/PH3 boundary is marked by a further steep drop in total AP, from 34% TP at 30cm to 15% TP at 25cm. This time it is Corylus and Betula which account for the decline in tree pollen, as these species decrease to 7% TP and 2% TP respectively. Quercus, Pinus and Carpinus values remain similar to those of PH2, but Alnus is reduced to about 3% TP. Ulmus, Tilia and Fagus do not occur at all in PH3.

Ericaceae values are almost unchanged between 30cm and 25cm, but then increase steeply, to 95% TP at 10cm. Cyperaceae increases to a maximum of 31% TP at 25cm, but then declines again as Ericaceae increases. Gramineae also increases in PH3, to a peak of 10% TP at 20cm. This peak coincides with relatively high values for Plantago lanceolata (4% TP) and Cerealia (2% TP), as well as the occurrence of a large number of other NAP types, including Rumex acetosella type, Filipendula, Knautia, and Primulaceae.

(iv) PH4: Corylus–Alnus–Gramineae–Cyperaceae L.P.A.Z. (7•5–0cm)

As figure 5.4 shows, there are considerable differences between all the pollen samples from 15cm to the surface, but the 7•5cm level marks the most dramatic change as the increase of Ericaceae at the expense of arboreal pollen is reversed. Total AP increases sharply from 2% TP at 10cm to almost 50% TP at the surface. Nearly all the AP types increase, including Ulmus and Fagus which were absent from PH3, but excluding Tilia and Carpinus, which do not occur at all in PH4. The % AP diagram (figure 6.6) shows that Betula, Pinus and Quercus proportions are reduced, while all the other AP types become relatively more frequent, particularly Ulmus.

Ericaceae pollen declines from its peak of 95% TP at 10cm to 33% TP at 0cm, while Cyperaceae and Gramineae increase slightly to values of 7% TP and 4% TP respectively. The number of other NAP types present is quite high, particularly in view of the swamping effect of the high Ericaceae values.

6.1.4 Thornton Mire (figures 6.7 and 6.8)

(i) TM1: Pinus-Betula-Cyperaceae L.P.A.Z. (315-312•5cm)

The base of this profile is dated to 8480 ± 90 radiocarbon years B.P. Whilst the basal zone comprises only one sample (315cm), the differences between the pollen assemblages at 315cm and 310cm, and indeed between 315cm and the whole of TM2 are so great that a separate zone is necessary (see figure 5.5).

Arboreal pollen predominates, at 67% TP, and Pinus is the most abundant type at 24% TP/36% AP, followed by Betula at 18% TP/27% AP. Corylus pollen constitutes 14% TP/21% AP and Salix 11% TP/16% AP, and the only other tree pollen in TM1 is a single grain of Quercus type.

The NAP spectrum is dominated by Cyperaceae, Filipendula and Gramineae, which contribute 15% TP, 7% TP, and 8% TP respectively. The next most abundant NAP type is Umbelliferae (2% TP), and Primulaceae, Rumex acetosella type and Compositae tubuliflorae are also represented at less than 1% TP.

(ii) TM2: Corylus-Salix-Pinus-Betula L.P.A.Z. (312•5-277•5cm)

This zone dates from shortly after 8480 (vide supra) to 7840 ± 60 radiocarbon years B.P. The TM1/TM2 boundary is marked by an increase in total tree pollen, which averages about 90% TP throughout TM2. The number of different AP types present also increases.

The Corylus curve rises steeply to about 45% TP/50% AP, and then declines slightly as Salix increases to a peak of 37% TP/40% AP at 295cm. Ulmus is present from 310cm and increases gradually through TM2 to 10% TP at 280cm. The AP types which decline in TM2 are Pinus and Betula, which drop to 10% TP and 7% TP respectively by 285cm. Quercus pollen is present in most samples, although generally only at less than

1% TP, and the other tree species present in very small quantities are Tilia (at 285cm and 280cm), Fraxinus (at 295cm) and Ilex (at 285cm).

All the NAP types decline at the TM1/TM2 boundary as AP increases, but the most frequent types are still Cyperaceae, Filipendula and Gramineae, which average about 2-3% TP each. Compositae tubuliflorae pollen increases to a peak of 3% TP at 290cm, and Ericaceae, Umbelliferae, Artemisia and Rumex acetosella type are amongst the other NAP types present. Pteridium spores also occur in small quantities in most TM2 samples.

(iii) TM3: Corylus-Salix-Pinus-Ulmus L.P.A.Z. (277•5-187•5cm)

Zone TM3 represents the period from 7840 $\pm$ 60 to 4550 $\pm$ 50 radiocarbon years B.P. Arboreal pollen remains dominant, averaging 90% TP throughout most of TM3, although it declines slightly towards the top of the zone.

Corylus pollen is the most abundant type overall, with an average value of about 30% TP/35% AP. However Salix, after a sharp decline at the TM2/TM3 boundary to only 9% TP/AP, increases slowly through TM3A and then rapidly at the TM3A/TM3B division from 17% TP/19% AP at 240cm to 58% TP/59% AP at 235cm. In TM3B, Salix and Corylus are alternately the most frequent types, before Salix declines sharply to less than 1% TP/AP at 190cm. Pinus, Betula, Ulmus and Quercus all increase at the TM2/TM3 boundary. Pinus averages 15% TP/18% AP in TM3A and then declines to 5% TP/AP at 235cm and continues to decrease through TM3B. Betula shows a similar pattern, reaching values of up to 13% TP/15% AP in TM3A but declining towards the top of this subzone and averaging only about 4% TP/AP in TM3B. Ulmus maintains values of around 11% TP/13% AP through TM3A, but like Betula and Pinus decreases at the

TM3A/TM3B boundary in response to the *Salix* rise and comprises about 8% TP/AP in TM3B. The other species to increase in early TM3, *Quercus*, remains at relatively low values (up to 7% TP/AP) throughout the zone. *Alnus* increases from mid-TM3A, to attain 19% TP/26% AP at the top of TM3B. *Tilia* occurs sporadically at less than 1% TP throughout TM3 but becomes more frequent in upper TM3B, where it reaches its peak in the profile of 1 % TP. *Ilex* is absent from TM3A but occurs in most samples in TM3B, at up to 1% TP, and occasional grains of *Fraxinus* and *Fagus* are also found.

NAP values remain similar to those of TM2, with Cyperaceae, Gramineae and *Filipendula* dominant, the former two increasing as total AP declines at the top of TM3. A large number of other NAP types occur, particularly in TM3B, including Umbelliferae, Caryophyllaceae and *Artemisia*, but Compositae tubuliflorae pollen is markedly less frequent than in TM2. Ericaceae pollen is more frequent than in TM2 but usually only occurs at less than 1% TP.

(iv) TM4: Cyperaceae-Gramineae-*Alnus*-*Corylus* L.P.A.Z. (187•5–137•5cm)

This zone dates from 4550 ± 50 to 3220 ± 50 radiocarbon years B.P., and is marked by a great reduction in total tree pollen. Total AP drops from 73% TP at the top of TM3 to a minimum of 10•5% TP at 150cm, and then increases again towards the top of TM4. A slight temporary recovery at 165cm is dated to 3600 ± 80 B.P. Whilst the differences between adjacent samples at the TM3/TM4 boundary are not particularly great, the assemblage of TM4 as a whole is very different to that of TM3 (see figure 5.5).

Most of the major tree pollen types decline at the TM3/TM4 boundary, but *Alnus* initially increases, to a peak of 28% TP, before its decline begins, and Quercus is completely unaffected, maintaining an average value of about 4% TP throughout TM4. Ulmus and Corylus values fall particularly rapidly. Tilia appears unaffected at first, being present at less than 1% TP (as in TM3) up to 170cm, but then disappears. Fraxinus is more frequent than in previous zones, but does not exceed 1% TP until the top of TM4. The % AP diagram (see figure 6.8) shows that Ulmus, Pinus and Salix in particular, and also Corylus, show a real decline rather than simply an apparent one caused by increasing NAP. Alnus and Quercus, and to a much lesser extent Fraxinus, correspondingly increase their share of the total AP in TM4, and the proportion of Betula remains quite constant. Occasional grains of Fagus, Ilex and Carpinus pollen also occur in this zone.

Cyperaceae and Gramineae pollen are the most abundant types overall in TM4, increasing at the expense of the tree species described above. Cyperaceae reaches a peak of 60% TP at 150cm and then declines again, and Gramineae attains a maximum value of 39% TP at 160cm and remains quite high through TM4. Filipendula is still the next most abundant type, at up to 5•5% TP, followed by Rumex acetosella type, which increases at the TM3/TM4 boundary and reaches values of up to 4% TP, and Caryophyllaceae. Plantago lanceolata occurs for the first time at the base of TM4 and is present in small quantities in all but one sample in this zone, and a large number of other NAP types occur, including Urtica, Primulaceae, and Artemisia. Ericaceae pollen is present in most samples but never attains 1% TP, while Pteridium is slightly more frequent than in previous zones.

(v) TM5: Corylus-Betula-Gramineae L.P.A.Z. (137•5-72•5cm)

TM5 extends from 3220 ± 50 to 2690 ± 50 radiocarbon years B.P.

The zone shows an unusual degree of variability between adjacent samples (see figure 5.5), and is subdivided at 97•5cm.

Total AP increases at the TM4/TM5 boundary, attaining 76% TP at 130cm, and remains higher than in TM4 throughout this zone, despite marked minima at 120cm and 100cm and a gradual decline from 85% TP at 90cm to 59% TP at 75cm.

Corylus increases in TM5 and is the dominant AP type at up to 30% TP. But it is the fluctuations in the Betula curve which correspond best with those of the total AP curve. This species is the first to recover after each decline in total tree pollen, reaching peaks of up to 55% TP before declining again as other tree types recover. The TM4/TM5 and TM5A/TM5B boundaries are marked by such sharp Betula increases.

Alnus, Quercus, Fraxinus and Salix also show marked increases in their % TP values in TM5, and Ulmus and Pinus recover to a lesser extent. Ilex and Carpinus occur occasionally throughout TM5, and a few grains of Tilia and Fagus also occur in TM5B.

The recovery of tree pollen is accompanied by a rapid fall in Cyperaceae values, and a lesser decrease in Gramineae frequencies. Filipendula values are initially low but then rise rapidly in TM5A to a peak of 17% TP before declining again to low values in TM5B. Plantago lanceolata shows a similar pattern, reaching up to 3% TP in TM5A but dropping again to low values in TM5B. Rumex acetosella type is fairly frequent, with a marked peak of 8% TP at 120cm corresponding to a minimum in the total AP curve and peaks in Urtica, Rosaceae, Artemisia and Ericaceae. The latter increases through TM5, attaining values of up to 5% TP. Marked peaks in the Pteridium curve occur at 105cm and 80cm.

(vi) TM6: Gramineae-Ericaceae-Cyperaceae L.P.A.Z. (72•5-27•5cm)

Zone TM6 dates from 2690 $\pm$ 50 to 650 $\pm$ 50 radiocarbon years B.P. The TM5/TM6 boundary is marked by a sharp fall in the total AP curve, from 59% TP at 75cm to 25% TP at 70cm and 11•5% TP at 65cm. The high degree of between-samples variability in terms of the AP assemblage (see figure 5.5) is probably attributable to the very low AP total throughout TM6, which makes % AP figures less reliable.

The % TP values for all the AP types are reduced in this zone, as NAP types increase, but only Corylus and Betula show a significant reduction in their % AP values. The proportions of the total AP spectrum represented by Quercus, Ulmus, Fraxinus, Pinus, Fagus and Carpinus show a corresponding increase, while Salix and Alnus maintain similar % AP values to those of TM5. Quercus and Fagus increase their relative proportions first, followed by Fraxinus and Carpinus, and then Ulmus and Pinus in TM6B. The rise in Pinus as a percentage of total AP at the TM6A/TM6B boundary is particularly marked. Tilia is absent from TM6, but Ilex is present in most samples.

Ericaceae, Cyperaceae and Gramineae pollen all increase at the expense of arboreal types, Cyperaceae being dominant in TM6A (at up to 51% TP), and then declining while Gramineae and Ericaceae become the most frequent types in TM6B at up to 35% TP and 39% TP respectively. Plantago lanceolata also shows a pronounced rise at the TM5/TM6 boundary and maintains an average of 3-4% TP throughout TM6. Filipendula is less abundant than in previous zones, but there is a general increase in the number of different NAP types present, and the TM6A/TM6B boundary marks significant increases in Rumex acetosella type and Urtica. Pteridium is less frequent than in TM5.

(vii) TM7: Gramineae-Cyperaceae L.P.A.Z. (27·5–0cm)

This zone covers the period from 650 $\pm$ 50 radiocarbon years B.P. to the present. Total AP values are generally low, showing an initial increase to 16% TP and then falling to 5% TP at 5cm and recovering slightly to 11% TP at the surface.

Quercus, *Betula*, *Fraxinus*, *Pinus* and *Ulmus* are the most abundant AP types, *Corylus* and *Alnus* being reduced to low % AP values. *Tilia* is still absent, and *Carpinus* occurs in only one sample.

Gramineae pollen is overwhelmingly dominant, at up to 65% TP, although Cyperaceae is temporarily the most frequent type at 10cm and 5cm. Ericaceae pollen declines sharply at the TM6/TM7 boundary, from 39% TP at 30cm to 5% TP at 25cm. *Plantago lanceolata*, *Rumex acetosella* type and *Urtica* are all comparatively frequent, and a considerable number of other NAP types occur, including Cerealia (2% TP at 25cm), Chenopodiaceae and Compositae liguliflorae. *Pteridium*, however, declines and is absent above 10cm.

6.2 Regional pollen assemblage zones

Whilst the local pollen assemblage zones described in section 6.1 apply only to the particular sites for which they were constructed, there are sufficient similarities to allow correlation between sites and hence the definition of regional pollen assemblage zones (R.P.A.Z.s). This facilitates the interpretation of the large-scale vegetation changes for the Wensleydale area as a whole.

Five R.P.A.Z.s have been established, and their relationships with the L.P.A.Z.s are shown in figure 6.9. They are based entirely on pollen content, and so are regarded as true assemblage zones. As such, they apply only to the Wensleydale area, and are not necessarily synchronous throughout this area.

For each R.P.A.Z., the L.P.A.Z. which best shows the characteristic assemblage is designated the type zone, and the regional zone takes its name from the most abundant pollen types in this assemblage. The equivalent L.P.A.Z.s belonging to the same regional zone at other sites may show slightly different assemblages due to local influences, but the components which typify the R.P.A.Z. must occur at similar relative abundances. The pollen diagrams from Whirley Gill, Fleet Moss and Penhill show very similar L.P.A.Z.s, and so fit easily into the R.P.A.Z. system. The Thornton Mire diagram, however, is strikingly different. For most of the regional zones, an equivalent L.P.A.Z. can be recognised at Thornton Mire on the basis of changes in particular components. However the major components of the type zone are sometimes completely absent, so that whilst the zones can be regarded as equivalent, and perhaps even contemporaneous, the Thornton Mire L.P.A.Z.s cannot strictly be regarded as belonging to the same regional <u>pollen assemblage</u> zone.

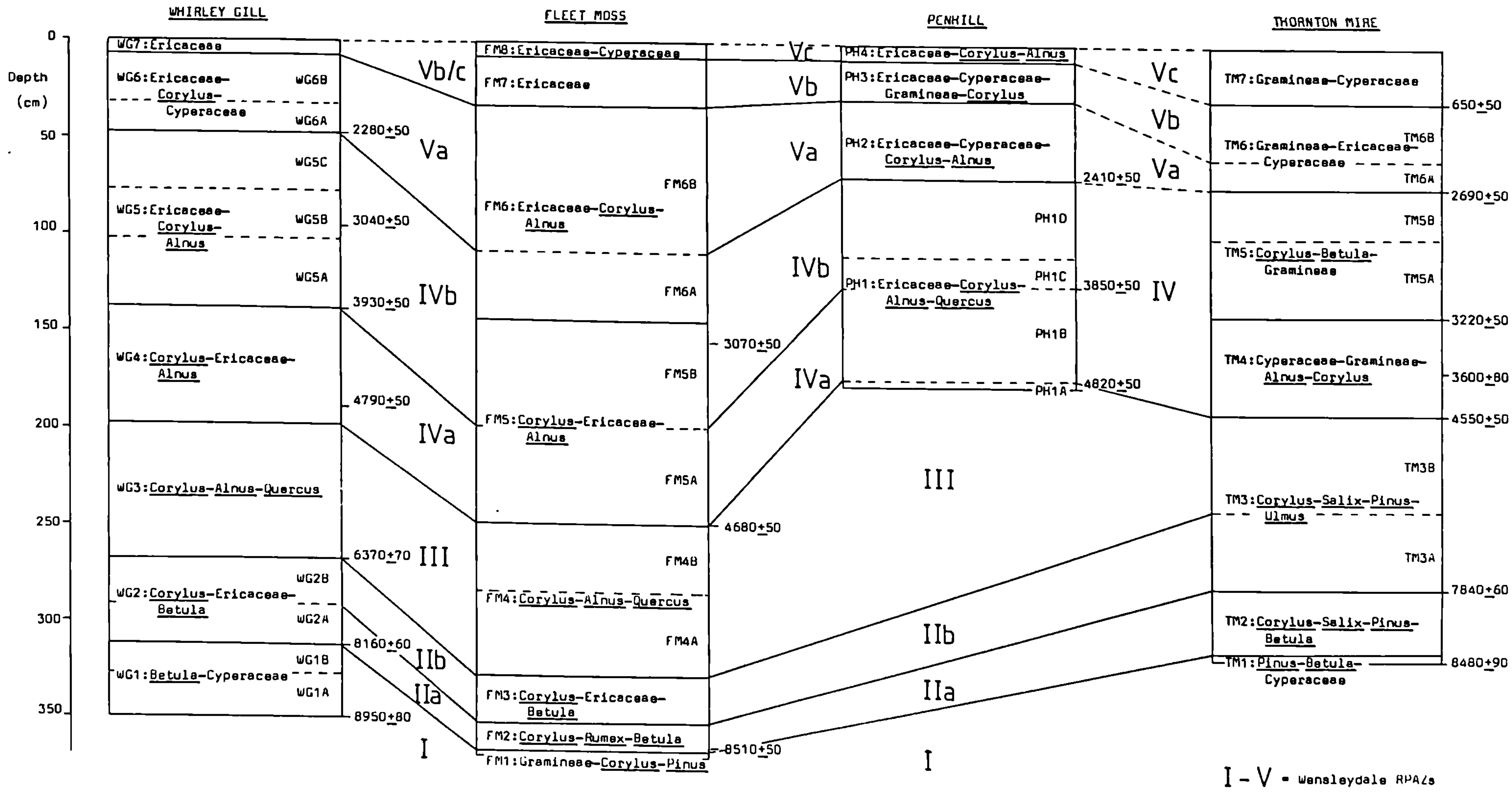


Figure 6.9: Correlation of the Wensleydale pollen records

CHAPTER 7: INTERPRETATION AND DISCUSSION OF THE VEGETATION HISTORY OF WENSLEYDALE

7.1 Zone Wensleydale I

7.1.1 Description

7.1.2 Interpretation

7.2 Zone Wensleydale II

7.2.1 Description

7.2.2 Interpretation

7.3 Zone Wensleydale III

7.3.1 Description

7.3.2 Interpretation

7.4 Zone Wensleydale IV

7.4.1 Description

7.4.2 Interpretation

7.5 Zone Wensleydale V

7.5.1 Description

7.5.2 Interpretation

INTERPRETATION AND DISCUSSION OF THE VEGETATION HISTORY OF WENSLEYDALE

7.1 Zone Wensleydale I: Betula-Cyperaceae R.P.A.Z.

Type zone: WG1 (figures 6.1 and 6.2)

Date: 8950 ± 80 to 8160 ± 60 B.P.

7.1.1 Description

Zone Wensleydale I represents the earliest phase in the vegetation history of the study area for which palynological data is available. Almost all of this data is provided by the Whirley Gill record, but pollen assemblages similar to those of the upper part of this R.P.A.Z. are also found in the L.P.A.Z.s FM1 (figures 6.3 and 6.4) and TM1 (figures 6.7 and 6.8).

The pollen assemblage of early Wensleydale I is dominated by Betula and herbaceous species, but no pollen of Betula nana, the dwarf birch, was identified. Pinus and Salix, together with some Juniperus at first, are the only other arboreal types to occur in significant quantities. The NAP spectrum is composed mainly of Cyperaceae and Gramineae, but Filipendula, Rumex acetosella type and Umbelliferae show marked peaks at the base of the zone. The proportion of arboreal pollen increases through the zone, from 42% TP at the base to over 70% TP at the top. Corylus increases rapidly at the expense of Betula and NAP types while occurrences of Ulmus and Quercus become more frequent.

7.1.2 Interpretation

The evidence of this assemblage, in conjunction with the radiocarbon dates, indicates that peat began to form at Whirley Gill during the early Boreal period. Unfortunately, as mentioned in section 4.2.1, the basal 15cm of the profile could not be sampled and so information concerning the cause of peat initiation is lacking. It does appear, however, that a considerable rise in the local watertable must have occurred at this time, although the topographical features of the site are not particularly suited to water collection. Three possible explanations for this change in local hydrology can be envisaged: climatic deterioration, pedogenic processes, or human interference with vegetation.

Independent evidence of the climate during the early Holocene is scarce, but it is thought that this was a time of comparatively dry, 'continental' conditions (Pennington, 1974; Goudie, 1977). In addition, climatic deterioration might have been expected to produce more widespread peat formation in the Wensleydale area; in fact other sites in similar topographical situations (for example Fleet Moss) did not begin to accumulate peat until considerably later. The climatic hypothesis for peat initiation is therefore not likely to apply in this case.

The pedogenic hypothesis cannot be conclusively proved or disproved, as details of the basal peat or soil are unknown. Blanket peat can be regarded as the terminal stage in soil maturation for high rainfall areas such as this, and indeed Godwin (in Lamb, 1964) took the view that podsolisation in high precipitation/evaporation conditions was a prerequisite for peat formation. However evidence is now available which refutes this idea. Dimbleby (1965) pointed out that many sub-peat profiles are immature and do not show fully developed podsolic characteristics. It is therefore unlikely that podsolisation, pan formation and the resultant drainage impedance is always an essential precursor to peat initiation. Other explanations are necessary in many cases, particularly those where peat began to form at such an early stage of the Post-glacial as it did at Whirley Gill. A considerably longer period of soil development would be required before blanket peat accumulation commenced by the pedogenic mechanism, and so this hypothesis is more appropriate to peat initiation in the later Holocene period. At Whirley Gill, the base of the peat was not seen at the core site, but stream incision in other parts of the bog has revealed this horizon and shows there to be virtually no soil present. The peat appears to have grown almost directly on the weathered sandstone, before any soil development had taken place. At most there may be about 1cm depth of minero-organic material which might be classed as an immature soil, but there is certainly no evidence of podsolisation. Pedogenic peat development therefore seems unlikely at this site.

Thus whilst no positive evidence is available in this instance, it does seem quite plausible that Mesolithic man may have played some part in the initiation of peat development at Whirley Gill. Clearing or merely thinning woodland could cause hydrological change of the magnitude required: evidence for this is supplied by Moore (1975), who cites modern examples of increased runoff and peat initiation resulting from human interference with forest vegetation. For many years it was thought that Mesolithic men were inadequately equipped and too few in number to have any significant effect on the landscape they inhabited.

However it is now recognised that even very small populations could have destroyed considerable tracts of woodland by means of fire. This destruction might at first have been accidental, perhaps caused by camp fires getting out of control, but as R.T. Smith (1982) points out, the beneficial after-effects of burning must have been observed by early man: the lush regrowth would have attracted large herbivores such as deer and aurochs which formed an important food source for human populations at this time.

Thus possible motives and methods for the removal of woodland by Mesolithic man can be envisaged, and in recent years a number of palaeo-ecological studies have linked habitat changes with this culture. Pennington (1975) has described evidence for increased runoff in parts of the Lake District in late Mesolithic times, and the pollen diagrams of Simmons (1964) suggest that clearance of forest by fire in the Mesolithic period was associated with the transition from forest to blanket bog on Dartmoor. At Great Close Pasture, in the Craven area of the Dales, a similar sequence of events is suggested by the presence of charcoal at the base of a peat deposit which began to accumulate during Mesolithic times (R. T. Smith, 1985, in press).

It is therefore apparent that Mesolithic man was theoretically capable of causing peat initiation; that he utilised the Pennine area has already been established in chapter 3. In fact the only Mesolithic artefacts recorded from Wensleydale were found on the moor edge above Carperby at Greenhaw Hut (altitude 442m), and on Newbiggin Pasture, north-east of Askrigg (366m) (Raistrick, 1933): these locations are both within 2-3km of the Whirley Gill site (488m). In the absence of incontrovertible evidence to support any of the three hypotheses proposed, it is therefore tentatively concluded that the initiation of peat development at Whirley Gill was caused by human interference with the original forests.

Whatever the cause of peat initiation, it is apparent that very wet conditions prevailed at Whirley Gill in early Wensleydale I. Pollen of a number of aquatic plants such as Menyanthes trifoliata, Myriophyllum alterniflorum and Alisma plantago-aquatica occurs in this zone, and the remarkably low degree of humification of the peat also testifies to rapid peat accumulation in a very wet environment (Aaby and Tauber, 1975).

Apart from the local, bog-derived component, which is composed largely of Cyperaceae and Sphagnum, the pollen/spore assemblage of Wensleydale I is typical of the early post-glacial period, and appears to correspond with those of Zones IV and V in Godwin's (1940) British System, or the Pre- and Early Boreal of the Blytt (1876) and Sernander (1908) climatic scheme. Birch woods were the dominant feature of the vegetation, but they were quite open at first, with willow and juniper shrubs and a variety of herbaceous plants of open ground including Filipendula ulmaria and Rumex acetosella as well as grasses and sedges. These shrubs and herbs were remnants of the late-glacial flora of Wensleydale; the assemblage bears some resemblance to that recorded at Lunds near the head of the river Ure by Walker (1954), which was found in mud beneath a solifluction earth and thought to represent Godwin's Zone III.

As the willow is insect-pollinated and therefore produces pollen which does not travel far, it is likely that the values of up to 9% TP/20% AP for Salix in this zone do represent trees growing in close proximity to the Whirley Gill site. Studies by Birks (1973a,b) in

Scotland demonstrated the pollen representation of willow: even in surface samples from willow scrub communities, willow pollen constituted only 1•6% TP. In contrast, pine is probably over-represented; this is indicated by a survey conducted in Canada by Ritchie and Lichti-Federovich (1967). By comparing surface pollen samples with the areal cover of different vegetation types, they found that pine pollen values of over 20% TP occurred in the forest tundra zone where there were no pine trees. Even 500km from the coniferous forest zone, in deciduous forest, pine constituted 6•1% TP, while at still greater distances from the source, values of 10–15% TP were found in areas of open grassland or parkland. Thus the pine proportions of up to 7% TP/11% AP in Wensleydale I at Whirley Gill are probably derived from trees growing at some distance from the site, in more southerly latitudes and in the North Sea basin. This hypothesis is further supported by the observation that many of the pine pollen grains (unlike grains of other types) were badly corroded, suggesting prolonged exposure to the air; again this accords with the evidence from Lunds, where only small quantities of damaged pine pollen were found in the late-glacial assemblage.

The vegetation of early Wensleydale I therefore appears to have been dominated by fairly open birch woods, with willow locally important on damper ground. Comparable zones elsewhere in the Pennines are rare, as most peat deposits are of later date; in addition, there are no dated pollen diagrams of this age. However, similar vegetation does appear to have existed in the Craven area of the Dales. Jones (1977) postulated that birch woods, with juniper, willow and herbs at first, covered most of Lowland Craven in the early Holocene, although pine was locally important. Whilst Jones suggested a date of 9800–8800 B.P. for this zone, this was based only on correlation with a dated diagram from Red Moss, in lowland Lancashire (Hibbert et al, 1971); the birch woods of Craven were most probably contemporaneous with those of Wensleydale. The vegetation of the Malham area was also dominated by birch woods at this time, as shown by the diagrams of Pigott and Pigott (1959, 1963), but pine was slightly more abundant than in the Whirley Gill area of Wensleydale. The only other site to provide evidence of this stage in the vegetation history of the Dales is Stump Cross, near Grassington (Walker, 1956), where again similar vegetation existed in Zone V.

No sites dating from this period have been analysed in the South Pennines. At Moor House in the northern Pennines, however, a layer of buried wood of birch with some willow and juniper at the base of peat deposits tends to indicate that the birch-dominated communities represented by the Wensleydale records were widespread in the Pennines during the early Holocene. In fact comparable 'early Boreal' assemblages are found throughout Britain, although pine tended to be more important in the south and east while birch generally predominated in the north and west.

The vegetation of Wensleydale at this time was by no means constant, however: continual change in response to various environmental factors is indicated. Whilst conditions were very wet at Whirley Gill around 8950 B.P., the humification profile shows that the site became progressively drier up to 8160 B.P., as the bog system adjusted to the initial hydrological change and streams were incised into the peat. This drying caused the decline of willow and aquatic plants, although Sphagnum remained abundant on the bog. At the same time, grasses, sedges and herbs of open habitats became less common as tree cover increased. The forest was not only becoming more dense; its composition was also changing. The later part of Wensleydale I saw a very rapid increase in hazel at the expense of birch. This is most clearly shown in the AP diagram in figure 6.2, where birch values drop from over 80% AP in early WG1 to only 15% AP by the start of WG2 and hazel increases from less than 1% AP to over 80% AP. Birch trees growing on the bog at Whirley Gill also died at this time, for their remains are found in the peat of L.P.A.Z. WG1B, but there is no stratigraphical evidence of hazel ever growing on the site.

This rapid hazel expansion in the early Holocene is a feature of pollen diagrams throughout Britain. Smith and Pilcher (1973) tabulated a large number of radiocarbon dates for this event and concluded that hazel spread over much of Britain c. 9000 years B.P. The traditional explanation of the high hazel pollen percentages was that considerable areas of hazel scrub developed in response to climatic change, possibly as a consequence of the hazel outstripping the migration of the mixed-oak forest (cf. Godwin,1975; Iversen, 1960). However, there are certain problems in applying such an interpretation: for example, Godwin (1975) claimed that "no such hazel-dominated period occurs in the vegetational development of any preceding interglacial period". Rapid increases in hazel did in fact take place, but as Deacon (1974) pointed out, the hazel rise has occurred progressively earlier in each interglacial episode.

More recently a few researchers, notably A. G. Smith (1970), have suggested that the hazel expansion may have been an anthropogenic effect. In north-west Europe, many Mesolithic sites have been shown to belong to the period of the Boreal hazel maximum (cf. Jessen, 1935).

Very few British sites combine the necessary archaeological and palynological evidence, but there are some where cultural remains are associated with this period. At Star Carr (Walker and Godwin, 1954) and Flixton (J. W. Moore, 1950 and 1954) in the Vale of Pickering, east Yorkshire, the Mesolithic occupation levels lie just at the point where the hazel curve begins to rise. Nearby, charcoal is found at this horizon, indicating that man and fire were both factors in the immediate environment at the time of the hazel expansion. It is well-known that hazel is fire-resistant, and it therefore seems reasonable to suppose that the use of fire by early man might have encouraged its spread. Rawitscher (1945), drawing on his experience of the effect of fires in Brazil, believed that a "predominant hazel vegetation would not be unexpected" if fire had been extensively used by Mesolithic man in Europe. Whilst the shade-tolerant hazel might have naturally replaced the light-requiring birch, it is clear that man had the capacity to hasten this process. As R. T. Smith (1982) points out, the fact that the hazel expansion occurred progressively earlier in each succeeding interglacial might be taken as evidence of the increasing ability of man to adapt to changes on retreat of ice and possibly also of successively larger human populations.

In Wensleydale, it has been noted that the hazel rise was associated with local drying at Whirley Gill. This would tend to support the traditional view of hazel increasing in response to climatic amelioration. However, the presence of Mesolithic man in the area has also been established, and it is worth noting that the flints found on the moors near Whirley Gill have strong affinities with those of Star Carr, being of the broad-bladed earlier Mesolithic type. Additional information is provided by the Fleet Moss and Thornton Mire sites, where peat began to form at the time of the hazel expansion. This fact in itself casts doubt on the climatic hypothesis. The base of the Fleet Moss profile consists of a thin, very compact mineral soil, overlain by peat containing abundant birch wood and bark. The pollen assemblage from the sub-peat soil is similar to that of late WG1B (i.e. late Wensleydale I), and shows quite high but still rising _Corylus_, with unusually high _Pinus_ and low _Betula_ values. _Pinus_ is another tree the regeneration of which is unquestionably favoured by fire. A marked peak in both Gramineae and _Rumex acetosella_ type also occurs in this horizon, and the microscopic examination revealed the presence of charcoal dust. A date of 8510 ± 50 B.P. was obtained just above this horizon. At Thornton Mire, a charcoal layer was clearly visible by eye at the base of the peat deposit, and again the pollen assemblage correlates with late Wensleydale I. _Corylus_ is increasing while _Betula_ falls, and _Pinus_ is high. The date obtained for this level was 8480 ± 90 B.P.

Thus at Fleet Moss and Thornton Mire the evidence points to wetter conditions at the time of the hazel expansion, and the involvement of fire. The situation is most plausibly explained by the destruction of birch woods by fire, which would lead to higher levels of soil moisture and hence peat initiation in topographically suitable locations. Hazel and pine would be the first trees to recover from the effects of fire, regenerating rapidly and inhibiting the re-establishment of birch. Although natural, lightning-induced fire cannot be totally discounted, the known presence of Mesolithic man in the area provides a more probable cause, whether his influence was deliberate or accidental.

It is therefore concluded that Mesolithic man was involved in the rapid transition from birch- to hazel-dominated vegetation which occurred between 8500 and 8100 B.P. in Wensleydale. Whilst climatic amelioration allowed the hazel to migrate into the area at this time, its abundance in relation to the trees of the mixed-oak forest which were also arriving was exaggerated by its greater resistance to fire. The fact that similar hazel rises occur at sites with no recorded evidence of human occupation does not detract from this explanation, as fire may still have been a significant factor in the local environment. The microscopic charcoal particles which might prove this are often undetected, particularly when there are no archaeological grounds for expecting signs of anthropogenic vegetation destruction.

By the end of Wensleydale I, then, the birch woods were giving place to hazel communities, with pine and willow locally important and few open habitats. The possible nature of the hazel-dominated vegetation will be discussed in the following section, as it is in early Wensleydale II that the hazel maximum is attained. Further indications of vegetation developments to come are provided by the occasional grains of elm, oak and alder pollen found in late Wensleydale I: these species were clearly migrating closer to Wensleydale by 8160 B.P., although not yet present in the immediate area.

7.2 Zone Wensleydale II: Corylus-Ericaceae-Betula R.P.A.Z.

Type zone: WG2 (figures 6.1 and 6.2)

Date: 8160 ± 60 to 6370 ± 70 B.P.

7.2.1 Description

This zone is represented at three of the pollen analysis sites, and is divided into subzones Wensleydale IIa and Wensleydale IIb. The former is typified by WG2A, and similar assemblages occur in FM2 and TM2; the latter has WG2B as its type zone whilst corresponding assemblages occur in FM3 and TM3A. That Wensleydale II is distinctly different from Wensleydale I is emphasised by the computer zoning results (figures 5.2, 5.3 and 5.5). All the methods applied selected this horizon as one of the major boundaries at each of the sites involved.

The boundary between Wensleydale I and Wensleydale II is marked by decreasing Betula and/or Pinus values. Corylus comprises up to 68% TP at Whirley Gill, and up to 45% TP at Fleet Moss and Thornton Mire. Betula remains the second most abundant AP type at Whirley Gill and Fleet Moss, but at Thornton Mire Salix and Pinus attain higher values. Ulmus and Quercus start to increase from the Wensleydale I/II boundary and increase further at the IIa/IIb boundary, but values for these species do not exceed 5% TP in Wensleydale II. The proportion of arboreal pollen is higher than in the preceding zone, attaining its maximum values of over 80% TP at Whirley Gill and over 90% TP at Thornton Mire, but still comparatively low (62-74% TP) and rising at Fleet Moss. Most NAP types decline, in particular Gramineae, Cyperaceae and Filipendula, but at Whirley Gill and Fleet Moss a marked increase in Ericaceae pollen occurs in this zone.

7.2.2 Interpretation

A predominantly wooded landscape is suggested by this assemblage; the precise nature of this woodland is, however, uncertain. Even taking into consideration the high pollen production of Corylus and its efficient dispersal by wind, it is apparent that hazel dominated the vegetation of Wensleydale between 8160 and 6370 B.P. This feature is characteristic of Zone VI in Godwin's (1940) British System, which has been correlated with the continental climate of the late 'Boreal' period. But whether the hazel grew in pure stands or merely as an understorey in a forest of taller trees such as birch has always been a matter for conjecture. Godwin (1975) claimed that the very high Corylus values must imply the widespread presence of hazel scrub; he also speculated that the hazel might have been associated with aspen (Populus tremula), as whilst the pollen of this tree has not been systematically recorded, macroscopic remains are quite common as early as Zone IV. R. T. Smith (1982) raised another possibility, suggesting that some of the Corylus pollen could have been derived from a partially herbaceous growth resulting from burning. Hazel sends up suckers rapidly after fire, and these may flower virtually the following season.

Evidence which might permit a confident choice between these theories with regard to the Wensleydale area is lacking, but their relative probabilities can be assessed. The idea of hazel/aspen woodland is discounted as there is no recorded macroscopic evidence for the existence of aspen in the Pennines during the period in question.

Whilst this species does not preserve well, some remains might be expected if it had been at all extensive in the area. The very high Corylus values of over 65% TP and over 80% AP found at Whirley Gill suggest that the hazel grew in almost pure communities rather than as a shrub layer beneath a birch canopy. Jonassen's (1950) studies in Jutland tend to support this, as he found that Corylus is under-represented in the pollen rain when it forms an understorey in tall forest. The hazel appears not to have simply infiltrated the birch forest, but to have almost totally replaced it. If this originally occurred as a result of burning, as suggested in section 7.1, then it is easy to envisage the logical continuation of this process as the long-term suppression of birch and encouragement of hazel by periodic firing. Whether hazel 'woodland' or merely a low 'herbaceous' growth resulted from this would depend on the frequency of burning. In view of the absence of macroscopic hazel remains, however, and the constraints imposed by the strong winds which sweep these uplands in the absence of tree cover, it seems likely that only a fairly low growth of hazel existed.

The hazel probably occupied the better-drained, higher land of the interfluves, where it would be associated with heath plants such as Calluna vulgaris and Vaccinium myrtillus. When heath communities attained their present dominance of the interfluves, it appears to have been hazel that they replaced: this is particularly well illustrated by the AP diagrams from Whirley Gill and Fleet Moss (figures 6.2 and 6.4). and is discussed further in sections 7.4 and 7.5. Support for this distribution comes from the work of Turner and Hodgson (1979) on the composition of the Boreal forests of the northern Pennines. By collating data from 52 sites, they found that the distribution of hazel was influenced primarily by altitude rather than geology, and that it was far more abundant at higher altitudes. Whilst no macroscopic remains of Corylus have been found at the Wensleydale field sites, the discovery of a hazel fruit in Zone VI deposits on the Nidd-Laver interfluve by Tinsley (1972) confirms that the hazel did grow in analogous situations elsewhere in the Dales. Birch may have persisted in the steep tributary valleys of the Ure, as it does today in the so-called 'gill woods'. Here it would be sheltered from the effects of wind and perhaps fire. At Thornton Mire, the AP spectrum was again dominated by Corylus, but willow was abundant on and around the bog, and some pine and perhaps birch probably remained on the drier limestone terraces to the north and south.

The vegetation of Wensleydale IIa is therefore thought to have been composed largely of hazel, with willow locally dominant on the wetter, lower-lying ground and pine and birch persisting in the gills and along the well-drained limestone scars of the main Ure valley. Similar vegetation existed throughout the Pennines at this time, with woodland or scrub of varying proportions of Corylus, Betula and Pinus. But whilst hazel was always the most abundant species, the extent to which it dominated the vegetation of Wensleydale, particularly north of the Ure, is unusual. In the Nidderdale area (Tinsley, 1972), birch was more abundant; in Craven (Jones, 1977 ; Pigott and Pigott, 1963), pine values were higher. In fact most parts of Britain show higher pine values than those of Wensleydale in the late Boreal. This may be a reflection of the higher altitude of the Wensleydale sites, as Turner and Hodgson (1979) found that Boreal Pinus values were negatively correlated with altitude, in contrast with Corylus (vide supra). The only valley site studied in Wensleydale, Thornton Mire, does indeed show a greater proportion of pine than the more exposed uplands. Geology may also have played a part, as it was the widespread shallow limestone soils of Craven which supported pine woods at this time (R. T. Smith, 1985, in press), and such soils are comparatively scarce in Wensleydale.

Hazel continued to dominate the vegetation of the uplands throughout Wensleydale II, but in the valleys considerable changes took place in the composition of the forest. At all three of the sites where this R.P.A.Z. is represented, expansions of elm, oak and later alder are apparent. Elm increases through Wensleydale IIa and maintains fairly steady values in Wensleydale IIb. The oak expansion tends to be somewhat slower, but it sustains a higher proportion of the pollen spectrum in Wensleydale IIb. Lastly the alder starts to increase from just before the Wensleydale IIa/IIb boundary.

Again this is a pattern which is repeated throughout Britain, and traditionally explained purely in terms of immigration in response to climatic amelioration. Comparatively dry conditions prevailed at this time, leading to the reworking of deposits marginal to lakes and the drying out of some mire surfaces (Goudie, 1977). The remarkably high degree of humification of the peat at Whirley Gill during Wensleydale II implies slow peat growth in dry conditions. Radiocarbon dating confirms this impression of the retardation of peat development, as on average 1cm depth of peat represents 40 years in L.P.A.Z. WG2, in contrast with 21 years in WG1. In addition, no pollen of aquatic plants occurs in WG2, and Sphagnum values are lower than in the previous zone. The humification profiles from Fleet Moss and Thornton Mire do not show such pronounced evidence of desiccation, but then peat development had not yet progressed very far at these sites, and so the watertable probably remained sufficiently close to the peat surface to permit continued accumulation. At Thornton Mire, however, the steep decline in Salix pollen values at the Wensleydale IIa/IIb boundary may be indicative of some drying out of the bog margins.

Whilst independent evidence is lacking, the climate must also have been becoming warmer at this time, to allow the spread of the more warmth-demanding elm and oak. This does not mean, though, that climate was the only environmental factor involved in the observed change in forest composition. As Iversen (1960) noted, the elm and oak are able to compete successfully with pioneer species like birch and pine when climate and soil permit, largely because of their longevity. Eventually they will overtop the pre-existing vegetation and thereby cause its suppression. But if Mesolithic man is held to have been at least partially responsible for the replacement of birch woods by bogs and hazel scrub, then it is essential to consider how he might have influenced subsequent developments. R. T. Smith (1982) points out a number of ways in which the continued presence of man can be reconciled with the establishment of mixed-oak forest. Unlike hazel and pine, the oak and elm would not have coped well with burning, as they are comparatively slow-growing trees. A reduction in the extent and frequency of fires might thus be envisaged as assisting in their spread: perhaps man was now more able to control his fires. But it is apparent that extensive areas of the uplands had already been cleared of tall forest by this time, probably providing sufficient open ground to meet the requirements of Mesolithic man and thus leaving the valley woods free from disturbance. It would appear that it was such areas that the new immigrants colonised, rather than the high interfluves. In addition, excessive hunting by early man might have reduced the populations of forest animals to the point where they were no longer a significant factor in preventing the advance of trees like the oak. Under intense grazing pressure from such animals as the wild boar and red deer, only the fast-growing birch, pine and hazel would be expected to survive. Oak in particular would be at a disadvantage because of the known preference of wild boar for acorns: this together with the wind dispersal of elm seeds might explain its slightly later expansion compared with elm.

By Wensleydale IIb, then, the vegetation of Wensleydale was becoming more variable as the climate was no longer limiting to a wide range of species. The interfluves continued to be dominated by hazel, probably associated with an increasing amount of ericaceous ground flora, while some birch and pine persisted on the valley slopes. At Thornton Mire, a decline in willow led to apparent increases in birch and pine, which may have grown on the drier margins of the mire as well as on the surrounding limestone terraces. In the woods of the main Ure valley and some of its tributaries, elm and oak were becoming established, although the mixed-oak forest was not fully developed until Wensleydale III. Thornton Mire again shows differences because of its more sheltered, lower-lying position. Elm attained its maximum of 19% TP here in Wensleydale IIb (the start of which is dated to 7840 $\pm$ 60 B.P. at this site) while willow was temporarily reduced in extent by the drier climate, but oak values remained quite low, rarely reaching 5% TP. Tinsley (1972) found that values of under 5·5% TP for Quercus pollen were unlikely to indicate oak forest nearby. It thus seems plausible to envisage the elm reaching Wensleydale before the oak, and penetrating up the side valleys like Thornton Mire at a time when oak had only just reached the main Ure valley. The elm would also be favoured above the oak by the preponderance of calcareous soils in such localities.

Alder was also beginning to approach the study area in Wensleydale IIb, but its values of less than 5% TP suggest that no trees grew near any of the pollen analysis sites. In their studies of surface pollen samples, Tinsley and Smith (1974) found values of up to 22% TP for Alnus in the absence of alder trees in the immediate vicinity. It therefore seems likely that in this dry period the alder was limited to the damp soils on the banks of the rivers and streams.

The other important immigrant of late Wensleydale II was the lime. A single grain of Tilia pollen occurs at the top of Wensleydale IIb at Whirley Gill, and it occurs occasionally from late Wensleydale IIa onwards at Thornton Mire. As lime pollen is not readily dispersed by wind, such low values may still represent trees not too distant from the pollen analysis sites. This is the final indication of the warming climate, as lime is the most thermophilous of the native British trees.

Although the abundance of tree pollen in Wensleydale II obscures details of the non-arboreal flora, a wide range of herbaceous plants probably grew in the mixed woodlands and scrub of this period. The hazel of the interfluves appears to have been associated with heath plants such as Calluna vulgaris and Vaccinium myrtillus, particularly in the drier Wensleydale IIb. High values for ericaceous pollen are found at the upland sites Fleet Moss and Whirley Gill, while this pollen type is only spasmodically encountered in this subzone at Thornton Mire. Gramineae and Cyperaceae values are low, and the variety of other NAP types is much less than in Wensleydale I. However, high proportions of Rumex acetosella type persist in Wensleydale IIa at Fleet Moss, and grass pollen is sometimes quite abundant here. As total AP values at this site are comparatively low, it seems that the landscape may have been more open in this part of Wensleydale than elsewhere. The discontinuous nature of the tree cover on the well-drained valley slopes is indicated by the occurrence of Pteridium spores at all the sites, and some open ground may have existed around Thornton Mire, where Filipendula values remain high and a considerable variety of other herbs is found, including Artemisia. The ground flora of the valley woodlands is represented by occasional pollen of plants which can tolerate shady conditions such as Mercurialis, Potentilla, the Rubiaceae and some Caryophyllaceae (for example Silene dioica).

In summary then, the main vegetation change within Wensleydale II is the start of the colonisation of the valleys by thermophilous broad-leaved trees. Whilst Mesolithic man appears to have had little influence on this woodland, it is possible that his activities may have indirectly affected its spread. The main impact of man at this time, however, was probably concentrated on the uplands, where the low growth of hazel and heaths may have been maintained by occasional burning for the benefit of the hunter-gatherer communities. This is supported by the presence of microscopic charcoal particles throughout Wensleydale IIb at Thornton Mire. The marked peaks of silica and aluminium which also occur in this subzone (see figure 4.13) suggest that bare soil may have been exposed to erosion by such activity. Thus at this early stage of the Holocene man was affecting the landscape but in a rather sporadic and localised fashion.

7.3 Zone Wensleydale III: Corylus-Alnus-Quercus R.P.A.Z.

Type zone: WG3 (figures 6.1 and 6.2)

Date: 6370 ± 70 to (approximately 5000 to 4550 ± 50) B.P.

7.3.1 Description

Wensleydale III is fully represented at Whirley Gill (WG3), Fleet Moss (FM4) and Thornton Mire (TM3B), and the latest stage is also found at the base of the Penhill profile (PH1A). Whilst the lower boundary of this R.P.A.Z. is dated from the type zone only, there is evidence that the upper boundary is variable in time between the four sites. The Wensleydale III/IV boundary is dated to 4550 ± 50 B.P. at Thornton Mire and 4680 ± 50 B.P. at Fleet Moss. A similar date probably applies at Penhill, as the date obtained 2·5cm below the division is 4820 ± 50 B.P. However at Whirley Gill a date of 4790 ± 50 B.P. 10cm above this boundary implies a significantly earlier date, perhaps about 5000 B.P.

The most marked feature of the Wensleydale II/III boundary is the rise in Alnus, which continues through Wensleydale III. Quercus also increases, but Corylus remains dominant, and Betula and Pinus decline. At Thornton Mire, Salix is particularly important. Tilia first occurs near the base of this zone at Fleet Moss, and becomes more frequent at Whirley Gill and Thornton Mire. Fraxinus also appears at Whirley Gill and Fleet Moss during Wensleydale III. Total AP values are higher in the earlier part of this R.P.A.Z. than in any of the other zones, but tend to decline towards the upper boundary. Cyperaceae and Gramineae pollen predominate in the NAP assemblage, Ericaceae values being considerably lower than in Wensleydale II.

7.3.2 Interpretation

The vegetation changes which occur at the Wensleydale II/III boundary, notably the expansion of alder and decrease in pine, are characteristic of the Boreal-Atlantic Transition (B.A.T.).

They have therefore generally been ascribed to the influence of climatic factors. Whilst dry conditions prevailed in the late Boreal, the establishment of full marine circulation around Britain at the end of this period is thought to have increased the oceanicity of the climate, so that the succeeding Atlantic period was comparatively wet and warm. It was at this time that blanket peat accumulation began in many formerly forested areas, as for example in the southern Pennines (Conway, 1947; Tallis, 1964a).

Certainly, the alder is primarily a tree of wet habitats, and as such would have been restricted in the dry Boreal period and favoured by the subsequent increase in rainfall. The associated reduction in pine might also be taken to indicate an increase in soil moisture and even waterlogging. But whilst climate may well have played an important role in the vegetation changes, it should not be considered in isolation from the other environmental influences present at this time. The possible interaction of pedogenic and anthropogenic factors cannot be ignored if a consistent approach to the interpretation of vegetation history is to be maintained.

The supposed synchroneity of the alder expansion over wide areas has been taken as evidence of its relationship to large-scale climatic change rather than more localised and variable factors such as soil development or human interference. As Godwin (1975) remarked, "It is difficult to explain the near-synchroneity and widespread expansion of an already established tree such as the alder save by some general climatic shift". However, there is now a growing body of evidence (Smith and Pilcher, 1973; Turner et al, 1973; Chambers, 1978) which suggests that the timing of the alder expansion actually varied significantly throughout the British Isles. In particular, it appears that the rise of alder was considerably delayed in certain upland areas. Thus whilst dates of 7100 to 7350 B.P. are generally obtained from sites in lowland England, as for example at Red Moss, Lancashire (7107 ± 120 B.P.; Hibbert, Switsur and West, 1971), those obtained from the Scottish highlands tend to be later: for example 5220 ± 115 B.P. at Quartbeg, north-west Scotland (Moar, 1969). Even within comparatively short distances, the behaviour of alder is quite variable, as shown by sites in northern England studied by Chambers (1978). At the low-lying Neasham Fen (Chambers, 1974) alder expanded soon after 6972 ± 90 B.P., whilst at the more elevated Valley Bog (Chambers, 1978) it was not yet present in any great abundance by 6779 ± 75 B.P. In Ireland the pattern is similar, with the alder rise occurring around 7000 B.P. at lowland sites and just before 5000 B.P. in the uplands (Smith and Pilcher, 1973).

In Wensleydale, the alder expansion is dated to 6370 ± 70 B.P. at Whirley Gill. This is relatively late, as might be expected in this upland area given the evidence described above, and thus supports the idea that the B.A.T. was in fact an asynchronous phenomenon. It is therefore clear that climate was not the only influence involved. Rainfall was undoubtedly increasing at this time, but the timing of the vegetational response to this change must have depended to a large extent upon local environmental factors, including the resistance of the soil to waterlogging, the nature and extent of anthropogenic activity, and the inertia of the existing vegetation (A. G. Smith, 1965).

The degree of expansion observed in the alder and the nature of the associated vegetation changes were also influenced by local factors. In the Wensleydale area, the alder increase is less pronounced than at many lowland sites, Alnus pollen comprising only 7% TP (9% AP) at Fleet Moss and 12% TP (14% AP) at Whirley Gill in early Wensleydale III. At Thornton Mire, there is even a temporary decline in Alnus at the Wensleydale II/III boundary, but this can be attributed to the local rise to dominance of Salix, another tree favoured by wetter conditions, which grew on the mire itself thus swamping the pollen contributions of plants growing further away. On the other hand, the Pinus decline which generally accompanies the alder expansion is quite marked at Thornton Mire and Fleet Moss, but at Whirley Gill this tree was never a significant component of the nearby woodland.

Thus whilst vegetation changes corresponding to those of the B.A.T. did occur in the Wensleydale area, they were both later and less marked than in other parts of Britain, especially lower-lying areas. It is now necessary, then to explain not only the causes of the expansion of alder, but also its comparative lateness and limited extent.

There is no doubt that conditions did become wetter in Wensleydale around the Wensleydale II/III transition. The Whirley Gill profile shows a pronounced decrease in humification values, indicating rapid peat accumulation in waterlogged conditions. This feature is less marked at Fleet Moss, although humification values in early Wensleydale III (FM4A) are significantly lower than in subsequent zones. The Thornton Mire site is believed to have been almost permanently water-logged anyway, on account of its topographic and geological situation, so that increased rainfall will not have had such clear effects on the humification profile. However the chemical analyses from Thornton Mire tend to confirm the postulated increase in precipitation. A sharp decline in ash weight, together with silica and aluminium values, suggests more rapid accumulation of organic material. A rise in total calcium is indicative of increased solutional weathering of the surrounding limestone slopes, which also implies wetter conditions although the action of humic acids in the increasingly peaty soils may also have been a factor.

The damp conditions thought by earlier workers to be solely responsible for the alder rise in other areas were therefore present in Wensleydale, and yet the expansion was limited. Delayed alder expansions in Craven (Jones, 1977) and in Upper Teesdale (Turner et al, 1973) have been linked with the persistence of pine and attributed to the preponderance of freely-draining soils. In Wensleydale, pine had never been abundant anyway. In addition, whilst the soils of the valley sides are too well-drained to allow alder to compete successfully, those of the interfluves and valley bottoms would have been susceptible to waterlogging, as they are today. So it would appear that it was not the resistance of the soils to waterlogging which prevented alder spreading more widely and more rapidly. The wettest ground of the interfluves was already accumulating blanket peat, as at Fleet Moss and Whirley Gill, and thus presented an environment too acidic and poor in nutrients for the alder. Where conditions were less extreme, hazel scrub persisted, leaving less scope for the alder to invade. There is no evidence that alder trees grew in significant numbers on the uplands of Wensleydale at this time, as no macro-remains have been found at the sites examined, and the proportions of Alnus pollen are very low compared with those of Corylus given that the two species are equally prolific pollen producers (Iversen, 1947, in Faegri and Iversen, 1975; Andersen, 1970). This is at odds with the situation on the Nidderdale Moors, where Tinsley (1972) found remains of alder wood together with Alnus pollen values rising from 20% TP to 70% TP in Zone VIIa peat, indicating that alder carr once grew on Fountains Earth Moor.

Thus it appears that in the Wensleydale area the alder would have been largely restricted to the valley bottoms, where the boulder clay deposits and high watertable might have made the soils susceptible to waterlogging. However, mixed-oak woodland was already established in this topographical zone by the Wensleydale II/III boundary, and the oak actually increased at this level rather than giving place to alder. It is therefore necessary to imagine alder spreading within the oak-dominated forest rather than replacing it. This is a situation which Dimbleby (1970) has considered, suggesting that the establishment of a stable, mixed deciduous oak-dominated ecosystem may actually have led to conditions of shelter and humidity conducive to alder. Tansley (1953) also thought it possible:

> " In periods of wet climate it (the alder) may also have spread widely through the general woodland, as it still does in Wales and western Scotland. The alder still grows in wet places in woods dominated generally by other trees, and by streams and lakes where humus and nutritive salts are available....In the wet climates of the west, as in Wales and the western Highlands, alder may be extremely abundant throughout the oakwoods."

However, as R. T. Smith (1982) points out, a reasonable degree of forest closure would surely suppress the alder, even if it is conceded that the oakwoods could provide more constant conditions of humidity and might also contain suitable naturally wet patches. It seems unlikely that the alder would be able to expand very rapidly in such an environment unless there were openings available for exploitation. This is where the intensity of local anthropogenic activity may be important. Any clearings created or maintained by Mesolithic people inhabiting the valleys during the preceding dry phase would probably have to be abandoned with the establishment of wetter conditions. The alder, already present in the area, would be able to colonise such damp, treeless clearings very quickly, and the oak might also have been able to take over the drier parts. This mechanism would therefore explain why the rapid expansion of alder is not necessarily accompanied by a reduction in the mixed-oak forest. Local variations in the timing and extent of the alder increase can be viewed as reflections not only of pedogenic factors and the stability of the existing forest, but also of the human utilisation of an area. Evans (1975) further argues that the dry conditions of the late Boreal period caused lake levels to fall and the surfaces of marshes and fens to dry out, and man was compelled to spread onto these areas of freshly exposed lake-edge sediments in order to reach water and to exploit the rich fauna of the receding marshy habitats. With the establishment of a wetter climatic regime, these same areas would obviously be the first to become uninhabitable again, and would provide ideal sites for alder colonisation. Also, within the forest itself, man-made clearings would permit more rapid penetration by alder than would otherwise be possible.

Thus it can be envisaged that where land susceptible to water-logging or flooding had been occupied by Mesolithic man in the Boreal period, there was scope for the rapid spread of alder with the onset of

Atlantic conditions. Conversely, where no terrain of this nature existed, or where man had not been present to keep it free of oak forest, the alder was largely restricted to habitats such as river banks and could only spread by slow infiltration of the already-stable oak forest. In Wensleydale, steep slopes and calcareous soils left few areas which would succumb readily to waterlogging, and the oak forest was comparatively stable and undisturbed. The valley bottoms were probably always sufficiently damp and choked with forest to discourage human utilisation, but sufficiently well-drained to allow the growth of oak and elm, so that the effects of Mesolithic man were confined to the interfluves. This accounts for the late and limited alder expansion, and for the continued dominance of hazel on the uplands, where fire was probably important in preventing the regeneration of other trees.

The hypothesis outlined above also helps in explaining the distribution of Mesolithic finds. A. G. Smith (1970) drew attention to the frequency with which archaeological or palynological evidence of Mesolithic activity is found coincident with or slightly preceding the alder rise. British examples include Seamer Carr, Yorkshire (Pilcher and Smith, 1981), Shippea Hill, East Anglia (Clark, Godwin and Clifford, 1935; Godwin and Clifford, 1938; Clark and Godwin, 1962), and Newferry, Northern Ireland (A. G. Smith, 1975; Smith and Collins, 1971). Early Danish work reviewed by Jessen (1935) also consistently shows cultural remains predating those of alder trees which grew over the bog surfaces, and at the Swedish site Baremosse II (Nilsson, 1967) a Mesolithic layer falls at the end of the Boreal period. It seems most probable that these sites were utilised by man in the dry late Boreal period, and subsequently abandoned and preserved by being buried under peat and lake clays. The fact that many Mesolithic occupation layers are found at the level of the B.A.T. is thus explained by the favourable preservation conditions. Occupation sites of a date earlier than the end of the Boreal period were necessarily further from the lake or bog margins and so less likely to be preserved.

Similarly, it might be expected that evidence of Mesolithic occupation after the alder rise would be concentrated on the uplands, and this is indeed the case. As discussed in chapter 3, most of the Mesolithic remains of the southern Pennines belong to the later, narrow-bladed or microlithic flint industries (Hallam, 1960; Woodhead and Erdtman, 1926). Accurate dating of the flints is not usually possible, as they tend to be found beneath, rather than within, the blanket peat. Thus whilst 'Atlantic' peat generally covers the archaeological remains, the time elapsed between the deposition of the flints and the onset of peat accumulation is unknown. However, the significantly greater frequency of Mesolithic sites of this later type has been linked to the wetter conditions of the B.A.T. by some researchers. Brothwell (1972) postulated that the later Mesolithic people were concentrated on higher ground at this time as watertables rose. But it is only at Stump Cross, near Grassington in Wharfedale (Walker, 1956) that the microlithic flint industry is dated with any degree of certainty. Here, the flints were stratified in organic material shown by its pollen content to date from the first half of Zone VIIa. Later radiocarbon analysis of charcoal from the same horizon (Godwin and Willis, 1959) gave a date of 6500 ± 310 B.P. The pollen curves at this level show sharp increases in *Corylus* and Ericaceae, an increase in Gramineae, and the occurrence of a grain of *Artemisia*. The *Pinus* curve has already fallen to low values and the Alnus curve is still rising. Walker regarded these changes as indicative of blanket mire inception due to climatic change, but as Simmons (1969a) points out, they would equally well bear the interpretation of the opening of woodland, particularly as charcoal is present. It was also suggested by Walker that there was no evidence of prolonged habitation near Stump Cross, but the microlithic workshop site examined by Davies (1963) on Blubberhouses Moor, not far from Stump Cross, and the many finds described by Raistrick (1933) in upper Wharfedale imply that the area was quite regularly exploited by Mesolithic people.

Microliths are also abundant in the Craven area of the Dales, and further support for the increased use of the uplands after the B.A.T. is provided by palynological studies. On Malham Moor, Pigott and Pigott (1963) found thin seams of charcoal and an increase in herb pollen (including grasses, Plantago lanceolata, Urtica dioica and Chenopodiaceae) just above the level of the B.A.T., and suggested that this was evidence of human activity associated with nearby Mesolithic microlith sites. A similar horizon was described by Jones (1977) from early Zone VIIa peat on Threshfield Moor in upland Craven, with a rise in herb pollen values and the occurrence of Plantago lanceolata, Cruciferae and Chenopodiaceae. Jones also postulated that the final decline of pine in Craven, c. 6200 B.P., might have been due to man's activity as it is associated with signs of human interference such as ruderal pollen, and pine (though arguably dependent on fire for widespread regeneration) is also vulnerable to fire (Godwin, 1975) which would have been Mesolithic man's most effective tool for forest clearance.

There is therefore evidence of increased Mesolithic utilisation of the higher parts of the Pennines following the onset of wetter conditions and the spread of alder in the valleys. In Wensleydale itself, there does not appear to have been such a marked expansion of human activity in the early Atlantic period, but rather a continued presence on the interfluves and a more gradual increase in anthropogenic disturbance towards the end of the zone. This would obviously preclude any widespread regeneration of forest.

With the concentration of human activities on the interfluves, and the restricted spread of alder in this area, the foothold gained by the mixed-oak forest in the preceding zone was strengthened during Wensleydale III. The increase in mean Quercus pollen values from about 6% TP to 13% TP at Whirley Gill and from 6% TP to 10% TP at Fleet Moss may be indicative of some upward extension of oak trees, which appears to have occurred at the expense of the hazel-heath scrub in the vicinity of Whirley Gill and the remaining pine and birch woods near Fleet Moss. At Thornton Mire the local over-representation of Salix growing on the mire tends to obscure the roles played by other trees, but a pattern similar to that of Fleet Moss is revealed when Salix is excluded from the pollen sum.

The surface pollen samples studied by Tinsley and Smith (1974) showed that Quercus pollen proportions were strongly related to the distance from the nearest oak trees. With oak confined to altitudes below 275m at the present time, Quercus pollen values of 5·5% TP were found on the higher parts of the Nidd-Laver interfluve. This contrasts with values of over 50% TP within oak woodland. The proportions found in Wensleydale III therefore suggest that whilst oak woods did not exist on the uplands around the pollen analysis sites, they were no longer confined to the lowest ground of the valley bottoms but were spreading up the valley sides.

The elm was also an important component of the deciduous forest of the valleys, although its frequency shows considerable local variation, probably due to edaphic factors. At Whirley Gill and Fleet Moss, Ulmus pollen percentages are lower than those of Quercus, averaging 10% TP at the former and 6% TP at the latter site. The high Salix values at Thornton Mire again conceal the true abundance of Ulmus, but it is immediately apparent that elm was more common than oak in this part of Wensleydale. This can be attributed to the predominance of limestone outcrops around Thornton Mire, on which elm would thrive more readily than oak. In fact, given that oak is often considered to be a more prolific pollen producer than elm (Andersen, 1970; Janssen, 1967; Davis, 1963), it would seem that elm was at least as important as oak throughout the study area.

The lime also grew in Wensleydale by this stage, appearing for the first time in the pollen records at the end of Wensleydale II at Whirley Gill, and at the beginning of Wensleydale III at Fleet Moss. The Thornton Mire profile, however, shows the presence of some Tilia trees in the area as early as mid-Wensleydale II (before 7840 $\pm$ 60 B.P.), although the record is not continuous until mid-Wensleydale III. Lime is the most thermophilous of the British forest trees, and its widespread occurrence serves to confirm that the climate of Wensleydale III was not only comparatively wet, but also warmer than that of preceding zones. This period has been designated the 'post-glacial climatic optimum', because of the higher temperatures implied by the spread of Tilia. But whilst the term is suitable to describe the corresponding period in Scandinavia, where a variety of warmth-demanding plants and animals reached their greatest abundance in the still fairly continental climate of this time, it is singularly inappropriate when applied to Britain, where the more oceanic regime led to the replacement of forests by blanket bog.

The climate was undoubtedly warmer during Wensleydale III, for apart from the lime (whose frequency may be seriously under-represented in the pollen records due to its insect pollination and consequent poor pollen dispersal), other plants often considered to indicate increased warmth occur in this zone. Ilex aquifolium (holly) becomes relatively frequent in the Thornton Mire area, reaching a peak in mid-Wensleydale III. There is little evidence of this evergreen tree at high altitudes, however, where temperatures would be significantly lower (see section 2.2). The ivy, Hedera helix, is another warmth-loving plant which spread in many parts of Britain during the Atlantic period. At Whirley Gill it is noticeably more frequent in Wensleydale III than in any other zone, although never abundant, but its only other occurrence is a single pollen grain in the early part of the equivalent zone at Fleet Moss (315cm). However the correlation between the spread of these plants and increasing temperature is probably not as direct in Britain as it was in Europe. Britain did not experience the intense summer warmth which favoured these species on the continent, but the oceanicity of the British climate and its lack of temperature extremes would have compensated for this. Ilex would also be assisted in its spread by being evergreen and so able to cope with heavy shading by making use of the light available when other trees are leafless.

As mentioned above, *Salix* was locally important at Thornton Mire. The presence of recognisable wood of this tree in the peat of TM3 confirms that it grew on the mire itself. The cause of the large fluctuations in *Salix* pollen values which occur in TM3B, the L.P.A.Z. equated with Wensleydale III, is uncertain. However it should be noted that *Salix*, although insect-pollinated, produces large quantities of pollen on catkins. This can lead to uneven distribution of pollen, as complete or fragmented catkins may be deposited at short distances from the trees. The observed fluctuations might therefore reflect the random scattering of large concentrations of pollen, or perhaps variations in the proximity of the trees to the core site in the centre of the mire.

It has been established, then, that Wensleydale III saw the consolidation of the mixed-oak forest in the valleys and its spread up the hillsides, while alder gradually infiltrated along the banks of rivers and streams. Whilst the oak-elm woodland remained quite stable throughout this zone, alder continued to increase, not reaching its maximum extent until early in the subsequent zone. Throughout this period, though, *Corylus* pollen continued to be the most abundant type at all of the sites examined. As discussed earlier, it is thought that the activities of Mesolithic man were concentrated on the interfluves at this time and that occasional fires (either accidental or deliberate) would have favoured the dominance of hazel scrub. But there is increasing evidence, as Wensleydale III progresses, of other anthropogenic effects on the landscape.

At all of the three sites where this zone is fully represented, distinct troughs in the total AP curves can be seen, accompanied by increases in Gramineae and Ericaceae values and in the diversity of other NAP types, including some which are often associated with clearance such as *Urtica dioica*, *Artemisia* and Chenopodiaceae. In addition the establishment of an almost continuous curve for *Fraxinus* at Whirley Gill and Fleet Moss suggests that there were openings in the woodland canopy, as the ash is intolerant of shading. The presence of *Pteridium* spores is also indicative of more open conditions on the well-drained valley slopes. However the culture concerned is still a Mesolithic one, and there is no evidence of cultivation. The recorded disturbances probably represent the cumulative effects of a number of small-scale, temporary clearances scattered over a wide area, rather than distinct individual clearance phases. Apart from the low level of resolution obtained by 5cm and 2·5cm sampling intervals, it is unlikely that the disturbances took place in the immediate vicinity of the sampling sites and so it is a rather generalised picture of overlapping events from a variety of sources which emerges. It can only be said that some clearings were made in the forests of Wensleydale between about 6400 B.P. and 5000 B.P., and that Mesolithic man must have been responsible. As Simmons (1975) pointed out, it is quite easy to envisage possible reasons for the manipulation of vegetation by pre-Neolithic man. The use of fire would result in more leafy browse and hence more large herbivorous mammals such as red and roe deer, at the same time making hunting easier by reducing the cover for game. A greater crop of hazel nuts, another important food source, might also be produced.

Towards the very end of Wensleydale III the first signs of a new type of human activity appear; single grains of cereal pollen occur at Fleet Moss and Whirley Gill, together with *Rumex acetosella* type and *Artemisia*. Gramineae pollen reaches a peak of 16% TP at Fleet Moss but is infrequent at Whirley Gill. In addition, the zonation results (figures 5.2, 5.3 and 5.5) show a general increase in the variability between adjacent pollen samples. Whilst this is not a distinct clearance phase, it does suggest that agriculture was being introduced into the area, and hence that the Neolithic culture had arrived. From the radiocarbon dates just above this horizon, it can be estimated to have occurred shortly before 4550 B.P. at Fleet Moss, and several hundred years earlier at Whirley Gill (probably before 5000 B.P.). The difference in timing may reflect the spread of the new culture from east to west across the country. In Craven, Jones (1977) noted similar episodes immediately prior to the 'elm decline' at Eshton Tarn and White Moss. There the evidence pointed to clearance for pastoral activity rather than cultivation, as Plantago lanceolata, a plant typical of grazed grassland, occurred for the first time but no cereal pollen was found. A corresponding phase can also be seen on Walker's (1956) diagram from Stump Cross, shortly before the level designated as the VIIa/VIIb boundary, with a peak in grass pollen and the start of the Plantago lanceolata curve. It is not possible to determine which of the arboreal communities was being cleared, although at both Stump Cross and Fleet Moss Corylus values were declining rapidly at this time. The clearances taking place at this early stage of the Neolithic must in any case be envisaged as very small and temporary, perhaps even taking the form of experimental plots. It is possible that the first attempts at agriculture in this area were made on the less densely vegetated uplands, but that this environment soon proved too hostile, with its cold, wet and windy climate and the resulting poor, leached soils. Later activities might then have been more concentrated at lower altitudes, where the difficulties of clearing tall forest would be offset by the benefits of richer soils and better climatic conditions.

The beginning of the pollen record at Penhill is placed in the final stage of Wensleydale III. Only the basal (175cm) sample from this site contains a pollen assemblage appropriate to this R.P.A.Z., and it is dated to 4820 ± 50 B.P. Blanket peat accumulation had not yet begun, the interface between the thin acidic soil and sedge peat occurring at the PH1A/PH1B (Wensleydale III/IV) boundary (about 172cm). This transition is discussed in section 7.4. However the basal pollen sample serves to confirm that the vegetation of the Penhill area was similar to that already described for the rest of Wensleydale at this time, with evidence of Corylus-Ericaceae scrub on the high ground and mixed-oak forest in the valleys below. The total AP value is comparatively low (62% TP) at Penhill, but this can be attributed to local over-representation of Ericaceae pollen. Very little grass pollen is present, and there is no cereal or ruderal pollen to suggest early Neolithic activity.

In summary, it can be said that the R.P.A.Z. Wensleydale III displays characteristics typical of 'Atlantic' peat throughout Britain, although the Alnus rise is less well-developed and Corylus is more important than elsewhere. Whilst climatic change is acknowledged as an important factor in vegetation changes during this period, it is clear that Mesolithic man was also a major influence on the landscape. Godwin's (1975) view of the Atlantic period as exhibiting "the major climax woodlands of the British Isles in stable equilibrium, their distributions determined by natural environmental controls" is therefore no longer tenable. Anthropogenic effects were becoming apparent even before the migratory movements of the arboreal plants were complete, and so no true 'climatic climax' vegetation distribution can be claimed to have been established in Britain following the last glaciation. The pattern was constantly changing under the combined influence of ecosystemic and anthropogenic factors.

7.4 Zone Wensleydale IV: Corylus-Ericaceae-Alnus R.P.A.Z.

Type zones: WG4 (Wensleydale IVa) (figures 6.1 and 6.2)

WG5 (Wensleydale IVb) (figures 6.1 and 6.2)

Dates: Start of Wensleydale IV:- approximately 5000 to 4550 ± 50 B.P.

Wensleydale IVa/IVb boundary:- 3930 ± 50 B.P. (Whirley Gill),

3850 ± 50 B.P. (Penhill)

End of Wensleydale IV:- 2280 ± 50 B.P. (Whirley Gill),

2410 ± 50 B.P. (Penhill)

7.4.1 Description

Wensleydale IV is the first of the regional zones to be fully represented at all four of the pollen analysis sites (see figure 6.9). Whilst the pollen record at Thornton Mire shows considerable divergence from those of the other three sites, it does correlate quite well when the vegetation of the mire itself is excluded from the picture. The L.P.A.Z.s TM4 and TM5 are therefore treated as equivalent to Wensleydale IV, although the total pollen assemblage is not strictly correct for inclusion in this R.P.A.Z. The sequence of regional vegetation changes is broadly similar to that shown elsewhere in Wensleydale, and the radiocarbon dates confirm that the timespan is also approximately the same.

As stated in section 7.3, the Wensleydale III/IV boundary has been dated to 4680 ± 50 B.P. at Fleet Moss and to 4550 ± 50 B.P. at Thornton Mire. At Whirley Gill and Penhill radiocarbon dates slightly above and below the boundary permit estimates of its age. Assuming constant rates of peat accumulation, and calculating from the dates on either side of the boundary, the estimated dates are 4988 ± 50 B.P. at Whirley Gill and 4774 ± 50 B.P. at Penhill. Given that high degrees of humification are thought to signify periods of slow peat accumulation and low values, periods of rapid peat accumulation (Granlund, 1932; Aaby and Tauber, 1975), some indication of the reliability of the estimated dates can be obtained. The Penhill humification profile suggests a fairly constant rate of peat accumulation over the period concerned, so the estimate is probably reasonable. At Whirley Gill the degree of humification is more variable, but the average value over the 10cm between the upper date and the Wensleydale III/IV boundary is very similar to the average over the 80cm between the two dates, and so, again, the estimated date is believed to be satisfactory. The upper boundary of the Wensleydale IV R.P.A.Z. is dated to 2280 ± 50 B.P. at Whirley Gill and 2410 ± 50 B.P. at Penhill. At Fleet Moss a date of 3070 ± 50 B.P. at 155cm leads to an estimate of about 2130 B.P. for the Wensleydale IV/V division, whilst the horizon thought to be equivalent at Thornton Mire is dated to 2690 ± 50 B.P.

The Wensleydale III/IV boundary is marked by a well-defined 'elm decline'. This is the classic feature of the Zone VIIa/Zone VIIb transition in the British system of zonation, and is therefore traditionally sought out as an important boundary when zoning pollen diagrams, regardless of its significance in comparison with other features. In fact this horizon is frequently not distinguished by purely numerical methods of zonation, because the total change in the diagram is so slight (Birks and Birks, 1980). However in the case of the Wensleydale diagrams, the numerical methods support the placing of a major zone boundary at the level of the elm decline, as it is accompanied by a number of small changes in other species which combine to make the total pollen assemblage of the zones on either side significantly different. On the basis of AP data only, each of the three numerical zonation techniques applied resulted in a relatively major boundary at this point on all four pollen diagrams. In most instances the same horizon was still selected when all of the major pollen types were included in the analysis, and so zone boundaries were justifiably placed here. This was not the case at Penhill, though, so at this site the elm decline horizon was only designated as a sub-zone boundary. It must be noted, however, that only the end of Wensleydale III is represented at Penhill, so its assemblage is less characteristic of the regional zone and less clearly distinguished from that of the subsequent zone.

Ulmus pollen values decline from an average of 6–8% TP in Wensleydale III to less than 1% TP at the base of Wensleydale IV at Fleet Moss and Penhill. At Thornton Mire the decline is slightly more prolonged, as Ulmus first falls to 1•5% TP and then to less than 1% TP. Only the Whirley Gill record shows some persistence of elm, with values of over 2% TP throughout Wensleydale IVa, although values recover to a similar level at the other sites later in this zone.

In most cases the elm decline is part of a general decline in AP values which begins at or just before the Wensleydale III/IV boundary and continues to mid-IVa. However the picture is somewhat confused by the rise of alder, which attains a peak of 27–28% TP in early Wensleydale IVa at Whirley Gill, Fleet Moss and Thornton Mire, and 20% TP at Penhill, before participating in the overall reduction of trees. Hazel, oak and birch are the other arboreal species affected by the decline, although to a much lesser extent than the elm. By mid-Wensleydale IVa, total AP values have fallen to about 60% TP at Whirley Gill, Fleet Moss and Penhill, but they then recover towards the IVa/IVb subdivision. In the equivalent zone at Thornton Mire, the reduction in tree pollen is much more pronounced, with a minimum of only 11% TP at 150cm. Here all the tree types decline very rapidly apart from the oak, which is hardly affected. Salix, formerly dominant, almost disappears.

Some AP types do become more abundant in Wensleydale IV, notably Fraxinus and Tilia. Fagus and Carpinus also appear occasionally, although they are more common in Wensleydale IVb. However these four species are relatively minor components of the pollen assemblage, and their expansion is limited compared to the reduction in the major forest trees.

As arboreal pollen becomes less frequent, Ericaceae in particular shows a substantial increase. The range of other NAP types present is extended, but there is little if any rise in grass or sedge pollen. The exception to this general pattern is Thornton Mire, where it is the Gramineae and Cyperaceae curves which respond to the dramatic decrease in AP values, and Ericaceae pollen remains extremely scarce. At all of the sites Plantago lanceolata occurs for the first time in early Wensleydale IVa, but a continuous curve is not established until Wensleydale IVb. Occasional grains of cereal pollen are also present, together with various ruderal species including Rumex acetosella type, Urtica, Chenopodiaceae and Artemisia.

The subdivision of Wensleydale IV is placed at the point where a secondary elm decline occurs, again as the most marked feature in an overall reduction of tree pollen. Ulmus values fall to less than 1% TP, and there is little subsequent recovery. Corylus also declines again, following some recovery in late IVa, as do Quercus and Alnus to varying degrees. Tilia becomes noticeably less frequent, although never abundant, but Fraxinus, Fagus and Carpinus are generally more common than in the previous subzone.

Two particularly marked troughs in the AP curve can be distinguished in Wensleydale IVb, and the degree of recovery after each is less, leading to a progressive reduction in arboreal pollen. As in Wensleydale IVa, it is the Ericaceae which show the greatest increase in response to lowered AP values, reaching up to 38% TP at Whirley Gill, 47% TP at Fleet Moss and 55% TP at Penhill. Cyperaceae and Gramineae values also rise, the latter attaining peaks of over 10% TP at Whirley Gill and Fleet Moss. These peaks are associated with increases in cereal and ruderal pollen, in particular Plantago lanceolata which peaks at 6% TP. Pteridium also expands, reaching values of up to 5% TP.

The features of the IVa/IVb boundary are not discernible at Thornton Mire, where the great reduction of AP in early Wensleydale IV is followed by a large expansion of Betula, up to 33% TP. Alnus and Corylus recover to some extent, while Quercus (like Betula) exceeds its previous values. A further two troughs in the total AP curve can be recognised, as at the other three sites, with great reductions in Betula, and much smaller reductions in all the other tree types. Fraxinus is more abundant in TM5 than in any other zone, comprising up to 8% TP, but Tilia becomes rare. As in early Wensleydale IV, it is the Cyperaceae and Gramineae curves which rise as the AP curve falls, although Ericaceae pollen is slightly more frequent than previously, at up to 5% TP. Filipendula is notably abundant, reaching up to 17% TP, and a wide range of ruderal types is present as at the other sites.

7.4.2 Interpretation

The elm decline and the Neolithic period

The 'elm decline' with which this zone opens has long been the subject of speculation, being widespread in much of western Europe as well as Britain. It was used by Godwin (1940) to define the Zone VIIa/VIIb boundary, and was originally assumed to be the result of climatic change. But although Scandinavian pollen diagrams and peat stratigraphy indicate increased continentality at this time, corresponding to the Atlantic-Sub-Boreal transition, there is no equivalent evidence in Britain. Whilst some climatic shift may have occurred, it appears that in the context of the comparatively oceanic British climate no critical temperature thresholds were crossed, and so there are no signs of climatically-induced vegetation change (Pennington, 1974; Godwin, 1975).

The apparent synchroneity of the elm decline, which was dated to between 5500 and 5000 B.P. over wide areas of western Europe, was taken as support for the climatic theory, but as the number of radiocarbon determinations has grown a wide range of dates has been revealed. It is now generally accepted that other factors must have been involved, but there is still no single and universally accepted explanation of the fall in the elm curve and the accompanying vegetation changes. The other vegetation changes which occur at this horizon vary between different sites, the pattern of the *Ulmus* curve being the only constant feature.

Working on the assumption that such a ubiquitous and striking vegetational phenomenon as the elm decline must have at least an indirect, if not a direct, relation to a climatic factor, the next theory advanced concerned soil deterioration. *Ulmus glabra* requires base-rich mull soils for regeneration, and so would be adversely affected by the progressive deterioration of soils through the post-glacial period. However it is unlikely that soils over such a wide area would all become intolerable to the elm at approximately the same time. In addition, the increase in ash casts doubt on the pedogenic hypothesis because this tree is equally demanding with regard to soil.

Thus it became necessary to consider the possible involvement of prehistoric man in the observed landscape changes. When Neolithic clearance phases were first recognised, slightly above the elm decline horizon in Danish diagrams (Iversen, 1941), the extent to which man was capable of influencing the vegetation at this stage was realised. Troels-Smith (1956) drew attention to the fact that the elm decline preceded the expansion of cereals, Plantago lanceolata and weeds of pasture in Denmark, and he attributed this to the selective gathering of elm foliage by early Neolithic farmers to provide fodder for penned cattle. This practice was seen to persist amongst primitive people in several parts of the world, and would drastically reduce elm pollen production. Troels-Smith argued that it would be necessary to introduce such a technique on a wide scale at the beginning of the Neolithic period, as western Europe was densely forested at this time with very little pasture immediately available for domestic animals.

The idea of such a sudden and extensive spread of Neolithic husbandry techniques met with initial resistance, but it was soon supported by abundant radiocarbon data and the growing body of evidence linking the vegetational and archaeological events (for example Clark and Godwin, 1962; Pilcher, 1969; Pilcher et al,1971). Whilst there is no direct evidence for the selective utilisation of elm as cattle fodder in Britain, the hypothesis has been accepted as satisfactorily explaining the elm decline in some areas (Pennington, 1964, 1965; Walker, 1966). Another possible mechanism for the decline of elm was put forward by Morrison (1959), who suggested that in Antrim forest clearance took place preferentially on calcareous areas within the generally basaltic region, and that these areas had supported most of the elm population. This 'deforestation for agriculture' explanation was also favoured by Mitchell (1956, 1965a, 1965b), but does not apply in all cases.

Yet another hypothesis proposed that a virulent disease could have selectively affected the elms. This idea has gained credibility in recent years following the decimation of the British elm population by Dutch Elm Disease, but it is difficult to prove or disprove. Pennington (1974) maintained that "the more the evidence connecting the elm decline with Neolithic farming and changes in other species accumulates, the less likely does the disease hypothesis become". However Rackham (1980) believed that disease was the most likely primary cause, with early agricultural activity providing the conditions which encouraged its spread. The pathogen could have been Dutch Elm Disease, which Rackham found had affected Ulmus at least during the historical period.

It is therefore widely accepted today that early Neolithic man was in some way responsible for the elm decline, but the precise process involved is uncertain. The use of elm leaves as fodder, the preferential clearance of elms because of the soils on which they grew, or the inadvertent encouragement of disease are all possibilities, either singly or in combination. In addition there may have been a background of climatic and pedological stress which made the trees more susceptible to other influences.

In Wensleydale the elm decline occurred comparatively late, between about 4988 and 4550 B.P. This is in keeping with recent suggestions that upland areas lagged behind the lowlands, as found by Chambers (1974) in Teesdale, where the elevated Valley Bog site yielded a date of 4794 ± 55 B.P. compared with 5468 ± 80 B.P. at the low-lying Neasham Fen. In the Yorkshire Dales area the elm decline has not previously been dated at any upland sites, but in lowland Craven Jones (1977) obtained dates of 5080 ± 100 B.P. at White Moss and 5010 ± 110 B.P. at Eshton Tarn. The change was therefore not synchronous throughout the Dales, nor even within Wensleydale, but whilst the dates do not show a simple correlation with altitude there is a clear distinction between the upland and lowland areas.

The radiocarbon evidence is sufficient in itself to discourage climatic and pedogenic explanations of the elm decline in Wensleydale, as it is unlikely that the lowland elm population would be the first to succumb if a drop in winter temperatures or the leaching of soils were the primary factors involved. The trees of the uplands, growing in more marginal climatic conditions and on soils more susceptible to leaching as a result of heavy rainfall, would surely have been affected earlier. In addition, the equally demanding ash is more frequent in Wensleydale IVa than in any previous zone. The wide range of dates (about 450 years) obtained for the elm decline in this small area also casts doubt on the disease hypothesis, as this mechanism is capable of destroying elm populations over much larger areas in a matter of decades.

Thus the Wensleydale data is in agreement with the general western

European pattern, and it would appear that some anthropogenic connection is required to explain the elm decline. Although this link cannot be proved, it is supported by abundant circumstantial evidence. The Wensleydale diagrams show a definite association between the first indications of clearance for agriculture and the fall in the elm curve. Whilst the vegetation changes differ in detail, each site exhibits the most significant trends: namely the commencement of the Plantago lanceolata curve immediately after the elm decline and the first occurrence of cereal pollen. Forest clearance appears to have begun shortly before the sharp drop in elm at Fleet Moss and Whirley Gill, with some reduction of hazel, oak and birch in late Wensleydale III together with a few grains of cereal pollen and an increase in grasses. At these two sites, then, the evidence points to the introduction of agriculture in the area just prior to the elm decline. All four sites then show the presence of cereals and Plantago lanceolata from the horizon with the minimum Ulmus pollen values. Other ruderal pollen types also occur occasionally, including Rumex acetosella type, Artemisia and Chenopodiaceae. Plantago lanceolata and Rumex acetosella type are particularly associated with pastoral conditions, while Artemisia and Chenopodiaceae, when accompanied by cereals, signify cultivation (Turner, 1964). Both arable and pastoral farming are therefore indicated, implying that the Neolithic culture reached Wensleydale between 5000 and 4500 B.P. At Fleet Moss and Whirley Gill there is some support for the subdivision of agricultural phases suggested by Pilcher et al (1971), into an earlier arable phase followed by a pastoral phase. However it would be unwise to attach too much significance to the small numbers of key pollen types which occur here.

The agricultural activity associated with the elm decline at Whirley Gill and Fleet Moss was probably only small in extent, and temporary, but it is not sufficiently well-defined to permit an estimate of its duration. It was followed by a recovery of _Ulmus_ values, and a decline of grass and ruderal pollen. In contrast, the clearance accompanying the elm decline at Thornton Mire was prolonged and extensive, although the effects seen on the pollen diagram are somewhat exaggerated by changes in the local vegetation of the mire. The replacement of willow carr by _Eriophorum_ bog, as shown by the stratigraphy (see section 4.2.4) accounts for a large part of the reduction in tree pollen, but it is still clear that hazel, birch, pine and later alder also declined. The oak, which is not thought to have grown very close to this site, was hardly affected. The continuity of the _Quercus_ curve suggests that the reduction in the other trees was real, rather than simply the relative effect of an increase in Cyperaceae pollen production from the mire, for instance. Destruction of woodland did then take place around 4550 B.P., and its link with Neolithic man is confirmed by the occurrence of cereal (mostly _Hordeum_ type), _Plantago lanceolata_, _Rumex acetosella_ type, _Urtica_, Chenopodiaceae and _Artemisia_ pollen. The comparatively large quantities of these cultural pollen types serve as further proof of the reality of the clearance phase, as they would have been suppressed if the phenomenon was merely the effect of local over-representation of other herbaceous species.

The elm decline is therefore clearly linked with early Neolithic agricultural activity in Wensleydale, but there is little evidence on which to choose between the various possible anthropogenic causes for this change. The fact that it is preceded by the first occurrence of cereal pollen and a peak in grasses at Fleet Moss and Whirley Gill does not conform to the pattern which would be expected if the elm foliage was being used for fodder as a temporary measure until pasture was established. It seems more likely that following a few initial experiments the Neolithic farmers found that the soils on which the elm grew made the best agricultural land. They are certainly known to have preferred light, easily-worked calcareous soils, and the fact that the most extensive clearance appears to have taken place on the limestone surrounding Thornton Mire, where Ulmus was particularly abundant in Wensleydale III, supports this theory. But it is also possible that a disease which selectively affected the elms could have been inadvertently spread by Neolithic man's intervention in previously wild ecosystems. For example, the increased area of grassland could have favoured the beetles which carried a fungal parasite.

At Penhill there is less evidence of Neolithic agriculture, but nevertheless profound vegetation changes took place at the time of the elm decline. Oak, birch and hazel were reduced, but it was mainly the heaths which increased, with Gramineae pollen reaching a peak of only 2% TP and only occasional grains of Plantago lanceolata. More significantly, though, it was at this time that blanket peat accumulation began on Penhill. If the elm decline is to be attributed to Neolithic man, then the coincidence of blanket peat initiation with this horizon suggests that it too had an anthropogenic cause.

Moore (1975) has collated data showing that many of the shallower blanket peats of Britain began to accumulate at or shortly before the elm decline; examples are found in the South Pennines (Tallis, 1964a; Bartley, 1975), the North Pennines (Chapman, 1964a), Mid-Wales (Moore, 1972) and on Exmoor (Merryfield and Moore, 1974). As there is very little independent evidence for climatic change at this time, and podsolisation did not necessarily precede peat initiation, Moore suggested that Neolithic man might have been involved. Hydrological data from recent deforestation projects demonstrated that forest clearance by the early farmers could have led to great increases in soil moisture levels and reductions in interception and evapotranspiration, resulting in waterlogging and peat formation. This, together with the frequent coincidence of peat initiation with vegetation changes of undoubted anthropogenic origin and its occurrence at just the time when the first agricultural communities settled in Britain led Moore to conclude that Neolithic man was most probably responsible. Whereas Mitchell (1972) stressed the role of pan formation following prehistoric ploughing as a cause of waterlogging, Moore showed that this was not a prerequisite, and that woodland clearance (by felling or fire) or even merely thinning (by selective felling or grazing of domestic animals) could have produced the observed effects.

Whilst there are no tree remains at the base of the peat at Penhill, the pollen curves indicate that the hazel and birch of the high ground were reduced at the same time as the elms were declining at lower altitudes. The scarcity of cultural pollens at this site suggests that the clearance and attempts at agriculture were shortlived and unsuccessful; a brief period of stock grazing may have been the critical factor which tipped the ecological balance in favour of peat formation, thereby causing peat development and rendering the land unfit for further agricultural use.

The woodlands of Wensleydale were therefore under increased human pressure from 5000 to 4500 B.P. onwards. Although the mixed-oak forest established in Wensleydale III persisted, both its composition and extent were gradually changing. The proportion of elm was obviously much reduced, but oak also suffered a slight temporary decline. On the other hand the lime was more widespread in this zone than in any other. When the low pollen productivity of Tilia (Erdtman, 1969) is taken into consideration, it appears that the lime may have been almost as abundant as the elm during Wensleydale IVa. A few birch trees probably remained on the thin soils of the upper valley sides, but pine was no longer present in the area. In the valley bottoms alder reached its maximum extent in early Wensleydale IV, taking over soils which had become too waterlogged for the oak. Its subsequent reduction was probably due to the return of drier conditions and hence other trees, as it is unlikely that Neolithic man would have deliberately cleared the damp ground on which alder thrives. The hazel scrub of the interfluves was also slightly reduced in extent, giving place to more Ericaceous communities as grazing animals prevented regeneration of the shrubs.

On the whole, the pollen diagrams show that the progressive deforestation of Wensleydale began with the arrival of the Neolithic culture. From the elm decline onwards, clearance episodes were followed by less complete recovery of the woodland as grassland and heath slowly spread. Only the light-loving ash tree appears to have benefitted from man's interference, rapidly taking advantage of the openings in the forest before being shaded out again by the regeneration of oak.

After the initiation of agricultural activity at the time of the elm decline, the three high altitude sites (Whirley Gill, Fleet Moss and Penhill) show no distinct clearance phases during the remainder of Wensleydale IVa. Occasional grains of cultural pollens occur throughout the zone, but the area of grassland appears to have diminished rather than increased. All the sites, however, exhibit a marked reduction of arboreal pollen in mid-IVa, in which all the trees participate apart from the elm. The proportion of arboreal pollen declines from about 80% TP to 60% TP, while Ericaceae increases to a peak of over 35% TP. Assuming constant peat accumulation rates, the minimum on the % AP curve is estimated to be almost synchronous at Whirley Gill and Penhill, at 4490 B.P. and 4450 B.P. respectively. A similar estimate for Fleet Moss gives a date of approximately 4200 B.P. , but this may be less accurate as the radiocarbon dates on which it is based are much further apart.

Diagrams based on pollen sums comprising AP types only and NAP types only suggest that the effects seen on the total pollen diagrams are probably due to an absolute increase in Ericaceae pollen, with little reduction of trees. The alder did decline, and was perhaps succeeded by a less prolific pollen producer such as the elm, leading to a decrease in total AP but not in actual tree cover. At Fleet Moss and Whirley Gill the increase in heaths can be attributed in part to some drying out of the bog surfaces, as Calluna remains are found in the peat and Sphagnum spores are less frequent than in earlier zones. It might also be the result of pastoral activity together with burning on the uplands, which would prevent the regeneration of hazel and favour the dominance of Calluna and other ericaceous plants, leading to the first wide expanses of heather moorland. Corylus pollen values always tend to be rather variable, which confuses the pattern of real variations in the number of plants, and it should also be noted that thinning of hazel scrub might also lead to increased pollen production and better dispersal from the remaining hazel (and indeed heath) plants.

Although few finds of Neolithic artefacts have been recorded from the uplands of the Yorkshire Dales, this may be partly due to the reduced chance of their discovery in such remote areas as compared with the better-known lowlands. But in addition, artefacts would be expected to be more frequent in the vicinity of settlements or where tools were in use for forest clearance or cultivation. The use of the interfluves for stock grazing, possibly only in the summer months, would not be likely to leave archaeological remains. Thus it is not surprising that all the recorded Neolithic remains in Wensleydale have occurred at lower altitudes, where the Thornton Mire pollen record indicates more intensive land utilisation.

The archaeological evidence suggests a concentration of Neolithic settlers on the southern side of Wensleydale. It is probably no coincidence that this is the area where a series of lakes were left behind at the end of the last glaciation (see section 2.1), as apart from the water supply, the stocks of fish and water fowl would have been attractive to the Neolithic people. Certainly Semerwater, the only lake remaining today, was utilised, as a number of axes and arrowheads of this age have been found on its shores. The pollen record from Thornton Mire, less than 3km from Semerwater, provides evidence of the agriculture of these people. Unfortunately, as the radiocarbon dates show, peat accumulation was very slow at this time: the period between about 4550 and 3600 B.P. is represented by only 22·5cm of peat. Whilst the pollen assemblage changes drastically between Wensleydale III and IV, neither this nor the stratigraphy indicates any break in peat accumulation, or erosion. However the resolution of this part of the diagram is poor, making it impossible to identify individual clearance phases.

Only a broad, general view of Neolithic land utilisation can therefore be obtained from the Thornton Mire record, but it is immediately apparent that the early agriculturalists had a profound effect on the vegetation of this part of Wensleydale. As discussed earlier, the replacement of willow trees by herbaceous communities on the mire itself was responsible for some of the fall in total AP values, but all the trees which grew in the area immediately surrounding the mire were drastically reduced. Between 4550 and 3600 B.P., the proportion of tree pollen fell to less than 30% TP, and grasses and sedges became dominant. The ferns which had grown in the shade of the woods also declined rapidly. Other NAP types were present in much greater quantity and variety than elsewhere, including cereal (*Triticum* and *Hordeum* types) at up to 2% TP, *Filipendula* at up to 5% TP, and *Rumex acetosella* type at over 1% TP as well as occasional pollen of other plants of cultivated and grazed land. The rise in NAP types is paralleled by a marked rise in the aluminium content of the peat, together with a smaller peak of silica (see figure 4.13). This is believed to be a reflection of the increased erosion brought about by the activities of man. At Coom Rigg Moss, Northumberland, Chapman (1964b) also found that silica and aluminium curves followed the NAP trends, and concluded that the presence of wind-blown silica and aluminium in peat was valuable evidence of the effect of deforestation.

An agricultural economy combining the cultivation of cereals (mainly wheat and barley) with cattle- and sheep-rearing is therefore believed to have been established in the Thornton Mire area during the

Neolithic period. Whilst climatic conditions were probably never very good for arable farming, the land on the southern side of the Ure, between Semerwater and Penhill, would be favoured for its shelter and light, base-rich soils. It seems likely that some of the enclosures near Thornton Mire originated at this time, although they are generally held to belong to the Bronze Age (see chapter 3).

The construction of the Castle Dykes henge on Aysgarth Moor (less than 3km due east of Thornton Mire) in late Neolithic times is further evidence of the establishment of a successful early agricultural community in this part of Wensleydale. A large number of Neolithic people must have been concentrated here for there to be a need for such a structure, whatever its purpose, and the amount of labour required implies that their economy was sufficiently stable and productive to allow the devotion of human resources to causes other than mere day-to-day survival. The scarcity of such monuments in upland areas like the Yorkshire Dales suggests that this particular area supported an unusually dense population. However a number of Neolithic henges are found around Ripon, which is also on the Ure, and it is possible that their builders travelled up the river into Wensleydale, stopping when they came to the unnavigable reach of waterfalls at Aysgarth.

Evidence of Neolithic activity in other parts of the Dales points to less intensive land use, and, by inference, smaller populations than around Thornton Mire. The Craven (Jones, 1977) and Nidderdale (Tinsley, 1972) areas both show a series of small, temporary clearance phases throughout this period, although no accurate dates are available. The agricultural economy appears to have been more exclusively based on pastoralism, as pollen of cereals and associated weeds is much less frequent than at Thornton Mire. However material suitable for pollen analysis is not commonly found as close to areas of prehistoric agriculture as is the case at Thornton Mire, and so it is possible that many similarly utilised areas are unrecorded.

The Bronze Age

Neolithic clearance and agriculture are estimated to have been practised until about 3810 B.P. in the Thornton Mire area, when the proportion of arboreal pollen reached a minimum of 21% TP. A slight increase in tree cover then took place, mainly involving the pioneer birch. However this was shortly followed by renewed agricultural activity from about 3600 B.P. Tree pollen was reduced to only 10% TP by about 3400 B.P., while grasses and weeds of open ground flourished. The dates suggest that this disturbance represents the beginning of the Bronze Age, but there may have been some continuity between the Neolithic and Bronze Age occupation of this part of Wensleydale. The frequent juxtaposition of artefacts of the two cultures at archaeological sites such as henges (Case, 1977) lends support to the idea of co-operation and intermingling between the old and the new settlers.

Thus an arbitrary division between the periods of Neolithic and Bronze Age influences on the landscape can be placed between about 3810 and 3600 B.P. in the Thornton Mire area. On the uplands, the Wensleydale IVa/IVb boundary is equated with this transition, and dated to 3930 ± 50 B.P. at Whirley Gill and 3850 ± 50 B.P. at Penhill. Although it is possible that the observed vegetation changes were brought about by late Neolithic people, their magnitude and abruptness imply the arrival of a new culture with improved agricultural tools and techniques. This corresponds well with the data from other parts of the Pennines. At Eshton Tarn in Craven, Jones (1977) noted a change in agricultural practice, with the replacement of shifting agriculture by more continuous land use from 3600 B.P.; on the Nidderdale Moors Tinsley (1972) attributed "profound changes" in the vegetation to clearance by Beaker Folk or early Bronze Age settlers; and in the South Pennines Hicks (1971) obtained a date of 3740 B.P. for similar early Bronze Age activity.

At all of the upland sites in Wensleydale, the new age represented by Wensleydale IVb began with a marked secondary elm decline. Following the gradual recovery of Wensleydale IVa, Ulmus pollen was again reduced to less than 1% TP. Tilia also became much less frequent, especially at Whirley Gill and Penhill where only occasional single grains of this pollen type occur from the IVa/IVb transition onwards. At Fleet Moss, though, Tilia persisted at low frequencies until about 3070 B.P. The oak did not participate in the general reduction of tree pollen at first, but soon began to decline slowly. The composition of the mixed-oak forest of Wensleydale therefore changed at the time when the Bronze Age culture is thought to have reached Wensleydale, and it is necessary to assess the possible causes of the reductions in both elm and lime.

The hypotheses advanced to explain the selective reduction of elm have already been discussed, and many of the same arguments apply here. In this case the decline is again associated with increased agricultural activity, as shown by the NAP curves. This again suggests the involvement of man, as does the evident rapidity of the decline - changes due to climatic or pedogenic factors might be expected to be more gradual. It is dated to 3930 ± 50 B.P. at Whirley Gill and 3850 ± 50 B.P. at Penhill, and estimated at about 3788 B.P. at Fleet Moss, giving a smaller range of dates than in the case of the primary elm decline at the same sites. The sequence is identical, though, with the elms of the Whirley Gill area disappearing first, then those of Penhill, and finally Fleet Moss. Again this argues against a climatic cause, as recent data shows that the Fleet Moss area has the most hostile climate, and would therefore be the first to lose its elm population if climatic change were responsible.

The coincidence of the secondary elm decline with a reduction of lime might be taken as evidence of a cooling climate, the lime being noted for its thermophilous nature. In fact the *Tilia* decline is seen in many British pollen diagrams and was used to define the VII/VIII zone boundary of Godwin's scheme (Godwin, 1940), on the assumption that it represented a climatic change. However Turner (1962) showed that it was always associated with human interference with the vegetation, and was not actually a single synchronous event throughout Britain. She concluded that the *Tilia* decline was of anthropogenic origin, and could be attributed to people of at least three distinct prehistoric cultures (Neolithic, Bronze Age and Iron Age). The Wensleydale data support this, for while the *Tilia* decline occurs at the Wensleydale IVa/IVb boundary, around 3900 B.P., at Whirley Gill and Penhill, it occurs much later at Fleet Moss, around 3070 B.P. As stated earlier, the latter site has the least favourable climate, so that any deterioration would lead to the critical threshold for lime being crossed first in that area. There are no dates for this horizon elsewhere in the Dales, although it can be recognised at Fountains Earth on the Nidderdale Moors (Tinsley, 1972) and at White Moss in Craven (Jones, 1977). Jones' estimated time scale suggests a date in the late centuries of the third millenium B.P., much later than any of the Wensleydale sites.

It seems most probable, then, that the reductions in both elm and lime at the beginning of Wensleydale IVb were brought about by human activities. Once more it is not possible to determine exactly how this happened, although the selective utilisation or clearance of the two trees seems the most plausible explanation. Like the elm, the lime was of use to early man in a variety of ways: its bast was useful and its leaves nutritious, and it also tended to grow on the better (more basic) soils (Pennington, 1974).

The reduction of the other components of the valley woods was more gradual, but the % TP values for oak, birch and to some extent alder did decline temporarily. In contrast, the interfluves witnessed a more dramatic change, with the rapid spread of heath vegetation at the expense of the hazel scrub. Altogether there was a pronounced decrease in tree cover in early Wensleydale IVb, or the early Bronze Age. The minima on the total % AP curves for the three upland sites, of 45–55% TP, occur shortly after the IVa/IVb division, thus dating from around the middle of the fourth millennium B.P. This corresponds with the further increase in clearance activities at Thornton Mire, where the minimum of 10% TP is dated to 3400 ± 50 B.P.

Whilst grazing and, especially, periodic firing, probably encouraged the spread of Callunetum from the high summits, the thinning of the woodlands further down the valley sides (again most probably due to grazing pressure) favoured the expansion of bracken. At the same time parts of the denser lowland forest were being deliberately cleared for agriculture and settlement. This is reflected in the NAP curves as marked increases particularly in the pollen of grasses and *Plantago lanceolata*, indicating predominantly pastoral land use. Cereals (particularly Hordeum) were also more frequent than in the Neolithic period, especially at Whirley Gill where a peak of almost 3% TP is attained. The latter site, on the northern side of Wensleydale, was clearly ideally placed to reflect the agriculture of the main Ure valley, in view of the prevailing south-westerly winds. All the sites show a large variety of other NAP types, though, confirming the expansion of open habitats.

Clearly Wensleydale supported a considerable number of early Bronze Age people, although there is little undoubted archaeological evidence of their occupation. Whilst the palynological data suggest that some cereal cultivation took place on the sheltered, fertile land of the valleys, the agricultural economy of these people was primarily based on pastoralism. The uplands would have provided rough grazing for sheep and cattle while pigs browsed in the oakwoods, suppressing the regeneration of the trees by eating the acorns as well as uprooting young seedlings. Some of the many 'Beaker People' who inhabited the Chalk wolds and limestone hills of east Yorkshire may have utilised the Pennines for summer transhumance, thereby influencing the vegetation without leaving material remains such as barrows.

Following the early Bronze Age activity, there was a short pause in the attack on the woodland. New areas may have been colonised, or the population concentrated in larger settlements, abandoning the scattered dwellings of the hills. This allowed some recovery of the woodlands to take place. The arboreal pollen diagrams show that the secondary forest contained higher proportions of ash and birch, which would grow rapidly after the cessation of clearance to exploit the open conditions before the canopy closed again. At Thornton Mire, birch pollen increased dramatically to 33% TP (43% AP) by the end of the fourth millennium B.P., and wood remains in the peat show that it spread onto the bog itself. Ash was also particularly frequent around this site, at up to 7% TP/13% AP. The pioneering role of these two trees is emphasised by their unusual abundance in the area where the most intense Neolithic and early Bronze Age clearance took place. Another tree to show a relative increase in Wensleydale IVb was the alder, and this effect can be explained by the settlers' avoidance of the damp ground on which it grew. Whilst there was probably no real increase in the number of alder trees, their proportional contribution to the total arboreal pollen would rise as the trees of the desirable well-drained land were cleared.

However, apart from the spectacular increase in birch at Thornton Mire, which can be attributed to a degree of local over-representation, the most rapid recovery was that of hazel. With the reduction of grazing pressure, the hazel scrub of the high ground regenerated very quickly and encroached once again on the Callunetum. The nature of this secondary 'scrub' is not known, but abundant Corylus pollen could be produced in a short time by a low, herbaceous type of growth before mature shrubs or trees developed.

The period of woodland regeneration was short-lived (perhaps 200 years at Thornton Mire), the total AP curve recovering to a maximum of 76% TP at Thornton Mire by 3220 $\pm$ 50 B.P. and to 72–78% TP at the other sites. Progressive deforestation was therefore underway, as the recovery was still incomplete when the next phase of human interference began. This time the proportion of arboreal pollen fell rapidly to 33–39% TP at Penhill, Whirley Gill and Thornton Mire, and 45% TP at

Fleet Moss. The minimum is dated to 3040 ± 50 B.P. at Whirley Gill and 3070 ± 50 B.P. at Fleet Moss, and estimated to about 3077 B.P. at Thornton Mire. At Penhill the radiocarbon dates are not sufficiently close to permit a satisfactory estimate, particularly as the humification profile suggests that considerable changes in the rate of peat accumulation may have taken place in the intervening period.

Once again the balance between the hazel and ericaceous plants of the interfluves was changed, as the heath communities spread more extensively than before. Ericaceae pollen reached 4% TP for the first time since Zone II at Thornton Mire, and increased to 35% TP at Whirley Gill, 43% TP at Fleet Moss, and 55% TP at Penhill. The particularly rapid replacement of hazel by Callunetum on Penhill appears to have resulted in significant hydrological changes. Humification values fall steadily through Wensleydale IVb, from over 80% to less than 30%, suggesting an acceleration in the rate of peat accumulation due to increased soil moisture and runoff. At the same time Sphagnum temporarily took over from Eriophorum as the dominant species of the bog itself, which is a further indication of comparatively wet conditions. A similar effect can be seen on the Thornton Mire diagram where the clearance of birch and ash on the surrounding limestone slopes combined with the decline of hazel at higher altitudes on Stake Fell to the south led to a rise in the watertable and hence lower humification values. This may have contributed to the further reduction of AP values by adversely affecting the birch trees which had begun to colonise the mire.

Whilst the spread of heath can be attributed mainly to grazing animals, the thin woodland around Thornton Mire may have been cleared by fire, as abundant microscopic charcoal particles were found in the 125cm pollen sample. However the cleared ground was probably also used primarily for pasture, Rumex acetosella type and Plantago lanceolata being more frequent in this agricultural episode than the previous one and cereals less common. Pollen of the Rosaceae family is unusually frequent, most of it being Filipendula ulmaria. This plant probably grew on the mire throughout its development, but it is also characteristic of meadows and may have spread during Wensleydale IV as this type of habitat became available. Other herbs found in this zone which are typical of grazed limestone grassland include Potentilla erecta, Poterium sanguisorba, Lotus spp., Primula spp. and various members of the Papilionaceae (Leguminosae) family.

Apart from the general expansion of heath and the unusually intensive agricultural activity around Thornton Mire, the other aspect of this episode of human vegetation disturbance was the creation of small, temporary clearings in the mixed-oak forest of the valleys. Such effects are particularly marked on the Fleet Moss and Whirley Gill diagrams, where the minima on the total AP curves are accompanied by well-defined, though small, peaks of Gramineae (10-12% TP) and Plantago lanceolata (4-6% TP). Rumex acetosella type is also more abundant than in previous zones, although not reaching 1% TP, confirming that pastoral land use predominated in these clearings as in the rest of Wensleydale. Indicators of cultivation and settlement are also present, however, including Artemisia, Chenopodiaceae and Urtica as well as cereal (Hordeum type) pollen which occurs in almost every sample and consistently comprises over 1% TP at Whirley Gill. The oak was particularly affected by this clearance phase, there being very little elm left by now, but at Fleet Moss it was only at this time that the lime became scarce. Stands of Tilia must have survived at the upper end of the dale and these were felled in preference to Quercus.

The radiocarbon dates show that this agricultural phase can be attributed to late Bronze Age people, and the increased intensity of human activity corresponds with a greater quantity of archaeological evidence for this period. Two ring cairns in Wensleydale, near Carperby and Redmire, are thought to have been the sites of late 'Urn' burials, and the pastoral farming of the Thornton Mire area can be linked with a local concentration of late Bronze Age artefacts centred on Semerwater. The people may have lived on the lake shores because of the water supply, and utilised the land around Thornton Mire for their domestic animals. However there may also have been some settlement in the vicinity of Thornton Mire itself: while the age of the enclosures and hut circles on the terraces of Addlebrough and Greenber Edge is uncertain (see chapter 3), the cairn on Greenber Edge is suggestive of late Neolithic and/or Bronze Age occupation. Most probably the structures first built by late Neolithic settlers were considerably extended during the Bronze Age.

Two major phases of interference with the vegetation of Wensleydale during the zone Wensleydale IVb are therefore ascribed to Bronze Age people. Progressive deforestation had begun, and whilst the mixed-oak woodlands were still firmly established in the valleys they were becoming increasingly open. Bracken was spreading on the well-drained slopes and heath communities on the interfluves. This pattern corresponds well with that found elsewhere in the Pennines. In the Nidderdale area Tinsley (1972) described two Bronze Age clearance episodes, the first of which began at about 3700 B.P. and was attributed to Beaker people and the second dating from the late Bronze Age. As in Wensleydale, both pastoralism and cultivation were practised, although the former was dominant, and there was a marked spread of heath over the higher ground. In Craven, Jones (1977) dated a dramatic increase in agricultural activity to the early Bronze Age (3600 $\pm$ 100 B.P.), with pastoralism again more important than cereal cultivation. Similarly, in the South Pennines Hicks (1971) found evidence for two major Bronze Age clearance phases, and also ascertained that there were fairly extensive areas of heathland by the end of this period but that hazel persisted locally.

Late Wensleydale IV saw the partial recovery of the arboreal communities, with birch spreading onto Thornton Mire again, and ruderal pollen types much reduced at all the sites. Once more the hazel regenerated rapidly, temporarily suppressing the ericaceous plants, and oak, alder and birch colonised the abandoned clearings of the valleys. Thus despite the effects of almost 2500 years of agriculture, Wensleydale was still predominantly wooded in character by the end of this R.P.A.Z., with total AP values of over 60% TP at all the sites examined. Whilst a net reduction in the area of forest had undoubtedly taken place, the most significant vegetation shifts were in the composition of the remaining forest. These changes, notably the virtual disappearance of first elm, and later lime, have all been interpreted as climatic effects in the past, but the evidence presented here suggests that they are satisfactorily explained by the activities of Neolithic and Bronze Age farmers.

7.5 Zone Wensleydale V: Ericaceae-Corylus-Cyperaceae R.P.A.Z.

Type zones: FM6B (Wensleydale Va)

FM7 (Wensleydale Vb) (figures 6.3 and 6.4)

FM8 (Wensleydale Vc)

Dates: Start of Wensleydale V:- 2280 $\pm$ 50 B.P. (Whirley Gill),

2410 $\pm$ 50 B.P. (Penhill)

7.5.1 Description

This zone spans the period from the mid- to late third millennium B.P. to the present day, and is represented at all four sites (see figure 6.9). The Thornton Mire sequence continues to differ from the general pattern found at the other three sites, but when allowances are made for the local vegetation of the mire it is possible to correlate the diagrams. Thus the TM5/TM6 boundary is thought to approximate to the start of Wensleydale V, and this is supported by its date of 2690 $\pm$ 50 B.P. The L.P.A.Z.s TM6 and TM7 are therefore equated with Wensleydale V for the purposes of this discussion, even though their total pollen assemblages do not conform to that defined for this R.P.A.Z.

Wensleydale V is distinguished from the preceding zone mainly by its much-reduced AP frequency and correspondingly increased proportions of Ericaceae, Cyperaceae and Gramineae pollen. At Fleet Moss, for example, total AP declines from an average of 59% TP in Wensleydale IVb to 42% TP in Wensleydale Va, 10% TP in Vb and 12% TP in Vc. Similar patterns are found at the other two high moorland sites. The initial fall in total AP values affects all the trees to some extent, but *Corylus* and *Alnus* show the greatest reductions, dropping to minima of

13–15% TP and 4–7% TP respectively. Quercus is only slightly reduced, while Betula tends to increase in Wensleydale Va. Of the more minor woodland components, Fraxinus declines to values generally less than 1% TP and Ulmus and Tilia become even scarcer than in Wensleydale IV. Fagus shows a slight increase, occurring for the first time at Penhill, although it never attains 1% TP. Carpinus is also more frequent than in previous zones.

At Thornton Mire all the AP types are severely reduced in early TM6, and total AP values remain well below 20% TP up to the present day. The most dramatic declines are those of Betula, which falls from a peak of 55% TP in TM5 to values of 2-3% TP in TM6, and Corylus, which drops from 30% TP in late TM5 to around 3% TP in TM6. As at the other sites, the decline in Quercus is relatively small, while Fagus and Carpinus become more frequent.

As the trees decline, it is the Ericaceae which come to dominate at the three upland sites, averaging 30–40% TP during Wensleydale Va, with Cyperaceae also important at 12–16% TP. Grasses are the third most important non-arboreal plants at these sites, with mean values of 9•5% TP at Fleet Moss, 6•5% TP at Whirley Gill and 4% TP at Penhill. The Thornton Mire record is again somewhat different, being dominated by grasses from the TM5/TM6 boundary onwards. In TM6 grass pollen comprises about 30% TP. However Ericaceae pollen starts to become important for the first time at Thornton Mire in TM6, averaging 12% TP in TM6A and 32% TP in TM6B compared with 2% TP or less in all other zones at this site. Cyperaceae pollen is also frequent, at about 21% TP.

At all of the sites, pollen types indicative of agriculture are abundant in Wensleydale V. Plantago lanceolata consistently comprises

3–4% TP at Thornton Mire, but at the other three sites there is a particularly marked peak in this species in early Wensleydale Va, of up to 9% TP at Penhill, 8% TP at Fleet Moss and 5% TP at Whirley Gill. The peak coincides with the Wensleydale Va AP minimum and with increased frequencies of other weed species such as Rumex acetosella and Urtica as well as high grass and cereal values.

The Wensleydale Va/Vb subdivision is placed at the horizon where a large increase in Ericaceae pollen occurs in conjunction with a further sharp drop in total AP. The effect is most marked at Penhill, where Ericaceae reaches 95% TP by the end of Wensleydale Vb and total AP is only 2% TP. At Fleet Moss the heath and tree proportions are 86% TP and 7% TP respectively, and at Whirley Gill they are 76% TP and 10% TP. Grasses, sedges and other NAP types remain comparatively frequent, although they are rather swamped by the large quantities of Ericaceae pollen.

The Va/Vb subdivision is not so easily recognised at Thornton Mire. However, on the basis of the Ericaceae record alone, it would appear that the TM6A/TM6B boundary may correspond to this horizon. As both the beginning and the end of TM6 are dated, this makes it possible to estimate an approximate age for the subdivision. Calculating on the basis of constant peat accumulation rates gives a date of 2010 B.P. (i.e. 60 B.C.). Whilst the humification profile suggests a fairly variable accumulation rate in TM6, the average humification percentages for TM6A and TM6B are actually very similar (24·4% and 21·2% respectively). This suggests that the estimated age (2010 B.P.) of the boundary should be reasonably accurate, but is more likely to be slightly too old.

At Fleet Moss and Penhill a further subzone, Wensleydale Vc, is distinguished. Its opening is marked by a decline of Ericaceae accompanied by some recovery of total AP values. FM8 is typical, with Ericaceae falling to 15% TP at the surface of the profile, and the AP proportion increasing to about 12% TP. The same trend can be recognised at the top of the Whirley Gill profile, although there are insufficient samples to justify the subdivision of WG7. At Penhill the effect is much more pronounced, with total AP rising to 48% TP at the surface, mainly comprising Corylus, Alnus and Quercus. However Ericaceae remains the dominant pollen type in this final subzone.

If the TM6A/TM6B horizon is accepted as equivalent to the Wensleydale Va/Vb transition, then it follows that the rapid decline in Ericaceae which marks the opening of TM7 (dated to 650 ± 50 B.P., or about 1300 A.D.) corresponds to the Wensleydale Vb/Vc boundary. The application of this date to the other diagrams implies a very slow rate of peat accumulation in recent times at Fleet Moss and Penhill as well as Whirley Gill. For example, at Fleet Moss 1cm depth of peat represents on average 33 years between 8510 and 4680 B.P., and 17 years between 4680 and 3070 B.P., compared with 91 years between 650 B.P. and the present day. As neither the stratigraphy nor the humification profiles show any sign of a break in peat accumulation, and the pollen records do not show the sudden changes which might be expected if a discontinuity were present, it must be concluded that peat accumulation has simply been extremely slow in recent centuries. This can be attributed to the natural drying out of the bogs as the surface is raised further away from the watertable. Although the humification values are rather low for a period of such retarded peat development, this can be explained by the presence of living roots in the peat near the surface.

The greater peat accumulation rate at Thornton Mire leaves a more detailed record of Wensleydale Vc vegetation changes at this site. In contrast to Fleet Moss and Penhill, it is the Gramineae in particular which respond to the reduction in Ericaceae, attaining values of up to 65% TP, although Cyperaceae are also important. The recovery of total AP values is seen here to be only a short-lived phase, followed by a further decline to only 5% TP at 5cm. However the surface AP proportion of 11% TP corresponds well with those of Fleet Moss (11% TP) and Whirley Gill (16% TP), the exception in this case being Penhill with its value of 48% TP.

7.5.2 Interpretation

In historical terms, Wensleydale V clearly represents the period from the beginning of the Iron Age to the present day. On the basis of the dates discussed above, its subdivisions can be related to the historical periods distinguished in chapter 3 as follows:-

Subzone	Approximate Dates	Historical Periods
Wensleydale Va	740-330 B.C. to 60 B.C.	Pre-Roman Iron Age
Wensleydale Vb	60 B.C. to 1300 A.D.	From late Iron Age through Roman, Anglo-Saxon and Scandinavian periods to mid-Norman and Monastic period.
Wensleydale Vc	1300 A.D. to present	From mid-Norman and Monastic period through Post-Monastic period to present day.

The Iron Age

The Wensleydale IV/V boundary, then, is thought to mark the introduction of the technology and lifestyle of the Iron Age into the Dales area. The range of dates for this transition lends support to the idea (discussed in chapter 3) of a degree of continuity between the Bronze Age and Iron Age, with a combination of indigenous development and the spread of knowledge from continental Europe. It is probably no coincidence that the vegetation changes attributed to early Iron Age people occur first at Thornton Mire, the site which witnessed the most intensive land use during the Bronze Age. An area with a comparatively large population would obviously be among the first to adopt new techniques, being more likely both to come into contact with ideas originated elsewhere and to develop its own technology and agriculture in response to the stimuli of population pressure and dwindling resources. Iron would be much more accessible to the people of Wensleydale than bronze, with plentiful iron ores in the Yorkshire area.

With the introduction of iron tools, by whatever means, man was evidently capable of drastically affecting the landscape. This is reflected in the extensive deforestation of Wensleydale Va. Once more it is the vegetation of the uplands which appears to have changed the most, with heath and grassland spreading at the expense of the hazel scrub. However the AP diagrams show that the proportion of hazel in the woodlands of Wensleydale remained high. Although the decline in total *Quercus* pollen is small compared with that of *Corylus*, and hence its proportion of the total AP increases, this can in part be explained by the much greater pollen production of *Corylus*. The true situation cannot be clarified without absolute pollen diagrams, but it seems likely that clearance affected the mixed-oak forest of the valleys as well as the secondary woody scrubland at higher altitudes. It may be that whilst the hazel-dominated communities of the interfluves were giving place to Callunetum, the opening of the mixed-oak woods of the valley allowed increased pollen production and dispersal from an understorey of hazel shrubs. This suggests that the tall trees were selectively felled to be used for timber or charcoal. The Iron Age people would certainly have had a requirement for such resources for their settlements and for smelting. Alternatively, the hazel might have been positively encouraged by man. As well as providing nuts, and wood suitable for weapons and construction purposes, the hazel is ideal for hedges and may therefore have been used to delimit land divisions. Growing in such situations its pollen would be abundant and well-distributed. A third possibility is that whole tracts of forest were cleared by burning, but then abandoned so that hazel, with its ability to recover from firing, was able to regenerate rapidly. However it is unlikely that a cleared area would be allowed to revert to woodland at a time of expanding population and agriculture, even if a natural or accidental fire were responsible for the initial clearance. A combination of the first two hypotheses therefore seems most plausible.

A great expansion of open, treeless environments is therefore envisaged in the early Iron Age, and this is supported by the Thornton Mire chemical analyses (figure 4.13). A peak in the silica curve at the beginning of TM6 can be attributed to an increased supply of wind-blown material as a result of deforestation and the creation of more open habitats. As peat accumulation continued at a fairly constant rate, this is thought to be a genuine increase in silica input to the mire surface. Small peaks in the sodium and potassium curves also indicate instability of the land surface, with erosion rather than leaching of the soil as the dominant process (Mackereth, 1965). Initial clearance of the upland scrub to provide pasture was probably achieved by firing. This is confirmed by the presence of microscopic particles of charcoal in late Wensleydale IV at Thornton Mire. It is most likely that these particles were blown or washed onto the mire from burned areas at higher altitudes, as greater quantities of charcoal might be expected if the firing had taken place in the immediate vicinity.

Whilst it was the Ericaceae (probably mostly Calluna but with a greater variety of other heaths than is found today) which came to dominate the higher ground of Wensleydale, grassy communities also spread at this time. The expansion of the Gramineae at the upland sites may be a response to increased grazing pressure on the already-established heather moors. Calluna is not tolerant of heavy grazing, and overstocking with sheep would rapidly convert the heath to grassland. Around Thornton Mire, though, the basic soils would naturally have favoured the Gramineae rather than the Ericaceae, once the thin secondary woodlands had been removed, and subsequent grazing would have maintained these communities.

Calculation of Turner's (1964) 'arable/pastoral index', which expresses the number of Plantago pollen grains as a percentage of the total number of Plantago, Compositae, cereal, Cruciferae, Artemisia and Chenopodiaceae grains, gives mean values of 75•6% for Fleet Moss, 73•2% for Thornton Mire, 67•6% for Penhill and 63•7% for Whirley Gill in this subzone. On the basis of surface pollen analyses, Turner found that this index was usually below 15% in arable regions and above 50% in pastoral regions. The Wensleydale Va values therefore confirm that the agricultural economy of the Iron Age in this area was based largely on pastoralism, and the higher values at Fleet Moss and Thornton Mire suggest that this type of activity was most widespread towards the head of the dale. Apart from the high proportions of Plantago lanceolata pollen which are responsible for the values of Turner's index, other evidence in the NAP assemblages points to extensive pastoral farming. Rumex acetosella type becomes more frequent in Wensleydale Va at all the sites, and Potentilla erecta, a plant which tolerates and therefore tends to increase under conditions of heavy grazing pressure, shows a marked increase at Thornton Mire and Fleet Moss.

Stock-rearing was therefore very important during the Iron Age in Wensleydale, the open heath and grasslands of the interfluves being grazed by numerous sheep and probably goats. Whilst there is no direct archaeological evidence of the type of animals kept at this time in the Dales, analysis of bones from settlement sites elsewhere in Britain, for example on the Downs, has shown that sheep largely displaced the forest-dwelling pigs and cattle of the Bronze Age (Godwin, 1975). This change may have been very important in initiating the treeless moorland landscapes seen today. The presence of sheep in the lower reaches of Wensleydale at least is suggested by finds of loom weights and spindle whorls near Leyburn (Raistrick, 1939). The enclosures around Thornton Mire and on Penhill were probably used by the Iron Age pastoralists. The name 'Penhill', which is of Celtic origins (A. H. Smith, 1928), tends to confirm this. Shepherds would have spent most of the year on the hills with their flocks, perhaps living with their families in the huts associated with the enclosures. The animals would have to be penned at night to protect them from predators like wolves.

In the woodlands at lower altitudes, small clearings probably supported some pigs and cattle and this would lead to the gradual retreat of the forest edge. Other clearings in the valleys may have been used to produce winter fodder for the livestock, as there is no evidence that Iron Age people carried out an annual autumn slaughter (Megaw and Simpson, 1981). The pollen diagrams provide some support for this, as they show a marked increase in NAP types characteristic of meadows such as Filipendula, Caryophyllaceae and Succisa, particularly at the sites lower down the dale. Enclosures in more sheltered areas, such as those around Thornton Mire, may have continued in use during the winter months, when the animals could be penned and fed on the hay produced in the summer.

Some arable farming was also practised, as shown by an increase in the frequency of cereal pollen (mainly Triticum and Avena types) and weeds associated with cultivation such as Artemisia, Chenopodiaceae and Compositae liguliflorae. However cultivation would have been limited to sheltered clearings on the flat Yoredale limestone terraces of the valleys and perhaps the lower slopes, where a more favourable micro-climate than that of the interfluves would prevail and the soils were light and fertile. Although the Iron Age people had powerful technology for the removal of the forests, they did not yet possess a plough capable of dealing with the heavy clay soils of the valley bottoms, and these areas probably remained largely unused. No grain storage pits have been found, but the discovery of several querns near Leyburn (Raistrick, 1939) tends to confirm that grain crops were produced in lower Wensleydale.

The palynological evidence of Iron Age man's impact on the landscape is fully corroborated by field monuments of this period. As in previous ages, the area on the southern side of the dale from Semerwater to Penhill appears to have been most heavily utilised, with a notable concentration of settlement and agriculture around Thornton Mire. Only a few hut circles and enclosures have been found on the northern side of the valley, in the Carperby-Bolton-Wensley area, although it is possible that others have been destroyed by later agriculture. However the broad tributary valleys joining the Ure from the south would certainly have offered better shelter and perhaps still contained small lakes at this time. As discussed in chapter 2, the retreat of the ice gave rise to lakes both in Bishopdale and in Coverdale, to either side of Penhill. Whilst these lakes, unlike Semerwater, have not persisted to the present day, it is quite possible that they too were an important feature of the Iron Age landscape, providing not only water but also fish and waterfowl for food and reeds for thatching huts.

What is remarkable about this expansion of settlement and agriculture is that it corresponds to a time when the climate is generally thought to have deteriorated. Both the radiocarbon dates and the increases in <u>Carpinus</u> and <u>Fagus</u> suggest that Wensleydale V represents Godwin's (1940) Zone VIII or the Sub-Atlantic period, when peat accumulation recommenced at many British bogs following a dry phase of little or no growth. Both raised bogs and blanket bog were revitalised, and new mires spread across land which had previously supported forest. The change clearly indicates a rise in watertables, but this could have been caused by either an increase in effective rainfall or a degradation of drainage conditions <u>via</u> vegetation changes.

In Wensleydale, there does not appear to have been any cessation or retardation of peat accumulation in Sub-Boreal times, and so there is no marked stratigraphic boundary at the beginning of the Sub-Atlantic. The humification profiles do not show any signs of accelerated bog development; indeed at Penhill there is a pronounced (though temporary) increase in humification in early Wensleydale Va. The water balance therefore remained constant in this area, so that even if the climate had become wetter, peat accumulation rates did not vary significantly. In fact there does not appear to be any evidence to support the idea of a wetter and cooler climate at this time. It is in any case difficult to reconcile with the spread of beech and hornbeam, which are continental rather than oceanic in their distribution. The possible role of man in both inadvertently disrupting natural drainage systems by forest clearance and in opening up the oak woods to permit colonisation by other trees cannot be ignored: anthropogenic effects must by this time have been the dominant influence on the landscape. The development of secondary forest following the abandonment of Bronze Age clearings would improve drainage and so perhaps halt the growth of some bogs. With the arrival of Iron Age people, the runoff resulting from renewed clearance might reactivate bog development. Thus areas which exhibit more continuity of occupation can be expected to show less abrupt changes in peat stratigraphy.

In Wensleydale most of the land susceptible to blanket bog formation had been cleared by the Iron Age. Where local topography favoured it, peat accumulation was already underway; where excess water could run off, it leached the soils and so contributed to the suppression of tree regeneration and the maintenance of Callunetum and rough grassland. Thus whilst vegetation changes in other parts of Britain can be attributed to deteriorating climatic conditions, there is no palynological or stratigraphical evidence of this trend in the Wenslydale records. The marked increase in human activity in the Iron Age, together with the long history of vegetation disturbance by earlier cultures, obscures any climatically-induced vegetation shifts which may have taken place in this area.

Pollen analyses from other parts of the Yorkshire Dales accord well with those of Wensleydale, identifying Iron Age man rather than climatic change as the major influence on the vegetation during this period. On the Nidderdale Moors, Tinsley (1972) dated the start of a prolonged, intensive agricultural phase to 250 ± 80 B.C. Calculation of Turner's arable/pastoral index gave mean values of 75% for all the sites on the Nidd-Laver interfluve, showing that pastoralism predominated, although as in Wensleydale there was evidence of limited arable farming in clearings at lower altitudes. In the Craven area, Pigott and Pigott (1963) linked the extensive Zone VIII clearance around Malham Tarn with the abundant remains of Iron Age hut circles and 'corn plots' on Malham Moor, whilst Jones (1977) estimated that large-scale arable agriculture began around Eshton Tarn c. 200 B.C. In the latter area cereals were remarkably frequent, although the remainder of Lowland Craven was used primarily for pasture.

The intensification of clearance and agriculture in the Iron Age is a feature of pollen records throughout the Pennines, although the exact timing and nature of this episode varies. In north Derbyshire, Hicks (1971) found that the pastoral activities of Iron Age people drastically affected the upland vegetation, the major deforestation phase commencing around 400 B.C. On Rishworth Moor, in West Yorkshire, Bartley (1975) also found evidence of intensive agriculture in the Iron Age, despite an almost complete lack of archaeological remains of this period. Once again grazing was dominant, although cereals were cultivated in the later pre-Roman Iron Age. In the northern Pennines too, large-scale forest clearance for pasture has been dated to the Iron Age; for example around Valley Bog in upper Teesdale (Chambers, 1978) and in Weardale (Roberts, Turner and Ward, 1973).

Thus the supposed climatic deterioration of this time does not seem to have deterred Iron Age man from expanding his agricultural activities in the Pennines. However the Roman record that the Celts of Highland Britain subsisted on meat and milk rather than bread appears to be substantially correct. In contrast to the lowland zones where large quantities of corn were grown (and even exported), cereals generally made only a minor contribution to the agriculture, and hence diet, of the upland regions. The marginal environment for cultivation meant that insufficient grain was produced to warrant special provision for its storage, which agrees with Piggott's (1961) statement that "all finds of carbonized grain from Brigantia or farther north are of Roman or later date."

The Romano-British period

By the end of Wensleydale Va, then, the landscape had been severely affected by early man. Much of the high ground had been permanently cleared of woodland, and whilst the valley bottoms remained well-wooded, the forest edge was in constant retreat under the attack of man and his domestic animals. In these circumstances only a slight climatic deterioration might have been sufficient to change the ecological balance in the direction of establishing heath vegetation, once it had been allowed to spread by the removal of forest. With the resulting intensification of podsolisation under stands of Calluna, soil conditions would have become such that the natural regeneration of forest was no longer possible even in the absence of anthropogenic pressure. Furthermore woodland regeneration would be prevented by grazing and burning, and become still more difficult as the seed source retreated downwards.

The further rapid expansion of heath or moorland which marks the Wensleydale Va/Vb subdivision is therefore envisaged as a response to a combination of factors. Human vegetation disturbance may have led to consequences out of proportion to its extent, because of the already precarious balance of natural environmental conditions. Callunetum appears to have become even more extensive during Wensleydale Vb than it is today, as Ericaceae pollen comprises a higher proportion of the total assemblage than it does in the surface samples. This is particularly noticeable at Thornton Mire, where it is only in this subzone (TM6B) that Ericaceae pollen is at all significant, reaching values of up to 38% TP compared with 2% TP at the top of the profile.

At Fleet Moss and Penhill, where the boundary is most clearly defined, the increase in Ericaceae appears to be largely at the expense of trees, although there is also a decline in Cyperaceae. The same is true of the beginning of WG7, which is the zone spanning both Wensleydale Vb and Vc at Whirley Gill. Stratigraphically, there is no evidence that heath species grew on the bog surfaces themselves, but the surrounding areas were clearly so overwhelmingly dominated by this type of vegetation that the contributions of other pollen types were severely suppressed. It is therefore difficult to assess which species gave way to the spreading heath. However the arboreal pollen diagrams for Fleet Moss and Penhill (figures 6.4 and 6.6) both show a definite increase in the proportion of Quercus and a concomitant decrease in Corylus. Taken together, then, the total and arboreal pollen diagrams suggest that the remaining hazel scrub of the uplands virtually disappeared at this time, giving place to heather moors, while the mixed-oak woodlands of the valleys remained relatively intact. Increased pastoral activity in conjunction with soil deterioration and perhaps a moister climate, as discussed above, could easily account for this transition. The behaviour of the other trees is less easily interpreted, but it seems likely that the treeline was generally retreating downhill, so that the particular species affected would depend very much on local edaphic factors.

The Ericaceae rise at Thornton Mire is also balanced partly by a fall in Cyperaceae values and partly by a further reduction of trees. As arboreal pollen values were already low in this area, however, it seems that heaths must have encroached upon land dominated by other herbaceous vegetation. Some of the increase in heaths may be attributed to their growth on the mire itself. Support for this hypothesis comes firstly from the greatly increased humification values between 34cm and 42cm depth, which suggest a temporary drying out of the mire surface favourable to Ericaceae, and secondly from the presence of Calluna remains in the peat around 33cm. Calluna was clearly not a dominant component of the mire community at this time, though, and much of the Ericaceae pollen must represent the expansion of the heather moors on the higher ground nearby such as Stake Allotments to the south.

The precise date of the human intervention which triggered this vegetation change is uncertain. It has already been stated that the Wensleydale Va/Vb boundary is calculated to date from 60 B.C. or later, on the basis of radiocarbon dates for the beginning and end of TM6. Given that this is only a crude estimate, based on radiocarbon dates which themselves have a recognised margin of error ($\pm$ 50 years in this case), and that the vegetation was rapidly and radically altered, it is proposed that the effects can be attributed to the major upheaval of the Roman Conquest.

As described in chapter 3, the Romans first invaded Britain in A.D. 43, and whilst the Iron Age way of life in the north continued with very little change for some years, new forts were built and existing ones extended in recognition of the Roman threat. It was not until A.D. 74 that the Brigantes were finally defeated at Stanwick and the Romans began to have a serious impact on the Dales area.

Many researchers have concluded that the effects of the Romans on the agriculture and vegetation of Britain were small in comparison with their military and urban constructions. Turner (1970) noted with some surprise that the pattern established during the Iron Age continued through the Roman occupation, there being "as yet comparatively little palynological evidence that new tracts of land were cleared and brought into cultivation." She quotes one isolated example of short-lived Roman clearance, from Flanders Moss in the Forth Valley (Turner, 1965), going on to say that, "It may be, indeed, that we have not looked in the right places but, with the data now available, there remains little positive evidence for further clearance until much later." More recent studies, including the current one, suggest that much of the early work was, in fact, poorly sited for investigation into the Roman influence. The most plausible explanation is that the Lowland Zone was already largely cleared of forest and under quite intensive agriculture when the invaders arrived, so that further improvements were neither necessary nor possible. The Highland Zone, on the other hand, still had enormous potential for development even without technological innovations, and so it was here that the stimulus to agriculture was most effective. Exceptions to this are the favoured areas which already supported agriculture on a scale resembling that of the lowlands. The Craven area of the Dales is an example, where Pigott and Pigott (1963), Jones (1977), and R. T. Smith (1985, in press) found evidence of intensive agriculture (including unusually widespread cereal cultivation) during the Iron Age but no marked change with the arrival of the Romans. More typical of the Pennines at this time, however, was an economy based mainly on pastoralism with only a little cultivation, and pollen records from such areas tend to show an increase in arable farming as well as a general intensification of clearance and agriculture after the Roman conquest. Thus at Leash Fen, in north Derbyshire, Hicks (1971) found that arable cultivation became important for the first time from A.D. 40 ± 100. Similarly, in Northumberland Davies and Turner (1979) dated extensive clearance with the first indications of cereal cultivation at Fellend and Steng Moss to the Roman occupation, and in the Nidd-Laver area of the Yorkshire Dales Tinsley (1972) suggested that the production of meat and grain increased during this period.

In Wensleydale, the most apparent landscape change linked with the Roman occupation was the spread of heaths across the interfluves which has already been described. The clearance which led to this was primarily intended to provide more grazing land, and the pastoral farming which was obviously best suited to this area remained dominant, particularly in the upper dale. Sustained high values of Plantago lanceolata at Thornton Mire and a marked increase in this species at Fleet Moss are indicative of this widespread pastoralism. The surface pollen studies carried out by Tinsley and Smith (1974) suggested that the efficient dispersal of Plantago lanceolata meant that peaks of this pollen type reflected the agriculture of a large area around the pollen analysis site. In contrast, peaks in the pollen of Rumex acetosella type emerged as indicators of very local grazing pressure. This implies that animals were kept on the grassland around Thornton Mire, as there is a pronounced increase in this pollen type at the beginning of Wensleydale Vb.

At both Fleet Moss and Thornton Mire, the values of Turner's arable/pastoral index become even higher (78% and 84% respectively) in early Wensleydale Vb than in late Wensleydale Va, confirming the preponderance of pastoral activity despite an increase in cereal pollen. The other two sites, though, show reductions in this index, to 42% at Penhill and 56% at Whirley Gill. These values are indicative of more mixed farming, and it is clear that cereal cultivation became important, if not extensive, in the lower dale. This is as might have been expected, because the Romans were accustomed to a diet based on grain and vegetable oil and so would have encouraged farmers to provide more of these foodstuffs. The construction and manning of the fort at Bainbridge would have meant a significant increase in the population of Wensleydale, and it would not have been practical to import supplies from Europe into this remote area. Occasional pollen of Secale type suggests that rye was the main cereal crop.

Some of the Celtic people must therefore have accepted Roman rule and co-operated with the invaders. Those who did not probably retreated to the higher ground and continued their pastoral way of life, causing more intensive use of the uplands. The hut circles and enclosures high on Penhill may have been used by a group of such refugees from the Romans. Apart from their influence on the upland heath vegetation, these rebels may have been responsible for considerable forest destruction due to their attacks on the Roman garrison at Bainbridge. Fire would have been their most powerful weapon, and this might have damaged quite large areas of woodland once out of control. In addition, each rebuilding of the fort would require more timber to be felled.

The lead industry also expanded under the Romans, and this would have had further repercussions on the vegetation of Wensleydale. Many trees had to be felled to produce charcoal for the smelting process, and more food had to be produced to support the slaves who worked the mines. The latter may have been Celts captured during the periodic uprisings, who were previously self-sufficient but now became a burden on the Romans and their suppliers.

It is concluded, then, that the intensification of agriculture and industry under the Romans had a pronounced impact on the Wensleydale landscape. In addition, their large-scale changes had less obvious side-effects. Many new species of weeds arrived in imported provisions (Godwin, 1975), and the Roman road system offered ideal conditions for their spread. The sloping embankments of the roads provided large areas of open ground for plant colonisation, and the heavy traffic on them was an efficient dispersal mechanism for various fruits and seeds. Unfortunately the great quantities of Ericaceae pollen at the Wensleydale sites overwhelms the contributions of minor components of the vegetation. Only the most common weeds can be expected to appear in the pollen diagrams in these circumstances, especially as most of the species concerned are not likely to have grown very close to the bogs themselves. However the Thornton Mire record shows marked increases in Urtica and Ranunculaceae pollen in Wensleydale Vb, and the Compositae increase similarly at Fleet Moss and Penhill.

Although the effects of the Roman occupation of Wensleydale are quite clearly reflected in the pollen records, it is difficult to determine which levels on the diagrams correspond to the end of Roman rule and the start of the so-called Dark Ages. From this point on, the close correlation of the pollen records with historical periods becomes untenable due to the poor level of resolution provided by samples at 5cm intervals, and the lack of sufficient radiocarbon dates. Wensleydale Vb is represented by six pollen samples at Thornton Mire, five at Fleet Moss and three at Penhill. The subzone is not distinguished at Whirley Gill, as there only two samples span the rest of Wensleydale V. Given that Wensleydale Vb is thought to date from the Roman Conquest to about 1300 A.D. (vide supra), it would appear that the distinct effects of the Romano-British, Anglo-Saxon, Scandinavian and Norman periods cannot be determined from the pollen records in any detail. In addition, the humification profiles suggest a retardation of peat accumulation at both Thornton Mire and Penhill in mid-Vb, and a similar though less marked feature is seen at Fleet Moss. It would therefore be misleading to attempt to estimate dates within the subzone from the dates of its start and finish.

However at this stage in the development of the landscape, alternative sources of information become available which can compensate for the lack of detailed palynological data. The remainder of the vegetation history of Wensleydale, from Romano-British times through to the present day, has therefore been constructed mainly from historical sources, but with reference to the pollen records where appropriate.

The Dark Ages

The Romans brought about an intensification of forest clearance and land use, but were not responsible for any major changes in agricultural practice in Wensleydale. Celtic ways persisted through the Romano-British period in this area, so the withdrawal of the Romans from Britain in 428 A.D. did not have quite such a drastic effect here as it did in other parts of the country. Those areas of lowland England which had become more 'Romanised', with the establishment of towns and villa estates, underwent considerable changes as the Celts reverted to their old way of life, artificial drainage systems collapsed, villas were abandoned and farmland became overgrown. However the reduction in the population of Wensleydale removed the need for intensive agriculture, and the people who had sought refuge in the uplands were now able to share in the comparative wealth of the lower land. Large-scale lead production probably ceased too, so that some regeneration of woodland might be expected. The slight upturns in the total AP curves at Fleet Moss (25cm) and Thornton Mire (40cm) may be reflections of this. At Thornton Mire it is birch and ash which increase, strongly suggesting the colonisation of abandoned clearings by pioneer species. Birch is the tree which shows the greatest increase at Fleet Moss as well, but oak and alder also rise a little. The persistence of the upland heaths, due to soil deterioration and grazing, is shown by the failure of hazel to recover at all. The continuity of the Plantago lanceolata and Rumex acetosella type curves together with a decline in cereal pollen at this point indicate that the cultivation which was encouraged by the Romans (but never easy in this area) was abandoned in favour of concentration on pastoralism.

Very little data is available from elsewhere in the Dales to support this conjecture, the main problem being the shortage of accurate dates. In Nidderdale, Tinsley (1972) envisaged the continuity of rural life from the Iron Age, through Romano-British times and sustained after the departure of the Roman legions. Meanwhile in Craven the pollen records of Jones (1977) provide conflicting evidence of the Roman withdrawal. Around Eshton Tarn, agriculture declined towards the end of the Roman period and there followed a gradual and partial colonisation of cleared land by trees (largely birch and alder). But the first major clearance eposode at White Moss was dated to 480 ± 100 A.D.

The evidence from other parts of the Pennines is equally variable. Tallis (1964a) suggested that agriculture declined in the southern Pennines from about 400 A.D., while Hicks (1971) found that soil deterioration prevented tree regeneration at this time and led to the development of thin peats where mixed-oak forest had formerly stood. In Northumberland, Davies and Turner (1979) found that tree regeneration began around 460 ± 60 A.D. at Steng Moss but not until about 620 ± 40 A.D. at Fell End, suggesting that the intensive farming of the Romano-British period was maintained for a considerable time in some areas but soon abandoned in others.

The explanation for the pronounced differences in land use must lie in the reduction of population following the Roman withdrawal. Not all of the land utilised for food production during the occupation would be needed when this episode came to an end, so the remaining Celtic people must have concentrated on a few areas while abandoning others. Larger, more defensible villages probably replaced much of the dispersed settlement, as a precaution against further invasions (Dodgshon, 1980). It may also be true, as Jones (1977) speculated, that "with a withdrawal of the Romans and a return to a more mobile, less rigidly controlled system settlers moved out from the populated areas to colonise those areas ignored by the Romans (e.g. White Moss)." Another possibility is that those Celts who rejected Roman rule and maintained their pastoral lifestyle on the hostile high ground were not welcomed back by those who had co-operated (and perhaps intermarried) with the Romans, so that they were forced to move on and clear new land for their agriculture.

The landscape which faced the Angles and Saxons on their arrival in the Dales in the early sixth century A.D. was therefore a mixture of productive agricultural land, abandoned clearings (often with secondary woodland) and mixed-oak forest in the valleys, with heather moorland and blanket bog on the interfluves. The settlers brought new technology and methods which were to further change the landscape of Wensleydale. With their heavy eight-ox ploughs, the Anglo-Saxon farmers were able to exploit the fertile deep loams and clays of the valleys. They therefore colonised the broad, flat valley bottom lands of lower Wensleydale, living in nucleated villages with agriculture organised on the open field system (Dodgshon, 1980). This is shown by the distribution of Anglian place-names together with lynchets indicative of former open fields, as discussed in section 3.7. Whilst occasional Anglian names occur in upper Wensleydale, suggesting that the new settlers did visit this area and perhaps used it for summer pasture, there are no names above Askrigg which point to the existence of villages. Place-names indicating woodland clearings are also restricted to the lower dale. Names such as Brindley, meaning "clearing in a wood caused by fire" and Nappa, meaning "turnip field", provide an insight into the methods and crops of the Anglian farmers in lower Wensleydale, while Hardraw, meaning "shepherds dwelling", indicates the less intensive use of the higher land to the west for pastoralism.

Thus it appears that the valley bottoms remained largely wooded in Anglo-Saxon times, with villages and their open fields confined to clearings in the mixed-oak forest of lower Wensleydale. These people do not seem to have made much use of the uplands, leading a settled existence in their well-organised agricultural communities, but some animals were grazed in upper Wensleydale in the summer months. At Penhill, a marked increase in both Plantago lanceolata and cereal pollen (mostly Hordeum type) in mid-Wensleydale Vb may be a reflection of the mixed farming of the lower dale. The virtual disappearance of Plantago lanceolata and the total absence of Rumex acetosella type at the same point in the Fleet Moss record may indicate a reduction of grazing pressure in the upper reaches of Wensleydale. However the decline of P. lanceolata could also be attributed to the spread of acid, peaty soils at this time.

As stated in section 3.7, the fate of the Celtic people living in

Wensleydale at the time of the Anglo-Saxon invasion is not known. The writings of Bede (Colgrave and Mynors, 1969) imply that many may have been slaughtered initially, while others escaped once more to the uplands. Celtic place-names are scarce in Wensleydale, and it may be significant that one of the few to survive is that of "Penhill". The hut circles and enclosures on this hill may have continued in use through the Anglo-Saxon period as a refuge of the Celts. However Faull (1984) suggests that the Celtic people of north-east England accepted Anglo-Saxon overlordship peacefully, and the two cultures coexisted and intermingled during the fifth and sixth centuries A.D.

Throughout the Dales the picture of this period is similar, the work of Tinsley (1972) in Nidderdale and Jones (1977) in Craven confirming that the Anglo-Saxons established their villages and agriculture in the valley bottoms and made less use of the upland pastures than their predecessors. At White Moss, Jones estimated that a second clearance peak (following that dated to 480 A.D.) occurred in the early seventh century, and was therefore attributable to the mixed farming of the Anglo-Saxons. Little palynological data is available for other parts of the Pennines, for the same reasons as those already discussed for Wensleydale. However the picture of the Pennine landscape obtained from historical sources is largely the same as that of Wensleydale: open heath and bog on the uplands, and woodlands in the valleys with clearings on the lower, flatter reaches containing Anglian agricultural communities practising mixed farming. From the late eighth century onwards, the increased summer temperatures of the 'little optimum' (Lamb, 1966) made the uplands more favourable for settlement and agriculture.

Following several hundred years of Anglo-Saxon influences, Wensleydale was next colonised by Danish and Norse settlers from the late ninth century onwards. Like their predecessors, the Danes favoured the heavier, more fertile soils of the lowlands and established their villages in the lower dale. They also preferred to live close to the rivers which were their main transport routes. But the Norse people, who came to this area from the west rather than the east, seem to have made greater use of the uplands. Their place-names are frequently encountered throughout Wensleydale, and the persistence of Norse language elements through to the present day suggests that they had a strong influence on the area.

The centuries of Anglian agriculture appear to have made little impact on the forests of Wensleydale, as Norse place-names continue to indicate clearings in a generally wooded area. Fire was still used to create these clearings, as shown by the name Swinithwaite, meaning "place cleared by burning", and the presence of valuable game in the forests is revealed by Hindlethwaite, which means "forest clearing for hinds". Specific trees referred to in place-names include oak, alder and apple. In upper Wensleydale, temporary summer settlements are indicated by a number of names containing the element "saetr". All in all, the evidence confirms the view of Raistrick (1976) that the Norsemen were essentially pastoralists, transhumance playing an important role in their economy, although their permanent farms were in the valleys.

The pollen records cannot add much to this picture of the Scandinavian period in Wensleydale. The recovery of grasses, cereal and <u>Plantago lanceolata</u> values towards the end of Wensleydale Vb at

Fleet Moss may represent the increased utilisation of the upper dale, but apart from this the level of resolution is insufficient to allow the separation of Anglo-Saxon and Scandinavian landscape change. In Craven, Jones (1977) attributed agricultural decline in the eighth and early ninth centuries to the periods of unrest caused by the invaders, but this was followed by a peak of agricultural activity (predominantly pastoral) at White Moss estimated to c. 880-1040 A.D. Pigott and Pigott (1963) also cited the Norse settlement of the Craven uplands as a period of renewed forest destruction. Tinsley (1972) suggested that grazing pressure on the Nidderdale Moors was reduced during the disturbed times of the Norse and Anglian invasions, allowing the regeneration of birch scrub, but the continued presence of agricultural indicators and the evidence of place-names indicate a similar pattern to that of Wensleydale.

Palynological studies from other parts of the Pennines have detected phases of renewed clearance dating from the Scandinavian period. In the south, an increase in pastoral activity at Leash Fen, North Derbyshire, was estimated by Hicks (1971) to have commenced around 860 A.D., while intense woodland clearance around Featherbed Moss, also in Derbyshire, (Tallis and Switsur, 1973) was dated to 927 $\pm$ 50 A.D. In Northumberland Davies and Turner (1979) also found evidence of extensive Scandinavian clearance dating from 865 $\pm$ 35 A.D. at Steng Moss and 1005 $\pm$ 40 A.D. at Fellend.

The Norman and Monastic period

The remainder of Wensleydale Vb represents the Norman and monastic period, up to 1300 $\pm$ 50 A.D. For this and subsequent periods documentary evidence is the main source of information on vegetation and land use. Following the devastation brought about by the Norman conquest of 1066 together with raids by Danes and Scots, the Domesday record compiled in 1086 implies that whilst lower Wensleydale remained prosperous, much of the study area was uninhabited. As described in section 3.8, between 1070 and 1086 the Norman landowners moved people from agriculturally poor regions such as this to the depopulated holdings of the more fertile lowlands (Bishop, 1948). This was only a temporary phase, though, and it cannot be detected in the pollen records. Of more interest in the context of this study is the extent of woodland at this time. The Domesday Book shows that all the villages up to Askrigg were in existence by 1086, but that to the west of this was the "Forest of Wensleydale". As discussed in section 3.8, the term "forest" did not have the same significance as it does today. It was used to describe an area reserved for royal hunting and strictly controlled by forest law, not necessarily comprising continuous stands of trees. The composition of the Forest of Wensleydale is therefore uncertain, although it probably consisted of discontinuous woodland or scrub. Oak, alder and hazel appear to have been dominant in late Wensleydale Vb according to the arboreal pollen diagrams, but there was also a considerable amount of secondary woodland composed of birch and ash. The most puzzling aspect of this woodland is its extent and density. At all of the pollen analysis sites, the total AP values for the end of Wensleydale Vb are lower than those at the surface. This is difficult to reconcile with the historical evidence that woodland was more extensive in Norman times than it is today. However it may be that the Norman forest was continuous in upper Wensleydale, with a closed canopy, thus leading to less pollen dispersal than the current situation of scattered trees and hedges which are able to produce and freely disperse large quantities of pollen. Alternatively, the woodlands might have been actively coppiced or pollarded, which would also reduce the production of tree pollen. This is perhaps the most likely explanation, as the centuries of interference with the forests by man and his animals would have left little in the way of dense, closed forest. Whilst the forest laws might initially have limited such practices, they gradually came to be disregarded and the forest shrank as the demand for wood increased. However the wooded parts of the "Forest" must have been restricted to the valley bottom, for heather moorland clearly dominated the interfluves, while the valley sides probably supported rough grassland with only a few trees in the steep gills inaccessible to grazing animals.

During the twelfth and thirteenth centuries agriculture expanded in Wensleydale under the influence of the monks of Jervaulx and the other large landowners. The Forest was supposedly protected from human interference, with no settlements permitted within its boundaries apart from the lodges of the foresters. However it must have been gradually shrinking due to grazing by pigs and cattle, and the monks of Fors (and later Jervaulx) played an important role in its destruction not only because of their large flocks of sheep but also through exercising their rights to use the timber and to extract and process lead. In addition, settlements soon spread into the protected area, Hawes for example being established by the early fourteenth century. Tree regeneration was also hindered by the introduction of the rabbit and the fallow deer during the Norman period.

Whilst most of Wensleydale was used to pasture sheep, cattle and horses, a variety of crops were grown in the open fields around the villages of the lower dale, and the area under cultivation was gradually extended as the population increased. By the end of Wénsleydale Vb, arboreal pollen was less frequent than at any time before or since, although the high values of Ericaceae probably disguise the true extent of woody vegetation, and woodland management (as mentioned earlier) would lead to the under-representation of trees in the pollen spectrum. Arable indicators such as cereal, Artemisia and Chenopodiaceae pollen are present, though rather overwhelmed by Ericaceae, and the Fleet Moss diagram suggests that cultivation was more important in the upper dale than at any time since the Bronze Age. This can be attributed to population pressure and the establishment of the monastic granges. The landscape changes of the Norman and Monastic period therefore seem to parallel those of other parts of the Dales, despite the attempts to conserve the royal hunting territory. In Craven (Jones, 1977) and Nidderdale (Tinsley, 1972) too, this was a time of agricultural expansion, the areas belonging to the monastic houses showing the most intensive exploitation. To meet the needs of the increased population, cultivation was extended further up the hillsides and valleys than would be practicable today. This was made possible by the favourable climate of the "little optimum"; an indication of the comparative warmth of this period is given by documented evidence of vineyards as far north as York (Lamb, 1966).

The period of expansion and prosperity came to an end in the fourteenth century, when the population of Wensleydale was drastically reduced due to a combination of factors. From about 1300 A.D. the climate began to deteriorate again, so that crop yields were reduced and agriculture was no longer able to support the large population which had developed during the years of good harvests. This together with the Black Death which devastated England in the mid-fourteenth century would have had a serious impact on the dale. Those who did not die from the plague would have been able to migrate to more hospitable land in lower-lying areas. In addition, raids by the Scots caused considerable losses throughout the fourteenth century, and many tenant farmers were compelled to follow their Lords to fight on the Borders. A number of medieval villages which were documented in tax records of the early fourteenth century were deserted by the fifteenth century and few traces of them remain today (Hartley and Ingilby, 1977).

A similar pattern of depopulation during the fourteenth century is documented for the rest of the Yorkshire Dales (Victoria History, 1914) and for the more northerly parts of the Pennines (Lapsley, 1905; Johnes, 1806). Recent palynological studies from these areas have detected this agricultural decline and tree regeneration. Pollen records from Weardale (Roberts, Turner and Ward, 1973), Northumberland (Davies and Turner, 1979) and Nidderdale (Tinsley, 1972) for example all exhibit these features. Diagrams from Craven (Jones, 1977), a more favourable area, show a less pronounced decline of agriculture with some cereal cultivation persisting, although there was a general shift towards pastoral farming.

The recovery of total AP values which marks the Wensleydale Vb/Vc subdivision is thought to reflect this period of decreasing population, particularly as it is dated to 1300 ± 50 A.D. at Thornton Mire. The interpretation of this boundary is not straightforward, however, for the apparent increase in tree pollen takes place largely at the expense of Ericaceae, while grasses and agricultural indicators tend to become more frequent or at least maintain steady values. Several hypotheses can be advanced to account for the observed pollen assemblage in the light of the historical evidence.

As Calluna is such a prolific pollen producer, any reduction in the heath community would lead to an apparent increase in other pollen types regardless of the absolute change in their frequency. The nature of the Calluna decline is therefore the key to the interpretation of this horizon, and three possible reasons for this change can be envisaged. The simplistic explanation is that trees extended onto former heather moorland under conditions of reduced grazing pressure. However the expansion of woodland in this way must have been limited, given that the soils had been impoverished by centuries of podsolisation under Calluna, and that climatic deterioration is known to have been underway at this time. Hazel may have spread on Penhill, though, as suggested by the pollen record and by the name "Hazelley Peat Moor". A second possibility is that increasing wetness brought about the replacement of Ericaceae by Sphagnum or Eriophorum on parts of the moors. The pollen records provide some support for this, as Sphagnum spores become more frequent at all the sites and Cyperaceae pollen also increases in Wensleydale Vc. The third alternative is that the decline of arable farming led to an increase in pastoralism rather than the complete abandonment of Wensleydale. Whilst trees were left to regenerate in the damp valleys the uplands may once more have been used intensively for summer pasture. This, together with a rapidly expanding rabbit population, could have converted large tracts of heath to grassland, thus explaining the increases in Gramineae and Plantago lanceolata pollen. It is also possible that there was little real expansion of woodland, but rather an increase in arboreal pollen production due to the abandonment of woodland management practices like pollarding and coppicing as the labour force declined.

The pollen assemblages of early Wensleydale Vc are probably attributable to a combination of these changes. It seems likely that whilst the surviving tenants who worked small farms on the land of the Lordship of Middleham and the Scrope family left Wensleydale for more hospitable areas, the monastic lands continued in use. The monks were tied to this area by their elaborate abbeys and the need to support themselves from the land they owned, and so they persevered with intensive sheep farming and even some cultivation despite cattle disease and poor harvests (see section 3.8). The work of Jones (1977) suggests a similar situation in Craven, with agriculture persisting on the land under monastic control but declining elsewhere. In fact the Cistercians had a deliberate policy of utilising unrewarding terrain in order to exercise manual labour and to attain isolation (Knowles, 1969), but it was soon realised that the finest wools are produced by sheep whose feeding grounds are least favourable for other agricultural purposes, and so economic motives also came into play (Evans, 1975).

The population of Wensleydale gradually increased again following the decline of the fourteenth century, but it was now supported almost entirely by pastoralism due to the deteriorating climate of the "Little Ice Age" (Lamb, 1966). A further rise in pollen of Gramineae and *Rumex acetosella* type together with falling AP values at Thornton Mire are indicative of the intensive grazing of livestock practised at this time.

The Post-Monastic period

During the sixteenth and early seventeenth centuries the great estates of the Middle Ages, including those of the monasteries dissolved in 1539, were broken up and passed into the hands of yeomen farmers. From this time on, the history of vegetation and land use in Wensleydale is known in considerable detail from historical sources (see section 3.9), and the pollen records can add little to the picture.

By the mid-seventeenth century, the Forest of Wensleydale had been replaced by fields and common pastures. Some wheat, oats, barley and rye were grown in the remaining open fields of the lower dale, together with a little hemp and flax, but enclosure was proceeding rapidly. The increases in arboreal pollen shown towards the tops of the pollen diagrams may be partly due to the growth of hedges, although dry stone walls were substituted for these as boundaries in the upper dale and on the high ground.

Towards the end of the seventeenth century the last surviving open fields were being eliminated, and the pattern of agriculture which remains today was established. The enclosed pastures of the valley bottoms and the lower slopes supported valuable dairy cattle, while the common pastures on the highest ground provided grazing for large flocks of sheep. During the seventeenth and early eighteenth centuries the lead industry was responsible for further reductions in the area of woodland, but with the adoption of peat as a fuel in the mid-eighteenth century it was the blanket bog communities which began to suffer and the few remaining woods were left alone. The final abandonment of coppicing and pollarding was probably another reason for the increased arboreal pollen values seen in Wensleydale Vc.

Since the mid-nineteenth century the population of Wensleydale has declined continuously, due to agricultural depression and the demise of the lead industry. Dairying remains important in the valleys, and sheep are still grazed on the moors, but much marginal land has been abandoned. The heather moors are strictly controlled, often managed for grouse, and drainage seems destined to accelerate the erosion of the blanket peats.

Although the population of Wensleydale is now lower than at any time since the beginning of the nineteenth century, the same pattern of agriculture is maintained with the assistance of modern methods and machinery. As part of the Yorkshire Dales National Park, the landscape which has undergone so much change in the past is now expected to remain constant. It is ironic that the main threat to the present landscape is man's appreciation of it - the pressure of thousands of visitors every year is the latest in the long history of anthropogenic disturbances of the vegetation of Wensleydale.

CHAPTER 8: SUMMARY OF CONCLUSIONS

8.1 Evaluation of subsidiary techniques

8.1.1 Humification analysis

8.1.2 Chemical analysis

8.1.3 Computerized calculation and presentation of pollen data

8.1.4 Numerical zonation methods

8.2 The Holocene vegetation history of Wensleydale

SUMMARY OF CONCLUSIONS

In this final chapter the main findings of the study, which have been discussed fully in the preceding chapters, are summarised in relation to the aims set out in chapter 1.

8.1 Evaluation of subsidiary techniques

Whilst pollen analysis is the principal technique used to reconstruct Quaternary environments, it is by no means an exact science. The results are generally open to more than one interpretation, and can often raise as many questions as they answer. A multi-disciplinary approach to palaeoecology is therefore preferable, drawing on evidence and techniques from a variety of sources to provide the fullest and most coherent reconstruction possible.

The particular subsidiary techniques employed in this study are assessed below.

8.1.1 Humification analysis

The detailed humification analysis proved valuable in detecting hydrological changes in the bogs and also in estimating peat accumulation rates from the radiocarbon dates. The degree of humification and the way in which this varies through a particular pollen zone is a useful indicator of the reliability of estimated dates. However the analysis was rather time-consuming, especially with the replication of samples thought to be necessary. Greater sampling intervals, of perhaps 5cm instead of 2cm, would reduce the work involved and still produce adequate results for a study of this type. In addition the technique produced such consistent results that replication could be substantially reduced.

8.1.2 Chemical analysis

The chemical analyses carried out for the Thornton Mire profile were of most use in understanding the development of the mire. The results show how the peat has formed under minerotrophic conditions throughout the Holocene, only recently becoming more acidic as the mire surface has become slightly raised and a more ombrotrophic regime has evolved. Periods of local deforestation and soil erosion can also be detected from the chemical profiles, lending support to the palynological data. Overall, the most useful chemical analyses were the exchangeable calcium/magnesium ratio, ash weight, and total silica, aluminium and iron. The other elements examined might be more applicable to other depositional environments, particularly lakes.

8.1.3 Computerized calculation and presentation of pollen data

The use of a computer program to calculate and plot pollen data greatly reduces the time and expense involved and also increases the accuracy of the results. Furthermore it is easy and very quick to experiment with different pollen sums and diagram layouts, which assists in the interpretation of pollen records and in comparisons with other work. Once a program has been developed and tailored to the specific needs of a research unit, the users do not need any knowledge of programming to be able to employ it effectively in their own research. The consistent use of a program in this way by a number of researchers would have the added advantage of building up a valuable palynological database. This would give scope for further use of computer techniques in the analysis, comparison and collation of data collected by different individuals, and would ensure that the data was stored safely and yet easily retrieved when required.

8.1.4 Numerical zonation methods

The numerical zonation of pollen records is an objective way of delimiting true pollen assemblage zones. However, it was found in the course of this study that the techniques could not be used to determine the final zones and subzones without a certain amount of human intervention. In particular, there was a tendency for zone boundaries to be placed between each of a number of adjacent samples. Whilst this highlights the variability of a section of the pollen record, zones containing only one sample each are of little value as an interpretive framework. Similarly, zones containing a very large number of samples are unwieldy and difficult to work with. Other problems arise with inconsistencies between the results of the different techniques, showing that no one method can be relied upon to pick out all the transitional horizons. Thus numerical zonation methods must be regarded as tools to assist in the selection of zone boundaries, by providing information on the degree of variability or uniformity between samples. They must not be regarded as fully automated zoning procedures providing an instant answer without thought from the investigator.

8.2 The Holocene vegetation history of Wensleydale

The vegetation history of Wensleydale is summarised in figure 8.1, which shows the main characteristics of the regional pollen assemblage zones and their relationships to the British Pollen Zones of Godwin (1940) and the climatic periods of Blytt and Sernander. This leads to the following principal conclusions:

(i) The regional zones of Wensleydale show a remarkable coincidence with the traditional British zonation scheme, despite being derived by numerical methods. This shows that whilst the original explanation of the British zones as representing synchronous, climatically-induced vegetation changes is no longer tenable, there is a surprising degree of similarity between the vegetation histories of sites throughout the country. Although there are many local variations in the timing and nature of vegetation changes, the fundamental pattern can still be recognised.

(ii) The Holocene vegetation sequence found in Wensleydale is broadly similar to that of the rest of the Pennine area. The main differences are as follows:

a) Blanket bog became established considerably earlier in the Wensleydale area than in most other parts of the Pennines, due to the interference of Mesolithic man.

b) Pine has never been an important component of the Wensleydale forests, although it was dominant or second only to birch in the Boreal forests of much of the rest of the Pennines. This is attributed partly

DATE	R.P.A.Z.	HISTORICAL PERIODS	AP:NAP	ZONE CHARACTERISTICS	INTERPRETATION	BRITISH POLLEN ZONES	BLYTT & SERNANDER PERIODS
	WENSLEYDALE Vc	POST-MONASTIC NORMAN/MONASTIC		Further great reduction in AP, but *Corylus* remains dominant AP type. Total AP reduced to 10%TP or less by Vb. Ericaceae pollen increases to maximum in Vb of 76%TP at Whirley Gill, 86%TP at Fleet Moss, 95%TP at Penhill, & 39%TP at Thornton Mire. Slight recovery of AP & decline of Ericaceae in Vc. Agricultural indicators frequent throughout V.	Great expansion of open ground in Iron Age, with increased pastoral activity on interfluves & around Thornton Mire, & also some cultivation. Further intensification of agriculture in Romano-British period, with rapid spread of heather moors under increased grazing pressure. Cereal cultivation in lower dale. Several further phases of agricultural contraction & expansion during the historical period, with AP increasing due to abandonment of woodland management practices in upper dale & establishment of hedges in lower dale.	VIII	SUB-ATLANTIC
650BP/1300AD (Thornton Mire)	WENSLEYDALE Vb	DARK AGES ROMANO-BRITISH					
2010BP/60BC (estimate)	WENSLEYDALE Va	IRON AGE					
2460BP/510BC (mean value)	WENSLEYDALE IVb	BRONZE AGE		Total AP declining, dominated by *Corylus*, *Alnus* & *Quercus*. Marked decrease in *Ulmus* at all sites, increase in *Fraxinus* & *Tilia*. Occasional *Fagus* & *Carpinus* pollen. NAP increasing especially Ericaceae. Peaks of Gramineae (including cereals), *Plantago lanceolata* & other weeds, associated with troughs in total AP curve. Peat development initiated at Penhill in early IVa. AP reduced to 11%TP by end of IVa at Thornton Mire, but then recovers. Secondary *Ulmus* decline & also *Tilia* decline at IVa/IVb boundary, followed by further troughs in total AP curve & peaks of cultural indicators.	Elm decline & Penhill peat development linked to Neolithic forest clearance & agriculture. Progressive deforestation begun. Heather moorland spreading on interfluves with increased grazing & periodic firing. Intensive Neolithic activity, mainly pastoral but also arable, around Thornton Mire. Decline of lime & secondary decline of elm associated with early Bronze Age man. Two major phases of Bronze Age agricultural activity predominantly pastoral but with more cereal cultivation than in Neolithic. Increased utilisation of Wensleydale area in late Bronze Age.	VIIb	SUB-BOREAL
3890BP/1940BC (mean value)	WENSLEYDALE IVa	NEOLITHIC					
4748BP/2798BC (mean value)	WENSLEYDALE III	MESOLITHIC		Increase in *Alnus* & also *Quercus* & *Ulmus*, but *Corylus* pollen still dominant. Small quantities of *Tilia* & *Fraxinus* at all sites. NAP values similar to II but Ericaceae reduced. *Salix* dominant at Thornton Mire.	Area well-wooded, becoming wetter & warmer. Alder expansion comparatively late, & restricted by lack of suitable habitats. Hazel scrub maintained by Mesolithic activities on interfluves. Mixed-oak forest consolidated in valleys & on lower slopes. Small temporary clearings created throughout III, but no agricultural indicators present until end of zone.	VIIa	ATLANTIC
6370BP/4420BC (Whirley Gill)	WENSLEYDALE IIb			*Corylus* pollen overwhelmingly dominant, *Betula* much reduced. *Salix* & *Pinus* also reduced at upland sites, but *Ulmus*, *Quercus* & *Alnus* increasing. NAP now only 20%TP at upland sites, mostly Ericaceae. *Salix* & *Pinus* still important at Thornton Mire, with NAP average 10%TP, nearly all Cyperaceae & Gramineae. Occasional *Tilia* & *Fraxinus* pollen at Thornton Mire.	Landscape predominantly wooded. Hazel scrub with heaths dominant on well-drained interfluves, maintained by periodic firing. Willow locally important at wet valley sites, pine & birch persisting in gills & on limestone terraces. Mixed-oak forest spreading into valleys.	VI	BOREAL
7840BP/5890BC (Thornton Mire)	WENSLEYDALE IIa						
8160BP/6210BC (Whirley Gill) 8950BP/7000BC (Whirley Gill)	WENSLEYDALE I			*Betula* dominant, *Salix* & *Pinus* relatively high. Rapid increase in *Corylus* towards top of I. NAP high (58%TP) at base, mostly Cyperaceae but also Gramineae & *Filipendula*. Peat accumulating pre-I at Whirley Gill, from late I at Fleet Moss & Thornton Mire.	Open birch woods with willow in damper areas. Mesolithic interference with birch woods causing peat development at Whirley Gill & later at Fleet Moss & Thornton Mire. Use of fire implicated in replacement of birch by hazel.	V	

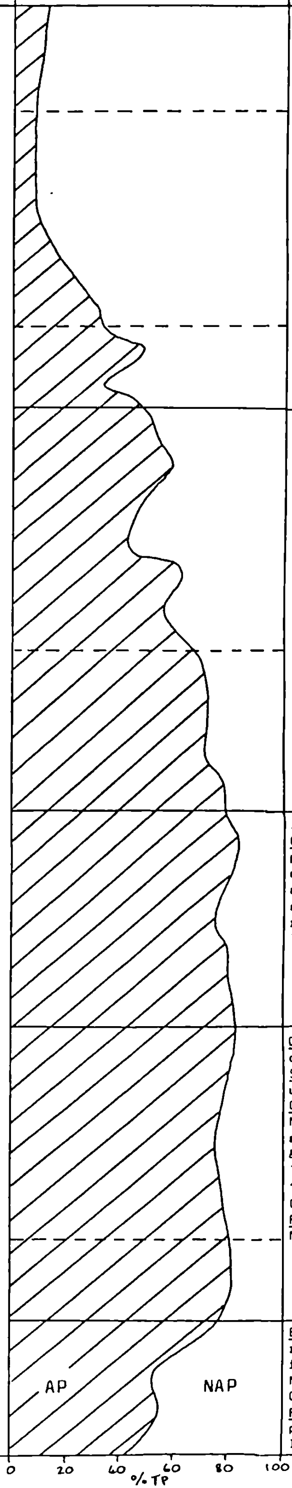


Figure 8.1: Summary of the Holocene vegetation history of Wensleydale

to the scarcity of the shallow limestone soils to which pine was no doubt well adapted elsewhere, and partly to the high altitude of the study area.

c) Hazel was unusually abundant throughout the Holocene in Wensleydale. Whilst accidental firing may have led to the initial establishment of hazel scrub on the interfluves, in later periods the shrub certainly survived because of its value to man, and may have been deliberately managed.

d) The expansion of alder associated with the Boreal-Atlantic transition occurred comparatively late in Wensleydale and was restricted by a shortage of suitable habitats. Whilst the geology and topography of the area were largely responsible for this situation, the apparent concentration of early human activities on the interfluves rather than in the valleys may also have been a significant factor.

e) The elm decline also occurred considerably later than is usual in the Pennines, and the evidence supports the idea that this phenomenon was delayed at high altitudes.

f) Evidence of the activities of early prehistoric man appears to be more abundant in Wensleydale than in most areas of the Pennines. This cannot be taken to indicate a genuine difference in the intensity of agricultural activity, however. It may simply reflect the consistent approach to interpretation and the deliberate siting of investigations close to archaeological evidence of prehistoric occupation.

(iii) The Wensleydale pollen diagrams do not provide any undoubted evidence of climatic change during the Holocene apart from the amelioration implied by the immigration of warmth-demanding trees like the elm and lime. The fact that man was influencing the vegetation even before the major forest dominants reached the dale casts further doubt on the validity of the climatic climax hypothesis, emphasising the truly plagioclimactic status of post-glacial vegetation.

(iv) Man has affected the timing, intensity and rapidity of floristic changes throughout the Holocene. Some of these changes might have taken place anyway, like the spread of blanket bog on the Pennine interfluves and the Boreal hazel expansion; others, like the elm decline and the establishment of extensive Callunetum, might never have happened in the absence of man. The research carried out in Wensleydale therefore confirms the view that human activity has been a major factor in vegetation changes since Mesolithic times.

BIBLIOGRAPHY

Aaby, B. and Tauber, H. (1975) 'Rates of peat formation in relation to degree of humification and local environment, as shown by studies of a raised bog in Denmark', Boreas, 4, 1-17.

Andersen, S. T. (1970) 'The relative pollen productivity and pollen representation of North European trees, and correction factors for tree pollen spectra determined by surface pollen analyses from forests', Danm. Geol. Unders., II Rk. 96, 1-99.

Atherden, M. A. (1976) 'Late quaternary vegetational history of the North York Moors: III. Fen Bogs', J. Biogeog., 3, 115-124.

Bahnson, H. (1968)* 'Kolorimetriske bestemmelser af humificeringstal i højmosetørv fra Fuglsø mose på Djursland', Medd. Dansk. Geol. Foren., 18, 55-63.

Barringer, J. C. (1982) The Yorkshire Dales. Dalesman Books, Clapham.

Bartley, D. D. (1964) 'Pollen analysis of organic deposits in the Halifax region: I. Deposits in the Cromwell Bottom gravel pit near Elland. II. Blanket peat on Rishworth Moor and Meltham Moor showing evidence of early human occupation', The Naturalist, 890, 77-87.

Bartley, D. D. (1975) 'Pollen analytical evidence for prehistoric forest clearance in the upland area west of Rishworth, West Yorkshire', New Phytol., 74, 375-381.

Birks, H. J. B. (1973a) Past and Present Vegetation of the Isle of Skye - a Palaeoecological Study. Cambridge University Press, London.

Birks, H. J. B. (1973b) 'Modern pollen rain studies in some arctic and alpine environments', in Birks, H. J. B. and West, R. G. (eds.), Quaternary Plant Ecology, Blackwell, London.

Birks, H. J. B. (1974) 'Numerical zonations of Flandrian pollen data', New Phytol., 73, 351-358.

Birks, H. J. B. and Berglund, B. E. (1979) 'Holocene pollen stratigraphy of Southern Sweden - reappraisal using numerical methods', Boreas, 8, 257- 279.

Birks, H. J. B. and Birks, H. H. (1980) Quaternary Palaeoecology. Edward Arnold, London.

Bishop, T. A. M. (1948) 'The Norman settlement of Yorkshire', in Hunt, R. W., Pantin, W. A. and Southern, F. W. (eds.), Studies in Mediaeval History presented to Frederick Maurice Powicke, Oxford.

Blytt, A. (1876)* Essay on the Immigration of the Norwegian Flora during Alternating Rainy and Dry Periods. Cammermeyer, California.

Bowen, D. Q. (1978) Quaternary Geology - a Stratigraphic Framework for Multidisciplinary Work. Pergamon Press, Oxford.

Brewster, T. C. M. (1963) The excavation of Staple Howe.

Brothwell, D. R. (1972) 'Palaeodemography and earlier British populations', World Archaeol. 4.1, 75–87.

Bullock, P. (1971) 'The soils of the Malham Tarn area', Field Studies, 3, 381–408.

Butler, L. A. S. (1967a) 'Prehistoric Archaeology', in Beresford, M. W. and Jones, G. R. J.(eds.), Leeds and its Region, British Association Handbook, Arnold, Leeds.

Butler, L. A. S. (1967b) 'Dark Age Archaeology', in Beresford, M. W. and Jones, G. R. J. (eds.), Leeds and its Region, British Association Handbook, Arnold, Leeds.

Case, H. J. (1977) 'The beaker culture in Britain and Ireland', in Mercer, R. J. (ed.) Beakers in Britain and Europe, BAR suppl. ser. 26, 71–101.

Chambers, C. (1974)* Vegetational History of Teesdale. Ph.D. Thesis, University of Durham.

Chambers, C. (1978) 'A radiocarbon-dated pollen diagram from Valley Bog, on the Moor House national nature reserve', New Phytol., 80, 273-280.

Champion, T. C. (1975) 'Britain in the European iron age', Arch. Atl., 1, 127-145.

Chapman, S. B. (1964a) 'The ecology of Coom Rigg Moss, Northumberland. I. Stratigraphy and present vegetation', J. Ecol., 52, 299-315.

Chapman, S. B. (1964b) 'The ecology of Coom Rigg Moss, Northumberland. II. The chemistry of peat profiles and the development of the bog system', J. Ecol., 52, 315-321.

Clark, J. G. D. (1938) 'A neolithic house at Haldon, Devon', Proc. Prehist. Soc., 4, 222-223.

Clark, J. G. D. (1954) Excavations at Star Carr. Cambridge University Press, London.

Clark, J. G. D. (1955) 'A microlithic industry from the Cambridgeshire Fenland and other industries of Sauveterrian affinities from Britain', Proc. Prehist. Soc., 21, 3-20.

Clark, J. G. D. (1972) Star Carr: a case study in bioarchaeology. Addison-Wesley Modular Publications, Reading (Mass.).

Clark, J. G. D., Godwin, H. and Clifford, M. H. (1935) 'Report on recent excavations at Peacock's Farm, Shippea Hill, Cambridgeshire', Antiq. J., 15, 284-319.

Clark, J. G. D. and Godwin, H. (1962) 'The Neolithic of the Cambridgeshire Fens', Antiquity, 36, 10-23.

Coleman, A. M. (1970) 'The conservation of wildscape: a quest for facts', Geog. J., June, 1970.

Colgrave, B. and Mynors, R. A. B. (eds.) (1969) Bede's ecclesiastical history of the English people. Oxford.

Conway, V. M. (1947) 'Ringinglow Bog, near Sheffield', J. Ecol., 34, 149-181.

Cowling, E. T. (1973) 'A Mesolithic flint site: The Sandbeds, Otley, Yorkshire', Yorks. archaeol. J., 45, 1-12.

Cushing, E. J. (1967) 'Late-Wisconsin pollen stratigraphy and the glacial sequence in Minnesota', in Cushing, E. J. and Wright, H. E. (eds.), Quaternary Palaeoecology, Yale University Press.

Dale, M. B. and Walker, D. (1970) 'Information analysis of pollen diagrams', Pollen Spores, 12, 21-37.

Damon, P. E., Long, A. and Wallick, E. I. (1973)* 'Dendrochronologic calibration of the carbon-14 time scale', Proc. 8th Int. Conf. Radiocarbon Dating, 18-25.

Davies, G. and Turner, J. (1979) 'Pollen diagrams from Northumberland', New Phytol., 82, 783-804.

Davies, J. (1963) 'A Mesolithic site on Blubberhouses Moor, Wharfedale, West Riding of Yorkshire', Yorks. archaeol. J., 41, 61-70.

Davis, M. B. (1963) 'On the theory of pollen analysis', Am. J. Sci., 261, 897-912.

Deacon, J. (1974) 'The location of refugia of Corylus avellana (L) during the Weichselian glaciation', New Phytol., 73, 1055-1063.

Dimbleby, G. W. (1962) 'The development of British Heathlands and their soils', Oxf. For. Mem., 23.

Dimbleby, G. W. (1965) 'Post glacial changes in soil profiles', Proc. Roy. Soc. B.161, 355-362.

Dimbleby, G. W. (1970) Plants and Archaeology. John Baker, London.

Dodgshon, R. A. (1980) The origin of English field systems. Academic Press, London.

Edwards, W. and Trotter, F. M. (1954) 'The Pennines and adjacent areas', _Br. reg. Geol._, 3rd edition, HMSO, London.

Elgee, F. and Elgee, H. W. (1933) _The Archaeology of Yorkshire._ The County Archaeologies, Methuen, London.

Erdtman, G. (1960)* 'The acetolysis method', _Svensk. bot. Tidskr._, 54, 561-564.

Erdtman, G. (1969) _Handbook of Palynology. Morphology. Taxonomy. Ecology._ Munksgaard, Copenhagen.

Erdtman, G., Berglund, B. and Praglowski, J. (1961) _An Introduction to a Scandinavian Pollen Flora._ Vol. I. Almquist and Wicksell, Stockholm.

Erdtman, G., Praglowski, J. and Nilsson, S. (1963) _An Introduction to a Scandinavian Pollen Flora._ Vol. II. Almquist and Wicksell, Stockholm.

Evans, J. G. (1971) 'Habitat change on the calcareous soils of Britain: the impact of neolithic man', in Simpson, D. D. A. (ed.), _Economy and Settlement in Neolithic and Early Bronze Age Britain and Europe_, London.

Evans, J. G. (1975) _The Environment of Early Man in the British Isles._ Elek Books, London.

Eyre, S. R. (1968) _Vegetation and Soils - a World Picture._ 2nd edition, Arnold, London.

Faegri, K. and Iversen, J. (1975) _Textbook of Pollen Analysis._ 3rd edition, Munksgaard, Copenhagen.

Faull, M. C. (1984) 'Settlement and society in north-east England in the fifth century', in Wilson, P. R., Jones, R. J. and Evans, D. M. (eds), _Settlement and Society in the Roman North_, School of Archaeological Sciences, Univ. of Bradford and the Roman Antiquities Section, Yorkshire Archaeological Society.

Fieldhouse, R. (1982) 'Some evidence of surviving open fields in the seventeenth century Pennine dales and the gradual elimination of communal agriculture', _Yorks. archaeol._ J., 54, 111-118.

Geikie, J. (1877)* The Great Ice Age. Daldy, Isbister and Co.

Gillespie, R. (1982) 'Radiocarbon users handbook', Quaternary Research Unit Occasional Publication No. 1, Macquarie University, New South Wales.

Godwin, H. (1940) 'Pollen analysis and forest history of England and Wales', New Phytol., 39, 370-400.

Godwin, H. (1962) 'Half-life of radiocarbon', Nature, 195, 984.

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

Godwin, H. and Clifford, M. H. (1938) 'Studies of the Post-glacial history of British vegetation. I. Origin and stratigraphy of Fenland deposits near Woodwalton, Hunts. II. Origin and stratigraphy of deposits in southern Fenland', Phil. Trans. R. Soc. B, 229, 323-409.

Godwin, H. and Willis, E. H. (1959) 'Cambridge University Natural Radiocarbon Measurements I', Am. J. Sci. Radiocarbon Suppl., I, 63-75.

Gordon, A. D. and Birks, H. J. B. (1972) 'Numerical methods in Quaternary palaeoecology. I. Zonation of pollen diagrams', New Phytol., 71, 961-979.

Gordon, A. D. and Birks, H. J. B. (1974) 'Numerical methods in Quaternary palaeoecology. II. Comparison of pollen diagrams', New Phytol., 73, 221-249.

Gosden, M. S. (1968) 'Peat deposits of Scar Close, Ingleborough, Yorkshire', J. Ecol., 56, 345-353.

Goudie, A. S. (1977) Environmental Change. Oxford University Press, Oxford.

Granlund, E. (1932)* 'De svenska högmossarnas geologi', Sver. geol. Unders. Afh. 26.

Hallam, J. S. (1960) The Mesolithic of the Central Pennines. M.A. Thesis, University of Liverpool.

Harkness, D. D. (1979) 'Radiocarbon dates from Antarctica', British Antarctic Survey Bulletin, 47, 43-59.

Harley, J. K. and Yemm, E. W. (1942) 'Ecological aspects of peat accumulation. I. Thornton Mire, Yorkshire', J. Ecol., 30, 17-56.

Hartley, M. and Ingilby, J. (1977) The Yorkshire Dales. Dent and Sons, London.

Helbaek, H. (1952) 'Early crops in southern England', Proc. Prehist. Soc., 18, 194-233.

Hibbert, F. A., Switsur, V. R. and West, R. G. (1971) 'Radiocarbon dating of Flandrian pollen zones at Red Moss, Lancashire', Proc. R. Soc. B, 177, 161-176.

Hicks, S. P. (1971) 'Pollen-analytical evidence for the effect of prehistoric agriculture on the vegetation of North Derbyshire', New Phytol., 70, 647-667.

Hicks, S. P. (1972) 'The impact of man on the East Moor of Derbyshire from mesolithic times', Yorks. archaeol. J., 129, 1-21.

Hughes, E. E. and Mann, W. B. (1964)* 'The half-life of carbon-14', Int. J. appl. Radiat. Isotopes, 15, 97-100.

Ingram, H. A. P., Anderson, M.C., Andrews, S. M., Chinery, J. M., Evans, G. B. and Richards, C. M. (1959) 'Vegetational studies at Semerwater', Naturalist, 113-127.

Iversen, J. (1941) 'Land occupation in Denmark's Stone Age', Danm. Geol. Unders., IIR 66, 20-48.

Iversen, J. (1960) 'Problems of the early Post-glacial forest development in Denmark', Danm. Geol. Unders., IV, 3, 1-32.

Janssen, C. R. (1967) 'A comparison between the recent regional pollen rain and the sub-recent in four major vegetation types in Minnesota', Rev. Palaeobot. Palynol., 2, 331-342.

Jessen, K. (1935) 'The composition of the forests in Northern Europe in Epipalaeolithic time', Kg. Danska Vidensk. Selskab., Biol. Medd., 12, 1-64.

Jonassen, H. (1950) 'Recent pollen sedimentation and the Jutland heath diagrams', Dansk. bot. Ark., 13, 1-168.

Johnes, T. (ed.) (1806)* Chronicles of England, France and Spain.

Jones, I. P. (1977) Studies in the Flandrian vegetational history of the Craven district of Yorkshire. Ph. D. Thesis, University of Leeds.

Jowsey, P. C. (1966)* 'An improved peat sampler', New Phytol., 65, 245-248.

Kent, P. E. (1974) 'Structural history', in Rayner, D. H. and Hemingway, J. E. (eds.), The Geology and Mineral Resources of Yorkshire, The Yorkshire Geological Society, Leeds.

King, A. (1970) Early Pennine Settlement. Dalesman, Clapham.

Knowles, D. (1969) Christian Monasticism. Weidenfield and Nicolson, London.

Lamb, H. H. (1964) 'Trees and climatic history in Scotland', Q. J. Roy. Met. Soc., 90, 382-394.

Lamb, H. H. (1966) The Changing Climate. Methuen, London.

Lapsley, G. T. (1905)* Victoria County History - Durham. London.

Longworth, I. H. (1965) Yorkshire. Regional Archaeology Series. Longmans, London.

Mackereth, F. J. H. (1965) 'Chemical investigations of lake sediments and their interpretation', Proc. Roy. Soc. B, 161, 295-309.

Manby, T. G. (1963) 'The excavation of the Willerby Wold longbarrow', Proc. Prehist. Soc., 29, 173-205.

Manley, G. (1956) 'The climate of the Northern Pennines', Q. J. Roy. Met. Soc., 62, 103-113.

Mattson, S., Sandberg, G. and Terning, P. E. (1944) 'Electrochemistry of soil formation. VI. Atmospheric salts in relation to soil and peat formation and plant composition', Lantbrukshogskolans Annaler, 12, 101-118.

Maxwell, I. S. (1962) 'Yorkshire: the North Riding', in Darby, H. C. and Maxwell, I. S. (eds.), The Domesday Geography of Northern England, Cambridge University Press, London.

Megaw, J. V. S. and Simpson, D. D. A. (1981) Introduction to British Prehistory. Leicester University Press.

Mellars, P. (1973) 'The affinities of the Sandbeds Mesolithic site', Yorks. archaeol. J., 45, 13-18.

Merryfield, D. C. and Moore, P. D. (1974) 'Prehistoric human activity and blanket peat initiation on Exmoor', Nature, 250, 439-441.

Mitchell, G. F. (1956) 'Post-boreal pollen diagrams from Irish raised bogs', Proc. R. Ir. Acad., 57B, 185-251.

Mitchell, G. F. (1965a) 'Littleton Bog, Tipperary: an Irish vegetational record', Geol. Soc. Amer. Special Paper 84, 1-16.

Mitchell, G. F. (1965b) 'Littleton Bog, Tipperary: an Irish agricultural record', J. R. Soc. Antiq. Ir., 95, 121-132.

Mitchell, G. F. (1972) 'Soil deterioration associated with prehistoric agriculture in Ireland', 20th International Geological Congress, Symposium 1, 59-68.

Moar, T. N. (1969) 'A radiocarbon-dated pollen diagram from north-west Scotland', New Phytol., 68, 209.

Moor, J. W. (1963) 'Excavations at Beacon Hill, Flamborough Head, East Yorkshire', Yorks. archaeol. J., 41, 191-202.

Moore, D. (1958) 'The Yoredale Series of Upper Wensleydale and adjacent parts of north-west Yorkshire', Proc. Yorks. Geol. Soc., 31, 91-148.

Moore, J. W. (1950) 'Mesolithic sites in the neighbourhood of Flixton, North-East Yorkshire', Proc. Prehist. Soc., 16, 101-108.

Moore, J. W. (1954) 'Excavations at Flixton, site 2', in Clark, J. G. D. (ed.), Excavations at Star Carr, Cambridge University Press, London.

Moore, P. D. (1972) 'The initiation of peat formation and the development of peat deposits in mid-Wales', Proceedings 4th International Peat Congress, 89-100.

Moore, P. D. (1975) 'Origin of blanket mires', Nature, 256, 267-269.

Moore, P. D. and Webb, J. A. (1978) An Illustrated Guide to Pollen Analysis. Hodder and Stoughton, London.

Morrison, M. E. S. (1959) 'Evidence and interpretation of "Landnam" in the North-East of Ireland', Bot. Not., 112, 185-204.

Moss, C. E. (1904) 'Peat moors of the Pennines: their age, origin and utilization', Geog. J., 23, 660-671.

Nilsson, T. (1967)* 'Pollenanalytische Datierung mesolithischer Siedlungen im Randgebiet des Ageröds mosse im mittleren Schonen', Acta Univ. Lund. II, 16, 1-80.

Overbeck, F. (1947)* 'Studien zur Hochmoorentwicklung in Nieder-Sachsen und die Bestimmung der Humifizierung bei stratigraphisch-pollenanalytischen Mooruntersuchungen', Planta, 35, 1-56.

Pearsall, W. H. (1950) Mountains and Moorlands. New Naturalist Series, Collins, London.

Peglar, S. (1979) 'A radiocarbon-dated pollen diagram from Loch of Winless, Caithness, North-East Scotland', New Phytol., 82, 245-263.

Pennington, W. (1964) 'Pollen analyses from the deposits of six upland tarns in the Lake District', Phil. Trans. R. Soc. B, 248, 205-244.

Pennington, W. (1965) 'The interpretation of some post-Glacial vegetation diversities at different Lake District sites', Proc. Roy. Soc. B, 161, 310-323.

Pennington, W. (1974) The History of British Vegetation. Unibooks, London.

Pennington, W. (1975) 'The effect of Neolithic man on the environment in north-west England: the use of absolute pollen diagrams', in Evans, J. G., Limbrey, S. and Cleere, H. (eds.), The effect of man on the landscape: the Highland Zone, Council for British Archaeology Research Report 11.

Penny, L. F. (1974) 'Quaternary', in Rayner, D. H. and Hemingway, J. E. (eds.), The Geology and Mineral Resources of Yorkshire, The Yorkshire Geological Society, Leeds.

Phillips, J. (1836)* Illustrations of the geology of Yorkshire. Part II. The Mountain Limestone district. John Murray, London.

Piggott, S. (1961) 'Native economics and the Roman occupation of north Britain', in Richmond, I. R. (ed.), Roman and Native in north Britain, Nelson, London.

Pigott, C. D. and Pigott, M. E. (1963) 'Late-glacial and post-glacial deposits at Malham, Yorkshire', New Phytol., 62, 317-334.

Pigott, M. E. and Pigott, C. D. (1959) 'Stratigraphy and pollen analysis of Malham Tarn and Tarn Moss', Field Studies, 1, 84-101.

Pilcher, J. R. (1969) 'Archaeology, palaeoecology, and 14C dating of the Beaghmore stone circle site', Ulster J. Archaeol., 32, 73-91.

Pilcher, J. R. and Smith, A. G. (1981) 'Post glacial history of Seamer Carr, Yorkshire', Phil. Trans. R. Soc. B, 289.

Pilcher, J. R., Smith, A. G., Pearson, G. W. and Cronder, A. (1971) 'Land clearance in the Irish Neolithic: new evidence and interpretation', Science, 172, 560-562.

Rackham, O. (1980) Ancient Woodland. Edward Arnold, London.

Radley, J. and Mellars, P. (1964) 'A Mesolithic structure at Deepcar, Yorkshire, England, and the affinities of its associated flint industries', Proc. Prehist. Soc., 30, 1-24.

Raistrick, A. (1926) 'The glaciation of Wensleydale, Swaledale and adjoining parts of the Pennines', Proc. Yorks. Geol. Soc., 20, 366-411.

Raistrick, A. (1929) 'The Bronze Age in West Yorkshire', Yorks. archaeol. J., 29, 354-365.

Raistrick, A. (1933) 'The distribution of Mesolithic sites in the north of England', Yorks. archaeol. J., 31, 141.

Rasitrick, A. (1938) 'Prehistoric cultivations at Grassington, West Yorkshire', Yorks. archaeol. J., 33, 166-174.

Rasitrick, A. (1939) 'Iron Age settlements in West Yorkshire', Yorks. archaeol. J., 34, 115-150.

Raistrick, A. (1967) Old Yorkshire Dales. David and Charles, London.

Raistrick, A. (1968) The Pennine Dales. Regions of Britain Series, Eyre and Spottiswood, London.

Raistrick, A. (1972) The Romans in Yorkshire. Dalesman, Clapham.

Raistrick, A. (1976) Malham and Malham Moor. Dalesman, Clapham.

Raistrick, A. and Blackburn, K. B. (1938) 'Linton Mires, Wharfedale. Glacial and Post-glacial history', Proc. Univ. Durham Phil. Soc., 10, 24.

Raistrick, A. and Holmes, P. F. (1962) 'Archaeology of Malham Moor', Field Studies, I, 73-100.

Raistrick, A. and Illingworth, J. L. (1949) The face of north-west Yorkshire. Dalesman, Clapham.

Raistrick, A. and Jennings, B. (1965) History of Lead Mining in the Pennines. Longmans Green, London.

Ramsbottom, W. H. C. (1974) 'Carboniferous', in Rayner, D. H. and Hemingway, J. E. (eds.), The Geology and Mineral Resources of Yorkshire, The Yorkshire Geological Society, Leeds.

Rawitscher, F. (1945) 'The hazel period in the post-glacial development of forests', Nature, 156, 302-303.

Ritchie, J. C. and Lichtie-Federovich, S. (1967) 'Pollen dispersal phenomena in Arctic-Subarctic Canada', Rev. Palaeobot. Palynol., 3, 255-266.

Roberts, B. K., Turner, J. and Ward, P. F. (1973) 'Recent forest history and land use in Weardale, Northern England', in Birks, H. J. B. and West, R. G. (eds.), Quaternary Plant Ecology, Blackwell, Oxford.

Sernander, R. (1908)* 'On the evidence of Post-glacial changes of climate furnished by the peat mosses of northern Europe', Geol. Foren. Forh., 30, 465-478.

Simmons, I. G. (1964) 'Pollen diagrams from Dartmoor', New Phytol., 63, 165-180.

Simmons, I. G. (1969a) 'Evidence for vegetation changes associated with mesolithic man in Britain', in Ucko, P. J. and Dimbleby, G. W. (eds.), The Domestication and Exploitation of Plants and Animals, Duckworth, London.

Simmons, I. G. (1969b) 'Environment and early man on Dartmoor, Devon, England', Proc. Prehist. Soc., 35, 203-219.

Simmons, I. G. (1975) 'Towards an ecology of Mesolithic man in the uplands of Great Britain', J. Archaeol. Sci., 2, 1-15.

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

Smith, A. G. (1970) 'The influence of Mesolithic and Neolithic man on British vegetation', in Walker, D. and West, R. G. (eds.), Studies in the vegetational history of the British Isles, Cambridge University Press, London.

Smith, A. G. (1975) 'Neolithic and Bronze Age landscape changes in Northern Ireland', in Evans, J. G., Limbrey, S. and Cleere, H. (eds.), The effect of man on the landscape: the Highland Zone, Council for British Archaeology Research Report 11.

Smith, A. G. and Collins, A. E. P. (1971) 'The stratigraphy, palynology and archaeology of diatomite deposits at Newferry, Co. Antrim, Northern Ireland', Ulster J. Archaeol., 34, 3-25.

Smith, A. G. and Pilcher, J. R. (1973) 'Radiocarbon dates and vegetational history of the British Isles', New Phytol., 72, 903-914.

Smith, A. H. (1928) The Place-Names of the North Riding of Yorkshire. English Place-Name Society, Cambridge University Press, London.

Smith, I. F. and Evans, J. G. (1968) 'Excavation of two long barrows in north Wiltshire', Antiquity, 42, 138-142.

Smith, L. P. (1976) 'The agricultural climate of England and Wales', MAFF Technical Bulletin 35, HMSO, London.

Smith, R. T. (1977) 'Bracken in Britain. I. Background to the problem of bracken infestation', Working Paper 189, School of Geography, University of Leeds.

Smith, R. T. (1982) 'Towards a more holistic view of British vegetation history', Working Paper 328, School of Geography, University of Leeds.

Smith, R. T. (1985) 'Aspects of the soil and vegetation history of the Craven district of Yorkshire', in Turnbull, P. and Manby, T. G. (eds.), Archaeology in the Pennines - Essays in honour of Dr. A. Raistrick, Council for British Archaeology Research Report, in press July 1985.

Smith, W. G. and Rankin, W. M. (1903) 'Geographical distribution of vegetation in Yorkshire. Part II, Harrogate and Skipton district', Geog. J., 22, 149-178.

Stead, I. M. (1965)* The La Tène Cultures of Eastern Yorkshire.

Suess, H. E. (1965)* 'Secular variations of the cosmic ray produced carbon-14 in the atmosphere', J. Geophys. Res., 70, 5937-5952.

Tallis, J. H. (1964a) 'Studies on southern Pennine peats. I. The general pollen record', J. Ecol., 52, 323-331.

Tallis, J. H. (1964b) 'Studies on southern Pennine peats. II. The pattern of erosion', J. Ecol., 52, 333-344.

Tallis, J. H. (1964c) 'Studies on southern Pennine peats. III. The behaviour of Sphagnum', J. Ecol., 52, 345-353.

Tallis, J. H. (1964d) 'The pre-peat vegetation of the southern Pennines', New Phytol., 63, 363-373.

Tallis, J. H. (1975) 'Tree remains in southern Pennine peats', Nature, 256, 482-484.

Tallis, J. H. and Switsur, V. R. (1973) 'Studies on southern Pennine peats. VI. A radiocarbon-dated pollen diagram from Featherbed Moss, Derbyshire', J. Ecol., 61, 743-751.

Tansley, A. G. (1953) The British Isles and their vegetation.

Thomas, N. (1976) A Guide to Prehistoric England. Batsford, London.

Tinsley, H. M. (1972) A palynological study of changing woodland limits on the Nidderdale Moors. Ph.D. Thesis, University of Leeds.

Tinsley, H. M. and Smith, R. T. (1974) 'Surface pollen studies across a woodland/heath transition and their application to the interpretation of fossil pollen diagrams', New Phytol., 63, 73-89.

Troels-Smith, J. (1956) 'Neolithic period in Switzerland and Denmark', Science, 124, 876.

Turner, J. (1962) 'The Tilia decline: an anthropogenic interpretation', New Phytol., 61, 328-341.

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

Turner, J. (1965) 'A contribution to the history of forest clearance', Proc. Roy. Soc. B, 161, 343-354.

Turner, J. (1970) 'Post-Neolithic disturbance of British vegetation', in Walker, D. and West, R. G. (eds.), Studies in the vegetational history of the British Isles, Cambridge University Press, London.

Turner, J., Hewetson, V. P., Hibbert, F. A., Lowry, K. H. and Chambers, C. (1973) 'The history of the vegetation and flora of Widdybank Fell and the Cow Green reservoir basin, Upper Teesdale', Phil. Trans. R. Soc. B, 265,327.

Turner, J. and Hodgson, J. (1979) 'Studies in the vegetational history of the northern Pennines. I. Variations in the composition of the early Flandrian forests', J. Ecol., 67, 629-646.

Varley, W. J. (1976) 'A summary of the excavations at Castle Hill, Almondbury, 1939-1972', in Harding, D. W. (ed.), Hillforts: Later prehistoric earthworks in Britain and Ireland.

Victoria History (1914) A History of Yorkshire North Riding. The Victoria History of the Counties of England. (Reprint for University of London, 1968).

Vries, de H. (1958)* 'Variation in concentration of radiocarbon with time and location on earth', Koninkl. Nederlands Akad. Wetensch. Proc., ser. B, 61, 1-9.

Walker, D. (1954) 'Late-glacial deposits at Lunds, Yorkshire', New Phytol., 53, 343-349.

Walker, D. (1956) 'A site at Stump Cross, near Grassington, Yorkshire, and the age of the Pennine microlithic industry', Proc. Prehist. Soc., 22, 23-38.

Walker, D. (1966) 'The late Quaternary history of the Cumberland Lowland', Phil. Trans. R. Soc. B, 251, 210.

Walker, D. and Godwin, H. (1954) 'Lake stratigraphy, pollen analysis and vegetation history', in Clark, J. G. D., Excavations at Star Carr, Cambridge University Press, London.

Watt, A. S. (1976) 'The ecological status of bracken', Bot. J. Linn. Soc.

Wensleydale WEA History Class (1978) 'Farming and the landscape in 17th century Wensleydale', North Yorkshire County Record Office Journal, 6, 47-58.

Wheeler, R. E. M. (1954) 'The Stanwick Fortifications', Society of Antiquitaries of London Research Report XVII.

Woodhead, T. W. (1929) 'History of the vegetation of the southern Pennines', J. Ecol., 17, 1-31.

Woodhead, T. W. and Erdtman, G. (1926) 'Remains in the peat of the southern Pennines', The Naturalist, 835, 245.

* = Not consulted in the original.

APPENDIX 1: FIELD AND LABORATORY TECHNIQUES

(i) Collection of samples in the field

Peat cores were obtained from the Whirley Gill, Fleet Moss and Thornton Mire sites using a sampler of the 'Russian' type as described by Jowsey (1966). This instrument causes a minimum of disturbance to the peat and is easy to clean, thus reducing the risks of contamination. It also has the advantage of providing a complete core of undisturbed sediment, which facilitates the description of the stratigraphic sequence. Alternate 50cm cores were extracted from two adjacent holes to avoid the effects of disturbance by the head of the borer. In order to preserve the cores intact for sampling in the laboratory (particularly necessary for very wet peats), they were placed in labelled plastic troughs made from longitudinally-split plastic drainpipes of the appropriate diameter. They were then wrapped in polythene sheeting to prevent desiccation and contamination.

At Thornton Mire complete cores of the organic sediments were obtained in this way, as the borer was able to penetrate far enough into the underlying clay to enable the peat-soil interface to be sampled. However at Whirley Gill and Fleet Moss the instrument hit solid rock, so that the bottom 15cm (the length of the borer head below the sampling chamber) could not be sampled. This is the main limitation of the 'Russian borer'. Nothing could be done to remedy the situation at Whirley Gill, where the high watertable precluded digging, but at Fleet Moss a monolith was dug from an adjacent peat face to complete the stratigraphic sequence. This was placed on a plastic tray and sealed in polythene.

The Penhill samples were taken near the margin of the deposit, so that they were as close as possible to the nearby prehistoric enclosures. Erosion had exposed the complete peat profile here, so after cutting back and cleaning the peat face, monoliths 50cm deep were dug and wrapped as described above for Fleet Moss.

All the peat samples were stored in a refrigerator at about 4 C, as recommended by Moore and Webb (1978). This reduces the tendency for evaporation to take place and lowers the metabolic rates of any microbes which may be active, without the distortion of the stratigraphy which freezing may cause.

(ii) Preparation of samples for pollen analysis

a) Pollen concentration. After cleaning the core (or monolith) surface with a scalpel, peat samples of approximately one cubic centimetre were taken using a spatula. In order to break down the sediment and remove soluble humic acids, the samples were first boiled for about 20 minutes in 20ml of 10% sodium hydroxide (NaOH), stirring at intervals with a glass rod. The occasional addition of distilled water ensured that the concentration of NaOH did not rise above 10%, thus preventing corrosion of the pollen. The material was then washed through 72 mesh nylon gauze, the filtrate being collected in 50ml centrifuge tubes and the coarser residue retained for macroscopic analysis. After centrifuging at about 3000 r.p.m. for 3 minutes, the liquid was decanted off and discarded whilst the insoluble residue was resuspended in distilled water and centrifuged again. This washing process was repeated until the supernatant was clear.

In most cases this method was found to produce perfectly adequate pollen samples for analysis. Although the presence of plant debris such as leaf cells did have the effect of 'diluting' the pollen to some extent, initial experiments showed that the improvement brought about by removing cellulose (using a modified form of Erdtman's (1960) acetolysis) was not sufficient to justify the extra preparation time.

Some samples, however, especially those from Thornton Mire, did require further treatment to remove inorganic particles (particularly silicates). In these cases, the residue from the NaOH digestion was placed in a polythene centrifuge tube and suspended in about 6ml of concentrated hydrofluoric acid (HF). The tube was placed in a boiling water bath for at least 10 minutes, until no further grittiness could be detected with a polythene stirring rod. While still hot, the sample was centrifuged and the waste supernatant collected in a polythene container to be neutralised with NaOH before it was discarded. The remaining material was then resuspended in 20ml of 10% hydrochloric acid (HCl) and warmed to remove any silicofluorides produced during the HF treatment. Finally it was centrifuged and washed twice with distilled water, heated for 10 minutes with a little 10% NaOH, centrifuged and washed again. The NaOH treatment was necessary to make the residue alkaline so that it would absorb stain.

b) Mounting and identification. The resulting pollen samples were prepared for mounting by adding a few drops of a 50:50 glycerine and water mixture stained with an aqueous solution of safranin. Although this mounting medium produces short-lived slides which can only be preserved by sealing prior to analysis, it is simple to use and has the great advantage of allowing pollen grains to be turned over by slight pressure on the coverslip so that different views can be obtained.

This makes identification easier, which was considered to be more important than creating permanent mounts.

Slides were prepared as they were required, and the pollen grains identified and counted using an Olympus binocular microscope with a magnification of x400. Occasionally it was necessary to use a x1000 oil immersion lens for detailed examination.

Pollen grains were identified by reference to type slides and by the use of pollen keys, particularly those of Erdtman, Berglund and Praglowski (1961), Erdtman, Praglowski and Nilsson (1963), Faegri and Iversen (1975) and Moore and Webb (1978). Cereal pollen grains were separated from other Gramineae types on the basis of their greater size. Grains over 40 microns in diameter were considered to be cereal types (Faegri and Iversen, 1975), their measurements being determined using a micrometer. To compensate for the possible swelling effects of the mounting medium, these measurements were compared to those of Corylus grains, which were assumed to be a standard size of 25 microns.

(iii) Macroscopic analysis

As stated in chapter 4, the vegetation of the bogs themselves was not of prime importance to this study, and so detailed macroscopic analysis was not undertaken. The main components of the peat were identified in fresh samples, and it was only when the peat was particularly well-humified that it was necessary to carry out any further analysis as a check. In such cases the coarse material filtered out following the NaOH digestion process was washed and spread on a white dish for identification.

The major constituents of the peat form part of the stratigraphic description of each profile given in chapter 4. This data serves to indicate the depositional context of the pollen records, enabling locally-produced pollen to be eliminated from the reconstruction of regional vegetation history where necessary.

(iv) Humification analysis

The degree of humification of the peat was determined using the method modified by Bahnson (1968) from that of Overbeck (1947). A translation from the original Danish description (Bahnson, 1968) provided by Aaby and Tauber (1975) was followed.

The technique depends on the fact that humic acids are soluble in dilute alkali. Treatment of peat samples with hot dilute NaOH therefore produces a solution whose colour intensity is proportional to the amount of humic matter dissolved. This colour intensity can be measured using a colorimeter, and the degree of humification can then be calculated from a calibration curve obtained by dilution experiments using a humic acid standard.

Contiguous 2cm slices were cut from the peat cores, and broken up into evaporating basins. They were left to air-dry for two days and then broken up further before being oven-dried to constant weight at 80°C. The samples were then ground with a pestle and mortar, any macroscopic plant remains being cut up finely with scissors, until they passed through a 25 mesh (0•6mm) sieve. Sub-samples of 0•2g were weighed into 200ml volumetric flasks, taking three replicates for each sample depth. 100ml of 0•5% NaOH solution was added to each flask and the samples were boiled for an hour on a hotplate. The samples were then made up to 200ml with distilled water and filtered on Whatman No. 40

filter paper. In each case, 50ml of the well-shaken filtrate was placed in a 100ml volumetric flask and diluted to the mark with distilled water. After shaking well, the absorption of the solution was measured on an EEL colorimeter with a filter No. 626, the zero point of the instrument being determined with distilled water. When the colorimetric reading exceeded 6•0 the sample was diluted again (making 50ml of the solution up to 100ml with distilled water) in order to obtain a uniform measuring accuracy from the logarithmic scale. Finally the humification percentage was calculated using the formula derived by Bahnson (1968) from his analyses of a humic acid standard:-

$$\text{humification percentage} = 8{\cdot}3(\bar{y} + 0{\cdot}1)\ \%$$

where $\bar{y}$ is the mean colorimetric reading of the replicate samples.

The main source of possible error in this technique was the fading of the colour intensity of the solutions with time. To minimise this problem, a strict time schedule was adhered to. The analysis of three samples from each depth also helped to reduce errors, and it was found that no measurable fading occurred within the hour which was required to analyse one batch of samples.

(v) Chemical analysis

To obtain chemical profiles for the Thornton Mire site, an additional core was taken adjacent to the one used for pollen analysis. This core was cut into 10cm slices, on which the following analyses were performed:- pH, exchangeable calcium/magnesium ratio, total calcium, magnesium, sodium, potassium, manganese, iron, aluminium and silica, and ash weight. The methods used are described below in the order in which they were carried out.

a) pH. The pH of the peat was determined on a suspension of fresh material in a small amount of distilled water, using a pH meter with combined glass and reference electrodes.

b) Exchangeable calcium/magnesium ratio. Fresh peat equivalent to about 0•5g dry weight was shaken in a flask with 100ml of N acetic acid for one hour. After filtering, the calcium and magnesium contents of the solutions were determined using a Pye/Unicam Atomic Absorption Spectrophotometer (A.A.).

The remaining peat was dried at 40°C for the total analyses.

c) Total calcium, magnesium, sodium, potassium and manganese. 5g of dried peat (or less where this much was not available) was shaken for one hour in 125ml of 2•5% acetic acid and then filtered. The filtrate was used directly for the determination of manganese on the A.A., and potassium and sodium on a flame photometer. For the calcium and magnesium analyses, 20ml of the filtrate was placed in a 100ml volumetric flask with 20ml of lanthanum stock solution, 5ml of 20% sulphuric acid, and 8ml of 25% acetic acid. The mixture was made up to the mark with distilled water, shaken, and then analysed on the A.A.

The rest of the peat was dried at 80°C and finely ground for the iron and aluminium determinations.

d) Total iron and aluminium. 0•5g of peat was boiled gently in 25ml of 6M HCl for 15 minutes, allowing the volume to decrease to about 5ml (but no less). 5ml of hot distilled water was then added and the mixture boiled. It was then filtered quantitatively into a 50ml volumetric flask and made up to volume with distilled water. The iron and aluminium contents were then determined using the A.A.

e) Ash weight. The remaining peat was placed in a weighed porcelain crucible and the combined weight of the peat and its container noted. It was then ashed in a furnace at 400°C for 16 hours, allowed to cool in a desiccator, and reweighed to determine the percentage weight loss.

f) Total silica. 0•5g of the ash (or all the remaining ash if this was less than 0•5g) was boiled in 25ml of 6M HCl for 15 minutes and then filtered. The filter paper holding the undissolved residue was then dried and weighed, to give the total silica content.

APPENDIX 2: POLLEN SAMPLE SIZES

(i) Whirley Gill

Depth (cm)	Sample size	Depth (cm)	Sample size	Depth (cm)	Sample size
0•0	626	120•0	512	240•0	527
5•0	991	125•0	512	245•0	503
10•0	523	130•0	525	250•0	561
15•0	578	135•0	503	255•0	512
20•0	539	140•0	511	260•0	541
25•0	503	145•0	505	265•0	503
30•0	644	150•0	515	270•0	587
35•0	503	155•0	528	275•0	565
40•0	573	160•0	520	280•0	583
45•0	517	165•0	530	285•0	668
50•0	505	170•0	574	290•0	599
55•0	506	175•0	552	295•0	537
60•0	510	180•0	530	300•0	550
65•0	686	185•0	576	305•0	601
70•0	534	190•0	604	310•0	531
75•0	507	195•0	529	315•0	532
80•0	532	200•0	637	320•0	528
85•0	543	205•0	585	325•0	514
90•0	560	210•0	501	330•0	535
95•0	615	215•0	530	335•0	513
100•0	553	220•0	539	340•0	519
105•0	587	225•0	580	345•0	514
110•0	511	230•0	608	350•0	526
115•0	503	235•0	599		

(ii) <u>Fleet Moss</u>

Depth (cm)	Sample size	Depth (cm)	Sample size	Depth (cm)	Sample size
0·0	517	155·0	503	247·5	664
5·0	507	157·5	541	250·0	578
10·0	1036	160·0	500	252·5	746
15·0	503	162·5	507	255·0	507
20·0	507	165·0	545	257·5	539
25·0	524	167·5	533	260·0	506
30·0	500	170·0	520	262·5	519
35·0	503	172·5	515	265·0	520
40·0	503	175·0	506	267·5	609
45·0	501	177·5	510	270·0	502
50·0	501	180·0	543	272·5	518
55·0	501	182·5	519	275·0	500
60·0	504	185·0	513	280·0	501
65·0	501	187·5	532	285·0	539
70·0	562	190·0	526	290·0	500
75·0	518	192·5	683	295·0	500
80·0	569	195·0	536	300·0	500
85·0	696	197·5	534	305·0	539
90·0	551	200·0	518	310·0	508
95·0	506	202·5	519	315·0	527
100·0	519	205·0	500	320·0	520
105·0	501	210·0	510	325·0	548
110·0	536	215·0	553	330·0	504
115·0	508	220·0	529	335·0	543
120·0	536	225·0	554	340·0	508
125·0	503	230·0	539	345·0	500
130·0	500	235·0	526	350·0	532
135·0	501	237·5	709	355·0	510
140·0	501	240·0	501	360·0	600
145·0	500	242·5	566	365·0	560
150·0	510	245·0	500	370·0	522
152·5	537				

(iii) Penhill

Depth (cm)	Sample size	Depth (cm)	Sample size	Depth (cm)	Sample size
0•0	533	75•0	509	127•5	514
5•0	513	80•0	500	130•0	511
10•0	2452	85•0	512	132•5	563
15•0	505	90•0	529	135•0	512
20•0	507	95•0	557	140•0	522
25•0	504	100•0	529	145•0	554
30•0	506	102•5	513	150•0	531
35•0	517	105•0	527	155•0	609
40•0	522	107•5	531	160•0	524
45•0	525	110•0	559	162•5	536
50•0	505	112•5	524	165•0	501
55•0	520	115•0	539	167•5	715
60•0	519	117•5	511	170•0	593
65•0	546	120•0	605	172•5	506
67•5	500	122•5	504	175•0	518
70•0	563	125•0	525		

(iv) Thornton Mire

Depth (cm)	Sample size	Depth (cm)	Sample size	Depth (cm)	Sample size
0•0	877	105•0	301	215•0	300
5•0	959	110•0	302	220•0	506
10•0	1007	120•0	303	225•0	516
15•0	869	125•0	305	230•0	301
20•0	694	130•0	502	235•0	305
25•0	555	135•0	504	240•0	301
30•0	1243	140•0	564	245•0	306
35•0	1107	145•0	548	250•0	524
40•0	605	150•0	990	255•0	500
45•0	824	155•0	829	260•0	506
50•0	309	160•0	625	265•0	504
55•0	594	165•0	540	270•0	300
60•0	691	170•0	538	275•0	502
65•0	714	175•0	545	280•0	677
70•0	569	180•0	502	285•0	774
75•0	499	185•0	530	290•0	801
80•0	502	190•0	513	295•0	778
85•0	311	195•0	512	300•0	538
90•0	502	200•0	511	305•0	502
95•0	561	205•0	512	310•0	512
100•0	518	210•0	566	315•0	503

APPENDIX 3: COMPOSITION OF THE 'VARIA' CURVES

All the pollen types included in the 'Varia' curves occur at values of less than 1% TP and are found in fewer than five of the pollen samples at the site concerned.

(i) Whirley Gill

Depth (cm)	Pollen types		
0•0	Potamogeton natans	Plantago media/major type	Unknown
15•0	Potamogeton natans	Drosera rotundifolia	
20•0	Potamogeton natans	Plantago media/major type	Unknown
35•0	Potamogeton natans	Plantago media/major type	Nymphaceae
50•0	Ulex type		
60•0	Epilobium type	Unknown	
80•0	Labiatae (Lamium type)		
85•0	Ulex type		
90•0	Labiatae (Lamium type)		
120•0	Mercurialis perennis		
125•0	Drosera rotundifolia		
155•0	Drosera rotundifolia	Unknown	
250•0	Leguminosae		
260•0	Leguminosae		
275•0	Leguminosae	Saxifragaceae	
285•0	Ulex type	Unknown	
290•0	Ulex type	Mercurialis perennis	
320•0	Labiatae (Lamium type)	Alisma plantago-aquatica	Unknown
330•0	Saxifragaceae	Rubiaceae	
335•0	Campanulaceae	Unknown	
340•0	Unknown		

(ii) Fleet Moss

Depth (cm)	Pollen types
5•0	*Viscum album* *Frangula alnus*
10•0	Labiatae (*Lamium* type) *Juglans regia* *Calystegia* type
20•0	Unknown
30•0	Rubiaceae
35•0	*Hedera helix* Unknown
40•0	*Euphorbia* type Saxifragaceae
105•0	*Drosera rotundifolia*
115•0	*Drosera rotundifolia* *Hedera helix*
145•0	*Succisa pratensis*
152•5	*Ulex* type
157•5	*Hedera helix*
165•0	Violaceae
167•5	*Euphorbia* type Scrophulariaceae
172•5	*Drosera rotundifolia*
175•0	Scrophulariaceae Unknown
180•0	Rubiaceae
187•5	Dipsaceae
197•5	Campanulaceae
290•0	*Succisa pratensis*
300•0	Campanulaceae
305•0	Saxifragaceae *Epilobium* type
315•0	*Hedera helix*
320•0	*Succisa pratensis*
335•0	*Lotus* type
340•0	*Lotus* type
345•0	*Lotus* type

(iii) Penhill

Depth (cm)	Pollen types			
0•0	Primulaceae	Unknown		
20•0	Primulaceae	Dipsaceae	Gerianaceae	*Menyanthes trifoliata*
75•0	*Succisa pratensis*			
80•0	*Mercurialis perennis*			
85•0	*Mercurialis perennis*			
95•0	*Mercurialis perennis*	Unknown		
110•0	*Mercurialis perennis*			
117•5	Primulaceae			
120•0	*Hedera helix*	*Ulex* type		
135•0	Dipsaceae			
150•0	Campanulaceae	Unknown		
155•0	Polygonaceae			
160•0	*Hedera helix*			

(iv) Thornton Mire

Depth (cm)	Pollen types
0•0	Labiatae (*Lamium* type) Linaceae Unknown
25•0	*Juniperus communis* *Castaneae sativa* Unknown
30•0	*Aesculus hippocastaneum*
50•0	*Juglans regia* *Viscum album*
55•0	Nymphaceae
60•0	Polygonaceae Unknown
65•0	*Euphorbia* type
75•0	*Myriophyllum alterniflorum*
85•0	*Typha latifolia* *Euphorbia* type
95•0	Polygonaceae
100•0	*Mercurialis perennis*
120•0	Unknown
135•0	Linaceae
140•0	*Mercurialis perennis* Unknown
145•0	*Viola arvensis*
150•0	Papaveraceae
155•0	*Epilobium* type
175•0	Liliaceae
200•0	Cruciferae (*Sinapsis* type) *Euphorbia* type Unknown
205•0	Campanulaceae
285•0	Scrophulariaceae Unknown

APPENDIX 4: POLLPLOT MANUAL

Honeyman, A. (1983) 'POLLPLOT: a program for the calculation and presentation of palynological data', Computer Manual No. 21, School of Geography, University of Leeds.

See copy provided in pocket inside back cover.

APPENDIX 5: THE RADIOCARBON DATES

The accuracy of radiocarbon dating is dependent upon the size and age of peat samples, the amount of material necessary to obtain dates with the same standard error increasing with the age of the material. Thus whilst only 2g of carbon is required to give a standard error of $\pm$ 50 years for samples up to 2000 years old, as much as 8g is needed if the samples are 11000 to 12000 years old (D. D. Harkness, personal communication).

As none of the Wensleydale samples were expected to be over 10000 years old, 5g of carbon was considered to be necessary to give the greatest possible accuracy. Assuming that carbon comprised approximately 40% of the dry weight of the peat, samples of 12•5g dry weight were therefore needed. However the NERC radiocarbon laboratory required the material to be submitted in as near its original state as possible, so fresh peat samples equivalent to at least 12•5g dry weight were forwarded for analysis.

The samples were taken no more than 2•5cm either side of the horizon to be dated, and so additional cores were necessary in most cases to provide sufficient peat. These cores were obtained as close as possible to the original ones, and correlated by pollen analysis. After removing the outermost layer of peat to minimise contamination, the samples were wrapped in double polythene bags, labelled, and submitted to the NERC radiocarbon laboratory, where the assays were carried out by Dr. D. D. Harkness. The results are provided below in stratigraphic order for each site.

(i) Whirley Gill

Code Number	Depth (cm)	Age (years B.P.)
SRR-2227	47•5	2280 ± 50
SRR-2106	95•0	3040 ± 50
SRR-2228	137•5	3930 ± 50
SRR-2229	187•5	4790 ± 50
SRR-2230	267•5	6370 ± 70
SRR-2107	310•0	8160 ± 80
SRR-2108	350•0	8950 ± 80

(ii) Fleet Moss

Code Number	Depth (cm)	Age (years B.P.)
SRR-2231	155•0	3070 ± 50
SRR-2232	247•5	4680 ± 50
SRR-2109	365•0	8510 ± 50

(iii) Penhill

Code Number	Depth (cm)	Age (years B.P.)
SRR-2233	67•5	2410 ± 50
SRR-2234	122•5	3850 ± 50
SRR-2110	175•0	4820 ± 50

(iv) Thornton Mire

Code Number	Depth (cm)	Age (years B.P.)
SRR-2235	27•5	650 ± 50
SRR-2236	72•5	2690 ± 50
SRR-2237	137•5	3220 ± 50
SRR-2111	165•0	3600 ± 80
SRR-2238	187•5	4550 ± 50
SRR-2239	277•5	7840 ± 60
SRR-2112	325•0	8480 ± 90

The calculation of the ages is based on the Libby (1955) half-life of carbon-14, 5568 ± 30 years. This is the time taken for half of the original carbon-14 (radiocarbon) to decay (by beta transformation) to nitrogen. More recent determinations (Hughes and Mann, 1964) have shown that a more accurate value for the half-life of carbon-14 is 5730 ± 40 years. However dates continue to be calculated and reported on the basis of the Libby half-life by international convention. This policy, agreed at the 1962 Cambridge Radiocarbon Conference (Godwin, 1962) and reaffirmed at subsequent Radiocarbon Conferences, is designed to avoid confusion and the possible need for future multiple corrections to published data (Harkness, 1979).

The amount of radiocarbon remaining in a sample is determined by measuring its beta-particle activity by means of liquid scintillation counting techniques. To obtain a statistical reliability for the number of counts per sample, a prolonged counting operation is necessary. At least 10,000 counts are required if an accuracy to ± 1% is desired, which takes about 24 hours (Gillespie, 1982).

The ± errors quoted refer to one standard deviation, derived from the counting errors of the sample, background radiation, and the present day standard sample. As radioactivity determinations scatter around a mean value as a normal distribution, it can be said that there is a 68% probability that the true value occurs within one standard deviation of the mean, 95% probability that it lies within two standard deviations, and a 99·7% probability that it occurs within three standard deviations.

The radiocarbon dates are usually quoted in this thesis as years B.P., meaning years before the standard zero year of 1950. In some cases they have been converted to years B.C. or A.D. No attempt has been made to correct the dates for the fluctuations in the carbon-14/ carbon-12 ratio through the Holocene. De Vries (1958) was the first to show that fluctuations had occurred in the production of atmospheric carbon-14, using tree ring data, and later dendrochronological studies (mainly using the long-lived bristlecone pine, *Pinus aristata*) have led to attempts at calibration (for example Suess, 1965; Damon *et al*, 1974). Unfortunately no generally agreed calibration yet exists, and so it is preferable to quote unconverted radiocarbon dates to lessen the difficulties when comparing them with dates obtained by other researchers. None of the dates obtained by other workers and quoted in this thesis have been converted and so the chronology is at least consistent. However the divergence between tree ring (or calendar) dates and radiocarbon dates must be borne in mind. In general the difference is not serious after about 3500 B.P., but before that time it becomes progressively larger, amounting to as much as 700 years by 4500 B.P.

In such circumstances, it seems unnecessary and confusing to adopt the convention suggested by an editorial in Antiquity (1972), whereby b.p., a.d. and b.c. are used for uncorrected radiocarbon dates and B.P., A.D. and B.C. for corrected calendar age equivalents. This was based on the assumption that realistic conversion from radiocarbon years to calendar years was possible, which does not yet seem to be justified (Bowen, 1978). The more common convention of using capital letters is therefore applied in this thesis.

Computer Manual

Computer Manual No. 21

POLLPLOT : A PROGRAM FOR THE CALCULATION AND PRESENTATION OF PALYNOLOGICAL DATA.

A. Honeyman
2

School of Geography

University of Leeds

Computer Manual No. 21

POLLPLOT : A PROGRAM FOR THE CALCULATION AND PRESENTATION OF PALYNOLOGICAL DATA.

A. Honeyman

School of Geography
University of Leeds
Leeds LS2 9JT

February, 1983.

CONTENTS

ABSTRACT

This paper describes a FORTRAN program which plots pollen diagrams from pollen counts or ready-calculated percentages. The user can specify which species are to be included in the pollen sum and select the style and scale of diagram to be produced. POLLPLOT runs interactively at the terminal, plotting either hard or soft copy graphics as requested.

LIST OF FIGURES

1. PURPOSE OF THE PROGRAM

POLLPLOT is a tool to assist in the production and interpretation of pollen diagrams. It enables pollen counts to be converted to percentages and plotted with great speed and accuracy. The data can easily be recalculated using different pollen sums, and the user can also choose to omit particular species from the diagram, or to plot them at different scales.

2. DESCRIPTION

POLLPLOT is written in FORTRAN, together with the Culham Laboratory's GHOST80 graphics package, for use on the Leeds University Amdahl V/7 computer. All input is by VDU.

The program is user-interactive, offering a number of options concerning the pollen sum to be used, species to be plotted/omitted, scale and style of plot, etc. The options given are described in detail below, in the order in which they are presented when running the program.

2.1 Degree of control. The user first inputs the appropriate response to give total control (all options available), partial control, or minimum control (essential options only). For high quality plots, full control will be required, but minimum control is useful for rapid tests of the program and data. The diagrams in figs. 1-3 show the paths taken through the program for each degree of control.

For the following options, the letter 'T' indicates that the choice is only available if total control is selected, and 'P' indicates that it is available with partial control. Options unmarked by either T or P are considered essential and are always given. Default responses are provided when the user does not have full control.

2.2 Type of data. Raw pollen counts are normally used, but it is also possible to use ready-calculated percentages (where the calculation method used in the program is not satisfactory).

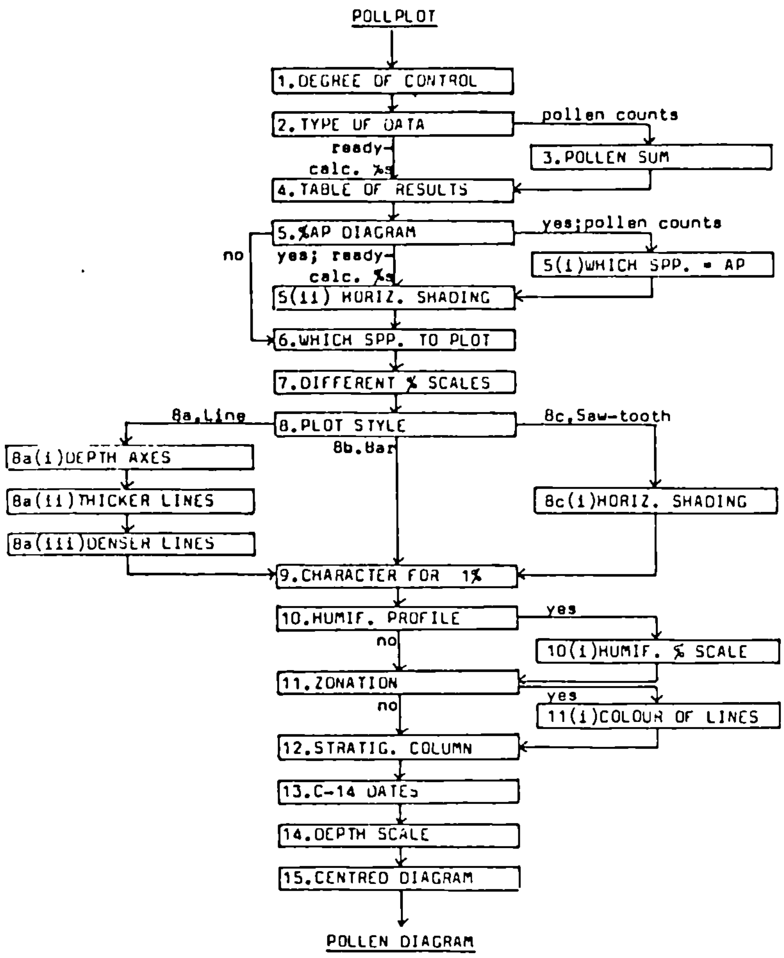


Fig. 1. Path through POLLPLOT with total control.

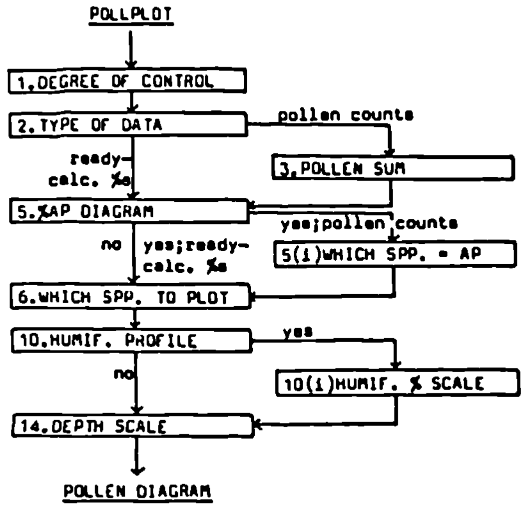


Fig. 2. Path through POLLPLOT with partial control.

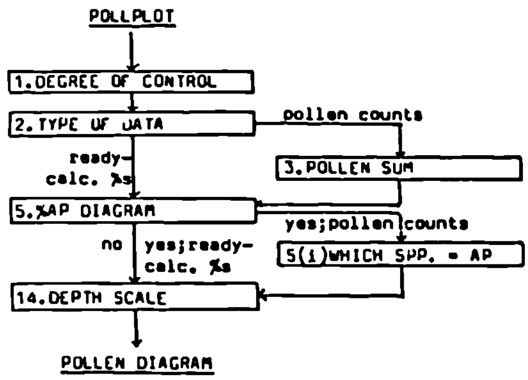


Fig. 3. Path through POLLPLOT with minimum control.

2.3 Calculation of percentages. When pollen counts are used, the pollen sum may comprise:-

(a) all the pollen/spore types in the data file;

(b) the first 'J' types only, where J is any number;

or (c) a more complex combination of pollen types.

Once the pollen sum has been selected, the percentage calculations are performed as follows:-

(a) Species included in the pollen sum:

$$\% = \frac{\text{count for species}}{\text{pollen sum}} \times 100$$

(b) Species excluded from the pollen sum:

$$\% = \frac{\text{count for species}}{\text{sum + count for sp.}} \times 100$$

This is in accordance with recent practice in pollen analysis, as it is now recognised that for the sake of both statistical validity and easier interpretation of a diagram, "the occurrence of any pollen category should be expressed in percentages of a universe of which it forms a part" (Faegri & Iversen, 1975).

2.4 Table of results. (T). When raw pollen counts are used, a table of results can be created. This will show the following data:-

(a) the pollen/spore types excluded from the pollen sum;

(b) the pollen sum for each sample level;

(c) the species included in the arboreal pollen (AP) sum;

(d) the AP sum for each sample level;

(e) the %AP for each sample level;

(f) the percentage of each pollen/spore type for each sample depth.

2.5 %AP diagram. A summary plot of the variation in the proportions of arboreal pollen (AP) and non-arboreal pollen (NAP) may be obtained. If this is required, and the data is in the form of pollen counts, the user will next be asked to indicate the species to be included in the AP sum. If the data is ready-calculated, %AP values must be included in the data file if a summary diagram is required.

The %AP values will be plotted in saw-tooth style, as shown in fig. 4. With total control, horizontal lines can be plotted for each value, as shown in fig. 5. This has the effect of shading the AP side of the diagram.

2.6 Which species to be plotted. (P,T). The pollen diagram can include:-

(a) all the pollen/spore types in the data file;

(b) the first 'N' types only;

(c) the last 'M' types only;

or (d) a more complex selection of pollen types.

With minimum control, all the pollen/spore types will be plotted.

2.7 Different % scales.(T) The default scale is 1cm to 10%. This can be multiplied by any factor for any or all of the species. This facilitates the reduction or magnification of species to assist in interpretation. An example is shown in fig. 6, where Ulmus has been plotted at twice the usual scale.

2.8 Plot style. (T). The species percentages can be plotted as line histograms, bar histograms, or 'saw-tooth'.

(a) Line histogram (see fig. 5). Further options are:-

(i) an unscaled depth axis for each species, as in fig. 5;

(ii) thicker lines (additional lines drawn either side of the original);

(iii) denser lines (additional lines drawn on top of the original).

(b) Bar histogram (see fig. 4). An unscaled depth axis will be provided for each species. The width of the bars is usually the minimum vertical distance between sample depths. If this sample interval is greater than 5cm, the bars will be 5cm wide (in terms of sediment depth represented).

(c) Saw-tooth (see fig. 6). An unscaled depth axis will be provided for each species, and if required, horizontal lines can be plotted from the depth axis to each value, as for the %AP diagram in fig. 5.

Line histograms without depth axes will be plotted when total control is not in operation.

2.9 Character for less than 1%. (T). The character 'x' can be plotted for percentages less than 1·0 (as in fig. 4). This will automatically be done with partial or minimum control. If this is not required, the % value will be plotted as usual (as in fig. 6).

2.10 Humification profile. (P,T). A plot of humification percentages (as obtained by the method of Bahnson, 1968) can be drawn, as shown in fig. 4. The humification data is held in data file 2.

2.11 Zonation. (T). A zoned diagram may be produced if required. For each zone boundary, either a solid or broken line is selected, enabling zones and subzones to be distinguished. The lines can be drawn in either black or red. Fig. 4 shows an example of a zoned pollen diagram. The zonation data is held in data file 1.

2.12 Stratigraphic column. (T). An outline stratigraphic column can be plotted, to be filled in later by hand, or else a series of symbols are available which can be plotted by the computer.

If stratigraphic symbols are required, details of the particular symbols to be used and the depth limits within which they are to be plotted will be needed in data file 3, as described later. In some cases, two symbols can be combined within one stratigraphic zone (see fig. 4).

2.13 Radiocarbon dates. (T). If C-14 dates are available for the profile, they can be plotted at the beginning of the diagram, as shown in fig. 4. Data file 3 will contain the relevant data.

2.14 Depth scale. The user chooses the number of mm required to represent 50cm depth. This is obviously limited by the width of the plotting paper. The maximum vertical extent allowed is 223mm, which allows the following scales:-

No. of mm to 50cm	Max. profile depth (cm)
10	1115·0
15	743·3
20	557·5
25	446·0
30	371·7

The diagrams in figs. 4–6 were plotted at a scale of 20mm to 50cm.

2.15 Centring. (T). The diagram can either be plotted at the top of the page or in the centre. With partial or minimum control it will be centred.

3. DATA PREPARATION

Files of type 'DATA' should be created as described below, as input for POLLPLOT. For each file the data required must be in the exact order and format given for the plot to be successful. The FORTRAN formats are provided, together with more detailed description and examples for users unfamiliar with this language. Essential data items are marked by an asterisk; the rest are optional. In the examples, each space is marked by a full-stop.

3.1 Data file 1. This is the principal data file, containing the sample depths, pollen counts or ready-calculated percentages, and zonation data if required.

3.1.1 Pollen counts

*(a)Title. (20A4). One line, maximum 80 characters.

Eg. TOTAL POLLEN DIAGRAM, EASTHEATH BOG

*(b)No. of samples & no. of pollen types. (2I5). Two integers on one line. The maximum number of samples permitted is 100, and the maximum number of pollen types is 50.

Eg. ..100...20

*(c)Sample depths. (10F7·1). Depths in cm, positive real numbers, 10 per line. Starting with the nearest to the top of the profile and working downwards.

Eg. ....0·0....2·5....5·0....7·5...10·0 etc.

*(d) i. Species name. (2A4). Name of pollen type, maximum 8 characters.

Eg. ...PINUS or .QUERCUS

ii. Pollen counts. (10I6). Numbers of grains counted for this pollen type at each sample depth, from the top of the profile downwards. 10 per line.

Eg. ...109....82.....6 etc.

i. and ii. are repeated for each pollen type.

(e)No. of zone boundaries. (I2). Maximum of 50 (i.e. 51 zones).

Eg. 10 or .6

(f)Depths of zone boundaries & types of lines required. (F7·2,I2). One line per boundary, with depth in cm and either 0 for a solid line or 1 for a broken one. Starting with the highest zone and working downwards.

Eg. ..52·50.1 for a broken line at 52·50cm depth.

(g)Zone names. (10(2X,A4)). Names of zones, from the top of the profile downwards. Maximum of 4 characters, 10 names per line.

Eg. ..EH1A..EH1B...EH2 etc.

An example of a data file of this type is shown in Appendix 1.

<u>or</u> 3.1.2 <u>Ready-calculated percentages</u>

*(a) as above

*(b) " "

*(c) " "

(d)%AP values. (10F7·1). Ready-calculated %AP values for each sample depth, from the top of the profile downwards. 10 per line.

Eg. ...82·5....9·3 etc.

*(e) i. Species name. As 3.1.1(d)i. above.

ii. Pollen percentages. (10F5·1). Percentage of this pollen type at each sample depth, from the top of the profile downwards. 10 per line.

Eg. ..10·4...5·7 etc.

i. and ii. are repeated for each pollen type.

(f) as 3.1.1(e) above.

(g) as 3.1.1(f) above.

(h) as 3.1.1(g) above.

An example of a data file of this type is shown in Appendix 2.

3.2 Data file 2. This is an optional file, containing ready-calculated humification percentages and the appropriate sample depths.

(a)No. of samples (I5) & sample interval (F5·2). One line for the number of humification samples (maximum 250) and the sample interval in cm.

Eg. ...70.5·25

(b)Humification percentages. (10F7·2). Ready-calculated humification percentages for each sample depth from the top of the profile downwards. 10 per line. See Appendix 3.

Eg. ..62·75...9·50 etc.

3.3 Data file 3. This file is also optional, containing stratigraphic and/or C-14 data.

(a)No. of stratigraphic boundaries. (I2). Maximum 50.

Eg. 15 or .4

(b)Depth of boundary (F7·2) & type of line required (I2). One line per boundary, with depth in cm and either 0 for a solid line or 1 for a broken one. Starting from the top of the profile and working downwards.

Eg. ..27·25.1 for a broken line boundary at 27·25cm depth.

(c)Stratigraphic symbol codes. (2I3). One line per stratigraphic zone, with code numbers of one or two symbols to be plotted in that zone (see fig. 7 for the symbol codes). If only one symbol is required, the second code number position should contain a zero.

Eg. ..8.10 or ..1..0

(d)Number of C-14 dates. (I3). Maximum 50.

Eg. ..7 or .12

(e)Depth of date (F7·2), date in years BP (I6), ± interval in years (I4). One line per date, depth in cm.

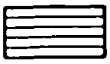
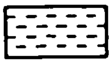
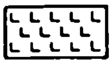
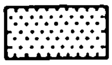
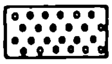
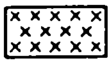
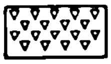
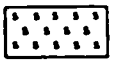
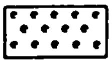
Symbol Code No.	Symbol	Possible 2nd Symbol
1		2–12
2		1,3–12
3		1,2,4–12
4		1–3
5		1–3
6		1–3
7		1–3
8		1–3
9		1–3
10		1–3
11		1–3
12		1–3

Fig. 7. Stratigraphic symbols,code numbers and possible combinations

Eg. ..90·75..2000..50 for 2000±50 years BP at 90·75cm depth.

An example of a data file of this type is shown in Appendix 4.

4. RUNNING THE PROGRAM

The POLLPLOT program is held on the Geography library disk. Undergraduates are automatically linked to this library upon logging on to a terminal. Postgraduates and staff must link the Geography library disk to their own workdisks as follows. After logging on, entering and leaving the filestore via the FILES command, the user should enter :-

LINK GEO6LIB 191 195 RR

ACCESS 195 B/A

Once the user is linked to the Geography Library disk and has the required data file(s) on his own workdisk, a run of the program on the Amdahl is initiated by simply entering :-

POLLPLOT name1 name2 name3

where name1 is the name (not type) of data file 1, etc.

Eg. POLLPLOT EHTP EHHUM EHSTRAT

If data file 3, or data files 3 and 2 are not used, they can simply be omitted from the call, eg.

POLLPLOT EHTP EHHUM

or POLLPLOT EHTP

However, if data files 1 and 3, but not 2, are required, a dummy filename should be used in place of data file 2, eg.

POLLPLOT FHTP DUMMY EHSTRAT

The user will be asked whether hard or soft graphics are required, and told the name of the plotfile if hard graphics are chosen - this will be 'name1 PLOT', eg. EHTP PLOT. The program will then run, the user entering responses when prompted, until finally either a 'soft' copy of the pollen diagram is produced on the screen of a graphics terminal, or a plotfile is produced which can then be used to create a 'hard' plot as follows :-

PLOT name1

This will cause the diagram to be produced in the User Access Area on level 10 in the Computing Centre. It is advisable to check that the diagram is satisfactory on the screen before having it plotted onto paper.

If a results table has been requested, this will be printed by entering :-

SP PR SYSTEM

PR name1 RESULTS

The output can again be collected from UAA Level 10.

If the program fails, it will in most cases be due to incorrect data formats, so these should be carefully checked.

QUERIES

All queries regarding the use of this program should be directed in the first instance to Dr. R.T. Smith.

REFERENCES

Bahnson, H. (1968). Kolorimetriske bestemmelser af humificeringstal i hojmosetorv fra Fuglso mose pa Djursland. Medd. Dansk. Geol. Foren., 18, 55-63.

Faegri, K. & Iversen, J. (1975). Textbook of Pollen Analysis (3rd edition), Blackwell.

Appendix 1. Example of a data file of type 1(I)

```
TOTAL POLLEN DIAGRAM, EASTHEATH BOG
   23    4
    0·0    5·0   10·0   15·0   20·0   25·0   30·0   35·0   40·0   45·0
   50·0   55·0   60·0   65·0   70·0   75·0   80·0   85·0   90·0   95·0
  100·0  105·0  110·0
  BETULA
    17     14     10      5      6      4      2      0      1      1
     3      7     19     26     35     37     49     50     47     52
    68     56     40
   PINUS
     5      5      6      7      6      8      9     11     13     12
     8      8      8      5      3      2      0      0      1      0
     1      5      1
   ULMUS
     4      2      2      6      7      5      1      1      0      1
     7      9      1      4     12     23     17     11      9     10
     8      6      3
 QUERCUS
    23     25     34     45     52     56     69     90    111    121
   104    100     87     76     98    103    106    102     99     92
    88     64     43
3
  25·00 0
  63·75 1
 100·00 0
   EH3  EH2B  EH2A   EH1
```

Appendix 2. Example of a data file of type 1(II)

```
EASTHEATH BOG III
   12     2
    0·0    5·0   10·0   15·0   20·0   25·0   30·0   35·0   40·0   45·0
   50·0   55·0
    4·5    8·9   12·7   23·6   32·8   45·3   57·9   65·2   47·0   32·6
   24·8   19·6
   ULMUS
   2·6   4·5   7·2   8·0  24·3  32·7  43·1  11·6   9·0   8·7
   3·2   1·4
PLANTAGO
   3·5   3·4   3·3   2·8   3·2   2·5   1·7   1·2   0·9   0·7
   0·2   0·0
 2
  15·50 0
  40·00 1
   EH2  EH1B  EH1A
```

Appendix 3. Example of a data file of type 2

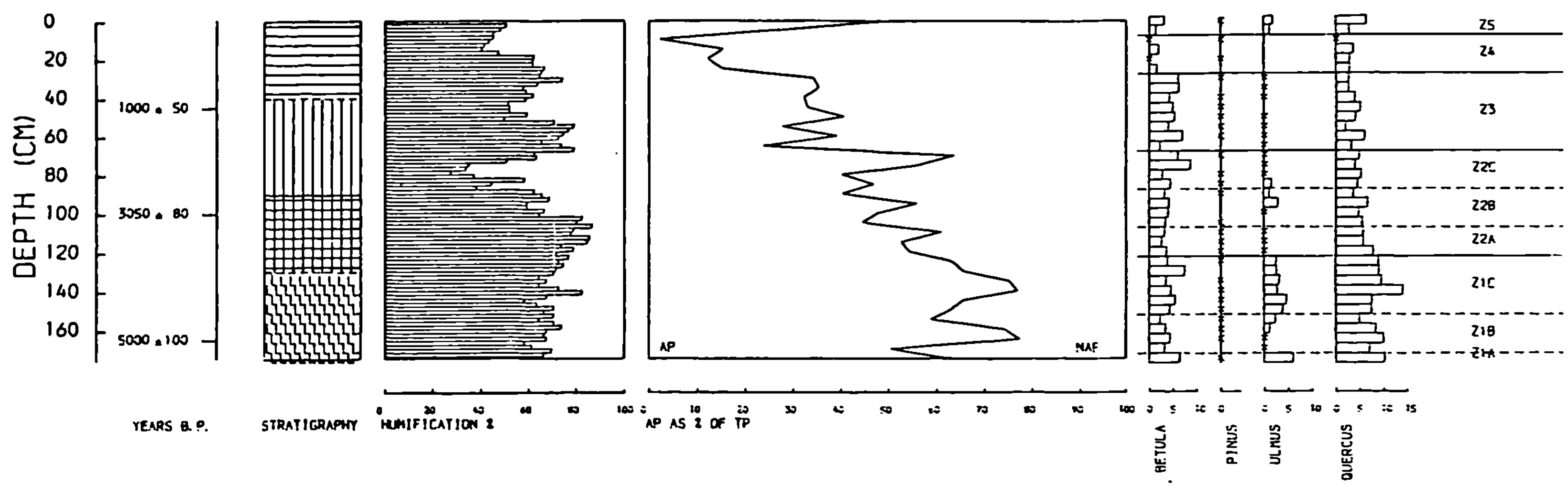
```
   55 2·00
  45·00  63·45  67·85  72·00  73·20  72·50  73·45  75·35  75·00  74·75
  69·00  67·50  66·65  65·45  59·70  56·75  56·70  56·70  56·60  55·95
  54·50  54·75  54·85  55·65  57·00  60·15  62·35  64·35  64·00  64·00
  64·00  65·40  64·55  66·00  66·75  67·00  67·00  64·25  62·15  69·75
  72·55  73·00  73·00  74·55  82·35  88·65  90·00  93·40  94·00  95·05
  96·00  96·00  87·65  76·55  66·50
```

Appendix 4. Example of a data file of type 3

```
 3
  42·25 1
  85·00 0
 100·50 1
  5  0
  1  2
 10  0
  1
  65·00  2500 100
```

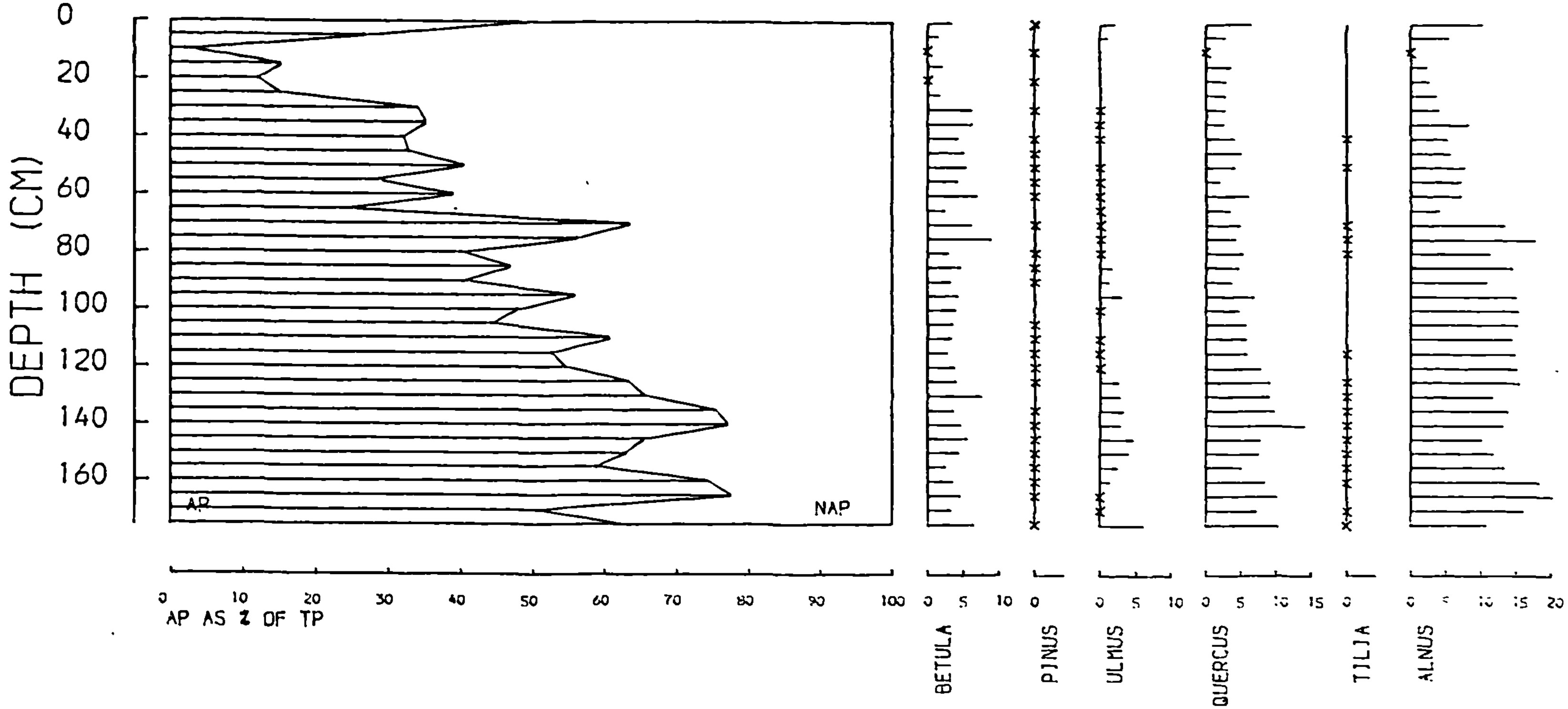
10/02/82 14:28:57 MANTP PLOT

FIG.4 BAR-HISTOGRAM STYLE.



GEO5AN 10/02/82 14:36:24 MANTP

FIG. 5 LINE-HISTOGRAM STYLE.



10/02/82 14:40:11 MANTP PLOT

N

FIG. 6 SAW-TOOTH STYLE.