Environmental alteration by mesolithic communities in the north York moors

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ENVIRONMENTAL ALTERATION BY MESOLITHIC COMMUNITIES IN THE NORTH YORK MOORS.

by

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F R O N T I S P I E C E

North Gill from Rosedale Moor.

ABSTRACT.

Environmental Alteration by Mesolithic Communities in the North York Moors.

Palynological and stratigraphic analyses have been conducted at eight sites in two areas of the North York Moors upland, supported in one case by radiocarbon analysis. Attention has been concentrated upon peat deposits of pre-Flandrian III age, in order to elucidate environmental alteration associated with Mesolithic communities in the region. Phases of forest recession apparently caused by fire clearance of the vegetation have been identified at each of these sites, and these have been attributed to the activities of Mesolithic man. The ecological changes associated with these forest clearance events have been illustrated using relative and concentration pollen diagrams, many of which have been drawn using the computer program NEWPLOT devised by Dr. I. Shennan and have involved the use of statistical confidence limits to assist in interpretation of the pollen data. The results of these analyses have been assessed, together with examples of pre-*Ulmus* decline forest recession in the region collated from previously published data.

The landscape of the North York Moors during Flandrian I and II has been discussed in terms of its resource potential for human communities, and a number of palaeoenvironmental zones have been identified on this basis. The origin, character and distribution of Mesolithic clearance activity in relation to these zones has been discussed, together with its ecological consequences. Finally the role of environmental alteration in Mesolithic economy and land-use in the region and its long-term effects upon the landscape have been considered.

DECLARATION

This thesis is the result of my own work and includes nothing which is the outcome of work done in collaboration. Data from other authors which are referred to in the thesis are credited to the authors in question at the appropriate points in the text.

STATEMENT OF COPYRIGHT

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INTRODUCTION

Since the rejection, in the early part of this century, of the theory of a cultural 'hiatus' between the Palaeolithic and Neolithic, and the acceptance of the Mesolithic as an authentic period of prehistory, British Mesolithic studies have undergone a series of changes in emphasis. Three main phases of research may now be recognised which, defined by J.G.D. Clark (1972 p.1), are in each case exemplified by his work. The first is a typological phase, concerned with the definition and classification of Mesolithic artefactual evidence (Clark 1932, 1936). In the second phase the importance of the social and environmental context of the evidence is noted (Clark 1939, 1952, 1954), and in the third the evidence is interpreted in functional, economic terms (Clark 1972).

In recent years this functional approach has given rise to critical re-evaluation of the relationship of Mesolithic man and the environment, in particular by Dimbleby (1961a), Simmons (1969a,b, 1975a,b, 1979) and Smith (1970), pointing to an increasing sophistication of land-use techniques, including a measure of deliberate environmental alteration. Much of the evidence for such activity, however, has been gathered incidentally in the process of palaeo-environmental research directed at other objectives, and research projects aimed at elucidating Mesolithic ecology remain relatively few. This means that there is a paucity of detailed evidence and the impact of human communities during the Mesolithic remains imperfectly understood. If environmental manipulation were indeed an habitual, conscious aspect of Mesolithic culture, it is not known whether it was casual and random, or formed part of a deliberate economic strategy. If the latter, it is not known how its use was adapted to the natural landscape evolution which took place during the Mesolithic, nor in which particular environmental situations it was most employed.

In particular we require more information about the scale and intensity of landscape changes initiated by Mesolithic societies, to ascertain whether their effects were ephemeral and temporary or of a more significant and perhaps even permanent nature.

Before such questions may be answered, many more detailed observations of Mesolithic clearance events are required and it is the general aim of this thesis to contribute further to the corpus of evidence. The North York Moors has been chosen as the study area because substantial peat deposits of mid to late Mesolithic age are known to exist there at all altitudes and much previous pollen research has been carried out, providing both material for new research and a background of comparative data. Artefactual evidence, which is both prolific and well documented, for the Mesolithic suggests that it was an attractive area for settlement and it is a small, discrete territorial unit incorporating both upland and lowland areas, allowing consideration of a wide range of palaeo-environments. The specific research objectives of this thesis will be threefold, a) to re-examine in detail the site of North Gill (Simmons 1969a) to clarify the character and spatial extent of the Mesolithic clearance event and its impact upon the landscape, b) to locate and examine comparative sites on the uplands of the Moors, c) to consider in the light of this and previous research the nature of environmental alteration during the Mesolithic in the North York Moors as a whole.

The thesis will be divided into three sections, of which the first (A) will be introductory and in which will be considered Mesolithic technology, ecology and previous evidence for environmental alteration as a background to the research topic. There will also be an introduction to the study area and to the research techniques employed. The second section (B) will be a presentation of the data derived from pollen and stratigraphic analyses, while the third (C) will contain a discussion of man-environment relationships in the North York Moors during the Mesolithic period.

It is hoped that the data presented and discussed in this thesis will contribute towards our understanding of Mesolithic activity, as the period is assuming increasing significance in the study of prehistory. The elucidation of the degree of sophistication of resource management, through an increasing control over the environment, during this period, is vital to the understanding of the context into which the Neolithic culture was introduced (Clark 1980).

CHAPTER ONE

Introduction to the research topic

1.1. Mesolithic Technology and Chronology

In recent years the industrial succession in the British Mesolithic has been reconsidered in detail by a number of workers (Jacobi 1975, 1976, Mellars 1974) and does not, therefore, require detailed exposition in this thesis. It is proposed, however, to consider briefly the general nature and development of Mesolithic industrial assemblages, in particular in the north of England, to provide a cultural, typological and chronological framework for the period with which the lithic material from the North York Moors study area may be compared. A fuller description of the Mesolithic archaeology of the North York Moors will be undertaken in chapter 2.4.

The classification, in purely typological terms, of the English Mesolithic industries into a range of technological groupings has been given a chronological, and therefore potentially environmental, context by the greatly increased number of radiocarbon dates which latterly have become available. With the establishment of a radiocarbon chronology it has become possible to recognise that a general division of flint assemblages, on the grounds of microlithic shape, into diagnostically 'broad blade' and 'narrow blade' industries also reflects a genuine chronological division into Early and Later stages of development, as suggested by Jacobi (1973). Table 1 shows the basic industrial succession for the Mesolithic linked to its radiocarbon chronology by the selection of critical radiocarbon dated sites. The youngest and oldest dates, with significant intermediate examples, are shown for each flint tradition.

c14 years b.p.	BROAD BLADE: Deepcar type	BROAD BLADE: Star Carr type	NARROW BLADE - GEOMETRIC: triangles	NARROW BLADE - GEOMETRIC: rods (R) trapezes (T)	SITE	LAB-CODE
c 5,000						
LATER MESOLITHIC				5,260 ± 130 (T)	Wawcott I	BM-449
				5,380 ± 80 (R)	Dunford Bridge B	Q-799
			5,611 ± 220		Lominot 4	Q-1189
				5,830 ± 100 (R)	Rocher Moss II	Q-1190
			5,850 ± 80		March Hill II	Q-788
			6,433 ± 115		Thorpe Common	Q-1116
			7,230 ± 110		Cherhill	BM-447
			8,573 ± 110		Broomhead Moor V	Q-800
			8,606 ± 110		Warcock Hill III	Q-789
	8,590 ± 90				Aberffraw	Har-1194
c 8,600						
EARLY MESOLITHIC			8,760 ± 140		Filpoke Beacon	Q-1474
	8,779 ± 110				Greenham Dairy Farm	Q-973
		9,210 ± 340			Warcock Hill South	Q-1185
		9,488 ± 350			Star Carr	C-353
	9,565 ± 350				Lominot III	Q-1187
	10,365 ± 170				Thatcham III	Q-659
c 10,600						

Table 1 - Radiocarbon chronology and Industrial Succession in the English Mesolithic - selected sites.

It is clear that a major transition in the form of Mesolithic industries occurred approximately 8,600 radiocarbon years ago, all of the assemblages dated prior to this time being of 'broad blade' type, and those of later date being dominated by microliths of 'narrow blade' geometric shape (Mellars 1976a). These newer types appear to be completely innovatory, but the earlier broad shapes do not disappear altogether, occurring in much smaller numbers on later sites until the end of the Mesolithic period.

Throughout this thesis the division in lithic technology based primarily on microlithic shape will be adopted as diagnostic of the transition between Early and Later phases of the Mesolithic. This point of transition is accompanied by other modifications in cultural equipment which suggest alterations of economic and social patterns and is coincident with major changes in the general environmental context of human communities. The possible causal relationship between environmental and cultural changes in the Mesolithic will be examined more closely below.

1.1.1. Early Mesolithic

The earliest radiocarbon determination available for a site with a characteristically Mesolithic tool-kit is that of 10,365 ± 170bp (Q-659), the oldest of a series from Thatcham III in southern England (Churchill 1962), although the way of life of these early communities is more clearly seen at Star Carr (Clark 1954) where the occupation is dated to 9,488 ± 350bp (C-353). The relationship of the Early Mesolithic with the final Upper Palaeolithic cultures of Britain is uncertain, but dates of 10,390 ± 90bp (BM-603) and 9,940 ± 115bp (BM-440A) for Cresswellian levels at Robin Hood's Cave (Campbell 1977) and Anston Cave (Mellars 1969) suggest, if they are correct, a temporal if not cultural overlap between them. Early Mesolithic assemblages are characterised by large simple microliths among which obliquely blunted points predominate, often showing retouch upon the opposing edge, prompting their description as broad blade assemblages by Buckley (1921, 1924), in referring to sites in the Pennines, many of which have been confirmed in their early provenance by radiocarbon dating (Switsur and Jacobi 1975). Other microlithic types present include isosceles triangles and longer points completely blunted along one edge.

It is possible to recognise two typologically distinct sub-groups within this general broad blade tradition, defined by the presence or absence of diagnostic microlithic shapes. The great majority of sites, including those in the south of England, conform with the assemblage described at Deepcar (Radley and Mellars 1964) in having many obliquely blunted points retouched on the opposing edge. These forms are lacking at Star Carr, and several other differences occur which indicate that these sites belong to two mutually exclusive industrial groupings. Fewer sites of Star Carr type have been recognised so far, but they are present in both lowland and upland contexts, one at Warcock Hill South in the Pennines (Mellars 1976a, Switsur and Jacobi 1975) being dated to 9,210 ± 340 (Q-1185), which correspond temporally with Star Carr itself. The distinctive nature of these sub-groupings is made explicit by their reliance upon differing types of raw material, sites of Star Carr type utilising brown and honey coloured flint only, while sites of Deepcar type employ exclusively grey or white flint. The nature and significance of this typological variability in Early Mesolithic assemblages is discussed at length by Radley and Mellars (1964) and by Jacobi (1978a), and in detail in this thesis where of relevance to the North York Moors, in chapter 2.4.

Other implements associated with Early Mesolithic assemblages include rounded end-scrapers and heavy flint tranchet axes made with a transverse flaking technique (Davies and Rankine 1960). Also characteristic is a wide range of bone and antler artefacts interpreted as projectile points and generally barbed for use as spear or harpoon heads. Many were present at Star Carr and others were recovered as chance finds, usually in lowland, often coastal, situations (Clark and Godwin 1956, Radley 1969b).

The typological affinities of these broad blade assemblages clearly lie with the early Maglemosian cultures of Northern Europe and while sites of this Maglemosian tradition have been recorded from most parts of the country (Radley and Marshall 1965, Wainwright 1960), a high percentage of them are located in the north of England (Jacobi 1978a). Little typological development or evolution can be discerned within the general Early Mesolithic industrial tradition (Jacobi 1976), tool morphology remaining largely unchanged throughout its duration, the latest radiocarbon dates at present available for broad blade industries being 8,779 ± 110bp (Q-973) at Greenham Dairy Farm (Sheridan, Sheridan and Hassel 1967) and 8,590 ± 90bp (Har-1194) at Aberffraw (Jacobi 1976 p.67).

1.1.2. <u>Later Mesolithic</u>

The commencement of the Later Mesolithic period in Britain is placed about 8,600 radiocarbon years ago, when a radical change took place in the morphology of microlithic tools. The new forms were smaller and more geometric in shape, most common being scalene micro-triangles, although a variety of other shapes occur, including narrow rods and trapezes. These may be equated with Buckley's narrow blade tradition, and prompted Clark (1955) to compare an assemblage of this type from Shippea Hill with artefacts of French Sauveterrian type, although it should be stressed that the parallel is typological rather than cultural (Mellars 1974 p.88, Megaw and Simpson 1979 p.63). The earliest radiocarbon date for a site with these Later Mesolithic geometric microliths is 8,760 ± 140bp (Q-1474) from Filpoke Beacon, Co.Durham (Coupland 1948, Jacobi 1976), closely followed by dates of 8,606 ± 110bp (Q-789) and 8,573 ± 110bp (Q-800) from Warcock Hill III and Broomhead Moor V in the Pennines (Radley et al. 1974, Switsur and Jacobi 1975). Manufacture of narrow blade assemblages continued in northern England until the end of the Mesolithic, around five thousand years ago, although an increasing proportion of sites is dominated by rod-like microliths (latest date 5,380 ± 80bp (Q-799) at Dunford Bridge B, Radley et al. 1974) rather than micro-triangles (latest date 5,611 ± 220bp (Q-1189) at Lominot 4, Switsur and Jacobi 1975). Rod-shaped microliths appear to predominate on sites in the North York Moors area (vide infra chapter 2.4.). The latest radiocarbon date for an English Mesolithic site, Wawcott I, dominated by rhomboid-trapeze shapes (Froom 1974) is 5,260 ± 130bp (BM-449) although later dates are recorded in Scotland, (Lussa River, Jura 4,620 ± 140 (BM-556) Mercer 1970) where the Mesolithic technology evidently persisted for rather longer.

Although many sites are exclusively geometric, early broad blade shapes do not disappear altogether and throughout the later Mesolithic still occur on some sites as a minor aspect of the assemblage, particularly in the south of England. An evenly mixed broad blade/narrow blade assemblage is dated to 7,600 ± 150bp (Q-587) at Peacock's Farm (Clark 1955). Few sites of mixed type are known from the north of England. Flint axes still occur in the non-microlithic part of the technology, but with a distribution apparently limited to south and east England while a marked reduction in both the number and variety of bone and antler tools is observed.

The environmental context of the artefactual assemblages described above will now be considered using evidence provided by palaeo-ecological research, particularly pollen analysis.

1.2. Pollen Analysis and the Mesolithic

The technique of pollen analysis has allowed the reconstruction of vegetation history since the last glaciation, detailing the successive stages by which the tundra landscape of the Late Glacial was transformed into mature deciduous forest by the time of the mid post glacial (Godwin 1975, Iversen 1973, Pennington 1974). The initial development of the technique in Scandinavia (von Post 1916) was as a means of reconstructing post glacial forest history, correlating with the Blytt-Sernander theory (Sernander 1908) of climatic change and, in providing a basis for the zonation of the post glacial, allowing the establishment of a relative chronological framework for the period. In summary (Godwin 1940), three Late Glacial pollen zones were followed by a period of birch dominance (Pre-Boreal, Zone IV) which rapidly gave way to pine and hazel (Early Boreal, Zone V). In the Boreal (Zone VI) occurred the successive immigration of the deciduous trees elm, oak and finally lime, into forest communities. A sharp rise of alder marked the beginning of Zone VII, a period of deciduous 'mixed-oak' forest dominance, which was divided into phases 'a' and 'b' on the basis of a decline of elm pollen midway through the zone. The elm decline is considered to be contemporary with the arrival of Early Neolithic settlers (Troels-Smith 1960) and this forms an approximate end to the Mesolithic cultural period.

This pollen chronology allowed the relative dating of archaeological material, and was applied with great success to the massive Danish bog complexes within which many Early Mesolithic settlement sites were stratified, (Jessen 1935, Iversen 1937) and which gave the Maglemosian culture its name (Sarauw 1903). The method was extended to other areas of north west Europe and enabled the recognition of a Maglemosian cultural techno-complex to be made, encompassing an area from Britain to the eastern Baltic, with early and later facies dated within pollen zones IV and V-VI respectively (Clark 1932, 1936). Maglemosian artefacts stratified in peat from Yorkshire, the North Sea bed, Denmark and Estonia were all referred by pollen analysis to an Early Boreal context (Godwin and Godwin 1933) and the results of later work have served to confirm the early post glacial date of these industries (Schutrumpf 1939, Althin 1954a, Clark 1954, Jorgensen 1954, Nilsson 1967).

Since the advent of the radiocarbon dating technique the primary function of pollen analysis has ceased to be that of a dating mechanism, although the relative chronology it provides remains of great value. Refinement of the technique of pollen identification and pollen assemblage interpretation today allows its use as a research tool of great potential for recording and explaining patterns of palaeo-environmental change, and for reconstructing past landscapes and man's responses to them (Smith 1979, Tooley 1981). Fundamental to the study of human settlement and land-use in the Mesolithic period is an understanding of the successive vegetation communities which developed after the last glaciation, for during that time man was active at an increasing level of technological sophistication, using powerful ecological tools such as fire and perhaps primitive forms of animal husbandry, such as herding and stalling (Jarman 1972, Simmons and Dimbleby 1974). The effects of these activities, as they can alter existing vegetation units and deflect ecological successions, may be detected in the pollen record. Thus the recognition of human disturbance of the environment, by the identification of pollen types from ruderal and heliophyte taxa and of tree pollen fluctuations characteristic of forest clearance, has meant that pollen analysis has developed as an archaeological tool, allowing inductions to be made regarding the economy and way of life of successive human cultures

(Dimbleby 1969, 1975, 1978). Such pollen data may also be correlated with standard radiocarbon dated regional pollen diagrams (eg. Godwin, Walker and Willis 1957, Hibbert, Switsur and West 1971, Hibbert and Switsur 1976), so that any ecological information induced may be considered within an 'absolute' chronological framework. While recognising the potential value of the technique to the archaeologist however, caution must be exercised in the particular interpretation of the results it provides. Edwards (1979) has pointed out some of the dangers inherent in the use of pollen data for precise archaeological inference, not least of which being the interpretive convictions of the palaeo-environmentalist himself. Having accepted these strictures, however, it remains clear that pollen analysis enables the reconstruction of landscape change, and allows an estimation of the character and scale of man's role within that process.

1.3. Archaeology and Post Glacial Landscape History

The landscape was constantly changing in post glacial times, creating new situations and posing new problems for its inhabitants with regard to shelter, communications, food resources and settlement potentialities. To begin with these changes were autogenic, induced by natural factors of climate and sea-level, soil development and consequent vegetational succession, but landscape evolution gradually came to be intimately related to man's innovative technology and his ability and willingness to modify his environment to his own advantage. His economy, technology and general way of life gained expression in the changes, both in character and intensity, he wrought upon the environment, and yet were to a large extent moulded and inspired by it. While the surviving artefactual evidence of past cultures is fundamental to our study of them and often diagnostic in our identification of them, it is but one aspect of the whole, and cannot be viewed in isolation. Implicit in our understanding of prehistoric cultures is a knowlege of their environmental context; the landscape within which people had to live, the constraints it placed upon them and the opportunities it proffered (Simmons 1981). It is to be expected that the functional component of a culture's tool kit will be governed largely by environmental considerations and their influence upon economic practice. To a large extent, therefore, the archaeological evidence which characterises various cultures has, especially in earlier prehistory, been environmentally prescribed. In prehistory food procurement systems, whether mobile, sedentary or of intermediate form, evolved as the most efficient response to the environmental circumstances prevailing at the time, and to the level of technological sophistication available. In turn, these will determine the relative attractiveness of different areas for human exploitation and therefore the settlement and land-use patterns which will be adopted.

A purely determinist view of prehistory is, however, rendered untenable by man's ability to alter his environmental parameters by cultural means, to a degree governed by the level of technological development which he has attained. Thus the distribution of human populations through the prehistoric landscape was not random, but dependent upon a complex and dynamic set of relationships between culture and environment. Landscape change, whether culturally or environmentally induced, alters these relationships fundamentally, influencing the locations of human settlement and activity in antiquity. The sequence of environmental change in prehistory is reflected most clearly in changing vegetation patterns. The attractiveness of an area for human occupation or exploitation is determined by its landscape, within which the nature of the vegetation is a major factor, as it controls the location and quantity of terrestrial biotic resources, and the potential for environmental management by human populations.

The influence of the landscape on human communities will be most critical at the hunter-gatherer level of organisation, for when man is dependent upon it for all his resources, including food and raw materials, it may be presumed that his way of life is dictated by it. The mesolithic technology described in section 1.2., characterised by hunting equipment, implies a hunter-gatherer economy (Althin 1954b, Clark 1952, 1968) and this has encouraged the view that Mesolithic man was dominated by, and therefore directly adapted to, the environmental conditions of the post glacial. The environmental context of the Mesolithic is considered in the next section.

1.4. Man-Environment Relationships in the Mesolithic

The Mesolithic settlement of Britain must be considered in relation to the environmental changes which took place as the post glacial period developed (Simmons and Tooley 1981), and these have been considered in detail with regard to the Mesolithic, together with their probable impact upon human communities, by Simmons *et al*. (1981). The Early Mesolithic was a time of very rapid environmental change, stimulated by ameliorating climate following the close of the glacial period. After a sharp initial rise, temperature rose steadily throughout the early Flandrian until under optimum climatic conditions of Flandrian II winter temperatures reached about $2^{o}C$ higher on average than those of the present day (Lamb *et al*. 1966, Taylor 1975). The increase in temperature had two major effects, to allow the spread and development of woodland communities and to bring about the eustatic readjustment of sea-level through the meltihg of the ice load. Although Thomas (1977) and Tooley (1980) cite evidence for a high sea-level stand accompanying deglaciation of the Irish Sea, it is apparent that sea-level was very low by the beginning of the Mesolithic, at c. 9,000bp relative sea-level being more than 21m below today's level (Tooley 1978a). At the latitude of the North of England, there is evidence that the Morecambe Bay area was transgressed by the sea shortly after 9,270 $\pm$ 200bp (Birm-141), suggesting that the northern Irish Sea was almost fully formed by this stage (Huddart et al. 1977, Tooley 1978c). To the east, however, there existed a broad lowland plain which extended across the present North Sea to Denmark (Jelgersma 1979).

The general amelioration of climate initiated the replacement of the open, herbaceous vegetation communities, which had characterised the Late Glacial, by woodland communities which increased in density as the post glacial progressed, being dominated in turn by trees of greater stature with higher nutrient and temperature requirements. As tree taxa migrated north the herbaceous tundra flora was replaced by an increasing cover of juniper, birch, willow and aspen, giving way to pine and hazel as temperatures increased. By mid chronozone Flandrian I (Zones V and VI of Godwin's scheme) tree cover was probably almost continuous especially at lower altitude, except where broken by lake or bog. As temperatures continued to rise, the thermophilous deciduous trees, oak and elm, assumed greater importance, hazel becoming reduced in abundance mainly through adverse shade factors as dominant tree size increased and canopies became progressively more closed in succession from pioneer to climax species (Iversen 1960, 1973). These Boreal woodlands, which would have characterised the lowland areas of the country, were overtaken by the progressive rise of sea-level. The area now covered by the North Sea was lost in stages between c. 8,600bp (Jelgersma 1961, 1979) and c. 7,800bp (Kolp 1976), until by c. 7,500bp the North Sea basin was completely inundated and Britain had become insulated from the European mainland. At the same time as vegetation successions were leading to the establishment of forested conditions, soil profiles were evolving as chemical and biological processes took place under increasingly warm and humid climatic regimes, although a drier interlude is postulated for late Boreal times (Lamb 1977, Pennington 1970). As a result, the raw periglacial soils which characterise the Late Glacial grew towards maturity by the end of Flandrian I.

Flandrian I, coinciding with the Early Mesolithic and the early phase of the Later Mesolithic, was a time of environmental change and succession, and the succeeding Flandrian II must be seen as a direct contrast, for it is a period of stability of climate, vegetation and soils. The creation of the North Sea and the insulation of Britain created a maritime and warmer climatic regime, reflected in higher temperatures, humidity, rainfall and much milder winters than obtained in the continental type of climate of Flandrian I (Taylor 1975, 1980). These altithermal conditions allowed the establishment of mixed deciduous forest, across most of England and Wales at least, with oak, elm, lime and, particularly, alder supplanting the birch, hazel and pine typical of the Boreal period. This Climatic Optimum (pollen zone VIIa in the Godwin scheme) was a time of ecological stability and inertia with dense, closed canopy woodland upon mature soil formations. Humus-rich mull soils, probably of brown forest type, may be assumed to be characteristic of the mature deciduous forest, with a trend towards podsolisation later in the period if acidification through nutrient deficiency occurred, perhaps on poor parent material, in marginal upland situations or following human activity, each of which might promote leaching (Limbrey 1975).

These changing environmental factors governed the spatial distribution and composition of the vegetation units which made up the post glacial landscape. Of most immediate concern to Early Mesolithic communities would have been the changes in quantity and distribution of food resources as a consequence of the change from tundra to forested conditions, as described by Clark (1968). The lowland plains of the earliest post glacial would have formed a great reservoir of biotic resources for grazing animals and the human communities which would have exploited them. A mosaic of lowland lake, grassland, estuary and developing shrub communities would have formed a rich concentration of food resources and it is likely that the Early Mesolithic economy concentrated upon this lowland zone and the populations of large mammals which would have existed there. Sea-level rise, however, progressively inundated these preferred hunting grounds until the line of the present coast was reached and in places transgressed (Tooley 1978a). As sea-level rise caused the attenuation and final loss of the lowland plains, Mesolithic groups were forced to turn inland in pursuit of adequate resources and to exploit more fully regions of higher altitude. This occurred at the very time during which new environmental characteristics of these areas were becoming established, as woodland canopies became increasingly closed and post glacial lakes were reduced in number. A forest fauna of red and roe deer, pig, aurochs and elk developed, with the latter becoming very rare by the mid Boreal (Degerbøl 1964, Grigson 1978). As the carrying capacity, or biomass, of forested areas is poor with a lower proportion of exploitable vegetable foods relative to more open ground, the populations of these game animals were probably relatively low with individuals dispersed widely through the forest making procurement difficult (Waterbolk 1968), causing a progressive diminution of potential food resources and placing the extractive systems of the Mesolithic under increasing stress.

In adapting to these changing environmental conditions man would have to expand the range, flexibility and intensity of his economic exploitation, perhaps involving a greater reliance upon fishing and fowling, more use of the range of vegetable foods described by Clarke (1976), and of coastal resources. An expected response of Mesolithic man to the impoverishment of the food supply by increased forest homogeneity and density might be an increased mobility, perhaps seasonal, of economic patterns enabling him to exploit preferentially those parts of the landscape which still retained vegetational diversity and therefore high resource potential. A further step would be to encourage this diversity by artificial means, the most effective of which would be fire clearance of woodland in favoured locations, perhaps by forest edge, spring head, lakeside or foreshore where natural concentrations of game were most likely to be found. It is most difficult to confirm this hypothesis, since the firm evidence regarding food resources exploited during the Mesolithic is quite limited. The vegetable aspect of the diet is represented almost exclusively by hazel nuts and the faunal evidence is still very restricted and probably unrepresentative (Grigson 1978). Our most informative body of economic evidence remains the assemblages from Star Carr (Clark 1954, 1972) for the Early Mesolithic and Morton Tayport (Coles 1971) for the Later Mesolithic, although these too, probably represent only the lowland facet of a seasonal economic system. If we are to test the plausability of a sophisticated Mesolithic economy which involved a degree of resource diversification through manipulation of the environment, it is initially through the use of palaeo-environmental techniques, and particularly the ecological application of pollen analysis described above, that the problem may be approached, for it is to be expected that alteration of vegetation communities such as that postulated would be recognisable in the pollen record. It is possible to interpret pollen data in cultural terms for, as has been noted above, the advantage to the prehistorian of ecological information such as that contributed by palynology lies in the realisation that the material recovered from archaeological sites relates directly to the way of life of prehistoric communities and reflects their responses to the contemporary environment. The assertion (Clark 1972 p.1) that the interpretation of cultural assemblages must be 'in terms of the utilisation of resources within the constraints imposed by physical environment' advocates a functional approach to archaeology which requires an understanding of landscape history and changing man-land relationships. The adoption of such an approach may allow the formulation of interpretive models which seek to explain the functioning of man within the ecosystem, and which in relation to the Mesolithic have encompassed economic strategies (Newell 1973, Price 1973), settlement patterns (Mellars 1976b, 1978), population structures (Meiklejohn 1976, 1978) and territorial organisation of subsistence patterns (Jochim 1976). Following Clark (1972) conceptual models for the British Mesolithic have been proposed using site-catchment analysis for both the upland (Simmons 1975a, 1975b, 1979) and the lowland zones (Jacobi 1978b).

1.5. Evidence for Environmental Alteration Associated with Pre-Agricultural Man

In palaeo-ecological reconstructions of this kind, instructive use may be made of inferences derived from ethnographic records of recent hunter-gatherer societies, which, when used with care, may provide valuable insight as to the subsistence patterns available to groups practicing a food-collecting, rather than food-producing, economy and the spatial and temporal distribution of population through the landscape. The implications of the comparative data assembled by Lee and DeVore (1968) are that our ideas of hunter-gatherer society may be largely preconceptive, and that cultures depending upon technologically simple equipment may operate relatively complex social and economic systems. Most striking is the attitude of many pre-agricultural societies towards the vegetational composition of the landscape, for rather than accepting an environmentally passive role, they try to mould it into one more favourable to them by increased productivity and availability of resources. This is most effectively done by the use of fire, a most potent ecological force, and the practice of deliberate burning as an instrument of economic policy is well documented among recent hunter-gatherers (Stewart 1956, Mellars 1976c). Mellars (1975) has discussed the economic benefits, in terms of increased yields of both plant and animal foods, which may be expected after manipulation of the environment by fire, an economic strategy which, although recorded from a range of contrasting environments, has been shown to be particularly effective within a woodland ecosystem, where available resources may naturally be rather low (Simmons 1975a).

The concept that hunter-gatherers may consciously and habitually initiate environmental change through firing of the vegetation as an integral part of their economic system is one of direct relevance to the British Mesolithic. While such ethnographic parallels are not strictly analogous to the Mesolithic situation, inferences may be made which may explain the extensive concentrations of charcoal which are met with in Britain, often in upland contexts, in sediments of Mesolithic age. This record of fire occurs both in association with flint artefacts and in isolation and is often accompanied by pollen assemblages indicative of forest recession, generally of a temporary nature. It would seem that the palaeo-ecological record describes periodic fire-clearance of woodland and while natural fires may not be discounted, the fact that hunter-gatherer societies have both the motive and instrument for modifying the environment suggests that such evidence may reflect the effects of the activities of Mesolithic man.

The apparent association of pre-agricultural man with environmental disturbance is not confined to the Mesolithic however, for there is evidence that Palaeolithic man also may be implicated in landscape change. Pollen analysis at the site of Marks Tey (Turner C. 1970) has revealed a clear phase of deforestation in zone HIIc, near the end of the mesocratic period of the Hoxnian interglacial. This phase of grassland and open country fell within a long period of deciduous forest dominance, and was accompanied in the stratigraphy by an abundance of charcoal fragments, suggesting fire as the probable cause of forest recession. Parallel evidence may be noted from the site of Hoxne itself (West and McBurney 1954, West 1956) where a temporary removal of woodland and establishment of open country appears to have taken place in zone HIIc, broadly contemporary with the Marks Tey clearance event, and again accompanied by prolific statigraphic charcoal. Pollen analysis has shown that the Acheulian occupation at this site occurred within this phase of deforestation. At Swanscombe this coincidence of Lower Palaeolithic settlement and forest clearance is again recorded in late zone HII, where molluscan and pollen evidence combine to record temporary replacement of dense woodland by grassland during a Clactonian occupation of the site (Waechter et al. 1971). From the same site, but in a zone HIV context, fire-reddened Middle Acheulian flint artefacts and charcoal occur together, again illustrating the association of fire and human settlement. Further examples from the late Hoxnian include the replacement of tree pollen by indicators of open ground at Fishers Green (Gibbard and Aalto 1977), and Hatfield and Stanborough (Sparks et al. 1969), as grassland apparently displaced woodland near the sites, with an increase in mineral inwash and breaks in sedimentation. While reduced water levels at these ancient lake sites may have been responsible for the creation of open areas, the possible influence of man cannot be discounted. It may be possible to perceive from the limited available evidence that Lower Palaeolithic man was capable of exerting a considerable influence, at least casually, upon the environment, and it is tempting to see in it a response to the restrictive interglacial forested environment around his lowland lakeside settlements.

Few indications of man's relationships with the environment exist in the full glacial periods; Sparks and West (1972) point, however, to the evidence of association of fire with man, in the form of hearths, which means that there was a potential for its wider employment. Tentative evidence for such use may be induced from the Mousterian occupation at Hortus in France (Bay-Petersen 1975) where a sharp fall in tree pollen frequencies occurs at an horizon recording heavy concentrations of Ibex remains. Herd exploitation through fire-driving of game may be suggested here.

Fire pressure upon the environment is recorded during the Late Glacial period in southern England (Kerney 1963, Kerney et al. 1964), where fossil soils of Allerød age were found to contain a heavy charcoal component, inviting comparison with widespread charcoal layers of similar age from the Netherlands (Van der Hammen 1953, 1957). These continental horizons are often associated with late Upper Palaeolithic implements, as at the type site of Usselo, suggesting man may have been responsible for the fires they represent. No cultural indications accompany the English sites, which record burning in a pollen zone II environment of marshy ground with a herbaceous and thin birch scrub vegetation, one of which (Kerney 1963) has yielded a radiocarbon date of 11,934 $\pm$ 210bp (Q-463). They may, however, represent part of the hunting activity illustrated more graphically by the elk skeleton and bone points of comparable age recovered from High Furlong in Lancashire (Hallam et al. 1973).

It is during the Mesolithic period, however, that the clearest correlation between environmental alteration and hunter-gatherer communities may be made, and preliminary summaries and discussion of the evidence have been made by Roux and Leroi-Gourhan (1965) and by Smith (1970). Since these publications many further examples have been recorded and in a methodical survey of the literature the present writer recognised over 180 distinct phases of forest interference or recession in Britain in a Mesolithic context*. While many examples occur in upland regions such as the Pennines (Hicks 1972, Tinsley 1975), Dartmoor (Simmons 1964, 1969d) and Bodmin Moor (Brown 1977), clearance activity is also recorded at lower altitudes at contemporary coastlines (Churchill and Wymer 1965, Tooley 1978a) or lakeside situations (Sims 1973, 1978, Taylor 1973). All recorded sites are comparable, however, in suggesting that clearance took place in ecotone situations where resource potential was already higher than in adjacent homogenous biota. This in itself may point to the clearance event being a deliberate act, carried out at selected locations as part of a conscious economic strategy. There are also indications that this clearance may locally have had severe and permanent effects upon the ecosystem, promoting the change from woodland to heathland (Keef et al. 1965, Rankine et al. 1960) or bog (Moore 1975), and at altitude preventing the regeneration of woodland at all (Jacobi et al. 1976). The existing evidence for Mesolithic man's impact upon the environment will be discussed in more detail in Section C, where of comparative relevance to the North York Moors.

* Detailed inclusion of this body of evidence is not practical in this thesis and so, pending publication, it is held in MS form (Innes 1980) and is available for consultation upon request.

CHAPTER TWO

Introduction to the Study Area

2.1. Location of the Study Area and Sites Investigated

The general study area comprises the North York Moors, an upland area in the north-east of Yorkshire which forms the most easterly substantial highland area in England. It is separated from the much larger and rather higher upland region of the Pennines by the Vales of Mowbray and of York and thus comprises a relatively small highland unit. Surrounded by low-lying alluvial land, the upland area of the North York Moors forms an isolated island which contrasts strongly with the fertile lowlands of the Vale of York to the west, and the Vale of Pickering to the south. This diversity of topography reflects the underlying geological formations and gives the upland massif of the Moors a degree of insularity and discreteness which lends itself to its adoption as an homogenous region for the purposes of scientific investigations.

Although the highest part of the Moors is only 454m above sea level, the main part of the central summit area lies above 300m, so that the area forms a raised plateau rather than a range of individual hills. (Fig. 1.). The isolation of this upland plateau is emphasised by the steep escarpment which forms its western boundary, known as the Hambleton Hills. To the south the Tabular Hills, fault-raised to a height of 150m, form a sharp boundary with the Vale of Pickering, while to the north the faulted escarpment of the Cleveland Hills delineates the boundary between the Moors and the lowlands of the river Tees. The eastern edge of the North York Moors is formed by the North Sea coast, which comprises a series of steep and irregular cliffs. The summit line of the highest part of the Moors, which reaches 454m on Urra Moor in the west, descends to 183m at

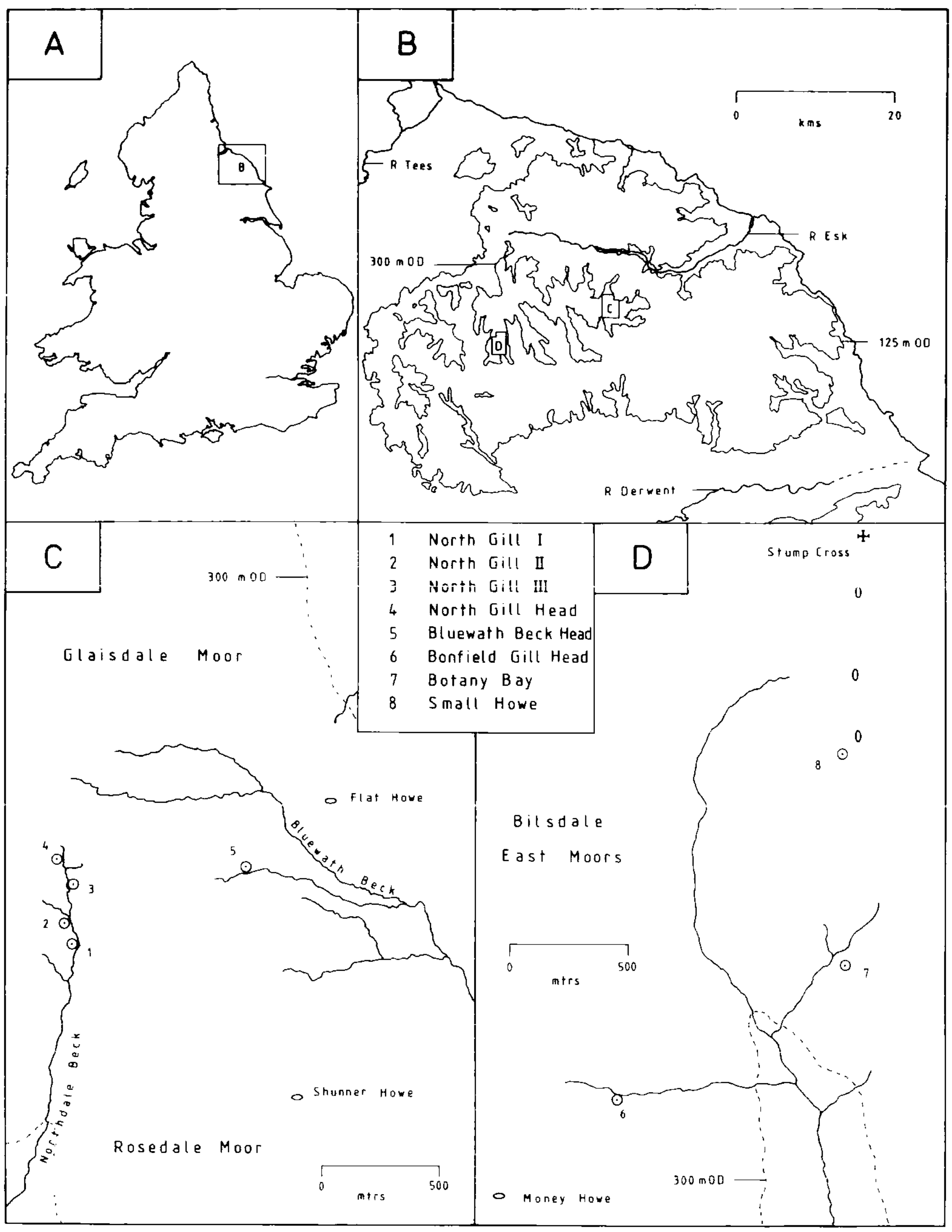


Fig. 1. North York Moors. Geographical location of the study areas and sites investigated.

the coast, so that the upland is tilted in an easterly direction.

The upland plateau area is broken by a series of river valleys. These dales radiate from the central highland area, in a mainly northerly and southerly direction, so that even the very highest areas are adjacent to sheltered lowland conditions, in which radically different vegetation and soil types exist. In the northern part of the area the valley of the river Esk runs in an east-west direction, separating the summit plateau of the Moors from the less elevated Cleveland Hills. The valleys of the Eller Beck, a tributary of the Esk, and Newton Dale merge to form a low-lying area which bisects the Moors from north to south. The highest parts of the plateau lie to the west of this line, while the moors to the east of it are significantly lower in altitude. It is with the higher plateaux to the west that the research to be undertaken in this thesis is concerned.

Previous research in this area has shown that the shallower blanket peats of the highland plateaux appear to have commenced formation in mid post glacial times (Cundill 1971), and that in some cases at least (Dimbleby 1962, Simmons 1969a) peat inception during Flandrian II may have been intimately connected with the activity of prehistoric communities. As the central brief of this investigation is to attempt to clarify the relationship between early man and his environment in this region, it was decided to concentrate upon the more elevated areas of the Moors, where Mesolithic hunting activity may be expected to have been of greatest potential impact upon ecosystems perhaps already tending towards instability, and where such indications have already been recorded. A more detailed investigation of the phenomena manifest at North Gill (Simmons 1969a, 1969b) is therefore the primary aim of this thesis, while it was also intended to find and investigate new sites upon the Central Watershed, which may throw further light upon the ecological history of the area in mid post glacial times.

It is proposed to retain the term 'Central Watershed' to describe the high plateau area between Urra Moor and Bilsdale Moor in the west and Wheeldale and Egton Moors in the east. Initiated by Elgee (1930), this terminology was adopted with reference to the central moorland plateau area by later workers (Anderson 1958, Farra 1961, Cundill 1971) and seems most suitable.

The location of the sites investigated in this thesis relative to the Central Watershed, and the geographical location of the study area is shown in figure 1. Most are spring-head sites at an altitude of 350m or greater, in a situation where stream erosion of the blanket peat mass had exposed an entire profile to analysis. Four new sites were studied at North Gill, designated North Gill I, North Gill II, North Gill III and North Gill Head respectively. Throughout this work the sites of Simmons (1969a) will be referred to as North Gill 'a' and North Gill 'b'. A profile was investigated at Bluewath Beck Head in the midst of the area of deep peat on Glaisdale Moor, and three sites were investigated upon East Bilsdale Moor, in a part of the study area not previously given attention, possibly due to its lack of large areas of deep peat. The site of Small Howe is at the highest part of the Moor, in unbroken blanket peat, while Botany Bay and Bonfield Gill Head are at a rather lower level associated with stream exposures.

2.2. Geology, Soils and Peat Cover

2.2.1. Geology

The solid geology of the North York Moors is worthy of attention in some detail, for since the earliest studies (Fox-Strangeways 1892) it has been apparent that the topography of the area is closely dependent upon the composition of the underlying rock types. More recent study (Wilson 1948) has resolved the geological history of the area in detail, and the

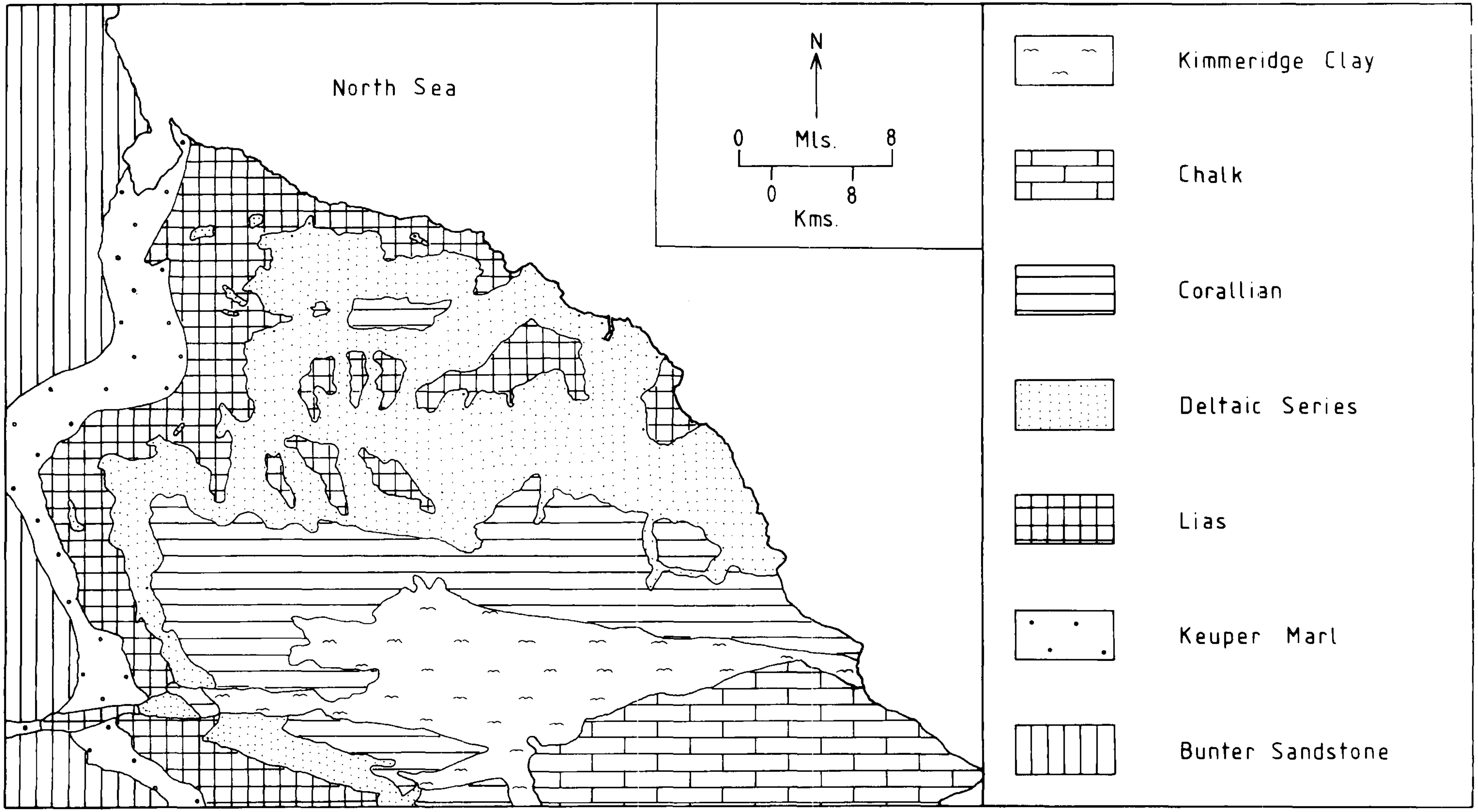


Fig. 2. Solid geology of the North York Moors. Surface distribution of the major rock types.

close relationship of geology with topography and soil type is of special relevance to the Central Watershed area. The surface distribution of the major rock types is shown in fig. 2, and Table 2 shows a simplified stratigraphic succession for the region.

Flanking the North York Moors upland on the west are lowland areas composed of Triassic Bunter Sandstones and Keuper Marl, now mainly masked by a covering of glacial drift, and fringing the area on the south is the Cretaceous Chalk of the Yorkshire Wolds. The upland itself is composed of Jurassic rocks, the earliest of which are termed the Lias and comprise soft clays, shales and limestones. Liassic deposits of the Lower Jurassic are exposed primarily to the western side of the upland, but also appear in the lower parts of the dales and at the coast. The Central Watershed area, and indeed the bulk of the moorland area of the North York Moors, is composed of rocks of Middle Jurassic age consisting of a succession of sandstones and shales of deltaic origin. The resilient nature of these Deltaic Series deposits has protected the softer Lias beneath and allowed the central arêa to assume its present topography. Of particular significance in this respect is the Scarborough Bed or Grey Limestone Series which is composed of shales, silty sandstones, ironstones and impure limestones and forms the topmost deposit across most of Egton, Rosedale, Glaisdale and Danby High Moors, although capped on occasion by the Moor Grit, a massive, strongly-bedded quartzite. These Middle Jurassic strata have moulded the topography of the central North York Moors. Upper Jurassic rocks, mainly Calcareous Grits and Oolites, known as the Corallian series, are exposed in the southern parts of the Moors and the Cleveland Hills, and are responsible for the imposing escarpment which delineates the moorland area. The latest Jurassic deposit in the area is the Kimmeridge Clay, which underlies the alluvial veneer of the Vale of Pickering.

Table 2. <u>Geological Sequence for North East Yorkshire</u>.

QUATERNARY		Peat Alluvium Boulder Clay Glacial deposits
CRETACEOUS		Chalk
UPPER JURASSIC		Kimmeridge Clay
	Corallian Series	(Upper Calcareous Grit (Osmington Oolite Series (Middle Calcareous Grit (Hambleton Oolite Series (Lower Calcareous Grit
		Oxford Clay Kellaways Rock Cornbrash
MIDDLE JURASSIC		Upper Deltaic Beds Scarborough Beds (Grey Limestone Series) Middle Deltaic Beds Millepore Bed Eller Beck Bed Lower Deltaic Bed Dogger
LOWER JURASSIC		Upper) Middle) Lias Lower)
TRIASSIC		Keuper Marl Bunter Sandstone

The structure of the North York Moors as it exists today was established in mid-Tertiary times by major earth movements, uplift of the Jurassic strata creating a series of gently folded anticlines and synclines. Since the chalk of the Cretaceous no further solid formations have been created, and it is this Tertiary uplift which is responsible for the character of the Moors, including the pronounced eastwards tilt of the region. The major folds are modified by a number of minor folds with a north-south axis and these have had the effect of converting what was hitherto essentially an east-west drainage pattern to one which is radial in nature, dissecting the main massif of the upland with the lowland arm of the dales, providing easy access to the most elevated areas of the upland during later periods of human exploitation. The structure established by the uplifting and folding processes was subsequently modified during the remainder of Tertiary time by a gradual denudation of the upland. Erosive forces and the cutting of the river valleys reduced the uplifted Jurassic block to its present subdued topography. Major planation surfaces may be recognised on the Moors (Gregory 1962a, Hemingway 1966) which form stages in this process of erosion. The highest is termed Summit Surface at above 400 metres, below which is the High Moors Surface which is considered to lie between 350 and 390 metres above sea level. Very gentle gradients are the main feature of these surfaces, producing the extremely flat and almost featureless landscape which is responsible for the essential character of the Central Watershed area.

During the glacial episodes which have occurred within the Quaternary period the North York Moors were influenced in a variety of ways. Only the most recent glaciation, the Devensian, has left features which are now easily discernable, its ice-sheets obscuring or removing deposits and features created by the earlier glacial advances of the Pleistocene. That an earlier glaciation may have entirely covered the upland with ice is suggested by Elgee (1912) and by Hemingway (1958) who regard superficial deposits of drift and pebbles upon the Central Watershed as evidence of this. Dimbleby (1952a) considered certain ice wedges within the region to support this view. The Devensian ice-sheets, however, have left a clear imprint upon the area.

Glacial drift deposited by the ice-sheets girdles the upland to the north and west to heights of up to 300 metres above sea level. Along the coast drift rises to 150 metres and extends across the entrance to the Vale of Pickering. The Scandinavian ice-sheet which deposited this eastern drift thus blocked the valley of the proto-Derwent river, the dammed-back waters having no outlet as the western end of the Vale was also blocked by ice, creating Lake Pickering within the Vale. This most famous of the glacial lakes created the lacustrine and alluvial deposits now mantling the Kimmeridge Clay in the area. Glacial drift, however, does not cover the Central Watershed, nor is it present in the Dales to the south, although it does appear in Eskdale and Glaisdale to the north. It seems, therefore, that the central upland area of the Moors remained unglaciated, an island or nunatak, above the level of the ice-sheet, throughout the last glaciation. Extreme conditions near the ice-front would, however, have caused some erosion due to solifluction processes. Indeed, solifluction deposits occur at a number of sites upon the Moors, especially in glacial drainage channels (Gregory 1962b). Today these in many cases do not have free drainage and provide suitable sites for the accumulation of post glacial organic deposits, in the same way as kettle-holes and depressions formed in the land surface under the ice-sheets today are filled with lacustrine and peat deposits. Thus a large area of the region was transformed by the glacial advance of the Devensian, and the Central Watershed area, although not covered by ice, was still profoundly affected at this time.

2.2.2. Soils and Peat Cover

Very poor, acid soils predominate upon this highest area of the Moors, having been subject to a high degree of podsolisation. Studies of pedological development have stressed the homogeneity of soil type upon similar rock strata within the area (Anderson 1958, Crompton 1961) and it would seem that such variations as do occur are the result of topographical factors. This direct and apparantly uncomplicated relationship between soil cover and rock type has led authors in the past (Jacks 1932) to suggest that podsolisation and extreme acidity may have been the natural characteristics of soils in the upland regions of the Moors throughout the post glacial period, and thus to contend (Elgee 1912) that moorland upon badly leached soils has been a virtually permanent feature of the Central Watershed. More recent studies (Dimbleby 1952b, 1952c) have suggested, however, that Brown Earth soils once existed upon the upland areas of the Moors, supporting full deciduous forest, and that the present heath vegetation is largely the result of non-autogenic processes in which man's effect upon the landscape is directly implicated. Fossil soils of Brown Earth type have been discovered sealed beneath Bronze Age barrows upon the high Moors (Dimbleby 1962), their pollen content showing that woodland conditions once prevailed in areas now dominated by heath and podsol. It must be assumed that not until Bronze Age times did the soils of these areas attain their present character, although in certain areas podsolisation may have been well advanced at an earlier atage.

Throughout the North York Moors region it would appear that topography, and consequently drainage, is the regulating factor which determines soil development in any particular area, once the general nature of the soil has been established by the underlying rock type. Where sandstones are the parent material, as with the Deltaic Series of the higher Moors, drainage is free and leaching is rapid, so that acid podsols are most common. Heavy clay soils, characteristically Brown Earths, exist in the Dales where the softer Liassic rocks are exposed, providing fairly fertile areas which contrast strongly with the acid podsols of the adjacent high moors. Some variety within the upland podsols does occur however, as local drainage differences affect soil development. Thus in situations where free drainage may exist peaty podsols will develop, whereas where drainage is impeded peaty gleys may become established (Wood 1970). The 'A' horizons of the upland soils seem to be uniformly a bleached sandy horizon with a raw humus layer above. In free draining situations a hard 'pan' may be formed in the 'B' horizon, especially where iron is present in the parent material. Impeded drainage leads to a gleying of the 'B' horizon. It seems clear that the Moorland soils are ones which have come into being under conditions of relatively high precipitation, causing a rapid removal of nutrients through leaching, especially upon bedrock which is in many cases nutrient-deficient sandstone. The bleached sandy layer of the 'A' horizon is created by the leaching capacity of humic acid solutions derived from the overlying 'mor' acid humus and litter cover. The organic material moved downwards through the soil during the leaching phase is arrested by the 'pan' horizon which prevents the normal soil maturing process from functioning and retains water above it, causing waterlogging and peat formation. Thus, in this area of mature humus-iron podsol soils, it is drainage conditions which determine the occasion and rate of development of peat deposits, and in the mid post glacial situation of high rainfall intensity, organic deposits of acid nature developed upon those areas where drainage was restricted.

Organic deposits have, however, been laid down at various times since the removal of the ice-sheets in widely differing situations across the North York Moors region, and their role in elucidating the post glacial history of the region will be described in chapter 2.5. Peat deposits in the area fall into four main types; lowland mires, channel mires, upland basin peat and upland blanket peat. In lowland situations organic deposits have accumulated in depressions left by the retreating ice, for example at Seamer Carrs (Jones 1971). Such depressions become small lakes which gradually full up with material, having no external drainage, and are transformed into mires by normal hydroseral development. Other organic deposits are formed by bodies of water which are remnants of glacial lakes, and which also slowly disappeared during early post glacial times, the ancient lake sites of Star Carr and Flixton being prime examples (Clark 1954). Mires formed over former lake basins tend to exhibit a characteristic development in that Late Glacial lake sediments are overlain by reedswamp peat, then by fen-carr peat with wood content and then by a fibrous bryophyte and monocot peat with Eriophorum and Sphagnum and perhaps Calluna. Most sites of this kind do not appear to have remained a lake for very long, being filled in at a rate dependent upon the depth of their basin and whether or not drainage was possible. The rate of British hydroseral development was investigated by Walker (1970) who concluded that the rate of change in such situations from open water to fen-carr may be relatively rapid. Certainly, mires formed above old lacustrine hollows may attain great depth and are thus of great potential for elucidating the earlier history of the post glacial period.

A second type of peat is that which has developed in the deserted glacial meltwater or overflow channels, termed 'slacks' or 'swangs' in north eastern Yorkshire. At first believed to be the overflow channels for the impounded waters of glacial lakes (Kendall 1902), it now seems that many of these channels may be sub-glacial meltwater features (Gregory 1962a). These channel mires are most numerous and many have been scientifically described (vide infra 2.5.). Pollen evidence (Simmons 1969c) suggests that peat commenced forming in these channels in pollen zones VI or VIIa in Godwin's scheme (Godwin 1975) and this is supported by radiocarbon assay of basal samples from a channel mire on Fylingdales Moor (Shotton and Williams 1973) which yielded dates of 7,230 ± 130bp.(Birm-315) and 7,070 ± 130bp. (Birm-316). In character with these channel mires of intermediate altitude are the bogs which have developed behind landslips at the heads of the main valleys. Such features are not widespread upon the North York Moors and the two main examples are fully discussed by Cundill (1971) and Simmons and Cundill (1974b). A third type of organic deposit is that which has formed at a higher altitude, in minor topographic basins where drainage was naturally impaired. A number of separate centres of the deeper basin peat are located across the moor at North Gill, Bluewath Beck, Loose Howe, Yarlsey Moss, Collier Gill and Pike Hill Moss and organic deposits have spread from these centres to cover the Watershed with shallow blanket peat, although deeper deposits are confined to these centres. Although the Central Watershed has the greatest concentration of peat deposits, isolated areas do exist to the east at May Moss and Harwood Dale, and to the west upon Bransdale and Danby Moors. Newly recognised areas have been recorded upon East Bilsdale Moor, and large areas of deep peat are known to exist upon Urra Moors (Taylor G. personal communication). Basin peat generally has wood remains at the base, while the shallower blanket peat in most cases does not. A wide variety of material is found beneath basin and blanket peat, ranging from solid rock, to fossil soil or minero-organic deposits. It has been suggested (Wood 1970, Moore 1972) that peat formation may be a natural response in upland areas to drainage impedence and gleying of soils, although in this area at least such a simplified view may not be sufficient explanation, and the activities of prehistoric man may be implicated in this process (v.i. page 273).

2.3. Climate and Vegetation

The present climate of the North York Moors appears to be mainly influenced by the location of the area and by its existence as an isolated upland region of moderate relief. In general terms the region falls into distinct upland and lowland climatic zones, for although the relief of the Moors is not unduly high in comparison to the Pennines, the treeless and flat nature of the moorland makes exposure to wind a major climatic factor. Indeed the present vegetation cover may well be the chief reason why the climate is unfavourable to agriculture, as the treeless nature of the upland maximises wind exposure and shortens the potential growing season. The North York Moors forms the most easterly upland region of England at a relatively high latitude of over 54° north, but is immediately adjacent to the moderating influence of the North Sea. This body of water has the effect of preventing extremes of temperature being felt within the area, this being true of even the summit areas of the upland which rise to over 400 metres above sea-level. Thus while cold, easterly winds occasionally dominate the upland, winter temperatures are never excessively low, and in early summer these easterly winds create a thick sea-mist known locally as 'haar' which brings with it poor visibility and extended periods of fine, misty drizzle. Predominantly, however, the region's winds are westerly but nevertheless rainfall is not unduly high, as the rain-shadow effect of the Pennines to the west reduces the rainfall potential of these winds, but does not cut the region off from the westerly airstreams. Relief therefore remains the regulating factor across the whole area and it has been pointed out (Atherden 1972) that the rainfall isohyets correspond strongly to the contour lines, only the very highest areas receiving 40 inches of rain a year. Highest monthly rainfall is generally recorded in November, although spring increases also occur. Much of the winter precipitation falls as snow, often remaining upon the ground until late April for although temperatures are never really low, they do not rise quickly as spring arrives. In the lowland areas temperatures are rather higher and incidence of snowfall much less. Precipitation generally is rather lower but the major difference is the much reduced influence of the wind, the absence of which makes the lowland warmer and far more attractive for agriculture, although in the areas over-shadowed by the plateau, frost incidence may be high as cold air descends from the moorland into the Dales. The main climatic disadvantage of the moorland areas, therefore, must remain its exposure to the wind, a factor greatly exacerbated by the nature of the dominant moorland vegetation.

The plateaux areas of the upland moors, including virtually the entire surface of the Central Watershed, are covered by a heathland community in which heather or ling, Calluna vulgaris, plays by far the most dominant role. It is this expanse of purple heather and the unrelieved flatness of the terrain which gives the moorlands their familiar colour and atmosphere, the ever present winds of the upland creating a sense of wildness which belies their almost completely artificial nature. The heather moors have been formed through continued exploitation by man and are in no respect natural, the vegetation itself, the soil beneath it and the fauna which inhabit it being the result of man's historical manipulation of the landscape. Converted to heathland by many tens of centuries of human use, the artificial climax vegetation of Callunetum is today deliberately maintained as a form of monoculture, primarily for grouse, although sheep also utilise parts of the moorland. As Calluna germinates primarily on bare, sandy soil, no new heather plants can grow in thick vegetation (Gimingham 1960), and so to create favourable regeneration conditions the existing plant cover must be removed, a factor of relevance to the status of Calluna throughout the post glacial as represented in pollen diagrams. Thus the dominance of Calluna is assured upon the grouse moors by its repeated but controlled burning (Pearsall 1950). Old, degenerating heather is burned off in the winter months to promote fresh growth, for it is the new fresh shoots which provide the main food of the young grouse. This is done across the moor in a phased manner, so that the moorland becomes a mosaic of Callunetum in differing stages of regeneration, ensuring a regulated and adequate supply of young birds for the annual autumn exploitation which makes Callunetum moorland a commercially viable proposition. On occasions fires are accidentally started upon the moorland, usually be walkers or holiday-makers, and may envelope large areas of Callunetum. These accidental fires are of high intensity and may damage the moorland semi-permanently. During the drought of the summer of 1976 a fire started upon the Central Watershed destroyed the heather moor across Glaisdale Moor, Egton High Moor and Wheeldale Moor, killing heather and birds alike and causing extreme problems of peat erosion in the area. This fire is of relevance to the sites at North Gill and Bluewath Beck Head and will be referred to again at a later stage. Heath fires destroy most of the vegetation and the heather renews itself from seeds in the surface soil, although these are also destroyed by the deep burning of wild fires over peat. Calluna produces large numbers of seeds, each capable of reaching maturity in five or six years, although the life span of the plant if left to itself may be twenty or thirty years. At this age the branches of the plant sag, dry out and die, and grasses flourish in the centre of the drooping plant and overwhelm it. Although Calluna is the ecological dominant due to fire, plants with underground runners remain active, in particular Vaccinium where the soils are very poor, and Pteridium upon rather better soils. In situations where damper conditions exist Erica tetralix may be locally important.

Variations in the type of Callunetum community have been recognised (Elgee 1912, Cundill 1971) which tend largely to correspond with peat depth and associated dampness. Calluna is completely dominant upon the flat plateau moorland upon deeper peat mosses, for example at Yarlsey Moss (NZ 755007) and Pike Hill Moss (NZ 772010). The continuing wetness of these peats allows Erica and Eriophorum vaginatum to be represented, and a Sphagnum blanket may develop in a flush situation at stream heads as at High Seaves (NZ 716002) and Botany Bay (SE 606958), with Empetrum and Juncus associations. Upon peats of about a metre in depth Eriophorum and Vaccinium will occur, whereas on shallow peat areas a more varied community exists, Nardus and Scirpus becoming important with lesser representation of Eriophorum, Molinia and Juncus (Jones 1971).

On the edges of the moorland plateaux, where slopes become steeper and improved drainage conditions may thus occur, the Calluna dominance ceases and the heather has to compete with Vaccinium and Pteridium. Bracken in many cases assumes dominance in such situations and supresses other taxa due to extreme shading by its fronds (Jarvis 1964, Jeffreys 1917) and by the exudation of toxic materials (Gliessman and Muller 1972, Gliessman 1976). Its main weaknesses are badly aerated soils and impeded drainage, and in slope vegetation it is able to compete most successfully with Calluna. The invasion of Calluna heath by bracken is a familiar feature in these situations (Farrow 1917) and may be seen today at the plateau edge of East Bilsdale Moor. The natural role of Pteridium is as woodland understory (Cousens 1974) and this led Elgee (1912) to maintain that its presence upon the Dale slopes indicated former existence of woodland there.

Mire vegetation may be found within the valleys, especially the channels of former glacial meltwater streams, which are in this area termed 'slacks', no longer occupied by watercourses and filled with organic deposits. Sphagnum and Carex are well represented while Juncus and Eriophorum bogs occur. Mire communities also exist within the dales themselves.

In summary, therefore, the Callunetum which dominates the Central Watershed is not of natural formation but is a fire-induced sub-climax vegetation, continued and long-term diversion of the natural seral succession by man having created the conditions which we see today. It is not possible therefore to agree with Elgee (1912) that the vegetation of the area has remained constant since the last glaciation, and the work of several authors has shown that woodland would have continued to clothe the Moors until the present day had not man exploited the area for his own use, as he continues to do at present.

2.4. Previous Research in the Study Area - Mesolithic Archaeology

In this section a survey of the archaeological evidence within the study area will be undertaken, with a view to describing the range, type and intensity of occupation in the region during the Mesolithic cultural period. A knowledge of the scale and distribution of Mesolithic settlement and activity in the area is clearly fundamental to the discussion of potential cultural-environmental relationships which will be attempted in chapter 7. This section, therefore, comprises a summary of our current knowledge of the Mesolithic archaeology of the North York Moors.

2.4.1. Historical

The microlithic industries of the region have attracted scientific inquiry since the middle of the 19th century, when the Rev. J.C. Atkinson discovered two large flint sites near Siss Cross; on Danby Low Moor (Atkinson 1863). These flint scatters were evidently prolific, for he records that sufficient tools and waste were recovered to 'half fill a fair sized fishing basket', and considered the assemblage of artefacts to be best explained as a 'Celtic flint implement factory'. Elgee, following the rediscovery of these sites by his wife in 1925 and subsequent collection of flakes and points, recognised their true provenance as Mesolithic flint sites. Sporadic recovery of microliths by amateur collectors continued throughout the early part of this century as sites became exposed by erosion, primarily following moorland fires or with the building of trackways and paths, and some of these chance finds are recorded by Elgee (1930). Early workers included Mr. A.L. Armstrong who located two sites between Hawnby and Chopgate on Bilsdale Moor in 1912, and Mr. L.G. Rowland, who picked up flints from all over the Moors, but most successfully from the Central Watershed on Farndale and Westerdale Moors. Although Armstrong (1923, 1926) contributed to the literature regarding Mesolithic archaeology, it is with the work of Frank Elgee that systematic investigation of the subject began (Elgee 1930, Elgee and Elgee 1933). Elgee searched for new sites across the Moors, identifying several major areas of flint concentration, in particular Brown Hill, Commondale and Cockheads, Glaisdale. With the addition of the products of his own researches to the collections of earlier workers, a large corpus of material was now available for study and Elgee began to differentiate the sites on the basis of lithic typology, adopting the newly derived Maglemosian-Tardenoisian terminology in his descriptions of the cultural succession on the Moors. He also realised the apparent link between the location of flint sites and the higher, sandy areas of the region and explained this in terms of the drier and thus more attractive character of the uplands. The work of Elgee was, in the years which followed, accepted by other workers as the definitive expression of Mesolithic archaeology in the region (Clark 1932, 1936, Raistrick 1933).

The era of modern research in the area begins with the recovery of a Maglemosian industry from Flixton in the Vale of Pickering (Moore 1950), which subsequently led to the excavation of the major Maglemosian settlement at Star Carr and adjacent sites (Clark 1954, Moore 1954). Contributions to the subject were made by Thornley (1959) and Gibbs-Smith (1960) and a review of the evidence undertaken by Hayes (1963), although this was confined to the south-western part of the region. He recorded twenty-two sites, all in the upland context recognised by Elgee. Further comment upon the Mesolithic in the area was made by Raistrick (1966) and Bartlett (1969) before a comprehensive reappraisal of the evidence was made by Radley (1969a). The great majority of the sites known at that time were of essentially the same type, small flint scatters on the highest parts of the Moors above 300m OD, which Radley considered to be specialised hunting camps, microlithic tools forming a very high proportion of the total flint assemblage. In this paper Radley described the distribution of sites in the area and examined the sites of White Gill, Farndale Moor and Mauley Cross in some detail. The sites appeared all to be referable to the late Mesolithic and to be typologically analogous, with only minor variations to suggest any degree of cultural diversity, whether on grounds of microlith shape or tool waste ratio. The proposed temporal and technological uniformity of the microlithic industries of this area has, in the light of more recent research, proved to be illusory, but Radley's work remains most valuable as a general statement of site type and location on the Moors. While most of the recorded flint sites may indeed be attributable to the later Mesolithic, earlier microlithic sites are now recognised, some of which may be equated with the cultural tradition recorded at Star Carr (Brown et al. 1974, Jacobi 1975, 1978a). A second type of later Mesolithic site has also been identified, at Upleatham (Spratt et al. 1976), where the increased proportion of food-processing artefacts, such as scrapers, and lower representation of hunting equipment, such as microlithic points and arrowheads, suggests a longer occupation settlement with a wider range of activity, perhaps supporting a greater aggregation of people. A similar site may have been recorded by Wood (1947) at Hutton-le-Hole on the southern edge of the Moors.

Today, as in the previous century, much of the newly exposed flint material is recovered by amateur workers and is thus housed in private collections. Fortunately recording of finds by modern workers, such as R.H.Hayes and G.V.Taylor, is both detailed and accurate, although unpublished, and data is accessible and reliable. This corpus of private material, as well as published records and the contents of Museum collections, has recently been brought together in a gazeteer of Mesolithic sites in England and Wales (Wymer 1977). It is this catalogue which forms the basis for the distribution maps of Mesolithic sites presented in this work (figs. 3 and 4), supplemented by data from the range of sources listed by Spratt and Simmons (1976) and by personal communication with workers currently active in the area. The body of research described above, and in particular the work of R.M. Jacobi, allows the following appraisal of the Mesolithic archaeology of the North York Moors to be made.

2.4.2. Early Mesolithic

On a purely typological basis the lithic material which represents the Mesolithic period in England may be divided into a number of industrial traditions, most particularly into technologies which are diagnostically 'early' or 'later' in character (see chapter 1). In his recent reappraisal of the evidence from Star Carr, Clark (1972) suggested that sites which may temporally relate to that lowland Maglemosian site should be forthcoming from higher ground in the region, most logically upon the nearby North York Moors. At that time no Early Mesolithic sites, save for Star Carr itself, were documented from the area, but in recent research Jacobi (1975, 1978a) has extended the distribution of the early Mesolithic cultures into an upland context. This distribution is shown on figure 3.

The earliest phase of the Mesolithic in this area is represented by the Maglemosian or 'proto-Maglemosian' site of Star Carr (Clark 1954) which yielded radiocarbon dates of 9,557 $\pm$ 210 (Q-14) and 9,488 $\pm$ 350bp (C-353). Both it and the adjacent site of Flixton I lie on the northern edge of the post glacial Lake Pickering at the foothills of the North York Moors, and are generally regarded as winter aggregation camps for the exploitation of ungulate populations retreating from their upland summer ranges to the more sheltered conditions of the lowlands, although Pitts (1979) has suggested a purely technological, rather than subsistence motive for the Star Carr occupation at least. They share a typically early lithic tool-kit of a non-geometric 'broad blade' character associated with Tranchet Axes and axe-sharpening flakes, as well as a range of bone and antler barbed points. The use of transversely sharpened axes in Northern England has been stated by Jacobi (1975) to have been restricted to the Early Mesolithic, and in the study area these are mainly recorded from the Vale of Pickering, although isolated examples occur at altitude from Simon Howe, Goathland,

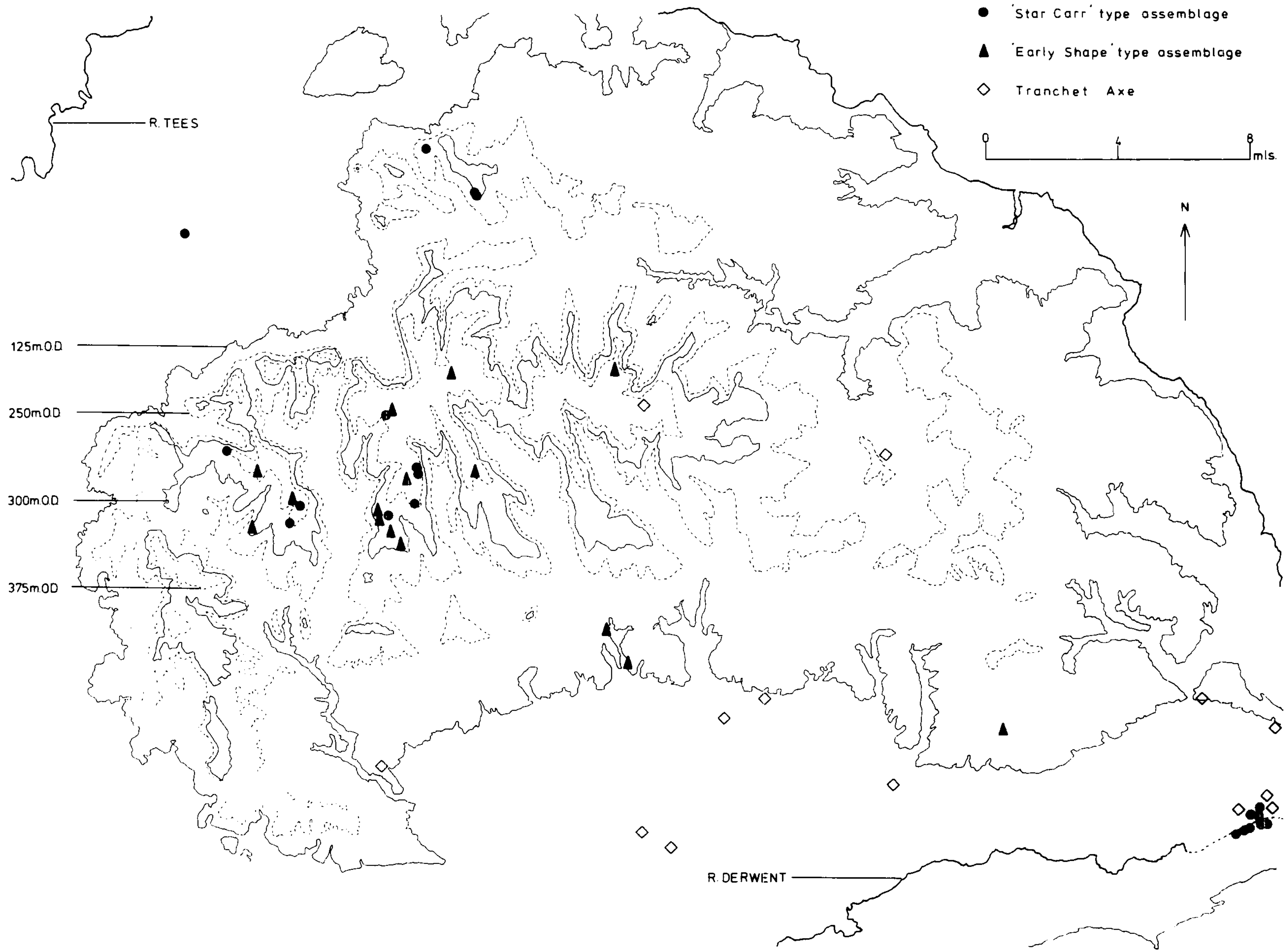


Fig. 3. Mesolithic archaeology of the North York Moors. Distribution of Early Mesolithic Sites.

Egton Moor and Cock Heads, although the latter is a dubious example.

The microlithic assemblages at Flixton I and Star Carr are characterised by short obliquely blunted points of the 'broad blade' tradition, showing no retouch upon their leading edge, in addition to some trapezes and isoceles triangle shapes. This range of microlithic equipment corresponds identically with the microlithic component of a number of sites, regarded as summer hunting stations, upon the Central Watershed of the Moors. These sites are recorded on figure 3 and the identification in the uplands of sites of 'Star Carr type' thus fulfills the requirements of the functional approach adopted by Clark in 1972. Points of Star Carr type were first noted from Sleddal Side on the Moors themselves, and more recently two sites discovered on East Bilsdale Moors by Mr. G. Taylor of Bradford have been fully excavated by Jacobi (1978a). These sites, Pointed Stone 2 and 3, are of Star Carr type and lie at an altitude of 400m OD. Although their range of artefact types is identical to Star Carr, it is clear from the proportional representation of those types that a functional dichotomy existed between them. Thus, according to Jacobi (1978a) microliths comprised up to 70% of the assemblage at the upland sites, but only 20% of finished tools at Star Carr. Scrapers are poorly represented in the Pointed Stone sites and burins are virtually unknown, while these artefacts predominate at Star Carr. Thus the assemblages of the upland sites confirm their postulated function as hunting camps, where the manufacture of projectile points, and the tools required for their creation, took place. The lowland sites, on the other hand, were evidently concerned primarily with the processing of food products, hides, bones and antlers. Unfortunately no radiocarbon dating exists for the upland camps of Star Carr type, but they may be assumed from the uniformity of their tool-kit to have been contemporaneous with the Vale of Pickering site, reflecting differing aspects of a single early Mesolithic economic system. Industries of this type are also recorded at low altitude from Seamer Carrs, where diagnostic blunted triangle shapes were found in association with an Early Mesolithic pick along the shoreline of an old post glacial lake, on the western fringes of the Moors.

A second group of Early Mesolithic sites may be recognised from the study area which are contemporary with, but apparently quite unrelated to those of Star Carr type. Following Jacobi (1975, 1978a), these are regarded as being industries with typologically early microlithic shapes within the general broad blade tradition and their distribution is shown on figure 3. Their obliquely blunted microliths are generally longer than those of Star Carr type, but differ most fundamentally in uniformly showing retouch and in many cases convex blunting. In these respects they relate directly to the major settlement site of Deepcar in the foothills of the Pennines (Radley and Mellars 1964) and a number of high altitude Pennine sites radiocarbon dated to between 9,200 and 9,600 years bp. (Switsur and Jacobi 1975). These sites of retouched 'early microlithic shapes' are thus temporally indistinguishable from the Star Carr group, and one of their number, from East Bilsdale Moor, Money Howe Site I, is dated to 9,430 $\pm$ 390bp (Q-1560) (Jacobi 1978a). Although this class of site is recognised mostly from high altitude, a few such as Mauley Cross (Gibbs-Smith 1960) are recorded from the foothills of the Moors, and may thus be more strictly comparable to the site of Deepcar itself.

In addition to their typological distinctiveness, these two Early Mesolithic traditions are also differentiated in their use of raw material, the Star Carr industries being based upon a translucent yellow or speckled flint, while those of Deepcar type rely on an opaque white flint. It would seem that upon the North York Moors two distinct and apparently mutually exclusive microlithic traditions existed during the Early Mesolithic. It may be possible, as suggested by Jacobi (1978a) to attribute this dichotomy to the occupation of the area by two co-existing but mutually exclusive groups.

2.4.3. Later Mesolithic

The later Mesolithic is represented upon the North York Moors by sites with a geometric microlithic assemblage, characteristic of the 'narrow blade' tradition recognised by Radley, Tallis and Switsur (1974) for the Pennines and applicable throughout Northern England for the period following c. 8,600bp (Table 1). Early tool types are no longer recorded and assemblages are dominated by narrow rod-like points, by small triangular shapes or by trapezes. Although rods appear to be the main microlithic type, triangles are by no means uncommon, and are actually dominant at the site of Cock Heads (Radley 1969a). It would appear that a regionally homogenous industrial tradition existed at this time, although the increased range of implement shapes now available allows for a certain variation of emphasis between individual sites. Certainly no clear cut typological division exists in this area such as that recognised in the Early Mesolithic. A further difference in this later period is in the great increase in the actual number of sites recorded, the great majority of which occur on the highest parts of the Moors, above the 300m contour. Their distribution is shown in figure 4. Their assemblages reveal a very high ratio of microliths to other tools and clearly they represent small, temporary hunting camps where the taking of game, and thus the use or manufacture of projectile points, was the primary function. A number of the campsites have been fully excavated. The sites at Farndale Moor and White Gill are fully discussed by Radley (1969a) while the best of the more recent studies are

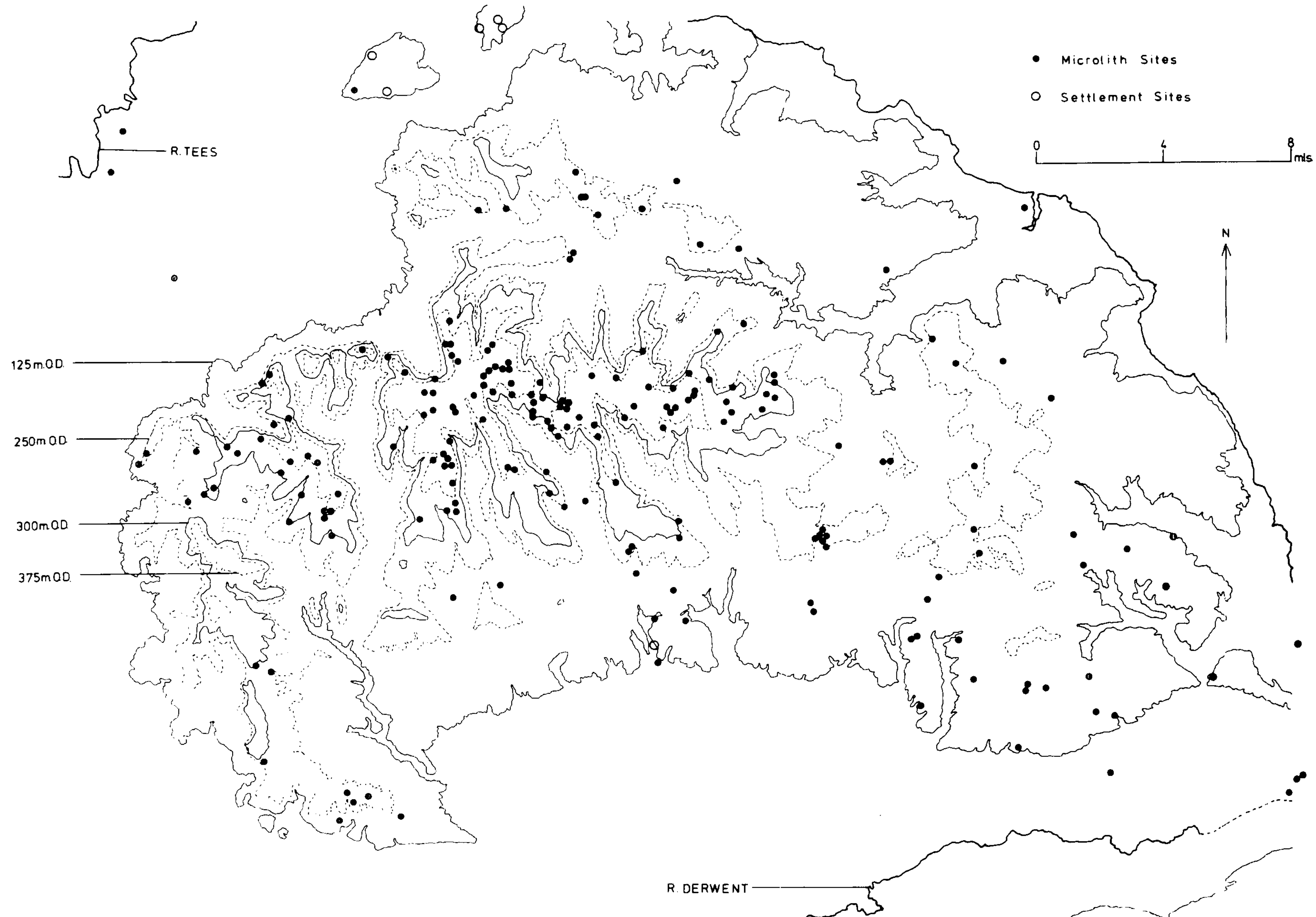


Fig.4. Mesolithic archaeology of the North York Moors. Distribution of Later Mesolithic Sites.

those of Clarke (1973) at Peat Moss on Bilsdale Moor, and of Jacobi (1975) at Cockayne Ridge, on Bransdale Moor. While microliths may be found throughout the moorlands, certain areas are especially prolific, particularly East Bilsdale, Westerdale, Farndale and Bransdale Moors. A distinction may again be made between these microlithic sites and sites at lower altitude with tool-kits suggesting a rather different function and season of occupation. Although the Late Mesolithic equivalent of Star Carr is lacking, the 'settlement' sites at Upleatham, described by Spratt et al. (1976) lie on the northern edge of the uplands at intermediate height, possessing a lithic assemblage in which microliths and 'food-processing' equipment such as scrapers are present in almost equal numbers. They clearly represent a component of the Mesolithic economy complimentary to, but distinct from, the microlithic sites of the uplands.

2.4.4. Conclusion

The archaeological evidence described above points to a continued exploitation of the study area throughout both the Early and Later Mesolithic periods (as defined in chapter 1), with indications of an increased intensity of occupation during the latter part of that time. The earliest hunting-gathering communities were clearly present in the area by ten thousand years ago, at the beginning of early post glacial (Flandrian) time, as recorded by the radiocarbon determinations for Star Carr and Money Howe I. A terminal date for the Later Mesolithic is less certain, but it seems probable that it was present until c.5,000bp (onset of Flandrian III) when the first Neolithic cultures are assumed to have arrived, and may even have persisted for rather longer in the upland areas. Pollen analysis of microlith bearing peats in Bartlett (1969), Simmons and Cundill (1969) and in this thesis (page 196) support this contention.

Radiocarbon dates of 5,380 ± 80bp (Q-799) and 5610 ± 120bp (BH-449) for analogous industries at Dunford Bridge B and Lominot 4 in the Pennines (Switsur and Jacobi 1975) also lend credence to this view.

With the temporal parameters of the Mesolithic equated with the Flandrian I and II chronozones, the relationship of Mesolithic man with his environment, and his possible implication in environmental change, may be inferred from a study of the regional vegetation history during this period.

2.5. Previous Research in the Study Area-Vegetational History

The first investigations into the history of the vegetation of the North York moors were undertaken during the latter half of the nineteenth century when, prompted by the climate of scientific inquiry which flourished at that time, studies of the stratigraphy of a number of peat deposits were carried out by a large body of enthusiastic local workers. The founding of a number of local learned societies took place during this period, including such well known examples as the Yorkshire Geological Society, the Yorkshire Archaeological Society and the Cleveland Naturalists Field Club. Much of the early work was essentially geological in spirit (Fox-Strangeways, Reid and Barrow 1885) or devoted to Natural History (Baker 1863) and this tradition of inquiry brought about the publication of a number of studies in which the local organic deposits were subject to stratigraphic interpretation. Cameron (1878) investigated deep peat deposits near Kildale, in the north-west of the region, and further borings were made in the area early in the following century (Hawell, Fowler and Huntingdon 1913). The first author to attempt an appraisal of the vegetational history as a whole, however, was Elgee (1912) whose account of the vegetational history of the moorland was thus a landmark in the scientific study of the region. He also published papers regarding aspects of the natural history of the North York Moors (1910, 1914) and came to the general conclusion that the Calluna domination existing on the high moorland today was representative of the natural vegetation and had been continuously in existence since the last glacial period. Although this theory is effectively disproven today and is not held to be accurate by any modern worker, there is no doubt that Elgee's contribution to ecological research in the region is very great, if only because of his breadth of vision in attempting a regional synthesis of the development of the vegetation and the stimulation which his work provided for later investigators withim the field.

The realisation that the upland areas of the Moors had been, to a greater or lesser extent, forested during the past did not occur until modern scientific techniques of inquiry, in the form of pollen analysis, became available to the research worker. The earlier workers' finds of tree remains at the base of deep lewland mires had not prompted speculation that woodland could also have existed upon the bleak high Moors. Whitaker (1921) continued the traditional stratigraphic approach to peat studies in her investigations at Harwood Dale Bog and stressed its potential value as evidence of changes in past climates and environments. Tree stumps were encountered near the base of this 6 metre deep bog and the prospect that the mire had passed through a wooded phase in the course of its seral development readily accepted, although at an altitude of 200 metres. It was, however, the reconstruction of past environments by pollen analysis which showed that such bog finds of tree remains were not evidence of isolated tree growth, but that in fact woodland had at one time been the dominant vegetation type, perhaps even upon the highest areas of the Moors, and had only recently been entirely displaced by Calluna heath.

The first application of pollen analysis in the region was through the work of Erdtman (1927, 1928). During an investigation of the post glacial history of the forests of north-west Europe, peat deposits of varying type were examined in north-east Yorkshire and results published in some detail. Analyses were taken in upland blanket peat at Collier Gill, Pike Hill Moss and Kildale Moss, and from channel mires at Randay Mere, Ewe Crag Slack and Moss Slack, Goathland from which the formerly wooded nature of the region became apparent. Further peat deposits were also recorded at Fen Bogs, Tranmire Slack, Harwood Dale and Roxby Peat Holes. As none of Erdtman's sites were situated upon the highest areas of the Central Watershed, some doubt remained as to whether forest had stretched to this elevated altitude, especially as much of the highest peat deposits appeared not to have wood remains below them.

Following Erdtman's work no further study was undertaken within the area until the early 1950's when Dimbleby (1952c) attempted to clarify the relationship between vegetation history and soil development by the study of fossil soil horizons preserved beneath Bronze Age barrows. It was beginning to be suspected that any study of the vegetational history of the area would have to take account of man's effect upon the landscape even in the earlier periods of antiquity, and that the archaeological cultures manifest within the area would be implicated in the environmental changes which had obviously occurred with the decline of woodland in the area. A body of evidence had been accumulated (Dimbleby 1962) that at the time of the construction of the Bronze Age earthworks the local vegetation had been deciduous woodland upon Brown Earth soils, and that this was true even of the Central Watershed, finally discarding the idea that the <u>Callunetum</u> heath was in any way 'natural' and of a permanent nature. He went so far as to show that should the artificial climax nature of <u>Callunetum</u> cease to be maintained, both soil and vegetation could revert to its former status (Dimbleby 1952b). Barrows investigated by Dimbleby included those on the highest points of the Moors, at Ralph Cross and Burton Howes, and upon the lower moorland to the east, at Troutsdale, Bickley Moor, Suffield Moor, Lun Rigg, Reasty Top Barrow and Springwood Barrow.

The ecological approach which the intimate relationship between man and environment made necessary was brought into archaeological investigation at Star Carr. Pollen analysis was undertaken at this site in the Vale of Pickering at a number of fossil lake deposits, at Star Carr, Flixton Carr, and Killerby Carr, by Godwin and Walker (1954) to elucidate the environmental context of the early Mesolithic cultural deposits discovered there, and producing a record of the vegetational succession there from Late Glacial to recent times.

Godwin (1958) performed further soil pollen studies upon material from Cock Heads on Glaisdale Moor, while Dimbleby reviewed the history of the ancient woodland of the Central Watershed in an article (Dimbleby 1961a) in which he raised the question of the influence of Mesolithic communities upon the post glacial forest. He was prompted to the conclusion that forest clearance may have begun in response to that culture's ability to use fire as a deliberate mechanism of environmental alteration, having discovered charcoal and pollen evidence of woodland recession in association with Mesolithic flints at White Gill, on Westerdale Moor.

It became apparent that the history of the development of vegetation upon the North York Moors was an extremely complex one in which the natural factors affecting forest succession and development had been inextricably linked with man's ability to exploit and modify his environment from the earliest times. All modern vegetational studies of the area, therefore, have had the dual objectives of monitoring vegetational history and clarifying man's role in environmental change. Flints found upon the surface of the peat on Glaisdale Moor were designated Zone VIIa in date following analysis carried out by Churchill (Bartlett 1969) and analysis of a microlith and peat sample was undertaken by Simmons and Beaumont (unpublished) to elucidate the age of the industry. In the same way pollen analysis of sites associated with later cultures has been carried out, for dating and ecological purposes, two suitable examples being the work of Dimbleby (1967, 1971).

Of most importance, however, four large scale investigations into ecological history in the area have taken place. Simmons (1969a, 1969b, 1969c) studied a small area on the east of the Central Watershed, demonstrating relationships between human activity and the environment, concentrating upon two blanket peat sites at Collier Gill and North Gill, and upon two channel mires, at Moss Swang and Lady Bridge Slack. Jones (1971) has studied the ecological history of Cleveland, this being the area to the north of the Esk Valley, comprising an altitudinal range of sites commencing in the lowland at Seamer Carrs, and moving eastwards through Kildale Hall, West House Moss, Ewe Crag Slack and Tranmire Slack. The sites included lake basins in the drift area and glacial drainage channels in the Cleveland Hills and thus provided a pollen record from Late Glacial until recent times.for the northern part of the North York Moors area. Most recently (Tooley unpublished) further analysis has taken place at Seamer Carrs on samples of peat associated with a skeleton of Cervus elephus which may shed light upon later Mesolithic hunting activity in the way that Jones' similar investigation of a Bos skeleton at Kildale Hall has provided evidence of early Mesolithic lakeside hunting (Jones 1971, 1976a). The work of Cundill (1971) was concentrated upon the blanket peat of the Central Watershed and discussed problems of peat inception and forest history in this area in the context of human influence. Cundill traced the development of the peat moss at the sites of Loose Howe, Yarlsey Moss, Howdale Hill,

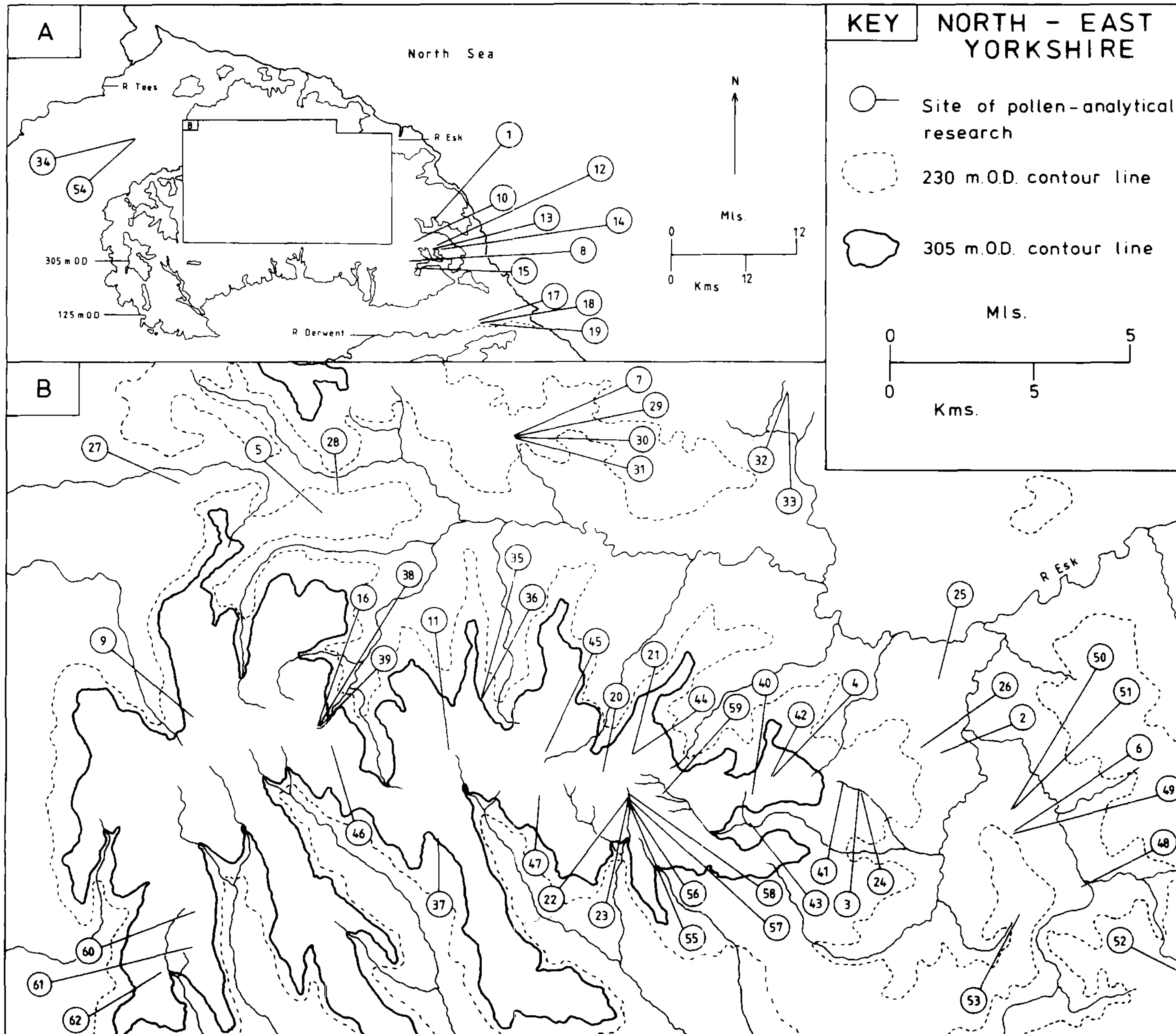


Fig. 5. North York Moors. Location of sites of previous pollen analytical research.

Key to Figure 5.

ERDTMAN (1927 & 1928)

1 Harwood Dale Bog
2 Randay Mere
3 Collier Gill
4 Pike Hill Moss
5 Kildale Moss
6 Moss Slack, Goathland
7 Ewe Crag Slack

DIMBLEBY (1962)

8 Bickley Moor
9 Burton Howes
10 Lun Rigg
11 Ralph Cross
12 Reasty Top Barrow
13 Springwood Barrow
14 Suffield Moor
15 Troutsdale
16 White Gill-Stony Rigg

GODWIN & WALKER (1954)

17 Star Carr
18 Flixton Carrs
19 Killerby Carr

GODWIN (1958)

20 Cock Heads

CHURCHILL (BARTLETT 1969)

21 Glaisdale Moor

SIMMONS (1969)

22 North Gill 'a'
23 North Gill 'b'
24 Collier Gill
25 Moss Swang
26 Lady Bridge Slack

JONES (1971)

27 Kildale Hall
28 West House Moss
29 Ewe Crag Slack 'A'
30 Ewe Crag Slack 'B'
31 Ewe Crag Slack 'C'
32 Tranmire Slack 'A'
33 Tranmire Slack 'B'
34 Seamer Carrs

CUNDILL (1971)

35 St.Helena 'A'
36 St.Helena 'B'
37 Blakey Landslip
38 White Gill
39 White Gill 'A'
40 Yarlsey Moss
41 Collier Gill Head
42 Pike Hill Moss
43 Wheeldale Gill
44 Glaisdale Moor
45 Trough House
46 Howdale Hill
47 Loose Howe

ATHERDEN (1972)

48 Fen Bogs
49 Moss Slack, Goathland
50 Gale Field-Clearing
51 Gale Field-Plantation
52 May Moss
53 Simon Howe Moss

TOOLEY (unpub.)

54 Seamer Carrs

INNES (this volume)

55 North Gill I
56 North Gill II
57 North Gill III
58 North Gill Head
59 Bluewath Beck Head
60 Small Howe
61 Botany Bay
62 Bonfield Gill Head

Glaisdale Moor, Wheeldale Gill, Collier Gill Head, Pike Hill Moss and Trough House. Interesting studies of the development of peat behind rotational landslips were also accomplished at St.Helena and Blakey Landslip, while new work was undertaken at White Gill to further clarify Dimbleby's study. To the east of the Central Watershed Atherden (1972) has investigated the ecological history of an area which includes the channel mire of Fen Bogs, Moss Slack Goathland and Gale Field, and the upland peat sites of May Moss and Simon Howe Moss, with special regard to the later archaeological cultures' impact upon the vegetation. This group of research projects has led to the publication of a number of papers (Simmons and Cundill 1969, 1974a, 1974b, Simmons et al. 1975, Jones 1976a, 1976b, 1977, 1978, Atherden 1976a, 1976b, 1979) and a summary of the archaeological implications of this evidence has been published by Jones et al. (1979). The purpose of the present work is to clarify the ecological history of the North York Moors even further, with special reference to the impact of the Mesolithic communities of the area upon their environment. Figure 5 shows the location of sites of previous pollen analytical research in the area.

CHAPTER THREE

Field and Laboratory Techniques

3.1. Introduction

A range of field and laboratory techniques was employed in the investigation of the sites selected for analysis. The majority of modern research methods are standardised, although perhaps differing in detail between workers, and have been discussed at length by several authors. Amongst the most relevant publications are Faegri and Iversen (1964, 1974), Kummel and Raup (1965), West (1968), Davidson and Shackley (1976), Chapman (1976), Moore and Webb (1978), Jones and Cundill (1978), Birks and Birks (1980) and Tooley (1981). Detailed description of the full range of Quaternary research techniques utilised by modern workers is, therefore, not required here, and the following discussion will be confined to those of immediate relevance to the collection and interpretation of the data to be presented in this thesis. Throughout this thesis the definition of lithostratigraphic, biostratigraphic and chronostratigraphic units is consistent with the principles proposed by the International Stratigraphic Guide (Hedberg 1976).

3.2. Levelling

The altitude of the selected sites was obtained by the use of a Kern Automatic Level, heights being reduced from Ordnance Survey Bench Marks. Closing errors on levelling runs never exceeded 0.02 metres, and all measured altitudes are expressed relative to Ordnance Datum (Newlyn).

3.3. Stratigraphic Analysis

The stratigraphy was investigated in the field and laboratory

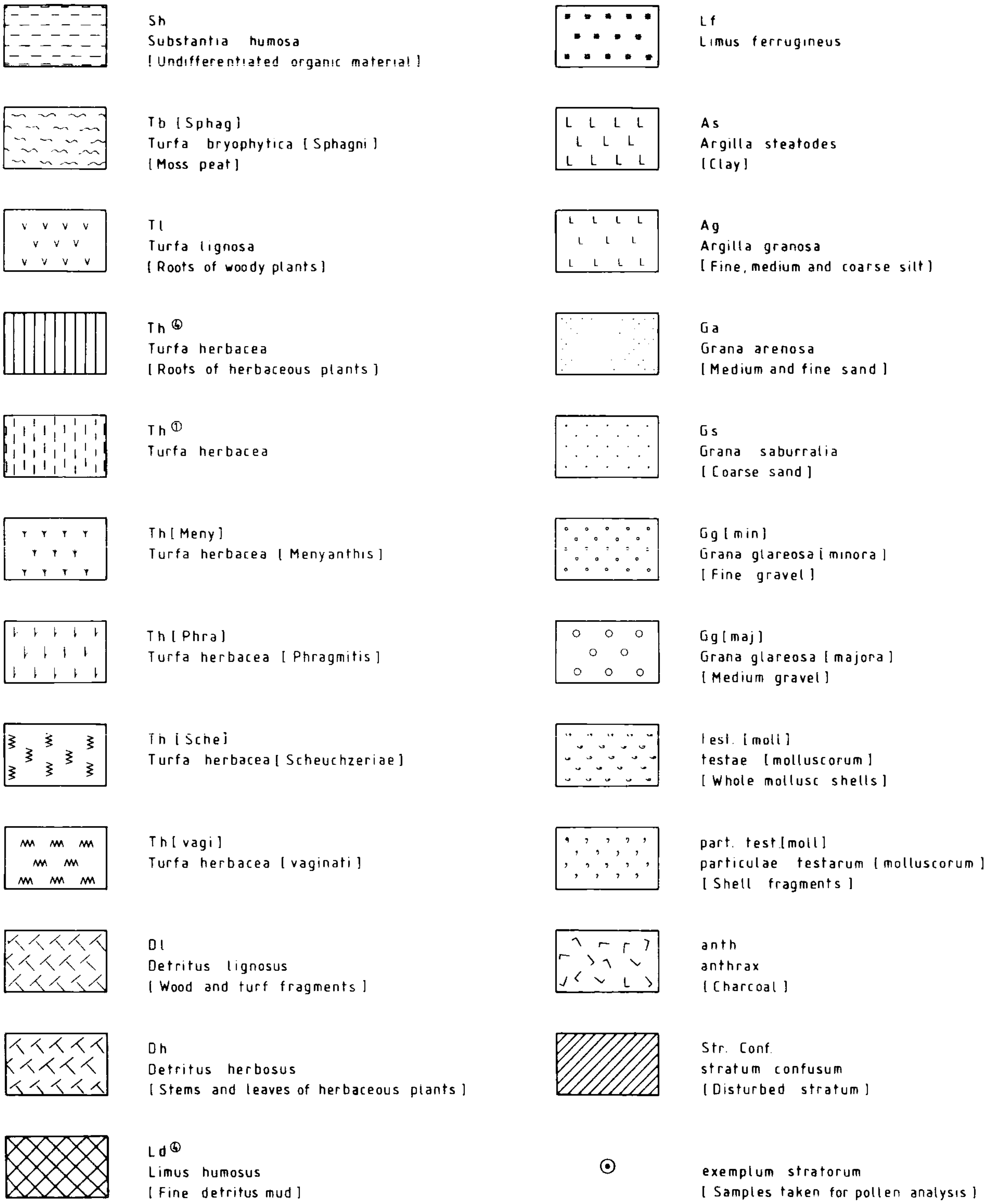


Fig. 6. Key to stratigraphic symbols after Troels-Smith (1955).

from samples recovered with a gouge sampler, a Russian-type peat sampler, or from free-face excavation. The stratigraphic successions recorded in the individual site reports and represented in the stratigraphic columns of the pollen diagrams are described according to the system of symbols and notation proposed by Troels-Smith (1955) for the characterisation of unconsolidated sediments. A key to stratigraphic symbols after Troels-Smith is shown as figure 6.

The stratigraphy at each site is described in a standard way. Each stratum identified is numbered from the base of the profile and its depth below the surface shown in centimetres. It is accompanied by a description of the sediment type in Troels-Smith's standardised notation and by a conventional description of the physical nature of the deposits. This standardised notation is explained in detail in Tooley (1978a), but may also be summarised briefly here.

The first line of the notation lists the components of the deposit, following fig.6, in the proportions in which they are present, plus a superscript number to indicate the degree of humification of biogenic deposits, both on a five-point scale (0-4). For example, stratum 8 at North Gill III is characterised as follows:-

$$Th^{3}2,\ Sh^{4}2,\ Th(\underline{vagi})^{2}+$$

This indicates that, a) 50% (=2) of the stratum is composed of peat formed from the roots of herbaceous plants, the superscript number showing it to be well humified: b) 50% of the stratum is composed of undifferentiated organic material: c) there are also present fibres of Eriophorum vaginatum, the superscript number showing the degree of humification.

The second line of notation describes the physical properties of the deposit as follows:-

Nigror	- the degree of darkness	abbreviated as	nig.
Stratificatio	- " " " stratification	" "	strf.
Elasticitas	- " " " elasticity	" "	elas.
Siccitas	- " " " dryness	" "	sicc.
Limes superior	- " " " acutness of the upper boundary	" "	lim. sup.

Each attribute is assessed on a five-point scale (0-4), where 0 represents complete absence and 4 represents maximum presence.

Deviation from the system of stratigraphic symbols shown on fig. 6 was allowed in figures 11 and 12 which show gross stratigraphic profiles and transects at North Gill. In these cases the scale of the diagram necessitated, for greater clarity, some slight modifications to the system. These diagrams therefore incorporate their individual stratigraphic keys.

Computer-drawn diagrams are also presented which represent graphically certain features of the stratigraphy, such as peat depth or the configuration of individual lithostratigraphic units. These diagrams were plotted in the University of Durham using the computer programs SYMVU and SYMAP (Muxworthy 1972) which were originally devised by the Laboratory for Computer Graphics, Harvard University.

3.4. Collection of Samples

At Small Howe and North Gill Head cores were extracted from the peat deposits with a Russian-type peat sampler, as described by Jowsey (1966). This consists of a half-cylinder of metal 50cms lohg and 5cms in diameter which is fixed to a borer head and may be rotated through 180 degrees to retain a half-core of sediment against a central anchor plate. This anchor plate remains stationary within the peat while the coring chamber rotates around it, enclosing the sample. Upon extraction of the borer the undisturbed half-core of peat was slid from the anchor plate into plastic containers constructed from longitudinally split drainpipe. These were labelled, sealed in polythene sleeving and removed to the laboratory for storage.

At all other major sites bulk samples were recovered from free-face excavation by the use of alluminium alloy monolith tins. Sections were cut back until vertical and cleaned by horizontal strokes with a spatula prior to sampling. Monolith tins were pressed into the peat face to include the selected sediments and labelled appropriately. These tins were then dug out of the peat face, squared off and sealed in polythene sheeting. In this way blocks of peat 50 by 10 by 10 centimetres were extracted and removed to the laboratory for storage.

All samples were stored under refrigerated conditions to await analysis. Laboratory sub-sampling of the monoliths and cores took place from time to time as they were subjected to varying analytical techniques, and they were securely resealed and stored on each occasion.

3.5. Macrofossil Analysis

In peat deposits plant macrofossil remains are generally derived from locally growing vegetation and thus provide an insight into environmental conditions in the immediate area of the sampling site. They are, therefore, good indicators of the local vegetation, particularly with regard to the development of the mire system. This is certainly the case with deposits characterised as turfa peats, although in the case of detrital peats more circumspection may be required as their components will have undergone a degree of transportation to the sampling site. The streamside situations of the majority of sites studied in this thesis lend themselves readily to the introduction of extraneous material, particularly by stream transport, or by wind transport and inwash from land marginal to the deposition area. Such material may provide valuable information regarding environmental change in these areas. In the event macrofossil analysis has not been central to this thesis, partly because the upland blanket peats under examination are mainly well humified and poor in identifiable remains, and partly because the main purpose of the study, clarification of man's role in environmental change is a task to which pollen analysis is better suited. When encountered, however, identification of seeds and fruits was undertaken with the aid of Katz, Katz and Kipiani (1965), and of mosses with Dixon (1954). Wood identifications were made with reference to Forest Products Research Bulletin No. 26 (Forest Products Research Laboratory, 1961) after thin sections had been taken with a microtome.

3.6. Radiocarbon Analysis

Material for radiocarbon dating was taken from monolith samples following the identification of suitable horizons by pollen analysis. Any extraneous rootlet material which had penetrated the peat from above was removed before the sample was sealed in thick polythene bags and labelled. 200 grams of peat was considered sufficient for analysis and this weight was achieved by the removal of two or three centimetre thick slices from the monolith blocks. Not all the deposit was removed from any one horizon, in case further samples were required. Radiocarbon dating was carried out at the Chemistry Department, University of Glasgow and the results are presented in Appendix I.

3.7. Charcoal Analysis

A method was required to quantify the charcoal content of the blanket peat, particularly in the lower levels where both macro and microscopic charcoal seemed to be abundant. Estimation of charcoal presence has been assessed from the amount of carbonised material found on slides during counting of pollen samples, for example by Walker (1966), Tallis (1975) and H.H.Birks (1975). This is somewhat subjective and only gives an estimate relative to other levels, normally expressed on a rough 1 to 5 scale. In an attempt to quantify the charcoal content absolutely, and to express it as an exact percentage of total sediment, the following procedures were used:-

a) It is possible to determine the total carbon content of a sample using the standard furnace combustion method (loss on ignition). This method determines inert carbon (coal/charcoal) as well as organic carbon.

b) A second method, that of chromic acid reduction as developed by Schollenberger (1927, 1931) is incapable of determining inert carbon, and thus provides a figure for organic carbon only.

If a homogenous sample is subjected to treatment by both methods it is possible, by subtracting the results of method b) from those of method a), to calculate the proportion of inert carbon in the sample. In the situations described in this thesis, this may be assumed to be charcoal. The chromic acid reduction method is considered in detail by Allison (1935).

The above method was originally devised for mineral rather than organic soils, and its use with peat necessitated the use of correction factors, which introduced an element of subjectivity into the analysis. To check the results obtained with the chemical method, the following mechanical method was designed. It does not attempt to determine absolute content by weight, but is able to yield relative proportions of charcoal as a percentage of total material.

A petrie dish was incised with a large square, which was itself divided into a hundred equal squares. The bottom of the dish was covered with water and a small peat sample disaggregated within it. At a magnification of x50, an estimate was then made of what percentage of each of the small squares was covered by charcoal and what percentage by the ordinary peat matrix. For example, square 1 may be estimated as charcoal 10%, peat matrix 90%; square 2 may be charcoal 25%, peat matrix 50%, blank surface 25%. By adding together a) charcoal percentages of all 100 squares, and then b) the peat matrix percentages of all 100 squares, two total figures are obtained. Figure a) may then be expressed as a percentage of figure a) + b), giving an approximate percentage for charcoal in the sample.

If the sample is spread evenly on the dish, this method gives results which are apparently replicable with error limits of <5%, and is quick and efficient to use. The chemical method was prone to error, but when it had apparently worked gave results comparable to the petrie dish method. The charcoal determinations presented in this work are therefore the results of the latter method.

3.8. Preparation of Samples for Pollen Analysis

In the laboratory, preparation of samples for pollen analysis was achieved by the standard methods (Dimbleby 1961b, Faegri and Iversen 1964, Gray 1965) modified according to Jones and Cundill (1978). Pollen extraction and concentration was accomplished by subjecting them to alkali digestion, followed where necessary by heating in hydrochloric and hydrofluoric acids to dissolve mineral particles, and finally by acetylation treatment. Tertiary butyl alcohol was preferred to benzene in the final stages of the process because it reduces flocculation. The resulting pollen material was stored in silicone fluid of standard viscosity and stained with safranin to assist identification of microfossils.

Immediately prior to counting, the pollen-bearing residue was stirred and a small quantity was placed upon a microscope slide and diluted further with silicone fluid. Silicone fluid was chosen as the mounting medium because it has a low refractive index relative to the refractive index of pollen grains, which aids microscopy, does not cause swelling of grains and as it forms a fluid suspension, enables individual grains to be manoeuvred under the coverslip (Andersen 1960, 1965, Berglund et al. 1960).

3.9. Pollen Counting and Identification

Counting and identification of pollen and spores was carried out at a magnification of x400, using predominantly Zeiss 'Standard WL', but also Vickers 'M15C' and Baker 'Patholette 2' microscopes. Detailed resolution of critical grain features was achieved using oil immersion techniques at x1000 or by phase-contrast microscopy.

Pollen counting involved repeated traversing of the slide and identification and recording of all types encountered. An interval of at least two field widths was maintained between traverses to avoid duplicate counting, as grains mounted in silicone fluid are potentially mobile, and may have to be moved to aid identification. Counting was designed to include all parts of the slide, for an even distribution of pollen types may not be assumed (Brookes and Thomas 1967). Each grain identified was recorded upon a standardised counting sheet, aided by mechanical counters for the more abundant types.

Identification of individual grains was made chiefly according to the pollen key of Faegri and Iversen (1964) followed by comparison with the departmental (Durham University, Department of Geography) type slide collection. Reference was also made to the keys and photomicrographs of

Hyde and Adams (1958), Erdtman, Berglund and Praglowski (1961), Erdtman, Praglowski and Nilsson (1963), Erdtman (1966) and Nilsson, Praglowski and Nilsson (1977).

Throughout this thesis plant nomenclature follows that in Clapham, Tutin and Warburg (1962), except for terminological groupings such as Tubuliflorae and Liguliflorae, which appear in Faegri and Iversen's pollen key and have no direct counterpart in Flora of the British Isles.

3.10. The Counting Sum

Identification and recording of pollen and spores continued until 150 tree pollen grains (including Pinus, Betula, Quercus, Ulmus, Tilia, Fraxinus and Fagus, but excluding Alnus) had been counted at each sampled level. The adoption of a tree pollen sum, rather than a total pollen sum, as the criterion for counting was considered satisfactory as the sites investigated in this thesis were found to be of mid post glacial age and had pollen assemblages dominated by tree pollen. Alnus was excluded from the total tree pollen count because most of the sites are in a stream-side location and alder may, therefore, have tended to dominate the local pollen rain, its over abundance causing difficulties in interpretation (Janssen 1959). Its exclusion has the further advantages of allowing comparability with other pollen diagrams from the area (Simmons 1969a, Cundill 1971), and of ensuring a higher total pollen count, between 500 and 1000 grains being counted at almost every level. At the site of Bonfield Gill Head the presence of Betula macrofossils throughout the stratigraphy and high levels of Betula pollen caused its exclusion from the counting sum, in addition to Alnus, on the grounds of local abundance and over representation. With this further restricted tree pollen sum, a total of 100 tree pollen grains was considered to be sufficient, as it entailed the counting of up to 1000 grains in total at each level.

3.11. Pollen Diagram Construction

Results of the pollen analyses are presented in the form of pollen diagrams of standardised construction. Conventions observed include, a vertical axis representing depth, a horizontal axis representing the relative abundance of the pollen types according to the scale upon the diagram, and a stratigraphic column at the left hand side of the diagram to assist in the interpretation of the pollen curves. Abbreviations used upon the pollen diagrams are listed in Appendix III. The following types of diagram have been employed.

3.11.1. Relative Pollen Diagrams: Hand Drawn

The principal diagrams are hand drawn relative diagrams based upon the total tree pollen count described above, and show all the pollen and spore types identified during counting, individually represented as a percentage of tree pollen by the length of the horizontal bars at each counted level. 'Bar histograms' rather than 'saw edge' style was used as it illustrates finer details much better, and avoids unjustified assumptions regarding pollen frequencies between sampled levels. Horizontal scales are consistent wherever possible, although taxa which are present in very high values, such as Alnus and Corylus, are shown at reduced scale for graphic convenience, the relevant scale for each taxon being clearly marked. A value of less than 1% of tree pollen (equivalent to the recording of a single grain) is represented by a + symbol. Where individual percentages exceed the upper limit of the space allowed to that taxa, they are indicated by the inclusion of the appropriate figure at the end of the histogram. On these diagrams types within the tree pollen sums are represented by upper case lettering and other types by lower case lettering. Taxa are arranged in a standard order, with arboreal types first, fòllowed by shrubs, dwarf shrubs, herbs and finally spores. At the end of the diagram is included a composite summary diagram, which shows pollen and spore types assembled into four larger classes (five at Bonfield Gill Head) and represented as percentages of the sum of total pollen and spores (excluding Sphagnum). This is intended to show gross changes in the kinds of pollen entering the bog. Sphagnum is not included in these calculations because of its entirely local nature and because its occasional super-abundance, which makes assessment of other taxa difficult, may not in all cases be attributable to environmental change, spore production being very variable (Tinsley and Smith 1974). The four groups chosen are Trees (excluding alder), Alder, Shrubs (including dwarf shrubs), and Others (including herbs, aquatics and ferns).

3.11.2. Relative Pollen Diagrams: Computer Drawn

The principal pollen diagrams are supplemented by a series of computer drawn diagrams, using the computer program 'NEWPLOT' devised by Mr. I. Shennan. These diagrams are designed to illustrate particular aspects of the pollen data and to check the validity of the pollen fluctuations apparent upon the principle diagrams. This is achieved in three main ways; by changing the tree pollen sums employed, by changing the method of calculation of the pollen frequencies and by the adoption of ecologically significant groupings of taxa. To aid assessment of the statistical reliability of the fluctuations shown upon these diagrams, pollen frequencies are displayed accompanied by statistical confidence limits to the 95% level (Mosimann 1965). Thus random changes in the pollen curves may be more easily distinguished from real alterations in the composition of the pollen assemblage. The following types of computer diagrams have been used.

a) % Trees + Group

The pollen taxa identified have been grouped into the life-form classes of the plants producing the pollen (c.f. Tooley 1978a, p13). Five such classes are recognised; Trees (including Alnus), Shrubs (including dwarf shrubs), Herbs, Pteridophyte Spores and Bryophyte Spores. At each level trees are shown as a percentage of total tree class pollen. The frequencies for each non-tree taxon are calculated not as percentages of tree pollen alone, but as percentages of total tree pollen plus the total pollen for that particular taxon's class, for example, Corylus percentages would be calculated in the following way:

$$\frac{\Sigma \text{ Corylus} \times 100}{\Sigma \text{ Trees} + \Sigma \text{ Shrubs}}$$

This method is based upon the premise that taxa within a single class compete with, and thus may be compared in ecological terms with, other taxa within that class, rather than with types outside it. It has the advantage of avoiding percentage frequencies in excess of 100%, as a taxon cannot logically occupy more than 100% of its available habitat.

b) % Total Land Pollen

Here the total number of grains counted forms the pollen sum and all taxa are calculated as a percentage of it, trees not being ascribed any special status. Fern and moss spores, although not included within the pollen sum, are also expressed as percentages of it.

c) % Total Land Pollen -'Clearance Taxa'

Upon these diagrams only those taxa considered to be instructive regarding forest clearance are illustrated, frequencies again calculated as a percentage of all pollen grains counted. A total tree pollen curve is included, and the horizontal scale is twice that of the other computer diagrams, to assist interpretation.

3.11.3. Pollen Concentration Diagrams

The 'relative' method of pollen analysis described above determines only the proportional representation of different pollen types expressed as percentages of a particular pollen sum. Frequencies are therefore interdependent and a change in one component will produce changes in all the others. Indeed, abundance of one local type (e.g. Alnus in an alder carr) may depress other pollen values almost to nil, and give an entirely erroneous impression of regional vegetation change. Pollen frequency changes may thus be merely apparent, statistical artefacts created by the method of presentation, rather than real.

Absolute pollen techniques allow the estimation of the densities of individual pollen types within the sediment, so that a taxon may be observed in isolation, independent of other pollen curves. A more critical assessment of the validity of the pollen fluctuations on the percentage diagrams may thus be made, and a more reliable interpretation permitted.

The three main ways of calculating pollen concentrations are;

a) the volumetric method, in which aliquots of material are removed from a sample of known volume (Davis 1965, 1966).

b) the weight method, in which a sub-sample of known weight is counted and extrapolated to find the number of grains in the original sample (Jorgensen 1967).

c) the 'exotic' pollen method, in which an exotic marker-grain suspension of known concentration is introduced to a sediment sample of known volume,

and the concentration of each type calculated relative to that of the marker (Benninghoff 1962, Matthews 1969, Bonny 1972).
These methods have been compared by Peck (1974).

The volumetric and weight methods involve the counting of all grains in the final preparation and are thus lengthy and prone to error, whereas the exotic pollen method is much less so, requiring counting to proceed only to a predetermined, mathematically convenient number of marker grains, followed by the application of a calculating formula.
The method adopted in this thesis is the simplified exotic pollen method described by Stockmarr (1972) in which the marker grains (Lycopodium clavatum) are introduced in tablet form in the early stages of the sample preparation schedule (v.s. section 3.7.) and thus homogenously mixed.

This technique was applied at the site of North Gill III and two pollen concentration diagrams are presented which express the frequency of the pollen types as numbers per unit volume of sediment (grains per cc.): the first diagram details concentration of all individual pollen and spore types, the second of 'clearance' taxa and groups only. In the absence of a series of radiocarbon dates, calculation of sedimentation rates and pollen influx rates was not possible.

3.11.4. Ecological Groupings

Upon the pollen diagrams, particularly those drawn by computer, certain taxa are assembled into larger categories according to their ecological affinities, as an aid to interpretation. Specific epithets, such as 'arable' or 'pastoral' herbs, which carry too clearly defined connotations and may have no relevance in a Mesolithic context, have been avoided. The ecological responses of a particular herb or shrub may not be the same in all situations and the unqualified inference from its appearance of a particular set of environmental circumstances may be delusive. Over rigorous definition of ecological preferences is not attempted therefore, and the constituents of the categories are best regarded as having broadly similar responses to particular environmental conditions. A list of the taxa included in each category is to be found in Appendix II.

3.12. Pollen Diagram Interpretation

Interpretation of the pollen diagrams presented in this thesis will follow their subdivision by a series of zonation schemes, erected independently on the basis of criteria which are described in detail below, and applied to both relative and concentration diagrams.

There are many other factors which require consideration in the interpretation of the basic pollen data, and some of the methodological problems involved have been studied by Davis (1963) and Crabtree (1975). Interpretation of pollen spectra in terms of reconstructing the constitution of plant communities is complicated by differential pollen productivity (Andersen 1967, 1970), dispersal ability (Tauber 1965, 1967, Berglund 1973) and mode of deposition (Peck 1973, Krzywinski 1977). Differential preservation of pollen during and after incorporation into the sediment also changes the pollen spectra (Cushing 1967, Havinga 1964, 1967, Konigsson 1969). Modern pollen rain studies in areas where vegetation composition is known (Turner 1964, Wright 1967, Tinsley and Smith 1974, Cundill 1979) have been undertaken, but may be of limited application to fossil pollen assemblages as very few natural plant communities remain which resemble those existing in antiquity. While the basic pollen data has not been modified in response to these complicating factors, they are taken into account in interpretation and referred to where appropriate in the text.

Additional diagrams have been constructed, however, in which the correction factors calculated by Andersen (1970, 1973) have been applied to the basic pollen counts for arboreal pollen types. These factors were deduced by comparing the modern pollen representation of tree types with the ground which they occupy within surrounding woodland and are thus applicable under forested conditions. These diagrams are intended to express more accurately actual woodland composition by compensating for high pollen productivity in certain tree taxa. The following correction factors are used:

Quercus, *Betula*, *Alnus*, *Pinus*	1 : 4
Ulmus	1 : 2
Fagus	1 : 1
Tilia, *Fraxinus*	1 x 2

Factors for *Corylus* and *Salix* were not employed, as these taxa exhibit differing productivity under differing ecological conditions.

Moore (1973) working in Wales, calculated taxa diversity in pollen spectra and found a tendency for total diversity to increase rapidly during human interference stages and to fall during regeneration phases. Diagrams using taxa diversity as an index of woodland clearance activity are presented in this thesis.

3.12.1. Diagram Zonation

Critical subdivision of pollen diagrams assists greatly in the description and interpretation of the pollen record and in correlation with diagrams from other sites. The traditional zonation scheme of Godwin for Southern Britain (1940, 1975) was constructed at a time when the chief use of pollen diagrams was as a register of changing climatic and vegetation history, with particular regard to forest composition, following Von Post (1916) and Blytt and Sernander (Sernander 1908) in Scandinavia. Based upon fluctuations in tree pollen frequencies for which climatic changes were held to be responsible, Godwin's pollen zones acquired climatic and temporal connotations, encouraging ecological and cultural assumptions which were quite unfounded.

It has become increasingly apparent that application of this classical zonation system produces an oversimplification of vegetation history, since the zone boundaries are not entirely synchronous across the country (Smith and Pilcher 1973), they may be anthropogenically rather than climatically determined (Turner 1962) and different regions may have radically different vegetation histories (Birks 1973).

The problems inherent in pollen diagram zonation have recently been considered by West (1970) who advocated the pollen assemblage zone (P.A.Z.) as the basic unit of zonation, defined as a group of spectra characterised by a particular pollen assemblage, and thus having internal uniformity, but without any temporal or climatic implications. It should be distinguished from the chronozone, a standard chronostratigraphic unit with limits difined by radiocarbon dating, and with which it may be subsequently correlated at local and regional stages. This system is generally superseding Godwin and has been adopted in this thesis (although the older system may also be employed in the text where appropriate), with zonation terminology defined as follows.

3.12.2. Local Pollen Assemblage Zones

The principal pollen diagrams have been subdivided independently into one or more Local Pollen Assemblage Zones (L.P.A.Z.) based upon significant changes in the major, mainly arboreal, pollen types which make up the assemblage. These local zones are applicable only to their particular sampling site, and are specified by the initials of that site and an appropriate postscript letter, consecutive from the base of the diagram. The zone components are included upon the principal diagrams, but omitted from those computer diagrams which use the L.P.A.Z. scheme.

3.12.3. Regional Pollen Assemblage Zones and Chronozones

Comparison of local pollen assemblage zones, and thus of individual diagrams, is achieved by correlating them with an established sequence of pollen assemblage zones which records regional changes in vegetation history. These Regional Pollen Assemblage Zones (R.P.A.Z.) are erected with reference to broad vegetational changes which appear to be applicable in a regional context and entirely ignore local vegetation successions. Correlation was attempted using the type sites for North-West England at Red Moss (Hibbert, Switsur and West 1971) and for North-East England at Din Moss (Hibbert and Switsur 1976). The temporal parameters for the Chronozone boundaries at these sites were, however, found to differ significantly from those radiocarbon dated upon the North York Moors, especially with regard to the end of Flandrian II. Available radiocarbon dates for the end of Flandrian II (Ulmus decline) in the North York Moors and adjacent areas are detailed on Table 3. A dichotomy of up to half a millenium seems to exist between the earlier lowland sites (Durham lowlands-Yorkshire Wolds), and the later upland sites (North York Moors-Pennines), even when standard deviations are taken into account. Dates from the regional type sites are included within the 'early' group.

A regional standard diagram for the North York Moors to which local pollen assemblage zones may be referred is not yet available. This

AREA	SITE	DATED ULMUS - DECLINE	REFERENCES
NORTH YORK MOORS	NORTH GILL'A'	4767 ± 60	JONES *et. al.* 1979
	FEN BOGS	4720 ± 90	ATHERDEN 1976a
DURHAM LOWLANDS	NEASHAM FEN	5468 ± 80	BARTLEY *et. al.* 1976
	MORDON CARR	5305 ± 55 5235 ± 70	
DURHAM COAST	WEST HARTLEPOOL - 2	5240 ± 70	TOOLEY 1978 b
	WEST HARTLEPOOL - 4	5215 ± 80	
YORKSHIRE WOLDS	GRASMOOR QUARRY	5099 ± 50	BECKETT 1976
NORTHERN PENNINES	VALLEY BOG	4794 ± 55	CHAMBERS 1974
SOUTHERN PENNINES	TOTLEY MOSS	4990 ± 140	TINSLEY 1975
N - E ENGLAND (type site)	DIN MOSS	5340 ± 70	HIBBERT & SWITSUR 1976
N - W ENGLAND (type site)	RED MOSS	5010 ± 80	HIBBERT *et.al.* 1971

TABLE 3 Radiocarbon dates for the end of Flandrian II (*Ulmus* - decline) in the North York Moors and adjacent areas.

problem has been circumvented by previous workers in the region by the use of sub-regional pollen assemblage zonation schemes which have a significance confined to their own particular research area. Such sub-regional summaries have been published for the Cleveland area by Jones (1977, 1978), for the Eastern-Central area by Atherden (1976a, 1979) and for the Central Watershed by Simmons and Cundill (1974a, 1974b).

While the diagrams presented in Chapter 4 and 5 of this thesis may be related directly to the Central Watershed sub-regional scheme (prefaced EGM, for Egton/Glaisdale Moors), those from East Bilsdale Moors, presented in Chapter 6, lie well outside the sub-region designated by Simmons and Cundill (1974a) to which this scheme was to be directly applicable. They are also, however, insufficient in number and range to allow the erection of a new sub-regional scheme for the Western Moors.

It has been decided, therefore, to refer all the diagrams in this thesis to a temporary regional scheme for the Central North York Moors, built up from the sub-regional schemes of Simmons and Cundill (1974a) and Atherden (1979). The basis of this scheme is the long pollen diagram from Fen Bogs which Atherden (1976a) presented as a standard diagram for the North York Moors south of Eskdale, and which carries radiocarbon dates for pollen zone boundaries throughout Flandrian III, although, unfortunately, not for Flandrian I and II.

Comparison of these two sub-regional schemes shows a close comparability of assemblage zones in Flandrian I, II and early Flandrian III, allowing a composite picture of vegetation history to be formed. Although slight differences in detail occur, the similarities are so marked as to reflect a common pattern of vegetation change and enabling zonal correlation to be made. The temporary regional scheme for the

Godwin (Blytt & Sernander)	Sub - Regional Zonation Eastern - Central Moors	Sub - Regional Zonation Central Watershed	14C Age b.p.	Flandrian Chronozone	Temporary Regional Zonation Central North York Moors
VIIb (Sub - Boreal)	FB 5 Quercus Alnus Ruderals	EGM Alnus Quercus Ruderals		Fl III	NYM - F Quercus Alnus Ruderals
			3400 ± 90		
	FB 4 Quercus Alnus	EGM Alnus Quercus			NYM - E Quercus Alnus
			4720 ± 90 4767 ± 60		
VIIa (Atlantic)	FB 3 Quercus - Alnus Ulmus - Tilia	EGM Alnus - Ulmus (Quercus - Tilia)		Fl II	NYM - D Quercus Alnus Ulmus (Tilia)
			6650 ± 290		
VI (Boreal) c	FB 2 Pinus Corylus	EGM Pinus Corylus		Fl I	NYM - C Pinus Corylus: c + Quercus Alnus Ulmus
b					b + Quercus Ulmus
a					a + Ulmus
			?		
V (Boreal)	FB 1 Betula Pinus	-			NYM - B Betula Pinus
			?		
IV (Pre - Boreal)	-	-			NYM - A Betula Salix (inferred)
			$10,350 \pm 200$		

TABLE 4 . Temporary Regional Zonation Scheme, correlated with Sub - Regional Schemes and Flandrian Chronozones for the Central North York Moors.

Central North York Moors, with its relation to the Flandrian Chronozones and the sub-regional schemes from which it is assembled, is described in Table 4. The basal assemblage zone and early C14 dates are inferred from Jones (1977). The R.P.A.Z. preface NYM has been adopted, with an appropriate suffix letter. In the absence of a series of radiocarbon dates, synchroneity of individual zone boundaries from site to site may not be assumed, but those dates which are available are shown in the Table.

The creation of a unified zonation scheme for the Central North York Moors in Flandrian I, II and early Flandrian III (e.g. of potential chronological relevance to the Mesolithic cultural period) is merely to make possible diagram comparison and discussion which will take place in Chapter 7 and to accord with West (1970). It is applicable only within this thesis, therefore, and has no wider significance. For this reason it has not been extended into later Flandrian III, which has no relevance in this thesis, nor does it incorporate the sub-regional schemes of Jones (1977, 1978) in Cleveland, although some correlations may be made in the text. It has no pretentions to form a permanent regional scheme.

3.12.4. Forest Clearance Zonation

The palynological record at each site, as it may reflect periods of human interference with the environment, has been subdivided into a series of 'Forest Clearance Stage' (F.C.S.) zonules. These are designed to describe the presence and absence of woodland clearance activity in terms of alternating zonules of interference (termed I zonules) and regeneration (termed R zonules). Interference zonules in Flandrian III are considered to be of higher intensity than those of Flandrian II and are termed zonules of clearance (C zonules). In this way fluctuations in the pollen spectra may be described in a cultural context without specific archaeological inferences. This system of descriptive zonation has been employed by other workers (Birks 1965, Moore 1973) and is intended to be consistent with the proposals of Edwards (1979) who has pointed out some of the dangers inherent in assuming cultural-environmental correlations.

CHAPTER FOUR

North Gill

Introduction

4.1. Site Location

The rivers which occupy the southerly dales of the North York Moors have their origin in the many small streams which flow from the high plateau area of the Central Watershed. The river Seven, which flows through Rosedale, has as its main northerly tributary the Northdale Beck, which joins the Seven at Rosedale Abbey (SE 724 960). The head-waters of this minor stream rise as a number of small springs, in three main clusters, on Rosedale Moor and Glaisdale Moor, at altitudes of between 360 and 390 metres. The most westerly cluster, West Gill Head, is the highest of the three at about 390 metres, while the central group of springs, Middle Head, lies at about 380 metres. The easterly tilt of the Central Watershed plateau ensures that the most easterly of the three, North Gill Head, is the lowest at about 370 metres, and it is this most easterly spring-head that constitutes the site of North Gill (NZ 726 007). The location of North Gill upon the Central Watershed, in relation to the North York Moors in general, is illustrated by figure 7.

The upper reaches of the North Gill Head stream have cut down through the margins of the peat blanket which covers the Central Watershed, exposing a section through the sequence of organic deposits. From this site the gently sloping moorland plateau rises gradually to Cock Heads (NZ 720 008) to the north west, which at 402 metres is the highest point on Glaisdale Moor. To the east of North Gill there is evidently a slight eminence in the plateau surface for, although the general dip of the Moors is to the east, the ground rises and forms a minor watershed beyond which

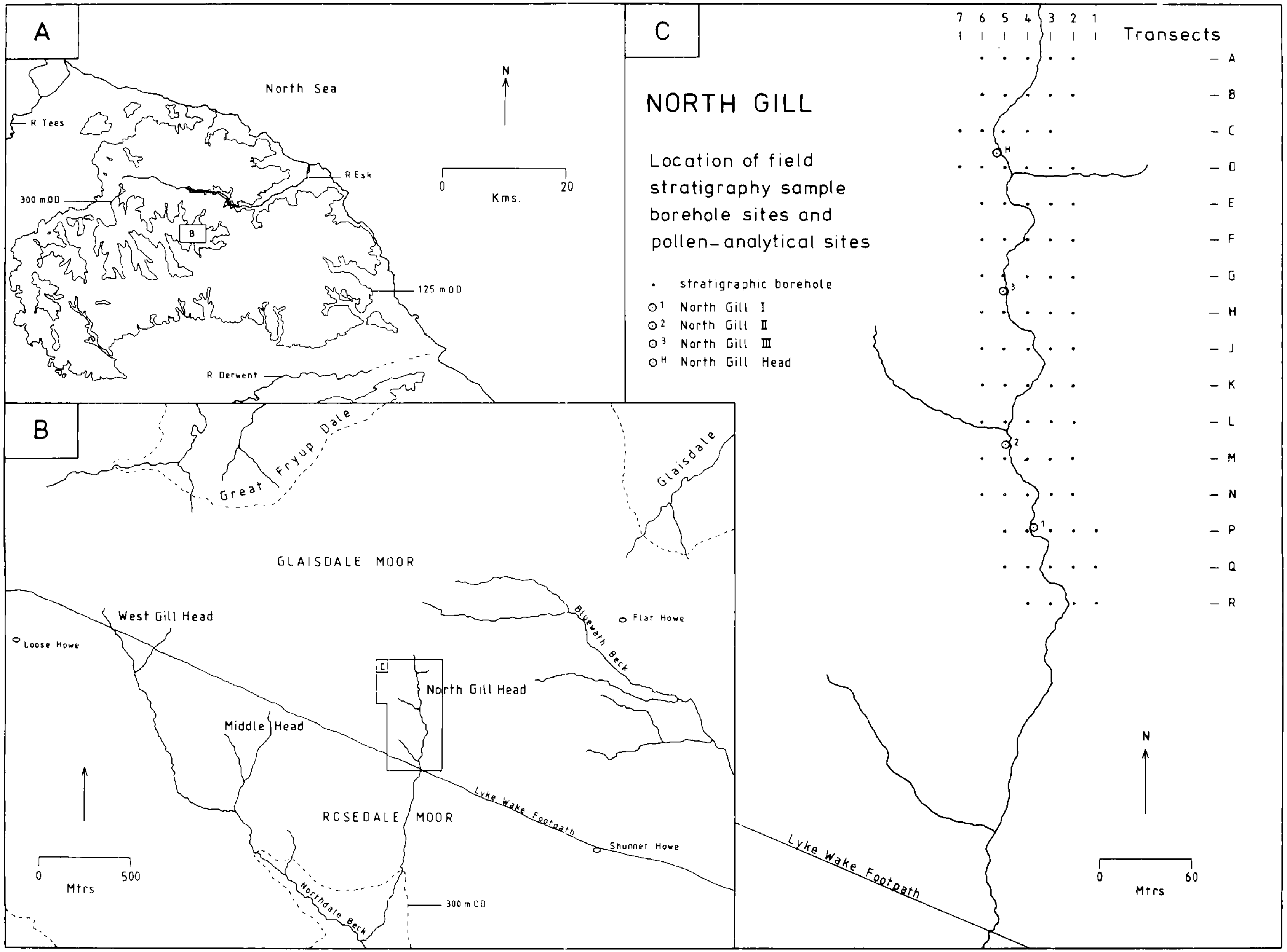


Fig. 7. North Gill. Location of field stratigraphic and pollen analytical sampling sites.

drainage of the moorland is achieved by the waters of the Bluewath Beck. Thus the environs of the North Gill spring-head form a shallow basin of localised extent and low gradient, being just above the major break of slope of the plateau edge, below which the valley falls away steeply to the dale below. Such a situation has clearly favoured the accumulation of organic deposits, for the depth of peat revealed in the sections cut by stream erosion is substantial, reaching over three metres in places (Plate 1).

4.2. Previous Research - Stratigraphy

The exposure of a full blanket peat profile of considerable depth at North Gill offered opportunities for stratigraphic research designed to elucidate the history of peat development on this part of the Central Watershed, and previous investigations at this site (Simmons 1969a) has revealed a complex stratigraphic succession within which a number of discrete stratigraphic units could be recognised. Field observation had proven a basal wood layer, lying upon mineral soil within which tiny flecks of charcoal were present. More than two metres of peat were recorded above this mineral soil, and further fragments of wood were noted at intervals within the profile. Bands of charcoal were identified near the base of the succession and charcoal and carbonised plant material occurred throughout the peat, to a greater or lesser degree, occasionally seeming to form distinct stratigraphic horizons which could be traced laterally for some distance.

Laboratory examination of monolith blocks removed from the peat face served to confirm and amplify this impression of an intricate depositional sequence. Two distinct types of peat were recognised above the basal sandy mineral soil. The first part of the profile to be examined

Plate 1. A section of over three metres depth cut through the peat blanket near the head of North Gill (NZ 726 008), viewed from the south-west. The graduated scale is one metre in length.

(North Gill 'a') was characterised by a peat formed almost exclusively from the leaves and stems of the bryophyte moss Polytrichum commune, and incorporating wood fragments and twigs. Adjacent to this deposit, and forming the basal biogenic unit of North Gill 'b', was a black organic layer suffused with fragments of charcoal and containing no other discernible macrofossils. The relationship of the charcoal-rich and moss peats was imprecise, but apparently both were implicitly bound up with the inception of organic accumulation at this site. In relation to both these basal layers, which do not exceed six or seven centimetres in thickness, the supervening deposit is comprised of an amorphous brown peat of homogenous structure and with occasional charcoal inclusions. Alnus twigs, some charred, were present within this peat and towards the top of the stratum appeared two layers of fresh, unhumified Eriophorum peat. A layer of fine silt particles was encountered at about fifty centimetres above the base of the profile, in association with bark and wood fragments. The uppermost metre of the section was composed of a fibrous Calluna and Eriophorum peat containing bands of fresher, poorly humified Sphagnum, and incorporating charcoal at several levels in the profile.

In his survey of blanket peat deposits upon the Central Watershed, Cundill (1971) also made stratigraphic recordings at intervals along the full length of the North Gill stream, and pointed out that the complexity of the succession was matched by its spatial variability, alluding to the discontinuity of certain of the stratigraphic units, and the great variation in the depth and type of peat. Wood macrofossils were found predominantly at the southern, downstream, end of the North Gill peat mass and were composed of Betula and Alnus. At one point, where the basal wood layer was charred and accompanied by charcoal, it rested directly upon solid rock, otherwise it lay above a sandy mineral material with slight wood and charcoal inclusions. Towards the spring-head itself much of the peat had no wood remains within or beneath it. At the northernmost section examined, a narrow mineral inwash stripe occurred which Cundill interpreted as the product of erosion of material from the flat moorland plateau area immediately to the north.

4.3. Previous Research - Pollen Analysis

Pollen analysis was conducted upon the peat monoliths recovered from North Gill (Simmons 1969a, 1969b) and indicated that biogenic accumulation had commenced early in Flandrian II, the pollen assemblage of the basal horizons suggesting that it was coincident with, and perhaps consequent upon, clearance of woodland in the immediate vicinity of the site. The basal charcoal-rich peats were characterised by a range of ruderal herb types, prominent among which were Artemisia, Plantago lanceolata, Rumex, Urtica, and Melampyrum. Values for Quercus and Alnus were depressed while there was an extremely high representation of taxa favoured by fire, Pteridium, Corylus and Pinus, and by increased light, Salix, Fraxinus and Betula. Such evidence was considered to be consistent with the creation of clearings in the deciduous woodland by fire, and their subsequent regeneration through seral communities. The presence of ruderal pollen and charcoal at the very base of the peat pointed to a possible relationship between the act of clearance and the initiation of peat formation. This basal phase of fire-induced recession was radiocarbon dated to 6316 $\pm$ 55bp. (BM 425).

Taxa indicative of open habitats were present throughout the remainder of Flandrian II, which terminated in a clearly-marked Ulmus decline radiocarbon dated to 4767 $\pm$ 60bp (BM 426), suggesting that truly closed-canopy conditions were never re-established at the site during this period. The silt and charcoal layer noted in the stratigraphy, and which occurred towards the end of Flandrian II, was accompanied by pollen fluctuations of a kind similar to those recorded during the basal clearance event, although of a rather less intensive nature. They were considered by Simmons to reflect the replacement of woodland by open-habitat communities, at perhaps a rather greater distance from the sampling site than upon the initial occasion. The incorporation of inwashed mineral material into the profile in the context of general forest recession suggested that soil erosion had been initiated by this renewed clearance.

That these fire-clearances of woodland occurred during Flandrian II, and therefore in a Mesolithic cultural context, implied that, if they were the result of human agency, they must be attributable to the activities of hunting and gathering communities.

4.4. Present Vegetation

At the time of the investigations by Simmons (1969a) and Cundill (1971), the vegetation cover of the site was typical of that of the rest of the Central Watershed, managed moorland dominated by Calluna, with an admixture of Erica tetralix and Eriophorum vaginatum upon the damper areas adjacent to the stream-course.

During the extremely hot and dry summer of 1976, however, intense moorland fires broke out upon this part of the Central Watershed, burning out of control for several days. The Lyke Wake footpath was widened, by bulldozing, and acting as a fire-break, prevented the flames from spreading to Rosedale Moor to the south (see fig. 7B), but to the north the entire area of Glaisdale Moor, and much of the adjacent Egton High and Wheeldale Moors, was very badly affected. As a consequence the vegetation cover around the site of North Gill was entirely destroyed and the surface and

Plate 2. A general view of the site of North Gill and its immediate environs from the south-east, illustrating the flat topography of the blanket peat surface. This area was devegetated by moorland fire in 1976, and a moss carpet of Polytrichum and Sphagnum is colonising the burned area as the first stage of regeneration.

upper layers of the peat blanket charred and cracked. In some areas disturbance of the peat has led to much removal of material by erosion. Regeneration of the burned-over areas has now commenced (Plate 2), and the site supports pioneer taxa, in particular small patches of bryophyte mosses, *Polytrichum* and *Sphagnum*, and occasional seedlings of *Epilobium angustifolium* and *Betula*. There is no sign of *Calluna* regeneration at present. Inspection of the peat at the site indicated that only the upper layers had been disturbed or contaminated with modern charcoal by the moorland fire, and that the basal sequence of relevance to this investigation remained unaffected, and suitable for analysis.

4.5. Research Objectives and Methods

It was clear from the previous research that the peat sections at North Gill contained a stratigraphic record that was both spatially and temporally variable, and included units which could be interpreted as the result of dynamic and non-autogenic processes, in particular the incorporation of charcoal and silt layers into the mire system. That a charcoal layer formed the basal stratigraphic unit over at least part of the area suggested that these processes may have been of significance regarding the initiation of peat formation itself. It has been considered necessary, therefore, to conduct a more detailed stratigraphic survey of the North Gill area, in order to define more closely the character and areal extent of the stratigraphic units recognised there. This has been accomplished by a series of borings through the blanket peat and by further examination of cleaned peat faces, and the results are described in sections 4.6 to 4.10.

A series of four pollen analytical sites have been sampled, and their pollen diagrams are intended to clarify and extend the palaeobotanical evidence for vegetational change revealed by previous work. These palynological sites have been chosen in an altitudinal transect along the upper course of the North Gill stream so that, allied to the stratigraphic information, it may be possible to elucidate the succession of environmental changes taking place over different parts of the site, as well as the size, intensity, and spatial distribution of these Mesolithic clearance events. This approach resembles the three-dimensional technique advocated by Turner (1970, 1975) for reconstructing the character and location of prehistoric forest clearance. Thus the pollen spectra may be considered in relation to their position laterally across the site, following correlation of levels upon the four diagrams which show evidence of environmental modification. The position of these pollen and stratigraphic boreholes is shown upon fig. 7C. Simmons' profile North Gill 'a' lies between sites North Gill II and III upon this diagram.

North Gill

General Stratigraphy

4.6. Introduction

As a first step in the stratigraphic investigation of the site, borings were carried out on a grid system, using a gouge sampler, supplemented at intervals by a Russian-type peat borer. The initial borehole was sunk at the very head of the Gill, at a point relative to Ordnance Datum and known to be exactly 370.00 metres O.D. This point was then adopted as a temporary bench mark and used in levelling the rest of the site, and is represented by sampling point A4 on figure 7C.

Further borings were made to east and west of this base point at fifteen metre intervals, and together these constitute lateral Transect A. Twenty-five metres to the south a second lateral series of borings were made, comprising lateral Transect B. Further transects were constructed in the same way until a point 375 metres down the Gill had been reached, beyond which the peat blanket considerably attenuates, and erosion and disturbance of the stratigraphy is very great. With the completion of lateral Transect R, over eighty borings had been carried out, and the altitude of each was levelled relative to the site temporary bench mark and thus to O.D. These borings provide the basis for describing the general stratigraphic content of the site.

4.7. Topography and Peat Depth

The impression conveyed by field observation of the peat blanket is one of gentle slopes and uniform topography, (Plate 2) except where dissected by erosive forces, and this is generally substantiated by the stratigraphic survey.

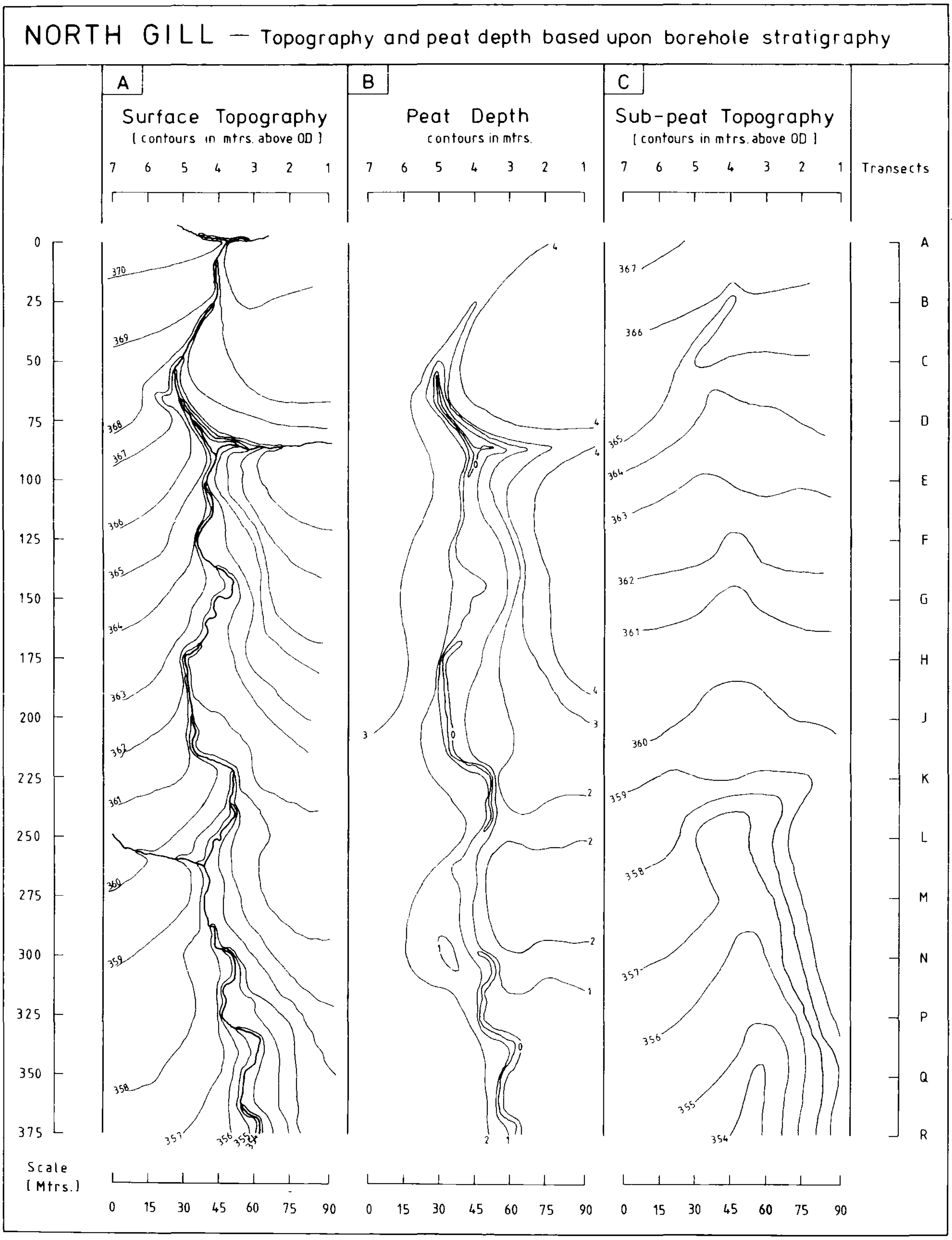


Fig. 8. Surface topography, peat depth and sub-peat topography based upon borehole data.

Figure 8A shows the surface topography of the site derived from the boring logs. From a height of 370.00 metres at point A4, the peat surface descends to 356.60 metres at point R4, a gradient of 1 : 27.9. This gentle declivity is interrupted by the channel of the North Gill stream, which is deeply incised at the upper part of its course, becoming broader as it progresses, having cut down to the mineral soil from transect H onwards, the bed of the stream at transect R being recorded at a height of 353.46 metres. A computer-drawn graphic representation of the peat surface at North Gill (fig. 9) illustrates this uniformity of relief and gradient.

The peat cover reaches its maximum depth in the north east part of the site, averaging 4.20 metres depth between transects A and H, except where the channel of a tributary spring reduces it to just over three metres to the south of transect D (fig. 8B). To the west of the main stream channel, along longitudinal transects 6 and 7, peat depth is rather less, being only 3.57 metres at point A6, but decreases down hill only slowly, as much as 2.52 metres of deposit being recorded at point R4. This is in contrast to the lower part of the site to the east of the stream, where the peat is less than 50 centimetres thick, apparently having been subject to erosion. The steep peat faces which reveal the gross stratigraphy of the site all lie on the western edge of the main stream channel. Figure 10 displays a computer-drawn graphic representation of peat depth around North Gill, reproducing three dimensionally the area shown on figure 8B.

4.8. Pre-Peat Topography

Subtraction of values for peat depth from the altitude of the peat surface allows the mapping of the sub-peat topography, which is

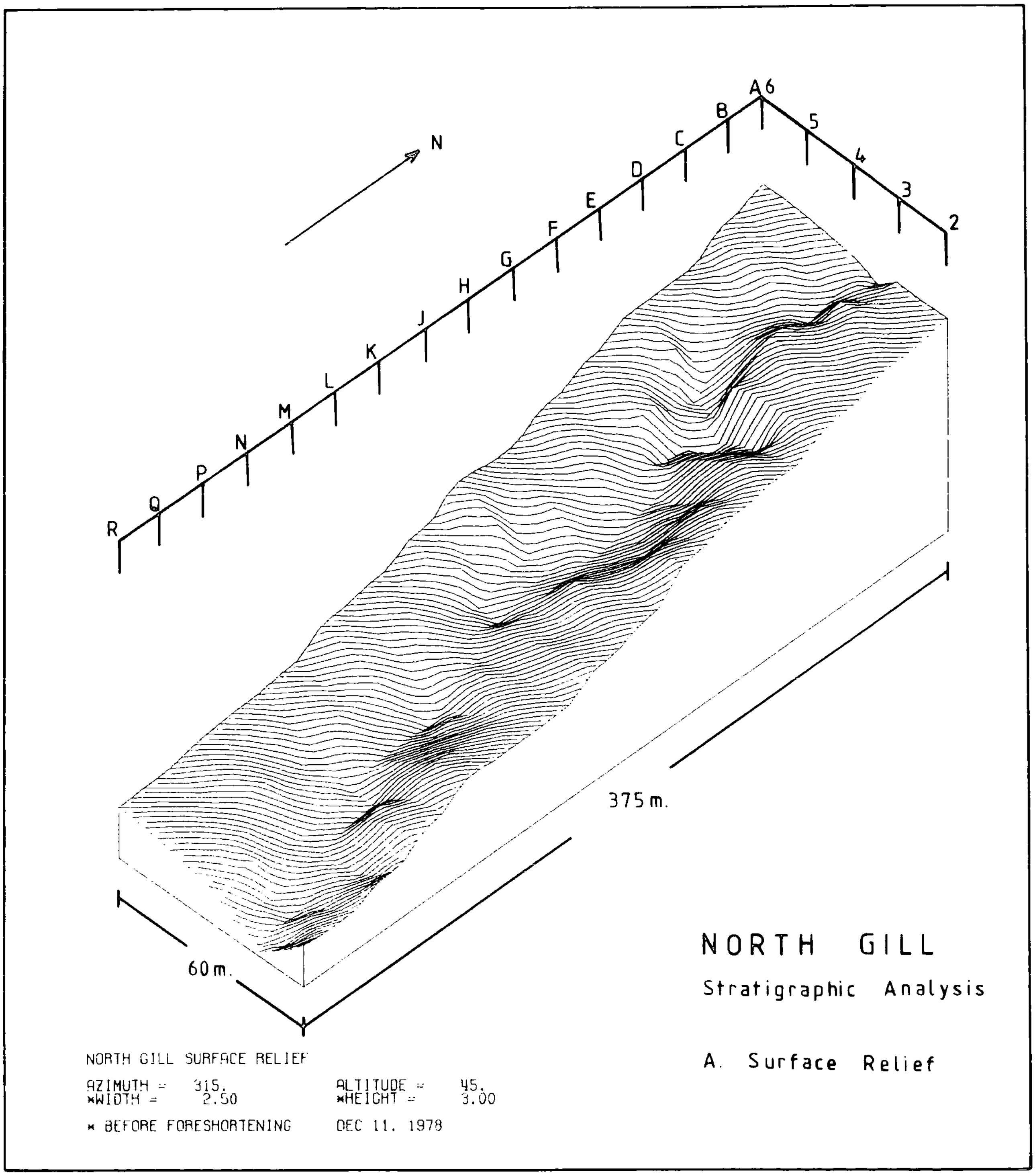


Fig. 9. North Gill. SYMVU : representation of surface relief.

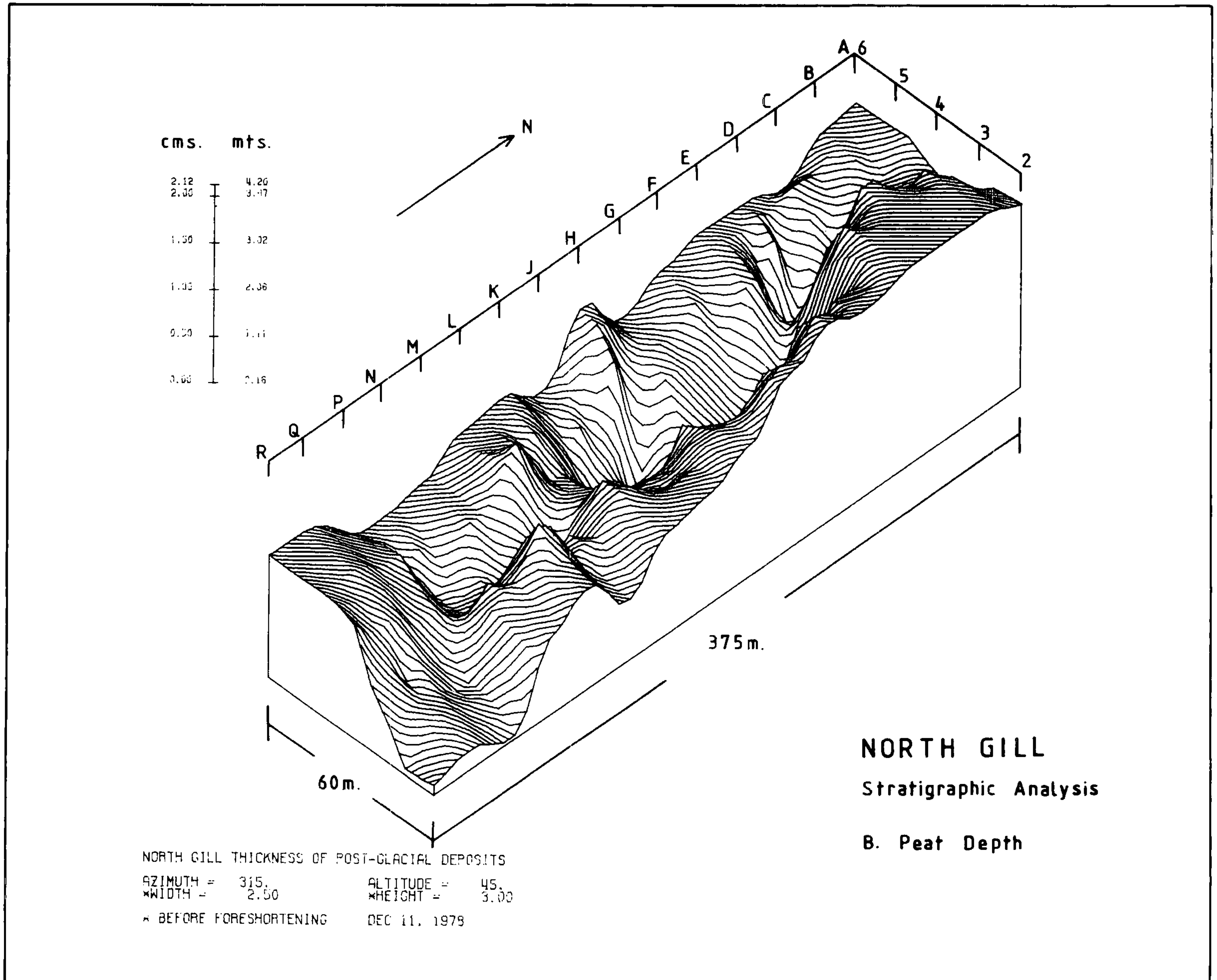


Fig. 10. North Gill. SYMVU : representation of peat depth.

illustrated in figure 8C. The pre-peat land surface shows little more variation than the present day relief, and the very low gradient of the sub-peat surface is very similar to that of the peat blanket, dropping from 366.78 metres at point A4 to 353.98m at point R3, an overall gradient of 1 : 29.2. The pre-peat North Gill stream channel may be recognised on figure 8C, however, and it is clear that there were significant variations in gradient, and therefore in rate of flow, at different points upon the original watercourse itself. The areas may be noted where the proximity of the contour lines indicate steeper gradients. The first lies immediately to the north of transect B where there occurs a rock step with a gradient of approximately 1 : 3, and may be partly attributed to the increased erosive power of the stream following the aggregation of the numerous small springs which rise between transects A and B. The second example occurs in the area of transect K, where the ground drops two metres in twelve, a gradient of 1 : 6.

In contrast to these two places, elsewhere the bed of the original stream was extremely flat, in particular below transect B, where the gradient was 1 : 40, between transects G and J where the land falls only two metres in seventy-five, a gradient of 1 : 37.5, and between transects L and M, where the gradient is as low as 1 : 50. It was considered likely that these very flat parts of the stream's valley would be prone to waterlogging and that peat formation may well have commenced earliest in these places. Pollen analytical sites were accordingly located there.

Figure 8 suggests that the course of the modern North Gill beck differs very little in general location from that of its early Flandrian II counterpart, and so the longitudinal stratigraphic transect number 4, which is displayed as part of figure 11, may be considered to

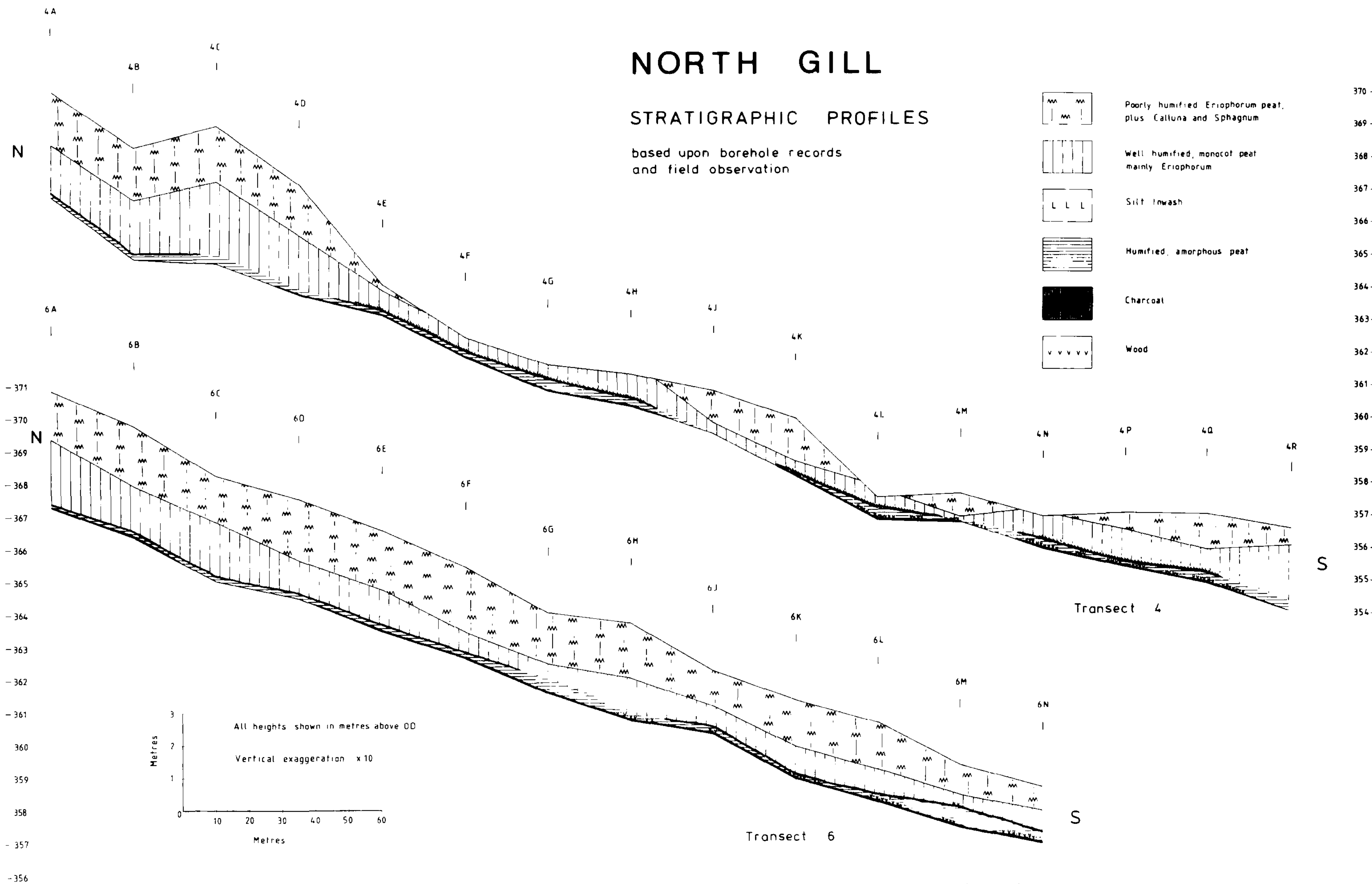


Fig. 11. North Gill. Selected stratigraphic profiles based upon borehole stratigraphy.

represent in its sub-peat surface the long profile of this original stream. The location of the areas of low gradient may be clearly seen upon this diagram, at points 4B, 4G, and 4L respectively. The more uniform gradients away from the stream course may be noted in the sub-peat surface of transect 6, which is also shown on figure 11.

4.9. Lithostratigraphy

Analysis of the stratigraphic data recovered from peat section and borehole records at North Gill makes possible the recognition of nine strata which, although showing a degree of internal variation, are sufficiently distinct to be afforded the status of lithostratigraphic units applicable to the site as a whole. The basal three such units are minerogenic in origin, comprising clay and sandy soil above a rock substratum. This sequence of deposits was observed only in exposed peat section, for the borers were unable to penetrate these clastic sediments. Records of these strata are confined, therefore, to those parts of the site adjacent to the stream channel and their character in other areas is not known.

The supervening organic deposits were penetrated and the minerogenic substratum proven at each stratigraphic borehole sunk at North Gill. It was thus possible to examine the stratigraphic integrity of each biogenic horizon identified and to plot its thickness and spatial extent within the sample area. Six biogenic lithostratigraphic units are recognised and these are described diagramatically by fig. 11 and by the computer-drawn graphic representation displayed as fig. 12, upon which their general succession is portrayed for longitudinal transect 2 and all sixteen lateral transects. Although some variation does occur within these six units, they would appear to represent discrete strata reflecting

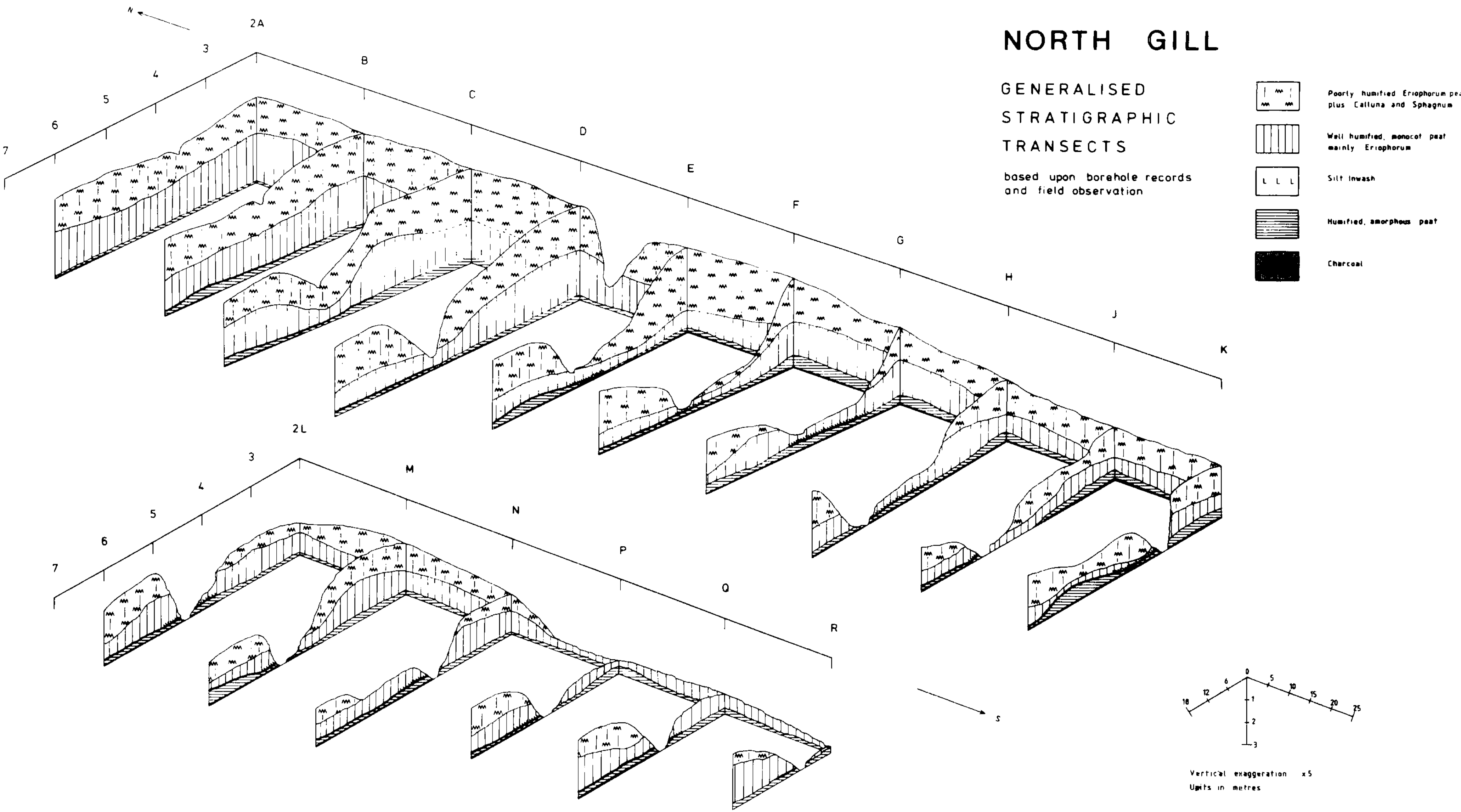


Fig. 12. North Gill. Generalised stratigraphic transects based upon borehole stratigraphy.

different depositional conditions. A further factor is the presence of wood remains in the peat. These occur mainly to the south of transect L, to the west of the stream, and transects 4 and 6 on figure 11 show where actual wood layers may be noted within the gross stratigraphy. Where identifiable, macrofossil wood was usually found to be Betula or Alnus, although Salix and Corylus also occurred. Tree-stumps, which had evidently been eroded out of the blanket peat, were observed in the stream, (Plate 3) but their original stratigraphic position could not be determined.

The stratigraphic evidence at North Gill may now be described using the following nine lithostratigraphic units, which are numbered consecutively from the base of the succession and designated by the prefix NG-L.

Unit NG-L1 Solid rock

The solid sandstones of the Deltaic series form the basal lithostratigraphic unit which is, however, subjacent to the basal organic strata at certain parts of the site, most particularly at points 4B, 4J and 4N upon figure 11. These are situations of steeper slopes and it is likely that the exposure of the bedrock has followed removal of mineral soils by erosion, probably after the initial clearance event recorded by Simmons (1969a). Where observed, the sandstone is fractured and decomposing, contributing a rotting 'ranker' hard-rock foundation.

Unit NG-L2 White clay

Over much of the site, and especially within the lower stream channel, bedrock is covered by an homogenous, stiff, white clay, containing occasional angular fragments of sandstone derived from the underlying

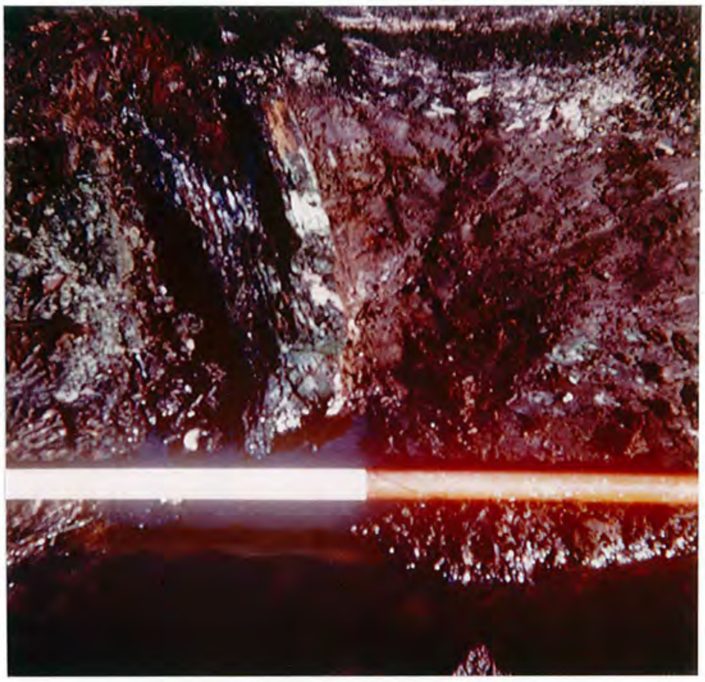


Plate 3. A tree stump lying in the bed of the North Gill stream following erosion from the blanket peat. The white segment of the graduated scale is fifty centimetres in length.

stratum. This clay does not extend far from the stream channel and underlies the mineral soil at this site. It was never found to attain more than ten centimetres depth, but since the borer did not always penetrate through it, greater thicknesses could occur. A similar clay has been described by Gregory (1962b) and Atherden (1972), and is interpreted as a solifluction deposit derived from the surrounding slopes during the severe periglacial conditions of the Late Glacial period. Material thus moved into the channel would be spread out into the consistently thin smear recorded at this site, its slight depth caused by the smaller catchment area of this upland stream, in contrast to the thicker deposits encountered in lowland drainage channels.

Unit NG-L3 Mineral soil

A siliceous, yellow-orange, mineral material is the pre-peat land surface over most of the site, and this is considered to be a fossil soil profile. Where the hillslope is shallower the upper levels of the soil grade into a minero-organic material, although at other points, mostly where slopes are steeper, a sharp break may be seen between pure sandy soil and the supervening biogenic strata. An erosive break may be postulated here. In the flat 'basin' areas of the stream channel, inclusions of wood (mainly *Alnus*) and organic material, including charcoal pieces, occur in the upper soil profile, suggesting that at least the upper layers may not be *in situ* but transposed by water action from the erosion points described above. Rounded quartz pebbles are often to be found in the soil.

Iron staining is prominent within the profile, and the mineral soil appears to be a well-leached acid podsol, of a kind often found under blanket peat (Pearsall 1950, Taylor and Smith 1972), especially where formed upon impoverished sandstone parent material. Soil particles are generally comprised of large coarse sand grains, and this very coarse, friable structure is consistent across the sampled area, varying little with depth, which is at no point very great. The clay-soil interface is at all points sharp and well defined.

Unit NG-L4 Lower charcoal

A basal charcoal layer is identified as the first post-soil deposit at North Gill. It is thickest in the flat 'basin' areas of the stream-channel where it is manifest as a charcoal-organic stratum of up to six centimetres in depth, corresponding directly to Simmons' 'charcoal-rich peat' at North Gill 'a'. Analysis of the charcoal shows a mixture of large, angular pieces and much smaller smooth, rounded, 'soot' fragments, the former considered to be indicative of rapid introduction from close by, through inwash or mass movement, the latter perhaps of wind transport from rather further away. In the lower part of the site, points 4K to 4Q on figure 11, the charcoal horizon is associated with charred wood pieces, mainly Alnus, and contains a high mineral fraction, indicating that burning of woodland and some soil instability was coincident with this onset of biogenic accumulation. Figure 13 is a computer-drawn graphic representation of the lower charcoal layer at North Gill, plotted from borehole data alone, without recourse to observations from stream-side profiles. It tends to support the contention of three main centres of deposition along the stream channel, with a maintenance of thickness towards the western part of the site, and a rapid attenuation of the layer to the east. It would appear that, although the deepest deposits are indeed those found in isolated depressions in the stream channel, where conditions for accumulation were at their best, the charcoal layer

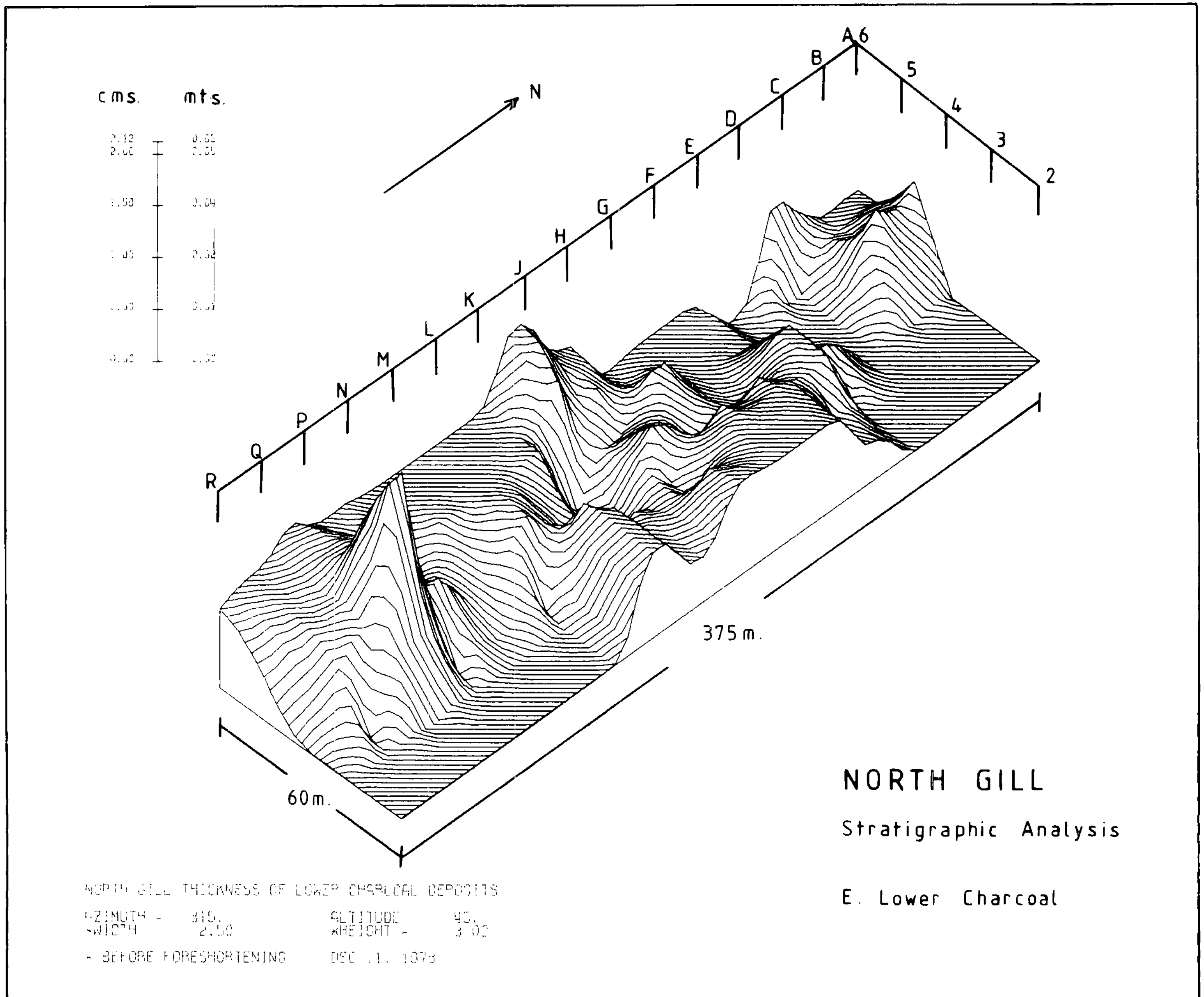


Fig. 13. North Gill. SYMVU : dimensions of lithostratigraphic unit NG-L4 (Lower Charcoal).

as a whole extends for some distance to the west of the sampled area, and that the fire which created it may have been concentrated upon the spring-head and the land to the west of it, rather than across the entire area.

NG-L5 Amorphous peat

The lower charcoal horizon is everywhere covered by a variable depth of dark brown amorphous peat, which thus forms the basal deposit on areas where the charcoal is absent, in particular on the eastern part of the site. It is at its thickest in the centre of the sampled area, between transects E and M, where it reaches up to 75cm depth, but thins out markedly towards the northern extremity of the site. Although its internal structure is quite homogenous, it does incorporate on occasion large pieces of wood, some of which exhibit signs of charring and are evidently detrital in nature. The great majority are Betula or Alnus with occasional Salix and Corylus. Tree trunks of a diameter greater than 30cms were noted (Plate 4), and some Betula wood pieces appear to be of root material, rather than branches. A very few seeds of Juncus and Potamogeton were present in the lowest levels. The upper part of this peat is very well humified and apart from the wood little macrofossil presence was recorded within it. It did include, however, speckles of charcoal dust at intervals, which small size and even distribution across the site suggested its incorporation by wind transport from elsewhere in the vicinity.

At the base of this amorphous peat, the moss peat recorded by Simmons (1969a) was recognised between transects H and J, although as an elusive and ephemeral deposit. It may have been partly removed by erosion since the earlier investigation. It may be traced laterally as far west as points 5H, 5J and 6J as a very thin covering of the basal charcoal peat

Plate 4. A large tree trunk of more than thirty centimetres diameter protruding *in situ* from the amorphous peat (lithostratigraphic unit NG-L5) at North Gill. The graduated scale is one metre in length.

material, but soon becomes indiscernable, merging with the basal layer of the general amorphous peat above. This moss peat is evidently thin and discontinuous, and its true distribution would require further scrutiny. It appears to be represented only on, and westwards of, longitudinal transect 4, however, and is not recorded to the east of the site. It is clearly stratigraphically superior to the basal charcoal peat, and little charcoal content was recorded within it.

Unit NG-L6 Upper charcoal

At the upper border of the amorphous peat a second charcoal layer occurs, and this is shown on figures 11 and 12 and is represented graphically by figure 14. It is conspicuously thinner than the basal charcoal horizon and nowhere attains more than three centimetres in thickness, generally being little more than one centimetre. It resembles it however, in being almost entirely absent from the eastern part of the site, and being most persistent to the west. The charcoal particles are in almost every case very small, although abundant, and the large jagged pieces characteristic of the basal layer are absent. A thin layer of charred birch bark fragments rests upon and within the charcoal at several places. The fire responsible for this charcoal layer may therefore have occurred in less immediate proximity to the sampling site with fewer of the resulting fragments capable of transportation to, and incorporation in the bog without comminution.

Unit NG-L7 Silt inwash

Immediately superior to the upper charcoal layer is an inwash stripe of mineral silt material. Its extent is shown on figures 11 and 12, and relative thickness is represented graphically by figure 15. It

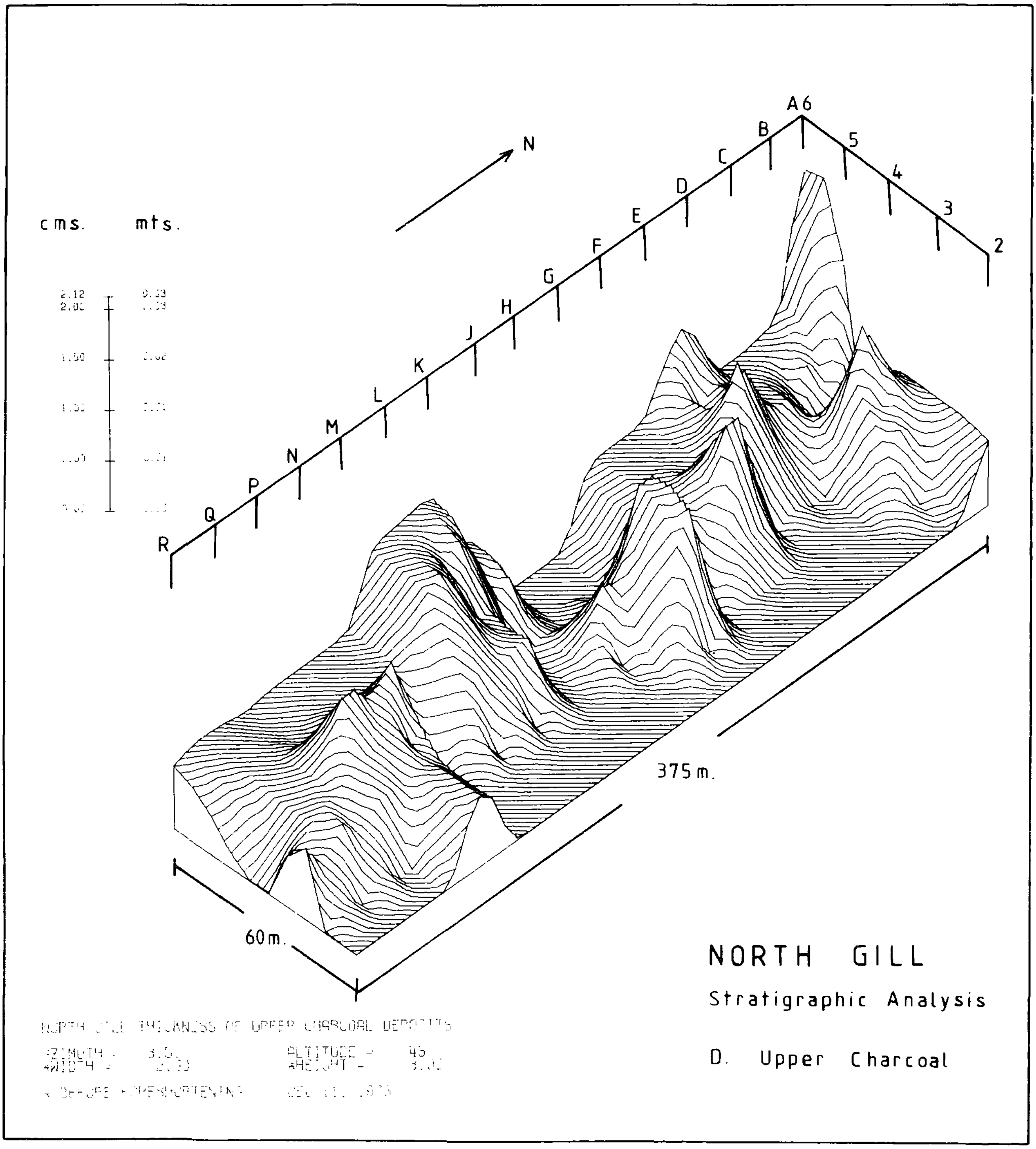


Fig. 14. North Gill. SYMVU : dimensions of lithostratigraphic unit NG-L6 (Upper Charcoal).

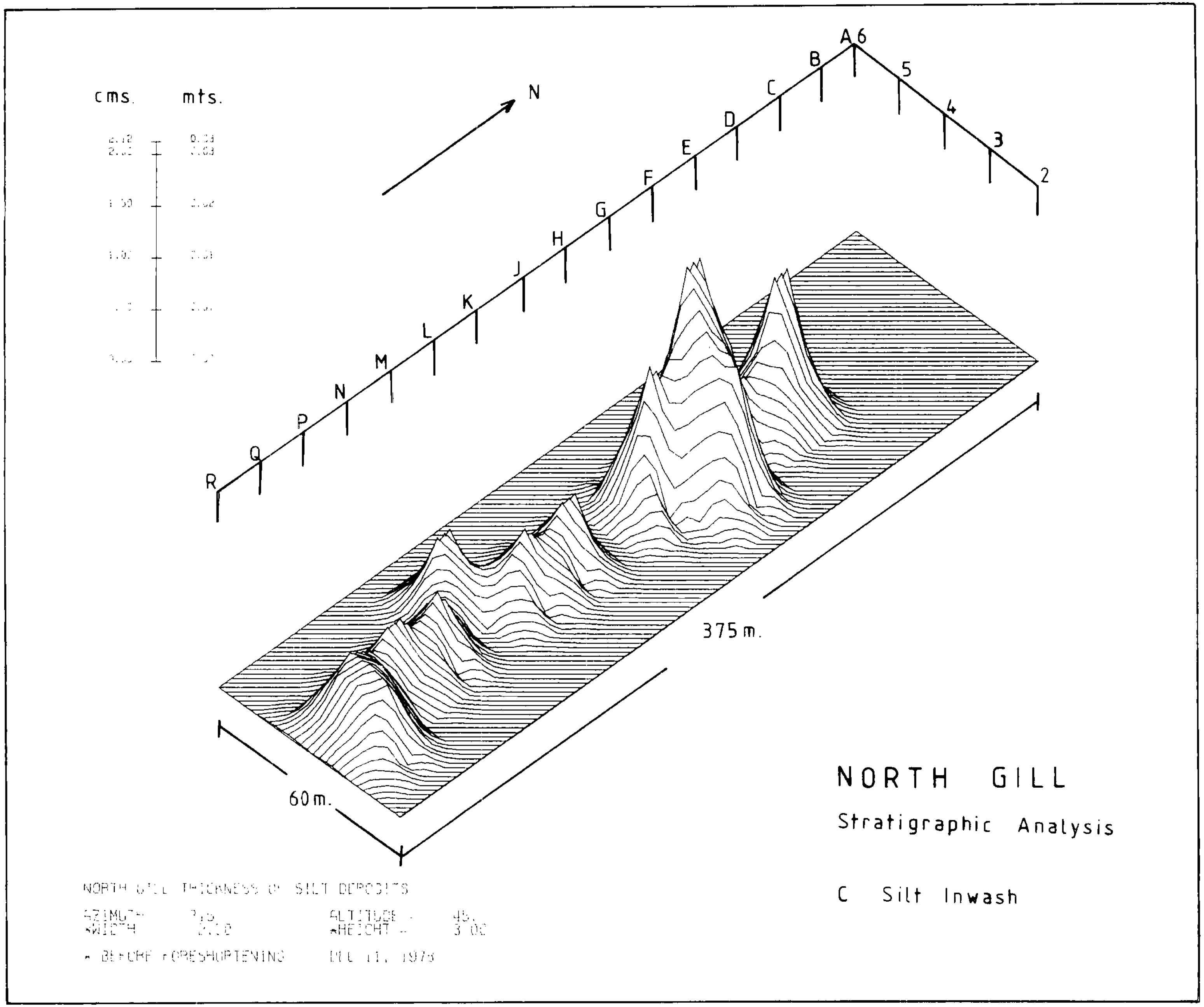


Fig. 15. North Gill. SYMVU : dimensions of lithostratigraphic unit NG-L7 (Silt inwash).

is thickest at transects G and H, and is not recorded above transect E. While thickest in mid-profile, the mineral layer is here incorporated within an organic matrix, which includes tiny fragments of charred birch bark. The inwash stripe is, although thinner, much more discrete to the south of the site and is composed almost entirely of coarse, siliceous particles, evidence of sorting and washing by water transport downstream. below transect Q, where the profile gradient increases suddenly, this stratigraphic unit is no longer recorded. If it ever existed further downstream, it has been removed with the peat overburden by recent erosion.

Although a significant silt fraction is noticeable at this level in transects 5 and 6, the silt layer is confined as a discrete stratigraphic unit to transect 4, and deposition of the inwashed material evidently took place predominantly in the centre of the stream channel.

Unit NG-L8 Humified Eriophorum peat

The succeeding stratigraphic layer is well humified peat, with a high macrofossil component of Eriophorum, particularly in the lower layers. This completely covers the site and increases in thickness towards the north, reaching 2.4 metres at transect C and above. Its depth and distribution is displayed in figures 11 and 12.

Unit NG-L9 Fresh Eriophorum, Sphagnum and Calluna peats

The uppermost biogenic stratum is represented by a poorly humified peat composed mainly of Eriophorum and Sphagnum, with occasional horizons containing ericaceous fragments and rootlets, mainly of Calluna. Figures 11 and 12 show that like the Eriophorum peat below, it increases in thickness towards the northerly limit of the site.

4.10. <u>Summary</u>

From the foregoing data, it is possible to describe nine distinct lithostratigraphic units at North Gill, and to define securely their spatial and chronological relationships. Although some variation does occur within the strata, chiefly in macrofossil content, they are sufficiently discrete to allow the construction of a lithostratigraphic conspectus profile, intended to summarise the general sequence of depositional events at the site, in contradistinction to the more detailed stratigraphic descriptions at the individual pollen sites. This is exhibited at figure 16, and utilises the system of stratigraphic symbols and notation according to Troels-Smith (1955).

North Gill is typical of upland 'basin' peats in having wood remains in the basal layers overlain by well humified amorphous peat and then by fresher *Eriophorum* - *Sphagnum* 'blanket' peats, as classified by Moore (1972) and examplified by the sites of Ringinglow (Conway 1947, 1954), Totley Moss (Phillips 1969, Hicks 1971) and Hambleton Dike (Tinsley 1975) in the Pennines. Topographical factors are of fundamental importance at this kind of site, peat forming characteristically during Flandrian II in water-retaining depressions, often within damp birch-alder woodland. In this context units NG-L5, NG-L8 and NG-L9 on figure 16 are autogenic in origin, caused by natural development of the bog, while units NG-L4, NG-L6 and NG-L7 are allogenic and intrusive, caused by dynamic events outside the mire system.

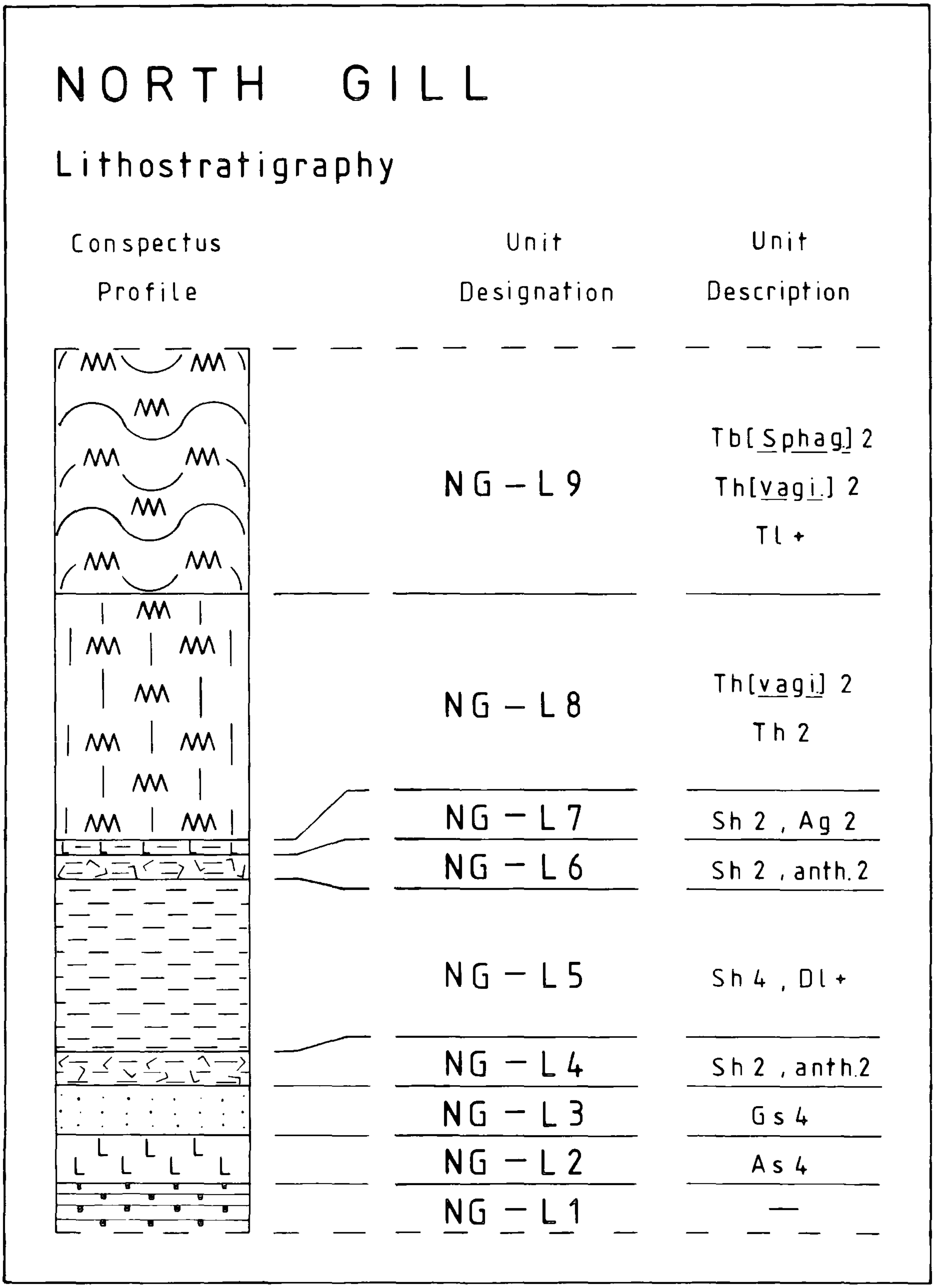


Fig. 16. North Gill. Lithostratigraphic conspectus profile.

North Gill I

4.11. Introduction

The first profile to be sampled for pollen analysis was situated on the line of lateral transect P and slightly to the east of longitudinal transect 4 (fig. 7). This location was selected as the most southerly major peat face exposure, and comprehended all of the major stratigraphic units. This basal metre of deposit was selected for recovery, encompassing a succession from lithostratigraphic unit NG-L3 to NG-L8. The sample was collected in monolith tins which were hammered into the prepared peat face. Prior to extraction, the top of the upper tin was levelled to 356.62m OD., and this was adopted as the site datum, above which lay a further eightly centimetres of unsampled deposit. This site was designated North Gill I, and its grid reference is NZ 726 006.

4.12. Site Stratigraphy

Following field and laboratory investigation, the following stratigraphy was recorded.

Stratum	Depth (cms)	Description
12	0 - 30	Th (<u>vagi</u>)^{3}4, Tb (<u>Sphag</u>)^1+ nig.3, strf.1, elas.1, sicc.2, lim. sup.0 Humified <u>Eriophorum</u> peat, with isolated fresher inclusions of <u>Sphagnum</u> moss.
11	30 - 50	Th^{3}2, Th (<u>vagi</u>)^{3}2 nig.3, strf.1, elas.1, sicc.2, lim. sup.1 Well humified monocot peat, composed primarily of <u>Eriophorum</u>.

10	50 - 68	Th (<u>vagi</u>)^{1}4 nig.2, strf.1, elas.2, sicc.2, lim. sup.1 Poorly humified <u>Eriophorum</u> peat.
9	68 - 72	Th^{3}4, Th (<u>vagi</u>)^{1}+ nig.3, strf.1, elas.1, sicc.2, lim. sup.1 Well humified herbaceous <u>turfa</u> with occasional strands of <u>Eriophorum</u>.
8	72 - 73	Ag 4, Sh^{4}+ nig.0, strf.0, elas.0, sicc.3, lim. sup.4 Coarse silt with a very slight organic fraction.
7	73 - 75	anth.2, Sh^{4}2, Dl+, Ag+ nig.4, strf.1, elas.1, sicc.2, lim. sup.4 Charcoal with an admixture of undifferentiated organic material. Slight presence of <u>Betula</u> bark and fine silt.
6	75 - 83	Th^{2}3, Dl 1 nig.2, strf.1, elas.1, sicc.2, lim.sup.3 Partly humified monocot peat of medium brown colour. Small fragments of wood throughout.
5	83 - 87	Sh^{4}4 nig.4, strf.0, elas.0, sicc.2, lim. sup.1 Undifferentiated amorphous peat, very well humified, no macrofossil content.
4	87 - 89	Tl 3, Sh^{4}1, Dl+ nig.2, strf.0, elas.0, sicc.2, lim. sup.3 Detrital <u>Betula</u> wood in amorphous peat matrix. Rootlet material predominantly.

3	89 - 93	$Sh^4 4$ nig.4, strf.1, elas.1, sicc.2, lim. sup.3 Well humified black amorphous peat.
2	93 - 98	anth.3, $Sh^4 1$, Dl+, Ag+ nig.4, strf.1, elas.1, sicc.2, lim.sup.1 Amorphous peat suffused with charcoal. A slight silt fraction throughout and pieces of charred <u>Alnus</u> wood near the base of the stratum.
1	98 - 100	Gs4, Sh^4+, Dl+, anth.+ nig.1, strf.0, elas.0, sicc.2, lim.sup.4 Coarse yellow sand with occasional inclusions of organic material, tiny flecks of charcoal and wood fragments.

Stratum 1 is correlated with lithostratigraphic unit NG-L3, (fig.16) stratum 2 with NG-L4, strata 3, 4, 5 and 6 with NG-L5, stratum 7 with NG-L6, stratum 8 with NG-L7 and strata 9, 10, 11 and 12 with NG-L8.

4.13. Pollen Analysis

Samples were taken for pollen analysis at 2 cm. intervals throughout the profile, and the resulting pollen diagram is shown as figure 17. Four Local Pollen Assemblage Zones are recognised, are applied to figs. 18a and 19a and are described as follows:

LPAZ NG1 - A 98 - 86 cms.

The basal pollen assemblage zone is characterised by <u>Quercus</u> and <u>Ulmus</u>, which contribute 50% and 25% of the tree pollen sum respectively,

NORTH GILL I


PINUS
BETULA
QUERCUS
ULMUS
TILIA
FRAXINUS
FAGUS
Alnus
Corylus
Salix
Calluna
Gramineae
Sphagnum
% TOTAL POLLEN (EXCLUDING SPHAGNUM)
TREES
ALNUS
SHRUBS
OTHERS
LOCAL PAZ
REGIONAL PAZ
CHRONOZONE
LOCAL FCS
NG1-D
BETULA
CALLUNA
RUDERALS
NYM-F
C2
NG1-C
BETULA
QUERCUS
CORYLUS
CALLUNA
NYM-E
FIII
R3
C1
R2
T2
NG1-B
QUERCUS
ULMUS
NYM-D
FII
R1
NG1-A
QUERCUS
ULMUS
CORYLUS
ALNUS
T1

and high frequencies of Alnus and Corylus, the latter providing 40% of total pollen in the lower part of the zone. Tilia is well represented at over 10% of tree pollen, while Fraxinus occurs sporadically and in low frequencies. Tree pollen, even with the inclusion of Alnus, accounts for only 30% of total pollen in the basal horizons, although increasing as the zone progresses. Betula and Pinus are significant, each providing about 20% of tree pollen, the latter declining towards the top of the zone. Corylus dominates shrub pollen, but Salix increases sharply in value in the upper horizons while Sorbus, Prunus, Hedera and, in particular, Lonicera are also recorded. Dwarf shrubs are represented only by Calluna which occurs in moderate, but sustained, values. Gramineae frequencies are consistently high, approaching 20% of total pollen, and Cyperaceae is also well represented. A complex herbaceous assemblage occurs, within which ruderal, dampland and aquatic types are recognised. Pteridophyte spores are present in very high frequencies, particularly in the basal horizons, with both Polypodium and Pteridium prominent. Filicales values fall from maximum frequencies as the zone proceeds, while Lycopodium is also noted. Sphagnum is present in low values. The upper boundary is drawn where Alnus and Corylus values decline.

LPAZ NG1 - B 86 - 67 cms.

Quercus and Ulmus are the major arboreal types in this zone, although Betula is also present in significant values, particularly towards the end of the zone. Pinus frequencies rise to a peak in mid-zone but are otherwise very low. Fraxinus forms a continuous curve for the first time, and Tilia maintains its frequency of 10% of tree pollen. Alnus falls in value throughout the zone. Shrub pollen falls to about

25% of total pollen during this zone, attributable primarily to a marked diminution in Corylus frequency to just over 20% of total pollen. Calluna and Salix percentages are sustained, while Prunus, Sorbus and Hedera are still recorded. Gramineae and Cyperaceae values are slightly diminished, but a wide range of herbaceous taxa are present, dampland and aquatic types being prominent. Sphagnum rises to high values in mid zone, but fern spores are of much less importance than hitherto. Pteridium does show occasional expansions in value, however, at horizons at which the incidence of ruderal herb types is much increased. N.A.P. frequencies are reduced relative to A.P. during this zone, although wide fluctuations do occur at certain levels. The upper boundary of the zone is drawn at a marked decline of Ulmus pollen frequency.

LPAZ NG1 - C 67 - 38 cms.

Coincident with the decline of Ulmus values which marks the opening of this zone is a sharp fall in frequency of Tilia pollen, which becomes discontinuously recorded. Betula achieves co-dominance of the assemblage with Quercus, while Alnus values remain steady at about 15% of total pollen. Ulmus recovers from its initial decline to reach about 10% of A.P. late in the zone, and Fraxinus is greatly increased in representation. Although Pinus is consistently present, its values remain low. Fagus is recorded in mid zone. Among shrub taxa Corylus increases in value, but the greatest expansion is shown by Calluna, rising to 20% of total pollen. The presence of other shrub types is noted, but in reduced frequencies, Salix being the only consistent constituent of the assemblage, although an isolated Ilex grain occurs. Herbaceous pollen frequencies are generally reduced, especially Gramineae, yet the range of types recorded is not diminished. Ruderal and open-habitat taxa are well in evidence early in the zone and Plantago lanceolata appears for the first time and is present throughout. Sphagnum continues its general decline, but spore frequencies are maintained, and in the case of Pteridium, increased. Tree and shrub pollen dominate the assemblage. The upper boundary of the zone is drawn where Ulmus frequencies again decline sharply.

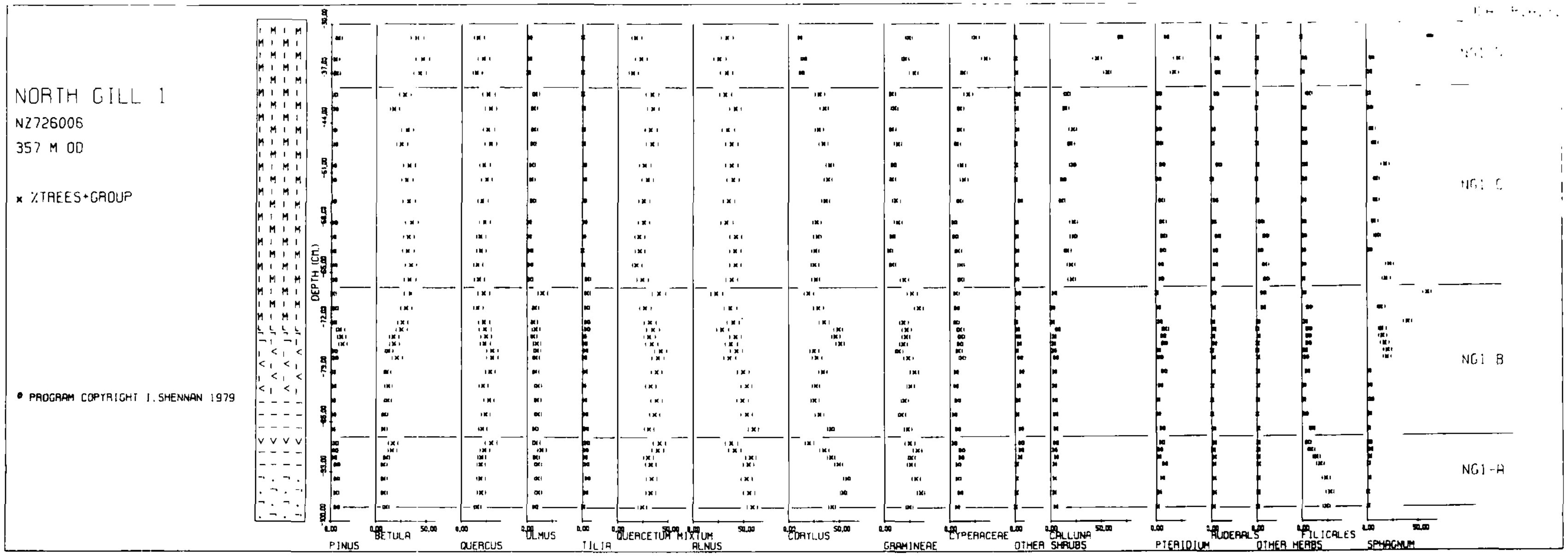
LPAZ NG1 - D 38 - 30 cms.

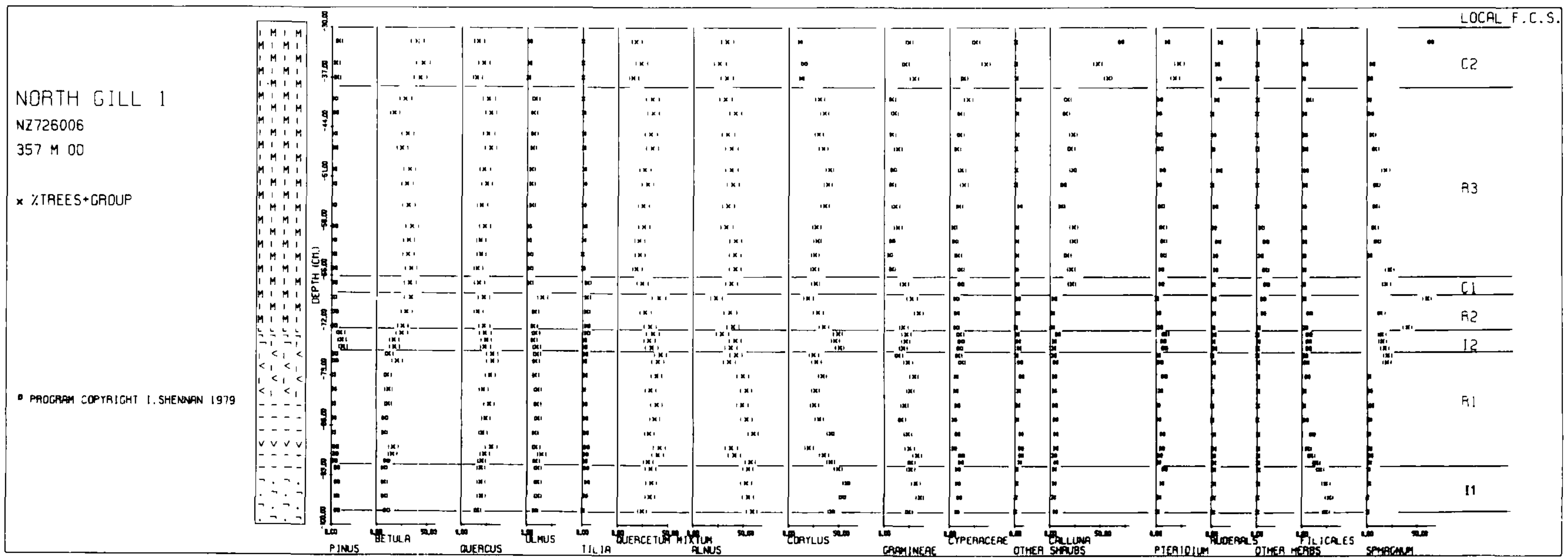
This zone is characterised by a distinct decline in tree pollen values which, including Alnus, fall from 40% to 14% of total pollen. In addition to Ulmus, Quercus values are much reduced and Tilia is no longer recorded. Betula assumes dominance within the A.P. sum, and Pinus also rises slightly. Fraxinus and Fagus are also present. Alnus and Corylus are reduced in value, forming only 5% and 8% of total pollen respectively. Calluna values expand sharply, rising to 55% of total pollen and a general increase of herbaceous pollen frequencies takes place. Gramineae and Cyperaceae contribute to this event, but other herbs, including ruderal types, also show enhanced values. Plantago lanceolata increases greatly. While other fern spores are less often recorded Pteridium rises to very high values, and an isolated peak of Sphagnum occurs at the end of the zone. N.A.P. types dominate the assemblage.

The lowermost pollen assemblage zones, NG1 - A and NG1 - B, are referred to regional zone NYM - D, zone NG1 - C to regional zone NYM - E, and zone NG1 - D to the beginning of regional zone NYM - F.

4.14. Forest Clearance History

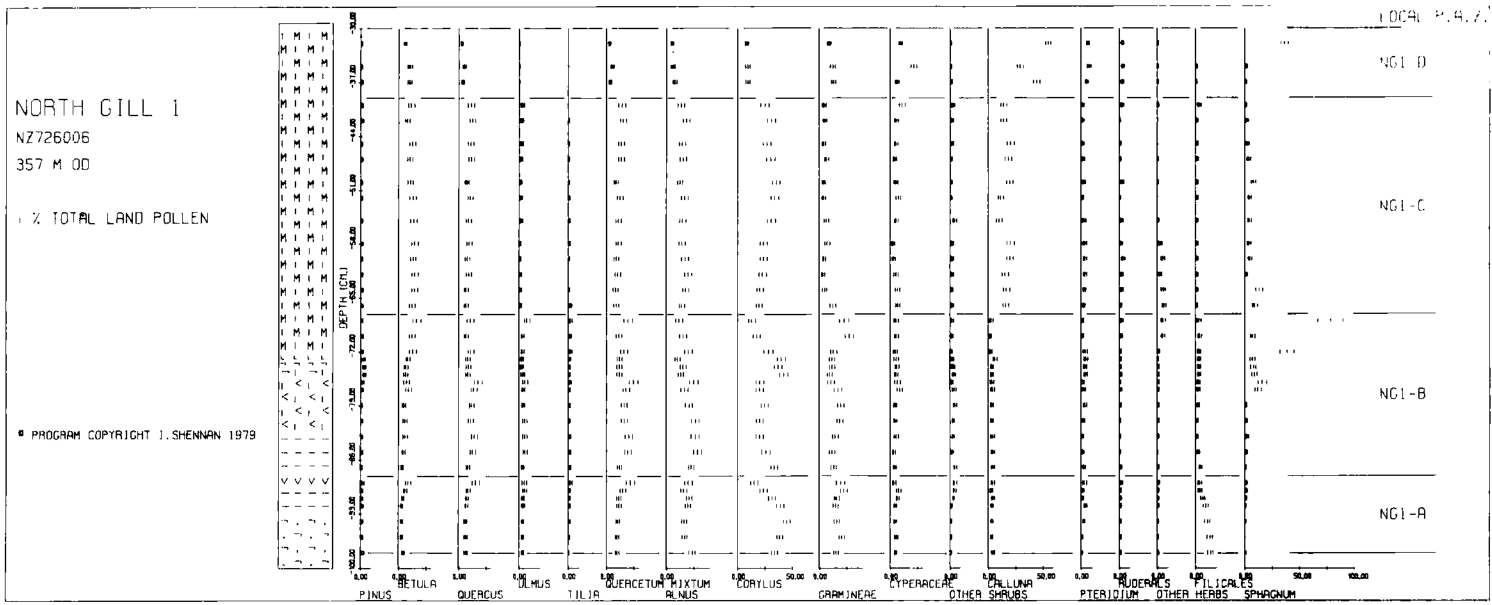
Vegetational changes which may be interpreted as the effects of human activity are apparent throughout the pollen record at North Gill I.



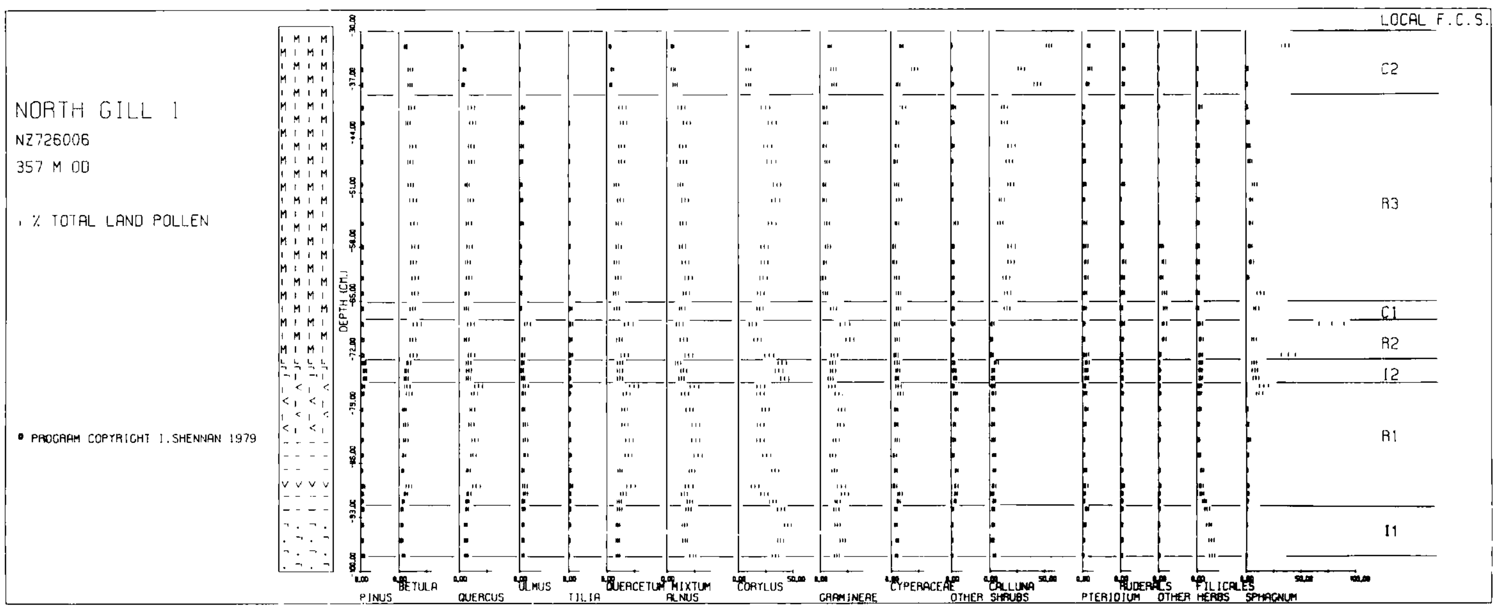


[illegible] Diagram [illegible] percentage of tree pollen [illegible] group.

A



B



[illegible] diagram : percentages of total land pollen.

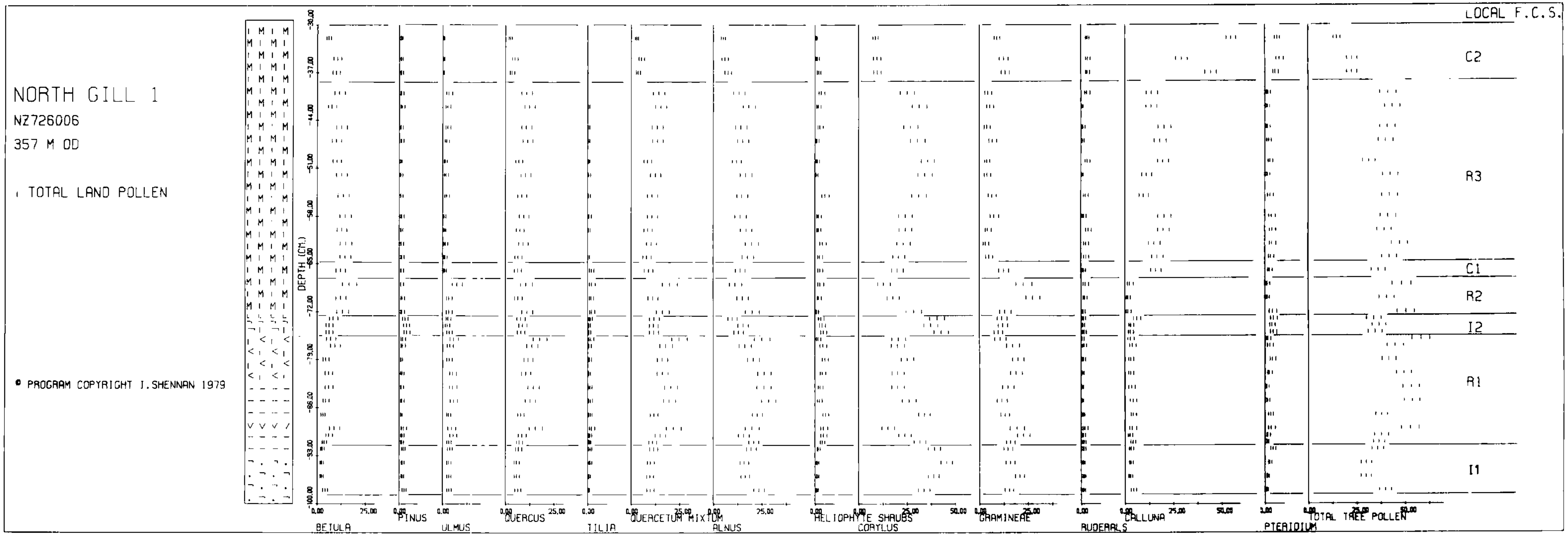


Fig. 27. North Gill 1. Pollen diagram : selected clearance taxa as percentages of total land pollen.

Seven local stages in the history of forest clearance are recognised upon fig. 17, are applied to figs. 18b and 19b, and are used to zone fig. 20 as a basis for description of the evolution of the landscape.

FCS Zonule I1 98 - 92 cms.

The basal zonule at this site records an intense phase of forest recession and the presence of charcoal in the stratigraphy suggests that fire was responsible. During this phase tree pollen values fall to only 30% of total land pollen and the assemblage is dominated by non-tree pollen types of heliophyte or ruderal character. Corylus frequencies are particularly high, reaching almost 50% of total land pollen and reflecting the removal of mature woodland from around the site. The existence of areas of bare ground nearby is shown by the presence of several ruderal herb taxa. Compositae Tubuliflorae and Compositae Liguliflorae occur at the base of the zonule, accompanied by Melampyrum, Succisa, Chenopodiaceae, Polygonum, Caryophyllaceae, Urtica and Artemisia, while Rumex and Umbelliferae join the assemblage towards the end of this phase. The replacement of woodland by taxa indicative of fire-disturbed habitats is evidenced by a sharp increase in frequency of Pteridium spores which is matched by the expansion of other taxa representative of open conditions, Gramineae and, less markedly, Calluna. Quercus, Alnus and Betula appear to be the trees most reduced in value during this episode of clearance, with the opening of the woodland canopy allowing increases in frequency for, besides Corylus, light demanding shrubs and trees such as Prunus, Sorbus and Fraxinus. Rosaceous types, probably including ecologically similar shrub taxa, rise in frequency also. A major reduction in tree cover appears to have taken place during this zonule, allowing the colonisation of newly cleared areas by pioneer taxa and their incipient regeneration through seral communities characterised by light demanding shrubs and trees.

FCS Zonule R1 92 - 75 cms.

A long phase of regeneration follows the basal clearance event, and during this period tree pollen values rise to about 55% of total land pollen, showing restoration of wooded conditions to have taken place. Major tree taxa of the Quercetum mixtum, especially Quercus characterised this woodland, although Alnus and Betula are also prominent. The heliophyte shrubs and trees Corylus, Prunus, Sorbus and Fraxinus are much diminished, the latter almost ceasing to be recorded, suggesting that closed canopy conditions prevailed near the site. Salix retains high values, perhaps growing in favoured locations adjacent to the stream course. Except for isolated spectra, Pteridium frequencies are low, and evidently few open areas remained nearby for it to occupy. No herbaceous indicators of open ground are recorded, with the exception of occasional grains of Rumex and Urtica, and with the A.P. : N.A.P. ratio remaining stable, the woodland apparently remained undisturbed during this period.

FCS Zonule I2 75 - 73 cms.

A second phase of fire induced forest recession is recorded between 75 and 73 cms., as, coincident with the appearance of charcoal in the stratigraphy, pollen fluctuations indicative of forest clearance are again recorded. Tree pollen values fall sharply from a peak of almost 60% to only 35% of total land pollen. Alnus and trees of the Quercetum mixtum, especially Quercus, are most seriously affected during this phase of clearance, but Betula is also reduced in frequency. Pinus, Fraxinus and, less markedly, Tilia appear to respond favourably to the disruption of the stable forest ecosystem. Several herb taxa indicative of open ground or disturbed conditions occur in the pollen record during this zonule, including Melampyrum, Compositae Tubuliflorae, Artemisia, Succisa, Chenopodiaceae, Caryophyllaceae, Umbelliferae, Rumex and Urtica, suggesting that the cleared area created during this phase was extensive. Peak values for Calluna and Pteridium correspond with this expansion of ruderal herb pollen frequencies, while Lycopodium is also recorded, suggesting more open conditions. Heliophyte shrub taxa are much encouraged by the breaking of the forest canopy through clearance, and Salix, Prunus and Sorbus are all well represented, as is the undifferentiated group Rosaceae. Hedera and Lonicera are also recorded during this phase. The greatest expansion in frequency at this time is exhibited by Corylus, however, which attains 45% of total land pollen and was apparently particularly favoured by clearance. This zonule evidently records a substantial removal of forest cover by fire and the incorporation of silt particles into the mire at this level indicates that soil erosion was initiated by clearance of the vegetation.

FCS Zonule R2 73 - 67 cms.

Woodland regeneration occurs during this zonule and tree pollen values increase to about 50% of total land pollen. A change in woodland composition appears to have taken place, however, for neither Quercus nor Alnus regain their pre-clearance values. Betula shows a marked increase and, with high Fraxinus frequencies, reflects the secondary nature of the post-clearance woodland. Indicators of clearance are much less in evidence, Corylus in particular falling sharply from its peak values of the previous zonule, reflecting the closure of the forest canopy. Ruderal herb pollen frequency is greatly reduced, although the identification of occasional

Rumex, Urtica, and Polygonum grains support the contention that some clearings may have remained within the less dense woodland. Calluna and Pteridium values, however, are very low, and it would appear that the vegetation remained undisturbed at this time.

FCS Zonule C1 67 - 65 cms.

Pollen fluctuations consistent with forest clearance are recorded during this zonule, in particular a sharp decline in Ulmus pollen frequency, together with a fall in total tree pollen from 50% to less than 40% of total land pollen. Quercus and Tilia are similarly reduced, causing a fall in total Quercetum mixtum frequencies from 20% to 10% of total land pollen. Betula too is initially reduced in frequency whereas Alnus, Salix and Corylus show a gradual expansion, their importance as woodland constituents increasing with the decline of the major forest trees. Ruderal herb values are enhanced following the creation of open areas within the forest and among the types recorded are Compositae Tubuliflorae, Taraxacum-type, Cirsium, Artemisia, Caryophyllaceae, Chenopodiaceae, Rumex, Urtica and Polygonum. Plantago lanceolata is recorded for the first time. Pteridium and Calluna frequencies also rise, the latter in particular rising sharply from low values to almost 20% of total land pollen, while a brief peak of Rosaceous pollen occurs.

FCS Zonule R3 65 - 38 cms.

A long period of woodland regeneration ensues during which there is little evidence for continued major interference with the vegetation. Tree pollen remains constant at about 45% of total land pollen and a stable oak-alder-birch woodland apparently prevailed although the moderate values for total tree pollen and substantial Corylus frequencies, accounting for

30% of total land pollen, suggest that it was not dense. The high values for Betula and Fraxinus, and the introduction of Fagus, together with high and sustained Calluna and Pteridium frequencies, support this view, as do the recurrent records for open-habitat herb grains. Compositae Tubuliflorae, Chenopodiaceae, Artemisia, Rumex, Urtica and Polygonum all make intermittent appearances in the assemblage, while a low but continuous Plantago lanceolata curve is present throughout the zonule. It would seem that either small clearances continued to be made in the local woodland, or some areas remained permanently deforested, failing to regenerate tree growth after the previous clearance. It may be possible however, to recognise a brief phase of clearance during this regeneration zonule at 50 cms., where a slight reduction in tree pollen is coincident with an increase in indicators of clearance, especially several ruderal herb taxa, otherwise it seems likely that the woodland remained undisturbed.

FCS Zonule C2 38 - 30 cms.

The final zonule at this site recognises a major period of deforestation during which all tree pollen curves are greatly diminished in value as a percentage of total land pollen (fig. 20). Trees of the Quercetum mixtum and Alnus appear to be particularly badly affected by clearance and Betula dominates the tree pollen sum (fig. 17). Corylus and other heliophyte shrubs are adversely affected by this clearance event and the most marked expansion in frequency is shown by Gramineae, Pteridium and Calluna all of which reach very high levels. Calluna achieves peak values of over 50% of total land Pollen. An extensive removal of tree cover from the locality of the site and its replacement by heathland vegetation took place during this phase of clearance, which was evidently of greater intensity than any occurring hitherto.

North Gill II

4.15. Introduction

The second pollen analytical site was located immediately to the south of lateral transect L, and between longitudinal transects 4 and 5 (fig. 7). This is within an area of low gradient which may have favoured biogenic accumulation, and corresponds with the lowest of the 'basin' areas described in sections 4.6 to 4.10. The lower ninety centimetres of deposits were sampled using monolith tins, the upper boundary of the sampled profile levelled to 359.02 metres OD., and was adopted as the site datum. A depositional sequence from lithostratigraphic unit NG-L2 to NG-L8 was recovered, above which lay a further fifty centimetres of unsampled peat. This site was designated North Gill II, and its grid reference is NZ 726 007.

4.16. Site Stratigraphy

Following field and laboratory investigation the following stratigraphy was recorded.

Stratum	Depth (cms)	Description
9	0 - 41	$Th^3 2$, Th (vagi)$^2 2$ nig.2, strf.2, elas.1, sicc.2, lim. sup.0 Mid brown humified monocot peat, composed mainly of *Eriophorum vaginatum*, macrofossil content increasing toward the base of the stratum.
8	41 - 42	Ag 2, $Sh^4 2$, anth.+ nig.2, strf.1, elas.1, sicc.2, lim. sup.2 Coarse silt mixed with amorphous material some of which is carbonaceous.

7	42 - 45	anth.2, $Sh^{4}2$, Dl+, Ag+ nig.4, strf.1, elas.1, sicc.2, lim.sup.3 Amorphous peat, rich in charcoal, most of very small size. Some mineral material present throughout, with a layer of charred birch-bark at the top of the stratum.
6	45 - 59	$Th^{3}4$, Th (*vagi*)^{1}+, Dl+ nig.3, strf.2, elas.1, sicc.2, lim. sup.3 Dark, well-humified monocot peat. Fragments of detrital *Betula* wood near the base of the stratum, and occasional fibres of *Eriophorum* above 50 cms.
5	59 - 64	Tl 4, anth.+ nig.2, strf.0, sicc.3, lim. sup.4 *Betula* wood, apparently rootlet material, slightly charred.
4	64 - 72	$Sh^{4}4$ nig.4, strf.0, elas.0, sicc.2, lim. sup.4 Black, amorphous organic material, very well humified.
3	72 - 78	anth.2, $Sh^{4}1$, Gs1, Dl+ nig.4, strf.1, elas.0, sicc.2, lim. sup.1 Charcoal rich minero-organic material. Tiny fragments of wood and bark in the lower layers, mainly charred. Mineral fraction decreases towards the top of the stratum.

2	78 - 84	Gs4, Dl+, anth.+ nig.1, strf.0, elas.0, sicc.2, lim. sup.2 Coarse sand, orange at base, becoming more yellow towards the upper boundary of the stratum, where very small wood pieces and charcoal particles also occur.
1	84 - 90	As4, Gg (maj)+ nig.0, strf.0, elas.0, sicc.2, lim. sup.4 Stiff, white clay which includes occasional sandstone pebbles of up to 20 mm., in diameter.

Stratum 1 is correlated with lithostratigraphic unit NG-L2 (fig. 16), stratum 2 with NG-L3, stratum 3 with NG-L4, strata 4, 5, and 6 with NG-L5, stratum 7 with NG-L6, stratum 8 with NG-L7 and stratum 9 with NG-L8.

4.17. Pollen Analysis

Samples for pollen analysis were taken from the profile at intervals of no greater than 2 cms., and the resulting pollen diagram is shown as figure 21. Three Local Pollen Assemblage Zones are recognised, are applied to figs., 22a and 23a, and are described as follows:

LPAZ NG2 - A 77 - 64 cms.

Tree pollen frequencies in the basal pollen assemblage zone are dominated by Pinus and Betula which contribute 30% and 50% respectively of total arboreal pollen. Ulmus represents 15% of A.P. and remains constant throughout the zone. Quercus frequencies are very low at the beginning of this phase, but recover to reach almost 20% of tree pollen

NORTH GILL II

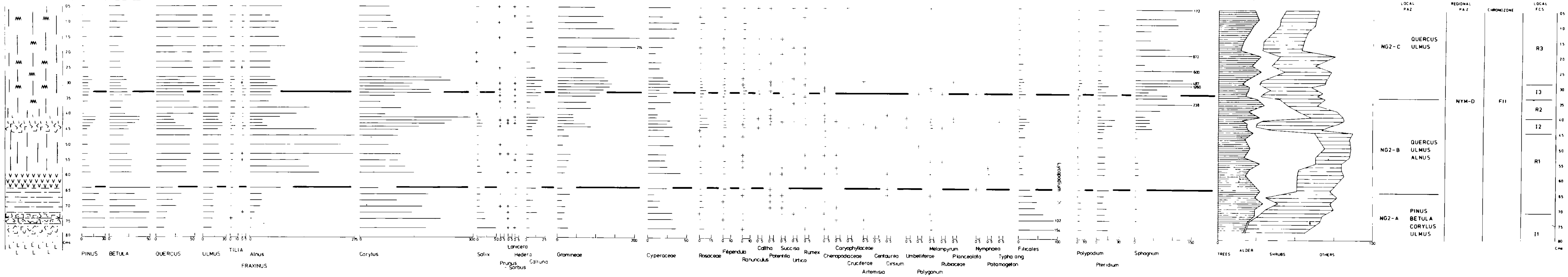


Fig. 21. North Gill II. Pollen diagram : percentages of tree pollen (excluding *Alnus*).

towards the end, as Pinus begins to decline. Alnus also rises in frequency as the zone progresses, from virtual absence at the base to almost 10% of total pollen at the end. Tilia is continuously represented, although in very low values, and Fraxinus is occasionally recorded. Tree pollen, including Alnus, accounts for only 25% of total pollen during this zone and so N.A.P. types are well in evidence. Corylus is the major shrub, fluctuating between 35% and 50% of total pollen. Salix values are initially also high but decline rapidly, while Hedera, Lonicera, Prunus and Sorbus also occur. Calluna values remain low and no other dwarf shrub pollen is recorded. Cyperaceae is the major supplier of herbaceous pollen, Gramineae remaining rather low. Individual herb taxa recorded are mainly mire and dampland types, like Filipendula and Ranunculus, although a number of open-habitat indicators do appear. High Filicales and Pteridium values characterise the fern spore assemblage, with restricted Polypodium frequencies. Sphagnum is almost absent. The upper boundary of this zone is drawn where Pinus and Betula values fall and are replaced by Quercus and Alnus.

LPAZ NG2 - B 64 - 33 cms.

During this zone Quercus and Ulmus pollen rise in frequency to characterise the tree pollen assemblage, contributing 50% and 30% of A.P. respectively. Tilia and Fraxinus are present in frequencies of up to 10% A.P., the latter however, discontinuously. While Pinus and Betula decline in frequency as the zone progresses, isolated peaks in value do occur later in the zone. Tree pollen represents on average 25% of total pollen throughout rising to 70% with the inclusion of Alnus. A marked expansion of Alnus values is a major feature of this zone, achieving 50% of all pollen recorded, and although decreasing later in the zone, its values remain high. A varied shrub pollen assemblage occurs, including Lonicera, Prunus, Sorbus and Hedera but dominated by Salix and, especially, Corylus. While the latter displays peak values of 50% of total pollen towards the end of the zone, these are not typical of its general level of representation, which averages 20% of total pollen. Dwarf shrub frequencies, contibuted only by Calluna, are low. Gramineae values are low at the beginning of the zone but rise towards the end, while Cyperaceae continues to show substantial frequencies. Herb taxa are well in evidence, particularly later in the zone when a marked expansion takes place, involving both ruderal and other types. Aquatic herb pollen is also recorded. Pteridium is the only fern spore recorded in high frequencies, while Sphagnum, low to begin with, rises to high frequencies at the end of the zone. The upper boundary is drawn where Alnus frequencies fall to a consistently low level.

LPAZ NG2 - C 33 - 0 cms.

Alnus recedes in value during this zone to less than 15% of total pollen and is thus no longer a primary assemblage component. Quercus and Ulmus remain the major tree taxa, together accounting for 75% of A.P., and thus characterising the zone. Tilia consistently represents 10% of A.P., while Fraxinus is also prominent. Pinus and Betula are secondary tree pollen contibutors, although the latter attains about 20% of the tree pollen sum. Corylus values are not greatly increased from the previous zone and all other types, including Salix and Calluna, are reduced in importance. N.A.P. percentages are greatly increased, reaching almost 50% of total pollen, and this is due mainly to a great increase in Gramineae frequencies. While herb pollen values are high, these are produced almost exclusively by dampland and mire types, open-habitat taxa having almost disappeared from the pollen spectra. Pteridophyte spores form an important part of the assemblage, Pteridium in particular being present in high frequencies. Sphagnum percentages fluctuate sharply during the zone, but are in general high, reaching occasional peaks of super-abundance.

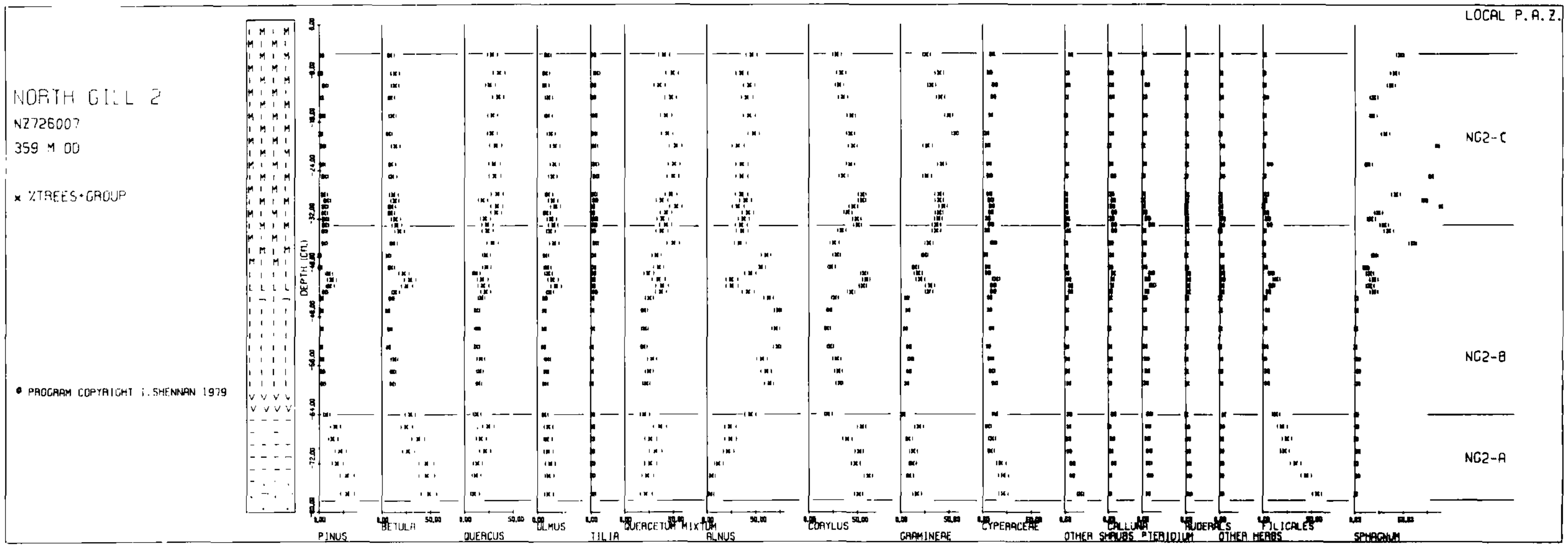
All three Local Pollen Assemblage Zones are referred to Regional Pollen Assemblage Zone NYM - D.

4.18. Forest Clearance History

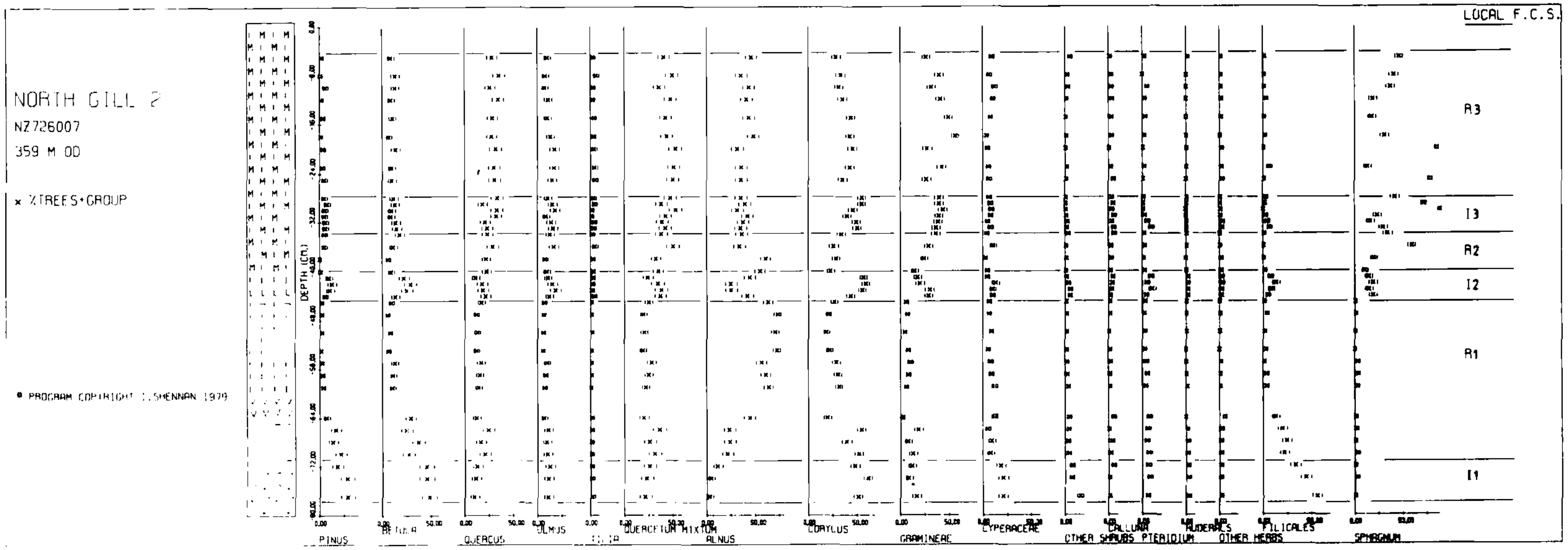
Six local stages in the history of forest clearance at North Gill II are recognised upon figure 21, are applied to figs., 22b and 23b, and are used to zone figure 24 as a basis for description of the evolution of the landscape.

FCS Zonule I1 77 - 71 cms.

The basal zonule records a phase of forest recession which, as charcoal is present in the stratigraphy at this level, may be attributable to fire clearance. Tree pollen accounts for only 25% of total land pollen at the beginning of the zonule, and taxa signifying disturbed and open habitat conditions dominate the assemblage. Herb values are high and include several taxa of ruderal character. Melampyrum and Artemisia are recorded in particularly high frequencies, and Rumex, Urtica, Caryophyllaceae, Succisa and Chenopodiaceae also occur, evidence of the existence of areas of bare, waste land nearby. Pteridium spore frequencies are consistently high and Calluna also expands in value, as these taxa colonised the freshly exposed ground. Heliophyte shrubs are present in high frequencies, favoured by the break in the forest canopy, with Salix, Rosaceae, Sorbus and Fraxinus all of significance. Corylus

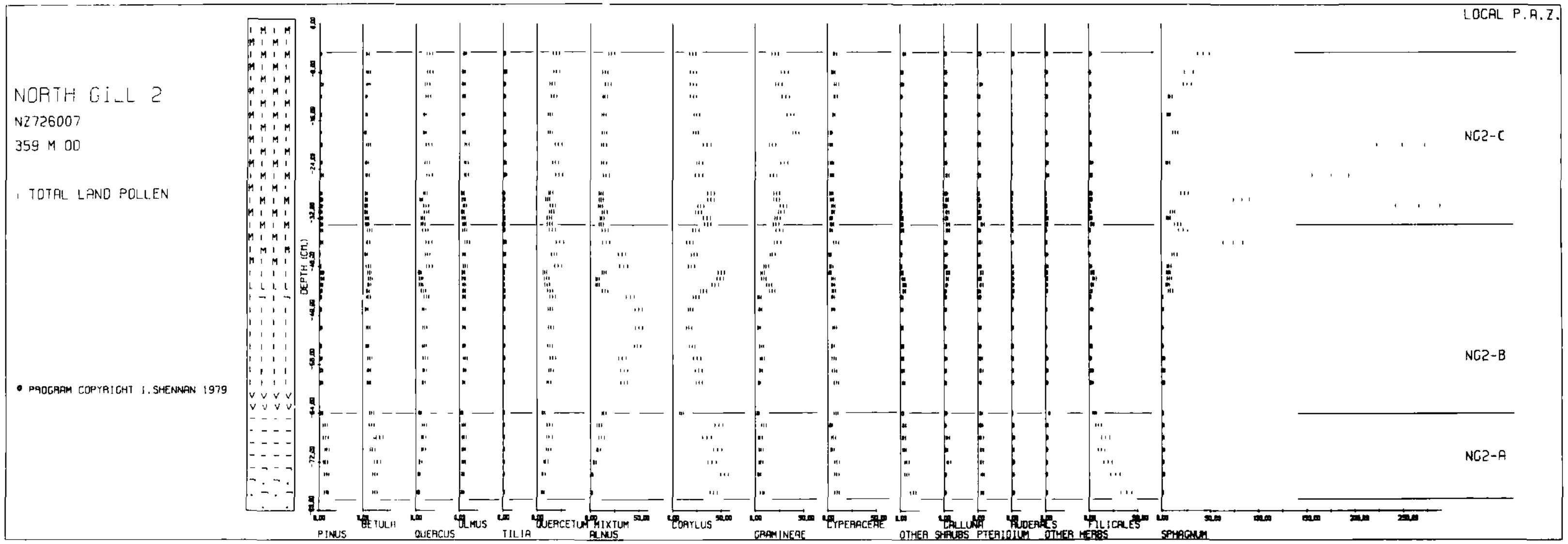


NORTH GILL 2
NZ726007
359 M OD
× %TREES+GROUP
● PROGRAM COPYRIGHT I.SHENNAN 1979
LOCAL P.A.Z.
NG2-C
NG2-B
NG2-A
DEPTH (CM)
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM



NORTH GILL 2
NZ726007
359 M OD
× %TREES+GROUP
● PROGRAM COPYRIGHT I.SHENNAN 1979
LOCAL F.C.S.
R3
I3
R2
I2
R1
I1
DEPTH (CM)
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM

[illegible] Pollen [illegible]



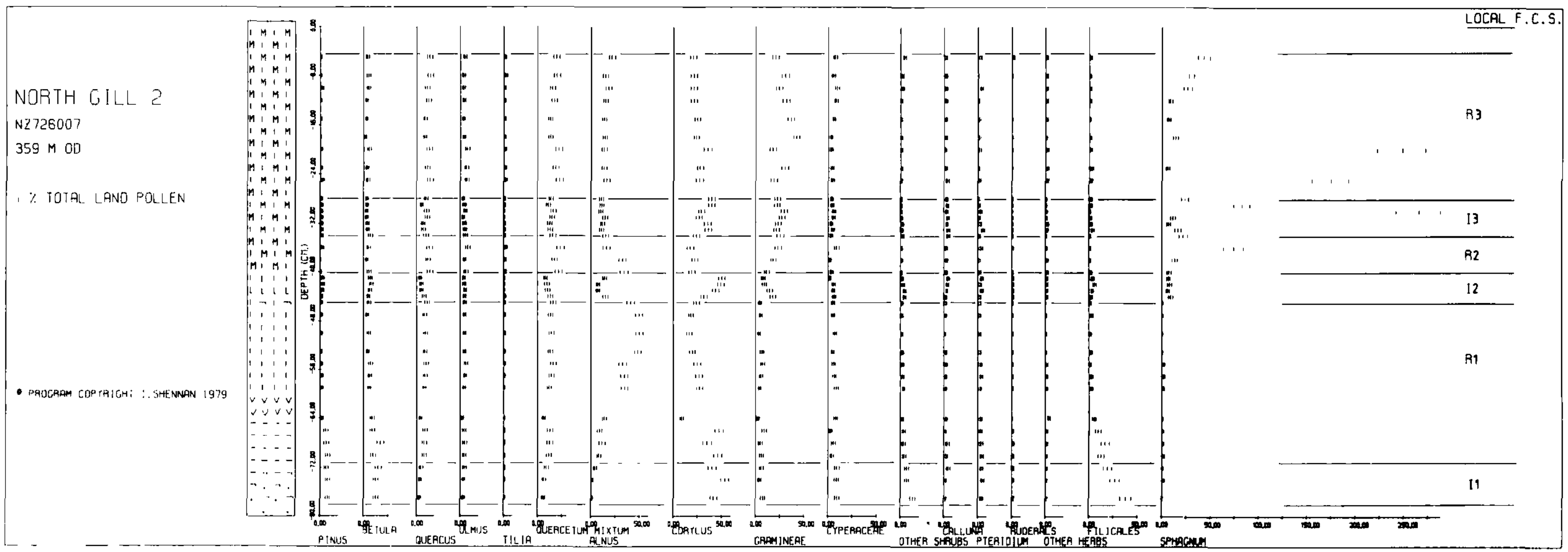
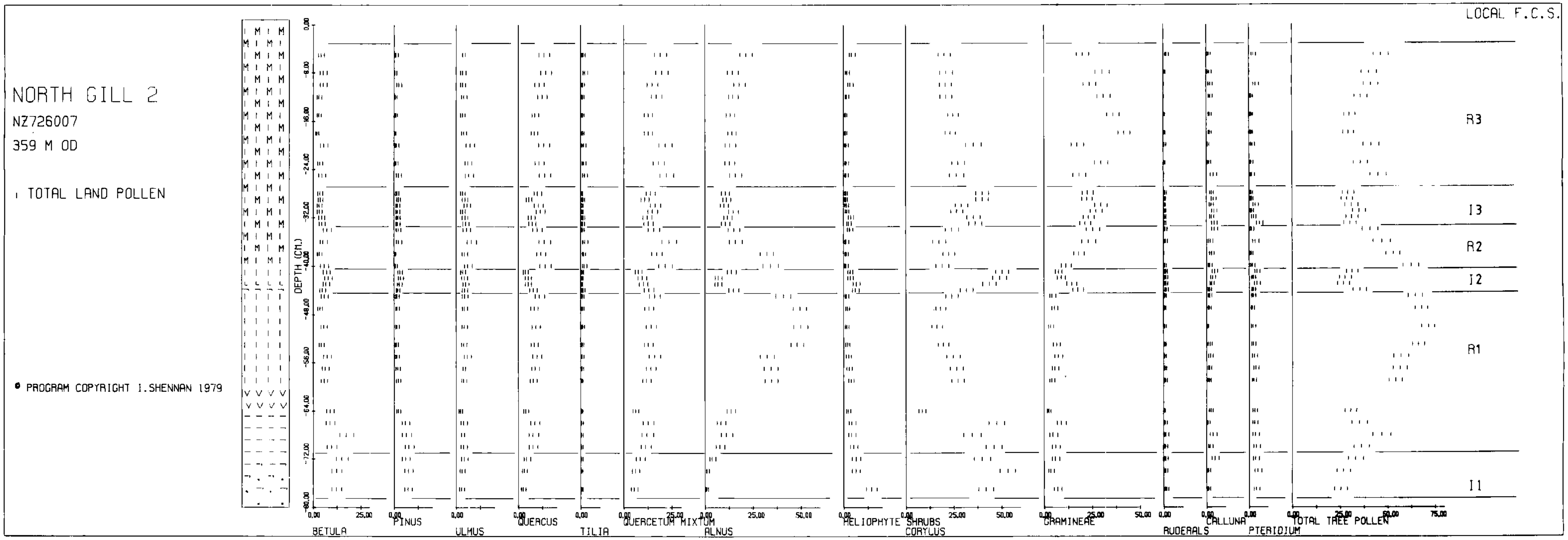


Fig. [illegible]. North Gill II pollen diagram : percentages of total land pollen.



[illegible] of total land pollen.

reaches frequencies of over 50% of total land pollen, evidence of an extensive local retraction of tree cover. Quercus and Alnus, registering extremely low pollen frequencies, may be considered to have been the trees most affected by this removal woodland.

FCS Zonule R1   71 - 45 cms.

A long period of woodland regeneration is described by this phase, as a steady increase in tree pollen frequency occurs until it accounts for over 70% of total land pollen. Regeneration of woodland would therefore appear to have been achieved, although continued high values for Calluna and Pteridium suggest that it may have been incomplete. That clearings remained in the local woodland is intimated by the sporadic occurrence of open habitat herb grains, with Cirsium, Chenopodiaceae, Rumex, Melampyrum, Succisa and Polygonum recorded at intervals. Little fluctuation occurs in tree pollen frequency, however, and it is unlikely that new openings in the forest were being created. Deciduous trees of the Quercetum mixtum expand in value during this phase, but Alnus is responsible for the progressive rise in total tree pollen frequencies, rising to over 50% of total land pollen in the latter part of the zonule, as closure of the tree canopy continued. A sample of peat from the level of a wood layer between 63 and 65 cms., yielded a radiocarbon date of 5,945 ± 90bp (GU-1072).

FCS Zonule I2   45 - 40 cms.

Within this zonule radical fluctuations of the pollen curves for almost all taxa record major forest recession in the vicinity of the site. Again the appearance of charcoal in the stratigraphy suggests that fire clearance was responsible for this reduction in tree cover. Tree pollen falls from 70% to 30% of total land pollen and the assemblage is dominated by ruderal and heliophyte types. A diverse group of dryland herbs is recorded, Melampyrum registering a sharp peak in frequency, as well as Plantago lanceolata, Cruciferae, Polygonum, Cirsium, Centaurea, Rumex, Artemisia, Succisa, Galium, Urtica, Chenopodiaceae and Umbelliferae. This assemblage indicates an extensive area of open ground. Removal of Quercus and Alnus woodland may be deduced from the extreme diminution of pollen frequency for these trees, and this will have provided opportunities for the expansion of a range of shrub and heath taxa. Corylus is most increased, rising to over 50% of total land pollen, but peak frequencies are also shown by Calluna, Pteridium, Salix, Rosaceae, Prunus, Sorbus, Fraxinus and Betula. Pinus values also rise and the beginning of a sustained rise in Gramineae frequencies occurs. A sample of peat from the level of this zonule yielded a radiocarbon date of 5,220 ± 75bp (GU-1073).

FCS Zonule R2 40 - 33 cms.

Following relaxation of clearance pressure upon the vegetation, regeneration of woodland took place and is described by zonule R2. Quercetum mixtum pollen dominates the tree pollen assemblage indicating the recovery of deciduous woodland although Alnus does not approach its former abundance. Fraxinus, Betula, Prunus and Sorbus are still recorded, reflecting the secondary nature of the woodland, but closed canopy conditions seem to have prevailed, Tilia values rising as Betula and Pinus fall. The decline of Corylus, Calluna and Pteridium frequencies records the reoccupation of open areas by tree taxa, confirmed by the absence of ruderal herb types from the assemblage.

FCS Zonule I3 33 - 28 cms.

A further episode of clearance is described by zonule I3 as fluctuations suggestive of woodland recession return to the pollen record. Quercus is again the tree most reduced in frequency, with the contraction of tree cover promoting light demanding taxa such as Corylus, Salix, Rosaceae, Prunus, Sorbus and Fraxinus. Freshly disturbed areas appear to have been colonised by a familiar group of ruderal herbs comprising Melampyrum, Artemisia, Chenopodiaceae, Rumex, Urtica, Succisa and Plantago lanceolata. Calluna and Pteridium also increased in frequency. Although a slight recovery of arboreal pollen types occurs between 30 and 31 cms., further clearance effects may be noted between 29 and 28 cms., when N.A.P. values again rise. A sample of peat from the level of this zonule yielded a radiocarbon date of 5,210 ± 75bp (GU-1071).

FCS Zonule R3 28 - 5 cms.

The final phase of clearance history reflects generally open, but not seriously disturbed, woodland conditions. Homogenous deciduous woodland appears to have existed, although heliophyte shrub types are well in evidence. Dryland herb pollen ceases to be recorded, except at the very end of the zonule, when isolated grains occur. For most of this period, therefore, fresh clearings were presumably not being made in the vicinity of the site. Continued high values for Pteridium, and to a lesser degree for Calluna, show that restoration of tree cover may not have been entirely successful, allowing areas of more open vegetation to remain within the woodland.

North Gill III

4.19. Introduction

The site of North Gill III is situated between lateral transects G and H and on the line of longitudinal transect 5 on figure 7. Figure 11 shows that this area of the site is one of low gradient and may be expected to have been an early focus for peat formation. It lies to the north of those areas of the site which incorporate major wood remains in the profile. The basal charcoal layer is particularly well defined here and the basal sixty centimetres of deposit were sampled. The upper boundary of the sample was levelled to 360.36m OD., and adopted as the site datum. Strata from lithostratigraphic unit NG-L3 to NG-L8 were recovered, although unit NG-L7, the silt layer, did not form a distinct stratum at this site, the grid reference of which is NZ 726 008.

4.20. Site Stratigraphy

After field and laboratory investigation the following stratigraphy was recorded.

Stratum	Depth (cms)	Description
9	0 - 29	$Th^3 2$, Th (vagi)$^2 2$ nig.2, strf.1, elas.1, sicc.2, lim. sup.0 Well humified mid brown peat, containing abundant strands of *Eriophorum vaginatum*, particularly in the upper layers.
8	29 - 31	$Th^3 2$, $Sh^4 2$, Th (vagi)$^2 +$ nig.3, strf.1, elas.1, sicc.2, lim. sup.0 Dark well humified monocot peat with a high fraction of undifferentiated organic material and fragments of *Eriophorum*.

7	31 - 33	$Sh^4$3, anth.1 nig.4, strf.0, elas.0, sicc.2, lim. sup.1 Amorphous black peat with tiny powdery charcoal fragments.
6	33 - 36	$Sh^4$4 nig.4, strf.0, elas.0, sicc.2, lim. sup.1 Undifferentiated, black, very well humified peat.
5	36 - 37	$Sh^4$2, anth.2, Ag+, Dl+ nig.4, strf.0, elas.0, sicc.2, lim. sup.1 Amorphous well humified black peat with a major charcoal content. A high fraction of coarse silt particles is included within the peat, especially at the upper limit of the stratum, and fragments of <u>Betula</u> bark occur.
4	37 - 49	$Sh^4$4, Dl+ nig.3, strf.1, elas.1, sicc.2, lim. sup.0 Well humified dark brown peat with small wood pieces at 47 and 39 centimetres.
3	49 - 54	$Sh^4$2, anth.2, Ag+ nig.4, strf.0, elas.0, sicc.2, lim. sup.2 Black amorphous peat with abundant charcoal pieces and a slight silt fraction near the base of the stratum.
2	54 - 56	Gs3, anth.1, Sh^4+ nig.1, strf.0, elas.0, sicc.2, lim. sup.3 Coarse yellow sand with slight organic partings and numerous small pieces of charcoal.

NORTH GILL III

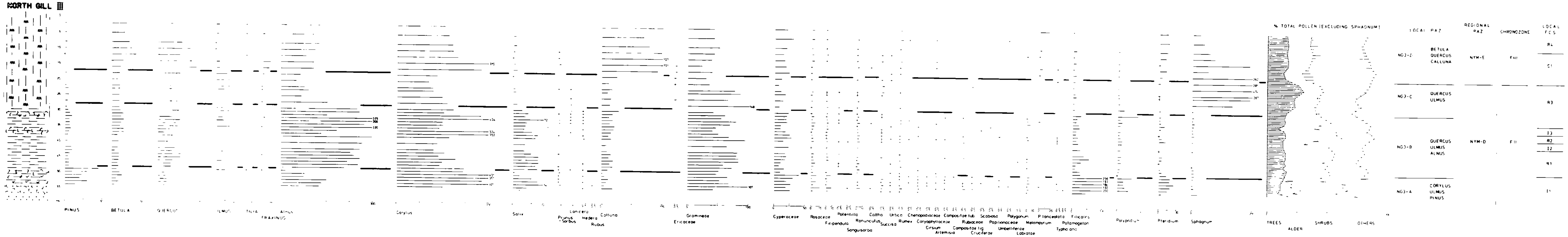


Fig. 25. North Gill III. Pollen diagram : percentages of tree pollen (excluding Alnus).

1	56 - 60	Gs4
		nig.1, strf.0, elas.0, sicc.2, lim. sup.1
		Coarse yellow sand.

Strata 1 and 2 are correlated with lithostratigraphic unit NG-L3, stratum 3 with NG-L4, stratum 4 with NG-L5, stratum 5 with NG-L6 and NG-L7, and strata 6, 7, 8 and 9 with NG-L8.

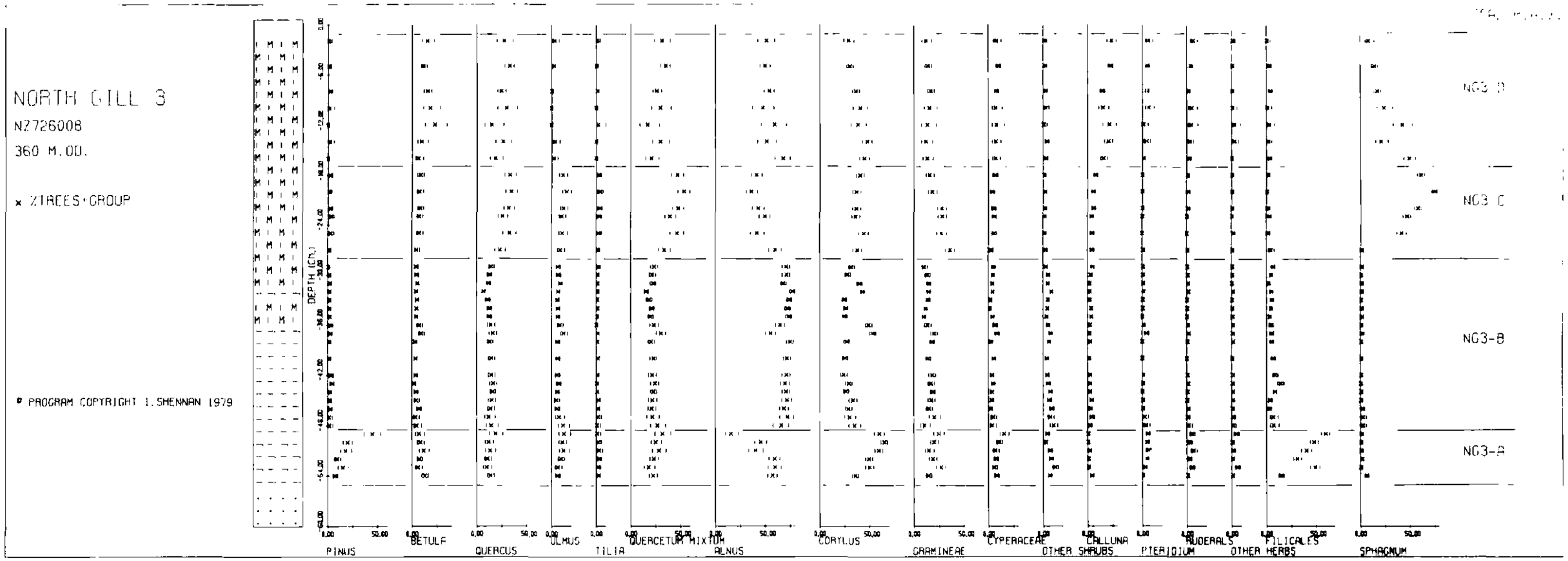
4.21. Pollen Analysis

Samples for pollen analysis were removed from the profile at intervals not exceeding 2 cms., and contiguously from the basal levels. The resulting pollen diagram is shown as figure 25. Four Local Pollen Assemblage Zones are recognised and are applied to figures 26a, 27a and to the pollen concentration diagram, figure 28. These Local Pollen Assemblage Zones are described as follows:

LPAZ NG3 - A 54 - 49

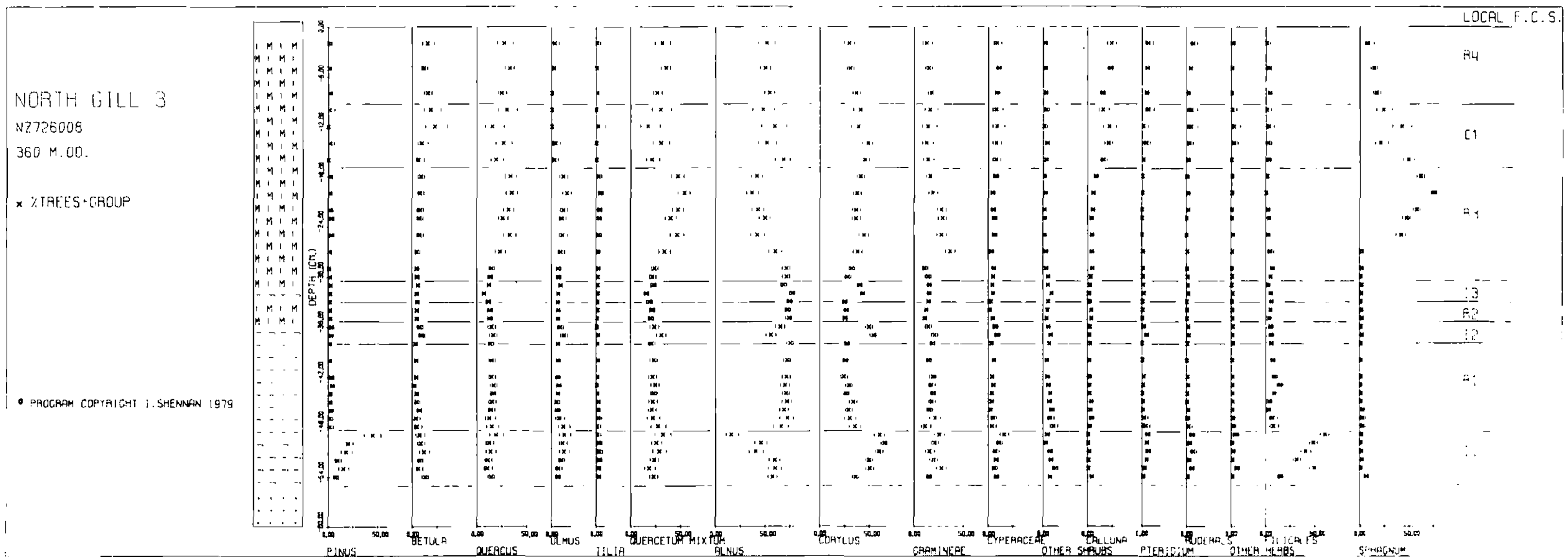
The basal pollen assemblage zone is characterised by *Pinus* and *Ulmus*, the former comprising up to 40% of arboreal pollen. *Quercus* and *Betula* values are depressed at only 20% of A.P., while their pollen concentration is slightly less than that of *Ulmus*. *Tilia* and *Fraxinus* are well represented, their continuous curves each approaching 10% A.P., although concentration of *Tilia* pollen is the higher. Tree pollen frequencies constitute less than 20% of total pollen during this phase and the dominance of N.A.P. types, in terms of both variety and frequency, is most clear. *Alnus* values decline throughout the zone from a peak of only 14% of total pollen. *Corylus* frequencies are very high, expressing more than 40% of total pollen. *Prunus*, *Sorbus*, *Hedera* and *Rubus* also occur, while *Salix* percentages and concentration are particularly

A

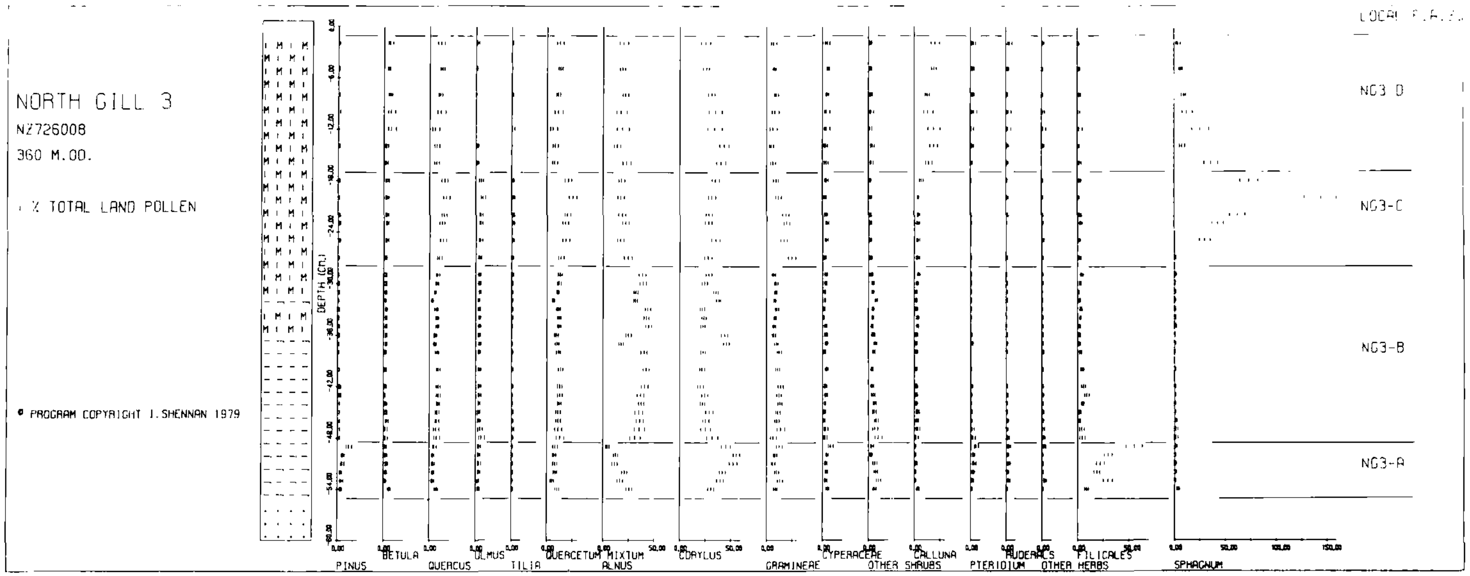


NORTH GILL 3
NZ726008
360 M.OD.
× %TREES+GROUP
© PROGRAM COPYRIGHT I.SHENNAN 1979
DEPTH (CM)
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM
NG3-D
NG3-C
NG3-B
NG3-A

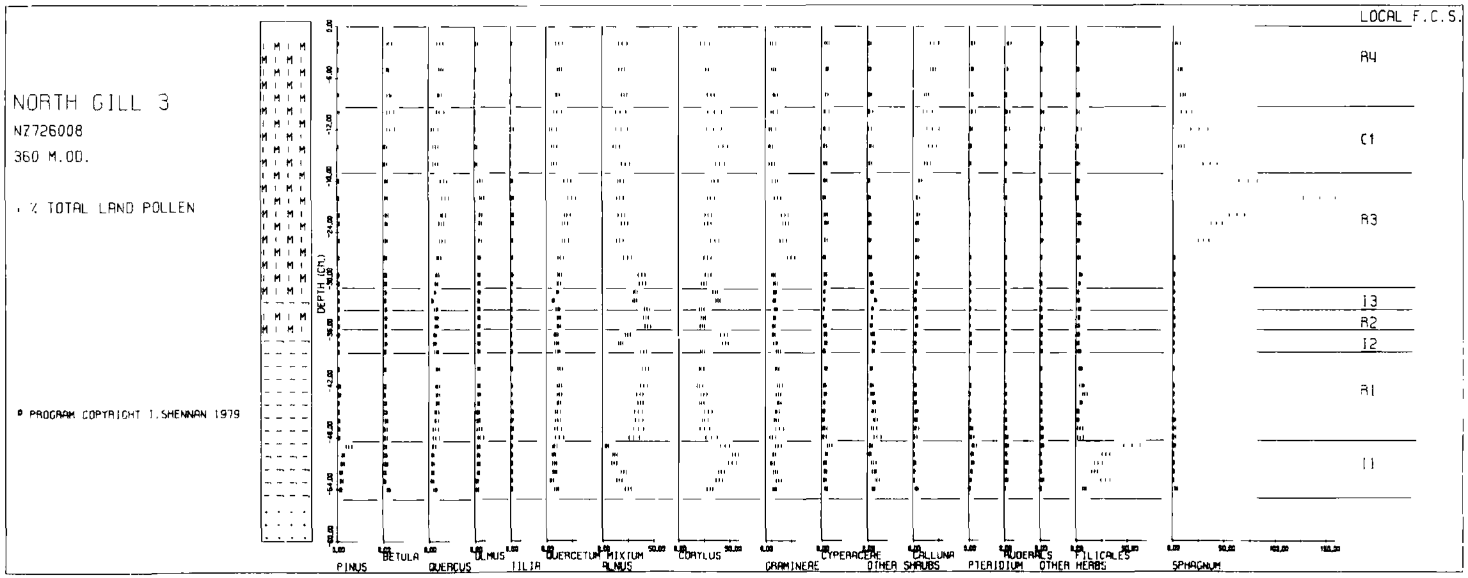
B



NORTH GILL 3
NZ726008
360 M.OD.
× %TREES+GROUP
© PROGRAM COPYRIGHT I.SHENNAN 1979
DEPTH (CM)
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM
LOCAL F.C.S.
R4
C1
R2
A1

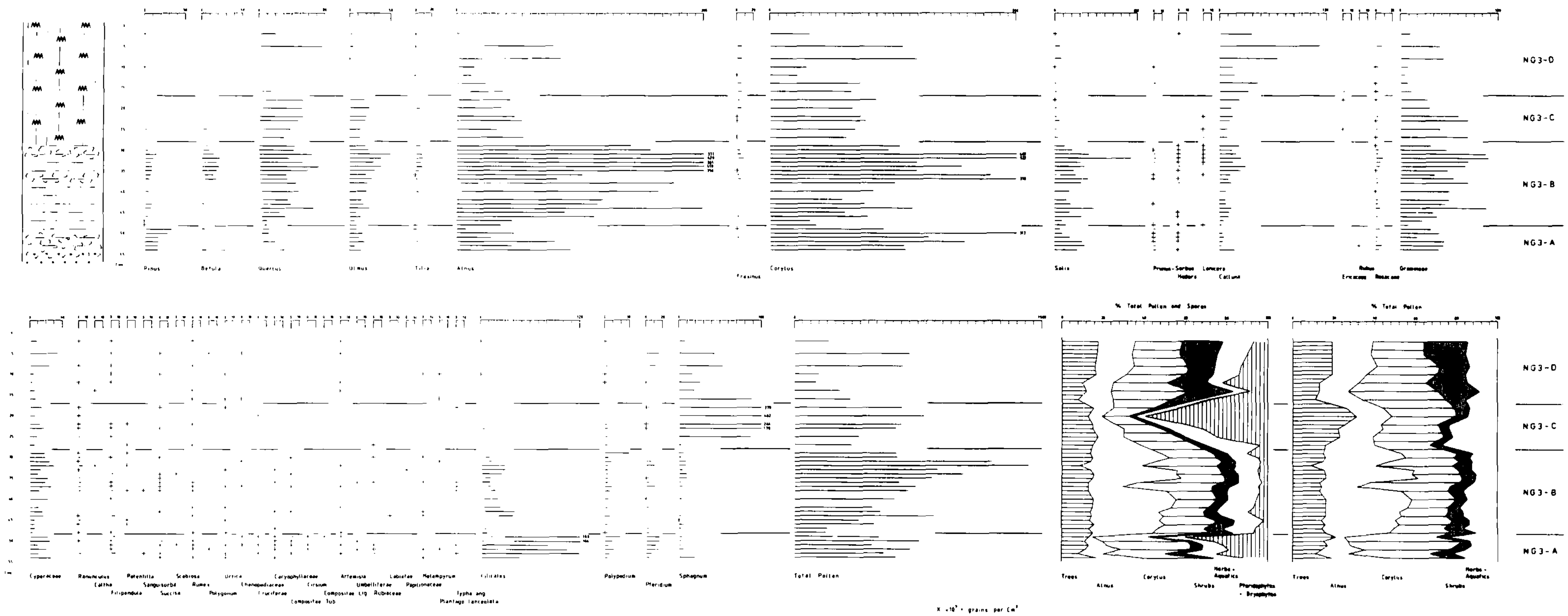


NORTH GILL 3
NZ726008
360 M.OD.
% TOTAL LAND POLLEN
© PROGRAM COPYRIGHT I.SHENNAN 1979
DEPTH (CM.)
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM
LOCAL P.A.Z.
NG3-D
NG3-C
NG3-B
NG3-A



NORTH GILL 3
NZ726008
360 M.OD.
% TOTAL LAND POLLEN
© PROGRAM COPYRIGHT I.SHENNAN 1979
DEPTH (CM.)
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM
LOCAL F.C.S.
A4
C1
A3
I3
A2
I2
A1
I1

NORTH GILL III



[illegible]

prominent. *Calluna*, however, is poorly represented. A varied herbaceous pollen assemblage is recorded, dominated by Gramineae and Cyperaceae. Dampland herbs *Ranunculus* and *Filipendula* are most important, but aquatic and ruderal types are also frequent, although the concentration of all herbaceous pollen is low. Very high Filicales concentrations and percentages are a feature of this zone, and *Polypodium* and *Pteridium* are major contributors to the assemblage. *Sphagnum* values are low. The upper boundary of the zone is drawn where *Pinus* values fall sharply, while *Quercus* and *Alnus* increase.

LPAZ NG3 - B 49 - 28 cms.

Quercus, *Ulmus* and *Alnus* characterise this zone, the latter rising to values of over 40% of total pollen. *Quercus* and *Ulmus* together comprise 75% of A.P., and *Tilia* continues to represent about 10% A.P. Pollen concentration of these taxa rises towards the end of the zone. *Fraxinus* values are high at the beginning and end of the zone. *Pinus* and *Betula* have become minor contributors to the assemblage, although *Betula* concentration does rise sharply near the end of the zone. This zone initially witnesses a decline in *Corylus* frequencies, but both concentration and percentage frequency show a marked expansion later, until peak values for this taxon are reached. *Salix* persists in recording high frequencies, while *Prunus*, *Sorbus*, *Hedera* and *Lonicera* are consistently present. *Calluna* expands steadily as the zone progresses. Shrub pollen as a whole, however, forms a rather less important component of the pollen spectra. Herbaceous taxa of all kinds continue to feature strongly, particularly Gramineae and dampland types, together with the ecologically diverse family Rosaceae. Open habitat indicators continue to be recorded. Pteridophyte spores are as a group much reduced in

Frequency, while Sphagnum spores are still poorly represented. Tree pollen, including Alnus, represents over 50% of the total pollen sum. Total pollen concentration increases throughout the zone until maximum values are reached near the end. The upper boundary of the zone is drawn where Alnus frequencies show a very marked decline.

LPAZ NG3 - C 28 - 17 cms.

The fall in Alnus pollen percentages and concentration continues in this zone until it constitutes less than 15% of total pollen. Quercus and Ulmus form the principal components of the tree pollen assemblage, being unchanged in percentage frequency and only slightly reduced in pollen concentration. Pinus is further reduced in value while Betula frequencies remain steady but low. Tilia is still present as about 10% A.P., and Fraxinus, although fluctuating, is continuously recorded. Corylus representation is once again reduced, but it remains a major contributor with 20% of the total pollen sum. Salix is severely depleted in value and almost ceases to be recorded, while other shrub types are only occasionally present. Calluna values remain low, but Erica tetralix appears for the first time. Herbaceous pollen representation is greatly reduced, both in frequency and variety of types recorded. Open habitat types almost disappear from the pollen spectra, and both Gramineae and Cyperaceae decline steadily during the zone. Dampland herbs still occur, but rather less frequently. Pteridophyte ferns are greatly reduced in value, especially Pteridium. Very high concentrations of Sphagnum spores are recorded, in contrast to the general decline in total pollen and spore concentrations which take place in this zone. Tree pollen percentages dominate the total pollen sum, as N.A.P., types show much reduced frequencies. The upper boundary of the zone is drawn where a decline in Ulmus pollen occurs.

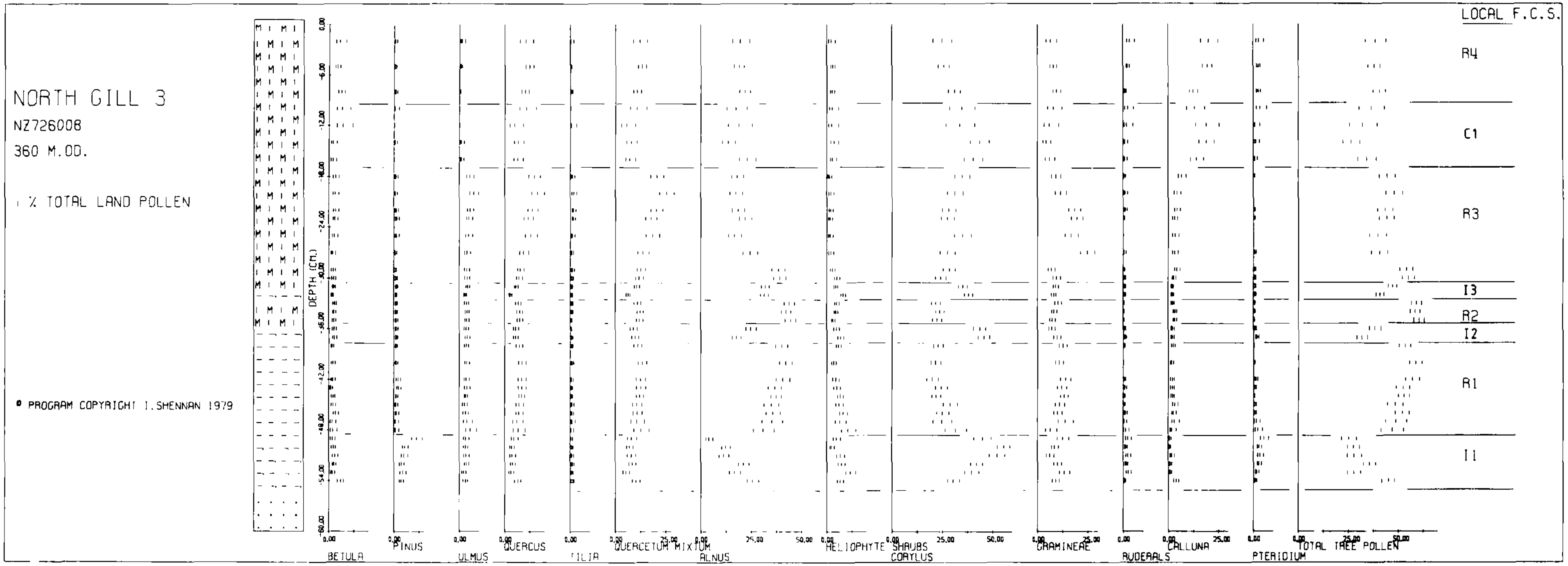
LPAZ NG3 - D 17 - 0 cms.

The diminution of Ulmus pollen frequency which marks the base of the zone is mirrored by Tilia and although both taxa recover slightly as percentages of tree pollen, they do not regain their previous importance and their pollen concentration remains extremely low. While total pollen concentration is at its lowest in the early stages of this zone it rises towards the end. Quercus and Betula are the characteristic tree taxa, but Fraxinus forms a major assemblage component for the first time. A slow rise of Alnus values also takes place. A feature of this zone is a sustained expansion of Calluna values which causes shrub pollen to account for over 40% of total pollen. Corylus is implicated in this rise while Salix and Prunus also contribute. A.P.:N.A.P., ratio remains steady during this zone and very little fluctuation is recorded following the initial fall in tree pollen at the base of the zone. Herbaceous taxa are represented mainly by Gramineae and Cyperaceae, but Plantago lanceolata rises to high frequencies late in the zone. Pteridium is also greatly increased, although the other fern types remain in low percentages and concentrations. Sphagnum values decline throughout the zone.

The three lower zones NG3 - A, NG3 - B and NG3 - C are assigned to regional assemblage zone NYM - D. Local zone NG3 - D is assigned to regional zone NYM - E.

4.22. Forest Clearance History

Eight local stages in the history of forest clearance at North Gill III are recognised upon figure 25, are applied to figures 26b and 27b, and are used to zone figures 29 and 30 as a basis for description of the evolution of the landscape.


NORTH GILL 3
NZ726008
360 M.OD.
% TOTAL LAND POLLEN
© PROGRAM COPYRIGHT I. SHENNAN 1979
DEPTH (CM.)
LOCAL F.C.S.
R4
C1
R3
I3
R2
I2
R1
I1
BETULA
PINUS
ULMUS
QUERCUS
TILIA
QUERCETUM MIXTUM
ALNUS
HELIOPHYTE SHRUBS
CORYLUS
GRAMINEAE
RUDERALS
CALLUNA
PTERIDIUM
TOTAL TREE POLLEN

NORTH GILL 3 NZ726008

Pollen Concentration $\times 10^3$ grains / cm^3

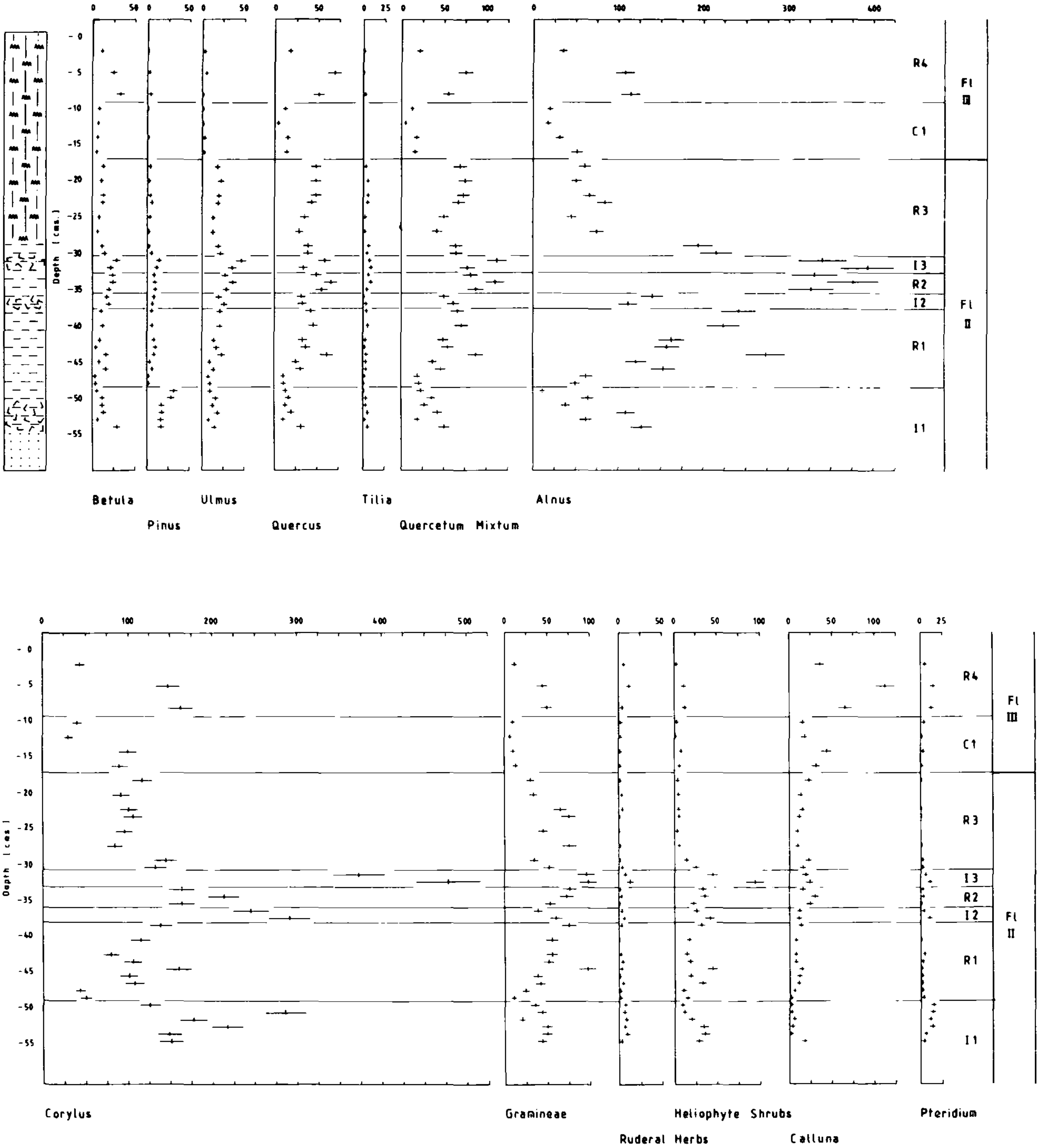


Fig. 30. North Gill III. Pollen diagram : pollen concentration of selected clearance taxa (grains x 10^3/cc).

FCS Zonule I1 54 - 49 cms.

The basal charcoal impregnated peat corresponds with the basal clearance zonule I1, suggesting fire clearance of woodland to be the origin of the pollen fluctuations recorded. Total tree pollen values are low, reaching only 25% of total land pollen and in their place is a great expansion of clearance indicators. Herbs of ruderal affinities are represented by a diverse assemblage, within which Melampyrum, Rumex, Urtica, Artemisia and Plantago lanceolata are prominent, but which also incorporates Cirsium, Succisa, Cruciferae, Chenopodiaceae, Caryophyllaceae, Compositae, Polygonum and Scabiosa. Indicators of fire-disturbed woodland are present in high frequencies, especially Corylus and Pteridium. Continuous Calluna and Fraxinus curves occur also. Heliophyte shrubs are also much encouraged, including Salix, Prunus, Sorbus, Rubus and other Rosaceous types, while Gramineae values are consistently high. Alnus especially, and Quercus, are present in very low frequencies, suggesting that they were the taxa most subject to clearance, and are replaced by a regeneration complex of herb and shrub communities. The pollen concentration diagram (fig. 30) shows similar fluctuations to those of figure 29, indicating that they reflect real, and not statistical events.

FCS Zonule R1 49 - 38 cms.

The period of woodland regeneration which follows sees the removal of clearance effects and the restoration of stable woodland communities. Tree pollen values achieve over 50% of total land pollen with Quercus and Alnus frequencies much increased. Herbaceous taxa, including dryland types, do not disappear from the diagram completely and it would appear that some areas of open ground still existed in the vicinity of the site. Pteridium and Fraxinus values fall slowly and

Corylus increases in both percentage and concentration. Pollen concentration curves confirm the regeneration character of this phase.

FCS Zonule I2 38 - 35 cms.

A further period of forest recession ensues which is described by zonule I2, again coincident with the appearance of charcoal in the peat profile. Alnus and Quercus are much reduced in value, amid a general fall in tree pollen frequencies to around 30% of total land pollen. The pollen concentration evidence supports the view that these taxa, and particularly Alnus, were less abundant during this phase. Ruderal pollen returns to the assemblage, with Melampyrum, Rumex, Compositae, Chenopodiaceae, Urtica, Succisa and Artemisia all recorded. Pteridium and Corylus again expand in both relative and concentration terms, the latter again to 50% of total land pollen. Supportive evidence of woodland dislocation and canopy opening again appears in the form of increased representation of heliophyte shrubs, principally Salix, but incorporating Prunus, Sorbus and Fraxinus. An increase in Rosaceous values may well be attributable to shrubs of this type. The pollen concentration evidence (fig. 30) highlights the extreme diminution of the amount of Alnus pollen and the sharp increase in Corylus pollen at this time, as deciduous woodland was locally replaced by Corylus dominated scrub or clearings containing herb, grass and heath associations.

FCS Zonule R2 35 - 33 cms.

A brief regeneration phase (R2) follows during which much of the ground lost by the deciduous woodland appears to have been recovered, for tree pollen values are amongst the highest attained on the entire diagram (fig. 29), approaching 60% of total land pollen. The concentration of Alnus pollen is high, as is that of Quercetum mixtum, and reflects increasingly dense forest cover. Corylus frequencies are reduced to only 25% of total land pollen, and comparable declines occur in the pollen or spore frequencies of most taxa indicative of open conditions, with the exception of Calluna. Dryland herb taxa are almost absent from the assemblage, and few clearings will have remained within the woodland.

FCS Zonule I3   33 - 31 cms.

A third clearance episode takes place between these levels and charcoal again occurs in the stratigraphy. Quercus especially, and Alnus, again decline on the relative pollen diagram (fig. 29), and total tree pollen falls to about 40% of total land pollen, although concentration of Alnus pollen (fig. 30) remains high. Plantago lanceolata, Artemisia, Melampyrum, Rumex, Succisa, Urtica, Chenopodiaceae and Compositae Tubuliflorae comprise the ruderal herb assemblage. Gramineae, Pteridium and Salix frequencies and concentrations rise markedly, but it is with Corylus that the greatest expansion occurs, suggesting local abundance of this shrub in the regenerating woodland. High frequencies for Fraxinus and Betula confirm the open, secondary status of the woodland during this phase, as ruderal herb and shrub communities expand with the removal of tree cover from the vicinity of the site.

FCS Zonule R3   31 - 17 cms.

Woodland regeneration continues unbroken during this phase with little variation in its composition occurring except a reduction in both the concentration and relative frequency of Alnus. Tree pollen remains steady at about 45% of total land pollen with Quercus increasingly dominant. Ruderal herb taxa do not contribute to the assemblage with the exception of occasional grains of Succisa and Rumex, while Pteridium, especially, and *Calluna* are restricted to low frequencies. While *Salix* values fall, *Corylus* and *Fraxinus* remain prominent, suggesting that the woodland, though undisturbed, was of an open nature. Failure to regenerate to stable mature woodland had occurred in some areas, so that clearings in the forest remained which supported heath or scrub vegetation only.

FCS Zonule C1 17 - 9 cms.

The decline in *Ulmus* pollen which marks the beginning of this zonule initiates a period of forest clearance which gains expression upon fig.29 by a sharp fall in tree pollen values, primarily those of *Quercus* and *Tilia* as well as *Ulmus*. *Pteridium* and *Corylus* values rise but most extensive are the rises in frequency of *Betula* and *Calluna* pollen. *Plantago lanceolata* rises to high frequencies and *Artemisia*, *Rumex* and *Urtica* are also recorded. Heliophyte shrubs and trees, *Salix*, *Prunus*, *Sorbus* and *Fraxinus* increase sharply in frequency, encouraged like *Corylus* by the opening of the woodland canopy.

FCS Zonule R4 9 - 0 cms.

Regeneration of woodland and the maintenance of stable, ecological conditions characterise this zone, with tree pollen values consistently representing about 40% of total land pollen. The open nature of the woodland is suggested by continued high frequencies for heliophyte types, including *Corylus*, *Pteridium* and *Calluna*. Occasional dryland herb grains are recorded, particularly *Artemisia* and *Rumex*, and a continuous *Plantago lanceolata* curve occurs, testifying to the existence of open ground nearby. *Quercus* and *Alnus* were the main constituents of the woodland, but *Betula* and *Fraxinus* were also important. Though of an open, secondary type, the stability of total tree pollen frequencies suggests that the woodland remained undisturbed during this phase.

North Gill Head

4.23. Introduction

The fourth pollen analytical site at North Gill was located to the south of lateral transect C and on the line of longitudinal transect 5, on figure 7. Designated North Gill Head, it is intended to record conditions at the northern edge of the site, and upon the nearby flat moorland plateau itself. As this site lies to the north of the major areas of stream erosion and exposure of peat faces, collection of samples was accomplished with a Russian Borer. The surface of the borehole was levelled to 366.48m OD., and 1.80 metres of deposit were recovered, representing a succession from lithostratigraphic unit NG-L3, to NG-L9, although unit NG-L7 is not recorded. The grid reference is NZ 726 008.

4.24. Site Stratigraphy

Following field and laboratory investigation the following stratigraphy was recorded.

Stratum	Depth (cms)	Description
11	0 - 22	Str. conf. Tl2, $Sh^4 1$, anth.1 Burnt, disturbed surface layers of *Calluna* dominated peat. Loose charred organic material with rootlets of ash and heather.
10	22 - 86	Th (*vagi*)^{2}3, Tb (*Sphag*)^{1}1, Tl+, anth.+ nig.2, strf.2, elas.2, sicc.2, lim. sup.1 Partly humified *Eriophorum* peat. Fresher *Sphagnum* layers at 47 cms., and 62 cms., with occasional *Calluna* rootlets and pieces of charcoal.

9	86 - 112	Th^{3}3, Th (*vagi*)^{0}1, Tb (*Sphag*)^1+, anth.+ nig.3, strf.1, elas.1, sicc.2, lim. sup.0 Well humified monocot peat with fresh strands of *Eriophorum* at 97, 101, and 108 cms. Poorly humified *Sphagnum* leaves at 104 cms., and small pieces of charcoal throughout, especially abundant in the lower part of the stratum.
8	112 - 125	Th (*vagi*)^{1}4 nig.2, strf.2, elas.3, sicc.2, lim. sup.0 Poorly humified peat composed entirely of *Eriophorum vaginatum*, with a heavy macrofossil content.
7	125 - 148	Th^{3}2, Th (*vagi*)^{2}2, anth.+ nig.3, strf.1, elas.1, sicc.2, lim. sup.1 Humified dark brown monocot peat with a high proportion of well humified fragments of *Eriophorum*.
6	148 - 162	Sh^{4}4, anth.+ nig.4, strf.0, elas.0, sicc.2, lim. sup.2 Black amorphous peat, very well humified. Carbonised plant tissue and tiny charcoal pieces at 158 cms.
5	162 - 164	Sh^{4}2, anth.2 nig.4, strf.1, elas.1, sicc.2, lim. sup.1 Black undifferentiated peat with a high proportion of charcoal fragments throughout.

4	164 - 170	$Sh^4 4$ nig.4, strf.0, elas.0, sicc.2, lim. sup.1 Very well humified black, amorphous peat.
3	170 - 174	$Sh^4 3$, Ga 1 nig.3, strf.0, elas.0, sicc.2, lim. sup.1 Dark, well humified undifferentiated organic material with a high mineral fraction, increasing markedly towards the base of the stratum, mainly fine sand particles.
2	174 - 176	$Sh^4 2$, Ga 1, anth.1 nig.3, strf.0, elas.0, sicc.2, lim. sup.0 Minero-organic material, incorporating a considerable amount of charcoal, primarily small, fragmented pieces.
1	176 - 180	Ga 2, Gs 2 nig.1, strf.0, elas.0, sicc.2, lim. sup.3 Sandy mineral horizon, including both fine and coarse particles, mixed nearly equally through the deposit. No organic inclusions noted.

Stratum 1 is correlated with lithostratigraphic unit NG-L3 (fig.16), stratum 2 with NG-L4, strata 3 and 4 with NG-L5, stratum 5 with NG-L6, strata 6 and 7 with NG-L8 and strata 8, 9, 10, and 11 with NG-L9. Unit NG-L7 is not represented at this site.

4.25. Pollen Analysis

Samples were taken for pollen analysis from the lower part of the core at 2cm., intervals, closing to contiguous sampling near the base.

Pollen diagrams were constructed and are displayed as figures 31, 32a and 33a. Four Local Pollen Assemblage Zones are recognised and are described as follows:

LPAZ NGH - A 176 - 171 cms.

This basal assemblage zone is characterised by low values of A.P., relative to N.A.P. Pinus and Ulmus are the major contributors to the tree pollen sum, at 35% and 25% of A.P., respectively. Quercus and Alnus values are very low indeed, together accounting for only 6% of total pollen, while Tilia occurs at a single horizon and Fraxinus is entirely absent. Betula representation rises throughout the zone. The assemblage is dominated, however, by shrub pollen and in particular by Corylus which consistently exceeds 50% of total pollen. High values are also reached for Salix and Calluna. A restricted range of herbaceous taxa is recorded, but includes ruderal as well as dampland types. Gramineae and Cyperaceae are present in moderate but sustained frequencies. Filicales and Pteridium are the major fern spore types, with Polypodium poorly represented. Sphagnum frequencies are low. The upper boundary of the zone is drawn where Pinus frequencies fall and those of Quercus rise.

LPAZ NGH - B 171 - 164 cms.

Quercus expands throughout this zone and, with Ulmus, which remains at 20% of tree pollen, characterises it, although other A.P. taxa are well in evidence. Pinus, while declining, is still recorded in values of up to 20% of the tree pollen sum, and Betula rises to a peak in the early part of the zone. Alnus increases but is still below 10% of total pollen, while the Tilia curve becomes continuous at about 5% of A.P. Corylus, although declining from the maximum frequencies of the previous

NORTH GILL HEAD

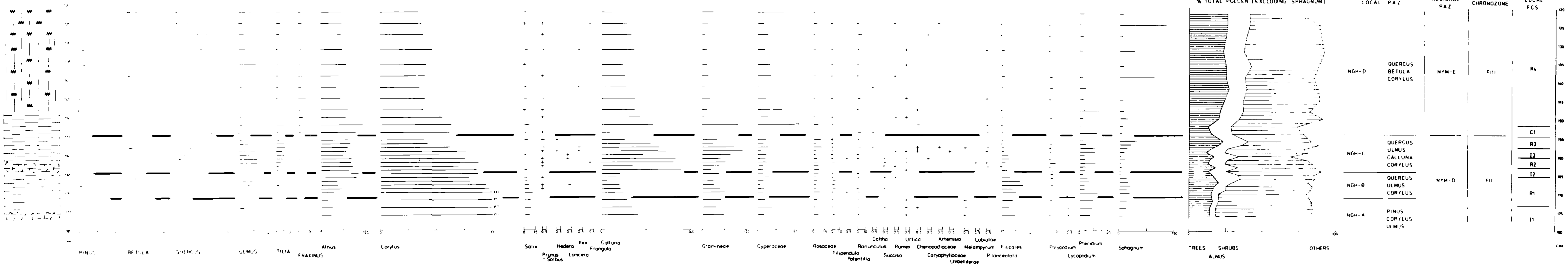
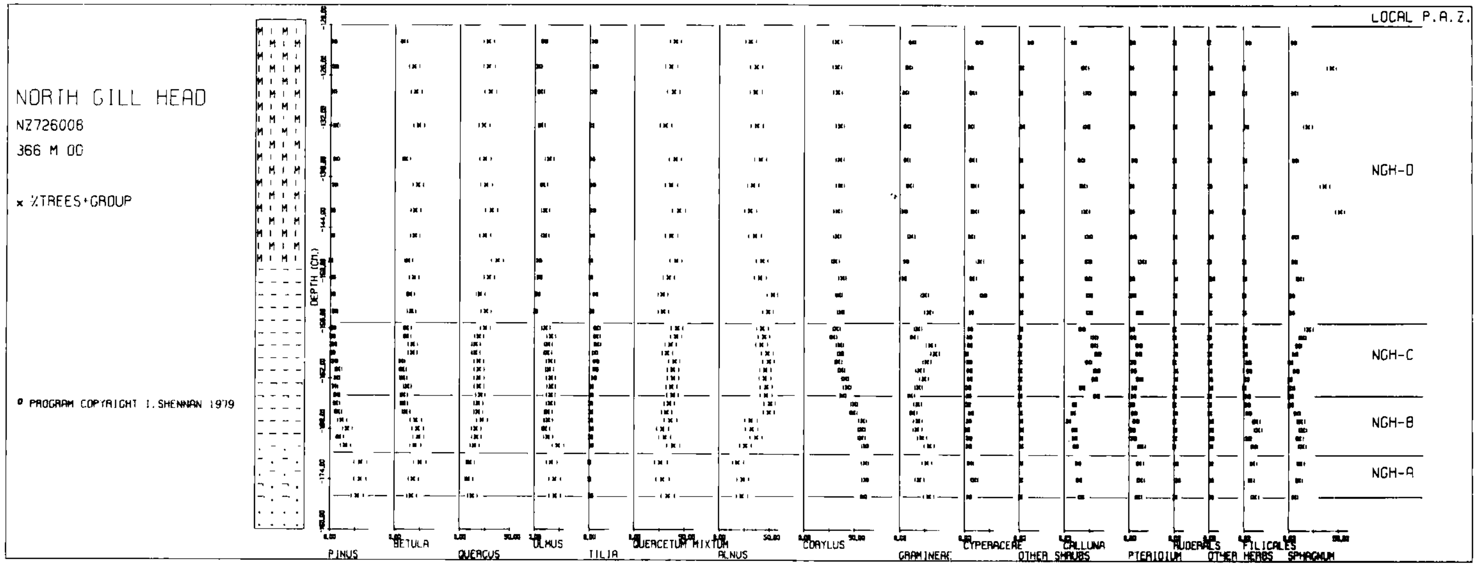
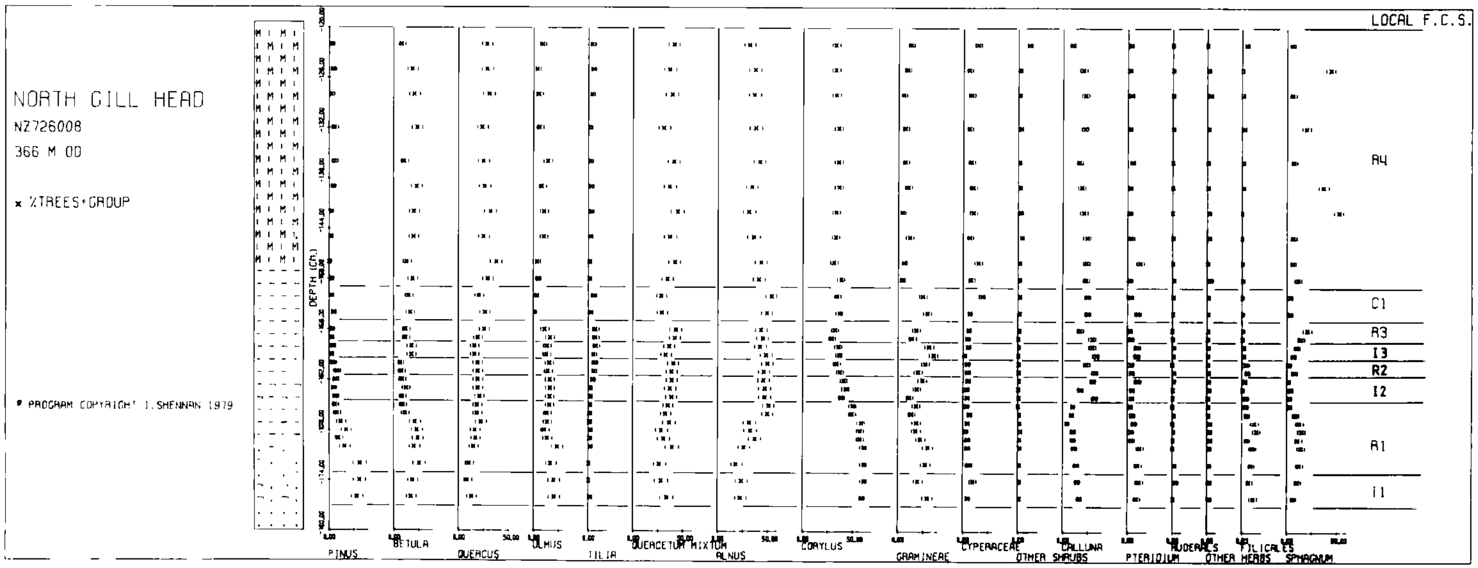
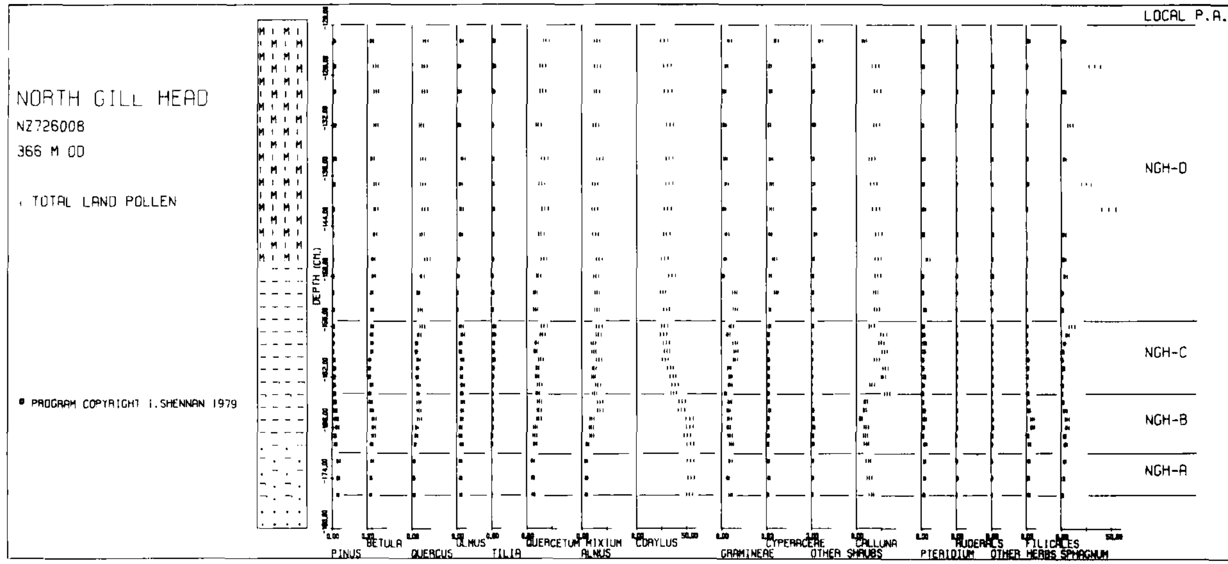
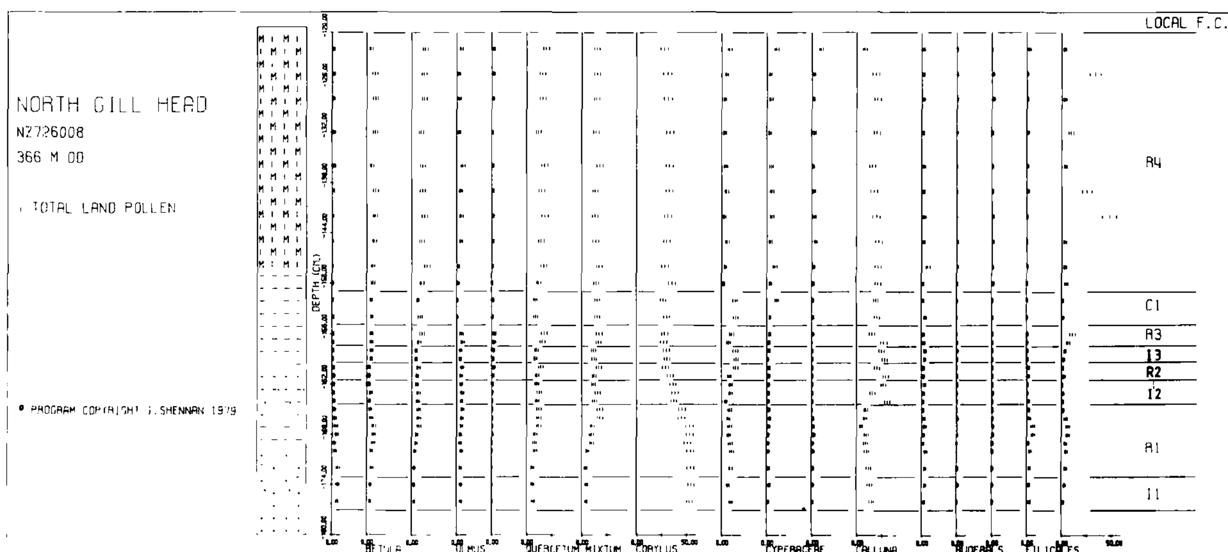


Fig. 31. North Gill Head. Pollen diagram : percentages of tree pollen (excluding *Alnus*).


NORTH GILL HEAD
NZ726008
366 M OD
× %TREES+GROUP
© PROGRAM COPYRIGHT I.SHENNAN 1979
DEPTH (CM.)
LOCAL P.A.Z.
NGH-D
NGH-C
NGH-B
NGH-A
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM


NORTH GILL HEAD
NZ726008
366 M OD
× %TREES+GROUP
© PROGRAM COPYRIGHT I.SHENNAN 1979
DEPTH (CM.)
LOCAL F.C.S.
A4
C1
A3
I3
R2
I2
A1
I1
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM


NORTH GILL HEAD
NZ726008
366 M OD
% TOTAL LAND POLLEN
© PROGRAM COPYRIGHT I.SHENNAN 1979
LOCAL P.A.Z.
NGH-D
NGH-C
NGH-B
NGH-A
DEPTH (CM)
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM


NORTH GILL HEAD
NZ726008
366 M OD
% TOTAL LAND POLLEN
© PROGRAM COPYRIGHT I.SHENNAN 1979
LOCAL F.C.S.
A4
C1
A3
I3
R2
I2
A1
I1
DEPTH (CM)
PINUS
BETULA
QUERCUS
ULMUS
TILIA
QUERCETUM MIXTUM
ALNUS
CORYLUS
GRAMINEAE
CYPERACEAE
OTHER SHRUBS
CALLUNA
PTERIDIUM
RUDERALS
OTHER HERBS
FILICALES
SPHAGNUM

zone, still accounts for over 35% of all grains recorded. While Salix remains prominent, Prunus, Sorbus and Lonicera are introduced to the assemblage. Fraxinus, however, is not present. Calluna and Gramineae are both somewhat reduced in value, and herbaceous pollen in general is less well represented, especially in the range of taxa recorded, ruderal types disappearing from the record almost entirely. Rosaceous pollen types occur in high frequencies, accompanied by Filipendula and Ranunculus. Filicales attains peak values in this zone and Pteridium, while declining, is still significant. Sphagnum values are slightly increased. While tree pollen, including Alnus, is improved in frequency, N.A.P. types still form 70% of the total pollen sum. The upper boundary of this zone is drawn where Calluna, in the context of a general expansion of N.A.P. types, rises to high frequency.

LPAZ NGH - C 164 - 155 cms.

Quercus and Ulmus continue to dominate the tree pollen assemblage during this zone, together providing 75% of A.P. Tilia also expands in value while Pinus and Betula are much reduced, although the latter recovers towards the end of the zone. Fraxinus is sporadically recorded for the first time. Corylus declines as the zone progresses, being replaced as major shrub taxon by Calluna which rises to 30% of total pollen. Salix, Prunus and Sorbus are joined by Hedera, Lonicera Ilex and Frangula. A major increase in the representation of herb taxa takes place, with many types appearing for the first time, and others, such as Gramineae, Rosaceae and Ranunculus increasing markedly. Open habitat taxa feature in this expansion, Artemisia and Plantago lanceolata occurring. Pteridophyte spores are low in frequency, with the exception of Pteridium which fluctuates markedly and attains peaks of over 20% A.P.

Sphagnum shows increased frequencies at the end of the zone. The upper boundary of the zone is drawn where Ulmus pollen values show a sharp decline.

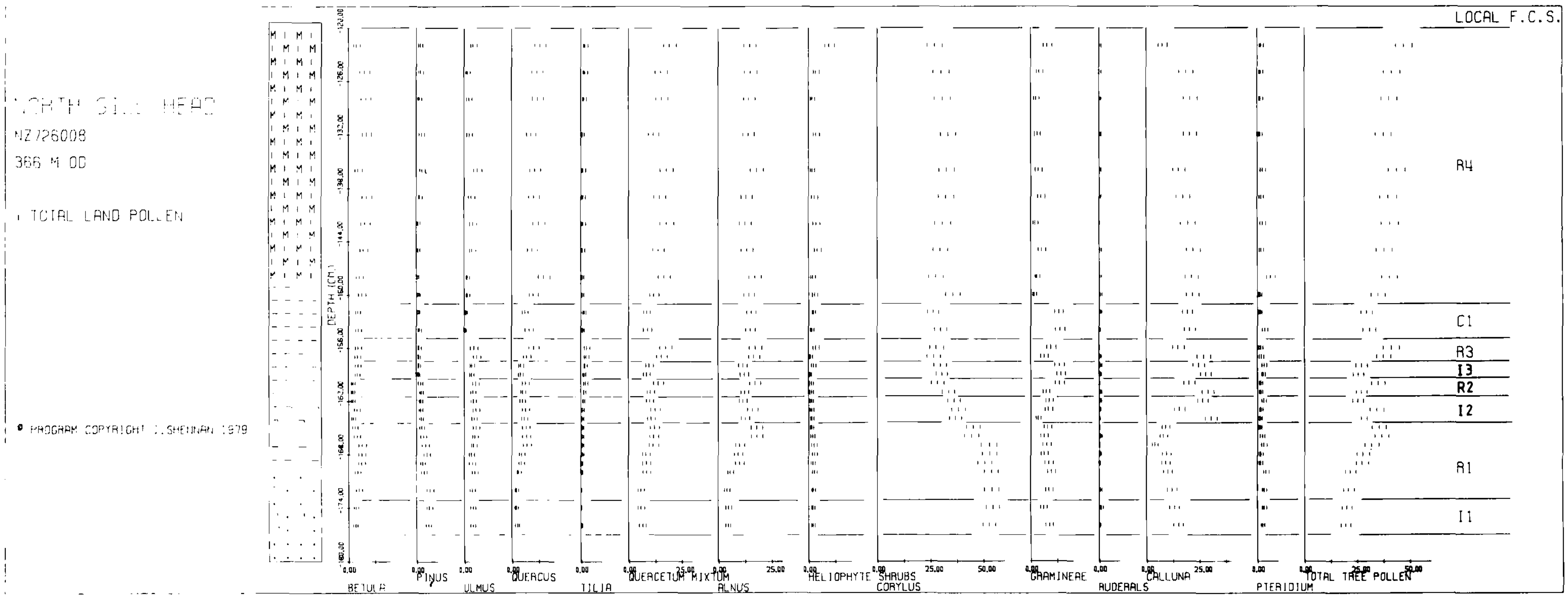
LPAZ NGH - D 155 - 120 cms.

Tree pollen rises in frequency in this zone until, including Alnus, it dominates the assemblage, representing over 40% of total pollen. Ulmus is restored to substantial values following its initial decline, but Quercus is the major tree pollen contributor, with the gradually expanding Betula. Tilia is less prominent, declining with Ulmus at the beginning of the zone, but is still responsible for 10% of the tree pollen sum, as is Fraxinus. This latter taxon, like Pinus, is continually present in moderate frequencies. Alnus is reduced in value from its maximum of the previous zone and Corylus shows consistent values of about 30% of total pollen. Other shrub pollen representation is reduced, although Salix, Prunus, Sorbus and Ilex are still recorded. Calluna suffers a steady diminution in frequency, as does Gramineae. N.A.P. as a whole is restricted, and while a wide range of taxa are recorded, they occur as individual grains or in reduced percentages. Sphagnum values are still low, although some horizons show isolated peaks. Only Pteridium is of significance among the fern spore count, but declines as the zone proceeds.

The three lower zones, NGH - A, NGH - B and NGH - C are all referred to regional assemblage zone NYM - D, while zone NGH - D is referred to regional zone NYM - E.

4.26. Forest Clearance History

Eight local stages in the history of forest clearance at North Gill Head are recognised upon figure 31, are applied to figures 32b and



NORTH GILL HEAD
NZ726008
366 M OD
% TOTAL LAND POLLEN
© PROGRAM COPYRIGHT I.SHENNAN 1979
DEPTH (CM)
LOCAL F.C.S.
R4
C1
R3
I3
R2
I2
R1
I1
BETULA
PINUS
ULMUS
QUERCUS
TILIA
QUERCETUM MIXTUM
ALNUS
HELIOPHYTE SHRUBS
CORYLUS
GRAMINEAE
RUDERALS
CALLUNA
PTERIDIUM
TOTAL TREE POLLEN

33b and are used to zone figure 34 as a basis for description of the evolution of the landscape.

FCS Zonule I1   176 - 173 cms.

The basal zonule I1 records a landscape dominated by shrub and herb communities, and the recovery of charcoalfrom the peat profile suggests that its treeless nature may be at least in part consequent upon disturbance of the environment by fire. Tree pollen values represent only 20% of total land pollen with Pinus, Betula and Ulmus apparently the major woodland constituents. Quercus and Alnus frequencies are very low and these taxa were evidently those most seriously affected by clearance activity. Dryland herb values are high, indicating the presence of open, disturbed environments nearby, and Melampyrum, Urtica, Chenopodiaceae and Succisa are recorded. Colonisation of cleared areas was effected by Pteridium and Calluna, both of which register peak frequencies, while the development of scrub thickets following the removal of tree cover is suggested by high values for most light-demanding shrub taxa. Corylus in particular is abundant in the regeneration communities, accounting for over 50% of total land pollen, with Salix frequencies also high.

FCS Zonule R1   173 - 164 cms.

The frequency of taxa indicative of open conditions is steadily reduced during this zonule and tree pollen increases gradually until it reaches 35% of total land pollen. Ruderal herb grains are not in evidence suggesting, in the context of the rise in tree pollen frequency, that no new areas were subject to clearance and regeneration of tree growth was progressing nearby. Non-tree pollen types continue to dominate the assemblage, however, and it seems that scrub woodland, rather than mature forest, characterised the local vegetation. Corylus was its major constituent, but also present were other shrub types Salix, Prunus, Rosaceae and Calluna, testifying to its heliophyte character, a feature supported by the increase in Betula frequency among tree pollen types and continued high values for Pteridium spores. Although forest was probably missing from the locality of the site the virtual absence of dryland herb pollen signifies that the Corylus scrub must have been dense, with areas of bare ground restricted. Tree pollen, particularly of Quercetum mixtum and Alnus, recovers in frequency near the end of the zonule, as tree growth perhaps became re-established around the site.

FCS Zonule I2   164 - 162 cms.

Indicators of clearance return to the pollen record at this level with tree pollen values fluctuating, and falling to just over 25% of total land pollen. The sharply declining Corylus curve recovers slightly and Fraxinus is recorded for the first time, but the greatest increases in frequency are shown by Pteridium and Calluna, the latter rising sharply to 30% of total land pollen. A number of ruderal herb taxa are reintroduced to the pollen assemblage, including Urtica, Rumex, Succisa and Plantago lanceolata. Charcoal was recovered from the stratigraphy at this level and the evidence may be interpreted as recording the creation of small clearings in the woodland by fire. The pollen fluctuations do not indicate that an extensive recession of woodland took place and this phase may be considered to have been of relatively low intensity.

FCS Zonule R2   162 - 160 cms.

This zonule describes a brief phase of woodland regeneration during which the vegetation was apparently not subject to clearance pressure. Tree pollen returns to its previous maximum of 35% of total land pollen and the trees of the *Quercetum mixtum* and *Alnus* are increased in value. *Calluna* and *Pteridium* decline, pointing to some recolonising of open areas by tree cover. Few dryland herb types are recorded, as the onset of woodland conditions reduces the habitats suitable for their growth. The high percentages of non-tree pollen, however, show that the regenerating woodland was still of a very open character.

FCS Zonule I3 160 - 158 cms.

A renewal of clearance activity occurs during this zonule, with total tree pollen reduced to 25% of total land pollen and the expansion in frequency of a number of indicators of open and disturbed conditions. Dryland herb pollen includes *Plantago lanceolata*, *Melampyrum*, *Artemisia*, *Urtica*, Chenopodiaceae, Umbelliferae and *Rumex*. Although only slightly increased in frequency *Corylus* still represents over 30% of total land pollen, while *Prunus*, *Sorbus* and *Fraxinus* are also present. *Calluna*, Gramineae and *Pteridium* show peak values during this phase, with *Quercus* and *Alnus* the trees most adversly affected and *Betula* encouraged. This zonule therefore describes the replacement of woodland by cleared areas occupied by herb, scrub and heathland communities.

FCS Zonule R3 158 - 155 cms.

Withdrawal of clearance activity during this phase allowed the restoration of woodland, tree pollen frequencies rising to their highest level, reaching almost 40% of total land pollen. Deciduous forest trees account for much of this expansion, with *Quercus*, *Tilia* and *Alnus* especially favoured. There are no indications of clearance, ruderal herb taxa being completely absent and *Calluna* falling to low frequencies.

Pteridium, Gramineae and *Corylus* all decline in value and it would appear that forest cover was denser than previously recorded at this site. Heliophyte shrubs *Salix*, *Prunus*, and *Sorbus* are, like *Corylus*, poorly represented and *Fraxinus* is absent, indicating a significant closure of the forest canopy.

FCS Zonule C1   155 - 151 cms.

The final phase of clearance witnesses a modest reduction in tree pollen frequency to about 30% of total land pollen with *Ulmus* and *Tilia* markedly reduced. In contrast *Quercus* and *Alnus* fall only slightly and *Betula* increases its representation. Ruderal herbs implying freshly cleared areas are again recognised, *Plantago lanceolata*, Chenopodiaceae, *Urtica* and *Rumex* all occurring. Generally more open conditions are evidenced by increases in frequency of *Calluna*, *Pteridium*, Gramineae, *Salix* and *Corylus*, and a continuous curve for *Fraxinus* is established, indicating with *Betula* the disturbed character of the woodland.

FCS Zonule R4   151 - 120 cms.

A long phase of regeneration ensues during which the woodland appears to have remained open but undisturbed for tree pollen values remain steady at almost 40% of total land pollen. Few fluctuations may be noted, in the pollen record and this was evidently a period of vegetation stability and little landscape change. Herbaceous pollen of ruderal character is recorded only sporadically, with *Rumex* and *Urtica* the most significant taxa. While open areas probably remained within the woodland, for *Calluna*, *Pteridium* and *Corylus* values are moderate but sustained, it would appear that new clearings were not being created.

NORTH GILL

4.27. Discussion

The lithostratigraphic and biostratigraphic information presented in the preceding sections provide details of a complex history of ecological change at the site of North Gill, expressing in the alternating stages of woodland recession and regeneration a record of recurrent fire-manipulation of the vegetation which may be attributable to the activities of prehistoric communities. The isolation and definition of a sequence of discrete lithostratigraphic units at this site, summarised by figure 16, enables the correlation of stratigraphic horizons, in particular the allogenic units NG-L4, NG-L6 and NG-L7, at each of the four pollen-analytical sampling points. In turn this permits the correlation of specific forest clearance stage zonules from the individual pollen diagrams, allowing their pollen assemblages to be regarded as chronologically synchronous units and interpreted as representative of coeval landscape events. This correlation of lithostratigraphic and biostratigraphic data is displayed in figure 35, and allows the compilation of a series of summary biostratigraphic zonules applicable to North Gill as a whole and which will be used to describe the sequence of environmental change at the site as successive stages in the evolution of the landscape. These summary zonules are shown as indicating interference (NG-I) or regeneration (NG-R) conditions, together with their major diagnostic taxa. Re-assessment of the data from Simmons' profile at North Gill 'a' (Simmons 1969a, 1969b) to be conformable with the forest clearance stage system of zonation adopted in this thesis has allowed its inclusion upon figure 35, and the radiocarbon dates from this profile have been combined with those from North Gill II to provide

NORTH GILL

Correlation of Lithostratigraphic and Biostratigraphic Units

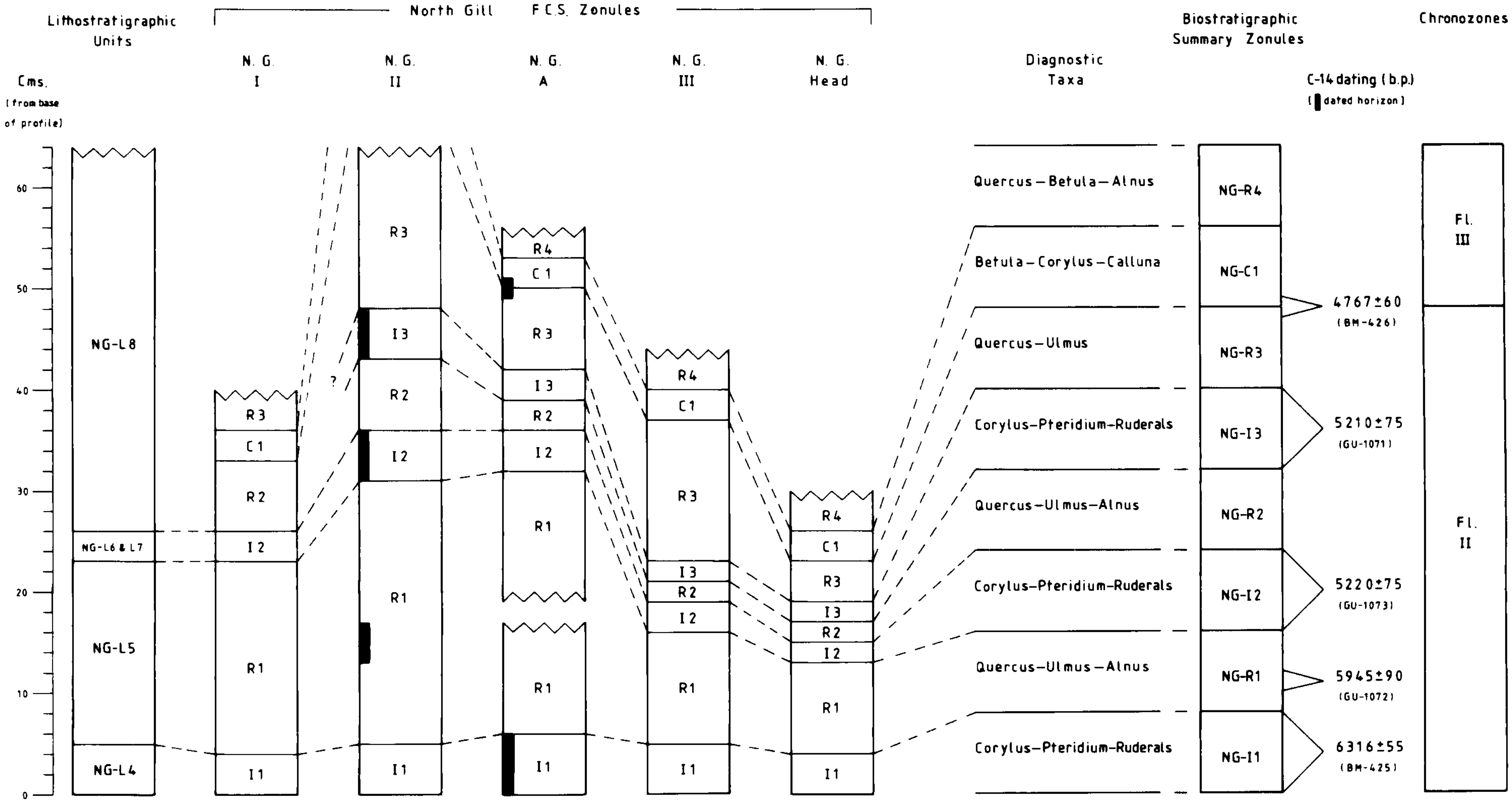


Fig. 35. North Gill. Correlation of lithostratigraphic, biostratigraphic and chronostratigraphic data.

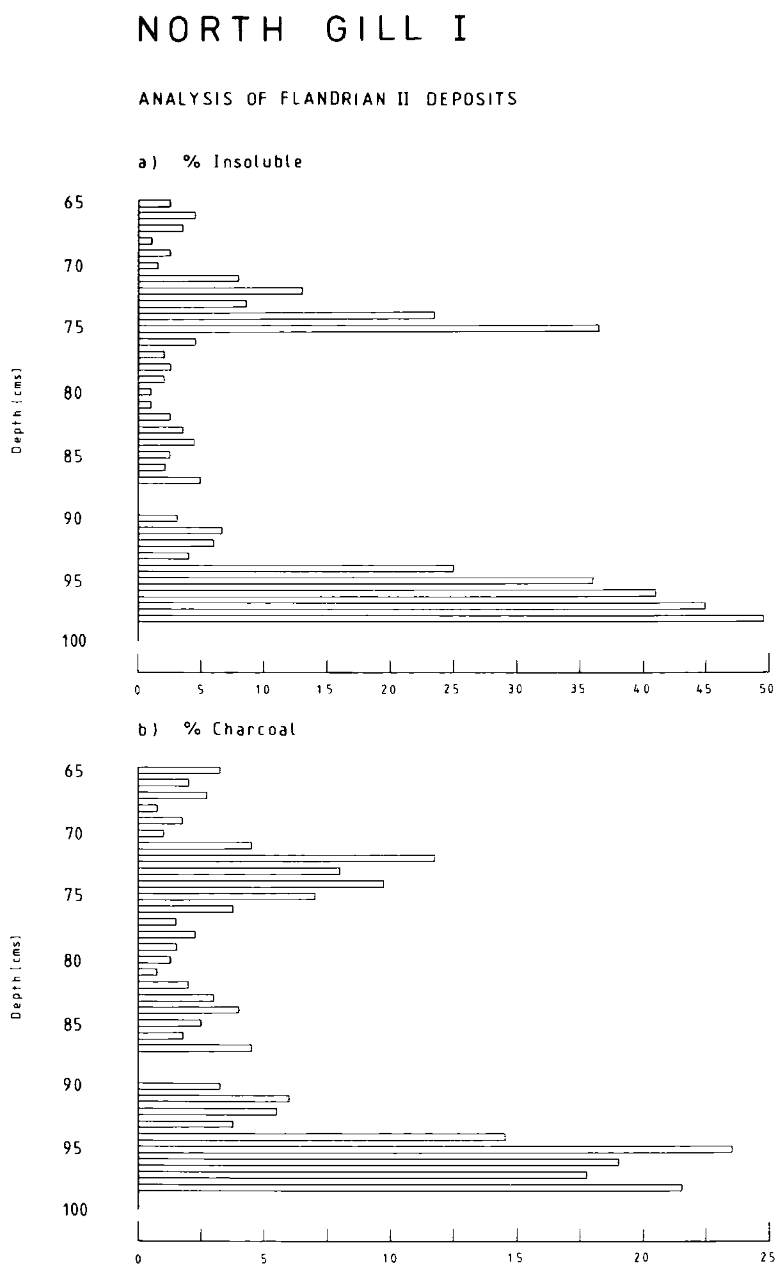


Fig. 36. North Gill I. Percentage charcoal and total insoluble material content of peat.

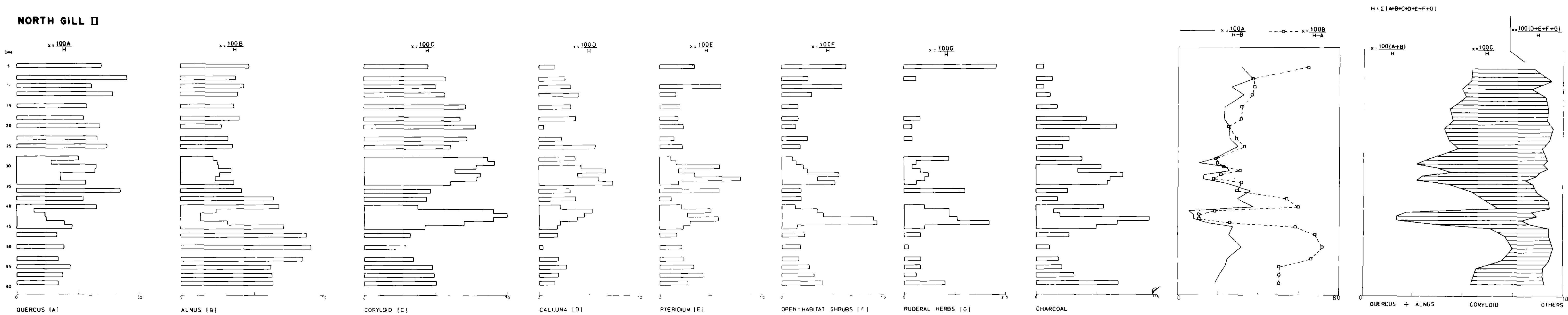

NORTH GILL II
Cms
x = 100A / H
x = 100B / H
x = 100C / H
x = 100D / H
x = 100E / H
x = 100F / H
x = 100G / H
H = Σ (A+B+C+D+E+F+G)
x = 100A / H−B
x = 100B / H−A
x = 100(A+B) / H
x = 100C / H
x = 100(D+E+F+G) / H
QUERCUS (A)
ALNUS (B)
CORYLOID (C)
CALLUNA (D)
PTERIDIUM (E)
OPEN-HABITAT SHRUBS (F)
RUDERAL HERBS (G)
CHARCOAL
QUERCUS + ALNUS
CORYLOID
OTHERS

Fig. 37. North Gill II. Pollen diagram : selected clearance
taxa as percentages of total clearance pollen sum

a radiocarbon chronology for the site. The Ulmus decline which forms the end of regional pollen assemblage zone NYM-D and the boundary between chronozones Flandrian II and III (Table 4) is recognised as the lower boundary of zonule C1 at each site, and this horizon at North Gill 'a' has yielded a radiocarbon date of 4,767 ± 60bp (BM 426). As no decline of Ulmus is recognised at North Gill II the entire profile is considered to fall within Flandrian II. All of the interference (I) zonules at North Gill may therefore be ascribed to Flandrian II and, if considered to reflect the activities of prehistoric communities, to an implied Mesolithic cultural context.

A clear synchroneity exists between stratigraphic charcoal and the interference zonules at North Gill. The macroscopic charcoal layers of stratigraphic units NG-L4 and NG-L6 are reflected in pollen zonules NG-I1 and NG-I2 by declines in arboreal pollen values, particularly Quercus and Alnus, the occurrence of a wide range of ruderal herb types, among which are Melampyrum, Artemisia, Rumex and Plantago lanceolata, and sharp increases in heliophyte taxa such as Corylus and Pteridium. This series of events suggests a succession through regeneration communities set in train by fire-clearance of mixed woodland in the neighbourhood of the spring-head. In addition to the discrete charcoal layers, however, microscopic charcoal particles, termed 'soot', were observed to occur throughout the pre-Ulmus decline deposits at North Gill. An estimation of the soot content of the Flandrian II peat at North Gill I, together with the total amount of insoluble material contained in this part of the profile, is displayed upon figure 36. This shows that, while soot values are extremely high in association with the interference phase charcoal layers, low but consistent values of up to 5% per unit volume of sediment are recorded during phases of woodland regeneration, when clearance was not going on in the immediate vicinity of the site. Examination of the Flandrian II deposits at North Gill II reveals a similar dissemination of charcoal material (fig. 37), and it would seem that burning of the vegetation was taking place somewhere in the region at all times during this period, so that a regionally ubiquitous deposition of charcoal soot was continuously occurring. In this respect the sites at North Gill resemble many other upland peat profiles from the Central Watershed, such as Loose Howe and Trough House (Simmons and Cundill 1974a), which incorporate charcoal throughout their pre-Ulmus decline deposits. It would appear that fire was a regionally unremitting feature of this area during Flandrian II and therefore a major ecological factor in landscape evolution.

Two ancillary diagrams are presented which assist in elucidating the changes in vegetation composition which were instigated by the repeated clearance-regeneration sequence at North Gill. In figure 38 a comparison is made between the number of taxa recorded at each level at each pollen site, which may be regarded as reflecting local vegetation diversity, and interpreted as an index of forest clearance activity, following Moore (1973). Figure 39 shows the representation of individual tree taxa calculated as a percentage of the corrected total tree pollen sum, using the correction factors of Andersen (1973), to assist in the following reconstruction of environmental history at North Gill.

NG-I1

The initial clearance event at North Gill is described by summary zonule NG-I1, which incorporates zonules I1 at each individual pollen site and correlates with lithostratigraphic unit NG-L4. The charcoal-rich peat which constitutes this stratum may be traced from transect B to transect R (fig. 12) below which it attenuates sharply. It reaches its greatest thickness between transects G and M, where the gradient of the sub-peat surface is at its lowest, and conditions for its accumulation were most favourable. The thickest deposits sampled for pollen analysis therefore occur at the sites of North Gill II and III, and at Simmons' sites of North Gill 'a' and 'b', where it has yielded a radiocarbon date of 6,316 $\pm$ 55bp (BM-425). It has been pointed out (v.s. page 91) that lateral extension of this charcoal layer to the east of the North Gill stream is poor, being no more than 26 metres (figs. 12 and 13), and that it is much less substantial in that area (fig. 13) than to the west, where it persists rather further. It seems probable therefore, that the focus of the burnt area lay to the west of the spring-head. The pollen zonules which are correlated with this lower charcoal layer (fig. 35) are alike, both in supporting the radiocarbon determination of an early Flandrian II provenance for this clearance event, and in recording a succession of major vegetational changes as its consequence. Disparities do occur, however, between the pollen assemblages of the various sampling points during NG-I1, and these are due to their contrasting situations relative to differing pollen sources. Three assemblage components at North Gill may be recognised : a) regenerating vegetation communities from within the cleared area, b) woodland edge ecotone communities from its margins, c) homogenous vegetation communities from beyond it. The relative proportions of these three components will be determined by the proximity of the pollen site to the centre of the cleared area, and their resulting differences in detail will allow discussion of the spatial variations in the character and magnitude of the changes in vegetation

At each site _Alnus_ and _Quercus_ are the trees apparently subject to clearance, with the former particularly affected, which may suggest an alder-fringed spring-head within a general oakwood matrix as the pre-burn local vegetation. Lowest frequencies of Alnus occur, however, at the sites of North Gill II and III during this phase (figs. 22 and 26) with a concomitant fall in Alnus pollen concentration (fig. 28), while at North Gill I Alnus values remain substantial at 20% of total land pollen (fig. 20) and over 50% of total tree pollen (fig. 18b). It would seem that sites II and III may have been within the area which suffered actual clearance, while North Gill I was peripheral to the burn, and recorded its effects somewhat less clearly. Figure 39 suggests that a measure of broad-leaf woodland dominance continued at and below the altitude of North Gill I, with Tilia rivalling Ulmus and Quercus in frequency. The presence of stands of Tilia in the vicinity of the sampling site thus seems likely, for the largely entomophilous nature of this genus' pollen dispersal mechanism suggests that transport of grains from a distance in quantity is unlikely, although Dimbleby (1978 p113) indicates that its pollen is partly anemophilous, and so this tree's pollen count may contain an extra-site quotient, reflecting a status in the Flandrian II woodland akin to that proposed by Iversen (1973). Thus an altitudinal variation in woodland density is apparent during this phase between the lowest site, North Gill I, where A.P. does not fall below 30% of total land pollen (fig. 20), the site of intermediate altitude, where the comparable frequency is less than 25% (figs. 24 and 29) and the highest site, North Gill Head, where it is less than 20% (fig. 34). Clearance effects are, however, rather less strongly demonstrated at the latter site, with a more restricted range of clearance indicators and less radical pollen fluctuations, and this site may have recorded conditions near the upper limit of the burn. As well as this clearance episode, low tree pollen values at North Gill Head may partly also reflect conditions upon the nearby plateau summit of the Moors, where the vegetation cover may already have been more open, for tree pollen values are consistently lower here than at the other sites.

Evidence of forest clearance, both stratigraphic and palaeobotanical, is most clearly manifest at the pollen sites of intermediate altitude, North Gill II, 'a', 'b' and III, for it is here that charcoal is most abundant and the most radical pollen fluctuations are recorded. It would appear that this area formed the focus of the initial clearance event, the intensity of which was sufficient to create bare ground conditions around these sites, confirmed by the recognition of Polytrichum commune as the initial post-fire peat-forming vegetation at North Gill 'a' by Simmons (1969a), for this moss is a pioneer coloniser of freshly-burned ground (Viro 1969) and has been seen to achieve local dominance, with Pohlia nutans, in such situations (Ahlgren 1974) especially under damp or acid conditions. Clearance also seems to have had the effect of instigating limited soil erosion from these devegetated areas, for a significant silt fraction is incorporated within the basal charcoal - organic material at North Gill II, 'b' and III. High Filicales frequencies and concentrations are recorded at these horizons (figs. 21, 25 and 28) and fern spore abundance is considered by Dimbleby (1957) to be associated often with inwash of mineral material, their high resistance to corrosion allowing their survival in acid mineral horizons and subsequent input into the mire system. This evidence concurs well with the stratigraphic evidence already presented (v.s. page 88) for erosive breaks in the lithostratigraphy in areas of steeper gradient. The pioneer moss carpet which colonised these areas of bare ground was succeeded by a diverse assemblage of open-habitat herbaceous taxa, among which were a number representative of post-fire habitats. Melampyrum is in particular indicative of clearance by fire and has been interpreted as denoting the formation of limited clearings in formerly closed woodland (Iversen 1949, 1964) and as a characteristic feature in the post-burn field layer vegetation (Florin 1957, Hafsten 1965). Ruderal herb pollen types are much more abundantly represented at North Gill II and III than at either North Gill I or North Gill Head and, as these taxa have entomophilous pollen which is poorly transported, they may thus be considered to be of immediately local origin, the recovery of aggregations of herb grains, mainly Rumex and Compositae, encouraging this view (Andersen 1970). This evidence again suggests that fire-clearance of the vegetation was most complete adjacent to these sampling sites, a contention also supported by figure 38, which illustrates the degree of taxa diversity recorded at each site during regeneration as an index of clearance intensity. The greater diversity of the flora during this phase at North Gill III is clearly shown, caused primarily by the great expansion in ruderal herb pollen, constrasting with the more stable vegetation reflected by the sites nearer the extremities of the cleared area.

Of significance among the herb taxa recorded is Polygonum, a herb capable of rapid immigration and regarded as a temporary fire-follower, often present during the first few post-burn years (Ahlgren 1974). It is associated in the herb assemblage at North Gill with a range of taxa which signify disturbed, open ground. Succisa has been implicated in this way by Adams (1955) and Rumex, Urtica and Chenopodiaceae, all of common occurrence at North Gill during this phase, have been cited as indicators of Mesolithic settlement or activity

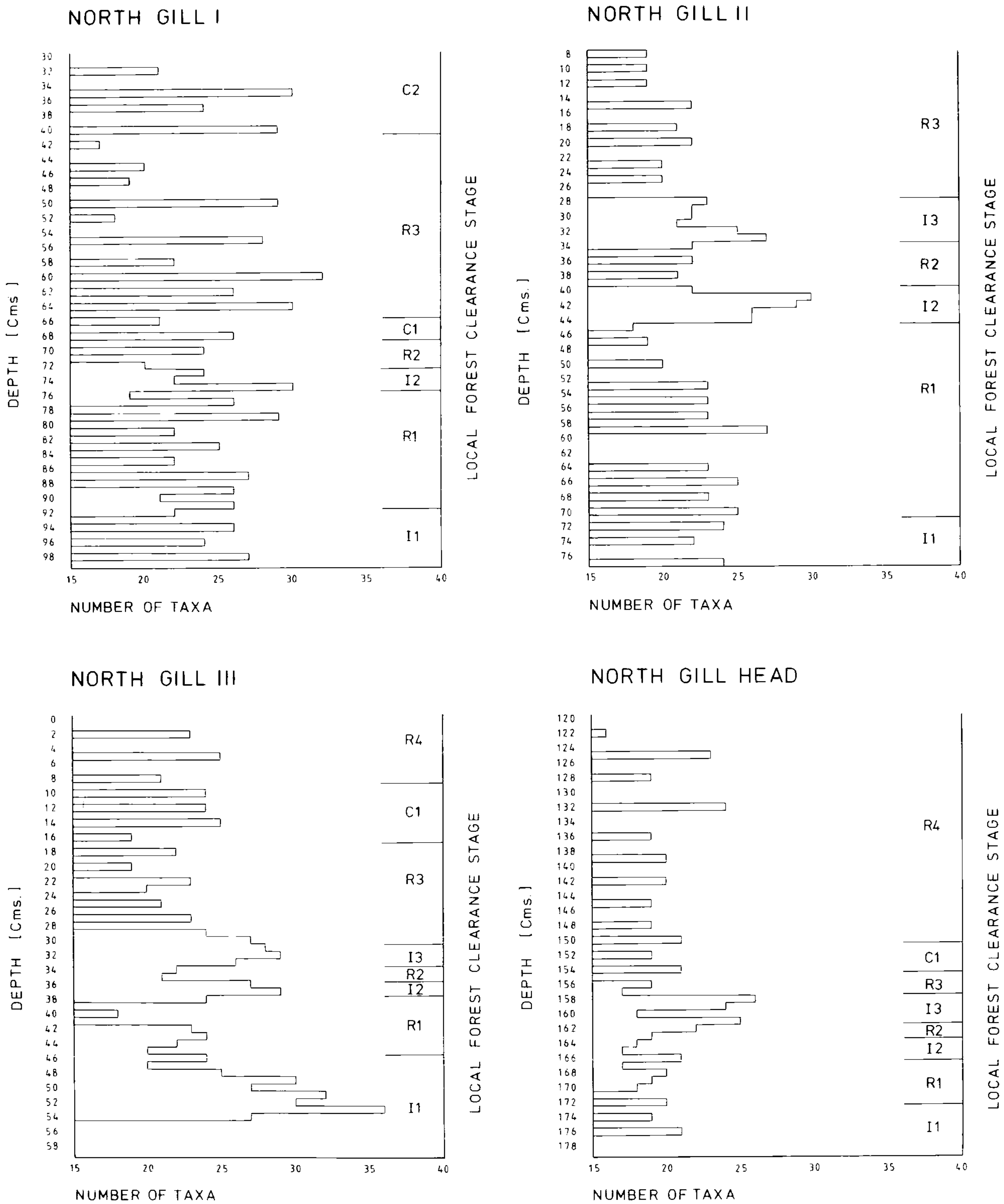


Fig. 38. North Gill. Taxa diversity as an index of clearance activity.

(Nilsson 1948, Jorgensen 1963) in addition to their natural hydroseral or halophyte character. This accords well with their recurrent appearance in association with Mesolithic clearances (Innes 1980), Rumex being often particularly prominent and achieving values of over 10% of tree pollen in an analogous situation at Postbridge (Simmons 1964). Peak frequencies and concentrations of ruderal herb pollen are recorded in the initial stages of zonule NG-I1 at North Gill III (figs. 29 and 30), amongst which the presence of Plantago lanceolata (Sagar and Harper 1964) and high Gramineae frequencies and concentrations point to the establishment of a rich herb-grassland community upon the cleared area at this early stage of regeneration.

While the direct consequence of this clearance activity was to provide open ground suitable for colonisation by dryland regeneration communities, it is clear from the pollen record that a wide range of wetland habitats existed in the neighbourhood of the site. Pollen of various aquatic taxa are recorded at intervals from all sites except North Gill Head and are attributable to the North Gill stream itself. They imply differing water depths and rates of flow in different parts of the site, with flow more sluggish at points of low gradient, as at North Gill II and III, perhaps forming small pools and quiet-water situations. Such areas of low gradient would naturally have a tendency towards impeded drainage, which would be accelerated by the release of extra water into the biosystem following clearance (Moore 1975) leading to paludification and initiating the formation of peat. The indirect effect of the removal of woodland and thus also the transpiration effect of the tree canopy, was that parts of the cleared area quickly became subject to waterlogging, creating marsh and wetland habitats, as the adjustment of local hydrobiological conditions increased the available ground surface water, itself a process implicit in the mechanism of mire formation. The pollen of Filipendula, Caltha, Potentilla, Ranunculus, Gramineae and Cyperaceae are prominent in the assemblage, and high concentrations of these wetland taxa are recorded at North Gill III (fig. 28), testifying to the prevalence of damp glades, marshland and incipient bog communities nearby. Although circumstantial in nature, this evidence of an abundance of wetland and mire habitats during this phase, together with the coincidence of peat inception with woodland clearance, suggests that the clearance event may have been motive to this major change in environmental conditions.

The increased wetness of the environment caused by clearance of Alnus-Quercus woodland appears to have provided suitable habitats for Salix, presumably replacing Alnus in damper streamside locations, for high willow frequencies (figs. 21 and 25) and concentrations (fig. 28) are recorded from North Gill II, 'a', 'b' and III, where it must have been of importance in the post-fire shrub regeneration. Much lower frequencies occur at North Gill I and Head, where Alnus was less severely affected. Salix also accounts for much of the peak heliophyte shrub concentrations which occur in the earliest pollen spectra of figure 30, at the same time as high grass and ruderal herb values show incipient recolonisation of the dryland cleared areas and prior to shrub regeneration there. Higher frequencies and concentrations for these woody taxa at this initial stage of regeneration, as well as for Corylus, Betula and major woodland trees, may be explained by the increased ease of pollen transfer (Tauber 1965) from the woodland margin around the cleared site to the sampling points, with increased provision of light to these clearing-woodland ecotone communities tending to stimulate pollen production among shrub taxa (Groenman-van Waateringe 1978).

This woodland edge component of the assemblage was progressively reduced in importance as regeneration proceeded upon the burned area itself and post-fire herbaceous communities were replaced by shrub growth (fig. 28, 29 and 30), in which various taxa will have participated. Rubus is recorded at North Gill III and 'b' and may have been encouraged by fire-clearance, for its seeds are able to survive fire in the soil and may be stimulated to germinate by heat (Uggla 1950) allowing it to be among the first post-fire shrubs present. Prunus, Sorbus and Salix would also have been favoured by fire (Ahlgren 1974) and very high pollen values for the latter at North Gill III show that it was indeed of importance in this respect, second only to Corylus in abundance. The ability of Corylus to survive forest fires and to sprout rapidly and vigorously from its burned stumps has been noted (Rawitscher 1945) and commented upon at length (Smith 1970, Mellars 1976c), its abundance in the pollen record from North Gill (consistently over 50% of total land pollen in the later phase of zone NG-I1 at all sites) probably reflecting the establishment of hazel scrub throughout the area of clearance and heavy flowering under high light intensities. The dominance of Corylus in the vegetation around the sampling points will be responsible for the extremely high concentrations recorded at this time (fig. 30), the extra-local component of the pollen rain being much reduced. That an homogenous Corylus thicket did not exist across the entire site is shown by high concentrations of Pteridium spores (figs. 28 and 30), suggesting occupation by this fern of parts of the site where drainage was a little freer, as it requires well drained soils for its growth. It is an opportunist invader of man-made clearings (Braid and Conway 1943, Rymer 1976) and its role in post-fire succession is particularly active (Vogl 1964, Ajlgren 1974). As a natural component of Quercus woodland on poorer, lighter soils (Jones 1959, Steele 1974) Pteridium will have been present at North Gill before clearance and may well have survived the burn by means of its fire-resistant rhizomes (Ahlgren, 1960, 1974), which exist much further below the ground surface than those of other ferns, and from which it may propagate itself vegetatively. It is thus able to regenerate and occupy newly created habitats more quickly than most other plants, being also able to colonise burned areas by its sporelings (Benson and Blackwell 1926). It has been shown that if Pteridium is able to colonise a burned area in this way it can form very dense stands and achieve dominance very quickly (Oinonen 1969, Gliessman 1976). Once formed, thick Pteridium stands may prevent other taxa from immigrating, both by shading and by allelopathic effects, the exudation of toxic chemical substances which inhibit their generation and growth (Gliessman and Muller 1972, Stewart 1975). The pollen diagrams suggest that such dense growths of bracken fern were a feature of the post-clearance vegetation at North Gill. This may not be said for Calluna, however, where higher frequencies (figs. 31 and 34) may again reflect conditions upon the adjacent plateau summit rather than a response to clearance at North Gill.

The disruption of stable woodland and the creation of seral communities in zone NG-I1 appears locally to have encouraged the increase of both Pinus and Betula representation. Betula values are particularly high at North Gill II (figs. 21 and 24) where fig., 39 shows it to comprise over 60% of the corrected tree pollen sum, with Alnus values extremely low. Artificial opening of woodland seems to have allowed Betula to replace Alnus in this area, in association with Corylus and Pinus. A measure of spatial variation may be noted in this respect across the site as a whole, for while Betula is dominant at North Gill II, Pinus appears to have been more favoured near the two more northerly sites,

NORTH GILL

PERCENTAGE OF CORRECTED TREE POLLEN SUM

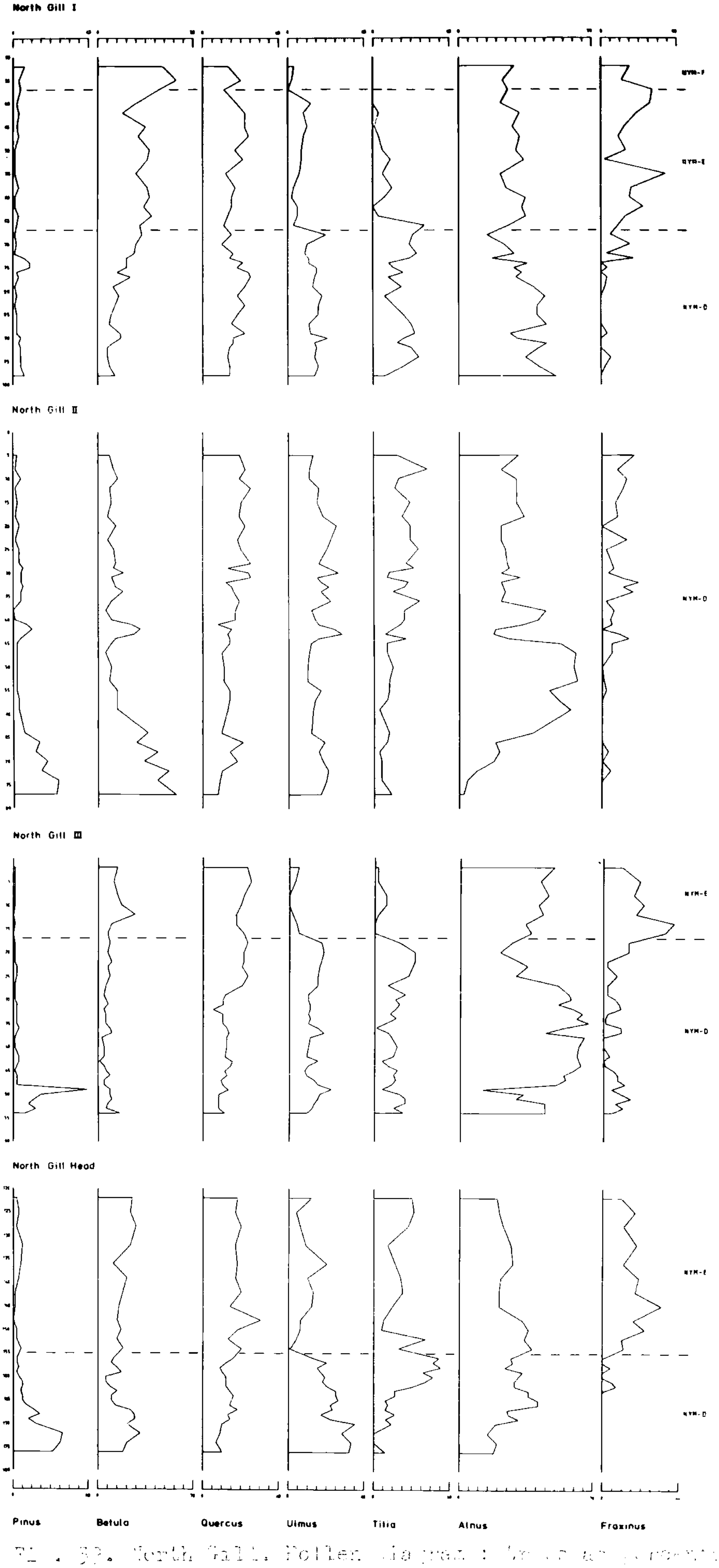


Fig. 32. North Gill. Pollen diagram: trees as percentages of total corrected tree pollen.

where its pollen frequencies are sufficiently high to suggest the presence of the tree within the regeneration complex. Pine is fire-resistant and shade-intolerant (Carlisle and Brown 1968), responding positively to fire-clearance, and its association here with charcoal and fire-succession taxa Melampyrum and Pteridium finds parallel in other upland regions (e.g. Birks 1975). Its presence as a major factor in woodland regeneration at North Gill suggests that it was of significance within the more open vegetation which appears to have characterised the Central Watershed of the Moors in early Flandrian II. Certainly the more open nature of the woodland near the centre and head of the gill is confirmed by the presence of Sorbus and Prunus. High values for Fraxinus also reflect open canopy conditions, for its autecology is such that it is highly light-demanding and indicative of disturbed but nutrient-sufficient soils (Goddard 1958, Wardle 1961), which suggests that clearance had not at this stage caused serious depletion of the environment. It is not recorded at North Gill I, where closed-canopy woodland evidently prevailed.

NG-R1

The ensuing period of woodland regeneration is described by summary zonule NG-R1, which corresponds to zonule R1 at each pollen site and correlates with lithostratigraphic unit NG-L5. Clearance effects are no longer in evidence and the restoration of stable woodland appears to have taken place. Tree pollen values rise upon all of the diagrams, although again an altitudinal variation may be noted, for while at the lower sites A.P. achieves over 50% of total land pollen throughout (figs. 20, 24 and 29), at North Gill Head A.P. values rise only slowly and barely reach 35% of total land pollen late in the zone (fig. 34). It would seem that the woodland remained open near the head of the gill and upon the plateau edge. Since there is little evidence that regeneration after clearance at North Gill was incomplete, once again this suggests that a much lighter vegetation cover existed upon the moorland plateau. The open woodland at this greater altitude appears to have contained much Corylus, for this shrub is hardly reduced from its frequencies of the previous zone, maintaining about 50% of total land pollen (fig. 34), whereas at the lower sites it has fallen to only 25% (figs. 20, 24 and 29) attributable to its having been shaded out by the closed canopy of the broad-leaved climax forest. Betula, Pinus and Calluna values also remain significant only at North Gill Head, and the association of these taxa with Corylus in scrub woodland at higher altitudes is indicated, although Pinus continues to decline and, in consideration of its high pollen production and long-distance transport potential, may have been an increasingly infrequent member of the woodland by this stage. These open conditions are in direct contrast to the site of North Gill I where deciduous forest trees of the Quercetum mixtum are, with Alnus, the main woodland constituents. Indicators of secondary woodland are few, and closed canopy conditions appear to have dominated. The role of Ulmus is of interest here, for its pollen values show little difference among the various sites, whether as percentage of total land pollen (figs. 20, 24, 29 and 34), of total tree pollen (Figs. 18b, 22b, 26b and 32b). Of corrected tree pollen (fig. 39) or as pollen concentration (figs. 28 and 30). As elm also shows little response to the preceding phase of clearance, its pollen may be interpreted as entirely regional in nature, and Ulmus may not have formed part of the local vegetation. Quercus, Tilia and Alnus are therefore considered to have comprised the deciduous woodland recorded around the southerly limit of the site. The heavy shade of the forest trees here will have reduced Corylus to understory status and prevented it from flowering profusely. Thus an actual fall in the number of hazel shrubs is not implied here, rather a great reduction in flowering and therefore in pollen production.

Upon the central cleared area around North Gill II and III regeneration of Alnus seems to have been entirely successful, for it contributes over 50% of total land pollen at these two sites (figs. 24 and 29), but only 25% at the two extremities of the transect (figs 20 and 34). The abundance of Alnus in this area is shown by figure 39, and by the very high concentrations of alder pollen recorded on figs. 28 and 30. Alnus pollen dispersal ability is weak, except by water transport (Tinsley 1975) and so these disparities in the Alnus pollen count may be held to mirror real changes in Alnus densities upon the ground. The establishment of a dense alder grove across this part of the site thus seems likely, encouraged by the damp, humid conditions near to the stream and the increase of dampland habitats caused by the clearance of the previous zone, and supporting such taxa as Filipendula, Lonicera, Hedera, Polypodium Potentilla, Ranunculus, Rubiaceae (Galium-type) and Labiatae (figs. 21 and 25). Soil nutrient-status was evidently still high to support such a rich carr community, and acid-tolerant taxa are poorly represented. That local regeneration of woodland took place is confirmed by the appearance of wood macrofossils in the amorphous peat of unit NG-L5 during the earlier part of this zone. These wood remains are predominantly Alnus and Betula, implying that the latter was still of some importance in the spring-head vegetation. The general distribution of wood remains at North Gill is shown on fig. 11, and their presence in the lower part of the site and absence near the head of the gill confirms the pollen evidence regarding woodland distribution. Much of the wood is detrital, but the great size of some pieces and the presence of rootlet material (v.s. page 92) suggest that some may represent in situ woodland and thus recolonisation of shallow upland peats (Tallis 1975). Radiocarbon dating of peat from immediately above the wood layer at North Gill II has yielded a date of 5,945 ± 90bp (GU-1072), providing an approximate final date for this phase of reforestation.

NG-I2

The second major phase of forest recession at North Gill is described by zone NG-I2, which corresponds with zonules I2 at each pollen site and is correlated with lithostratigraphic units NG-L6 and NG-L7. Radical pollen fluctuations occur which record the replacement of woodland by seral herb and shrub communities across the site, and the reintroduction of charcoal to the stratigraphy (unit NG-L6) suggests that local burning of the vegetation was again responsible for environmental change. This upper charcoal layer's distribution is similar to that of unit NG-L4 and is represented diagramatically by figures 11, 12 and 14. Its thickness and lateral extent are greatest to the west of the stream, the focus of the burn lying in approximately the same area as the previous example, although at perhaps a slightly greater distance from the site (v.s. page 93). The upper charcoal layer never achieves a thickness comparable to unit NG-L4, reaching only three centimetres at the centre of deposition near to the stream, and attenuating sharply to the west. An estimation of the charcoal content of the peat at North Gill I and II (fig. 36 and 37) shows up to 15% per unit volume of sediment to be comprised of carbonised material during this phase. Resting upon the charcoal layer and associated with small charcoal fragments was a layer of charred bark pieces, presumably blown into the bog surface during the high intensity firing of the site. The bark is mainly Alnus but includes Betula and suggests that the latter formed a minor component of the carr woodland fringing the site.

A general fall of tree pollen frequencies takes place at all sites during this phase, but the fluctuations are less marked than in zonule NG-I1, so that clearance was either less intense, or as suggested above, at a greater distance from the site. The decline in tree pollen values is again less clear at North Gill I, where A.P. comprises 30% of total land pollen (fig. 20), than at the other sites where it falls to 25% or less (figs. 24, 29 and 34). At North Gill Head however, A.P. values were in any case little in excess of this figure prior to clearance. The centre of clearance again appears to have lain near to sites North Gill II, 'a' and III, with North Gill Head and North Gill I again peripheral to the event, although still affected by it. Alnus and Quercus are the taxa most reduced in frequency at North Gill II and III, indicating the destruction of the alder carr, which had formed during the previous zonule, and the surrounding oak woodland, this zonule of clearance yielding a radiocarbon date at North Gill II of 5,220 ± 75bp (GU-1073).

Reductions in the concentration of Quercus and Alnus pollen (fig. 30) at this point indicate an actual removal of these taxa from areas they had previously occupied. Figure 37 calculates the pollen frequencies of Quercus and Alnus during this phase at North Gill II (44-40 cms.) as a percentage of a total 'selected clearance' pollen sum, with those taxa considered to be most directly encouraged by their clearance, e.g. ruderal herbs, Pteridium, Calluna, Corylus and other open-habitat shrubs. The almost total replacement in the assemblage of the trees' pollen by that of the clearance indicators at the level of the charcoal layer may clearly be seen. A slightly different situation occurs at North Gill I, where Alnus pollen values are rather less conspicuously reduced, and clearance appears to have affected Quercus and Tilia equally strongly (fig. 20), a reflection of the more mature woodland in existence at the lower extremity of the site. A direct contrast occurs at North Gill Head where clearance is manifest most markedly by an expansion of Calluna pollen frequency at the expense of Corylus as well as Alnus, pointing to degeneration of the open scrub woodland vegetation at the edge of the moorland plateau.

The most marked ecological changes, however, evidently took place near the centre of the burn, around North Gill II and III. It is in this area that the greatest diversification of the vegetation took place (fig. 38), and the clearest fluctuations occur in the corrected tree pollen sum (fig. 39). Ruderal pollens return to the assemblage in quantity at these sites (v.s. page 113 and 123), with Melampyrum, Rumex, Artemisia and Plantago lanceolata prominent, while certain herb taxa which occur, Cruciferae, Centaurea and Cirsium, are strong indicators of anthropogenic effects (Godwin 1975). Pteridium and Corylus again expand in both relative and concentration terms, in a record of clearance similar to that of NG-I1. Betula assumes the role that Pinus played in the earlier phase of clearance, apparently being favoured, with Fraxinus, by the opening up of the woodland. The pollen concentration evidence (fig. 30) highlights the extreme diminution in the amount of alder pollen and the sharp incease in hazel pollen, suggesting that the most significant landscape change accomplished by this clearance was the replacement of oak-alder woodland by hazel scrub. The great expansion of Corylus is a feature of all diagrams from the site, except at North Gill Head, where hazel was in any case abundant. Salix frequencies and concentrations are again exceptionally high at North Gill III and willow will have replaced alder in damp locations near the stream. While increases do occur in <u>Pinus</u> pollen frequencies upon the relative diagrams (e.g. figs. 20, 24 and 39), they are not paralleled by increased <u>Pinus</u> pollen concentration (fig. 30) suggesting that they are either purely statistical events caused by the relative decline of other tree pollen types, or perhaps reflect easier access of long-distance, wind transported <u>Pinus</u> pollen to the bog surface. Communities of low stature, such as those following clearance, may considerably facilitate such pollen transfer (Dimbleby 1957), and a significant reappearance of <u>Pinus</u> within the sampling area is not regarded as likely.

Clearance during zone NG-I2 seems to have given an impetus to the development of the mire system, for the peat above this level is less well humified, indicating more rapid bog growth following increased run-off from adjacent cleared areas and increased water influx into the bog. Incipient acidification of the ecosystem may be noted, probably accelerated by nutrient loss following clearance (Dimbleby 1962), and <u>Sphagnum</u> spores begin to be of significance at this stage. While increased <u>Sphagnum</u> values may not always signify increased wetness and environmental change (Tallis 1964), they occur here in association with higher values for other acid-tolerant taxa, for example <u>Betula</u> and <u>Calluna</u>, and for mire vegetation components Cyperaceae and Gramineae, and mark the beginning of the transition to blanket peat around the site. The rise in Cyperaceae pollen frequencies and concentrations during this phase (figs. 24b, 26b and 28) may also be due directly to the effects of clearance, for <u>Eriophorum</u> <u>vaginatum</u> may be stimulated to flower profusely by firing (Ratcliffe 1964). Taxa indicative of wet woodland and damp glades are still prominent, especially Cyperaceae, <u>Filipendula</u>, <u>Ranunculus</u> and <u>Caltha</u>, and these rich sedge-rush-herb communities were evidently well developed nearby.

Local instability and erosion of soils within the catchment area of the stream appears again to have been a consequence of clearance, for a layer of silt (unit NG-L7) is recorded in the stratigraphy. Its distribution is shown in figs., 11 and 12 and its thickness by figure 15. It rests upon the charcoal layer and relates stratigraphically with the early post-clearance pollen spectra, at a stage prior to major recolonisation of the cleared areas. This inwash stripe of mineral material represents the erosion of mineral material from cleared areas following their exposure to greatly increased rainfall impact and run-off pressure (Simmons _et_ _al_. 1975). Burning makes the soil friable and prone to erosion and also destroys humus material so that the resulting inwash is almost completely mineral (Dimbleby 1957), a feature of unit NG-L7 in the lower parts of this site.

NG-R2

There follows a brief period of regeneration, zone NG-R2, which corresponds to zonules R2 at each of the pollen sites, but which may not be strictly correlated with the lithostratigraphy, falling within the early part of unit NG-L8. Much of the ground previously lost by the deciduous woodland appears to have been recovered, for tree pollen values are amongst the highest attained during the entire pollen record at the site, although again significantly lower at North Gill Head (35% of total land pollen, fig., 34) than at the other sites (50% of total land pollen, figs., 20, 24, and 29). The concentration of _Alnus_ pollen is high, as is that of the _Quercetum_ _mixtum_ (fig. 30), and agrees with the general interpretation of increasing woodland cover. To balance this view, however, an increased concentration of most pollen types is observed (fig. 28) which may reflect increased flowering and therefore an increased production of pollen of most local taxa, and an increased ability of pollen to reach the deposition site. Both would argue for a much more open type of woodland, with a reduced canopy density and hence an increased input of light to the forest floor. This could well be a legacy of the clearance activity of the previous zone, and suggests a diversification of the ecosystem. Higher Betula and Calluna than in previous periods of regeneration support this contention, while the continued presence of Fraxinus, Prunus, Sorbus and Rosaceous types, and the persistence of Corylus, show that this secondary woodland was of a more open nature. A slowing down of peat accumulation rates following relaxation of clearance pressure may also be implied.

NG-I3

The third clearance episode at North Gill is described by zone NG-I3, during which charcoal again appears in the stratigraphy and pollen fluctuations indicative of woodland recession take place. This phase has yielded a radiocarbon date at North Gill II of 5,210 $\pm$ 75bp (GU-1071). It corresponds with zonule I3 at North Gill II, III and Head, but is not recorded at North Gill I. In addition the charcoal presence is intermittent and may not be recognised as a discrete stratigraphic unit across the entire site. It is visible as small pieces at the northerly sites of North Gill III and Head, is present as an abundance of microscopic particles at North Gill II (fig. 37) and is not recorded at North Gill I, except perhaps as a small peak in soot frequencies at 71-72 cms., on fig. 36. Where present as a macroscopic feature the individual pieces were small, rounded pellets, as though carried from a distance, perhaps by wind transport. Nowhere at the site is there a mineral inwash accompaniment to this charcoal horizon. The interpretation of this body of stratigraphic evidence is that the focus of this clearance episode lay not at North Gill but at a moderate distance from it.

This interpretation is supported by the pollen evidence. Quercus especially, and Alnus decline upon the relative diagrams (figs. 24, 29 and 34) as percentages of total land pollen, although much less conspicuously than during previous clearance phases, while their diminution is even less marked as a percentage of total tree pollen, including Alnus (figs. 22b, 26b and 32b). At North Gill I however, these pollen fluctuations are not registered at all (figs. 20 and 18b). It would appear that clearance took place at a distance from North Gill, but close enough for the transport of microscopic particles, such as soot and pollen, to the sampling sites to be effected. These microscopic particles were incorporated into the stratigraphy at the higher pollen sites of II, III and Head, where the vegetation was sufficiently open to allow pollen transfer to occur, although the effects of clearance are recorded in only muted terms. The vegetation at the lowest site of North Gill I, not having been subject to actual removal during the previous phase of clearance, was still sufficiently dense to filter out both soot and extra-site pollen. Peat accumulation appears to have been very slow at North Gill I however, and so pollen analysis at much closer sampling intervals may still reveal signs of this episode of clearance. The character of this clearance evidence replicates those recognised earlier. Plantago lanceolata, Artemisia, Melampyrum and Rumex occur within a complex herb assemblage, Pteridium, Gramineae and Calluna values rise, while Salix and Corylus greatly expand in both frequency and concentration, suggesting local abundance of these shrubs in the regenerating woodland.

Concentration of Alnus pollen remains very high however (fig. 30), supporting the view that local conditions at North Gill remained unchanged as damp, open woodland, while the pollen fluctuations recorded are referable to a clearance event of quite high intensity, but at a distance from North Gill itself. The location of this clearance must remain conjectural, but I have recorded a thick charcoal layer at the site of West Gill Head (NZ 712 009), 1200 metres to the north-west of North Gill Head (fig. 7), which preliminary pollen analysis suggests may be referable to a late Flandrian II context, and which may represent the focus of the clearance event recorded at North Gill during zone NG-I3.

NG-R3

The period of woodland regeneration which follows is described by zone NG-R3, which corresponds to zonule R3 at each pollen site, with the exception of North Gill I, where it is not recorded. Some variation in woodland composition does occur however, in particular a marked reduction in both the concentration and relative frequency of Alnus pollen. This may be attributable to edaphic factors, with perhaps a general acidification of the ecosystem towards the end of Flandrian II, shown also by increased frequencies for acid-tolerant taxa Quercus, Betula and Calluna. Alnus requires not only moist, humid conditions but also relatively fertile soil (McVean 1953) and it seems that pedogenic degeneration was by now so well advanced at North Gill as to prevent its regeneration. Tilia and Fraxinus show enhanced frequencies during this final woodland phase of Flandrian II (fig. 39), which is in accord with other diagrams from the Moors (Cundill 1971, Simmons 1969a). While Fraxinus concentration also rises (fig. 28) and indicates an actual increase of that tree's pollen representation in the assemblage, Tilia is less clearly increased, and an actual expansion of lime at this stage of the region's forest history must remain equivocal. The pollen of ruderal herbs and other indicators of freshly deforested areas no longer appear in the pollen record, Corylus frequencies remaining low, and it appears that fresh clearings were no longer being made in the vicinity of this spring-head. While the woodland remained undisturbed it was nevertheless relatively open, for higher Fraxinus, Prunus, Sorbus and Salix representation reveals its secondary nature. Ilex, Hedera and Lonicera are also in evidence during this phase, and open aspect of the woodland at this time was probably a legacy of the clearance activity of the previous zones. High concentrations of Salix pollen in late Flandrian II, such as those recorded at North Gill III (fig. 28), have been noted upon other diagrams from northern England (Pennington 1975), so that climatic and edaphic factors may be motive here, encouraging willow to replace alder under degenerating ecological conditions, particularly where anthropogenic effects have been operative.

A great contrast may be seen in late Flandrian II at North Gill between the rapid bog growth in the area of previous clearance near North Gill II and III, and the much slower rates of accumulation at the more peripheral sites of North Gill I and Head. For example 40 cms., of peat were deposited at North Gill between phase NG-I2 (5,220 ± 75bp, GU-1073) and the elm decline (4,767 ± 60bp, BM-426), in contrast to only 5cm., of peat at North Gill I in the same period. The effects of the impetus to bog growth given in cleared areas due to greatly increased water input, in contrast to those areas not subject to devegetation may be clearly marked here. The rapid rate of peat accumulation during this phase seems to explain the very low concentrations of all pollen types recorded at North Gill III during this phase (fig. 28), in addition to reduced rates of flowering and pollen production following the cessation of clearance. The only exception to this pattern is Sphagnum, which rises to super-abundance in both frequency (figs. 21, 22b, 23b, 25, 26b and 27b) and concentration (fig. 28). Clearly the transition to Sphagnum-dominated acid blanket bog had taken place by this stage, perhaps accelerated by the input of water from acid soils during and after local deforestation. Cyperaceae frequencies remain significant and will have remained part of the bog vegetation, indeed Eriophorum vaginatum is the main peat-forming material.

NG-C1 & NG - R4

Zone NG-C1 corresponds with zonule C1 at each pollen site. The decline of Ulmus pollen at its lower boundary marks the Flandrian II-III transition, and with the exception of North Gill II is a clear feature of pollen diagrams from North Gill, both relative and concentration, and evidently represents a real and major decline in elm. This initiates a period of forest clearance (Zone NG-C1) which gains expression upon the relative diagrams by a sharp fall in tree pollen values, primarily those of oak and lime as well as elm. Pteridium, Corylus and ruderal herbs increase but most impressive are the rises in frequency of Betula and Calluna pollen. Most striking throughout this zone are the very low concentrations of all pollen types entering the mire, with the single exception of Calluna which reaches its highest values thus far. Such low concentrations have been noted in this context before by workers in East Anglia (Sims 1973) and the Lake District (Pennington 1975), both in association with heavy oakwood clearance. They are best explained as resulting from increased run-off and input of material following clearance and consequent rapid deposition rates of sediment. When clearance ends in the succeeding zone, NG-R4, concentrations return to normal, with the expected exception of elm. The clearances of early Flandrian III are characterised by the spread of heathland taxa Betula, Pteridium and, especially, Calluna, and the deciduous woodland which had hitherto formed the climax vegetation in this area appears to have been locally, and probably permanently, replaced by moor and heathland, a culmination of the history of environmental alteration at this site which began in early Flandrian II.

CHAPTER FIVE

Bluewath Beck Head

5.1. Introduction

In order to determine if the phenomena manifest at North Gill were exceptional to that site, or whether similar clearance evidence may occur elsewhere within the region, it was necessary to investigate other areas of deep peat upon the Central Watershed. The survey of peat depths in this area carried out by Cundill (1971) had indicated that several concentrations of deeper 'basin' peats existed, and some of those which he had examined in detail showed evidence, in the form of charcoal and fluctuations in the pollen record, of vegetational disturbance in Flandrian II. These will be considered in more detail in chapter 7 of this thesis.

A large area of deeper peat exists around the headwaters of the Bluewath Beck, on Glaisdale Moor, and while Cundill did not examine this area in detail, he did perform a single basal pollen count which showed that peat formation had begun in Flandrian II. At this site (NZ 739 006) Betula was found to be the major component of a basal tree pollen sum which reached only 35% of total pollen, suggesting possibly open conditions and secondary woodland near to the site.

In the light of this evidence a field survey of the area was undertaken in order to find a profile for detailed analysis. Examination of a number of peat faces exposed by stream erosion showed a gross stratigraphy similar to that of North Gill and typical of basin peat deposits, including in many cases wood remains in the lower parts of the profiles. Charcoal was also evident in some places, although not so obviously as at North Gill. A profile for recovery was selected which had charcoal at more than one level, and appeared to have a thin mineral layer within its lower stratigraphy. Its grid reference was NZ 735 008 and the site was designated Bluewath Beck Head. The altitude of the site is 375m OD., and 1.70 metres of deposit was recovered for analysis, above which lay sixty centimetres of charred and disturbed organic material, created by the moorland fire of 1976. The location of Bluewath Beck Head relative to the study area is shown on fig. 1.

5.2. Site Stratigraphy

Following field and laboratory investigation the following stratigraphy was recorded.

Stratum	Depth (cms)	Description
11	0 - 20	Tb (Sphag)^{2}2, Th (vagi)^{2}1, Tl 1 nig.2, strf.1, elas.2, sicc.2, lim. sup.0 Poorly humified mid-brown peat comprised of *Sphagnum* moss and *Eriophorum vaginatum* with a high content of *Calluna* and other ericaceous rootlets.
10	20 - 54	Th^{3}3, Th (vagi)^{1}1, Tb (Sphag)^1+, Tl+ nig.3, strf.1, elas.1, sicc.2, lim. sup.0 Well humified monocot peat with many fresher fibres of *Eriophorum*, particularly at 36 and 48 cms. Occasional ericacious rootlets occur, in addition to a layer of fresh *Sphagnum* at 27 cms.
9	54 - 76	Th (vagi)^{3}3, Tb (Sphag)^{2}1, anth.+ nig.3, strf.1, elas.1, sicc.2, lim. sup.0 Dark, well humified *Eriophorum* peat, with bands of lighter *Sphagnum* peat at 58 and 72 cms. Fragments of charcoal occur between 55 and 60 cms., mainly very small in size.

8	76 - 110	Th^{3}2, Th (*vagi*)^{1}2, anth.+ nig.2, strf.1, elas.2, sicc.2, lim. sup.0 Well humified monocot *turfa* with a high proportion of macrofossil *Eriophorum*, much fresher and increasing in frequency near the base of the stratum. Charcoal occurs between 85 cms., and the base of the stratum.
7	110 - 139	Th (*vagi*)^{2}3, Th^{3}1, Tb (*Sphag*)^{1}+, anth.+ nig.2, strf.2, elas.2, sicc.2, lim. sup.0 Fresh, mid-brown, poorly humified *Eriophorum* peat, rich in macrofossil content with many fibrous strands of *Eriophorum*. Charcoal is abundant although restricted to very small fragments. *Sphagnum* moss between 120 and 134 cms., but in small quantities.
6	139 - 142	Th^{3}2, Tl 1, anth.1 nig.3, strf.2, elas.1, sicc.2, lim. sup.3 Well humified, homogenous dark brown monocot peat with little plant macrofossil content. Rich in charcoal, especially at 140 - 142 cms., with a large piece of charred wood, apparently *Betula* rootlet material at 139 cms.
5	142 - 156	Th^{3}2, Th (*vagi*)^{1}1, Dl 1, anth.+ nig.2, strf.1, elas.1, sicc.2, lim. sup.3 Brown, humified monocot peat with some

		fresher pieces of <u>Eriophorum</u> and large fragments of detrital wood and bark, identified as <u>Betula</u>, at 144, 146, 149, 151 and 155 cms. Charcoal occurs in small quantities throughout, with larger pieces at 143 - 145, 148 and 154 cms.
4	156 - 159	$Th^2 2$, Ag.1, anth.1, Dl+ nig.3, strf.2, elas.1, sicc.2, lim.sup.2 Dark, well humified monocot peat, very rich in charcoal between 157 and 159 cms., and with a thin but discrete layer of fine silt between 156 and 157 cms. Fragments of charred <u>Betula</u> bark occur above the charcoal rich peat.
3	159 - 164	$Th^2 2$, Th (<u>vagi</u>)$^1 1$, Dl 1, anth.+, Sh^4+ nig.3, strf.1, elas.1, sicc.2, lim. sup.2. Moderately humified monocot peat with fresh strands of <u>Eriophorum</u> and occasional pieces of detrital <u>Betula</u> wood. Tiny fragments of charcoal at 150 and 163 cms.
2	164 - 167	$Sh^4 4$, Ag.+ nig.4, strf.0, elas.0, sicc.2, lim.sup.1 Black, amorphous peat with no discernable macrofossil content. A very slight mineral fraction appears at the base of the stratum.
1	167 -170	Gs.4 nig.1, strf.0, elas.0, sicc.2, lim. sup.3 Coarse, yellow -orange sand.

5.3. Pollen Analysis

Samples were taken for pollen analysis at intervals of 2cms., throughout the lower half of the profile, closing to contiguous samples near the base, and the resulting pollen diagram is displayed as fig. 40. Four Local Pollen Assemblage Zones are recognised, applied to figs., 41a and 42a and are characterised as follows:

LPAZ BBH - A 167 - 157 cms.

Arboreal pollen is dominated by Pinus and Betula in this basal assemblage zone, and generally comprises up to 40% of the total pollen sum. Values for Quercus and Alnus are low but rise throughout the zone. While Tilia is almost absent, Ulmus values are moderate, but maintained, at about 4% of total pollen (15% of tree pollen). Shrub pollen is contributed mainly by Corylus (40% total pollen), for Calluna values are low throughout the zone. Isolated grains of Salix, Prunus and Hedera are recorded. Herb pollen values, including Gramineae, are generally low, but Cyperaceae is significant, approaching 35% of tree pollen. Dampland herbs Filipendula and Potentilla are present, and there are sporadic occurences of ruderal types, in particular Succisa. Pteridophyte spores are represented towards the end of the zone by Polypodium and Pteridium, with Filicales (undifferentiated) and Lycopodium near the base. Sphagnum spores are prominent in the assemblage, achieving over 100% of tree pollen. The zone is characterised by the dominance of tree and shrub pollen types, which together account for 80% of the total pollen sum. The upper boundary of the zone is drawn where Pinus values fall sharply.

LPAZ BBH - B 157 - 145 cms.

The assemblage continues to be dominated by tree and shrub pollen,

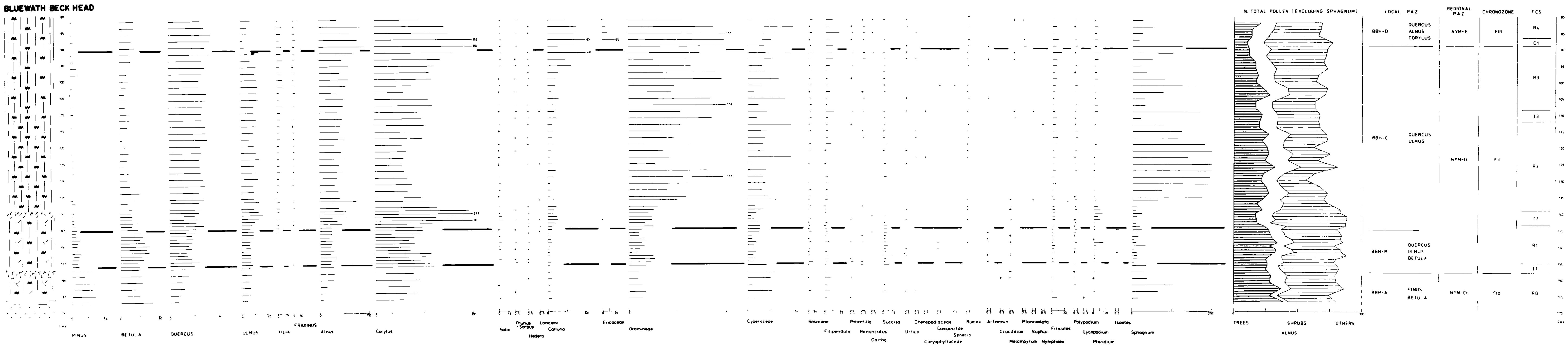
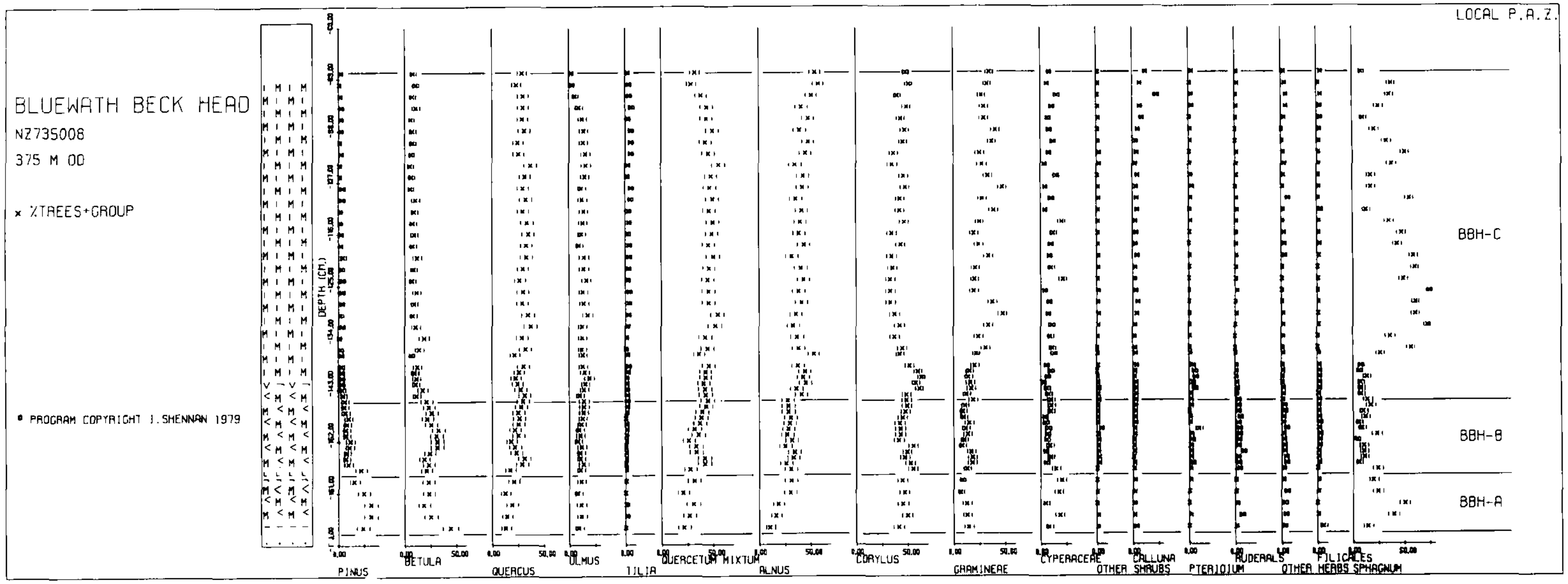

BLUEWATH BECK HEAD
PINUS
BETULA
QUERCUS
ULMUS
TILIA
FRAXINUS
Alnus
Corylus
Salix
Prunus
Sorbus
Hedera
Lonicera
Calluna
Ericaceae
Gramineae
Cyperaceae
Rosaceae
Filipendula
Potentilla
Ranunculus
Caltha
Succisa
Urtica
Chenopodiaceae
Compositae
Senecio
Caryophyllaceae
Rumex
Artemisia
Cruciferae
Plantago lanceolata
Melampyrum
Nuphar
Nymphaea
Filicales
Polypodium
Lycopodium
Pteridium
Isoetes
Sphagnum
% TOTAL POLLEN (EXCLUDING SPHAGNUM)
TREES
SHRUBS
ALNUS
OTHERS
LOCAL PAZ
BBH-D
QUERCUS ALNUS CORYLUS
BBH-C
QUERCUS ULMUS
BBH-B
QUERCUS ULMUS BETULA
BBH-A
PINUS BETULA
REGIONAL PAZ
NYM-E
NYM-D
NYM-Cc
CHRONOZONE
FIII
FII
FId
FCS
R4
C1
R3
I3
R2
I2
R1
I1
R0

Fig. 40. Bluewath Beck Head. Pollen diagram : percentages of tree pollen (excluding *Alnus*).

A



B

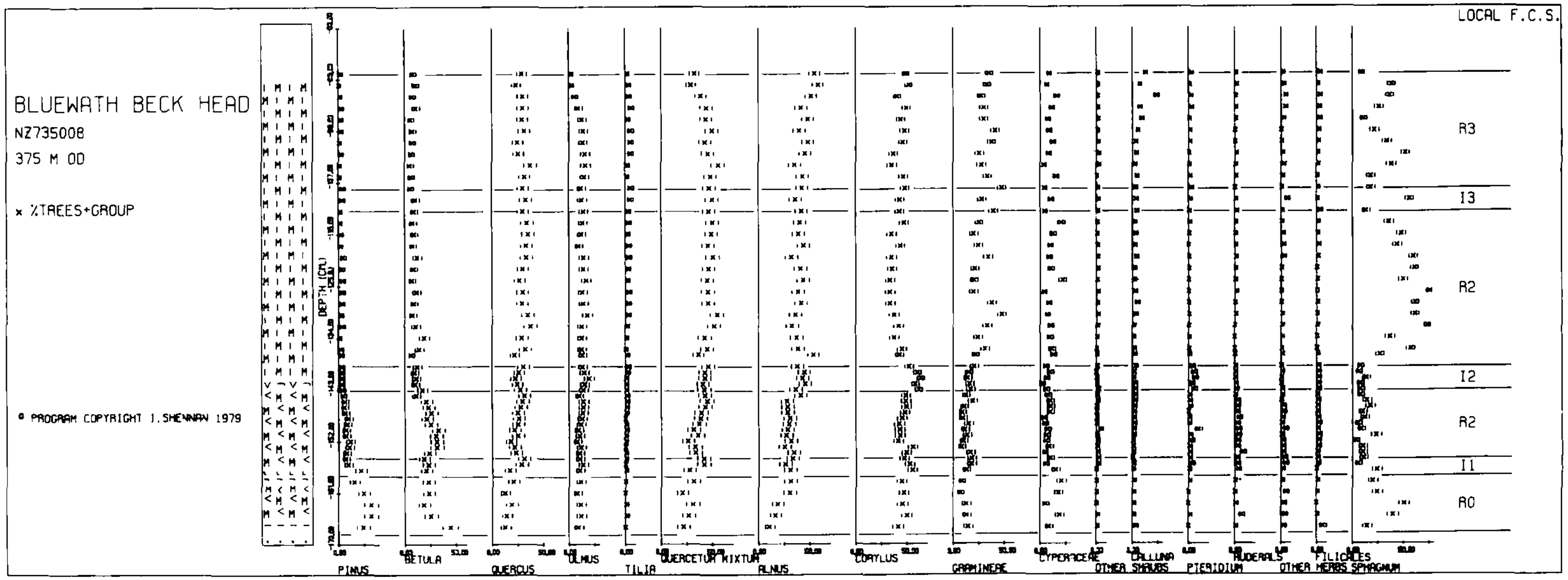
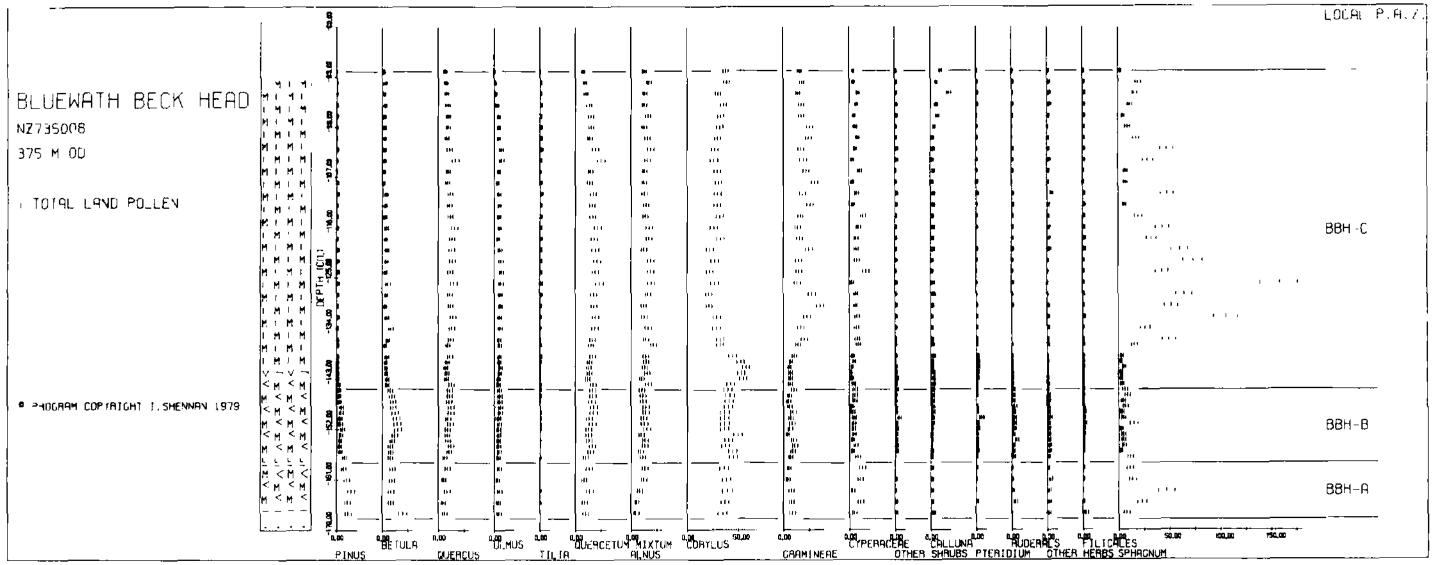


Fig. 11. Bluewath Beck Head. Pollen diagram: percentages of tree pollen + group.

A



B

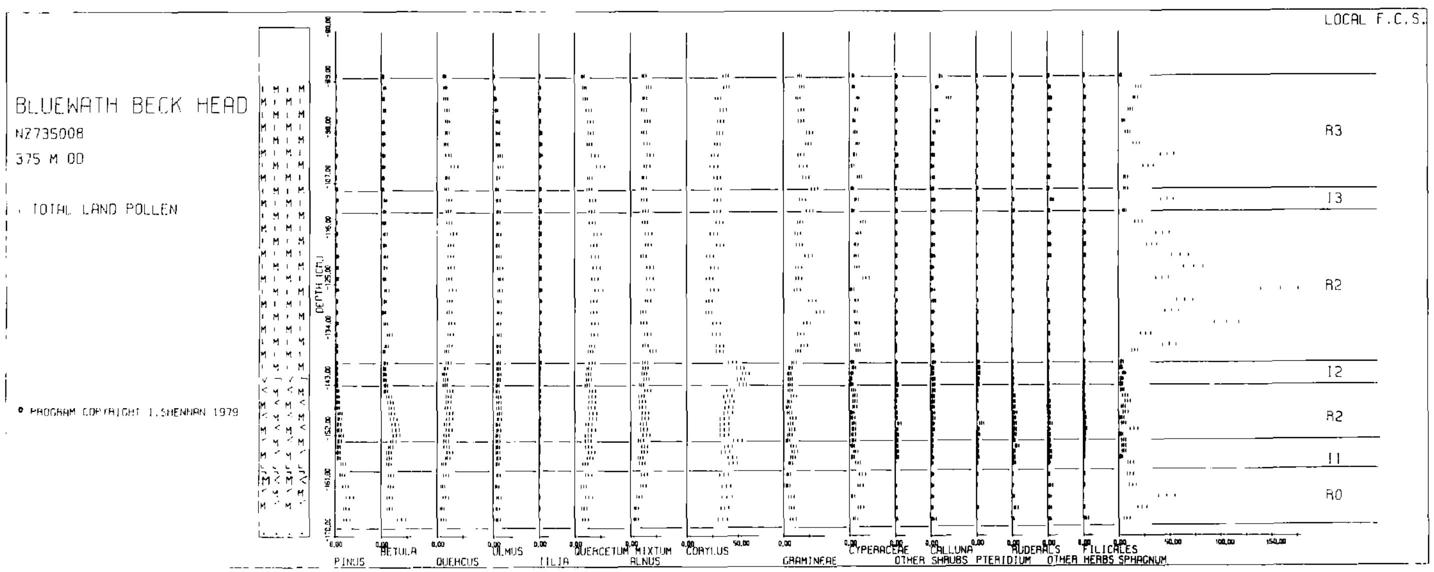


Fig. 42. Bluewath Beck Head. Pollen Diagram : percentages of total land pollen.

while herbaceous values, although showing an increased diversity of taxa, remain at less than 20% of total pollen. _Betula_ assumes dominance, providing up to 50% of the A.P. sum (15% total pollen), while _Quercus_ and _Ulmus_ increase their representation as the zone progresses. _Pinus_ declines sharply from its ascendancy of the previous zone, until it represents just over 10% of the A.P. sum (3% of total pollen). _Fraxinus_ appears for the first time and is recorded at intervals throughout the zone, while _Tilia_ is almost continuously present, although still in low values. _Alnus_ frequencies remain at less than 15% of total pollen, and _Corylus_ declines from a peak of 160% of tree pollen at the opening of the zone to more moderate values, rising again towards its upper boundary. _Prunus_, _Sorbus_, _Lonicera_ and _Hedera_ contribute to a shrub pollen assemblage within which _Salix_ and _Calluna_ exhibit increased frequencies. Declining Cyperaceae values are replaced by higher Gramineae representation, and a greater range of herbaceous taxa occurs, including types of both dampland and ruderal affinities. _Sphagnum_ occurs in much reduced frequencies but fern spores are rather more prominent than hitherto, particularly _Pteridium_. The upper boundary of the zone is drawn where _Betula_ frequencies fall, and are replaced by increased _Quercus_, _Ulmus_ and _Alnus_.

LPAZ BBH - C 145 - 90 cms.

The tree pollen assemblage is characterised in this zone by an increased representation of thermophilous taxa, especially _Quercus_ (50% A.P.) and _Ulmus_ (over 20% A.P.). _Tilia_ is also present in higher values, approaching 15% of tree pollen towards the end of the zone. _Betula_ and _Pinus_ are much reduced in frequency, although the former is still significant at up to 20% A.P. _Alnus_, while present in enhanced values, never becomes abundant and is a secondary feature of the assemblage

(c. 15% of total pollen). Light -demanding trees and shrubs are repeatedly recorded, Prunus, Sorbus, Salix and Hedera being present, while the Fraxinus curve is almost continuous, although still at low frequencies. Calluna remains but poorly represented and shrub pollen continues to be dominated by Corylus. The general rise in N.A.P. values is accounted for by a pronounced expansion of Gramineae, supported by increases in Cyperaceae and dampland taxa Filipendula and Ranunculus. Ruderal herb pollen is recorded intermittently throughout the zone. Aquatic pollen, contributed by Nuphar and Nymphaea, is recorded for the first time. Fern spores are a significant aspect of the assemblage, Polypodium and Pteridium being almost continually recorded. Although poorly represented at the beginning of the zone, Sphagnum rises to high frequencies before gradually declining in importance again. The upper boundary of the zone is drawn where a temporary but marked diminution of Ulmus frequencies occurs in the context of a general decline in A.P. values.

LPAZ BBH - D 90 - 82 cms.

Quercus and Alnus, with Corylus, are the major constituents of this zone. Betula and Fraxinus increase their representation slightly while Ulmus, severely depressed at the start of the zone, recovers later. Tilia and Pinus are unchanged in value. Corylus attains a peak in frequency (40% total pollen) although declining later, while other shrub taxa, Salix, Prunus and Sorbus, are much in evidence. Dwarf shrub values increase greatly during this zone, Calluna showing a marked expansion, as well as other members of the Ericaceae, particularly Erica tetralix. Gramineae frequencies remain very high and ruderal herb values increase, among which Plantago lanceolata is recorded for the first time. Dampland herbaceous types are very prominent, as are Pteridophyte spores, particularly those of <u>Pteridium</u>. <u>Sphagnum</u> frequencies are greatly reduced. Total N.A.P. exhibits its greatest recorded expansion in the early part of the zone, receding in value toward its end.

Assemblage zone BBH - A is assigned to R.P.A.Z. NYM - Cc, zones BBH - B and BBH - C are considered to lie within R.P.A.Z. NYM - D, and zone BBH - D may be referred to R.P.A.Z. NYM - E.

5.4. Forest Clearance History

Nine local stages in the history of forest clearance at Bluewath Beck Head are recognised upon fig. 40, of which the lower seven are applied to figs. 41b and 42b, and are used to zone fig. 43. These local stages are used as a basis for description of the evolution of the landscape.

FCS Zonule R0 167 - 158 cms.

Pollen fluctuations diagnostic of forest clearance are not observed during the basal zonule R0, for tree pollen values remain relatively steady, representing 45% of total land pollen (fig. 43). Occasional grains of the open-habitat herbaceous taxa Chenopodiaceae, <u>Urtica</u> and <u>Succisa</u> are recorded but other possible indicators of open environments, <u>Pteridium</u>, <u>Calluna</u> and Gramineae, are present only in low values. <u>Corylus</u> frequencies are high, at 35% of total land pollen, but do not fluctuate and there is little evidence of landscape change during this phase. The woodland, dominated by <u>Betula</u> and <u>Pinus</u>, although open in character, was apparently undisturbed and stable.

FCS Zonule I1 158 - 153 cms.

The presence of charcoal and silt inwash in the stratigraphy

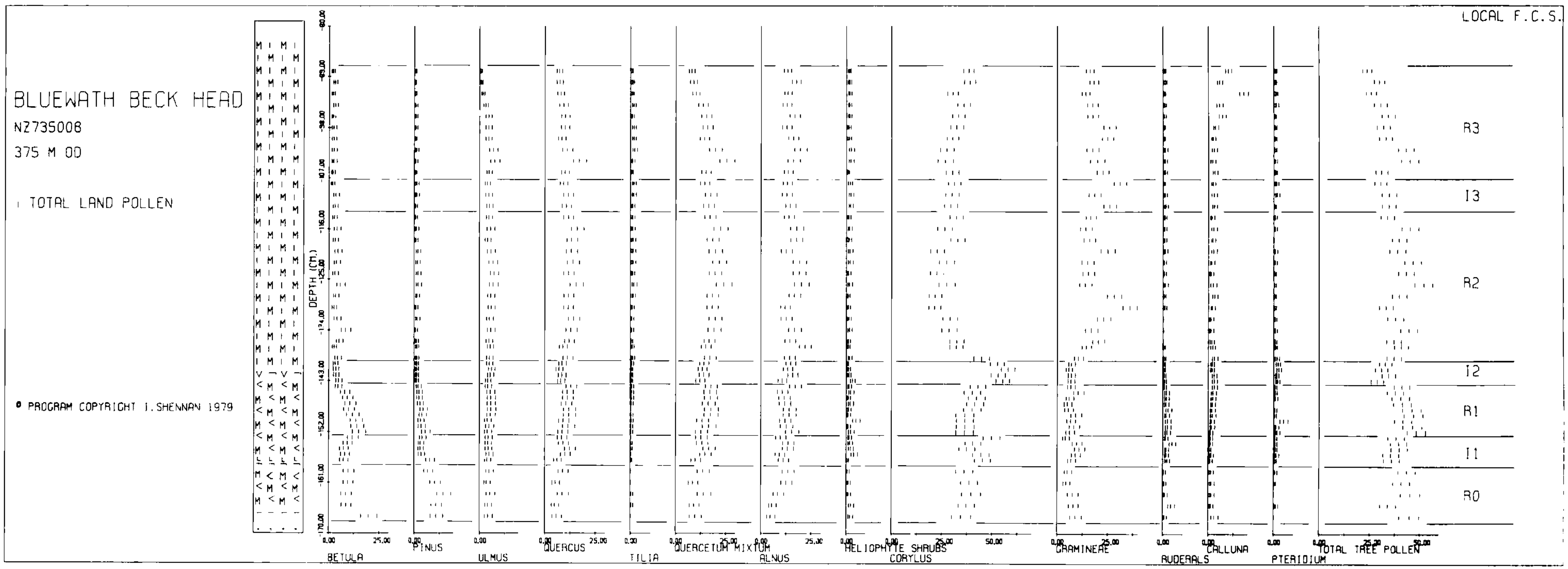


Fig. 45. Bluewath Beck Head. Pollen diagram : selected clearance taxa as percentages of total land pollen.

suggests possible environmental change near the site and fluctuations in the pollen record may be observed at this level which are diagnostic of forest clearance. Total tree pollen frequency falls to 35% of total land pollen, both Betula and Pinus being reduced in value, the latter particularly so. Deciduous forest trees are encouraged during this period of woodland disturbance, Quercus and Alnus showing enhanced frequencies. Tilia becomes continuously recorded and Fraxinus is recorded for the first time. The increase in non-tree pollen during this zonule is contributed largely by Corylus, which rises from 35% to 50% of total land pollen. Peaks occur in the pollen curves of other taxa favoured by clearance, including Gramineae, Salix, Rosaceae, Prunus and Sorbus. Pteridium spores show a marked increase in frequency also and the increase in importance of heliophyte taxa reflects the increased input of light to the ecosystem following the thinning of the tree canopy. Areas of disturbed ground allowed the ingress of ruderal herb taxa, among which Succisa, Melampyrum, Cruciferae, Artemisia, Rumex and Urtica were prominent.

FCS Zonule R1   153 - 143 cms.

The following zonule sees a cessation of clearance activity and the re-establishment of tree cover, for taxa indicative of disturbed environments are much reduced, both in range and frequency, and tree pollen values are restored to their former level of almost 50% of total land pollen. Although Quercus and Alnus increase in value, Betula is particularly augmented in frequency, and will have figured strongly in regenerating woodland communities. While Corylus recedes from its maximum values of the previous zone, it remains high at 35% of total land pollen and, with Salix, Fraxinus, Prunus and Sorbus still present, suggests that regeneration may have been incomplete. The continued, albeit sporadic, recognition of open-habitat taxa in the pollen record demonstrates the survival of non-wooded areas. Occasional grains of Melampyrum, Artemisia, Compositae, Urtica, Rumex and Succisa occur, but irregularly and without suggesting fresh clearance activity. Similarly Calluna and Pteridium are poorly represented, although a single large peak of the latter does occur.

FCS Zonule I2 143 - 139 cms.

A second and more distinct phase of forest clearance occurs within this zonule, as tree pollen is once again displaced in the assemblage by that of herb and shrub taxa characteristic of more open environments. Tree pollen frequency is reduced to a little over 30% of total land pollen, Quercus and Betula values falling sharply but other trees apparently remaining unaffected. While Melampyrum, Rumex and Urtica are recorded, herbaceous pollen types are not prominent, though Gramineae frequencies are enhanced. An expansion of shrub pollen representation is the main feature of this interference zonule, exemplified in the contribution by Corylus of 60% of total land pollen. Peak values are also displayed by the curves for Salix, Calluna, Fraxinus and Prunus pollen, and for Pteridium spores. A replacement of woodland by scrub and heath vegetation seems to have resulted from this clearance.

FCS Zonule R2 139 - 113 cms.

A long period of woodland regeneration and stability is described by zonule R2, as tree pollen values gradually recover until they again account for 50% of total land pollen. Major evidence of forest clearance is missing from the pollen record, although a peak in Gramineae frequencies occurs in mid-zonule. Corylus declines steadily to a mean of about 25% of total land pollen, while other indicators of open conditions such as *Pteridium*, *Fraxinus* and *Calluna* are poorly represented. Later in the zonule, however, these taxa show a slight but consistent increase in frequency and sporadic records of ruderal herb grains occur, including *Rumex*, *Urtica*, *Succisa*, Chenopodiaceae and Caryophyllaceae, suggesting a gradual thinning of the tree canopy and the maintenance of open areas within the woodland. Distinct episodes of clearance may not be discerned, however, and total tree pollen frequencies are only slightly reduced.

FCS Zonule I3 113 - 107 cms.

The trend towards more open conditions culminates in a phase of interference, described by zonule I3, during which a temporary recession of woodland takes place. Tree pollen values fall to 35% of total land pollen and the existing assemblage of ruderal herb types is augmented by taxa diagnostic of freshly-cleared ground, particularly *Melampyrum* and *Artemisia*. A corresponding expansion of heliophyte taxa occurs, with *Corylus*, *Pteridium*, *Calluna*, *Fraxinus*, *Salix*, *Prunus*, *Sorbus* and Rosaceae all increasing in value. *Quercus*, *Betula* and *Alnus* all show moderate reductions in frequency.

FCS Zonule R3 107 - 90 cms.

Few indications of clearance activity are present in this zonule which describes a phase of woodland regeneration during which tree pollen values initially rise to 50% of total land pollen, although gradually declining thereafter. *Quercus*, *Alnus* and *Ulmus* are mainly responsible for this increase, but *Tilia* and *Fraxinus* are also important. As the zonule progresses pollen of *Quercus* and *Ulmus* is supplanted by that of non-tree pollen types, especially *Corylus* and *Calluna*. *Pteridium* spore frequencies also increase. Restricted tree regeneration would appear to have allowed scrub and heathland communities partially to supersede woodland during this phase.

FCS Zonule C1 90 - 86 cms.

Clear indications of forest recession return to the pollen record between 90 and 86 cms. (fig. 40), as the declining tree pollen curve reaches its lowest recorded values, due to a fall in Ulmus frequencies. Ruderal herb taxa reflecting open, disturbed habitats enter the assemblage, most significant being the first record of Plantago lanceolata. Also present are Artemisia, Melampyrum, Rumex, Urtica, Succisa and Chenopodiaceae. Corylus, Calluna and Gramineae all show considerably enhanced frequencies, and Pteridium also responds to this phase of clearance.

FCS Zonule R4 86 - 80 cms.

Indications of environmental disturbance are reduced during this zonule and taxa specifying open conditions recede from their peak values of the previous clearance stage, suggesting a renewal of tree cover as cleared areas regenerated. The continued presence of ruderal and heliophyte indicators and the greater frequencies of Fraxinus and Betula, suggest that where re-establishment of woodland proved possible, it was of reduced density.

5.5. Discussion

The site of Bluewath Beck Head is comparable to North Gill in recording in its lower profile an iterative sequence of woodland recession and regeneration, for which periodic fire-clearance of the vegetation appears to have been responsible. The recognition of the decline in Ulmus pollen frequency, which occurs around 90 cms., and forms the lower boundary of P.A.Z. BBH-D (fig. 40), as diagnostic of the Flandrian II-III transition, refers the sequence of interference and regeneration zonules RO-R3 (fig. 43) to a Flandrian II and therefore Mesolithic context. Although radiocarbon determinations are not available for this site, the pronounced nature of this elm-decline, and the character of the accompanying pollen spectra, suggest that it is correctly identified as the upper limit of chronozone Flandrian II, and thus may be dated to c. 4,750bp (Table 3). It is particularly marked upon fig. 44, which shows the relative frequencies of the major woodland trees, calculated as a percentage of the corrected tree pollen sum. The basal pollen spectra at this site, described by zone BBH-A (figs. 40 and 41a), have been assigned to late Flandrian I (R.P.A.Z. NYM-Cc) on the basis of low Alnus and high Pinus pollen values, affirmed by figure 44. In this respect these tree pollen spectra do, however, resemble those from the basal zonule NG-I1 at North Gill (fig. 35) which are radiocarbon dated to early Flandrian II. While the North Gill tree pollen spectra are attributed to clearance effects for which there is accompanying evidence in the form of macroscopic charcoal and ruderal pollens, those from Bluewath Beck Head do not contain such a record and are assigned to a zonule of regeneration (RO, fig. 43), with stable woodland communities. The status of Pinus in this area during and after the Flandrian I-II transition is equivocal, being involved, probably, with anthropogenic effects, and is discussed more in Chapter 7 (v.i. page 249). Thus while zonule RO at Bluewath Beck Head may yet prove to be of early Flandrian II date, it is designated as late Flandrian I pending radiocarbon dating. This designation finds a measure of support by comparison with the late Flandrian I pollen spectra

BLUEWATH BECK HEAD

Percentage of Corrected Tree Pollen Sum

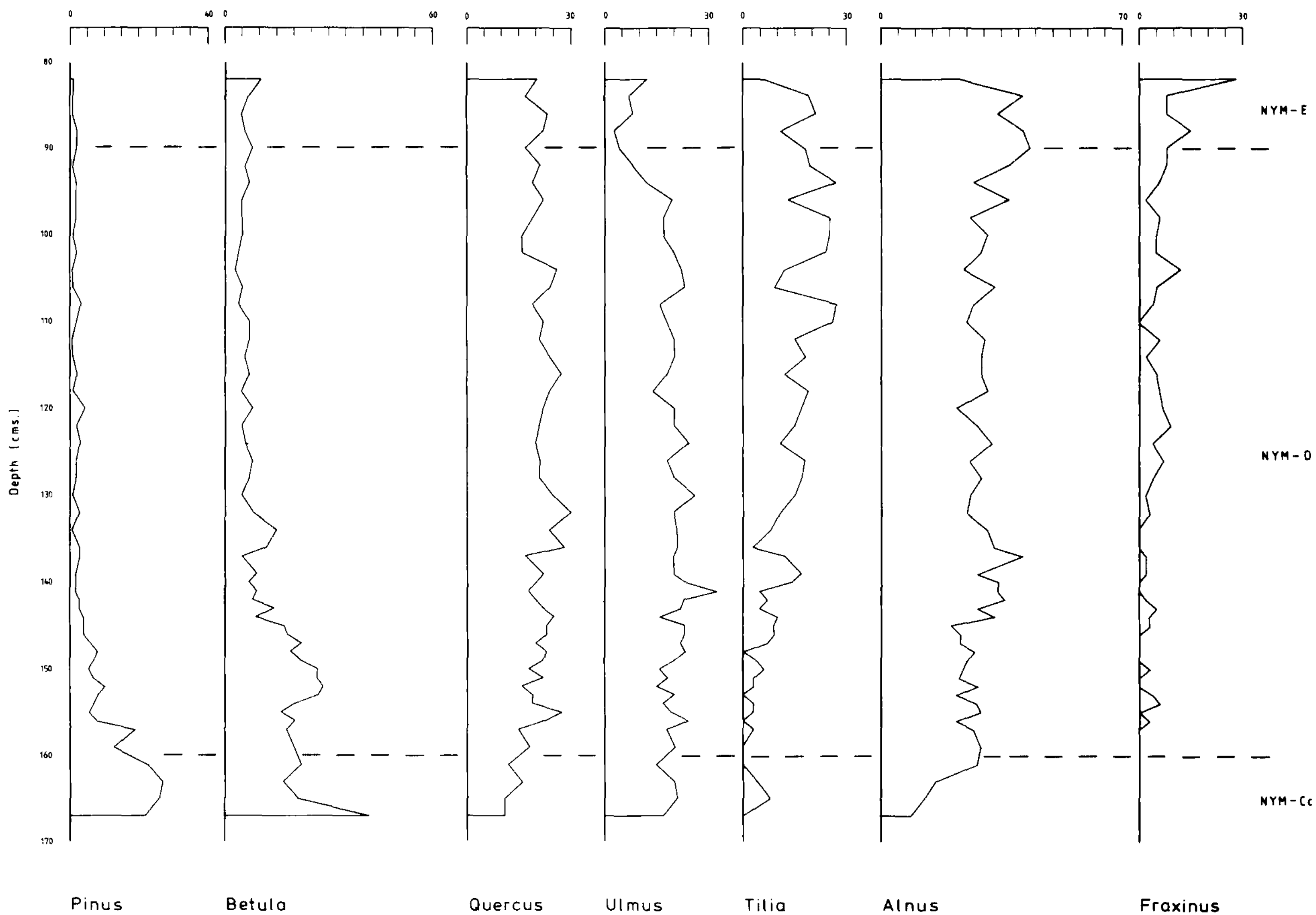


Fig. 44. Bluewath Beck Head. Pollen diagram : trees as percentages of total corrected tree pollen.

from the nearby site of Glaisdale Moor (NZ 728 015, Simmons and Cundill 1974a).

Conforming with evidence from North Gill, the pre-elm decline deposits at Bluewath Beck Head were found to contain microscopic charcoal material at all levels, increasing in abundance at certain horizons, particularly during zonules of interference I1 and I2, where a distinct macroscopic presence could be discerned. These discrete layers do not, however, rival those at North Gill in thickness, being much less substantial. While a detailed estimation of microscopic charcoal content at Bluewath Beck Head is not presented, its occurrence at consistently high levels throughout the deposits of Mesolithic age is further support for the hypothesis that burning of the vegetation was a continuous factor in the Central Watershed area during this period. Significantly, microscopic charcoal ceases to be recorded in the stratigraphy above 85 centimetres, which corresponds with the end of clearance zone C1 (fig. 40), although quite large fragments do occur between 55 and 60 cms. Such evidence mirrors that from North Gill and argues cogently that the cessation of fire-pressure upon the environment which took place at that site during early Flandrian III was applicable in the eastern Central Watershed area as a whole. This may be interpreted as a retraction of human influence from the uplands of the Moors during the Neolithic period, with a later resumption of clearance activity, perhaps in the succeeding Bronze Age (Jones et al. 1979).

The phases of woodland clearance which occur at Bluewath Beck Head during Flandrian II follow the familiar pattern recorded in detail at North Gill, with declines in tree pollen types and their replacement by ruderal herb, heliophyte shrub and heathland taxa typical of woodland regeneration through seral communities. The most intense phase of clearance appears to have been the earliest, described by zonule I1, during which destruction of birch and pine woodland appears to have taken place, charred Betula bark appearing in the stratigraphy, although pollen values for other trees also fluctuate. Bare, disturbed ground was evidently created over an area sufficiently large to allow substantial inwash of mineral soil into the mire following erosion from cleared slopes, prior to its recolonisation by post-fire taxa such as Artemisia, Melampyrum and Pteridium. Although lacking the silt inwash accompanyment, the clearance of zonule I2 was also an event of some intensity, involving actual removal of what would have been a dense birch-oak-alder scrub woodland from around the streamside and its environs. The effects of these two episodes of forest clearance upon local woodland composition appear in each case to have been a great increase in Corylus representation in the short term, either by increased flowering after sprouting or by an actual expansion of the shrub, while regeneration was progressing. In the longer term, Betula appears to have become established as the local sub-climax woodland. Very distinct peaks in Betula pollen frequencies may be noted during the earlier parts of post-clearance zonule R1 and R2, and Betula wood occurs in the stratigraphy at these points, some being rootlet material indicative of in situ re-establishment of woodland. A steady decline in the importance of Betula occurs from mid-zonule R2 onwards and, with Pinus already at low levels, the forest of later Flandrian II was characterised by the mixed deciduous woodland trees Quercus, Alnus and Ulmus, with Tilia becoming an increasingly important component according to the corrected tree pollen diagram (fig. 44), surpassing elm late in the zone. This woodland was of open character, however, with progressively increasing Fraxinus and Corylus and other heliophyte shrubs continually prominent. It would appear that while there were many gaps in the tree canopy which allowed the development of herb and shrub communities of lower stature, this part of the Central Watershed was covered by mature broad-leaf woodland. Alnus presumably formed stands around the stream with oak, ash, hazel and lime comprising the surrounding woodland. The probability of tree growth at this high altitude in Flandrian II upon the drier area of the Central Watershed is in accordance with the evidence from Glaisdale Moor (Simmons and Cundill 1974a) where wood remains are abundant in pre-Ulmus decline levels.

The openness of the later Flandrian II woodland and the gradual thinning of its canopy is shown by the sporadic occurrence of the pollen of ruderal types. These may record the effects of clearance at a distance from the site, perhaps masked by the screening effect of the dense Alnus carr which appears to have fringed the stream. The most significant of these later phases is described by zonule I3, during which pollen fluctuations and the appearance of indicator taxa are sufficiently clear to demonstrate genuine woodland recession, but perhaps not intense enough for it to have taken place immediately adjacent to Bluewath Beck Head itself. The absence of major charcoal or silt presence tends to support its extra-site location. It may be of relevance here that North Gill is situated less than 1,000 metres to the west of Bluewath Beck Head (fig. 1), and it is possible that zonule I3 at the latter site may record the vegetation changes which took place during the high intensity clearance of zonule NG-I2 at North Gill (v.s. chapter 4) during later Flandrian II. Transport and reception of pollen over such a comparatively short distance may well have been possible, for if prevailing winds were chiefly westerly, as is the case today (v.s. page 35), transfer of pollen to Bluewath Beck Head from the clearance site at North Gill could easily have been effected through the open woodland considered to have existed at that time. It may be significant that many of the clearance indicators in zonule I3 at Bluewath Beck Head, with the exception of most ruderal herbs, are anemophilous in character. The whole question of the possible correlation of the clearance zonules at North Gill and Bluewath Beck Head however, is one which may be capable of resolution only after radiocarbon dating of the relevant horizons. There is little doubt that phases I1 and I2 at Bluewath Beck Head are intrinsic to the site for they initiate changes within the mire system itself, in addition to their introduction of allochthonous material. A stimulation of bog growth seems to have occurred following zonule I2, for expansion of Gramineae and Sphagnum frequencies is well marked (fig. 41b and 42b), supported by rises in Cyperaceae and wetland and aquatic herb taxa.

CHAPTER SIX

East Bilsdale Moor

6.1. Introduction

In the preceding two chapters attention has been devoted to sites on the eastern part of the Central Watershed, which has been subject to previous paleoenvironmental research, particularly by Simmons (1969a) and Cundill (1971). This previous research, allied to the data presented in this thesis, permits the formulation of models of environmental change during Flandrian II, and consideration of the role of Mesolithic communities within them. So that these models may be applied to the uplands of the North York Moors as a whole, in this chapter results of research carried out upon the western area of the Central Watershed will be presented. In this way, any regional differences in character or intensity of human activity may become apparent. East Bilsdale Moor was chosen as the westerly study area and its location, with the sites sampled for pollen analysis, is shown on fig. 1.

Because of its extremely high concentration of microlithic flint sites, this area was considered to be of high potential for evidence of Mesolithic activity. It has long been recognised as a prolific find spot for later Mesolithic geometric industries (fig. 4 and page 47), but has more recently witnessed the discovery of industries of Early Mesolithic, non-geometric traditions, of Star Carr and general broad blade affinities (fig. 3 and page 44). East Bilsdale Moor appears therefore to have served as a hunting territory throughout the Mesolithic occupation of the region, during Flandrian I and II.

The area was visited in the company of Mr. G. V. Taylor of Bradford, who was engaged in the excavation of sites at Money Howe.

A field survey was conducted to ascertain peat depths and to locate suitable sites for pollen analysis. The area is characterised by a thin peat cover, which, over much of East Bilsdale Moor, is less than fifty centimetres thick or absent altogether. Three centres of deeper peat were found, two of which were situated at the head of small streams which form the headwaters of the Bonfield Gill, while the third occupied the crest of the ridge which runs to the north towards Bransdale Moor and Stump Cross (SE 606 982). The location of archaeological and pollen analytical sites, and the depth of peat within the study area, is shown upon a choropleth map which is displayed as figure 45.

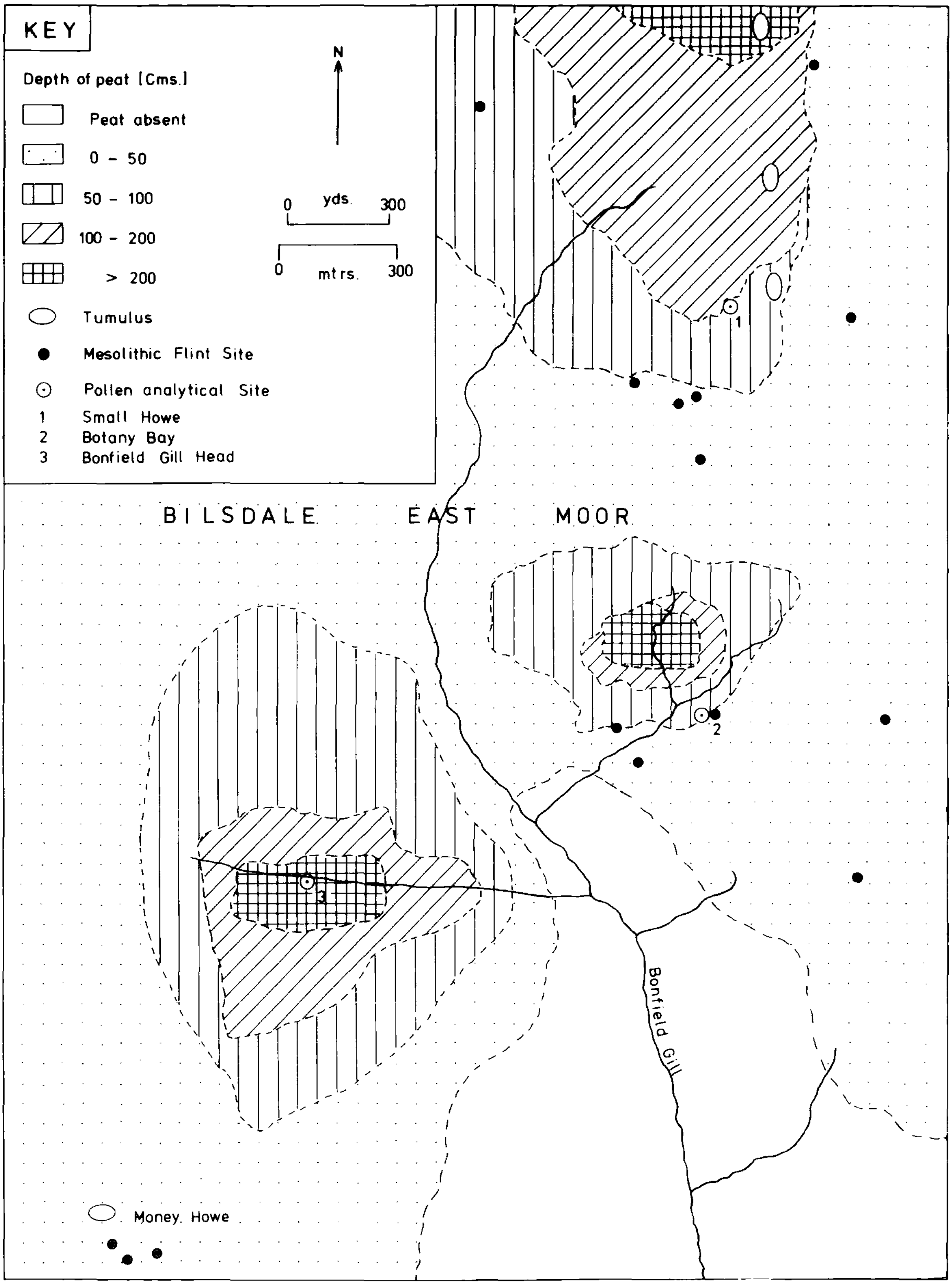


Fig. 45. East Bilsdale Moor. Peat depth and location of microlithic and pollen analytical sites.

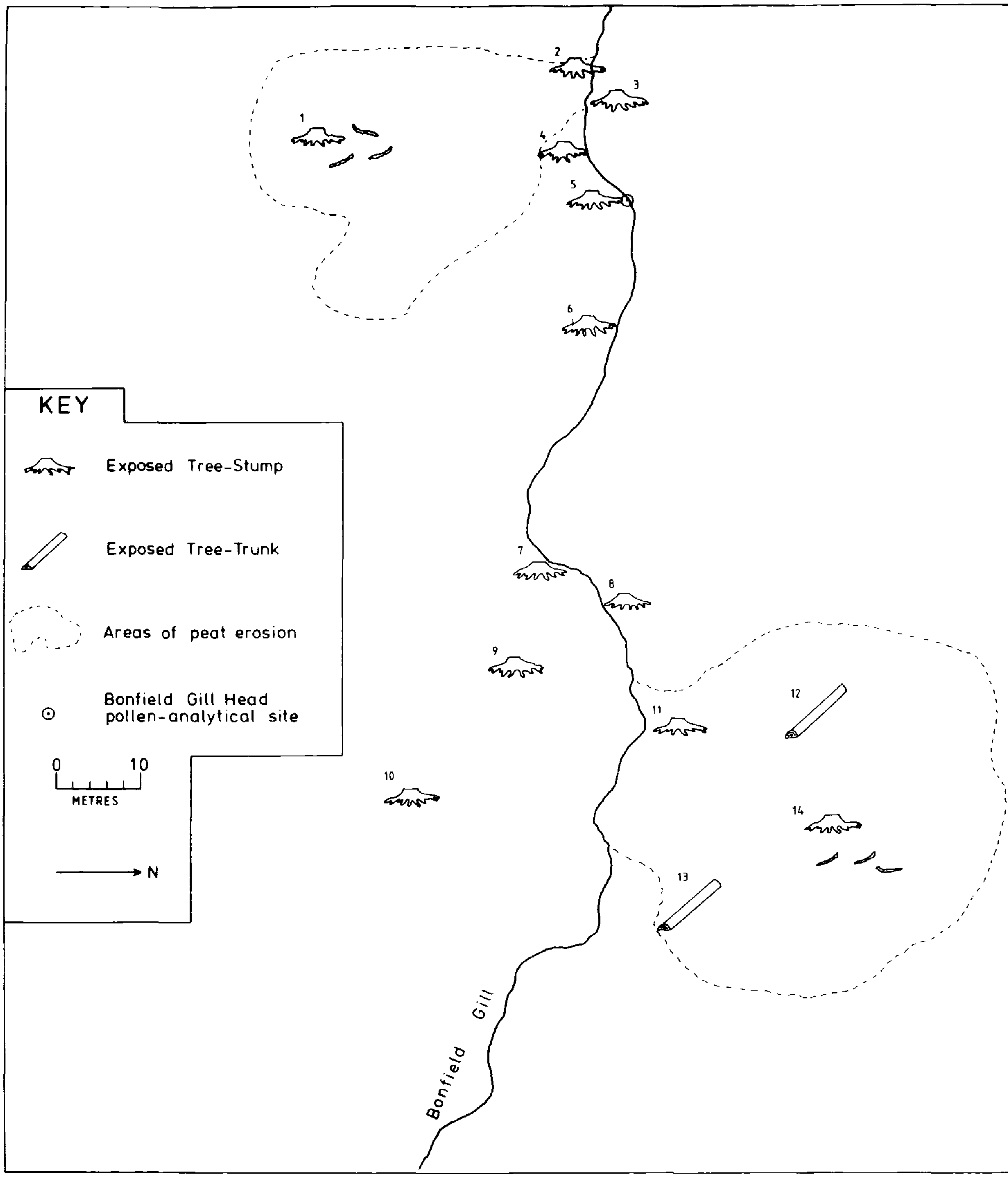


Fig. 46. Bonfield Gill Head. Distribution of tree stumps and location of pollen analytical site.

Bonfield Gill Head

6.2. Introduction

The major pollen analytical site on East Bilsdale Moor is located near the head of the most westerly tributary of the Bonfield Gill. Rising on the ridge above Bilsdale and flowing eastwards, it cuts down through an area of deeper peat, exposing a profile to examination. This site, designated Bonfield Gill Head and located upon fig. 45, lies at an altitude of 346m OD., and has a grid reference of SE 598 958.

Peat depth in excess of two metres was noted in the sections cut by stream erosion. Away from the immediate environs of the stream, the blanket peat is shallower and undergoing severe wind erosion in places. These erosion patches have revealed several trunks and stumps of trees of quite a considerable size, some *in situ* rooted in peat or mineral soil. Tree stumps also occur within the stream sections, but in this case rooted within the peat profile itself, more than half a metre above the level of the basal mineral material. These stumps are clearly *in situ* and seem to record colonisation of a considerable depth of peat by woodland. Distinct layers of detrital wood were noted in the peat below the level of the tree stumps, alternating with more amorphous pieces of charcoal. A concentration of wood remains lay at the base of the organic deposit, where it graded into sandy mineral soil, below which was a stiff white-grey clay. Above the level of the tree stumps the deposit is composed of monocot and *Sphagnum* peats typical of upland blanket peat profiles.

6.3. Tree Remains

Investigation of the exposed tree stumps and trunks revealed them to be *Betula* and *Quercus*, and their distribution is recorded upon fig. 46.

They may be described briefly as follows, and are *Betula* except where stated.

Macrofossil	Number	Description
Stump	1	A bole about 40 cms., in diameter and a number of associated large roots and wood fragments. Situated within a large erosion area.
Stump	2	Less than 30 cms., in diameter, eroded from the peat by stream action.
Stumps	3 & 4	About 30 cms., in diameter, *in situ* in the peat face above sixty centimetres of peat.
Stump	5	About 40 cms., in diameter with large roots, *in situ* in the peat face above sixty centimetres of amorphous and wood peat.
Stump	6	Bole around 20 cms., thick, with thin fragmented roots, eroded from peat.
Stumps	7 & 8	Stumps about 60 cms., in diameter, with roots spreading a further 100-120 cms. Virtually eroded from the peat, and with a lesser depth of organic deposit below them, no more than 40 cms.
Stump	9	About 30 cms., thick, with roots, and associated with much fragmented rootlet material.
Stump	10	About 50 cms., in diameter, beginning to protrude from the blanket peat.
Stump	11	About 30 cms., thick lying upon mineral soil in a large erosion patch.
Treetrunk	12	About 15 cms., in diameter, aligned NW-SE, lying upon mineral soil.

Treetrunk	13	About 25 cms., in diameter, also aligned NW-SE and lying upon mineral soil.
Stump	14	A massive stump, about 80 cms., in diameter with long roots, somewhat fragmented, spreading wide. Identified as Quercus.

6.4. Site Stratigraphy

A profile, immediately adjacent to stump number 5, containing a sequence of deposits typical of those exposed throughout the site, was selected for analysis. The peat face was cut back until the largest root of stump 5 was exposed to view within the peat, and the surface was cleaned. This root, which was 12 cms., thick, was then cut from the profile after its exact stratigraphic position had been recorded, so that it could be used for radiocarbon dating. The peat deposits behind the root were then available for sampling. The profile was recovered with monolith tins, the basal metre of deposit being extracted and removed to the laboratory. The upper limit of the sample was adopted as the site datum, above which lay a further metre of unsampled humified Sphagnum peat.

Following field and laboratory investigation of the sampled profile, the following stratigraphy was recorded.

Stratum	Depth (cms).	Description
12	0 - 20	Tb (Sphag)^{3}4 nig.3, strf.2, elas.1, sicc.2, lim. sup.0 Dark, well humified Sphagnum peat.
11	20 - 40	Th^{3}3, Th (vagi)^{2}1 nig.3, strf.1, elas.1, sicc.2, lim. sup.2 Well humified monocot peat with some fresher remains of Eriophorum vaginatum.

10	40 - 52	Th (vagi)^{2}3, Th^{3}1, Dl+, anth.+, Stirpes betulae nig.2, strf.2, elas.1, sicc.2, lim. sup.1 Less well humified Eriophorum peat, with twigs of Ericaceae near the top of the stratum, with a high proportion of undifferentiated monocot peat. Powdery charcoal 'soot' at intervals in the peat. Base of a large Betula tree stump at 38-41 cms.
9	52 - 54	Th^{4}2, Tl 1, Dl 1. nig.2, strf.2, elas.0, sicc.2, lim. sup.2 Amorphous monocot peat with large pieces of Betula wood of all kinds, bark, branches, twigs and roots. Well defined wood layer.
8	54 - 58	Th^{4}2, anth.2 nig.4, strf.0, elas.0, sicc.2, lim. sup.2 Amorphous monocot peat within which are many charcoal pieces, some of great size, the largest up to 15x9 mm.
7	58 - 70	Th (vagi)^{2}2, Th^{3}2 nig.2, strf.2, elas.1, sicc.2, lim. sup.1 Mid-brown monocot and Eriophorum peat, quite well humified.
6	70 - 77	Th^{3}2. Tl 1, Dl 1 nig.3, strf.1, elas.1, sicc.2, lim. sup.2 Well humified amorphous monocot peat with high wood content, small fragments mainly, with both rootlet and branch material present.

5	77 - 81	$Sh^4 2$, anth.2, Th^2+ nig.4, strf.0, elas.0, sicc.2, lim. sup.1 Black, well humified undifferentiated peat with abundant charcoal pieces of all sizes up to 10 mm., in diameter, and a slight admixture of undifferentiated herbaceous rootlet material.
4	81 - 90	Dl 4, Tl+ nig.2, strf.0, elas.0, sicc.2, lim. sup.1 Woody detrital peat, composed of fragments of branches, twigs and bark of <u>Betula</u>. Occasional pieces may be recognised as rootlet wood.
3	90 - 97	$Sh^4 3$, Ag 1 nig.2, strf.0, elas.0, sicc.2, lim. sup.2 Minero-organic amorphous peat
2	97 - 105	Ga4, Dl+ nig.2, strf.0, elas.0, sicc.2, lim. sup.2 Medium texture yellow-grey sand with tiny pieces of woody material, detrital wood and bark fragments.
1	105	As4 nig.0, strf.0, elas.0, sicc.2, lim. sup.0 Stiff, white clay.

6.5. Pollen Analysis

Samples for pollen analysis were taken from the profile at intervals not exceeding 2 cm., and a pollen diagram was constructed which is displayed as fig. 47. Three Local Pollen Assemblage Zones are

BONFIELD GILL HEAD

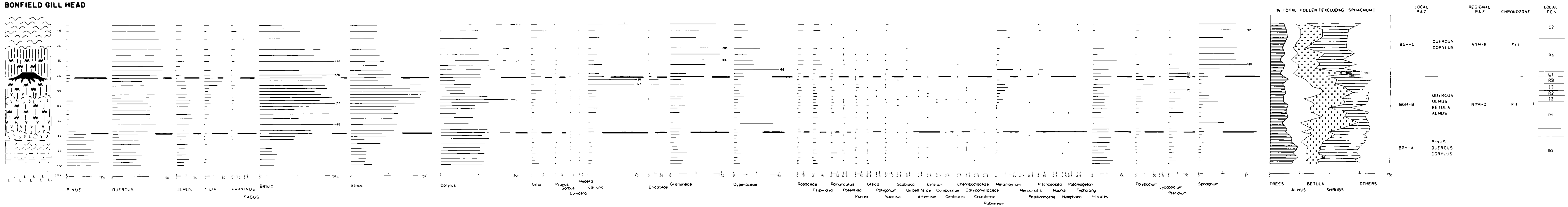
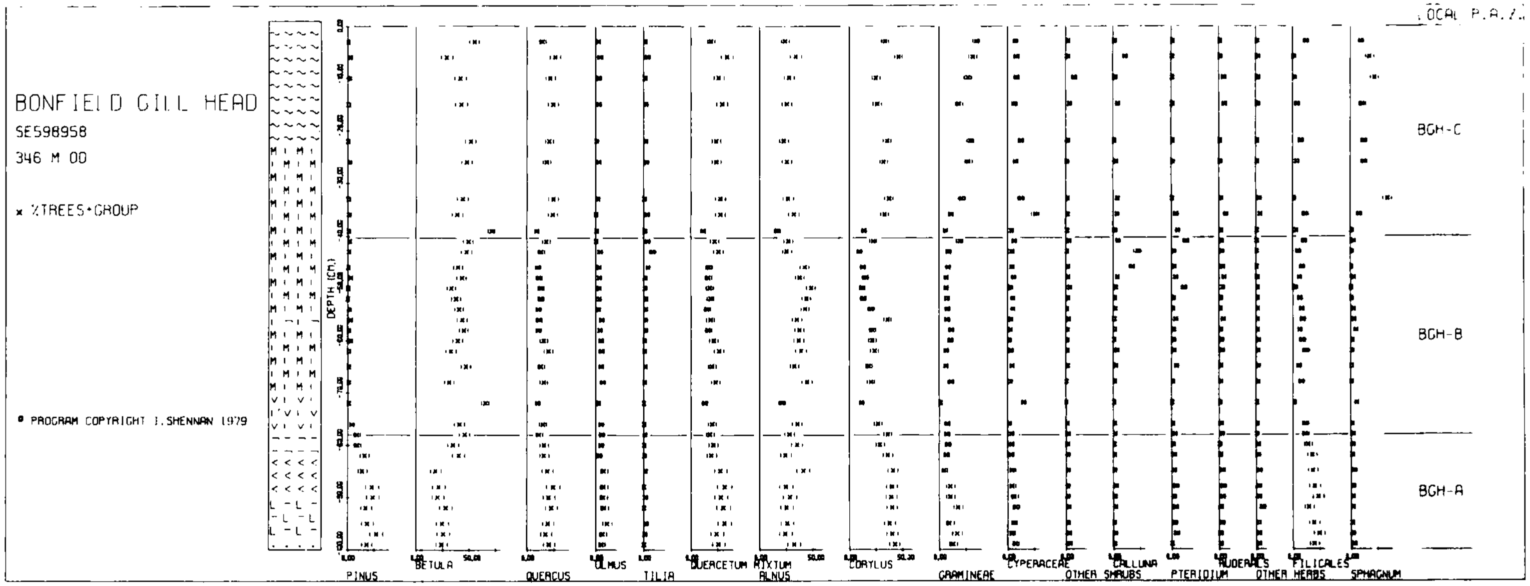


Fig. 47. Bonfield Gill Head. Pollen diagram : percentages of tree pollen (excluding Alnus).

A



B

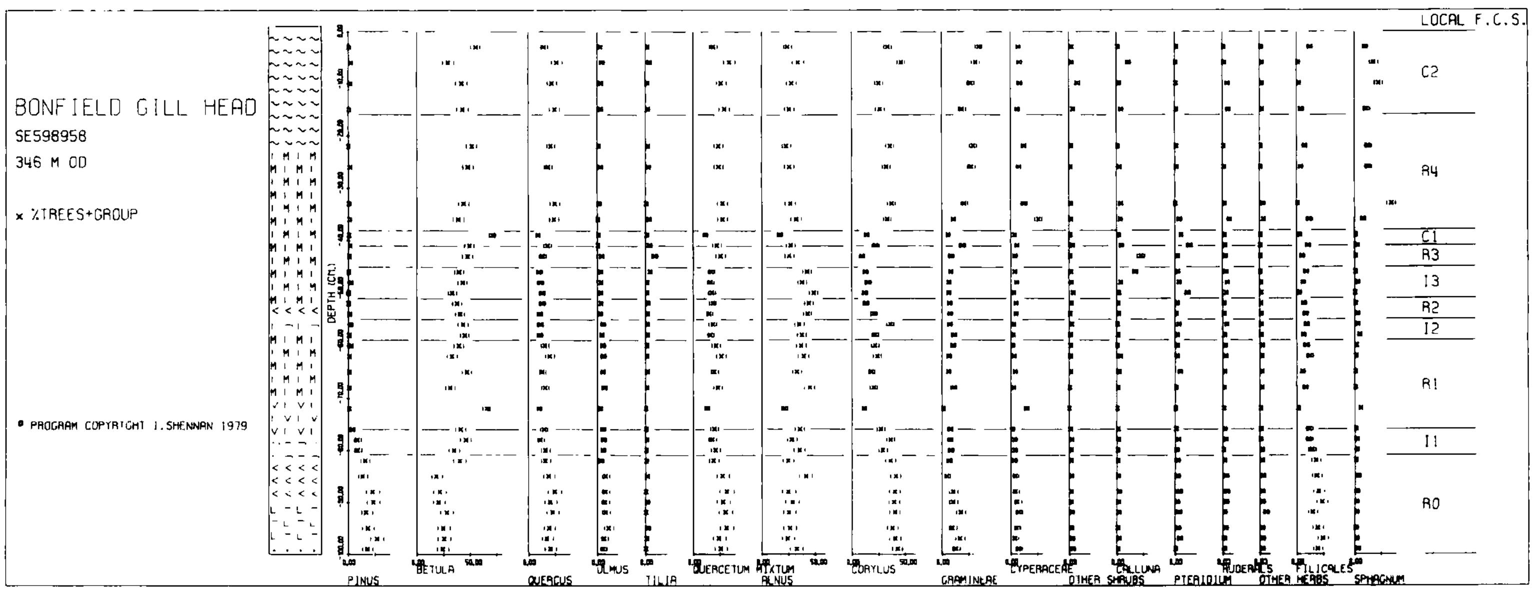
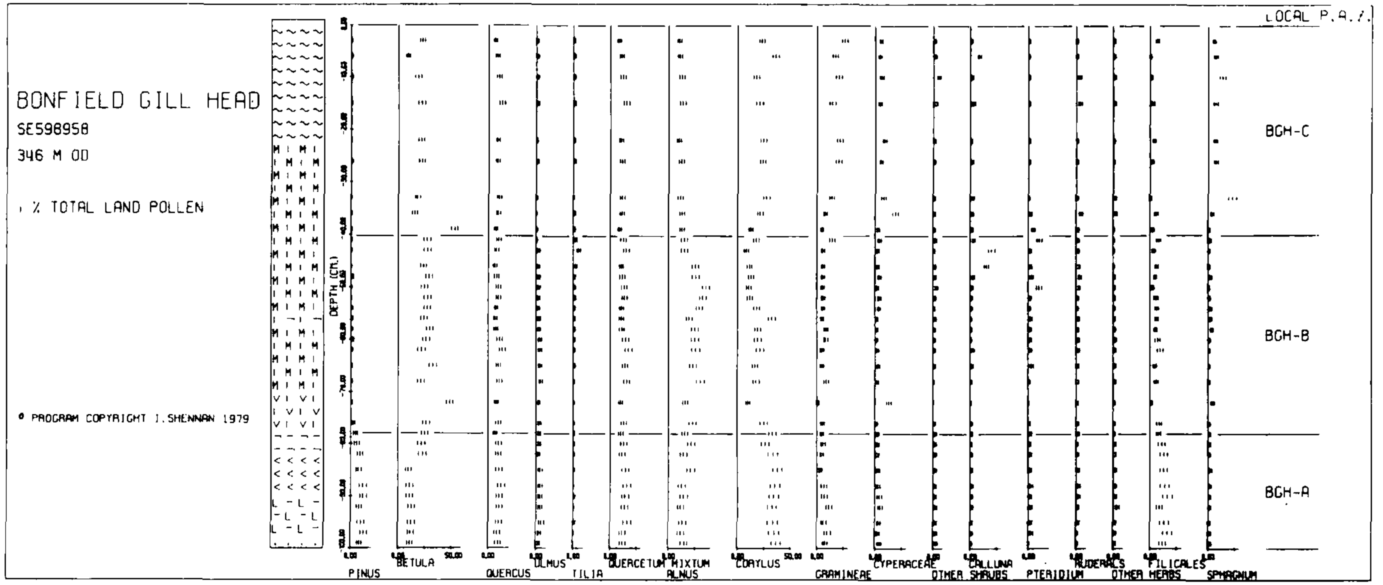


Fig. 4. Bonfield Gill Head. Pollen diagram : percentages of tree pollen + group.

A



B

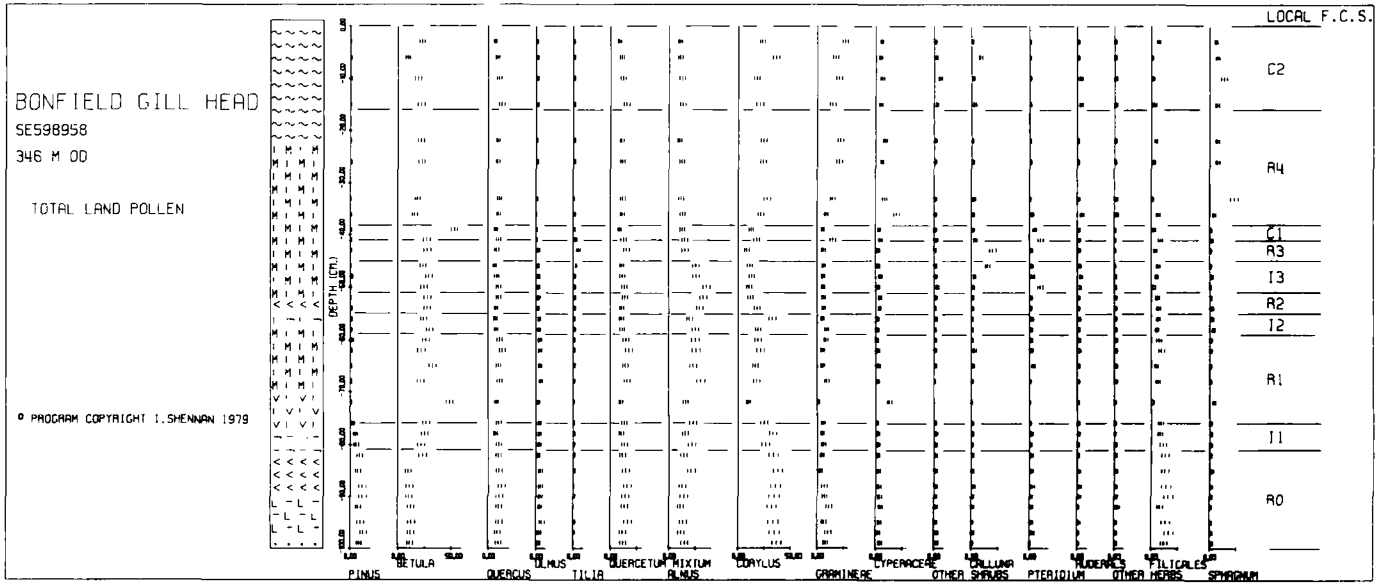


Fig. 4[illegible]. Bonfield Gill Head. Pollen diagram : percentages of total land pollen.

recognised, applied to figs., 48a and 49a, and are described as follows:

LPAZ BGH - A 99 - 77 cms.

Tree pollen values are high during this basal pollen assemblage zone, with Pinus and Quercus as the characteristic taxa. Each provides more than 40% of the tree pollen sum used in fig. 47. Values for Betula and Alnus are also substantial during this phase, however, and when introduced to the tree pollen sum (fig. 48a) represent over 20% of A.P., rivalling Pinus and Quercus. These four tree taxa together account for up to 50% of total pollen. Ulmus and Tilia are also present, the former significantly, the latter sporadically and in low frequencies. Fraxinus is absent except at the very end of the zone. Shrub pollen represents 40% of total pollen and is contributed mainly by Corylus, although Salix is of significance throughout this zone. Calluna, Hedera, Lonicera and Prunus complete the shrub assemblage. Gramineae frequencies approach 10% of total pollen and are the largest single component of the herbaceous group, Cyperaceae pollen being consistently infrequent. Herbaceous taxa indicative of dampland conditions are well represented, in particular Ranunculus, Filipendula and Potentilla, while open-habitat indicators also occur, albeit less regularly. Isolated grains of aquatic herbs are recorded. Pteridophyte spore frequencies are high and this group forms a major feature of the assemblage. Filicales is continuously present in values of up to 15% of total pollen and spores, while Pteridium values are also high. Sphagnum is continuously, although poorly, represented. The upper boundary of this zone is drawn where Pinus values fall, and Quercus, Betula and Alnus values rise.

LPAZ BGH - B 77 - 41 cms.

Characteristic of this assemblage zone is the rise of Betula and Alnus, until together they represent 50% of total pollen. Of the major tree taxa, Quercus and Ulmus assume dominance of the arboreal assemblage, although Tilia reaches very high frequencies near the end of the zone. Fraxinus pollen is more frequently récorded as the zone progresses, but always in low values. Pinus frequencies have declined markedly from their maxima of the previous zone and represent a minor feature of the assemblage, with less than 1% of total pollen. With the inclusion of Betula and Alnus, tree pollen types comprise 70% of total pollen, while shrubs have fallen to less than 20% of total pollen, due primarily to a decline of Corylus frequencies. Salix and Calluna representation is slightly greater than hitherto, with the latter especially approaching high frequencies near the end of the zone. Other ericaceous types are recorded for the first time in Erica tetralix. Herbaceous pollen representation is little increased during this phase at slightly more than 10% of total pollen and again Gramineae is the major contributor, although Filipendula and Ranunculus are the most important individual herb taxa. Ruderal and aquatic types rémain in evidence and Melampyrum is particularly abundant at over 2% of total pollen late in the zone. Fern spores are of increased importance with Filicales and Pteridium attaining high frequencies and Polypodium rising to occasional peak values. Sphagnum spores remain of little consequence in the assemblage. The upper boundary of the zone is drawn where a sharp fall in Ulmus values occurs.

LPAZ BGH - C 41 - 0 cms.

The Ulmus decline which marks the beginning of this zone takes place in the context of a general decline of tree pollen types. With

Betula and Alnus included (fig. 48a), tree pollen represents 40% of total pollen, shrubs and herbs each about 30%. Alnus and Betula frequencies fall, the latter more sharply, and together they comprise 25% of total pollen. Ulmus recovers from its initial decline, but never regains its former status, while Quercus values are increased. Fraxinus increases in frequency and Tilia values are maintained, but together they form less than 5% of all arboreal types recorded. A single Fagus grain is recorded near the top of the zone. Corylus, Salix and Calluna are all increased in frequency, while Prunus, Sorbus and Hedera are consistently present. Although herbaceous pollen as a whole increases in frequency, the variety of types recorded falls, with open-habitat types in particular reduced. Gramineae, Cyperaceae and the dampland herbs Ranunculus and Filipendula are mainly responsible for the herbaceous expansion, while Melampyrum still attains sporadic peaks in value. The representation of pteridophyte spores is markedly reduced, all types being affected. In contrast Sphagnum frequencies show a great increase.

Local Pollen Assemblage Zones BGH - A and BGH - B are considered to correspond to regional zone NYM - D, while zone BGH - C is referred to regional zone NYM - E.

6.6. Forest Clearance History

Ten local stages in the history of forest clearance at Bonfield Gill Head are recognised upon fig. 47, are applied to figs. 48b and 49b, and are used to zone fig. 50 as a basis for description of the evolution of the landscape.

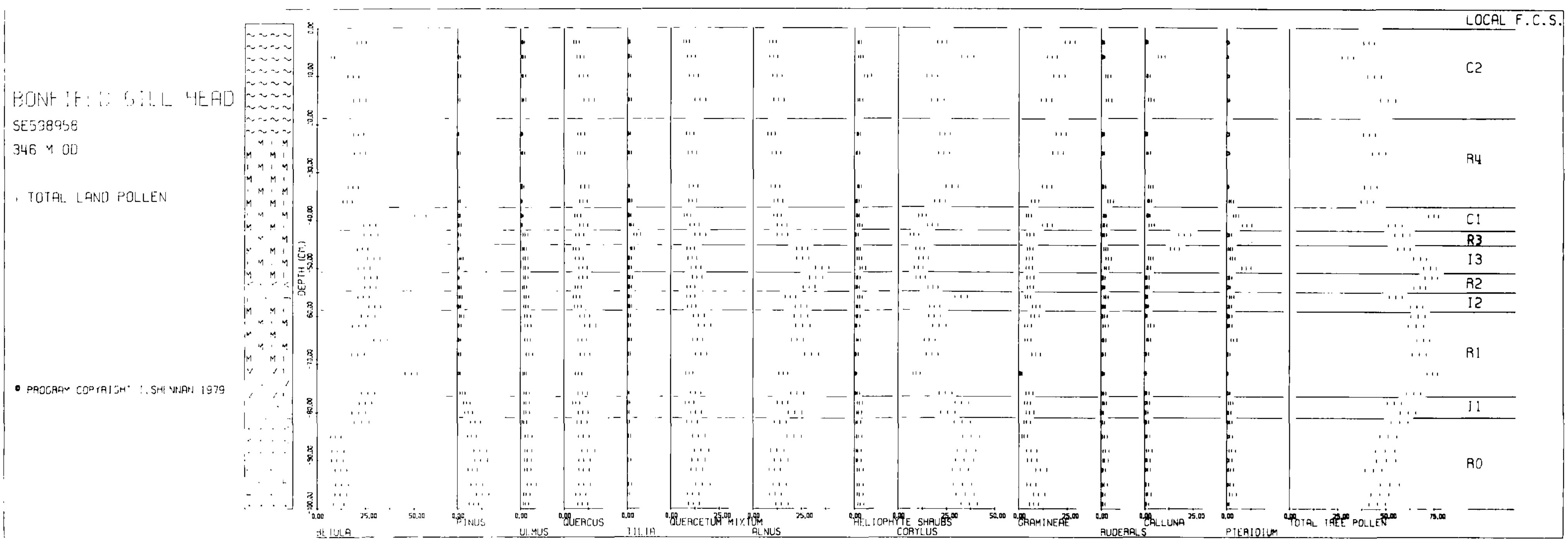


Fig. 5[illegible]. Bonf[illegible] Gill Head. Pollen diagram: selected clearance taxa as percentages of total land pollen.

FCS Zonule RO 99 - 81 cms.

The basal zonule RO apparently describes a time during which there is no active clearance at the site, for no charcoal appears in the stratigraphy. Dryland non-tree pollen values are high, however, accounting for 50% of total land pollen, with the heliophytes Corylus, Salix, Prunus and Sorbus prominent, as well as a high representation of Pteridium spores. The open aspect of the assemblage is confirmed by the presence of many xerophytic herb grains, including Rumex, Melampyrum, Artemisia, Cirsium and Succisa. The open nature of the vegetation at this stage may be the legacy of an earlier episode of forest clearance, occurring prior to the inception of peat formation at this site, although the pollen assemblage could also be interpreted as representing naturally open ground. The presence of many dryland taxa indicative of seral communities, however, and the gradual decline of heliophyte types, suggest regeneration to woodland and a progressive closure of the forest canopy. From a peak at the base of the zonule, non-tree pollen values decrease steadily as a trend to more wooded conditions ensues, caused primarily by an expansion of deciduous forest trees, particularly Quercus and Alnus. If clearance pressure were indeed exerted prior to peat inception, it evidently took place within an open woodland environment which contained Pinus, Betula and Corylus, for these taxa are most encouraged in the shrub-woodland which characterises early zone RO. Although no macrofossil charcoal is recorded at the base of the profile, fire may be indicated as a clearance mechanism by the presence in high values of taxa encouraged by burning, such as Pinus, Corylus, Pteridium, Artemisia and Melampyrum.

FCS Zonule I1 81 - 77 cms.

The trend towards more wooded conditions which characterises the basal zonule is abruptly reversed during zonule I1, as changes in both the density and composition of the woodland take place. A fall in total tree pollen frequency and the introduction of a range of open habitat taxa indicate a phase of forest recession and tree canopy opening, and the presence of large charcoal fragments in the stratigraphy suggests that fire was responsible for the clearance. A distinct increase in Betula frequency occurs, while Quercus and Alnus are adversely affected and Pinus sylvestris representation is greatly diminished. A sharp but temporary peak in the declining Corylus curve, echoed by both Calluna pollen and Pteridium spores, affirms the more open nature of the woodland, within which Betula replaced Quercus, Alnus and Pinus, the latter permanently. Fraxinus is recorded for the first time while the heliophyte shrubs Salix, Prunus and Sorbus are encouraged, as are taxa of the undifferentiated Rosaceae family, which may include shrubs of open habitat. Ruderal pollen types, particularly Melampyrum, Rumex, Cruciferae and Chenopodiaceae, show a first presence or enhanced frequencies. That the area of disturbed, open ground created during this clearance episode was substantial is indicated by the wide range of herbaceous taxa indentified which, in addition to those already mentioned, includes Scabiosa, Succisa, Urtica, Umbelliferae, Centaurea and Rubiaceae. This zonule clearly records an episode of forest clearance, and the temporary replacement of stable woodland conditions by a more diverse vegetation of pioneer and seral communities, within which taxa encouraged by fire were particularly favoured.

FCS Zonule R1 77 - 58 cms.

The disturbed conditions of the previous zonule are succeeded by a phase of regeneration in which a return to stable woodland takes place.

The zonule R1 is characterised by high tree pollen values, particularly for Betula and Quercus, less so for Ulmus and Tilia, while Corylus and Fraxinus diminish, virtually to nothing in the latter case. Light-responsive taxa, especially shrub types, are but poorly represented and clearly the closure of the forest canopy had been sufficiently complete to prevent their continued contribution to the pollen record. Herbaceous pollen grains occur sporadically, but these are confined in the main to wetland types such as Filipendula and Potentilla which will have been concerned with mire communities. While it is probable that damp glades were présent within the woodland as a consequence of the earlier forest recession, no evidence exists to record the creation of newly-cleared areas, and apparently the woodland remained undisturbed during this time. Low frequencies for Calluna and Pteridium support this view. As tree pollen represents 75% of total land pollen, relatively dense woodland evidently existed, within which Betula was at least locally dominant, although deciduous forest trees of the Quercetum mixtum, with Alnus are prominent.

FCS Zonule I2 58 - 55 cms.

A second phase of interference is recognised between 58 and 55 centimetres, as pollen fluctuations indicative of forest recession occur. Tree pollen values fall from 70% to 50% of total land pollen, Quercus, Alnus and Betula all declining sharply in value. Charcoal fragments were recovered from the stratigraphy at this level, suggesting that fire clearance of woodland in the vicinity of the site was the cause of this diminution of tree pollen frequency. The creation of open areas and disturbed ground near to the sampling point is attested by a marked expansion of taxa associated with ruderal conditions. Most prominent among the ruderal herb assemblage are Melampyrum, achieving 15% of total tree pollen, Rumex, Chenopodiaceae and Succisa, but lesser values are recorded for a wide range of analogous taxa, including Cirsium, Centaurea, Artemisia, Polygonum, Urtica, Cruciferae, Caryophyllaceae, Compositae, Umbelliferae and Scabiosa. This imposing assemblage denotes the creation of a considerable area of disturbed ground, into which Pteridium, Calluna and Gramineae are shown to have expanded by their sharply increased frequencies. Shrub types appear to have been greatly favoured by this reduction in tree cover, and Corylus in particular exhibits peak pollen values of over 30% of total land pollen. Other heliophyte shrubs which increase in representation are Salix, Prunus and Sorbus, while high Rosaceae values will again include taxa of this type. Trees which show increased frequencies due to this clearance event are Fraxinus, a component of regenerating woodland, and Pinus, pollen of which may be more regional in origin and finding conditions of transfer to the sampling point more favourable following the removal of the filtering effects of local tree cover.

FCS Zonule R2   55 - 50 cms.

A short phase of woodland regeneration and stability follows during which tree pollen regains its previous high value of over 70% of total land pollen. Alnus in particular increases in value, although Betula and Quercus also recover from their decline of the provious zonule. Fully wooded conditions seem to have been restored, for herbaceous indicators of newly open ground disappear from the pollen record, except for taxa confined to dampland environments such as Filipendula. Tilia appears to have formed an important constituent of the regenerated woodland and the dense, closed forest canopy severely reduced the representation of heliophyte shrub types, with Corylus, Fraxinus and Salix much depleted in frequency. Pinus values return to low levels, while Calluna and Pteridium are no longer major contributors to the assemblage, and the woodland appears to have remained both closed and undisturbed during this zonule, dominated by Quercetum mixtum types, plus Betula and Alnus.

FCS Zonule I3   50 - 45 cms.

Zonule I3 records a further period of extensive forest clearance, evidenced by a considerable fall in tree pollen frequency from 70% to 50% of total land pollen. Alnus is the tree most sharply reduced in frequency, falling from 35% to 25% of total land pollen, but Quercus is also adversely affected. Non-tree pollen types of all kinds are greatly increased both in range and frequency, with the exception of Corylus, which responds only weakly to this reduction in tree cover. Most favoured by clearance of woodland in this case is Pteridium which rises to very high values of 75% of tree pollen (fig. 47) and over 10% of total land pollen (fig. 50). Calluna also appears in very high values for the first time. Many herbaceous indicators of cleared ground return to the pollen record, including Urtica, Succisa, Artemisia and Caryophyllaceae. Most prominent within this herb assemblage, however, are Rumex and Melampyrum, the latter reaching 25% of total tree pollen (fig. 47) and being the major contributor to a combined ruderal curve which represents 5% of total pollen (fig. 50). Among light-responsive shrub taxa Salix and Fraxinus increase substantially in value, and their expansion is mirrored by the Rosaceous pollen curve. Again Pinus frequencies are enhanced during the clearance episode, due to the more open nature of the vegetation. This zonule clearly represents a recession of forest cover and the replacement of trees by open ground and scrub vegetation.

FCS Zonule R3   45 - 41 cms.

In the succeeding phase of regeneration, zonule R3, forest cover is again established across the site, although a more open kind of woodland seems to have come into existence, as total tree pollen values do not regain their previous high level, remaining at 55% of total land pollen. The composition of the woodland appears to have changed, with Tilia assuming a more important role, and Alnus much reduced in value. Although occasional herb grains are recognised, little evidence of continued disturbance of the environment is present and the reduced density of tree cover is probably due to incomplete regeneration following the previous episode of clearance. While Quercus, Alnus and Betula characterise the tree pollen assemblage, with Ulmus and Tilia also important, Fraxinus, Corylus, Pinus and Salix still occur in low frequencies, while the high Calluna values of the previous zonule persist into this phase of regeneration.

FCS Zonule C1   41 - 38 cms.

During the succeeding zonule C1, evidence of forest opening may once again be detected in the pollen record, for indicators of clearance return to the assemblage in the context of a general fall in all tree pollen frequencies except Betula. The decline of Ulmus pollen which occurs at the beginning of the zonule is accompanied by a reduction in Tilia pollen and the sharp rise in Betula frequencies suggests a significant change in woodland composition. The more open aspect of the woodland is denoted by rises in Gramineae and Corylus frequencies, with a commensurate increase in Pteridium spores which attain 80% of total tree pollen (fig. 47) and 12% of total land pollen (fig. 50). Among the herbaceous indicators of woodland disturbance are Succisa, Rumex, and Chenopodiaceae, while

Melampyrum values are very high, reaching 30% of total tree pollen (fig. 47). Of particular significance is the first appearance of Plantago lanceolata pollen, indicating the high intensity of this phase of clearance.

FCS Zonule R4   38 - 18 cms.

Regeneration zonule R4 sees a return to wooded conditions during which indicators of active clearance are almost absent from the pollen record. Regeneration of woodland after the previous phase of clearance appears not to have been complete, however, for tree pollen values do not recover their former magnitude and generally account for only 50% of total land pollen. This general diminution of total tree pollen values is caused mainly by a decrease in the contribution of Betula to the assemblage, and the increase of Corylus and Gramineae frequencies. Fraxinus appears to have formed an important constituent of the more open woodland. Herbaceous pollen grains attributable to ruderal taxa are few, represented by a continued presence of Melampyrum and Rumex in low values. Dampland types Filipendula and Potentilla are significant, however, and with high Gramineae values point to the abundance of dampland environments within the woodland. That dry, open ground was virtually absent is suggested by the poor representation of both Calluna and Pteridium. This zonule, therefore, apparently describes a period of damp, open, but relatively undisturbed woodland.

FCS Zonule C2   18 - 0 cms.

The final zonule C2 sees a renewed application of clearance pressure and the replacement of woodland by light-demanding herb and shrub communities. Total tree pollen frequency falls to 35% of total land pollen and all tree taxa participate in this woodland recession except *Fraxinus* which appears to have been encouraged by it. The identification of *Fagus* points to the secondary nature of the woodland during this phase. *Corylus*, *Salix*, *Calluna* and Gramineae show sharp rises in value in response to woodland recession, and an expansion of ruderal herb frequencies takes place, particularly *Plantago lanceolata*, *Melampyrum*, *Rumex* and *Succisa*. This phase of clearance appears to have been of a rather greater intensity than hitherto, and marks a major retraction of forest cover in the area.

Botany Bay

6.7. Introduction

In the course of the field survey of East Bilsdale Moor, Mr. Taylor retrieved a small peat sample containing a flint microlith which upon closer examination proved to be embedded in situ. Although this peat fragment was detached and its exact provenance and stratigraphic context therefore unknown, the association of peat and microlith was unquestionable and the sample had evidently been recently detached en bloc from the peat mass by erosion. Its original location was probably adjacent to its point of collection at SE 605 960 (c. 335m. OD.) in the shallow basin of Botany Bay, within which rise the springs which form the eastern headwaters of Bonfield Gill (fig. 45), and after which the site is named. The microlith-bearing peat sample from Botany Bay is illustrated in Plates 5 and 6, following sub-sampling for pollen analysis.

6.8. Stratigraphy

The sample was composed mainly of very well humified amorphous peat and was a little over eight centimetres is depth, no stratigraphic variations being discernable within it during field or laboratory investigation. A slight herbaceous rootlet presence suggested the original orientation of the sample by the direction of growth, although too well humified to be identifiable, and samples were removed for pollen analysis accordingly. The following stratigraphy was recorded.

Stratum	Depth (cms)	Description
1	0 - 8	$Sh^4 4$, $Th^3 +$, Rudimenta culturae b2 nig.4, strf.0, elas.1, sicc.2 Well humified black amorphous peat with slight herbaceous rootlet presence. Flint microlith at 6 cms.

Plate 5. Microlith-bearing peat sample from Botany Bay (NM 005 960).

View from below.

Plate 6. Microlith-bearing peat sample from Botany Bay ([illegible] 605 960).
View from the side.

6.9. Pollen Analysis

Samples were removed for pollen analysis at intervals of one centimetre and the resulting pollen diagram is shown as fig. 51. The diagram is described by a single Local Pollen Assemblage Zone as follows:

LPAZ BB1 8 - 0 cms.

Quercus, Ulmus and Betula characterise the tree pollen assemblage, which accounts for about 25% of total pollen throughout the zone, rising to more than 50% of total pollen with the inclusion of Alnus. Pinus and Tilia each contribute 10% of tree pollen, while Fraxinus is present in low frequencies throughout. Alnus at over 25% of total pollen is a major zone component. Shrub pollen also contributes over 25% of total pollen and Corylus accounts for most of this. although Salix is also prominent. Hedera, Lonicera, Prunus and Sorbus are also recorded. Calluna is continuously present in moderate frequencies. Herbaceous pollen values are low and provided mainly by Gramineae and Cyperaceae. Individual herb taxa are represented mainly by the dampland types Filipendula and Ranunculus, although open-habitat taxa do occur at intervals. Sphagnum moss spores are poorly represented, but spores of pteridophyte ferns are a significant assemblage group with Filicales, Polypodium and Pteridium registering high frequencies.

The single Local Assemblage Zone BB1 is referred to Regional Pollen Assemblage Zone NYM-D.

6.10. Forest Clearance History

Three local stages in the history of forest clearance are recognised at Botany Bay and are shown upon fig. 51 as a basis for description of the evolution of the landscape.

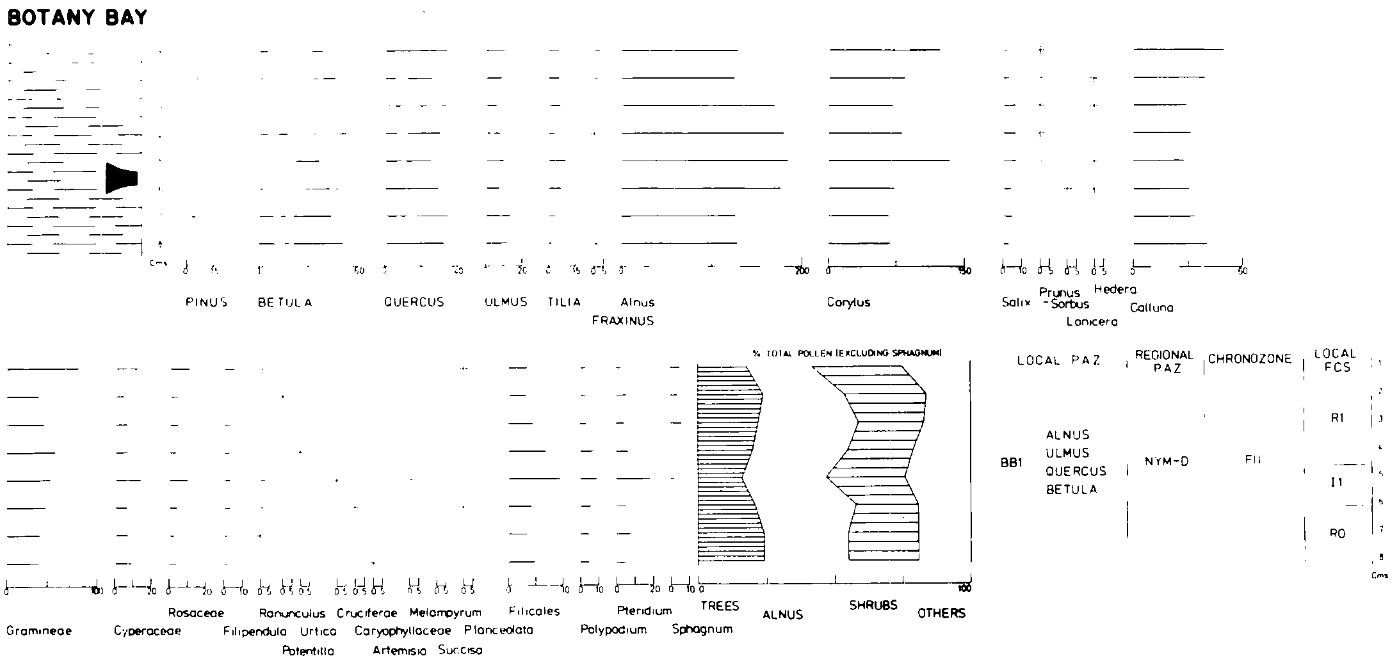


Fig. 4. Botany Bay. Pollen diagram : percentages of tree pollen (excluding *Alnus*).

FCS Zonule RO 8 - 6 cms.

The basal zonule RO describes a period during which major disturbance of the environment was not taking place, for the tree pollen curve, including Alnus (fig. 51), continuously represents about 55% of total pollen. The stable woodland which characterised the local landscape was, however, not unbroken, for non-tree pollen types are present in sufficient quantity to suggest that openings in the tree canopy were present. Thus, although deciduous trees of the Quercetum mixtum are prominent, others indicative of a more open kind of woodland, Betula and Fraxinus, are also important. That some clearings existed is shown by the presence of considerable frequencies of Calluna and Pteridium, and a grain of Artemisia.

FCS Zonule I1 6 - 5 cms.

A brief episode of forest opening occurs during this zonule, during which the stable woodland of the previous phase is subject to clearance, allowing the expansion of a range of light-demanding herb and shrub taxa. Quercus and Betula are the trees most reduced in frequency, and are responsible for a marked diminution of tree pollen values, as a percentage of total pollen. A group of ruderal herb grains are introduced to the assemblage, testifying to the creation of open ground nearby, and includes Plantago lanceolata, Melampyrum, Succisa, Artemisia, Caryophyllaceae and Cruciferae. Spores of Pteridium are greatly increased in frequency, although Calluna does not respond during this phase of clearance. Heliophyte shrubs are much encouraged, however, and Salix, Prunus, Sorbus, Corylus and Rosaceous types all exhibit greatly increased values. Among tree taxa, Tilia and Pinus values increase during this phase. The first appearance of Hedera and Lonicera, and increased frequencies for Filicales and

Polypodium may also reflect the more open nature of the woodland.

FCS Zonule R1 5 - 0.cms.

Stable woodland conditions are restored during this zonule, as indicators of clearance are either reduced in value or disappear from the pollen record. Tree pollen resumes its previous magnitude contibuting, with *Alnus*, almost 60% of total pollen, with *Quercus* and *Betula* again present in high values, although *Fraxinus* has increased in importance. Ruderal herb grains are no longer recorded, except for a single grain of *Plantago lanceolata* at the top of the diagram. As this grain is accompanied by rises in frequency of *Corylus*, Gramineae and *Calluna* and slight tree pollen reductions, especially for *Alnus*, some renewed forest opening may be suggested at this point. Throughout the rest of this zonule, which is considered to be one of regeneration, there is no evidence of environmental disturbance at all.

Small Howe

6.11. Introduction

The third site on East Bilsdale Moor lies upon the ridge which runs northward towards Bransdale Moor (fig. 45) and which forms an area of higher ground where peat depth is generally in excess of two metres, although suffering considerable wind erosion. Fragments of charcoal on the mineral soil of an erosion patch appeared to be issuing from the base of the blanket peat, and subsequent investigation with a peat sampler proved a basal charcoal layer which, although discontinuous across the area, was, in places, of considerable thickness.

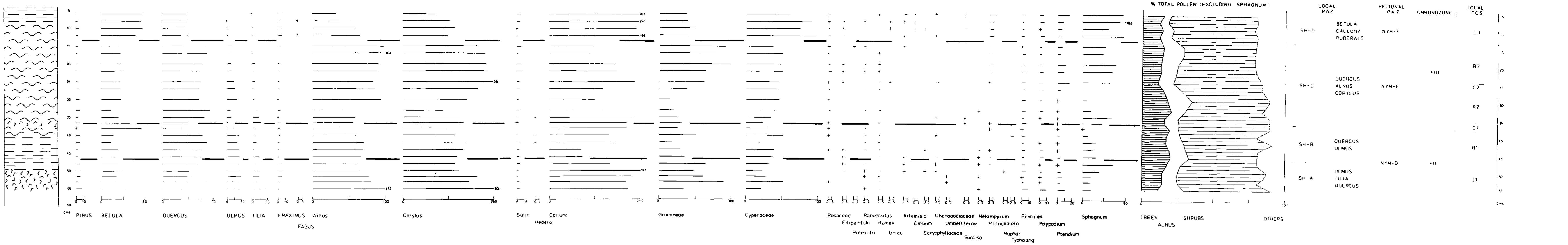
A core was collected by Russian borer at a point, one hundred metres from a small tumulus, where five centimetres of charcoal was recorded at the base of the peat. This site was designated Small Howe, has a grid reference of SE 606 971 and lies at an approximate altitude of 402m OD.

6.12. Site Stratigraphy

Peat depth at the sampling points was less than sixty centimetres, having probably been severely reduced by erosion. Following field and laboratory investigation of the sampled profile, the following stratigraphy was recorded.

Stratum	Depth (cms)	Description
5	0 - 8	Str. conf. $Sh^4 4$, Dl+ Disturbed, loose organic material with ericaceous rootlets.
4	8 - 39	Tb (Sphag)$^2 4$, anth.+ nig.2, strf.1, elas.2, sicc.2, lim. sup.1 Poorly humified *Sphagnum* peat, with occasional tiny charcoal fragments at 37 cms.

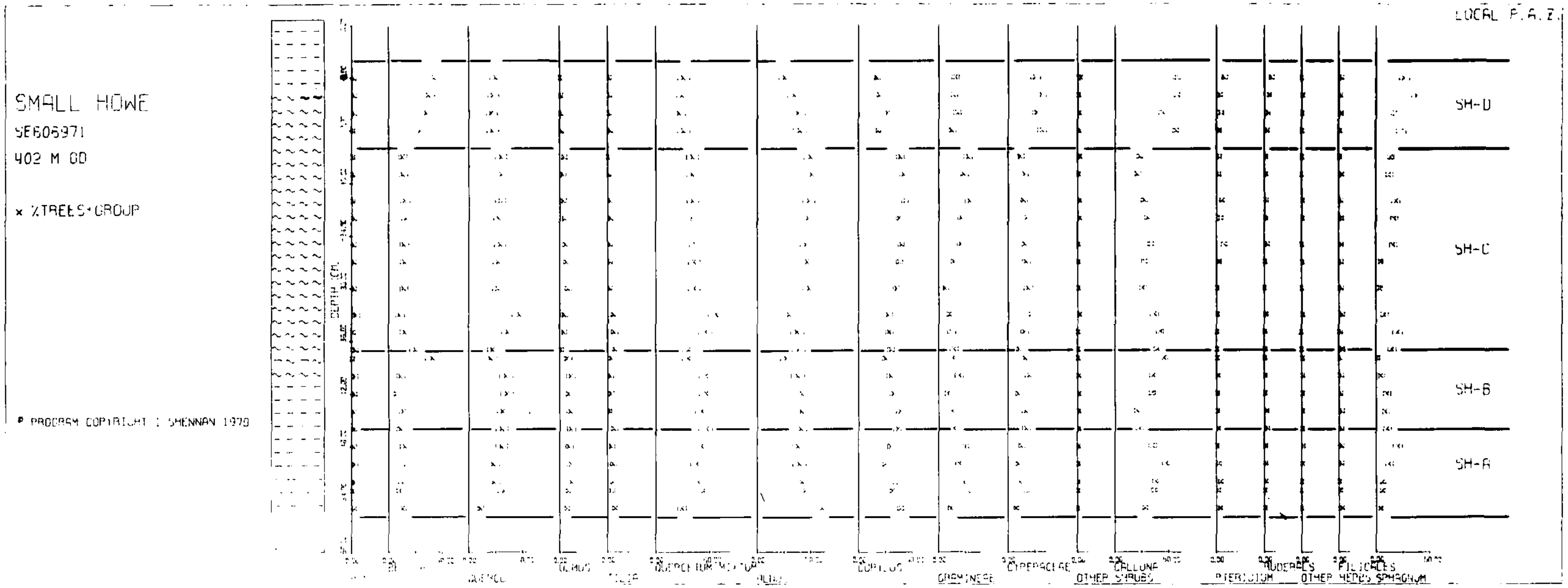
SMALL HOWE



PINUS
BETULA
QUERCUS
ULMUS
TILIA
FRAXINUS
FAGUS
Alnus
Corylus
Salix
Hedera
Calluna
Gramineae
Cyperaceae
Rosaceae
Filipendula
Potentilla
Ranunculus
Rumex
Urtica
Artemisia
Cirsium
Caryophyllaceae
Chenopodiaceae
Umbelliferae
Succisa
Melampyrum
P.lanceolata
Nuphar
Typha ang
Filicales
Polypodium
Pteridium
Sphagnum
% TOTAL POLLEN (EXCLUDING SPHAGNUM)
TREES
ALNUS
SHRUBS
OTHERS
LOCAL PAZ
REGIONAL PAZ
CHRONOZONE
LOCAL FCS
SH-D
BETULA
CALLUNA
RUDERALS
NYM-F
C3
R3
FIII
SH-C
QUERCUS
ALNUS
CORYLUS
NYM-E
C2
R2
C1
SH-B
QUERCUS
ULMUS
R1
NYM-D
FII
SH-A
ULMUS
TILIA
QUERCUS
I1
Cms

Fig. 52. Small Howe. Pollen diagram : percentages of tree pollen (excluding Alnus).

A



B

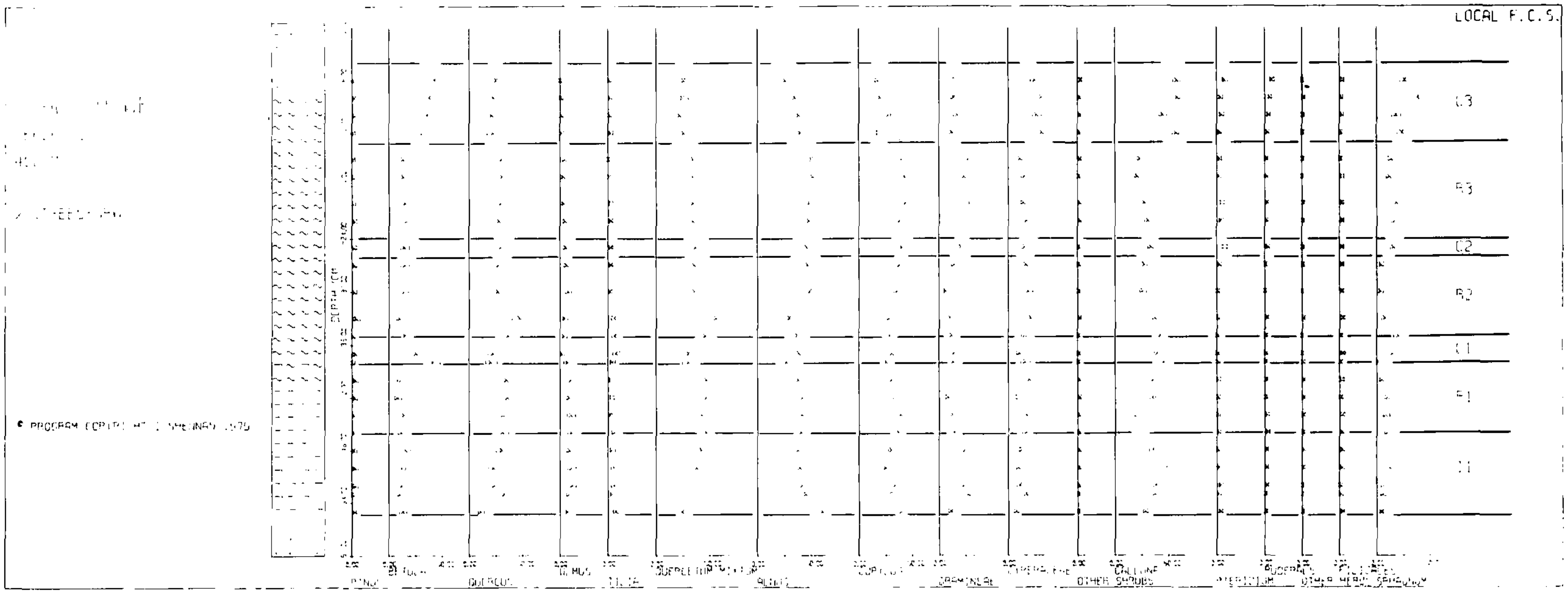
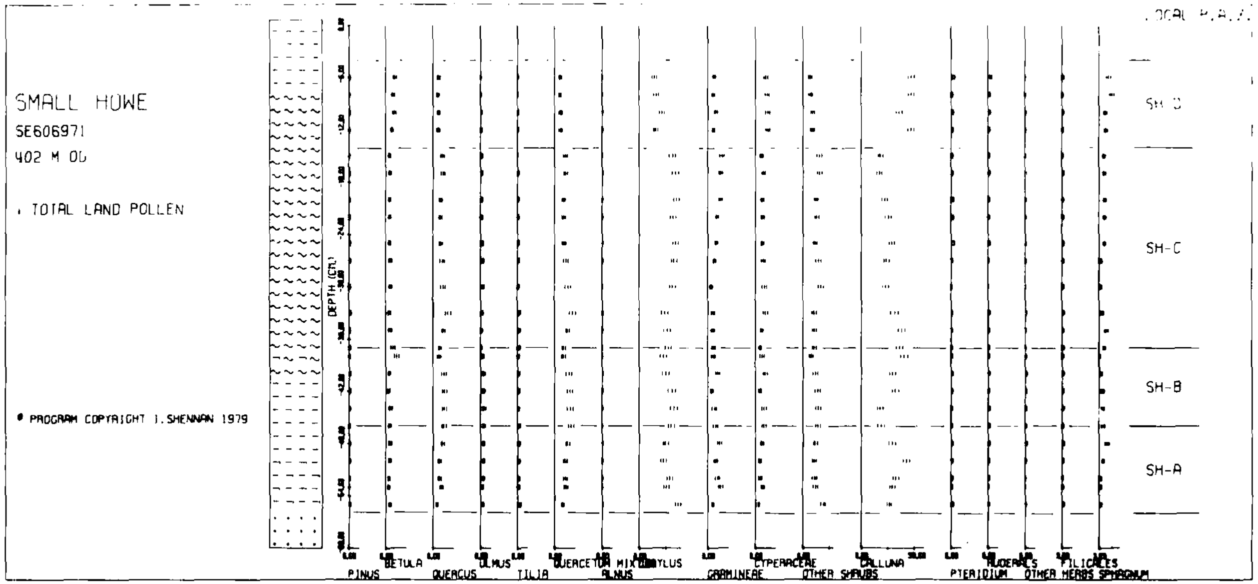


Fig. . Small Howe. Pollen diagram: percentages of tree pollen + group.

A



B

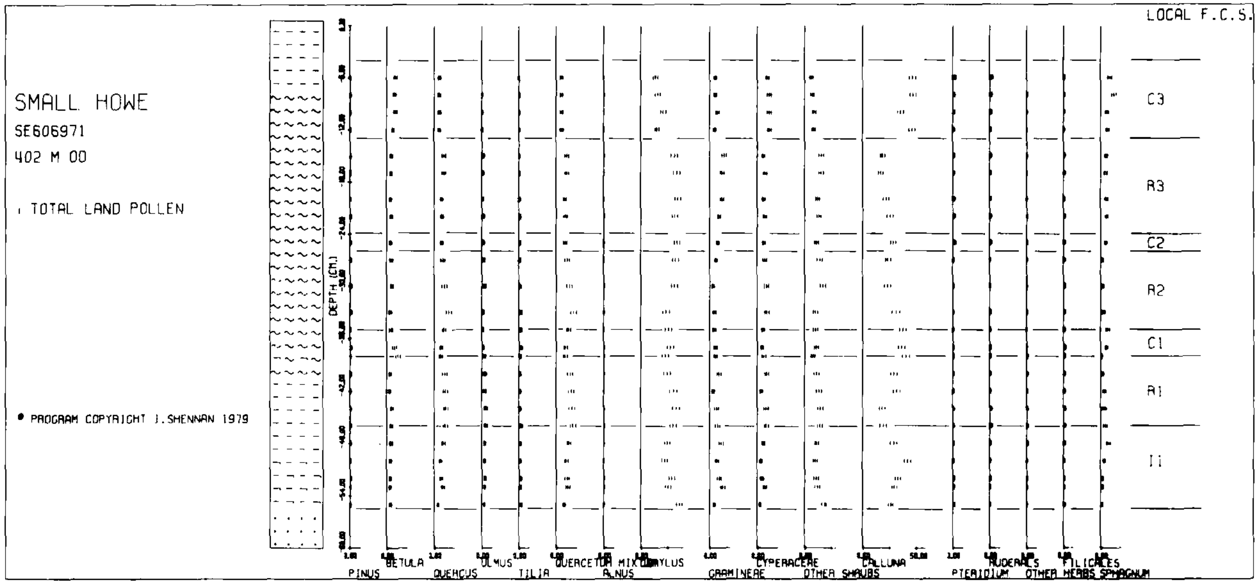


Fig. C4. Small Howe. Pollen diagram : percentages of total land pollen.

3	39 - 50	$Sh^4{}_4$
		nig.4, strf.0, elas.0, sicc.2, lim. sup.1
		Black amorphous well humified peat.
2	50 - 55	anth.3, $Sh^4{}_1$
		nig.4, strf.0, elas.0, sicc.2, lim. sup.1
		Charcoal-rich organic material.
1	55 - 60	Gs4
		nig.2, strf.0, elas.0, sicc.2, lim. sup.2
		Coarse orange sand.

6.13. Pollen Analysis

Samples were taken for pollen analysis at 2 cm., intervals throughout the core and the resulting pollen diagram is shown as fig. 52. Four Local Pollen Assemblage Zones are recognised, applied to figs.53a and 54a, and are described as follows:

LPAZ SH - A 55 - 47 cms.

Total tree pollen values are depressed during this zone and most NAP types are recorded in high frequencies. *Quercus* values average about 35% of tree pollen, but fluctuate widely. In contrast *Ulmus* consistently represents 20% of tree pollen. *Tilia* is also a principal member of the assemblage, varying between 10% and 20% of tree pollen, while *Fraxinus* values are high. *Pinus* and *Betula* together contribute 30% of the tree pollen sum. *Alnus* falls from initially high frequencies until it averages 10% of total pollen. Shrub pollen types are dominant in the assemblage, with *Corylus* and *Calluna* each accounting for 30% of total pollen. *Salix* is also constantly in evidence. Gramineae and Cyperaceae values are both high and sustained, while a complex suite of herbaceous taxa appears. These are mainly ruderal and open-habitat types, although some dampland herbs also occur. <u>Sphagnum</u> values are high and rise throughout the zone while pteridophyte spores form a major feature of the assemblage, particularly <u>Pteridium</u>. NAP types constantly exceed 75% of total pollen. The upper boundary of the zone is drawn where <u>Quercus</u> increases and <u>Tilia</u> declines in value.

LPAZ SH - B 47 - 37 cms.

Tree pollen values increase as a percentage of total pollen recorded during this zone, providing, with <u>Alnus</u>, over 30% of the assemblage. <u>Ulmus</u> values remain unchanged at 20% of AP but <u>Quercus</u> has increased in frequency while <u>Tilia</u> has receded slightly from its previous maxima. <u>Betula</u> shows a gradual decline until late in the zone. <u>Alnus</u> and <u>Corylus</u> frequencies are unchanged throughout the zone, each representing about 25% of total pollen. <u>Salix</u> retains its previous importance and <u>Hedera</u> is introduced to the assemblage. <u>Calluna</u> frequencies have fallen sharply in the early part of the zone, but recover towards the end. Gramineae values are lower, and herbaceous pollen as a whole is less in evidence. Sporadic ruderal herbs occur, but significant frequencies are confined to dampland or mire types. <u>Sphagnum</u> values decline as the zone progresses. Filicales are the main fern spore constituent, both <u>Polypodium</u> and <u>Pteridium</u> being much reduced in value. The upper boundary of the zone is drawn where a marked decline of <u>Ulmus</u> pollen values takes place.

LPAZ SH - C 37 - 14 cms.

Although <u>Ulmus</u> recovers from the decline in value which marks the beginning of this zone, it never regains its previous magnitude and <u>Quercus</u> is now the characteristic tree taxon. <u>Tilia</u> is present in very high frequencies at the base of the zone, but quickly declines until, like Fraxinus, it remains constant at rather less than 10% of AP. Betula and Pinus frequencies remain moderate, together representing 30% of AP. Alnus frequencies exhibit an expansion to almost 15% of total pollen and are characteristic of the zone, within which tree pollen, with the inclusion of Alnus, seldom exceeds 30% of total pollen. The NAP assemblage is again dominated by shrub pollen among which Corylus is the main contributor, rising through the zone and reaching values consistently in excess of 30% of total pollen. Calluna is well represented throughout, while Gramineae, low at first, increases in value later. Ruderal herb taxa are in the main not recorded, although a continuous Plantago lanceolata curve commences midway through the zone. A strong fern spore presence is recorded, however, in particular of Pteridium, and Sphagnum rises late in the zone. The upper boundary is drawn where Quercus, Ulmus, Alnus and Corylus fall, and Betula rises in value.

LPAZ SH - D 14 - 4 cms.

Betula is the characteristic tree pollen type of this zone, providing up to 60% of AP. Pinus, and more particularly Fraxinus, are present in higher values, while Fagus appears for the first time. A marked decline in deciduous forest trees occurs, with Ulmus, Quercus and Tilia greatly reduced in frequency. Alnus has declined to less than 10% of total pollen. Calluna dominates the shrub pollen assemblage, reaching almost 50% of total pollen, while Corylus has fallen to 15%. Gramineae values are low and the increased herbaceous pollen representation is due to a rise in Cyperaceae and ruderal herbs, among which Plantago lanceolata is prominent. Pteridium values rise while Sphagnum is recorded in very high frequencies. NAP frequencies in general are at their highest at the end of this zone, owing to the massive increase in Calluna frequencies.

Local Pollen Assemblage Zones SH - A and SH - B are assigned to Regional Zone NYM - D. LPAZ SH - C is referred to regional zone NYM - E and LPAZ SH - D to Regional Zone NYM - F.

6.14. Forest Clearance History

Seven local stages in the history of forest clearance at Small Howe are recognised upon fig. 52, are applied to figs. 53b and 54b, and are used to zone fig. 55 as a basis for description of the evolution of the landscape.

FCS Zonule I1   55 - 47 cms.

Pollen fluctuations consistent with forest clearance are recorded from the basal zonule I1. Tree pollen values are depressed during this phase of interference, with Quercus and Alnus most seriously affected. Although never attaining very high values at this site, tree pollen during this phase is reduced to only 25% of total land pollen. The creation of areas of bare ground and disturbed conditions is shown by the identification of a wide range of ruderal herb types, some of which are present in high frequencies, especially Rumex and, near the end of the phase, Plantago lanceolata. Artemisia, Chenopodiaceae, Caryophyllaceae, Umbelliferae and Melampyrum complete the assemblage. Other taxa favoured by the retraction of tree cover and the creation of open ground are Pteridium and initially Corylus, but it is Calluna which shows the most significant expansion in frequency. Opening of the forest canopy allowed light-responsive shrubs Salix and Fraxinus to increase their representation also, while a sharp increase in Gramineae pollen frequency occurs. At this site Tilia seems

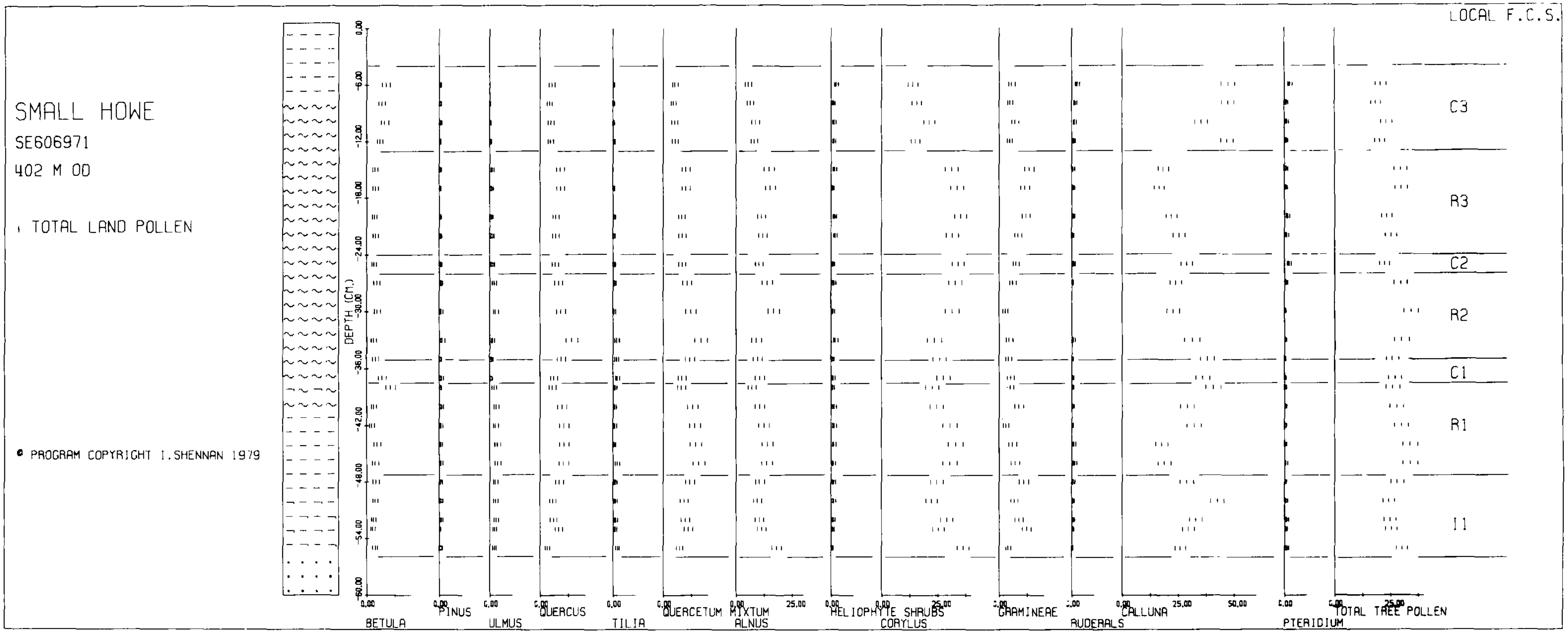


Fig. 55. Small Howe. Pollen diagram : selected clearance taxa as percentages of total land pollen.

to have been favoured by this period of woodland disruption in the same way as *Fraxinus*.

FCS Zonule R1 47 - 37 cms.

A restoration of wooded conditions to the area appears to have taken place during this zonule, which is therefore designated a stage of regeneration , R1. Tree pollen values assume a mean of about 35% of total land pollen, and frequencies of taxa indicative of open ground decline from their peak of the previous zonule. It is clear, however, that regeneration of woodland was only partial and that some parts of the area remained open, for non-tree pollen frequencies remain relatively high and occasional herb grains representative of ruderal habitats are still recorded, in particular *Rumex*, *Melampyrum* and *Plantago lanceolata*. The frequency and intensity of such indicators is much reduced, however, so that it is probable that active interference was not going on. *Calluna*, Gramineae and *Pteridium* frequencies all fall, while *Quercus* and *Alnus* are increased in value. *Corylus*, *Salix* and *Fraxinus* remain present in substantial frequencies, testifying to the continued open nature of the woodland. It would seem that recolonisation by closed woodland of all of the cleared area created during the previous zonule did not occur, but that substantial areas remained occupied by herb and scrub vegetation.

FCS Zonule C1 37 - 35 cms.

Ulmus pollen values fall during this phase, but a coincident rise of *Betula* frequencies maintains the curve for total tree pollen at slightly below the level of the previous zonule. A change in the composition of the forest may be postulated, however, for *Quercus*, as well as *Ulmus*, is reduced in value and replaced by trees suggestive of secondary woodland, *Betula* and

Fraxinus. Tilia, which responded favourably to the previous clearance event at this site, was again encouraged by disturbance of the forest. Opening of the canopy through clearance assisted heliophyte taxa to expand their representation, for Corylus, Salix and Calluna all increase in frequency. While Pteridium remains poorly represented, other taxa denoting open ground do occur, the ruderal herb assemblage containing Plantago lanceolata, Rumex, Chenopodiaceae, Melampyrum and Succisa. Although this phase of interference appears not to have been of great intensity, the fluctuations in the pollen record are sufficient to show that significant alterations in the environment took place at this time.

FCS Zonule R2 35 - 26 cms.

A phase of woodland regeneration occurs between 35 and 26 cms., as tree pollen values are restored to their peak values of 35% of total land pollen. Deciduous forest trees of the Quercetum mixtum, especially Quercus, are present with Alnus in high values while indicators of more open conditions are reduced in frequency, as the woodland became rather more dense once again. Calluna, Gramineae and Pteridium values either decline or remain low, while herbaceous grains indicative of freshly disturbed ground are absent from the assemblage. It is evident that no new clearings in the forest were being made at this stage and regeneration of major tree taxa was leading to the re-occupation of open areas created in the previous periods of clearance. Although low, Salix and Corylus values are sustained and an element of shrub vegetation remained within the vegetation cover.

FCS Zonule C2 26 - 24 cms.

A brief phase of forest recession occurs between 26 and 24 cms., when taxa indicative of newly cleared ground are reintroduced to the pollen spectra. Plantago lanceolata, Rumex, Chenopodiaceae and Urtica are recorded and a sharp diminution in total tree pollen frequency occurs. All tree taxa appear to be affected by the clearance, although Quercus and Alnus are the most reduced. Heliophyte tree and shrub taxa are greatly increased in frequency following the opening of the forest, with Salix, Corylus, Fraxinus and Calluna all showing a marked expansion. The Gramineae curve begins a rise to high values during this phase and a very sharp increase in the frequency of Pteridium spores is recorded, pointing to the colonisation of bare ground after the creation of clearings in the woodland.

FCS Zonule B3   24 - 14 cms.

The succeeding zonule is considered to be a period of woodland regeneration, for tree pollen frequencies recover somewhat and the representation of shrub and herb pollen subsides from their maxima of the previous zonule. While stability is restored to the vegetation, full regeneration of woodland and re-occupation of cleared areas did not prove possible, for a number of non-tree pollen types remain present in high values. A continuous Plantago lanceolata curve, with records of Rumex and Ranunculus, suggests that areas of open ground remained in existence. Similarly, values for Pteridium, Gramineae and Calluna remain high, while the prominence of Corylus, Salix, Rosaceae and Fraxinus shows the open nature of the woodland during this stage. Quercus and Alnus remain the dominant tree taxa with Betula frequencies rather low.

FCS Zonule C3   14 - 4 cms.

The final zonule at this site represents a major phase of forest recession, during which tree pollen values fall to their lowest recorded point, and a wide range of clearance indicators are introduced to the assemblage. Ulmus and Tilia frequencies are diminished to almost nothing, while Quercus and Alnus are also greatly reduced. Those trees characteristic of open, secondary woodland are, in contrast, present in enhanced values, Betula and Fraxinus increasing markedly and Fagus being recognised for the first time. Corylus, which was a major consituent of the woodland in the previous zone, was apparently adversely affected by this clearance, for its pollen representation falls sharply. Most encouraged by the retraction of woodland during this stage are Calluna and Pteridium, the former in particular rising to frequencies of 50% of total land pollen (fig. 55). Although Gramineae frequencies are lower than in the previous zonule, many herbaceous grains are recorded which reflect open ground and disturbed conditions near the site. The curve for Plantago lanceolata rises in frequency throughout the zonule and is supported by particularly high values for Artemisia and Cirsium. Also recorded are Caryophyllaceae, Chenopodiaceae, Succisa, Rumex and Urtica. It would seem that this phase of clearance is one of high intensity, involving a considerable recession of woodland from the site and its replacement by open habitat and seral communities.

East Bilsdale Moor

6.15. Discussion

The palynological evidence from the East Bilsdale Moor sites records periodic woodland recession which, associated with stratigraphic evidence of fire in the form of charcoal, may be interpreted as the result of fire clearance of woodland by prehistoric communities. The fall in *Ulmus* pollen frequencies which occurs at the lower boundary of zone BGH-C and zonule C1 at Bonfield Gill Head, and at the lower boundary of zone SH-C and zonule C1 at Small Howe, may be correlated with the *Ulmus* decline which marks the end of Regional P.A.Z. NYM-D (Table 4) and thus with the end of chronozone Flandrian II. The diagram from Botany Bay is characterised by high *Ulmus* values and is considered to fall entirely within Flandrian II. The phases of forest clearance I1, I2 and I3 at Bonfield Gill Head, I1 at Small Howe and I1 at Botany Bay all therefore fall within Flandrian II and, if of human origin, may be expected to have resulted from the activities of Mesolithic man.

Correlation of the pollen and stratigraphic data from Bonfield Gill Head reveals the same synchroneity of interference phase and stratigraphic charcoal as illustrated at North Gill. The macroscopic charcoal which was recovered from the interference (I) horizons at this site, particularly from I1 and I2, consists of quite large pieces (up to 15 x 9mm) and may be interpreted as resulting from the burning of the woodland vegetation at, or quite near to, the site. Microscopic charcoal fragments, termed 'soot particles', occur throughout the profile, however, and an estimation of their frequency at different horizons is shown as fig. 56. Although soot particles are most abundant in association with the discrete charcoal layers which occur during the I phases, as would be

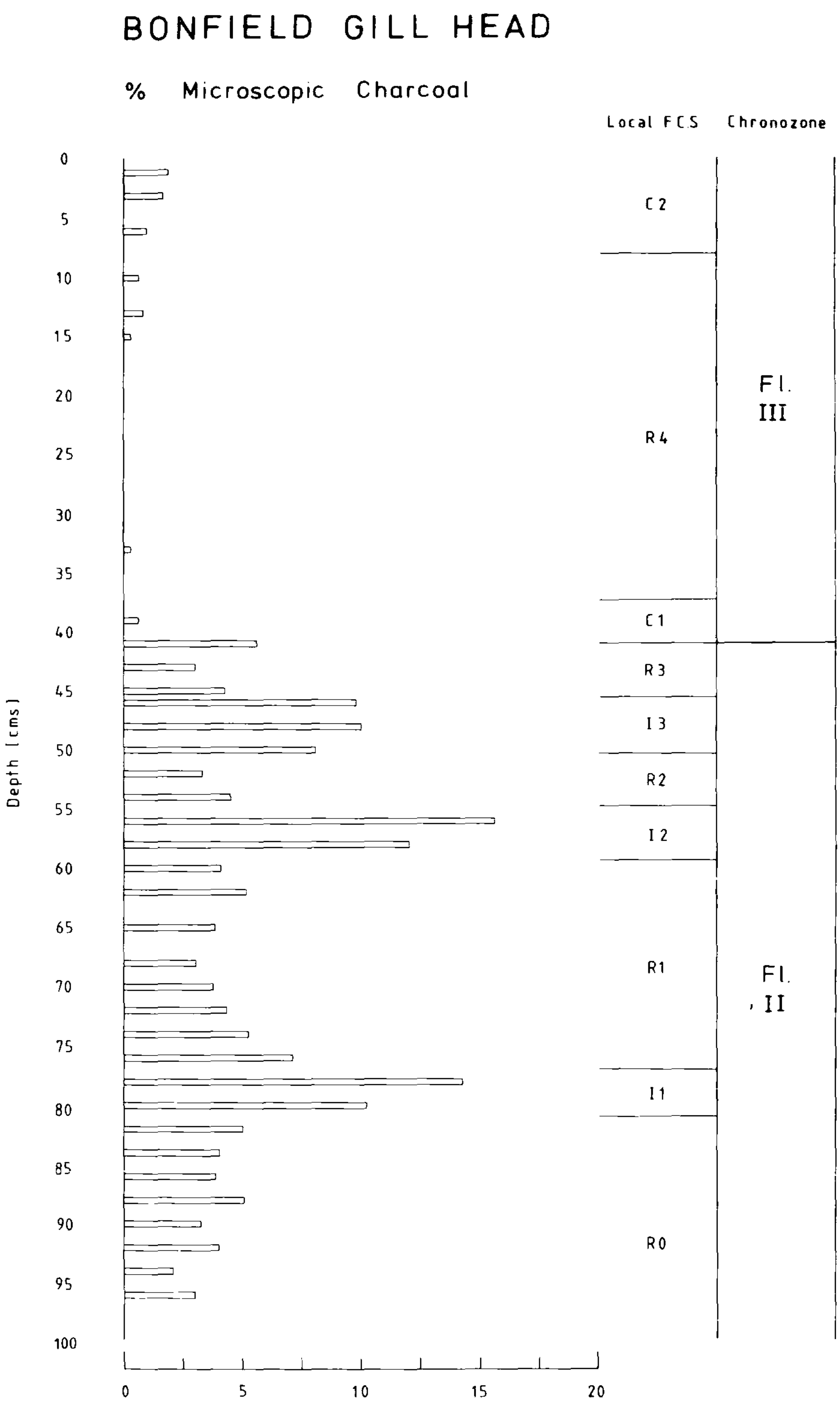


Fig. 56. Bonfield Gill Head. Percentage charcoal content of peat.

expected, they are also present at a reduced but constant level during the regeneration (R) phases when clearance activity is considered to have been absent from the site. It seems likely that the soot in the R phases results from burning somewhere in the region, but at a sufficient distance from this site to be registered only as background 'fallout'. It does imply, however, that firing of the vegetation was going on somewhere in the East Bilsdale Moor region at all times during Flandrian II, and therefore in an implied Mesolithic cultural context, with individual sites subject to clearance at intervals. In this respect it is consistent with evidence reported from the Pennines by Tallis (1975) and Jacobi _et al_ (1976). The regeneration phases which intercalate the interference episodes at Bonfield Gill Head reflect periods when woodland was able to re-establish itself on or near the site. This is shown not only by increased tree pollen frequencies, particularly for _Betula_, but also by the appearance of _Betula_ wood in the stratigraphy at these levels. These wood remains comprise rootlet material as well as birch bark, twigs and branch wood, and some fragments are of such a size that they cannot have travelled far, and may indeed represent _in situ_ woodland. The alternation of interference and regeneration phase is most cogently explained as evidence of rotational burning of the same site, with woodland recolonisation when clearance pressure was relaxed. Cessation of this fire-manipulation of the environment seems to have taken place at the end of Flandrian II, for a large _Betula_ treestump occurs in the profile at a point corresponding to zonule C1 and the base of zonule R4 and is evidence of major recolonisation of the blanket peat by woodland at the beginning of Flandrian III. Figure 56 suggests that the elimination of human pressure upon the environment may have been instrumental in permitting the regrowth of trees. While the Flandrian II deposits at Bonfield Gill Head contain a continuous record of the presence of fire as an ecological factor, the Flandrian III deposits of zonule R4 are almost devoid of both charcoal and soot. This fact, and the reforestation of the uplands, suggests that either the form of land use which requires fire-manipulation of the ecosystem was no longer employed, or that a complete withdrawal of human presence from the uplands of the Moors took place. In either case we have clear evidence for the cessation of burning practices on the upland at the end of the Mesolithic. If a retraction of human presence is considered to be the most likely factor, this would comply with the circumstantial archaeological evidence, for while East Bilsdale Moor has one of the highest densities of Mesolithic flint sites in the country (Radley 1969a), evidence for Neolithic activity is almost entirely lacking (Spratt and Simmons 1976). That the treestump exposed in the Bonfield Gill Head profile is representative of forest growth rather than scrub is suggested by its substantial size and by the number and size of stumps and trunks associated with it (fig. 46). Betula and Quercus stumps of up to a metre in diameter with roots in proportion, are recorded at distances of less than twenty metres apart, often considerably less. This seems to indicate mature, dense, closed-canopy birch-oak woodland around the site during early Flandrian III, and effectively corroborates the pollen evidence for the same period.

This evidence for the prevention of tree growth in the uplands in Flandrian II through the application of fire pressure to the environment, followed by afforestation during Flandrian III when this pressure was relaxed, finds analogy with sites in other upland regions of northern England. Tallis (1975) has cited examples of tree growth after a period of peat accumulation (Woodhead 1906, 1924, Conway 1954), and has drawn attention to the probable role of Mesolithic hunters in this context. His estimation of the microscopic charcoal content of a Pennine site at Lady

Clough Moor has revealed a record of persistent burning with which the evidence from East Bilsdale Moor corresponds well, with the exception that soot particles continue into early Flandrian III at the Pennine site, whereas deposits of post-Mesolithic age at Bonfield Gill Head are devoid of soot until later clearance phase C2, which is provisionally correlated with the later Neolithic or early Bronze Age by comparison with other North York Moor diagrams (Jones et al. 1979). This would suggest that a degree of continuity of activity may be attributed to the Pennine Mesolithic-Neolithic transition which is absent from the North York Moors situation, and re-afforestation of the upland was evidently permitted to occur rather earlier in the latter area.

It may therefore now be postulated, following Jacobi et al. (1976), that burning of the vegetation during Mesolithic times prevented the growth of trees in the uplands of the North of England, and that recolonisation by woodland occurred in these areas in later periods of prehistory, when the adoption of agriculture diminished the environmental impact of the hunter-gatherer economy. A corpus of stratigraphic evidence comparable with that presented above certainly exists to support this contention. Tinsley (1975) has noted early Flandrian III Betula wood layers above monocot., Flandrian II peat at Hambledon Dike and Skell Gill I in the Pennines, and Hicks (1971) noted similar wood layers at her nearby sites of Totley Moss and Hipper Sick. An Alnus layer above two metres of peat is radiocarbon dated to 4,780 ± 120bp (Birm-664) at Gordale Beck, North Yorkshire (Williams and Johnson 1976) increasing the number of early Flandrian III examples, while recolonisation of blanket peat by Betula in late Flandrian II is recorded at Foolmire Sike Moss by Turner et al. (1973). Early Flandrian III forest layers are reported from the Northern Pennines, at Hartleyburn Common (Precht 1953), comprising rooted Betula stumps, and overlying varying thicknesses of Flandrian II amorphous peat. While Mesolithic clearance evidence is not forthcoming from this site, more recent studies have suggested that Mesolithic clearance activity in this area during Flandrian II was widespread (Squires 1970, Rendell 1971, Chambers 1974, 1978, Simpson 1976). This stratigraphic situation is more directly related to a Mesolithic presence at Saltonstall Moor (Davies 1881) where flints underlie amorphous peat containing Betula stump layers, many of which are charred, while twin Betula layers occur in a profile containing indicators of forest opening at Johns Burn (Godfree 1975). The site of Truckle Pits (Raistrick 1933) exhibits this type of stratigraphic record very clearly, with microlith bearing sand overlain by amorphous black peat, over which occurs a layer of wood peat containing Betula stumps. Although investigation of the amorphous peat layer was insufficiently detailed to permit any assessment of ecological history, it is unequivocally Flandrian II, and lies in an area in which a Mesolithic cultural presence (Cowling and Stickland 1947, Gowling 1973) and clearance activity (Pigot and Pigot 1959) are known to have existed. Although the Flandrian II peats at many of these sites remains to be sampled for charcoal content, this type of stratigraphic evidence is sufficiently widespread to suggest that Mesolithic man may have played a major part in determining the height of the tree line in parts of Northern England.

Although the pollen fluctuations which comprise the successive interference phases of the East Bilsdale Moor sites differ in detail and magnitude, they are alike in recording the diversification of stable forest ecosystems and the creation of seral plant communities dominated by heliophyte herbs and shrubs. Bonfield Gill Head yields the longest Flandrian II profile and suggests a repetitive sequence of burning, woodland recession and woodland regeneration around the spring head. The use of fire to create small clearings is intimated, not only by the charcoal which is present, but also by the high pollen frequencies of taxa promoted by fire clearance, particularly for Melampyrum, which is a characteristic feature in the field layer of burned woodland (Berglund 1966, Mamakowa 1968). The character of these clearance episodes remains similar; the provision of bare ground and its recolonisation by a range of dryland and ruderal herbs, the promotion of a diversity of woody scrub taxa in the regeneration phase, and the re-closure of the forest canopy when the climax stage of regeneration is reached. Each, however, seems to have been associated with progressive changes in landscape composition, which are reflected in the constitution of the woodland. Figure 57 shows the representation of individual tree taxa calculated as a percentage of the corrected total tree pollen sum, using the correction factors of Andersen (1973), to assist in the reconstruction of forest history. That the episodes of fire clearance were capable of initiating significant changes in forest composition is indicated by the variety and intensity of pioneer, ruderal herbs which follow clearance (fig. 47), some of which, for example Scabiosa (Adams 1955), signify treeless conditions. A ground fire of sufficient intensity to remove all plant growth is therefore envisaged, rather than a light tree-canopy burn. The ability of Betula, through its highly efficient seed production and dispersal mechanism, to invade fresh fire cleared areas may encourage permanent birch dominated scrub (Ovington 1965) and the consistently high pollen frequencies for Betula from zonule I1 onwards suggests that this may have been the case in this area. It effectively replaces Pinus as the major individual tree taxon, although also affecting deciduous trees. The earlier Flandrian II vegetation in this area, described by zonule RO, appears to have been a mosaic of seral communities, with open areas within which pioneer herbs and Pteridium were established,

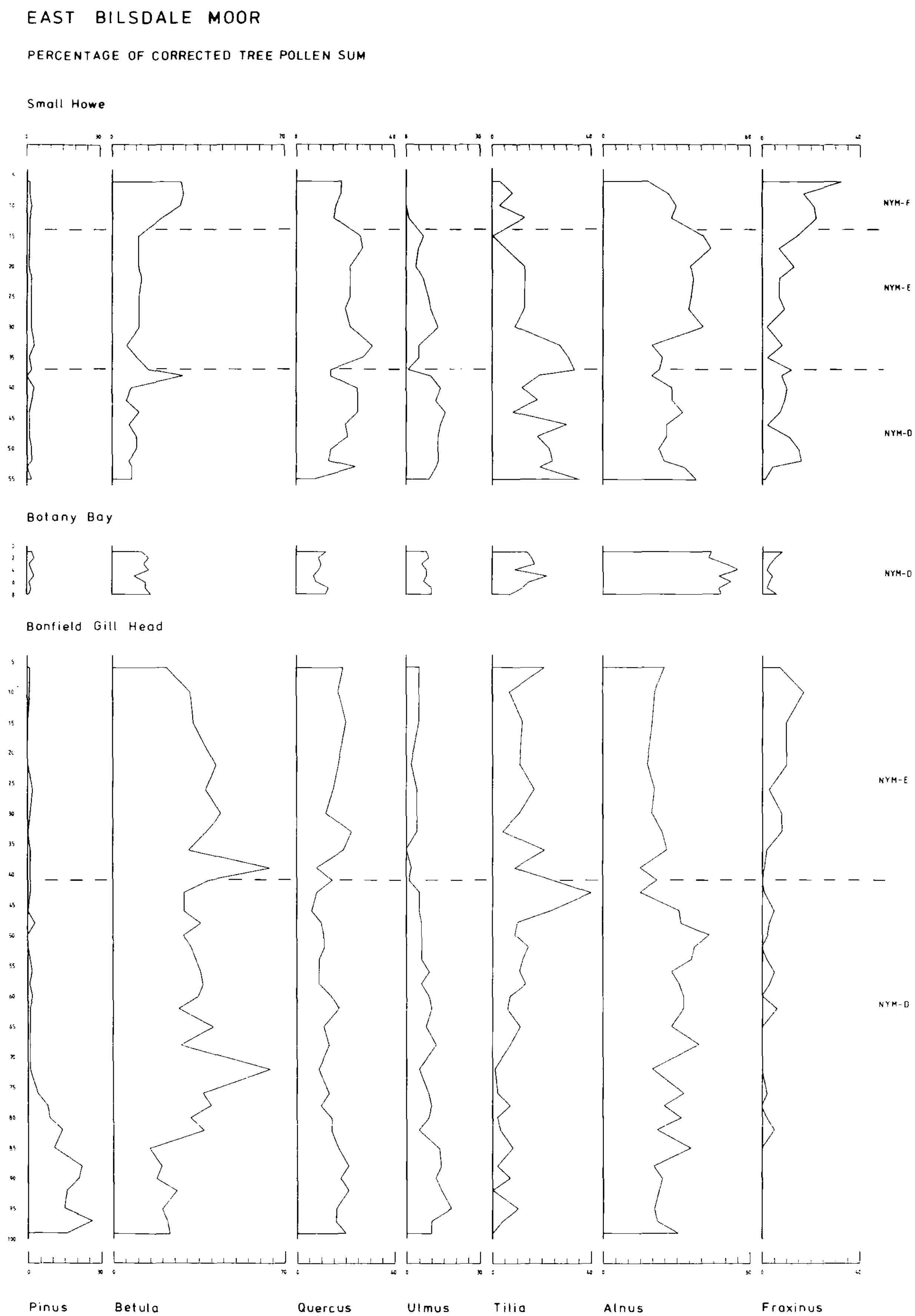


Fig. 57. East Bilsdale Moor. Pollen diagram : trees as percentages of total corrected tree pollen.

occurring within a light Betula-Pinus-Quercus woodland and Corylus scrub matrix. Damp, marshy glades within which grasses, sedges and wetland herbs such as Filipendula, Potentilla, Ranunculus and Urtica grew were also present, with Nymphaea and Potamogeton recording open water, presumably the nearby stream itself. The presence of these wetland environments reflects conditions suitable for the initiation of peat formation, with Alnus and Salix responding to the increasingly moist conditions of the Atlantic climatic regime (Smith 1972), providing damp shady environments for climbers like Hedera and Lonicera, and for ferns like Polypodium, probably growing in epiphytic situations. This pollen assemblage may well represent a post clearance regeneration complex within mixed woodland, with clearance having provided a stimulus to peat formation (Merryfield and Moore 1974). The high levels of Pinus pollen point to it having been locally present in the woodland, and it appears to have been permanently removed by the clearance of zonule I1. This is surprising, for the pine possesses a thick insulating bark which enables it to survive forest fire easily (Zackrisson 1977). While this may be effective in dry Boreal forests, Pinus may have been under stress from excess water supply in the increasingly damp Flandrian II forest, and the additional moisture released into the ecosystem by the clearance event of zonule I1 may have accelerated paludification and prevented its regeneration. Minor but contributing factors in the demise of Pinus may be that charcoal has been seen to inhibit, on occasion, the growth of conifer seedlings (Liebundgut 1960), while Pinus itself may have its regeneration retarded by chemical exudates from Prunus and, less completely, from Salix (Brown 1967), taxa present in high frequency among the zonule I1 regener tion shrubs.

The later Flandrian II clearance of zonules I2 and I3 at Bonfield Gill Head take place within closed woodland of Betula, Alnus and Quercus.

Significant changes which accompany these events include a transition to raised bog at the site itself and an apparent gradual change in woodland structure. Fraxinus excelsior becomes firmly established, being encouraged by disturbance of the forest and signifying secondary communities (Gordon 1958). Calluna enters the pollen assemblage in zonules I3 and R3 in very high values and, since there is no evidence of a drying out of the bog surface itself, may be regarded as indicating the acidification of the dryland ecosystem, probably accelerated by clearance pressure, with increased run off and rainfall effectiveness on bare areas promoting leaching and depleting the nutrient store. This process will have assisted the trend towards the acidification of the mire system (Moore 1972). The role of Calluna in heathland associations on acid soils has been described by Gimingham (1960) and Dimbleby (1962), and high frequencies of Betula and Pteridium in late Flandrian II at this site point to the existence of this kind of acid environment. In this context the high Melampyrum values which persist at this part of the diagram (fig. 47) may mark the transition from closed 'mull' forest to an open acid 'mor' woodland, as at Mantingerbos in the Netherlands (Stockmarr 1975). The rising importance of Tilia in the late Flandrian II forest is revealed by figure 57. Its introduction as a significant forest component apparently began after the clearance of zonule I2 and this event may have assisted Tilia to expand in two ways. Firstly, it may be in any case encouraged by fire clearance, for Berglund (1966) noted Tilia peaks associated with charcoal layers in south east Sweden, and it seems to respond to clearance in this way upon a number of North York Moor diagrams. Secondly, the very high Corylus frequencies of zonule I2 suggest the temporary establishment of hazel scrub, for it seems likely that Corylus may have to be locally present in dense growths as the canopy dominant for its pollen to be abundantly recorded (Jonassen 1950). Corylus thickets may be extremely dense and cast a very heavy shade, so that Quercus, with its light-demanding seedlings (Shaw 1974), may be prevented from successfully regenerating. Tilia seedlings are far more shade tolerant and, in this situation, may be encouraged to succeed at the expense of Quercus and locally to replace it in the regenerated woodland (Mikkelsen 1949).

This expansion of Tilia in later Flandrian II is evidently a regional feature, for it may also be recognised upon the other diagrams from East Bilsdale Moor. If its increase were indirectly stimulated by human activity, it would tend to suggest that this was a regionally operative factor also. Tilia is greatly enhanced during the basal clearance zonule I1 at Small Howe, and maintains high values for the rest of Flandrian II at that site, while it also achieves peak frequencies at Botany Bay during interference zonule I1. The pollen assemblage from Botany Bay may thus be assigned to late Flandrian II on the basis of its low Pinus but high Tilia and Fraxinus frequencies (fig. 57), and this date is in accord with the Late Mesolithic geometric character of the incorporated flint and pollen analysis of other flint bearing peats from the region. It corresponds very well with assemblages of similar date from Bonfield Gill Head in recording a landscape dominated by closed, damp woodland, with high Betula and Alnus representation, although figure 57 suggests a greater proportion of Quercetum mixtum trees and less Betula than at the spring head site. Perhaps the forest composition at Botany Bay reflects the more typical regional woodland at this altitude (c. 340m OD.) than the Betula dominance at Bonfield Gill Head, which may be a locally induced fire-climax. The microlith at Botany Bay was apparently dropped into a shallow muddy pool in a marshy woodland glade, for wetland taxa, Filipendula, Ranunculus, Cyperaceae and Gramineae, and indicators of damp, shady environments, Polypodium, Hedera, Lonicera and Filicales, are prominent. It was deposited at approximately the same time as human activity is recorded in zonule I1 by ruderal indicators of freshly disturbed ground and a decline of tree pollen. This clearance episode is not intense, however, and no macroscopic charcoal is recorded, although 'soot' is present in low quantities. It would seem that clearance was not immediately adjacent to Botany Bay, and its influence may have been muted by the screening effects of the heavy Alnus scrub which apparently surrounded the site.

Botany Bay invites comparison with other microlith bearing peat profiles, most of which share its Flandrian II provenance. Sites where flints are stratified within peat are rare, microliths normally occurring at the interface between peat and mineral soil. Although charcoal accompanied by pollen evidence of forest recession exists at the Mesolithic site of Dozmare Pool (Connolly et al.1950, Brown 1977) and Westward Ho! (Churchill and Wymer 1965), in neither case are the flints reliably stratified with the clearance evidence. Several other sites exist at which a similar situation occurs. More apposite is the evidence from Kingsteps Quarry, Nairn (Knox 1954) where early Flandrian II peat contains a pollen record of woodland clearance stratified with both flints and charcoal, chronicling Mesolithic activity in a lowland lakeside situation. Clearance effects are also shown at the horizon of peat-stratified flints in the uplands of the north of England at Stump Cross in the Pennines (Walker 1956), and at White Gill A in the study area (Simmons and Cundill 1969, Cundill 1971). Such association is not always the case, however, for there are no indicators of vegetation change at the flint horizons in Flandrian II peats at Glaisdale Moor, North York Moors (Bartlett 1969), nor in a number of examples around Hard Hill in Upper Teesdale (Johnson and Dunham 1963) even though in the latter case the artefacts are associated with Bos bones and horncases, and both areas provide evidence for Mesolithic clearance from nearby sites (Cundill 1971, Chambers 1978). Clearly a Mesolithic cultural presence need not always imply, even in the uplands, coeval clearance activity.

In contrast to the wooded landscape of the other two sites, the higher altitude site of Small Howe (402m OD) records much more open conditions throughout its history, with total tree pollen generally less than 30% of total land pollen. The clearance of zonule I1 appears to have taken place within an open scrub-woodland, with Corylus as greatly affected as Quercus and Alnus, and to have encouraged its replacement by open ground and heathland dominated by dryland herbs, grasses, Pteridium and, particularly, Calluna. These taxa, with high Sphagnum values, signify acid, nutrient poor conditions at this higher altitude. Whether the Corylus scrubland of this plateau summit area of the Moors was the natural vegetation or the result of previous clearance cannot be known, but the fire clearance of zonule I1 evidently converted areas into Calluna heath on a long term basis. A similar process may be observed in high altitude sites from the Pennines (Squires 1970, Radley et al.1974) and from lowland sites on sandy, acid soils in the south of England (Rankine et al.1960, Keef et al.1965), resulting from inability to regenerate due to poor edaphic conditions. Figure 57 shows the importance of Tilia and Fraxinus in the regional woodland of regeneration zonule R1, although at this higher altitude the local landscape evidently remained but lightly wooded, a feature exacerbated by the later clearances of Flandrian III, especially during zonule C3 which may be attributed to Bronze Age communities (Jones et al.1979). The increase in Betula woodland at the end of Flandrian II at Bonfield Gill Head does, however, find parallel at Small Howe in a sharp rise of Betula pollen at the end of zonule R1, and probably reflects a regional elevation of the tree line at this time. Reforestation of the uplands at the beginning of Flandrian III apparently did not extend to the most elevated summit ridges of the Moors, for despite the shallowness of the contemporary peat deposits at Small Howe no macrofossil wood remains occur to indicate that woodland reached to this altitude. This suggests that, while the upper limit of the forest advanced uphill at this time, ecosystem degeneration had progressed sufficiently far to render the maintenance of woodland communities untenable at the highest altitudes. While evidence of tree growth in the form of fossil roots, stumps and trunks has not so far been observed in these areas this is not in itself conclusive proof that no tree growth occurred for such wood remains may rot and leave no trace, unless quickly overwhelmed by peat growth. The low frequencies of tree pollen at Small Howe and at the analogous sites of Trough House and Loose Howe (Simmons and Cundill 1974a) also suggest, however, that the summit areas of the Moors remained above the tree line. While it remains a possibility that such treeless habitats may have been a feature of the moorland summits throughout the Flandrian (Simmons 1975a) the evidence presented in this chapter makes it seem more likely that suppression of tree growth by human activity in Flandrian II was primarily responsible for the absence of trees at high altitude, and for the maintenance of scrub (especially Corylus) and then heathland (especially Calluna) communities. The implications of the evidence for Small Howe are that, at least at the most extreme altitudes where the nutrient balance of the ecosystem would have been at its most precarious, fire clearance of the vegetation by Mesolithic man may have initiated environmental changes which were irreversible, most particularly in the establishment of the Calluna heath which still characterises the East Bilsdale Moor area today.

The conclusions which may be reached from the evidence presented in this chapter are that East Bilsdale Moor is similar to the eastern part of the Central Watershed in recording environmental alteration, attributable to Mesolithic communities during Flandrian II, which takes the form of recurrent fire clearance of woodland. This activity appears to have caused significant changes in the composition of the vegetation units which comprised the regional landscape, of a kind again comparable to the changes notdd in the Glaisdale Moor-Egton Moor area. It would seem feasible, therefore, to consider the impact of Mesolithic communities upon the environment in the context of the North York Moors as a whole, and consideration will be given to this subject in the final chapter of this thesis.

CHAPTER SEVEN

Discussion

7.1. Introduction

The environmental context of Mesolithic settlement and land-use has been considered in general terms in Chapter 1, together with man's potential technological and economic adaptations to the landscape changes which took place during Flandrian I and II. In Chapter 2 the physical characteristics of the North York Moors study area have been described, followed by detailed presentation in Chapters 4 to 6 of palaeoecological data which has been interpreted as a record of environmental alteration during the Mesolithic period in upland areas of the Moors. In this final chapter the implications of this evidence will be considered so that the possible role of Mesolithic communities in bringing about environmental change may be discussed in detail with particular reference to the North York Moors. Firstly the composition of the landscape and its environmental characteristics will be considered, secondly the nature and extent of the evidence for environmental alteration will be assessed and thirdly the purpose and effects of such alteration will be discussed.

The broad themes of post glacial landscape evolution which have been outlined in chapter 1, although appropriate in general terms, will assume a regional diversity of expression according to the variation in character of a wide range of environmentally influential factors. These would inevitably promote variations both within a given region and between it and adjacent areas of the country. Topography, climate, geology and soils are all factors which will have played a major role in determining the local composition of the vegetation in different parts of the North York Moors region during Flandrian I and II. The inter-relationship of these factors, and their individual spatial or temporal variability, will have encouraged the development of contrasting landscape units in different parts of the area, with differing vegetation patterns creating a diversity of environmental situations. It may be possible, therefore, to divide the area of study during this period into a number of theoretical palaeo-environmental zones, each encompassing a differing range of environments and consequently each of differing resource potential for exploitation by Mesolithic communities. An understanding of the character and location of these palaeo-environmental zones, and their evolution as Flandrian I and II progressed, will assist in discussion of the land-use patterns adopted by the Mesolithic inhabitants of the region, of which deliberate environmental alteration may have formed an important part.

7.2. Regional Vegetation History

Reconstruction of regional vegetation patterns during Flandrian I and II is made possible by recourse to the large body of palaeobotanical research which is available for the North York Moors region (chapter 2.5 and figure 5). The sequence of post glacial vegetation changes has been reviewed in general terms for the North York Moors by previous authors (Spratt and Simmons 1976, Jones *et al*. 1979). A brief statement of the composition of the region's vegetation during Flandrian I and II is required at this point, however, so that consideration may be given to the range of land-use opportunities it would have presented, together with its potential for environmental manipulation.

Our appreciation of the landscape units existing in earliest Flandrian times is constrained by the irregular distribution of the surviving organic deposits upon which we have to rely. Such deposits are confined to lower altitudes in the region, so that our knowledge of the uplands relies upon extrapolation from them of any environmental trends which may become apparent. The earlier part of Flandrian I has been labelled the 'Preforest' stage of landscape development by Simmons (1975a), with reference to a schematic range of upland habitats. The higher altitude pollen records we have from the North York Moors for this period are Kildale Hall, West House Moss and Ewe Crag Slack (Jones 1977, 1978) and are in accordance with this description in exhibiting a range of herb, heath and shrub communities, with an increasing admixture of Betula and Pinus as succession towards woodland proceeded. Empetrum, Filipendula, Gramineae, Salix and Rosaceae are typical of these open, successional communities, within which a Late Devensian floral element persisted. This contrasts, however, with the evidence from lowland lake side sites such as Seamer Carrs (Jones 1976b) and the Star Carr - Flixton area (Godwin and Walker 1954), where the rapid establishment of dense Betula woodland apparently took place at the very beginning of the Flandrian. This decline in the relative density of tree cover with altitude established a botanical gradient in the region and had the consequence of maintaining the existence of suitable habitats for heath, herb and shrub taxa on the higher ground. While no evidence is available for the Central Watershed during this period, it may be surmised that tree cover was even more sparse, and that the vegetation may even have consisted entirely of communities of low stature life forms.

As Flandrian I proceeded the altitudinal variation in vegetation type established at the beginning of the Flandrian continues to be apparent, both in the range and importance of woodland components, and in overall woodland density. It is clear that succession progressed much more slowly upon higher ground, for while the deciduous trees Ulmus and Quercus appear in Flandrian Ib at the lowland sites amid a closed, forested environment, they are almost absent from some sites of higher altitude at this time, for example May Moss (Atherden 1979). Moreover, a contrast in the character of the Boreal forest may be noted, with _Betula_ retaining dominance in the lowlands, whereas _Pinus_ was of more importance at altitude, and _Corylus_, after its initial expansion, maintaining higher values on higher ground, reflecting the more open conditions there.

When pollen spectra become available for the highest part of the Moors, during late Flandrian I at Glaisdale Moor (Simmons and Cundill 1974a), they serve to confirm the presence of an environmental gradient between low and high ground in the region. Pine and hazel were dominant in an open woodland within which deciduous trees were poorly represented and much open ground seems to have existed, for _Calluna_, Gramineae, _Pteridium_ and herbaceous types were all represented. During the same period a dense oak-elm-birch forest appears to have dominated the lowlands, with few indications of shrub or heath communities, and _Alnus_ rising in frequency. An intermediate situation seems to have occurred upon lower slopes and lower watershed areas of the upland, where tree pollen values generally indicate a continuous tree cover, but of a greater diversity than that of the lowland plains, with _Pinus_, _Corylus_ and _Quercus_ in a mixed woodland environment.

At the beginning of Flandrian II mature, deciduous woodland was established upon the lowland plains of the region, with _Quercus_, _Ulmus_, _Alnus_ and _Tilia_ the major components. Upon the uplands themselves, however, _Quercus_ and _Corylus_ would appear to have been the major dryland trees, with _Alnus_ widespread, presumably in damper situations but also perhaps throughout the forest. _Tilia_ was not of great importance until late in the period, with _Ulmus_ recorded in persistent but moderate amounts. Of greater interest, _Pinus_ remains an important woodland constituent in the uplands during the early part of Flandrian II, particularly at higher altitudes. The high plateaux of the Central Watershed, and to a lesser degree the mid altitude watershed areas also, appear to have carried a lighter form of woodland in general, and the substantial presence of heath taxa, such as Calluna and Pteridium, as well as woody taxa, such as Corylus, Pinus and Betula, possibly referable to scrub rather than true forest, suggest that open areas may have existed within it. Indeed, non-tree dryland pollen is recorded in sufficiently high frequencies at upland sites to suggest that the highest regions may not have sustained woodland at all. If a tree line did exist, plant communities above it would probably have been of grassland, heath, scrub or bog type. Such a theoretical suite of habitats beyond the tree line has been labelled the 'Hyper-forest' zone by Simmons (1975a), and if such a zone existed and was of natural origin, may have been present in the area throughout Flandrian I and II. If woodland did extend to the highest areas of the region, however, it was certainly of a very open character.

Throughout Flandrian I and II therefore, it would appear that differences in both the density and the composition of the vegetation were maintained between the lowland, intermediate and highland areas of the region. It is not possible to recognise within any of these areas fundamental variations in major vegetation type which may be spatially defined on a regional basis. They may thus be regarded as biotically homogenous. While it is accepted that local variations in the woodland mosaic would have existed, with stands at different stages of succession towards climax, dissimilarity of climax conditions may only be recognised for the three major zones described above, with altitude as the regulating factor.

7.3. Palaeoenvironmental Zones

The three vegetation belts which have been identified above for the North York Moors region may be used as a basis for the recognition of a series of palaeoenvironmental zones, for it is suggested that the variation in landscape type between them will have offered widely different opportunities for land-use, resource potential and environmental management during the Mesolithic period. These zones are located and described schematically upon fig. 58, which takes the form of an altitudinal transect from the highest part of the Moors to sea-level and upon which are recognised three major terrestrial zones (A, B and C) and one major coastal zone (D). Figure 58 also attempts to express the characteristics of these zones, induced from their physical configuration. The three terrestrial zones may be differentiated on the grounds of their contrasting geology, soils, topography and drainage, as well as their altitudinal range, and the combination of all these factors will have caused them to support the contrasting vegetation types during the early Flandrian which are indicated by the available palaeobotanical evidence.

Palaeoenvironmental zone A incorporates the upland plateau surfaces of the Moors above about 300m OD. and thus corresponds to the area termed as the Central Watershed in this thesis. Its physical characteristics include a generally flat topography, with sandstone parent material of the Deltaic series and free drainage encouraging rapid leaching and the evolution of infertile acid podsol soils. Zone B incorporates the lower slopes of the upland region itself, between about 125m OD. and 300m OD. Deltaic series deposits are the parent material in part of this zone also, but Corallian limestones comprise the main bedrock type, particularly in the south but also upon the Cleveland plateau to the north, providing a much more variable topography and generally more fertile soil complex than

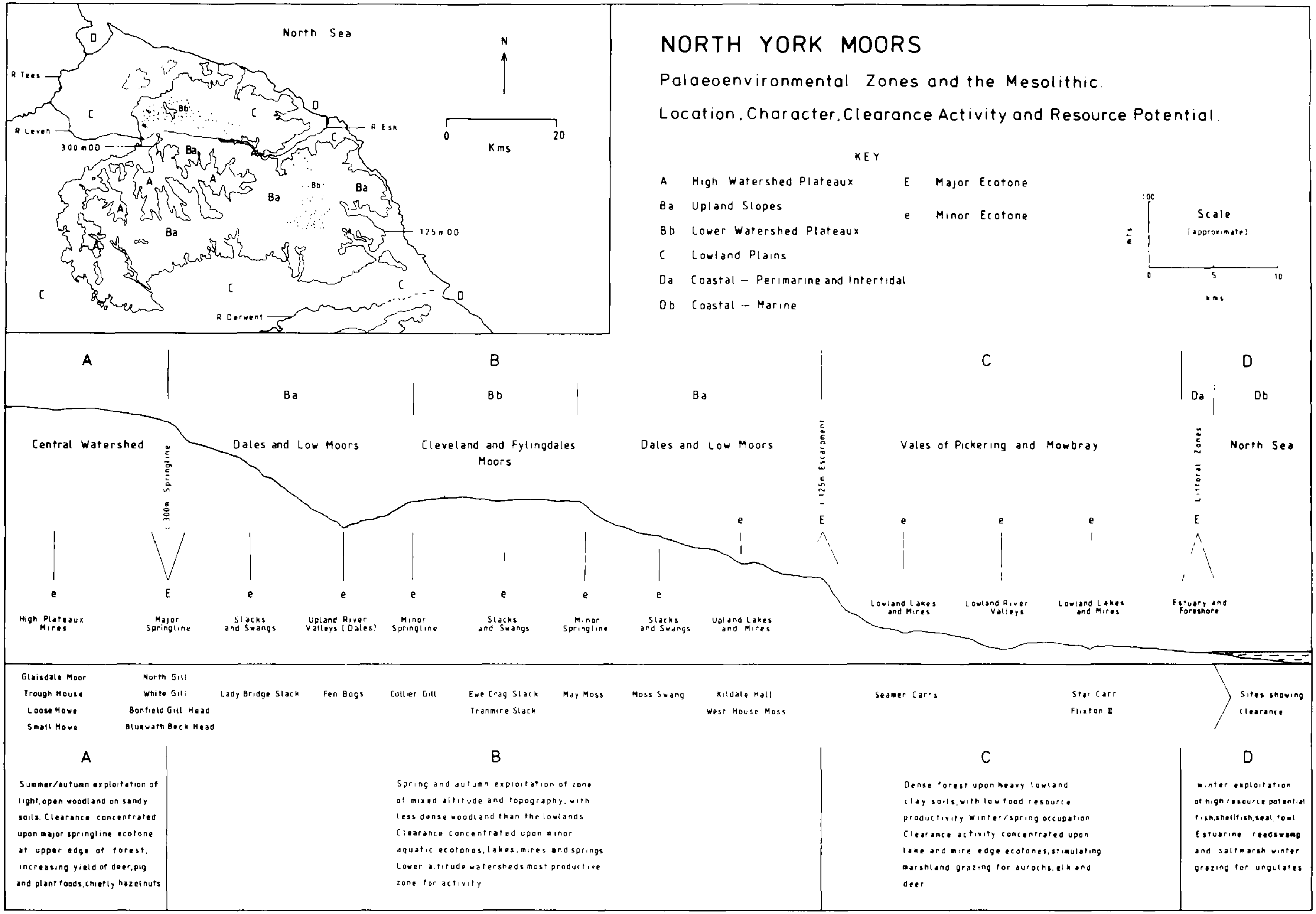


Fig. 58 North York Moors. Schematic altitudinal transect illustrating the location of palaeoenvironmental zones and their resource potential.

the high plateaux of zone A. Terrestrial zone C includes the areas of lower altitude upon the periphery of the upland, mainly lying below the c. 125m OD. escarpment formed by the boundary of the Corallian rocks and which delineates the edge of the moorland area proper. The heavy, fertile clay soils of these areas are derived from the Kimmeridge Clay of the Vale of Pickering to the south and the glacial drift boulder clay of the Vale of Mowbray to the west. Boulder clay soils also occur in the north eastern part of the upland, however, at rather higher altitude, and are included within zone C.

Apparently, therefore, geographical factors have produced three terrestrial zones with divergent vegetation histories which may be distinguished spatially by contrasting altitudinal ranges. This assessment, based upon palaeoenvironmental data, agrees with that of Baker (1906), who recognised the importance of altitude, with rock and soil type, in determining the region's geographical character. Even climatic factors such as rainfall, temperature and length of snow-lie are regulated in this region almost directly by height above sea-level (v.s. chapter 2.3., and Atherden 1972). Thus dominant vegetation patterns in Flandrian I and II may be envisaged as showing a high degree of stability and homogeneity within these three zones, with a transition in composition between them at points of steep altitudinal gradient, although there may have been a gradual reduction in general vegetation density with increasing height. Only at these points of steep gradient, however, might vegetation patterns be expected naturally to show abrupt changes which could be recognisable in regional terms, and these form the boundaries between the three major zones. They occur, a) at c. 300m OD. where the geological formation boundary described above creates the spring-line and major break of slope at the edge of the Central Watershed and b) at c.125m OD. where the Corallian escarpment marks the edge of the North York Moors upland. These boundaries are shown on fig. 58 as 'major ecotones' forming areas of transition between the zones of homogenous vegetation. A third major ecotone would in theory have existed between the terrestrial zones and the Coastal Zone (D) on the north eastern and eastern sides of the region, although if the coastline were marked by steep boulder clay cliffs as it is today, exploitation of this ecotone may have been difficult.

Such a view of the regional landscape potential is, of course, too idealised a model, for local variations would have been sure to occur within these altitudinally defined zones of broadly similar vegetation, most obviously where wetland habitats provided a contrast with the dominant dryland vegetation. The major palaeo-environmental zones may thus be sub-divided into smaller areas where 'minor ecotones' would exist. Although of local importance only, these minor ecotones would be of great significance in providing areas of diversity within zones of otherwise uniform character. These sub-zones are also displayed schematically upon fig. 58, although their distribution in reality would not conform to this simplistic pattern, but would have been far more complex, their spatial juxtaposition varying from area to area. It is, however, the relationship of these zones which would largely have decided the spatial distribution of human communities during Flandrian I and II, by the evolution of diverse landscape units.

Aquatic habitats within palaeo-environmental zone A would have been confined to spring-head locations at its lower fringe, particularly during the earlier Flandrian when the free draining sandy soils of the area would have provided little opportunity for the development of marshland communities, despite its flat topography. Mires represent the other main wetland type but did not develop generally in zone A until mid

Flandrian II, except for a few isolated examples in later Flandrian I, formed behind landslips at St.Helena and Blakey Landslip (Simmons and Cundill 1974b) or in basin areas upon the high plateau, as at Glaisdale Moor (Simmons and Cundill 1974a). A much greater variety of aquatic habitats may have been associated with palaeo-environmental zone B, however, for the upper courses of the regional rivers occur within it, together with the many small lakes which would have been a feature of early Flandrian landscapes. Lower altitude watershed areas, such as the Cleveland plateau to the north and the Fylingdales Moor watershed to the east, are recognised as a separate sub-zone on fig. 58. They would present lower-altitude spring-lines, together with glacial drainage channels or 'slacks' (v.g. chapter 2.2.), as additional wetland areas and minor ecotone opportunities. Mire development began in this zone relatively early in the period, as lake basins and slacks began to fill up and grow over. The lowland zone C would find diversity in the lower valleys of the main rivers of the area, the Tees, Esk, Leven and Derwent. The large number of lakes which would almost certainly have occupied the depressions in the undulating boulder clay plain on the periphery of the upland would have created similar minor ecotone situations. Extensive lowland bog growth took place in this zone from early Flandrian I onwards. Finally the Coastal Zone D would have offered marine, intertidal and perimarine sub-zones to which access would have been available via the minor dales which run eastwards to the coast, and especially at the major river estuary of the Tees, on the fringes of the region.

In summary, therefore, while three zones of surmised vegetation uniformity characterise the study area, a multiplicity of potential ecotone situations would have existed both within and between them, It was these areas of environmental diversity, so often incorporating the added attraction of access to water supply, which would have formed the foci for human activity in Mesolithic times. Existing evidence for that activity, as manifest by alteration of the environment, will be considered in the next section.

7.4. Evidence for Environmental Alteration during the Mesolithic

Inspection of previously published palaeo-environmental research from the North York Moors suggests that evidence of environmental disturbance analogous to that presented in section B of this thesis may be forthcoming from a number of sites in this area during both Flandrian I and Flandrian II. This evidence takes the form of fluctuations in the pollen record which indicate temporary changes in the local vegetation cover, most often interpreted as the creation of small openings in the woodland, but also occurring as deflections of vegetation successions in the pre-woodland communities of earlier Flandrian I. In both cases, particularly where accompanied by charcoal or cultural remains, these vegetational changes may be attributable to the actions of Mesolithic communities, and on fig. 59 the distribution of those sites where the evidence is consistent with pre-*Ulmus* decline environmental alteration of this kind is recorded. Several of these phases of interference are referable to chronozone Flandrian I, and these are described in detail upon Table 5. The majority of examples, however, are of Flandrian II date, of which those recognised in previously published work are shown upon Table 6, while Table 7 summarises the data presented in this thesis. In each case the taxa most adversely or favourably affected by clearance are noted, together with other ecologically relevant information, such as altitude or the presence of charcoal, silt inwash or cultural remains.

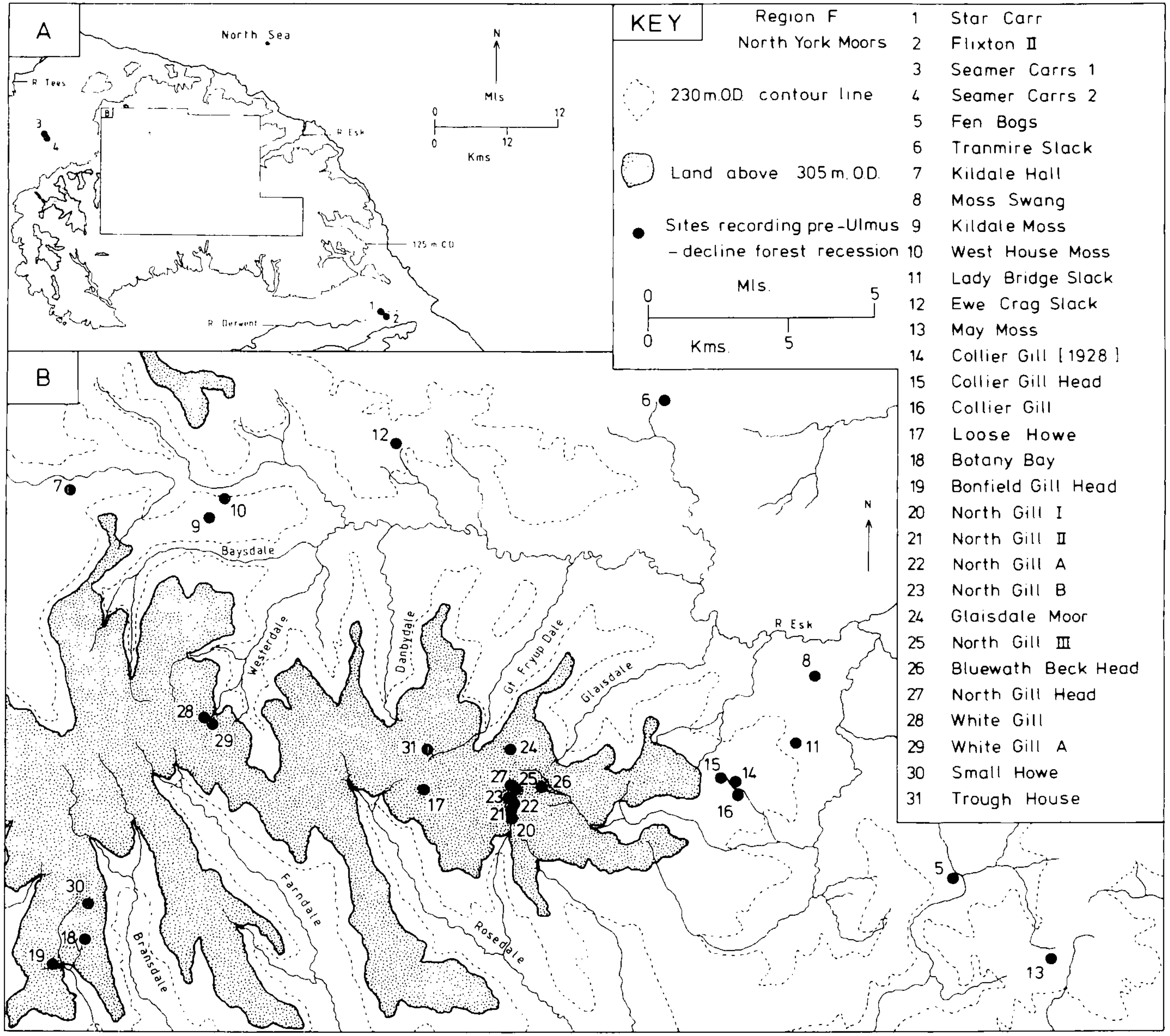


Fig. 5[illegible]. North York Moors. Distribution of sites at which evidence for pre-_Ulmus_ decline forest recession has been recorded.

7.4.1. Flandrian I

Included within the sites possibly showing evidence of man-induced environmental change are the major lowland occupation areas of Star Carr (TA 827 810) and Flixton II (TA 035 810) in the Vale of Pickering (Clark 1954, 1972). The Maglemosian cultural deposits from these sites, which have been described previously (*v.s.* page 43), fall at the boundary between Flandrian Ia and Ib, with Star Carr yielding radiocarbon dates of 9,488 $\pm$ 350bp (C-353) and 9,557 $\pm$ 210bp (Q-14). While most previous authors have not considered that signs of major vegetation clearance occur at these sites (Simmons 1975a, Jones *et al*. 1979), some indications of the interaction of the Star Carr inhabitants with the woodland environment may be discernable in the pollen record, for at the level of the occupation the pollen frequency of *Betula* temporarily falls, and *Corylus* pollen values rise sharply. Records of *Chenopodium*, *Urtica* and Caryophyllaceae are associated with this change, pointing to the effects of human activity in the creation of open areas in the vicinity of the settlement. At this point in the stratigraphy, mineral silt inwash appears in the deposit, and the implication is that disturbance of the birch woodland adjacent to the site was taking place, creating open ground, encouraging the establishment of hazel scrub, and causing some erosion of soil from the affected areas. Similar pollen fluctuations are recorded at the nearby site of Flixton II, with *Corylus* pollen frequencies rising to replace those of *Betula*. *Rumex* and *Plantago lanceolata* also occur, confirming that conditions suitable for the establishment of ruderal communities were created around the settlement.

While the landscape changes which apparently took place around these lowland lakeside settlements were not sufficiently great to warrant their description as evidence of major woodland clearance, it is evident that a significant alteration of the local vegetation communities resulted from the activities of the Mesolithic occupants. Clearance of birch woodland by felling is proven by the construction of the wooden living platform at Star Carr (Clark 1972), within which were axe-scarred trunks of considerable size. A number of tranchet axes have been recorded from nearby (fig. 3). The incorporation of a thick charcoal layer into the cultural horizons at both of these sites, however, would suggest that fire was a major biotic factor here, as alsewhere on the Moors, with the use of fire in the hinterland birchwoods, in addition to its presumed domestic application, producing the environmental changes implied by the pollen evidence. It is a factor of some significance in consideration of the _raison d'etre_ of these lakeside stations (_v.s._ page 43).

A clearer manifestation of the hunting activities of early Mesolithic man may be provided by the evidence from Kildale Hall (NZ 609 097, 168m OD.), where aurochs (_Bos primigenius_) bones were discovered stratified within organic deposits (Jones 1976a, 1977). The site was a swampy lake basin in early Flandrian times and a considerable quantity of _Betula_ and ericaceous charcoal and a high silt fraction were encountered at the level of the _Bos_ skeleton, coincident with fluctuations in the pollen record which suggested that temporary modification of the local vegetation had taken place. Pollen analysis indicated that the area adjacent to the lake had supported heath vegetation with some _Betula_ scrub woodland, an association suggesting a Flandrian Ia date which is broadly confirmed by a radiocarbon determination for peat encasing the bones of 10,350 $\pm$ 200bp (Gak-2707) which Jones (1976a) considers may be rather too early due to contamination from molluscan remains within the sediment. The true age may be more strictly comparable with the dated occupation horizons at the Vale of Pickering sites of _c_. 9.5 millenia ago. An increase in Rosaceae, Compositae, Umbelliferae and Caryophyllaceae pollen is associated with this evidence, which may reflect the hunting activities of Maglemosian people around the edge of a small lake, with an expansion of herbaceous vegetation following the fire clearance and erosive effects which the presence of charcoal and silt in the stratigraphy suggest.

Indications of clearance return to the pollen record during later Flandrian I at this site (Jones 1977), when expansions of herbaceous taxa occur which suggest temporary disturbance of the coniferous woodland, allowing the contribution of open habitat communities to the pollen record. No substantiating evidence of unstable conditions, such as charcoal or silt, is recorded, and these indications of a reduced forest cover may be regarded only as the possible expression of human activity. Considerable fluctuations of the pollen curves do occur, however, with Pinus, Quercus and Ulmus reduced in frequency and replaced by Betula and a range of taxa encouraged by environmental disturbance, including Melampyrum, Artemisia, Rosaceae, Umbelliferae, Rumex, Salix and Gramineae. Isolated peaks of herb pollen continue to be present in later Flandrian I at Kildale Hall, although in no case so clearly defined as that described above, so that a continued instability of the woodland may be assumed, whether or not human activity may be invoked as a motive factor. Analogous evidence is, however, forthcoming from other sites in the Cleveland area of the Moors (fig. 59 and Table 5), for similar pollen records have been published from the nearby sites of West House Moss (Jones 1977) and Ewe Crag Slack (Jones 1978), both of which the author considers to show possible interference with the vegetation by Mesolithic man (Jones 1976a). Pollen fluctuations occur at West House Moss (NZ 635 095, 178m OD.) which may be interpreted as reflecting the type of activity noted at Kildale Hall, as Pinus and Betula pollen values are slightly depressed while sharp peaks in value are registered for Melampyrum, Rumex, Compositae and Artemisia. Sharp rises in Corylus and Calluna in mid Flandrian I would be expected due to climatic and edaphic factors, its association here with established indicators of temporary environmental disturbance suggest that diversification of the boreal woodland by human agency may have assisted its expansion. Further indications of woodland opening occur at this site towards the end of Flandrian I, when a more closed canopy type of woodland, with a greater admixture of broad-leaf trees, would probably have come into existence. In this instance Betula, with Pinus, appears to be adversely affected, with a range of clearance indicators admitted to the pollen record or showing enhanced frequencies. Tree pollen frequencies in total are clearly depressed. Corylus and Calluna are again the beneficiaries of any canopy opening which may have taken place, and are intermittently joined in the pollen record by Succisa, Chenopodiaceae, Rumex and Melampyrum, with Rosaceae and Pteridium rising to peak values, This evidence for decreasing woodland density accords with the more tenuous evidence from Kildale Hall.

A more secure inference of clearance may be drawn from the site of Ewe Crag Slack (NZ 695 110, 235m OD.), where the disturbance of coniferous woodland by fire evidently took place in mid Flandrian I, for an horizon occurs in the stratigraphy containing both charcoal and silt, both presumably washed into the mire following fire clearance of adjacent slopes (Jones 1976a, 1978). The silt layer is up to two centimetres thick, suggesting considerable erosive effects subsequent to the burn, at least locally. The pollen spectra endorse this reconstruction of events, with a marked fall in Betula and Quercus representation coincident with an expansion of Corylus and Salix frequencies and the appearance of herbaceous taxa indicative of freshly cleared ground including Rumex, Melampyrum, Succisa, Polygonum and Rosaceae. Pteridium values also rise significantly, in what appears to have been an intensive phase of clearance. Indications of early Flandrian human activity are not confined to the northern part of the Moors, however, for comparable evidence has been recorded by Atherden (1976a) at Fen Bogs (SE 853 977, 164m OD.) where the first of a succession of clearance episodes is referable to mid Flandrian I. A temporary drop in tree pollen values is due to a sharp diminution in Betula pollen frequency, while indicators of disturbed habitats, including Pteridium and Melampyrum, become prominent. Calluna is apparently also affected by the clearance, while Rumex, Artemisia, Cruciferae, Gramineae and Umbelliferae all suggest areas of open or disturbed ground near to the mire. Charcoal is present in the stratigraphy at this point, so fire is likely to have been the mechanism by which clearance of birch-oak woodland was achieved around this site.

Few examples of Flandrian I clearance may be cited from the higher areas of the region, but this must be due primarily to an absence of deposits of suitable age rather than to an actual avoidance of the uplands by Maglemosian groups, for figure 3 shows that Early Mesolithic hunting camps have now been recognised at altitude, a facet of this culture's archaeology which may well have its known distribution extended by future research. Atherden (1979) has recorded charcoal at the base of her profile from May Moss (SE 876 960, 244m OD.), together with pollen fluctuations which suggest disturbance of woodland in mid Flandrian I. Betula, Pinus and Corylus fall in frequency, with the latter recovering quickly and then greatly expanding in value. During the phase of tree pollen recession, in which A.P. contributes only 25% of the total pollen sum, Salix pollen values rise sharply while many open habitat types are recorded, including Pteridium, Rosaceae, Plantago lanceolata and Compositae. Peat inception at this site appears to have been accompanied by an instability of the surrounding woodland which the charcoal suggests may have been fire-induced.

Similar evidence of vegetation disturbance in an upland context

Site Name	Site Phase No.	Altitude (m. OD)	**Betula**	Pinus	Quercus	Ulmus	**Charcoal**	Cultural Remains	Silt Inwash	Corylus	Salix	Fraxinus	Rosaceae	Calluna	P. Lanceolata	P. Major	Melampyrum	Rumex	Artemisia	**Urtica**	Cruciferae	Chenopodiaceae	Compositae	Caryophyllaceae	Umbelliferae	Polygonum	Succisa	Gramineae	Pteridium
			A				B			C																			
Star Carr		20	x	·	·	·	x	x	x	x	·	·	·	·	·	·	·	·	·	x	·	x	·	x	·	·	·	·	·
Flixton II		20	x	·	·	·	x	x	·	x	·	·	·	·	·	x	·	x	·	·	·	·	·	·	·	·	·	·	·
Fen Bogs		164	x	·	·	·	x	·	·	·	·	·	·	·	·	·	x	x	x	·	x	·	·	·	x	·	·	·	x
Kildale Hall	1	168	x	·	·	·	x	·	x	·	·	·	x	·	·	·	·	·	·	·	·	·	x	x	x	·	·	x	·
Kildale Hall	2	168	x	·	x	·	·	·	·	·	x	·	x	·	·	·	x	x	x	·	·	·	·	·	x	·	·	·	·
West House Moss	1	178	x	x	·	·	·	·	·	x	·	·	·	x	·	·	x	x	x	·	·	·	x	·	x	·	·	x	·
West House Moss	2	178	x	·	·	·	·	·	·	x	·	·	x	·	·	·	·	x	·	·	·	x	·	·	·	·	x	·	x
Ewe Crag Slack		235	x	·	·	·	x	·	x	x	x	·	x	·	·	·	x	x	x	·	·	·	·	·	·	x	x	·	x
May Moss		244	x	x	·	·	x	·	·	·	x	·	x	·	x	·	·	·	·	·	·	·	x	·	·	·	·	x	·
Glaisdale Moor		372	x	·	x	x	·	·	·	x	·	x	·	x	·	·	x	·	·	·	·	·	·	·	·	·	·	·	x

Table 5. Environmental Alteration on the North York Moors during Flandrian I
(A. Taxa subject to clearance. B. Other environmental factors. C. Taxa encouraged by clearance)

comes from Glaisdale Moor (NZ 728 015, 372m OD.) during late Flandrian I (Simmons and Cundill 1974a). A phase of woodland opening is implied by sharp falls in the pollen frequencies of Betula, Quercus and Ulmus and their replacement by Pinus and Fraxinus. Other indicators of open canopy conditions which show increased values are Corylus, Salix, Calluna and Pteridium, while Melampyrum enters the pollen record on high frequencies. Although unaccompanied by macroscopic charcoal, the pollen fluctuations recorded during this phase of clearance are typical of the results of fire in mixed woodland, and the presence of Mesolithic flints at this site, although not stratified with the palaeobotanical evidence, intimates its possible anthropogenic origin.

7.4.2. Flandrian II

Examples of environmental disturbance which may be attributable to the actions of Mesolithic man increase markedly in number during Flandrian II. While this may be due merely to a far wider distribution of peat deposits of suitable age than in Flandrian I, particularly in the upland areas of the Moors, the matching increase in the number of Mesolithic flint sites (figs. 3 and 4) suggests that an actual intensification of land use patterns may have taken place during the later Mesolithic. Until a more complete knowledge of the number and distribution of early Mesolithic sites becomes available, howevér, it must be remembered that the apparent imbalance between the early and later Mesolithic occupations of the region may be illusory. Table 7 summarises the evidence for Flandrian II clearance which is presented in chapters 4 to 6 of this thesis, and which has been fully described therein. A number of examples may be cited from previously published work, however, and these are shown on Table 6.

The first intimation that Mesolithic man may have been implicated in environmental change, and in particular in the alteration of vegetation communities during Flandrian II was recognised in the pollen analysis and soil profiles from the highest parts of the Moors (Dimbleby 1961a, 1962). Dimbleby analysed the pollen content of soil immediately below a prolific flint scatter associated with charcoal at White Gill on Westerdale Moor (NZ 639 026, 387m OD.) and concluded, on the basis of a very low ratio of non-tree pollen to tree pollen (NTP/TP = 39%) that the landscape at the time of the Mesolithic occupation had been densely wooded, with the site below a closed tree canopy. In the sample above the occupation layer, however, this ratio had risen to 104%, with Quercus and Alnus declining in pollen frequency and Betula, Calluna and Corylus much more prominent. This indicated that a much more open type of woodland had come into existence, which would have been a change much to the benefit of Mesolithic man, and one for which the charcoal and flints suggested to Dimbleby that human activity may well have been responsible. Re-examination of the White Gill site by Cundill (Cundill 1971, Simmons and Cundill 1969) has broadly substantiated Dimbleby's conclusions. A Flandrian II peat profile was investigated which lay above a microlith horizon incorporating charcoal. Charcoal particles were found to pervade the profile above the basal industrial levels, associated with a sharp fall in Quercus pollen values and marked increases in a wide range of open habitat taxa which included Melampyrum, Plantago lanceolata, Artemisia, Pteridium, Corylus and Calluna (Table 6).

The distribution of the sites listed upon Table 6 is displayed upon fig. 59, showing a concentration upon the high watershed areas of the Moors, generally on the headwaters of streams above 300m OD., although Collier Gill and May Moss are rather lower at 275m OD. A significant number do occur at intermediate altitude, however, (c. 150m OD.) particularly

Site Name	Site Phase No.	Altitude (m.OD)	Betula	Quercus	Alnus	Ulmus	AP:NAP ratio	Charcoal	Cultural Remains	Silt Inwash	Corylus	Salix	Prunus-Sorbus	Fraxinus	Rosaceae	Calluna	P. lanceolata	P. major	P. coronopus	Melampyrum	Rumex	Artemisia	Urtica	Cruciferae	Galium	Chenopodiaceae	Compositae Tub.	Compositae Lig.	Caryophyllaceae	Umbelliferae	Labiatae	Succisa	Epilobium	Gramineae	Pteridium
			A					B			C																								
Seamer Carrs 1		64	.	x	x	.	.	.	.	.	x	.	.	x	.	x	.	x	.	.	x	x	.	.	.	.	x	.	.	x	.	.	.	.	x
Seamer Carrs 2		64	x	x	.	.	.	.	.	.	x	.	.	x	.	x	x	.	.	.	.	.	.	.	.	.	.	.	x	.	.	.	.	.	x
Fen Bogs	1	164	.	.	x	.	.	x	.	.	.	.	.	.	.	.	x	.	.	x	.	.	.	.	.	.	x	.	.	.	.	.	.	x	.
Fen Bogs	2	164	.	.	x	x	.	.	.	.	.	x	.	x	.	.	.	.	.	.	.	.	.	x	x	.	.	.	.	.	.	x	.	x	.
Fen Bogs	3	164	.	.	x	x	.	.	.	.	.	x	.	x	x	x	.	.	.	x	x	x	.	x	.	x	.	.	.	x	.	x	.	.	x
Tranmire Slack	1	165	.	x	x	.	.	.	.	x	x	.	.	x	x	.	x	.	x	x	.	x	.	.	.	x	x	x	x	.	.	.	x	x	x
Tranmire Slack	2	165	.	x	x	.	.	.	.	x	x	.	.	x	x	.	x	.	.	x	.	x	.	.	.	x	x	x	x	.	.	.	.	x	x
Moss Swang		175	.	x	x	x	.	.	.	x	x	.	.	x	.	.	.	.	.	x	x	.	.	.	.	x	x	.	.	.	.	.	.	.	x
Kildale Moss		175	x	x	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
West House Moss		178	x	x	.	.	.	.	.	.	.	.	x	.	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x
Lady Bridge Slack		212	.	x	.	.	.	.	.	.	x	.	.	x	.	.	x	.	.	x	x	x	.	.	.	.	.	.	x	x	x	.	.	.	x
Ewe Crag Slack		235	.	x	x	.	.	.	.	x	.	x	.	x	x	.	.	.	.	x	.	x	.	.	.	.	.	.	.	x	.	.	.	.	x
May Moss		244	.	x	.	x	.	x	.	.	.	.	.	x	x	.	.	.	.	.	.	.	.	.	.	x	x	.	.	.	.	.	.	x	.
Collier Gill (1928)		244	.	x	x	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Collier Gill Head		274	x	.	.	.	.	x	.	.	x	.	.	.	.	x	.	.	.	x	x	x	.	.	.	.	.	.	.	.	.	x	.	.	x
Collier Gill	1	274	.	x	.	.	.	x	.	.	x	.	.	.	.	x	.	.	.	x	x	x	.	.	.	.	.	.	.	.	.	x	.	.	x
Collier Gill	2	274	.	x	x	.	.	x	.	.	.	.	x	x	.	.	.	.	.	x	.	.	.	.	.	.	.	.	.	x	.	.	.	.	x
Collier Gill	3	274	.	x	.	.	.	x	.	.	x	x	.	x	.	.	x	.	.	x	.	x	.	.	.	.	.	.	.	.	.	.	.	.	x
North Gill A	1	362	.	x	x	.	.	x	.	.	x	x	x	x	.	.	.	.	.	.	x	x	.	.	.	.	.	.	.	x	.	.	.	.	x
North Gill A	2	362	.	x	x	x	.	x	.	x	x	.	x	.	.	.	.	.	.	.	x	x	x	.	.	.	.	.	.	x	.	.	.	.	x
North Gill B		362	.	x	x	.	.	x	.	.	x	x	.	x	.	.	x	.	.	x	x	x	.	.	.	x	x	x	.	x	.	.	.	.	x
Glaisdale Moor		372	x	x	.	x	.	x	.	.	x	.	.	x	.	.	.	.	.	x	x	.	.	.	.	.	.	.	x	x	.	x	.	.	x
White Gill		387	.	x	x	.	.	x	x	.	x	.	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x	.
White Gill A		387	.	x	.	.	.	x	x	.	x	x	.	x	.	x	x	.	.	x	.	x	.	.	.	.	x	.	.	x	.	x	.	.	x
Trough House		418	.	.	.	.	x	x	.	.	x	.	.	x	.	x	.	.	.	.	.	x	.	.	.	x	.	.	.	.	.	.	.	.	x
Loose Howe		430	.	x	.	.	.	x	.	.	x	.	.	x	x	x	.	.	.	x	.	.	.	.	.	.	.	.	.	.	.	.	.	.	x

Table 6. Environmental Alteration on the North York Moors during Flandrian II - Previous Evidence

(A. Taxa subject to clearance. B. Other Environmental Factors. C. Taxa encouraged by clearance.)

upon the lower watershed of the Cleveland plateau, and two instances are suggested for the lowland lakeside site of Seamer Carrs (NZ 484 097, 64m OD.) At this site Jones (1971, 1976b) records a phase in early Flandrian II during which the stability of the broad-leaf forest surrounding the lake was disturbed and a number of heliophyte taxa increased their pollen representation. Peaks of Corylus, Pteridium and Pinus, and the begining of a constant Fraxinus presence, combine with the appearance of Artemisia, Plantago major, Rumex, Cruciferae and Compositae (subfamily Tubuliflorae) to suggest the creation of open ground and scrub communities not far from the lake. Similar pollen fluctuations are recorded by Tooley (personal communication) from a neighbouring site, where a very sharp increase in Corylus frequency occurs in association with skeletal remains of Cervus elaphus and this may be seen as the legacy of Mesolithic hunting around the margin of the lake. Considerable provision of open ground seems to have taken place, for tree pollen frequencies are reduced and Artemisia, Plantago lanceolata, Stellaria and Pteridium occur.

Similarly the deposits at Ewe Crag Slack, in a watershed situation at 235m OD (Jones 1978), record two episodes during which reductions in tree pollen values, primarily for Alnus and Quercus, are coincident with the introduction of herbaceous indicators of freshly cleared ground, in particular Melampyrum and Artemisia. Pteridium and heliophyte shrubs and trees were encouraged, with Corylus, Salix, Sorbus and Fraxinus reflecting the more open nature of the woodland. The clearance of areas adjacent to the mire resulted in soil erosion and the deposition of sediment in the form of inwash stripes of mineral material. Similar phenomena are recorded from Fen Bogs (Atherden 1976a), Moss Swang (NZ 806 035, 175m OD. Simmons 1969a), Lady Bridge Slack (NZ 804 081, 212m OD., Simmons 1969a) and West House Moss (Jones 1977), where dislocation of woodland ecosystems and the creation of open areas are represented by an increased contribution of ruderal and regeneration types to the assemblage, accompanied on occasion by the deposition of silt inwash and charcoal in the mire. Characteristic indicators of clearance at these sites include Melampyrum, Artemisia, Rumex, Stellaria cf. holostea, Compositae, Cruciferae and Chenopodiaceae. The individual clearance assemblages are described upon Table 6. The lower altitude palaeo-environmental evidence represented by these sites is consistent in demonstrating rather less intensive clearance than from the higher parts of the Moors, perhaps reflecting the greater woodland density in these areas. In lower altitude clearance phases A.P. values fall from an average of about 70% of total pollen to about 50%, and clearance indicators, while present in the same range as in upland examples, do not show such high frequencies. An exception to this is a mid Flandrian II forest recession at Tranmire Slack (NZ 766 119, 165m OD.) during which A.P. falls from 70% to 30% of total pollen (Jones 1978). The full assemblage of ruderal types mentioned above is joined by Plantago lanceolata, Plantago coronopus and Epilobium, while peaks of Pteridium, Gramineae, Fraxinus and Corylus occur. The deposition of a mineral inwash stripe in the mire again accompanies clearance.

The intensity of this clearance phase is analogous to those recorded from the high Moors, of which the sites of North Gill and Bonfield Gill Head are typical examples, tree pollen falling from an average of about 50% to less than 30% of total pollen following clearance. A number of such woodland clearances have been recorded from around the headwaters of Collier Gill (NZ 786 009, 274m OD.) by Simmons (1969a) and by Cundill (1971), in each case associated with indications of forest fire, denoted by the recovery of charcoal from the stratigraphy. The lowermost phase of clearance from Simmons' site corresponds with the onset of peat formation in mid Flandrian II, and is radiocarbon dated to 5,504 ± 108bp (BM-427). Each phase of clearance is characterised by reductions in tree pollen frequency and an expansion of the pollen or spore values of taxa favoured by fire clearance of woodland, among which are Corylus, Artemisia, Melampyrum, Rumex, Pteridium and Salix. In the light of these investigations at Collier Gill, fluctuations in the pollen record published by Erdtman (1928), with a distinct replacement of Quercus and Alnus pollen by that of Corylus in mid Flandrian II, may also be interpreted as the effects of forest clearance. Further examples from May Moss (Atherden 1979), Loose Howe (NZ 703 009, 430m OD.), Glaisdale Moor (Simmons and Cundill 1974a) and Trough House (NZ 704 815, 418m OD. Cundill 1971), although differing in detail, provide similar evidence of fire induced forest recession in the uplands of the Moors during Flandrian II.

In addition to the contrasting density of the woodland in which clearance took place, other differences are apparent between upland and lowland examples, although both record a fundamentally similar event. Charcoal is present in every case in upland contexts both as discrete concentrated layers and suffused throughout the profile, indicating that firing of the vegetation was a common and perhaps even regionally continuous event at this altitude, and therefore central to its environmental history. Charcoal is not in every case recovered from the stratigraphy at lowland clearance horizons, but the use of fire is nevertheless implied by the almost universal expansion of taxa held to be characteristic of succession after fire. Several sites exhibit more than one clearance horizon, and so were the foci of activity at intervals throughout the Flandrian, but where deposits of similar age are available for comparison, those in the upland appear to have been visited rather more often. This may, however, be illusory due to the more open upland sites having had a rather greater pollen catchment area than those in the more densely wooded lowland.

While the type of assemblage changes which constitute clearance phases are all relatively similar, being the replacement of stable woodland component taxa by those representative of seral communities, the behaviour of individual taxa is worthy of comment. Calluna, for example is strongly represented in clearance assemblages of late Flandrian II, particularly in the uplands, but is much less prominent at lowland sites or in Flandrian I, probably indicating contrasting soil development after clearance in differing situations. The regular occurrence of Plantago lanceolata in the post clearance assemblages recorded upon Tables 5, 6 and 7 is of interest, for in Neolithic contexts it is regarded as a secure agricultural indicator and has been so associated with 'landnam' following the Ulmus decline (Iversen 1941, 1949) that the numerous records of its pollen in Mesolithic contexts have invited similar interpretation, or else dismissal, even when associated with other indicators of clearance (Van Zeist 1955). Thus it was possible until quite recently to remark that 'in post glacial peat deposits in Western Europe, lanceolate plantain is never met with before the elm decline' (Van Duinen and Van Zeist 1960), a conclusion which had previously been reached by Iversen (1949). With the increasing number of Mesolithic identifications, however, often associated with woodland clearance, it would appear that Smith (1970) is correct in stating that Plantago lanceolata functions as a dryland ruderal herb in pre-Neolithic contexts. Numerous other instances of its appearance in Mesolithic clearance situations may be cited, for example those at Malham Tarn Moss (Pigot and Pigot 1959, 1963) and Broomhead Moor V (Radley et al. 1974) in the uplands, and Hockham Mere (Sims 1973, 1978), Simonswood Moss C (Innes and Tomlinson 1980) and Downholland Moss 16 and The Starr Hills, Lytham (Tooley 1978a) in the lowlands.

The distribution of Mesolithic clearance evidence displayed upon fig. 59 may not of course be considered to show the full range of Mesolithic activity upon the Moors, for is is inevitably determined to a high degree by the spatial and temporal distribution of organic deposits suitable for the preservation of such evidence. Thus more examples are forthcoming from Flandrian II situations than from Flandrian I, during which environmental disturbance upon the almost mire-free upland areas would go unrecorded, as would similar activity conducted well away from sites of pollen capture at any stage of the period. The last point would imply that the apparent concentration of activity upon wetland habitats may be a function of the method of data collection rather than reality, if it were not for the corroboration provided by the archaeological evidence. Flint sites, whether of Early or Late Mesolithic type (figs. 3 and 4), are mainly concentrated in the same ecotone situations described in chapter 7.3, and thus have a parallel distribution with sites in which clearance activity has been recorded. Microlithic sites cluster around the spring line, whether at the major ecotone between A and B, or upon the lower altitude ecotones of spring, river, or lakeside within zone B. At lower altitude they tend to lie upon the line of the escarpment which forms the major ecotone between zones B and C, and the settlement sites such as those at Upleatham are also situated upon this line. Microlith sites in zone C are found upon river or lakeside ecotones also. The sites which we may presume to have lain upon the littoral ecotone area of zone D are now almost all destroyed by coastal erosion or sea-level rise, or in the case of estuarine locations, by burial beneath later deposits. While the typology of these various sites suggests that their function may have been rather different (v.s. chapter 2.4.) they are alike in their situation away from zones of homogenous landscape type. The ecotone areas shown upon fig. 58 do seem, therefore, to have

Site Name	Site Phase No.	Altitude (m. OD)	A						B			C																									
			Betula	Pinus	Quercus	Alnus	Tilia	Corylus	Charcoal	Cultural Remains	Silt Inwash	Corylus	Salix	Prunus-Sorbus	Fraxinus	Rosaceae	Calluna	P. lanceolata	Melampyrum	Rumex	Artemisia	Urtica	Cruciferae	Galium	Chenopodiaceae	Compositae Tub.	Compositae Lig.	Centaurea	Caryophyllaceae	Umbelliferae	Cirsium	Polygonum	Succisa	Scabiosa	Labiatae	Gramineae	Pteridium
North Gill I	I1	357	x	•	x	x	•	•	x	•	•	x	•	x	x	x	x	•	x	x	x	x	•	•	x	x	x	•	x	x	•	x	x	•	•	x	x
North Gill I	I2	357	x	•	x	x	x	•	x	•	x	x	x	x	x	•	x	•	x	x	x	x	•	•	x	x	•	•	x	x	•	•	x	•	•	•	x
North Gill II	I1	359	•	•	x	x	•	•	x	•	•	x	x	x	x	•	x	•	x	x	x	x	•	•	x	•	•	•	x	•	•	•	x	•	•	•	x
North Gill II	I2	359	•	•	x	x	•	•	x	•	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	•	•	x	x	x	x	x	x	•	•	x	x
North Gill II	I3	359	•	•	x	•	•	•	•	•	•	x	x	x	x	x	x	x	x	x	x	x	•	•	x	•	•	•	•	•	•	•	x	•	•	•	x
North Gill III	I1	360	•	•	x	x	•	•	x	•	•	x	x	x	x	x	x	x	x	x	x	x	x	•	x	•	x	•	x	•	x	x	x	x	•	x	x
North Gill III	I2	360	•	•	x	x	•	•	x	•	•	x	x	x	x	x	•	•	x	x	x	x	•	•	x	•	x	•	•	•	•	•	x	•	•	•	x
North Gill III	I3	360	•	•	x	x	•	•	x	•	•	x	x	•	x	•	•	x	x	x	x	x	•	•	x	x	•	•	•	•	•	•	x	•	•	x	x
North Gill Head	I1	366	•	•	x	x	•	•	x	•	•	x	x	•	•	•	x	•	x	•	•	x	•	•	x	•	•	•	•	•	•	•	x	•	•	•	x
North Gill Head	I2	366	•	•	•	x	•	x	x	•	•	•	•	•	x	•	x	x	•	x	•	x	•	•	•	•	•	•	•	•	•	•	x	•	x	•	x
North Gill Head	I3	366	•	•	x	x	•	•	•	•	•	x	•	x	x	•	x	x	x	x	x	x	•	•	x	•	•	•	•	x	•	•	•	•	•	x	x
Bluewath Beck Head	I1	375	x	x	•	•	•	•	x	•	x	x	x	x	x	x	•	•	x	x	x	x	x	•	•	•	•	•	•	•	•	•	x	•	•	x	x
Bluewath Beck Head	I2	375	x	•	x	•	•	•	x	•	•	x	x	x	x	•	x	•	x	x	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	x	x
Bluewath Beck Head	I3	375	x	•	x	x	•	•	•	•	•	x	x	x	x	x	x	•	x	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x
Bonfield Gill Head	I1	346	•	x	x	x	•	•	x	•	•	x	x	x	x	x	x	•	x	x	•	x	x	x	x	•	•	x	•	x	•	•	x	x	•	•	x
Bonfield Gill Head	I2	346	x	•	x	x	•	•	x	•	•	x	x	x	x	x	x	•	x	x	x	x	x	•	x	•	x	x	x	x	x	x	x	x	•	x	x
Bonfield Gill Head	I3	346	•	•	x	x	•	•	x	•	•	•	x	•	x	x	x	•	x	x	x	x	•	•	•	•	•	•	x	•	•	•	x	•	•	•	x
Botany Bay	I1	335	x	•	x	•	•	•	•	x	•	x	x	x	•	x	•	x	x	•	x	•	x	•	•	•	•	•	x	•	•	•	x	•	•	•	x
Small Howe	I1	402	•	•	x	x	•	•	x	•	•	x	x	•	x	•	x	x	x	x	x	•	•	•	x	•	•	•	x	x	•	•	•	•	•	x	x

Table 7. Environmental Alteration on the North York Moors during Flandrian II - Evidence presented in this Thesis.

(A. Taxa subject to clearance. B. Other Environmental Factors. C. Taxa encouraged by clearance.)

been foci of activity during the Mesolithic. Almost all types of ecotone areas seem to record clearance nearby, so that environmental alteration appears not to have been restricted to any palaeo-environmental zone, but to have been applied on a regional basis, although with locally different scale and intensity, with spring heads at high altitude as perhaps the primary zone of activity. In summary, however, deliberate environmental alteration appears to have been carried out in the North York Moors throughout the Mesolithic period, radiocarbon dated examples ranging from the start of Flandrian I (Kildale Hall, 10,350 $\pm$ 200bp, Gak-2707) to the end of Flandrian II (North Gill II, I3, 5,210 $\pm$ 75, Gu-1071). Moreover, clearance appears to have taken place in ecotone locations across the full altitudinal range of the area from Star Carr (20m OD.) to Loose Howe (430m OD.) Comparison of the North York Moors data with Mesolithic clearance evidence from Britain as a whole tends to confirm this impression of ubiquity, for examples of clearance have been cited from other regions (v.s. pages 23 and 242) which range spatially from sea-level to high altitudes. Also, while the total number of Mesolithic clearance events which have been radiocarbon dated remains small (Table 8), those available encompass the whole of Flandrian I and II. Environmental alteration was apparently an integral feature of Mesolithic land-use in many areas of Britain, and the North York Moors evidence, although much more plentiful than elsewhere, is of a similar character. The origin of fire clearance, its effects upon the ecosystem and the role of such environmental alteration in Mesolithic land-use patterns will be discussed in the following sections, and, while detailed analysis of the data from throughout Britain is beyond the scope of this thesis, it seems likely that the conclusions reached in the following sections regarding its role in the Mesolithic economy of the North York Moors may well be of relevance to the Mesolithic occupation of other regions of Britain.

Table 8. Radiocarbon dated examples of pre-Ulmus decline (Mesolithic) forest recession in Britain.

SITE	DATE	LAB-CODE	REFERENCE
North Gill II (I3)	5210 ± 75	Gu-1071	this thesis.
North Gill II (I2)	5220 ± 75	Gu-1073	this thesis.
Dunford Bridge B	5380 ± 80	Q-799	Radley et al. 1974
Collier Gill	5504 ± 108	BM-427	Simmons 1969a.
Barfield Tarn	c. 5650*		Pennington 1975.
Blea Tarn	c. 5700*		Pennington 1975.
High Rocks (F)	5730 ± 150	BM-91	Money 1960.
Valley Bog	5945 ± 50	SRR-93	Chambers 1978.
Oakhanger	6300 ± 120	-	Rankine et al. 1960
North Gill 'a'	6316 ± 55	BM-425	Simmons 1969a.
Stump Cross	6500 ± 310	Q-141	Walker 1956.
Westward Ho!	6585 ± 130	Q-672	Churchill and Wymer 1965.
Dozmare Pool	6793 ± 70	Q-1024	Brown 1977.
Coire Bog	6980 ± 100	Q-887	Birks 1975.
Oulton Moss A	c. 7200*		Walker 1966.
Hockham Mere	7447 ± 125	Q-1088	Sims 1978.
Cooran Lane	7541 ± 180	Q-874	Birks 1975.
The Starr Hills, Lytham	8390 ± 105	Hv-4343	Tooley 1978a.
Broomhead Moor V	8570 ± 110	Q-800	Radley et al.1974.
Star Carr	9557 ± 210	Q-14	Clark 1972.
Kildale Hall	10350 ± 200	Gak-2707	Jones 1976a.

* estimations calculated by the respective authors from adjacent radiocarbon dated horizons.

7.5. The Origins of Fire Clearance

In the previous sections the spatial distribution and composition of the vegetation units which formed the landscape of the North York Moors during Flandrian I and II, and the location and nature of the palaeobotanical evidence for environmental alteration have been discussed. It remains to decide whether it is justifiable to attribute these instances of fire clearance to the activities of Mesolithic communities, and to assess the implications of fire clearance for resource potential and landscape change, and the possible role of environmental alteration in the relationship of Mesolithic man with his ecological background.

The implications of the type of evidence presented in detail in chapters 4 to 6 of this thesis and described in general in chapter 7.2. are clear: repeated firing of the woodland was taking place in Flandrian I and II on the North York Moors. The first point to consider, however, is whether or not it is justifiable to ascribe these fires to human agency, particularly when Tables 5 to 7 show that relatively few of the charcoal deposits of the Moors are stratified directly with cultural remains, although almost all are adjacent to microlith sites. Natural fire may not be discounted entirely, and a good case can be made out for their probable occurrence in the drier boreal woodland of Flandrian I.

Natural fires occasioned by lightning strike do occur, for such events have been witnessed (Jones 1945, Allison 1952, Weatherall 1952) and must be invoked as an explanation for the many records of fire from much earlier geological periods, before man could possibly have been involved (Harris 1958). While other natural causes of forest fire have been observed, such as the striking of sparks by boulders rolling downslope (Moir 1923), lightning must be by far the most common originator. It seems likely that major fires would be started only during lightning storms which are unaccompanied by rain, and that the incidence of such storms would be much greater in areas of dry, continental climate, conditions much more applicable in the British Isles to boreal Flandrian I than to the more oceanic Flandrian II. The flammability of the boreal forest is much higher than that of moist deciduous woodland, for coniferous needle litter remains relatively dry at all times, and surface litter is regarded as crucial as both a fire starter and spreader after lightning strike (Rowe and Scotter 1973). Indeed, previous authors, writing with reference to both North America and Europe, have stressed that fire naturally plays an integral role in the ecology of the boreal coniferous forest, to such an extent as to be central to its successful regeneration (Ahlgren 1960, Heinselman 1973). In this respect coniferous woodland may be described as fire-adapted, with Pinus peculiarly able to survive forest fires through its thick heat resistant bark and to regenerate quickly although fire damaged (Zackrisson 1977). It has been suggested (Much 1970) that the dependence of Pinus forest on fire for its regeneration is such that the genus has evolved high flammability characteristics. Whether of not this is the case it is quite clear that the association of fire and Pinus dominated coniferous forest is natural and of long standing, for Swain (1973) has found charcoal to be continuously present in lake sediments from 9,000 years ago to the present day in Minnesotan conifer forest, for which he believes lightning to be the main causative agent.

Having made the point that fire is a natural feature of the coniferous forest ecosystem, however, is not to say that man may not have played the major role in initiating fire clearance in the North York Moors situation. The modern incidence of lightning strike in the region is very low in comparison with the rest of Britain (Lacy 1977) and may well have been so in antiquity, for Jelgersma (1979) has shown the Flandrian I coastline at the latitude of North Yorkshire to have been only a few kilometres to the eastward of the modern, so that the greater continentality of climate assumed for southern Britain at this time may not have been relevant to the Moors. In addition, the boreal woodland of Flandrian I in Northern England was significantly different from the recent coniferous forest of either North America or Northern Europe, not least in its restriction to a single major coniferous tree, Pinus sylvestris, lacking the spruce, fir and other pine species which diversify American and European coniferous forests. Scots pine may well not be fire adapted to the same degree as American jack and red pine species, due to its association with pioneer deciduous trees in European forests. Indeed, the high proportion of Betula in the lowlands of the North York Moors during this period renders the concept of habitual lightning fires in that zone most implausable. Deciduous trees such as birch (and aspen, almost certainly a component of Flandrian I woodland although hardly represented in the pollen spectra due to poor preservation of its grains) act almost as fire preventers in mixed broad leaf/coniferous woodland (Rowe and Scotter 1973) so that it burns neither so readily nor so extensively. Transmission of fire through the dense birch woodland of lower altitudes as a natural process is most unlikely, especially later in the period when oak and elm become significant constituents, and the instances of fire clearance recorded during Flandrian I (within which Betula is consistently the taxon affected by fire - Table 5) probably refer to man-set fires of localised intention and effect, rather than natural ecosystem events.

The vegetation of the highlands of the area, with dominant pine and hazel, is much more likely to have been a fire-controlled association, although again the relative importance of lightning and man as ignition sources require consideration. Of some relevance at this point to the discussion of the status of Pinus in the region, both in Flandrian I and its persistence at altitudes into Flandrian II, are the observations by Wright (1974) that 'many pine stands are confined to sandstone ridges, crests and plateaus, where dry soils and wind exposure are favourable for fire' and that under these situations the 'upland vegetation mosaic is controlled by fire rather than by topography'. Both statements may, it seems, be as applicable to the North York Moors as to the Appalachian mountains.

The probability that lightning fires had an influence on the vegetation of the higher parts of the Moors (i.e. the regeneration of Pinus in zone A, the Central Watershed) must be accepted. This does not however mean that Mesolithic man was not also responsible for deflection of the vegetation successions by firing of the woodland. We know that man had been an extrinsic factor in the development of the region's ecosystems since the earliest part of Flandrian I, and active in both the lowlands (Star Carr, 9,488 ± 350bp, C-353) and upon the high plateaux (Money Howe I, 9,430 ± 390bp, Q-1560). The slightly earlier site of Kildale Hall (10,350 ± 200bp, Gak-2707) records the effects of his hunting techniques, and is comparable with sites from outside the region, for example the elk from High Furlong, Lancashire (11,665 ± 140bp St-3836, Hallam et al. 1973). Man was therefore present during the development of the Flandrian I woodland and capable of utilising fire during both its preforest and forest stages. The radiocarbon date for the Money Howe I site is actually derived from a charcoal sample, so that man was active with fire in the uplands from the beginning of the period, and with it he would have helped to mould the Flandrian I woodland communities, if only locally and casually. As it would appear that these communities were more in the nature of a mixed Pinus-broadleaf woodland, and therefore not intrinsically flammable on a large scale, the case for cultural ingnition becomes much better. Moreover, while comparative evidence for lightning fires in boreal woodland is strong, examples of deliberate firing by hunter-gatherer societies is also well documented. Heinselman (1973) states that Indian populations in North America, although few in number, used to burn pine woodland to stimulate production of Vaccinium berries, while Kilgore (1973) quotes a number of authors (e.g. Driver 1937, Reynolds 1959) who state that Indian groups used fire as a management tool and hunting aid. Collation of documentary evidence for the deliberate burning of forested areas by hunter-gatherers has been undertaken by Stewart (1956) and more recently by Mellars (1976c), both of whom conclude that the practice was an almost universal feature of the way of life of aboriginal populations. Two of the many references cited by Mellars may be quoted with relevance here, for they refer to the burning of mixed deciduous/coniferous boreal forest. Thus Thompson and Smith (1970) observed that in eastern North America Indian groups used fire throughout the range of their activities so that mixed woodlands were dramatically affected, and the boreal forest may have been influenced by fire to a great degree (Mellars 1976c p.16). Not only was burning widespread in this type of ecosystem, but very frequently used, perhaps even on an annual basis (Thompson and Smith 1970, Lewis 1973). It is likely that this body of evidence, of which the two references quoted above are but two of many, may be closely comparable to the activity of man in the mixed deciduous/coniferous boreal woodland of Flandrian I on the North York Moors.

Both the location and character of the clearance evidence in the study area are consistent with man-set fires rather than wild fires. The pollen spectra, together with other factors such as silt inwash and the large size of the charcoal fragments, suggest that wetland ecotone situations were the foci of the clearance events, and the pollen evidence suggests high intensity fires causing temporary large scale forest recession in the immediate vicinity of these areas. This points to clearance being a deliberate act, for such wetland zones are the areas of boreal forest least frequently affected by natural fires (Heinselman 1973). Wild fires also tend to register rather differently in the pollen record, as they are generally of lower intensity and move quickly through the woodland, perhaps spatially adjusting the overall forest mosaic rather than being concentrated on a small area, and thus causing less radical pollen fluctuations (Swain 1973). The conscious selection by man of favoured locations for clearance activity seems the most cogent explanation for the immediacy of forest burning to wetland areas. Whether or not microscopic charcoal particles present within Flandrian I deposits reflect a regional expression of man's activities or wild fire must remain conjecture, being almost certainly a combination of both, but it is suggested that in the environmental context of the North York Moors, man will have been the most common ignition source. Boreal charcoal layers occur at other sites in Northern England, for example at Downholland Moss 16 and The Starr Hills, Lytham (Tooley 1978a), Fountains Earth (Tinsley 1975), Broomhead Moor V (Radley et al. 1974), and at a number of sites in Upper Teesdale (Squires 1970). Human agency is considered likely in these cases also, especially at Broomhead Moor V where flints are present on site. The fires which created the charcoal layers recorded from Boreal *Pinus* forests in Scotland at Cooran Lane (Birks 1975) and Beinn Eighe (Durno and McVean 1959) are likely also to have resulted from the activities of man, as the authors state that a damp oceanic climate pertained in the area at the time.

While lightning-ignited fires may have been an integral, if minor, part of the Flandrian I ecosystem of the North York Moors, the occurrence of such natural events would probably not be great in the damp oak-hazel-alder woodland of Flandrian II under the increased humidity and precipitation of the Atlantic climatic regime (Taylor 1975, 1980, Lockwood 1979). It seems likely that these woodlands would be sufficiently damp and fire-resistant to make even this deliberate burning a difficult task, and to render accidental ignition virtually impossible. It is precisely these environmental conditions, however, with the establishment of damp, dense deciduous forest which would have made the application of fire ecology by Mesolithic man all the more necessary as a means of altering a closed forest environment which was economically unfavourable to him. With respect to resource potential and food-winning opportunities, the deciduous forests of Flandrian II were depleted in comparison with the more diverse ecosystems of Flandrian I. Woodland canopies were generally dense and continuous, reducing the input of light to the forest floor and with it the quality and quantity of available resources in terms of both plant and animal foods. The environmental characteristics of Flandrian II - ecological stability, forest inertia and much reduced plant and animal resource diversity - would place the extractive systems of the Mesolithic under increasing pressure. The consequences for a hunting and gathering community of a steady diminution of exploitable vegetable foods, and thus of game animals, were likely to be increasingly severe. Reductions in game stocks and restrictions of human movement by the dense broad leaf forest potentially would have combined to cause an increase in hunting encounters with individual animals (Noe-Nygaard 1974) putting further pressure upon the meat resource. This enforced sedentism, if combined with human population increases as envisaged by Meiklejohn (1978), would necessitate an increased economic sophistication which might eventually manifest itself in herding (Fleming 1972, Simmons and Dimbleby 1974) and ultimately tillage (Steensberg 1973). It is to be expected, therefore, that man's response to the reduction in resource potential by the establishment of the Flandrian

II forest was a) to exploit preferentially those parts of the region which naturally retained vegetational diversity, and b) to encourage this diversity by artificial means, in particular by fire clearance of woodland in favoured locations, generally by forest-edge, spring-head, lakeside or foreshore, the ecotone areas described in chapter 7.3. where natural concentrations of game were most likely to be found. The distribution of the clearance evidence for Flandrian II (fig. 59 and Tables 6 and 7) supports this view. It has been pointed out above (chapter 7.2.) that the North York Moors uplands (zones A and B on fig. 58) carried a lighter, more open woodland during this period than the lowland zone C, with oak accompanied by a great deal of hazel and with tree cover lightest in the Central Watershed area, zone A. It is likely that this association was in part a natural one for an upland area with a proportion of poorer, sandy soils. This open woodland on dry sandy soils, however, is well drained and may thus dry out sufficiently well in summer to have made its deliberate ignition possible at that season (Simmons 1969b). Its richer field layer enables it to carry fire well, in contrast to heavy, closed canopy forest on damp clay soils, and so invites the application of fire ecology as the only Flandrian II zone lending itself at all readily to the support of significant fires. This is demonstrated by the high proportion of all attested Mesolithic clearance phases which have been recorded from areas of this type, particularly the uplands of Northern England or the sandy heaths of Southern England (Mellars 1976c) and explains the concentration of both Mesolithic settlement and economic activity in the areas of this geological type (Mellars and Reinhardt 1978). The high level of fire clearance activity recorded upon the upland plateaux (zone A) of the Moors is in accordance with this and the importance of hazel in this area may well have been a result of continued environmental manipulation by man and, therefore, culturally induced. The evidence from North Gill and Bonfield Gill Head that burning of the vegetation was a regionally continuous phenomenon is strong support for this contention.

7.6. The Ecological Effects of Fire clearance

The introduction of fire to a woodland ecosystem initiates rapid changes in its character through its deflection of natural successions, involving the abrupt removal of all or part of the existing vegetation and its replacement by transitory, seral communities. While the consequences of such an event may differ in detail between the mixed boreal woodland of Flandrian I and the deciduous forest of Flandrian II in the North York Moors, they remain comparable in that they represent the addition of a degree of diversity to the ecosystem which is most important in increasing the availability of resources. The ecological effects of forest fires have been described in detail by previous authors (Ahlgren and Ahlgren 1960, Heinselman 1973, Kozlowski and Ahlgren 1974) and their implications for Mesolithic economy and land-use have been examined by Mellars (1975, 1976c). A detailed account of the full corpus of ecological evidence is therefore not required at this point, but a brief statement of the effects of fire clearance upon resource potential is necessary to explain its apparently widespread application during the Mesolithic in the North York Moors.

The creation of open areas within woodland by fire clearance of the vegetation allows the input of light to the forest floor and provides a concentrated supply of nutrients in the form of mineralised humus and ash derived from combusted plant material. Good growing conditions are thus provided for some plants which may have survived the burn and those which quickly colonise the clearing, fast immigrants able to survive the hard environmental conditions after the burning, so that the area becomes occupied by rapidly developing successional communities as regeneration ensues. A rich carpet of grasses, herbs and sedges represents the first stage in this process, with flowering and seed production stimulated, to be followed by the establishment and vigorous growth of a range of shrub taxa, particularly those which sprout prolifically from burnt stumps, such as hazel, birch and willow. Thus while regenerating to woodland, the area of clearance supports a rich and diverse mosaic of herb and shrub taxa and provides an oasis of productivity within the species-impoverished mature forest, where the shading effect of the tree canopy supresses the growth of understory plants.

These post-fire communities make productive feeding grounds for many kinds of wild life, but large herbivores in particular are attracted to these areas by the abundance of forage and browse plants which proliferate in early post-fire successions (Bendell 1974), deer being especially encouraged (Leopold 1950). A number of authors have shown that deer populations tend to concentrate within these areas, responding quickly to a food supply increased both in quantity and quality by the lush growth of their favoured browse plants (Dills 1970, Vogl and Beck 1970, Leege and Hickey 1971). This is of great relevance to the role of fire clearance in the Mesolithic, as red deer are presumed to have formed a major human food resource during that period, and the subject has been examined by Mellars (1975, 1976c) and Mellars and Reinhardt (1978). The consequence of forest burning relative to game stocks appears to be that a dramatic increase in the absolute numbers and density of deer occurs, due to increased carrying capacity of the forage-rich regeneration community and its restriction to a relatively limited area. There is also evidence that growth-rate, body size and fecundity of individual animals is enhanced. The increased availability, size and productivity of animal populations applies to other types of game animals as well as deer. The 'productive habitat complex' of post-burn areas (Heinselman 1973) would provide suitable feeding areas for elk (Bendell 1974), aurochs (Evans 1975) and pig, the latter attracted by the newly created woodland edge habitats, providing the mixed vegetation it is believed to prefer (Simmons 1975b, 1979).

The diversity of vegetation created by fire increases the diversity of wild life present in the area, as well as the density of game animals. Fur-bearing animals would have been an equally valuable resource. Bears are attracted by the abundance of berry-producing shrubs, such as Prunus, Rubus, Vaccinium, Ribes and others, while beavers are attracted by the stands of willow, birch and aspen which are characteristic of post-fire shrub regeneration in damper, streamside locations, particularly in Flandrian I (Rowe and Scotter 1973). The important role of Salix in this context is reflected in its high frequencies upon pollen diagrams from the North York Moors. Other, non-human predators, such as wolves, would presumably find post-burn ungulate concentrations conducive to successful hunting. High populations of lesser animals are also to be found exploiting the regeneration complex feeding grounds, including a variety of small mammals and game birds attracted to the nuts, berries and young shoots (Heinselman 1973, Bendell 1974).

For hunter-gatherer communities the advantages of fire clearance of woodland are therefore obvious. During regeneration the productivity and range of vegetable food resources increase dramatically. This in itself is vital for an economy to which collection of vegetable foods may have been central (Clarke 1976). An abundance of berries, nuts, seeds, tubers and rhizomes would have been available in season, with a probable increase in edible fungi also (Ahlgren and Ahlgren 1960). The post-fire herb and fern community contains several which are proven food plants, including Pteridium, Rumex, Galium, Polygonum, Urtica, Chenopodium and Taraxacum (Dimbleby 1978), and are familiar from the pollen record. Hazelnuts would, however, have been by far the most important plant food resource for Mesolithic man in season, made available and abundant by the impact of fire. In addition to food, the post-fire vegetation offers other material benefits, such as fibre plants Polytrichum and Urtica for the manufacture of rope, bags and netting (Dimbleby 1978) and hazel coppice stems for spear or bow shafts.

The concentration of economic resources which results from the controlled use of fire in woodland would have been of fundamental importance to Mesolithic hunting strategies. The ability to localise the distribution of game stocks, as well as increasing their quantity and quality, would have been to dramatically increase the efficiency of Mesolithic hunting. Not only would the probability of encountering suitable game animals upon burnt over areas be much greater than within undisturbed, dense forest, but hunting would be easier due to better visibility in more open vegetation and reduced cover for the animals. As Mellars (1976c) has pointed out, the removal of the element of uncertainty from the game quest may have allowed a degree of selectivity over which individual animals were killed, whether on age, sex or species. The culling of suitable individuals, probably with the avoidance of juveniles and females, may be the end product of such a system, perhaps resulting in the kind of imbalance in faunal assemblages as noted at Star Carr (Clark 1972, Jacobi 1978a).

In summary therefore, if the Mesolithic economy were based, at least seasonally, upon the exploitation of larger ungulate populations, supplemented by smaller animals and vegetable foods, improvement of food stocks and increased ease of procurement would follow forest burning. It has been pointed out that the grazing and browsing of woodland is much increased, both in quality and quantity, after fire and that ungulate populations tend to increase and to become concentrated in the cleared area. Deer are attracted to the freshly burned ground by the lush grass and herb complex which develops and also to the ash which the fire created, an important source of salt (Evans 1975). The birds and small mammals which would also be attracted to the area (Ahlgren 1966) would form an additional food supply for humans, while the fur-bearing animals which favour such areas, such as bear and beaver, would also be of value for their pelts. Increased sprouting of shrubs would be sure to occur, and of particular relevance here is hazel, which is tolerant of all but the highest intensity fires. Increased access of light to the cleared area would stimulate flowering of Corylus and therefore nut production, and as the shrub may be expected to sprout from its base following fire (Rawitscher 1945), the development of hazel scrub may well ensue. Other fruit and berry producing shrubs would be encouraged also. This induced succession on cleared areas, probably culminating in hazel scrub with heavy nut production, would provide a considerable reservoir of plant food resources, leading to a commensurate multiplication of game animal resources for Mesolithic man. If forest burning were as regular an occurrence as our current evidence appears to show, the oak-hazel woodland which the pollen diagrams suggest characterised Flandrian II on the Moors may well be at least partially a man-produced or cultural vegetation.

7.7. The Role of Environmental Alteration in Mesolithic Land-use Patterns

From the discussion in the preceding sections of this chapter, it would appear that the land-use patterns of the Mesolithic in the North York Moors involved the exploitation of zones of high resource potential, primarily the ecotone situations described in Chapter 7.3., and that man was capable of increasing this potential through fire clearance of the vegetation, with its attendant economic benefits. The major and minor ecotones shown upon fig.58 would have formed zones of transition between separate ecological communities, and within which the variety and density of food resources would have been especially high (Odum 1971). It seems very likely that Mesolithic people would have been familiar with this fact and located their campsites to exploit it to their best advantage. It has already been pointed out that in the study area Mesolithic flint sites are almost invariably located adjacent to such zones. The provision of fresh water at spring, stream or lake ecotone would of course be a major attractio to settlement, especially if good local visibility were also available. It seems likely therefore that Mesolithic man chose the optimal situations for his hunting camps and then attracted game to him by fire clearance of woodland at the ecotone margin, expanding its area and increasing its productivity. While clearance activity took place in varying locations throughout the region, all cases were probably comparable in having immediate access to water, whether from stream or lake, which is a natural focus for both human and animal activity.

Hypothetical models of settlement patterns for the Mesolithic of the North York Moors have been constructed by a number of authors, founded primarily upon the assumed exploitation of resources which may be expected to have been variable in location and abundance on a seasonal basis (Clark 1972, Jacobi 1978a, Simmons 1975a, b, 1979). The information presented and collated in this thesis regarding environmental alteration during the Mesolithic does not call into question the overall validity of these models, and so their reinterpretation or restatement is not required at this point. The recognition that manipulation of the environment by fire was a technique habitually employed by Mesolithic man does, however, invite discussion of the importance of this process within these models of Mesolithic economic strategy.

The Mesolithic economy may well have depended upon the advantages which ecotone areas would have held in terms of food resources over surrounding areas of homogenous vegetation. These areas of high productivity, however, while vital to human economic success would have formed a relatively small percentage of the total area of the North York Moors region. The implications of this fact are that a large proportion of the study area remained unexploited and unoccupied, if perhaps not entirely unvisited, during the Mesolithic. The energies of hunting groups would have been much more efficiently expended if concentrated within zones of greatest economic reward. The concept of random hunting through the woodland is untenable and the obvious clustering of microlithic flint sites into quite restricted groups within the ecotone zones confirms that hunting activity was concentrated upon small, favoured, preselected areas. It was within these areas that fire ecology could be most efficiently applied, both in increasing their total resource productivity and in augmenting them spatially. The selective, controlled use of fire would have ensured that, not only did game stocks increase, but that their concentration would be predictable, and it is the spatial predictability of high food resources that was the key to the success of the Mesolithic economy. A more widespread use of fire might improve the food supply throughout the forest generally, but would not achieve the predictable concentration of resources which was necessary. It may also have been simply beyond the human resources available if high intensity fire-setting and controlling were the difficult task it would have been in Flandrian II. The examples of fire clearance cited in chapter 7.4. thus almost certainly reflect the conscious selection of those types of area by man.

Mesolithic extractive systems, however, had to be essentially mobile, as the relative availability of the wide range of foods utilised would have changed with the seasons. The most simple seasonal pattern envisaged for the Moors by the authors quoted above presumes a reliance upon large ungulates, mainly red deer, in their dispersed upland ranges in summer and in their sheltered lowland aggregation areas in winter. A range of coastal resources (fish, shellfish, seals) would help to supplement the winter diet, for the coastline was not far to the east of its present position at this latitude (Jelgersma 1979), while plant foods would be most important in the warmer months of the year. Bulbs, roots and seeds would be available in the spring/summer, and berries and nuts (especially hazel) in the summer/autumn. A seasonal migration of people would be necessary to accommodate this shift in resources, and presumably this would follow the river systems as the only real routeways through the area, and these would provide freshwater fish, fowl and plant resources during the seasons of transition between the lowland winter and upland summer occupations. Such a seasonal organisation of settlement patterns implies a basically transhumant economy rather than a nomadic one. This seasonal pattern of activity is reflected in the differences in size and assemblage character between the flint sites within each seasonal exploitation zone, with larger scale winter aggregation camps in the lowland (Star Carr), sites of intermediate size occupied during seasons of transition at the upland edge (Upleatham) and small summer hunting camps (Glaisdale Moor, White Gill) in the upland. Thus while the mechanics of fire clearance would be fundamentally the same in whichever environmental zone it were practiced, its rewards would be enjoyed at different locations in different stages of the economic sycle, and perhaps be manifest in rather different ways.

In the above context perhaps the most rewarding zone for such manipulation, especially during Flandrian II, might have been the upper edge of the forest, wherever animals might naturally congregate for water supply, a description which fits all of the high altitude sites show on fig. 59. Sites of southerly aspect may have been preferred for their extra warmth, and this factor may have played a major part in determining the frequency of burning at individual sites, with south-facing slopes burned much more often (Rowe and Scotter 1973, Zackrisson 1977). The major ecotone would have been exploited during summer, red deer being the major food resource most increased in abundance in this zone, with perhaps pig also important, as these animals show a preference for forest fringes. As these upland sandy soils would naturally carry more Corylus than other parts of the region, improvements to the hazelnut crop would be greatest within this zone also. Clearance sites such as North Gill, Bonfield Gill Head and White Gill would thus probably be the foci of human activity during summer and autumn when the above three resources were the main fruits of environmental alteration in this zone. The lower altitude forest clearances appear to have been concentrated adjacent to marshland or large bodies of water, such as at Seamer Carrs, Star Carr, Ewe Crag Slack or Fen Bogs. Exploitation of these sites would presumably have been a spring or winter activity, although probably not exclusively, for reedswamp and marshland vegetation would have formed highly nutritious winter pasture for ungulates. The reedswamp stage of hydroseral succession is apparently one of high productivity (Welinder 1978), which is further increased following fire, with rapidly regenerating dense, lush vegetation. All ungulates would have been attracted to this zone, but it may well have had a special importance for the hunting of elk and aurochs, as well as red deer. Elk in particular shows a decided preference for shallow lake edges, feeding on aquatic vegetation (Bendell 1974, Bay-Petersen 1978) while lacustrine swampland grazing would be most attractive to aurochs (Evans 1975, Grigson 1978). The occasional remains of Bos and Alces in early Flandrian lake deposits of the region may reflect the exploitation of this habitat, both by the animals and their hunters (Blackburn 1952, Jones 1976a). All such lowland wetland habitats, coastal and estuarine sites as well as lake and riverside in zones B and C, would be improved by the use of fire to stimulate reed, sedge and marshland vegetation.

The most efficient exploitation of the hunting territory during the Mesolithic would require a controlled programme of burning within the zones selected for such treatment. A certain percentage of the favoured area would have to be burned each year, so that the full range of successional stages and community types would be in existence simultaneously. Such a strategy of regular burning, as discussed by Jacobi et al. (1976) and Simmons et al. (1981) would cause the creation of a 'slowly changing mosaic of communities' (Heinselman 1973), with areas at different stages of the fire cycle. Thus while one site was being cleared of vegetation by fire (North Gill ?), a second would be at early regeneration-complex productivity and undergoing exploitation (Bonfield Gill Head ?) while a third may have been almost recolonised by woodland and abandoned by man (Bluewath Beck Head ?). In this way fire clearance would have formed the mechanism by which Mesolithic man could achieve a control over the location and density of his plant and animal food resources amounting to long-term management of the environment.

The spatial dimensions of a Mesolithic clearance event are difficult to deduce. The detailed plotting of the extent of the charcoal layer at North Gill, however, and the possible three dimensional interpretation of the pollen data from that site, allow some speculations to be made, at least regarding clearance in the uplands. If firing of the vegetation had an economic motive, it is clear that there would have been an optimum intensity of burn and time of execution to produce the maximum benefit in increased vegetable and deer yields. Mellars (1976c) has considered this question and quotes a number of authors who state that maximum deer populations are to be found in a relatively small cleared area. Diversity of habitat is the objective here, for forest-edge vegetation is as important as the cleared area itself. A particular value of this edge vegetation would have been in the provision of a range of fruit-bearing shrubs which characterise the forest fringes (Groenman-van Waateringe 1978). The provision of cover (both for deer and hunter) is also a vital constituent of the area in question, for deer will not readily occupy too large an area of bare ground. Too small a clearing is equally unsatisfactory, but a combination of bare ground, cover and regenerating browse supply is ideal. The concensus of opinion (Mellars 1976c, p 28) seems to be that the optimum diameter for the clearing may be rather less than 400 metres. If this is so, it corresponds very neatly with the evidence from North Gill where the charcoal layers extend along the stream edge for a little more than 375 metres. The pollen evidence from North Gill is also consistent with a clearing of this scale, and pollen referable to bare ground, forest edge and woodland communities may be recognised in the pollen spectra, conforming to the idealised pattern outlined above. Before final conclusions may be made, however, we require rather more evidence regarding the character and distribution of Mesolithic clearance over the Moors as a whole.

7.8. The Consequences of Environmental Alteration for Landscape Evolution

Environmental alteration during the Mesolithic period of the kind described in this thesis has been referred to as temporary in nature, implying that its ecological consequences were both limited in scale and transitory. It remains to consider, therefore, what lasting changes, if any, Mesolithic man may have wrought upon the landscape through his periodic clearance of the vegetation during Flandrian I and II. The changes in forest composition and density brought about by fire clearance have been stressed in the previous sections, and the instabilities thus caused by Mesolithic man in the woodlands of Flandrian I and II may have rendered them more susceptible to deterioration in later periods of prehistory, particularly in relation to soil quality. In addition to affecting forest composition, however, a long-term retraction of the extent of forest cover also seems a possibility, for pollen analysis suggests that the upland plateaux of the Moors did not carry high forest during Flandrian II, but may have supported at best scrub or open communities only. There is no reason why this should naturally have been the case, for in other upland regions of the country proven tree lines were altitudinally far in excess of the highest parts of the Moors. It seems likely that repeated firing of the woodland at higher altitude, allied to the consequent heavy browsing pressure (both very destructive and prohibitive of tree regeneration) could have led to removal of woodland entirely. Man-induced pressure on the forest margin may even have gradually moved the tree line downhill as the cleared areas failed to regenerate. Certainly the woodland was kept more open than would have been the case had human controls not been operative. If human pressure were continuous from early Flandrian I times, woodland may even have been prevented from forming at these highest areas at all. The early Flandrian III Betula and Quercus treestumps at Bonfield Gill Head, and similar wood remains from Glaisdale Moor, suggest that the tree line was indeed kept at an artificially low altitude during the Mesolithic period. Nor should the possibility of permanently open areas at lower altitude be neglected, for we do have records of clearance at these levels. Until further evidence is forthcoming, however, it is perhaps prudent to assume successful regeneration at lower altitudes due to better soils and denser woodland.

The most serious effects of Mesolithic activity may have been in relation to soils. Developed on nutrient-poor rock, and exposed to heavy rainfall pressure during Flandrian II, the mature upland soils of the North York Moors may have already been under some stress, and may even be characterised as marginal. Heavy leaching would make them prone to acidification, and clearance of woodland would have accelerated this trend towards acidity in a number of ways. Much of the nutrient store of the ecosystem would be lost, as vegetation combusted and ash and charcoal were transported away. Increased rainfall effectiveness would promote leaching, further depleting the soil. A rise in soil acidity is represented at both North Gill and Bonfield Gill head by the rise of Betula and Calluna and the decline of Alnus following later Flandrian II clearance phases. There is evidence of Flandrian II soil degeneration upon the Moors (Dimbleby 1962) which is comparable with evidence from other regions (e.g. Crampton and Webley 1966) which often occurs in association with a Mesolithic presence, as at Oakhanger (Rankine et al. 1960) or Iping Common (Keef et al. 1965). In addition, increased temperature and dryness of soil after fire increases soil friability, encouraging soil erosion, especially under conditions of greatly increased run-off from cleared slopes. There is physical evidence of such erosion, both at altitude (North Gill, Bluewath Beck Head) and from lower down (Tranmire Slack, Ewe Crag Slack, Moss Swang) in the form of mineral inwash stripes at Mesolithic clearance horizons. A number of these have been considered by Simmons et al.(1975), but several examples from other regions may be quoted, e.g. Bodmin Moor (Connolly et al. 1950), the Pennines (Phillips 1969), and the Cumberland Lowlands (Walker 1966). If the above mechanism of highly increased run-off after clearance operated on any scale in the North York Moors we should also expect the silt-load and water volume entering the region's watercourses to be much greater than would naturally have been the case, perhaps leading to flooding and silt deposition in their lower courses of a transitory, but perhaps recurrent and intense nature. Any such change in the regime of the region's streams may well have had repercussions upon fish and aquatic plant resources, and may also have led to increases in the rate and extent of bog growth.

It has been noted (Siren 1955) that repeated firing of woodland may eventually lead to a degenerative phase, and the examples of acidification of the ecosystem and soil deterioration described above may represent the consequences of the long-term application of fire ecology during the Mesolithic. The environmental stress caused by clearance may have become more acute in later Flandrian II, at a time when long-term management and localisation of food resources may have led to a seasonally more sedentary way of life and to a rise in the Mesolithic population. Both Newell (1973) and Meiklejohn (1978) have considered population rise in the later Mesolithic to be probable, and its consequence may have been to increase the number of social units, whether extended family group or clan, comprising the regional population. Since ownership of territory, and thus of food resources, appears to be a feature of hunter-gatherer organisation (Campbell 1968, Jochim 1976), an increase in social group numbers would cause a reduction in the size of the territory available to each for exploitation. Such a process may have been coincident with an overall reduction of the area's resource capacity caused by continued and exhaustive exploitation of its productive areas by Mesolithic man. The evidence presented in this thesis for the rotational burning of individual favoured sites, primarily in the uplands, suggests that forest clearance, although temporarily rejuvenating the vegetation communities, had a cumulative and damaging effect upon the ecosystem as a whole. These factors in combination may have led to an intensification of land-use towards the end of Flandrian II, with a shorter interval between burns at individual sites. Such an increase in fire frequency would have reduced the time available for site recovery, and accelerated the processes of deterioration inherent in the ecosystem. Failure to regenerate woodland upon the cleared area may well have resulted from this ecosystem deterioration, so that in areas of poor soils at least, Mesolithic activity may have been instrumental in causing a transition from woodland to heathland environments (Dimbleby 1962, 1976). The Betula-Calluna-Pteridium association recorded after later Flandrian II clearances in the uplands of the Moors may have been a stage in this transition, with the establishment of final Calluna dominance under conditions of extreme acidity following the senescence of birch stands (Kinnaird 1974). Examples of this conversion of woodland to heathland under Mesolithic clearance pressure, often via hazel scrub, may be cited from several regions of Britain. As well as the sites of Iping Common and Oakhanger, similar evidence has been recorded in Southern England at Wareham (Seagrief 1959), Cranes Moor (Seagrief 1960) and High Rocks E (Money 1960). The absence of such ecological change from the Mesolithic site of Addington (Dimbleby 1963) suggests that individual site conditions will have been crucial in determining the effects of Mesolithic occupation. That a similar process of degeneration occurred in the uplands is shown by the sites of Cooks Study (Hallam 1960, Dimbleby 1969), Broomhead Moor V and Dunford Bridge (Radley et al. 1974), Clay Works and Black Ridge I (Staines 1972) and several sites in Upper Teesdale (Squires 1970), all with clearance associations.

It would appear that the long-term effects of repeated burning were much more serious in areas of poor quality, sandy soils, such as the North York Moors upland, where the effects of fires would have accelerated the tendencies towards soil degeneration inherent in the ecosystem. A crucial factor in determining whether forest regeneration would be successfully accomplished or not may bave been the rate of vegetation succession after clearance. Vegetation succession is known naturally to proceed more slowly on less fertile soils and recovery of the vegetation from the effects of fire would have taken longer than upon nutrient-rich lowland soils. If regeneration proceeded too slowly, a sufficinetly high proportion of the nutrient resources may have been removed from the ecosystem and the land may have become incapable of supporting woodland again. Of relevance in this respect may be that among the post-fire herb community found in Mesolithic clearance phases are several capable of inhibiting seed germination and growth of tree taxa by the exudation of toxic substances. Pteridium has already been mentioned in this respect (v.s. page 146), but other toxically effective taxa include Artemisia, Rumex, Galium, Chenopodiaceae, Plantago lanceolata, Ranunculaceae and Calluna (Funke 1943, Muller 1969, Rice 1974, Newman and Rovira 1975). The main effect of the allelopathic properties of these early stage colonisers is to retard plant succession, to postpone regeneration of higher stage communities and maintain for a longer period a primary community of lower nutrient requirement, especially if, like Pteridium, they are capable of achieving local dominance in the vegetation patterns. In marginal, unstable ecosystems where the forest's own inertia may may have been its main sustaining factor, any delay in tree regeneration caused by allelopathy may have helped to render reforestation less likely and assisted in the transition to heathland.

The possibility that Mesolithic man may have initiated the inception of peat growth on the Moors has already been touched on. Evidence of clearance is often found at the base of the blanket peat in the form of ruderal pollen or charcoal, as though the creation of open ground was the stimulus for its growth (Moore 1975). Clearance of deciduous forest would have released great quantities of water into the ecosystem which would previously have been bound up in the vegetation. Excess water would no longer have been removed through the tree canopy by transpiration and, in a time of high rainfall and humidity such as Flandrian II (Thom and Oliver 1977) waterlogging of the soil may well have occurred, particularly if compaction of the soil surface had followed trampling of the site by the concentrations of animals that the clearance was designed to attract. The germination of seeds of Plantago lanceolata has been found to be stimulated by the trampling of animal hooves (Harper et al. 1965) and its presence in the herb community may be evidence for such local concentration of animal populations. Acidification of soils and impedence of drainage under high rainfall are conditions suitable for peat formation. The areas of bog interspersed in the woodland milieu which have been postulated for Flandrian II may well have been created by the woodland clearance discussed in this thesis and will have served as the initial nuclei of blanket mire formation. Thus the activities of Mesolithic man may have formed the first stage in the process of deforestation of the uplands and the establishment of heather clad blanket bog which dominates the modern landscape of the North York Moors.

7.9. Conclusion and Proposals for Future Research

The evidence presented and discussed in this thesis suggests that the Mesolithic period in the North York Moors was characterised by a tendency towards ecological instability and biotic diversity which was stimulated by the activities of man. The landscape appears to have been a mosaic of open woodland and regenerating seral communities within which semi-permanent areas of open ground, bog and heathland existed. The techniques of environmental modification employed by man which maintained this diversity of landscape may also have led locally to ecological degeneration of a severe and permanent nature.

The presentation of palaeobotanical data undertaken in this thesis forms the basic stage in the study of Mesolithic man's role in initiating environmental change in the North York Moors. Consideration of this corpus of evidence allows the formulation of specific research objectives and the definition of problems requiring resolution by future study. A basic need is for the accumulation of much more detailed palaeobotanical data for, although a considerable amount of pollen work has been done in the area, very little has been designed expressly to elucidate Mesolithic ecology. As a result much of the evidence for environmental alteration in Flandrian I and II has been randomly gathered and lacks substantiation. This lack of detailed analysis of Mesolithic deposits, and the irregularity in its distribution, has meant that the conclusions reached in this thesis regarding the impact of Mesolithic man upon the landscape and Mesolithic land-use in general must be preliminary and speculative. If possible, deposits of Mesolithic age should be studied from each of the zones and ecotone types designated in chapter 7, from both Flandrian I and II, and as near as possible to Mesolithic flint sites. High resolution pollen analysis techniques such as absolute frequency, concentration and very fine sampling intervals need to be applied in these situations, supported by radiocarbon, chemical and stratigraphic analysis. Detailed comparison may then be made between the degree, character and effects of environmental alteration by Mesolithic communities in different parts of the region. Without a greater balance in both the quality and distribution of the evidence, secure conclusions cannot be drawn regarding possible regional variations in scale and emphasis of human activity. To this end, a major priority must be the detailed scrutiny of sites from the lower altitude zones of the Moors, for our present understanding of man's activities in these areas is poor. Until we can establish if fire ecology was applied around lowland lake or bog margins with the same vigour and regularity as it seems to have been in the uplands, the respective roles of these contrasting areas in the annual Mesolithic economic cycle will remain unclear.

Much work also remains to be done at high altitude sites. We need to know the 'return interval' of the fire cycle at upland sites where evidence for rotational burning exists. Many more such spring-head sites need to be studied by pollen analysis and radiocarbon dating, to determine whether the frequency of burning at individual sites increased or not as the period progressed and if all spring-head locations were subject to fire clearance in turn. It may thus be possible to assess in detail the character and duration of exploitation of the upland ranges of the Moors, and make inductions regarding the size, mobility and territorial distribution of Mesolithic populations in the region.

Finally, the conduct of further research will assist in resolving problems which have become apparent from the data collated in this thesis. The Late Mesolithic-Neolithic transition is one such area of uncertainty, and work must be directed to elucidating any changes in economic patterns which took place towards the end of Flandrian II. It remains to be seen whether the transhumant Mesolithic economic system broke down when the lowland areas were lost to agricultural immigrants, or whether that system was in any case under stress due to deterioration of the ecosystem typified by the advance of bog and heathland in the uplands. It seems possible that the techniques of environmental alteration which contributed to the success of the Mesolithic economic strategy may have been partly responsible for its eventual failure, making necessary the transitions in economy and technology which mark the end of the Mesolithic.

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APPENDIX I

Radiocarbon Dates

Dating was carried out at the Chenistry Department, University of Glasgow, by Dr. M.S. Baxter and Dr. M.J. Stenhouse, and yielded the following results, after determination of ^{13}C value my mass spectrometer, and correction for isotope fractionation.

Code No.	Sample	Age (years bp.)
GU-1071	North Gill II 28 - 33 cms.	5210 ± 75
GU-1072	North Gill II 63 - 65 cms.	5945 ± 90
GU-1073	North Gill II 40 - 44 cms.	5220 ± 75

The above dates are conventional ages and should be multiplied by 1.029 to yield dates calculated using the value of 5730 ± 30 years for the half-life of carbon 14 (Stuiver and Suess 1966).

APPENDIX II

List of taxa included within the various ecological groupings used upon the pollen diagrams.

Computer Diagrams - types a and b.

Quercetum mixtum - *Quercus*, *Ulmus*, *Tilia*.

Other Shrubs - *Salix*, *Prunus*, *Sorbus*, *Ilex*, *Hedera*, *Lonicera*, *Frangula*.

Ruderals - Chenopodiaceae, Caryophyllaceae, Cruciferae, Compositae Liguliflorae (*Taraxacum* type), Compositae Tubuliflorae, *Artemisia*, *Cirsium*, Centaurea, Umbelliferae, Rubiaceae (*Galium* type), *Melampyrum*, *Plantago lanceolata*, *Plantago major*.

Other Herbs - *Ranunculus*, *Caltha*, *Filipendula*, *Potentilla*, *Sanguisorba*, Labiatae, Papilionaceae, *Mercurialis*.

Computer Diagrams - type c, and Pollen Concentration (Clearance Taxa).

Quercetum mixtum - as above.

Heliophyte Shrubs - *Salix*, *Fraxinus*, *Prunus*, *Sorbus*.

Ruderals - as above.

Total Tree Pollen - *Betula*, *Pinus*, *Ulmus*, *Quercus*, *Tilia*, *Alnus*, *Fraxinus*, *Fagus*.

APPENDIX III

List of Nomenclature Abbreviations used on Pollen Diagrams.

Compositae Lig.	-	Compositae Liguliflorae.
Compositae Tub.	-	Compositae Tubuliflorae.
P. lanceolata	-	*Plantago lanceolata*.
P. major	-	*Plantago major*.
Typha ang.	-	*Typha angustifolia*.

APPENDIX IV

Pollen Counts.

NORTH GILL 1 POLLEN COUNTS

DEPTH	-32	-35	-37	-40	-42	-45	-47	-50	-52	-55	-58	-60	-62	-64	-66	-68	-70
PINUS	15	8	11	5	9	4	7	4	4	4	7	5	5	8	7	3	9
BETULA	90	93	96	61	44	69	59	78	73	73	79	83	80	89	80	66	70
QUERCUS	36	43	32	57	73	58	68	52	60	45	51	48	49	40	41	42	37
ULMUS	4	3	1	17	15	14	12	9	9	11	3	4	7	7	5	29	18
TILIA	0	0	0	0	1	1	1	2	3	2	4	3	0	1	12	9	9
FAGUS	0	1	1	1	0	0	0	2	0	2	0	0	0	0	0	0	0
FRAXINUS	5	2	9	9	9	4	3	3	1	13	6	6	9	5	4	2	7
ALNUS	75	52	74	69	107	77	91	91	97	80	74	110	107	108	92	44	87
CORYLUS	129	83	94	132	184	147	182	274	199	169	130	159	125	127	133	51	103
SALIX	2	1	0	3	0	6	1	3	1	7	2	1	0	2	6	4	2
PRUNUS-SORBUS	0	0	0	1	0	0	0	0	0	2	0	3	1	0	0	1	0
ILEX	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
HEDERA	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
LONICERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CALLUNA	934	260	439	73	79	112	103	151	65	52	110	130	81	103	106	10	8
ROSACEAE	0	7	9	3	1	4	1	4	1	5	2	1	11	7	6	3	2
GRAMINEAE	135	110	131	22	31	20	40	28	22	34	40	28	16	29	82	90	160
CYPERACEAE	142	193	61	57	32	29	21	38	43	29	12	19	26	41	46	19	32
RANUNCULUS	5	2	1	1	0	0	1	1	0	1	3	3	2	1	0	10	0
FILIPENDULA	2	0	0	1	0	0	0	1	0	0	10	30	10	30	40	10	30
POTENTILLA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
SANGUISORBA	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUCCISA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUMEX	2	2	5	0	0	4	0	3	0	4	1	1	2	1	4	2	2
URTICA	0	1	0	5	0	0	0	1	0	0	0	0	2	0	0	1	0
POLYGONUM	0	2	0	1	0	0	0	3	0	0	0	0	2	1	0	1	1
CHENOPODIACEAE	3	1	3	0	0	0	0	2	0	3	0	2	1	1	0	0	5
CARYOPHYLLACEAE	0	4	4	1	0	0	0	1	0	1	0	1	1	1	2	1	0
COMPOSITAE	1	3	1	0	0	0	0	9	0	1	0	2	1	5	0	0	1
TARAXACUM	5	1	1	0	0	0	0	0	0	0	0	1	1	3	0	0	0
ARTEMISIA	0	0	1	1	0	0	0	2	0	0	2	6	1	1	0	0	1
CIRSIUM	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUBIACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LABIATAE	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
PAPILIONACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MELAMPYRUM	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
PLANTAGO LANC	30	8	14	6	1	1	3	4	1	3	4	10	1	2	1	3	0
PLANTAGO MAJOR	5	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MERCURIALIS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NUPHAR	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POTAMOGETON	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1
TYPHA ANG	0	1	0	6	0	0	0	2	0	0	0	0	1	1	0	1	0
FILICALES	0	9	3	18	6	5	9	12	8	5	6	9	5	8	4	11	22
POLYPODIUM	0	4	1	5	5	5	8	9	8	1	2	2	0	1	1	5	4
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PTERIDIUM	94	67	53	8	7	7	11	21	7	14	18	25	20	18	16	4	6
SPHAGNUM	552	14	8	3	9	12	22	62	26	23	19	33	7	82	60	315	41
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NORTH GILL 1 POLLEN COUNTS-CONTINUED

DEPTH	-72	-73	-74	-75	-76	-77	-79	-81	-83	-85	-87	-89	-90	-91	-92	-94	-96	-98
PINUS	6	18	26	27	8	9	5	9	5	8	7	10	10	11	19	19	16	23
BETULA	64	52	44	42	31	43	31	39	33	26	28	40	40	35	24	24	25	37
QUERCUS	54	43	62	54	79	71	83	67	79	75	76	70	57	68	62	59	64	58
ULMUS	15	17	15	22	25	19	23	33	28	33	27	20	36	29	34	32	35	29
TILIA	10	8	3	4	7	3	7	3	5	8	12	9	7	7	11	14	9	3
FAGUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FRAXINUS	1	7	0	1	0	1	1	0	0	0	0	1	0	0	0	3	1	0
ALNUS	98	60	108	89	112	84	146	169	142	169	223	90	104	199	180	166	185	217
CORYLUS	139	251	262	296	92	104	179	130	110	154	334	68	160	302	360	480	437	312
SALIX	1	4	9	12	4	14	30	15	12	7	41	16	25	27	7	4	6	3
PRUNUS-SORBUS	0	0	10	10	0	1	1	2	0	0	2	0	0	2	0	1	0	0
ILEX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HEDERA	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0
LONICERA	0	0	0	0	0	1	0	0	0	0	2	1	0	1	2	1	0	1
CALLUNA	8	38	21	19	12	20	21	18	19	25	42	17	16	40	29	32	29	40
ROSACEAE	1	7	6	5	2	3	3	7	2	5	8	1	4	4	6	2	6	3
GRAMINEAE	64	70	84	65	47	88	141	121	80	67	128	87	152	152	133	166	234	140
CYPERACEAE	20	32	44	34	29	45	29	26	30	16	43	13	53	62	38	40	64	42
RANUNCULUS	5	0	0	0	0	0	2	0	2	0	1	0	0	0	0	3	0	2
FILIPENDULA	0	1	5	1	1	1	2	4	1	0	4	2	2	4	5	1	2	3
POTENTILLA	0	0	1	1	0	3	0	1	0	0	0	0	1	0	1	0	1	0
SANGUISORBA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
SUCCISA	0	1	0	3	1	2	3	0	0	0	4	4	4	5	5	6	8	5
RUMEX	0	2	1	1	0	2	1	0	1	1	0	2	0	1	0	0	0	0
URTICA	0	0	0	1	0	2	1	1	0	0	0	0	0	1	0	0	0	1
POLYGONUM	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
CHENOPODIACEAE	3	0	0	2	0	0	1	1	0	0	2	1	1	3	2	0	1	2
CARYOPHYLLACEAE	0	1	0	0	0	0	0	0	0	0	1	1	1	3	3	0	2	0
COMPOSITAE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
TARAXACUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0
CIRSIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0
RUBIACEAE	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
LABIATAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PAPILIONACEAE	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
MELAMPYRUM	0	1	4	1	0	1	0	0	0	0	1	0	0	0	0	3	3	0
PLANTAGO LANC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLANTAGO MAJOR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MERCURIALIS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
NUPHAR	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
POTAMOGETON	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
TYPHA ANG	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0
FILICALES	15	20	22	22	10	12	18	6	4	11	45	14	25	60	82	112	144	125
POLYPODIUM	4	4	3	6	10	5	8	6	4	3	14	9	4	15	19	27	34	18
LYCOPODIUM	0	0	3	1	0	0	0	0	0	0	1	0	0	1	0	0	1	1
PTERIDIUM	19	27	24	29	6	12	27	14	4	6	27	14	10	9	38	26	15	7
SPHAGNUM	190	43	54	61	72	62	4	7	12	7	4	4	8	9	3	6	0	4
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NORTH GILL 2 POLLEN COUNTS

DEPTH	-5	-8	-10	-12	-15	-18	-20	-23	-25	-28	-29	-30	-31	-32	-33	-34	-36
PINUS	6	2	16	4	9	3	7	6	12	11	20	12	13	15	14	12	11
BETULA	23	30	34	21	27	18	29	21	23	27	33	21	23	33	34	42	25
QUERCUS	78	82	68	87	75	79	69	69	70	78	45	73	84	50	53	55	65
ULMUS	28	19	20	28	27	38	38	39	34	25	39	40	23	34	37	30	38
TILIA	6	13	6	5	9	8	7	9	10	7	10	3	3	9	7	4	10
FRAXINUS	9	4	6	5	3	4	0	6	1	2	3	1	4	9	5	7	1
ALNUS	127	92	115	103	114	138	68	82	81	82	99	69	109	90	80	85	76
CORYLUS	119	122	132	147	218	228	186	178	135	317	351	206	196	271	277	138	83
SALIX	12	3	6	2	0	3	1	1	3	2	2	1	2	5	3	5	0
PRUNUS-SORBUS	1	0	2	0	1	0	0	0	0	0	0	1	0	1	2	1	1
HEDERA	1	1	0	0	0	0	1	0	0	2	0	1	0	1	0	1	1
LONICERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CALLUNA	6	8	12	15	14	18	2	9	19	19	32	16	29	19	30	24	8
ROSACEAE	2	1	8	4	3	1	4	2	2	2	3	5	5	12	8	4	3
GRAMINEAE	119	176	152	219	317	412	90	194	93	180	195	210	201	178	162	147	111
CYPERACEAE	42	28	58	55	50	27	14	25	21	29	38	43	41	22	36	16	42
RANUNCULUS	3	0	6	5	5	2	3	2	4	1	0	1	3	8	4	0	2
CALTHA	1	0	0	0	2	0	2	0	3	0	0	0	0	2	3	0	0
FILIPENDULA	1	5	0	4	1	1	2	6	2	3	2	3	2	5	3	1	0
POTENTILLA	1	0	0	0	2	0	0	1	0	0	1	1	0	1	2	0	0
SUCCISA	0	0	0	0	1	0	1	0	0	0	2	0	0	0	0	3	0
RUMEX	5	1	0	0	0	1	1	1	0	3	0	1	0	0	0	1	2
URTICA	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1
POLYGONUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
CHENOPODIACEAE	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1
CARYOPHYLLACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRUCIFERAE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CIRSIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CENTAUREA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUBIACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
MELAMPYRUM	1	0	0	0	0	0	0	0	0	2	0	0	1	2	0	0	0
PLANTAGO LANC	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
POTAMOGETON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPHA ANG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILICALES	9	3	4	9	3	8	6	18	9	16	21	5	10	14	28	4	3
POLYPODIUM	1	1	0	1	3	3	3	1	4	7	7	3	1	0	5	1	1
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PTERIDIUM	13	0	22	6	9	9	8	5	7	6	9	22	8	16	40	6	15
SPHAGNUM	258	162	170	62	60	137	1309	38	900	189	731	1891	86	52	127	128	358
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NORTH GILL 2 POLLEN COUNTS-CONTINUED

DEPTH	-38	-40	-41	-42	-43	-44	-45	-47	-50	-53	-55	-57	-59	-64	-66	-68	-70	-72	-74	-77
PINUS	1	3	25	25	21	14	9	13	11	10	8	12	16	19	32	26	41	30	44	44
BETULA	22	30	59	57	50	34	37	27	39	34	44	42	43	78	48	72	50	76	71	74
QUERCUS	83	74	29	35	37	55	69	65	64	67	58	58	59	32	47	31	39	21	17	14
ULMUS	30	32	28	30	37	31	28	35	29	32	35	32	30	18	21	18	19	21	17	16
TILIA	10	9	6	3	2	9	4	6	7	6	4	4	2	3	2	1	1	1	1	2
FRAXINUS	4	2	2	0	3	7	3	4	0	1	1	0	0	0	0	1	0	1	0	0
ALNUS	232	182	117	49	50	108	257	404	351	393	195	230	267	119	45	46	40	19	6	4
CORYLUS	162	100	427	354	329	232	151	149	113	162	149	177	210	74	264	144	242	202	311	256
SALIX	0	1	8	17	24	20	4	8	8	9	8	12	19	12	14	10	12	29	33	76
PRUNUS-SORBUS	2	0	2	1	3	1	0	0	1	1	0	0	0	0	2	0	1	0	0	0
HEDERA	2	0	1	2	1	0	0	0	0	3	2	2	4	4	3	0	4	0	0	1
LONICERA	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	1	1	1	1
CALLUNA	19	8	36	23	20	10	10	12	2	13	12	10	9	20	3	14	9	22	6	6
ROSACEAE	1	2	14	3	17	16	1	3	1	0	3	4	5	4	4	5	8	1	2	10
GRAMINEAE	130	60	62	63	107	129	25	44	22	52	44	37	30	20	49	18	31	29	19	42
CYPERACEAE	14	19	16	42	36	46	30	40	49	35	34	42	64	360	13	22	19	46	48	54
RANUNCULUS	3	2	4	2	1	3	0	1	0	1	1	1	0	50	1	1	1	2	2	1
CALTHA	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILIPENDULA	6	5	2	4	5	6	0	4	1	0	5	4	5	60	4	1	2	2	1	3
POTENTILLA	1	1	1	3	1	0	0	0	0	0	0	0	1	10	1	1	1	0	0	0
SUCCISA	0	0	0	1	0	0	0	0	0	0	0	1	1	0	1	3	1	2	0	0
RUMEX	0	0	2	0	3	0	0	0	0	1	0	1	0	0	0	0	2	0	0	1
URTICA	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
POLYGONUM	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
CHENOPODIACEAE	0	1	2	1	0	0	3	3	3	1	0	0	1	0	0	2	0	1	0	1
CARYOPHYLLACEAE	0	0	0	1	0	0	0	0	0	1	0	1	3	0	0	0	1	0	1	0
CRUCIFERAE	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
CIRSIUM	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0
CENTAUREA	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUBIACEAE	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
MELAMPYRUM	0	0	2	1	3	4	0	0	0	0	1	0	1	0	1	0	0	1	3	4
PLANTAGO LANC	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
POTAMOGETON	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0
TYPHA ANG	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILICALES	3	7	29	41	24	17	5	25	8	18	5	16	18	44	51	69	62	95	154	232
POLYPODIUM	5	1	3	1	0	0	2	0	1	1	2	6	2	4	1	6	8	5	4	8
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
PTERIDIUM	6	8	34	14	30	14	12	11	12	15	15	22	16	24	14	12	19	16	26	22
SPHAGNUM	97	40	56	59	43	67	3	6	2	2	12	15	14	4	4	2	9	2	9	2
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NORTH GILL 3 POLLEN COUNTS

DEPTH	-2	-5	-8	-10	-12	-14	-16	-19	-20	-22	-23	-25	-27	-29	-30	-31	-32
PINUS	1	5	8	1	0	2	0	6	3	6	10	6	3	4	9	25	20
BETULA	19	45	60	14	12	10	8	22	19	22	22	14	10	20	25	51	38
QUERCUS	34	131	96	23	8	29	26	90	89	90	31	65	53	73	72	109	62
ULMUS	4	8	1	0	0	4	3	31	39	34	33	22	21	33	38	84	64
TILIA	1	1	5	0	1	0	0	6	10	10	10	5	3	12	9	14	17
FRAXINUS	2	11	10	3	1	9	8	6	7	1	1	3	1	2	6	8	12
ALNUS	64	200	212	37	32	57	95	112	93	121	156	83	138	358	397	627	725
CORYLUS	81	273	301	75	57	186	167	217	170	187	196	177	156	267	244	689	882
SALIX	1	9	12	1	0	3	3	1	2	5	9	2	7	21	37	70	156
PRUNUS-SORBUS	0	0	0	1	0	3	0	0	0	2	0	0	0	0	1	3	4
HEDERA	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
LONICERA	0	0	0	0	0	0	0	0	0	1	0	1	2	1	1	1	1
CALLUNA	66	207	120	28	32	81	58	42	24	28	21	17	17	41	28	35	44
ERICACEAE	0	0	0	0	2	3	3	1	2	0	0	1	0	0	0	0	0
ROSACEAE	3	11	3	1	3	1	1	1	3	4	1	2	1	1	6	4	15
GRAMINEAE	21	81	91	17	10	18	24	56	62	120	139	83	140	63	95	177	181
CYPERACEAE	14	58	42	8	6	11	13	24	11	21	30	17	10	32	31	42	52
RANUNCULUS	1	3	1	0	1	3	0	1	1	1	1	4	0	1	5	1	9
CALTHA	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
FILIPENDULA	1	1	1	1	1	0	0	0	0	1	1	1	2	2	1	3	7
POTENTILLA	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1
SANGUISORBA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUCCISA	0	1	0	1	0	0	0	1	5	6	1	0	0	0	1	2	0
SCABIOSA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUMEX	1	6	1	0	2	1	1	0	0	1	0	0	1	2	2	5	3
UPTICA	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	2
POLYGONUM	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHENOPODIACEAE	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0
CARYOPHYLLACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRUCIFERAE	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
COMPOSITAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
TARAXACUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
CIRSIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUBIACEAE	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	4
LABIATAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PAPILIONACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MELAMPYRUM	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	5	11
PLANTAGO LANC.	9	12	6	1	0	2	1	0	0	0	0	0	0	0	0	1	0
TYPHA ANG.	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
FILICALES	1	15	22	1	3	3	9	14	5	16	21	6	11	41	28	24	49
POLYPODIUM	1	3	6	1	1	2	2	4	3	4	6	6	8	50	8	16	8
PTERIDIUM	9	26	22	7	1	6	3	1	0	1	1	0	2	4	4	11	20
SPHAGNUM	12	72	90	27	43	32	149	456	780	412	301	148	3	10	4	16	15
LYCOPODIUM	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200

NORTH GILL 3 POLLEN COUNTS-CONTINUED

DEPTH	-33	-34	-35	-36	-37	-38	-40	-42	-43	-44	-45	-46	-47	-48	-49	-50	-51	-52	-53	-54
PINUS	14	16	17	14	11	9	9	14	18	15	5	11	2	2	58	52	31	32	29	30
BETULA	42	42	34	29	34	17	21	15	7	29	13	28	5	6	9	21	20	24	11	52
QUERCUS	91	122	102	57	60	78	84	61	68	114	46	56	19	20	24	31	23	36	19	57
ULMUS	48	65	51	34	46	36	36	24	30	41	15	23	12	16	16	28	21	32	12	25
TILIA	11	16	8	1	6	7	10	5	2	7	6	6	3	1	1	6	5	10	3	10
FRAXINUS	3	2	1	3	7	0	0	2	0	2	2	4	3	2	1	4	4	4	3	2
ALNUS	610	693	602	258	205	445	412	300	290	504	223	282	114	91	20	118	70	201	114	235
CORYLUS	302	394	302	453	537	256	212	147	195	295	186	198	80	93	232	528	327	401	274	279
SALIX	53	61	39	43	68	55	31	24	33	80	31	55	16	23	11	16	31	58	60	46
PRUNUS-SORBUS	3	0	0	1	1	0	0	0	1	0	0	0	0	1	4	1	1	1	4	4
HEDERA	1	3	1	0	1	3	0	0	0	0	1	1	0	1	0	1	1	1	0	1
LONICERA	1	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
CALLUNA	29	55	44	22	20	25	14	13	14	26	21	19	10	5	2	5	11	7	4	33
ERICACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROSACEAE	9	9	1	2	4	6	1	6	5	9	5	5	2	3	9	2	5	4	14	7
GRAMINEAE	141	134	99	72	111	140	102	102	94	179	70	77	44	18	64	80	37	92	91	80
CYPERACEAE	23	17	39	34	47	21	40	18	27	30	12	10	10	6	40	42	17	36	19	44
RANUNCULUS	1	4	5	6	5	6	3	2	2	1	4	1	2	1	2	1	3	4	6	2
CALTHA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILIPENDULA	3	6	4	1	1	4	1	3	3	9	0	2	0	1	9	1	1	1	12	5
POTENTILLA	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0
SANGUISORBA	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
SUCCISA	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	4	1	4	1	1
SCABIOSA	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
RUMEX	0	2	0	1	1	1	0	1	0	1	0	5	0	1	0	1	1	1	3	1
URTICA	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	1	1
POLYGONUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
CHENOPODIACEAE	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
CARYOPHYLLACEAE	1	0	0	1	0	0	0	0	1	0	0	0	1	0	1	1	1	1	2	1
CRUCIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0
COMPOSITAE	0	1	0	0	1	0	0	0	1	0	0	0	0	0	2	1	1	0	1	0
TARAXACUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
ARTEMISIA	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	0	1	0	1	0
CIRSIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0
UMBELLIFERAE	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
RUBIACEAE	0	0	0	1	0	3	0	0	3	3	0	0	0	0	0	0	1	1	5	0
LABIATAE	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
PAPILIONACEAE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MELAMPYRUM	0	0	0	1	5	0	0	0	1	1	0	4	0	0	5	3	5	1	2	1
PLANTAGO LANC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
TYPHA ANG.	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0
FILICALES	49	46	29	19	22	32	42	41	71	66	11	12	12	12	285	281	138	176	204	78
POLYPODIUM	8	8	6	5	14	10	8	6	5	12	0	6	2	1	30	15	7	18	9	5
PTERIDIUM	5	6	1	7	19	0	1	9	4	2	2	3	4	6	27	26	21	25	11	7
SPHAGNUM	7	15	17	3	8	4	6	3	2	5	1	10	4	4	7	4	3	10	2	33
LYCOPODIUM	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200

NORTH GILL HEAD POLLEN COUNTS

DEPTH	-122	-125	-128	-132	-136	-139	-142	-145	-148	-150	-152	-154	-156	-157	-158	-159	-160
PINUS	5	11	6	14	15	9	4	4	1	6	7	14	8	6	10	6	13
BETULA	22	44	48	56	26	51	43	45	33	47	47	47	30	31	45	50	18
QUERCUS	79	67	71	56	63	58	69	57	98	73	64	76	66	51	40	44	55
ULMUS	25	8	12	14	36	18	22	23	9	11	9	2	28	44	34	36	46
TILIA	11	11	8	3	5	6	6	5	2	2	17	6	18	18	19	14	18
FRAXINUS	50	9	5	7	5	9	7	16	7	11	6	5	0	0	2	0	0
ALNUS	87	87	84	89	105	75	66	82	112	102	171	142	112	121	108	138	146
CORYLUS	161	172	179	215	190	184	164	184	178	259	289	286	178	192	283	349	240
SALIX	3	1	0	9	1	0	4	4	1	0	10	6	5	0	0	0	3
PRUNUS-SORBUS	0	1	1	2	0	1	0	2	1	1	0	1	1	0	3	1	0
ILEX	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0
HEDERA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
LONICERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
CALLUNA	44	106	121	132	87	96	103	137	136	159	210	196	94	197	234	321	169
ROSACEAE	5	9	3	5	2	6	6	4	2	9	10	2	15	6	17	4	5
GRAMINEAE	47	24	14	19	20	27	10	32	19	11	145	134	61	45	129	165	116
CYPERACEAE	55	15	22	16	24	27	25	18	50	23	111	29	18	13	21	7	18
RANUNCULUS	0	2	8	2	1	1	3	4	1	9	5	2	2	0	4	2	1
CALTHA	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0
FILIPENDULA	0	1	0	1	1	1	0	1	0	1	2	2	1	1	1	1	1
POTENTILLA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUCCISA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUMEX	0	1	0	0	0	1	0	0	0	3	0	0	0	0	0	3	0
URTICA	0	0	0	1	1	0	0	1	0	1	0	0	0	0	0	1	0
CHENOPODIACEAE	0	0	0	0	0	0	0	0	1	0	5	0	0	1	1	0	0
CARYOPHYLLACEAE	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
MELAMPYRUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
PLANTAGO LANC	0	0	0	1	0	0	0	1	0	0	1	2	0	0	3	1	0
FILICALES	14	1	1	7	3	6	1	0	1	2	1	2	3	1	4	4	14
POLYPODIUM	0	1	1	1	0	7	5	1	0	5	0	0	0	5	1	3	0
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PTERIDIUM	10	9	9	7	14	9	13	9	40	7	12	35	8	12	31	31	11
SPHAGNUM	16	191	14	61	19	142	253	16	17	33	11	10	69	46	31	21	6
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NORTH GILL HEAD POLLEN COUNTS-CONTINUED

DEPTH	-161	-162	-163	-164	-165	-166	-167	-168	-169	-170	-172	-174	-176
PINUS	22	18	12	19	19	23	26	39	22	31	56	59	53
BETULA	20	22	34	23	26	32	45	50	56	40	46	36	32
QUERCUS	52	51	53	58	55	53	49	35	39	29	19	16	24
ULMUS	39	44	46	45	49	39	29	23	31	47	30	39	39
TILIA	15	11	5	5	3	3	2	4	2	3	0	0	2
FRAXINUS	2	4	0	0	0	0	0	0	0	0	0	0	0
ALNUS	127	124	132	131	154	146	68	71	87	52	33	46	43
CORYLUS	346	397	317	388	393	359	364	426	440	500	473	536	528
SALIX	0	0	0	5	0	6	7	9	9	16	12	14	10
PRUNUS-SORBUS	1	1	1	0	0	1	0	1	1	0	0	0	0
ILEX	0	0	0	0	0	0	0	0	0	0	0	0	0
HEDERA	0	0	0	0	0	0	0	0	0	0	0	0	0
LONICERA	1	0	0	0	0	0	0	7	0	0	0	0	0
CALLUNA	300	291	126	322	77	63	24	74	77	91	103	126	149
ROSACEAE	9	9	10	12	10	6	9	5	6	11	7	4	10
GRAMINEAE	74	97	69	36	69	49	52	49	74	92	76	58	88
CYPERACEAE	17	20	12	13	12	24	11	6	14	12	15	29	13
RANUNCULUS	1	0	0	0	1	2	0	0	1	2	2	4	2
CALTHA	0	0	0	0	0	0	0	0	0	0	0	0	0
FILIPENDULA	2	5	7	2	2	1	6	5	8	2	2	2	4
POTENTILLA	1	0	0	0	0	0	0	0	0	1	0	0	0
SUCCISA	2	3	1	0	0	3	0	2	2	0	2	4	0
RUMEX	0	0	1	0	0	2	0	0	0	0	0	0	0
URTICA	1	2	0	1	0	0	0	0	0	0	1	1	1
CHENOPODIACEAE	0	0	0	0	0	0	0	0	0	0	0	1	0
CARYOPHYLLACEAE	1	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	0	0	0	0	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0
MELAMPYRUM	0	0	0	0	0	0	0	0	0	0	1	5	1
PLANTAGO LANC	2	0	0	1	0	0	0	0	0	0	0	0	0
FILICALES	17	0	1	12	12	17	38	47	12	32	24	18	28
POLYPODIUM	1	90	1	7	8	6	2	7	0	0	4	2	1
LYCOPODIUM	0	20	0	0	0	0	0	0	0	0	0	1	1
PTERIDIUM	13	0	13	12	9	16	20	10	11	38	27	31	23
SPHAGNUM	24	330	11	7	8	30	33	47	30	43	32	28	15
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0

BLUEWATH BECK HEAD POLLEN COUNTS

DEPTH	-83	-90	-92	-94	-96	-98	-100	-102	-104	-106	-108	-110	-112	-114	-116	-118	-120
PINUS	8	3	5	7	7	6	3	7	3	3	11	9	4	4	6	5	10
BETULA	26	38	22	27	16	18	21	16	12	17	14	24	23	19	22	20	26
QUERCUS	96	84	92	76	84	77	71	69	87	34	78	77	77	85	86	88	73
ULMUS	6	9	17	23	36	34	38	42	38	40	31	29	36	33	29	25	31
TILIA	6	11	10	14	6	12	14	13	5	4	14	11	7	8	5	9	7
FRAXINUS	3	5	4	3	1	3	3	3	5	2	2	0	3	1	2	3	3
ALNUS	181	209	158	106	139	93	139	123	82	114	111	84	108	101	95	117	70
CORYLUS	533	465	361	301	277	252	264	173	135	255	268	200	216	238	141	219	127
SALIX	6	5	4	4	4	0	1	3	1	2	2	1	2	2	1	1	1
PRUNUS-SORBUS	1	4	2	1	3	0	1	3	1	0	3	6	1	2	0	1	0
HEDERA	0	0	1	1	3	2	3	1	2	0	1	1	2	1	0	1	1
LONICERA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CALLUNA	139	65	210	44	58	27	18	18	9	27	19	18	22	12	14	13	15
ERICACEAE	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROSACEAE	2	4	9	3	2	3	3	5	2	0	6	6	7	1	5	2	4
GRAMINEAE	222	216	165	145	145	202	217	108	100	190	267	122	192	122	74	105	141
CYPERACEAE	55	41	99	55	35	42	72	34	14	89	25	46	22	100	47	42	36
RANUNCULUS	3	2	6	7	0	0	0	0	1	7	2	3	2	0	1	4	0
CALTHA	0	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0
FILIPENDULA	11	18	16	16	11	2	4	6	10	5	5	22	7	5	7	8	14
POTENTILLA	1	2	4	0	3	0	1	0	0	0	0	3	0	1	0	0	0
SUCCISA	0	2	1	2	3	1	1	1	3	2	2	1	3	3	1	1	5
RUMEX	7	4	1	1	2	0	0	1	1	6	0	1	2	3	1	2	1
URTICA	0	1	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0
CHENOPODIACEAE	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0
CARYOPHYLLACEAE	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
CRUCIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COMPOSITAE	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
ARTEMISIA	0	1	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0
MELAMPYRUM	0	0	1	1	0	0	0	0	0	0	0	1	5	0	0	0	0
PLANTAGO LANC	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NUPHAR	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
FILICALES	14	9	20	10	11	7	9	8	6	3	5	6	11	7	6	12	10
POLYPODIUM	4	5	1	2	4	1	2	5	3	2	5	3	1	1	4	4	3
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PTERIDIUM	11	6	12	11	2	4	6	2	3	5	10	11	2	5	3	0	4
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

BLUEWATH BECK HEAD POLLEN COUNTS-CONTINUED

DEPTH	-122	-124	-126	-128	-130	-132	-134	-136	-137	-139	-140	-141	-142	-143	-144	-145	-146
PINUS	8	11	9	9	5	9	3	6	10	8	9	9	9	9	12	13	12
BETULA	21	18	27	22	17	24	45	34	20	29	25	29	28	40	28	43	48
QUERCUS	75	70	72	74	80	84	69	79	70	73	70	59	67	64	80	61	59
ULMUS	35	44	31	35	41	28	30	30	42	31	40	51	42	33	25	29	29
TILIA	7	5	8	8	6	4	3	1	6	7	6	2	3	2	4	3	3
FRAXINUS	4	2	3	2	1	1	0	0	2	2	0	0	1	2	1	1	0
ALNUS	103	115	93	106	83	73	89	94	173	91	121	112	125	85	105	57	59
CORYLUS	147	136	127	138	149	171	152	214	254	290	433	495	422	454	266	220	219
SALIX	1	1	1	2	3	4	4	1	2	3	0	3	6	12	2	2	1
PRUNUS-SORBUS	1	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	1
HEDERA	0	0	1	0	2	0	0	1	0	1	0	3	0	1	3	3	0
LONICERA	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	3	1
CALLUNA	9	7	10	20	14	7	6	10	16	20	15	14	22	24	18	13	11
ERICACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
ROSACEAE	4	2	1	0	0	1	4	4	1	4	1	2	2	6	1	3	1
GRAMINEAE	79	94	63	180	253	135	89	134	113	67	57	47	55	54	40	57	30
CYPERACEAE	39	101	12	41	37	43	35	49	68	18	37	22	9	19	25	30	29
RANUNCULUS	2	0	0	0	0	0	0	0	2	1	2	0	0	0	0	0	2
CALTHA	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
FILIPENDULA	1	2	1	2	7	5	6	4	7	1	3	3	2	4	6	2	5
POTENTILLA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
SUCCISA	1	0	4	2	6	0	0	0	0	0	0	2	4	2	3	7	8
RUMEX	1	1	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0
URTICA	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0
CHENOPODIACEAE	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
CARYOPHYLLACEAE	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRUCIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
COMPOSITAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MELAMPYRUM	0	0	0	0	0	0	0	0	1	2	1	0	0	2	0	0	0
PLANTAGO LANC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NUPHAR	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILICALES	2	5	4	7	3	9	2	2	6	4	6	8	6	6	2	4	3
POLYPODIUM	4	1	3	4	0	2	0	1	5	3	6	6	0	1	3	1	6
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PTERIDIUM	3	1	1	1	2	2	3	3	5	9	16	21	10	15	3	3	4
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

BLUEWATH BECK HEAD POLLEN COUNTS-CONTINUED

DEPTH	-147	-148	-149	-150	-151	-152	-153	-154	-155	-156	-157	-159	-161	-163	-165	-167
PINUS	14	21	17	15	15	25	21	18	16	19	47	33	54	59	57	40
BETULA	54	46	51	68	62	58	62	54	41	46	44	49	51	34	45	74
QUERCUS	52	56	51	45	51	39	43	52	69	57	36	44	27	35	25	21
ULMUS	28	27	23	19	21	17	23	23	23	27	22	24	18	21	21	15
TILIA	2	0	1	2	1	1	0	1	1	0	1	0	0	1	2	0
FRAXINUS	0	0	0	1	0	0	1	2	0	1	0	0	0	0	0	0
ALNUS	59	66	60	59	55	69	50	78	74	52	65	67	66	34	29	17
CORYLUS	210	189	157	183	162	164	262	235	210	254	273	180	205	161	197	129
SALIX	2	3	2	6	3	5	2	2	7	2	0	0	2	1	8	3
PRUNUS-SORBUS	0	0	0	5	0	1	0	2	1	6	0	0	0	0	1	0
HEDERA	1	0	0	4	0	1	2	0	1	1	0	0	1	0	2	0
LONICERA	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
CALLUNA	10	8	9	7	7	4	5	6	2	8	5	6	9	6	6	11
ERICACEAE	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0
ROSACEAE	7	2	1	6	0	3	1	3	2	11	1	2	1	2	6	3
GRAMINEAE	24	25	39	32	36	27	20	55	61	51	41	25	22	30	41	33
CYPERACEAE	27	10	12	21	17	15	22	15	33	15	48	63	56	12	59	19
RANUNCULUS	0	1	0	3	0	2	0	2	0	1	1	0	0	0	0	0
CALTHA	1	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
FILIPENDULA	8	4	3	10	3	3	6	6	10	6	5	4	14	7	13	5
POTENTILLA	0	0	0	0	0	0	0	0	1	4	0	0	3	0	0	1
SUCCISA	6	9	5	6	10	7	6	21	8	7	12	0	0	3	8	2
RUMEX	0	2	0	1	0	0	0	2	0	0	0	0	0	0	2	0
URTICA	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0
CHENOPODIACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
CARYOPHYLLACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CRUCIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
COMPOSITAE	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	1	0	1	2	0	0	0	1	0	1	0	0	0	0	0	0
MELAMPYRUM	0	1	0	1	0	0	0	1	0	0	0	1	1	0	0	0
PLANTAGO LANC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NUPHAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILICALES	2	3	5	3	8	4	4	2	2	3	0	2	3	0	2	12
POLYPODIUM	2	1	0	5	0	2	1	0	2	0	3	1	2	3	0	0
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
PTERIDIUM	0	2	1	24	4	7	2	3	3	7	2	3	1	0	5	0
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

BONFIELD GILL HEAD   POLLEN COUNTS

DEPTH	-6	-10	-15	-22	-26	-3	-33	-36	-39	-41	-43	-46	-48	-50	-52	-54	-56
PINUS	5	5	2	1	7	3	2	4	7	7	4	2	14	2	1	9	12
BETULA	78	137	135	203	182	266	150	134	585	209	176	217	225	181	204	241	200
QUERCUS	72	72	78	82	70	70	85	83	74	76	49	54	58	71	70	62	51
ULMUS	11	10	9	4	11	13	7	1	8	2	15	17	18	18	18	16	25
TILIA	9	4	6	7	10	8	2	11	10	15	31	22	8	7	11	11	8
FAGUS	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FRAXINUS	3	9	4	6	2	6	4	1	1	0	1	5	2	2	0	2	4
ALNUS	92	91	81	89	99	116	91	111	136	114	94	233	196	266	238	254	160
CORYLUS	319	128	125	230	193	262	225	184	135	136	51	103	100	77	84	157	271
SALIX	11	29	12	4	4	7	2	7	8	17	3	6	9	18	9	1	8
PRUNUS-SORBUS	1	1	0	2	0	3	3	1	1	0	0	1	0	2	1	2	3
HEDERA	0	1	0	1	1	2	0	0	1	0	0	1	0	1	1	1	2
LONICERA	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1
CALLUNA	75	11	19	6	15	10	23	19	18	26	129	142	23	14	8	13	5
ERICACEAE	0	1	1	0	1	1	0	0	2	4	16	21	0	0	0	0	1
ROSACEAE	10	9	0	6	5	9	9	1	5	2	1	3	6	6	1	5	4
GRAMINEAE	151	153	86	206	164	306	115	70	53	112	36	53	40	39	43	52	37
CYPERACEAE	38	47	27	86	43	63	68	168	31	34	15	23	34	15	30	33	15
RANUNCULUS	1	0	1	1	0	0	0	20	3	1	1	0	1	6	0	3	3
FILIPENDULA	9	12	7	7	4	12	14	4	3	2	1	3	5	3	7	7	5
POTENTILLA	0	0	1	1	1	1	2	0	0	0	0	0	1	0	0	0	0
SUCCISA	4	2	0	0	1	1	7	3	1	2	1	1	1	0	0	0	1
SCABIOSA	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
RUMEX	0	2	0	0	1	2	0	1	0	1	1	5	6	2	0	1	2
URTICA	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	1
POLYGONUM	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
CHENOPODIACEAE	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	2
CARYOPHYLLACEAE	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
CRUCIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
COMPOSITAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
ARTEMISIA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
CIRSIUM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0
CENTAUREA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
UMBELLIFERAE	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	1	0
RUBIACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PAPILIONACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MELAMPYRUM	2	17	23	6	4	4	1	28	14	6	6	14	19	15	7	3	10
PLANTAGO LANC	1	3	0	0	0	0	0	7	1	2	0	0	0	0	0	0	0
NUPHAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
POTAMOGETON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPHA ANG	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILICALES	4	8	15	38	17	81	6	54	27	64	20	58	36	16	39	56	52
POLYPODIUM	8	5	1	3	1	6	5	9	4	11	14	30	6	8	4	8	8
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
PTERIDIUM	2	3	3	5	6	7	2	18	51	80	9	15	22	75	11	8	20
SPHAGNUM	62	101	41	63	59	62	189	35	9	16	4	5	17	2	5	18	16
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

BONFIELD GILL HEAD POLLEN COUNTS-CONTINUED

DEPTH	-58	-60	-62	-65	-68	-72	-76	-78	-80	-82	-85	-88	-90	-92	-95	-97	-99
PINUS	6	12	4	5	4	7	16	33	30	45	33	42	46	36	37	53	41
BETULA	257	163	116	230	130	482	169	175	116	113	44	39	39	59	49	50	55
QUERCUS	59	64	71	63	65	72	61	42	53	44	46	45	39	48	39	34	47
ULMUS	22	20	19	24	27	20	20	21	16	8	18	13	13	16	21	12	12
TILIA	11	4	3	9	4	1	1	4	1	1	3	0	2	0	3	1	0
FAGUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FRAXINUS	2	0	3	0	0	0	1	0	1	2	0	0	0	0	0	0	0
ALNUS	213	152	138	159	186	154	145	106	117	68	100	45	55	53	52	47	74
CORYLUS	161	115	114	112	108	93	157	231	139	163	180	131	132	156	128	145	185
SALIX	4	5	2	5	2	0	3	10	5	4	4	2	1	7	3	7	13
PRUNUS-SORBUS	3	0	0	2	0	0	2	3	0	0	3	1	2	1	1	0	1
HEDERA	0	1	0	1	0	0	0	0	1	0	0	1	0	1	1	1	0
LONICERA	0	0	0	1	0	0	0	1	1	1	1	1	1	0	0	1	0
CALLUNA	9	2	16	13	6	3	7	10	3	4	5	7	4	7	2	7	4
ERICACEAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ROSACEAE	4	4	1	4	3	4	3	5	4	1	2	1	2	4	4	1	1
GRAMINEAE	76	50	24	31	54	9	35	30	31	20	12	23	25	55	23	43	38
CYPERACEAE	16	7	10	21	11	130	7	14	13	9	11	9	14	23	13	9	21
RANUNCULUS	4	2	1	4	0	0	0	1	1	0	1	2	0	9	3	0	0
FILIPENDULA	4	8	4	6	7	4	5	2	5	5	5	2	4	7	1	5	7
POTENTILLA	1	1	2	1	3	3	0	0	1	0	2	0	1	2	0	1	0
SUCCISA	2	0	0	2	1	1	1	1	0	1	2	1	2	1	1	1	0
SCABIOSA	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
RUMEX	2	4	0	3	3	3	4	1	0	1	0	2	1	0	3	0	2
URTICA	0	1	0	1	1	0	1	2	0	0	1	0	1	1	0	1	2
POLYGONUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CHENOPODIACEAE	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0
CARYOPHYLLACEAE	1	0	0	0	0	0	0	0	0	0	2	1	1	0	0	0	0
CRUCIFERAE	0	0	0	2	0	0	1	0	1	0	0	0	0	0	0	1	0
COMPOSITAE	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0
CIRSIUM	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0
CENTAUREA	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0	3	0	1	0	1	1	0	0	0	0	0	0
RUBIACEAE	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
PAPILIONACEAE	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
MELAMPYRUM	4	5	11	2	1	1	1	4	0	0	1	0	2	1	0	0	0
PLANTAGO LANC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NUPHAR	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
NYMPHAEA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
POTAMOGETON	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
TYPHA ANG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FILICALES	41	42	51	28	37	12	56	53	58	63	59	50	63	39	51	70	59
POLYPODIUM	11	2	5	4	2	0	4	8	5	1	1	1	1	2	0	2	2
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PTERIDIUM	12	8	7	25	4	1	4	14	5	7	6	9	4	9	6	12	1
SPHAGNUM	32	7	5	3	3	43	5	10	7	3	9	4	4	4	2	4	8
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SMALL HOWE POLLEN COUNTS

DEPTH	-6	-8	-10	-12	-15	-17	-20	-22	-25	-27	-30	-33	-35	-37	-38	-40	-42
PINUS	3	5	6	3	4	3	3	6	6	6	6	9	3	9	1	8	7
BETULA	84	84	83	73	38	40	42	45	39	41	40	20	36	61	84	26	19
QUERCUS	50	51	49	55	90	93	84	78	81	76	77	99	87	54	41	83	91
ULMUS	0	1	1	3	12	9	9	12	15	17	22	8	9	3	14	24	21
TILIA	1	3	1	6	0	2	6	6	6	6	4	11	14	17	7	5	8
FRAXINUS	12	5	8	9	6	3	6	3	3	4	1	3	1	6	3	4	4
ALNUS	51	79	90	99	148	156	133	135	126	130	141	62	89	94	55	90	106
FAGUS	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
CORYLUS	135	195	219	186	315	345	438	354	426	312	266	165	240	248	178	213	261
SALIX	8	6	1	3	10	3	9	12	6	4	3	6	3	1	0	3	7
HEDERA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
CALLUNA	461	588	363	582	186	168	272	285	358	226	191	220	354	322	323	251	276
ROSACEAE	1	1	5	3	1	1	3	6	1	3	2	3	0	1	1	2	0
GRAMINEAE	55	60	74	57	136	117	148	96	93	57	22	31	38	46	38	76	25
CYPERACEAE	91	138	114	147	55	77	72	78	70	66	70	65	50	34	46	78	29
RANUNCULUS	0	1	0	0	1	0	3	1	0	2	0	2	0	0	2	2	2
FILIPENDULA	0	3	1	2	0	0	1	1	1	0	0	0	0	0	0	2	0
POTENTILLA	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
SUCCISA	1	0	3	0	0	0	0	0	0	0	0	0	1	1	0	0	0
RUMEX	1	0	0	0	0	1	1	1	3	2	0	3	0	1	0	2	1
URTICA	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
CHENOPODIACEAE	1	0	0	2	0	0	1	0	7	0	0	0	1	0	0	1	0
CARYOPHYLLACEAE	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ARTEMISIA	6	6	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
CIRSIUM	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MELAMPYRUM	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
PLANTAGO LANC	11	9	7	9	5	5	7	3	1	0	0	0	0	1	1	0	0
NUPHAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TYPHA ANG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
FILICALES	8	5	5	3	2	9	6	7	7	6	5	6	4	9	2	5	3
POLYPODIUM	7	9	1	4	3	4	4	8	4	4	3	4	2	0	0	0	2
PTERIDIUM	23	12	12	9	9	6	18	12	26	7	1	1	1	1	1	3	2
SPHAGNUM	83	154	54	82	48	43	70	61	58	12	10	17	62	43	2	11	28
LYCOPODIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

SMALL HOWE   POLLEN COUNTS-CONTINUED

DEPTH	-44	-46	-48	-50	-52	-53	-55
PINUS	4	5	5	8	9	1	10
BETULA	35	27	37	40	31	27	49
QUERCUS	80	77	74	56	60	89	40
ULMUS	25	26	21	26	28	22	25
TILIA	3	14	8	12	13	9	26
FRAXINUS	3	1	5	8	9	2	1
ALNUS	105	101	92	97	107	122	228
FAGUS	0	0	0	0	0	0	0
CORYLUS	250	226	216	229	304	274	459
SALIX	4	5	5	3	1	4	5
HEDERA	0	0	0	0	0	0	0
CALLUNA	132	139	252	439	344	320	327
ROSACEAE	2	0	0	2	0	1	0
GRAMINEAE	44	52	96	69	92	133	51
CYPERACEAE	60	62	50	34	43	78	33
RANUNCULUS	2	0	5	1	1	0	1
FILIPENDULA	1	1	1	2	0	0	0
POTENTILLA	0	0	0	0	0	0	0
SUCCISA	0	0	0	0	0	0	0
RUMEX	2	2	0	2	1	2	2
URTICA	0	0	0	0	0	0	0
CHENOPODIACEAE	0	3	1	1	0	0	0
CARYOPHYLLACEAE	1	0	0	1	3	0	0
ARTEMISIA	0	1	1	1	0	0	0
CIRSIUM	0	0	0	0	0	0	0
UMBELLIFERAE	0	0	0	0	1	1	0
MELAMPYRUM	2	1	1	0	1	0	1
PLANTAGO LANC	1	2	2	0	0	0	0
NUPHAR	0	0	1	0	0	0	0
TYPHA ANG	0	0	0	0	0	0	0
FILICALES	7	5	8	7	1	3	12
POLYPODIUM	5	8	2	3	1	1	14
PTERIDIUM	2	4	2	6	11	5	15
SPHAGNUM	23	29	64	35	16	16	17
LYCOPODIUM	0	0	0	0	0	0	0

BOTANY BAY   POLLEN COUNTS

DEPTH	-1	-2	-3	-4	-5	-6	-7	-8
PINUS	11	11	5	7	16	4	8	5
BETULA	57	67	63	74	51	72	61	70
QUERCUS	53	41	53	46	40	45	53	49
ULMUS	17	19	16	16	24	17	21	19
TILIA	8	9	11	6	16	10	6	4
FRAXINUS	4	3	2	1	3	2	1	3
ALNUS	195	190	255	271	280	266	191	194
CORYLUS	186	126	107	122	202	110	103	102
SALIX	6	5	10	11	11	6	7	4
PRUNUS-SORBUS	1	2	1	1	2	0	0	0
HEDERA	0	1	1	0	1	1	0	0
CALLUNA	75	60	45	48	42	47	51	61
ROSACEAE	19	7	8	6	15	6	5	6
GRAMINEAE	122	54	63	82	75	67	56	55
CYPERACEAE	18	8	10	11	21	11	13	14
RANUNCULUS	4	0	3	2	5	4	1	0
FILIPENDULA	9	3	5	5	5	5	3	3
POTENTILLA	2	1	0	0	0	0	0	2
SUCCISA	0	0	0	0	2	0	0	0
CARYOPHYLLACEAE	0	0	0	0	3	1	0	0
CRUCIFERAE	0	0	0	0	1	0	0	0
ARTEMISIA	0	0	0	0	0	0	0	1
MELAMPYRUM	0	0	0	0	3	2	0	0
PLANTAGO LANC	1	0	0	0	0	1	0	0
FILICALES	16	15	21	32	44	20	17	22
POLYPODIUM	5	5	4	11	13	9	8	7
PTERIDIUM	5	9	8	11	29	9	12	7
SPHAGNUM	7	6	9	2	4	3	2	2
LYCOPODIUM	0	0	0	0	0	0	0	0