A PALYNOLOGICAL STUDY OF CHANGING WOODLAND LIMITS ON THE NIDDERDALE MOORS

A thesis presented for the Degree of

Doctor of Philosophy

by

Heather Mary Tinsley B.Sc.

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SUMMARY

Observations have been made on the stratigraphy of peat deposits at a number of sites varying in aspect and altitude on an area of upland moorland in the West Riding of Yorkshire. Pollen diagrams have been prepared from these sites and a sequence of local pollen zones established. These zones have been subdivided on the basis of changing frequencies in the pollen of species considered to be cultural indicators.

An absolute chronology has been established for the pollen diagrams from a series of eight radiocarbon dates. Attempts have been made to relate the sequence of subzones to established archaeological periods and, more recently, to documented historical events.

A survey of surface pollen samples was carried out from the moorland and from within the remaining woodland communities on its flanks. The results of this survey have been used in the ecological interpretation of the fossil pollen diagrams. The early forest history of the area and the gradual decline of trees since 2,000 B.C. has been traced. It has been shown that both soil deterioration and human factors have been significant in the reduction of woodland and the establishment of heath.

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TABLE OF CONTENTS

page

page

FIGURES IN TEXT

TABLES IN TEXT

SECTION I INTRODUCTION

I.i. Aims and Objectives

The uplands to the east of Nidderdale, in the West Riding of Yorkshire, are today valued as grouse moors; they are practically treeless, supporting heath vegetation with occasional patches of bog. In the thin peat which covers the moors tree stumps and buried timbers occur, evidence that in the past woodland was considerably more extensive. The aim of this study has been to establish the nature of this woodland and to investigate the fluctuations in its limits through time.

The method adopted has involved the examination of the pollen record at a number of sites, varying in aspect and altitude, within a limited area 6.5 kms square. A study of fluctuations in the woodland edge has necessitated detailed assessment of the ecological significance of the pollen records at each site. A study of the modern pollen rain has therefore been undertaken in an attempt to develop an objective approach to the interpretation of pollen percentages.

Earlier studies have established the course of vegetation history on the southern Pennines (Conway, 1947, 1949; Tallis, 1964; Hicks, 1971) and on the northern Pennines (Johnson and Dunham, 1963; Turner, 1970), but previous palynological studies in the Nidderdale area are lacking. It was hoped that the current work would provide information about the vegetation history of the gritstone of the central Pennines and, in addition, enable an assessment of the relative roles of human and environmental factors in the decline of woodland within the study area.

I.ii. The Physical Background

The moors to the east of Nidderdale form part of the margin of the central Pennines overlooking the Vale of York. This study has been carried out on the interfluve between the tributaries of the Rivers Nidd and Laver, in an area approximately 6.5 kms square (Figs. I.1, I.2). In this thesis the study area will be referred to as the Nidd-Laver interfluve.

I.ii.a. Topography

The Nidd-Laver interfluve is an upland plateau comprising Pateley Moor, Bishop's Moor, Dallow Moor and Fountains Earth. Above the moorland limit at about 290 metres the land rises gradually in a broad dome. Four isolated hills, High Ruckles, High Hill, Kettlestang Hill and Hambleton Hill project above the surrounding plateau surface to over 366 metres along the line of the watershed (Fig. I.2).

On the western and southern edge of the plateau there is an abrupt break of slope and a steep descent to the valley of the Nidd. In the east the land descends more gradually to the Vale of York, while to the north the plateau stretches on to join the area of highland which forms the watershed between the River Nidd and the River Ure. The plateau is dissected by a number of streams with deeply incised valleys. The principal drainage is to the south-east towards the Rivers Skell and Laver via Skell Gill and North Gill Beck. The valleys of both these streams are steep sided and craggy in their middle sections. On the west of the watershed three short streams flow into the Nidd.

FIG I.1 THE POSITION OF THE STUDY AREA

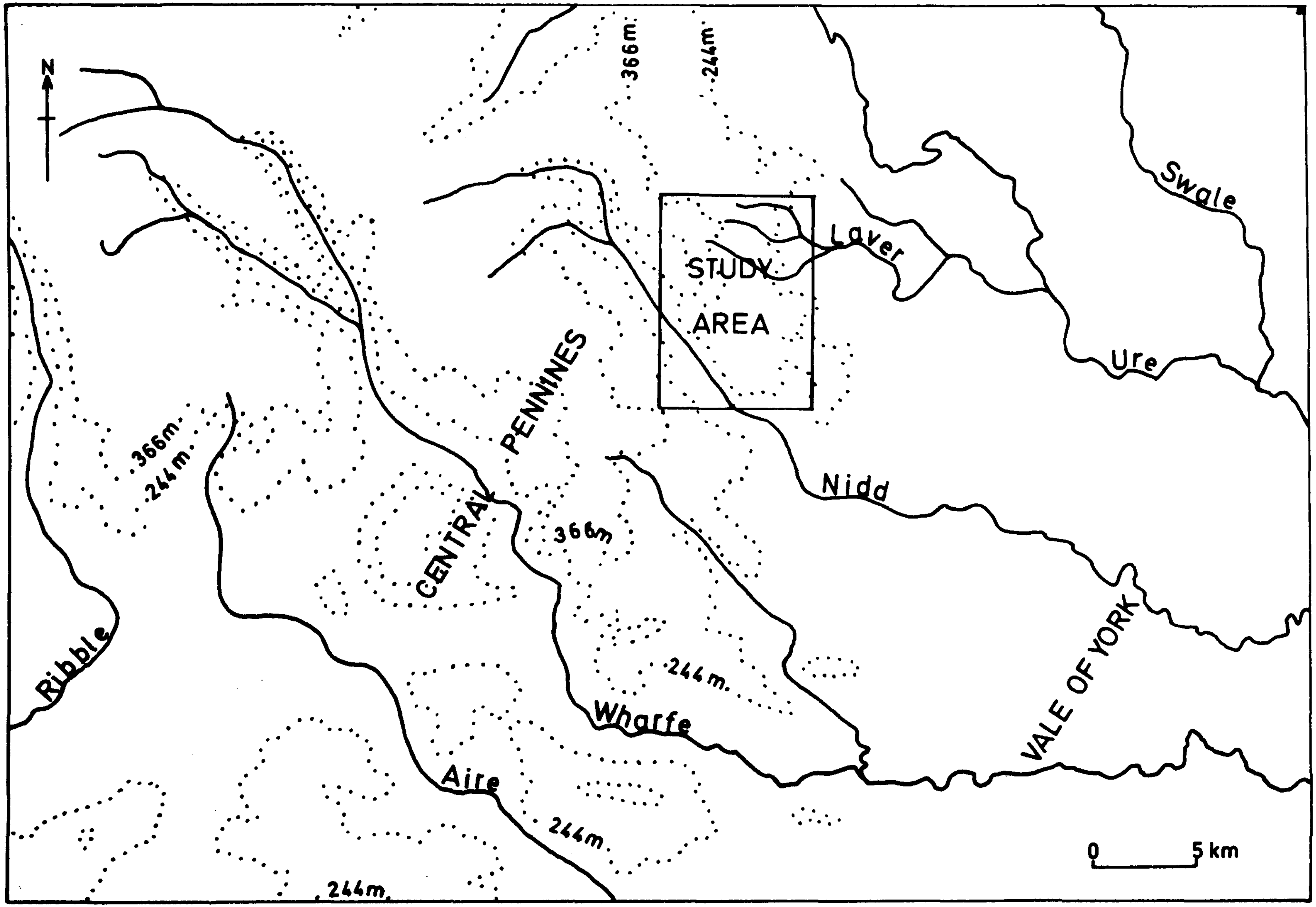


FIG I·2 THE STUDY AREA

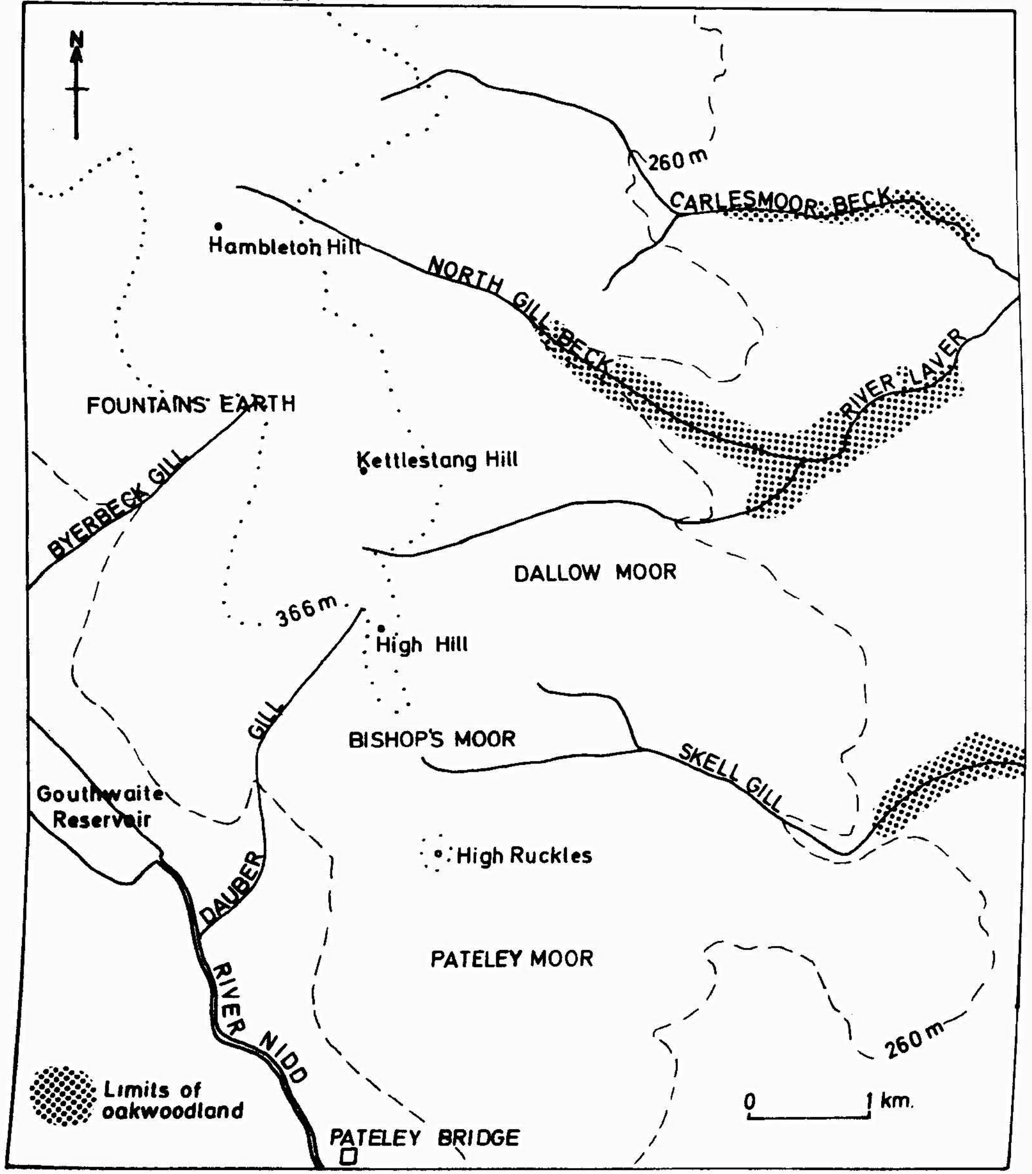
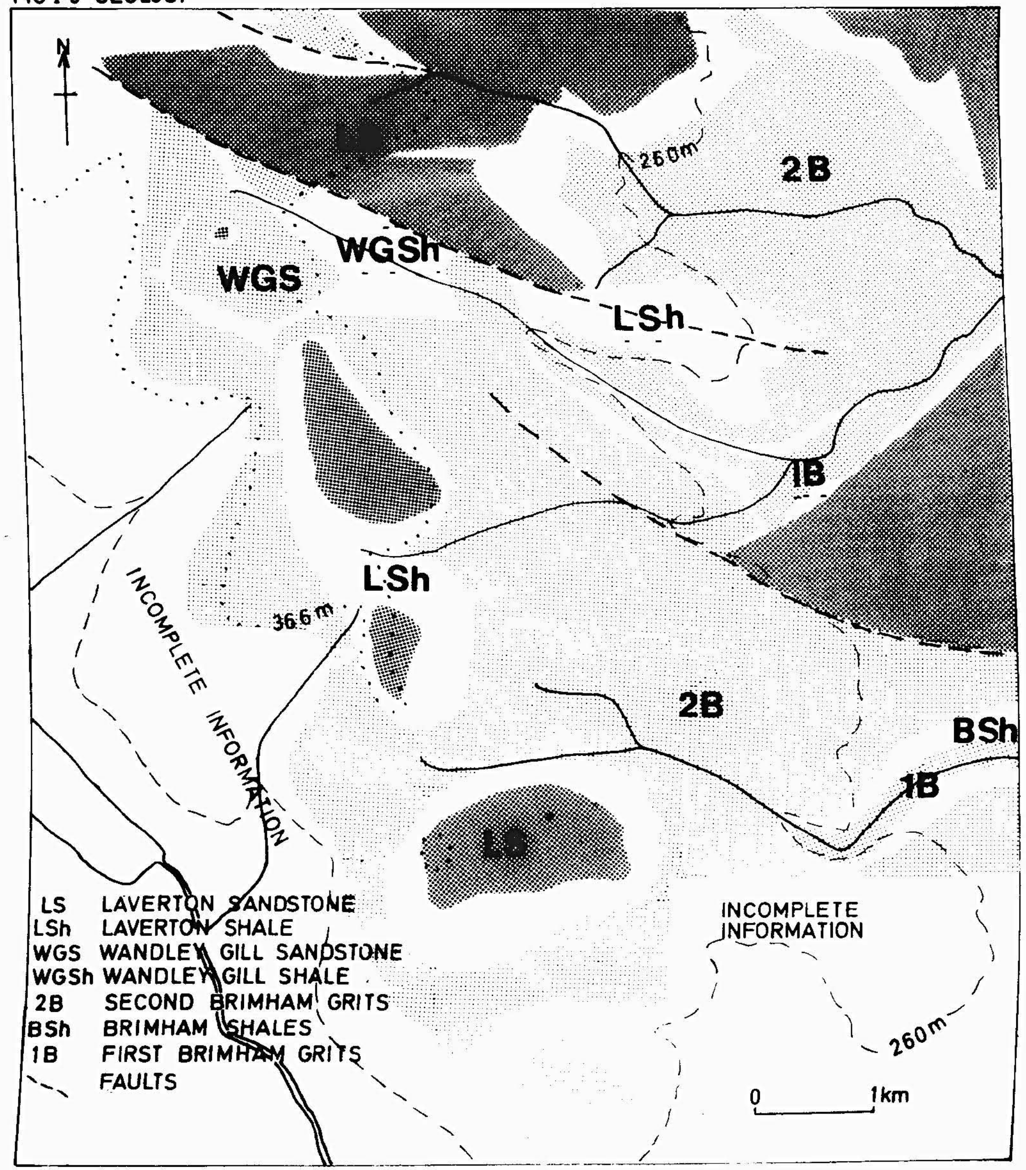


FIG I·3 GEOLOGY



I.ii.b. Geology

There is no current Geological Survey map for the Nidderdale area. The southern part of the Nidd-Laver interfluve was included in an area mapped by Thompson (1957) and the northern part was described in a survey by Wilson and Thompson (1965). Figure I.3 is therefore based on these two sources.

The interfluve is formed from rocks of Carboniferous age; the whole area lies within the main Millstone Grit outcrop of the Askrigg Block. The stratigraphic succession is simple; hard bands of gritstone alternate with softer shale beds and produce marked topographic features. These rocks were deposited in Namurian times, as part of a broad delta complex filling the synclinal depression of the Central Pennine Basin. The sequence of sandstone and shale bands represents part of a regular cycle of sedimentation during which sandstones, shales and marine bands were laid down. The stratigraphic sequence is shown in Table I.1.

The First Brimham Grit is a massive, coarse-grained, feldspathic sandstone; where it is exposed at the surface it forms crags which are particularly well developed in the valleys of the Skell and North Gill Beck. Stratigraphically, the Brimham Shale separates the First and Second Brimham Grits; exposures of these shales are limited, but sapping associated with them has resulted in the development of peaty flushes in many valleys. The Second Brimham Grit resembles the First, but forms a less marked topographic feature in this area; its outcrops form low sandstone ridges on the plateau surface. Wilson and Thompson (1965) first recognised the Wandley Gill Sandstone, which outcrops around

Table I.1

THE NIDD-LAVER INTERFLUVE: GEOLOGICAL SUCCESSION

		Thickness in metres
	Laverton Sandstone	25
	Laverton Shale	15 - 22
MILLSTONE	Wandley Gill Sandstone	5 - 12
GRIT	Wandley Gill Shale	3
SERIES	Second Brimham Grits	12
	Brimham Shales	9 - 28
	First Brimham Grits	11 - 31

(After Wilson and Thompson, 1965)

Hambleton Hill, and differentiated this from the Second Brimham Grit because of its quartzitic nature. They also described the Laverton Shale, a formation containing <u>Lingula</u> bands and abundant black, micaceous material, which overlies the Wandley Gill Sandstone and separates it from the Laverton Sandstone. The latter is coarse and hard and forms the cap-rock of High Ruckles, High Hill, Kettlestang Hill and Hambleton Hill.

These rocks have been tilted slightly and there is a regional dip of about 2^{o} to the east. A number of faults with only small throws occur, trending approximately west-north-west to east-south-east.

The Quaternary history of the uplands around Nidderdale has aroused much interest. Kendall (1924), Raistrick (1926, 1934) and Wilson (1957) have suggested that the higher parts were unglaciated in the last Ice Age. They postulated that the Nidd-Laver interfluve separated the Nidderdale valley glacier from the combined mass of the Wensleydale glacier and the main Vale of York ice-sheet to the east. The drift free surface of the interfluve, the absence of erratics and the widespread occurrence of channels, attributed to the action of meltwater, were cited as evidence for an upper ice margin around these moors. However, Johnson (1969) suggested that these criteria were insufficient to establish that the interfluve was free from ice during the last glaciation. He suggested that during an early phase even the highest ground in the area was glaciated; he attributed the complex systems of channels and drainage features to the influence of sub-glacial meltwater.

The superficial deposits on the Nidd-Laver interfluve are of two types, the inorganic deposits and the peats. Shallow well humified peat covers much of the plateau and in places deeper deposits of topogenous peat have developed. On Fountains Earth over four metres of peat have filled a channel which Johnson (1969) considered to have been formed by the action of sub-glacial meltwater. Rapidly accumulating flush peats occur in the bottoms of the river valleys. The sub-peat soils are developed mainly in sandy material resulting from in situ rotting of sandstones but in places grey or blue/grey clay overlies the bedrock and forms the soil parent material. In most cases the clay is only a surface smear between 10 and 20 cms deep, but at isolated sites much greater thicknesses occur: over 82 cms at Iron Well Hill (SE 17006990) and over a metre on Fountains Earth, in the upper valley of Byerbeck Gill (SE 151723).

The origin of this clay is problematical. It seems possible that it may represent a denuded remnant of a former drift cover; however no erratics have been recovered from it. Pemberton (1971) recorded a superficial clay deposit on Brimham Moor 6.5 kilometres to the south of the Nidd-Laver interfluve. The examination of its mechanical composition led him to believe that the clay was a product of the weathering of shale. On disaggregation of his material in a solution of sodium hexametaphosphate minute laths of easily broken, well weathered shale could be distinguished. Structures within the clay suggested deformation by frost pressure and this, together with the presence of transported sediments between the clay and the bedrock, led Pemberton to suggest that the transport and weathering of the shale took place under periglacial conditions. He assumed that the Brimham Shales were the source of this material, and that these beds were totally removed from the summit of Brimham Moor during an early stage of the last glaciation.

In present laboratory studies, no clay laths could be distinguished after deflocculation of clay samples from Fountains Earth. However, the mechanical composition of the material from Fountains Earth and Brimham Moor is similar, and both clays are rich in muscovite. The stratigraphic relationship of the clay at Fountains Earth is different from that at Brimham Moor. At the former site the clay overlies the Second Brimham Grit and the Brimham Shale is buried far below the surface. However, the Laverton Shale, or the Wandley Gill Shale could have provided a source of material for the development of the clay. The presence of rounded pebbles of gritstone up to 10 cms in diameter was noted beneath the clay at Iron Well Hill and could be equivalent to the frost heaved pebble bed observed by Pemberton (1971) beneath clay on Brimham Moor. On the basis of existing field evidence, it is not possible to decide whether the clay on the Nidd-Laver interfluve has originated from the weathering of a drift cover or a shale bed.

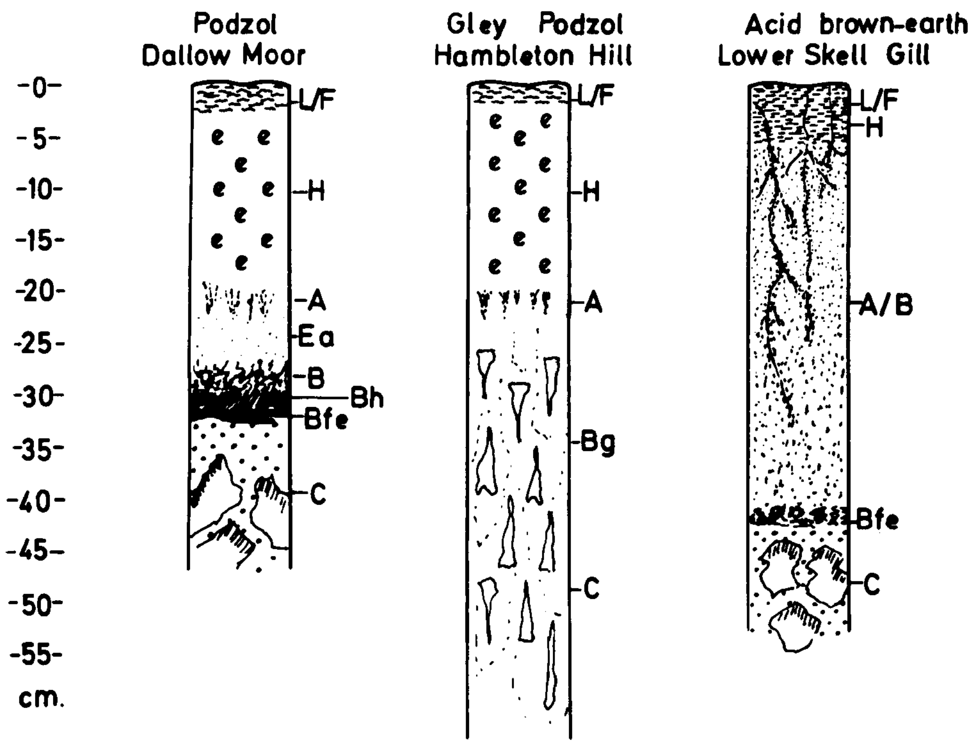
Sandstone boulders are widely distributed on the surface of the plateau; in some cases these are almost completely buried beneath the peat cover. The boulders are generally angular and formed of gritstone; on Dallow Moor Thompson (1957) recorded the presence of tabular ganister boulders, the remains of a now denuded horizon. In places these boulders are aggregated into blockfields; the origins of similar exposures of shattered bedrock in other parts of the country have been attributed to periglacial conditions.

I.ii.c. Soils

The Nidd-Laver interfluve and the surrounding areas have not yet been mapped by the Soil Survey of Great Britain and therefore the

FIG I.4

REPRESENTATIVE SOIL PROFILES FROM THE NIDD-LAVER INTERFLUVE



PODZOL

ACID BROWN EARTH

FIG.I.5 IGNITION PROFILES.

following account is based on profiles examined in the field. Typically the soils are acidic, developed on parent rock which is deficient in bases. Podzols, peaty-gley podzols and gleys are the dominant soil types. It has often proved difficult in the field to assign a profile to one of these categories, as many exhibit transitional features, and the degree to which the characteristic horizons are developed varies markedly from site to site. The following descriptions utilise the horizon nomenclature of the Soil Survey of Great Britain.

Podzolic soils (Fig. 14) have developed on the gritstones, on sloping sites with free drainage where there is no surface clay horizon. The L, F and H horizons are represented by Calluna litter grading into compact, well humified, black peat, pH 3.5-4. This averages about 20 cms in depth on the plateau surface but decreases in thickness on the valley sides. The A horizon, characterised by humus staining, is usually very thin or absent, and the transition to the bleached Ea horizon is sharp. The bleached layer is in most cases clearly distinguished in the field as an ashy horizon about 10 cms thick. The development of the B horizon varies greatly. In some cases it is merely represented by a zone of gradually intensifying brown staining beneath the bleached horizon; after ignition in the laboratory this was interpreted as a dispersed sesquioxide enriched horizon. A Bh horizon of humus accumulation can be differentiated in some profiles, consisting of a dark brown or black band of earthy sand 2-3 cms thick. An ignition profile prepared for a podzol with a Bh horizon (Fig. 15) revealed that the band of humus accumulation lay immediately above the zone of maximum reddening due to sesquioxide deposition. The indurated moor pan (Bfe horizon) which has been widely supposed to underlie heather moors (Smith and Rankin, 1903; Moss, 1904; Cheetham, 1924) appears to be an exceptional occurrence on this interfluve. However, one good example of a pan has been observed at a depth of 30 cms in a soil profile from Dallow Moor. In most cases the zone of sesquioxide enrichment grades into the rotted parent rock of the C horizon, the soil auger has penetrated as much as 70 cms of this material in some places.

At many sites gleying is characteristic of the lower horizons of the podzolic soils, particularly in those places where clay overlies the parent rock. Characteristic orange and grey mottling develops in the B and C horizons of these profiles (Fig. 14). At some sites on the gritstone gleying occurs in the absence of a clay C horizon; in these cases it may be related to the creation of an impervious layer, by the gradual leaching of clay-size particles from the upper horizons of the profile and their accumulation at a lower level (Taylor and Smith, 1972).

Ground water gleys occur at some sites associated with the seepage of water at the surface along shale bands. The seepage water is frequently rich in iron and, on reaching the surface, deposits ferric oxide which stains the surrounding peat a bright orange-red. The sub-peat material at such water-logged sites is usually clay which is completely gleyed to a blue/grey colour. Pearsall (1950) commented that iron-rich flushes are frequent in upland areas and that they are usually indicated by the presence of ferric iron deposits on or in the surface layers of the peat. According to Johnson and Dunham (1963) iron-rich flushes occur where soluble ferrous iron compounds, formed under anaerobic conditions in blanket bog, are brought to the surface and oxidised. However, on the Nidd-Laver interfluve there appears to be a marked association between iron-rich flushes and outcrops of shale. Some vertical shale outcrops have been observed coated with colloidal ferric iron and water has been noted seeping from such exposures.

In the valleys thin podzols have developed on the slopes but in places flows of earth and mud have occurred along seepage lines and on this material deeper soils have developed. The valley floors are occupied by flush peat deposits alternating with banks of coarse, sandy alluvium. On the steep slopes of the lower reaches of the valleys acid brown earths have developed beneath oakwoodland. A representative profile from the Skell valley is illustrated in Figure I4 and the ignited sequence from the same site is shown in Figure I5. The L and F horizons consist of a mat of bracken and leaf mould 5 cms thick, overlying a shallow H horizon with a relatively high pH of 5. The A/B horizon consists of 25 cms of finely divided black earth with a weak crumb structure and a pH of 3.5; ignition revealed no marked bleaching in this horizon. It is sharply differentiated from the Bfe horizon which consists of 2.5 cms of pale yellow sandy material; ignition revealed reddening in this horizon due to iron accumulation. The soil auger penetrated about 10 cms into the weathering gritstone of the C horizon. Laboratory tests suggested that the dark colour of the A/B horizon was due to the presence of finely divided charcoal in the soil profile (*vide infra* Section II.ii.k.).

Apart from the absence of an A horizon at some of the sites examined there is no obvious evidence within the profiles for truncation of the sub-peat soils on the interfluve. Similarly at Brimham Moor, 6 kilometres south east of the Nidd-Laver interfluve, Pemberton (1971) could find no evidence to suggest truncation of the soils by erosion.

However, at a number of sites, both on the plateau and in the valley flushes, lenses of mineral material have been observed within the peat. The material consists of sub-angular, bleached quartz grains, essentially similar to the material in the Ea horizon of the sub-peat podzols. This suggests either a phase of soil erosion prior to peat formation on certain parts of the interfluve, or the washing out of material from the Ea horizon after peat formation. A phase of soil erosion prior to peat formation might have been induced by deforestation of the interfluve; however, as the valley flushes are more recent in origin than the plateau peats, the washing out of sub-peat material is probably a more likely explanation for the presence of the sand lenses.

I.ii.d. Climate

No meteorological statistics are available for the Nidd-Laver interfluve. Reference has been made to data from the nearest station, R.A.F. Leeming, on the River Swale in the Vale of York. The mean monthly temperatures range from 5°C in January to 15°C in July. On the moors average winter temperatures are undoubtedly lower than these figures indicate. Air frost is common and the incidence of bright sunshine is low, particularly in winter when hill mists frequently occur.

The extremes of rainfall experienced at high altitudes in the central Pennines are modified on the eastern flanks. The Nidd-Laver interfluve has an average annual precipitation of about 90 cms, with a mean annual snowfall of 30 cms.

The prevailing direction of the circulation is from the west or south-west, but at Dishforth, 20 kms to the east, southerlies claim a high proportion of the frequencies. The exact distribution of winds is probably much influenced by the orientation of the valleys and the pattern is probably somewhat complex (Mr. B. Ingham, N.A.S. Meteorological Officer, personal communication).

I.ii.e. Vegetation

Smith and Rankin (1903) classified the moorlands of Yorkshire into a number of types and they placed the Nidd-Laver interfluve into the category of "pure heather moor". A current assessment must agree with this as the dominant species throughout the whole area is *Calluna vulgaris*. This dominance, although apparently natural, has been encouraged by decades of careful management which has been aimed at the production of a pure *Calluna* sward, which will support large populations of game. These moors form part of a chain of highly prized grouse moors which flank the eastern edge of the central Pennines. Burning is practised on a ten-year rotation, to stimulate new growth and reduce competition. *Calluna vulgaris* can tolerate a wide range of soil depths and drainage conditions and therefore colonises both podzolic and gleyed soils; it also extends on to the drier parts of the flush peat deposits. *Calluna* generally has few associates though on excessively drained sites, where gritstone bedrock is close to the surface, *Vaccinium myrtillus* is co-dominant. *Vaccinium* is dominant on the crags which edge the valleys of the Skell and North Gill Beck, where it forms "bilberry edges" (Tansley, 1949).

The chief competitor to *Calluna vulgaris* is *Pteridium aquilinum*. Its range of tolerance is restricted to fairly deep, free draining soils, and therefore it is most abundant on the valley sides. However, with improved drainage techniques, Pteridium is extending widely on to the moors at the expense of Calluna and it is only partially controlled by annual mowing.

The sheep walks across the moors are in some places edged with a turf of Festuca ovina or Agrostis tenuis, and this provides a habitat for a variety of herbs which would otherwise be excluded by the Calluna sward. Rumex acetosella, Potentilla erecta, Galium saxatile, Polygala serpyllifolia, Taraxacum officinale and Bellis perennis are common in such areas.

The vegetation of the moorland and valley flushes is dominated by species of Sphagnum. Sphagnum papillosum is the most common species, with S. cuspidatum in the wettest areas and S. rubellum on slightly drier ground. Polytrichum commune forms tussocks on the margins of the Sphagnum carpets. Juncus squarrosus and Juncus effusus are abundant and a variety of herbs tolerant of wet conditions occur, including Narthecium ossifragum, Erica tetralix, Vaccinium oxycoccos and Drosera rotundifolia. In places, where the peaty flushes are enriched by iron, Molinia caerulea forms prominent tussocks.

The only natural woodland on the Nidd-Laver interfluve is confined to the steep sides of the gills (Fig. I2), a situation which is typical of the gritstone Pennines at the present day (Tansley, 1949). These woods are dominated by Quercus petraea; the trees normally grow to a moderate size but are stunted on the upper slopes where they are exposed to the wind. On the steepest slopes Betula pubescens and Sorbus aucuparia are associated with the oaks and these two species also occur as isolated trees in the upper parts of the valleys beyond the woodland edge. Alnus glutinosa colonises the damp ground nearest the streams and occasional trees of Ilex aquifolium are found on the slopes. The shrub layer is poorly represented apart from occasional Salix bushes (S. atrocinerea and S. caprea). The field layer is dominated by Pteridium aquilinum with Holcus mollis in the damper places. A variety of herbs including Vaccinium myrtillus, Galium saxatile, Endymion non-scriptus and Oxalis acetosella occur.

Planting has taken place in the valley of the North Gill Beck below 230 metres, in the valley of Carlesmoor Beck, and along the western margins of the interfluve overlooking Nidderdale. Smith and Rankin (1903) recorded that in some of the woods in this region oak was being systematically replaced by pine and that pine and larch plantations had been established on the moorland edge above Nidderdale. Forestry in this area is now in the hands of the Leeds Corporation Waterworks Department and a variety of conifers have been planted since 1950 including Larix decidua, Larix leptolepis, Picea abies, Picea sitchensis, Pinus sylvestris, Pinus radiata and Pseudotsuga taxifolia.

The margin of improved land has fluctuated throughout historic time. At present it approximates to the 260 metre level and below this poor quality upland pasture grades into better quality meadows at lower altitudes. Though stone walls form the usual field boundaries, hedges of Corylus avellana and Crataegus monogyna are common with isolated trees of Fraxinus excelsior and Ulmus glabra at intervals along them.

I.iii. Previous Palaeoecological Studies in the Pennines

I.iii.a. Studies of Macroscopic Remains

C. E. Moss, writing in 1904, commented "there is a remarkable consensus of opinion that the peat moors of the present day occupy the sites of former forest." Throughout the Pennine moors the macroscopic remains of former woodland are widespread and nineteenth century naturalists observed compressed birch bark and hazel nuts in peat and identified a variety of types of timber. The existence of this former forest has always been appreciated by the local population; peat cutting for fuel has been practised throughout historic time and tree stumps, unearthed during this process, were highly prized (Woodhead, 1929). The Kirkby Malzeard Court Papers for 1751 contain a reference to "the digging of firewood" on the moors.

Lucas (1872) published observations of tree remains in the peat on the Nidderdale moors. He recorded the sites of buried timber of birch, oak and willow, and he also noted the occurrence of hazel nuts in the peat. Lucas made a detailed comparison of the altitudes attained by living trees and the altitudes at which remains of the same species were buried. He used these observations to reconstruct the former forest and he distinguished two zones: a lower one, up to about 1,200 feet (366 metres), where oaks predominated, and a higher zone of birch trees which he describes in the following passage:

"the birch must have formed a thick and almost universal forest by itself, such as may be seen on the west coast of Norway at the present day. The upper parts of the moorland gills and much of what is now the moors, must formerly have made a beautiful appearance with its light gauze-like forest of birch and mountain-ash." (Lucas, 1872)

Lucas made no mention of alder remains in the peat although they can be observed commonly on the Nidderdale moors at the present time. It is possible that the wood which he recognised by its red colour as "sealh" (i.e. willow) was alder.

Moss (1913) also referred to the distribution of buried bark and timber in the central Pennines and described a former upland birch zone. In an account of the vegetation of the Leeds-Halifax district, he observed that at high altitudes and in exposed situations the oak was often replaced by the birch, and that these fringing birch woods were once more extensive.

In a vegetation survey of Yorkshire, Smith and Rankin (1903) referred to Lucas's work on the Nidderdale moors, and added their own observations on buried tree remains in the area. They suggested that a continuous thicket of birch and its associates covered the present moorland edge and much of the moors. They drew attention to the "gill-woods" in the upper valleys of certain of the Nidd's tributaries. These are characterised by birch scrub and mountain ash and Smith and Rankin suggested that they were remnants of the former woodland. The success of pine plantations on the moors led Smith and Rankin to speculate about the former existence of a zone of natural pine forest above the altitudinal limit for oak and birch. However, as neither they nor Lucas recorded buried pine timber in the peat they were forced to conclude that there was no positive evidence that pine was ever indigenous to these moors.

Since these surveys no systematic observations of macroscopic remains in the peat have been made in this area. None of the studies cited above discussed the possible date at which the upland woodlands disappeared. There is no evidence in documentary sources for any widespread upland clearance on the Nidderdale moors in medieval times. The status of the upland vegetation during the Dark Ages is less certain and must be inferred from place-names.

I.iii.b. Pollen Analytical Studies

No detailed pollen analytical investigations have been carried out on the gritstone region of the east-central Pennines. However, further south in Derbyshire the vegetation history of the Millstone Grit has aroused much interest. During the Boreal period (7,800 B.C. to 5,500 B.C. approximately) the southern Pennines supported a pine-hazel forest (Hicks, 1971) and at high altitudes, where this thinned out, a "late-glacial type" flora survived (Tallis, 1964). During the Atlantic period (5,500 B.C. to 3,000 B.C. approximately) mixed oak forest spread over the upland replacing the pine and hazel, and at damp sites patches of alder/birch carr developed (Conway, 1947). There is evidence that the growth of basin peats and blanket bog was initiated at some sites on the south Pennines during this period, depending on local conditions of relief and altitude (Tallis, 1964). At Rishworth Moor, on the western Pennine flank, peat formation was also initiated during the Atlantic period, at about 3,500 B.C. (Bartley, 1964).

The spread of peat and the decline of upland forest in the southern Pennines has been attributed to climatic deterioration which began about 5,000 B.C. (Conway, 1947). However, an increasing body of evidence points to the significance of man's role in deforestation from 3,000 B.C.

onwards (Hicks, 1971). It is clear that at many south Pennine sites the spread of shallow peat of less than half a metre in depth has taken place relatively recently following upland clearance during Roman times (Eyre, 1966).

The vegetation history of sites on the limestone of the central Pennines has been studied at Malham Tarn (Pigott and Pigott, 1959), and in the Ingleborough district (Gosden, 1965). The limestone has always supported a richer flora than the base deficient gritstones and therefore, despite the relative proximity of these sites to the Nidd-Laver interfluve, direct parallels cannot be drawn between the vegetation history of the two regions. The general pattern of a gradual reduction of the upland forest from the Atlantic period onwards is, however, similar to that seen in the south Pennine diagrams. At Malham Tarn, forest decline appears to have been initiated in the late Neolithic or early Bronze Age and can be closely correlated with successive population increases (Pigott and Pigott, 1959). At Ingleborough, the decline of alder/hazel woodland and the associated spread of peat over the limestone pavement appears to have resulted from marked climatic deterioration during the Sub-Atlantic period (Gosden, 1965). The eastern gritstone region is at a lower altitude and also drier than the south Pennines and the Carboniferous Limestone areas and consequently significant differences in the course of vegetation history might be expected.

At Stump Cross near Grassington, only 12 kms west of the Nidd-Laver and at a comparable altitude (366 metres), Walker (1956) investigated sediments in which Mesolithic artifacts had been discovered. Though this site is on limestone, the Millstone Grit outcrops only 90 metres to the north and 800 metres to the south-east, and therefore the pollen analytical results are of considerable interest in relation to the present study. During the Boreal period Betula/Corylus scrub surrounded the Stump Cross site; Pinus does not appear to have been as common as it was in the flora of the south Pennines at this time. Quercus and Alnus became increasingly well represented in the pollen record during the Atlantic, but at the end of this period rising values for Ericaceae pollen indicate that heath was developing over the leached upland soils. Walker's investigations were limited to a short sediment core, his main interest being to establish a date for the microlithic industries at Stump Cross and therefore he did not speculate about the nature and causes of the spread of heath.

In the pollen analytical studies which have been briefly surveyed both climatic and human influences have been cited as the primary cause of upland woodland decline. The evidence from other Pennine sites in favour of each of these explanations has been considered in the interpretation of results from the Nidd-Laver interfluve.

I.iv. The Historical Background

A consideration of the history of the moors east of Nidderdale provides an essential background for the interpretation of changes in vegetation and land use.

I.iv.a. Prehistory

There are no studies referring specifically to the prehistory of this area and therefore the information must be derived from that relating to the Pennines as a whole.

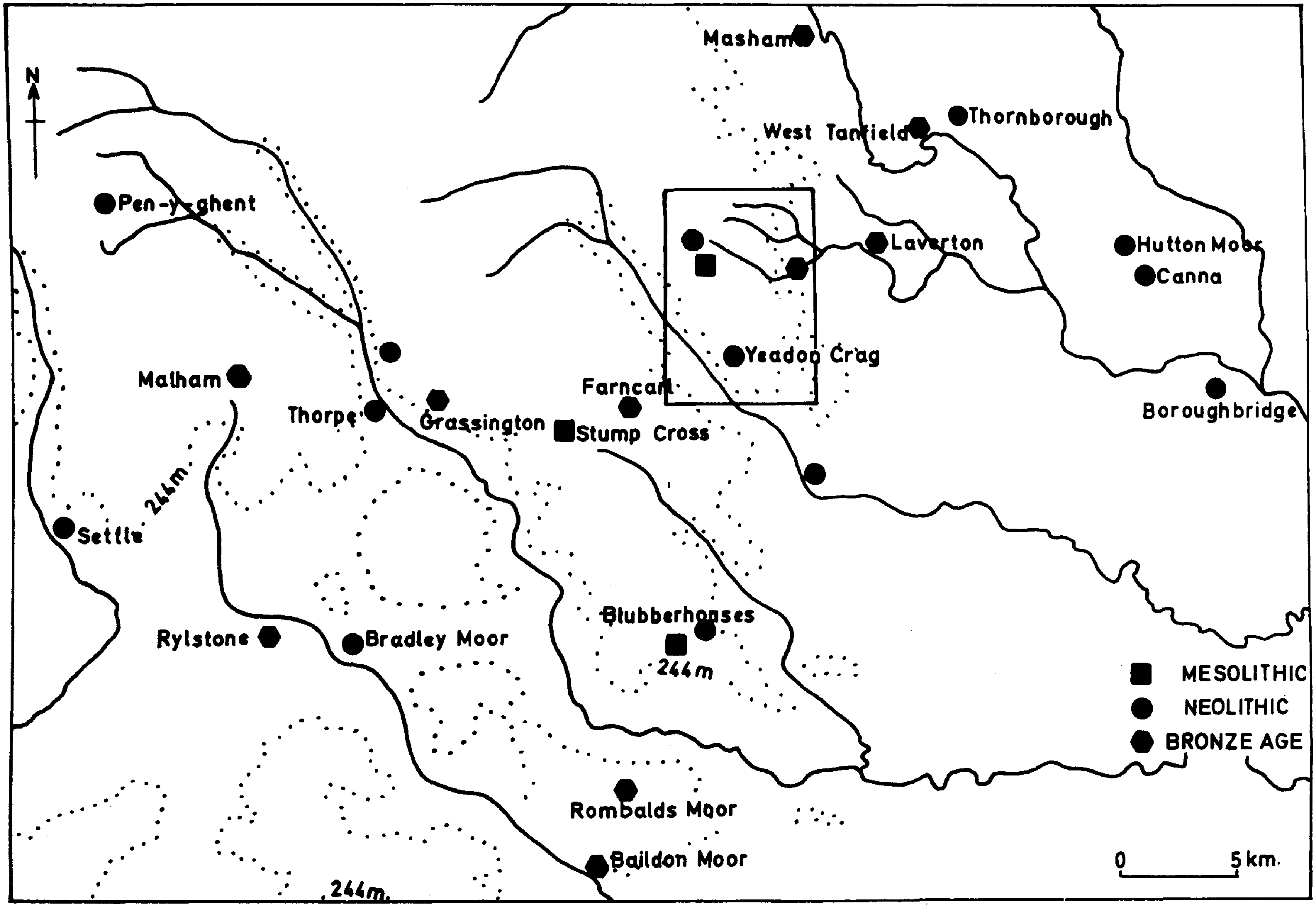
There is limited evidence for man's penetration into the uplands of Britain prior to the post-glacial period. Palaeolithic people inhabited the lowlands in the interglacials but hunting forays were probably made into the highland zone. Stone and bone implements have been found in caves at Cresswell Crags, Derbyshire, and in Yorkshire three bone implements of Magdalenian type have been found at Victoria Cave, Settle, in the Carboniferous Limestone area of the central Pennines. In Nidderdale, Collins (1930) identified a number of Upper Palaeolithic hand axes which were recovered from morainic gravels, but his identification was not generally accepted (Elgee, 1933).

Mesolithic (Fig. I.6). The warming of climate which followed the end of the glacial period resulted in floral and faunal changes; gradually forest replaced the tundra and the herds of reindeer and other large mammals moved north. The Mesolithic peoples adapted to these new conditions and their economy was based on the hunting of small animals, fishing, fowling, and the gathering of nuts and berries (Clark and Piggott, 1965). Two distinct culture groups are represented in the

British Mesolithic, the Maglemosians who occupied forested lowlands and whose settlements are often associated with lakes; and the Sauveterrians who occupied sandy areas and upland regions above about 300 metres. Most of the Maglemosian finds in Yorkshire have been confined to the east of the county, in Holderness and the Vale of Pickering (Longworth, 1965). However, these hunters must have penetrated the Pennines, as axes of Maglemosian type have been found at Rishworth in Calderdale and on Blubberhouses Moor, about 15 kilometres from the Nidd-Laver interfluve (Longworth, 1965). Microlithic assemblages from Deepcar, near Sheffield, and from Marsden, near Huddersfield, also compare closely with those from Maglemosian sites farther south (Radley and Mellars, 1964). Artifacts of Sauveterrian type are common in the Pennines; characteristic geometric flint microliths are often found exposed by peat erosion lying on the sandy, sub-peat soil (Raistrick, 1933). Isolated flints of Sauveterrian type have been found on the higher parts of the Nidd-Laver interfluve (Ordnance Survey Index, 1950) and assemblages of Sauveterrian flints have been identified on Blubberhouses Moor (Davies, 1963) and at Stump Cross near Grassington, west of the Nidd-Laver interfluve (Walker, 1956).

A number of pollen analyses have been made of the basal layers of the blanket bog peat overlying certain Sauveterrian sites in the Pennines. In most cases these have suggested that the peat began to form during the Atlantic period (Woodhead and Erdtman, 1926; Davies, 1943) and it is therefore clear that Sauveterrian man occupied the Pennines prior to 5,000 B.C. At the Stump Cross site the microliths are statified into the sediments and can be definitely associated with the early Atlantic period (Walker, 1956). Charcoal found with the flints was dated to 6,500 ± 310 B.P. (4,550 ± 310 B.C.) (Godwin and Willis, 1959).

FIG I.6 MESOLITHIC NEOLITHIC AND BRONZE AGE SITES



It has traditionally been supposed that prior to the adoption of agricultural techniques man exerted little influence on his environment. However, there is an increasing body of evidence which suggests that Mesolithic man used fire to open up the forest for hunting purposes (Dimbleby, 1962; Smith, 1970). Simmons (1969) has pointed out that the effects of Mesolithic clearance would be most marked in marginal upland areas. However, there is at present no evidence for forest clearance by Mesolithic man in the Pennines.

Neolithic (Fig. I.6). The first major impact on the forested lowlands of the British Isles resulted from the introduction of agriculture by the early Neolithic people who arrived in this country during the fourth millennium B.C. They practised mixed farming, cultivating emmer (*Triticum dicoccum*) as a principal crop, and breeding cattle, sheep, goats and pigs (Clark and Piggott, 1965). They brought with them a knowledge of pottery and the polished stone or flint axe, an effective implement for forest clearance (Piggott, 1964). These first agriculturalists settled mainly in areas where the soils were of high base status and avoided the infertile uplands. Consequently people practising a Mesolithic economy were able to survive in these areas for long periods after the initial influx of agricultural techniques into Britain (Cole, 1965).

The area of primary Neolithic settlement was centred in Wessex and from there spread north. On the chalk wolds and limestone hills of east Yorkshire there are many traces of Neolithic occupation but there are few remains in the west of the county. Pottery of the Peterborough type has been found in caves near Settle and Thorpe (Longworth, 1965) and megalithic chambered cairns have been identified on Bradley

Moor near Skipton and in Pen-y-ghent Gill in the upper catchment of the Wharfe (Bennet, 1937). The distribution of polished stone axes suggests that the Pennine passes were being used at this period for trading contacts with the west coast of Britain. Axes of Langdale shale and Graig Lwyd rock are common in Yorkshire and an axe from the factory at Tievebulliagh in Ulster has been found on Blubberhouses Moor (Butler, 1967a). Two axes of Borrowdale Volcanics and one of Graig Lwyd have been found in Nidderdale (Harrogate Museum Collection) suggesting that some local woodland clearance must have taken place in this period. Neolithic flints have been recorded from Kettlestang Hill on the Nidd-Laver interfluve (Ordnance Survey Index, 1950) and close by at the base of Yeadon Crag a Neolithic rock shelter and hearth have been identified. (Mr. C. E. Hartley, personal communication).

The scarcity of finds relating to this period in the Nidderdale area and the lack of interment or settlement sites suggests a sparse population living a semi-nomadic life. A system of shifting cultivation may have been practised, areas being cleared for crops or grazing and then abandoned when soil fertility declined (Clark , 1945). Webely (1969) has suggested that in south Wales a semi-migratory Neolithic people may have utilised the land above 300 metres, following herds of sheep to their feeding areas in the open upland vegetation. It seems likely that hunting made an important contribution to the diet in these marginal regions where Mesolithic practices may have persisted despite the spread of agricultural techniques.

Towards the end of the Neolithic period, between 2,000 and 1,700 B.C., immigrants of a new culture group arrived in Britain. They are identified by the decorated beaker-shaped pots which they produced. The Beaker people were primarily herdsmen, but cultivated some crops. They buried their dead under round barrows and these are common on the lowlands between the Ure and the Swale immediately to the east of the Nidderdale moors. These lowlands appear to have held a ritual significance for the Beakers as in addition to barrows they erected a series of circular henge monuments in this area. At Thornborough three henge circles about 184 metres in diameter are aligned along an axis running north-west to south-east. An earlier sacred use is indicated by a cursus, or avenue, which underlies the central circle and which has been attributed to a pre-Beaker phase of the Neolithic (Thomas, 1955). Two similar henges, now nearly ploughed up, occur to the south at Canna and Hutton Moor; further south, by the Ure at Boroughbridge, there are three aligned standing stones known as the Devil's Arrows and these are also thought to belong to the same period. The concentration of barrows and religious monuments suggests a significant population on the Ure-Swale lowlands during the phase of Beaker activity and some exploitation of the adjacent uplands is likely to have taken place.

The Bronze Age (Fig. I.6). The knowledge of bronze in the British Isles was acquired through trade and a native bronze industry developed during the second millennium B.C. (Clark and Piggott, 1965). New forms of pot, the Food Vessel and the Collared Urn, developed as a result of the fusion of Beaker techniques with those of the native Neolithic people. The Food Vessels show the greatest Beaker influence; they were made in Yorkshire until about 1,300 B.C. Collared Urns probably developed slightly later and were in use until about 1,000 B.C. (Longworth, 1965). Food Vessels have been found associated with the Pennine trade routes, at West Tanfield on the Ure, on Baildon Moor near the Wharfe, at Ferry Fryston on the Aire, and at Pule Hill near Huddersfield. Coffin burials from this period have been identified from West Tanfield and Rylstone, on the Wharfe (Elgee, 1933). Large numbers of boulders carved with cup and ring markings occur widely on the gritstone moors and are assumed to date from this period (Butler, 1967a), the greatest concentration of these occurring on the moors to the south of the Nidd and the Aire. Isolated flints associated with this period have been found on the Nidderdale moors (Harrogate Museum Collection) and early Bronze Age maceheads have been recorded at Dallowgill and at Laverton (Ordnance Survey Index, 1959).

Collared Urns are not widespread in the West Riding but a few have been found associated with the main trade routes through the Pennines: in the Calder valley at Tower Hill, Halifax, at Blackheath Cross, Todmorden, near the Aire on Baildon Moor, and on the Wharfe at Tarnbury, near Grassington (Longworth, 1965). A number of cairns and stone circles occur on the Pennine moors and are generally associated with the Collared Urn people (Butler, 1967a). Circles have been identified on Hebden Moor and at Farncarl near Greenhow, only 8 kilometres from the Nidd-Laver interfluve (Raistrick, 1968).

Bronze Age sites associated with habitation and agriculture have been identified on Malham Moor, on the Carboniferous Limestone (Raistrick, 1931), and some enclosures on Rombalds Moor, on the Millstone Grit, may date from the same period (Butler, 1967a).

The paucity of finds from the Food Vessel and Collared Urn cultures make estimates of the relative population in the Nidderdale region during the early Bronze Age difficult. The large number of rock carvings on the moors to the south suggest that in the central Pennines as a whole the population was expanding. Small upland enclosures dated to this period suggest that sedentary agricultural communities existed at this time.

There is a lack of direct evidence relating to the size of the population in the Pennine uplands during the late Bronze Age. It is clear, however, that the lowlands to the east of Nidderdale were well populated at this time as a number of hoards of late Bronze Age implements have been identified in the area between Ripon and Masham (Longworth, 1965). A hoard of 36 socketed bronze axes was discovered near Laverton in 1887 (Anon., 1909) and two bronze palstaves have been found on the moors near Pateley Bridge (Harrogate Museum Collection). Late Bronze Age ornaments made of gold have been recovered near Masham and at Ripon (Elgee, 1933). The nature of these finds suggests that the communities which occupied the margins of the Nidd-Laver interfluve during this period enjoyed considerable prosperity.

The Iron Age (Fig. 17). Iron was first introduced into southern Britain by Celtic traders and colonists from continental Europe. The duration of the British Iron Age was estimated by Hawkes (1959); he divided it into three periods, viz:

Iron I	550 - 350 B.C.
Iron II	350 - 150 B.C.
Iron III	150 - Roman invasion A.D. 43

However, recent radio-carbon dates suggest that the opening of Iron I was considerably earlier. Within this chronological framework Hawkes devised a scheme for the division of British Iron Age cultures. He recognised a "Pennine Province" in which almost all the Iron Age archaeological remains could be assigned to Iron A, the first Iron Age culture to be brought to Britain.

The earliest evidence of this new culture in Yorkshire occurs in the east of the county at Castle Hill, Scarborough, where a large number of storage pits have been discovered and their contents assigned to the early Iron Age (Smith, 1928). A farmstead of First Iron A has been excavated at Staple Howe on the northern slopes of the Yorkshire Wolds.

It is probable that the change from a bronze-using to an iron-using society was very gradual in the Pennine region. At Grafton, on the Swale, a settlement site belonging to the First Pennine A has been identified and sporadic occupation of this site appears to have taken place until Roman times (Butler, 1967a). On the limestone to the east of Nidderdale there are abundant traces of the Iron Age population; scattered groups of round huts and associated irregular fields are common in upper Wharfedale and on Malham Moor. Iron implements are exceptional though, and these people were probably relatively isolated from the new influences which had spread to the lowlands (Raistrick, 1962).

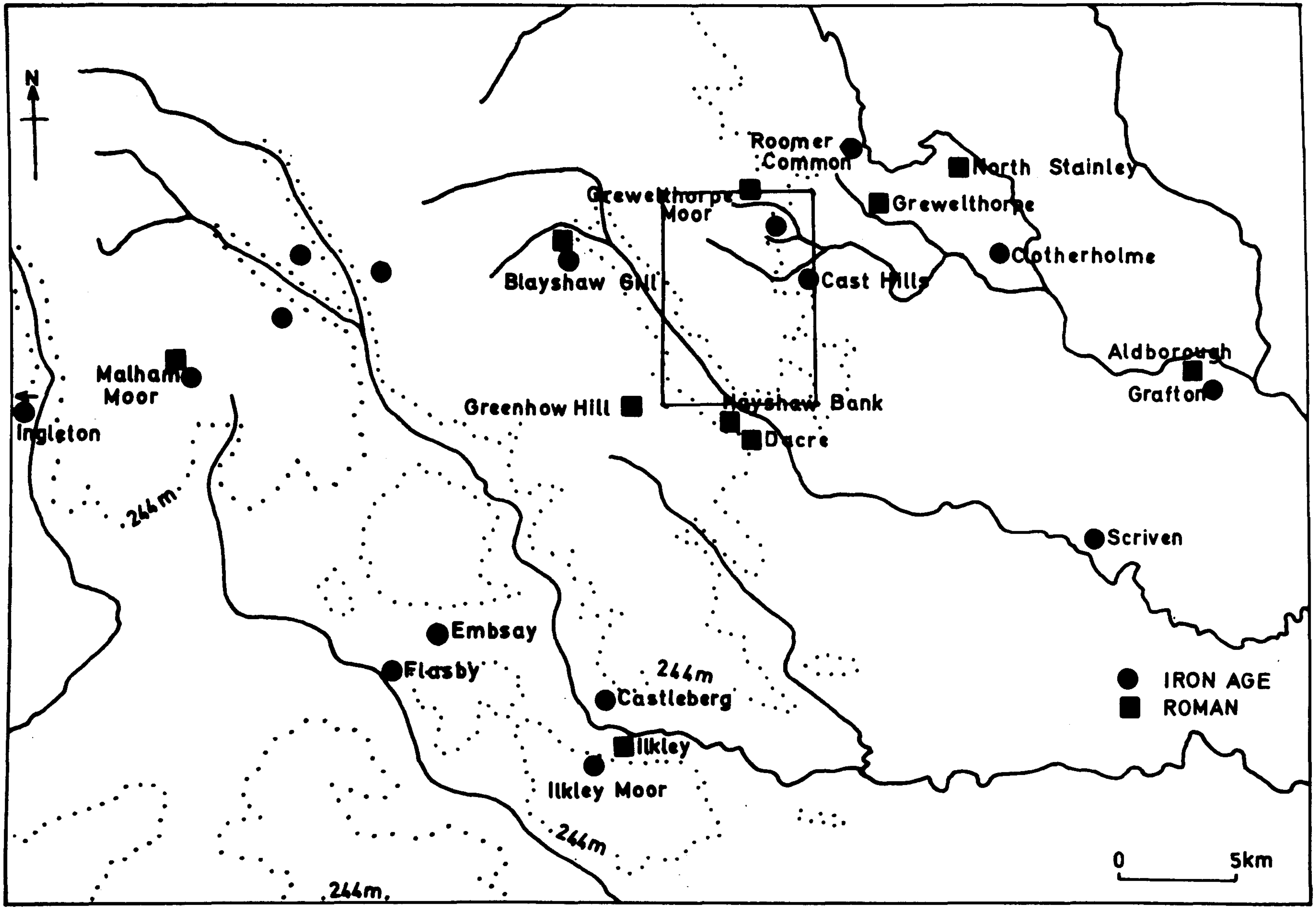
Hillforts are somewhat rare in the Pennines but there are two good examples at Almondbury near Huddersfield and at Castle Hill, Meltham (Varley, 1948). A recent radio-carbon date of 555 B.C. $\pm$ 110 for the fourth rampart on the site at Almondbury (Dr. L. Butler, personal communication) has established the presence of an Iron Age culture in the Pennines by the sixth century B.C. The promontory fort at Castleberg, Nesfield, on the Wharfe, may have been built in the same period as

Almondbury (Butler, 1967a). Cast Hills on the Laver and the promontory fort at Scriven on the Nidd are probably of similar age (Ordnance Survey Index, 1963).

The Second Pennine A contains elements of both the Hallstadt and the La Tène cultures. Celtic immigrants brought La Tène influences to Britain between 400 and 360 B.C. In east Yorkshire a number of cemeteries associated with these people have been identified and dismantled chariots are associated with some of the interments (Elgee, 1933). The La Tène people were skilled craftsmen and produced decorative metalwork of high quality, examples of which have been found in the lowlands around the Nidd-Laver interfluve. Iron swords with scabbards have been recorded at Flasby near Skipton, at Clotherholme near Ripon, in Cotterdale and in Wensleydale (Raistrick, 1968). A bronze mirror handle found at Ingleton and a bronze collar from Embsay also date from this period (Elgee, 1933). In the Pennine uplands La Tène influences can be seen in carvings such as the Swastika Stone on Ilkley Moor. A burial at Roomer Common just north of the Nidd-Laver interfluve has been attributed to the Second Pennine A, and fragments of two saddle querns were associated with the site (Ordnance Survey Index, 1954). Various small enclosures on the gritstone moors have also been assigned to this period (Raistrick, 1939).

The archaeological evidence from the central Pennines suggests that the Iron Age inhabitants were principally pastoralists. Piggott (1958) claimed that cultivation played no part in their economy; however, the fairly widespread occurrence of querns associated with this period points to cereal production, though possibly on a limited scale. The lower half of a beehive rotary quern has been discovered in Blayshaw

FIG I.7 IRON AGE AND ROMAN SITES



Gill, Nidderdale, close to the Nidd-Laver interfluve (Ordnance Survey Index, 1953). From the evidence of hut circles associated with enclosures at Malham and on Ilkley Moor, these Celtic peoples appear to have lived a settled and organised community life. The frequency of finds which have been assigned to this period suggests a considerable expansion in population since the Bronze Age.

The Roman Period (Fig. I.7). The Romans first invaded Britain in A.D. 43 and their attempts to control the north met with resistance. During the latter part of the Iron Age there emerged in northern England a loose federation of tribes known as the Brigantes whose principal strength lay in the Pennine region. The main centre of Brigantian defence was at Stanwick, near Richmond, to the north of the Nidd-Laver interfluve. Massive earthwork fortifications were raised at this site which was the scene of the final defeat of the Brigantes in A.D. 74 (Wheeler, 1954).

It seems likely that the Roman occupation resulted in little change in civilian life on the central Pennines. Hut clusters and fields on Malham Moor, similar to those of Iron Age times, have been dated to the Romano-British period (Raistrick and Holmes, 1962). However, the occupation of the Roman forces must have resulted in increasing movement and trade in these areas. The Nidd-Laver interfluve is adjacent to the Roman lead mines on Greenhow Hill. Although these mines were a state monopoly and therefore had only a marginal effect on the local economy (Hartley, 1967), the influx of population into the area must have been considerable. The mines were probably worked by slaves (Raistrick and Jennings, 1965) and the food requirements for this labour force must have been drawn from the surrounding area. It is also reasonable to suppose that the charcoal requirements for smelting were supplied by local timber, causing some destruction in the forests.

There is evidence for the presence of the Romans in the Nidderdale area from finds of coin hoards and pigs of lead. Grainge (1863) recorded that two pigs of lead cast in A.D. 81 were dug up at Hayshaw Bank in 1735, and one has been recorded from Monk Ing, Dacre, dated A.D. 98 (Speight, 1906). A hoard of 32 Roman silver pieces was discovered in a cave in Nidderdale in 1868 (Lucas, 1872). One of the most startling discoveries relating to this period was made in 1850 when the partially preserved body of a man in Roman dress was dug out of a peat bed on Grewelthorpe Moor, part of the Nidd-Laver interfluve (Grainge, 1886; Elgee, 1933).

Roman military control depended heavily on a good road system and a number of the Pennine passes were used for east-west communication. Each road had a chain of forts associated with it. No forts have been discovered in Nidderdale but the main road between Ilkley (Olicana?) and Aldborough (Isurium Brigantum) passed through the valley only a kilometre to the south of the Nidd-Laver interfluve.

On the lowlands to the east of the interfluve the influence of the Romans on the civilian life in the area is apparent. The site of a Roman villa has been excavated at Castle Dykes, North Stainley, to the north of Ripon (Berry, 1953) and a bronze Roman statuette was found at Grewelthorpe, six and a half kilometres from this latter site (Ordnance Survey Index, 1953). However, on the moors there is evidence for nothing more than a continuation of the agricultural practices of Iron Age times.

I.iv.b. The Historic Period

The Dark Ages. In the early 5th century the Roman armies were withdrawn from Britain and the Celtic inhabitants were unable to defend themselves against invaders from Europe. The Angles of Deira penetrated the country from the east and may have reached Ripon by about the year 500 A.D. (Jennings, 1967). The history of Nidderdale and the moors to the east may be traced in detail from this period onwards using evidence derived from place names and documentary sources.

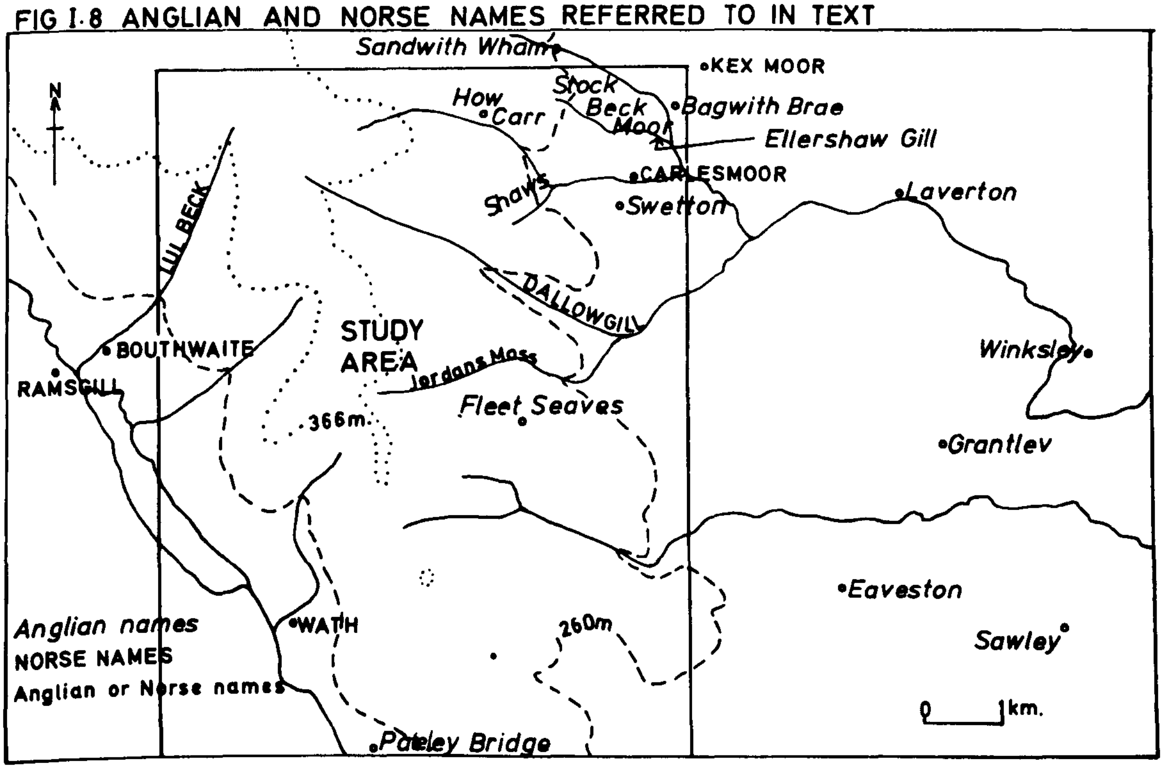
Few Celtic place names have survived in this area; only the names of the rivers, Nidd (shining) and Laver (noisy), remain to testify to the pre-Anglian settlement (Thomson, 1967). The Angles were agriculturalists, who penetrated this area making clearings in the woodland at sites on well drained river gravels. The element "ley", which is common in the village names of Nidderdale, is derived from the English "leah", a woodland glade or clearing; Jennings (1967) commented "the line of the 'leys' up the valley - Whipley, Winsley, Darley, Bewerley and Pateley - marks the progress of the English in carving their settlements and fields out of woodland". On the eastern margin of the Nidd-Laver interfluve Sawley, Winksley and Grantley are derived from the same source; also in this region the Anglian element "tūn", an enclosure, farmstead or village, is common as in Eaveston, Laverton and Swetton (Fig. 18). The Anglian invasion must have had a profound effect on the life of the native peoples of this area. According to Jones (1961) Bede described how Ethelfrid of Northumbria in A.D. 603 "overran a greater area than any other kings or chiefs, exterminating or enslaving the (British) inhabitants, extorting tribute, and annexing their lands for the English". The Anglians settled on these annexed lands establishing their own system of agriculture and led a settled existence for two or three centuries.

The invasion of Northumbria by a Danish army in 865 initiated a further period of unsettled times in the Dales. Exploratory expeditions were followed by permanent Danish settlement in east Yorkshire and at the same period Viking settlers of Norse-Irish descent penetrated the western dales (Butler, 1967b). Norse elements are common in the place names of the Nidd-Laver interfluve and its margins: "thwaite", a clearing or meadow as in Boulthwaite and Braithwaite; "beck", a stream as in Lul Beck; "gill", a ravine as in Ramsgill and Dallowgill; and "wath", a ford, for example Wath above Pateley Bridge. Linguistic evidence suggests that the Norse settlers and the Anglians mixed freely as a number of names containing elements from both languages are found in Yorkshire. It is difficult to assess the impact of this period of settlement in terms of population. Norse place names may merely indicate the renaming of existing settlements rather than large scale colonisation of new land. In the West Riding of Yorkshire more Anglian than Norse names are recorded in Domesday Book and this led Thomson (1967) to suggest that "though the Norsemen imposed their authority and form of local government in these areas, the land had already been fully taken up by the Anglian settlers before the ninth century and there was no large area remaining unsettled."

Jones (1971) has established that during the Dark Ages some of the settlements on the margins of the Nidd-Laver interfluve formed part of a multiple estate which included settlements in the Vale of York and on the Pennine margins. This form of territorial organisation may be extremely ancient with origins in Iron Age times.

Some of the place-names around the Nidd-Laver interfluve contain elements referring to vegetation, and these are of interest for the

FIG I.8 ANGLIAN AND NORSE NAMES REFERRED TO IN TEXT



reconstruction of former woodland limits. However, deductions based on the use of place-names must be treated with caution as in some cases their significance is debatable. Reference to particular plants or trees in place-names may relate either to their common, or exceptional, occurrence. Neither is it possible to be certain that a name was first given during a particular period as the application of Anglian and Norse names may have continued for some time after these particular phases of occupation. However, in spite of these limitations, some information can be gleaned from the place names of this area.

The widespread occurrence of the Anglian element "ley" in the place names of this area suggests that the lowlands around the Nidd-Laver interfluve were well wooded in the sixth century. However, there is little evidence to suggest the existence of any large stretches of woodland on the present-day moor, except on the eastern margin of the interfluve where the Anglian name "shaws", a woodland, occurs on Carle Moor between 260 and 320 metres (Fig. 18). The same element suggests that woodland was once more extensive in Ellershaw Gill which drains Stock Beck Moor (228-275 metres); "stock", a stump, suggests woodland clearance on this moor during the Anglian period. Within the same area the Norse element "with", a wood, occurs in Sandwith Wham (305 metres) and Bagwith Brae (199 metres), and the Norse element "carr", wet land overgrown with brushwood, occurs on Stock Beck Moor at How Carr (275 metres).

There are also names on the eastern margin of the interfluve which might suggest that parts of this area were already moorland at the time of the Norse colonisation, for example Carlesmoor and Kexmoor, which are both derived from Norse personal names. Over the higher parts of the interfluve both Norse and Anglian names indicating moorland conditions occur. The name moor is itself derived from either the Anglian "mōr", or the Norse "mór", both meaning a high tract of barren uncultivated land. The element "moss", in the name Jordan's Moss, is derived from the Anglian "mos" or Norse "mosi", and presumably refers to areas of bog moss (Sphagnum spp.). In the name Fleet Seaves, the second element is derived from the Anglian "sef", a sedge.

The evidence from place names therefore suggests that the greater part of the Nidd-Laver interfluve was probably deforested by the sixth century, but that the lowlands were well wooded and trees extended up the steep sides of the Nidd valley and up the more gentle slopes on the east of the interfluve. On these eastern slopes tongues of woodland extended up to about 300 metres, between cleared areas with heath vegetation, at least until after the initial phase of Norse settlement in the ninth century. These conclusions based on place-name evidence are supported by the results of the pollen analyses described in Section IV.

The Norman Conquest and the Monastic Period. The period of Norse authority ended with the Norman conquest in 1066. At this time the Nidd-Laver interfluve and its margins were in the hands of two major land-owners, Gospatric, a Northumbrian lord, and the Archbishop of York. Resistance to the Normans was strong in Yorkshire and the area suffered heavily from King William's punitive action following the Northumbrian rebellion of 1069. In 1086 when Domesday Book was compiled all of the 14 places mentioned for Nidderdale are described as "waste", as are most of the settlements on the eastern margin of the Nidd-Laver interfluve; Kirkby Malzeard, Laverton and Grewelthorpe were all valued at half of their 1066 level. According to Maxwell (1962), an entry of waste for a

West Riding vill seems to imply that such a holding had no population. It is possible that the depopulation suggested by these figures was only partly the result of devastation in the area. An organised migration may have taken place, at the instigation of the landowners, from the less productive lands in the dales to the wasted holdings of more fertile districts. (Bishop, 1962). It is difficult to assess the length of this period of depopulation. Jennings (1967) has suggested that the correspondence of settlements mentioned in early medieval records with those listed in Domesday suggests a comparatively early re-occupation. However, some settlements, such as Poppleton in Upper Nidderdale, never recovered their former population.

The Domesday record yields little information regarding the distribution of woodland in this area in the eleventh century, perhaps because most of the entries are brief owing to the wasted condition of many of the holdings. The only mention of woodland is at Bewerley and Dacre, where woodlands three leagues in length and three in width are recorded. Underwood one league in length and one in breadth is noted at Kirkby Malzeard and half a league in length and four furlongs in breadth at Grewelthorpe (Gowland, 1938). There is no indication of the criteria used to distinguish underwood from woodland and as the exact significance of the linear measurements is not clear they cannot be converted into modern areal units. Twelfth and thirteenth century documents have records for extensive tracts of woodland in vills which at Domesday have no mention of trees, therefore it is clear that the record is incomplete.

Early in the twelfth century the lands in this area which had formerly been owned by Gospatric were granted to the Mowbray family.

FIG. I·9 NIDDERDALE IN THE ELEVENTH CENTURY

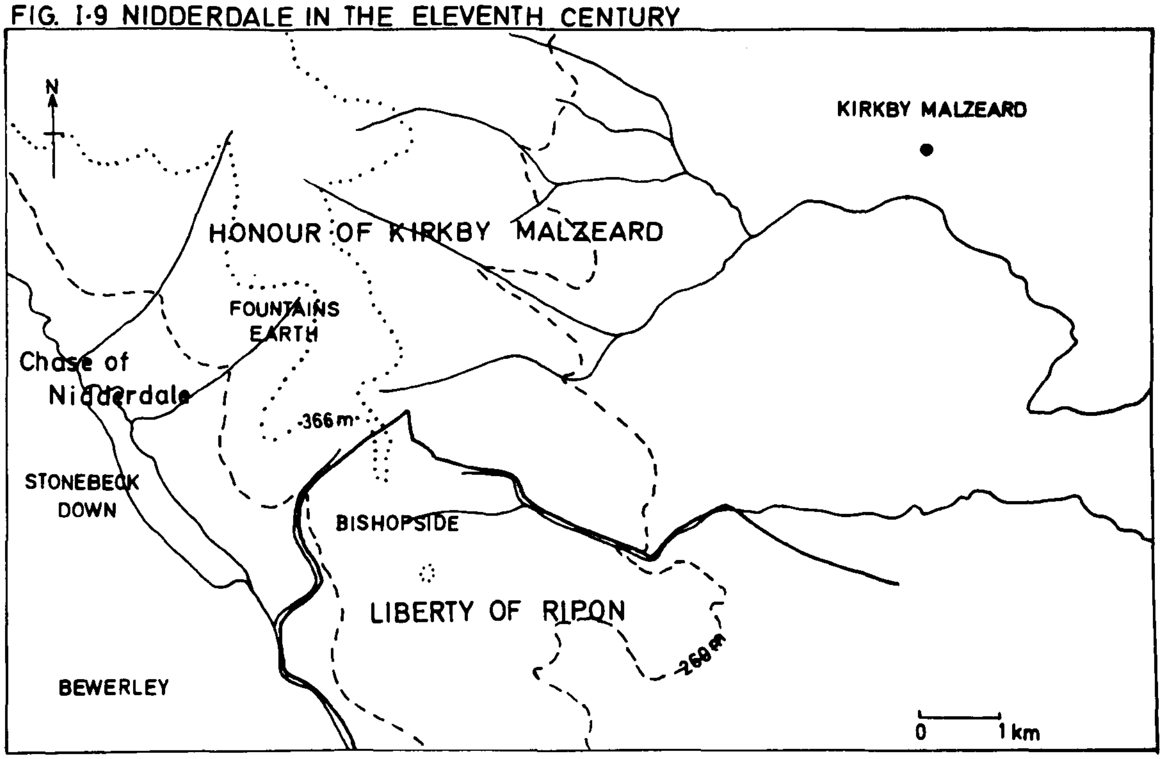
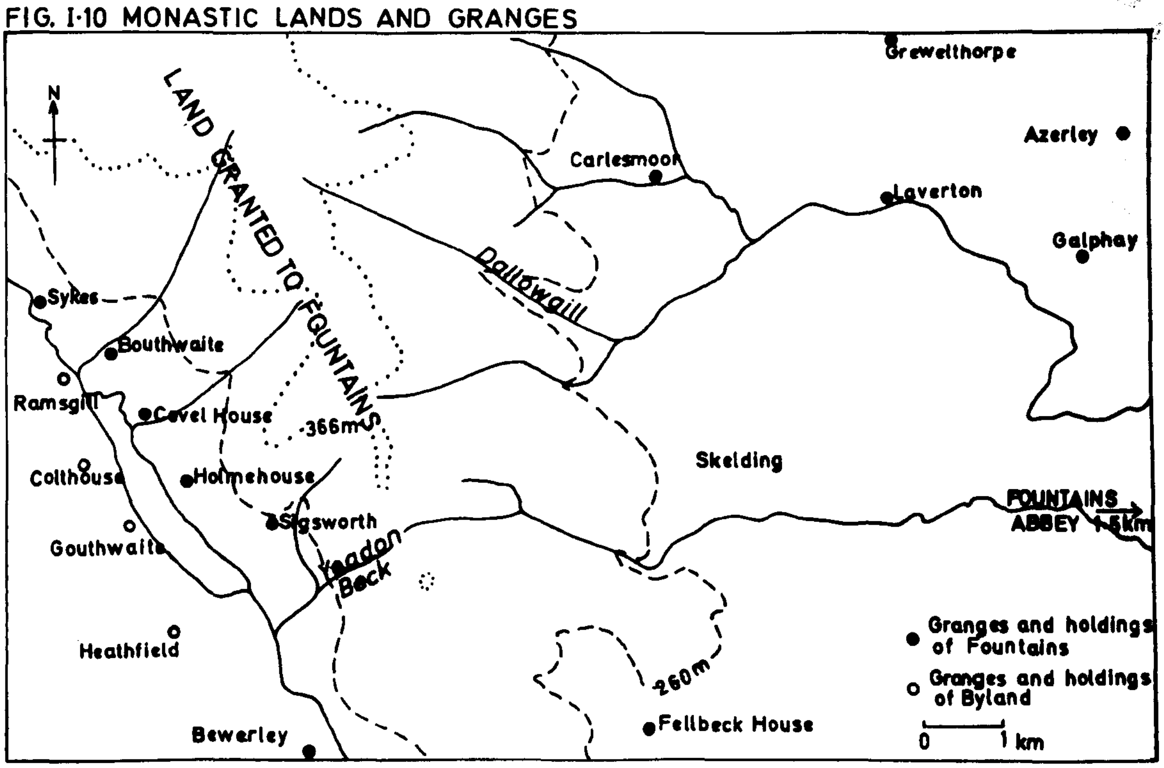


FIG. I·10 MONASTIC LANDS AND GRANGES



The Mowbrays became Lords of the Honour of Kirkby Malzeard which comprised the manor of Kirkby and various sub-manors and estates including the upper Nidd valley and its surrounding moors, known as the Chase of Nidderdale (Gowland, 1938). The Chase was a hunting area, one of a large number of hunting forests created in the Dales at this time, in which game rights were strictly controlled and agriculture not encouraged. Its creation may well have militated against the repopulation of the upper dale (Fig. I.9).

The re-establishment of agriculture in this area was largely due to monastic influence. After the Norman conquest increasing numbers of monks came to Britain to form religious communities. The Cistercians were particularly prominent in Yorkshire, establishing religious houses in isolated areas. In 1132 Fountains Abbey was founded on the lower Skell, a stream draining from the Nidd-Laver interfluve, on land granted by the Archbishop of York. Byland Abbey was founded in 1138, by the Mowbray family, on the edge of the Hambledon Hills about 40 kilometres from Fountains. Between them, these two Abbeys came to own almost all of upper Nidderdale, the surrounding moors and the land marginal to the moors on their eastern edge.

In the latter half of the twelfth century Roger de Mowbray granted the western side of upper Nidderdale and the moors to the north to Byland Abbey, in return for a fixed rent. In this area, which comprised the modern parishes of Stonebeck Up and Stonebeck Down, the monks had rights of pasture, and timber and mineral extraction. The Mowbray family retained the hunting rights and for this reason arable cultivation was not included in the charter (Jennings, 1967). Fountains Abbey received various small grants of land in lower Nidderdale but in 1175 Roger de Mowbray granted them a large area of upper Nidderdale to the east of the river and including the Nidd-Laver interfluve. The area involved is described as follows:

> "namely all Nidderdala on the east of the water from Iwdene (Yeadon Beck) upward along the Nidd as far as Beckermote, and all the wood of Lofthusum, and that wood of Poppleton, and from Beckermote as far as the moor and so to Frosildehau (Throstle Hill) and thence to Dalhagha (Dallowgill) and all Dalhagha downwards on either side as far as it extends, and thence across the moor towards Scheldene (Skelding) as far as the bounds of the Archbishop and thence to the west as far as Jwdene."
>
> (Lancaster, 1915)

Fountains also received land from de Mowbray to the west of the Nidd, south of Stonebeck Down, in Bewerley and they had the right to mine the valuable lead ores of this area. In later years they were also granted much land on the eastern margin of the Nidd-Laver interfluve, in Laverton, Carlesmoor, Grewelthorpe and Azerley (Lancaster, 1915).

There is evidence of widespread woodlands in the Nidderdale area at the time when the Abbeys first received their grants of land. The rights to timber are frequently mentioned in the charters, for example de Mowbray granted Fountains Abbey "dead wood in his forest of Kirkeby standing or lying whatsoever bears no leaf" and included rights to "a certain shrubbery in the territory of Lauverton." Woodland is mentioned in grants of land to the monks at Carlesmoor, Galphay and Grewelthorpe. In Nidderdale, woods are mentioned at Bewerley, Lofthouse, Poppletun (probably later Covel House Grange) and Backstone Beck (Lancaster, 1915).

As with the Domesday record the detail in these charters is insufficient to establish the areas or the exact positions of the woodlands mentioned; however, it seems likely that the woods chiefly occupied the steep valley sides in Nidderdale and the slopes below about 230 metres. There is no evidence to suggest that at this date there was woodland on any of the present moors. In some cases the status of the upland is obvious as rights of turbary are included in the grants of land at Grewelthorpe and Laverton.

The lands which were not subject to Cistercian control during the Middle Ages included those belonging to the Archbishop of York in the parish of High and Low Bishopside. Here continuity of settlement from pre-Domesday times is fairly well established (Jennings, 1967). The land was worked by small tenant farmers, a variety of crops was grown on open fields, and sheep, hogs and cattle were pastured on the common land of the moors.

During the latter part of the thirteenth and early fourteenth centuries the population of Nidderdale was increasing and much assarting of new land took place. This period of expansion came to an end in the mid fourteenth century when the Black Death ravaged West Yorkshire. There was a sudden reduction in population and a contraction in the area under cultivation. Raistrick and Jennings (1965) quoted a passage from the records of Ripon Cathedral for 1361: "some of the faithful of Christ of either sex have begun to inhabit the places of Dacre and Bewerley, formerly waste, a moor lacking human dwellings"; they suggested that this referred to a recovery of population after the Black Death which could be attributed to an expansion in monastic mining activities.

It is clear that there must have been very great reductions in the woods of this area during the thirteenth and early fourteenth centuries. Not only did the monks have the right to income from the sale of firewood but they utilised the timber for charcoal to smelt local lead ore. A thirteenth century agreement, relating to the Chase of Nidderdale, allowed the Abbot and Convent of Fountains to "burn charcoal within the said Chase from every kind of wood when and as they chose" (Lancaster, 1915). The thirteenth century was the time of the maximum demand for lead for monastic building and the mines near Pateley Bridge were extensively worked in this period. Early in the fourteenth century a forge at "Thoresdene" in the Forest of Knaresborough, south of the River Nidd, is recorded as having ceased production as the local timber supplies were exhausted (Jennings, 1967).

The monks created a series of large farms or granges (Fig. I,10) on their Nidderdale estates, under the management of lay brothers or tenants. The granges were spread at intervals along the dale and round the eastern margins of the moors. The agricultural system was almost entirely pastoral, much of the valley being devoted to cattle, though small areas were used for corn at some of the granges (Donkin, 1962). Dairying and cattle breeding were the main occupations on the Fountains estate. The tenants or lay brothers acted as managers and they had to deliver a fixed quota of produce to the Abbey each year. An agreement of 1537 made between Robert Browne and the Abbot and Convent of Fountains appointed him as Keeper of Bouthwaite Grange in return for thirty stones of cheese, forty stones of butter and thirty calves to be delivered to the Abbey each year (Walbran, 1863). In 1496, according to Jennings (1967), the Fountains granges in Nidderdale supported 612 dairy cattle, 1,700 sheep and 380 steers and bullocks. The sheep may have been pastured on the moors in the spring but were then driven to richer pastures on the limestone of the Craven estate; the steers and bullocks spent the summer on the Nidderdale moors. A form of transhumance may have been practised between upland and lowland granges. Donkin (1962) suggested that the granges of Cayton and Brimham were linked for this purpose.

The post-monastic period. The dissolution of the monasteries in 1539 resulted in profound changes in the social organisation of those areas which had been controlled by the Cistercians. The lands belonging to Byland in upper Nidderdale were bought by Sir John Yorke and the Fountains estate by Sir Richard Gresham. The Gresham estate was soon divided and sold; many farms in Fountains Earth passed to the occupying tenants. In the Kirkby Malzeard area, where much of the land became the property of the Earls of Derby, many long leases were granted (Gowland, 1938). Thus during the late sixteenth century a group of independent yeoman farmers worked the land marginal to the moors.

During the following century the population of these areas increased, open arable fields in the valley bottoms were enclosed, and pressure on the cultivated land resulted in increasing numbers of intakes being made from the common pastures. Cattle were the main source of income during this period. The flocks of sheep were generally small, except in upper Nidderdale, and arable crops were grown only for local use. The cultivation of hemp and flax became increasingly important during the seventeenth century, providing the raw materials for the local cottage textile industry. The production of linen was largely concentrated in lower Nidderdale, though it was also important in Bishopside and Bewerley (Jennings, 1967). The development of lead mining contributed to the prosperity of upper Nidderdale during this period.

A valuation of the woods belonging to the Fountains estate at the time of the Dissolution suggested that along the eastern side of upper Nidderdale only patches of scrubby oak woodland, similar to that of the present day, remained. An entry recorded "brushey wood and underwood worth10 shillings a year at the granges of Calfhouse (Covel House), Westholme house, Eastholme house and Sixforth (Sigsworth)". At Dacre and Fellbeck more extensive woods must have remained for these were valued at £30 per year (Walbran, 1863). There was no mention of woods at Lofthouse or Bouthwaite, or on the eastern margins of the Nidd-Laver interfluve and presumably any stands in these areas were small and of little economic importance; therefore they were not included in the survey.

The woods in the region of Fellbeck and Dacre were probably greatly reduced in the late sixteenth and the seventeenth centuries as the demand for charcoal increased with the expansion of lead mining. Much local timber must have been consumed before peat was adopted as a fuel in the mid-eighteenth century (Raistrick and Jennings, 1965). Since this period the amount of woodland in the area has probably remained fairly static.

During the eighteenth century population and prosperity increased in the area around the Nidd-Laver interfluve. Large-scale, organised linen and wool production replaced the cottage industries and from this a mechanised textile industry, based on water power, developed during the nineteenth century. A chain of flax and cotton mills grew up between Dacre and Pateley Bridge during this period. Increasing numbers were employed in the mines and technological improvements resulted in increased output. Dairy farming provided the chief source of agricultural income owing to the need to supply the greatly increased industrial population. This period also saw a gradual expansion in the area of improved land; large parts of the commons marginal to the moors were enclosed by Act of Parliament or private agreement. However, it is clear from comments made by Robert Brown, in a survey of the agriculture of the West Riding in 1799, that attempts to improve the moors were considered futile:

> "The quantity of waste is diminishing every day as enclosure bills are frequently passed for that purpose, but still a great deal remains to be done. There are many parts of these wastes capable of great improvement if divided and inclosed. But far the greatest part would not repay the expense of inclosing."
>
> (Brown, 1799)

Despite the introduction of hardier strains of sheep to the Nidderdale moors in the eighteenth century, it is clear from further comments made by Brown that there had been little rational use of upland pasture since the ending of the monastic system:

> "the kind of sheep bred are the most miserable that can be imagined. As they generally belong to poor people and are mostly in small lots, they can never be improved, the number that are put on the commons that are not stinted beggar and starve the whole flock."
>
> (Brown, 1799)

At this period it was estimated that two or three acres (approximately 1 hectare) of moorland were needed to support one sheep. However, towards the end of the nineteenth century there was a marked intensification in grazing on the moors owing to an increasing demand for meat. Lucas, writing in 1872, described the Nidderdale moors as "one large grazing field, vast flocks of sheep are reared on the moor and sheep gates, or the right to turn sheep on to the moors, are let in specified numbers with each farm, and now it is difficult to get gates, though 30 years ago there were not sheep in the dale to stock the moors" (Lucas, 1872).

At the end of the nineteenth century the population of Nidderdale and the surrounding area began to decline. A depression in the lead industry caused the abandonment of many mines between 1880 and 1882 (Raistrick and Jennings, 1965). A contraction in the linen industry took place in the mid nineteenth century and an agricultural depression resulted in a decline in the acreage of arable land and a reduction in the numbers of farms on the more marginal land (Lucas, 1872). It was during this period that it became more profitable for landlords to let shooting rights on the moors than to keep the land for pasture (Jennings, 1967).

During the twentieth century the contraction in upland farms has continued and many deserted farmsteads near the limit of enclosed land testify to a former, more intensive, utilisation of the moors. The Nidd-Laver interfluve is now carefully managed to maintain a good sward of ling for the grouse. The tenant farmers are strictly limited in the numbers of animals which they are allowed to put on the land; this at present maintains about 1,300 sheep to 400 hectares. Leeds Corporation have recently planted large stands of conifers in the valleys of North Gill Beck and Carlesmoor Beck, and on the western edge of the interfluve overlooking the Nidd valley.

The history of this area provides the background against which changes in vegetation and land use must be viewed. From the available evidence it appears that the major impact on the former upland woodlands came at an undetermined time prior to the historic period. The reduction in woodland at lower altitudes along the valley sides has been primarily in response to the demand for charcoal for lead smelting and also to increased grazing pressures. The main phase of exploitation of timber during historic time was associated with the monastic period.

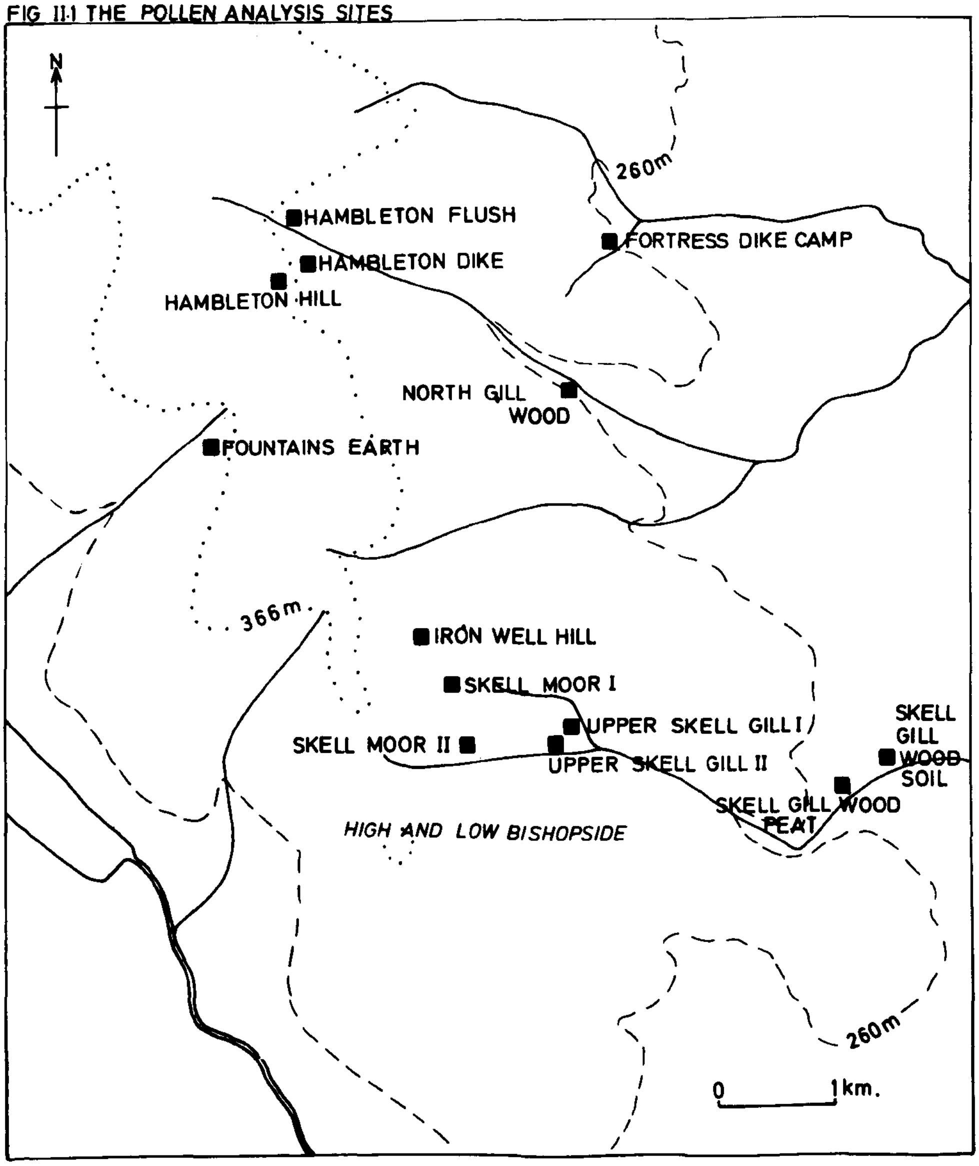
SECTION II THE POLLEN PROFILES

II.i. The choice of the sampling sites

Peat cover on the Nidderdale moors is extensive and within the study area a variety of peat types have been identified. The most wide-spread are the thin highly humified peats between 20 and 30 centimetres deep, which extend over the whole upland. Deep topogenous peat has accumulated in the sub-glacial meltwater channel at Fountains Earth and at the heads of some of the valleys shallower topogenous peat has formed. Rapidly accumulating flush peats commonly occur along the valley bottoms and at some sites where springs rise flush peats have developed on the open moors. Pollen analytical investigations have included each of these peat types, and in addition the soil pollen record has been examined at two sites.

Initially sites were chosen in the upper catchments of two streams dissecting the upland, Skell Gill and North Gill Beck (Fig. II.1). In both cases sites were investigated on the open moorland, in the upper reaches of the valleys, and within existing woodland in the lower parts of the valleys. Subsequently sediments at Iron Well Hill and the topogenous peat at Fountains Earth were sampled as it was anticipated that the pollen record at the base of these sites might be considerably older than the record at other sites on the interfluve. Pollen analysis has also been carried out on peat and buried soil associated with an earthwork on Carlesmoor, to determine whether occupation of this site had any marked effect on woodland decline. The thirteen pollen analysis sites were chosen with a view to providing detailed information on changes in the limits of former woodlands. The sites were concentrated in an area 6.5 kilometres square and varied in aspect and altitude.

FIG II.1 THE POLLEN ANALYSIS SITES



These sites fall into two distinct groups on the basis of the tenurial history of the surrounding land. The sites on the southern part of the Nidd-Laver interfluve are on the boundary of the parish of High and Low Bishopside where, since the Dark Ages, the land has been held by smallholders, tenants of the Archbishop of York (Figure II.1). The sites on the northern part of the interfluve are on land which passed into the hands of Fountains Abbey in the eleventh century and was managed for over 500 years as part of a large monastic estate. It was hoped that differences in land management since the Dark Ages might be reflected in the pollen records from the two groups of sites.

II.ii. The sampling sites

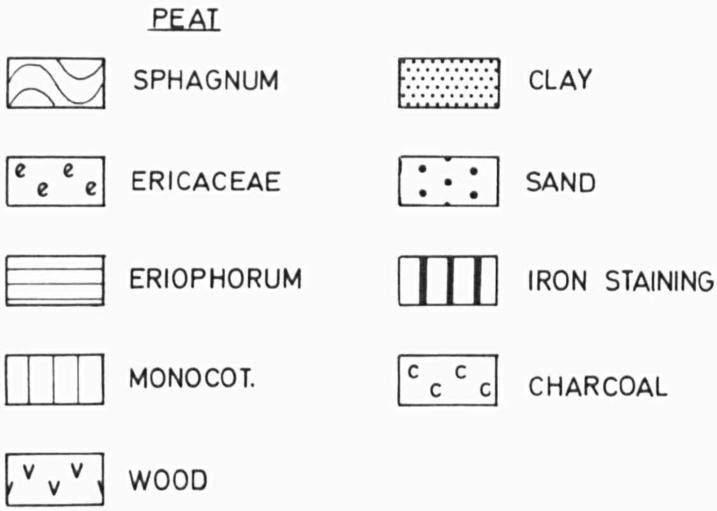
At each site the extent and nature of the deposit was noted. Observations were made on peat type and stratigraphy in the field and these were supplemented by a brief laboratory survey of the principal macroscopic remains in the peat from each sampling site. Macroscopic remains could not be recognised in the thin peats owing to their high humification. At a number of sites peat formed from the remains of Gramineae, Juncaceae and Cyperaceae was identified, but the chief peat forming constituents could not be distinguished. In these cases this is referred to as undifferentiated monocotyledonous peat. The examination of the macroscopic remains was not intended to provide a detailed record of vegetation succession but merely to indicate the depositional context of each deposit. The stratigraphy for each site is represented in a column at the left hand side of the appropriate pollen diagram. A key to the stratigraphic symbols used is given in Figure II.2.

II.ii.a. Fountains Earth. SE 15197238. Altitude 365 metres

(Deep topogenous peat)

On Fountains Earth peat has filled a sub-glacial meltwater channel which links the headwaters of North Gill Beck and Byerbeck Gill (Fig. II.3). The channel is about 100 metres wide and 4.5 metres of peat have formed in its deepest part. On the southern margin the sandstone ridge of Kettlestang Hill rises steeply, but to the north the land rises more gently and extensive patches of flush peat less than a metre deep border the channel (Fig. II.4 and Fig. II.5).

FIG II.2 STRATIGRAPHIC SYMBOLS



The closer the symbols the greater the humification

FIG.II.3 FOUNTAINS EARTH POLLEN ANALYSIS SITE.

FIG II.4 FOUNTAINS EARTH

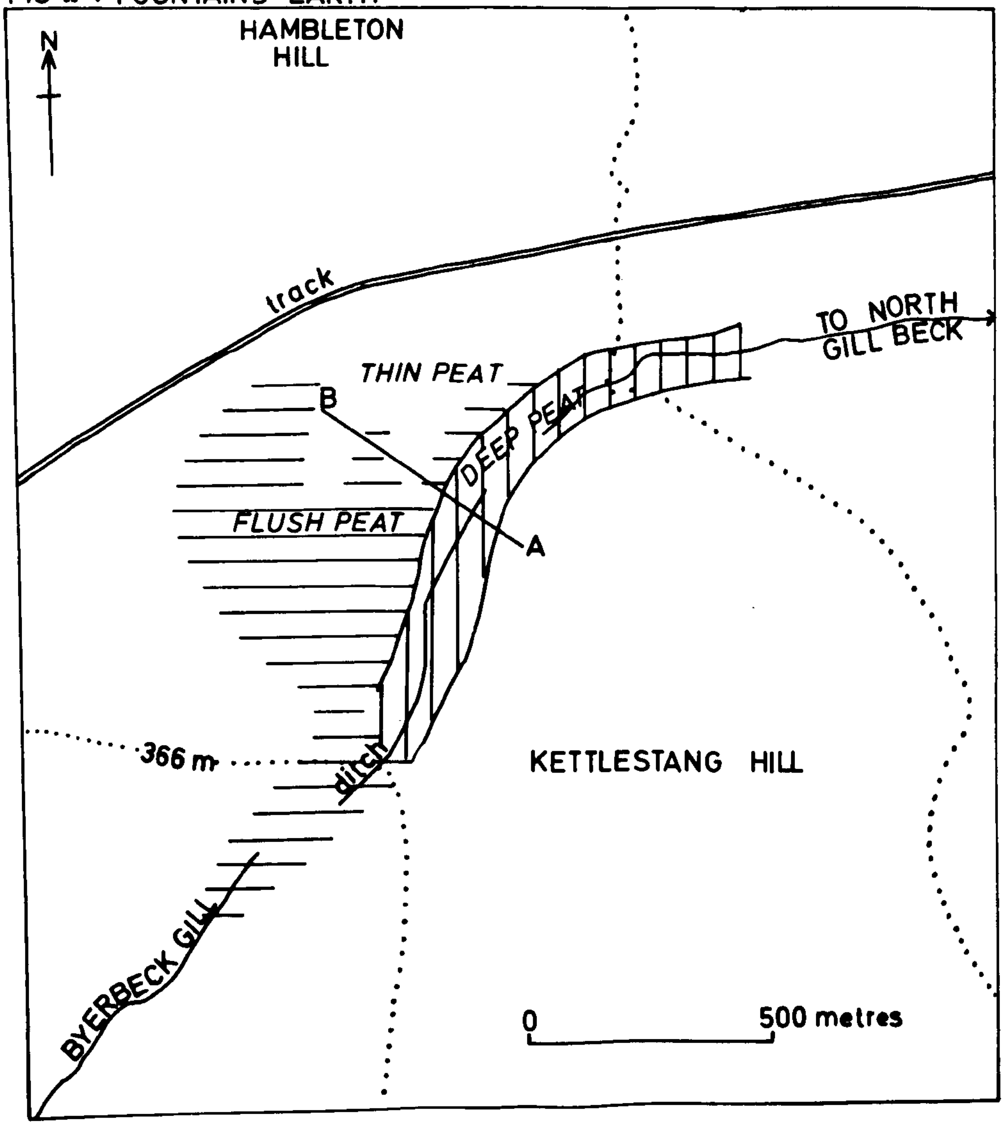
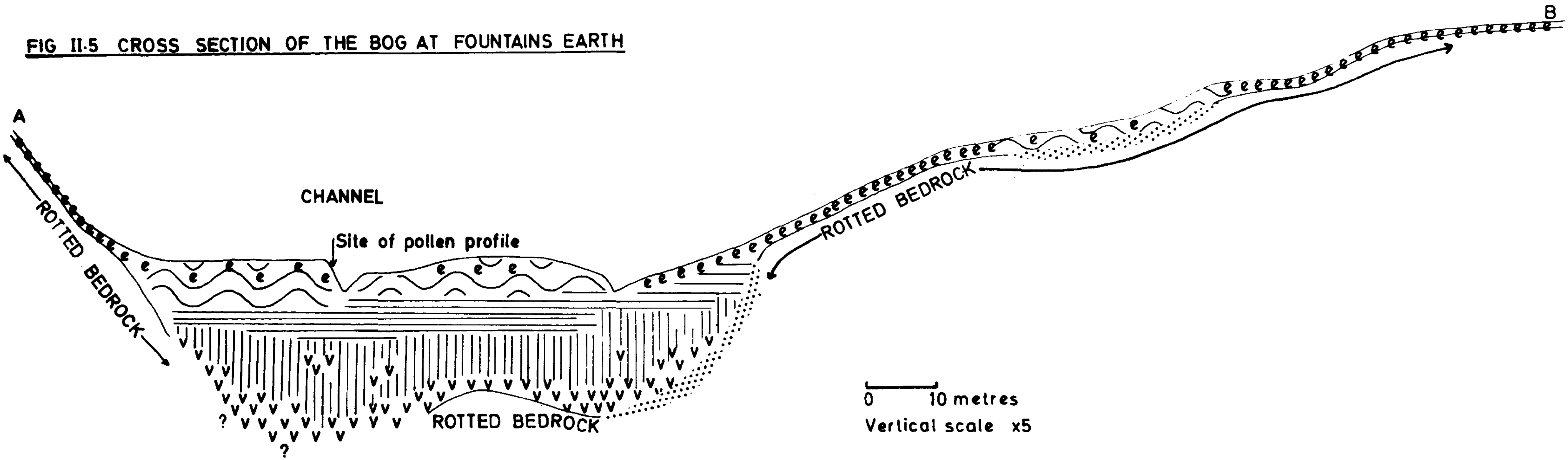


FIG II·5 CROSS SECTION OF THE BOG AT FOUNTAINS EARTH



The surface vegetation of the bog is dominated by Juncus effusus and Sphagnum spp. with occasional clumps of Erica tetralix and Eriophorum vaginatum. The main natural drainage is to the west towards Byerbeck Gill; in addition ditches have been cut into the surface layers of peat to partially drain the deeper part of the bog; these may date from the enclosure of Fountains Earth in 1855. Probably as a result of this drainage the upper peat has dried out and in some areas Calluna vulgaris and Empetrum nigrum have invaded.

The overall stratigraphy of the bog was determined by a series of borings which were made at 10 metre intervals along the line A - B in Figure II.4. The peat is underlain in places by heavily gleyed blue clay over 30 cm deep, containing occasional wood remains. In no case did the borer penetrate through the clay to the parent rock. At the point where the peat was deepest the borer would not penetrate below 420 cm and the junction of the peat with the mineral substratum was not reached, though smears of clay were detected on the head of the borer. The possible origins of this clay were discussed in Section I.ii.b. In places on the north side of the basin, a layer of coarse brown sand 10-20 cm thick and containing small pebbles separates the base of the peat from the clay. This was interpreted as wash material deposited prior to peat growth.

A layer of wood peat with abundant remains of Betula and Alnus overlies the mineral material in the channel. Above this there is a layer of well humified monocotyledonous peat, the upper part containing abundant remains of Eriophorum. Towards the surface Sphagnum remains are common; the upper peat is almost pure Sphagnum, though in the drier parts of the bog Calluna fragments are also present.

The stratigraphy at the site chosen for pollen analysis is described below:

0 - 50 cm	Well humified dark brown Sphagnum peat, partly oxidised; Calluna fragments abundant; fruits of Juncus effusus at 10 cm; charcoal fragments common in surface layers.
50 - 108 cm	Fairly well humified dark brown Sphagnum peat with occasional fragments of Calluna.
108 - 200 cm	Well humified dark brown Eriophorum peat; wood and bark fragments 200 - 160 cm; occasional fruits of Juncus effusus.
200 - 250 cm	Well humified fibrous Eriophorum peat, red-brown in colour penetrated by black rootlets; occasional Sphagnum leaves, fruits of Carex rostrata, Juncus effusus and Betula; fragments of Calluna at 260 cm; an Alnus fruit at 240 cm.
250 - 300 cm	Very well humified brown monocotyledonous peat; fragments of Eriophorum and compressed wood.
300 - 320 cm	Wood peat formed predominantly of compressed fragments of Alnus and Betula; fruits of Alnus glutinosa common; occasional fruits of Juncus effusus.
320 - 380 cm	Very well humified monocotyledonous peat; fragments of compressed bark and wood common; occasional fruits of Betula, Carex rostrata and C. acutiformis; very small fragments of charcoal at 320 cm.
380 - 420 cm	Dark brown well humified wood peat; fragments of compressed bark and small twigs of Betula/Alnus type abundant throughout.

The abundance of wood fragments throughout the lower peat suggests that a damp woodland dominated by Betula and Alnus must have existed on this site for a long period during which peat was accumulating. This carr vegetation was later replaced by a bog community dominated by grasses and sedges. The occurrence of fruits of Alnus and Betula between 200 and 300 cm suggests that trees remained close to the site while this peat was forming. The last wood fragments were identified at 180 cm just after Sphagnum replaces Eriophorum as the principal constituent of the peat. The stratigraphy of the top 100 cm of peat suggests that during the formation of this peat the site was surrounded by vegetation similar to that at present covering Fountains Earth.

II.ii.b. Iron Well Hill. SE 17006990. Altitude 320 metres.

(Upland flush peat)

The name "Iron Well Hill" is applied to the eastern shoulder of Far High Hill, in an area where a number of springs bring iron-rich water to the surface. At the site of one of these springs deposits were examined with a view to pollen analysis. On the gently sloping hillside a hummock of Sphagnum peat 75 cm high and about 3.5 metres in diameter has formed. Water stained red by ferric iron drains downslope from the hummock. It is carpeted by Sphagnum spp. and supports clumps of Juncus effusus, a few plants of Cirsium palustre and tussocks of Molinia caerulea, a species which can tolerate a high iron supply (Pearsall, 1950).

A pit 182 cm deep was excavated in one side of the hummock; the exposed profile was completely waterlogged and rapidly rising water precluded detailed examination or sampling. At this site a metre of pale brown Sphagnum peat overlies the mineral substratum. The upper 25 cm of peat are heavily stained by ferric iron, but below this the peat is a uniform mid-brown with only occasional red mottles. Towards the base of the peat fragments of Betula wood were observed. The peat is underlain by 82 cm of fine, stoneless grey clay containing abundant wood fragments, apparently of Betula/Alnus type although poor preservation of the wood made identification difficult. A fragment of a hazel nut was recovered from the clay at 150 cm. A layer of rounded gritstone pebbles, up to 10 cm in diameter, was observed at the base of the pit.

The wood within the grey clay apparently represents the remains of in situ rooting systems of trees which occupied this site prior to the development of peat. The anomalous occurrence of a hazel nut well below the junction of the clay with the overlying peat may be due to channel formation and disturbance of the profile by the spring water. The lack of any surviving soil horizons in the clay can be attributed to heavy gleying at this continuously waterlogged site.

II.ii.c. Skell Moor I. SE 17216962. Altitude 320 metres.
Skell Moor II. SE 17506941. Altitude 305 metres.
Hambleton Hill. SE 15027330. Altitude 381 metres.
(Thin moorland peat)

The thin peats which blanket much of the upland have been examined at three sites on the exposed summit of the interfluve. At these sites the surface vegetation is dominated by Calluna vulgaris with few associates. In all cases the peat is highly humified and amorphous; few plant remains other than fragments of Calluna can be identified. The peat is dry to the touch and has a high mineral content consisting of fairly large sub-angular quartz grains. At the Skell sites, 20 - 25 cm of peat has developed over a layer of pinkish-brown sand 10 cm deep which merges with the weathering Millstone Grit. A layer of compressed Betula bark occurs at the base of the peat at both sites. At the Hambleton Hill site (Figs. II.6, II.8) 15 cm of peat has developed. The sub-peat material consists of 30 cm of stoney grey clay with orange mottles; this overlies angular blocks of weathering Millstone Grit.

II.ii.d. Hambleton Dike. SE 15177342. Altitude 366 metres
(Shallow topogenous peat)

The eastern slopes of Hambleton Hill are covered with thin peat but at the side of the stream known as Hambleton Dike a small deposit of topogenous peat has formed in a channel about 35 metres wide. A gully through the deposit takes water down into the dike and about two metres of peat are exposed containing abundant wood remains of Alnus/ Betula. Large branches up to 10 cm in diameter and some complete tree stumps are visible in this section (Fig. II.7). The surface vegetation of the whole hillside is an almost pure sward of Calluna vulgaris.

Borings revealed that the channel was steep-sided (Fig. II.8), like that at Fountains Earth, though on a smaller scale. It is possible that the Hambleton Dike channel is also the result of the action of sub-glacial meltwater. The peat filling the channel has accumulated on top of a layer of grey clay which can be seen in the exposed section. The bulk of the deposit is a pale brown monocotyledonous peat in which wood remains are abundant. There is a marked change between 15 and 30 cm where this is overlaid by black, partly oxidised Calluna peat.

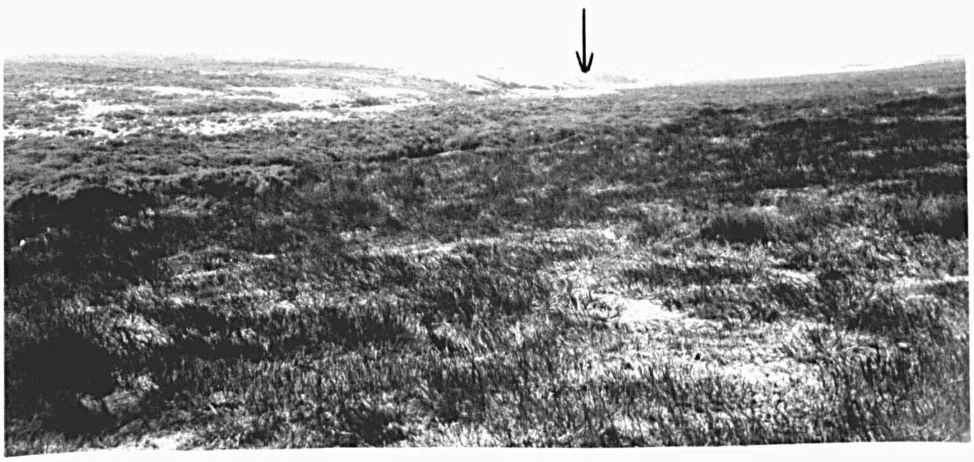
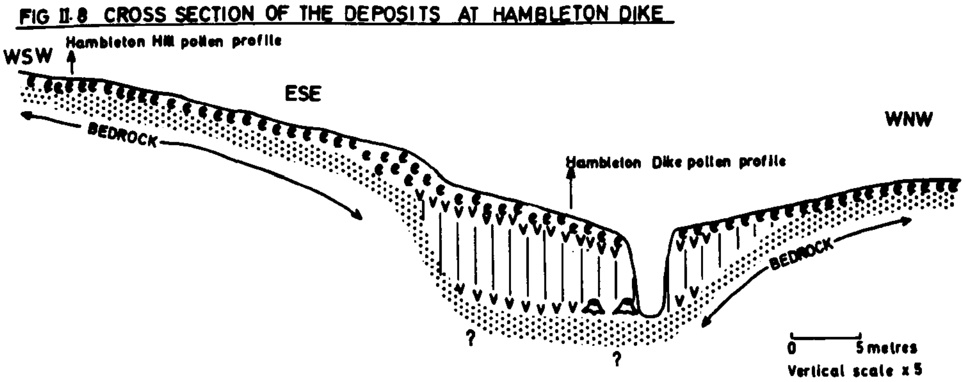


FIG.II.6 HAMBLETON HILL. POLLEN ANALYSIS SITE.

FIG.II.7 PEAT FACE. HAMBLETON DIKE.

FIG II.8 CROSS SECTION OF THE DEPOSITS AT HAMBLETON DIKE



A site was chosen for pollen analysis away from the edge of the gully and the stratigraphy at this point is as follows:

0 - 18 cm	Highly humified black Calluna peat, partly oxidised towards the surface; stems and flowers of Calluna vulgaris abundant; occasional fruits of Juncus effusus; charcoal fragments throughout.
18 - 32 cm	Dark brown very well humified wood peat; bark and wood of Betula abundant; fruits of Juncus effusus throughout.
32 - 78 cm	Pale brown earthy monocotyledonous peat, well humified; fruits of Juncus effusus common; abundant fragments of wood and bark in some cases carbonised; fruit of Betula at 73 cm and of Alnus at 53 cm. Occasional moss leaves of Grimmia type; small fragments of shale and quartz throughout.

The frequency of wood remains in the peat below 21 cm suggests that Alnus/Betula carr occupied this site prior to the formation of the Calluna peat. The very sharp nature of the contact between the wood peat and the Calluna peat suggests that there may be a hiatus at this level.

II.ii.e. Upper Skell Gill I. SE 17726930. Altitude 290 metres

(Shallow topogenous peat)

At this site peat has accumulated to a depth of about 1.5 metres at the head of the Skell valley where the two streams which form Skell Gill converge (Fig. II.9). The bog is colonised by species of Sphagnum with clumps of Juncus effusus; Erica tetralix and Drosera rotundifolia are found on the dampest parts and Calluna vulgaris has spread on to the drier areas.

FIG II.9 UPPER SKELL GILL BOG

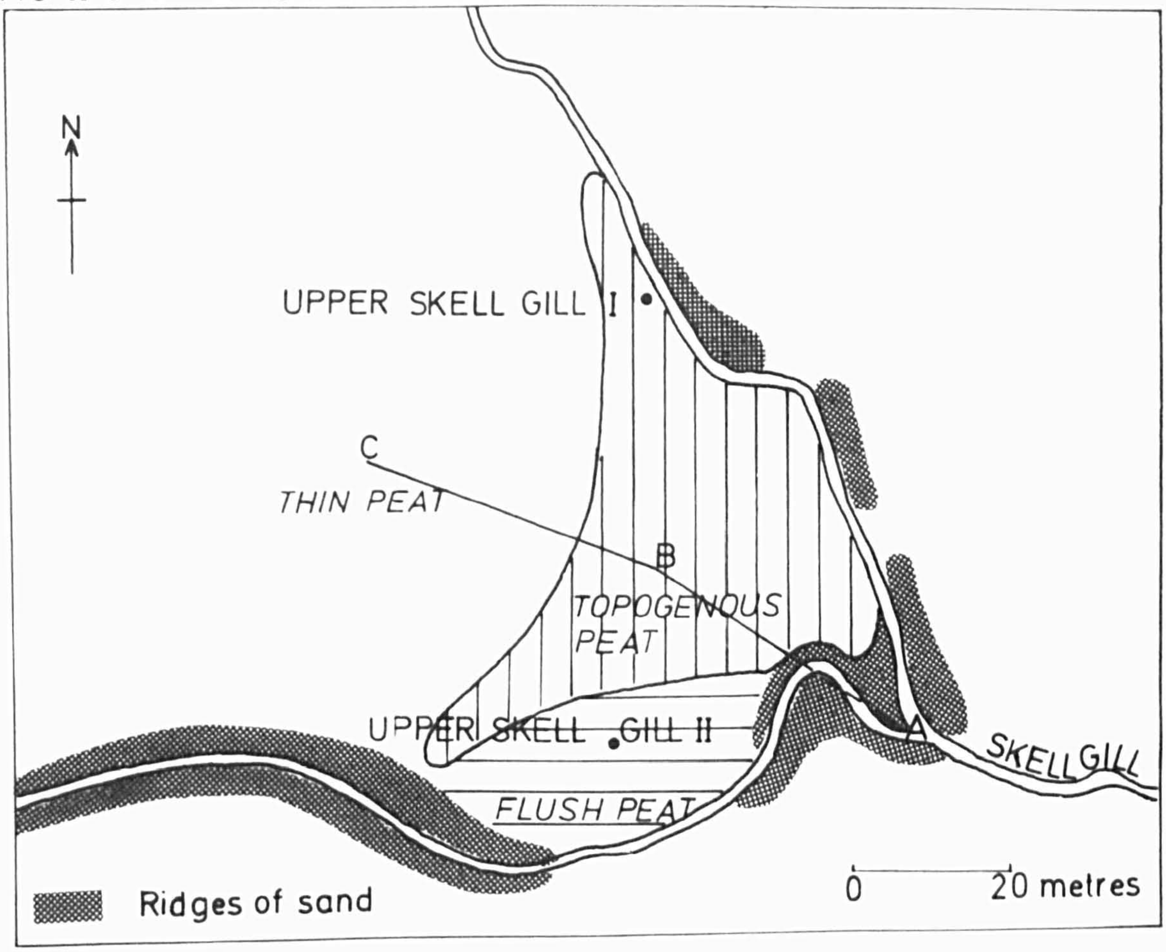


FIG II.10 CROSS SECTION OF UPPER SKELL GILL BOG

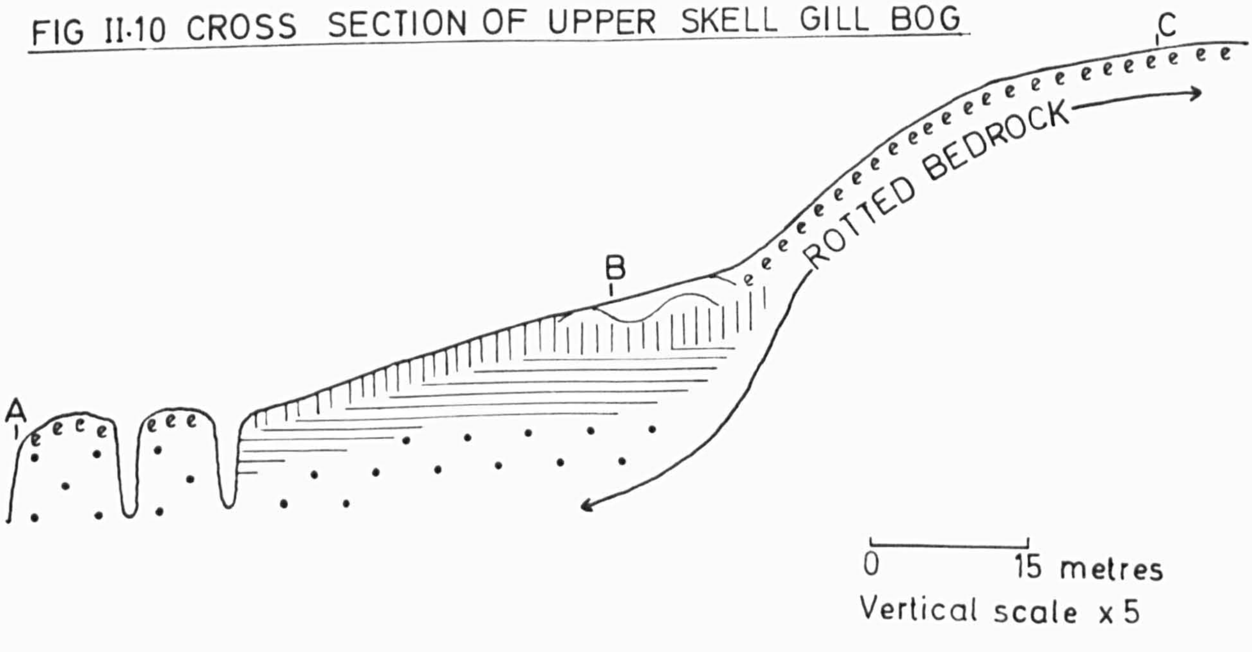


FIG.II.11 PEAT FACE. UPPER SKELL GILL I.

Augering along the traverse A - B - C (Fig. II.9) revealed that the bog has developed in a hollow formed between the valley sides and banks of sandy alluvial material deposited by the two streams (Fig. II.10). The peat has accumulated either directly over the weathering Millstone Grit, or over gravelly material of alluvial origin. The southern stream appears to have changed course since the development of the bog and rapidly accumulating flush peat has filled the abandoned channels. On the northern margin the stream has exposed a face of peat just less than two metres deep with gritstone pebbles in a clay matrix at its base. A layer of wood of Alnus/Betula type occurs at the junction of the peat with the mineral substratum (Fig. II.11).

The stratigraphy at the first site chosen for pollen analysis is described below:

0 - 8 cm	Well humified black monocotyledonous peat with a high silt content; fragments of carbonised Calluna wood and fruits of Juncus effusus common; abundant fragments of charcoal and sub-angular quartz grains.
8 - 14 cm	Well humified reddish-brown Eriophorum peat; a fruit of Betula at 12 cm; fruits of Juncus effusus common.
14 - 23 cm	Well humified black Eriophorum peat with a high silt content; fruit of Betula at 18 cm; charcoal fragments abundant throughout.
23 - 65 cm	Poorly humified red-brown Eriophorum peat; fruits of Juncus spp. throughout; fruits of Carex echinata at 35 cm.
65 - 103 cm	Well humified dark brown Eriophorum peat; fruits of Carex echinata and Juncus bulbosus throughout. Occasional small charcoal fragments.

103 - 132 cm Very well humified earthy monocotyledonous peat; Eriophorum fibres in the upper 15 cm; fragments of Betula bark and leaves abundant towards the base; occasional fruits of Carex spp. and Juncus spp.; Juncus articulatus fruit at 180 cm; leaves of Sphagnum palustre and fruits of Molinia caerulea at the base.

132 - 140 cm Wood of Betula/Alnus type - apparently an in situ rooting system.

Prior to the development of peat at this site carr vegetation appears to have occupied a damp hollow at the head of the Skell valley. Soon after the initiation of peat growth, Eriophorum spread on to the site, and remains of this plant form the bulk of the deposit. The presence of Betula fruits at 12 cm and 18 cm suggests that trees may have grown close to this bog throughout most of the period of peat formation. The concentration of charcoal in the upper 8 cm of peat and between 14 and 23 cm must reflect large scale burning, probably initiated by man.

II.ii.f. Upper Skell Gill II. SE 17726913. Altitude 290 metres.

(Valley flush peat)

Rapidly accumulating flush peats occur in the valleys of the Skell and North Gill Beck, in most cases occupying the sites of abandoned meanders. Their occurrence appears to be related in part to the seepage of water from shale beds which are exposed at intervals along both valleys (Fig. I.3). In some cases water flowing into these flushes has deposited ferric salts both within the peat and on its surface. The flushes are colonised by a variety of species of Sphagnum with clumps of Juncus effusus. Four of these flushes at differing altitudes were chosen for pollen analysis.

The Upper Skell Gill II site is on the southern margin of the topogenous bog previously described at the head of the Skell valley (Fig. II.9). Sphagnum peat has accumulated on a pebbly substratum during a phase of rapid regrowth of the bog following stream erosion. The former stream channel has been completely infilled up to the level of the surrounding bog surface. The stratigraphy at the site chosen for pollen analysis is as follows:

0 - 8 cm	Fresh Sphagnum cuspidatum and Polytrichum commune with occasional Calluna leaves.
8 - 25 cm	Partly humified Sphagnum cuspidatum and S. recurvum.
25 - 80 cm	Moderately humified Sphagnum peat, stained red by ferric iron deposition; fruits of Juncus articulatus and Molinia caerulea; occasional charcoal fragments.
80 - 99 cm	Partly humified yellow-brown Sphagnum peat; leaves of S. cuspidatum and S. compactum identified. Fragments of Alnus/Betula type wood.

The wood fragments at the base of the peat suggest trees must have been growing close to the site when the peat began to develop. However, the bulk of the peat has formed from plants similar to those occupying the site at the present day.

II.ii.g. Hambleton Flush. SE 15057350. Altitude 366 metres (Valley flush peat)

88 cm of moderately humified Sphagnum peat have accumulated in the valley of Hambleton Dike in a hollow about 90 metres long formed by an abandoned meander (Fig. II.12). The stratigraphy at the pollen analysis site is described below:

FIG II.12 CROSS SECTION OF HAMBLETON FLUSH

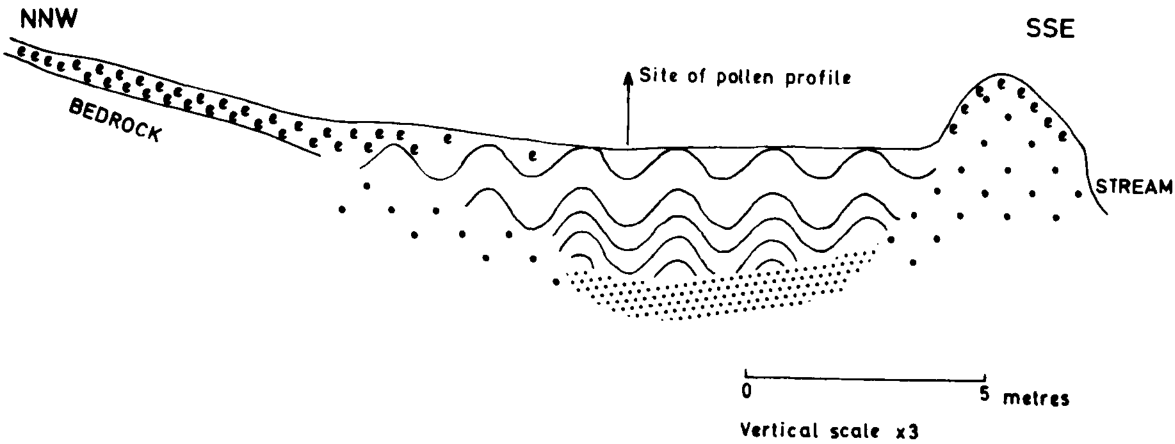
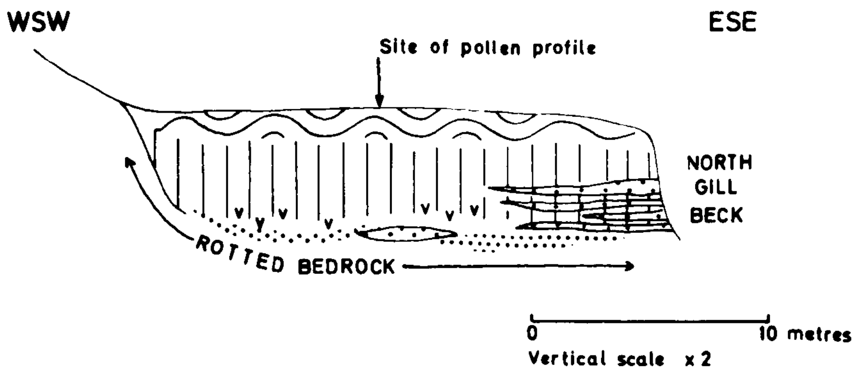


FIG II.13 CROSS SECTION OF THE BOG AT NORTH GILL WOOD



0 - 36 cm Very dark brown partially humified Sphagnum peat, the colour apparently due to abundant charcoal fragments; stems and flowers of Calluna vulgaris.

36 - 50 cm Partially humified Sphagnum peat; occasional fruits of Carex rostrata.

50 - 88 cm Moderately humified Sphagnum peat with a high clay content and occasional fruits of Carex rostrata.

88 - 100 cm Grey clay mottled with orange; charcoal fragments common and abundant unidentified organic remains.

The absence of wood fragments in the peat at this site is notable. There is no evidence that trees grew near Hambleton Flush during the period in which the peat has accumulated.

II.ii.h. Skell Gill Wood. SE 19536852. Altitude 229 metres.

(Valley flush peat)

At this site a peaty flush has developed in a depression about 30 metres wide on the side of the Skell valley. The flushed area is colonised mainly by Juncus effusus and species of Sphagnum and it is surrounded by Quercus petraea woodland with Pteridium aquilinum dominant in the ground flora. Material was obtained for pollen analysis from the deepest part of the flush where 80 cm of peat has accumulated. The stratigraphy at this point is described below:

0 - 4 cm Fresh Sphagnum cuspidatum and S. plumulosum.

4 - 12 cm Partly humified yellow Sphagnum peat.

12 - 16 cm Coarse sub-angular bleached quartz grains.

16 - 40 cm Partially humified yellow-brown Sphagnum peat; leaves of S. recurvum identified; fruits of Juncus effusus; charcoal fragments throughout; occasional deposits of ferric salts causing red staining.

40 - 80 cm	Well humified brown Sphagnum peat; increasing percentage of angular quartz grains and silt particles towards the base; occasional wood and charcoal fragments.
80+ cm	Sandy material derived from weathering gritstone.

The nature of the peat suggests that this flush has accumulated quickly. The fairly high silt content throughout, and the sand lens between 12 and 16 cm, are probably due to the washing in of material from the moor above. The grains of sand are similar in shape to those which are sometimes washed out of eroding thin peat; small deposits of this sand occur frequently on the moors.

II.ii.i. North Gill Wood. SE 16727265. Altitude 267 metres.

(Valley flush peat)

This site is the largest and best developed of the valley flushes investigated. 180 cm of peat have accumulated in a hollow 22 metres by 60 metres at the side of North Gill Beck (Fig. II.13). Borings revealed that the peat had accumulated on a fairly level sandy surface, suggesting that this bog also occupies the site of an abandoned meander. North Gill Beck flows along the north-east edge of the bog and borings revealed successive layers of silt and sand in the marginal peat, indicating periods of flooding. These mineral lenses gradually diminished away from the river.

The flush forms a level area of open bog within the surrounding woodland (Fig. II.14). Well grown trees of Alnus glutinosa and Betula pubescens surround the bog, but the woodland as a whole is dominated by Quercus petraea. The surface is carpeted by species of Sphagnum,

FIG.II. 14 NORTH GILL WOOD.POLLEN ANALYSIS SITE.

S. cuspidatum and S. rubellum in particular, and tussocks of Polytrichum spp. and Juncus effusus also occur.

A site in the centre of the bog was chosen for pollen analysis and the stratigraphy at this point is described below:

0 - 10 cm	Fresh Sphagnum cuspidatum.
10 - 65 cm	Partially humified Sphagnum peat; leaves of S. cuspidatum identified; small fragments of Betula wood.
65 - 190 cm	Fairly well humified pale brown monocotyledonous peat; leaves of Sphagnum cuspidatum; fruits of Carex spp. and Gramineae seeds throughout; Betula wood, bark, cone scales and fruits becoming increasingly abundant towards the base; Calluna stem at 150 cm; Cerastium seed at 175 cm.
190 - 201 cm	Pinkish-brown sand derived from weathering Millstone Grit.

Initially the bog appears to have developed in a wooded environment; however, in the upper layers of peat no macro-remains of trees occur, despite the fact that the site is at present surrounded by woodland.

II.ii.j. Fortress Dike Camp. SE 17847322. Altitude 259 metres.
(Archaeological site)

Fortress Dike Camp is a rectangular enclosure on Carlesmoor formed by a ditch with an inner and outer rampart. The form of the earthwork suggests that it dates from the Iron Age or Romano-British period. Thin highly humified peat, averaging about 20 cm in depth, covers the banks and enclosure. In the ditch deeper, less well humified peat has accumulated. The thin peat is colonised by Calluna vulgaris, while on the damper sites in the ditches the vegetation is dominated by Sphagnum moss. A section through the inner mound revealed a buried soil surface and a series of samples was taken through this surface for pollen analysis. The ditch peat was also sampled for pollen analysis and its stratigraphy is described below:

0 - 6 cm	Calluna litter.
6 - 18 cm	Very well humified Calluna peat, penetrated by modern Calluna roots; abundant finely disseminated charcoal fragments; fruits of Juncus spp.; moss rhizoids.
18 - 27 cm	Well humified earthy Calluna peat; silt content high, numerous sub-angular quartz grains; occasional charcoal fragments.
27 - 37 cm	Well humified earthy Sphagnum peat; occasional fruits of Juncus spp.; fragments of Betula bark.
37 - 42 cm	Grey clay.
42 - 44 cm	Black earthy horizon of organic matter accumulation (Bh horizon).
44 - 46 cm	Red indurated horizon of iron accumulation (Bfe horizon).
46 - 49 cm	Black highly humified peat, no plant remains identifiable.
49+ cm	Saturated grey clay with yellow mottles.

The organic material between 46 and 49 cm must have accumulated some time after construction of the earthwork. The clay horizon above it may be due to erosion following abandonment of the site. The Bh and Bfe horizons are residual soil features, and iron pan having been intensified by continual gleying at this site. The presence of Betula macro-remains in the peat above 37 cm suggests that the site may have been wooded during the early stages of the ditch peat accumulation. Calluna remains occur above 27 cm indicating the presence of heath similar to that at present surrounding the site.

A complete description of Fortress Dike Camp and a full account of the investigations undertaken there is given in Appendix 4.

II.ii.k. Skell Gill Wood (Soil Pit). SE 19786881. Altitude 198 metres.

A soil pit was excavated and sampled for pollen analysis at this site on the steeply sloping side of the lower Skell valley. The soils of both the lower Skell and North Gill Beck are shallow acid brown earths. The ground flora at this site is dominated by *Pteridium aquilinum* with *Endymion non-scriptus* and the site is surrounded by *Quercus petraea*. The description of the soil profile is given below:

Horizon		
L	0 - 3 cm	Undecomposed bracken and oak leaf litter.
H	3 - 6 cm	Black humic horizon, low mineral content pH 5.25
A_1/B	6 - 30 cm	Fine crumb structure, very dark brown sandy loam pH 5.6
Bfe	30 - 32.5 cm	Pale yellow sandy horizon pH 5.75
C		Weathering Millstone Grit

The dark colour of the A_1/B horizon appeared to be due to the presence of finely divided charcoal in the soil profile. The colour persisted after treatment with potassium hydroxide for the removal of humus, followed by oxidation with concentrated sulphuric acid and acetic anhydride for the removal of cellulose. However, after ignition the dark colour disappeared revealing a uniformly reddish horizon (Fig. I.5). The charcoal within this profile may have resulted from the use of fire for clearing woodland around this site at some time in the past. However, it is more likely to have been washed down and incorporated within the profile following firing of the moors above the Skell valley.

II.iii. Construction and zonation of the pollen diagrams

Pollen diagrams have been constructed for each of the sites described. The field and laboratory techniques involved are outlined in Appendix 1. In almost all cases the pollen diagrams are based on a count of at least 500 pollen grains, excluding spores. The results are expressed as percentages of total pollen. In a very few samples pollen was so scarce as to make counting to this total impractical; the actual totals counted for each sample are given in Appendix 5. The use of diagrams based on a total pollen sum, rather than on an arboreal pollen sum, was considered appropriate in this study, as it is concerned with the changing relationships between cleared and wooded land (Mitchell, 1965). However, for three sites the results have also been expressed as percentages of tree pollen, in order to indicate regional changes in woodland composition. These tree pollen diagrams also provide a means of comparison with the data of other workers. For this purpose at least 150 grains of tree pollen, excluding shrubs, were counted for each sample. In the upper parts of the peat at most sites tree pollen was very scarce and a considerable amount of labour was required to reach this total; therefore fewer samples have been included in the tree pollen diagrams than in the corresponding total pollen diagrams. The tree pollen diagrams are presented in an abbreviated form with only the arboreal components included as the interpretation is based largely on the total pollen diagrams.

The diagrams have been constructed with reference to the suggestions of Faegri and Iversen (1964). Each taxa is represented by a histogram and all taxa included in the pollen sum are shown as solid bars. Those excluded from the sum are usually shown as open bars; however, in certain diagrams this is impractical owing to the scale, and in these cases excluded taxa have been bracketed together. The stratigraphy at each site is shown in a column on the left hand side of each diagram, beside a summary of the variation in the tree, shrub and herb components at each level. The distinction between trees and shrubs follows the standard practice in pollen analysis; Corylus, Ilex and Salix spp. are grouped as shrubs and are excluded from the tree pollen sum. However, in an upland environment, the distinction between trees and shrubs is somewhat arbitrary. In the Pennine gills Ilex aquifolium in particular may form well grown trees of equal status to Quercus petraea or Betula pubescens.

Changes in the values of Ulmus and Plantago lanceolata pollen were considered to be particularly significant for the zonation of the pollen diagrams. As these taxa are present at low frequencies, their values on the diagrams have been over-plotted at a scale of x10. Where pollen of a certain taxa is present at less than 1% of total pollen this is indicated in the diagrams by a dot. The "Varia" histogram, found in certain of the diagrams, is made up of a number of taxa encountered very infrequently; tables of the composition of these histograms are given in Appendix 6. The record for cereal pollen at each site consists of those grains of the Gramineae over 40μ in diameter. This size differentiation is based on data quoted by Faegri and Iversen (1964) for the minimum size of cereal pollen grains after pretreatment in potassium hydroxide.

Pollen which has been designated as Rumex acetosella type is present in significant quantities in most of the diagrams. These grains could be attributed to either Rumex acetosella or R. acetosa. Sorbus pollen has been recorded in low frequencies in most of the diagrams. It was distinguished from the pollen of other Rosaceae by careful reference to type slides. The grains identified as Sorbus are tricolporate and prolate, as are most Rosaceae grains but they lack an equatorial bulge, have a thin exine and very delicate striate sculpturing. Grains of this type were often found ruptured owing to the fragile nature of the exine. These features are also characteristic of Prunus pollen but it is unlikely that Prunus was ever represented significantly in the vegetation of this area.

It is significant to note at this point that the two pollen diagrams from Fortress Dike Camp archaeological site are slightly different in layout from all the other pollen diagrams.

•

Zonation involves the division of a pollen diagram into a series of horizons which are correlated with changes occurring in the relative proportions of the pollen of different species. It is essentially an instrument for the interpretation of pollen diagrams. The correspondence in vegetational development at a number of sites in the British Isles enabled a system of pollen zones to be devised (Godwin, 1956), based on the conception that the zone boundaries indicated synchronous climatic changes. This conventional British Pollen Zone scheme has not been used in this study, primarily because local similarities between sites were considered to be of greater significance in establishing the course of woodland decline than large scale regional correlations. In addition, at a number of sites the peat deposits have developed recently and the conventional system would have been too crude an instrument to aid in the interpretation of these diagrams.

Six zones, A - F, have been established on the basis of major changes in the dominance of individual species. These zones are of local significance only and are considered to be synchronous throughout the study area. The pollen assemblages characteristic of each zone differ in detail at some of the sites depending on aspect and altitude. The A/B boundary is drawn at the level where the Alnus curve rises and the values for Pinus decrease to less than 1% of total pollen. The B/C boundary occurs where Alnus values fall and the Betula curve rises. At the C/D boundary the Ericaceae curve rises abruptly for the first time to over 30% of total pollen at the most exposed sites, but rises more gradually at the valley sites. A decline in all the tree pollen curves is initiated at the sites on the summit of the interfluve. The D/E boundary is defined by a marked rise in the pollen of the Gramineae, while at the E/F boundary there is a second expansion of both the Ericaceae and the Gramineae and tree pollen is reduced to very low levels at all sites. The growth of the valley flush peats was initiated at this period.

The zones A - F are chronological but the complete sequence is not represented at any one site. However, the Fountains Earth diagram spans zones A - E and therefore provides a frame of reference in relation to which the other diagrams may be considered. Zone F is only represented in the rapidly accumulating flush peats and in the top few centimetres of peat at some of the sites on the summit of the interfluve.

Zones D, E and F are subdivided on the basis of changes in the frequency of the pollen of those species considered to be weeds of agriculture, and a series of agricultural phases followed by abandonment have been identified. The pollen record for Plantago lanceolata was considered most significant for the establishment of these phases. The importance of _P. lanceolata_ was first recognised by Iversen (1941), who identified clearance or "Landnam" phases just after the opening of the Sub-Boreal period in a number of Danish diagrams. The phases were defined by a decline in the pollen curves for the trees of the mixed oak forest (_Quercus_, _Ulmus_, _Fraxinus_ and _Tilia_), and a rise in the values first for _Betula_ and then for _Alnus_. These changes were accompanied by a _Corylus_ maximum and an increase in the frequency of the pollen of herbaceous plants. In particular the first appearance of _Plantago lanceolata_ was associated with landnam; this weed was unknown in Denmark prior to Neolithic times. At a later date Iversen commented:

> " . . . first and foremost it is the curve for _Plantago lanceolata_ which in Danish pollen diagrams registers the commencement and changing intensity of the farmer culture in the Stone and Bronze Ages."
>
> (Iversen, 1949)

He particularly connected the occurrence of _Plantago lanceolata_ with cultures that practised cattle grazing as this species grows well on grassland kept low by domestic animals or by mowing (Iversen, 1941).

Since Iversen's work the occurrence of _P. lanceolata_ in British pollen diagrams has been accepted as an indicator of human activity associated with a predominantly pastoral economy (Turner, 1964, 1965). Hicks (1971) used variations in the intensity of occurrence of _Plantago lanceolata_ pollen to devise a scheme of zones associated with particular archaeological periods for a number of pollen diagrams from upland Derbyshire.

The pollen of certain other herb species has also been associated with phases of agricultural activity in pollen diagrams. Iversen (1941) suggested that Artemisia vulgaris, a common weed of modern arable cultivation, was troublesome in the grain fields of primitive economies. He also commented that increases in the pollen of Rumex acetosella and Rumex acetosa occurred only in conjunction with agriculture, and that these weeds were characteristic of washed-out sandy fields. The possible association of increases in the pollen of Rumex acetosella/acetosa with the creation and extension of acidic pasture was noted by Oldfield and Statham (1965) at sites in north Lancashire. The pollen of Rumex acetosella/acetosa type was also considered significant in terms of agricultural activity by Moore and Chater (1969) at sites in central Wales; in addition they associated peaks in the pollen of the Rosaceae (Potentilla type) and the Rubiaceae (Galium type) with increased grazing pressure. Turner (1964) suggested that the occurrence of pollen of Artemisia vulgaris, the Compositae, Cruciferae, Chenopodiaceae and cereals could be closely associated with arable cultivation.

Variations in the relative abundance of the pollen of all these taxa indicative of agricultural activity were therefore critical in the subdivision of zones D - F. However, as these changes in abundance are most marked in the curve for Plantago lanceolata, this species has been of greatest value in establishing the subzones.

II.iv. The Pollen Diagrams

The pollen diagrams from each site investigated are described individually in this section, and in Section IV the interpretation of the zonal sequence will be discussed in detail.

II.iv.a. Fountains Earth (Fig. II.15, II.16)

The pollen diagram for this site spans zones A to E. The early pollen record suggests a predominantly wooded environment, but there is a decline in woodland above 200 cm and pollen of the heath plants dominates the upper part of the diagram.

Zone A is characterised by high values for Betula pollen and relatively high values for Pinus, which forms 28% of total tree pollen at 385 cm. Corylus averages about 68% and Quercus about 12% of total pollen throughout the zone. Alnus is scarcely represented, though values rise slightly towards the A/B boundary. The presence of Ulmus at an average value of 5% of total pollen is very significant as in general this species is hardly represented in the pollen diagrams from the Nidd-Laver interfluve. Non-arboreal pollen, principally of the Gramineae, is present in very small quantities throughout zone A.

The presence of Pinus pollen at higher values than in any subsequent zone, in conjunction with the low values for Alnus pollen, suggests that zone A falls within Pollen Zone VI of the British System. At Stump Cross near Grassington, 12 kilometres to the south-west of Fountains Earth, Walker (1956) examined sediments which had accumulated in a cleft rock and assigned the lower part of his diagram to Pollen Zone VI. Betula and Pinus are represented in proportions similar to those at Fountains Earth zone A, but Corylus is considerably more abundant at Stump Cross where it forms 230% of total tree pollen. The dominance of

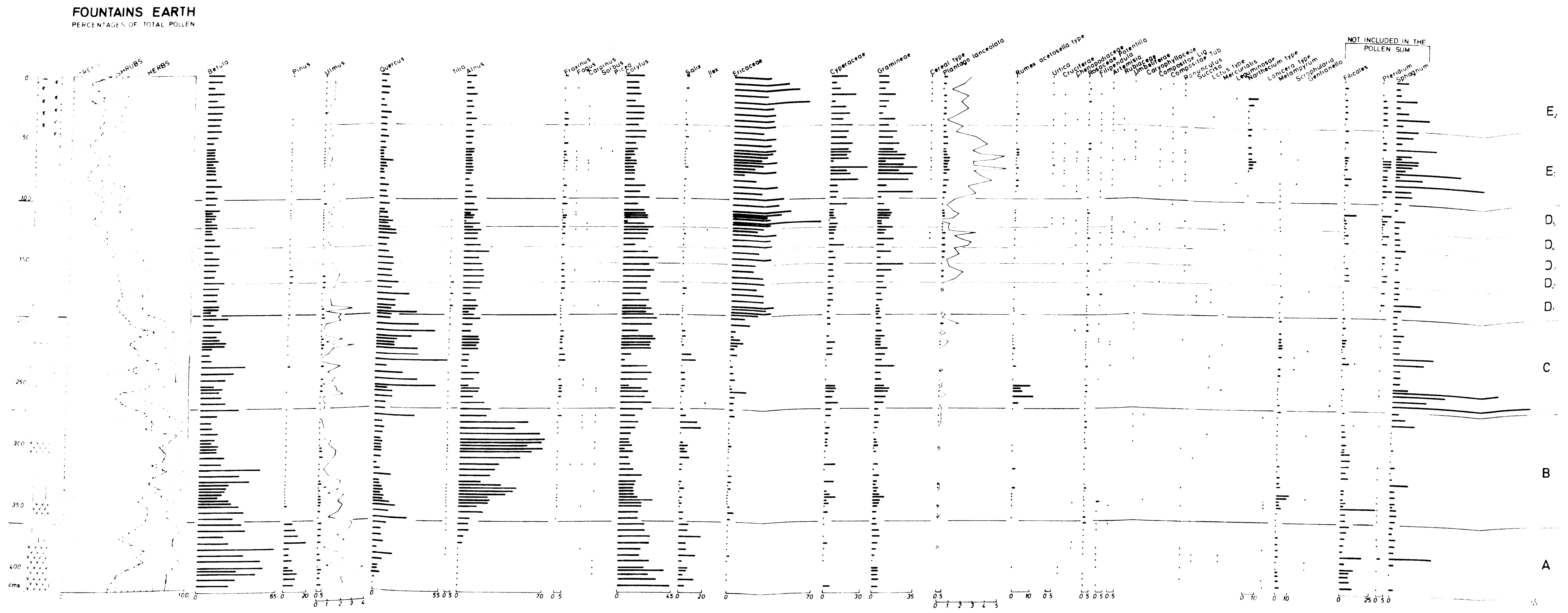
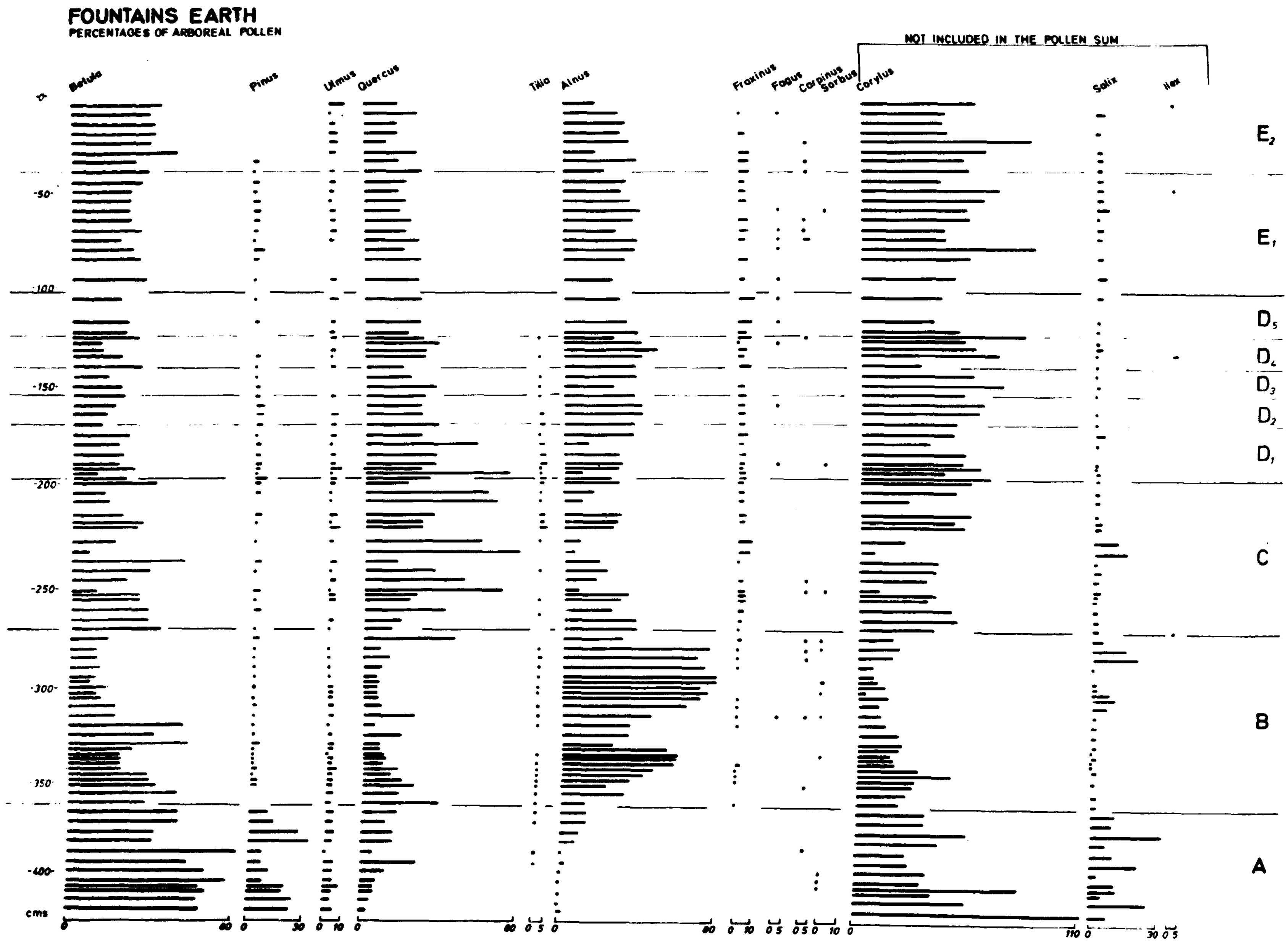

FOUNTAINS EARTH
PERCENTAGES OF TOTAL POLLEN
TREES
SHRUBS
HERBS
Betula
Pinus
Ulmus
Quercus
Tilia
Alnus
Fraxinus
Fagus
Carpinus
Sorbus
Picea
Corylus
Salix
Ilex
Ericaceae
Cyperaceae
Gramineae
Cereal type
Plantago lanceolata
Rumex acetosella type
Urtica
Cruciferae
Chenopodiaceae
Rosaceae
Filipendula
Potentilla
Artemisia
Rubiaceae
Umbelliferae
Caryophyllaceae
Compositae Lig
Compositae Tub
Ranunculus
Succisa
Lotus type
Mercurialis
Leguminosae
Narthecium type
Lonicera type
Melampyrum
Scrophularia
Gentianella
NOT INCLUDED IN THE POLLEN SUM
Filicales
Pteridium
Sphagnum
E2
E1
D5
D4
D3
D2
D1
C
B
A
cms

FIG. II·16


FOUNTAINS EARTH
PERCENTAGES OF ARBOREAL POLLEN
NOT INCLUDED IN THE POLLEN SUM
Betula
Pinus
Ulmus
Quercus
Tilia
Alnus
Fraxinus
Fagus
Carpinus
Sorbus
Corylus
Salix
Ilex
-50-
-100-
-150-
-200-
-250-
-300-
-350-
-400-
cms
E2
E1
D5
D4
D3
D2
D1
C
B
A

Betula pollen at the base of the Fountains Earth diagram suggests over-representation due to trees growing on or close to the pollen analysis site. The 10-20% Salix pollen occurring in this zone indicates that willows were important colonisers of the damper parts of the Fountains Earth site; Salix is insect pollinated and therefore only a small pollen producer. Herbaceous pollen grains occur sporadically, and at low frequencies throughout this zone. Melampyrum, Lonicera and the Rosaceae (Potentilla type) could probably tolerate conditions beneath the fairly open canopy of a Betula-Corylus woodland; Filipendula is a plant which particularly colonises damp sites.

At the A/B boundary Pinus values decline suddenly to 1% or less of total pollen, and the Alnus curve begins to rise as Betula declines. By the end of Zone B Alnus accounts for nearly 80% of total tree pollen in some samples, suggesting the replacement of birch trees by alder immediately around the site. Corylus declines to about 15% of total tree pollen in zone B, but rises slightly towards the B/C boundary. Quercus values rise at the beginning of zone B but later the swamping effect of Alnus pollen artificially depresses the curve. Extreme local over-representation of Alnus is also a feature of certain diagrams prepared by Cundill (1971) for sites on the North Yorkshire Moors.

The decline in Pinus and Corylus at the A/B boundary suggests that this marks the end of the Boreal period and the start of the Atlantic, about 5,500 B.C. The expansion in the curve for Alnus pollen does not become marked until well above the A/B boundary, i.e. until Pollen Zone VIIa of the British System is well established. This is consistent with the pattern at some other north of England sites in the Lake District (Pennington, 1964) and Yorkshire (Bartley, 1962; Cundill, 1971), though somewhat later than the normal sequence as established in the south of England (Godwin, 1956).

During zone B continuous curves are established for Fraxinus and Tilia. Herbaceous pollen values remain low, Filipendula is less common than in zone A, but small peaks occur in the pollen of Melampyrum. The record for Melampyrum, in conjunction with the occurrence of occasional grains of Plantago lanceolata, may suggest some small scale interference with the woodland canopy. Iversen (1949) has suggested that in some Danish pollen diagrams Melampyrum pollen may be an indicator of clearance. Simmons (1969) considered that small peaks in the pollen of Melampyrum in diagrams from the North Yorkshire Moors might indicate openings in the forest canopy created by Mesolithic man.

A steep decline in the values for Ulmus pollen has been almost universally recognised in pollen diagrams from western Europe, and this has been used to define the transition from Pollen Zone VIIa to VIIb of the British Pollen Zone System. At Fountains Earth, which is the only deposit investigated from the Nidd-Laver interfluve that covers the period of the VIIa/VIIb transition, no sharp decline in Ulmus can be recognised owing to the very low incidence of the pollen of this species. Certainly the gritstone upland would have been an unfavourable habitat for Ulmus glabra, but this species was presumably able to thrive on the Carboniferous Limestone only 10 kilometres to the west. Despite the direction of the prevailing winds very little Ulmus pollen appears to have blown into this area. However, it seems likely that at Fountains Earth the Ulmus decline must lie somewhere in the upper part of zone B and it has been tentatively placed at 300 cm. At the opening of this zone the values of Ulmus pollen average about 2% of total tree pollen, whereas towards the end of the zone, between 300 cm and 275 cm, they never rise above 1% of total pollen.

Originally the fall in the values of Ulmus in pollen diagrams from western Europe was attributed to climatic change (Godwin, 1956). However, an increasing body of evidence suggests that this horizon can be explained in terms of the expansion of the Neolithic farmers throughout Europe (Clark, 1965). Various changes in the pollen curves of taxa other than Ulmus have been identified at this same level and attributed to human activities. Troels-Smith (1953) associated the occurrence of definite agricultural indicators, including cereals and Plantago lanceolata, with the Ulmus decline. Oldfield (1963) suggested that at sites in the Lake District the Ulmus decline was followed by a landnam phase; at this level increases occurred in the pollen of Corylus and Fraxinus, two pioneer species which exploit gaps created in woodland cover.

None of these secondary indicators is particularly helpful in establishing the level of the Ulmus decline at Fountains Earth. Grains of Plantago lanceolata pollen are associated with the 300 cm level, but they also occur sporadically below this. At 270 cm, both the Fraxinus and Corylus curves rise, but at this level the Ulmus curve has started to recover from its minimum values. However, despite these difficulties it seems likely that the Atlantic/Sub-Boreal transition (Pollen Zone VIIa to Pollen Zone VIIb) occurs just before the end of local pollen zone B.

The B/C boundary is located at the point where Alnus values decrease sharply and there is a marked rise in the curves for Betula and for Quercus. In the early part of zone C Betula values average 35% of total pollen, but they later decline and Quercus values increase markedly, reaching 75% of total pollen in some samples. This over-representation suggests that the woodland immediately around the site must have been dominated by Quercus during this zone. The nature of the Quercus curve in zone C at Fountains Earth is unusual as fluctuations of up to 30% occur between some adjacent samples; the significance of this will be considered in the light of the results of the surface pollen analyses (vide infra Section III.v). Corylus values increase markedly in zone C after their low zone B levels. The incidence of Salix pollen is reduced compared with preceding zones, except for a small peak between 230 cm and 235 cm.

If arboreal values are considered together they show a slight decline throughout zone C and there is a corresponding increase in the non-arboreal pollen. There are small peaks in Gramineae pollen between 267.5 cm and 252.5 cm and between 240 cm and 225 cm, both peaks are associated with slight increases in the Ericaceae. Occasional grains of Plantago lanceolata, Melampyrum and Rosaceae (Potentilla type) are found between 265 cm and 252.5 cm, and there is a massive proliferation of Rumex acetosella type pollen at this level. Towards the top of zone C the variety of herbs recorded increases to include Ranunculus, Artemisia, other Compositae, the Umbeliferae and the Caryophyllaceae; grains of Plantago lanceolata also become more frequent. Artemisia in particular is a species associated with open sites and waste habitats (Clapham, Tutin and Warburg, 1962).

The most significant change at the C/D boundary is a sudden marked increase in the pollen of the Ericaceae. The gradual decline in arboreal pollen initiated in zone C continues at an increasing rate throughout zone D, suggesting a decline in trees upon the upland and their replacement by a heath community. From the tree pollen diagram it appears that Betula, Alnus and Quercus were well represented in the lowland woods during this period. The pollen of Fraxinus, Ulmus, Tilia and Pinus is present in small but consistent quantities throughout this zone.

In subzone D_1 the incidence of pollen of agricultural indicators and of the Gramineae is relatively low, though a variety of herbs similar to those in zone C occurs. Subzone D_2 is differentiated on the basis of a peak in the curve for Plantago lanceolata and in the pollen of the Gramineae which forms 15% of total pollen. There is no increase in the incidence of pollen of taxa associated with cultivation, and in the tree pollen diagram there are no marked changes in the curves at this level. These features suggest an intensification of human activities during subzone D_2, but that this phase of land use was confined to the uplands and predominantly pastoral. In subzone D_3 there is a slight decline in the incidence of Plantago lanceolata, the Gramineae and all herbs, suggesting a temporary decline in pastoral activities around the site. Subzone D_4 is defined on the basis of a fairly marked and lasting peak in Plantago lanceolata pollen and a small peak in the pollen of the Gramineae. There is a pronounced increase in the number and variety of herb pollens recorded in this subzone. The presence of Artemisia in every sample, the occurrence of grains of the Compositae Liguliflorae and the Chenopodiaceae, and the first record for cereal pollen suggest that cultivation as well as pastoralism was characteristic of this subzone. Subzone D_5 is initiated by a decline in the curves for Plantago lanceolata and the Gramineae, indicating the termination of agricultural activity. The incidence and variety of herbs is also reduced.

The D/E boundary is defined by a marked rise in the incidence of Gramineae pollen to much higher levels than previously recorded (28% of total pollen). Throughout zone E tree pollen remains constant at about 20% of total pollen, there is a gradual increase in the relative proportion of Betula at the expense of both Quercus and Alnus (shown in the tree pollen diagram). Subzone E_1 appears to be a period of intensive and sustained agricultural activity. Between 50 cm and 100 cm Plantago lanceolata averages between 3% and 4% of total pollen and there is a marked increase in the incidence of Rumex acetosella type and Rosaceae (Potentilla) pollen. Cereals are present throughout this subzone and pollen of herbs associated with cultivation is common including Cruciferae, Chenopodiaceae, Artemisia and other Compositae. In the middle of subzone E_1, where the values for the pollen of the Gramineae are highest, the values for the Ericaceae show a marked decline. Subzone E_1 is also characterised by a pronounced increase in the pollen of the Cyperaceae and there is an increase in the incidence of Sphagnum spores. This could suggest a deterioration in drainage at this site. At the same level pollen of Liliaceae (Narthecium type) is first recorded. Narthecium ossifragum is a common species of wet, acidic sites and is found on the surface of the bog at Fountains Earth today. Just prior to the opening of subzone E_1 a major change occurs in the stratigraphy from an Eriophorum to a Sphagnum peat, and this may also be connected with a possible change in hydrology.

In subzone E_2 a reduction in the intensity of agricultural activity is indicated by the decline in the curves for Plantago lanceolata and the Gramineae. There is a break in the record for Artemisia and the cereals, but otherwise the incidence and variety of herb species remains unchanged. A rise in the pollen values of both Betula and Corylus suggests that some limited regeneration of trees may have resulted from the reduced agricultural activity of this subzone.

Towards the surface of the peat Ericaceae pollen increases to nearly 50% of total pollen. A decline in the pollen of Alnus and Quercus in response to increased Betula values can be detected in the uppermost samples in the tree pollen diagram.

The pollen record at the Fountains Earth site is incomplete. Some parts of the bog at Fountains Earth are actively growing at the present time; the pollen spectrum in fresh surface Sphagnum from one such site revealed tree pollen percentages which were somewhat lower than those in the upper samples of the Fountains Earth diagram, but similar in magnitude to tree pollen percentages associated with zone F at other upland sites. This suggests that at the point chosen for pollen analysis, where the upper peat is fairly dry and somewhat oxidised, erosion of the surface has taken place. It is possible that this drying out and erosion may have been initiated by efforts to drain the area after the Enclosure Act of 1855.

The sequence of zones at Fountains Earth has been described in some detail as this is the reference diagram for all the sites on the Nidd-Laver interfluve. The pollen diagrams for the other sites will be considered in relation to the Fountains Earth sequence.

II.iv.b. Iron Well Hill. (Fig. II.17)

A detailed pollen diagram has not been prepared for this site owing to problems both in the collection and preparation of the samples. The waterlogged state of the site made the collection of uncontaminated material difficult. Samples were collected by inserting glass tubes into the peat and sediment face. Pollen counts could not be obtained from all the samples as at some levels the grains were very highly corroded and also obscured by the presence of a red-brown iron precipitate (Appendix 2). However, the data from these samples for which counts were possible are particularly interesting, therefore the individual spectra are illustrated in Figure II.17 with indications of the sample depth.

FIG. II·17 IRON WELL HILL
PERCENTAGES OF TOTAL POLLEN

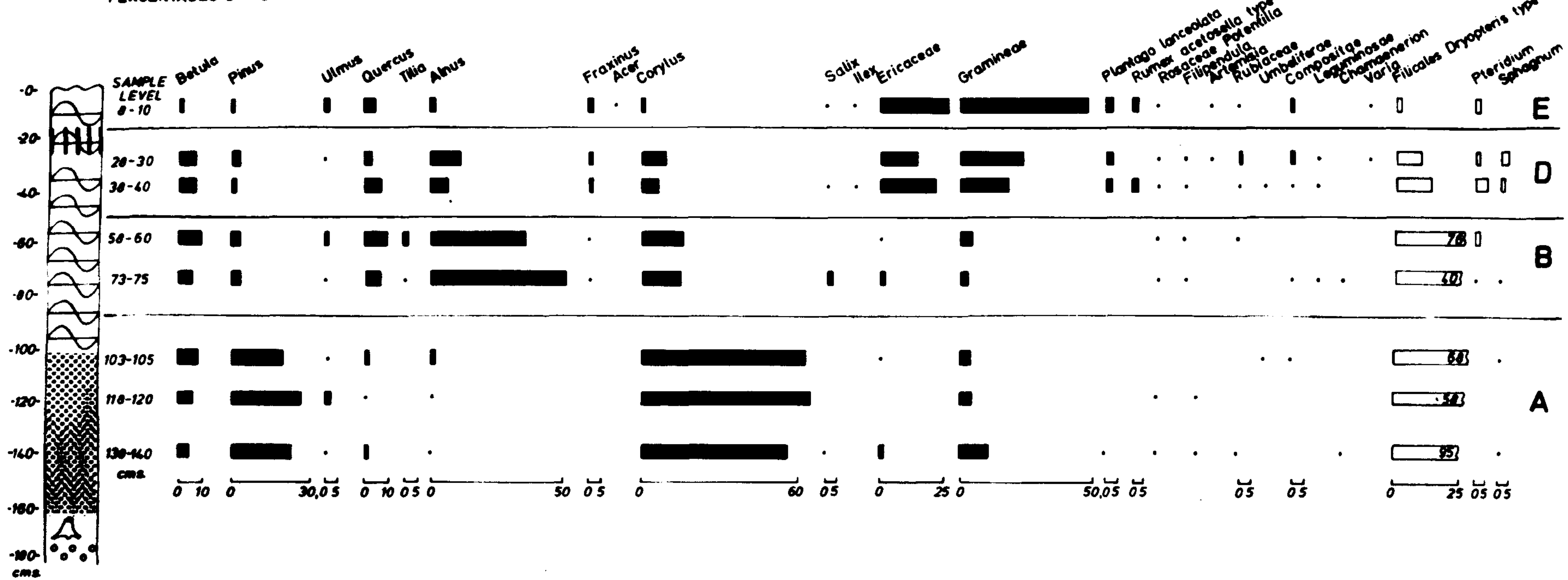


FIG. II·18

SKELL MOOR I

PERCENTAGES OF TOTAL POLLEN

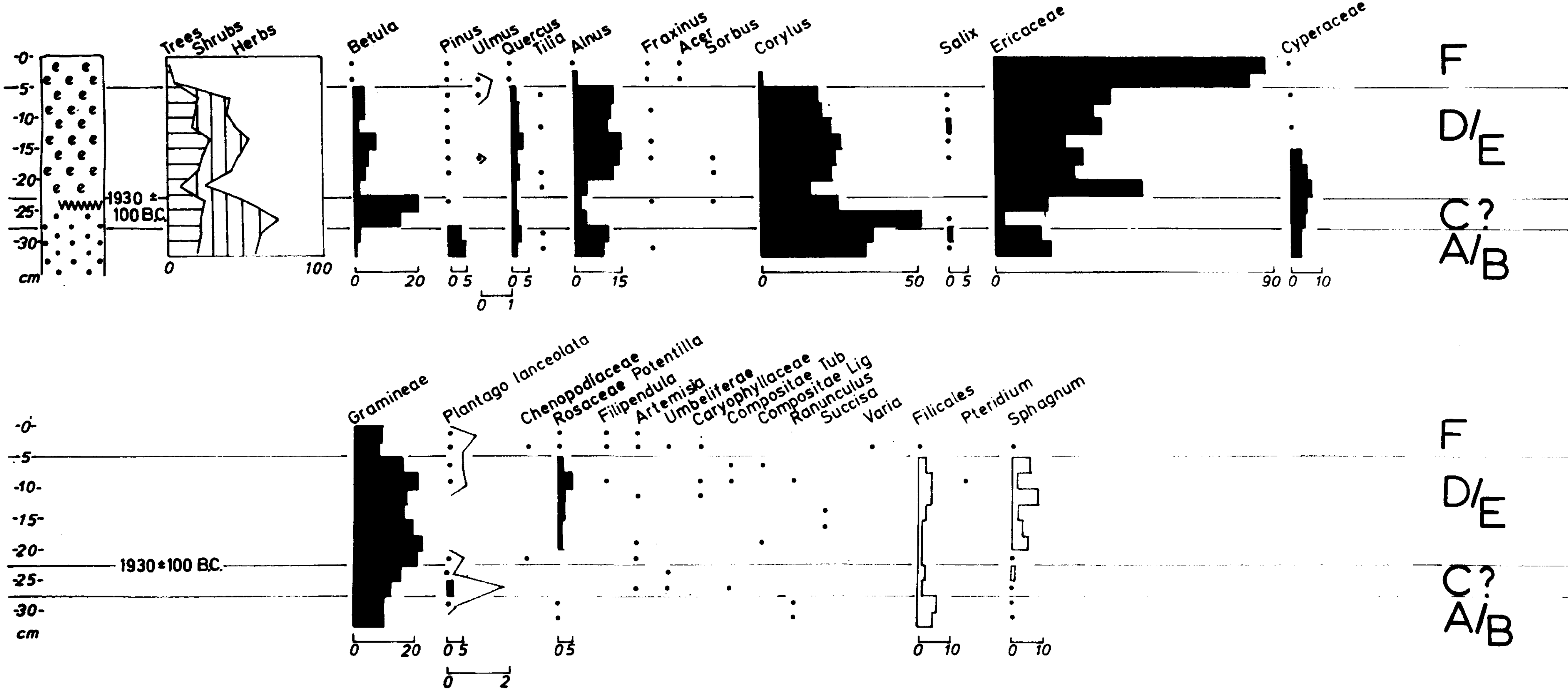
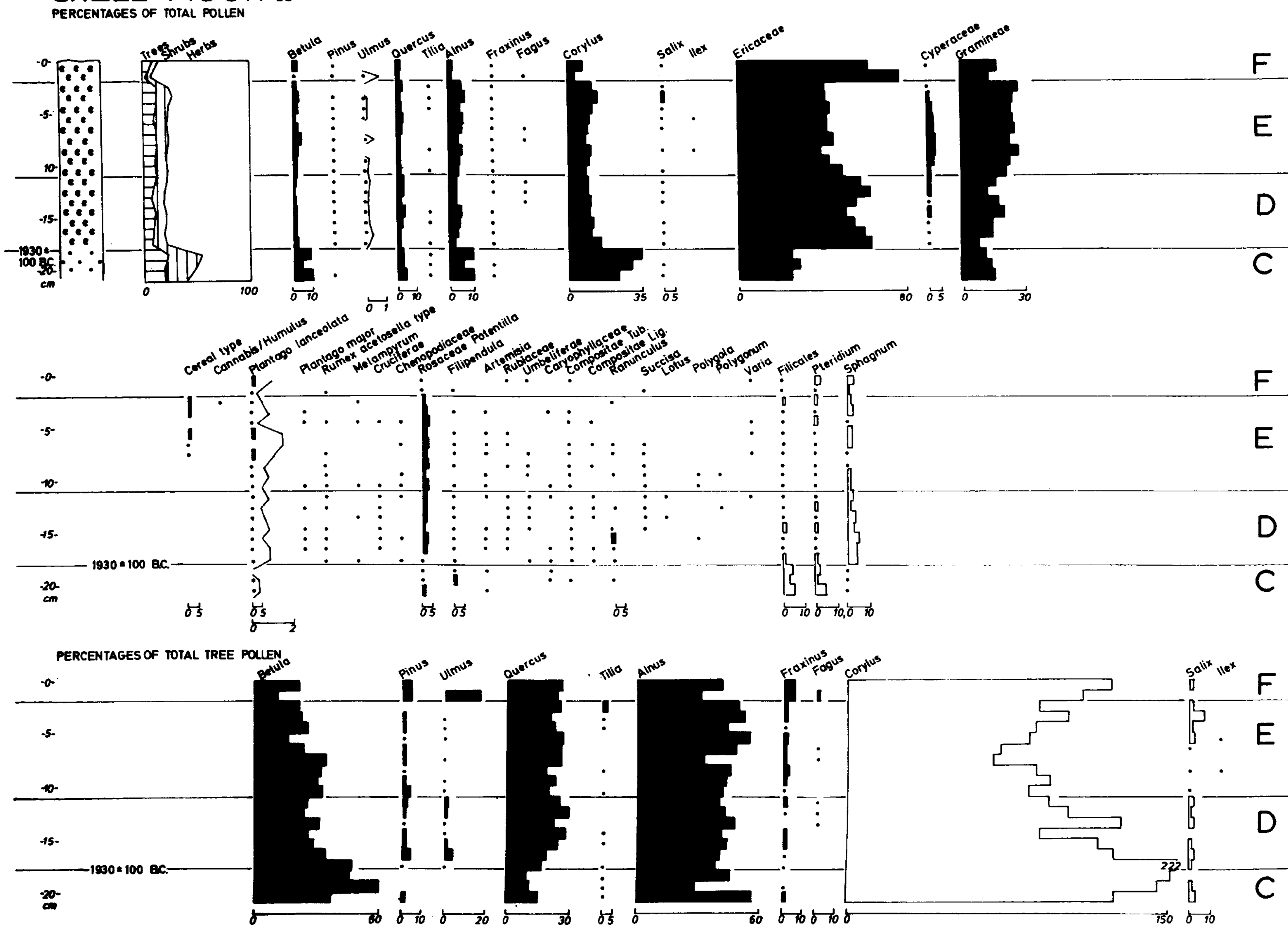


FIG. II·19

SKELL MOOR II



The lower three spectra from the clay have features typical of zone A: an absence of Alnus pollen and relatively high values for Pinus and Corylus. Pinus percentages are much higher than at Fountains Earth, forming 20% of total pollen, that is nearly 80% of tree pollen. Betula is much less abundant than at Fountains Earth and Ulmus is not so well represented. However, Corylus percentages are very high at this site, averaging nearly 60% of total pollen (200% of total tree pollen). This is the only site apart from Fountains Earth at which spectra attributable to Pollen Zone VI of the British System have been identified.

Pollen spectra 4 and 5 are assigned to zone B; they exhibit the high Alnus percentages and reduced values for Pinus and Corylus which are typical of this zone at Fountains Earth. The sixth, seventh and eighth spectra are assigned to zone E on the basis of their reduced values for arboreal pollen and the high values for the pollen of the Gramineae and Ericaceae.

II.iv.c. Skell Moor I and Skell Moor II (Figs. II.18, II.19)

The pollen diagrams from the Skell moors exhibit very similar features and are therefore described together. In both cases it is difficult to assign the pollen spectra from the sub-peat material to a particular zone. Some of the pollen grains in this horizon are somewhat corroded, and it is therefore likely that the spectra may be distorted owing to the differential susceptibility of grains to decay. In contrast, the grains of the Ericaceae in this horizon are fresh and undecayed, which suggests that they are not contemporary with the rest of the pollen at this level, but have been washed into the sub-peat horizons from the Calluna peat above. The values for Betula pollen are fairly high just below the peat/mineral interface which might suggest affinities with the early part of zone C. The high values for Pinus in the mineral material below 27.5 cm at Skell Moor I may be a relict of zone A. It is interesting to note that at Skell Moor I pollen of Plantago lanceolata is recorded at the peat/mineral interface.

The earliest thin peat at both sites belongs to zone D, and above this level a sequence of zones similar to that at Fountains Earth can be recognised, but in a highly condensed form. Zone D opens with a sudden marked expansion in the Ericaceae followed by a less marked expansion of the Gramineae. The tree pollen diagrams from the basal peat at Skell Moor II and from Fountains Earth zone D are similar, with Alnus, Betula and Quercus represented in more or less equal proportions, and Fraxinus, Ulmus, Tilia and Pinus all present in small but consistent quantities. Owing to the condensed nature of the sequence at the Skell Moor sites it is not possible to distinguish any of the subzones of D. However, the pollen of herbs typical of the agricultural phases at Fountains Earth (Plantago lanceolata, Artemisia, Chenopodiaceae, Compositae and Rumex acetosella type) are all represented at the Skell Moor sites.

A sample of organic material from immediately above the peat/mineral interface has been radiocarbon dated to 1930 ± 100 B.C. It seems reasonable to assume that the first marked rise in the pollen of the Ericaceae was contemporaneous on the moors above the Skell and at Fountains Earth, as these sites are at similar altitudes and are both in exposed situations. Therefore, the spread of the heath community which gave rise to the initiation of thin peat formation at the Skell Moor sites is probably represented by the increase in Ericaceae pollen at the C/D boundary at Fountains Earth. By inference this boundary can also be dated to around 1930 B.C.

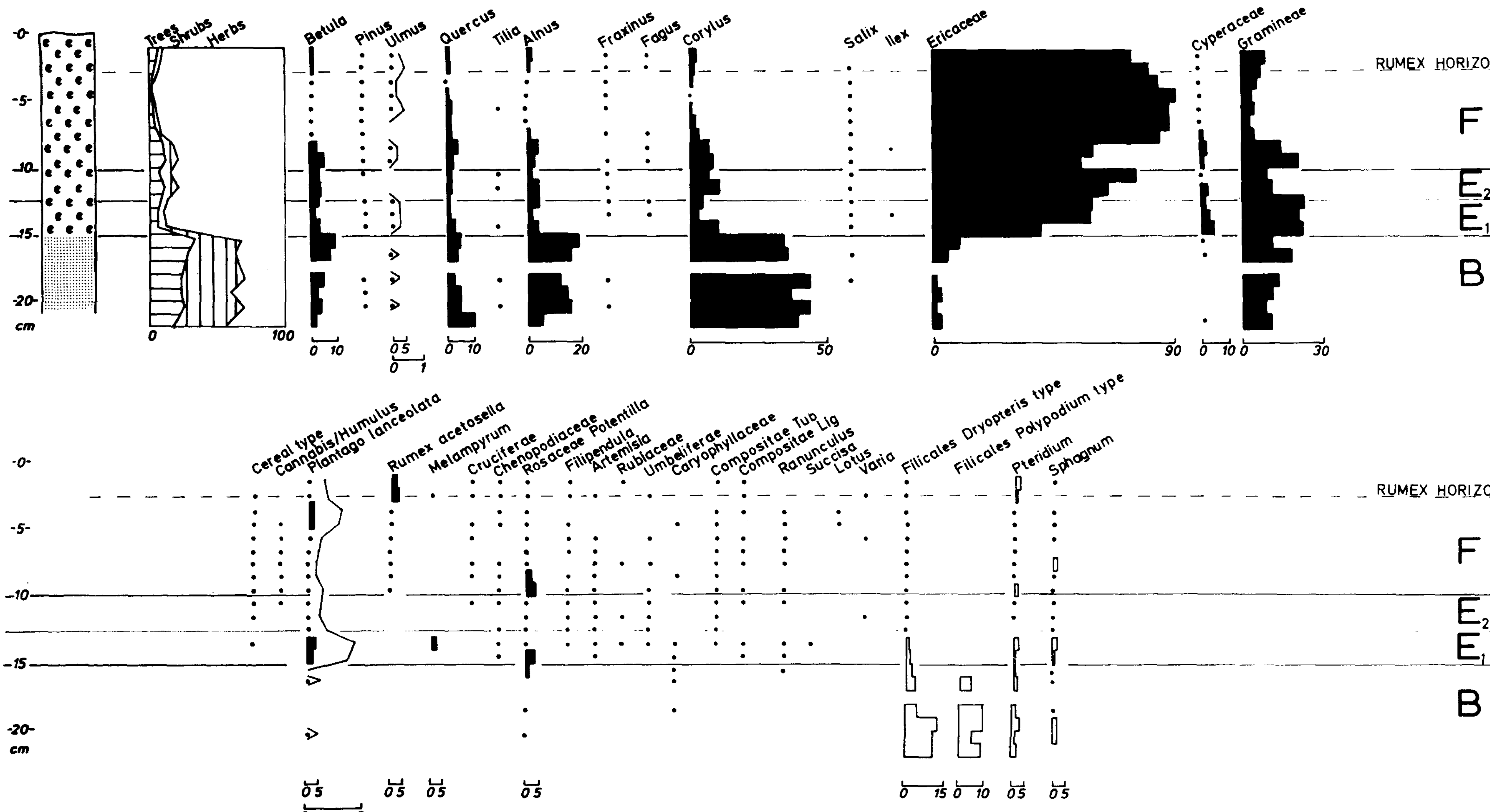
A fall in the relative proportion of the pollen of the Ericaceae, and a corresponding rise in the Gramineae marks the opening of zone E at the Skell sites. At both sites there is also an increase in the pollen of two taxa considered to indicate grazing, Plantago lanceolata and the Rosaceae (Potentilla type). Cereal pollen is also present at this level which represents the agricultural phase of subzone E_1. The reduced intensity of agricultural activity, recognised in subzone E_2 at Fountains Earth, is indicated by a decline in the curves for the Gramineae and the pollen of "weed" species at both sites. The pollen spectra in the upper few centimetres of both diagrams show a massive proliferation in Ericaceae pollen and this has been assigned to zone F. At the same level the tree pollen diagram for Skell Moor II shows small increases in the proportions of Fraxinus, Pinus and Ulmus pollen.

II.iv.d. Hambleton Hill (Fig. II.20)

The zonation of the diagram from the thin peat on Hambleton Hill differs from that at the Skell sites. The pollen in the sub-peat material is in this case better preserved, and there is very little contamination by Ericaceae grains. The relatively high values for Alnus suggest that this spectrum may represent zone B. The base of the thin peat at this site has been placed in subzone E_1, and if this is correct there must be a hiatus in the stratigraphy between the mineral material and the thin peat at this site. This could be accounted for by a period of erosion, and there is evidence for a similar occurrence at the nearby Hambleton Dike site (vide infra II.iv.e).

FIG. II·20 HAMBLETON HILL

PERCENTAGES OF TOTAL POLLEN



The base of the thin peat at Hambleton Hill has been placed in subzone E_1 because of the relationship between the curves of Ericaceae and Gramineae. The initial marked increase in the Ericaceae which was recognised at the opening of zone D at the Skell sites and at Fountains Earth, is absent at Hambleton Hill. Instead there is a more gradual rise in pollen of the Ericaceae; the Gramineae, which are initially present at over 20% of total pollen, decrease proportionally towards the top of the diagram. There are small peaks in Plantago lanceolata (1.5% of total pollen) and Rosaceae (Potentilla type) (3.1% of total pollen) just above the peat/mineral interface between 15 cm and 13 cm, and grains of the Caryophyllaceae, Compositae and Rubiaceae are associated with this level. Cereal grains are present throughout the pollen diagram. All these features are typical of the agricultural phase of subzone E_1. Therefore the base of the thin peat at this site is considerably younger than the basal peat at the Skell Moor sites. A radiocarbon date of 250 ± 80 B.C. for the base of ericaceous peat at nearby Hambleton Dike supports this interpretation.

Between 12 cm and 10 cm at Hambleton Hill there is a decline in the pollen of the Gramineae and Plantago lanceolata, and an associated increase in the pollen of Betula and Corylus. These features are similar to those recorded in subzone E_2 at Fountains Earth. The proliferation in the pollen of the Ericaceae and the reduction in arboreal pollen to a minimum above 10 cm is characteristic of zone F. When the results are expressed as percentages of total tree pollen slight increases in the pollen of Pinus, Fraxinus and Ulmus can also be recognised in this zone. The record for zone F is larger at this site than at the others so far described and pronounced peaks in the pollen of Plantago lanceolata, Rumex acetosella type and the cereals can be identified.

II.iv.e. Hambleton Dike (Fig. II.21)

The pollen diagram for this deposit is sharply divisible into a lower section in which arboreal pollen values are relatively high and a shorter upper section in which they are very much reduced. The lower 46 cm of peat are assigned to zone B on the basis of the Alnus values which average 25% of total pollen. Ulmus values are negligible throughout the deposit suggesting that at this site peat formation probably began in the upper part of zone B above the Ulmus decline. However, in view of the problem of the identification of the Ulmus decline no exact correlations with zone B at Fountains Earth are possible.

The lack of over-representation of Alnus, such as characterises zone B at Fountains Earth, in conjunction with slightly increased values for the Gramineae, may indicate a more open woodland at the Hambleton Dike site during this period. This interpretation is supported by the greater variety of herb pollens which are recorded at this site. Occasional grains of Plantago lanceolata, Melampyrum, Artemisia, Caryophyllaceae and Compositae Liguliflorae could be indicative of human disturbance of the vegetation during zone B.

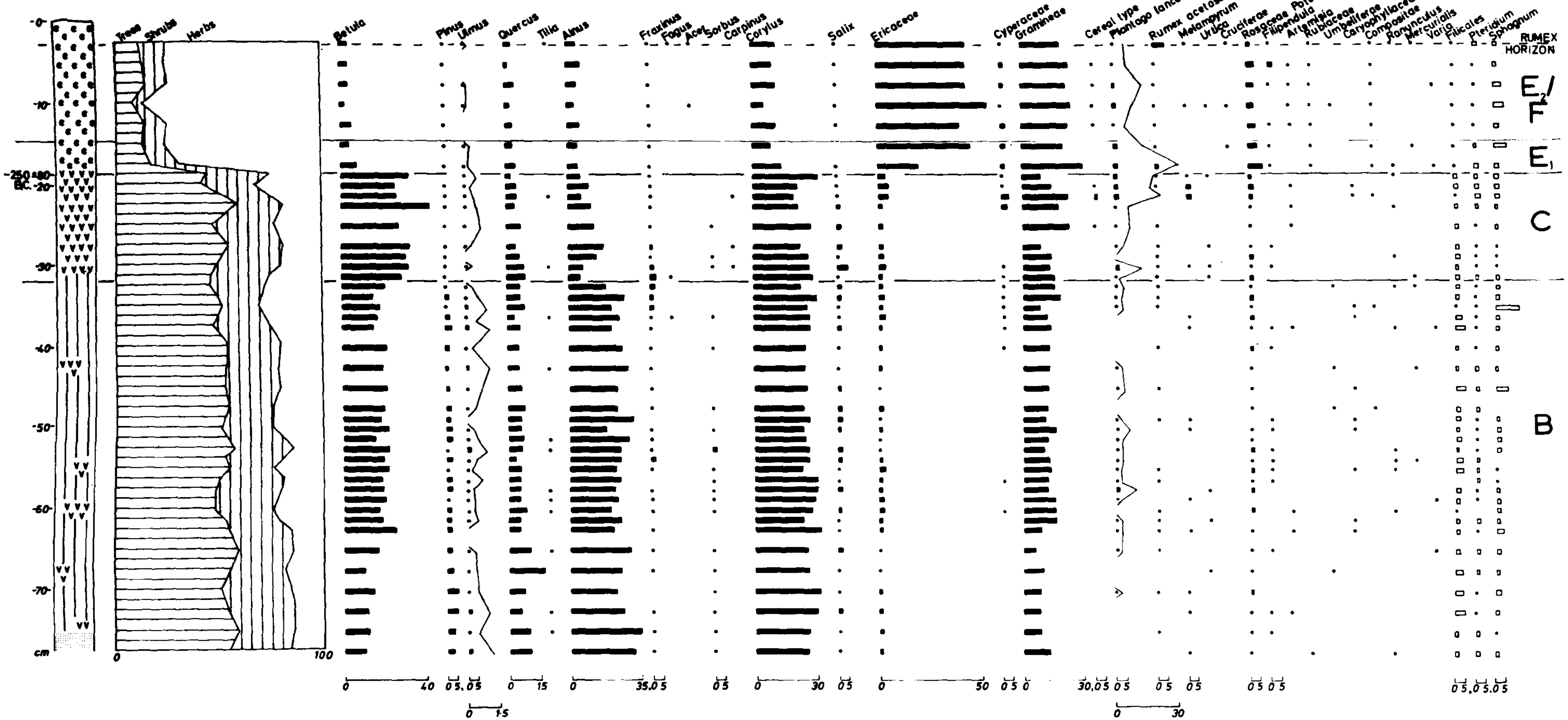
At 32 cm a rise in the curve for Betula and a decline in that for Alnus marks the start of zone C, but the increase in Quercus pollen associated with the latter part of this zone at Fountains Earth does not occur at Hambleton Dike.

At 20 cm there is a sudden break in the continuity of the pollen curves, and this is associated with a marked change in the stratigraphy from a well humified wood peat to a very well humified Calluna peat. The sharp nature of the stratigraphic change and associated discontinuity in the pollen curves suggests a hiatus at this level probably due to the

FIG II.21

HAMBLETON DIKE

PERCENTAGES OF TOTAL POLLEN



loss of material by erosion. The peat between 18 cm and 14 cm is assigned to zone E_1 on the basis of the high values for the Gramineae (30% of total pollen) compared with the Ericaceae (20% of total pollen). Small peaks in Plantago lanceolata, Rumex acetosella type and the Rosaceae occur at this level. Peat from immediately above the hiatus was collected at a depth of 30 cm from a pit close to the site of the boring. This has been radiocarbon dated to 250 ± 80 B.C.

Increasing values for the Ericaceae above 14 cm and a decrease in the curves for Plantago, Rumex and the Rosaceae mark the transition to subzone E_2. Zone F is not distinguished but a peak in Rumex acetosella type pollen at the top of the diagram can be correlated with the similar peak in zone F at Hambleton Hill.

II.iv.f. Upper Skell Gill I. (Fig. II.22)

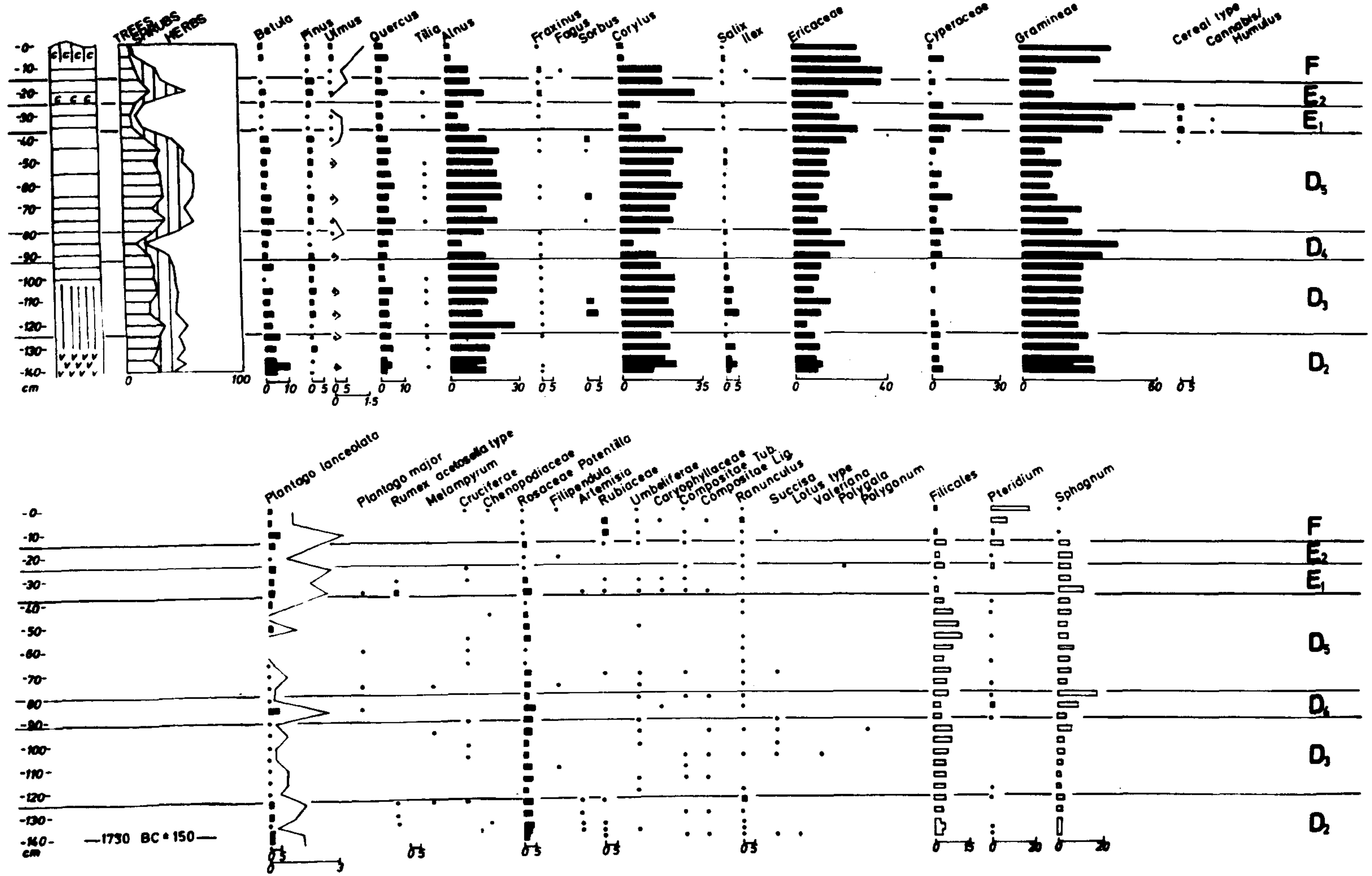
Non-arboreal pollen averages just less than 50% of total pollen throughout most of the pollen diagram from Upper Skell Gill I and this suggests that the whole profile lies within zones D, E or F. Peat from the base of this site has been dated by radiocarbon analysis to 1,750 ± 110 B.C., therefore this deposit must have started to form fairly soon after the initiation of thin peat development on the moors around the Skell.

Throughout the diagram Alnus is the most significant contributor to the tree pollen rain, averaging just over 20% of total pollen at most levels. The low incidence of Betula pollen (less than 5% of total pollen in all but one sample) is surprising as wood remains of Betula are abundant at the base of the peat, and Betula fruits and bark fragments are recorded at intervals in the macroscopic remains throughout the

FIG II·22

UPPER SKELL GILL I

PERCENTAGES OF TOTAL POLLEN



profile. Cundill (1971) also noted anomalously low percentages of Betula pollen in diagrams from some sites on the North Yorkshire Moors where he had observed macroscopic remains of Betula.

If the pollen record and macroscopic remains are considered together, it seems likely that Alnus and Betula have grown close to this site throughout most of its history and Corylus may also have been present; the high values for the non-arboreal pollen suggest that the trees were scattered, forming an open woodland.

Subzone D_2 between 140 cm and 125 cm was identified on the basis of small peaks in the pollen of Plantago lanceolata; relatively high frequencies of the Rosaceae (Potentilla type) are associated with this level and Rumex acetosella type, Artemisia, Ranunculus, the Rubiaceae and the Compositae also occur. The variety of herbs is greater than that encountered in subzone D_2 at Fountains Earth which could indicate a higher intensity of local activity in the Skell valley; however, there is no decline in arboreal pollen at this level.

In subzone D_3 there is a marked decrease in the frequency of Plantago lanceolata pollen between 125 cm and 90 cm, and the record for some of the other herb types ceases, suggesting a decrease in the intensity of agricultural activities. The relatively high percentages of Gramineae pollen throughout this subzone suggest an open woodland environment. At 92.5 cm there is a sudden decrease in arboreal pollen values to only 11% of total pollen and there is an associated increase in the pollen of both the Gramineae and the Ericaceae. A peak in the curve for Plantago lanceolata occurs at 95 cm, within the phase of reduced arboreal pollen values. This represents the agricultural period of subzone D_4 which ends abruptly with the recovery of arboreal pollen values above 80 cm. During subzone D_5 open woodland appears to have re-established around the site.

There are certain features of zone D at Upper Skell Gill I which are markedly different from zone D at the moorland sites already described. At Upper Skell Gill I arboreal pollen percentages consistently average 50% of total pollen except for the short period of subzone D_4, whereas at Fountains Earth there is a progressive decline in arboreal pollen values. Arboreal pollen values are below 20% of total pollen throughout zone D at the Skell moorland sites. At the moorland sites the Ericaceae are considerably more abundant than the Gramineae throughout zone D, whereas the reverse is true at Upper Skell Gill I. Despite these differences the synchronous nature of the zones is established by the radiocarbon date for the opening of subzone D_2 at Upper Skell Gill I; this is only 180 years later than the date for the opening of zone D at the Skell moorland sites.

The difference in the pollen curves between Upper Skell Gill I and the moorland sites during zone D may be due to differences in altitude and exposure. Upper Skell Gill I is in a valley, somewhat lower in altitude than the other sites and protected from strong winds. In this relatively favoured position trees may have survived longer than on the summits of the interfluve. They were certainly present close to this site until the fourth century B.C. as wood from an Alnus or Betula rooting system found in the peat has been radiocarbon dated to 340 ± 100 B.C. The open woodland must have supported a grassy ground flora, the heath pollen which is recorded at the site having originated on the surrounding moorland.

Subzone E_1 opens with a marked decline in arboreal pollen values to only 5% of total pollen at 35 cm suggesting active clearance of trees from the valley. There is a corresponding rise in the Ericaceae followed by a marked increase in the pollen of the Gramineae to 50% of total pollen at 30 cm. There is also an increase in the pollen of Plantago lanceolata and Rumex acetosella type and a marked peak in cereal type pollen. As at Fountains Earth, subzone E_1 appears to be a phase of sustained agricultural activity. At the same level there is an increase in the incidence of Cyperaceae pollen, a feature also noted in E_1 at Fountains Earth.

In subzone E_2, between 25 cm and 15 cm there appears to be a temporary regeneration phase. The values of Alnus and Corylus rise and those of the Gramineae decline. Subzone E_2 terminates at 15 cm and above this level in zone F arboreal pollen values are again reduced to only 5% of total pollen and there is a second marked expansion in the Gramineae. A significant increase in Pteridium spores occurs in the uppermost sample.

II.iv.g. Upper Skell Gill II. (Fig. II.23)

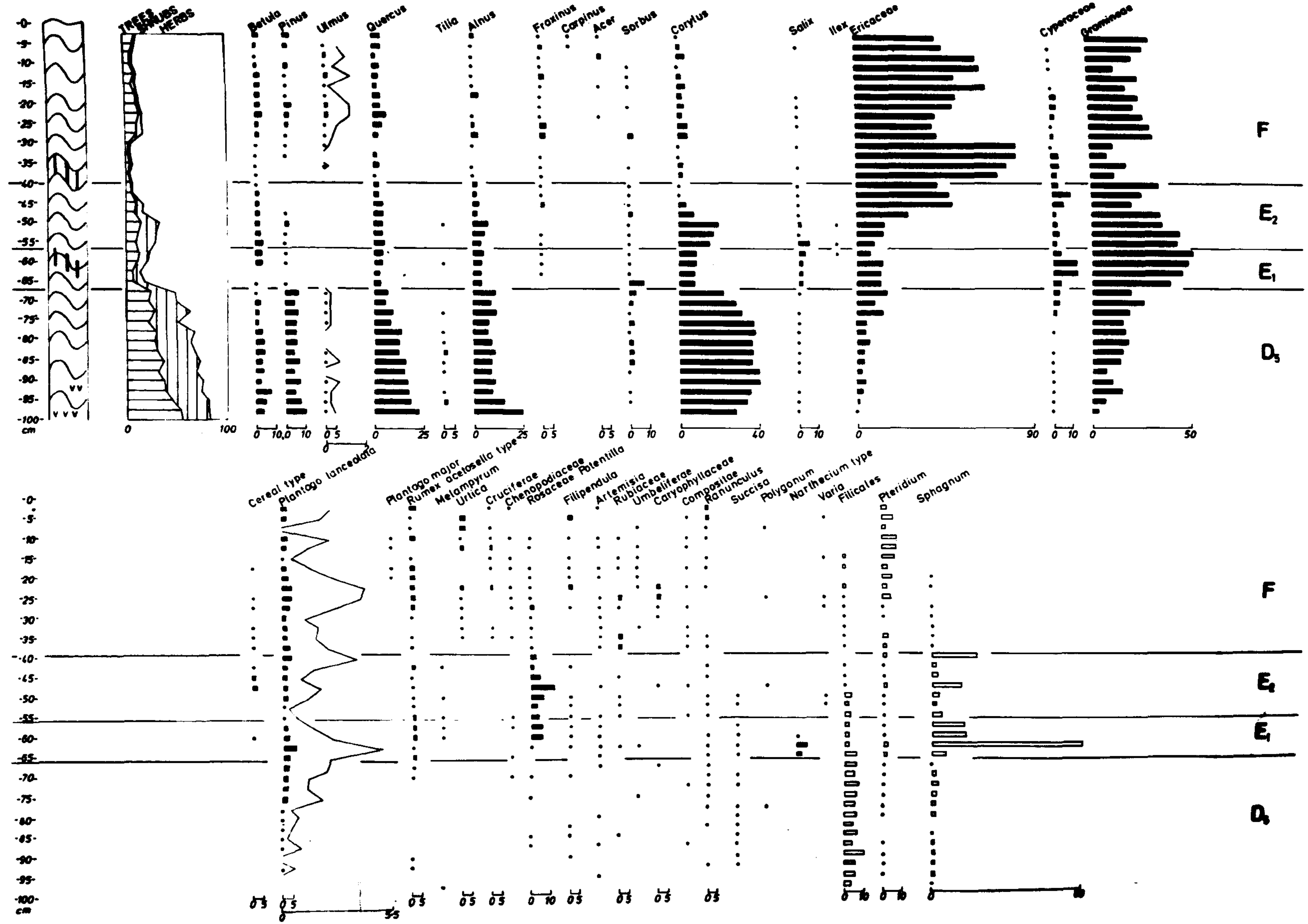
The flush peat deposits are all characterised by having accumulated quickly, and in all cases they are still actively growing. The pollen record for these deposits therefore provides detailed information regarding recent vegetation changes.

At Upper Skell Gill II a flush has formed following the erosion of part of a topogenous deposit by a stream. The pollen diagram from the Upper Skell Gill I site provides the complete record for this bog. The pollen record at Upper Skell Gill II is equivalent to that in the upper 70 cm of peat at Upper Skell Gill I.

FIG. II·23

UPPER SKELL GILL II

PERCENTAGES OF TOTAL POLLEN



The lower part of the Upper Skell Gill II diagram, below 67 cm, falls within subzone D_5. Arboreal pollen percentages gradually decline throughout this subzone, evidence of the decline in woodland which took place in this valley around the third century B.C. The low arboreal pollen percentages associated with subzone E_1 at Upper Skell Gill I are evident at this site between 67 cm and 57 cm; the associated increase in the pollen of the Gramineae and in the incidence of agricultural indicators is very marked. The increase in the Cyperaceae, which was noted in this subzone at Upper Skell Gill I is also apparent at this site and it is accompanied by other changes which may indicate increasing wetness. These include a proliferation in _Sphagnum_ spores and a small peak in the pollen of _Narthecium_ type. In addition, _Salix_ pollen occurs at this level. The recovery of the arboreal pollen values associated with subzone E_2 is only a temporary feature and the values of the Ericaceae rise markedly at the end of this subzone. A second increase in Gramineae pollen occurs in zone F similar to that at the Upper Skell Gill I site, but the expanded pollen record for this zone enables an early phase of increased Gramineae and reduced Ericaceae pollen to be distinguished from a later phase when Ericaceae pollen is again dominant.

II.iv.h. North Gill Wood (Fig. II.24)

The pollen diagrams from the three remaining flush sites exhibit marked similarities; an absolute chronology has been obtained for the diagram from North Gill Wood and this site has therefore been examined in greater detail than the others. The zonation of the diagrams from the two woodland sites proved difficult as they are at considerably lower altitudes than the other sites examined and both are in well sheltered valleys. They are therefore subject to environmental influences significantly different from those operating at the upland sites, and consequently vegetation changes on the interfluve and in the valleys are not directly comparable. In an attempt to overcome the problem of correlation, a tree pollen diagram has been prepared for the North Gill Wood site for comparison with the tree pollen diagram from Fountains Earth.

At its base, the tree pollen diagram for North Gill Wood is dominated by Betula which averages 80% of tree pollen. Alnus values are low, less than 10% of tree pollen, and the values for Quercus are only slightly higher. Corylus averages between 70% and 80% of tree pollen. If this spectrum is compared with the tree pollen diagram for Fountains Earth equivalent values of Betula, Alnus and Corylus are found only in zone A. However, the Pinus values at this level are not comparable. A radiocarbon date of 900 ± 90 A.D. has been obtained for the base of the peat at North Gill Wood. It is therefore clear that there can be no chronological association between the base of the North Gill Wood peat and zone A at Fountains Earth, which has been estimated to be over 7,000 years old.

The North Gill Wood peat must, therefore, have started to form towards the end of subzone E_2. In the upper 5 cm of peat at Fountains Earth there is a decline in Alnus and Quercus and a corresponding rise in the pollen of Betula. This trend towards increasing Betula pollen percentages in subzone E_2 can be identified in a number of the other diagrams, it suggests the spread of secondary woodland in this area. This appears to have been well established around the North Gill Wood site by the time the peat began to form.

Above 180 cm in subzone F_1 there is marked increase in non-arboreal pollen to over 50% of total pollen. This rise is mainly due to increased values for the Gramineae, but there is also a slight increase in the

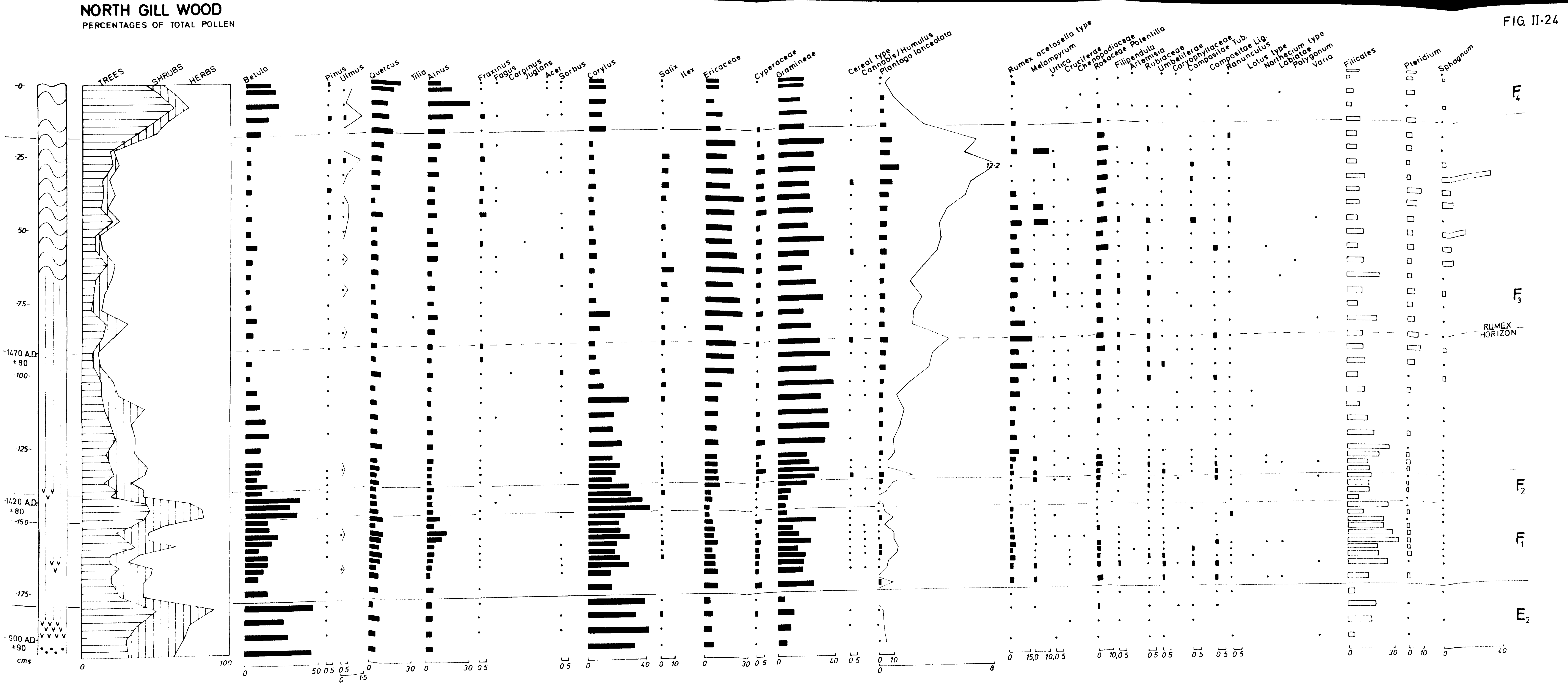
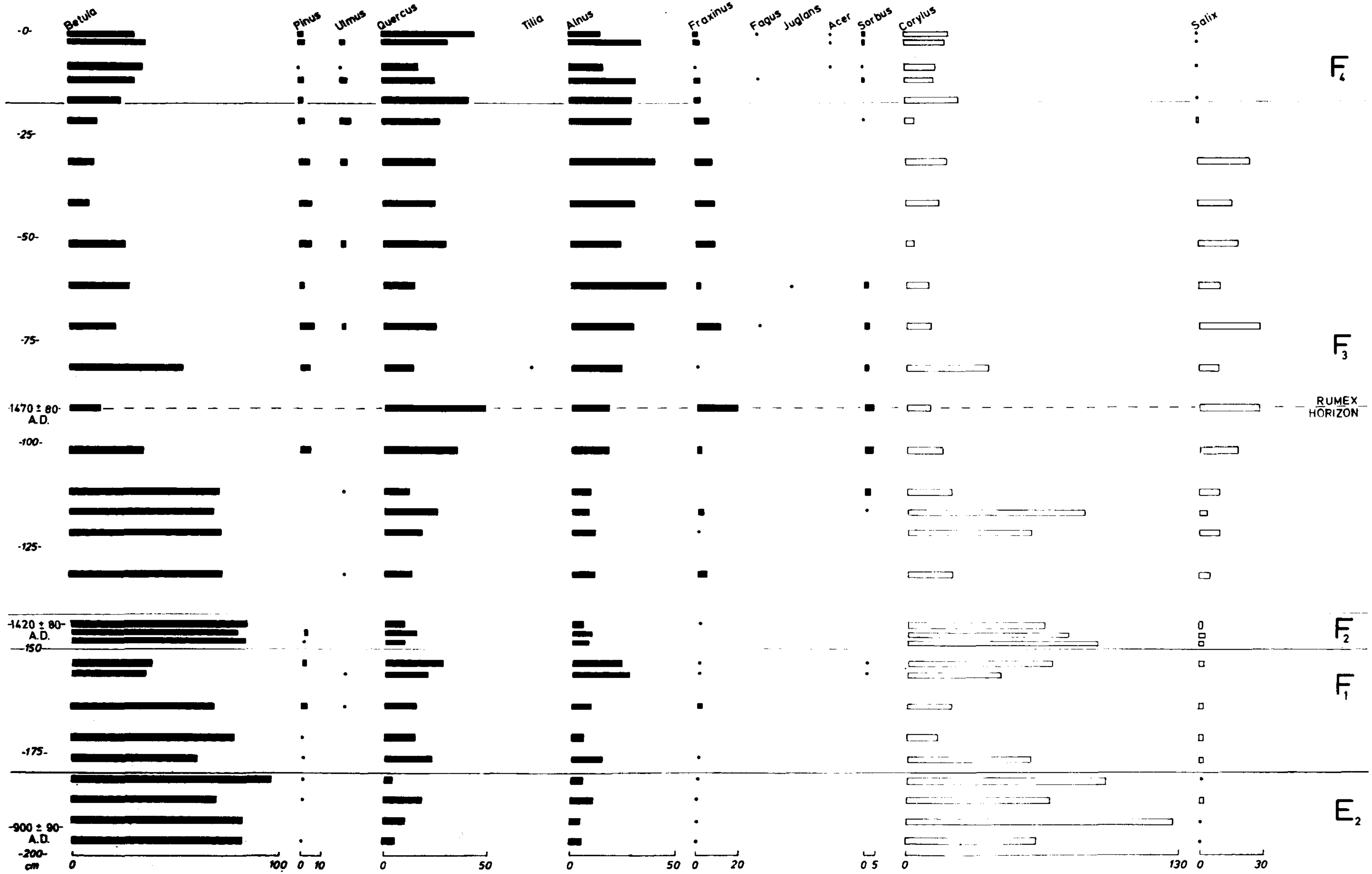

NORTH GILL WOOD
PERCENTAGES OF TOTAL POLLEN
FIG. II·24
TREES
SHRUBS
HERBS
Betula
Pinus
Ulmus
Quercus
Tilia
Alnus
Fraxinus
Fagus
Carpinus
Juglans
Acer
Sorbus
Corylus
Salix
Ilex
Ericaceae
Cyperaceae
Gramineae
Cereal type
Cannabis/Humulus
Plantago lanceolata
Rumex acetosella type
Melampyrum
Urtica
Cruciferae
Chenopodiaceae
Rosaceae Potentilla
Filipendula
Artemisia
Rubiaceae
Umbelliferae
Caryophyllaceae
Compositae Tub.
Compositae Lig.
Ranunculus
Lotus type
Narthecium type
Labiatae
Polygonum
Varia
Filicales
Pteridium
Sphagnum
F4
F3
RUMEX HORIZON
F2
F1
E2
1470 A.D. ± 80
1420 A.D. ± 80
900 A.D. ± 90
cms
12·2

FIG. II.25

NORTH GILL WOOD

PERCENTAGES OF TOTAL TREE POLLEN



Ericaceae, and the incidence and variety of herb pollens increases. There are small peaks in the pollen of Plantago lanceolata and Rosaceae (Potentilla type) and a more marked peak in Rumex acetosella type; Ranunculus, the Umbelliferae, Compositae and Rubiaceae are all represented in significant amounts. Pollen of cereals and of Cannabis/Humulus type is also present throughout this subzone.

The distinction of Cannabis pollen from that of Humulus on the basis of morphology is extremely difficult, but Godwin (1967a) suggested that most of the pollen of this type in British diagrams could be assigned to the genus Cannabis, and he established that Cannabis pollen is invariably associated with arable cultivation (Godwin, 1967b). The pollen assemblage of subzone F_1 therefore indicates a period of agricultural activity, primarily pastoral but with some arable cultivation. The reduction in the tree pollen indicates an active clearance of the area around the site.

A sudden increase in the pollen of both Betula and Corylus occurs at 150 cm and marks the opening of subzone F_2. The Gramineae decline and both the incidence and variety of herbs is reduced, though cereals are still present in some samples from this subzone. This increase in arboreal pollen is followed by an equally sudden decline at 142.5 cm. Peat from the upper part of subzone F_2 has been radiocarbon dated to A.D. 1420 ± 80.

The pollen assemblage of subzone F_3 is typical of a further period of active clearance and agricultural activity; arboreal pollen values are reduced to very low levels and pollen of first the Gramineae and then the Ericaceae increases. Cereal type pollen is present throughout the subzone and pollen of a wide variety of agricultural weeds occurs. The pollen of Rumex acetosella type is represented at values greater than 4%

of total pollen throughout the subzone and at 92.5 cm there is a very marked peak in this pollen type which forms 13% of total pollen. Associated with this level there are small peaks in pollen of cereals and of Plantago lanceolata; Cannabis/Humulus type pollen is present in adjacent samples and the pollen values for Corylus and the trees are at a minimum. A peak in Rumex pollen in zone F was also noted in the Hambleton Hill and Hambleton Dike diagrams. At North Gill Wood the association of this peak with pollen of taxa indicating agricultural activity suggests that this feature may mark a horizon of some cultural significance. A sample of peat from the level of the Rumex horizon was radiocarbon dated to A.D. 1470 ± 80.

During this period the bog in North Gill Wood must have been growing very rapidly as the radiocarbon dates from 145 cm and from 92.5 cm differ by only fifty years. This suggests a rate of accumulation of one centimetre of peat per year. Statistically these two dates cannot be separated as both have been quoted with an error of 80 years on either side, but they are internally consistent and therefore there is no suggestion of disturbance in the profile.

Above 92.5 cm, in subzone F_3, there is a very gradual and slight increase in the pollen of Quercus. The curve for Rumex acetosella type pollen declines but there is an increase in the curve for Plantago lanceolata which represents 11% of total pollen at 32.5 cm. A marked change occurs above 15 cm as all the tree pollen curves, and also the Corylus curve, show a marked increase. By 5 cm the tree pollen component forms over 50% of total pollen, consisting of approximately equal proportions of Alnus, Betula and Quercus pollen. This has been designated subzone F_4 which appears to be a period of decreased agricultural activity. The arboreal pollen percentages are similar to those in surface samples from the modern wood which occupies this valley. The occurrence of occasional grains of Acer pollen is an interesting feature of the upper part of this diagram; these may reflect the introduction and the extension of cultivation of Acer pseudoplatinus from the late sixteenth century onwards (Godwin, 1956).

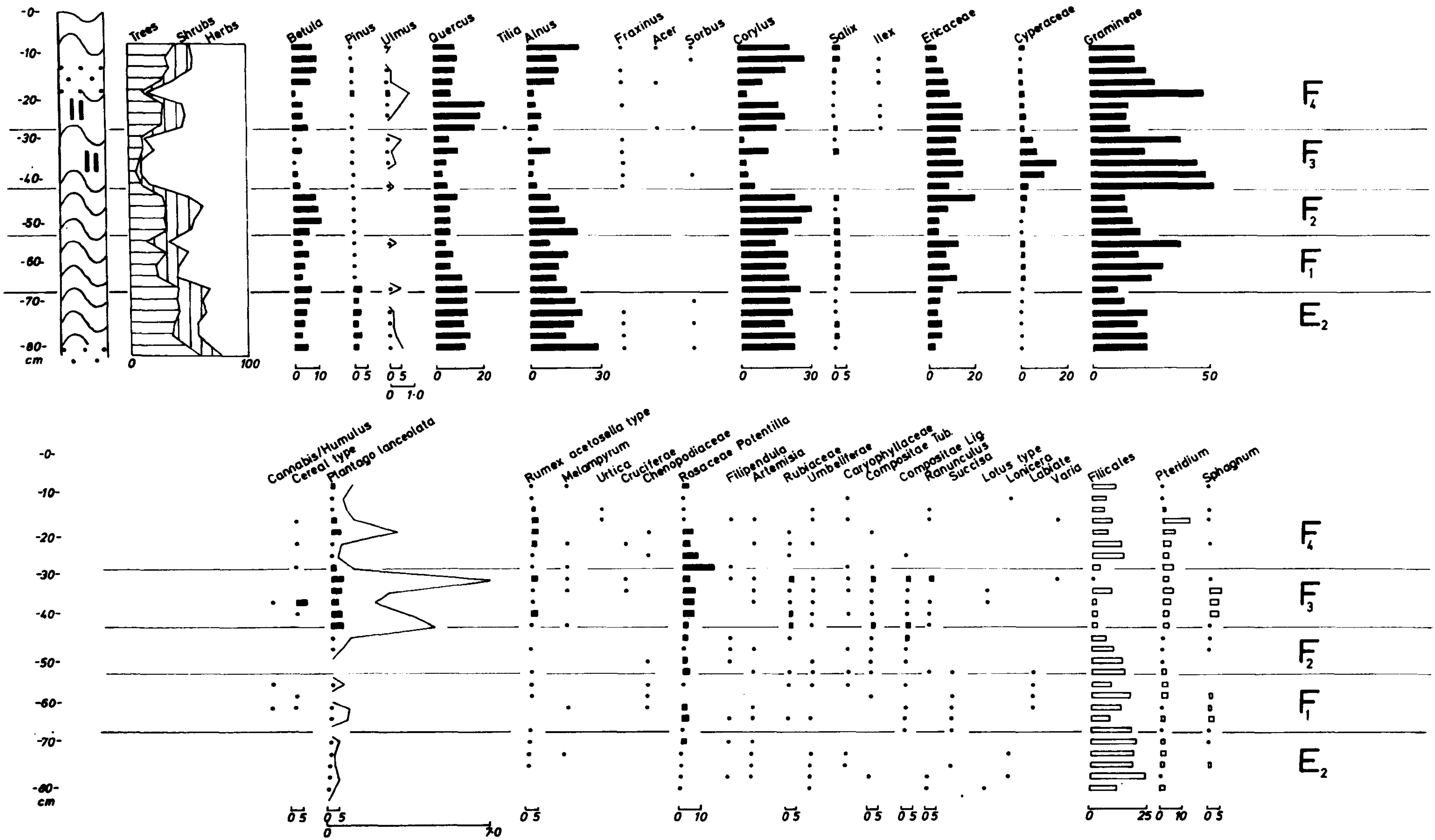
II.iv.i. Skell Gill Wood. Peat. (Fig. II.26)

The pollen diagram from the Skell Gill Wood site illustrates the same general pattern of woodland decline followed by regeneration as is shown at North Gill Wood and the same sequence of subzones has been identified. However, the features associated with agricultural activity are less marked at this site. Fairly high percentages of Filicales (Dryopteris type) spores occur in the early wooded period (subzone E_2). Smith and Taylor (1969) have suggested that relatively high frequencies of fern spores may be indicative of the shady environment in a closed woodland. The reduction in arboreal pollen in subzone F_1 at this site is only slight but a clear peak in the pollen of the Gramineae at 54 cm may indicate an increase in agricultural activity and a wide variety of herbs including Umbelliferae, Compositae, Succisa, Rubiaceae and Cruciferae also occur. Pollen of cereal and Cannabis/Humulus type are recorded sporadically in this subzone.

The regeneration phase of subzone F_2 is represented mainly by an increase in the pollen of Corylus, though increases in the pollen of Alnus and Betula are also recorded. Pollen of the Gramineae declines during this subzone but increases markedly at 42 cm, where it forms 52% of total pollen; this marks the opening of subzone F_3. Between this level and 28 cm arboreal pollen values average less than 10% of total pollen and there is a peak in the pollen of Plantago lanceolata. However,

FIG. II.26 SKELL GILL WOOD PEAT

PERCENTAGES OF TOTAL POLLEN



Rumex acetosella type pollen is not as prominent in this subzone as it is at North Gill Wood and the Hambleton sites.

As at North Gill Wood subzone F_4 is a period of regeneration during which woodland similar to that at present occupying the Skell valley was established around the site. The occurrence of grains of Acer pollen at equivalent levels to those noted in the North Gill Wood diagram is interesting.

II.iv.j. Hambleton Flush (Fig. II.27)

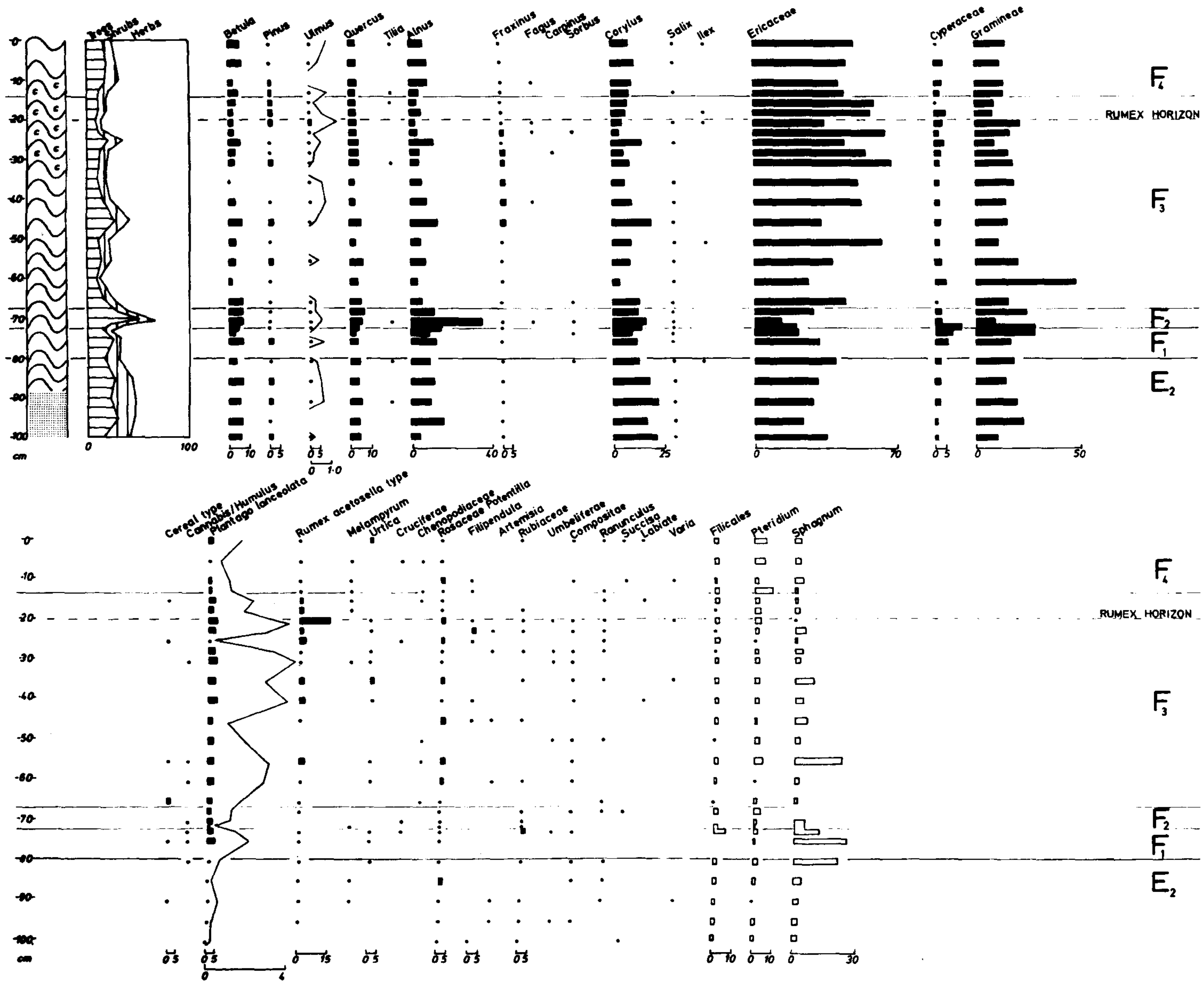
This site is over 100 metres higher in altitude than the woodland flushes just described, and it is at present surrounded by open moorland. However, the stratigraphy of the peat and the pollen diagram show similarities with North Gill and Skell Gill Wood. The marked difference between this diagram and those from the woodland sites is in the form of the Ericaceae curve. This dominates the pollen diagram from Hambleton Flush suggesting that heath has been established around this site throughout the period of peat growth.

Subzone E_2 extends from 100 cm to 80 cm, the relative proportions of arboreal and non-arboreal pollen in this subzone are similar to those in subzone E_2 at the adjacent moorland sites of Hambleton Hill and Fountains Earth. These apparently reflect trees growing at some distance down the valley of North Gill Beck, rather than directly around the site, and it is significant that there are no tree macro-remains in the peat at this site. The expansion of the Gramineae and agricultural indicators which occurs in subzone F_1 at the valley sites is not so well marked at Hambleton Flush, suggesting that this agricultural expansion was predominantly in the lowlands. However, there is an increase in the pollen of Gramineae at the expense of Ericaceae registered in the two samples between 75 cm

FIG. II·27

HAMBLETON FLUSH

PERCENTAGES OF TOTAL POLLEN



and 72 cm and this is accompanied by the appearance of *Cannabis/Humulus* type pollen. There is also an increase in the frequency of *Plantago lanceolata* pollen at this level. There is a slight decline in the Gramineae above 72 cm and slight increases are apparent in the curves for *Betula*, *Quercus* and *Corylus*. These changes are suggestive of subzone F_2, though it seems that this regeneration phase did not affect the area immediately around this site. The behaviour of the *Alnus* pollen curve is unusual: at 71 cm a small increase occurs, but at 70 cm there is a sudden proliferation of *Alnus* pollen, which forms 35% of total pollen in this one sample, and then declines again. The significance of this *Alnus* peak will be considered in the light of the results from the surface sample analyses in Section III.v.

At 60 cm arboreal pollen values are reduced to less than 10% of total pollen and at the opening of subzone F_3 the Gramineae form 50% of total pollen. Above 60 cm Ericaceae pollen expands at the expense of the Gramineae but the agricultural indicators which characterise subzone F_3 at the woodland sites are present throughout. At 20 cm the pollen of *Rumex acetosella* type forms 14% of total pollen and this level can be correlated with the *Rumex* horizon at North Gill Wood and the Hambleton sites. These features suggest that the agricultural phase of subzone F_3 involved both the lowlands and the uplands.

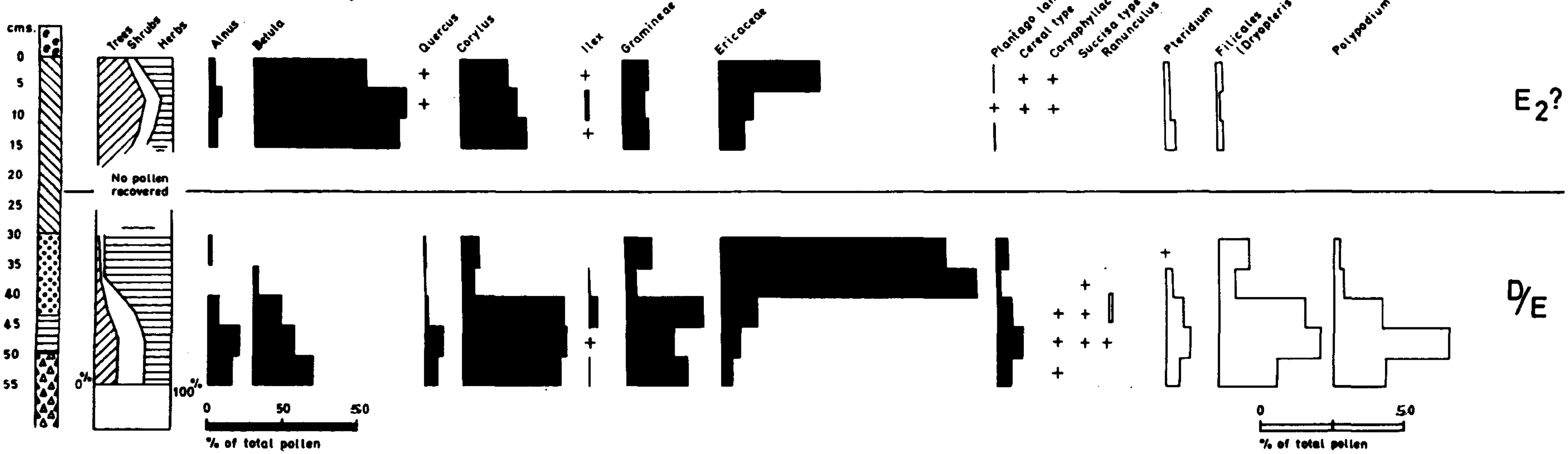
Above 15 cm small increases in the tree pollen curves and the curve for *Corylus* reflect the regeneration which occurred during subzone F_4 at the valley sites. Around this flush moorland conditions persisted, a reduction in the frequency of pollen of agricultural indicators in the uppermost samples suggests a decrease in the intensity of upland agriculture during the recent past.

II.iv.k. Fortress Dike Camp. (Fig. II.29, II.28)

The two pollen diagrams prepared for this site are described in detail in Appendix 4. However, no account is given there of their relationship to the zonation scheme that has been established for the other diagrams from the Nidd-Laver interfluve. The earliest pollen record at this site occurs in the buried soil between 55 cm and 30 cm in the mound section; the sudden increase in Ericaceae pollen suggests that heath was becoming established around the site at this period. On archaeological grounds a late Iron Age or Romano-British date has been suggested for construction of the earthwork (Mr. B. Hartley, personal communication). It seems probable that the pollen record in the buried soil belongs to the upper part of zone D or early subzone E_1. The expansion of heath at this site was probably later than at Fountains Earth, which is 106 metres higher in altitude and in a much more exposed situation.

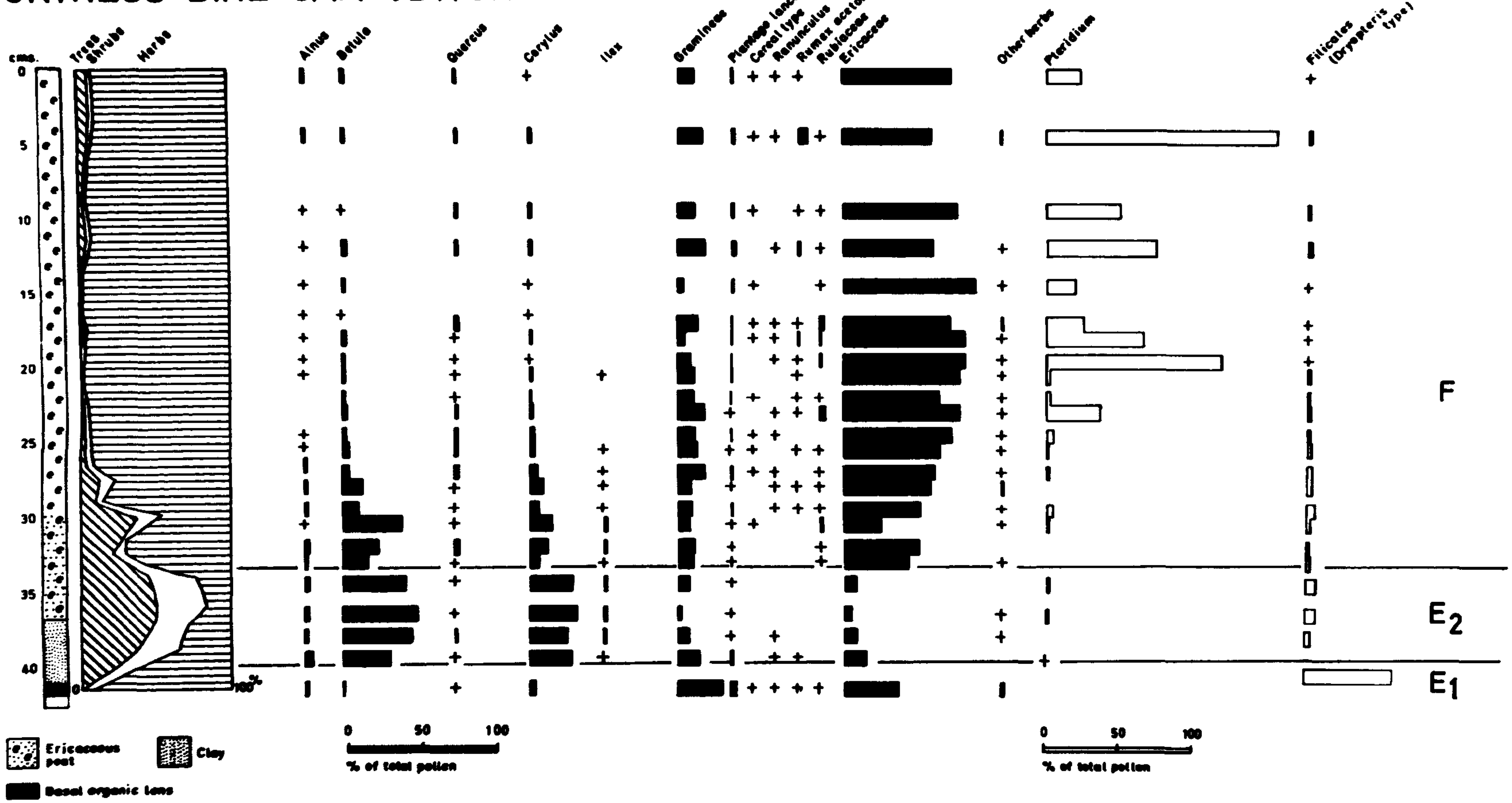
The earliest pollen record which post-dates construction of the earthwork occurs in the thin organic band at the base of the ditch peat diagram. This spectrum, with high percentages of Gramineae, Plantago lanceolata and other weed species is suggestive of a marked phase of agricultural activity. These features are characteristic of subzone E_1. Material from this horizon has been radiocarbon dated to A.D. 630 ± 90. As the opening of subzone E_1 has been dated to around 250 ± 80 B.C., the phase of occupation represented by this organic band must have taken place towards the end of subzone E_1. The abrupt decline in indicators of agriculture above the organic band suggests that the site was abandoned soon after this date. The absence of organic deposits representing earlier phases of occupation of the site is puzzling, if the archaeological assessment of its age is accepted. It is possible that debris was cleared

FIG. II·28 FORTRESS DIKE CAMP: MOUND



Stratigraphy : see Appendix 4

FIG. II·29 FORTRESS DIKE CAMP: DITCH



out of the ditch at intervals when the site was occupied and thus evidence was destroyed. (Tinsley and Smith, 1972. Appendix 4.)

In subzone E_2 there is a rapid expansion in the pollen of Betula and Corylus and at 35 cm these two species form 70% of total pollen. These high arboreal pollen percentages, in conjunction with the occurrence of bark fragments and Betula fruits in the peat, indicate a period of woodland regeneration around this site. An abrupt increase in the pollen of the Ericaceae at 33 cm marks the opening of zone F and the curves for Betula and Corylus gradually decline. The subzones of F are difficult to recognise at Fortress Dike Camp. There is no peak in the Gramineae to associate with subzone F_1; however, a temporary recovery in the values of Betula and Corylus between 32 cm and 30 cm is suggestive of subzone F_2. Subzone F_3 is characterised by higher values for the pollen of the Ericaceae and rather lower values for the Gramineae than at the other sites. However, the increase in the incidence and variety of herbs during this period is marked and the peak in Rumex pollen at 5 cm can be correlated with the equivalent feature at other sites in the area. Pteridium spores reach high values in this subzone at Fortress Dike Camp. There is some suggestion of an increase in arboreal pollen in the uppermost samples which may represent subzone F_4, but the recent pollen record for this site has been destroyed by burning of the uppermost peat.

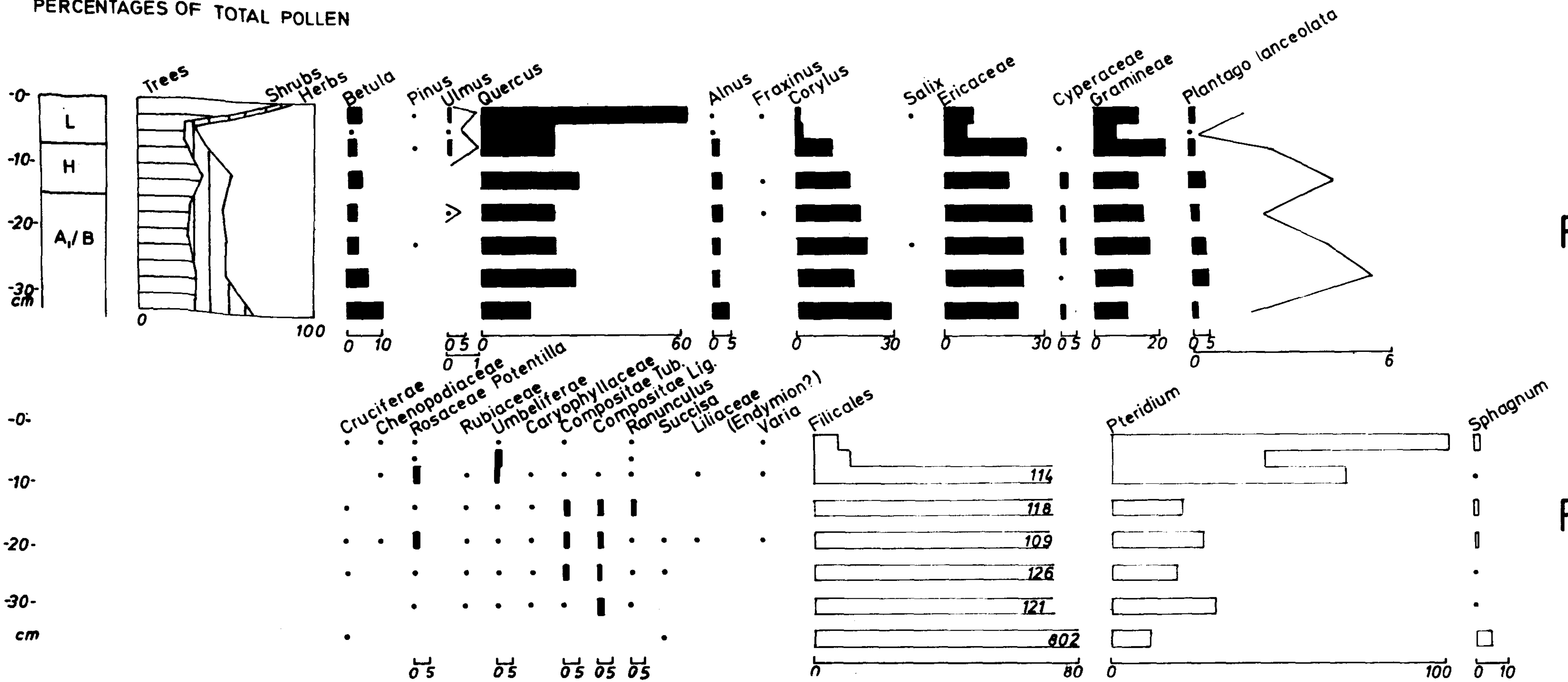
II.iv.1. Skell Gill Wood. Soil. (Fig. II.30)

Investigations into the pollen record of the mineral soils on the Nidd-Laver interfluve yielded disappointing results. In most cases the pollen was scarce and in a poor state of preservation. Only samples from the upper few centimetres of soil yielded countable results and the

FIG. II·30

SKELL GILL WOOD SOIL

PERCENTAGES OF TOTAL POLLEN



lower soil horizons were often completely barren. It appears that the coarse sandy nature of most of the soils result in the very rapid percolation of pollen and only recent pollen spectra are retained. To illustrate this a pollen diagram has been constructed for one soil profile from beneath woodland in the lower Skell valley.

If this diagram is compared with the diagram from the flush peat deposit in Skell Gill Wood, the record in the soil profile apparently covers only subzones F_3 and F_4. In the lower part of the soil diagram fairly high values for Gramineae and a continuous record for Plantago lanceolata associated with pollen of the Compositae and Caryophyllaceae suggests the agricultural phase of subzone F_3. In the upper soil horizons rapidly increasing values for Quercus are indicative of the expansion of trees recorded in subzone F_4 at the flush peat sites. There is a vast increase in the spores of Pteridium above 7.5 cm indicating the spread of bracken which is the principal component of the modern ground flora at this site. The very high percentages of Filicales (Dryopteris type) spores in the lower soil horizons of this profile may represent a relict feature from subzones F_1 or F_2.

SECTION III THE SURFACE POLLEN ANALYSES

Interpretation of ecological significance is one of the fundamental problems posed by pollen diagrams. The difficulties of interpretation are magnified when the object of the investigation is to trace small-scale, local changes in vegetation, rather than to establish the regional picture. The present study of woodland edge fluctuations gave rise to a number of specific questions:

1. Can a pollen spectrum from a woodland site be distinguished from a spectrum from a site a short distance from the edge of the wood, on the basis of the arboreal pollen values?
2. Is it possible to distinguish between a pollen spectrum from a site on the edge of a dense wood and a spectrum from a site within open woodland?
3. What is the ecological significance of the sharp peaks in the _Quercus_ pollen values at Fountains Earth and in the _Alnus_ values at Hambleton Flush?
4. What was the likely status of _Betula_ in the former upland woodland, in view of the apparently anomalous association of abundant _Betula_ macro-remains with low _Betula_ pollen values at some sites?

Recent studies of the modern pollen rain have been successfully applied to the interpretation of fossil pollen assemblages, and it was therefore felt that a surface sample survey on the Nidd-Laver interfluve might provide a solution to these problems. The literature which provided a background for this work is reviewed briefly below.

III.i. The relationship between vegetation composition and the recovered pollen rain - a review

III.i.a. Theoretical Aspects

The investigation of vegetation history by means of pollen analysis involves the reconstruction of pre-existing plant communities from fossil pollen assemblages. Three main stages link the living community with the fossil assemblage: pollen production; dispersal and deposition, together considered as transfer, and alteration of the grains subsequent to deposition. At each of these stages factors operate to distort the relationship between the community and the pollen assemblage. A knowledge of these distorting factors is essential for the ecological interpretation of pollen diagrams. Erdtman (1943) recommended that the relationship of surface samples to the contemporary vegetation was the key to the interpretation of pollen diagrams in terms of vegetation history. Recent studies of this type have provided a theoretical basis against which the assumptions of pollen analysis may be tested. They have also provided estimates of the degree of distortion at each stage in the sequence from the living community to the fossil assemblage.

Variations in pollen productivity have a profound influence on the pollen spectrum from any one site. Plants differ in the amount of pollen they produce, and they also vary in their frequency of flowering. In general the anemogamous species produce greater quantities of pollen than the zoogamous species, but within these two broad categories very large differences exist. Faegri and Iversen (1964) quoted estimates of total pollen production in one season from a ten-year-old branch

Table III.1

THE REPRESENTATION OF ARBOREAL SPECIES IN THE POLLEN RAIN

Relative Pollen Productivity

	Pohl (1937) Germany	Andersen (1967) Denmark
Alnus	17.7	1.5
Pinus	15.8	
Tilia	13.7	0.7
Corylus	13.7	
Betula	13.6	4.1
Picea	13.4	
Carpinus	7.7	
Quercus	1.6	4.1
Fagus	1.0	1.0
Fraxinus		0.6

Representation Ratios $\left(\frac{\%\text{ of species in plant community}}{\%\text{ of species in pollen rain}}\right)$

	Müller (1937) Switzerland	Steinberg (1944) Germany	Tsukada (1958) Japan	Andersen (1967) Denmark
Alnus			5.8	2.3
Pinus	6.6	7.7	22.4	
Tilia			0.13	0.5
Betula	6.0	7.9	1.5	4.4
Picea	0.9	1.1	0.5	
Carpinus			0.6	
Quercus	2.8	1.8		3.6
Fagus	0.3	0.2	0.9	1.0
Fraxinus				0.4

Table III.1 (continued)

Relative Representation

	Davis and Goodlett (1960) U.S.A.	Janssen (1967) U.S.A.	Mullenders (1962) France	Bastin (1964) Belgium
Over-represented	Quercus Alnus Pinus Betula	Betula	Betula Carpinus	Quercus (slight)
Proportionally represented	Fagus Picea Tsuga Ulmus Fraxinus Ostrya	Quercus Ulmus Fraxinus	Quercus Fagus	Betula Pinus (sometimes over-represented)
Under-represented	Acer Thuja Abies Populus Larix Tilia	Tilia Picea Acer Populus Larix	Acer Fraxinus Tilia Prunus Hedera	Carpinus Acer Larix Fagus

of _Fagus_ as 28 million grains with an equivalent figure for _Pinus_ of 350 million grains, although both species are wind pollinated. Pohl (1937) and Andersen (1967) have investigated the relative pollen productivity of different forest tree species and a number of authors have estimated the representation of tree species in the pollen rain, by comparing the composition of surface pollen samples with the composition of the surrounding vegetation. These results are summarised in Table III.1. The results from the different areas vary and it is not possible to arrive at a universally acceptable representation ratio for each species. The reasons for this are diverse. Environmental factors may operate to selectively influence pollen productivity and dispersal; Potter and Rowley (1960) stated that pollen production was favoured by warmth, dryness, sunshine, favourable precipitation and lack of killing frosts in winter. In addition the relative representation of a species in the pollen rain depends on its relationship in the surrounding vegetation with other species of differing productivities.

The calculation of representation ratios for taxa producing only a small amount of pollen is virtually impossible. Such plants, which include _Ilex_, _Viscium_, _Vitis_ and _Lonicera_ are often those which are insect pollinated. Faegri and Iversen (1964) have observed that the occurrence of pollen of these taxa in deposits usually used for pollen analysis is accidental and unreliable. Their pollen may give indications of great value but nothing can be deduced from its absence.

In the light of the information available on differential pollen productivity and dispersal from surface sampling Iversen (Faegri and Iversen, 1964) has suggested correction factors to be applied to raw pollen data before drawing up percentage curves. He proposed the division of pollen types into four groups:

A - Species that contribute great quantities of pollen, in northern Europe Pinus, Betula and Corylus, should be reduced by a factor of 4.

B.1 - Species that contribute moderate quantities of pollen, in northern Europe Picea, Quercus, Fraxinus, Fagus, etc., should be plotted without correction.

B.2 - Species which though important in the vegetation may produce or disperse very little pollen, e.g. Tilia and Hedera, should be multiplied by a factor of 4.

C - Species which produce so little pollen it is immaterial whether they are included in the pollen sum or not, e.g. Ilex, Viscium, etc.

Iversen (1949) found that spectra converted by the above factors gave a better representation of the actual composition of the vegetation around his sites than did the raw data.

From his work in the Draved Forest, Jutland, Andersen (1967) suggested a similar set of corrections to be applied to the pollen counts prior to the percentage calculations:

Betula	$1 \times \frac{1}{4}$	Quercus	$1 \times \frac{1}{4}$	Alnus	$1 \times \frac{1}{2}$
Fagus	1×1	Tilia	1×2	Fraxinus	1×2

He suggested that in open forest, where Betula may flower profusely, the correction factor should be as high as $1 \times \frac{1}{6}$, and that in some areas a correction for Alnus of $1 \times \frac{1}{4}$ might be more appropriate. Andersen's correction factor for Quercus is high compared with Iversen's and in Table III.1 Andersen's values for Quercus are noticeably higher than those obtained by other workers. This might suggest that conditions in the Draved Forest are abnormally favourable for the flowering of oak.

The theoretical relationship between the composition of the vegetation and the pollen sample is not only influenced by variations in pollen productivity; the structure of the community itself is also important if the pollen diagram is drawn up on a percentage basis. The problems inherent in the use of percentage calculations have been discussed by Fagerlind (1952) and in more simplified terms by Faegri and Iversen (1964). Detailed work on the significance of this problem in practical terms has been carried out by Davis (1963). She discussed a system in which three hypothetical plant species, a, b, and c, were equally represented in the vegetation but had differing productivities, and contributed pollen to a sampling point in the ratio 10 : 5 : 1. She used the letter R to represent the ratio between the pollen percentage and the vegetational percentage for each species, thus:

$$\text{Ra} = \frac{\text{Species a pollen percentage}}{\text{Species a vegetational percentage}}$$

In this system the ratio of the R values, Ra : Rb : Rc always equals 10 : 5 : 1, but the actual R value for each species varies depending on its frequency in the vegetation. Davis argued that as the total number of pollen grains deposited at a sampling point is a function of both abundance of species and productivity, variation in the gross rate of pollen contribution due to the elimination of one source of production would cause a change in the percentage values for other pollen types, contributed at a constant rate, though no change need have taken place in their vegetational frequency. Therefore the representation of a species in the pollen rain depends on its relationship in the vegetation with species having differing R values. Davis (1963) observed: "it is a mistake to assume that a species is 'characteristically' over- or under-represented by pollen. No species except the two with extreme R values can be expected to be consistent in this regard". This must explain some of the differences in representation ratios obtained by different workers (Table III.1).

The relative representation of non-arboreal pollen species has been neglected in comparison with the work done on arboreal species. This reflects the fact that for many years non-arboreal pollen was ignored by palynologists. Recently, however, the examination of non-arboreal pollen has enabled the history of forest clearance in Europe, and the United States, to be traced. The calculation of representation ratios for herb species is a greater problem than for trees, owing to the extremely local nature of the non-arboreal pollen. This is shed at low levels and is therefore less widely distributed by turbulence in the atmosphere than the pollen liberated from trees. Jonassen (1950) found that Calluna was generally under-represented except on heathlands. Heim (1962) and Mullenders (1962) both concluded that the Ericaceae and the Gramineae were generally under-represented in woodlands. None of these writers, however, attempted to compute representation factors for the non-arboreal species.

The importance of differential pollen transfer in the distortion of pollen diagrams has been recognised for many years. Studies on the long distance transport of pollen grains were made by Hesselman (1919), who exposed glycerine-filled petri-dishes on light-ships in the Gulf of Bothnia and collected large amounts of Picea, Betula and Pinus pollen. However, as Faegri and Iversen (1964) have pointed out, the quantities of pollen produced by the local vegetation are generally so great that in absolute amounts pollen derived from long-distance transport is insignificant. Long distance transport becomes of greater significance in regions of low absolute pollen productivity, particularly in arctic and sub-arctic areas. Bartley (1967) recorded values of 8.5% and 3.8% of total pollen for Pinus and Picea respectively in barren areas around Deception Bay, Labrador, where the nearest source was over 600 kilometres to the south.

The initial stage in the transfer of pollen involves its dispersal from the plant. In many cases the pollen of zoogamous species is never exposed to the atmosphere and the pollen is only deposited on the ground when the male flowers are dropped. In most wind-pollinated species the male flowers expose the pollen freely and it is liberated to the atmosphere. Experimental work on the distribution of pollen is complicated by the fact that vegetation communities are complex sources. Gregory (1961) described experimental studies in pollen and spore dispersal from a point some 10 cms above the ground; the relationship between deposition and distance away from the source followed a curve, with 90% of deposition taking place within the first 100 metres. As the height of the source was increased the percentage deposition immediately around the source decreased. This accounts for the fact that the average dispersal distance of pollen from non-arboreal species is so much reduced compared with arboreal species. Wright (1953) carried out studies on the dispersion of pollen away from individual isolated trees, and showed that the relative pollen frequency decreased markedly with distance from the source, a conclusion also reached by Lanner (1966).

The traditional concept of the "pollen rain" is somewhat at variance with these observations on the very rapid deposition of pollen close to the source. According to Erdtman (1943) pollen grains are "easily carried by the wind, some of them are transferred into higher regions by vertical air currents and remain there for days, weeks or even months before they settled back to earth." Though it was accepted that direction, velocity and turbulence of air currents had some effect on pollen transfer (Potter and Rowley, 1960), this model of an evenly distributed pollen rain was implicit in many early palynological studies. Recently, however, in a paper entitled "Differential pollen dispersion and the interpretation of pollen diagrams", Tauber (1965) produced a more complex theoretical model for the transfer of pollen which has great importance for the interpretation of fossil data. This was based on a consideration of the distribution of atmospheric pollutants and fungal spores and took into account the specific gravity of individual pollen grains. The model was developed with reference to conditions in closed deciduous forests analogous with those covering most of the European lowland in the Atlantic period.

Tauber suggested that the transfer of pollen was composite in nature and he distinguished at least three components: pollen carried through the trunk space of the trees; pollen carried above the canopy, and pollen brought down by rain. Tauber suggested that pollen which was dispersed below the tree canopy would be transported some distance horizontally by air currents in the trunk space; the remaining pollen would be carried up by convection and turbulence; some would be transported by winds above the canopy, some however would ascend by thermal currents into the atmosphere where it would be distributed and later washed out by falling rain drops. Meshkov (1950) has recorded striking data illustrating the efficiency of rain in scouring pollen from the atmosphere. He noted a deposit of pine pollen sufficiently heavy to colour the soil of the main street in a village in central Russia following a rainstorm; the nearest pine stands were about 10 km distant.

One of the most important implications of Tauber's model is that the extent of the area represented in the pollen rain at any one site will depend on the relative importance of each of the three transfer components, as these will have essentially different origins and therefore different pollen spectra. He introduced the concept of the "effective area" - the area from which at least 80% of the pollen grains deposited at any one point originate. The trunk space component is very local in origin. Tauber suggested that for heavy pollen grains, e.g. Tilia and Fagus, the range would be a few hundred metres or less, but for light pollen grains it might be up to ten times this distance; this component will reflect the local vegetation. Pollen brought down by rain will reflect the vegetation of a very wide region, and the canopy component will have an intermediate origin ranging from a few to many kilometres.

Thus in very small basins the trunk space component will dominate and the effective area will extend from 300 to 1000 metres away from the basin, depending on the species present; the resultant pollen diagrams will reflect predominantly local vegetation changes. In the centres of large basins the trunk space component will be of little significance and the pollen diagrams will have a regional character, the effective area varying from 30 to 100 kilometres around the basin. This reasoning therefore implies that if the area around a basin is cleared the pollen rain will gradually reflect the vegetation of an increasingly wide area.

Tauber (1967) has produced experimental data from Gantekrogsø, a small forest lake in Zealand, to support the hypothesis that the trunk space component is dominant in the transfer of pollen to small basins. Pollen transferred in this way must be subject to filtering by the vegetation and therefore the density of the stand will strongly influence the proportion of pollen deposited by the trunk space component. This effect was predicted by Tauber in his original paper on pollen dispersion, and the data from Gantekrogsø provide experimental evidence for the filtration effect.

The data of Janssen (1966) from the United States and Berglund (1972) from Sweden provide further support for Tauber's composite model for pollen transfer. Janssen identified extra-local and regional elements in his curves of the relationship between pollen rain and distance from the source along lines of transect in Minnesota. The former is equivalent to Tauber's trunk space component and the latter is equivalent to the canopy and rain-out components. In studies of the modern pollen rain in south-east Sweden, Berglund (1972) recognised components of local, regional and extra-regional dominance at increasing distances from the forest edge which accord with Tauber's categories.

Pollen which is deposited on the ground surface may become incorporated into accumulating peat deposits or lake sediments where it may be subjected to various processes which tend to alter the grains. The differential susceptibility of pollen and spores to damage following deposition provides a further means for the distortion of the relationship between the vegetation and the pollen counted. Havinga (1964) attempted to simulate natural conditions of oxidation in the laboratory.

He investigated a number of pollen and spore types and arrived at the following sequence in which susceptibility to decay increased from one to seven.

1. _Lycopodium_
2. Conifers
3. _Tilia_
4. _Corylus_
5. _Alnus-Betula_
6. _Quercus_
7. _Fagus_

Pollen of certain taxa such as _Populus_ and the Juncaceae are rarely recovered from deposits and are assumed to be rapidly destroyed (Erdtman, 1943). In addition to corrosion of the exine as a result of oxidation, pollen grains may also be subject to varying degrees of compression and fragmentation following deposition. Grains with thin exines are most subject to this type of alteration. This can lead to over-representation of the more resistant grains, or of those which have easily identifiable features, for example _Tilia_ and the Compositae. The state of preservation of the pollen grains in a fossil assemblage is therefore very important in pollen analysis, and if there is evidence of differential decomposition this may have to be compensated for when the diagrams are interpreted.

III.i.b. Applications of surface pollen analysis to the interpretation of fossil assemblages

"Much of the uncertainty in the interpretation of Late Quaternary pollen assemblages can be removed by judicious use of pollen surface samples from a variety of vegetational formations."

(Wright, 1967)

The use of studies on the modern pollen rain in the interpretation of fossil pollen assemblages is now widely accepted. The majority of studies are from the United States where the search for analogues for the reconstruction of past vegetation is relatively simple as large areas of natural vegetation still exist. The method that has generally been adopted in these studies has involved the delimitation of sample plots within which vegetation composition has been determined on a percentage basis, using parameters such as frequency, basal area of species, or crown area of species. Comparisons have then been made between the vegetation percentage and the pollen percentage at each site. Fossil pollen assemblages similar to the modern spectra can then be assigned to a particular vegetation type.

Some of the studies carried out in the United States have been on a very large scale. Potter and Rowley's work on the relation between the pollen rain and vegetation on the San Augustin Plains, New Mexico, was carried out over an area of 5,200 square kilometres. They reported reasonable correlations between the pollen collected in traps and the vegetation of the surrounding area (Potter and Rowley, 1960). Lichtie-Federovich and Ritchie (1965) have published data from surface samples collected along a belt transect 700 kilometres by 400 kilometres that spanned the forest-grassland transition in Manitoba. Within this region they identified a series of "landform-vegetation regions" and attempted to establish a characteristic pollen spectrum for each of these. Their results indicated a positive relationship between these units and the regional pollen rain. Davis (1967) has reviewed data from surface samples collected throughout Canada by many workers, in order to interpret late-glacial pollen sequences from southern New England.

The use of surface samples to solve problems on a more restricted areal scale has been carried out by Davis (1963), McAndrews (1966; 1967) and Janssen (1966; 1967). Davis (1963) employed surface sample data from an earlier survey in Vermont (Davis and Goodlett, 1960) to compute R values for various species, and these were then used to interpret fossil pollen assemblages from lake sediments. McAndrews (1966; 1967) worked out the post-glacial vegetational history of an area of north-west Minnesota, with particular reference to recent land disturbance. He analysed surface samples and short sediment cores along a transect across several major vegetational formations. He was able to assess the forest composition prior to the settlement of the area in 1855, from the records of the Government Land Survey. The settlement phase was identified in the lake sediments by the abrupt rise in pollen of species characteristic of disturbance, Ambrosia, Chenopodiaceae, and Zea mays. McAndrews compared the vegetation survey with the immediate pre-settlement pollen spectra and identified a characteristic pollen rain for each of the major vegetation formations. He used this data to interpret four long cores through post-glacial sediments along the transect, and he was able to trace the advance of prairie into forest in mid post-glacial time. Janssen (1966), working in the same area as McAndrews, studied the effect of distance from pollen source on transects approaching distinct local forest types. He was able to distinguish between local and regional components in the pollen rain and concluded that the regional component differed little from site to site. From this work Janssen obtained detailed information regarding the pollen rain in different vegetational regions in north-western Minnesota and he used this to interpret the post-glacial vegetational history from sediments in a small basin in the area.

One of the most extensive studies of regional pollen rain was carried out by Wright, McAndrews and Van Zeist (1967) in western Iran. The modern regional pollen rain was determined at intervals along transects from the steppe of the Mediterranean piedmont, across the oak woodland of the Zagros Mountains, to the Artemisia steppe of the Iranian plateau; results were used to interpret vegetation changes in lake sediments from the region (Van Zeist, 1967).

In Europe studies on surface pollen analysis have tended to concentrate on limited investigations to provide solutions for individual problems. The degree of disturbance in the vegetation would make historical reconstructions based on the pollen rain of large regions of little value. One of the most comprehensive and detailed studies was carried out by Jonassen (1950). He produced pollen diagrams from a number of lakes and bogs in the heath area of Jutland which were difficult to interpret and he therefore undertook an extensive study of the relationship between surface pollen spectra and the surrounding vegetation. He investigated the surface pollen rain in forests dominated by a variety of single species, and in mixed forest, taking samples from both amongst the trees and from open lakes and bogs within the forest. He also collected samples from cleared areas within the forested region and from open heathland. Jonassen concluded that it was possible to distinguish spectra from cleared and wooded country on the basis of the non-arboreal pollen values. He obtained estimates of the degree of representation of various species in the pollen rain in a variety of vegetation communities. These results were then applied to the Jutland pollen diagrams and Jonassen was able to establish the early forest history of the present heathland.

Andersen (1967) carried out a detailed investigation into the tree pollen rain in a mixed deciduous forest in south Jutland. He calculated pollen representation rates for Betula, Quercus, Alnus, Fagus, Tilia and Fraxinus (vide supra Table III.1) by comparing the pollen recovered from moss polsters with the vegetation within a radius of 30 metres from the sampling site. One of the most significant points to emerge from Andersen's investigations was that dispersal distances within the forest for the majority of pollen types were very short, i.e. less than 20 - 30 metres. As the height of the trees averaged 20 metres, vertical fall of pollen appeared to equal horizontal drift in importance for pollen dispersal. The pollen spectra therefore reflected local vegetation very closely. Andersen (1972) has used these data to interpret the vegetation history of a site in the Draved Forest. Ninety centimetres of sediment were analysed from a small hollow, only two metres across, surrounded by Fagus sylvatica. Andersen was able to trace the changing composition of the forest immediately around the site from the Atlantic period until the present.

Recent work by Heim (1962), Mullenders (1962) and Bastin (1964) has provided further information on the relationship between the surface pollen spectra and the vegetation in European forests. However, these studies have not been applied directly to the interpretation of pollen diagrams.

Limited use has so far been made of surface pollen analyses in the interpretation of post-glacial vegetation history in Britain. Watts (1959) drew attention to the possibility of using pollen diagrams from small basins surrounded by uniform vegetation, for the detailed reconstruction of plant communities. He pointed out that the evaluation of the results from such sites would require a study of the modern pollen rain of well characterised woodland communities. Proctor and Lambert (1961) examined the pollen spectra of modern Helianthemum communities, in an attempt to provide information about the plant communities associated with late-glacial pollen assemblages.

Recent studies by Peck (1972) in north Yorkshire, have provided information on the transport and deposition of arboreal and non-arboreal pollen in lake sediments. However, there is little information regarding the dispersion of pollen from woodlands in Britain. There are no studies in existence similar to those described for the forests of continental Europe, primarily because natural, undisturbed woodland is so rare in Britain. Turner (1964b) has studied the dispersion of Pinus pollen away from a plantation on a bog in Ayrshire. The investigation enabled the size of the local and regional pollen components to be assessed. Turner established that, at this site, the local (β) component supplied by the Pinus plantation became insignificant between 300 and 500 metres from the edge of the trees. She deduced from these results that small clearances which affect a forest edge over a radius of about 100 metres will only be registered clearly in pollen diagrams from sites within 100 metres of the original forest edge. At distances of over 500 metres small clearances would not be detected. Thus any clearance phases identified in deposits from the centres of fairly large bogs or lake basins must represent periods of considerable clearance in the surrounding region.

Thorley (1971) carried out a limited investigation into the dispersion of Fagus pollen away from a beech woodland in Kent. She discovered that although Fagus pollen was well represented in surrounding grassland communities it hardly penetrated the canopy of nearby mixed oakwoodland. She therefore concluded that in recent times the effective dispersion of _Fagus_ pollen has increased with increasing clearance.

A surface pollen study of direct relevance to the present work on the Nidd-Laver interfluve was carried out by Cundill (1971), on the North Yorkshire Moors, to aid in the interpretation of pollen diagrams from that region. Cundill showed that deposition of arboreal pollen (expressed as a percentage of total pollen) decreased very rapidly as distance from the woodland edge was increased. He also noted that although the general nature of the woodland was well represented in pollen spectra from moss polsters, wide variations occurred in the frequencies of individual tree species from site to site. Cundill's data were based on the analysis of 31 samples from an area of about 80 square kilometres.

This review has provided an outline of the variety of problems which have been investigated by means of surface sampling, ranging from the very general to the specific. In view of the success with which workers in Europe have applied surface pollen studies to the solution of particular problems, a programme of surface sampling was devised for the Nidd-Laver area. Over a hundred moss samples, collected from within the study area, were analysed. This provided a detailed picture of pollen deposition across a woodland/moorland transition. Despite distortion due to the differential susceptibility to decay of pollen grains, a comparison between this modern pollen deposition data and the fossil assemblages seemed the soundest available basis for the interpretation of the pollen diagrams.

III.ii. Surface pollen sampling on the Nidd-Laver interfluve

III.ii.a. The Sampling Medium

In this research surface samples were collected from moss polsters; wherever possible species of *Sphagnum* were chosen, but in some cases cushion forming mosses had to be used instead. The advantages of surface samples obtained from moss polsters over those obtained by pollen traps have been outlined by Jonassen (1950). Samples from polsters represent the average composition of the pollen rain over the period of years during which the moss has been growing. A pollen trap yielding a sample obtained during only one season of production is not comparable with a fossil spectrum which reflects the production of several years. Various environmental factors may cause anomalous pollen production during one season and result in an unrepresentative sample being trapped. In addition Hyde (1952) has shown the existence of a cyclical production of pollen by trees, independent of environmental conditions, such that maximum production occurs every five years for *Quercus*, every three years for *Fraxinus* and *Ulmus* and every two years for *Pinus* and *Fagus*. Differences such as these will be averaged out in samples from moss polsters. One possible problem regarding the use of polsters has been reported by Crowder and Cuddy (1972), who mentioned the possibility of sieving taking place, resulting in large pollen grains being retained by the top of the plant and smaller grains accumulating towards the base. For this reason they recommended the use of the whole polster in order to obtain a representative sample. Moss polsters have been considered a satisfactory sampling medium by the majority of workers who have investigated the modern pollen rain for comparison with fossil data (Jonassen, 1950; Potter and Rowley, 1960; Heim, 1962; Bartley, 1967; and Wright et al., 1967).

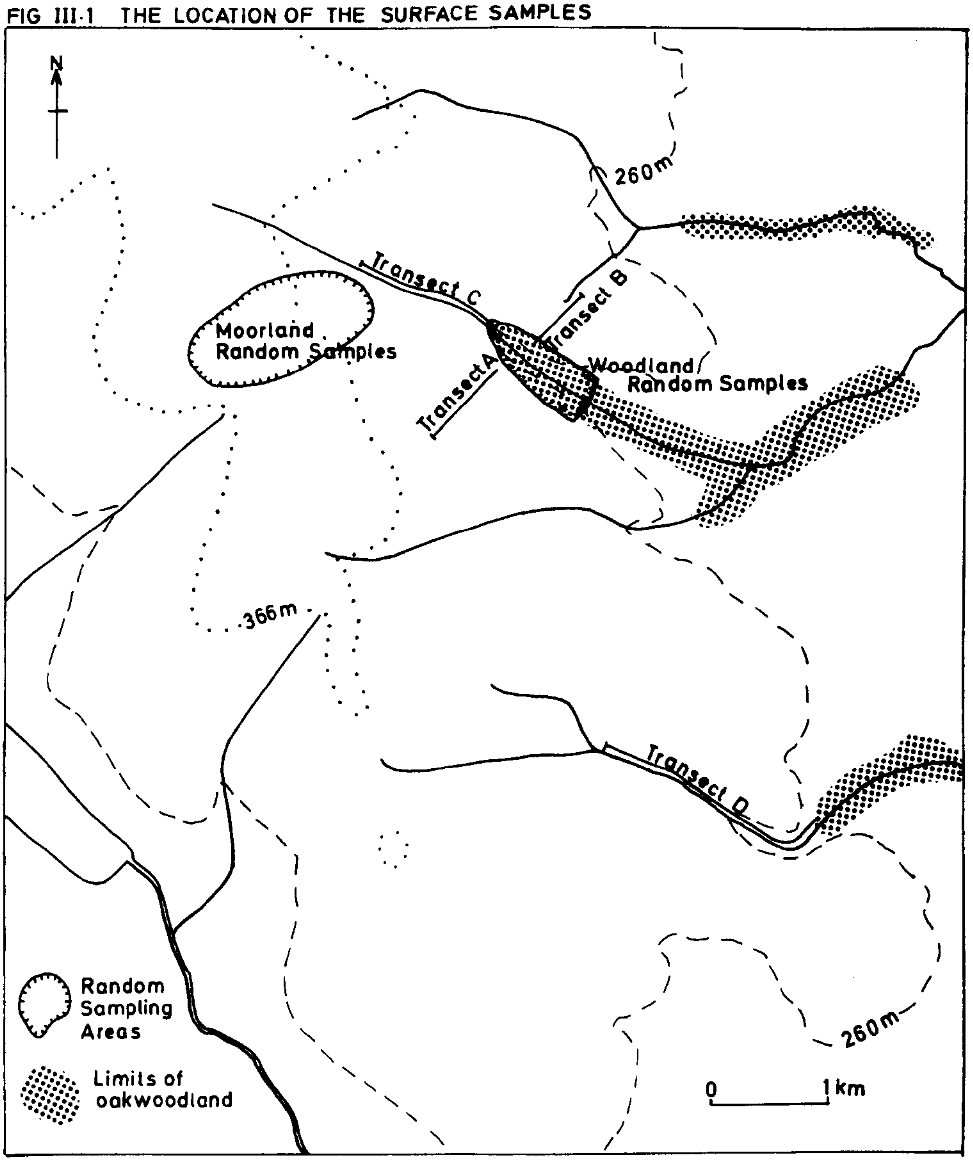
III.ii.b. The Location of the Surface Samples

The surface sampling programme was designed to investigate four main problems:

1. The relative representation of various types of arboreal and non-arboreal pollen in the gill woodlands.
2. The relative representation of various types of arboreal and non-arboreal pollen on the moorland.
3. The nature of the dispersal of arboreal pollen away from the edge of the gill woodlands.
4. The pollen productivity of Betula at upland sites.

Moss polsters were collected from the moors at the head of the North Gill Beck and from North Gill Wood. In order to obtain a random distribution of samples, two axes were chosen within each of the sampling areas. A track which runs in an approximately straight line from east-north-east to west-south-west, across the Nidd-Laver interfluve from the head of North Gill Beck to Bouthwaite in Nidderdale, was chosen as the axis for the heath community; in the wood the line of the North Gill Beck was used as the axis. Samples were collected alternately from the right and left sides of each axis, the sampling points being determined by the use of co-ordinates derived from tables of random numbers. The measurement of distances along the axes and at right-angles

FIG III·1 THE LOCATION OF THE SURFACE SAMPLES



to them was carried out by pacing. In almost all cases suitable moss polsters were found within a radius of two metres of the appropriate spot. At each sampling point a note was made of the vegetation within this radius.

In order to investigate the dispersal of arboreal pollen away from the woodland edge, moss polsters were collected at predetermined intervals along lines of transect from the edge of the woodland, out on to the moors. Three main transect lines were chosen (Figure III.1); Transect A running south-west for 550 metres perpendicular to the south-west edge of North Gill Wood; Transect B running north-east for 400 metres perpendicular to the north-east edge of North Gill Wood; and Transect C running north-west for 600 metres following North Gill Beck valley from the edge of the wood out on to the moors. These three transects were chosen with a view to investigating the effect of the prevailing westerly winds on pollen dispersal. A fourth transect, D, followed the valley of Skell Gill from the edge of the wood out on to the moor; a limited number of samples were collected and the results were used only to provide a check on certain features of Transect C.

The investigation of pollen production in upland Betula communities necessitated a slightly different approach as there are only isolated Betula trees on the Nidd-Laver interfluve at the present time. Samples were therefore collected in and around an area of regenerating Betula scrub on Ramsley Moor south-east of Sheffield (SK 285755). Ramsley Moor is on the eastern edge of the gritstone plateau which forms the southern Pennines in this area, and it is at an altitude of between 270 and 305 metres. It is therefore very closely comparable with the plateau of the Nidd-Laver interfluve. It is an area of mixed Calluna heath and Molinia grassland which has been invaded since 1945 by Betula (Dr. S. R. Eyre, personal communication); in places this forms a dense cover with trees averaging about six metres high. As Betula species begin to bear fruit at about fifteen years (Anderson, 1950) many of these trees should now be mature, and this was confirmed by field observations in the spring of 1972.

In all cases the whole of the moss polster was collected and processed in order to avoid filtration effects (vide supra). The laboratory technique used was similar to that adopted for the fossil material and is outlined in Appendix 1. The pollen count for each sample was based on a total of 500 grains, excluding spores. This pollen sum was used in order that the results obtained in the surface pollen survey would be directly comparable with those from the fossil pollen diagrams, and therefore of direct relevance to the problem of interpretation. The use of this pollen sum, however, inevitably means that the data are not directly comparable with those of most other workers, as the majority of studies on representation ratios have been based on an arboreal pollen sum (e.g. Jonassen, 1950; Davis and Goodlett, 1960; Andersen, 1967).

In all samples the preservation of the pollen grains was good, and there were no obvious indications that differential destruction of grains was distorting the results, even in the well aerated cushion mosses.

III.iii. The Results of the Surface Pollen Survey

III.iii.a. The pollen rain in North Gill Wood

Surface samples were collected from the upper part of North Gill Wood in an area which extended 400 metres down the valley from the margin of the wood, as defined by the limit of enclosure (Figure III.1). The valley at this point is only about 150 metres wide and about 30 metres deep. The valley sides, which descend steeply to the stream, are covered with woodland dominated by Quercus petraea, with occasional Alnus glutinosa near the stream. Betula pubescens and Sorbus aucuparia are associated with the Quercus in places. The open nature of the woodland canopy has allowed a fairly rich ground flora to develop which is dominated by Pteridium aquilinum. In order to make a generalised assessment of the representation of various species in the pollen rain a brief survey of the vegetation was undertaken. The composition of the tree layer was determined by counting all the trees within the area of woodland sampled; the results are expressed in percentages in Table III.2. The relative importance of the different species in the ground flora was estimated by calculation of a frequency index based on the presence or absence of each species in a sample of 50 randomly placed metre quadrats. The results are given in Table III.2, the value of the frequency index indicating the probability of finding the species growing within any one square metre.

The results of the pollen analysis of 22 moss polsters are shown in Figure III.2. The notations used are similar to those adopted for the fossil pollen diagrams. Calculations are based on a total pollen sum, excluding spores. The summary diagram shows the relative proportions in each sample of:

Table III.2

THE SPECIES COMPOSITION OF NORTH GILL WOOD

Canopy - percentage composition

Quercus petraea	71%
Betula pubescens	11%
Alnus glutinosa	13%
Sorbus aucuparia	3%

Ground Flora

	Frequency Index
Pteridium aquilinum	80%
Festuca altissima	44%
Holcus lanatus	42%
Galium saxatile	32%
Vaccinium myrtillus, cushion mosses	22%
Blechnum spicant	16%
Sorbus aucuparia seedling	14%
Sphagnum spp.	12%
Betula pubescens seedling, *Carex panicea*, *Oxalis acetosella*	10%
Endymion non-scriptus	8%
Polytricum commune	6%
Quercus petraea seedling, *Ranunculus ficaria*, *Rumex acetosella*, *Polypodium vulgare*	4%
Lysimachia nemorum, *Potentilla erecta*, *Cirsium palustre*, *Ranunculus acris*	2%

Table III.3

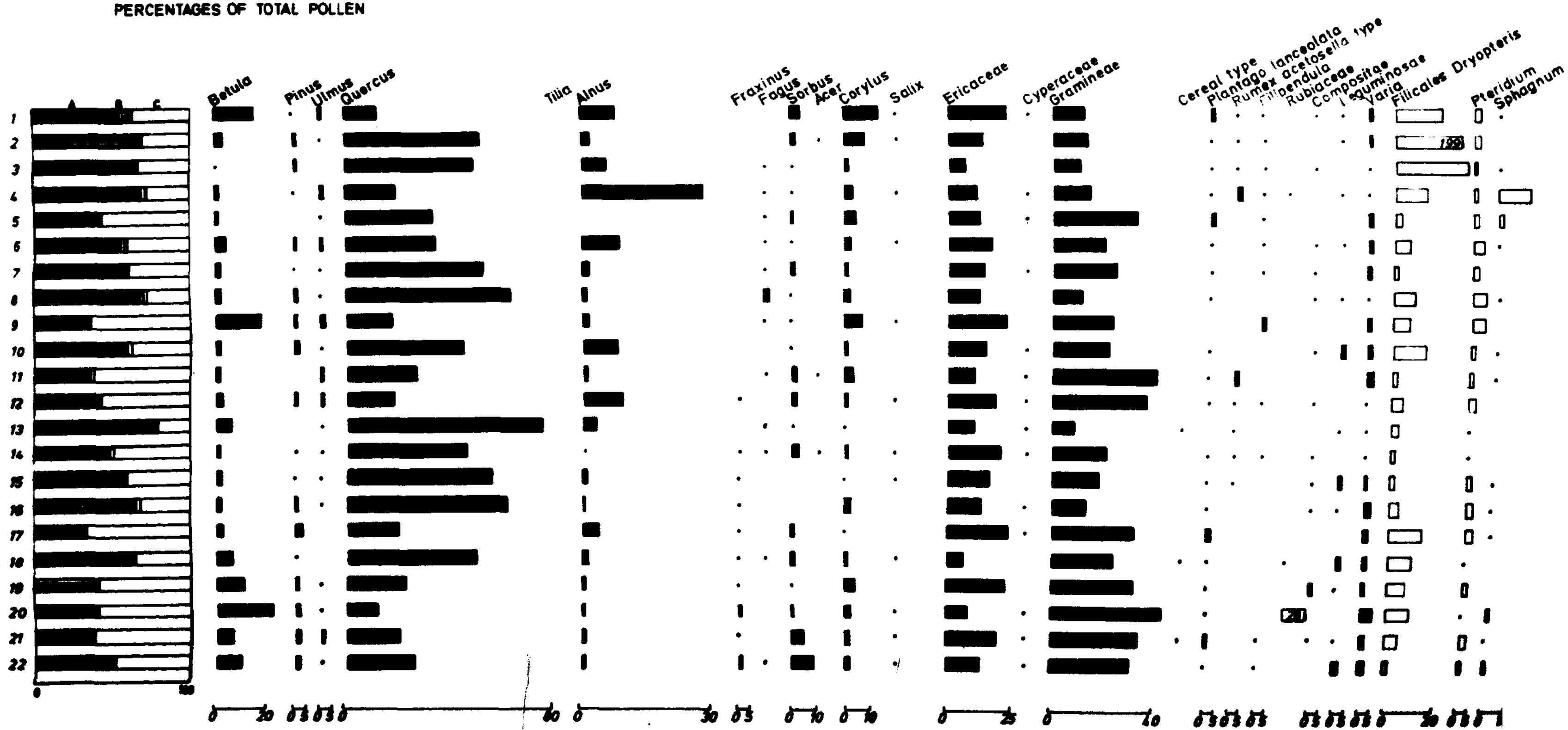
NORTH GILL WOOD RANDOM POLLEN SAMPLES (MAIN POLLEN TYPES)
N = 22

	Mean	Range	Standard deviation	Coefficient of variation
Alnus	6.7	0.6-47.2	10.3	152.2%
Betula	5.6	0.6-21.8	5.8	104.5%
Quercus	36.8	12.2-62.8	18.5	50.3%
Ulmus	0.6	0-1.4	0.4	74.0%
Pinus	0.9	0-2.6	0.6	65.8%
Fagus	0.3	0-2.6	0.5	208.7%
Sorbus	1.5	0-8.0	1.8	130.0%
Corylus	3.2	0.6-13.6	3.0	95.4%
Salix	0.2	0-0.6	0.2	106.7%
Ericaceae	14.7	5.6-23.4	5.3	36.5%
Cyperaceae	0.3	0-0.8	0.3	107.3%
Gramineae	23.9	8.8-43.0	10.7	44.8%
Other herbs	4.1	1.6-7.6	1.8	44.5%
Total tree pollen	51.6	28.6-78.5	14.5	28.0%
Total non-arboreal pollen	44.7	20.5-67.8	14.0	31.4%
Filicales	16.4	1.5-199.6	41.4	252.3%
Pteridium	2.3	0.2-5.8	1.6	68.2%

FIG. III·2

SURFACE SAMPLES NORTH GILL WOOD

PERCENTAGES OF TOTAL POLLEN



A. pollen from trees growing within the sample area;

B. pollen from trees and shrubs not growing within the sample area;

C. pollen of herbs.

Table III.3 gives the mean, range, standard deviation and coefficient of variation for the main pollen types in all 22 samples; those types present in less than half of the samples are excluded from this table. The flowering herbs, apart from the Ericaceae, are treated together.

The tree pollen frequencies vary from a maximum of 79% of total pollen (sample 13) to a minimum of 29% (sample 9). The open nature of the canopy is reflected by the relatively low mean of 51% for tree pollen. The minimum value for tree pollen is from a moss sample from the centre of a clearing 60 metres by 15 metres.

In order to compare the representation of each tree species in the vegetation with its representation in the pollen rain, the mean pollen value for each tree species has been expressed as a percentage of the mean for total tree pollen. These figures are compared with the percentage composition of the canopy in Table III.4.

Table III.4

	Composition of Canopy	Mean Composition of Arboreal Pollen Rain (n = 22)
Quercus	73%	71%
Betula	11%	11%
Alnus	10%	13%
Sorbus	6%	3%
Not represented in sample area		2%

There is close agreement between the two sets of figures showing that for the sample area as a whole the average composition of the arboreal pollen rain reflects well the average species composition of the canopy. No major differences in productivity between species can be detected in these figures, except in the case of Sorbus aucuparia where the mean value for representation in the arboreal pollen rain is only half the value for representation in the canopy. This suggests that Sorbus has a lower pollen productivity than Quercus, Betula and Alnus.

However, these mean values conceal wide variations in the representation of tree species between samples (Figure III.2). The individual sample spectra reflect strongly the vegetation immediately surrounding them, thus samples 1, 9 and 20 reflect the proximity of Betula trees, and the high percentage of Alnus pollen in sample 4 is due to an Alnus tree close to the sampling site. These observations agree with those of Andersen (1967) who obtained strongly local pollen spectra from moss polsters collected in the Draved Forest. Despite these fluctuations, the overall dominance of Quercus in the wood is reflected in all the samples; the minimum value of 12.2% occurs in sample 20, from a clearing surrounded by Betula trees.

The degree of variability in the distributions of the pollen of the main species has been measured by calculation of the coefficient of variation, a statistic which may be used to compare distributions with the same variables, but with widely different arithmetic means (Yeomans, 1968). It is computed from the formula:

$$\text{Coefficient of Variation} = \frac{100 \times \text{Standard Deviation}}{\text{Mean}}$$

The degree of variability can be used as a measure of the evenness of the dispersion of the pollen of a particular species. Variability will be high for those species which have very local peaks in pollen representation and therefore for which lateral transfer of pollen within the wood is low. Variability will be reduced for those species where lateral transfer of pollen has counteracted the effect of local pollen sources. If the coefficients of variation are examined for the four canopy forming species they form a series of descending magnitude in the order Alnus, Sorbus, Betula, Quercus (Table III.3). Thus within the wood lateral transfer of pollen appears to be at a minimum for Alnus and a maximum for Quercus.

The frequencies of Betula pollen recovered from samples in the wood are somewhat surprising; the maximum value, 22% of total pollen, is from a sample close to Betula trees (sample 20); this is considerably lower than the peak of 47% reached by Alnus in sample 4, though these two species are similarly represented in the canopy. Many workers have reported that Betula is an extremely prolific pollen producer. Andersen (1967) proposed that in open woodland a correction factor of at least $1 \times \frac{1}{6}$ should be applied to the Betula pollen values in order to estimate the importance of this tree in the vegetation. The pollen production of the Betula trees in this area of North Gill Wood apparently does not conform to this pattern.

The summary diagram in Figure III.2 distinguishes between the pollen of arboreal species present within the sampling area and the pollen of those absent from the sampling area. Corylus is the largest contributor to this latter group. Corylus pollen is recorded in all 22 samples in frequencies varying from 0.6% to 13.6%; the pollen must originate from sources in the hedgerows on the farm land to the south and east. It is clear that pollen production by Corylus must be prolific and dispersal efficient. The contribution to the total pollen sum from trees growing outside the sampling area, other than Corylus, is small. Ulmus is present in 20 of the samples and Pinus in 19, but neither is represented by values greater than 3% in any sample. The source of the Ulmus pollen must be isolated roadside trees, on the surrounding lowlands. Pinus plantations occur about four kilometres from the sampling site, in Dallowgill valley, an easterly continuation of the valley of the North Gill Beck. Fagus is present in just over half of the samples, with a maximum of 2.6% in sample 8; the nearest beech trees occur along the roadsides on the lowlands, or in cultivated stands on private estates to the east of the Nidd-Laver interfluve. Fraxinus is present in 10 samples, and this probably represents pollen blown up from Nidderdale or from the limestone areas to the west and north west.

The variation in the frequencies of the non-arboreal pollen reflects the variation in the density of cover within the wood. This is due to two factors. Firstly, in shady conditions ground flora species flower sparsely and therefore pollen production by the ground flora is inversely proportional to the density of the trees. Faegri and Iversen (1964) stated "within the same climatic region the pollen production of an area is roughly of the same order whether the area is forest clad or covered by lower vegetation, and the relation between the pollen produced by forest trees and that produced by ground vegetation is an indication of the density of the forest." Secondly, in open woodland pollen from outside the wood is able to penetrate the canopy; in a predominantly cleared environment this will result in increasing deposition of non-arboreal pollen.

The curve for the Gramineae (Figure III.2) probably represents pollen from grasses flowering in small clearings, though some may have blown in from other areas. The curve for the Ericaceae consists almost entirely of the pollen of Calluna which has blown in from the surrounding moors. Calluna is not recorded in the ground flora of the wood, whereas Vaccinium myrtillus, which has a frequency rating of 22% in the ground flora, is represented by only occasional grains in the pollen samples. Certain of the herbs which are significant members of the ground flora (Table III.2) are scarcely represented in the pollen rain. The Cyperaceae never form more than 1% of total pollen, and pollen of the Juncaceae was not recovered from any of the samples. The pollen of Plantago lanceolata, the Leguminosae and the Compositae occurs regularly in the samples, but the first of these species is not recorded in the ground flora and the source is probably along the edges of the sheep tracks on the moors. The surprising occurrence of 28% of pollen of the Rubiaceae in sample 20 must be attributed to Galium saxatile growing at this site. (N.B. pollen of Rubiaceae was counted outside the pollen sum in sample 20 so as not to distort this pollen spectrum).

The frequencies of spores which were counted outside the pollen sum are of great interest. The dominance of Pteridium in the ground flora is not reflected by the pollen spectra from any of the samples. Pteridium values vary from a maximum of 5.8% in sample 8 to 0.2% in sample 20. It is possible that the relatively shaded environment within the wood results in a reduced capacity to sporulate, but low values for Pteridium spores have also been recorded in more open environments. The frequencies of Filicales (Dryopteris type) spores have the highest coefficient of variation of all the pollen and spore types recorded in the woodland samples. They are present at values ranging from 1.5% in sample 11 to 200% in sample 2, and this suggests a highly erratic and local production of spores.

III.iii.b. The pollen rain on the moorland

Surface samples were collected at random from the moors at the head of North Gill Beck, using the method of co-ordinates described previously. The extent of the sampling area is indicated in Figure III.1. It included the eastern flanks of Kettlestang and Hambleton Hills and the intervening saddle. This is an area of Calluna heath with Vaccinium myrtillus co-dominant in the better-drained areas. The nearest trees are in North Gill Wood, about one kilometre to the south-east; a small wood similar in composition to that in North Gill occupies part of the valley of Byerbeck Gill, about 1.5 kilometres to the south-west. The floristic composition of this area of moorland was assessed by the calculation of frequency indices based on presence or absence of species in 50 randomly placed quadrats. Part of the saddle region had been burned the year prior to the survey and therefore areas of bare ground occurred. The results are included in Table III.5 with the species listed in order of importance in the vegetation.

32 moss polsters were collected and the results of the pollen analyses are presented in Figure III.3. The summary diagram shows the relative composition of each pollen spectrum in terms of:

Table III.5

DALLOW MOOR: FLORISTIC COMPOSITION COMPARED WITH THE AVERAGE COMPOSITION OF THE POLLEN SAMPLES

	Frequency Index	Mean incidence in the pollen samples
Calluna vulgaris	96%	42%
Vaccinium myrtillus	74%	1.2%
Cyperaceae	42%	1.3%
(*Carex bigelowii*)	(32%)	
(*Carex pulicaris*)	(10%)	
Rumex acetosella	14%	0.8%
Pteridium aquilinum	6%	1.9%
Juncus effusus	4%	NIL
Sphagnum spp.	4%	2.6%
Agrostis tenuis	2%	17.2%
Empetrum hermaphroditicum	2%	NIL

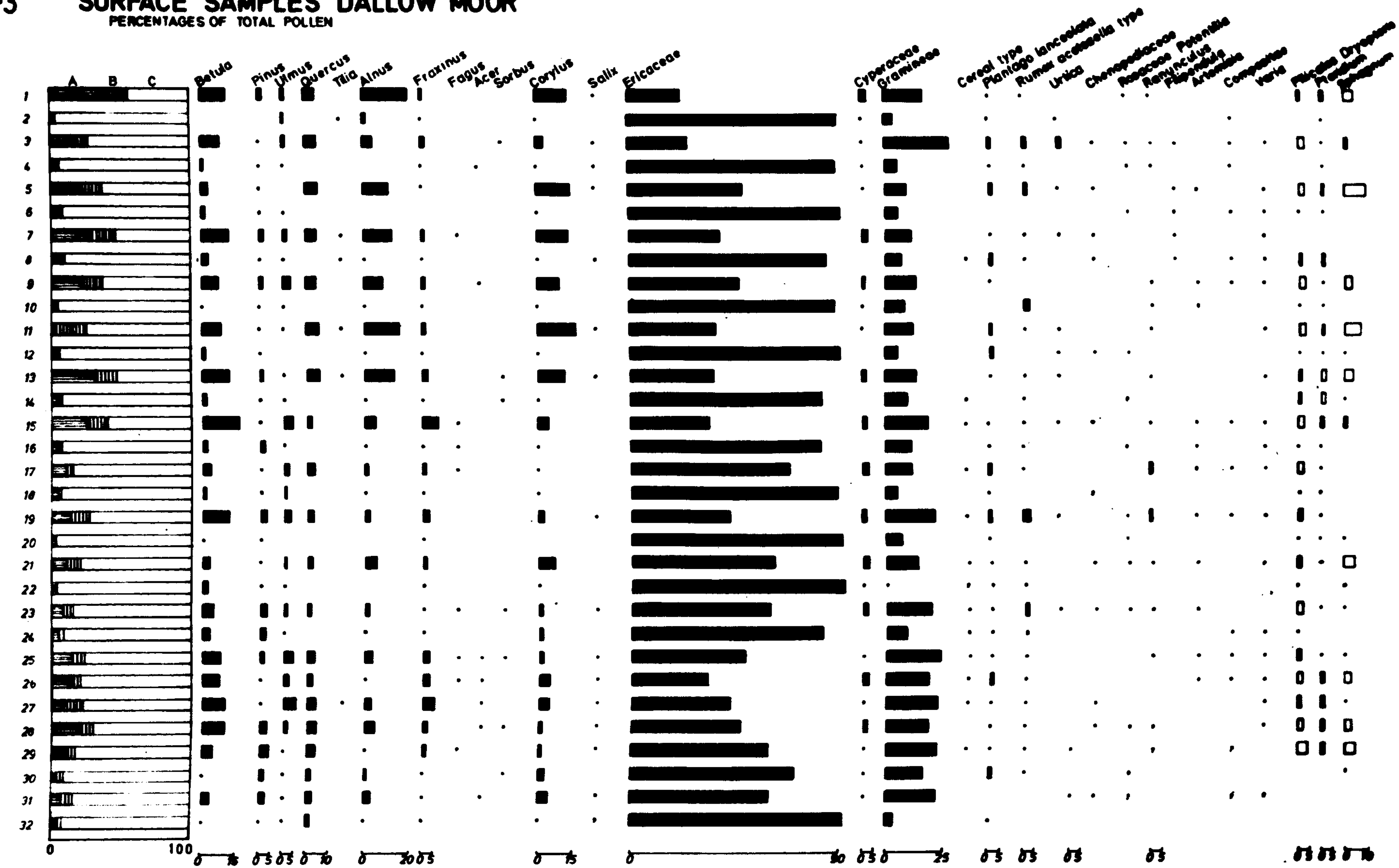
Table III.6

MOORLAND RANDOM POLLEN SAMPLES
N = 32

	Mean	Range	Standard deviation	Coefficient of variation
Alnus	3.7	0-20.6	5.1	137.7%
Betula	4.9	0.2-16.4	4.3	88.6%
Quercus	2.5	0.2-5.4	1.6	125.8%
Ulmus	1.2	0-5.2	1.3	62.5%
Pinus	1.0	0-3.8	0.9	108.5%
Fraxinus	1.3	0-7.4	1.4	90.0%
Corylus	3.9	0-16.8	5.0	113.0%
Ericaceae	63.4	23.2-96.6	22.9	36.2%
Cyperaceae	0.8	0-3.2	0.9	123.4%
Gramineae	12.8	0.3-28.2	6.8	53.3%
Other herbs	2.6	0.2-8.9	2.4	92.0%
Total tree pollen	14.5	2.0-41.2	12.5	86.2%
Total non-arboreal pollen	78.9	44.8-98.0	44.67	56.6%
Filicales	0.8	0-2.4	0.7	85.6%
Pteridium	1.3	0-10.8	3.7	287.6%

FIG. III·3 SURFACE SAMPLES DALLOW MOOR

PERCENTAGES OF TOTAL POLLEN



A. pollen from trees growing within the gill woodlands

B. pollen from trees and shrubs not growing within the gill woodlands

C. pollen of herbs

Table III.6 shows the mean, range, standard deviation and coefficient of variation for each of the main pollen types.

Despite the lack of trees upon this upland, tree pollen forms a significant proportion of the pollen spectrum of most of the samples, the average value being 14.5% with a maximum of 41% in sample 1 and a minimum of 2% in sample 20. The high level of some of the arboreal pollen values is surprising. Those samples containing values greater than 14.5% were all collected within the saddle area of the moors, while the samples collected on the lee-side of Hambleton and Kettlestang Hills generally had lower proportions of tree pollen. It is probable that the orientation of the valleys of the North Gill Beck and Byerbeck Gill results in a funnelling of air currents bringing pollen from the woods up on to the moor. It is also possible that the arboreal component of the pollen rain has been artificially increased in the saddle area owing to some reduction in the pollen producing capacity of the surrounding heath species following burning.

The pollen types represented in the arboreal pollen rain fall into two groups: those species which are present in the nearby gill woodland, Quercus, Alnus, Betula and Sorbus, and those which are not. Ulmus, Pinus, Tilia, Fagus, Fraxinus and Corylus are included in this latter group. Quercus is present in every sample and has a mean of 2.5%. Betula is also present in every sample and has a mean of 4.9% and Alnus, which is absent from four samples, has a mean of 3.7%.

The range of values for Alnus and Betula (Table III.6) is significantly higher than that for Quercus, and if the coefficients of variation are compared they form a descending series in the order Alnus, Betula, Quercus. This order is the same as that established for the coefficients of variation of these trees in the North Gill Wood samples. Thus in both the woodland and the moorland environment variability of representation of the main arboreal pollen types is greatest for Alnus and least for Quercus. Sorbus occurs as single grains in only seven samples from the moorland, and this not only supports the evidence for the low productivity of this species but also indicates that the effective dispersal distance is short. This conclusion is predictable as Sorbus is zoogamous. The effective dispersal distances for Alnus and Betula are greater than for Quercus; Alnus and Betula are represented by consistently higher values than Quercus in the moorland samples despite the dominance of Quercus in the nearby woodlands.

Those arboreal species which do not grow in the gill woodlands yet which occur in the pollen rain feature more prominently in the pollen spectra from moorland sites than from woodland sites (compare the summary diagrams in Figures III.2 and III.3). This supports Tauber's hypothesis that as a cleared area is enlarged, an increasing proportion of the pollen deposited at any one point will be derived from distant sources (Tauber, 1965). As in the case of the woodland pollen spectra, Corylus makes the largest contribution to this sector of the pollen spectrum. Its average value is only 3.9% but in a number of samples values of over 10% of total pollen occur with a maximum of 16.8% in sample 11. Ulmus, Pinus and Fraxinus are all present in the majority of the samples and the mean value for each of these species is higher in the moorland spectra than in the spectra from the woodland. The frequencies of 5.2% for Ulmus in sample 27 and 7.2% for Fraxinus in sample 15 are anomalously high.

The non-arboreal pollen rain dominates the moorland pollen spectra. The relative importance of the different species in the vegetation composition has been assessed by calculation of a frequency index (Table III.5). Table III.5 also includes data on the average composition of the moorland pollen spectra. A comparison of these values with the vegetation frequency indices gives an indication of the representation ratios for the various species. However, these two sets of figures are not directly comparable owing to the quite considerable amounts of arboreal pollen which originates from outside the moorland community.

In all cases Calluna is the chief contributor to the pollen spectrum and this has a swamping effect on the pollen values for other species. It is clear that in comparison with Calluna, Vaccinium is vastly under-represented. Although it is co-dominant with Calluna over much of the moor, it is present in only seven pollen samples and in six of these at less than 2% of total pollen. The exceptional occurrence of 18.2% Vaccinium pollen in sample 17 is anomalous, and it could reflect macroscopic deposition of pollen by a fallen flower head. It is possible that Vaccinium pollen productivity is artificially reduced by selective grazing of this plant by sheep on the moors. Cyperaceae and Rumex acetosella type pollen also seem to be somewhat under-represented in the pollen spectra. However, the Gramineae are over-represented; grass pollen must be easily dispersed up on to the moors from the meadows and pastures of the surrounding lowland. The occasional grains of cereal pollen recorded also reflect lowland agriculture.

The remaining types of herb pollen in the moorland spectra can be considered in two groups. The first consists of pollen of taxa characteristic of the damp valley bottoms and the meadows of lower altitudes, including the Chenopodiaceae, Mercurialis, Lotus, Endymion, Filipendula and Ranunculus. These species are represented by occasional grains occurring in some samples. The second group consists of pollen of species characteristic of disturbed ground and the edges of sheep walks. These include the Rubiaceae, Rosaceae, Compositae, Polygola, Plantago lanceolata, Urtica, Melampyrum and Artemisia. These pollen types may occasionally be over-represented in samples as they are present locally on the moors, although not in sufficient abundance to have registered in the survey quadrats.

The frequency of occurrence of pteridophyte spores in the moorland surface samples is low, despite the abundance of Pteridium in the valleys which dissect the moor. This plant also grows at some sites within the sampling area and, though sample 5 was taken from beneath a bracken patch, only 3.6% of Pteridium spores are recorded in the pollen spectrum. Though in most cases Sphagnum polsters were used as the sampling medium, none of the surface samples examined from the moorland contained many Sphagnum spores, the maximum frequency recorded being 10.8% in sample 5.

III.iii.c. The dispersal of arboreal pollen from the edge of the gill woodlands

In order to investigate the dispersal of arboreal pollens from the woodland edge, surface samples were collected initially along the three main transect lines indicated in Figure III.1. Transect A crosses an area of grazed *Festuca* turf with *Rumex acetosella* and *Pteridium aquilinum* immediately adjacent to the wood; the remainder of the transect crosses moorland dominated by *Calluna vulgaris* and *Pteridium aquilinum*. Transect B crosses an enclosed area of rough *Molinia* pasture 100 metres wide and then runs across moorland dominated by *Calluna vulgaris* with *Vaccinium myrtillus*. The vegetation along Transect C which follows the valley of the North Gill Beck is more varied; immediately beyond the woodland edge the ground flora is dominated by *Pteridium* and *Vaccinium*. In the middle section of the valley there are grassy areas dominated by *Agrostis* and *Molinia* with *Juncus* flushes. The steep valley sides are covered with *Calluna*, *Vaccinium* and *Pteridium*. Isolated trees of *Betula* and *Sorbus* with one *Ilex aquifolium* occur on the slopes. The upper part of the valley is steep and rocky and dominated by *Vaccinium* and *Pteridium* with some *Calluna*.

The results of the analyses are presented in the form of pollen diagrams in Figures III.4, III.5 and III.6. Summary diagrams have been excluded but the data for the tree species growing in North Gill Wood are presented separately in Figures III.7, III.8, III.9 and III.10, to enable results from the three transects to be compared directly. In all cases data are expressed as percentages of total pollen, excluding spores.

The three diagrams which show the frequencies of tree pollen from species growing in the wood at increasing distances from the woodland edge (Figure III.7) all exhibit the same general form. At the edge of the wood tree pollen values are greater than 40% of total pollen, but decrease dramatically within 100 metres of the edge of the wood. In Transects A and C values level off at between 10 and 12% of total pollen

FIG. III-4

SURFACE TRANSECT A

PERCENTAGES OF TOTAL POLLEN

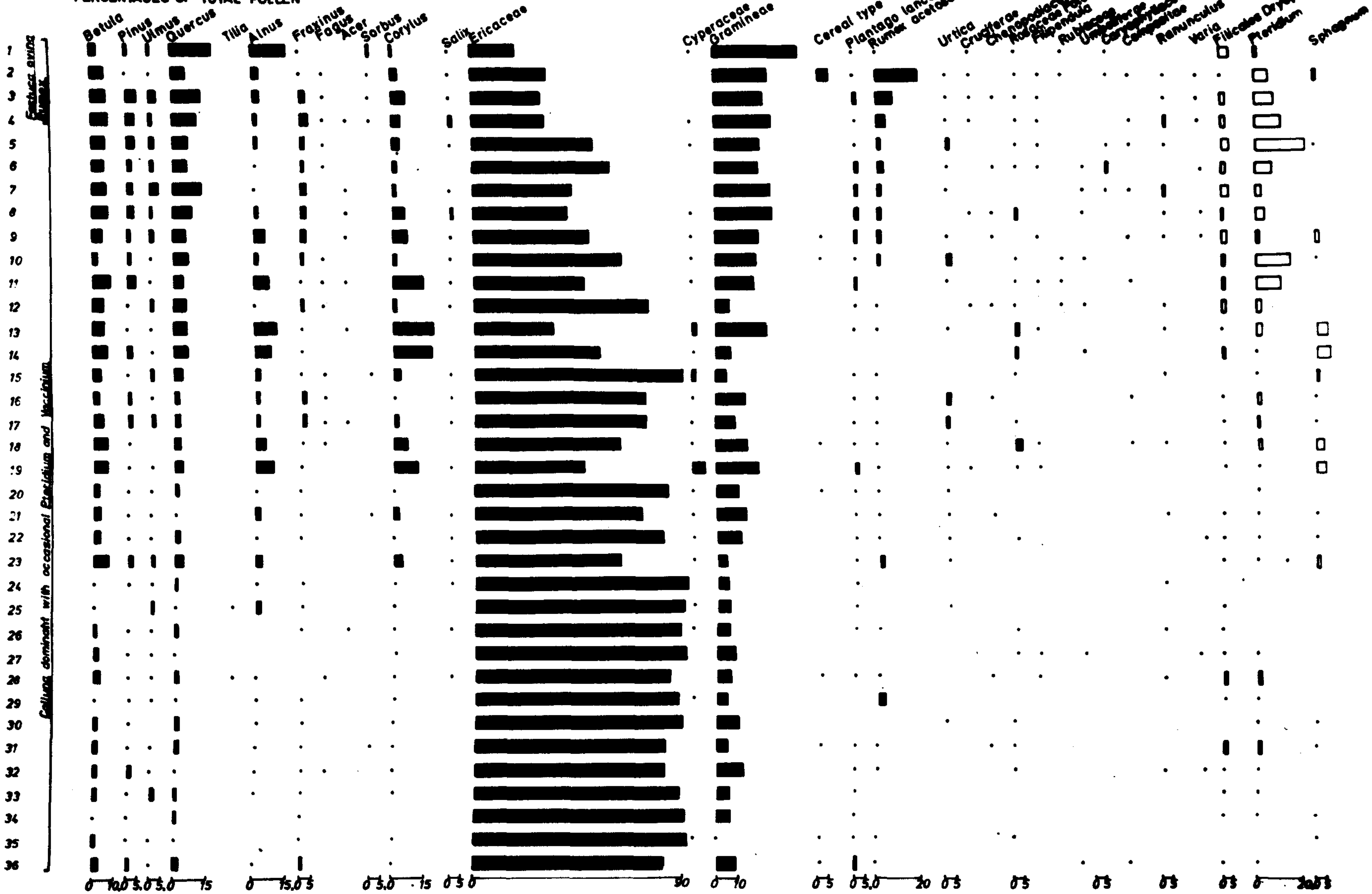


FIG. III·5

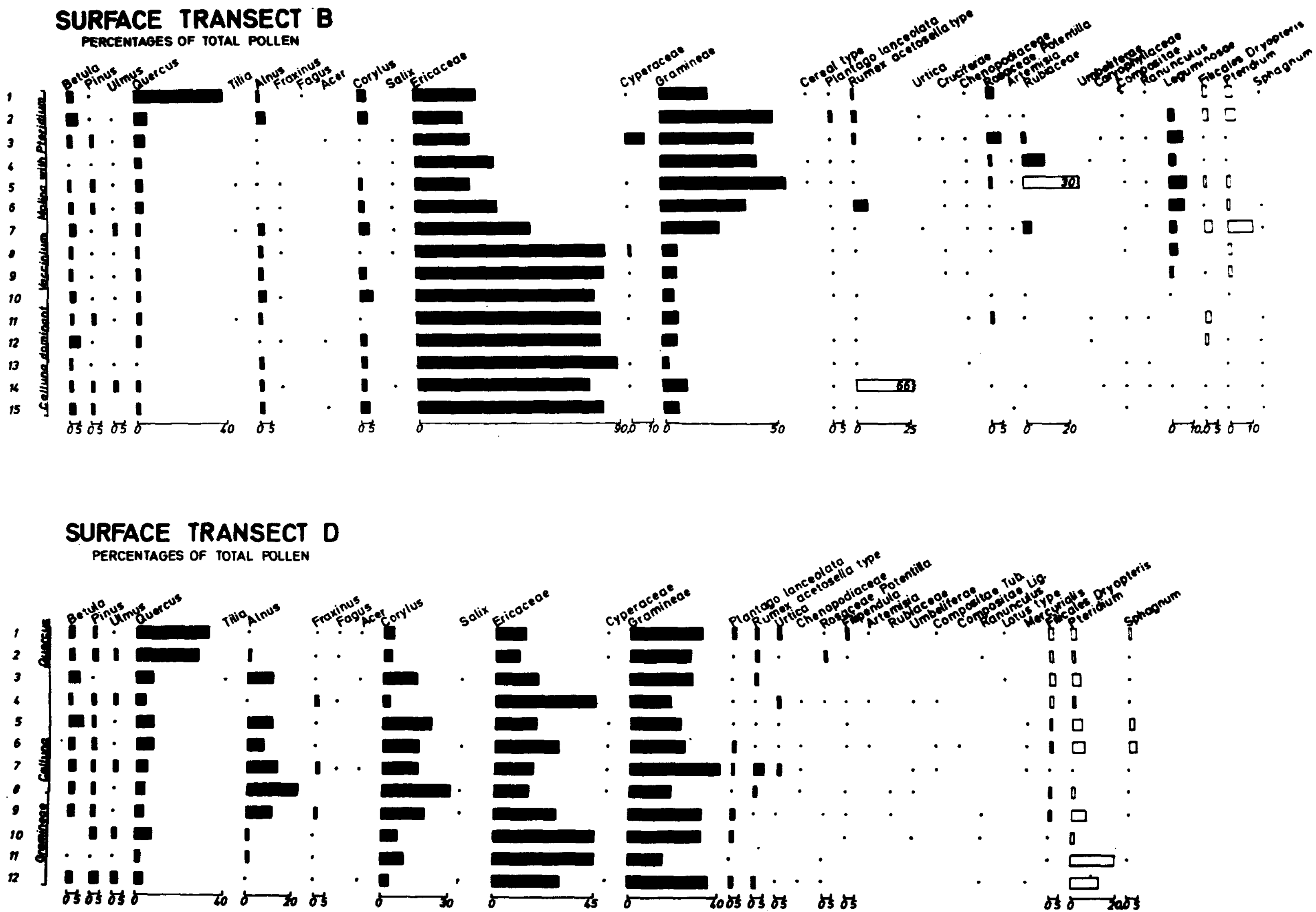

SURFACE TRANSECT B
PERCENTAGES OF TOTAL POLLEN
Betula
Pinus
Ulmus
Quercus
Tilia
Alnus
Fraxinus
Fagus
Acer
Corylus
Salix
Ericaceae
Cyperaceae
Gramineae
Cereal type
Plantago lanceolata
Rumex acetosella type
Urtica
Cruciferae
Chenopodiaceae
Rosaceae
Potentilla
Artemisia
Rubiaceae
Umbelliferae
Caryophyllaceae
Compositae
Ranunculus
Leguminosae
Filicales
Dryopteris
Pteridium
Sphagnum
Molinia with Pteridium
Vaccinium
Calluna dominant
SURFACE TRANSECT D
PERCENTAGES OF TOTAL POLLEN
Betula
Pinus
Ulmus
Quercus
Tilia
Alnus
Fraxinus
Fagus
Acer
Corylus
Salix
Ericaceae
Cyperaceae
Gramineae
Plantago lanceolata
Rumex acetosella type
Urtica
Chenopodiaceae
Rosaceae
Potentilla
Filipendula
Artemisia
Rubiaceae
Umbelliferae
Compositae Tub.
Compositae Lig.
Ranunculus
Lotus type
Mercurialis
Filicales
Dryopteris
Pteridium
Sphagnum
Quercus
Calluna
Gramineae

FIG. III·6 SURFACE TRANSECT C

PERCENTAGES OF TOTAL POLLEN

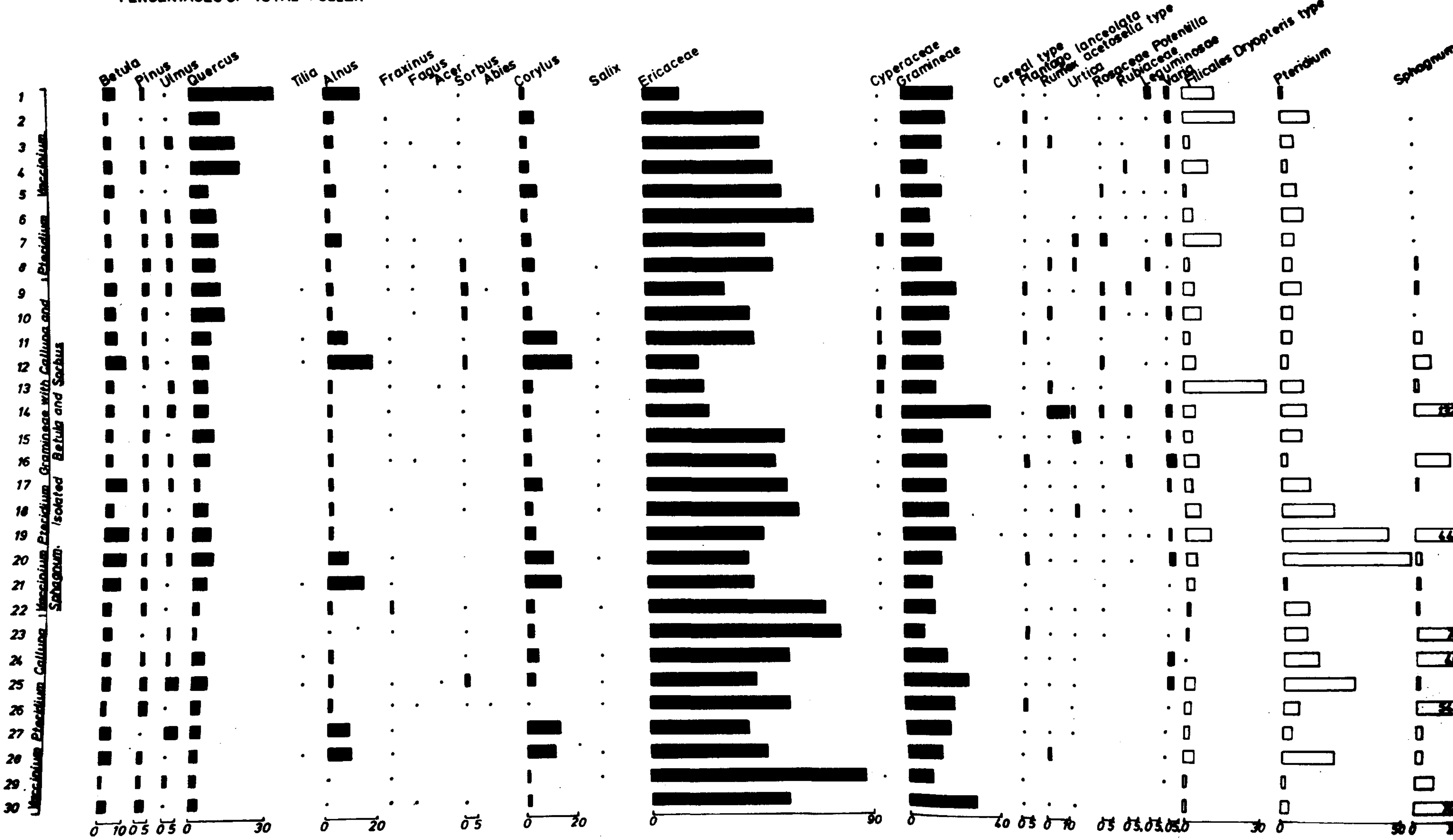


FIG III.7

The frequency of pollen of tree species present in the North Gill Wood at increasing distances from the woodland edge

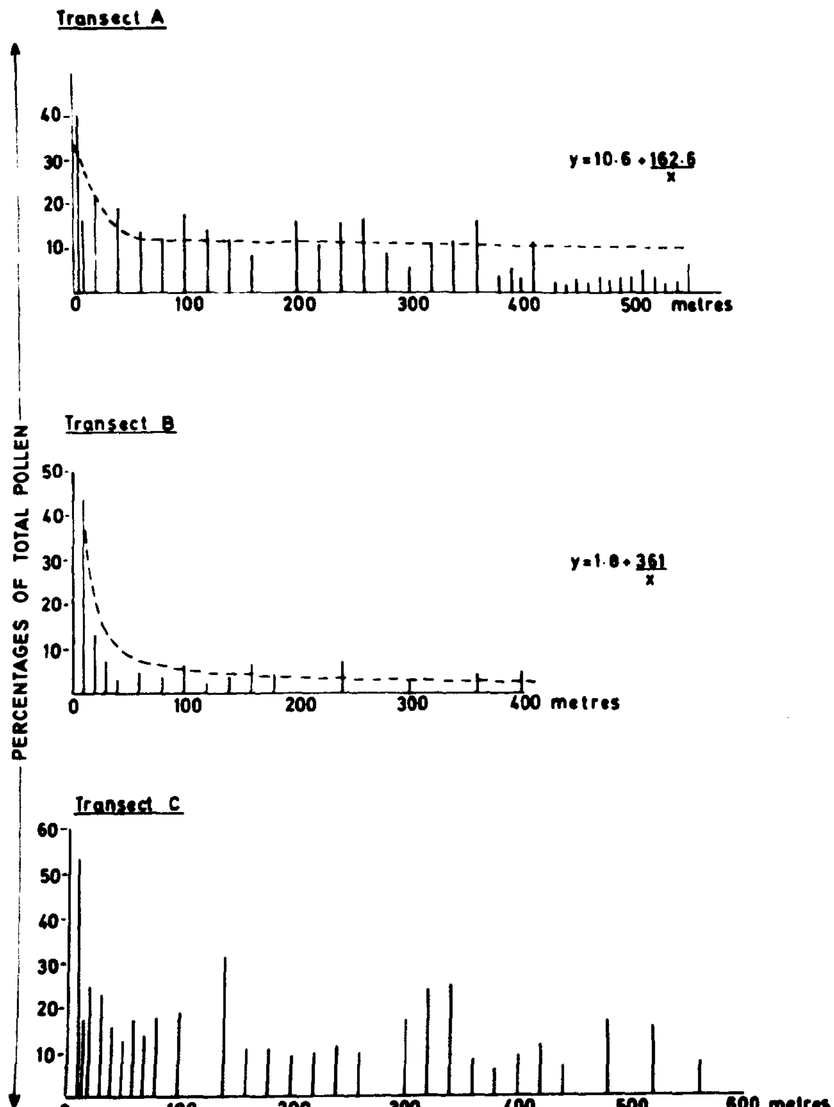


FIG III.8

The frequency of Quercus pollen at increasing distances from the woodland edge

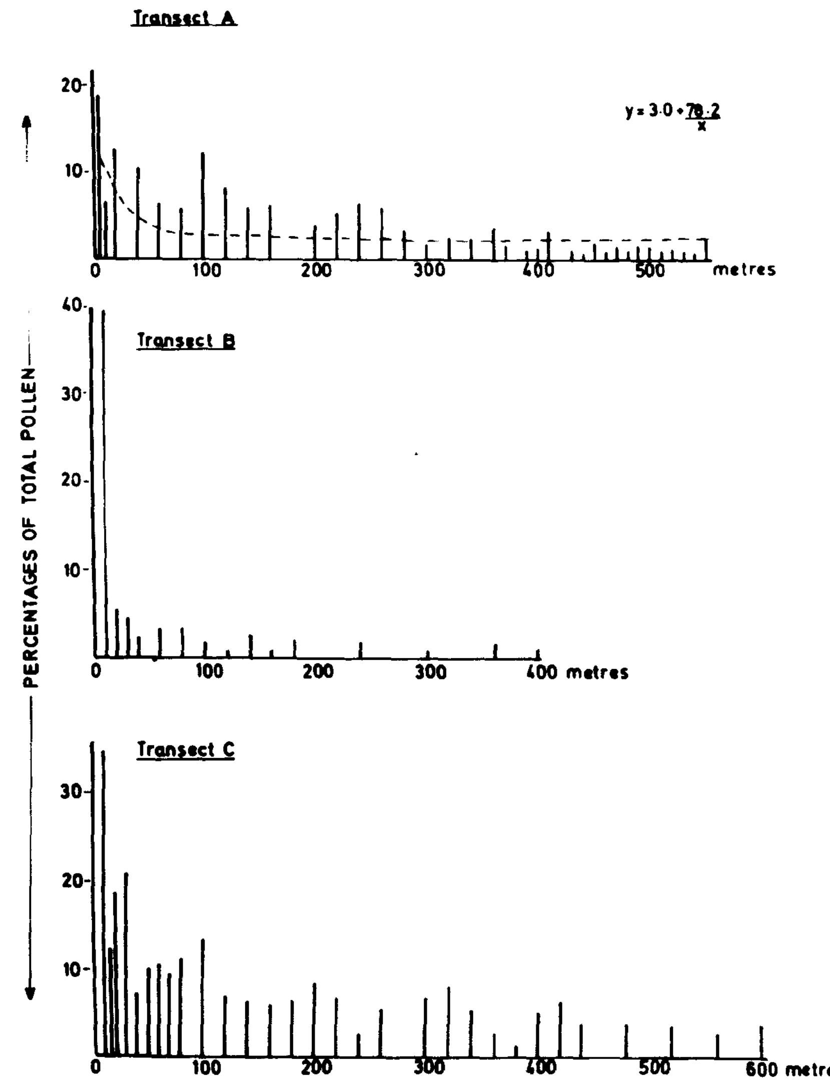


FIG III·9

The frequency of *Betula* pollen at increasing distances from the woodland edge

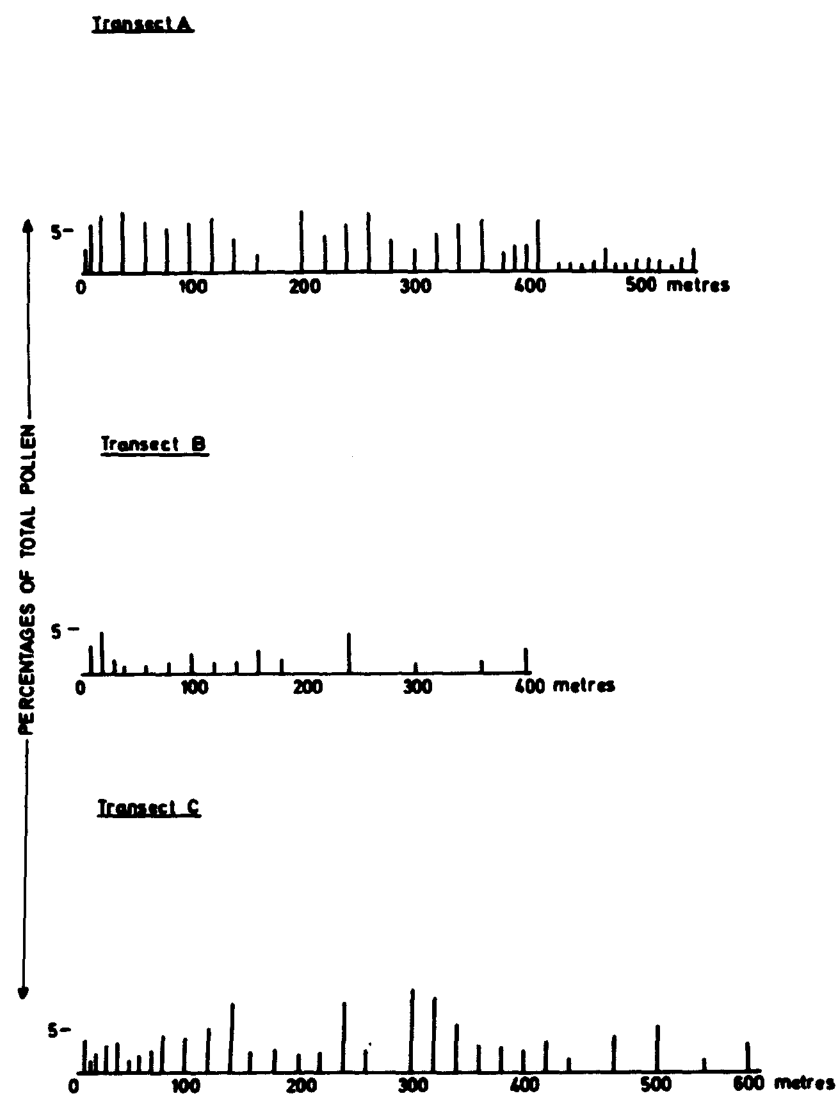
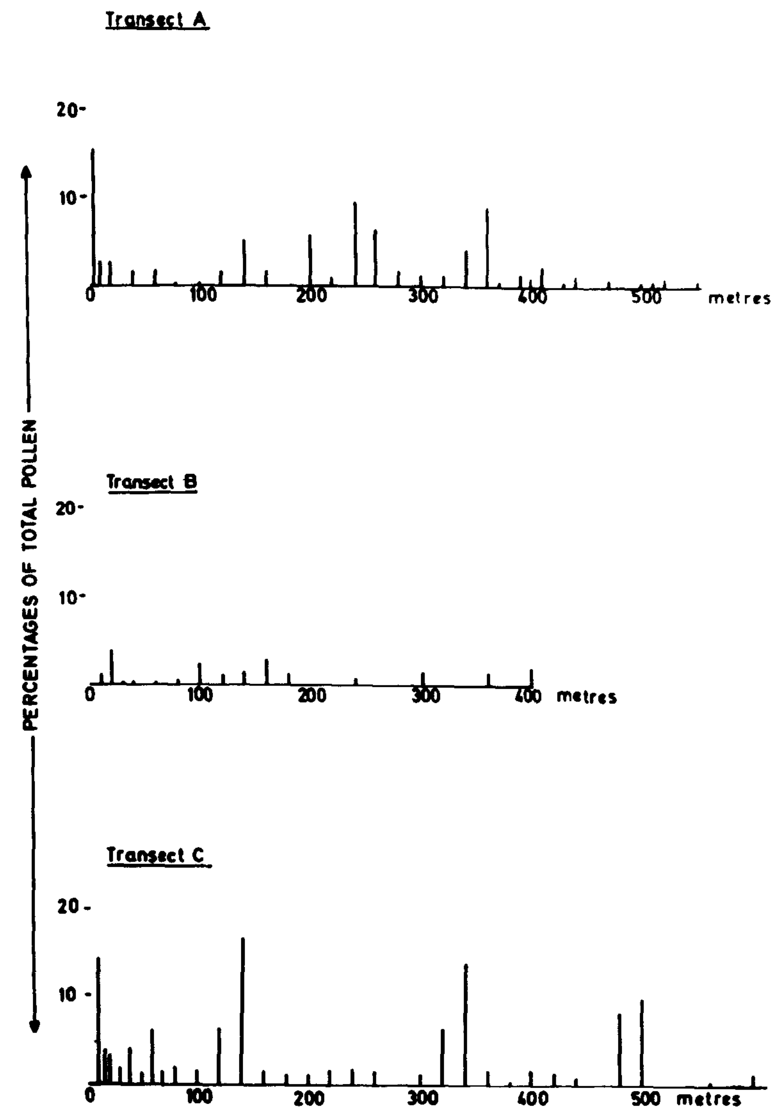


FIG III·10

The frequency of *Alnus* pollen at increasing distances from the woodland edge



beyond 100 metres, though wide deviations occur. In Transect B values level off at between 2 and 3% of total pollen beyond 100 metres. The significance of the lower average values for tree pollen on Transect B beyond 100 metres is uncertain. It was initially suspected that arboreal pollen frequencies on this transect, which runs from south-west to north-east, might be higher than on Transects A and C owing to the prevailing westerly winds. It is possible that in this area local topography may affect wind direction so that the influence of the regional prevailing winds is obscured. The levelling off at between 10 and 12% on Transects A and C is in quite good agreement with the average value of 14.5% for tree pollen in the moorland samples. This latter figure includes a small percentage of pollen from tree species not growing in the gill woodlands and this accounts for the slight discrepancy between the two figures.

A curve of the form $y = a + \frac{b}{x}$ was fitted to these three sets of data. Correlation coefficients of 0.62 and 0.64, calculated for Transects A and B respectively, were significant at the 95% level, but no significant correlation was obtained for Transect C. The relationship $y = 10.6 + \frac{162.6}{x}$ accounts for 39% of the variation in Transect A, and the relationship $y = 1.8 + \frac{361}{x}$ accounts for 46% of the variation in Transect B. Clearly in all three cases factors operate to distort the overall trend of decline in tree pollen with distance from the woodland edge. This distortion is most marked in Transect C where the samples at 140, 300, 320, 340, 480 and 510 metres deviate strongly from the remaining values.

Figures III.8, III.9 and III.10 show, at a magnified scale, values of the three component species of the tree pollen curve for each transect. The values of _Quercus_ pollen (Fig. III.8) show trends similar to those for tree pollen as a whole. The highest values occur at the edge of the wood and there is a rapid decline, with a tendency for values to level beyond 100 metres. The curve $y = 3.0 + \frac{78.2}{x}$ explains 45% of the variation on Transect A; the correlation coefficient of 0.64 is significant at the 95% level. This curve levels off at a value of just over 3% which compares with an average value of 2.5% for Quercus pollen from the random moorland samples. A curved relationship of this type cannot be fitted to the data for Quercus pollen in Transects B and C because the massive decline in pollen between 10 and 20 metres distorts the relationship; however a gradual levelling off in the deposition of Quercus pollen with distance from the wood is clear. The level portion of these curves represents "background noise" - that is, pollen which has not necessarily been derived from the adjacent woodland.

The frequencies of Betula (Fig. III.9) and Alnus (Fig.III.10) show no tendency to decrease with distance from the edge of the wood. The distribution of Betula pollen is fairly even along Transects A, B and C, averaging just over 3.5% of total pollen for Transects A and C and 2.0% for Transect B; these figures compare with an average value of 4.9% from the moorland samples. The presence of isolated Betula trees in the middle section of Transect C is reflected in the slightly inflated values for Betula in samples from 140, 240, 300 and 320 metres. However, no very large peaks are associated with the occurrence of these trees.

The patterns exhibited by the Alnus frequencies in Transects A and C are highly irregular when compared with Betula and Quercus. In both cases values of 14 - 15% at the woodland edge reflect the proximity of Alnus trees, but isolated peaks in Alnus pollen occur at 240 metres and 360 metres on Transect A, and on Transect C more marked peaks occur at

140, 340 and 500 metres. As no Alnus trees occur along either of these transects these peaks are difficult to explain. The highest frequencies of Alnus occur on the valley transect, C; it is possible that local turbulence within the valley may operate at the time of Alnus pollen production and cause irregular pollen deposition. Alnus flowers in March and April whereas the flowering of Betula and Quercus takes place later in the spring. It is also possible that "macroscopic" deposition of pollen may be involved; the Alnus catkin can break into pieces in high winds and thus whole masses of pollen grains might be dispersed as a unit, or birds might act as the dispersal agency. In addition, the tendency of Alnus pollen grains to stick together has been recorded (Faegri and Iversen, 1964). However, when "macroscopic" deposition has taken place it is usually obvious during the counting of the pollen slide as clumps of grains occur. No clumping of grains was observed in any of the samples analysed from these transects. A third possible explanation for the abnormally high Alnus frequencies on Transect C is that they might be caused by a filtration effect. The leaves and branches of the trees in the valley might act as a trap to catch the Alnus pollen, which could later be washed off and redeposited, causing peaks in Alnus frequencies. Instances of filtration and redeposition of pollen grains have been recorded by Tauber (1967) around a forest lake on the island of Zealand, Denmark. It is difficult to explain why filtration of this nature should differentially favour Alnus rather than Quercus, but there is certainly some coincidence between the peaks in Alnus pollen and the distribution of Betula and Sorbus trees in the valley.

It is clear from these results that the overall trend of a rapid and then a gradual decline in tree pollen deposition as distance from the woodland edge is increased is due solely to the contribution of *Quercus* pollen. *Quercus* is the dominant tree in the woodland and forms the woodland edge on all sides, therefore the very high pollen percentages in the immediate vicinity of the trees are to be expected. *Betula* and *Alnus* occur in the interior of the wood. The fairly regular frequencies of *Betula* on all three transects suggest that by the time the woodland edge is reached deposition of *Betula* pollen has levelled off; a pattern similar to that for *Quercus* deposition can be envisaged with the values for *Betula* rising sharply in the immediate vicinity of the trees. *Alnus*, however, does not conform to this pattern and exhibits the erratic behaviour described above. The two striking features of these results are the rapidity of the decline in tree pollen in the first 100 metres from the woodland edge and the extremely gradual decline beyond this distance.

The frequencies of pollen of arboreal species not present within the gill woodlands are fairly constant along all three transects. *Pinus*, *Ulmus* and *Fraxinus* are present regularly in frequencies of up to 4%; the occurrence of *Tilia*, *Acer* and *Fagus* is more sporadic and the frequencies of these species are in all cases less than 1% of total pollen.

In order to investigate the deposition of arboreal pollen at increasing distances into the wood, Transect A was extended by 80 metres. The percentages of tree pollen from species present within the wood was determined for a further four samples taken at 20 metre intervals (Fig. III.11). The results show that there is a tendency for tree pollen values to rise very gradually as the interior of the wood is approached; a similar observation was made by Bastin (1964), working in the Fôret de Soignes, south of Brussels.

FIG III.12

The frequency of pollen of arboreal species present in Skell Gill Wood at increasing distances from the woodland edge. Transect D

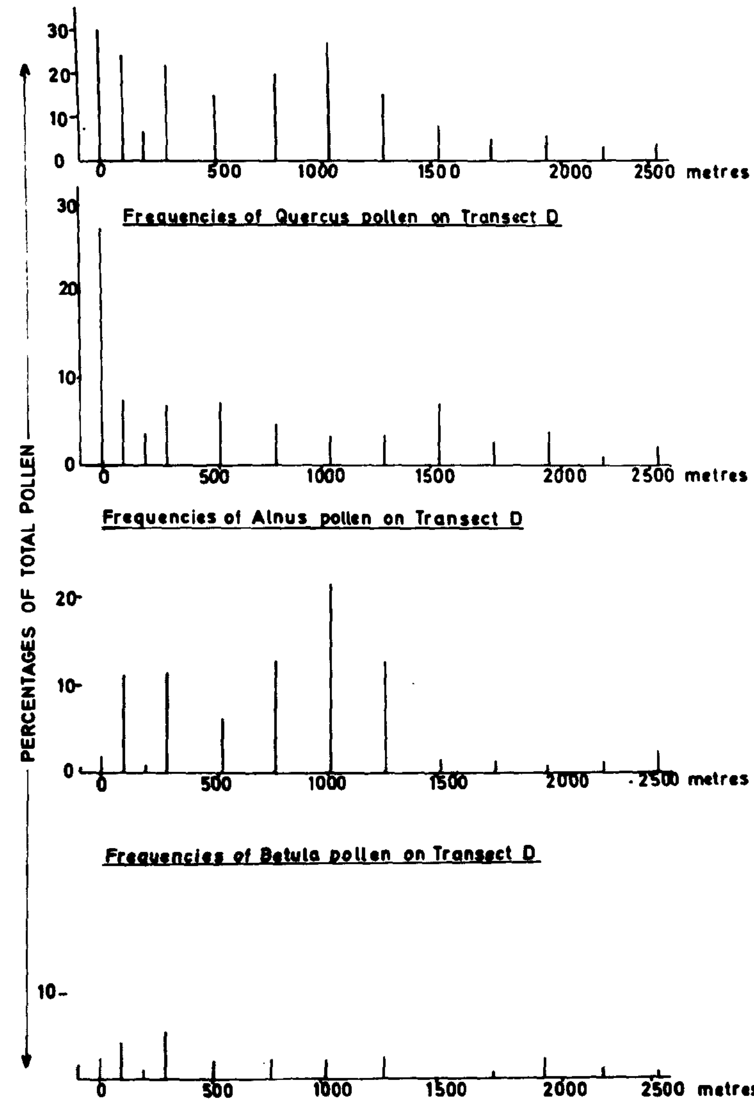
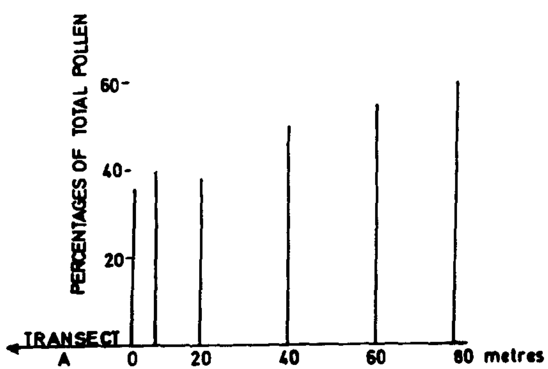


FIG III.11

The frequencies of pollen of tree species present in North Gill Wood, at increasing distances into the wood



In order to establish whether the results obtained from Transects A, B and C and the random samples were representative of pollen deposition on the Nidd-Laver interfluve as a whole, 14 further surface samples were examined from Transect D in the Skell valley. The shape of this valley is similar to that of the North Gill Beck and the vegetation communities within the two valleys are comparable, except that beyond the woodland edge in Skell Gill the isolated trees are all Sorbus aucuparia. Both valleys dissect the moorland plateau, but in Skell Gill the distance from the edge of the wood to the valley head is considerably greater than in North Gill. The composition of the woodland in the lower Skell valley is similar to that of North Gill Wood.

Samples were collected initially at 100 metre intervals. This was increased to 250 metres at greater distances from the wood. Closer sampling was considered unnecessary as these results were only required as a check on those from North Gill. The results are expressed in the form of a pollen diagram in Figure III.5 and as in the case of the North Gill samples the data relating to the pollen of tree species present in the wood are shown separately in Figure III.12. The data are expressed as percentages of total pollen and the scale of the histograms is directly comparable with those from Transects A, B and C. The abrupt decline of Quercus pollen within 100 metres from the edge of the wood is similar to that at North Gill, and the low and fairly constant Betula pollen frequencies which show no definite trend are comparable with the North Gill Betula data. The behaviour of the Alnus pollen frequencies at Skell Gill is even more erratic than on the North Gill transects. Abnormally high Alnus frequencies occur at 100 metres, 300 metres, 800 metres and 1,300 metres, and at 1,050 metres Alnus forms 22% of total pollen, the maximum value recorded on any of the transects. At this point the nearest trees of Alnus glutinosa are over 1.2 kilometres distant. Three possible explanations for over-representation by Alnus pollen have been suggested already; differential filtration by isolated trees and the subsequent washing off and deposition of pollen seems unlikely in Skell Gill as the Sorbus trees, which occur at intervals beyond the woodland edge, are generally high on the valley sides and somewhat distant from the sampling points. However, both local turbulence factors and macroscopic deposition could be important.

The results of the surface sampling from the Skell valley therefore provide support for the conclusions drawn from the North Gill transects. These can be summarised as follows:

1. When a total pollen sum is used there is a very rapid decline in tree pollen within the first 100 metres of the edge of a wood. This is due to pollen from the trees actually forming the woodland edge, in this case Quercus petraea.

2. Consequent upon this, the "edge effect" exerted on pollen deposition by the woodland does not extend beyond 100 metres.

3. There is no obvious extension of the "edge effect" according to the direction of the prevailing winds.

4. The magnitude of deposition of Betula and Quercus pollen is fairly predictable if the distance to the nearest trees is known; on the other hand the deposition of Alnus pollen is extremely unpredictable.

The attempts to establish a statistical relationship between the magnitude of tree pollen deposition and the distance from the woodland edge did not meet with great success. Regression analysis was carried out on all the transects but significant correlations were obtained only in the few instances described above, and in these cases the percentage of explained variation is only moderate. It is clear that pollen deposition away from a woodland edge is complex; only a proportion of the pollen deposited appears to be directly derived from the woodland. Other pollen sources are clearly involved and the trend of decreasing tree pollen deposition away from a woodland edge is distorted by local factors which are difficult to isolate.

These results from the surface pollen survey relating to dispersal from the woodland edge are in general supported by the observations of other workers. Lanner (1966) quoted data on arboreal pollen dispersal from a number of sources. In most cases the main decrease was recorded within 160 metres of the point of pollen production and was followed by a very gradual decrease beyond this distance. Cundill (1971) noted a very rapid decrease in arboreal pollen away from a gill woodland edge on the north Yorkshire Moors. He recorded that at a site close to the edge of woodland in Wheeldale Gill tree pollen contributed 75% of all pollen, yet 100 metres away the arboreal pollen deposition had decreased to 7% of total pollen.

A comparison with the data published by Turner (1964b) on dispersion of pine pollen is difficult, as her data are expressed as percentages of total tree pollen. However, her results indicate a more gradual decline of Pinus deposition with distance from the source plantation than the decline in Quercus deposition that has been described for the Skell Gill and North Gill transects. This may be due to the more effective dispersal of *Pinus* pollen grains, which are equipped with air bladders. Turner identified a β component of pollen deposition which was due to pollen derived directly from the nearest source, in this case the plantation. Beyond the influence of the β component she maintained that *Pinus* pollen could have been derived from sources other than the plantation. In the case of the results from Skell Gill and North Gill, the high values for tree pollen and for *Quercus* pollen associated with samples from within the first 100 metres of the woodland edge are clearly attributable to the influence of the local woodland. Pollen deposited beyond 100 metres, where the frequencies have levelled off, is probably derived from a larger source area. If these observations are considered in the light of Tauber's model for pollen dispersal (Tauber, 1965 - *vide supra*) it seems likely that the high tree pollen frequencies within the first 100 metres represent deposition by the trunk space component and that beyond this distance deposition is due to a combination of the canopy and the rain-out components. Distinction between these latter types of pollen deposition is not possible as the results in this survey were obtained from an area which is predominantly cleared, with only isolated patches of woodland, whereas Tauber's model was designed to fit forested conditions interrupted by only small basins.

III.iii.d. The shrub and non-arboreal pollen values on the transects

Corylus pollen values along the transects are irregular, a maximum of 27% of total pollen occurring in sample 8, Transect D, and yet there are no hazel bushes in the area. The close parallel between the behaviour of *Alnus* and *Corylus* along the four transects is interesting. Both these trees flower early in the year, well before the other trees and before their leaves have opened; also both are catkin-forming species. However, Betula, which also forms catkins, does not exhibit the same variable pollen deposition. The factors which have been suggested to explain the anomalous deposition of Alnus pollen could also apply to Corylus.

Salix is the only other shrub whose pollen occurs regularly in the samples, usually at frequencies of less than 2% of total pollen. Some Salix bushes are present in Skell Gill and North Gill Woods, though not within the sampling area. Low pollen values are characteristic of Salix which is insect pollinated and has sticky pollen which is not easily dispersed by the wind (Faegri and Iversen, 1964).

The non-arboreal pollen spectra from the four transects are dominated by the Ericaceae, and the swamping effect of the heath pollen becomes marked as distance from the wood increases. In most cases the highest values for the pollen of the Gramineae and the flowering herbs occur on the wood margins, reflecting the mixed vegetation of the woodland edge. The grazed turf on the woodland margin on Transects A and B results in values of between 30 and 50% of Gramineae pollen. Peaks in the pollen of herbs of pasture, for example Rumex acetosella type, also occur associated with the Gramineae peaks. The pollen of the Rubiaceae, the Leguminosae and Potentilla type is well represented in the first 150 metres of Transect A. The massive peak of 66% of Rumex acetosella type pollen in sample 14, Transect B, is exceptional. This sample came from a Calluna dominated area, the over-representation of Rumex pollen being apparently due to Rumex acetosella which was colonising a small burned patch close to the sampling point. Peaks in Rumex acetosella type pollen also occur in sample 14, Transect C, and sample 7, Transect D. Apart from these exceptions the low frequencies of the pollen of the flowering herbs reflect the absence of these species from the Calluna and Vaccinium dominated moors[1].

The frequencies of spores along the four transects are generally low. Exceptionally high values for Sphagnum spores occur in some samples on Transect C but the significance of these is uncertain. High Pteridium values of between 30 and 50% of total pollen occur in samples 21 and 22 of Transect C, but in general Pteridium values are very low compared with the importance of bracken in the vegetation.

1 In some cases where abnormal peaks in herb pollen occurred, the species in question were excluded from the pollen sum when counting. This is indicated by open bars on the pollen diagrams.

III.iv. The pollen productivity of upland Betula communities

Twelve surface moss samples were collected at random, in and around dense regenerating Betula pubescens scrub on Ramsley Moor. This area is owned by the North Derbyshire Water Board; the soils, altitude and aspect are similar to the Nidd-Laver interfluve. The vegetation of the area is heath dominated by Calluna vulgaris. In contrast to the Nidd-Laver interfluve the Gramineae, particularly Molinia caerulea, are well represented. This merely reflects the difference in management policy as between grouse moor and in a catchment area. Therefore, in physical terms, Ramsley Moor appeared to be suitable for the examination of the pollen productivity of an upland Betula community simulating what might have covered the Nidd-Laver interfluve in the past.

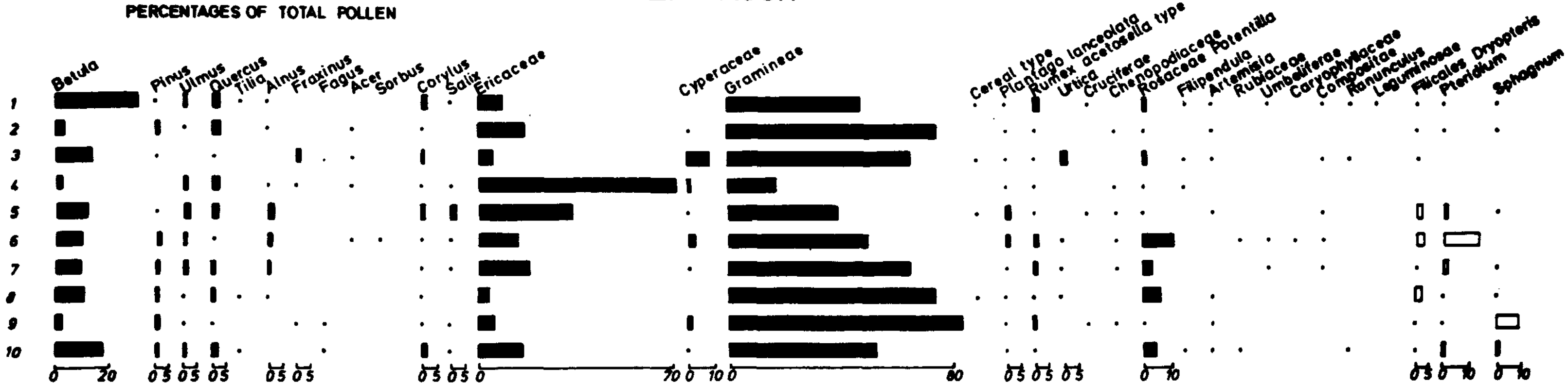
The results of the surface sample analyses are given in Figure III.13 which includes for comparison the results of the analysis of one surface moss sample from a Betula woodland in a sheltered situation in Glen Lyon, Perthshire (altitude 210 metres). The striking feature of the Ramsley Moor samples is the low mean frequency of Betula pollen (10.4%). The maximum frequency is 29% in sample 1, but three samples have less than 3% of Betula pollen, even though all were collected within a hundred metres of birch trees.

Many workers have maintained that Betula is always over-represented in the pollen rain (Table III.1). Heim (1962) and Bastin (1964) considered that, though within forest Betula pubescens was normally represented, it was over-represented in open woodland and in cleared areas marginal to woods. Faegri and Iversen (1964) suggested that a correction factor of 1 x ¼ should be applied to raw Betula data, prior to its

FIG. III·13

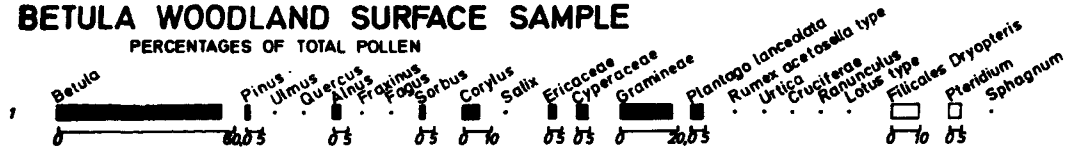
BETULA SCRUB SURFACE SAMPLES RAMSLEY MOOR

PERCENTAGES OF TOTAL POLLEN



BETULA WOODLAND SURFACE SAMPLE

PERCENTAGES OF TOTAL POLLEN



expression in percentage form, in order to obtain an accurate impression of the importance of Betula in the vegetation. Tsukada (1958) and Andersen (1967) derived a similar correction factor for Betula after consideration of data from Japan and Denmark, respectively. Andersen stated that in open woodland conditions, where Betula flowers profusely, a correction factor as high as $1 \times \frac{1}{6}$ was appropriate.

If correction factors of the magnitude suggested above were applied to the Ramsley Moor data, the resulting figures would give an inaccurate impression of the surrounding vegetation, suggesting that Betula was an unimportant tree on the moorland. The representation of Betula pollen in the Ramsley Moor samples is clearly low compared with the results obtained by other workers. An examination of the trees on Ramsley Moor in the spring of 1972 confirmed that they were forming catkins and that these were producing pollen; however, the number of catkins appeared to be small. It is widely held that the initiation of flower buds depends on a number of external factors of which climate and nutrition are claimed to be important (Mr. J. W. Kinnaird, Nature Conservancy, personal communication). Sarvas (1952) has suggested that if cold weather coincides with the period of flowering in Betula pubescens and Betula verrucosa it may result in a considerable reduction in the amount of pollen released.

It therefore appears possible that on exposed sites, with poor soil, flowering capacity and hence pollen productivity may be reduced. This could explain the apparently anomalous association of abundant Betula macro-remains with low Betula pollen frequencies at some sites on the Nidd-Laver interfluve and the North Yorkshire Moors.

There is a very marked difference between the mean value for Betula pollen in the Ramsley Moor samples (10.4%) and the frequency of Betula pollen in the Glen Lyon woodland sample (57%). The latter is from a mature woodland in a sheltered valley with fully grown trees 7 or 8 metres high; this is in contrast to the stunted nature of the Betula scrub on Ramsley Moor. It is widely accepted that exposure of the tree crown is an important factor in the quantity of pollen produced (Matthews, 1963). It is possible that pollen productivity in scrub woodland is reduced compared with fully developed woodland, owing to the crowding of the individuals. If scrub woodland was characteristic of certain upland areas in the past this might be a further reason for the anomalously low Betula pollen frequencies in some peat profiles.

In order to resolve this problem a systematic survey of surface pollen samples from British Betula woodlands with varying aspects and altitudes is necessary. In addition, comparative studies are needed of the absolute pollen output from upland and lowland Betula communities. Such work is beyond the scope of the present study. However, from the data obtained it seems fairly certain that the pollen productivity of Betula may vary markedly depending on the environment in which the trees are growing.

III.v. Implications of the results of the surface pollen survey for the interpretation of the fossil pollen diagrams

The results of the surface sample analyses to some extent provide an objective basis for the ecological interpretation of the pollen diagrams. However, the use of modern analogues in the interpretation of fossil pollen diagrams is limited by the number of variables involved which cannot at present be quantified. These relate to changes in climatic conditions; past pollen productivity of individual species and communities, and the exact relationship between samples obtained from moss polsters and samples obtained from peat. The present results act only as a guide to interpretation and indicate that for certain species extreme caution is necessary in deducing ecological information from pollen percentages.

One of the principal questions which the surface pollen survey was designed to answer related to the feasibility of predicting woodland limits from tree pollen percentages. The average frequency of tree pollen in the samples from the woodland was 51%, the maximum 78% and the minimum 28%; on the moorland the average frequency of arboreal pollen was 14.5%, the maximum 41% and the minimum 2%. Therefore it is clear that arboreal pollen percentages greater than 51% are a fairly certain indicator of woodland conditions. This figure is in accordance with results obtained by Heim (1962) who suggested that in the forested part of the Ardennes tree pollen values were always greater than 50% of total pollen. According to the results from the Nidd-Laver interfluve tree pollen percentages between 28% and 41% may or may not indicate woodland conditions, and in this case careful examination of the composition of the tree pollen rain is necessary. If Alnus, which has been shown to have highly variable values in surface samples, forms a high percentage of the tree pollen then interpretation in ecological terms is less certain than if Quercus is the principal contributor. Tables III.3 and III.6 give average, maximum and minimum values for the species recorded in the woodland and moorland pollen rain and these form the basis for the following comments.

Quercus pollen percentages of over 50% of total pollen almost certainly originate within Quercus woodland; values well above 50% indicate that the canopy of this woodland is likely to have been closed. In small clearings the Quercus pollen values may drop as low as 12%, but this can be clearly distinguished from open cleared conditions, where Quercus pollen blown in from other areas does not exceed 5.5%. The majority of workers have concluded that the representation of Quercus in the pollen rain reflects fairly accurately its representation in the vegetation. However, Andersen (1967) found Quercus over-represented in the Draved Forest and proposed a correction factor of 1 x ¼ for the pollen percentages in order to obtain a correct assessment of its role in the vegetation. The data from the Nidd-Laver interfluve, which suggest approximately equal representation in the pollen rain and in the vegetation, are in agreement with observations by Heim (1962), Mullenders (1962) and Janssen (1967).

Alnus pollen frequencies are extremely variable; the maximum value encountered in this survey was 47% from a site beneath an Alnus tree and within Quercus dominated woodland. It is reasonable to suppose that higher percentages would be associated with a pure Alnus stand. In the absence of trees a maximum of 21% Alnus pollen was recorded on Dallow

Moor and 22% in the Skell valley, and therefore it is clear that _Alnus_ pollen values of this magnitude need have little significance in terms of the vegetation immediately surrounding a site. If variability in pollen deposition were established as a general feature of _Alnus_ in areas other than the Nidd-Laver interfluve, this might account for the local over-representation of this species noted by Thorley, at her Lewes I site (Thorley, 1971), and by Cundill, at his St. Helena sites (Cundill, 1971). Erratic values for _Alnus_ pollen in fossil diagrams have often been attributed to _Alnus_ trees growing directly on the bog surface. In this situation Janssen (1959) advocated the exclusion of _Alnus_ from the total pollen sum. However, the results of this survey show that even when the trees are growing some distance from a site, the magnitude of _Alnus_ pollen deposition is unpredictable and therefore pollen percentages of this species must always be interpreted with caution.

The results of the surface sample analyses from the two types of _Betula_ communities discussed in Section III.iv. clearly suggest that the aspect and altitude of the site must be taken into account when interpreting _Betula_ pollen values in ecological terms. Very high _Betula_ values of 60 - 70% of total pollen indicate that _Betula_ was prominent in the vegetation around the site. However, low values need not necessarily indicate that the role of _Betula_ was unimportant. It seems possible that at some upland sites, _Betula_ values of between 10 and 15% may indicate that _Betula_ played a very significant part in the surrounding vegetation, particularly if evidence from macro-remains lends support to this conclusion.

Sorbus is generally under-represented in the surface pollen samples, and is rarely present at values greater than 2 to 3% even along Transects C and D, where Sorbus aucuparia trees are frequent. An exceptional sample, taken directly beneath a Sorbus tree, gave a value of 18.8% for the frequency of Sorbus pollen. Sorbus is therefore one of those species where low pollen percentages may be important ecological indicators.

The behaviour of Corylus in the surface pollen samples is extremely variable. It is not present in the gill woodlands, and the most likely source of the pollen appears to be from the hedgerows on the surrounding lowlands. The similarity between the mean values for Corylus from the woodland (3.2%) and the moorland (3.9%) might suggest fairly even distribution of the pollen, but these figures conceal wide variations. On the moorland, Corylus values range from 0 - 16.8%; the maximum value recorded for Corylus in the whole surface pollen survey was 30% of total pollen, in sample 8, Transect D. It is therefore clear that little ecological significance can be attached to the occurrence of Corylus values of 30% or less in pollen spectra dominated by non-arboreal pollen beyond the assumption that Corylus bushes were present within the general region. There is less variation in the values of Corylus recorded in the samples from within the wood; the maximum of 13% of total pollen occurred in a clearing, but apart from this values were much lower. It is reasonable to conclude that Corylus values of 20 - 30% will be of greater significance in terms of bushes growing close to the site, if they occur in a spectrum which is generally suggestive of wooded conditions. Jonassen's results from Jutland suggest that when Corylus forms an understory in the forest it is under-represented in the pollen rain (Jonassen, 1950). The pollen productivity and dispersal of Corylus is clearly very much dependent on the nature of the surrounding vegetation. Therefore interpretation of Corylus percentages in terms of the prevailing vegetation requires careful examination of the proportions of arboreal and non-arboreal pollen in the pollen spectrum.

With the exception of Corylus, none of the arboreal species absent from the gill woodlands occurred in any of the pollen spectra at values greater than 5%. It is therefore not possible to come to any conclusions regarding the relative representation of these species in the pollen rain.

The surface pollen survey was also designed to investigate the deposition of tree pollen at increasing distances from the woodland edge. In a study of fluctuations in woodland limits it is important to know the distance over which pollen dispersed from a woodland will dominate the pollen rain. It is clear from the transects that, when a total pollen sum is used, the effect of pollen dispersed through the trunk space is negligible beyond 100 metres of the woodland edge. At greater distances than this tree pollen values of more than 15% are exceptional, and therefore tree pollen values of over 50% in a fossil spectrum indicate woodland within 100 metres of the site. If tree pollen values of between 25 and 50% occur in a series of samples in a fossil pollen diagram this may be interpreted as either a site within 100 metres of a woodland edge, or as a site surrounded by dispersed trees.

The representation of non-arboreal species in the pollen rain from specific plant communities is less predictable than the representation of the tree species. Within the present moorland community the average value for Ericaceae is 63% of total pollen, but values of 80 or 90% are common. Such high values for Ericaceae pollen must reflect the fairly pure Calluna sward which has developed as a result of current moorland management. A more mixed vegetation, producing a pollen rain in which the swamping effect of Calluna was less marked may well have characterised the moors in previous centuries. However, some interesting points have emerged from the examination of the non-arboreal pollen percentages. Vaccinium is scarcely represented in the surface pollen samples, yet it is an important member of the moorland and woodland plant communities and occurs frequently along the transects. It seems certain that the role of Vaccinium in former heath communities cannot be deduced directly from its representation in fossil pollen diagrams, unless its present production is restricted by factors such as grazing. The Gramineae pollen values reflect the surrounding local vegetation well, and are highest in areas subject to grazing. Peaks in the pollen of Rumex acetosella type, the Rubiaceae and the Leguminosae emerge from the surface pollen survey as indicators of very local grazing pressure. Plantago lanceolata pollen values appear to be less subject to marked fluctuations, suggesting a more even dispersal of pollen from this plant. These observations have important implications for the interpretation of agricultural phases from pollen diagrams. Peaks in Plantago lanceolata pollen may well reflect activities taking place over a larger area than that reflected by peaks in pollen of some of the other weeds of cultivation.

The values of spores recorded in the surface pollen survey have been shown to be subject to wide variations and they therefore have very little significance in ecological terms. The highest value for Pteridium in this survey, 54% recorded on Transect C, was associated with Pteridium aquilinum close to the site, but at other sites, where Pteridium was equally represented in the vegetation, very low frequencies of spores (less than 2%) were recorded. Dispersal of Pteridium spores appears to be poor and production erratic, and therefore although high Pteridium percentages are probably a safe indicator of bracken close to the site, nothing can be deduced from the absence of Pteridium spores from the pollen spectrum. This is of particular importance in the light of the use made of Pteridium as an indicator of pastoralism (Oldfield, 1963; Simmons, 1969b). Though some correlations between diagrams based on the occurrence of this species may be valid, there are serious drawbacks in the use of an indicator with unpredictable pollen or spore production.

The frequencies of Filicales spores recorded in the surface pollen survey are generally low. The peaks in sample 2 from the Quercus woodland (Fig. III.2) and sample 13 from Transect C (Fig. III.6) are difficult to account for in terms of the vegetation surrounding the sampling site. In the case of Sphagnum, the erratic spore production is even more marked, and enormous peaks of Sphagnum spores are associated with certain samples in Transect C. Marked peaks in Sphagnum spores have been noted in a number of fossil pollen diagrams. Conway (1954) suggested that sudden excessive sporulation by Sphagnum might be induced by an increase in wetness on a bog surface and Tallis (1964) suggested that a sudden change in environmental conditions might be responsible. However, neither of these explanations can apply to these results from surface samples occurring within a small area. It appears that spore production by pteridophytes and bryophytes is governed by different factors from those governing pollen production, and therefore the two types of data should be interpreted accordingly.

The results of the surface pollen survey are applied to the interpretation of the pollen diagrams from the Nidd-Laver interfluve in Section IV. Their applicability to other areas may be limited by the influence of factors such as local turbulence which have been discussed above. It also appears likely that pollen productivity may alter between areas with differing environmental conditions, thus affecting the magnitude of the representation factors for each species. The use of surface pollen studies for the ecological interpretation of pollen diagrams may also be limited by climatic changes which cross the threshold for a major alteration in the prevailing plant species in an area. Thus the results obtained in this survey have only been applied to the interpretation of the pollen diagrams from the Boreal/Atlantic transition to the present day.

SECTION IV INTERPRETATION

In this section the vegetation changes which characterise zones A-F are discussed chronologically.

IV.i. Zone A

Pollen assemblages from this zone occur at only two sites on the interfluve. On the basis of the relatively high values for Pinus and Corylus zone A has been assigned to Pollen Zone VI of the British System. At Scaleby Moss, Westmorland, this was estimated to have spanned the period between about 7,000 and 5,500 B.C. (Godwin, Walker and Willis, 1957). Pollen Zone VI is correlated with the later part of the Boreal period, which is usually considered to have been more continental than the present British climate (Pennington, 1969).

Pinus, Betula and Corylus are the principal contributors to the zone A pollen assemblage. The high Pinus pollen values at Iron Well Hill may be derived from a pine-dominated woodland which grew around this site during an early phase of zone A. In the basal peat at Fountains Earth Pinus values are significantly lower than those in zone A at Iron Well Hill, perhaps indicating that the Fountains Earth deposit began to form towards the end of zone A, when the decline in Pinus on this upland had already begun. However, it is possible that Pinus and Betula formed separate stands on different parts of the interfluve throughout this time giving rise to local peaks in the pollen representation of these species. Corylus may have formed a shrub layer beneath the fairly open canopy which is characteristic of both these trees, though at some sites patches of pure Corylus woodland may have existed. The presence of Corylus shrubs on the interfluve in this zone is confirmed by a fruit of Corylus avellena which was found in the mineral material at Iron Well Hill. During Zone VI Betula/Corylus woodland also appears to have surrounded the Stump Cross site, 12 kilometres south-west of Fountains Earth (Walker, 1956).

It is clear that _Salix_ played an important role in the vegetation around the Fountains Earth site at this period, probably lining the banks of streams. The regular occurrence of _Quercus_ and _Ulmus_ pollen throughout the zone suggests that on the margins of the interfluve mixed oak woodland was established at this period. Isolated grains of _Tilia_ pollen occur in zone A at Fountains Earth and this tree was probably also present in the lowland woodland by the end of Zone VI. This is typical of many sites in the British Isles (Godwin, 1956), though at some sites in north-east England _Tilia_ was not established until Pollen Zone VIIa (Bartley, 1966).

There is no firm evidence for any permanent population in this area during the period of zone A as Collins's (1930) records for Palaeolithic hand axes recovered from the morainic gravels of the Nidd valley are unsubstantiated. Geometric microliths found on Kettlestang Hill indicate the presence of Sauveterrian people in the area but it is difficult to date the exact period of this activity. The base of peats above Mesolithic sites at Marsden and at Blubberhouses have been assigned to Pollen Zone VIIb (Davies, 1943; Davies, 1963), but in neither case was a correlation possible between the age of the peat and the artifacts. It is conceivable that a considerable period of time may have elapsed between the deposition of the microliths and the initiation of peat formation. Mesolithic occupation probably began in the Pennines during the latter part of Zone VI, certainly Maglemosian sites in east Yorkshire have been assigned to this period (Walker and Godwin, 1954). Thus it is possible that the Sauveterrians were present on the Nidd-Laver interfluve during zone A.

Palynological evidence for human interference with the vegetation during zone A is inconclusive. Herbaceous pollen forms not more than 10% of total pollen during this zone and consists principally of pollen of the Gramineae and the Cyperaceae. The flowering herbs which are recorded have very low values; of these Lonicera, Mercurialis, Succisa, the Rubiaceae and Potentilla are natural members of the woodland flora and can tolerate shady conditions; Filipendula probably colonised the stream sides. Herbaceous pollen frequencies of this magnitude may indicate that the zone A woodland had a fairly open canopy. Turner (1970) described a pollen diagram from 490 metres on Widdybank Fell in the northern Pennines. In this diagram non-arboreal pollen formed between 30% and 40% of total pollen in Zone IV and this was interpreted as representing natural open woodland, capable of maintaining a rich ground flora. It is possible that grains of Cruciferae, Urtica, Artemisia, Compositae and Plantago lanceolata pollen, found in zone A at Fountains Earth resulted from limited artificial opening of the woodland canopy. The Sauvet errians may have created clearings for hunting, and it has been suggested that they used fire for this purpose (Simmons, 1969). However, no charcoal has been recorded in the zone A deposits from the Nidd-Laver interfluve.

The overall impression of the vegetation of the Nidd-Laver interfluve during zone A is of a fairly open woodland made up of a mosaic of Betula, Pinus and Corylus stands, with mixed oak woodland occupying the surrounding valleys. Turner (1970) has suggested that a similar type of woodland, changing in species composition over relatively short distances, covered the northern Pennines at this period.

IV.ii. Zone B

The A/B zone boundary is defined on the basis of a decline in Pinus and an expansion in the pollen of Alnus. In Section II.iv.a. this boundary has been equated with the transition from Pollen Zones VI to VIIa, the Boreal/Atlantic transition. At Scaleby this horizon was dated to 5,475 ± 350 B.C. (Godwin, Walker and Willis, 1957). Dates from certain sites elsewhere in the British Isles accord closely with this, though Oldfield (1965) has suggested that the main expansion of alder is not necessarily synchronous throughout the British Isles. It has traditionally been accepted that the expansion in Alnus pollen at this boundary reflected the spread of this tree in response to a climatic change towards increasing oceanicity. This is thought to have occurred throughout northern Europe, between 5,000 and 6,000 B.C. The increase in rainfall resulted in rising water tables and the creation of new habitats suitable for Alnus to colonise. Topogenous and blanket peat formation was initiated at a number of sites at this period (Conway, 1947; Johnson and Dunham, 1963). The climatic change may have been influenced by a general rise in sea-levels which took place at this period, resulting in the final separation of Great Britain from the European mainland. Recent work (A. G. Smith, 1970) has drawn attention to correlations between Mesolithic occupation layers and the pollen analytical changes associated with the Boreal/Atlantic transition. Smith has suggested the possibility that human activity also played a part in the vegetation changes of this period.

The reduction in Pinus pollen at the A/B boundary suggests that the role of pine in the vegetation of the interfluve was reduced. The values of Corylus and Betula pollen also decline gradually throughout zone B in response to the increasing values of Alnus pollen. These changes probably indicate some contraction in the area occupied by

Betula and *Corylus* as the water-table rose, and a general expansion of *Alnus* on to the damp flushed sites. The role of *Salix* as a coloniser of stream sides also appears to have been reduced in this zone.

The results of the surface pollen analyses have been applied to the interpretation of zones B-F from the Boreal/Atlantic onwards. By this time all the native arboreal species were established in Britain (Pennington, 1969). The modifications in climate which have occurred since the Atlantic period have been minor, compared with the changes which preceded the establishment of the climatic optimum. It has been estimated that during the Atlantic period mean annual temperatures were only 2°C above present values (Manley, 1964).

The expansion of *Quercus* pollen to over 20% of total pollen at the A/B boundary at Fountains Earth is significant. Surface pollen analyses have shown that at the present time, with *Quercus* confined to altitudes below 275 metres, an average of 5.5% of *Quercus* pollen occurs in surface samples from the higher parts of the interfluve. In view of the predictable nature of *Quercus* pollen deposition which was established in Section III, an increase from 5% to over 20% of *Quercus* pollen must represent an actual upward extension of oak trees. Values of between 15% and 30% of *Quercus* pollen have been associated with the area about 100 metres away from a *Quercus* woodland edge. Therefore it seems reasonable to assume that at the opening of zone B oak trees extended up the ridge of Kettlestang Hill alongside the Fountains Earth site. *Quercus* must have partially replaced *Betula* on the ridge, though birch probably remained dominant on the actual summits of the hills. At the same time *Alnus* was replacing *Betula* on the damp peaty sites in the channel. Soon after the opening of zone B the *Alnus* carr at the Fountains Earth site became so dense that, at 340 cm in the pollen diagram, pollen of *Alnus* masks the contribution of *Quercus* and *Betula*. At 330 cm there is a sudden reduction in the deposition of *Alnus* pollen and in response to this values of *Betula* and *Quercus* rise. However, above 320 cm there is a second and more marked peak in *Alnus* pollen.

The results of the surface pollen analyses have suggested that caution is necessary in the interpretation of peaks in *Alnus* pollen. However, in the case of the zone B data from Fountains Earth *Alnus* pollen reaches values of over 50% of total pollen and these are sustained through nearly 40 cm of peat. *Alnus* pollen values of this magnitude were only found in the surface survey at one site directly beneath an *Alnus* tree in North Gill Wood. Clearly, dense *Alnus* carr must have filled the channel at Fountains Earth during zone B; the presence of *Alnus* macro-remains in the zone B peat supports this interpretation. The recession in *Alnus* values between 330 cm and 320 cm probably represents no more than a natural variation in the density of trees within the carr. In Section III.iii.a. it was observed that *Alnus* does not disperse its pollen to any great distance laterally within a wood. Small variations in the density of *Alnus* trees could therefore produce large fluctuations in a pollen diagram. There is no associated rise in the pollen of taxa indicating disturbance between 330 cm and 320 cm and therefore the decline in *Alnus* is unlikely to be due to man's influence.

The taxa which respond to the decreased *Alnus* values are those which were already growing close by, i.e. *Betula*, *Corylus* and *Quercus*. This might be expected if the density of alder trees growing on the site decreased, allowing pollen from a wider area to be deposited on the surface of the bog. This interpretation is supported by the occurrence of wood layers in the stratigraphy at the levels of the two *Alnus* peaks. The zone B pollen spectrum from Hambleton Dike is less subject to over-representation by *Alnus* pollen, presumably as the vegetation around this site was more open than the dense carr at Fountains Earth.

At lower altitudes during zone B, dense Quercus woodland probably covered most of the ground with Alnus lining the rivers; Tilia and Ulmus were also present, and Fraxinus was growing at some sites in this area. In the majority of diagrams from the British Isles a continuous Fraxinus curve is not established until after the Ulmus decline (Pennington, 1969). Fraxinus is a light-demanding tree and is thought to have expanded into the clearings that were made in the forest by the early agriculturalists (Godwin, 1956). The presence of Fraxinus in zone B at Fountains Earth could indicate that clearings had already been made in the woodland on or near the interfluve at this time. However, it is significant that at Malham Tarn, on the Carboniferous Limestone, Fraxinus is present from the end of Zone VI onwards as a minor but consistently represented species. Pigott and Pigott (1963) considered that there was no evidence for man's interference in the Malham woodland prior to Zone VIIb and therefore considered Fraxinus a natural member of the limestone flora. Subsequently A. G. Smith (1970) reinterpreted their data and suggested that the woodland might have been locally opened by Mesolithic activity in the early part of Zone VIIa. If this were the case Fraxinus could represent part of the regeneration sequence. The Carboniferous Limestone outcrops only 8 kilometres to the west of Fountains Earth and it is possible that Fraxinus pollen may have blown in to Fountains Earth during zone B. The low frequencies of Fraxinus correspond to the present-day surface pollen values from the moors and these have been attributed to pollen blown in from the west.

Only a very approximate estimate can be made of the length of zone B. The problem of defining the Ulmus decline on the Fountains Earth diagram has already been discussed (vide supra Section II.iv); this horizon has been tentatively placed within zone B just above the 300 cm level.

Radiocarbon dates for the Ulmus decline in Britain range from about 5,400 B.P. to 5,000 B.P. (Clark and Godwin, 1962).

No very significant changes in the pollen record have been identified at Fountains Earth to correspond with this horizon; the B/C boundary being placed about 25 cm higher at 275 cm. If, however, the 300 cm level at Fountains Earth is accepted as the Ulmus decline, this horizon can be assumed to date from somewhere between 3,400 and 3,000 B.C. The opening of zone B at 370 cm has been correlated with the Boreal/Atlantic transition which occurred about 5,500 B.C. On this basis the peat between 300 cm and 370 cm represents a period of around 2,300 years, and the estimated rate of peat formation is one centimetre in 33 years. If, furthermore, this rate is assumed constant for the whole of zone B, then it can be estimated that the zone lasted for about 3,100 years, extending from 5,500 B.C. to around 2,400 B.C.

There is clear evidence that during this period Sauveterrian people were active in this part of the Yorkshire Pennines. The radiocarbon date for charcoal associated with Sauveterrian flints at Stump Cross, only 12 kilometres from Fountains Earth, is 4,550 ± 310 B.C. (Godwin and Willis, 1959). This falls within the earlier part of zone B. Walker (1956) suggested that two or more separate visits may have been made to the site by people of the same cultural group. A flint was discovered stratified within the deposits at Stump Cross, and at this level the Alnus curve was beginning to rise rapidly and increases in the Gramineae and the Ericaceae were also observed. Walker attributed these changes to the inception of blanket bog development around the Stump Cross site in response to an increase in rainfall at the Boreal/Atlantic transition. However, Simmons (1969) commented that Walker's results could indicate local opening up of the woodland by Mesolithic people.

No equivalent rises in the Gramineae or Ericaceae occur at the sites on the Nidd-Laver interfluve. Potentilla and Filipendula continue to be represented in zone B at Fountains Earth and Hambleton Dike. However, occasional pollen grains of weed species are recorded and the record for Melampyrum, a plant typical of woodland clearings, is interesting. It is represented at both sites throughout the zone but between 355 cm and 345 cm at Fountains Earth it reaches values of between 5% and 10% of total pollen. Just above this level some small fragments of charcoal were recovered from the boring and small peaks in Rumex acetosella type pollen occur. These features may indicate some opening up of the woodland by the Mesolithic hunters.

IV.iii. Zone C

Zone C falls within Zone VIIb of the British Pollen Zone System. The B/C boundary has been established on purely local criteria, *viz* a decline in *Alnus* pollen and a corresponding rise in the pollen of *Betula*; this is accompanied by a rise in *Quercus* values at Fountains Earth. The decline in *Alnus* appears to have been sudden and the upland carr vegetation must have been much reduced during zone C. The decline in *Alnus* probably did not result in an expansion of *Betula* and *Quercus* trees but rather in an increase in their relative contributions to the pollen rain. From the zone C pollen assemblages at Fountains Earth and Hambleton Dike it appears that *Betula-Corylus* woodlands persisted over parts of the interfluve, with *Quercus* the dominant tree in certain areas.

The interpretation of the erratic series of peaks and troughs in the *Quercus* pollen values at Fountains Earth in zone C is difficult. Surface pollen studies have established that the dispersal of *Quercus* pollen away from a woodland edge is very predictable and follows a regular pattern. *Quercus* pollen values of over 50% of total pollen have been associated with woodland conditions, and it has been established that at distances greater than 100 metres from the woodland edge *Quercus* values exceeding 10% of total pollen are exceptional. At Fountains Earth in zone C *Quercus* values vary from below 15% to more than 50%, in consecutive samples, without exhibiting any visible trend throughout the zone. It appears that during zone C this site was within 100 metres of the edge of *Quercus* woodland. Small changes in the position of the woodland edge would therefore register as very large fluctuations in the *Quercus* pollen curve.

Just above the B/C boundary at Fountains Earth there is a stratigraphic change from *Alnus* swamp peat to *Eriophorum* peat; the establishment of *Eriophorum* on the bog is reflected by an increase in Cyperaceae pollen at this level. At the same boundary at Hambleton Dike Alnus swamp peat is overlain by dry wood peat formed of Betula remains. This change in peat types probably indicates a partial drying out of these sites. It is clear from the bog stratigraphy at Fountains Earth that after the opening of zone C trees were never able to recolonise this site. The significance of the proliferation in Sphagnum spores above the B/C boundary is uncertain as it has been shown in the surface pollen survey that Sphagnum spore production is extremely unpredictable.

Thus it appears that during zone C the interfluve was covered by woodland dominated by Quercus and Betula, probably with some Sorbus. Sorbus pollen occurs in certain samples in this zone at values of less than 1% of total pollen, but the surface pollen survey indicated that even very low values of this pollen type are significant in terms of nearby trees. A shrub layer of Corylus was probably present in parts of the woodland and in places the trees were interrupted by damp, boggy areas.

The introduction of the early farming cultures into Britain has been widely correlated with the Ulmus decline in British pollen diagrams (Seddon, 1967). One explanation for this association was suggested by Faegri (1944). He claimed that a marked decline in the pollen representation of Ulmus might have been caused by farmers collecting elm foliage for animal fodder. Troels-Smith (1953) later suggested that the initial decline in Ulmus could be associated with the practice of stall-feeding livestock, which was common in early Neolithic economies. Mitchell (1956) suggested that the Ulmus decline might have been caused by Neolithic farmers selectively felling elm stands which grew on base-rich soils that were suitable for agriculture. On the southern Pennines, Hicks (1971) has attributed changes in the non-arboreal pollen curves at the level of the Ulmus decline to the activities of Neolithic herdsmen. At Fountains Earth no significant changes in non-arboreal pollen occur at the 300 cm level, but in zone C a series of small peaks in the pollen of the Gramineae can be distinguished at both Fountains Earth and Hambleton Dike. Small increases in the pollen of the Ericaceae accompany the Gramineae peaks, and these can be correlated with the occurrence of pollen of Plantago lanceolata and Rumex acetosella type. There is a general increase in the frequency of occurrence of herbaceous pollen types during this zone. These features suggest that gaps were being created in the woodland canopy.

The abnormally high values of Rumex acetosella type pollen (8-20% of total pollen) in the samples between 250 cm and 265 cm at Fountains Earth coincide with one of the Gramineae peaks. In the surface pollen survey, high values for pollen of Rumex acetosella type were found to be characteristic of grazed turf on the Nidd-Laver interfluve at the present day. The Rumex acetosella type peak at Fountains Earth could therefore be a result of local over-representation. There is no indication of any intensification of human activity as correspondingly high values for pollen of other weeds do not occur. It is difficult to distinguish any changes in the tree pollen curves associated with the Gramineae peaks in zone C. However, it is clear that a general decrease in Alnus occurred during this zone and there is a small but significant increase in Fraxinus pollen.

The duration of zone C can also only be assessed very approximately. The date of the B/C boundary has been estimated at around 2,400 B.C. The C/D boundary has been radiocarbon dated to 1,930 ± 100 B.C. at a site on Skell Moor, therefore on this basis zone C lasted for about 500 years. The estimated rate of peat accumulation during zone C is therefore about one centimetre in 7 years, considerably faster than the rate of accumulation during zone B.

Archaeological evidence suggests that during the period 2,400 B.C. to 1,930 B.C. the population of the central Pennines was sparse. By this time farming techniques were well established in lowland Britain and it seems possible that the peaks in the pollen of the Gramineae during zone C were connected with the pastoral activities of Neolithic peoples. These farmers may have periodically used this upland as pasture for their flocks and herds. The occurrence of pollen of the herbs associated with pastoralism, Plantago lanceolata and Rumex acetosella, at equivalent levels to the peaks in the Gramineae supports this interpretation. The Neolithic polished stone axes which have been found in Nidderdale, on the margins of the interfluve, are certainly suggestive of active woodland clearance during this period.

Gramineae values of up to 10% of total pollen (20% of total arboreal pollen) indicate that any clearings created by these Neolithic herdsmen were very limited in size. Turner (1965) has identified "small temporary clearances" in pollen diagrams from Bloak Moss, Ayrshire, and Tregaron Bog, Cardiganshire, on the basis of increases in the values of the Gramineae to about 20% of total arboreal pollen. It is probable that clearances of this type involved only a few acres of land. At Bloak Moss and at Tregaron Bog, Turner calculated that each "small temporary clearance" lasted approximately 50 years. At Fountains Earth, assuming an even rate of peat formation throughout zone C, the first clearance which is correlated with the Rumex proliferation lasted for about 105 years, but subsequent zone C clearances appear to have been of shorter duration.

The Neolithic flints recorded from Kettlestang Hill and the rock shelter and hearth at Yeadon Crag are the legacy of the farmers who made these clearances and who probably practised a combined hunting and herding economy. It is quite possible that larger clearances for the purpose of cultivation were made on the lower land around the Nidd-Laver interfluve. The increase in the pollen of Fraxinus in this zone is probably a response to the creation of these openings in the woodland.

IV.iv. Zone D

Profound changes appear to have taken place in the vegetation of the Nidd-Laver interfluve at the C/D boundary. At Fountains Earth there is a sudden marked increase in the pollen of the Ericaceae, reflecting the development of heath over the highest part of the interfluve and the initiation of thin peat formation at sites such as Skell Moor I and II. During zone D tree pollen values at Fountains Earth decrease from about 50%, to between 20 and 30% of total pollen by the end of the zone. On the basis of the figures obtained in the surface pollen studies it is fairly certain that at the beginning of zone D woodland surrounded, or was very close to, the Fountains Earth site. A very rapid decline in arboreal pollen deposition within 100 metres of the woodland edge has been observed in the surface pollen survey. Therefore it is reasonable to assume that if an altitudinal lowering of the woodland edge occurred it would be registered in a pollen diagram as a marked decline in total arboreal pollen, provided that the linear distance involved in the fluctuation was greater than 100 metres.

The arboreal pollen values at Fountains Earth do not follow this pattern, but decline gradually and evenly. This could suggest a progressive thinning of the woodland along the flanks of Kettlestang Hill rather than a sudden reduction in altitudinal limits. In response to the reduction in trees there appears to have been a gradual extension of heath vegetation down from the summits of the interfluve on to the flanks.

This reduction in woodland and the initiation of thin peat accumulation, must have resulted in changes in hydrology on the interfluve as it is at this period that topogenous peat began to form in the upper valley of the Skell. The abundance of macro-remains of <u>Alnus</u> and

Betula in the Upper Skell Gill I peat demonstrates that trees grew in this valley during zone D, but that oakwoodland was confined to lower altitudes. Tree pollen values for this zone at Upper Skell Gill I average 30% of total pollen throughout, suggesting open woodland similar to that around the Fountains Earth site at this period. However, at Upper Skell Gill I, which is in a fairly sheltered valley, there is no trend towards a progressive reduction in the number of trees throughout the zone. The values of *Betula* pollen are low throughout the pollen diagram from Upper Skell Gill I, rarely forming more than 5% of total pollen. However, macro-remains are abundant, and in view of the observations made in Section III.iv, it seems possible that environmental factors may have operated to limit *Betula* pollen production at this site. The high values for Gramineae pollen in the Skell valley during zone D suggest that a grassy ground flora surrounded the site, with heath confined to the moorland above where thin peat was starting to accumulate.

Two agricultural phases, subzones D_2 and D_4, have been identified on the basis of peaks in *Plantago lanceolata* pollen. The results of the surface pollen analyses suggest that the use of fluctuations in the values of *Plantago lanceolata* pollen for the establishment of the subzones is acceptable. Pollen of this taxa was not subject to erratic representation, as was pollen of some of the other agricultural weeds. Subzones D_2 and D_4 appear to have been predominantly associated with pastoral activities, but grains of *Artemisia*, Compositae and Chenopodiaceae suggest that some cultivation may have taken place on the lowlands. Two grains of cereal pollen are recorded in subzone D_4 at Fountains Earth. These phases of activity must have had a considerable impact on the vegetation of the interfluve. In subzone D_4 at Upper Skell Gill I arboreal pollen values are temporarily reduced to only 11% of total pollen, suggesting active clearance in the vicinity of the site. The arboreal pollen values recover their former level in subzone D_5, in contrast to the Fountains Earth site where the reduction is continuous throughout this zone.

The overall picture of the vegetation of the interfluve during zone D is one of a gradual development of heath on the highest and most exposed parts and a progressive decline in the mixed Quercus/Alnus/ Betula woodland on the slopes. Quercus appears to have suffered first, stands of Betula and Alnus remaining in sheltered spots until the end of zone D. The change from predominantly Eriophorum peat to Sphagnum peat towards the end of zone D at Fountains Earth suggests a deterioration in drainage on the interfluve.

The C/D boundary has been equated with the base of the thin peat on Skell Moor and this has been radiocarbon dated to 1,930 ± 100 B.C. The opening of zone E at Hambleton Hill has been radiocarbon dated to 250 ± 80 B.C. Zone D therefore lasted about 1,680 years. The base of the peat at the Upper Skell Gill I site has been radiocarbon dated to 1,750 ± 110 B.C.; subzones D_2, D_3, D_4 and D_5 must therefore span a period of about 1,400 years and it is clear that each of the phases of agricultural activity represents a period of several centuries.

It is probable that the agricultural phase of subzone D_2, which began about 1,750 B.C., can be attributed to the activities of the Beaker people who occupied the Ure-Swale lowlands between about 1,900 to 1,600 B.C. The size and number of the henge monuments attributed to these people is suggestive of a considerable population and an extended occupation of this area. The Beaker people were primarily nomadic pastoralists (Hawkes, 1948) and they may have used the marginal uplands for their herds; in these areas the woodland cover would have been less dense than on the river flood plains. Any cultivation was probably carried out in the valleys where the soil was more fertile. It is possible that subzone D_4 can be associated with occupation by people of the Food Vessel culture, who are thought to have carved the many boulders on the moors to the south of the River Nidd. The early Bronze Age flints and stone mace-heads which have been found on the Nidderdale moors could also be attributed to these people. However, if subzone D_4 is assigned to the early Bronze Age, on the basis of the chronology established by radiocarbon dating the whole of the middle and late Bronze Age and the early Iron Age (more than 700 years) would be represented by subzone D_5. Despite the changes in stratigraphy in this subzone at Fountains Earth such a slow rate of peat accumulation appears unlikely. It is more probable that the D_4 agricultural phase can be associated with the Late Bronze Age people who left the hoards of axes and ornaments that have been found in the area between Ripon and Masham. These people presumably practised both cultivation and pastoralism and it is possible that a form of summer transhumance involving use of the upland areas may have been carried out, such as Webley (1969) has suggested for south Wales.

IV.v. Zone E

There was a further expansion of heath at the opening of zone E and thin peat extended over new sites which until this time had remained clear. Peat began to form at the Hambleton Hill site, where some trees probably survived until the end of subzone D_5, sheltered by Hambleton Hill. Regrowth of peat was initiated at the adjacent Hambleton Dike site following a hiatus during the later part of zone C and all of zone D. The start of ericaceous peat formation has been dated by radiocarbon analysis to 250 $\pm$ 80 B.C. at the Hambleton sites, and this date has been adopted for the opening of zone E. However, it is accepted that at the Fountains Earth site, where the stratigraphic record is complete, the D/E boundary may somewhat predate the extension of thin peat at the Hambleton sites.

The pollen diagram from the Upper Skell Gill I site suggests that open woodland had also survived around this site until the opening of subzone E_1. The radiocarbon date of 340 $\pm$ 100 B.C., obtained for part of an in situ rooting system recovered from this site, supports this interpretation. It seems likely that open *Betula*/*Alnus* woodland survived in scattered patches on the lower slopes until around 250 B.C., but that the whole of the upper part of the interfluve was treeless by this date.

The tree pollen values recorded at Fountains Earth average 18% of total pollen during subzone E_1, compared with an average of about 14.5% from the random surface samples collected on the present day moorland. The average tree pollen content of the thin peats for this period is lower, presumably due to the swamping effect of on-site Ericaceae pollen. It is clear that in the generally wooded environment that prevailed throughout much of lowland Britain at least until the Dark Ages, tree pollen would form the bulk of the regional component of pollen deposition. At the present time, with the largely agricultural landscape of the West

Riding, tree pollen will play a less significant part in the regional component. This difference in composition of the regional components compensates for the discrepancy between the mean for tree pollen in the surface samples and the mean for tree pollen in subzone E_1. It therefore seems likely that in subzone E_1 the moorland limits were similar to those of the present day, with trees confined to the land below 275 metres. However, the lowland woodland must have been far more extensive than it is now, though similar in composition to the modern gill woodlands.

The reduction in woodland at the opening of zone E is accompanied by the start of a prolonged and intensive agricultural phase. This is registered at all sites by a sustained rise in the pollen of the Gramineae. At Fountains Earth, Hambleton Hill, Hambleton Dike and the Skell Moor sites this increase is at the expense of the Ericaceae. At Upper Skell Gill I and II it is at the expense of the arboreal pollen values, suggesting active clearance of trees from around these sites. At all sites the rise in the values of pollen of the Gramineae is accompanied by a very marked increase in pollen of those taxa which are considered to be "cultural indicators". Plantago lanceolata forms 3-4% of total pollen and there are marked peaks in the pollen of Potentilla at the thin peat sites. Increases also occur in the incidence of pollen of Rumex acetosella type, which is associated with pastoralism and in the pollen of the Compositae, Cruciferae, Chenopodiaceae and Artemisia, which are associated with cultivation. Thus both arable and pastoral activities appear to have taken place during subzone E_1.

Turner (1964) has calculated an "arable/pastoral index" by expressing the number of Plantago grains as a percentage of the total number of grains of Plantago, Compositae, cereal, Cruciferae, Artemisia and Chenopodiaceae. On the basis of surface pollen studies she established that this index was usually greater than 50% in pastoral regions and less than 15% in arable regions. Turner used this index to characterise phases of agricultural activity at Tregaron Bog, Cardiganshire, and Whixall Moss, Shropshire. If this index is calculated for subzone E_1 at all the sites on the Nidd-Laver interfluve a mean value of about 75% is obtained. It seems likely that on the Nidd-Laver interfluve itself there was widespread pastoral activity during this period, cultivation was probably mainly confined to woodland clearings at lower altitudes.

This phase of activity appears to have resulted in an extension of the grassy communities at the expense of heath on top of the interfluve, and at lower altitudes, in the clearance of trees and the creation of new, open habitats. This expansion of the Gramineae may be a response to increased grazing pressure. Boulet (1939) commented on the profound effect of sheep grazing in restricting the spread of Calluna vulgaris in the Welsh uplands. He also noted an increase in Potentilla erecta under conditions of high grazing pressure, a feature which has been recorded in subzone E_1.

In addition to the features already described, subzone E_1 also appears to have been characterised by deteriorating drainage conditions, initiated at the end of zone D. At a number of sites there are increases in the pollen of two taxa which colonise damp sites, the Cyperaceae and the Liliaceae (Narthecium type). Peaks in Sphagnum spores recorded at this level may possibly be significant in this context.

The radiocarbon date of 250 ± 80 B.C. has been obtained for the opening of subzone E_1. It was suggested in Section II.iv.k. that the construction of Fortress Dike Camp probably took place during subzone E_1. The organic band from the base of the ditch at Fortress Dike has been attributed to the most recent phase of use of this site (Appendix 4), and the pollen spectrum from this material has features characteristic of subzone E_1. Therefore the date of A.D. 630 ± 90 for the organic band enables the duration of subzone E_1 to be estimated as at least 880 years.

It is clear that widely differing rates of peat formation were characteristic of the various sites on the Nidd-Laver interfluve throughout this period; at Fountains Earth about 50 cm of peat have been assigned to subzone E_1, whereas at the Skell Moor and Hambleton Hill sites less than 15 cm of peat formed in this subzone.

Archaeologically the period from 250 B.C. to A.D. 630 spans the late Iron Age, Romano-British period and the early Dark Ages, and it can be termed the Brigantian period, after the British inhabitants of this area. There is evidence for the presence of an Iron Age culture in the Pennines by the sixth century B.C. However, most of the Iron Age archaeological remains which have been found in the Nidd-Laver area exhibit La Tène influences and are therefore attributable to a somewhat later period. This is in accordance with the date for the opening of subzone E_1. Towards the end of the Iron Age the federation of tribes known as the Brigantes emerged in the northern and central Pennines. The traditional view of the Brigantes as nomadic pastoralists growing no crops is not supported by the evidence from the pollen diagrams. The presence of cereal type pollen in subzone E_1 suggests that cultivation was practised, though it must have had a subsidiary role in the economy. The quern fragments from Roomer Common, and the quern found in Blayshaw Gill (Fig. I.7) are significant in this context.

The end of the Brigantian kingdom was marked by the battle at Stanwick in A.D. 43. There is no evidence in the pollen diagrams for any cessation or decrease in intensity of agricultural activity following this defeat. This supports the view that the Roman occupation had little influence on the civilian life of the central Pennines (Hartley, 1967) and that the traditional Brigantian way of life continued. It is even possible that production of meat and grain was increased in the Nidd-Laver area in order to provide food for the slaves in the Greenhow Hill lead mines. Both archaeological and palynological evidence suggests continuity in rural life from the Iron Age and through Romano-British times, and this was probably sustained after the departure of the Roman legions. There is, however, documentary evidence that in the latter part of the Dark Ages the invasions of the Anglians and Danes disrupted the Brigantian way of life (vide supra Section I.iv.b).

The role of Fortress Dike Camp during the Brigantian period is uncertain. The pollen spectrum from the buried soil suggests that prior to the construction of the earthwork, heath was already replacing open woodland around this site. It is probable that this spread of heath was related to the extension of thin peat formation at Hambleton Hill at the opening of subzone E_1, as Fortress Dike Camp is only 2.2 kilometres from the Hambleton sites. It is unlikely that a site at this altitude, surrounded by heathland, was connected with arable agriculture. The enclosure was probably used for the safe keeping of animals perhaps during times of stress. The final period of use of the site in the seventh century came at the end of subzone E_1 (Appendix 4).

Subzone E_2 is marked by a decline in the Gramineae pollen values and in the values of some cultural indicators. This is accompanied by an increase in Ericaceae pollen at the sites high on the interfluve. However, at the Upper Skell Gill sites and at Fortress Dike the decrease in the Gramineae occurs in response to slightly increased arboreal pollen values. At Upper Skell Gill I and II tree pollen reaches about 26% of total pollen. The Alnus and Betula values do not fully recover their subzone D_5 levels and this suggests that during this regeneration phase only occasional trees managed to re-establish in the Skell valley. The Corylus values increase markedly to nearly 30% of total pollen. However, in the surface pollen survey high Corylus values frequently occurred in the absence of hazel bushes and therefore this rise in Corylus pollen at the Upper Skell Gill sites may merely reflect a regional increase in hazel during subzone E_2.

At Fortress Dike Camp the regeneration phase is far more marked and in subzone E_2 the tree pollen increases to 50% of total pollen; in the surface pollen survey values of this magnitude were associated with on-site woodland. The presence of Betula bark fragments at the base of the ditch peat is confirmation of this interpretation. Betula contributes the majority of the tree pollen in subzone E_2 at this site. It was suggested in Section III.iv. that Betula may be somewhat under-represented in the pollen rain on this upland, and therefore it seems probable that a fairly dense Betula stand grew at Fortress Dike Camp in this subzone.

The regeneration in the valleys and on the lower slopes is reflected in the pollen diagrams from the higher parts of the interfluve by a very slight increase in total arboreal pollen. The increase is chiefly in the pollen of Betula which, at Fountains Earth, rises from a mean of 6% of total pollen in subzone E_1 to a mean of 11% of total pollen in subzone E_2. It is significant that at certain favoured sites regeneration was able to take place in this period of reduced activity, even though heath was already established. The macro-remains in the ditch peat at Fortress Dike Camp give positive evidence of an upward movement in the limits of woodland during subzone E_2.

Deterioration in drainage appears to have continued during subzone E_2 and flush peats began accumulating in the valleys of Skell Gill and North Gill Beck. From the pollen assemblage in the basal peat at the Skell Gill Wood and Dallow Gill Wood sites it appears that the lower parts of the valleys were wooded at this time. Tree pollen values average over 30%

of total pollen at both sites; at North Gill Wood this consists principally of pollen of Betula, while at Skell Gill Wood the main contributor is Alnus. The wood and fruits of Betula are common in the basal peat at North Gill Wood. It is interesting to note that these tree pollen values are less than the mean for tree pollen obtained from the random surface pollen survey in North Gill Wood. This suggests that in subzone E_2 the gill woodlands had a more open canopy than at the present time.

The composition of the present day woodland is described in Section III.iii. They are dominated by Quercus petraea and this is reflected in the surface samples where on average Quercus forms 37% of total pollen. The minimum value for Quercus pollen in the woodland surface samples is 12.8%. The mean values of Quercus pollen in subzone E_2 is less than 5% of total pollen at North Gill Wood and less than 12% of total pollen at Skell Gill Wood. This implies that the role of Quercus was less important in subzone E_2 than it is at present.

The role of Corylus in the lowland woodland during subzone E_2 is difficult to assess. Corylus pollen forms over 20% of total pollen at Skell Gill Wood and over 30% of total pollen at North Gill Wood. In the random surface samples from North Gill Wood Corylus has a mean value of only 3.2% of total pollen and a maximum of 13.6%. It was concluded in Section III.v that in predominantly arboreal pollen spectra Corylus values of 20-30% of total pollen may be significant in terms of bushes growing close to the site. Corylus may have formed an understorey in the gill woodlands during subzone E_2. Betula/Corylus or Alnus/Corylus communities are typical of regeneration phases and it seems probable that the gill woodlands were cleared during the agricultural phase of subzone E_1 and that later regeneration took place.

The radiocarbon date of A.D. 630 has been proposed for the boundary between subzones E_1 and E_2 at Fortress Dike Camp. Subzone E_2 probably lasted for at least 300 years as the basal peat from the North Gill Wood site has been dated to A.D. 900 ± 90, and the boundary between zones E and F occurs about 20 cm above this level. There are Anglian and Norse names referring to woodland on the slopes of the interfluve near to Fortress Dike Camp (vide supra Section I.iv.b). The Anglian name "shaws" which occurs on Carle Moor between 260 and 320 metres must refer to the Betula woodland which regenerated in this area during subzone E_2. The Norse elements "with" and "carr" which occur in the same area suggest that this woodland was still in existence after the Norse invasion in A.D. 845. Therefore the heath vegetation which at present covers this area was established some time after this date.

The pollen analytical evidence suggests that the Anglian and Norse periods were ones of reduced pastoral activity, but the pollen of some taxa considered to be agricultural indicators is present throughout subzone E_2. The Anglians are known to have been agriculturalists but their settlements were mainly confined to the valley bottoms. The effects of the Anglian invasion on the native British inhabitants must have been severe. The pillage and slaughter recorded by Bede (vide supra Section I.iv.b) probably resulted in the abandonment of marginal upland pastures as the population was reduced. Thus Betula was able to regenerate.

IV.vi. Zone F

The pollen record for zone F is best illustrated by the diagrams from the flush peat deposits. The pollen record for this period in the topogenous and thin peats is extremely compressed and in some cases has been lost as a result of burning. From the available pollen record it seems clear that the interfluve was heath covered throughout zone F. At Fountains Earth, the thin peat sites, the Upper Skell Gill sites, and Fortress Dike Camp, the tree pollen curves decrease to very low values. Very high values of 70% and more are characteristic of the Ericaceae in this zone at the thin peat sites. It is clear that at the opening of zone F, the regenerated Betula scrub disappeared from the interfluve.

At the valley flush sites the opening of zone F is also marked by declining arboreal pollen values and at these sites there is a corresponding increase in the pollen of the Gramineae. Increases in the pollen of herbs associated with agriculture, including Plantago lanceolata, Rosaceae, Potentilla, and Rumex acetosella type occur at this level and a continuous record for the pollen of cereals and Cannabis/Humulus type is established. The pollen diagram from Hambleton Flush, high on the interfluve, is dominated by the pollen of Ericaceae contributed by the heath communities which were established around the site at this time. However, it is possible to differentiate subzone F_1 on the basis of a small peak in the Gramineae and the first appearance of Cannabis/Humulus type pollen. Subzone F_1 appears to represent a new phase of agricultural activity in this area which involved clearance of the valley woodlands. The high values of Plantago lanceolata and Rumex acetosella type pollen suggest that pastoralism was again the dominant form of land use, though on the flatter land in the main valleys crops were probably cultivated.

On the basis of the timescale established for the North Gill Wood diagram, the clearance of subzone F_1 is considered to date from the opening of the Monastic period in Nidderdale in the twelfth century. It is known from documentary sources that most of the uplands were used as spring pasture for sheep and summer pasture for cattle. It is possible that the valleys were also used for grazing and pannage. However, the reduction in the gill woodlands was probably primarily a response to the increased demand for firewood and charcoal as a result of the exploitation of local ores by the monks (vide supra Section I.iv.b). Cereals and flax were cultivated on some of the granges holding land in the lower Nidd valley.

It is interesting to note that the changes associated with subzone F_1 are less marked at the Skell Gill Wood site than at North Gill Wood. North Gill Wood, all of Dallowgill and the surrounding moors passed to Fountains Abbey in 1175, whereas Skell Gill and the moors to the south-west of the Skell remained part of the Archbishop of York's land and was let to smallholders (Fig. I.9). The apparent contrast in the intensity of this agricultural phase in the two valleys may reflect the difference between the organised use and exploitation of the land by the monastic community and a more haphazard use of resources by the smallholders.

In subzone F_2 there is a temporary recovery in arboreal pollen values to their E_2 levels. There is a decrease in the pollen of the Gramineae and of the herbs associated with agriculture. This suggests some regeneration of trees as a consequence of reduced agricultural activity. At Fortress Dike Camp a temporary increase in Betula pollen occurs in subzone F_2. The Betula woodland which grew on the slopes of Carle Moor during subzone E_2 may have been only partially cleared during subzone F_1 and expanded again during the phase of reduced pressure on the land in subzone F_2. There is no evidence for a corresponding regeneration at the Upper

Skell sites. At Hambleton Flush a very slight increase in the pollen frequencies of the arboreal species can be detected at the opening of subzone F_2, but at 71 cm there is a sudden pronounced peak in Alnus pollen which forms 35% of total pollen in a single sample. In view of the observations made on the erratic behaviour of Alnus values in surface samples, this peak has little significance in terms of an increase in Alnus trees growing close to the site, particularly as it is not sustained in adjacent samples.

A radiocarbon date of A.D. 1420 ± 80 has been obtained for peat from subzone F_2 at the North Gill Wood site. The standard deviation of 80 years which accompanied this figure places the date of the sample between A.D. 1340 and A.D. 1500. The reduction in population and consequent abandonment of land caused by the Black Death in the mid-fourteenth century have been described in Section I.iv.b. It seems probable that the regeneration phase of subzone F_2 can be attributed to this period.

At all the flush peat sites subzone F_3 opens with a renewed increase in the pollen of agricultural weeds and a reduction in the arboreal pollen frequencies to very low values. As with subzone F_1, this phase is more marked in the North Gill valley than at Skell Gill Wood. The pronounced peak in pollen of Rumex acetosella type at 92.5 cm at North Gill Wood can be correlated with similar peaks which occur in this subzone at Hambleton Hill, Hambleton Dike, Hambleton Flush and Fortress Dike Camp. At North Gill Wood the Rumex horizon has been radiocarbon dated to A.D. 1470 ± 80 and therefore its actual date lies between A.D. 1390 to A.D. 1550, a period associated with the main expansion of monastic activities in the Nidderdale area. The peak in Rumex acetosella type pollen has been recognised at all the pollen analysis sites which are on the land that once belonged to Fountains Abbey, with the exception of Fountains Earth, where the upper peat has been lost by erosion. The peak in Rumex is not present at the sites on or adjacent to the land which belonged to the Archbishop of York at this period.

In the surface sample survey high values for Rumex acetosella type pollen occurred where areas of grazed turf directly surrounded the sampling site. Rumex acetosella is a species typical of acid, sandy pastures (Salisbury, 1961). It thrives in areas which have been heavily grazed and it is also sometimes associated with over-manuring by animals. At the present time Rumex acetosella is regarded as a particular problem of old and poorly managed pasture. The Rumex horizon may represent deteriorating grazing conditions as a result of overstocking of upland pasture by the monastic granges. Rumex acetosella can also be widely observed at the present time colonising bare, eroding peat on the Nidd-Laver interfluve. It is therefore also possible that as a result of overstocking peat erosion was initiated on the north and east of the interfluve in medieval times. It is probable that the smallholders farming the Archbishop of York's land made less intensive use of the commons and therefore these effects were avoided.

In the thin peat diagrams the Rumex horizon is very close to the surface owing to the compressed nature of the peat. However, at the flush peat sites it is seen to lie in the middle of the agricultural phase of subzone F_3, at a point where the arboreal pollen percentages are at a minimum and when trees were obviously greatly reduced in the gills. A comparison of the records for woodland in the original charter of Fountains Abbey, with the survey of Abbey woodlands at the Dissolution quoted by Walbram (1863), reveals the extent to which lowland woodland must have been reduced in the 400 years of Fountains' power.

Agricultural indicators continue to be well represented above the Rumex horizon until the end of subzone F_3. The boundary between subzones F_3 and F_4 has been placed at the point where the arboreal pollen frequencies once again begin to rise. This phase can only be distinguished in the pollen diagrams from the woodland valley flushes and in the diagram from the soil profile in Skell Gill. The flush peat deposits are actively growing at the present time and the surface peat is poorly humified which suggests that subzone F_4 must represent the recent past. In the uppermost peat layers the arboreal pollen values are similar to those obtained from surface samples collected in the modern woodland. It seems likely that regeneration of trees in these valleys began at the time when farms on marginal land were being abandoned during the agricultural depression of the last century.

The upper peat layers from the sites high on the interfluve also exhibit features characteristic of recent changes in land use. The high charcoal content is a result of burning. This is a long established practice on the Nidd-Laver interfluve and medieval records mention the value of burning for the improvement of pasture. However, it is only since the last century that regular and systematic burning has been used to encourage the growth of new Calluna shoots, and much peat has been destroyed in the process. The extremely high values for pollen of the Ericaceae (principally Calluna) in these surface peat layers also reflects the management policies of the past 60 or 70 years. In Section II.iv. small increases in the pollen of Pinus, Fraxinus and Ulmus were noted in zone F in some diagrams. The planting of Pinus sylvestris in this area was first recorded by Smith and Rankin in 1903, this must have resulted in increased deposition of the pollen of this species. The increased frequencies for the pollen of

TABLE IV.I SUMMARY OF ZONE CHARACTERISTICS AND CORRELATIONS

AGE *	LOCAL ZONE	BRITISH POLLEN ZONE	INCEPTION OF PEAT GROWTH	ALTITUDE (metres)	CHARACTERISTICS OF ZONES	ECOLOGICAL INTERPRETATION
A.D. 1470 A.D. 1420	F_4 F_3 F_2 F_1	VIII	Hambleton Flush Skell Gill Wood (Peat)	366 229	Upland sites; second marked expansion Ericaceae and Gramineae. Valley sites: Decline arboreal pollen less than 10% total pollen recovery towards end of zone.	Upland heath used for pasture. Clearance of valley woods for pasture, followed by regeneration in F_4
A.D. 900 A.D. 650	E_2 E_1		North Gill Wood Fortress Dike Camp Hambleton Hill	267 259 381	Upland sites: Increase Gramineae and Cyperaceae pollen. N.A.P. greater than 60% total pollen. Valley sites: Peak in Gramineae followed by increase in tree pollen	Initial phase pastoral activity extension Gramineae on interfluve and reduction trees in valleys Regeneration trees in E_2
250 B.C.	D5 D4 D3 D2 D1	VIIb	Upper Skell Gill II Upper Skell Gill I Skell Moor I	290 290 320	Upland Sites: Abrupt rise Ericaceae pollen. Gradual decline arboreal pollen. Valley sites: Alnus and Corylus form 50% total pollen.	Recession of trees and spread of heath on interfluve. Valleys up to 290 metres still wooded. 2 phases pastoral activity D_2 & D_4
1930 B.C.	C		Skell Moor II	305	Decline Alnus pollen, rise Betula pollen, followed by rise Quercus pollen at Fountains Earth, N.A.P. less than 20% total pollen.	Decrease in Alnus at high altitudes and spread of Eriophorum on damp sites. Quercus established to 365 metres on dry sites.
3200 B.C.	B	Elm Decline VIIa	Hambleton Dike	366	Decline Pinus pollen rapid increase Alnus pollen to more than 50% total pollen. Increase Quercus pollen.	Expansion Alnus on to flushed sites. Expansion Quercus at expense Betula on flanks interfluve.
5000 B.C.	A	VIc	Fountains Earth Iron Well Hill	365 320	Corylus or Betula pollen dominant. Pinus and Ulmus pollen relatively high. N.A.P. less than 10% total pollen.	Stands Betula & Pinus understorey of Corylus

* Dates refer both to radiocarbon dates quoted in this thesis and correlations with other areas.

Fraxinus and *Ulmus* in the surface layers of peat may reflect the current popularity of these two species as hedgerow trees.

Table IV.i. summarises the characteristics and interpretation of the zonal sequence at all the sites which have been included in this study.

SECTION V CONCLUSIONS

V.i. Changes in woodland limits on the Nidderdale Moors: a summary

Prior to the Boreal/Atlantic transition around 5,500 B.C., the Nidd-Laver interfluve and the surrounding valleys supported a mixed forest of pine, hazel and birch. Soon after peat formation was initiated at Fountains Earth this was replaced by mixed oak forest. The oak forest was probably established first in the valley of the Nidd and on the Vale of York, but gradually extended on to the flanks of the upland. The birch appears to have remained co-dominant with the oak in some places at higher altitudes, and a birch consociation may have covered the summits of Hambleton and Kettlestang Hills. High altitude birch woods can still be found fringing oakwoodland in parts of the central Pennines (vide supra Section I.ii.e.). It has, however, been established from the pollen records at Fountains Earth that between 5,000 B.C. and 1,930 B.C. oaks extended at least to 365 metres on the interfluve.

During zone B tree cover was fairly complete over the whole of the interfluve; there is evidence for only occasional, small openings in the canopy. However, at the end of zone B a major reduction in *Alnus* appears to have taken place on the upland, and as the alder carr died back *Eriophorum* began to colonise the damp sites. Thus, during zone C, patches of open bog were established within the woodland. Man-made openings in the canopy have been distinguished in this zone but these were of limited extent.

At the opening of zone D, around the beginning of the second millennium B.C. the first major decline in the upland woodlands occurred. This appears to have begun on the highest land where heath was quickly established. In the next thousand years the limits of the woodland gradually retreated downslope and heath became widespread. There is clear evidence of two successive periods of farming activity on the interfluve during zone D.

These have been attributed to Bronze Age folk who grazed their animals on the open summits and also made clearances in the woodlands on the flanks.

Subzone E_1 has been associated with fairly intensive Iron Age and Romano-British activity starting in the third century B.C. During this phase heathland limits similar to those of the present day appear to have been established, and woodland must have become confined to the land below 260 metres. The recession in woodland limits was not, however, continuous. In the later part of the Dark Ages Betula scrub regenerated at favourable sites on the flanks of the interfluve, such as the natural ampitheatre in which Fortress Dike Camp lies. With the opening of the monastic period in the eleventh century A.D., renewed grazing pressure on the uplands prevented further regeneration and active clearance resulted in very considerable reductions in the gill woodlands and the lowland oak forest. This exploitation was temporarily halted when the population of the area was severely reduced by the Black Death in the mid-fourteenth century. The impact on the woodland was renewed in the fifteenth and sixteenth centuries as the demand for fuel for smelting grew. Only in the last 120 years, with the decline in the lead industry and in the numbers of farms, has there once again been an increase in trees in the gill woodlands. This same period has seen the creation of grouse moors on the old common grazing lands, and the adoption of a management policy to promote the growth of Calluna at the expense of other species.

V.ii. The vegetation history of the Nidderdale Moors in its regional context

It is now widely recognised that woodland once occupied almost the whole of upland Britain with the exception of the mountain peaks. Three major factors have been suggested to account for the decline in upland woodland.

First, climatic change since the Atlantic period. This has involved a general cooling, accompanied by increased precipitation effectiveness, particularly since about 600 B.C. These changes must have tended to suppress the more thermophilous species in the British flora, as conditions for flowering and seed production became less favourable. It was thought that the restriction of *Tilia* in the British Isles at the opening of the Sub-Atlantic period was primarily due to climatic deterioration (Godwin, 1956). However, more recently it has been suggested that the disappearance of *Tilia* can mainly be attributed to human activity (Turner, 1962). One of the fundamental effects of the increase in the ratio of precipitation to evaporation has been the waterlogging of upland soils and the extension of blanket peat at high altitudes in the Pennines (Conway, 1947).

The second major factor in upland woodland decline since the Atlantic period has been the over-exploitation of the environment by man and his animals. The combined effects of burning, overgrazing and consequent erosion have in some cases prevented the regeneration of trees after clearance. The third factor is the natural deterioration in the base-status of the soil which has been brought about by the continuous process of leaching. This has resulted in the creation of acid soils, the build-up of mor humus and the accumulation of peat, all of which discourage regeneration.

In pollen diagrams it is difficult to distinguish between climatic, edaphic and man-induced woodland decline; in most upland areas all three processes have operated individually and collectively towards the creation of the modern landscape. It is interesting, however, to note the regional variations which are becoming apparent, particularly with regard to the role of man in later post-glacial vegetation changes.

On the Nidd-Laver interfluve the changes in woodland composition at the zone A/B transition involve the extension of Alnus and Quercus at the expense of Pinus and Corylus. These changes follow the usual pattern observed at the Boreal/Atlantic transition at sites throughout the British Isles, and fit the accepted theory of a change towards a more oceanic climate between 5,000 and 6,000 B.C. (Conway, 1947). There is some evidence that during zones A and B Mesolithic people may have created small clearings in the upland oak/birch woods. The presence of occasional Plantago lanceolata pollen grains, the small peaks in the pollen of other weeds, and the occurrence of small charcoal fragments in the zone B peat at Fountains Earth support this view.

At the present time the pollen analytical evidence for woodland interference by Mesolithic man in this country is limited. Dimbleby (1962) has outlined evidence for woodland modification in Mesolithic times from sites on the North Yorkshire Moors and from some of the lowland heaths in the south-east of England. The Mesolithic population of the Pennines was probably limited in size, however, the very widespread occurrence of Sauveterrian chipping sites testifies to a protracted and regular occupation. The Sauveterrians were hunters and gatherers who preferred upland country; the lowland Mesolithic people, the Maglemosians, included fishing in their economy and appear to have congregated on rivers and lake sides (Clark and Piggott, 1965). It is interesting to note that in the pollen diagram from the classic Maglemosian site at Star Carr no significant inflexions occur in the tree pollen curves, even though there is evidence of trees having been felled (Clark, 1954). It appears that this encampment did not result in any permanent modification of the vegetation. However, Simmons (1969) has pointed out that the effects of the Sauveterrian hunters on the vegetation of the uplands could have been more far reaching. Simmons suggests that these people may have used fire to clear underwood and to confine game; in marginal areas these clearances may have been followed by soil and vegetation deterioration.

A. G. Smith (1970) has re-interpreted data from a number of sites in upland and lowland Britain and he concluded that the influence of Mesolithic man on vegetational change might be much greater than previously recognised. He postulated a causal connection between the initiation of blanket peat at some Pennine sites and the Sauveterrian microlithic industries. The present investigations throw little light on this hypothesis beyond providing some supporting evidence for man's activities in the Pennine woodlands prior to the Neolithic. No lasting effects on the vegetation of the Nidd-Laver interfluve can be attributed to Mesolithic activities.

The decline in _Alnus_ which characterises the end of zone C has been correlated with the spread of _Eriophorum_ over the site of the alder carr at Fountains Earth. At the same horizon at Hambleton Dike damp, monocotyledonous peat is overlain by a layer of dry peat formed chiefly from _Betula_ remains. Both these features suggest an improvement in drainage conditions on the interfluve, and this can only be attributed to a change towards a somewhat drier climate. This resulted in a reduction in the role of _Alnus_ as a coloniser of damp upland sites. The possibility of a dry Sub-Boreal period was originally suggested by Blytt (1876) and Sernander (1908), and this was later equated with Pollen Zone VIIb of the British System. However, in recent times there has been much dispute about the reality of the Blytt-Sernander climatic periods (West, 1968; R. T. Smith, 1972), and in the southern Pennines and the Humber area stratigraphic evidence suggests that the Sub-Boreal was wetter than the preceding Atlantic period (A. G. Smith, 1958). It seems that in the Nidd-Laver area a very localised climatic variation must have affected the distribution of Alnus at what was undoubtedly a marginal upland site. There is no reason to suspect that the decline in Alnus was due to selective felling as these trees occupied damp boggy sites which would probably have been unattractive to Neolithic man.

The small clearances in the Quercus/Betula woodland which have been identified in the pollen record for zone C have been atributed to the activities of the Neolithic cultivators. At both upland and lowland sites in the British Isles the effects of clearance by these early farmers have been observed in pollen diagrams. In the majority of cases the "landnam" clearances which accompany and follow the Ulmus decline are followed by the regeneration of secondary woodland. However, at some exposed upland sites above 400 metres in the central Lake District Neolithic clearances resulted in the permanent expansion of grassland and heath communities (Pennington, 1970). In the southern Pennines the picture of small temporary clearances followed by regeneration of the surrounding woodland (Hicks, 1971) is similar to that which has been established by this study for the Nidd-Laver interfluve.

The reasons for the expansion of heath and the initiation of thin peat formation at the opening of zone D appear to be complex. The C/D transition has been radiocarbon dated to 1930 ± 100 B.C. At the same period blanket peat had begun to form at upland sites in the Lake District engulfing high altitude birch woods (Pennington, 1969). Evidence from a number of upland sites in this area led Pennington (1970) to suggest that, in north-west England, this decline of high altitude woodland around the second millennium B.C. was primarily the result of soil degeneration consequent upon leaching.

The concept of a progressive natural deterioration in upland soils was first described in detail by Pearsall (1950). He claimed that the exposure of upland soils to continual leaching would inevitably result in a deterioration in base-status and hence a degeneration in the vegetation. Iversen (1964) illustrated this type of retrogressive succession with reference to pollen diagrams from the Draved Forest, Jutland. He showed that in the later part of the Atlantic period Tilia, Corylus, Alnus, Ulmus and Fraxinus receded for edaphic reasons from areas where they had formerly thrived. Iversen pointed out that in Sub-Boreal and Sub-Atlantic times this edaphic succession is usually masked by the effects of human interference which tend to act in the same way.

The Nidd-Laver interfluve is at a lower altitude than the sites discussed by Pennington; however, it is probable that even under oak forest the soils would tend to be acid because of the inherently low base-status of the parent material. During the mid post-glacial, leaching must have reduced the base-status further. The effects of soil deterioration would first have become critical on the summits of the interfluve where the soils were thinnest. In these areas mor must have gradually accumulated, preventing tree regeneration. Thus heath became established and the trees died back leaving their bark and wood remains preserved in the basal layers of the thin peat. A similar sequence of events has been outlined for northern Cardiganshire by Smith and Taylor (1969).

When the pollen spectra from zone D at the Fountains Earth site are considered in the light of the results from the surface pollen analyses the evidence is consistent with a progressive thinning of the woodland along the upper margins. This suggests a gradual dying back of trees rather than any sudden reduction in altitudinal limits, and tends to support the hypothesis that soil conditions had become unsuitable for the survival of trees at the highest altitudes.

Despite the evidence for soil deterioration as the primary cause of the initial expansion of heath on the Nidd-Laver interfluve, the influence of man cannot be discounted. The Neolithic pastoralists made clearings in the woodland during zone C and this disturbance may have accelerated the process of woodland decline, particularly in view of the poor soils. Pearsall (1934) stressed the role of grazing in preventing regeneration and therefore in causing reduction of upland woodland. However, with the exception of the Skell Moor I site, the initial increase in heath pollen at the C/D boundary is not accompanied by any rise in the pollen of "cultural indicator" species, and therefore does not appear to be linked directly with agricultural activity.

During zone D two phases of fairly widespread and intensive agricultural activity have been recognised and attributed to the Beaker folk and to the late Bronze Age inhabitants of the Ure/Swale lowlands. The marked clearance phases in the Upper Skell Gill I diagram indicate the substantial effect which they had on the upland woodland. It seems very probable that the extension of heath during zone D was favoured by this agricultural activity.

There is insufficient evidence to show any significant climatic change at around 2,000 B.C. to account for the initial recession in woodland. No marked changes in peat type occur at this level in the topogenous deposits, though at Fountains Earth there is a change in the humification of the peat which might suggest some increase in precipitation. However, it is possible that exposure may have been an important factor in woodland decline on the summits. This would be particularly important in a situation where conditions for tree growth were becoming critical due to soil deterioration. It has been shown in Section IV.iv that at sheltered sites such as Upper Skell Gill I, regeneration of trees followed the Bronze Age clearances of zone D, whereas on the summits of the interfluve the decline in woodland was progressive. This emphasises the importance of the exposure factor in limiting regeneration. Experimental work in Scotland by Pears (1967) has established that in places the present tree line is considerably lower than is theoretically possible, and that regeneration of tree seedlings beyond the woodland edge is prevented by the strong winds. Once the protective shelter of the mature trees along the woodland edge has been removed it becomes virtually impossible for any readvance to take place on an exposed hillside.

Thus the initiation of heath at the C/D boundary and its extension during zone D appears to have been due to a combination of exposure, edaphic and human factors. Similar changes were taking place 40 kilometres to the east on the North Yorkshire Moors at the same period. The initiation of heath on the central part of these moors, and on the Cleveland Hills, has been attributed to the activities of Bronze Age man (Dimbleby, 1952). There is also some evidence for even earlier alteration of the woodland by Mesolithic man (Dimbleby, 1962; Simmons, 1969). Comparisons between the causes of heath expansion on the Nidd-Laver interfluve and the North Yorkshire Moors are difficult, as despite the proximity of the two areas, the population of the North Yorkshire Moors in Bronze Age times appears to have been significantly greater than the population of the Nidd-Laver area. In the study area the Bronze Age archaeological remains are concentrated on the lowlands to the east of the interfluve. It was suggested in Section IV.iv. that the subzone D_2 and D_4 clearances were carried out by semi-nomadic pastoralists who were settled on the lowlands and who may have practised a form of transhumance using the uplands as summer pasture. Numerous Bronze Age tumuli have been identified on the North Yorkshire Moors suggesting a far more intensive exploitation of this upland. Consequently the influence of man was probably of greater significance for the spread of heath on the uplands of east Yorkshire than on the Nidderdale Moors.

On the southern Pennines the extension of heath during the Bronze Age appears to have been far less marked. Though woodland clearance has been attributed to the activities of the Food Vessel people at around 1,790 B.C. this appeared to result mainly in the extension of grassy communities (Hicks, 1971). The main expansion of Ericaceae pollen in this area is associated with the Iron Age and later times. Eyre (1966) has shown, with reference to a pollen diagram constructed by Bartley, that in the southern Pennines the extensive shallow peats which underlie many of the heather moors have accumulated very recently. Hicks (1971) placed their onset in the Dark Ages. It therefore appears that there is a fundamental age difference between these south Pennine shallow peats and the ancient thin peat formation which covers much of the Nidd-Laver interfluve.

In the Lake District, Pennington (1970) has attributed a permanent reduction in upland oak woodland, and its replacement by grassy communities to the Bronze Age people. This phase was dated to 1,080 B.C., and is therefore considerably later than the opening of zone D on the Nidd-Laver interfluve.

The further reduction in trees on the lower flanks of the Nidd-Laver interfluve during subzone E_1 can, without doubt, be attributed to the pronounced phase of Iron Age agricultural activity which has been recorded in all the pollen diagrams. At this time pressure of grazing effectively prevented regeneration on the interfluve and the woodland became restricted to the lowlands. The secondary nature of the woodland surrounding the North Gill Wood site at the time of peat initiation (vide supra Section IV.v) may indicate that some clearance took place even in the steep valleys. There is a notable difference between the initial expansion of heath at the C/D transition and the expansion associated with the Iron Age. The latter is accompanied by a marked rise in the pollen of the Gramineae, a feature which has been associated in this area with increased grazing pressure. This serves to emphasise the expansion in population which must have taken place since the Bronze Age. From Iron Age times onwards man's interference with regeneration has been the principal factor involved in woodland decline. This has to a large extent masked the influence of edaphic and climatic deterioration.

The influence of Iron Age people on the decline of upland woodland can be seen at a number of sites in different parts of Britain. On the west central Pennines (Bartley, 1964) and in Derbyshire (Hicks, 1971) intensive clearance culminating in extensive removal of forest started in the fifth century B.C.; somewhat earlier than in the Nidd-Laver area. Moore and Chater (1969) attributed extensive reduction and alteration in the woodland of west-central Wales to the Iron Age population. Marked clearance also seems to have taken place during this period in some of the valleys which dissect the North Yorkshire Moors (Miss M. Attherden, personal communication).

This intensive phase of activity on the uplands occurs at a time when the climate is known to have been deteriorating. In the bog stratigraphy at sites throughout the British Isles there is evidence of an acceleration of peat growth between 800 and 500 B.C. On the Nidd-Laver interfluve there is clear evidence for increasing precipitation in subzone E_1, both from the topogenous peat stratigraphy and from the increase in the pollen of the Cyperaceae and Liliaceae (*Narthecium* type). It may be significant that in the Lake District, where the increase in precipitation was probably more marked than on the eastern parts of the Pennines, no major Iron Age clearances have been identified in the uplands (Pennington, 1970).

In the Nidd-Laver area this phase of upland land use continued through Roman times and into the Dark Ages, supporting the theory of continuity of settlement in the Brigantian kingdom which has been proposed by Jones (1961). A similar phase of continuous settlement through Iron Age and Romano-British times has been identified by Turner and Roberts (1972) from sites in Weardale in the northern Pennines. This is in contrast to the area around Blackstone Edge in the west central Pennines where there is evidence of a decrease in agricultural activity just after the Roman invasion. This suggests suppression or a forced movement of the local population (Dr. D. D. Bartley, personal communication).

In the Lake District a very marked phase of human activity has been identified in the uplands starting towards the end of the second century A.D. and involving both pastoralism and cereal cultivation (Pennington, 1970). This corresponds with the latter part of subzone E_1 in the Nidd-Laver area and was probably contemporaneous with the later periods of use of Fortress Dike Camp. Pennington has attributed this phase to the British farmers; a number of native farmsteads have been identified in the Lake District and their occupation has been associated with this period (Dr. W. Tutin [Pennington], personal communication).

The effects of these farmers on the natural environment were markedly different in the Lake District and the east central Pennines. Permanent reduction in woodland and widespread soil erosion have been recorded in the Lake District (Pennington, 1970), whereas on the Nidd-Laver interfluve during subzone E_2 it has been established that birch scrub regenerated in some areas. This phase of regeneration has been correlated with the disturbed times of the Norse and Anglian invasions when grazing pressure on the uplands was probably reduced. It is extremely interesting that after such a long period during which tree regeneration was suppressed woodland limits were able to readvance in some places.

The regeneration is well illustrated by palynological and place-name evidence at Fortress Dike Camp on the eastern flank of the interfluve.

This site lies on the edge of a shallow natural ampitheatre with land rising to the north and west. It is possible that patches of deeper soil may have survived in this hollow until subzone E_2, and that these were suitable for regeneration of Betula, a tree which is undemanding in its soil requirements. The investigations at Fortress Dike Camp showed clearly that during subzone E_1 heath surrounded the site. However, there was only indirect evidence to suggest the existence of a buried mor layer (Appendix 4). A thin layer of raw humus probably would not have prevented Betula seedlings from establishing. The sheltered nature of the site and its southerly aspect must have provided a favourable environment for regeneration. Subzone E_2 coincided with a time when the climate was starting to improve slightly following the main Sub-Atlantic deterioration and this may also have helped the regeneration process.

The vegetation changes which have been noted in zone F have all been correlated with documented historical events. There are close parallels between woodland history on the Nidd-Laver interfluve during this period and in many other parts of the country. Evidence for the widespread penetration of sheep farmers into upland Britain has been demonstrated in pollen diagrams from Wales (Turner, 1964; Moore and Chater, 1969), the Lake District (Oldfield, 1963) and the northern Pennines (Turner and Roberts, 1972). It is interesting to note that in Weardale Turner and Roberts recorded evidence for woodland regeneration associated with the period of the Black Death, similar to the phase that has been described for Nidderdale.

Perhaps the one factor which has had the greatest influence on the maintenance of the modern heath is burning. Firing of the moors to improve grazing has been practised regularly since Medieval times. Burning is not only effective in preventing tree regeneration and encouraging new growth of Calluna, it is responsible in places for the removal of peat cover and the consequent emergence and erosion of the sub-peat soils. It has been suggested in Section IV.vi. that peat erosion was initiated on the Nidderdale Moors in Medieval times. Repeated burning has also resulted in the creation of an extremely acid, compact peat cover, with a high ash content. Should human pressure on the moors ever be reduced it is doubtful whether a spontaneous regeneration of trees such as occurred in the Dark Ages could now take place.

The productivity of the Nidd-Laver interfluve is at present maintained by very careful management, but the balance is precarious. Accidental, uncontrolled firing could result in the loss of the whole organic cover, and erosion would inevitably follow leading to the creation of a sterile landscape. From this study it seems probable that the reduction in woodland on the Nidderdale Moors was initially natural. However, man's activities have vastly accelerated this process, and in recent centuries management practices have deflected the succession and produced an inherently unstable environment.

APPENDIX 1

Field and laboratory techniques

(i) Collection of samples in the field

The material for the pollen profiles of the flush peats and the deep topogenous peat from Fountains Earth was obtained by boring. A Russian peat sampler of the type described by Jowsey (1966) was used. This sampler produces a minimum of compression and deformation in the peat, and is easily cleaned. Cores at successive depths were removed alternately from adjacent holes to avoid disturbance to the peat by the head of the borer and thereby contamination. The 50 cm cores were lifted from the chamber, placed in labelled plastic troughs ("Marley" guttering) and wrapped in polythene sheet for transportation to the laboratory.

At the thin peat sites and at Upper Skell Gill I monoliths were cut; these were wrapped in polythene sheet, labelled, and transported to the laboratory.

The mineral samples from the Skell Gill Wood soil pit, and from the buried horizons at Fortress Dike Camp were collected at measured intervals from a cleaned profile face. These samples were fastened into labelled polythene bags.

Moss polsters for the surface pollen analyses were collected from sampling points determined by random number tables or at predetermined intervals along transects, as described in Section II.ii.b. The polsters were enclosed in labelled polythene bags.

Four of the samples for radiocarbon dating were obtained from monoliths dug out of the peat. The wood which was dated from Upper Skell Gill I was removed directly from the peat face; this had first been cleared and cut back. The samples from the North Gill Wood site were obtained by boring.

(ii) Macroscopic analysis of peat

Peat samples about one centimetre deep were cut from the cores and monoliths. The sampling interval depended on the degree of humification of the peat. The samples were digested in concentrated nitric acid for two hours; this was then diluted with distilled water and the samples were left a further 24 hours. The fine material was then washed away using a 60 mesh copper sieve. The coarse fraction was retained and placed in a large white dish, and the macro-remains were then identified with the aid of a Wild M4A stereo-microscope.

(iii) Preparation of samples for pollen analysis

Peat samples of about one cubic centimetre were removed from the inner part of the core or monolith to avoid any risk of contamination. Samples were taken initially at wide intervals, the size of these being determined by the degree of humification of the peat. This was followed by closer sampling where necessary.

Removal of humic acids. The sample was placed in a small conical flask and covered with about 20 ml of 10% sodium hydroxide. It was heated gently for about an hour and stirred at intervals with a glass rod until completely broken down. The sample was then washed through 72 mesh nylon sieving cloth and the filtrate collected in a 50 ml centrifuge tube. This was then centrifuged, decanted and washed in distilled water. The washing was repeated until the supernatant was clear.

Removal of mineral material. (For soil samples and peat samples with a high mineral content). The sediment was transferred to a nickel crucible which was placed on a hot plate in a fume cupboard. The crucible was two-thirds filled with 40% hydrofluoric acid and boiled gently for a few minutes while the contents were stirred with a polythene spatula. The mixture was then poured into a polythene centrifuge tube containing 10 ml of 7% hydrochloric acid and centrifuged. The sediment was heated with 20 ml 7% hydrochloric acid in a boiling water bath. The sample was then centrifuged, the supernatant decanted and the sample washed with distilled water.

Removal of cellulose. The modified form of Erdtman's acetolysis, outlined by Faegri and Iversen (1964) was adopted, but after some initial experimentation it was decided that this treatment was unnecessary for the samples in this study.

Mounting. A few drops of 10% sodium hydroxide and safranin stain were added to the final distilled water wash. The supernatant was poured off and the centrifuge tube was inverted over filter paper and left to drain. Sufficient glycerine jelly, stained with safranin, was added to disperse the sediment. Two or more slides were prepared for each sample. A Wild M.20 microscope with magnifications of x 400 and x 1000 (oil immersion) was used for counting.

The above procedures are based on those described by R. T. Smith (1966) and West (1968).

Preparation of the moss polster surface samples was essentially similar to the method used for soil and peat samples. The whole polster was placed in a conical flask and immersed in 10% sodium hydroxide; this was heated gently for about half an hour and shaken frequently during this time. Sieving, washing and mounting was carried out as described above.

APPENDIX 2

Problems in the analysis of samples from thin, highly humified peats

In some of the samples the pollen grains were difficult to count due to the presence of a high proportion of charcoal in the thin peats from the interfluve. Tallis (1964) encountered a similar problem in the analysis of samples from southern Pennine blanket peats. No satisfactory method for the removal of charcoal was found. Charcoal absorbs safranin, and therefore in these samples considerably more stain than usual had to be applied to ensure correct staining of the pollen grains.

Counting was also difficult for peat samples rich in ferric iron. Certain profiles contained reddened peat, indicating that iron had been deposited from water seeping into the surface layer (vide supra Section I.ii.c.) In such cases a red-brown iron precipitate often obscured the pollen grains on the slide. In addition, the preservation of grains in these iron-rich peats was poor. It is possible that ferric iron could act as an oxygen donator for bacteria in the peat and therefore decomposition of pollen grains would be accelerated due to bacterial action (Dr. R. T. Smith, personal communication). In the laboratory a pollen-rich sediment was immersed in a solution of iron salts and left for a period of twelve weeks. After this time very little pollen was recovered. In some cases (particularly at the Iron Well Hill site) samples with a high iron content had to be discarded.

APPENDIX 3

The radiocarbon dates

The peat for radiocarbon dating was sliced from the cores or monoliths and the material from the outside of each sample was carefully removed to minimise contamination. The samples were dried in an oven at 60°C until they reached constant weight (about three days). They were then weighed, enclosed in double polythene bags and labelled. A minimum of 2 gm of carbon was required for the assay, and therefore to ensure adequate material over 20 gm of the sample was sent to the radiocarbon dating laboratory. In the case of the wood remains from Upper Skell Gill I, about 80 gm dry weight was sent. The assays were carried out by Professor K. Kigoshi at the Gakushuin University, Tokyo.

Code No.	Site	Age B.P. (years before 1950)
Ga k - 2932	Upper Skell Gill I. Wood	2290 ± 100
Ga k - 2933	Upper Skell Gill I. Base	3700 ± 110
Ga k - 2934	Skell Moor	3880 ± 100
Ga k - 3670	Hambleton Dike	2200 ± 80
Ga k - 3671	North Gill Wood. 90 cm	480 ± 80
Ga k - 3672	North Gill Wood. 140 cm	530 ± 80
Ga k - 3673	North Gill Wood. Base	1050 ± 90
Ga k - 3851	Fortress Dike Camp	1320 ± 90

The calculation of ages is based on the Libby half life of C^{14}, 5570 years. The ± errors quoted are the years corresponding to the standard deviation, calculated from the statistical errors in the beta rays counting.

These dates are quoted throughout this thesis as years B.C. or A.D., and have been converted without any corrections for variations in the

C^{14}/C^{12} ratio. Recent work by Suess (1970) has established a calibration for the radiocarbon time-scale using dendrochronologically dated wood samples from the bristlecone pine (Pinus aristata). This shows an increasing divergence between tree-ring dates and radiocarbon dates earlier than 2000 B.P. Conventional radiocarbon ages are calculated with the assumption that the C^{14} content of the atmospheric carbon dioxide has remained constant during Pleistocene and recent times. The bristlecone pine calibration curve has the effect of pushing back conventional radiocarbon dates earlier than 2000 B.P. by increasing amounts for progressively older samples. However, all the radiocarbon dates obtained by other workers and quoted in this thesis are in conventional radiocarbon years. Therefore the chronology established should be internally consistent. The correlations which have been drawn between some of the radiocarbon dates and documented events since the Roman period are valid; these fall within the period 0 - 2000 B.P. where the divergence between conventional radiocarbon dates and tree-ring dates is at a minimum.

The samples which have been dated from the Skell Moor II, Hambleton Dike and Fortress Dike Camp sites were obtained from between 30 and 40 cm below the present peat surface. Despite this there was no visible evidence of any penetration by modern roots into the samples and therefore the material was thought to be acceptable for dating purposes. It is interesting to note that Olsson (1972) has recently presented evidence to show that contamination by very small amounts of younger material has very little effect on the resultant radiocarbon date. If modern rootlets had penetrated any of the peat samples concerned the relative contamination would be very small compared with the bulk of the sample. Olsson suggests that where the age difference between contaminant and sample is in the region of 2800 years the error in dating for a 2% contamination is less than 100 years, though the errors become somewhat greater in older samples.

APPENDIX 4

Working Paper 24

ECOLOGICAL INVESTIGATIONS AT A BRITISH CAMP IN THE YORKSHIRE PENNINES

Heather M. Tinsley and Richard T. Smith

Department of Geography

University of Leeds

Working Paper 24

ECOLOGICAL INVESTIGATIONS AT A BRITISH CAMP IN THE YORKSHIRE PENNINES

Heather M. Tinsley and Richard T. Smith

Department of Geography,
University of Leeds.

September 1972.

Abstract

An earthwork of Romano-British affinity is described from the West Riding of Yorkshire. Pollen analyses have been carried out in order to identify vegetation and land use changes occurring both before and after construction of the earthwork. Soil analyses have permitted an explanation of stratification within the inner mound, of ancient buried soil characteristics and of subsequent soil evolution in the area. Treated together with the remaining structures a possible function for the site is discussed within the context of an upland area. Evidence so far assembled suggests that use of the earthwork continued until the Anglian Period.

This has been an exercise in the coordinated use of scientifically-derived information and some explanation appropriate to technique has therefore been included. Precise records for one site may appear trivial in themselves but the authors are of the opinion that the Dark Age data presented here should lead to a re-appraisal of the role of many similar upland sites and their impact on the evolution of vegetation cover and soils.

A preliminary report on this excavation was circulated in November 1971.

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ECOLOGICAL INVESTIGATIONS AT A BRITISH CAMP IN THE YORKSHIRE PENNINES

1. Introduction

Fortress Dike Camp is sited on the gently sloping eastern margins of Carle Moor, (S.E. 179732) at an altitude of 259 metres, 4.8 kms. west of the village of Laverton in the West Riding of Yorkshire. The site lies within heather moorland, at the side of a stream known as Fortress Dike, with the upward limit of improved pasture some 300 metres from the earthwork (Fig.1).

The investigations at this earthwork were undertaken as part of a project concerned with post-glacial vegetation and soil changes on the moors east of Nidderdale.* It was considered that an examination of this site and the analysis of soils and peat associated with it, might reveal information about its age, the nature of activities associated with its construction, and the course of vegetation and soil development in the immediate vicinity.

The earthwork is sub-rectangular enclosing an area of about three quarters of a hectare, or just over one and a half acres (Fig.2). It is surrounded on three sides by an inner and outer bank with an intervening ditch. The maximum height of the banks above the ditch level (in the south west corner) is 2.5 metres. The southern margin of the enclosure is markedly convex and where structures are still visible the corners are seen to be curved. On the fourth side no ditch is visible and only a slight break of slope testifies to the former existence of a bank. On the western margin there are two distinct breaks in the rampart; a stream passes through the larger of these and flows east, parallel with the northern rampart. This gap is also utilized by a track which crosses the enclosure and passes through the southern rampart at which point there is what appears to be an original entrance suggested by the inturned banks. Traces of a low mound 30 metres long can be detected within the enclosure parallel to the northern margin, and traces of a circular structure (conceivably a hut foundation) adjacent to the inner mound are visible in the north-east corner of the enclosure. Similar types of enclosure are not infrequent on the Pennines but little attention has been paid to their age and function. They have been generally supposed to be associated with agricultural activities (Wood, 1963).

* Mrs. Tinsley, one of the present investigators, is now at the Department of Geography, University of Keele.

2. Construction and stratigraphy

The inner bank, the ditch, and part of the outer bank were excavated along the line B - C in Fig.2. This revealed that the banks were formed from clay subsoil, almost certainly excavated from the ditch. At this section gritstone boulders, which are abundant on the moor, were aligned along the axis of the inner mound. A lens of upcast material (Fig.3) could be clearly recognised. It was 50 cms. deep at the axis of the mound and consisted of heavy clay with frequent lumps of ganister. This overlay a discontinuous, apparently truncated, grey horizon of leached sand with a maximum depth of about 15 cms. An isolated pocket of brown earthy material, 2 cms. thick, lay on top of this leached horizon near the centre of the mound. The grey sand was interpreted in the field as the buried eluvial horizon of an original shallow podzolic soil, on which the mound had been constructed. Below this a 15 cm. deep, rusty coloured, horizon of iron accumulation was evident, becoming grey (gleyed) in the vicinity of the ditch. There was a comparatively sharp junction between this horizon and the heavy clay subsoil, the latter contained grey and orange mottles, formed as a result of fluctuations in ground water level.

A thin layer of peat averaging 20 cms. in depth covered the surface of the mounds and the enclosure, while in the ditch, peat had accumulated to a depth of 37 cms. at the point of excavation. The mineral content increased towards the base of the ditch peat and a lens of clay separated off a lower peat horizon 5 cms. deep. This clay band formed the lateral continuation of a slope-wash deposit which mantled the side of the bank above the ditch.

3. Pollen Analysis

A monolith of peat was removed from the ditch infilling and taken to the laboratory for analysis. Consecutive 5 cm. samples of mineral material from the mound were collected for analysis along the line A - A[1] in Fig.3. The peat samples were prepared according to standard techniques by digesting in 10% sodium hydroxide, sieving, centrifuging and staining with safranin, (Faegri and Iversen, 1964; Smith, 1966). Samples of soil were boiled in hydrofluoric acid to dissolve mineral particles. Five-hundred grains of all pollen types excluding spores were counted for each sample except for certain of the soil horizons where pollen was very scarce, but no counts are based on less than 300 grains. The results are presented in Figures 4 and 5

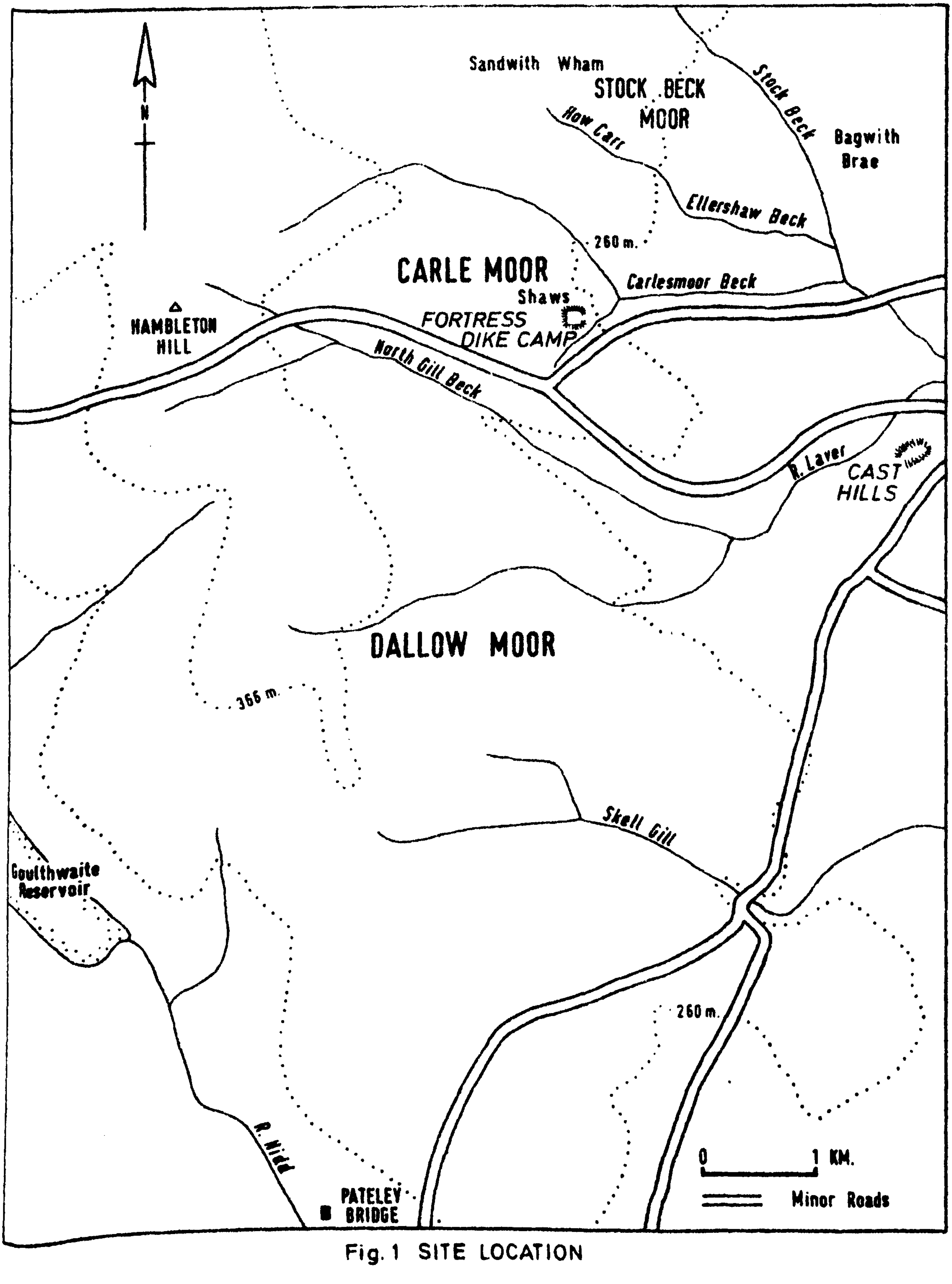

Fig. 1 SITE LOCATION

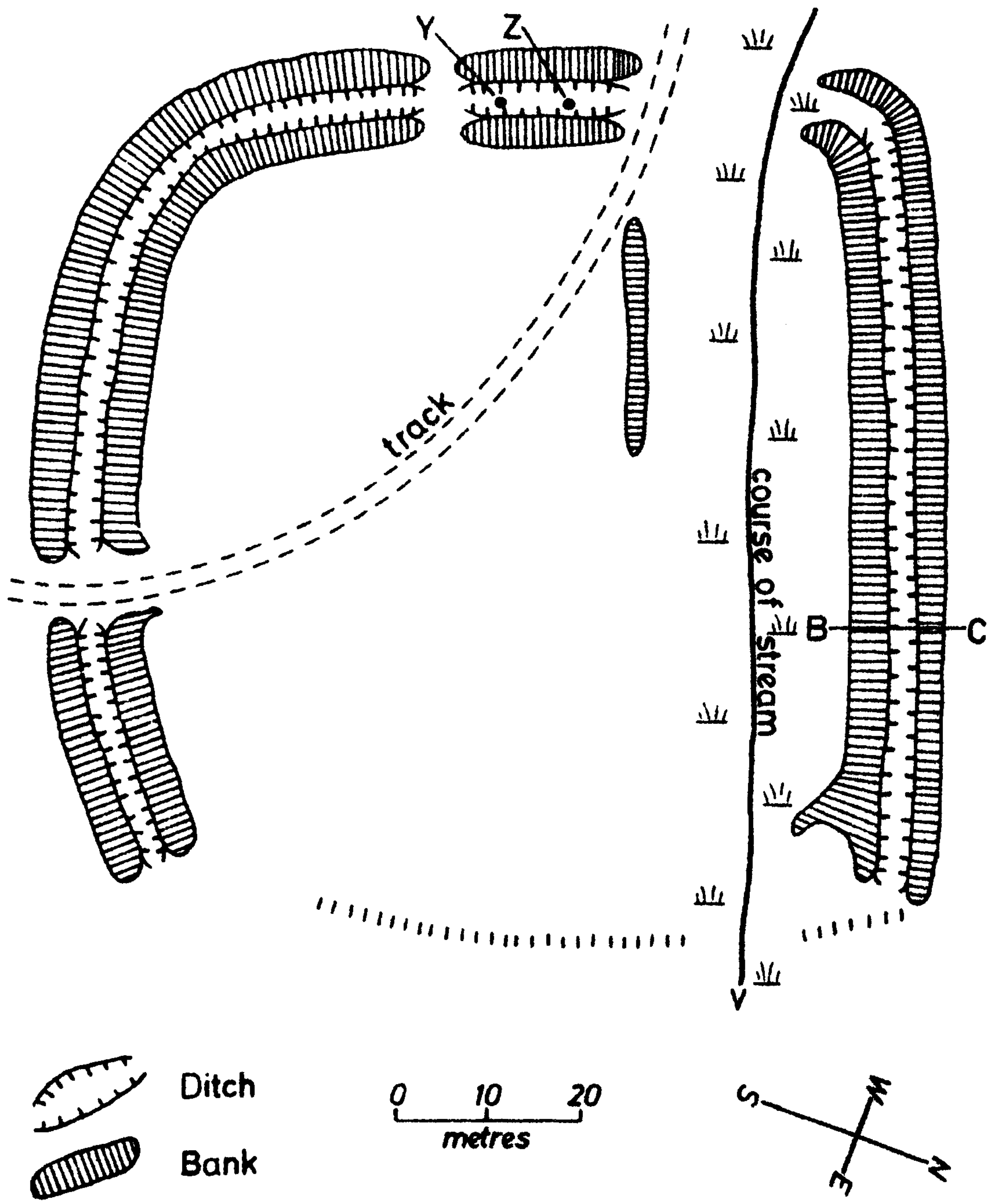

Fig. 2 PLAN OF EARTHWORK

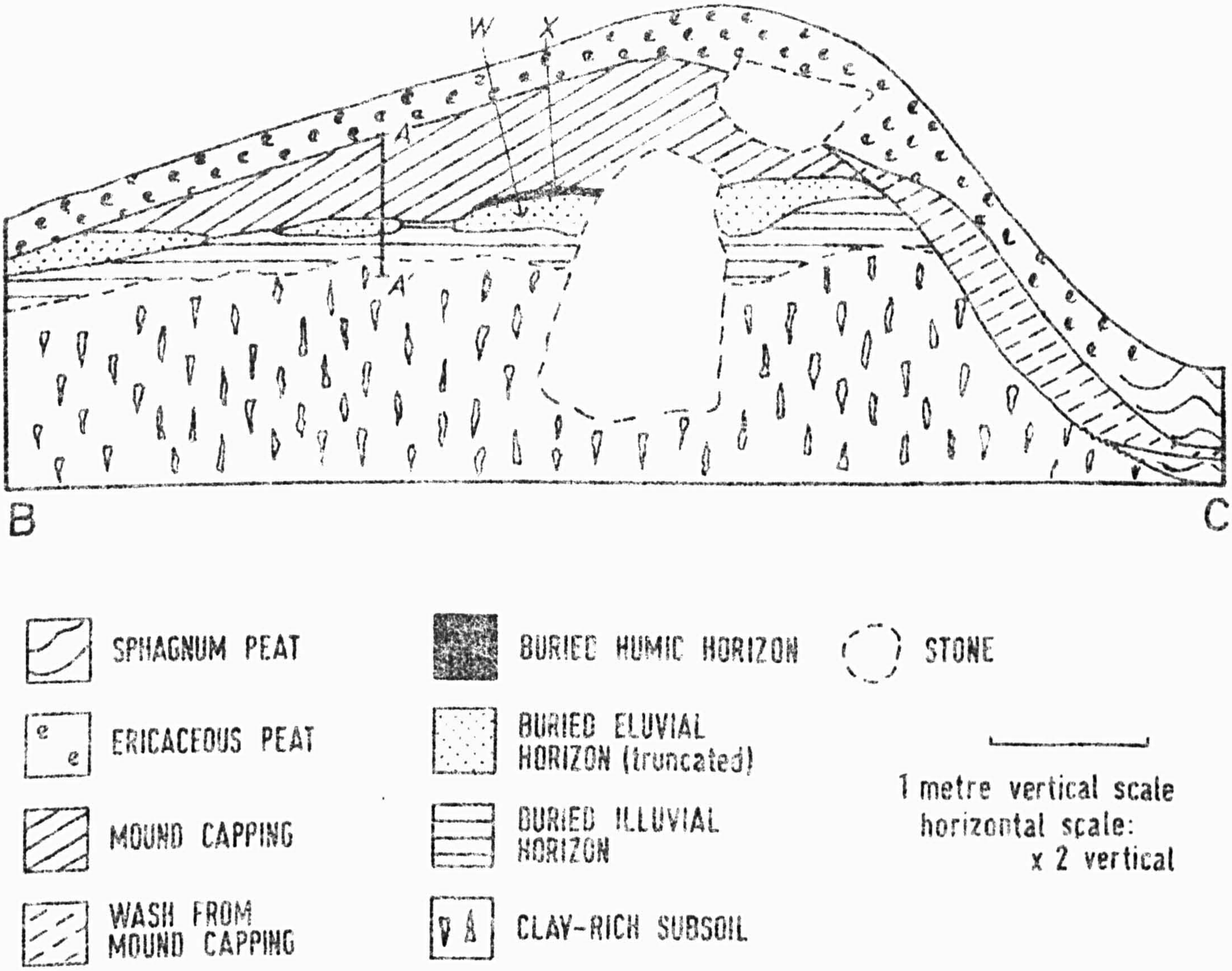

Fig. 3 EXCAVATED SECTION ALONG B-C

For correlative purposes two mineral samples were analysed from points W and X in Fig.3. An organic lens, identified beneath a clay horizon at the base of the ditch monolith, was exposed at two other sites on the earthwork margin, (Y and Z, Fig.2) and material from these exposures was also analysed. The results of these analyses are shown in Table 1, which includes, for comparison, data from selected horizons of the pollen diagrams.

Interpretation of the pollen records

In the pollen diagram for the soil section (Fig.4) the pollen spectra of the three samples between 55 and 40 cms. (the rusty and bleached layers), suggest a partially cleared woodland environment. Alnus (alder) and Betula (birch) are present, Corylus (hazel) is important and the Gramineae (grasses) are well represented. The relatively high pollen percentages of Plantago lanceolata (ribwort plantain) and certain other weeds including the Caryophyllaceae (stitchwort) Succisa (scabious) type and Ranunculus (buttercup) suggest human interference in this woodland. A high percentage of fern spores in these lower horizons is probably not ecologically significant and may reflect preferential decay of other pollen types (e.g. Pennington, 1965; Smith, 1970). The samples of partially bleached material from 30 - 40 cms. show a reduction in arboreal pollen to negligible amounts; pollen of the Ericaceae (heaths) increases dramatically and Plantago lanceolata is well represented. No pollen was recovered from the lower part of the horizon interpreted as mound capping (Fig.3) and therefore there is a break in the pollen record above 30 cms. The top 15 cms. of the mound capping have a uniform pollen spectrum with large quantities of Betula pollen, Corylus and the Gramineae are also well represented. This suggests a birch woodland with an open canopy. The pollen of Plantago lanceolata and other weeds is reduced in comparison with the lower horizons, but pollen of the Ericaceae increases in importance in the top sample.

The pollen diagram for the ditch monolith is illustrated in Fig.5. The spectrum from the basal peat lens indicates an open environment, the pollen of the Gramineae and the Ericaceae are important, with arboreal pollen less than 10% of the total. Plantago lanceolata is well represented and the pollen of other weeds such as Taraxacum (dandelion), Ranunculus and the Rubiaceae (bedstraw) also occurs. This horizon, which also contains cereal pollen, has been radiocarbon dated to 630 ± 90 A.D.

A clay horizon separates the basal peat lens from the main peat accummulation above. In this clay and the overlying peat, arboreal pollen increases, and at 36 cm. Betula pollen reaches a maximum of 50%

total pollen and fragments of birch bark and wood are present. Corylus is also well represented and grains of Ilex aquifolium (holly) are common. The pollen of the Gramineae and Ericaceae is reduced and the weed component becomes insignificant. At 32 cms., Betula and Corylus pollen begins to decline and that of the Ericaceae increases dramatically. From 25 cms. to the surface of the peat, arboreal pollen remains below 12% of total pollen and the Ericaceae maintain their importance. In the upper horizons spores of Pteridium aquilinum (bracken) occur in large numbers.

4. Soil Analysis

A continuous vertical series of samples was collected from the mound section along A - A^1. These were oven-dried, crushed and then ignited in a furnace at 450°C, the results being displayed in Fig.6. Larger samples were extracted from the four distinct horizons in the mound together with two from material which appeared to have been washed from the original mound. These six samples were subjected to a particle size determination by a combined pipette and dry sieving method (Piper, 1947). Oven-dried samples were lightly crushed and passed through a 2mm sieve. 50g portions were treated with hydrogen peroxide and then dispersed with sodium hexametaphosphate before starting the sedimentation. The results are presented in Figures 7 and 8.

Interpretation of soil data

In cases where soil is affected by gleying or organic staining - especially when such features affect limited portions of soil profiles - it becomes hazardous to estimate the genetic soil type from field inspection alone. Furthermore buried soil materials should not necessarily be expected to remain in their pristine state for many centuries save under the most favourable circumstances. With this in mind the ignition sequence shows that the buried bleached (and somewhat gleyed) layer was almost certainly the eluvial horizon of a podzol. The fact that subsequent podzolization of mound capping is barely perceptible may be a function of time, yet could be dependent on the previous enrichment of this material in iron oxides and clay.

It seems likely that the near absence of raw humus above the buried podzol, together with obvious truncation of this soil, indicates some disturbance of the old ground surface prior to mound construction. This could easily have been associated with the location of heavy boulders. In view of the water-table height beneath the mound it is thought that the former was raised through mound construction and has now caused excessive iron-enrichment of the buried illuvial horizon.

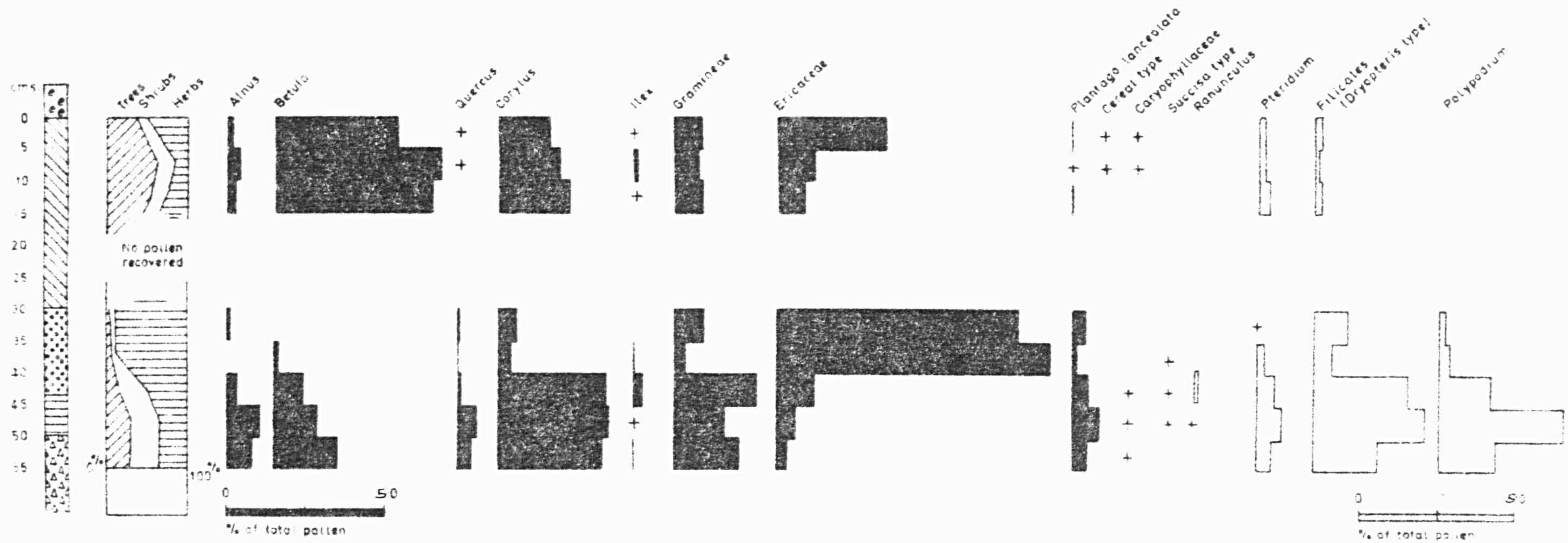

Fig. 4 POLLEN RECORDS FROM THE MOUND

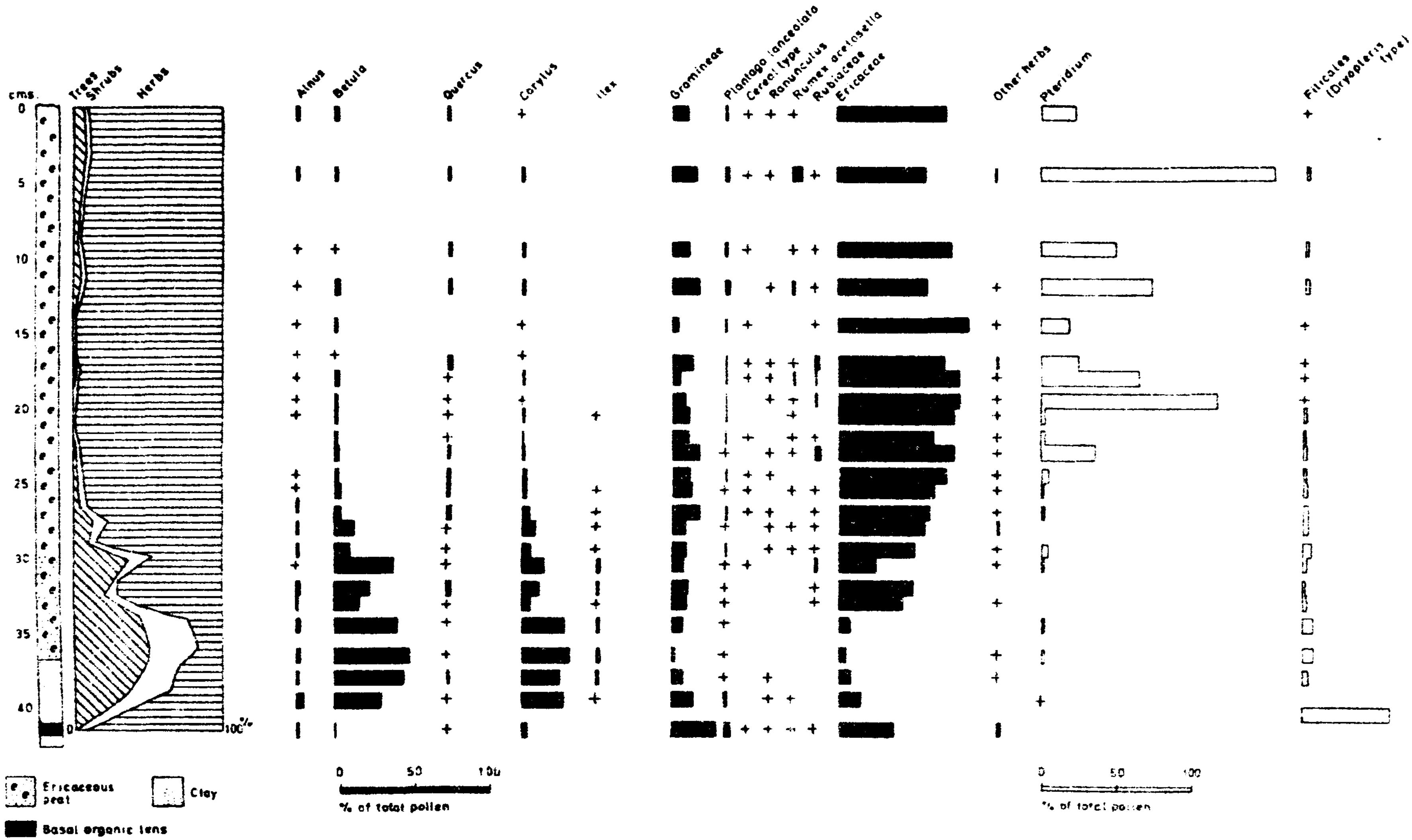

Fig. 5 POLLEN RECORDS FROM THE DITCH

TABLE 1 CORRELATIVE POLLEN RECORDS FROM ISOLATED SAMPLES

	BLEACHED HORIZON W	SOIL 40-45 cm	BURIED HUMUS X	SOIL 30-35 cm	BASAL PEAT LENS Y	Z	MONOLITH
Alnus	6.3	3.2	+	1.8	1.6	3.1	3.6
Betula	9.0	9.6	6.2	4.3	4.2	10.3	1.8
Quercus	3.6	1.9	+	+	2.2	2.0	+
Corylus	26.5	33.2	9.2	1.0	8.0	6.8	5.2
Ilex	1.0	2.5			+	+	
Gramineae	28.4	26.5	5.3	3.3	46.6	45.1	42.6
Ericaceae	2.7	11.5	73.7	85.9	19.0	15.8	37.8
Plantago lanceolata	5.6	5.4	+	1.8	5.4	4.6	2.4
Taraxacum type				+	2.4	1.8	1.2
Rumex acetosella type					+	1.3	+
Rubiaceae					1.6		+
Ranunculus	+	4.1	+		1.4	1.0	+
Caryophyllaceae	+	+	+			+	+
Succisa		+		+	+		
Cereal type					3.0	+	+
Filicales Dryopteris type	26.2	31.9	1.0	6.0	4.6	7.6	60.6
Polypodium	11.3	16.9	+	3.9	+	+	+

Data are percentages of total pollen with + representing values less than 1%

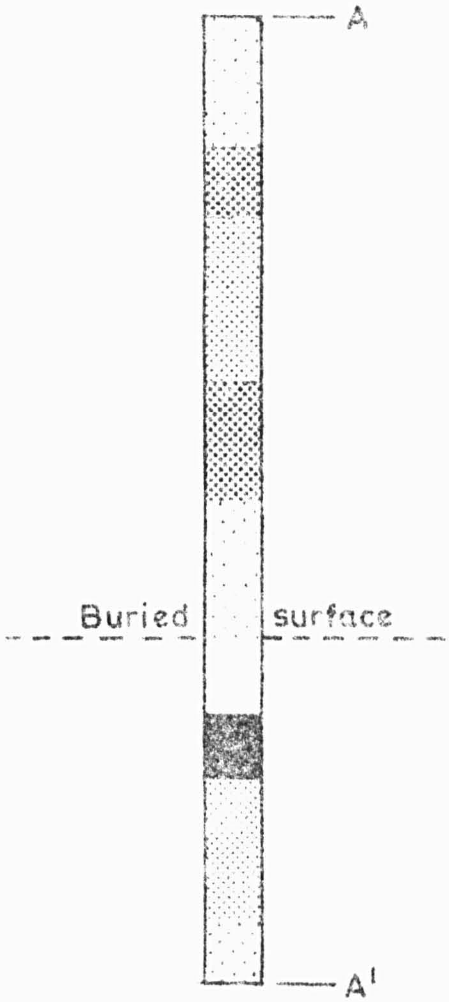

Fig. 6 IGNITED SOIL SEQUENCE A–A'

In Figure 7, curve 1 represents mound capping and curve 4 the clay subsoil, while curves 2 and 3 represent respectively the buried eluvial and iron-rich illuvial horizons. The almost identical paths followed by the former support the initial assumption that the capping comprises subsoil from the vicinity of the present ditch. In addition, curves 2, 3 and 4 form a pedogenic gradient illustrating the former movement of clay from the eluvial horizon. In the absence of an obvious buried humus layer this evidence reinforces the case for the buried soil beyond doubt. Furthermore, when the sample from the eluvial horizon was ignited the loss in weight was considerably greater than for the adjacent layers. When treated with peroxide, sulphurous gases were evolved indicating a concentration of sulphides in the sample. Although fragmentation of the buried eluvial horizon suggests interference, it is equally clear that anaerobic decomposition of an original humus could have led to the observed presence of sulphides.

Curves 5 and 6 (in Figure 8) are somewhat similar, both representing a coarser over-all texture than the mound capping. While undoubtedly derived from the mound it is likely that the clay component has more readily washed into the ditch. Curve 4 material is 0.5m nearer the ditch axis, but while it has a slightly higher clay content it is unfortunately not clear whether this is a depositional feature or developed through gleying. In view of the limits of accuracy of the technique, such small variation must be regarded as barely significant. The relatively smooth form of the latter two curves is similar to those which have previously been interpreted by Cornwall (1953, 1958) as evidence of mixing, characteristic of flood loams and wash deposits. Complete smoothing would be the exception, and in this instance the local Millstone Grit provides a high proportion of medium sand grade as shown by the inflection on the cumulative curve.

5. Discussion

The earliest pollen record, in the lower horizons of the buried soil, indicates partially cleared woodland (Fig.4 and sample W, Table 1). At this stage, before the earthwork was built, it appears that the surrounding area was already being used by man. High percentages of weed pollen, particularly of Plantago lanceolata, suggest pastoral activity. However the pollen of cereals and other indicators of cultivation are absent.

Today, podzolic soils in the immediate vicinity of the earthwork have eluvial horizons which are on average 30 cm. deep. It appears that up to the time when the earthwork was built a shallow podzol had evolved, with an eluvial horizon about 15 cm. deep. The pocket of dark earthy material from which sample X was extracted, appears to be all that remains of the buried surface layer of raw humus normally associated with podzols. The pollen record from this sample is similar to that in the sample from 40 - 30 cms. in the soil section and is significantly dominated by the Ericaceae. The change from open woodland to heath implies a deterioration in the edaphic environment which could be attributable to man's activities as pastoralist. Similar sequences of change have been observed at archaeological sites in the North York Moors where Bronze Age activities appear to have been responsible (Dimbleby, 1962). It was after the initial expansion of this heath that the earthwork was constructed, presumably during a period of increased pressure on land. The form of the earthwork with its inner and outer banks, its sub-rectangular shape and surviving inturned entrance suggests its construction during the late Iron Age or Romano-British period (Hartley, 1972 - private communication). An Iron Age date has been postulated for an enclosure similar to Fortress Dike Camp, on Roomer Common near the river Ure (G.R. SE 22527883), eight kilometres north-east of this site (Ordnance Survey Index, 1962). Defensive structures at Cast Hills, Laverton, three kilometres from Fortress Dike Camp are also thought to have Iron Age affinities (Ordnance Survey Index, 1963 - and see Fig.1).

The pollen spectrum from the basal organic lens in the ditch (Samples Y and Z, and the basal monolith sample) postdates the construction of the earthwork. The spectrum is characterised by high frequencies of the pollen of Plantago lanceolata and other weeds generally regarded as indicators of pastoral land use. The reduced pollen values for the Ericaceae, high Gramineae values and the occurrence of charcoal fragments in these samples may indicate that periodic efforts were made to control the heath by setting it on fire. Furthermore, the presence of cereal pollen indicates that there was certainly cultivation nearby. Cereals, with the exception of rye, are self-pollinated and liberate only small quantities of pollen so that 3% cereal pollen in sample Y should be regarded as highly significant.

The basal organic lens is very thin and the record for this agricultural phase finishes abruptly at the level where the peat lens is overlain by clay. The date of 630 AD. for the agricultural phase probably then indicates the most recent period of intensive use of the site. It is conceivable that deposits associated with earlier occupations were destroyed by periodic clearing out of the ditches and it is indeed remarkable that evidence for this is lacking.

The isolated position of the earthwork and the lack of any obvious hut structures or artifacts suggest that it could have functioned as an animal

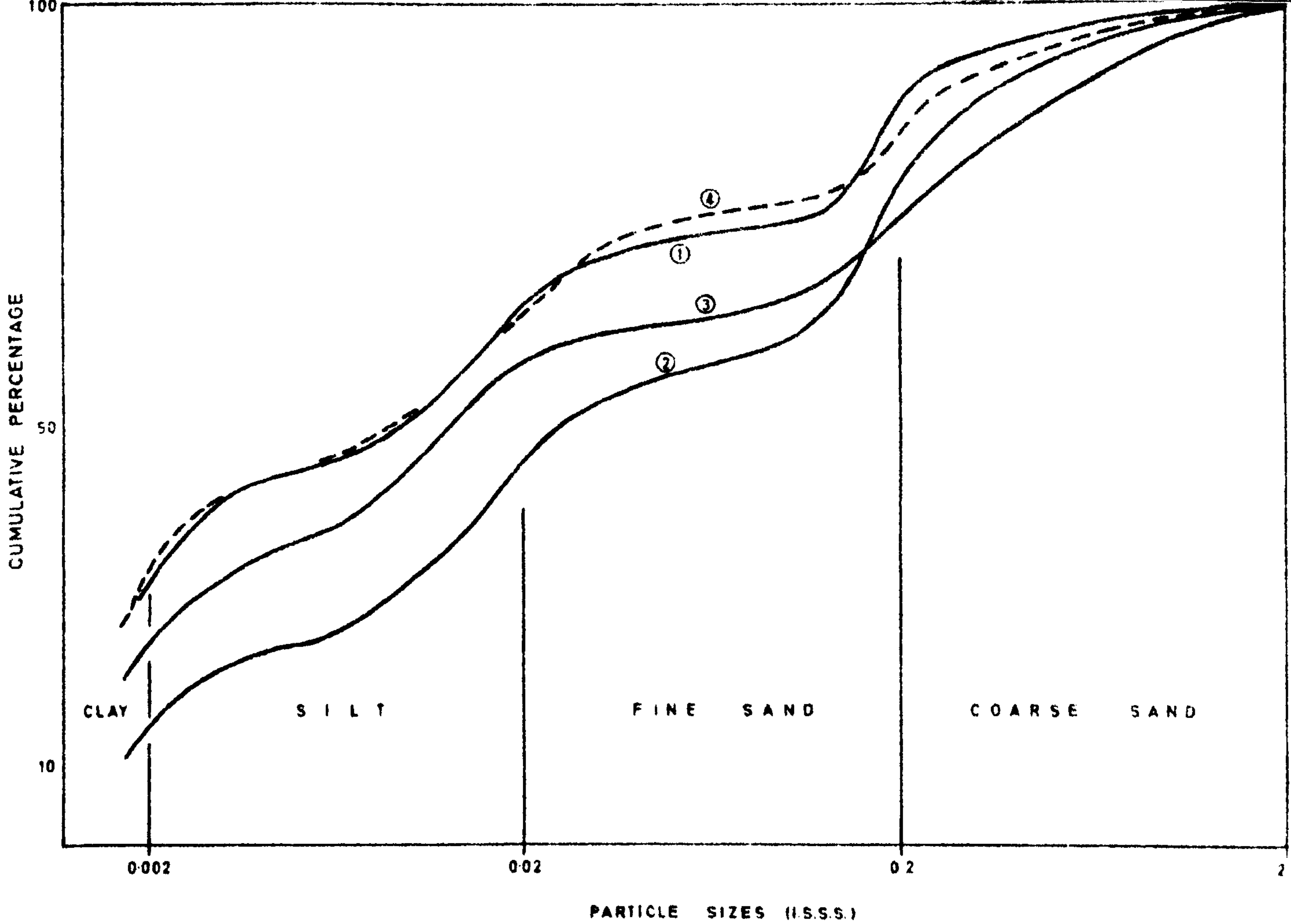

Fig. 7 MECHANICAL ANALYSES FROM THE MOUND

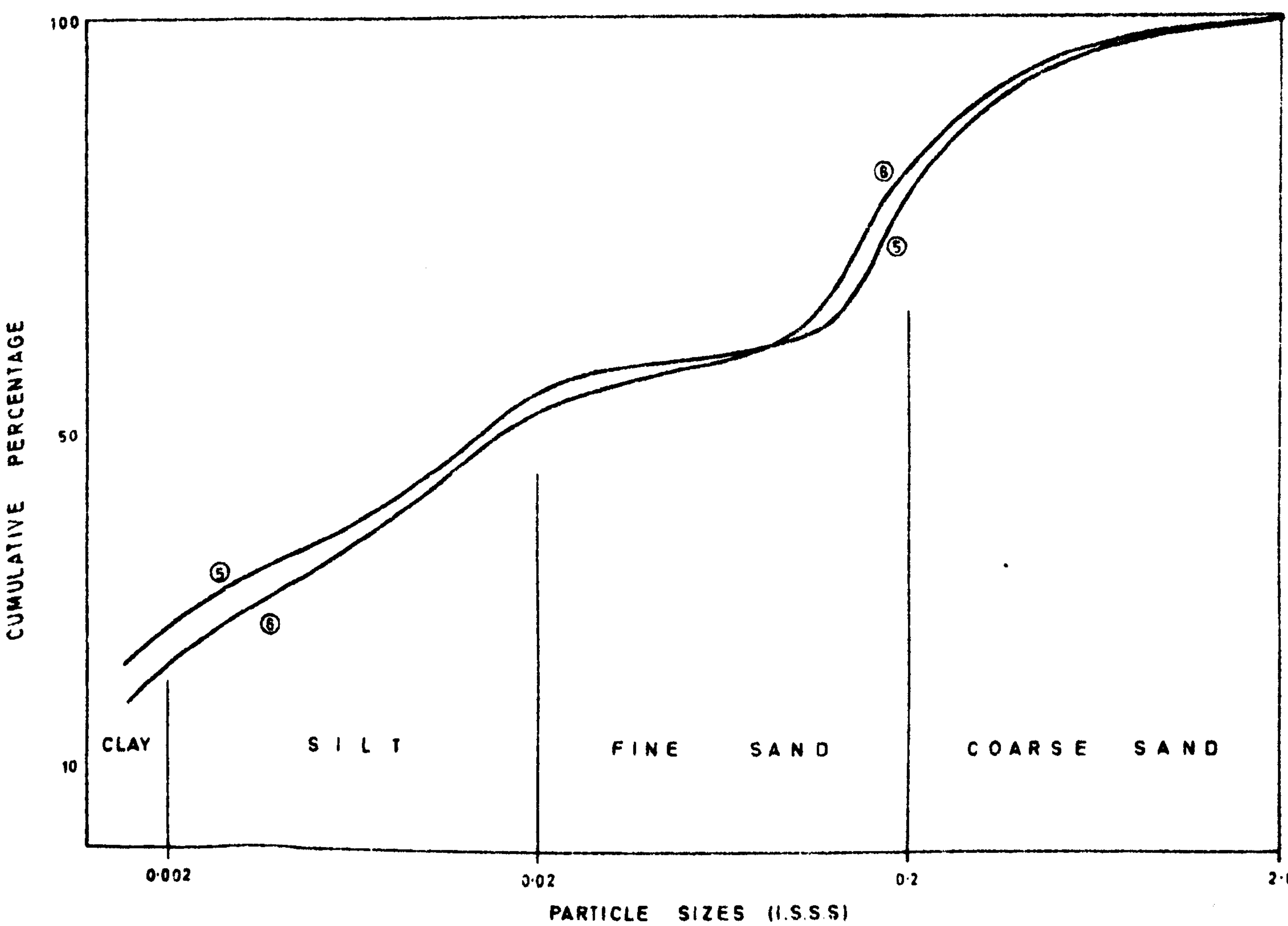

Fig. 8 MECHANICAL ANALYSES OF WASHED MATERIAL

pound, although it is fair to say that timber or turf huts could effectively disappear after more than a thousand years! The stream which passes through the enclosure (Fig.2) and which appears from field examination to have existed before the earthwork's construction may conceivably have played a role in relation to the animal hypothesis. If this interpretation is sustained, the enclosure may have been used for the protection of stock during times of stress from the late Iron Age until the seventh century A.D. The termination of the most recent phase around A.D. 630 happens to correspond to the period of the Anglian invasion of Yorkshire, which must have resulted in considerable disruption to rural life. According to Jones (1961), Bede described how in A.D. 603 Ethelfrid of Northumbria "overran a greater area than any other Kings or chiefs, exterminating or enslaving the (British) inhabitants, extorting tribute and annexing their lands for the English".

The pollen assemblage in the clay and peat which overlies the organic lens indicates that regeneration of birch woodland took place around Fortress Dike Camp following its presumed abandonment. The pollen of Plantago lanceolata and other weeds is greatly reduced in this phase and the cereal record ceases. This regeneration of woodland is unusual as it represents a temporary reversal of the trend towards reduction of trees and establishment of heath. This may perhaps be a function of the marginal-upland location of this archeological site, as at all other sites studied on these moors the initial expansion of heath is observed to continue practically unchecked to the present.

It is interesting to note that this woodland regeneration on Carle Moor and surrounding areas is reflected by some Anglian and Norse place-names. The Anglian name 'Shaws', a woodland, occurs on Carle Moor between 260 and 320 metres elevation. The same element suggests that trees once grew in Ellershaw Gill, draining Stock Beck moor and lying to the north of Carle Moor. The element 'stock', a stump, is indicative of woodland clearance during Anglian times. On the same stretch of moorland the Norse element 'with', a wood, occurs in Sandwith Wham and Bagwith Brae; the Norse element 'carr', wet land overgrown with brushwood, also occurs on Stock Beck moor at How Carr.

The pollen record from the ditch peat suggests that at some time following the Norse and Anglian period heath was re-established around the site of Fortress Dike Camp and a thin, highly humified peat cover began to develop over all the structures.

6. Conclusions

The earthwork described in this paper appears to date from the Iron Age or Romano-British period but was utilised sporadically into the Dark Ages. The variation in intensity of land use around Fortress Dike Camp had important effects on the surrounding vegetation. In addition, differentiation of soil horizons has certainly intensified with time leading to clay accumulation at depth and perhaps to enhanced surface peat development even though the surrounding land may at one time have been desirable for arable farming. It is clear however, that the abandonment of the site and the final establishment of heath were separated by a distinctive interval of time.

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Appendix 5

Pollen Sample Sizes

Fountains Earth

. Depth cm.	.Sample size.	Depth cm	.Sample size	Depth cm	Sample size.
0	504	145	500	285	500
5	785	150	504	290	502
10	656	155	607	295	507
15	585	160	510	300	509
20	1014	165	507	302.5	505
25	1075	170	500	305	501
30	641	175	507	307.5	518
35	751	180	499	310	508
40	664	185	559	315	792
45	528	190	564	320	499
50	517	192.5	560	325	501
55	921	195	504	330	514
60	854	197.5	500	335	503
62.5	505	200	555	337.5	500
65	1001	202.5	521	340	509
67.5	507	205	511	342.5	523
70	506	210	501	345	525
72.5	556	215	236	347.5	311
75	827	217.5	500	350	500
77.5	510	220	500	352.5	504
80	1182	222.5	504	355	500
85	503	225	173	360	540
90	964	230	512	365	539
95	700	235	567	370	526
100	525	240	500	375	509
105	513	245	500	380	560
110	520	250	509	385	500
112.5	500	252.5	505	390	575
115	522	255	554	395	527
117.5	514	257.5	525	400	503
120	500	260	584	405	500
122.5	511	262.5	522	408	500
125	671	265	539	410	500
127.5	526	267.5	510	413	500
130	217	270	521	420	500
135	562	275	501		
140	501	280	513		

Iron Well Hill

Depth cm	Sample size
8	412
28	492
38	564
58	322
73	356
103	372
118	498
138	412

Skell Moor I

Depth cm	Sample size
0	500
2.5	502
5	565
7.5	503
10	501
12.5	500
15	505
17.5	521
20	507
22.5	408
25	405
27.5	500
30	463

Skell Moor II

Depth cm	Sample size
1	1046
2	1002
3	1029
4	1692
5	1127
6	1159
7	1093
8	1094
9	1221
10	1315
11	1336
12	1446
13	1586
14	1717
15	1250
16	1375
17	1699
18	1982
19	700
20	782
21	784

Hambleton Hill

Depth cm	Sample size
1	1844
2	2213
3	2662
4	2486
5	3218
6	2333
7	3748
8	1500
9	1546
10	2389
11	1591
12	1761
13	3040
14	1359
15	500
16	571
18	705
19	297
20	626
21	250

Hambleton Dike

Depth cm	Sample size	Depth cm	Sample size
2	1147	42	545
4.5	1030	44.5	544
7	1032	47	523
9.5	1782	48.5	522
12	909	49.5	500
14.5	1071	51	504
17	839	52	509
18.5	500	53.5	500
19.5	500	54.5	540
21	528	56	500
22	501	57	506
24.5	532	58.5	521
27	608	59.5	514
28.5	506	61	500
29.5	523	62	632
31	500	64.5	520
32	537	67	506
33.5	500	69.5	569
34.5	563	72	529
36	512	74.5	574
37	529	77	514
39.5	512		

Upper Skell Gill I

Depth cm	Sample size
0	500
5	500
10	530
15	500
20	500
25	530
30	500
35	500
40	520
45	510
50	500
55	500
60	500
65	530
70	510
75	500
80	500
85	500
90	524
95	510
100	500
105	510
110	500
115	500
120	510
125	500
130	517
135	500
138	521
140	500

Upper Skell Gill II

Depth cm	Sample size
2.5	406
5	458
7.5	455
10	510
12.5	464
15	508
17.5	500
20	565
22.5	416
25	504
27.5	566
30	575
32.5	502
35	579
37.5	596
40	504
42.5	521
45	517
47.5	521
50	512
52.5	525
55	523
57.5	538
60	558
62.5	500
65	565
67.5	517
70	500
72.5	516
75	503
77.5	514
80	526
82.5	520
85	502
87.5	512
90	527
92.5	501
95	536
97.5	502

North Gill Wood

Depth cm	Sample size	Depth cm	Sample size
0	513	122	510
2	500	127	524
7	515	132	518
12	520	134.5	503
17	507	137	544
22	506	139.5	501
27	501	142	512
32	560	145.5	503
37	526	147	518
42	504	149.5	564
47	490	152	694
52	673	157	449
57	506	159.5	501
62	713	162	569
67	500	164.5	526
72	521	167	515
77	692	169.5	515
82	594	172	500
87	500	177	718
92	794	182	528
97	490	187	516
102	793	192	566
112	566	197	494
117	810		

Skell Gill Wood Peat

Depth cm	Sample size
8	520
11	542
13	500
17	552
19	500
22	505
25	500
27	509
30	500
32	500
37	500
39	500
43	508
47	500
50	571
52.5	520
55	511
57.5	540
60	512
62.5	527
65	500
67.5	505
70	513
72.5	510
75	517
77.5	526
80	534

Hambleton Flush

Depth cm	Sample size
0	500
5	613
10	514
12.5	554
15	500
17.5	523
20	500
22.5	561
25	502
27.5	500
30	500
35	503
40	508
45	500
50	505
55	501
60	500
65	504
67.5	507
70	500
71	500
72.5	489
75	500
80	520
85	523
90	501
95	500
99	486

Skell Gill Wood Soil

Depth cm	Sample size
0	507
2.5	500
5	530
10	509
15	500
20	501
25	500
30	401

Fortress Dike Camp

(ii) Mound

Depth cm	Sample size
0	542
5	509
10	501
30	300
35	427
40	431
45	281
50	419

Fortress Dike Camp

(i) Ditch Peat

Depth cm	Sample size
0	500
4	403
9	506
11.5	561
14	663
16.5	502
17.5	500
19	526
20	503
21.5	517
22.5	509
24	515
25	556
26.5	518
27.5	573
29	514
30	543
31.5	593
32.5	589
34	508
36	512
37.5	500
38.5	519
41	507

Random Surface Samples

Woodland

Sample No.	Sample size
1	515
2	500
3	501
4	500
5	500
6	504
7	563
8	500
9	561
10	513
11	520
12	500
13	511
14	501
15	518
16	502
17	547
18	501
19	500
20	508
21	500
22	500

Random Surface Samples

Moorland

Sample No.	Sample size
1	511
2	560
3	510
4	500
5	505
6	500
7	518
8	502
9	494
10	504
11	529
12	500
13	480
14	507
15	500
16	504
17	455
18	500
19	500
20	502
21	503
22	500
23	500
24	530
25	528
26	532
27	598
28	580
29	532
30	615
31	552
32	528

Surface Transect A

Sample no.	Sample size
1	515
2	503
3	500
4	500
5	505
6	510
7	414
8	501
9	517
10	557
11	501
12	500
13	508
14	503
15	312
16	505
17	501
18	500
19	500
20	504
21	535
22	510
23	547
24	528
25	552
26	528
27	530
28	532
29	598
30	527
31	516
32	528
33	552
34	615
35	528
36	513

Surface Transect C

Sample no.	Sample size
1	520
2	508
3	509
4	500
5	500
6	500
7	500
8	510
9	486
10	500
11	500
12	508
13	407
14	500
15	545
16	409
17	505
18	500
19	431
20	500
21	502
22	500
23	501
24	489
25	502
26	485
27	499
28	520
29	560
30	500

Surface Transect B

Sample no.	Sample size
1	503
2	576
3	574
4	568
5	750
6	597
7	562
8	552
9	574
10	555
11	528
12	544
13	547
14	500
15	500

Surface Transect D

Sample no.	Sample size
1	450
2	482
3	492
4	530
5	521
6	523
7	500
8	513
9	543
10	423
11	518
12	482

Ramsley Moor Surface Samples

Sample no.	Sample size
1	558
2	528
3	500
4	519
5	583
6	500
7	533
8	518
9	515
10	512
11	510

Perthshire Birch Wood Surface Sample

Sample size: 509

Appendix 6

Composition of the "Varia" curves

All the pollen types present in the "Varia" curves occur at values of less than 1% of total pollen.

Iron Well Hill

8-10 cm	Chenopodiaceae	Urtica	Ranunculus
28-30 cm	Cruciferae	Caryophyllaceae	

Skell Moor I

2 cm	Rubiaceae	Unknown

Skell Moor II

1 cm	Scrophulariaceae	
5 cm	Unknown	
6 cm	Leguminosae	Unknown
8 cm	Labiatae	
12 cm	Unknown	

Hambleton Hill

2 cm	Urtica
5 cm	Leguminosae
11 cm	Unknown

Hambleton Dike

7 cm	Chenopodiaceae
17 cm	Polygala
37 cm	Lonicera
58.5 cm	Unknown
64.5 cm	Scrophulariaceae

Upper Skell Gill II

5 cm	Unknown
15 cm	Unknown

25 cm	Labiatae			
27.5 cm	Unknown			
50 cm	Scrophulariaceae			
52.5 cm	Scrophulariaceae			

North Gill Wood

52 cm	*Succisa*	
82 cm	Campanulaceae	*Lonicera*
137 cm	*Succisa*	
142 cm	Campanulaceae	
172 cm	*Succisa*	
197 cm	*Valeriana*	

Skell Gill Wood

17 cm	Leguminosae
30 cm	*Polygonum*

Hambleton Flush

15 cm	*Polygonum*
20 cm	*Lotus* type
35 cm	*Lotus* type Liliaceae (*Narthecium* type)

Fortress Dike Camp Peat

4 cm	Compositae	*Urtica*	*Artemisia*	Umbeliferae
11.5 cm	Compositae	*Urtica*		
14 cm	*Lotus* type			
16.5 cm	Compositae	*Urtica*	*Lotus* type	Umbeliferae
17.5 cm	Compositae			
19 cm	Compositae			
20 cm	Compositae			

21.5 cm	Compositae	Leguminosae	Umbeliferae
22.5 cm	*Urtica*	Chenopodiaceae	*Artemisia*
24 cm	Compositae		
25 cm	Compositae	Caryophyllaceae	*Urtica*
26.5 cm	Compositae	Caryophyllaceae	
27.5 cm	Compositae	Caryophyllaceae	
29 cm	Compositae	*Melampyrum*	
30 cm	Compositae	Caryophyllaceae	
31.5 cm	Leguminosae	Umbeliferae	
32.5 cm	Compositae	Caryophyllaceae	*Artemisia*
34 cm	*Melampyrum*		
37 cm	*Urtica*	Chenopodiaceae	
38 cm	Compositae	Caryophyllaceae	
41 cm	Compositae	Caryophyllaceae	Cruciferae

Skell Gill Wood Soil

0 cm	*Filipendula*	Leguminosae
5 cm	*Melampyrum*	
15 cm	*Mercurialis*	

Random Surface Samples: Woodland

1. *Urtica* Cruciferae Caryophyllaceae
2. *Urtica* Cruciferae *Convolvulus* *Ranunculus*
3. *Urtica* *Ranunculus*
4. *Ranunculus* Chenopodiaceae *Artemisia*
5. Chenopodiaceae *Succisa*
6. *Ranunculus* Chenopodiaceae *Artemisia*
7. Cruciferae *Ranunculus* *Artemisia* *Melampyrum*
8. Chenopodiaceae Cruciferae
9. *Urtica* *Ranunculus* Umbeliferae
10. *Artemisia* *Ranunculus* Cruciferae *Melampyrum* Unknown
11. *Urtica* Cruciferae *Melampyrum* *Ranunculus* *Chamaenerion*
12. *Urtica* *Ranunculus* *Artemisia* *Melampyrum* *Lotus* type
13. *Urtica* Umbeliferae *Polygonum*
14. *Urtica* *Ranunculus* Umbeliferae
15. Chenopodiaceae *Melampyrum*
16. *Urtica* *Ranunculus* *Melampyrum*
17. *Ranunculus* Umbeliferae
18. Cruciferae *Melampyrum*
19. *Urtica* Caryophyllaceae *Artemisia* *Ranunculus*
20. *Urtica* *Ranunculus*
21. Cruciferae *Artemisia* Umbeliferae
22. *Artemisia* *Melampyrum*

Random Surface Samples: Moorland

3	Melampyrum	Unknown	
5	Melampyrum		
6	Melampyrum	Scrophulariaceae	Lotus type
7	Melampyrum		
8	Melampyrum	Lotus type	
9	Unknown		
11	Polygola		
13	Umbeliferae		
15	Unknown	Lotus type	
16	Lotus type	Caryophyllaceae	
17	Umbeliferae		
19	Leguminosae		
21	Lotus type		
24	Melampyrum	Unknown	
25	Melampyrum	Umbeliferae	
26	Unknown		
27	Lotus type		
28	Melampyrum	Scrophulariaceae	
31	Leguminosae	Umbeliferae	

Transect A

2	Leguminosae	*Cornus* type	
3	*Lotus* type	Leguminosae	Unknown
4	Unknown		
6	Unknown		
8	*Artemisia*	*Lotus* type	
9	*Artemisia*		
21	Unknown		
27	*Artemisia*		
32	*Artemisia*	*Lotus* type	

Transect C

1 *Artemisia* Chenopodiaceae *Ranunculus* Compositae Cruciferae *Melampyrum*

2 *Artemisia* *Ranunculus* Compositae *Melampyrum* *Lotus* type

3 Chenopodiaceae *Ranunculus* Cruciferae *Lotus* type

4 *Filipendula* Cruciferae *Melampyrum* Caryophyllaceae

5 Chenopodiaceae *Ranunculus* Compositae Cruciferae

6 *Artemisia* *Ranunculus* Cruciferae Caryophyllaceae

7 *Ranunculus* Compositae Cruciferae *Impatiens*

8 Chenopodiaceae *Ranunculus*

9 *Ranunculus* Cruciferae Compositae *Melampyrum*

10 *Artemisia* *Ranunculus* Compositae Caryophyllaceae

11 *Artemisia* Chenopodiaceae *Ranunculus* *Melampyrum*

12. *Ranunculus* Cruciferae *Melampyrum*

13 *Filipendula* Chenopodiaceae *Ranunculus* Caryophyllaceae

14 *Filipendula* *Artemisia* *Ranunculus* Caryophyllaceae Compositae Cruciferae

15 *Filipendula* *Artemisia* Chenopodiaceae *Ranunculus* Compositae *Mercurialis*

16 *Filipendula* *Ranunculus*

17 *Filipendula* *Artemisia* *Ranunculus* Compositae *Lotus* type

19 *Filipendula* *Ranunculus* *Lotus* type Liliaceae (*Narthecium*)

20 *Ranunculus* *Impatiens* *Melampyrum*

21 *Filipendula* Chenopodiaceae Compositae *Lotus* type

22 *Ranunculus*

23 *Artemisia* *Ranunculus*

24 *Filipendula* Chenopodiaceae *Ranunculus* Compositae *Succisa* *Impatiens* *Melampyrum*

25 *Filipendula* *Artemisia* Chenopodiaceae *Ranunculus* Cruciferae Compositae *Melampyrum*

26 *Lotus* type

27 *Filipendula* *Artemisia*

28 *Artemisia* *Ranunculus* Compositae *Melampyrum*

29 *Artemisia*

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Construction and stratigraphy

The inner bank, the ditch, and part of the outer bank were excavated ong the line B - C in Fig.2. This revealed that the banks were formed om clay subsoil, almost certainly excavated from the ditch. At this ction gritstone boulders, which are abundant on the moor, were aligned ong the axis of the inner mound. A lens of upcast material (Fig.3) uld be clearly recognised. It was 50 cms. deep at the axis of the mound d consisted of heavy clay with frequent lumps of ganister. This over- y a discontinuous, apparently truncated, grey horizon of leached sand th a maximum depth of about 15 cms. An isolated pocket of brown earthy terial, 2 cms. thick, lay on top of this leached horizon near the centre the mound. The grey sand was interpreted in the field as the buried uvial horizon of an original shallow podzolic soil, on which the mound d been constructed. Below this a 15 cm. deep, rusty coloured, horizon iron accumulation was evident, becoming grey (gleyed) in the vicinity the ditch. There was a comparatively sharp junction between this orizon and the heavy clay subsoil, the latter contained grey and orange ottles, formed as a result of fluctuations in ground water level.

A thin layer of peat averaging 20 cms. in depth covered the surface of the mounds and the enclosure, while in the ditch, peat had accumulated to a depth of 37 cms. at the point of excavation. The mineral content increased towards the base of the ditch peat and a lens of clay separated off a lower peat horizon 5 cms. deep. This clay band formed the lateral continuation of a slope-wash deposit which mantled the side of the bank above the ditch.

3. Pollen Analysis

A monolith of peat was removed from the ditch infilling and taken to the laboratory for analysis. Consecutive 5 cm. samples of mineral material from the mound were collected for analysis along the line A - A[1] in Fig.3. The peat samples were prepared according to standard techniques by digesting in 10% sodium hydroxide, sieving, centrifuging and staining with safranin, (Faegri and Iversen, 1964; Smith, 1966). Samples of soil were boiled in hydrochloric acid to dissolve mineral particles. Five-hundred grains of all pollen types excluding spores were counted for each sample except for certain of the soil horizons where pollen was very scarce, but no counts are based on less than 300 grains. The results are presented in Figures 4 and 5

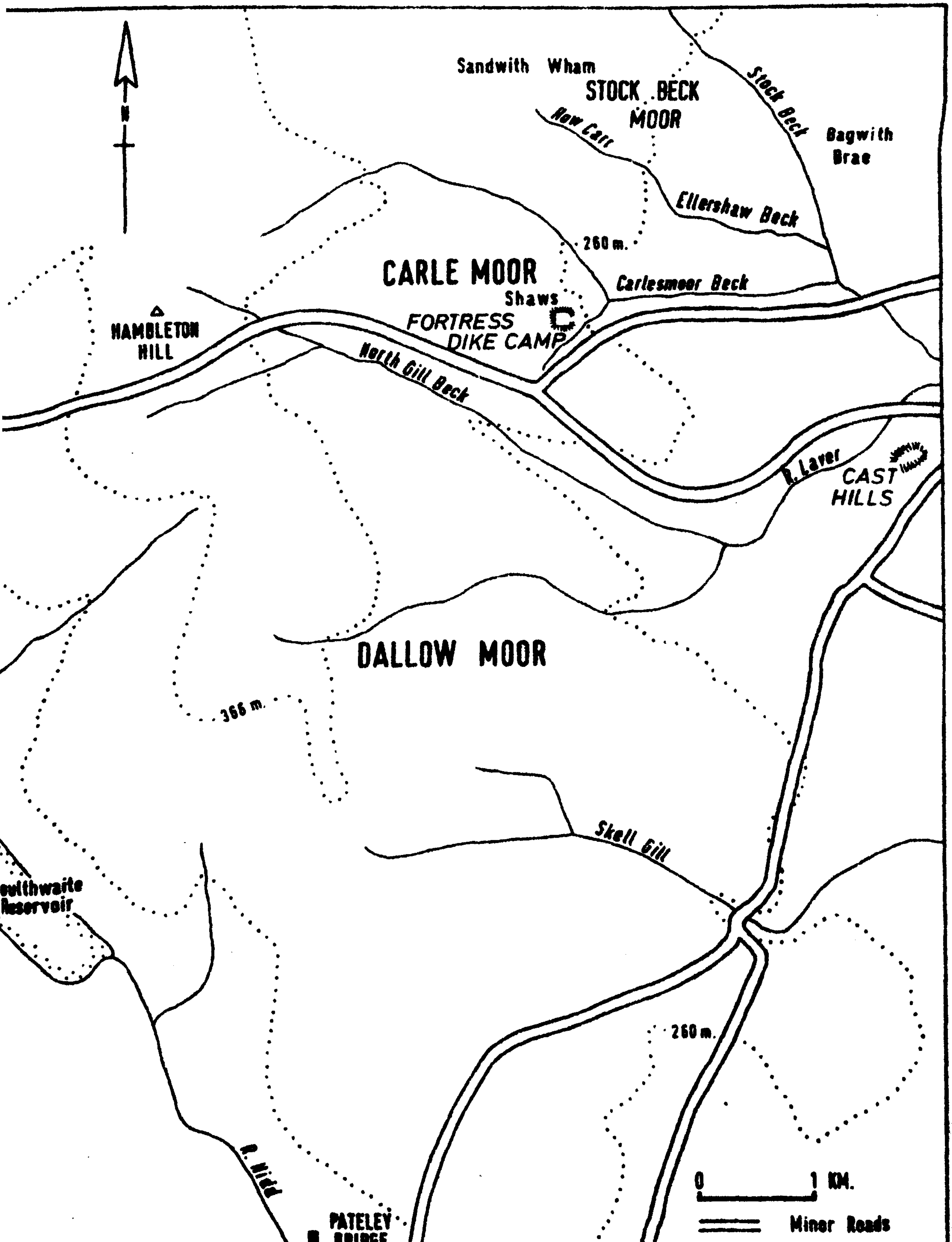

Fig. 1 SITE LOCATION