A contribution to the late quaternary ecological history of Cleveland, North-East Yorkshire

R.L. Jones

A CONTRIBUTION TO THE LATE QUATERNARY ECOLOGICAL HISTORY OF CLEVELAND, NORTH-EAST YORKSHIRE

R.L. JONES

Thesis submitted for the Degree of Doctor of Philosophy (Faculty of Pure Science) of the University of Durham by R.L. Jones, B.Sc. (1967), St. Cuthbert's Society.

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ABSTRACT

The characteristics of Cleveland in terms of the existing physical elements of the landscape and its settlement history are presented as a background to the study of Late Quaternary ecological changes there.

Late-glacial and Post-glacial landscape evolution is traced by the interpretation of stratigraphical and palynological records obtained from five mire sites by established techniques of Quaternary research. The sites lie upon an altitudinal transect from around 70 metres O.D. on the Cleveland Plain in the west of the region to about 235 metres O.D. upon the North Cleveland Moors, and range over some 30 kilometres distance.

Apart from a proposed three stage oscillation of interstadial rank within the Late-glacial period, the normal sequence of a predominantly open Late Weichselian vegetation followed by a largely closed forest cover in early Post-glacial time is encountered. Differences existing between lowland and upland habitats at particular times are explained in terms of ecological (mainly climatic and edaphic) factors. The later Post-glacial period is considered in the context of Cleveland's suitability as a dwelling place for prehistoric and early historic man, and the effects of his successive occupations upon the natural vegetation cover are discussed as late in time as reliable ecological evidence permits. It is suggested that the earliest settlers in the region may have had considerably greater effects upon their environment than has formerly been credited to them, and that the uplands had reached a stage of ecological imbalance by early historic time, the

lowlands achieving this somewhat later and with a lesser degree of permanent and not easily ~~ir~~reversible change.

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INTRODUCTION

1. Aim and Scope of the Work

The aim of this thesis is to attempt, using primarily techniques of Quaternary Research, to elucidate the ecological history of a relatively small and diverse part of north-eastern Yorkshire since the retreat of the ice of the last glaciation.

The selection of Cleveland, comprising the North Cleveland Moors and the adjacent Cleveland Plain was influenced by a number of factors.

Firstly, the presence of both upland and lowland with quite different contemporary environmental conditions, offered the possibility of an altitudinal transect across the region to test for similarities or differences which may have existed in past landscapes.

Secondly, the fact that Weichselian ice covered the region (Gregory, 1962), leaving behind it a variable mantle of deposits and landforms containing sites which were both suitable and accessible for investigation of Late Quaternary environmental evolution.

Thirdly, information concerning various facets of the physical and cultural landscapes, particularly from the geomorphological and archaeological standpoints is readily available, if not all recently contrived, therefore making possible certain correlations between different lines of evidence.

Finally, the work was conceived as a contribution to a wider research programme in this part of Northern England, concerned with numerous interrelated problems pertaining in Quaternary Studies there.

The initial part of the thesis is devoted to a brief survey of the study area, with particular emphasis paid to its contemporary environmental conditions, and also to its history of settlement and land use. It would be extremely difficult to consider the evolution of past landscapes without some knowledge of the geography of those of the present. Moreover, it is a fundamental principle of environmental reconstruction that comparisons with present day distributions conditions and tolerance limits of phenomena form the basis of many hypotheses relating to such in the past (for example, Conolly and Dahl, 1970).

The second unit consists firstly of a general description of the sites investigated and their location, and secondly the detailed results of the work are presented separately for each site examined.

The penultimate section is a discussion of the results obtained, with correlations between the sites and an attempt to reconstruct the ecological history of the region from these and allied sources.

The final part summarises and compares the available evidence with that of adjacent areas, and suggests possible relationships between their Late Quaternary evolution, and with that of the accepted scheme for England and Wales as proposed by Godwin (1956) and updated by West (1968).

2. Previous Scientific Research in the Region

In spite of a generally bleak, inhospitable character and a limited scenic appeal, this thinly populated, mainly agricultural area has attracted a great deal of attention for the past 150 years. A formidable body of information concerning its natural history has been produced, particularly during the first 30 years of the present century. The last four decades have seen no broad based regional studies but rather more a profusion of wide ranging, spatially isolated and specialist researches.

The earliest accounts were those of amateur naturalists, such as J. C. Atkinson of Danby in Cleveland, whose papers in the '*Gentleman's Magazine*' in the early 1860s, and book entitled '*Forty Years in a Moorland Parish*' (1891) reflect his various interests, mainly archaeological. The early volumes of the *Proceedings* of the Yorkshire Geological Society, and the Cleveland Naturalists Field Club, *The Naturalist* and *Yorkshire Archaeological Journal* contain a multitude of short notes and papers concerning discoveries and hypotheses in north-east Yorkshire by Hawell, Burton, Mortimer, Sheppard and others. The activities of such enthusiasts have fortunately been perpetuated by the Yorkshire Naturalists'Trust, the Yorkshire Archaeological Society and numerous local natural history societies. To their members credit for a large proportion of recent important finds must be given.

The late nineteenth and early twentieth century saw the advent of scientific approaches to topics previously treated in isolation and often ascribed to highly improbable causes.

J. G. Baker (1863) produced a related account of the Botany, Geology, Climate and Physical Geography of North Yorkshire, and the Geological Survey Memoirs of the region were published in 1885, 1886 and 1888, the results of the work of Fox-Strangways, Barrow, Cameron and other well-known geologists of the period.

Professor P. F. Kendall's studies of 'The Glacier Lakes of Cleveland' (1902, 1903) received wide acclaim, and had considerable implications on the interpretation of glacial retreat phenomena in other areas for the succeeding half-century. Together with H. E. Wroot, Kendall synthesised his researches in '<u>The Geology of Yorkshire</u>' (1924).

As fundamental and influential as Kendall's geological hypotheses were those of the Commondale Naturalist, Frank Elgee. A memorial at Ralph Cross on Westerdale Moor today stands as a token for his massive contribution to natural history and archaeology in the region. His major publications '<u>The Moorlands of North-East Yorkshire</u>' (1912); '<u>The Romans in Cleveland</u>' (1923); '<u>Early Man in North-East Yorkshire</u>' (1930) and (together with his wife) '<u>The Yorkshire County Archaeology</u>' (1933), summarise a lifetimes work and innumerable papers, unrivalled as yet as a source of regional understanding and synthesis.

While it is perhaps untrue to state that research in the decades following Kendall and Elgee's major publications was totally conducted within the framework of their conclusions, their combined efforts were no doubt instrumental in providing the impetus for much of the work. Versey (1939) investigated geological structure and denudation chronology, while Gaynor and Melmore (1936a, 1936b) and Harrison (1936) in the Vale of York and Radge (1939) in North Cleveland examined the glacial sequence.

The initial Quaternary ecological studies were performed by Erdtman (1927, 1928). The peat deposits of Cleveland were examined as part of a wider investigation into the Post-arctic history of the forests of north-western Europe. His conclusions suggested that the area had carried forest during the greater part of Post-glacial time, a fact which Elgee (1912) had considered improbable. The outline nature of the analyses, carried out when palynology was a young and little developed science, together with widespread belief in Elgee's ideas, saw his views make only a minor impact in north-east Yorkshire.

It was not until the early 1950s, that renewed interest and fresh approaches to both ecological and geomorphological problems in the region were made. The work of Dimbleby (for example, 1952, 1962) led him to state quite firmly that Erdtman had shown the area to have been forested throughout the greater part of Post-glacial time, with forest clearance the result of anthropogenic activity late in this period. Godwin and Walker (1954) at sites in the Vale of Pickering, established beyond all reasonable doubt that this was the case, producing a vegetational succession from Late-glacial until relatively recent time for that area.

Denudation chronology and Pleistocene geomorphology were not overlooked in this challenge to traditional ideas. Agar (1954) produced an account of the glacial and Post-glacial geology of the Tees Lowland and Henry (1956) made a comprehensive study of the development of the Esk drainage system in relation to topography. The glaciations of West Cleveland received some new suggestions from Best (1956), while Hemmingway et al (1958) provided a good summary of geology in the Whitby area. Anderson (1958) produced the first major work on Cleveland soils and their potential uses. Sissons (1961) suggested that Kendall's hypothesis of the deglaciation of part of Eskdale was wrong; and this was followed by Gregory's (1962) comprehensive thesis on the geomorphological evolution of the whole region, which reinterpreted many traditional ideas, particularly concerning the Pleistocene. Dimbleby (1962), consolidated his ideas upon the moorland's status, and new archaeological views, for example, those of Hayes (1966) and Radley (1969) began to emerge, concerning particular sites and periods. Studies of historical documents, for example,by Waites (1957), Chapman (1961), Farra (1961) and Mitchell (1965), have provided a new and detailed analysis of changing land use for historic times until the present.

The most recent study of vegetational changes in the region has been that of Simmons (1969a, 1969b) who, restricting himself to a small area on the central watershed of the moorlands, demonstrated relationships between human activity and the environment, with particular reference to Mesolithic man's influence on the landscape. The research to be described is intended to provide further evidence of ecological changes in Late Quaternary time, particularly those of a general rather than a specific nature. The main aims of this, and other work in preparation, (Cundill, personal communication), is the presentation of a more complete picture of such changes in the period considered by Gregory (1962), to "have shaped the detailed anatomy" of the contemporary landscape of the region.

CHAPTER 1

DESCRIPTION OF THE STUDY AREA

1.1 Topography

Cleveland lies at and around the northern fringes of the North Yorkshire Moors National Park, and comprises two distinct landscape regions, the North Cleveland Moors and the Cleveland Plain (Figure 1).

The moorland has the greater areal extent stretching some 22 kilometres (14 miles) from Guisborough Moor in the west, to Egton Low Moor in the east, at an average elevation of 240 metres (800 feet). The northern boundary of this gently undulating plateau is marked by an imposing escarpment, reaching between 275 and 395 metres (900 - 1,300 feet) to the south of Guisborough, while further to the east it meets the coast between 120 and 213 metres (400 - 700 feet) O.D., giving a very striking cliff coastline. In front of the main escarpment, the outliers of the Eston and Upleatham Hills rise sharply only a few kilometres south of the Tees estuary. They are separated from the main moorland block by a shallow flat bottomed valley containing the town of Guisborough. From the North Cleveland watershed, drainage to the north is to the Tees and to the south to the Esk; in both cases by short, swift flowing and often deeply incised streams. The River Esk which rises in the west of the upland massif flows eastwards, joining the sea at Whitby, and to the south of it the moorlands rise to form the lofty central watershed of the North Yorkshire Moors, trenched by broad dales

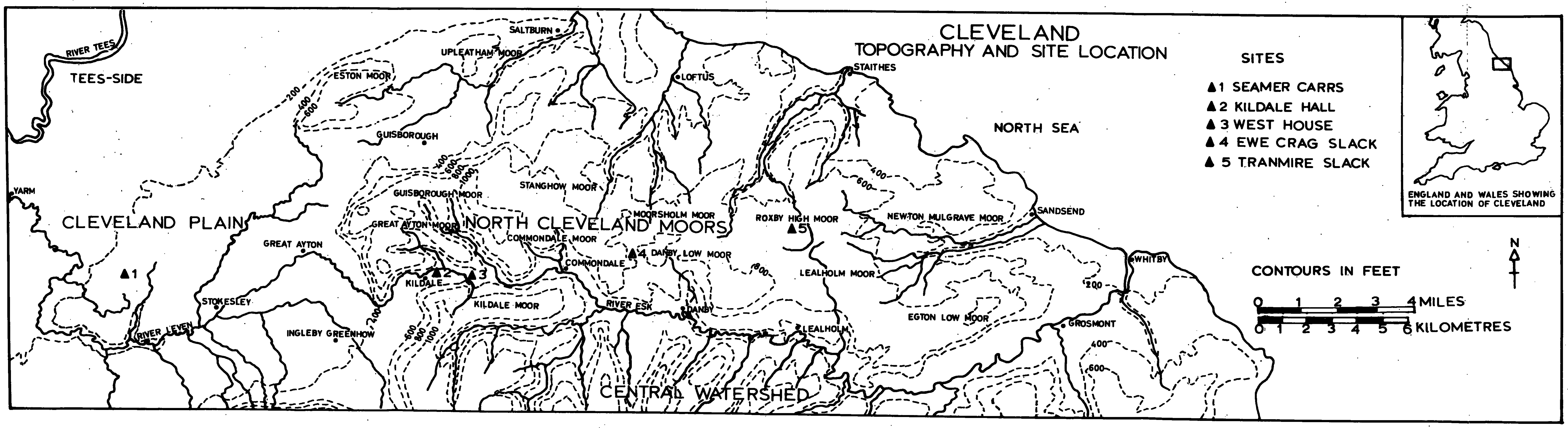

CLEVELAND
TOPOGRAPHY AND SITE LOCATION
SITES
▲1 SEAMER CARRS
▲2 KILDALE HALL
▲3 WEST HOUSE
▲4 EWE CRAG SLACK
▲5 TRANMIRE SLACK
ENGLAND AND WALES SHOWING THE LOCATION OF CLEVELAND
CONTOURS IN FEET
MILES
KILOMETRES
N
NORTH SEA
TEES-SIDE
RIVER TEES
YARM
CLEVELAND PLAIN
NORTH CLEVELAND MOORS
CENTRAL WATERSHED
SALTBURN
UPLEATHAM MOOR
ESTON MOOR
GUISBOROUGH
GUISBOROUGH MOOR
GREAT AYTON MOOR
GREAT AYTON
STOKESLEY
RIVER LEVEN
INGLEBY GREENHOW
KILDALE
KILDALE MOOR
STANGHOW MOOR
LOFTUS
MOORSHOLM MOOR
COMMONDALE MOOR
COMMONDALE
DANBY LOW MOOR
RIVER ESK
DANBY
ROXBY HIGH MOOR
LEALHOLM MOOR
LEALHOLM
STAITHES
NEWTON MULGRAVE MOOR
SANDSEND
EGTON LOW MOOR
GROSMONT
WHITBY

FIGURE 1

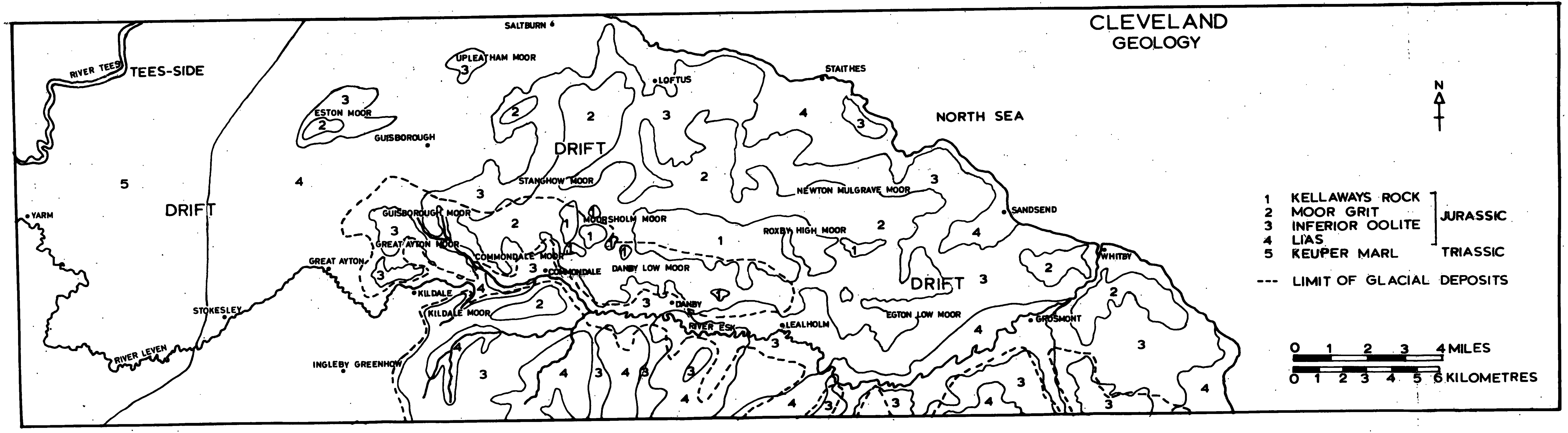
radiating north and south. The highest point in this area is 456 metres (1,489 feet) O.D. at Burton Head on Urra Moor.

The lowland has a gentle but distinct relief, averaging around 60 - 90 metres (200 - 300 feet) O.D., encircling the estuarine lowlands of the Tees to the north, and merging imperceptibly with the hummocky topography of the northern part of the Vale of York to the south, while to the west it stretches to the foot of the Cleveland escarpment. The main drainage system is that of the River Leven, which has its source in the upland very near to that of the Esk, but in contrast to the latter, follows a westward course, eventually entering the Tees at Yarm.

1.2 Geology

In outline, the geology of the area is essentially simple, consisting of a series of sedimentary rocks dipping south-eastwards and ranging in age from Triassic in the lowlands to Jurassic in the uplands. Sediments of the periods between the Jurassic and the Pleistocene are absent, having been removed by prolonged erosion. Pleistocene deposits, the results of the glaciations and associated phenomena to which the area was subjected during this period are the most important element in the present day landscape of the Cleveland Plain, but are absent from a large proportion of the upland. Here, despite distinct structural forms, the landscape is primarily a reflection of the differential hardness of the beds which make up the succession (Figure 2).

The North Cleveland Moors are composed of a considerable thickness of nearly horizontal Jurassic strata, and are capped


CLEVELAND
GEOLOGY
N
NORTH SEA
1 KELLAWAYS ROCK
2 MOOR GRIT
3 INFERIOR OOLITE
4 LIAS
5 KEUPER MARL
JURASSIC
TRIASSIC
--- LIMIT OF GLACIAL DEPOSITS
0 1 2 3 4 MILES
0 1 2 3 4 5 6 KILOMETRES
RIVER TEES
TEES-SIDE
YARM
DRIFT
SALTBURN
UPLEATHAM MOOR
ESTON MOOR
GUISBOROUGH
GREAT AYTON
STOKESLEY
RIVER LEVEN
INGLEBY GREENHOW
KILDALE
KILDALE MOOR
GUISBOROUGH MOOR
GREAT AYTON MOOR
COMMONDALE MOOR
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STANGHOW MOOR
MOORSHOLM MOOR
DANBY LOW MOOR
DANBY
RIVER ESK
LEALHOLM
LOFTUS
STAITHES
NEWTON MULGRAVE MOOR
ROXBY HIGH MOOR
EGTON LOW MOOR
SANDSEND
WHITBY
GROSMONT

FIGURE 2

by hard flaggy sandstones and intercalated shales of Inferior Oolite age and Estuarine Formation. These rocks make their first appearance south of the Tees as the resistant cappings of the Eston and Upleatham Hills. Along the main escarpment of the plateau mass, a conspicuous shelf is often formed by the Middle Lias Sandstones which are more resistant than the shales above and below them. The highest geological formation of the area, the Kellaways Rock, a massive sandstone of Middle Oolite age forms the cappings of several knolls such as Freebrough Hill on Moorsholm Moor and Brown Hill on Commondale Moor, but the majority of the rather monotonous moorland landscape is covered by the outcrop of the Moor Grit (Barrow, 1888).

Glacial Drift occurs widely between the Tees Estuary, and the slopes of the upland to a height of about 215 metres (700 feet). Above this, however, it occurs in thin isolated patches, for example, at 245 metres (800 feet) on Eston Nab and at 307 metres (1,000 feet) on Roseberry Topping. Eskdale, and some of its tributaries are filled to a considerable depth with glacial deposits. Solifluction deposits are found mantling slopes and filling depressions over a wide area, but River Alluvium is much rarer, the upland streams are generally too short and swift flowing to have developed a flood plain of any magnitude. Peat occurs in small quantity, usually in depressions which are often at the base of the Kellaways Rock. There are no major areas of blanket peat such as exists on the central watershed south of the Esk, but the dales contain peat filled hollows where they are floored with glacial deposits.

The Cleveland Plain has very few outcrops of solid rock, owing to the extensive drift cover. In what few exposures there are, Permo-Triassic Marls overlain by Bunter Sandstone and Keuper Marl can be seen, passing upwards towards the Cleveland Massif into the Lower Lias formations. The drift deposits here are of variable thickness, attaining over 30 metres (100 feet) in places, and are mainly composed of a reddish boulder clay overlain by a belt of sands and gravels having the form of a series of parallel aligned ridges trending ENE - WSW. Patches of a blue lacustrine clay at a height of around 90 metres (300 feet) O.D. occur in some localities. Solifluction deposits are less conspicuous than in the uplands, though many hollows in the drift have infillings of stony clay, often overlain by fairly recent Colluvium. Peats and other organic accumulations are also restricted in distribution, mainly being found in hollows between mounds of outwash material, locally known as 'Carrs', as for example, at Seamer Carrs and Tanton Carrs. There is evidence, in isolated remnants, that a large area of the plain was covered by swampy ground (in the flat area between Seamer and Hilton, for example), but this has now been removed by drainage and cultivation. River Alluvium is quite extensive along the lower courses of the streams, particularly, the Leven, which has also become deeply incised into the drift, the Triassic formation being exposed in several valley sections.

1.3 Structure

The region is structurally a series of gently folded and little faulted anticlines and synclines which can be detected in the topography.

In the uplands, the more important structures have their axes lying a little north of west and south of east, the others lying roughly north and south. A major syncline commences near Lockwood Beck Reservoir and passes across Moorsholm Moor, Scaling Dam and Ugthorpe, dying out at Whitby where it is truncated by a fault, a similar feature marking its western termination at Lockwood Beck. In this syncline occur the highest beds in the geological succession of the district, the Kellaways Rock being practically confined to it. A smaller similar structure crosses the highest part of the North Cleveland watershed, commencing at White Cross on Danby Low Moor and traversing Guisborough Moor, ending at Pinchingthorpe in the west. The Esk Valley follows the course of a major synclinal trough in the southern part of the area, while in the northern boundary region an anticline can be detected between Guisborough and the coast, with its northern limb bisected by the escarpment.

Faulting is generally localised, and not of widespread significance; however, the Upsall Fault, with a downthrow of 120 metres (400 feet) to the north is responsible for the separation of the Eston and Upleatham Hills, and the consequent duplication of the escarpment in the Guisborough area. (Smailes, 1960).

The lowlands also are comprised of anticlinal and synclinal forms which find their expression in the general dip of all formations, excepting the Oolites, at angles of less than 5°, to the east. This causes the Millstone Grit and the Permian beds outcropping to the west to pass gradually beneath the several members of the Trias and Lias, which in their turn pass under the steep Oolitic escarpment. Major faults are absent, but the intrusive Cleveland Dyke, composed of Tholeite and trending NW - SE across the plain from near Stockton to Kildale and into Eskdale provides the only evidence of igneous activity in the area, probably of Tertiary age. (Barrow, 1888).

1.4 Pre-Quaternary Landscape Evolution

The development of Pre-Quaternary, and generally of Post-Cretaceous landscapes of the region, have been traced by several investigators; notably Cowper Reed (1901), Fawcett (1916), Versey (1939), Peel and Palmer (1955), Henry (1956) and Gregory (1962). The work of the latter summarises the previous research and suggests the following sequence of events:-

1. The emergence of the Cretaceous sea floor as a surface inclined to the east.
2. The initiation and development on this surface of a major eastward flowing river, the Proto-Esk.
3. The capture of the Upper Esk, probably by the Tees, and the isolation of the North Yorkshire Moors as an "island", with the formation of an escarpment commencing.
4. Mid-Tertiary uplift of the region in the form of a dome, with deformation of the early Tertiary surface, and accentuation of the form of the moorland block.
5. Major planation forces, producing a Summit surface, over 308 metres (1,330') O.D., and a High Moor surface 355 - 395 metres (1,150 - 1,290') O.D., both now very restricted in area in the south-west of the upland.

6. The production of two partial peneplains, the Low Moor surface (a) 290 - 338 metres (950 - 1,100') and the Low Moor surface (b) 235 - 283 metres (770 - 930') associated with these were drainage changes, mainly river captures, resulting from structural adaption and scarp recession, with the resultant extension of the Cleveland Plain at its foot. Low Moor surface (a) can be seen on Guisborough and North Ings Moor, mainly developed on the Middle and Upper Deltaic series. Low Moor surface (b) is the most extensive and well developed, extending across a number of outcrops in the Kellaways, Cornbrash and Middle and Upper Deltaics.
7. The Calabrian Transgression at the close of the Tertiary period, with the formation of a well marked strandline at 210 metres (700') around the uplands, related to Calabrian sea levels, accompanied by some drainage diversions.

1.5 The Pleistocene Period

The first major contribution to Pleistocene studies in the area was by Kendall (1902,- 1903). He was first attracted by the many dry watercourses traversing the uplands in intricate patterns. From their form and distribution a system of pro-glacial lakes and overflow channels, with associated strandlines, deltas and lake deposits was envisaged in relation to the drift limits. Ice was considered as surrounding the upland massif in the last glaciation, and extending into Eskdale to Kildale on the west and Lealholm on the east. Inside the remaining area, which was ice free and took the form of a nunatak, drainage was impounded and a series of lakes and overflows developed, becoming operational at various heights as the ice retreated north-eastwards. Lake Eskdale, between two terminal moraines at Kildale and Lealholm was the main water body in North Cleveland, the drainage of which was to the south into Lake Pickering. His ideas gained widespread acclaim, and later workers suggested only minor amendments to his interpretations. Elgee (1908) offered some more evidence concerning the glaciation of North Cleveland, equating the outwash phenomena of the Cleveland Plain with Kendall's ideas for the uplands. The distribution and sequence of drift deposits was examined by Bisat (1939) and Radge (1939), though their evidence brought the solution of the extent and number of glaciations into not much clearer light. Similarly, Gaynor and Melmore (1936a), while establishing the presence of lake deposits, and postulating the existence of glacial lakes felt unable to offer a chronology for the lowlands, with the evidence available.

Agar (1954), somewhat followed earlier ideas in dealing with the characteristics of the glacial and Post-glacial deposits of the Tees Lowlands, and it was Best (1956) in a paper on north-west Cleveland glacial drainage channels who suggested a fresh approach to the problem. While retaining the conventional interpretation of overflow channels, and the ice limits of Kendall, a more complex sequence of channels led Best to invoke two glaciations to account for their presence.

Sissons (1961) described the glacial landforms of the Stonegate Valley in eastern Eskdale and took them to indicate the former presence of stagnant ice there, differing in his interpretations from Kendall. Following this, Gregory (1962), as part of a major study of the geomorphological evolution of the area, reinterpreted the glacial history of the uplands, and offered the following as the sequence of Pleistocene evolution:-

(1) An early Pleistocene glaciation, with the production of a series of valley stages, before, during and after this time. The evidence of this is lacking due to the removal of drift deposits and other modifications by subsequent glaciations.

(2) A second glaciation, equated with the Weichselian on the basis of the erratic content and fresh form of the features, described first by Kendall. In the last glaciation, ice advanced into the area from west, east and north, well beyond the limits proposed by Kendall, filling Eskdale and totally covering the North Cleveland Moors. Some of of the glacial drainage channels have 'hump' profiles, their operating heights suggesting a sub-glacial rather than a sub-aerial origin. Some sub-aerial drainage may have been impounded, resulting in the deposition of scattered laminated clays. Depositional features over the area suggest a total cover of ice, with a maximum of advance (perhaps equivalent to the Escrick stage in the Vale of York) represented by a moraine near Castleton in the Esk Valley.

(3) Deglaciation, marked by a thinning of the ice and the emergence first, of the North Cleveland Moors and a nunatak, joining the ice free area of the central watershed (which may have had neve fields, but not ice, throughout the last glaciation). The first ice to become stagnant

was that in western Eskdale, with the Kildale moraine, deposited at the margin of the active ice in the Vale of York, a recessional rather than terminal feature. Soon afterwards, ice in eastern Eskdale became stagnant with the Lealholm moraine formed (in a similar manner to the one at Kildale) by the margin of the coastal ice. Both moraines are perhaps the equivalent of the 'York stages' in the Vale of York.

(4) The final disappearance of the stagnant ice, with meltwater escaping southwards in eastern Eskdale, and western and central Eskdale with a reduced volume of water and a veneer of fluvio-glacial deposits on the valley floor. The deposition of this material caused the alteration in course of the River Leven when drainage was resumed after deglaciation. Formerly it flowed eastwards as a headwater of the River Esk, but was diverted westwards through Kildale by a barrier of outwash, now constituting the watershed between Kildale and Eskdale.

Gregory did not extend his hypothesis to the Cleveland Plain where the ideas of Gaynor and Melmore (1936a), Radge (1939) and Agar (1954), have been re-examined by Land (personal communication) and touched upon by Francis (1970).

The early workers assigned the exposed drift in the lowlands to the Weichselian glaciation on the basis of its erratic content, with the vast majority of landforms depositional and related to a quite rapid retreat of the ice from the northern end of the Vale of York. At this time they contend, the area was occupied by a large volume of meltwater impounded behind ice which melted for a time with its inland margin near Seamer, north-west of Stokesley. The veneer of sands and gravels covering the till and often forming marked ridge topography in this area was regarded as resorted outwash of a very complex phase of ice-retreat (Radge, 1939). In some places a boulder clay capping to the sands and gravels suggested to Elgee (1908) a readvance of the ice to account for it, but Radge (1939) favoured a halt in ice retreat to explain its presence. The final stages of deglaciation were associated with lake formation. Lake Humber lay to the south and was joined to Lake Weardale to the north by water in the Cleveland Plain, held up behind the shrinking ice-mass. Radge regarded a high level blue clay at 90 metres (300 feet) O.D. as the deposit of this lake, occurring over a wide area. The existence of this water body was short lived, however, lowered by drainage of the southern lake systems which it fed. A low level blue-clay, found over a restricted area in the Tees Basin (Agar, 1954), marks the position of a small independent remnant of the large lake, when the ice front was somewhere off the position of the present mouth of the River Tees. Large amounts of meltwater were draining away and kettle holes beginning to form in the drift as ice blocks thawed out and melted. The drift was being cut into, and the deeply incised valleys of the plain were formed, at a time when periglacial activity was intense also.

Francis (1970), and Land (personal communication) suggest that all the tills, clays, sands and gravels of the area are the deposits of one glaciation during the Late Weichselian.

Land regards the rounded hills between Stokesley, Crathorne, Yarm and Ormesby as drumlins. The Hunter Hill - Seamer - Hilton Ridge, regarded as a terminal moraine by Elgee, is placed in this category. He also finds no evidence for Radge's 300 foot Seamer Lake. There has been folding of the sands around Seamer since deposition and they have been carved into drumlin form with the deposition of the upper till. The closed hollows are regarded as either inter-drumlin features, or in some cases, kettle holes formed by in situ melting of blocks of ice.

The recent evidence of Late Weichselian readvance stages in east Yorkshire (Fenny, Catt and Coope, 1969), perhaps suggest that a similar sequence of events prevailed in Cleveland, but the absence, as yet of interglacial and interstadial deposits here, makes delimitation of even major phases of activity impossible. Drift limits are summarised in Figure 2 (after Barrow, 1888, and Gregory, 1962).

1.6 Climate

The regional climate of Cleveland is modified to a considerable extent by local topographic and maritime features, superimposed upon the larger scale pressure systems of the European land mass and the Atlantic Ocean. As with the other aspects of the environment, two climatic provinces can be distinguished, each with characteristic components. Detailed information on local climates is, however, almost entirely lacking. The North Cleveland Moors are encircled by the 762 mm. (30") isohyet, with no area receiving over 1016 mm. (40") per annum. The main effect of the elevated plateau is its function as a barrier for weather coming off the North Sea, particularly in winter, when Polar Continental air masses give considerable snowfall over high ground. Guisborough Moor, 889 mm. (35") per annum, has the maximum precipitation of the upland, with the majority falling as heavy winter showers. Far more noticeable as an upland climatic factor is wind. The elevated, exposed and treeless nature of the moors, together with the "funneling" effect of the dales, make its effects more marked, and surely, always a major climatic influence. The winter months are characterised by a bitterly cold easterly airstream, while in spring and early summer, the same winds, coming off the sea, produce the 'Haar', a low formless cloud, accompanied by poor visibility and drizzling rain (Eyre, 1959, Smailes, 1960, House and Fullerton, 1960).

Temperature values indicate that the warmest months on the moorland are all below 15°C (59° F), with cold winters, mean 3.9°C (39° F), or less. The incidence of spring, and consequently the growing season (and its associated effects), are delayed, therefore.

The Cleveland Plain is isolated from marine influences. Both to west and east lie uplands taking the brunt of the bad weather. It is only from the north and the south, along the lowland corridor, that relatively undisturbed air masses can penetrate the area. The climate is typical of an eastern England coastal lowland, with a low annual precipitation of variable incidence, but with a tendency towards a summer maximum. Available data gives an average of less than 635 mm. (25") per annum over the area, some stations recording under 508 mm. (20") per annum and others 635 - 762 mm. (25 - 30"). The driest zone is in the centre of the lowland with a progressive increase in rainfall totals west and east towards the uplands, owing to the reinvigoration of frontal systems and resultant slight instability of air masses with increasing altitude. The majority of rainfall is of a convectional type, occurring between July and October; with evaporation rates at a high level and a poor P/E ratio. At this time the area suffers water deficits in the majority of years. Winter rainfall is, however, sufficient to provide replenishment for the water table enabling plant growth to commence in early spring. Snow can be expected in the plain on about 20 days a year, increasing by one day for every 15 metres (50') rise in altitude over 60 metres (200'). Winds are much less severe, both in speed and frequency, but are still easterlies mainly. Temperatures are a few degrees higher than in the upland, but do not exceed 15.6^{o} C (60^{o} F) in summer and 5.6^{o} C (42^{o} F) in winter. The incidence of frost hollows, especially at the foot of the escarpment where cold air sinks from the plateau and displaces the warmer air of lower levels, is an important feature of the lowland climate. The 35 week growing season is about 2 weeks more than can be normally expected at the higher altitudes.

Overall, altitude, aspect and plant cover (or the lack of it), serve to delimit two quite distinct climatic regions at present. There can be no doubt that some, if not all these factors, have played an important part in landscape evolution, together with the changing climatic elements of the past.

1.7 Soils

No complete survey of the soils of the area has yet been made. Detailed pedological studies in widely separated localities, such as those of Jacks (1932), Dimbleby (1952, 1962), Anderson (1958), and Curtis (unpublished) have provided information on soil morphology, while Crompton (1961) has attempted a review of the major soil groups of the whole area.

The dual division of the landscape is again applicable, the solid sedimentary rocks of the upland, of limited range as soil parent material, can be contrasted with the drift covered lowland of reasonable soil forming potential. The threshold for marked changes in soil profiles owing to environmental influences in the region seems to be around 210 metres (700') O.D. Above this altitude, as a result of increased precipitation, the heavier soils on the flatter sites are poorly drained, leading to the build up of a peaty top-soil and the development of peaty-gleyed podsols, with in the wettest areas, the accumulation of deep peat, especially in hollows, usually of limited areal extent.

The soil profile common to virtually all areas of the North Cleveland Moors where oolitic sandstones and grits make up the major parent material, consists of :-

A_1 0 - 10 cm. Black decomposed peat, matted with <u>Calluna</u> rootlets.
A_2 10 - 20 cm. Light grey sand with occasional pebbles.
B_h 20 - 22 cm. Black humic sand with some decomposing roots.
B_1 22 - 23 cm. Brown, indurated iron pan.
B_2 23 - 35 cm. Compact reddish-brown sand with a laminar structure.
C 35 - 50 cm. Yellowish sand with angular rock fragments.

This is the major soil type of the upland, and is a thin iron-humus podsol. The peat is usually well decomposed and very acid, giving a pH reading of between 3 and 4, thus placing fairly narrow limits on the type of plant community which can exist with it as a substrate. Calluna is often the only plant growing upon it, sometimes with an admixture of moorland grasses. Peat thicknesses can vary owing to micro-topography, but there are no large expanses of blanket peat on the North Cleveland Moors. The main control of peat depth here seems to be firing, which destroys an already poorly vertically developed cover, reducing the water holding capacity of what remains and allowing vegetation with greater water requirements to develop, which gives way to Calluna again as soon as the effects of burning disappear. The sandy horizon is the result of leaching by humic acid solutions percolating from the overlying peat cover. In spite of the low rainfall and the consequent poorly developed peat layer, this essential podsolisation process is very effective. This layer is often found at the surface, particularly in areas where burning and subsequent erosion by water and wind have removed the vegetation cover and the peat.

At the base of the sandy horizon, a slight darkening is indicative of organic matter accumulation which has been moved down from above. It also contains decaying roots whose progress downward has been halted by the next horizon the iron pan. This is an indurated layer about 1 cm thick, normally being level and unbroken over wide areas, at approximately the same sub-surface depth, sometimes becoming wavy, broken and nearer the surface. Both types are found, the first instance signifies mature podsolisation, the latter an early stage or incipient evolution. The presence of a pan is a barrier to vertical movement of water and roots, and it limits the development of a thick soil profile by isolating all below it from the main soil forming processes. Waterlogging is caused and runoff occurs, accompanied by erosion of the upper horizons which become redeposited in hollows as peaty sand, often stratified. (Curtis, unpublished). Conversely, in dry conditions, it restricts the upward movement of moisture, and the exposed surface peat dries, cracks and blows. Below the pan is the remainder of the illuvial horizon, lighter in colour and a less concentrated zone of deposition than it.

The bedrock is generally tough and siliceous, impermeable and lacking nutrients, not a good parent material for soil formation.

Moorland hydrology is closely related to the differing permeabilities of soil horizons. Peat and its supporting vegetation are good water holders, moisture which does penetrate going through the A horizon as far as the pan, and then laterally. Since the pan occurs at a fairly constant depth, drainage tends to follow the moorland contours, unimpeded where there are slopes,but accumulating in hollows.

At a slightly lower altitude, in the moorland valleys floored mainly by Liassic Shales and Glacial Deposits, there is less tendency for organic matter to accumulate at the surface. The more basic parent material, lower rainfall and better drainage give quite good brown earth soils with well incorporated humus. Some gleying occurs in imperfectly drained localities, but peat is limited to isolated hollows in the drift of Kildale and Eskdale.

The Cleveland Plain has as its dominant parent material, glacial drift of mixed origin, but mainly sandy boulder clays with spreads of sand and gravel and lacustrine clay, providing a quite good substrate for soil development. The boulder clays were originally quite calcareous throughout, but are now leached to a depth of a metre or more.

A typical soil profile in the area showed:-

0 - 30 cm.	Dark brown sandy loam
30 - 60 cm.	Brown clayey loam
60 - 100 cm.	Lighter brown sandy clay
100 cm.+	Stiff reddish-brown boulder clay

A general translocation of clay down the profile has resulted in a clay enriched sub-soil. The lowland soils are generally well-drained, particularly on the hummocky drift, but quite extensive areas between hummocky deposits are often poorly drained, and occasionally contain great depths of organic material. Many such areas in what is now almost exclusively good quality agricultural land, have been reclaimed, drained and cultivated. The quite extensive spreads of river alluvium in the lowlands give freely drained sandy or silty loams which make good arable land if they are not subject to flooding.

Jacks (1935) suggested that the soils of the area were representatives of those which had always existed there. The brown earth of the lowlands had in the past, and still in places, supported a deciduous forest cover; the podsol of the uplands showed that forests of this type had not existed there, with no evidence of degeneration from a brown earth soil to a podsol present. This supported the earlier views of Elgee (1912) that the majority of the higher moorland had always carried a heath vegetation. Dimbleby (1952, 1962), by comparative evidence with fossil soils under archaeological sites, and examination of their pollen content, challenged these views, concluding that in the Post-Glacial period, podsolisation should have developed naturally on the uplands by Atlantic times, but that this, in fact, was not always the case. At this time, a mixed deciduous forest, rather than heath, was their dominant vegetation cover, and although podsolisation must have occurred in some localities, it was not until Bronze Age time that it became really effective. From then onwards, brown forest soils and others, including peaty-gleyed podsols, became subjected to intensive podsolisation as a result of man's "assault" on the landscape. It was accompanied by the disturbance of the upper soil horizons, especially by forest clearance and by cultivation. The presence of podsols today are largely the result of this anthropogenic process, which has continued in various ways until the present, when many instances of soil erosion can also be found on the North Cleveland Moors.

1.8 Vegetation

The first ordered account of the vegetation of Cleveland was given by Baker (1863) in '<u>North Yorkshire. Studies in its Botany, Geology, Climate and Physical Geography</u>'. The relationships between plant life, geology and climate were traced, with Smith (1909), providing a similar account of the vegetation types associated with particular geological formations. In Tansley's '<u>Types of British Vegetation</u>' (1911), the same author gave a description and a classification of the district's heathlands. Elgee (1912, 1914) as part of a major analysis of the natural history and origin of the moorlands, adopted a topographical classification of their vegetation types. This has remained the only overall, detailed study of the region, and as the present research was not intended to include an analysis of the contemporary flora, it has provided the basis for the account given below. Tansley (1939) drew upon the work of both Smith and Elgee in his account of the vegetation of Cleveland.

The vegetation of the North Cleveland Moors may be classified under four broad groups:- (1) The Heath Formation, (2) The Slope Vegetation, (3) The Slack Vegetation, and (4) Bog Vegetation.

(1) Heathland

The majority of the uplands are dominated on their plateau areas by a heath formation, with Calluna the main constituent of the vegetation; variations in type of heath being caused by the form of the Calluna, and the presence of other plant species.

On the driest areas with sandy and stony soils and a minimum of peaty humus (under 15 cm), apart from Calluna, the following are the most characteristic associates of what was termed by Elgee (1912), "Thin Moor" - Empetrum nigrum, Erica cinerea, Vaccinium myrtillus, Potentilla erecta, Hypnum cupressiforme (var. ericetorum) and Cladonia
Sometimes the Calluna has a dwarfed and downy life-form, as for example, on the Kellaways Rock of the moorland between Commondale and Danby. This may be a response to the very dry soil conditions and the south facing aspect (one of the few

in the region), giving exposure to the sun and high evaporation rates. On slight inclinations, especially where burning has taken place, Vaccinium myrtillus becomes abundant, and Erica tetralix is often sub-dominant on slightly damper areas of similar association.

Some moorland areas have damper environments overall, with three types distinguishable:- (a) Calluna-Nardus moor, found at the plateau edge where the boundary falls away in gentle inclinations, and also inland in some localities, for example, on parts of Danby Low Moor. Calluna is interspersed with tussocks of Nardus, Erica tetralix, Juncus squarrosus, and Cladonia spp. growing on a slightly more humic podsol than that of the Kellaways Rock, (b) Trichophorum caespitosum moor, localised, at badly drained sites on a bedrock of clayey shale. The humus is still shallow but wetter, with Trichophorum and Erica tetralix co-dominant, Eriophorum vaginatum, Molinia caerulea, Juncus squarrosus and Juncus conglomeratus sub-dominant, (c) An intermediate type between (a) and (b) with Erica tetralix as the chief species, followed by Nardus, Trichophorum and Eriophorum vaginatum.

The moorland having a thin cover of glacial drift has a slightly different floristic composition with Molinia caerulea occurring frequently among the Calluna, becoming dominant in a few localities, but never over wide areas.

A very distinct plant association is found on burnt moorland, or in local terminology, "swiddens". The Cleveland moors are fired regularly at intervals of several years, and the vegetation existing on burnt areas at any time is a function of a number of factors. The nature of the soil, the plant associations present initially, the effects of burning and the position with regard to slope and drainage are important. Where fire passes over heather with the wind behind it, the plants come again much earlier than if burning has been against the wind, when a plant may be completely destroyed, and reseeding of the area necessary. The first species to appear on a well burnt moor are usually lichens, liverworts and mosses. Cladonia spp. covers large areas, and the principal liverwort under such conditions is Lophozia inflata, Sphagnum papillosum develops in damper habitats, and Pohlia nutans is also abundant, with, at a later stage Polytrichum commune and Ceratodon purpureus frequently found. The succession to higher plants is quite rapid with Calluna, Vaccinium myrtillus, Potentilla erecta, Juncus squarrosus and Agrostis canina appearing, Polytrichum being the only remaining moss. Occasionally, sward composed of Agrostis canina, Aira praecox and Festuca ovina overspread burnt areas, while, if it is very dry Erica cinerea becomes dominant. In some swiddens Empetrum nigrum can be found interspersed with large spreads of Rumex acetosella.

(2) Slope Vegetation

Slopes in North Cleveland usually form the sides of the dales and their tributaries, but also include the escarpment and its foothills, therefore being in some ways transitional to the lowland vegetation of the Cleveland Plain. Slopes here vary much in altitude, steepness, form and direction, all of which exert an influence on the vegetation and amount of cultivated land that they bear. In some dales, the sides are reclaimed almost to the moor edge, in others fields extend only half way up the slope. Varying lithologies and colluvial downwash produce differing soil types and plant communities on different slope facets. The succession can range from Calluna, on the upper parts, through intermediate types to mature Quercus-Betula woodland at lower levels. Perhaps the most characteristic slope species is Pteridium aquilinum, dominant over large areas with often only a few grasses, a little Vaccinium and some Polytrichum growing beneath its shade. A more open growth enables Agrostis canina, Festuca ovina and Ulex spp. to form an understorey; and another common association is mixed Calluna/Pteridium with moorland grasses and Vaccinium myrtillus or Vaccinium vitis-idaea. The escarpment proper shows well marked vegetational zonation. Below the Calluna moor of the summit level is a band of Vaccinium myrtillus, corresponding to the outcrop of Estuarine Sandstones. Following this is Pteridium, covering the Upper Liassic Shales, while the lower slopes, if unreclaimed, show masses of Ulex europaeus with grassy interspaces, and if there is a flattish, wet slope foot, Juncus prevails.

The slope vegetation, in contrast to the moorland plateau, contains a tree and shrub component, albeit small. Elgee maintained that the presence of bracken indicated the former presence of trees and shrubs, a variety of which still can be found on slopes in the area. The principal tree species are Quercus petraea, Betula verrucosa, Fraxinus excelsior, Alnus glutinosa and Pinus sylvestris, while Sorbus aucuparia Crataegus monogyna and Ilex aquifolium dominate the shrub components. Quercus and Betula often form fragmentary woodland, with Sorbus and Crataegus frequent but not in continuous stands. Pinus sylvestris is planted, and would seed well in open moorland if destruction by burning and grazing could be avoided. The moorland contains small valleys or "gills", headwaters of the dales, here Quercus, Betula and Sorbus are undergrown by Vaccinium, Calluna and Pteridium, and the presence in some such associations of Oxalis, Primula and Viola are indicative of more extensive woodland in the past, the Callunetum not being yet able to become completely dominant.

(3) Slack Vegetation

Cleveland generally lacks a wide range of vegetation types, particularly those of true wetland habitats. However, there exists here, an opportunity to examine most moorland associations within a limited area, where, owing to peculiar topographic configuration, they are nearly all developed in contiguity. Such sites exist in small valleys locally termed "slacks", which represent the former channels of glacial meltwater streams. The essential features of these are a broad, flat, streamless, floor and steep sides. Within them Calluna moors, Pteridium slopes, Sphagnum bogs, Juncus swamps, Eriophorum-Calluna bogs, Erica tetralix moors and a number of intermediate associations exist. The majority of the central parts of such features normally contain Eriophorum-Calluna moor, with the absence of drainage and slight inclination giving rise to an infilling of organic matter up to 6 metres thick in places, but diminishing quite rapidly in thickness in all directions, with consequent changes in plant communities, due to both decreased peat depth and changes in bog hydrology.

(4) Bog Vegetation

Apart from the "slack" bogs, a very limited number of localities exhibit mire vegetation. These sites are mainly situated in the dales containing a mantle of glacial drift. In these topogenous mires, Trichophorum, Nardus and Eriophorum angustifolium are generally dominant, and along with Carex, Vaccinium and Calluna support well developed organic deposits, which, however, are in various stages of degeneration due mainly to human interference. Grassland, with Molinia, Deschampsia and Agrostis dominating, is encroaching upon the margins of the bogs, displacing the normal succession found there.

The vegetation of the Cleveland Plain is far less varied than that of the moorland, which if not natural, is at least evident over wide areas. The lowlands in contrast are largely agricultural, with a high proportion of arable land. There is virtually no heathland, and fen and bog communities have been drastically reduced in the past few centuries by drainage and reclamation of the "Carrs", where only isolated patches of badly drained, Juncus infested grassland remain as evidence of former conditions. Woodland is quite well developed, with Quercus, Betula and Fraxinus dominant, and Alnus and Salix in wetter situations. A number of coniferous plantations are found, some acting as windbreaks, particularly on the slopes near to the escarpment.

The mosaic of vegetation at present existing in Cleveland can be considered in two ways. Firstly, contemporary environmental conditions support quite well marked categories of plants. At approximately the same latitude and elevation, the *Sphagnum* bogs of Ireland are succeeded on the Pennines by *Eriophorum* bogs which yield finally in Cleveland to *Calluna* heathland. The common denominator in this eastward movement and changing plant communities is decreasing precipitation, and if an extension is made across to the North German Plain, this type of eretical vegetation befomes more and more restricted with decreasing rainfall in an easterly direction towards the continental interior. (Elgee, 1914. Osvald, 1949). Secondly, the present day plant communities may or may not be those which have always existed in particular localities. Certain areas, for example, Upper Teesdale, have been regarded as refuges for plants with a present day sub-arctic distribution which have remained there in their habitats since before the onset of the Pleistocene cold periods. (Bellamy, Bridgewater, Marshall and Tickle, 1969. Squires, 1971). Elgee (1907) suggested that the North Yorkshire Moors, having not been subjected to glaciation over most of their area. fulfilled a similar function. The present heathland was considered by Elgee to contain elements of an arctic flora, living in an environment not dissimilar from that of Polar regions. The rudiments of this community lived on the drift-free (i.e. unglaciated) areas during the Pleistocene, spreading on the retreat of the ice to the remaining moorland and lower ground. The natural vegetation of the uplands therefore, was envisaged to be a heath formation, having survived from pre-glacial times in a refugia, spreading and developing a slightly more temperate form in Late and Post-glacial time, to assume its present distribution. Forest cover, Elgee contended, was absent, with trees and shrubs present only in depressions such as the "slacks", where they were subsequently choked by bog growth, leaving isolated remnants that can be seen at present. The Cleveland Plain, and some lower moorland, were accepted as carrying woodland, along with the dales, though quite extensive heathland was envisaged here also. Clearance of this vegetation was ascribed to human activity, probably in quite recent times. These hypotheses were formulated before palynology, and its inferences concerning the interpretation of vegetational changes had developed. It was Erdtman (1927, 1928) who established that forests had covered most, if not all, of the Cleveland area for much of Post-glacial time, and had not been of the same composition throughout. Later researches, notably those of Dimbleby (1962) and Simmons (1969a), have sought to elaborate the findings of Erdtman, particularly with a view to establishing the causes of forest disappearance, and the development of the vegetation, for so long regarded as natural over most of the region.

1.9 Human Settlement and Land Use

Although Cleveland has been a land surface for about sixty million years, evidence of human occupation is confined to the relatively recent past, covering the last 10,000 years, with the earliest cultures virtually non-existent, or at best, poorly developed. Figure 3 provides a summary of the main archaeological sites for pre-historic and early historic time in Cleveland. The work of Elgee (1930) concerning the regional archaeology, particularly that of the pre-historic period, is now, quite naturally, dated as far as recent finds and developments, but nevertheless remains the only comprehensive

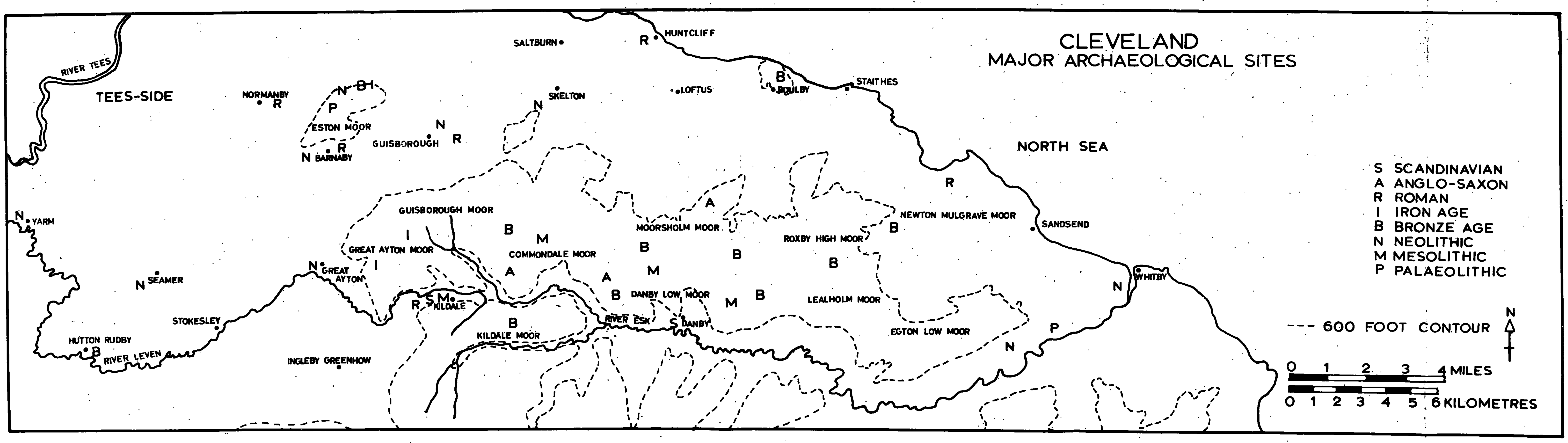

CLEVELAND
MAJOR ARCHAEOLOGICAL SITES
NORTH SEA
TEES-SIDE
RIVER TEES
YARM
SEAMER
HUTTON RUDBY
RIVER LEVEN
STOKESLEY
INGLEBY GREENHOW
NORMANBY
ESTON MOOR
BARNABY
GUISBOROUGH
GREAT AYTON
GREAT AYTON MOOR
GUISBOROUGH MOOR
KILDALE
KILDALE MOOR
SALTBURN
SKELTON
COMMONDALE MOOR
HUNTCLIFF
LOFTUS
MOORSHOLM MOOR
DANBY LOW MOOR
RIVER ESK
DANBY
BOULBY
STAITHES
ROXBY HIGH MOOR
LEALHOLM MOOR
NEWTON MULGRAVE MOOR
EGTON LOW MOOR
SANDSEND
WHITBY
S SCANDINAVIAN
A ANGLO-SAXON
R ROMAN
I IRON AGE
B BRONZE AGE
N NEOLITHIC
M MESOLITHIC
P PALAEOLITHIC
--- 600 FOOT CONTOUR
N
0 1 2 3 4 MILES
0 1 2 3 4 5 6 KILOMETRES

FIGURE 3

account of its kind. Later workers, for example Hayes (1966) have analysed the problems of particular localities, while Radley (1969) has provided the most recent statement on a single period, (the Mesolithic), otherwise work has been confined to lists of sites and finds, many of them unpublished. Historical aspects of settlement and land use have received attention from Waites (1957), Farra (1961), Chapman (1961) and Mitchell (1965).

The Earliest Inhabitants

Palaeolithic man was found quite widely in southern England, but he rarely ventured to the north. A very early Palaeolithic implement, (perhaps even pre-Palaeolithic in age), was discovered on Eston Moor (Elgee, 1930) suggesting the presence there, or nearby in the lowlands of Palaeolithic man. A Mousterian implement found in the Upper Boulder Clay of the region (a deposit of the last glaciation), has led to the correlation of this period with the Mousterian culture, as has been done at Cresswell Caves in Derbyshire, where Mousterian implements when related to the stratigraphy, showed that the people lived before and after a period of intense cold.

The accumulated evidence for early man in the region is therefore not great. However, several factors may have combined to give this paucity of information. Since the Lower Palaeolithic, two glaciations could have removed the artifacts. North-east Yorkshire moreover, was neither a producer of flint, nor possesses extensive deposits, so implements can be expected to be fairly scarcely distributed. As a consequence of this, other materials such as quartz and whinstone could have been utilised for such purposes, and being 'non regular' have not been sought after. A general absence of flint may, also, have caused later cultures, for example, Neolithic and Bronze age dwellers to rework the ones available, rendering their recognition even more difficult.

As the ice of the last glaciation began to retreat northwards, the bitterly cold and very barren landscape of southern England contained flourishing representatives of first the Aurignacian and then Magdelanian cultures. The limit of the wanderings of these cave-dwelling huntsmen was Cresswell, the environment there must have been intolerably cold, so it is not surprising that they did not venture north to Cleveland. Reindeer antlers found at the base of two peat bogs in Kildale, suggest from their relationship to the stratigraphy, that these animals, whom such men hunted, were living there towards the end of this cold period as the climate was, perhaps, becoming slightly less severe.

After about 8,000 B.C. it is known that the climate began to improve, and the landscape began to become forest covered (Godwin, 1956). The first culture to make an impact on this environment was that of the Maglemose people, well developed in east Yorkshire, particularly in the Vale of Pickering at Star Carr. (Clark, 1954). They were hunters and fishermen, using distinctive harpoons made from reindeer bone, but preferring a lakeside habitat rather than a cave. Star Carr has been referred to an earlier phase of Post-glacial time than the classic Maglemosian sites, such as those of Mullerup, Holmegaard, Svalrdborg and Lundby in Denmark which date from Boreal time. The settlement at Star Carr, dated by radiocarbon to 7638± 209 B.C., has been considered to belong to a late phase of the Pre-boreal period, with a material culture representative of a transition phase between Upper Palaeolithic and Mesolithic type, hunting in the Palaeolithic tradition and Maglemosian settlement form being found together (Clark, 1954). Cleveland has so far yielded no remnants of Maglemosian culture, but the recent discovery of a complete skeleton of Bos primigenius associated with charcoal, at the site of a former lake near Kildale village, has given a radiocarbon date of 8,400± 200 B.C. (Gak, 2707) from its embedding material, suggesting some form of activity here in early times. The moorlands, however, have given no indication of being inhabited by early Mesolithic man.

The succeeding period of the Mesolithic, the Sauveterrian, occurring roughly between 8,000 - 6,000 B.C., also finds little representation over the region. Even though there is evidence at most flint sites of components of this culture, they, as yet, have not been isolated (Radley, 1969), and it is to the late Mesolithic that the bulk of the flint finds of this period are ascribed. Basically, they are regional variations of the Maglemosian and Sauveterrian technologies, together with representatives of a later cultural group, the Tardenoisian type. At about this time, (around 6,000 B.C.), the North Sea "land bridge" was in process of submergence, and the easy access to this part of Britain by continental peoples was prevented. The Tardenoisian culture was an example, probably arising out of a mixing of previous peoples and ideals rather than the results of a fresh invasion (Radley, 1969). It was also characterised by its preference for an upland environment (at any rate for part of the year), and a general hunting, food gathering and shifting nature. The majority of flint sites are at heights of over 250 metres (820') O.D. on sandy soil below peaty humus, and probably represent the flint working and sometimes camping sites of men who traversed the moorlands before peat formation started, presumably in a drier and forested environment. Siss Cross Hill, on Danby Low Moor was the earliest discovered Mesolithic site in Cleveland, Atkinson (1863), describing it as a Celtic flint implement factory. Later investigation there by Elgee in 1925, showed it to be a Tardenoisian flint site. The implements occupy the base of a peaty soil and the upper parts of the sub-soil. Some 3 kilometres (2 miles) south-east of Siss Cross, another smaller flint site of similar type was discovered, and other less numerous finds have been made on Brown Hill, Commondale 275 metres (900') O.D., Low Brown Hill nearby, and close to Danby Beacon at 295 metres (975') O.D. All of these sites occur on a 10 kilometres watershed from Brown Hill to Danby Beacon, which is capped by a considerable thickness of Kellaways rock, whose distinctive landscape forming qualities have already been discussed. The elevated and dry environment of this outcrop is accentuated by the fact that it is surrounded by wet moorland resting on impervious clays and shales. The fact that Mesolithic flints are commonly found in such situations probably reflects the preference of nomadic huntsmen for drier and perhaps more open and easier traversable terrain. Elsewhere in Cleveland, Seddale, Barnaby, Upleatham and Eston Nab have yielded Tardenoisian type implements, and it is clear that Mesolithic people were the first consistent inhabitants of the area after the ice age, moving mainly from ridge to ridge in the uplands, with possibilities of some lowland settlements, all at a time before peat formation had begun, and the area was quite well forested, perhaps as late as 4,000 B.C.

The Neolithic Period

In north-east Yorkshire the chief remains of Neolithic man are of two kinds, stone axes and long barrows. The period has been divided into an earlier age, dominated by an axe culture and a later long barrow phase. However, axes were used throughout the Neolithic and into the Bronze Age, just as there is little doubt that Mesolithic man and his culture was contemporaneous with Neolithic activity in some localities (Elgee, 1930). Many stone axes have been found, especially in the Cleveland Plain at Guisborough, Great Ayton, Yarm, and Seamer, and in the uplands on the Eston Hills overlooking the Tees Valley, and near Egton in the Esk Valley. The distribution shows that Neolithic man much preferred the lowlands and valley environment, avoiding moorland whenever possible. The Long Barrow culture did not affect the region, the Neolithic herdsmen finding adequate pastureland on the chalk and limestone of the Wolds to the south of Cleveland. About 1,500 B.C., at the close of Neolithic time, Cleveland must have had a small, scattered and cosmopolitan population consisting of both Mesolithic and Neolithic cultural types, as well as representatives of the ensuing period.

The Bronze Age

This period has been sub-divided in the area as follows:- (Elgee, 1930, Hayes, 1963), (1) The Early Bronze Age c. 1700 - 1400 B.C. (2) The Mid-Bronze Age c. 1400 - 700 B.C. (3) The Late Bronze Age 900 - 600 B.C. The early and late phases of the Bronze Age were times of invasion, racial amalgamation and social readjustment, the Mid-Bronze Age a period of comparative security and stability during which an insular culture became paramount.

In the Early Bronze Age there were three distinct peoples in various parts of the region. (1) Beaker people, (2) Stone battle axe people, (3) Food vessel people, all to some extent contemporaneous. Not much metal working took place in the early part of this period, and stone axes survived through to the Iron Age in many isolated districts (Elgee, 1930). Specimens of beakers have been found on the North Cleveland Moors, their makers regarded as invaders from Holland and Germany who entered the area via Whitby, a natural inlet on an otherwise unindented coastline. Stone battle axes are rare and their users do not appear to have been very influential in the cultural evolution of the area. Food vessels are more numerous, having been found on Guisborough Stanghow and Eston Moors. It seems therefore, that Early Bronze Age man was largely a peripheral settler to the moorland, making his existence as a small farmer, a grazier and near the coast, a fisherman.

The Middle Bronze Age is known as the Urn Period, the inhabitants of which made the first serious attempts to live on the moorlands and in the dales. There must have been quite a sizeable population at this time, over 10,000 Round Barrows over the whole area indicate this, found usually on dry elevated topography, but also in the lowlands. The heads of Commondale, Kildale, Sleddale and Lounsdale have marked groupings of small Round Barrows, while larger ones run in lines following ridge summits and marking ancient trackways between settlement sites. Isolated barrows are found in the Cleveland Plain, for example, at Hutton Rudby. Elgee (1930) maintained that the rural economy of the Urn people was such that they cultivated, and possessed small herds which grazed on a small amount of grassland. Swine were probably more numerous, finding pannage in the oak forests of the dales, and goats important, browsing all year round, helping to clear forest and scrub, and preventing tree regeneration by stripping off the vegetation. Goats provided the people with food and clothing, and were easily fed on heather, ivy, bracken, brambles, wood, bilberry and moss in severe winters. Sheep were important and tillage included that of wheat and oats. Urns have been found on Great Ayton, Kildale and Hutton Moors, enclosures of the Urn people on Danby Low Moor, Moorsholm and Kildale Moors, while Girrick and Eston Moors and Easington High Moor contain remains of their defensive sites.

Elgee (1930) also suggested that the moorland was clothed with heather at this time and the climate was quite wet, with the dales forested but with some grassland. Animals formed trackways in this terrain which the inhabitants followed leading them to game, springs, streams, fords, and clearings.

As well as this they formed new ways both north-south and west-east across ridges. White Cross on Danby Low Moor marks the junction of a major east-west route from Whitby to the moors north of Castleton, with another running north-south. Also hollow ways, down which stock were driven towards springs and pasture are quite frequent, being found on Eston Moor and in Sleddale. Dimbleby (1961, 1962) states that agricultural activity in this period was responsible for the deforestation and subsequent desolation of the area. This activity, he suggests, was mainly pastoral in contrast to the arable farmers of the limestone hills to the south. Fleming (1971) does not concur to this view, believing that they had a well mixed farming economy, and did not merely turn their animals into the forest without making clearances from which to obtain produce such as cereals. He points to the existence of many stones in burial chambers of this period; forest browsing by animals is not likely to have made these available, but soil truncation by agricultural practice, followed by erosion would do so. Cereal growing may not have been very successful at the higher altitudes, giving a lack of evidence for it in the landscape, where soil exhaustion would be quicker and subsequent movement to a new area accomplished quite rapidly, the clearings becoming covered with heather and not used again. Fleming also examines the distribution of barrows over the area, and attempts to estimate the population at this time. A large number of barrows could mean either a large population (not likely on poor quality land) or a long occupation (not feasible really because of homogeneity of artifacts). Barrows could have housed up to 10 people; a theoretical death rate combined with a known group size and burial number is used to give a population estimate for the period. Also the amount of land under grain needed to feed a population of known size is postulated at around 2 acres per head. The North Cleveland Moors have a barrow density of 1 per 100 ha, in contrast to the high moors, where it is 1 per 250-500 ha. A barrow cemetery of 3 would therefore have used 300 ha. of land (this being the normal maximum cemetery size). On this land unit, not all would be cropped. The trees would either be felled or ring barked and left to rot with planting taking place between the stumps. By virtue of their poorer quality, and from the estimates, the Central Watershed clearings are thought to have been exhausted four times as quickly as those of the North Cleveland Moors, where overall a population of under 1,000 occupied the area for 250 - 500 years. The Cairnfields noted by Elgee (1930) on the lower moorland slopes were established at the end of this period in an attempt to keep cereal cultivation going in the face of increasing grazing at higher altitudes.

There is not much evidence of Late Bronze Age invasion in Cleveland, though some of the people came to the lowlands, perhaps assisting in the expulsion from there to the uplands of preceding cultures, where they engaged in such activities as outlined above, being mainly shifting cultivators.

The Iron Age

Until quite recently, there had been little indication that this cultural period, from about 500 B.C. to around 70 A.D., had much impact in Cleveland. It is now known that settlements were established in the district on Guisborough and Great Ayton

Moors (Hayes, 1963), and inter-tribal warfare during the last few centuries B.C. and first century A.D. led to the building of Eston Nab Hill Fort. The inhabitants appear to have been quite extensive farmers of a largely deforested landscape, into which by the middle of the first century A.D., Roman invaders had come.

The Roman Occupation

The Romans, according to Elgee (1923), settled on the Cleveland Plain quite intensively but largely avoided the moorland. There were probably still representatives of the Urn people in Cleveland in Roman times, when, certainly, Romano-British settlements were important, as, for example, at Kildale (Hayes, 1966). Mitchell (1965) subscribes to the view that a good deal of the supposed 'Romanisation' of the Cleveland lowland is more strictly likely to be Romano-British. However, there can be no doubt that Roman influence generally was strong in the region, with cultivation on the lower areas of wheat, barley and spelt, and grazing on the moorlands important activities in this period, up to about 450 A.D.

Anglo-Saxon Settlement

Cleveland was an area of British settlement during Anglican times, acting as a refuge against the Angles who ~~butchered~~ made their way to the most fertile lands in the district. Wapley and Commondale Moors have settlements of this age, and Celtic fields are numerous at the head of Kildale, near Borrowby and at Wayworth, their chess board like pattern of lynchets due to cross ploughing with foot ploughs or oxen.

Scandinavian Occupance and the Norman Conquest

Scandinavian invaders overran Cleveland between the ninth and eleventh centuries A.D., with two main movements into the district. (a) The Danes - post 870 A.D., Danby was their centre, with other settlements in Eskdale and Cleveland, (b) The Norwegians, who occupied the region in the tenth and eleventh centuries. Kildale Church has yielded important Viking relics with many place names, "Gill", "Foss" and "Slack", for example, originating at this time. The Scandinavian settlement was interrupted by the Norman Conquest of 1069 A.D., which devastated the landscape and disrupted the inhabitants. After this, the last major influx of people to Cleveland began, with Norse speaking colonists from the north-west coast and Vale of Eden moving into the area and peacefully resettling many of the old vills, establishing new settlements plus cultivating open fields (Farra, 1961). Vills were the basic holdings, according to the Domesday Survey. They comprised one or more manors, with ploughland, meadow and woodland, the population showing a remarkable concentration in settlements in the Cleveland Plain and the lower, boulder clay covered upland.

The Medieval Period

Apart from the gradual evolution of the vills and the open field system, numerous monasteries were established at about this time in the twelfth century, and grew rapidly, having an organised system of land exploitation, fully studied by Waites, (1957). By the end of the thirteenth century six monastic granges had been set up, and records show that the area was developed primarily as grazing land for cattle and sheep, with arable farming assuming insignificant proportions. The monks reclaimed moorland and cleared the remaining vestiges of woodland on land free from manorial restrictions, often starting at the scarp foot and working upwards to around 180 metres (600') O.D. They were often assisted by the lay farmers in a task which records indicate to have been feasible, encouraged and needed to sustain an expanding population (Farra, 1961).

The monasteries were dissolved in 1539, and this marked the beginning of a new phase in the landscape evolution of the area, with four hundred years of monastic influence ending and the lands of Guisborough and Whitby Abbeys being split between lay tenants. A gradual closure of the open field system was effected, with emphasis on pastoral activities and moorland reclamation, again below 180 metres (600'). The higher moors were largely unchanged but at lower altitudes, for example, round Lanby and Kildale, moorland enclosure took place, being well advanced by the early eighteenth century. As early as 1550, the Cleveland Plain is recorded as being almost devoid of woodland and even hedgerows were relatively rare (Mitchell, 1965), with enclosure commencing in many localities.

Enclosure and Agricultural Expansion

Enclosure, which had been in progress for two centuries, reached its climax after 1750, with Acts of Parliament ensuring that all open-fields and common grazing land was enclosed. It was virtually complete by this time in Cleveland, with recourse to acts unnecessary in the majority of localities, and the landscape must have looked then, much as it does today. The Industrial Revolution, followed by the Napoleonic Wars caused intensification of the regions agriculture, to be followed by twenty years of depression due to cheap foreign food imports, all such activities reflected in changing land-use patterns. Marshall (1788) and Tuke (1800) wrote on the region's agriculture, noting that wheat farming increased in importance in the early nineteenth century, along with moorland reclamation, and, for the first time, the plantation of trees. Mitchell (1965) regards Seamer and other Carr areas in the Cleveland Plain to have been reclaimed about 1815, in the general expansion of cultivated land, whose upper limit was now about 260 metres (850') O.D. in some places. The moorlands still remained largely untouched, however, and according to Marshall (1788) were completely devoid of all traces of woodland by this time.

The Last One Hundred Years

Cleveland developed its own industrial history, especially in the early nineteenth century with prosperous mines extracting Jet, Alum, Shale, Ironstone and Coal. However, fortunately for the quality of an already much altered landscape, they declined almost as rapidly as they had boomed, and have not left a great and lasting visual impression over wide areas. Undoubtedly, though, the earlier industrial processes utilised any remaining, suitable woodland in their workings.

Two World Wars caused expansion of arable farming and some moorland reclamation, with reversion to largely pastoral activities between and after them. Afforestation has been piecemeal, and only since 1951, when the Forestry Commission initiated the Cleveland Forest Scheme, have serious attempts been made to restore something nearer the natural landscape of the area. Douglas fir, larch and beech have been planted at low altitudes, and larch and red oak at higher elevations, mainly on poor quality land of valley sides and the escarpment. Considerable acreages of moorland are being left to revert from partial reclamation to pure heath, with grouse rearing now far more important than agricultural reclamation on the Calluna monoculture, in an area composed of isolated farmsteads and hamlets. The relative agricultural and industrial prosperity of the Cleveland Plain, and the designation of the moorland as part of the North Yorkshire Moors National Park, with emphasis upon workable multiple land-use schemes including agriculture, forestry and recreation, may just serve to maintain an acceptable ecologically balanced environment in the region.

CHAPTER 2

SITE LOCATION AND ANALYTICAL TECHNIQUES

2.1 The Sites Investigated

The sites were chosen in order that a minimum number should yield the maximum of information on the main problems envisaged in the elucidation of the ecological history of what are, at present, two quite distinct environments within a relatively small region.

The basic principle was that of an altitudinal transect from west to east across the whole region, using, as a safeguard against the representation of a purely local succession, pairs of sites wherever possible in each critical locality, at which relatively uncomplicated hydroseres were likely to have developed over a long period of time. Details of each individual site are given at the appropriate point in the text, and their locations can be seen in Figure 1. Only comments upon their general distribution are appropriate here.

As the whole region was glaciated at the Weichselian maximum, theoretically, any site selected could have yielded a complete record of ecological changes since that time. The effects of the glaciation, however, were quite different in the two major areas.

The Cleveland Plain has extensive depositional features, with a hummocky form pitted with kettle-hole like depressions, normally sites most suitable for analysis of long-term ecological evolution. However, the majority of such localities proved unproductive, and in the event, only one adequate site was found in the lowland. This was Seamer Carrs, near Seamer, 3 kilometres north-west of Stokesley, at an altitude of 70 metres (225') O.D. In the absence of a comparable site in the 60 - 90 metres O.D. category, an eastward progression to the main west-east dale system of the Esk - Leven was made. This area is also largely floored with glacial drift and stands some 100 metres higher than the lowland. Here two suitable sites were found; the first, Kildale Hall, near Kildale village at 168 metres O.D. (550') 13 kilometres east of Seamer Carrs, the other West House Moss on the Esk - Leven watershed at the head of Kildale 178 metres (585') O.D., 3 kilometres further east. At both localities mamalian remains had been recovered from the mire deposits, and Bronze and Iron Age finds made nearby upon the moorlands.

The North Cleveland Moorland plateau, averaging 210 - 250 metres O.D. (700 - 800') is largely devoid of glacial drift, with the resistant bedrock providing few opportunities for mire development, apart from in erosional landforms of the ice and its meltwater, which are quite widely distributed over the area, as depressions of various dimensions. Two such sites were examined, both occupying the sites of former glacial drainage channels. Ewe Crag Slack, 235 metres (771') O.D., on Danby Low Moor in the west-central upland area, and Tranmire Slack, 198 metres (650') O.D., on Roxby High Moor in the eastern plateau area, 6 kilometres (4 miles) distant, were taken for comparative purposes for this region, where numerous major archaeological finds ranging from Mesolithic to Viking age have been made.

The overall dimensions of the five site transect from Seamer to Tranmire is some 30 kilometres, and the altitudinal range from 70 - 235 metres.

2.2 Analytical Techniques

The majority of techniques employed in the research were standard methods widely used in Quaternary studies, and drawn from a variety of sources. Fuller discussions of such methods can be found in Brown (1960), Faegri and Iversen (1964), Kummel and Raup (1965) and West (1968), and only an outline of the most important is given below.

Fieldwork Techniques

(1) Levelling and Distance Measurement

Levelling was carried out using a direct reading "Autoset" level and tripod, and an alloy measuring staff graduated in metres. No sites were near accessible Bench Marks, therefore a fixed initial point was established, with all subsequent levels relative to it. Levelling was primarily between stratigraphic boreholes, while also taking in major relief features of the site, using normal Foresight and Backsight procedures to obtain the rise or fall of the ground between two stations.

Distance measurement was also carried out using the level whenever possible. The values on the measuring staff corresponding to the upper and lower interstadia of the level at a particular station were subtracted from each other and the difference multiplied by a factor of 100, giving the distance in metres between the level and the staff. This is a very accurate method, and was found to be much quicker than laying out a 60 metre linen tape between stations, especially where fences or ditches had to be surmounted. For quite permanent marking, and ready recognition of borehole sites, stout, metre long bamboo canes were securely pushed into the ground, with a small quantity of coloured plastic flagging attached to them.

(2) Stratigraphical Investigations

In the investigation of extensive fossiliferous deposits, it is first necessary to carry out a programme of boring to determine their extent and stratigraphy. In order to do this, lines of boreholes were made and the stratigraphy reconstructed. Once the stratigraphy was clear, the best site for detailed sampling was chosen, normally where the deposits were most completely preserved and thickest. Care is needed because Quaternary sediments are apt to vary considerably over short distances, single borings often giving unreliable evidence as to the whole sequence. As no open faces were available, sampling was done exclusively with hand-operated boring equipment of two types. The majority of samples were taken with the Soil Survey of Scotland Peat Sampler (Jowsey, 1966). This consists of a 50cm. long and 5 cm. diameter half cylinder, fixed to a sampler head and which can be rotated through 180^{o} to retain a half cylinder of peat or other sediment against a central anchor plate. The cylinder rotates around the anchor plate which projects into the sediment on one side, this remaining stationary while the cylinder rotates. A fin plate at right angles to the anchor plate bisects the core obtained if that particular side of the plate is outwards when the sampler is pushed down to the required depth by means of a rigid string of rods topped by a handle. Each rod is one metre in length, and is attached to the next by a coupling enclosed by a sliding tube held in place by spring loaded pins.

Some sampling was done with perhaps the best known and most widely used general purpose peat sampler, the Hiller borer. This consists of a sampling chamber 50 cm. long and 3 cm. in diameter, with a 2 cm. wide slit down one side. This is covered by a close fitting outer tube, with a similar slit bordered by a 3 cm. wide flange set at a tangent. An inner removable liner of light alloy can be used inside the chamber so that cores obtained can be removed and taken back intact to the laboratory (Thomas, 1964). The attachment system is identical to the Soil Survey of Scotland Sampler, but the Hiller is pushed down not straight, but with a slightly clockwise pressure when the outer tube is covering the slit in the inner tube, thereby keeping it closed. On reaching the required depth the sampler is rotated anticlockwise, the two slits coincide and the chamber opens. Two or three further anticlockwise rotations cause sediments to be scooped by the flange into the inner tube. Clockwise rotation closes the inner tube off again and the sampler is withdrawn, maintaining a slight clockwise pressure to keep it shut.

Whereas the Soil Survey of Scotland Sampler causes very little disturbance of the sediments as they are sampled, the Hiller borer, by the nature of its scooping action, does so, and is therefore less useful for analytical samples. However, it is more robust than the Jowsey borer, being able to penetrate quite stiff clays and gravels by its screwing action, the Soil Survey sampler being intended for soft sediments only.

Apart from the merits of individual samplers, certain other general principles were adhered to in sampling. It was, whenever possible done at a time of year when pollen production and dispersal was low, (i.e. late winter and early spring and autumn and early winter). The components of the vegetation surrounding the sampling site were noted so that if contamination was suspected by recent pollen at any level it could be related to local conditions. When boring, a sod was first removed from the surface and the first samples taken from it. Thereafter, sampling was carried out in alternate holes at successive depths, the distance between the holes being only a few centimetres, thus lessening the risk of carrying material down the borehole, and preventing the disturbance of sediment where one sample ended and the other began. All samplers were pushed down vertically, and not screwed unless absolutely necessary, thereby keeping the holes clean, preventing distortion of sediment and ensuring that any errors in sampling depth were minimal. Before sampling took place, as much detail as possible was recorded about the sediment, for example, type, macro-fossils, colour and degree of humification. Samples from the Soil Survey of Scotland borer were taken by placing a 50 cm. length of plastic guttering over the half cylindrical sample on the anchor plate and carefully sliding it off. It was then marked with its appropriate depths and securely wrapped in polythene sheet or aluminium foil, labelled again for safety, sealed and removed to the laboratory.

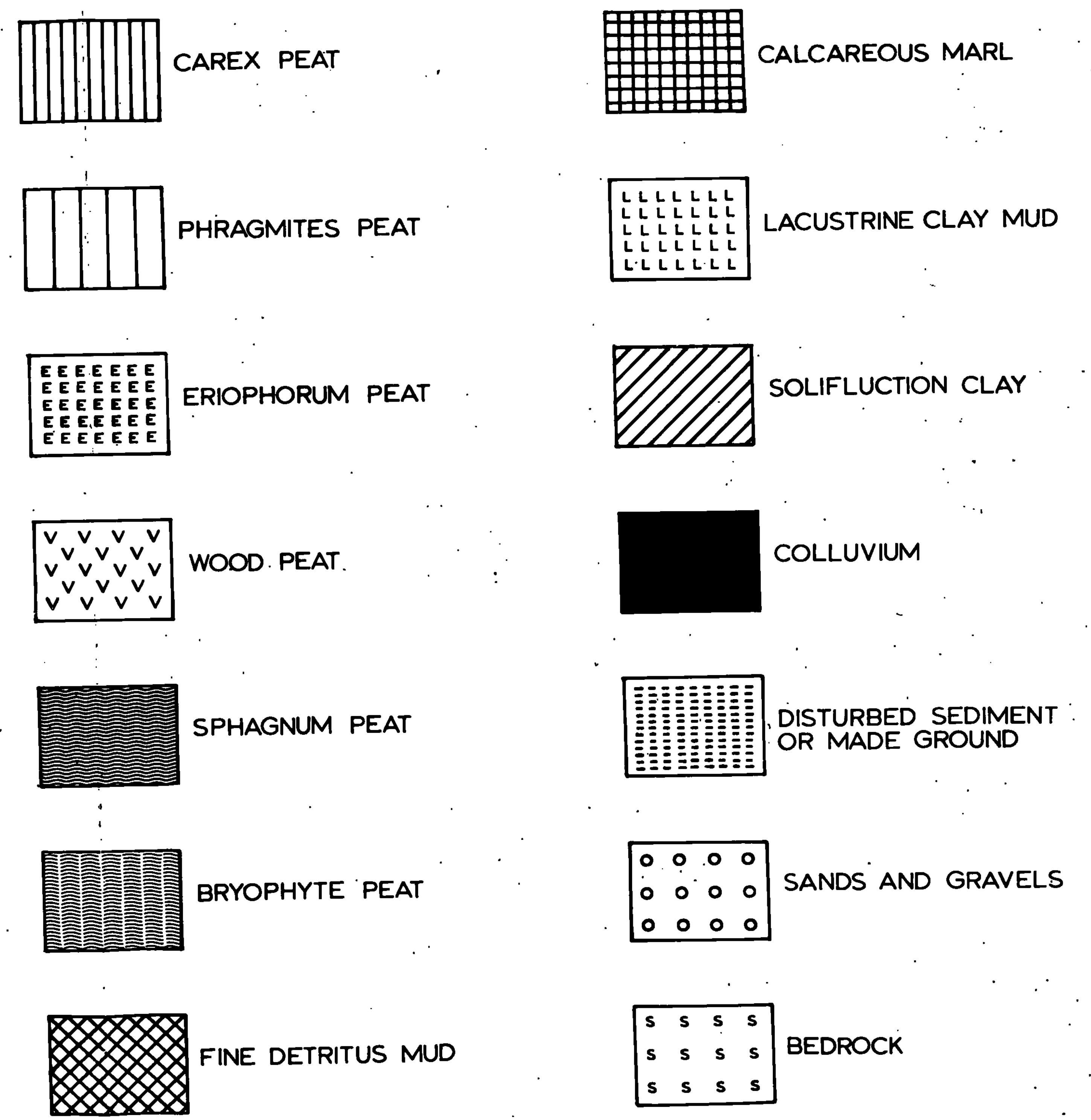
Hiller samples from the liners were removed, marked and sealed in exactly the same way; or alternatively, samples at required intervals taken directly from the chamber with a spatula and placed in small glass tubes which were then stoppered and labelled for laboratory examination.

All sampling devices, after each sample, were thoroughly cleaned and sluiced with water (a much easier task with a Soil Survey type sampler than a Hiller), ready for the next 50 cm. core. In the laboratory, the samples were checked, recorded and then stored at a low temperature and in damp conditions. Damp samples are far more easy to work and a low temperature reduces any chemical changes tending to occur. (West, 1968).

The designation of various sediment types (Figure 4) was largely based on determinations made in the field, but also laboratory examination was used in some cases. The systems used by various authors; principally Osvald (1923, 1949), Troels-Smith (1955), Faegri and Iversen (1964) and West (1968) have been drawn upon in the categorisation of the following sediment types. The nomenclature used in describing flowering plants is that of Clapham, Tutin and Warburg (1962), and bryophytes that of Warburg (1963).

<u>Carex Peat</u> Telmatic and eutrophic, dominated by sedges of terrestrial and semi-terrestrial habitats.

SEDIMENT SYMBOLS



Eriophorum Peat. Telmatic or terrestrial and oligotrophic, characterised by the shiny fibrous tussocks of Eriophorum vaginatum.

Phragmites Peat. Limnic and eutrophic, formed by reed swamp.

Wood Peat. Terrestrial and eutrophic, usually the result of a fen community, and dominated by alder or birch wood.

Sphagnum Peat. Telmatic or terrestrial and oligotrophic, containing either or both of pool and hummock forming species of Sphagnum bogs.

Bryophyte Peat. Telmatic and eutrophic, containing fen mosses such as Acrocladium, Aulacomnium, Campylium, Cratoneuron, Dicranum and Drepanocladus, as well as Sphagna, principally S. plumulosum and S. sub-secundum.

Fine Detritus Mud. Limnic and eutrophic comprising not easily identifiable plant remains and few fruits and seeds. A deep water deposit.

Calcareous Marl. A limnic and eutrophic detritus mud rich in shells and shell fragments, with a fairly coarse matrix containing sedges and bryophytes.

Lacustrine Clay Mud. Limnic and eutrophic. A mixture of clay and organic remains of a fairly fine texture.

Solifluction Clay. Limnic or terrestrial. A coarse, sandy and often tenacious deposit with sub-angular pebbles and few organic remains. A product of a periglacial environment.

Colluvium. Terrestrial. Fine and silty with organic remains, and sometimes stones in the matrix. Formed under temperate conditions by slope processes.

Sands and Gravels. Limnic or terrestrial fluvio-glacial deposits formed either under ice or near its margin.

Bedrock. A Pre-Quaternary, solid basal deposit.

Disturbed Sediment or Made Ground. Any sediment which has been altered in some way, usually by human influences such as removal, redeposition, drainage or cultivation.

Laboratory Techniques.

(1) The Preparation of Samples for Pollen Analysis

Samples for pollen analysis are chemically treated to remove the organic and inorganic material which obscures the pollen. Not all samples need every treatment, and a fairly wide range of procedures are available for use on any particular sediment. The methods used were those from which the best results were obtained, with certain basic principles common to all treatments. Using freshly made-up reagents for each set of preparations, all samples were washed and centrifuged between each treatment. 50 ml. polypropylene centrifuge tubes were used in nearly all cases, except for samples which did not settle, when 15 ml. ones were better. Centrifuge times for 50 ml. sample tubes were about 4 minutes at 2,000 R.P.M.; for 15 ml. tubes, 2 minutes at 2,000 R.P.M. Before centrifuging, the tube contents were mixed with a small quantity of distilled water and balanced in pairs for the process, after which decanting of the supernatant liquid was carefully done in one movement over a sink, in the fume cupboard.

The methods outlined below, were used in analysis :-

Breaking up of Sediments

A. Non-siliceous Muds and Clays

Put a small quantity of the sample on a watch glass and add dilute HCl. If effervescence occurs, put about 2 grams in a beaker with 7% HCl, stir adding more acid until the reaction is complete. Frothing can be minimised by a jet of acetone or alcohol. Filter as for Peats.

B. Peats

(1) Put about 2 grams of sample in a boiling tube (normally eight were used in each preparation), with about 20 ml. of 10% NaOH. and break up with a glass rod. Place in a boiling water bath until a thorough breakdown of the sediment occurs, with no lumps remaining. This may take up to one hour.

(2) Filter the suspension through a fine sieve (100 mesh to the inch) into a centrifuge tube.

(3) Wash the remaining sediment towards the centre of the sieve with distilled water. Invert sieve, washing the sediment into a Petri-Dish. Label and keep the residue damp for subsequent examination.

(4) Centrifuge and decant supernatant liquid, which at first will be dark brown, indicating the presence of a lot of humic material.

(5) Repeat washing, centrifuging and decanting until the supernatant liquid is clear.

C. Siliceous Samples

A combination of methods A and B or one of them, may be a prerequisite to this process, or a fresh sample could be used.

(1) To the residue of a previous process, or to about $\frac{1}{2}$ cc. of material placed in a polypropylene tube, add a small quantity of HCl. and mix thoroughly.

(2) Add to this $\frac{2}{3}$ of a tube full of 60% Hydrofluoric Acid (HF).

(3) Boil gently in a water bath for as long as is required to effect a breakdown of the silica content (30 minutes to 12 hours).

(4) Carefully balance tubes with 7% HCl, centrifuge, decant into fume-cupboard sink, flushing with water constantly.

(5) Add $\frac{2}{3}$ tube of 7% HCl, mix, place in a water-bath, heat for 5 - 10 minutes, but do not boil the sample. This removes colloidal silicon dioxide and silicofluorides.

(6) Centrifuge and decant.

(7) Add a few drops of NaOH to the next washing water, helping the neutralisation of the acidic treatments. Centrifuge and decant.

The Preparation of Pollen Mounts

(1) From the final residue of any of the processes A - C, carefully expel all water by inverting the tubes over a filter paper to drain.

(2) When this is complete, add 3 - 6 drops of glycerol to each tube with a glass rod, and 1 drop of basic aqeous fuchsin stain with a pipette.

(3) Thoroughly mix the contents of the tube, using an electric, pressure contact mixer.

(4) Transfer preparation to a small stoppered tube labelled appropriately.

(5) Make up one slide, using a glass rod to streak out the material on to it, then gently lower a large (22 x 40 mm.) coverslip over it. Examine under a low power microscope to see if the preparation is satisfactory. If this is so it can be sealed around the coverslip edges with paraffin wax or nail polish. This prevents drying out, and movement of material on the slide, which is then labelled, and is ready for pollen counting.

Pollen Counting

A Zeiss, "Standard WL" Research Microscope with a mechanical stage was used for counting, which was carried out at a magnification of X 400 for routine work, and up to X 1200 for grains requiring critical resolution with oil immersion media. Anisol was used as immersion liquid, drying quickly and being easily removable from slides and lenses, though tending to dissolve nail polish sealing. For Phase-Contrast work, a Vickers Research Phase-Contrast unit was used with a Vickers "M15C" Research Microscope, enabling detailed sculpturing patterns to be seen on individual pollen grains.

Counting was done by traversing the length of the slide at a standard interval of 2 field diameters apart. The whole slide was traversed to compensate for the uneven distribution of pollen grains on microscope slides. (Brooks and Thomas, 1967). A note of the number of traverses was kept, thereby giving a rough idea of the pollen frequency on each slide. Each grain identified was recorded on a Multi-Unit hand operated Counting Machine, later being transferred to a sheet with the main pollen types printed on it, as a total number of grains. Traversing was continued until the requisite number of grains were encountered, this sometimes involving several slides per sample. Positions of unknown grains were marked with Indian ink, and a note made of the mechanical stage co-ordinates for that point. At the conclusion of each count, the slide was traversed quickly at a lower magnification for the possible presence of isolated grains not recorded in the main count; and finally, attempt was made at unknown identifications.

The Pollen Keys of Faegri and Iversen (1964) were used, supplemented by that of Erdtman (1966), and the various specialised keys for problematical taxa, for example, that of Oldfield (1959) for the *Ericales* and Birks (1968) for *Betula nana*.

The Pollen Sum and the Pollen Diagrams

The basic principle of pollen analysis involves the expression of the relative frequency of pollen grains as percentages of a total. The variations of these percentages may be followed through the section of a deposit, and give a quantitative expression of the changes in the vegetation cover during the period of its formation. It has been assumed that pollen grains are evenly distributed and that their absence from a surface indicates that the species in question did not occur at that time in that locality. However, as the science of palynology has progressed, considerable thought has been given as to the validity of such concepts, and reference to the work of M. B. Davis (1960, 1963), on the statistical theory of pollen analysis, and H. Tauber (1965), on problems of differential pollen dispersion and the interpretation of pollen diagrams, provides examples of such research frontiers.

The basis for all calculations is the pollen sum, this should comprise all anemophilous species that are part of the plant communities under consideration, and from it, percentage frequencies are worked out (Faegri and Iversen, 1964). In the research undertaken, with the main aim the elucidation of regional environmental conditions in both Late and Post-glacial time, two types of pollen sum were used. Firstly, for the relatively low pollen frequencies characteristic of Late-glacial deposits, and related to the generally open habitats of this period, a total pollen sum of at least 300 dry land pollen grains was used (including all trees, shrubs and herbs, excluding pollen of aquatic plants and spores of pteridophytes and bryophytes). The purpose of such a sum is to ensure a balanced indication of the types of vegetation that existed at local and regional level at this period. Secondly, for the forested environments of Post-glacial time, when pollen production was high, a sum of 200 total tree pollen was used. (including _Pinus_, _Betula_, _Ulmus_, _Quercus_, _Tilia_, _Alnus_, _Fraxinus_ and _Fagus_, excluding _Corylus_ and _Salix_). Problems of over-representation at particular sites were considered, particularly in relation to _Betula_ and _Alnus_ pollen, but it was felt that their total exclusion from the sum, when there was evidence of their existence from macro-fossils at a limited number of horizons only, was not warranted. Any such exclusions must be consistent throughout the work, for unweighted comparability, and this would have been impracticable.

Percentage results of analyses are best expressed in the form of a diagram. Diagram format varies from author to author, but a basic component are horizontal lines representing the percentage of each species at a particular sample level. Each horizontal line is called a pollen spectrum, with a pollen diagram consisting of a number of such spectra from different vertical levels. The diagrams from Cleveland have been drawn on the "Resolved" pattern (Faegri and Iversen, 1964), in the form of "saw blades", as the main aim was inter-regional comparison, where finer details (as revealed well by "bar" diagrams), are less important than general features. At the left hand side of each diagram, is a stratigraphical column showing the nature of the deposits analysed, while at its right extremity a composite diagram based on a Tree/Shrub/Herb/total pollen sum has been drawn. No original data tables are appendixed, the contents of such tables are difficult to grasp, publication of both tables and diagrams is costly and, in the view of the author, unnecessary in the case of the former.

<u>Pollen Analytical Zones</u>

Consistent and careful zonation of pollen diagrams is essential, and it is usually based upon a scheme relevant to the particular area of study. For north-east Yorkshire, Dimbleby (1962) and Simmons (1969a) have followed the scheme of Godwin (1956), related to England and Wales, though Simmons zoned his later Post-glacial deposits according to his own system, based upon indications of human activity. Earlier, Godwin and Walker (1954) established a regional vegetational history for the Vale of Pickering area, using the scheme finalised by Godwin (1956), and the present research follows this in large part, as it has similar objectives, though there is a local sub-division of combined zones VIIb and VIII in the Post-glacial, and of Zone II in the Late-glacial.

Macrofossil Analysis

Plant macrofossils are mostly derived from vegetation growing locally, near the site of deposition, either actually in situ, or from a short distance away, where they may have been brought by running water or solifluction. They are thus good indicators of local environmental changes through time, and can be used, together with microfossil evidence, to build up a more complete picture of past landscapes. This was considered an important part of the work in Cleveland, and the following methods of analysis of macrofossils were used :-

Sieve Fragment Examination

The material which would not pass through a 100 mesh sieve during pollen preparation was retained for analysis under a low power (X 6 - X 10) binocular microscope. Any preserved plant fragments were removed using a small paint brush or a pipette, and temporary slide mounts made for higher power examination. In this way fragments of moss, seeds, fruits, wood and charcoal can be identified with the aid of keys such as Dixon's 'Student's Handbook of British Mosses' (1954), Katz, Katz and Kipiani's 'Atlas and Keys of Fruits and Seeds occurring in the Quaternary Deposits of the U.S.S.R.' (1965) and Korber-Grohne's 'Key to sub-fossil *Juncus* remains' (1964).

Extraction from Fresh Material

(1) Break up lumps of material along the bedding planes and pick out any leaves or large moss stems.

(2) Put small pieces of material into a basin and cover with either 10% HNO_3 or 5% NaOH. The former is suitable for plant tissues, the latter for finely comminuted muds. Leave in a fume cupboard for 1 day, stirring occasionally until all the lumps have broken down.

(3) Remove any seeds or other fossils that have floated to the top.

(4) Put about 2 ml. of the sediment on a 100 mesh sieve, and wash until the washing water becomes clear. Coarse detritus may require a larger mesh sieve (about 35 mesh to the inch), placed above the finer one, the 2 fractions being examined separately.

(5) Tip the fractions into dishes, add water and lift out seeds, fruits, and other identifiable remains using a fine paint brush. Magnification of the remains with a low power binocular microscope may be necessary for this purpose.

(6) Collect identifiable remains on a damp filter paper in a Petri-dish.

(7) After identification (using the appropriate keys and type collections), the remains should be stored in small tubes in a mixture of glycerine, alcohol and formalin, and labelled for future reference.

Radiocarbon Dating

Radiocarbon dating was carried out at the Radiocarbon Dating Laboratory of Gakushuin University, Tokyo, Japan, by Professor K. Kigoshi. Two samples, the ages of which are quoted in the relevant parts of the text, were dated. The calculation of age is based on the half life of carbon ^{14}, 5568 years (Johnson, 1966), with the error in years, the standard deviation, calculated from the counted number of beta rays, and the reference year for all dates, either on the BP or BC/AD system is 1950.

Additional Techniques

These mainly took two forms. Firstly, field collection and recording of such data concerning the physical landscape of the region considered necessary to supplement individual site data. Secondly, literature searching for documentary evidence of the evolution of both the physical and cultural environments of the area.

CHAPTER 3

RESULTS OF INVESTIGATIONS

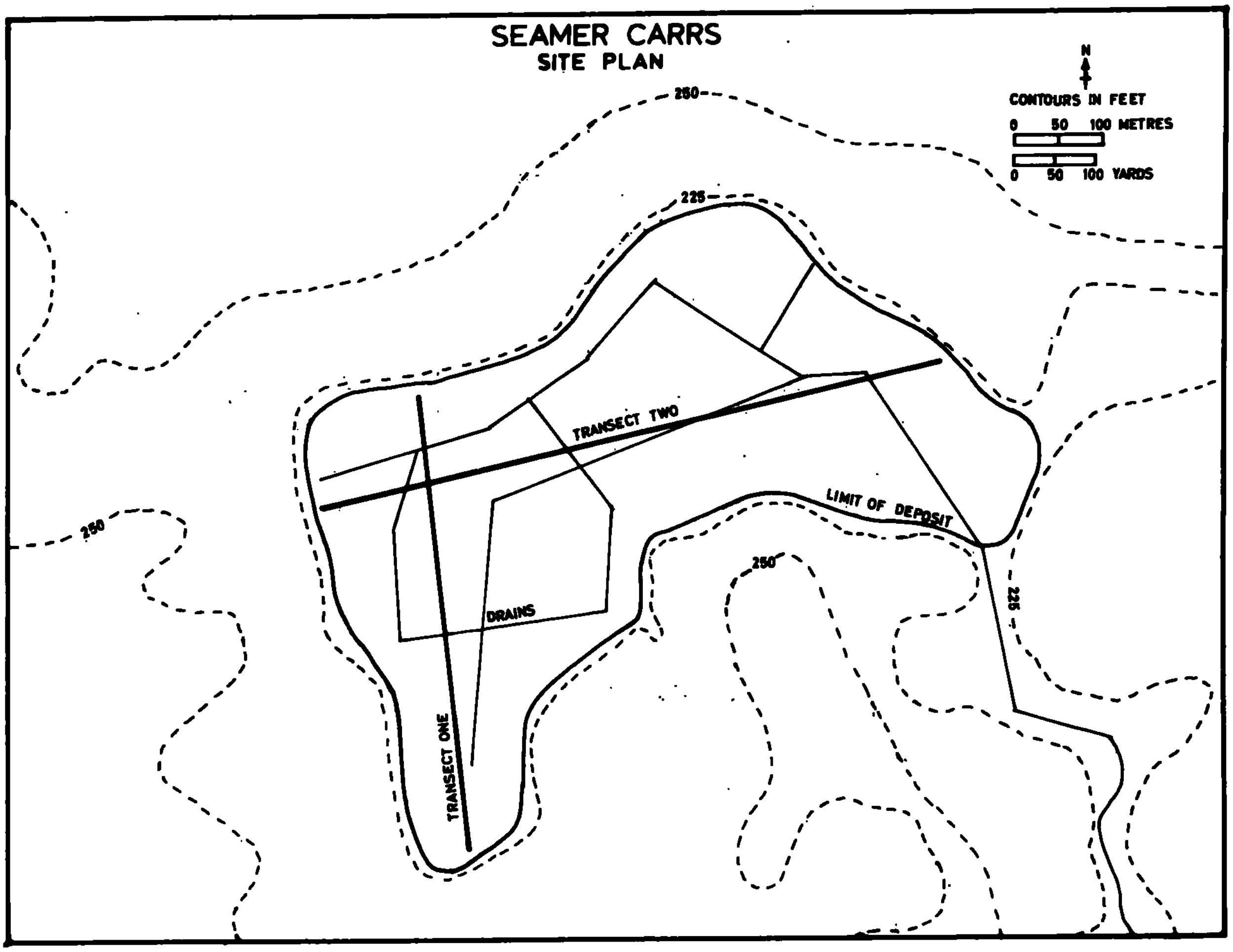
This chapter consists of systematic descriptions of the results obtained for each of the five sites, together with a specific outline of the ecological evolution of each and its environs.

3.1 Stratigraphy and Pollen Analysis at Seamer Carrs

Seamer Carrs are situated some 10 kilometres (6 miles) south of Teeside and 2 kilometres (1 mile) north-west of Stokesley, occupying a hollow in the drift of the Weichselian glaciation at just below 70 metres (225 feet) O.D., well within the ice limits of this glacial period which are found around York 70 kilometres (45 miles) to the south (Figure 1) (Plate 1).

Topography

The landforms in the neighbourhood of Seamer consist of a series of well developed WSW-ENE trending sand and gravel mounds underlain by a reddish boulder clay. The most southerly and distinct of these runs from near Hilton (NZ 466115) to the east of Seamer taking the form of mounds of outwash separated by slight but quite extensive hollows, some of which contain an infilling of sediments. Elgee (1908) and Radge (1935) suggested that the whole complex of features here was morainic, marking a stage in the retreat of the last ice sheet. Land (personal communication) considers that the deposits around Seamer belong to one



SEAMER CARRS
SITE PLAN
N
CONTOURS IN FEET
0 50 100 METRES
0 50 100 YARDS
250
225
TRANSECT TWO
TRANSECT ONE
DRAINS
LIMIT OF DEPOSIT

FIGURE 5

glaciation of the Late Weichselian, with the landforms mainly drumlins with intervening hollows, some of which are kettle holes.

Seamer Carrs (Figure 5), occupy an irregularly shaped depression within this belt, extending some 1,000 metres from west to east. At the western end an arm extends north-south for 600 metres, but the majority of the site is less than 200 metres wide at any point.

Vegetation

At present, the Carrs are under improved land, mainly good quality damp pastureland but with some arable also. The network of drains (known locally as "stells") and their pumping station, the peaty topsoil and a small area of *Juncus* infested grassland, provide the only evidence as to their former status. Local farmers state that within the last century a vast morass clothed with sedges existed here, and Mitchell (1965) suggests that attempts to reclaim the Carrs were made about 1815. Cameron (1878) noted that "Seamer Carr (once a lake), near Stokesley in Cleveland, when being drained was found to be a peat bog from which numerous skulls and antlers of deer and the skeleton of a large ruminant are said to have been dug out. A stone celt was also picked up".

Stratigraphy

The stratigraphy was explored by means of two intersecting transects of levelled borings, one north-south through the central part of the western arm, and one west-east across the middle of the

SEAMER CARRS LOOKING SOUTH-WESTWARDS
TOWARDS THE CLEVELAND ESCARPMENT

PLATE 1

deposits (Figure 5). The results are presented in Figures 6 and 7.

The basal deposits are sands and gravels overlain by a pink sandy clay, up to 3 metres in thickness. This clay is tenacious and very pure but not varved. Intercalated with it are two distinct black organic horizons separated by a mixed organic-inorganic deposit. The lower organic horizon is the thinner, about 12 cm. as compared with 15-20 cm. for the upper one, the mixed facies is about 25 cm. thick. The clay becomes coarser and greyer above the organic layers, when bryophytes are also found and it eventually passes to 25-30 cm. of organo-mineral mud. The topography of the basin is such that about 300 metres from the western edge, a marked north-south ridge exists, thereby dividing the hollow into two parts. The basal clays are similar in both parts but they thin towards the ridge where they are overlain by about a metre of calcareous marl with mollusca remains. This deposit also occupies a similar stratigraphic position over much of the western 'arm'. The interfaces of these sediments are quite well marked but give no indication of breaks in sequence. They are followed by a fine textured brown detritus mud which fills the majority of the basins, attaining a thickness of over 6 metres and containing fruits of _Potamogeton_, nodes of _Equisetum_, _Carex_ and _Menyanthes_ seeds, and _Betula_ twigs. Above this is a peat, with _Phragmites_ dominant, twigs of _Betula_, _Alnus_ and fruits of _Corylus_ present, especially near the margins of the mire. Two well marked bryophyte-rich horizons occur within this peat

SEAMER CARRS

TRANSECT ONE

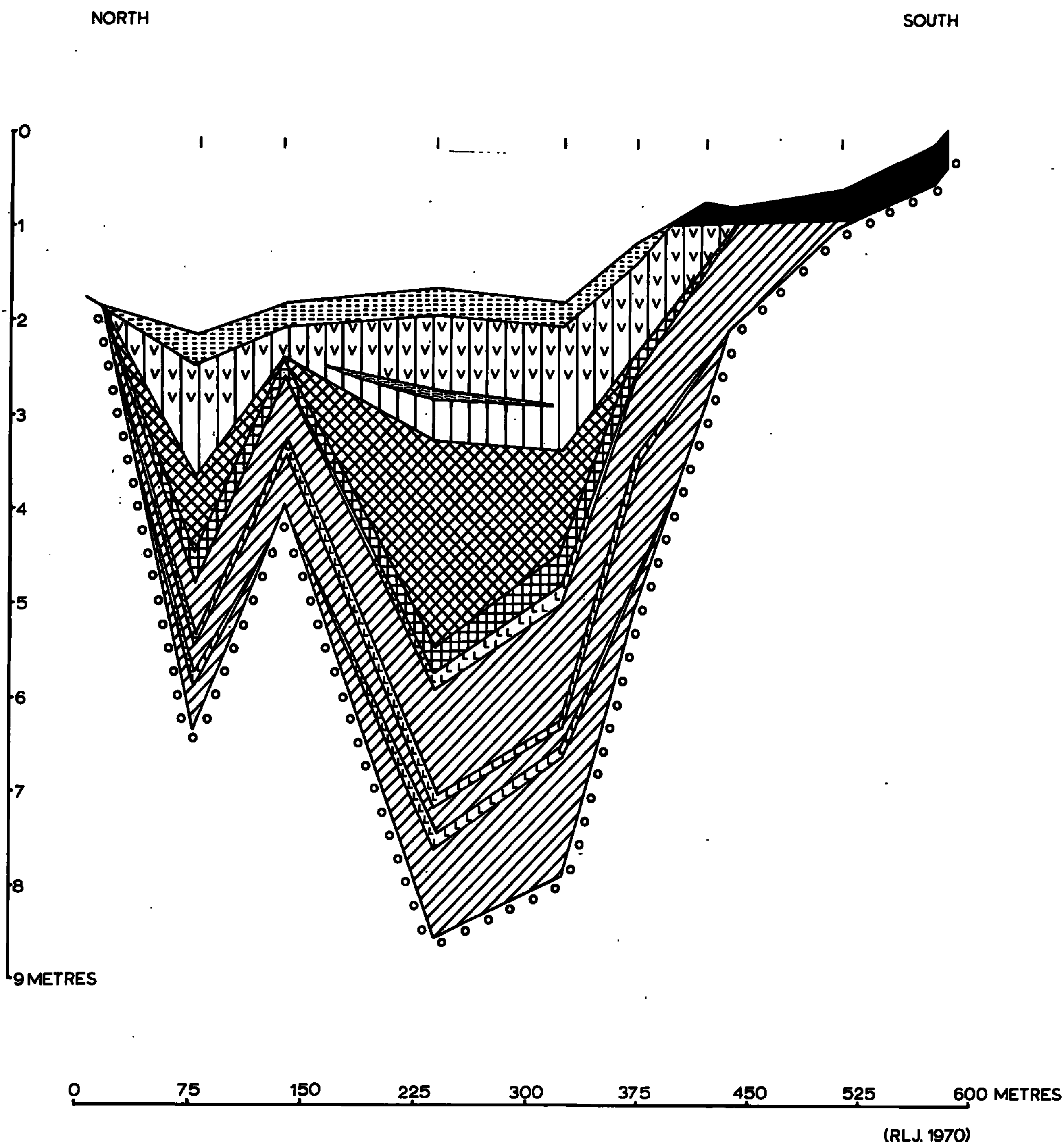


FIGURE 6

containing a wide variety of 'rich fen' mosses such as Acrocladium spp. and Scorpidium scorpioides and some Sphagnum spp. The first bryophyte layer is at the junction of the detritus mud and Phragmites peat, the second mid-way through the peat, immediately prior to the wood remains, the overall thickness of this deposit is about 2 metres.

The majority of the mire is sealed by a layer of made ground, 30-50 cm. thick. On the south and east, however, where the adjacent slopes are steepest, a covering of colluvium is present and extends some 150-200 metres across the site to a depth of about 50 cm. gradually thinning towards the central areas.

The maximum depth of deposit recorded at Seamer Carrs was in excess of 11 metres from a site with an area of about 6 square kilometres.

Pollen and Macrofossil Analysis and Chronology

Samples for pollen and macrofossil analysis were collected in 1969. The stratigraphic record from field and laboratory examination of the sediments of the sampled site is :-

0-30 cm. Made ground.

30-62 cm. Pure yellowish-brown bryophyte peat with Sphagnum plumulosum, S. teres, S. palustre, Acrocladium giganteum, A. cordifolium, Cratoneuron commutatum, Scorpidium scorpioides, Aulacomnium palustre, Drepanocladus aduncus, Dicranum scoparium and Pleurozium schreberi, occasional Carex, Molinia and Ericoid fragments with charcoal.

62-164 cm. Mid-brown damp Phragmites peat with Carex spp.,

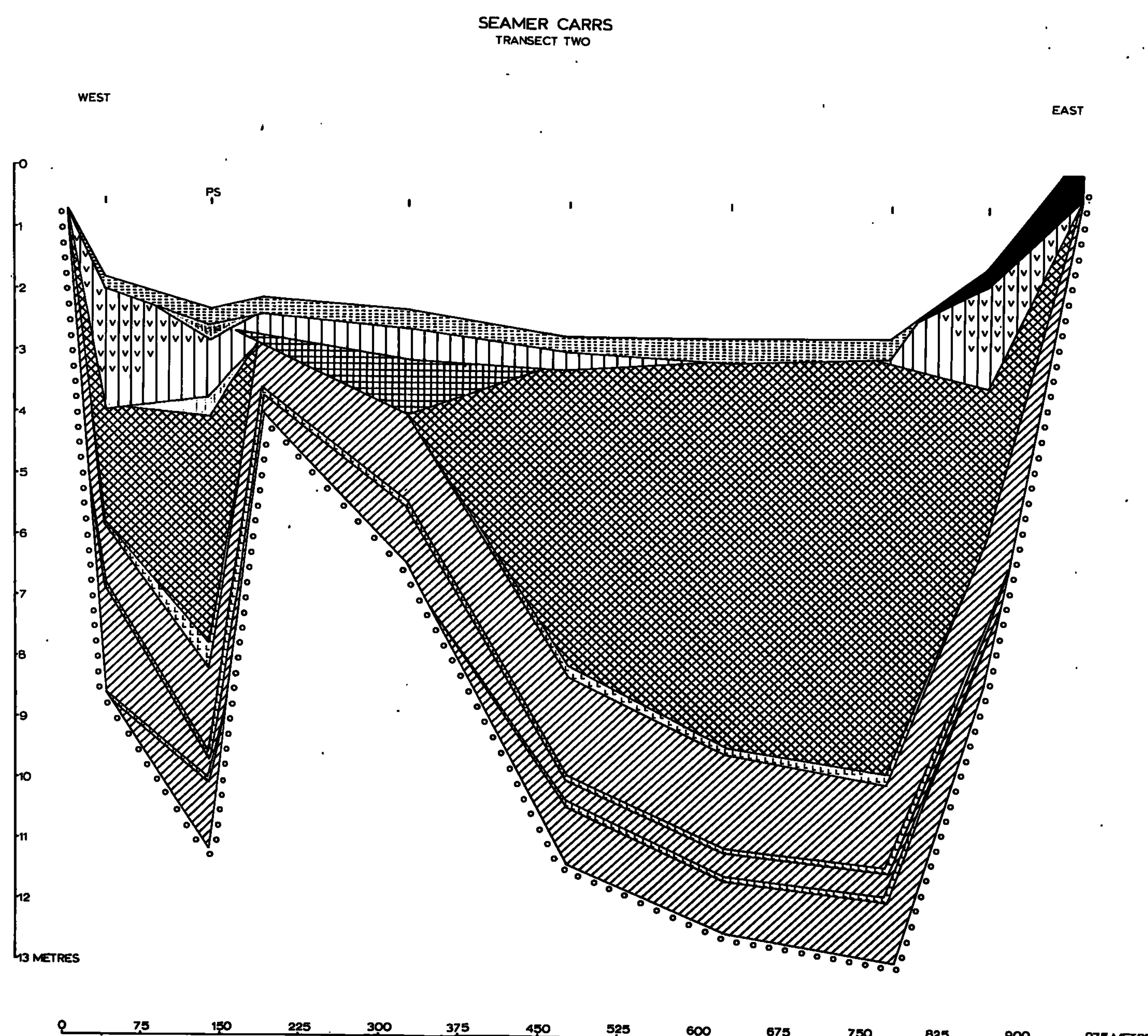

SEAMER CARRS
TRANSECT TWO
WEST
EAST
PS
0
1
2
3
4
5
6
7
8
9
10
11
12
13 METRES
0
75
150
225
300
375
450
525
600
675
750
825
900
975 METRES
(R.L.J. 1970)

FIGURE 7

Molinia and Wood. Bryophyte remains locally abundant 62-130 cm, especially Sphagnum spp.

164-190 cm. Pure mid-brown bryophyte peat with Acrocladium giganteum, A. cordifolium, Aulacomnium palustre, Drepanocladus fluitans, Dicranum scoparium, Sphagnum teres, S. sub-secundum, S. squarrosum, S. fimbriatum, S. tenellum, S. cuspidatum, S. plumulosum, S. acutifolium, S. rubellum, S. palustre, Pleurozium schreberi and Polytrichum commune.

190-603 cm. Mid-brown fine detritus mud with abundant Chara oospores and Carex stems. Scattered remains of Phragmites, seeds of Juncus sub-nodulosus and Sporangia of Thelypteris sp., seeds of Schoenoplectus lacustris, Nymphaea sp., Carex spp. Twigs and leaves of Betula and Alnus. Leaves of Sphagnum sub-secundum (var contorta) and Acrocladium cuspidatum. Leaves of Salix spp.

603-634 cm. Coarse greenish-grey clay-mud with Chara oospores, Carex stems and leaves of Campylium stellatum.

634-754 cm. Fairly coarse grey sandy clay becoming finer textured and pinker with depth. Carex and Juncus remains abundant. Leaves and stems of Cratoneuron commutatum, Campylium stellatum, Acrocladium cuspidatum, A. giganteum and Drepanocladus aduncus frequent.

754-773 cm. Black organic mud with Chara oospores. Leaves of Acrocladium cuspidatum at 755 cm., Salix sp. at 770 cm.

773-790 cm. Organo-mineral mud with Chara oospores and Carex stems.

790-805 cm. Black organic mud with Chara oospores, Fruit of Betula pubescens at 792 cm.

805-940 cm. Stiff, pink sandy clay with Carex remains in upper 20 cm. Fruit of Betula nana at 810 cm.

940 cm. + Sands and gravels.

One pollen diagram (Figure 8) covers the Late-glacial period only and is based on a total pollen sum; the other (Figure 9) covers both the Late-glacial and the Post-glacial periods and is based on a total tree pollen sum.

The Late-Glacial Period (Figure 8)

Here it is possible to recognize the following Zones and Sub-Zones :-

Zone I (940-810 cm.)

Herbaceous dominance, particularly Gramineae and Cyperaceae, also Empetrum, Artemisia, Rumex acetosa, Polemonium, Helianthemum, Thalictrum and Rubiaceae (Galium). Shrubs important, especially Betula nana, Salix, Juniperus and Hippophae, the latter two increasing towards the upper zone boundary. Arboreal pollen low and represented by a steady Betula but fluctuating Pinus curve. Aquatics quite important with Potamogeton and Typha latifolia well represented Lycopodium clavatum, L. selago, Ophioglossum and Polypodium notable pteridophytes Pediastrum present in low values.

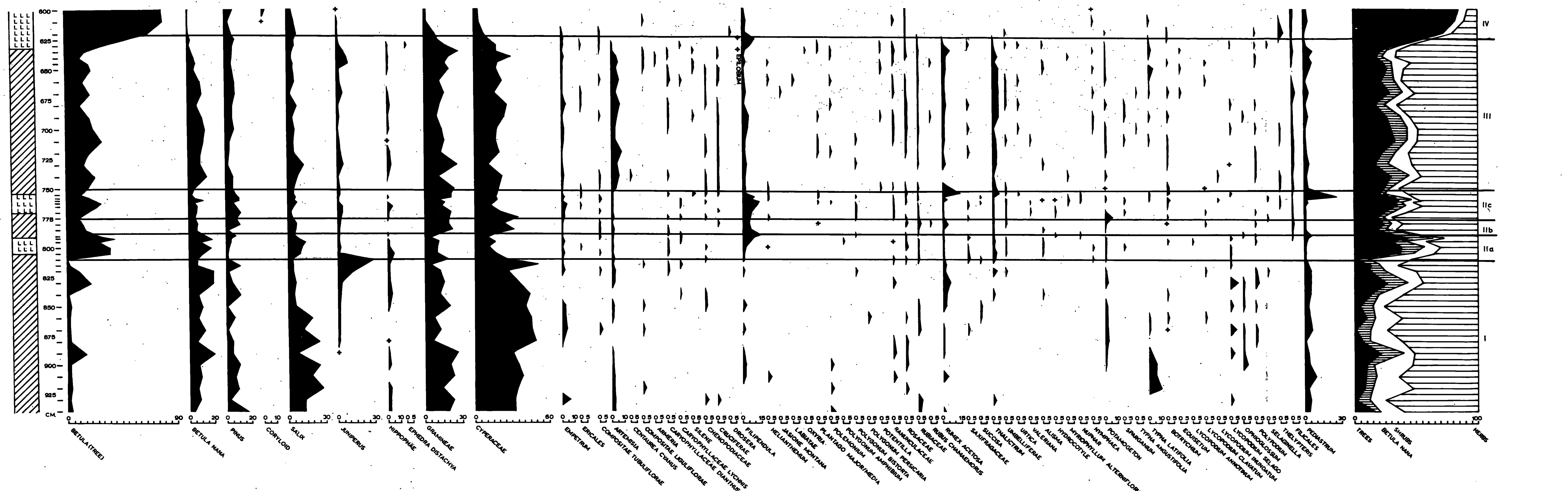
Zone II (810-750 cm.)

Can be sub-divided thus :-

IIa (810-788 cm.)

An overall rise in pollen frequency, also in the

SEAMER CARRS



PERCENTAGES OF TOTAL POLLEN

(R.L.J. 1970)

proportion of trees and shrubs to that of herbs. Tree birches comprise about 20% of the total pollen sum. Salix expands, Betula nana, Juniperus and Hippophae decline, so do Gramineae and Cyperaceae. Filipendula rises to about 10% of total pollen, Potamogeton and Pediastrum expand. Lycopodium annotinum recorded.

IIb (788-773 cm.)

Tree birches fall to about 15% of total pollen and Betula nana expands slightly, as do Juniperus and Hippophae near the upper sub-zone boundary. Gramineae and Cyperaceae re-expand, Filipendula declines but not to Zone I proportions. Rubus chamaemorus recorded.

IIc (773-750 cm.)

Arboreal pollen increases to 30% of total pollen. Tree birches expand along with Pinus. Betula nana, Juniperus, Hippophae, Gramineae, Cyperaceae and most herbs decline, but Filipendula increases sharply. Aquatics, especially Potamogeton, Sparganium and Typha latifolia expand, and Pediastrum increases. Lycopodium inundatum recorded.

Zone III (750-622 cm.)

Herbaceous dominance, but arboreal pollen remains about 20% of total pollen. Betula nana, Salix, Juniperus and Hippophae re-expand. Ephedra distachya recorded near the upper zone boundary, where Juniperus rises. Gramineae and Cyperaceae the dominant herbs, with Empetrum, Tubuliflorae, Artemisia, Caryophyllaceae, Cruciferae, Ranunculaceae, Rosaceae, Rumex, Thalictrum and Filipendula. Armeria, Epilobium, Drosera, Jasione montana, Polemonium and Rubus chamaemorus recorded. Pteridophytes expand. Aquatics present in small amounts.

The Post-Glacial Period (Figure 9)

The following zones and sub-zones are discernable :-

Zone IV (622-600 cm.)

Total pollen frequency increases, especially arboreal pollen, principally of Betula, with Pinus the only other tree present. Betula nana gradually declines to extinction. Non arboreal pollen frequency low, only Rosaceae retaining significant values. Aquatics and Pediastrum expand. Corylus appears near the upper zone boundary.

Zone V (600-562 cm.)

Lower zone boundary characterised by a massive increase in Corylus which soon attains 250% of total tree pollen values. Betula declines, but Pinus expands near the upper zone boundary. Ulmus and Quercus immigrate and begin a slow expansion. Herbs make up less than 10% of total pollen. Aquatics, especially Potamogeton and Nymphaea important, as are Filicales and Pediastrum.

Zone VI (562-370 cm.)

Can be sub-divided :-

VIa (562-506 cm.)

Betula dominant with Pinus expanding. Ulmus reaches 40% of total pollen, Quercus expands more slowly and Alnus first appears. Corylus values still exceed


C
B
VIIb + VIII
A
VIIa
VIc
VIb
VIa
V
IV
III
IIc
IIb
IIa
I
HERBS
SHRUBS
BETULA NANA
TREES
PERCENTAGES OF TOTAL POLLEN
PEDIASTRUM
SPHAGNUM
FILICALES
THELYPTERIS
SELAGINELLA
PTERIDIUM
POLYPODIUM
OPHIOGLOSSUM
LYCOPODIUM SELAGO
LYCOPODIUM CLAVATUM
LYCOPODIUM ANNOT
EQUISETUM
BOTRYCHIUM
UTRICULARIA
TYPHA LATIFOLIA
TYPHA ANGUSTIFOLIA
SPARGANIUM
POTAMOGETON
NYMPHAEA
NUPHAR
MYRIOPHYLLUM VERTIC
MYRIOPHYLLUM SPICAT
MYRIOPHYLLUM ALTER
MENYANTHES
HYDROCOTYLE
ALISMA
URTICA
UMBELLIFERAE
THALICTRUM
SUCCISA
SCROPHULARIACEAE
SAXIFRAGACEAE
RUMEX
RUMEX ACETOSA
RUBUS CHAMAEMORUS
RUBIACEAE
ROSACEAE
RANUNCULACEAE
POTENTILLA
POLEMONIUM
PLANTAGO MAJOR
PLANTAGO CORONOPUS
PLANTAGO LANCEOLATA
PRIMULACEAE
VICIA
LOTUS
ONONIS
PAPILIONACEAE
CYTISUS
GENTIANA
LABIATAE
KNAUTIA
JASIONE MONTANA
HUMULUS/CANNABIS
HELIANTHEMUM
FILIPENDULA
DROSERA
CRUCIFERAE
CIRCAEA
CHENOPODIACEAE
STELLARIA HOLOSTEA
SPERGULARIA
SILENE
CARYOPHYLLACEAE
ARMERIA
COMPOSITAE LIGULIFLORAE
CENTAUREA CYANUS
CIRSIUM
BIDENS
ARTEMISIA
COMPOSITAE TUBULIFLORAE
ERICALES
EMPETRUM
CALLUNA
CYPERACEAE
CEREALIA
GRAMINEAE
SORBUS
SAMBUCUS
LONICERA
VIBURNUM
HEDERA
ILEX
HIPPOPHAE
LITTORELLA
EPILOBIUM
FRANGULA

200% of the total tree pollen sum. Herbaceous values low. Myriophyllum alterniflorum, Sparganium, Potamogeton and Nymphaea dominate the aquatic components and Thelypteris and Filicales those of the pteridophytes. Hedera recorded.

VIb (506-444 cm.)

Betula and Pinus retain their VIa porportions but Quercus now exceeds Ulmus in frequency. Alnus expands slowly and Corylus remains impor tant. Herbaceous components low. Ilex recorded.

VIc (444-370 cm.)

Corylus falls and Betula and Pinus give way late in the sub-zone to a Quercus - Ulmus - Alnus dominated spectrum. Fraxinus first appears near the zone's conclusion. Lonicera recorded.

Zone VIIa (370-225 cm.)

Lower zone boundary characterised by a marked rise of Alnus. Betula and Pinus decline and Quercus, Ulmus and Alnus dominate, Tilia and Fraxinus accounting for about 10% of arboreal pollen. Corylus expands early on then declines. Aquatics well represented, especially Nymphaea, Myriophyllum spp., Typha spp. and Potamogeton. Filicales, especially Polypodium, abundant. Hedera recorded.

Zones VIIb and VIII (225-20 cm.)

The two main zones not separable, but the whole characterised by 3 sub-zones :-

Sub-Zone A (225-114 cm.)

A clear Ulmus fall marks its opehing followed by a recovery, *Tilia* follows a similar but less distinct pattern. *Fraxinus* expands and *Fagus* first appears. *Corylus* fluctuates. *Gramineae*, *Calluna*, *Tubuliflorae*, *Ranunculaceae* increase in frequency. *Plantago lanceolata* and *Rumex acetosa* first appear. *Sambucus* and *Sorbus* recorded.

Sub-Zone B (114-36 cm.)

Lower boundary marked by a secondary *Ulmus* decline, accompanied by a lesser one of *Tilia* which disappears temporarily near the upper boundary. Arboreal pollen decreases overall but *Fraxinus* expands. *Corylus* continues to fluctuate at fairly high values. *Calluna*, *Gramineae* and *Cyperaceae* expand, and *Cerealia* first appear and increase along with *Artemisia*, *Chenopodiaceae*, *Cruciferae*, *Plantago lanceolata*, *Caryophyllaceae* spp., *Potentilla*, *Ranunculaceae*, *Rosaceae*, *Rubiaceae*, *Rumex acetosa*, *Succisa*, *Umbelliferae* and *Urtica*. *Pteridium* and *Filicales* increase in value as does *Sphagnum*. *Plantago coronopus* and *Rubus chamaemorus* recorded.

Sub-Zone C (36-20 cm.)

Arboreal pollen by now only 10% of total pollen. Herbaceous dominance especially *Gramineae*, *Cerealia*, *Calluna*, *Ericales*, *Tubuliflorae*, *Liguliflorae*, *Dianthus*, *Lychnis*, *Plantago lanceolata*, *Filipendula*, *Potentilla*, *Ranunculaceae*, *Rosaceae*, *Rubiaceae*, *Rumex acetosa*, *Succisa* and *Urtica*. *Centaurea cyanus*, *Cirsium*, *Spergularia*, *Stellaria holostea*, *Humulus/Cannabis* and *Vicia* present. *Pteridium* reaches its maximum development. Aquatics and *Sphagnum* well represented.

The Development of the Mire System

The large, deep, steep-sided double basin which at present contains Seamer Carrs, contained a lake for much of their evolution. This lake had its origins at the melting of an ice block left after the retreat of the Weichselian ice from the Cleveland Plain. This ice block occupied and moulded the depression, which, when it melted, became a centre for a rapid accumulation of a considerable thickness of inorganic, fine pink clay, derived from the surrounding sands and gravels, by solifluction processes. At this time, the general instability and lack of vegetation cover on the surrounding slopes, was paralleled by a very impoverished lacustrine flora consisting mainly of _Potamogeton_ spp. with a fringing swamp comprising largely of grasses and sedges. A distinct environmental change is indicated by two layers of black organic mud separated by a mixed inorganic-organic facies, the pollen content indicating the presence of the Allerőd interstadial divisable into two phases of quite well developed wooded conditions around the sites, separated by one of a reversion to a minor solifluction phase. Throughout this period, however, the lake flora and the fringing swamps and fen was much more diversified. Pollen and macrofossil evidence shows that _Potamogeton_, _Alisma plantago-aquatica_, _Myriophyllum alterniflorum_, _Nymphaea_ and _Nuphar_ grew in the open water, with _Typha latifolia_, _Sparganium_, _Hydrocotyle_, _Filipendula_, _Thalictrum_, _Rubus chamaemorus_ joining _Gramineae_, _Cyperaceae_ and _Salix_ in the fringing complex, where hypnoid mosses also found a suitable habitat.

The coarse sandy clay overlying the organic mud is the product of another phase of solifluction and referable by its pollen content to Zone III. In spite of a reversion to quite treeless conditions in the landscape, the lake and its surrounds appear to have maintained a fairly consistent base-rich flora, but Gramineae and Cyperaceae came to dominate once again along with dwarf pteridophytes in the swamps. Bryophytes flourished here also, particularly late in the period; no doubt the constant supply of freshly eroded inorganic matter, rich in bases, was a good substrate for their development. A gradual cessation of solifluction is suggested by the overlying deposit, a clay-mud with appreciable organic matter, especially sedges, Juncus and bryophytes, laid down at around the opening of the Post-glacial period, over much of the lake bed, except in those areas near the gravel ridge where then, and for a good deal of succeeding Post-glacial time, somewhat different conditions existed. Here, a quite pure shell marl was deposited in the shallower water which must have existed near the barrier. Over the majority of the basin, during the greater part of the Post-glacial, extensive deposits of a fine detritus mud were formed, in which there are few plant remains, suggesting a deep water origin in a lake which still had no major outward drainage. Of the minute organisms there is a continuous record for Chara spp. and Pediastrum, and a wider range of floating and submerged aquatic pollen types are present. The densely forested landscape around wouldhave been reached from the open water through a quite luxuriant fringing swamp and fen-carr where Phragmites, Carex, Schoenoplectus lacustris, Sparganium, bryophytes, Thelypteris, Salix, Betula and Alnus flourished, without making any appreciable reductions in the extent of the lake right through the climatic optimum and well into Zone VIIb. The effects of human activity were already being shown in the pollen diagram when a quite distinct change in the environment took place. The water level was reduced, and a Phragmites dominated reedswamp covered much of the former lake area. Bryophytes of the rich fen variety (Acrocladium, Aulacomnium, Cratoneuron, Scorpidium, Drepanocladus, Dicranum, as well as Sphagnum plumulosum and Sphagnum tenellum) were abundant around the fringes, where fen-carr also expanded somewhat, but never managed to colonise the whole mire. Recent drainage and agricultural operations have made the succession above this very difficult to elucidate. A layer of colluvium has been deposited from the surrounding slopes on the south and east of the Carrs, presumably as a result of anthropogenic activity in fairly recent times, and remnants of Juncus in the southern part of the north-south 'arm' of the deposit, suggest that when they were finally reclaimed they were primarily a fairly base-rich reedswamp, with some areas of well developed fen carr at its margins, all of which has now disappeared.

Vegetational History in the Seamer Area

The earliest pollen assemblages for Seamer Carrs represent Zone I of the Late-glacial period, when the majority of the land vegetation was of a very open nature and consisted of unstable communities of dwarf shrubs and herbs. Trees were of minor importance, only Betula and Pinus existed, both in very low frequencies, and the latter probably the result of transport from distance, where pine was already established. (There is no evidence, either biological or climatic, to indicate that Pinus could have existed in north-east Yorkshire at this time). Of the shrubs Betula nana, Salix, and later on, Juniperus and Hippophäe (probably present throughout, but unable to flower due to snow patches (Iversen, 1954) until later in the period), were most important. Herbs were dominated by Gramineae, Cyperaceae, Empetrum, Artemisia and Rumex acetosa. A variety of dampland and dryland habitats must have existed, with dwarf pteridophytes also well represented on the unstable spreads of fluvioglacial material and Boulder Clay in the Cleveland Plain which were being subjected to fairly severe periglacial action at this time.

The first significant change in vegetational composition occurred in Zone IIa, when, after a sharp increase in the amounts of Juniperus and Hippophäe tree birches expanded, along with Filipendula (regarded by Iversen (1954) as indicating an increase in temperature in Late-glacial times). Herbaceous plants still retained a major importance however, with an overall more complete development than in Zone I, accentuated in Zone IIb by a very slight recession in tree development due to some retrogressive local or regional factors of the environment. Juniperus and Hippophäe showed increased development after this interruption to the interstadial succession, as did Filipendula, and they were followed by a further extension of trees, principally Betula, but now perhaps some Pinus also. The overall mosaic of vegetation must have been something akin to Iversen's (1954) conception of 'park-tundra', with scattered patches of tree birches and a large expanse of quite luxuriant herbaceous and shrub vegetation, occupying the localities around the lakes and fringing swamps, most suited to them, where organic deposits were being formed.

Zone III saw a reversion to something like the vegetation which existed in Zone I. Herbs and shrubs once more achieved dominance but trees did not recede to their almost non-existent earlier status. Open conditions with unstable soils and equally varied and unstable plant communities once more were present. Dwarf shrub-heath, with Betula nana, Juniperus, Hippophae and Empetrum appears to have been widespread. The steppe like character of the environment is indicated by the presence of Ephedra distachya (Gams, 1927); Polemonium and Helianthemum illustrating the presence of base rich fresh soil conditions produced by the solifluction processes.

The cessation of Late-glacial time, with the ending of mass-movement and commencement of organic matter accumulation on land was once more preceded by an expansion of Juniperus, Hippophae and Filipendula in response to a climatic amelioration. Trees now colonised the open landscape with some rapidity, especially Betula, but there must have been some areas where habitats remained much as they had done in Zone III, if perhaps more fully developed. Pinus was also present in small amounts at this early Post-glacial stage, its consistent curves suggesting that here at least it was now probably a genuine component of the vegetation rather than a long distance intruder, most likely confined to sandier soils, of which there would have been plenty in the Cleveland lowland at this time. Zone V saw this development of birch forests joined by a massive extension of Corylus which must have found an abundance of suitable habitats to colonise, which birch had not already covered. It was joined soon by Ulmus and Quercus, which too expanded into favoured localities, indicating that there were expanses of base-rich soils available on the boulder clay areas. The open conditions of Zone IV must by now have been severely reduced, with only the areas fringing the mires remaining as such. The development of a mixed deciduous forest continued throughout Boreal time, with Ulmus making up a very high proportion of it in this area. Pinus increased in value during Zone VI, but did not achieve dominance, though Corylus was important in the vegetation cover. Towards the close of Boreal time, Quercus, Ulmus and an ever increasing proportion of Alnus dominated the forest components. Fraxinus and Tilia immigrated, and found restricted but suitable places in which to become established and begin a steady expansion. The Atlantic period (Zone VIIa) opened with Alnus reaching a maximum of extension, (due presumably to an increase in precipitation about this time), and a corresponding rise in the water tables, especially in the stream and lakeside habitats. The other deciduous forest components expanded quite fully throughout the period of the climatic optimum leaving only the immediate surroundings of the mires as open habitats.

Zones VIIb and VIII saw the initiation of the first major changes in vegetational composition since the end of the Late-glacial period. It is divisible into three main sub-zones, each with rather similar characteristics. The first changes occurred soon after the start of Sub-Zone A when certain tree species, notably _Ulmus_ and _Tilia_ were reduced in amount, to recover later, with _Fagus_ first entering, and _Fraxinus_ expanding in the arboreal sector. This was accompanied by the reappearance in small quantities of open habitat plants, such as _Gramineae_, and _Calluna_, and the first appearance of _Plantago lanceolata_, suggesting a shift in the ecological balance and openings, albeit temporary, of the forest cover, presumably under human influences. A main factor of this period was, in spite of a small decrease in tree cover, the regenerative power of many of the tree species. It was left to a second decrease in _Ulmus_ and _Tilia_, marking the opening of the second Sub-Zone, B, to signify the commencement of the first lasting clearances of trees. Although phases of regeneration are shown, there was a more widespread general decline of trees, with shrubs also beginning to be affected, and open habitat types (weeds or clearance indicators) showing sustained expansions into cleared areas. Cereal pollen, mainly _Triticum dicoccum_ and _Hordeum_ is first recorded, and weeds of both arable and pastoral agricultural practices, (such as _Plantago lanceolata_, _Artemisia_, _Chenopodiaceae_, _Cruciferae_, _Rumex acetosa_, as well as _Gramineae_, _Calluna_ and _Pteridium_) show that increasing acreages were being given over to either crop production, pasture or being left fallow or waste, with tree regeneration reduced, and a more open landscape resulting though in a somewhat fluctuating state. Sub-Zone C shows that the activities being carried on in late B were intensified, with further indications of agricultural activity in the expansion of cereals, now mainly Hordeum and Secale, and the occurrence of Centaurea cyanus, Spergularia, Humulus-Cannabis T. and Cirsium. Pastoral activity, with Plantago lanceolata, Pteridium and Gramineae, is also indicated, and Calluna expansions suggests that trees and shrubs, by now quite drastically reduced in extent, were to some degree even in the lowland, replaced by a form of heath association.

3.2 Stratigraphy and Pollen Analysis at Kildale Hall

The Kildale Hall site (NZ 609097) is situated near the village of Kildale, and is about 100 metres north of Kildale Hall, and between it and the River Leven. It is about 13 kilometres (8 miles) east of Seamer Carrs, and 3 kilometres (1½ miles), west of West House (Figure 1) (Plate 2).

Topography

Cameron (1878) described a peat deposit exposed in a railway cutting close to Kildale Station. It was circular in shape, 4.3 metres (14 feet) at its maximum thickness, thinning in all directions. It was a tough pale brown wood peat from the lower part of which remains of Rangifer tarandus (Reindeer) and Cervus elaphus (Red deer) were recorded. Beneath the peat was a sandy underclay about 60 cm. thick (2 feet), the base of the section being formed by 4.6 metres (15 feet) of

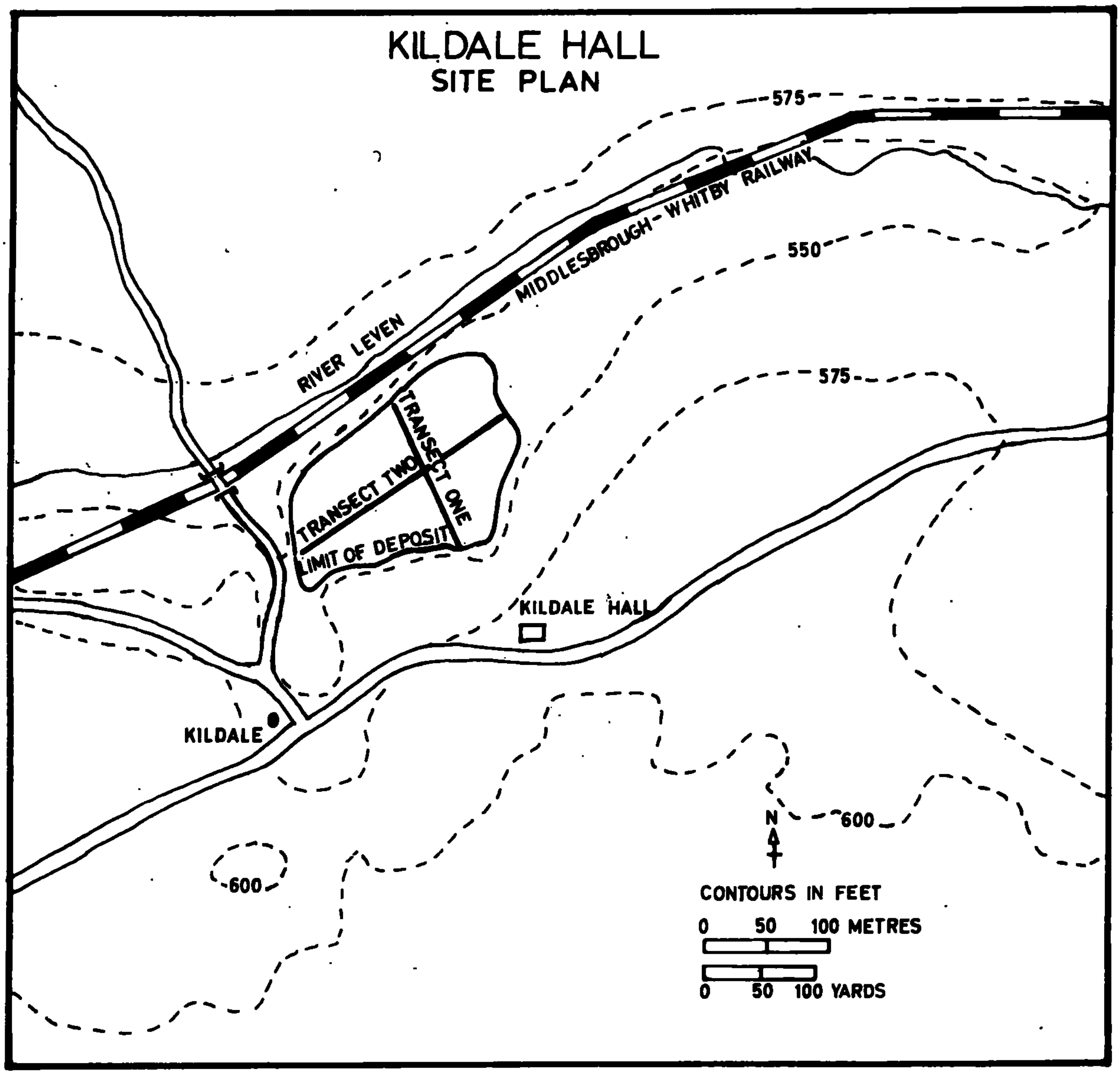

KILDALE HALL
SITE PLAN
575
RIVER LEVEN
MIDDLESBROUGH - WHITBY RAILWAY
550
575
TRANSECT ONE
TRANSECT TWO
LIMIT OF DEPOSIT
KILDALE HALL
KILDALE
N
600
600
CONTOURS IN FEET
0 50 100 METRES
0 50 100 YARDS

FIGURE 10

pale marly sand with abundant mollusca remains, the whole deposit resting on the Middle Glacial Sands. Cameron concluded that the deposit was not of any great antiquity and was probably connected with the moat of the old castle which formerly stood nearby.

Barrow, in the North Cleveland Geological Memoir, (1888), regarded the Kildale section as, "perhaps the most interesting peat deposit in the district", (p. 73) A large hollow in the Middle Glacial Gravels was stated to contain a calcareous marl formed in the bottom of a hollow by the growth and decay of Chara, and mollusca such as Planorbis nautileus, Limnea peregra and Psidium pusillum. Above this was a sandy underclay overlain by 4.3 metres (14 feet) of peat, from the lower parts of the latter antlers of Reindeer and Red-deer were obtained.

Hawell (1900) discussed the Kildale deposit in relation to one at Stokesley, on the bank of the River Leven, 10 kilometres (6 miles) to the west. A similar stratigraphy was recorded and the conclusion that a small tarn of relatively recent age had existed there, surrounded by "scanty forest growth".

Erdtman (1927, 1928) in his study of the Cleveland Peat Deposits, referred to a deposit at Kildale from which faunal remains had been recovered, and which lay on a moraine. According to Frank Elgee, who assisted him, "it could no longer be observed in its entirety", however.

In 1968 during field drainage operations on an area of damp pastureland to the north of Kildale Hall, peaty marl was brought to the surface by excavators,

THE KILDALE HALL SITE LOOKING EASTWARDS TOWARDS THE HEAD OF KILDALE

PLATE 2

and the skull, a horn and a part skeleton of an animal was discovered embedded in it. Subsequent systematic investigations revealed more scattered disarticulated bones of the same animal. The whole assemblage has been identified by Mr. R.H. Hayes of Hutton le Hole, and Mr. R. Close of Baysdale as a specimen of Bos primigenius.

The area of the finds must be close to the deposits described by Cameron et al., yet on superficial examination there was no trace of them. Glacial deposits fill this part of Kildale, overlying Liassic Shales. They are associated just to the west of the village with a morainic complex (Kendall, 1902, 1903. Gregory, 1962). Kendall regarded the Kildale moraine as marking the maximum inward limit of the Vale of York ice in the glaciation of the area. Behind this moraine, a pro-glacial lake was formed, extending through to Lealholm, where another moraine marked the eastward limit of the coastal ice into Eskdale, and impounded the lake. At some stage, a barrier was formed at West House, with Lake Kildale between the Kildale moraine and the West House watershed, and Lake Eskdale between West House and the Lealholm moraine. Gregory rejected these hypotheses on the grounds that a number of features in Kildale can be interpreted as sub-glacial rather than sub-aerial in origin. The Vale of York ice got up to 305 metres (1,000 feet) O.D. on the flanks of the Cleveland escarpment, and as far south as York and Escrick; it is almost certain therefore to have gone through Eskdale. Gregory's Escrick limit is a moraine near Castleton 10 kilometres (6 miles) east of Kildale, and he regards the Kildale complex equivalent to the York moraine stage. The recession to Kildale of the Eskdale ice led to the formation of a moraine at the margin of the active ice in the Vale of York. The deposits described, and sought, must have occupied a kettle-hole in this complex, perhaps dissected by railway building when the geological surveyors were working in the area.

Stratigraphy

The vegetation of the area gave no indication as to the present or former existence of large scale organic deposits, being mainly improved pastureland.

In the area around Kildale Hall, two levelled transects of borings were made, intersecting as shown (Figures 10 and 11). A north-south line through the area of bone finds, revealed little more than could be seen in the drainage ditches; Basal sands and gravels overlain by 10-15 cm. of tenacious dark blue clay, followed by 30 cm. of well humified compact, silty, *Carex* peat (in the upper layers of which the bones were found), are succeeded by 25 cm. of very impure peaty marl, and 20 cm. of *Carex* peat with wood remains. The highest undisturbed horizon consists of about 50 cm. of tough wood peat with abundant *Betula* and *Pinus* fragments, the top 25 cm. or so having been subjected to drainage, peat cutting and cultivation for a large number of years.

A transect from west to east revealed the same stratigraphic detail for 50 metres from the most westerly boring, and 80 metres from the most easterly one. Intervening, there are 30 metres which provide a quite remarkable contrast, however. Here, the upper

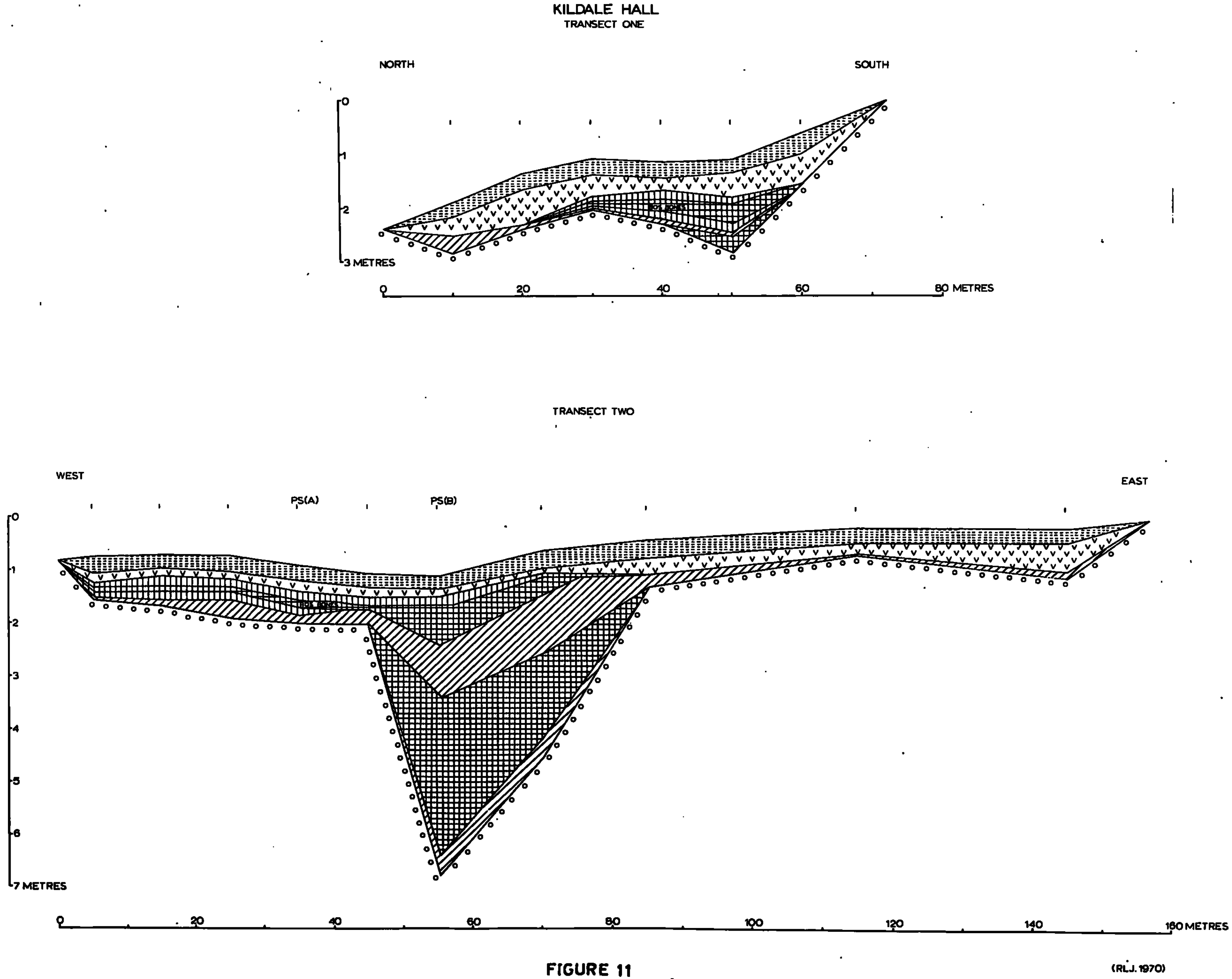

KILDALE HALL
TRANSECT ONE
NORTH
SOUTH
0
1
2
3 METRES
0
20
40
60
80 METRES
TRANSECT TWO
WEST
EAST
PS(A)
PS(B)
0
1
2
3
4
5
6
7 METRES
0
20
40
60
80
100
120
140
160 METRES
(RLJ. 1970)

FIGURE 11

limit of the basal sands and gravels falls very steeply, from about 1.5 metres below the surface, to nearly 6 metres below. In the small, deep, steep-sided hollow thus formed, a succession of the following is encountered. Approximately 40 cm. of very stiff, silty clay, grey in colour, is overlain by up to 3 metres of wet, pure, cream-coloured calcareous marl with mollusca and bryophyte remains. This is covered by about a metre of stiff, silty grey clay and succeeded by a stratigraphy almost identical in type and thickness to that described for the area around this depression.

The maximum depth of deposits encountered at this site was 5.45 metres (17.5 feet). It cannot be the one described by Cameron et al., because a ridge of sand and gravel exists between it and the railway; but its overall dimensions, and thicknesses of the clays and marl, are very similar to those enumerated in the early literature.

Pollen and Macrofossil Analysis and Chronology

Samples for pollen and macrofossil analysis were collected from Site (A) in 1968 and from Site (B) in 1970.

The stratigraphy appropriate to the pollen diagram for Site (A) is :-

0-30 cm. Disturbed sediment.

30-53 cm. Compact, tough, mid-brown wood peat with abundant remains of Betula and Pinus. Carex remains throughout. Leaves of Sphagnum papillosum 35-53 cm., S. cuspidatum at 40 cm., S. teres 50-53 cm.

53-65 cm. Well humified dark brown Carex peat with Molinia stems. Sporangia of Thelypteris sp. at 56 cm.

Leaves of Sphagnum rubellum 56-59 cm., S. papillosum at 56 cm. Occasional fragments of Betula.

65-82 cm. Impure peaty marl, slightly calcareous, with Carex and Molinia remains, diatomaceous spicules and mollusca fragments. Leaves of Sphagnum papillosum 68-71 cm.

82-98 cm. Very well humified Carex peat with silt, especially in the last 10 cm. Skeleton of Bos primigenius 82-85 cm. Charcoal, (probably Betula and Ericales), 82-90 cm.

98-106 cm. Tenacious, silty grey clay with some Cyperaceae remains.

106 cm. + Sands and gravels.

The stratigraphy corresponding to Site (B) indicates :-

0-25 cm. Disturbed sediment.

25-45 cm. Compact, tough, mid-brown wood peat with abundant remains of Betula and Pinus. Carex stems and Sphagnum papillosum leaves abundant.

45-58 cm. Well humified dark brown Carex peat with some Eriophorum vaginatum. Leaves of Sphagnum papillosum and S. teres at 55 cm.

58-138 cm. Impure peaty marl, with Carex spp., Chara oospores and mollusca fragments. Leaves of Sphagnum papillosum, S. plumulosum, S. teres, and Camptothecium nitens 60-75 cm.

138-190 cm. Stiff, silty grey clay with occasional Chara oospores and twigs of Ericaceae.

190-496 cm. Pure, soft, wet, yellow calcareous marl. Mollusca remains, bryophytes and Chara oospores throughout. Leaves of Sphagnum teres at 220, 260 and 300 cm., Paludella squarrosa at 260 cm., Camptothecium nitens at

220-460 cm., *Acrocladium giganteum* at 260 cm. *A. cuspidatum* at 300 cm., *Drepanocladus aduncus* at 300 cm., *Cratoneuron commutatum* at 300 and 480 cm. *Campylium stellatum* 400-490 cm. Silt 320-390 cm.

496-545 cm. Tenacious silty grey clay with angular stones. Occasional *Carex* fragments.

545 cm. + Sands and gravels.

The pollen diagram for Kildale Hall (A) site is based on a total tree pollen sum (Figure 12) and indicates that the following zones are present :-

Zone IV (97-85 cm.)

Herbaceous and shrub dominance; with only 15% of arboreal pollen, *Pinus* and *Betula* only representing the tree component early in the zone. Near its conclusion *Ulmus* and *Quercus* are found and *Corylus* first appears. *Salix*, *Gramineae*, *Cyperaceae*, *Empetrum*, *Tubuliflorae*, *Liguliflorae*, *Filipendula*, *Rosaceae* and *Rubiaceae* have high values throughout and *Rumex acetosa*, *Ranunculaceae* and *Succisa* later in the zone. *Potamogeton*, *Sparganium*, *Lycopodium clavatum*, *Polypodium*, *Thelypteris* and *Filicales* present. A Radiocarbon date for the peat encasing part of the *Bos* skeleton (at 84 cm., the level at which the Zone IV/V boundary occurs), yielded 10,350 ± 200 B.P : 8,400 ± 200 B.C (Gak - 2707).

Zone V (85-64 cm.)

Near the lower zone boundary a rise in arboreal pollen frequency occurs, *Pinus* declines with *Betula* becoming dominant. Throughout, fluctuations take place with *Pinus* and later *Betula* increasing in importance. *Ulmus*, *Quercus* and *Corylus* expand slowly, *Salix* values

SALIX
HEDERA
GRAMINEAE
CYPERACEAE
CALLUNA
EMPETRUM
COMPOSITAE TUBULIFLORAE
ARTEMISIA
COMPOSITAE LIGULIFLORAE
CARYOPHYLLACEAE
FILIPENDULA
MELAMPYRUM
RANUNCULACEAE
ROSACEAE
RUBIACEAE
RUMEX ACETOSA
SAXIFRAGACEAE
SUCCISA
UMBELLIFERAE
POTAMOGETON
SPARGANIUM
BOTRYCHIUM
LYCOPODIUM CLAVATUM
POLYPODIUM
PTERIDIUM
THELYPTERIS
FILICALES
SPHAGNUM
TREES
SHRUBS
HERBS
VIIa
VIc
VIb
VIa
V
IV
PERCENTAGES OF TOTAL POLLEN

high, but non arboreal pollen declines generally. Early in the zone Gramineae, Cyperaceae, Empetrum, Artemisia, Filipendula, Umbelliferae and Rosaceae important and Melampyrum recorded. High values of Thelypteris and Filicales.

Zone VI (64-30 cm.)

Can be sub-divided :-

VIa(64-47 cm.)

At the lower boundary Betula falls and Pinus expands ~~together with Corylus~~. Salix declines but later re-expands together with Gramineae, Cyperaceae and Filicales. Hedera recorded.

VIb (47-35 cm.)

Pinus - Corylus dominance. Quercus and Ulmus increase, Betula declines. Alnus, Fraxinus and Tilia immigrate. Salix and other non arboreal pollen decline except for Rosaceae, Tubuliflorae and Umbelliferae. Calluna recorded. Trees and shrubs account for 85% of the total pollen sum.

VIc (35-30 cm.)

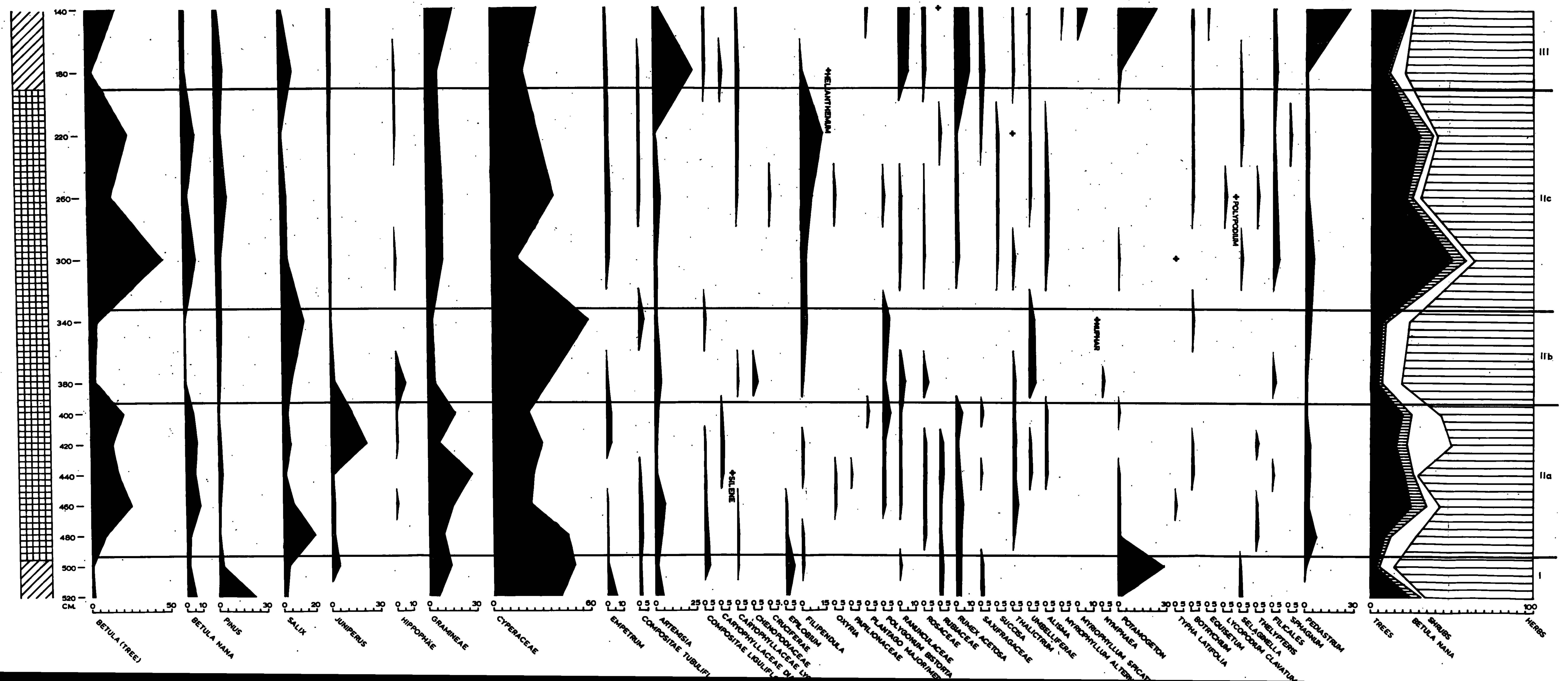
Pinus declines, Quercus, Ulmus, Alnus, Tilia and Fraxinus expand, and trees assume dominance.

Zone VIIa (30-28 cm.)

Lower zone boundary marked by an Alnus rise and a decline of Pinus and Betula, a Quercus dominated spectrum taking over.

Kildale Hall (B) covers the Late-glacial period and is based on a total pollen sum (Figure 13). The following

KILDALE HALL (B)



zonation is suggested :-

Zone I (520-496 cm.)

Herbaceous dominance. Betula and Pinus the only arboreal pollen. Betula nana present, Juniperus appears and expands near the upper zone boundary. Gramineae, Cyperaceae, Empetrum, Artemisia, Epilobium, Rubiaceae, Rumex acetosa and Saxifragaceae constitute the majority of the herbs. Selaginella recorded. Potamogeton and Pediastrum expand near conclusion of zone.

Zone II (496-190 cm.)

Can be sub-divided :-

IIa (496-395 cm.)

Increase in total pollen frequency, especially of tree birches. Pinus and Betula nana decline. Arboreal pollen about 25% of total pollen. Juniperus declines then expands again, Salix showing an opposite trend. Hippophae recorded. Herbs of Zone I generally decline but Gramineae values remain high. Filipendula, Polygonum bistorta, Alisma, Typha latifolia, Botrychium and Thelypteris recorded. Pediastrum expands.

IIb (395-335 cm.)

A slight fall in arboreal pollen. Salix re-expands, Juniperus continues at quite high values then declines. Hippophae increases. Herbs comprise 70% of total pollen with Cyperaceae, Empetrum, Artemisia, Tubuliflorae, Lychnis, Dianthus, Chenopodiaceae, Rosaceae and Umbelliferae dominant. Nuphar and Nymphaea recorded.

IIc (335-190 cm.)

A rise in total pollen frequency with arboreal pollen about 50% of the sum. Betula most important. Pinus increases also. Salix, Juniperus and Hippophae decline, Filipendula expands but most herbs show reduced frequencies. Succisa recorded. Selaginella, Equisetum, Lycopodium clavatum and Polypodium important pteridophytes. Alisma and Potamogeton dominate the aquatic component.

Zone III (190-140 cm.)

The opening of the zone marked by a drop in arboreal pollen and an increase of Betula nana, Juniperus, Salix and Hippophae. Gramineae and Cyperaceae dominate the herbs, while Empetrum, Artemisia, Tubuliflorae, Ranunculaceae, Rumex acetosa, Saxifragaceae and Thalictrum occur frequently. Helianthemum recorded. Aquatics expand near the upper boundary. Botrychium, Selaginella and Filicales important pteridophytes.

The Development of the Mire System

The mire system at Kildale Hall originated in a kettle hole, formed by the melting out of an ice block of Weichselian age, embedded in the fluvioglacial gravels filling this part of Kildale. In the deep, but quite small hollow thus formed, the first deposit, a stiff, dark grey clay was the result of the extensive, and intensive, solifluction processes operating immediately after deglaciation. The landscape around the kettle hole(s), containing open water and a poor lacustrine flora (Potamogeton is the only aquatic in the Zone I pollen record), consisted of some fairly poor swamp species, dominated by grasses and sedges, but with some Filipendula, Epilobium and Salix. This lasted until the climatic oscillation of the Allerød interstadial, when a distinct environmental change for the area is recorded in the depositional sequence. The warmer climate led to the formation in the lake of a very base-rich marl, with abundant Chara, Pediastrum and mollusca. The lake was fed by springs and base rich ground water from the glacial deposits, the deposition was rapid and in quite deep water. Apart from a more active lacustrine environment, pollen of Numphaea, Nuphar, Alisma plantago-aquatica and Potamogeton indicate a richer flora; and of Typha latifolia, Polygonum bistorta, Filipendula, Epilobium, Thelypteris, Lychnis flos-cuculi, Umbelliferae, Thalictrum, Succisa and Equisetum, a more varied reedswamp and fen community, to which Salix and perhaps even Betula contributed, along with the rich fen mosses, Paludella squarrosa, Camptothecium nitens, Cratoneuron commutatum, Campylium stellatum and Acrocladium cuspidatum. A minor change in the succession was effected in mid-zone II, when more silt was washed into the basin, presumably a result of the slight fluctuation of the climatic factors back towards a cooler environment. This, however, was only a temporary feature, and did not really affect much, the rather luxuriant lacustrine, and extremely open fringing vegetation types, which quickly recovered. This recovery was fairly short lived though, and a second, tenacious, silty clay containing Carex and ericaceous fragments illustrates the effects of the Zone III cold period on the mire system. The clay, again a product of solifluction, accumulated over the whole area, especially in the deeper hollows, sealing off the marl;

its thickness and composition indicative of the effectiveness of the periglacial action, in what is known to be a relatively short chronological period (Godwin, 1956). The vegetation returned to something akin to that of Zone I, with grasses and sedges, accompanied mainly by Thalictrum and isolated occurrences of Salix dominating. The cessation of solifluction, and the opening of the Post-glacial, saw organic matter accumulate once again, especially at the lake site, where a marl began to form. The impurity of this with much Carex, Sphagnum and fragmentary mullusca remains, suggest a much less effective lake system, more likely an ill drained swamp, though Pediastrum, Potamogeton and Myriophyllum pollen increase in amounts, implying that there were still some patches of open water. Reedswamp, dominated by Sparganium, and fen, with Salix, Thelypteris, Filipendula, Umbelliferae, Lycopodium clavatum and Lychnis were present, and the expanding Boreal forests of birch and pine, began to encroach at its margins. The essential feature though was the openness of the site, which no doubt influenced the presence of a skeleton of Bos primigenius and associated charred wood within the marl - silty peat complex; and from the encasing material of which, a Radiocarbon date of 8,400 B.C. was obtained. It seems highly likely, that at this time, the Kildale site was an ideal feeding and watering place for such animals, (the remains of a Reindeer and a Red deer have been recovered from the upper clay and marl interface), and a focal point for the people who hunted them in Boreal times. This hydroseral stage existed, with minor modifications, (mainly an expansion of shrubs and trees adjacent to the lake site), until late Boreal time, when quite suddenly, the lake dried up, passing from a silty sedge deposit, to an environment where trees, principally *Betula*, *Pinus*, and later *Alnus*, established themselves, towards the time of the Boreal/Atlantic transition. At this time (shown by the rapid rise of the *Alnus* curve to a maximum on the pollen diagram), woodland occupied the area, with some development of sedges and bryophytes within it. An abrupt truncation of the deposits at this level, due to peat cutting and cultivation, leaves no conclusive evidence as to whether the mire developed beyond a fairly basic, fen-carr wood stage, into a raised bog community. In view of the widespread occurrence of the thin wood peat, it is perhaps unlikely, because a massive removal would have been needed over a large area, to reduce it to its present, quite uniform characteristics, near the surface. It is more likely that the damp fen woodland itself was cleared, by later prehistoric and historic man, and cutting has been confined to small areas in relatively recent time, for domestic uses.

Vegetational History in the Kildale Area

The lowest levels from the Kildale mire have a pollen flora which indicates an early Late-glacial landscape, with well over 80% of it covered by dwarf shrub and heath, dominated by *Betula nana*, *Salix* and *Empetrum*. The general environment seems to have been unstable, with a variety of changing plant communities occupying the spreads of sand and gravel, themselves subjected to extensive mass movements. *Gramineae* and *Cyperaceae* were important constituents of the vegetation and towards the conclusion of the zone, Juniperus and Hippophae spread quite rapidly, before the first major changes in the plant cover were initiated. Tree birches now colonised the area in some quantity, with the shrub and heath communities of Zone I being slightly reduced in extent, but still important. Those parts of them which could withstand some shade and higher temperatures attaining a more luxuriant development, for example, Filipendula. This development was maintained throughout Zone II, but especially at the commencement (IIa) and conclusion (IIc) of the period. The intervening phase (IIb) saw a slight recession in the build up of a 'park-tundra' landscape (Iversen, 1954), when a small environmental change led to a minor decrease in trees and a corresponding spreading of shrubs and herbs. This was short-lived, however, and the last part of the Alleröd saw a reasonable tree cover in the form of copses of birch and perhaps even isolated occurrences of pine in favoured localities; a contrast to Zone I where trees were virtually absent, and Pinus though present in the pollen record was in all probability not growing in the area.

Zone III conditions were quite different. Now, shrubs and herbaceous communities regained dominance over most of the area, though trees did not fall to their almost non-existent Zone I proportions. Open swards of Gramineae, Artemisia and Empetrum on the drier slopes, and Betula nana, Salix, Cyperaceae and Thalictrum in the damper situations were widespread. Helianthemum was present, indicating abundant base-rich habitats, the fresh soils being a consequence of the solifluction processes operating at the time, and moving inorganic and organic material into the basins. The opening of the Post-glacial period, marked by a cessation of solifluction and organic matter accumulation in the stratigraphic record, and accompanied by a radiocarbon date of 8,400 B.C. (Gak-2707) for late Pre-boreal time, did not seem to have the conventional effects of rapid tree colonisation in the Kildale area. While the shrubs and herbs characteristic of the Late-glacial period contracted somewhat in extent, (particularly *Betula nana*, *Juniperus* and *Hippophae* which disappeared, and *Artemisia* and *Rumex acetosa* which declined), others expanded to form what must have been a local, quite luxuriant heath vegetation dominated by *Empetrum* *Gramineae* and *Rosaceae*. Trees accounted for under 20% of the vegetation cover, in spite of the presence of both *Betula* and *Pinus*, and the immigration of *Ulmus*, *Quercus* and *Corylus*, none of which could make great inroads into the open conditions. Such situations were no doubt favourable for the congregation of the Reindeer (*Rangifer tarandus*), Red deer (*Cervus* ~~alces~~ elaphus) and the Aurochs (*Bos primigenius*), as feeding and watering places. Remains of all have been found at the Kildale site, and their feeding habits, and the practices of their pursuing hunters may have contributed to the maintenance of these open conditions.

Whatever factors were responsible for such conditions, they were not able to keep pace with ecological succession for long. The later Boreal period, V and VI, saw a distinct increase in tree cover.

First Betula, with Quercus, Ulmus and Corylus playing a subsidiary role, and then Pinus and Corylus dominated the landscape. Tilia and Fraxinus managed to colonise some areas, but did not contribute greatly to the composition of the forests at this time. Minor incursions of heath plants suggest that perhaps some sporadic activities were still being carried out around the lake site, which did not dry up until the late Boreal period.

The opening of Atlantic time was marked by a further major change in the pattern of forest growth, but not in its percentage cover, which continued to increase steadily. Now Alnus, which immigrated in the Boreal, expanded sharply, and Quercus, Ulmus, Betula, Tilia and Fraxinus formed a mixed deciduous forest in place of a predominantly coniferous one, Pinus declining quickly and Corylus having reduced representation. This persisted towards the 'climatic optimum' of Zone VIIa, the deposits of and above which were not available for analysis, due to removal or cessation of bog growth at the site.

3.3 Stratigraphy and Pollen Analysis at West House

West House Peat Carr (NZ 634196), lies on the watershed between Kildale and Sleddale, about 6 kilometres (4 miles) south-west of Ewe Crag Slack, at a height of 178 metres (585 feet) O.D. Its overall dimensions are approximately 200 metres (north-south) by 450 metres (west-east), with the shape of an elongated oval (Figure 1) (Plate 3).

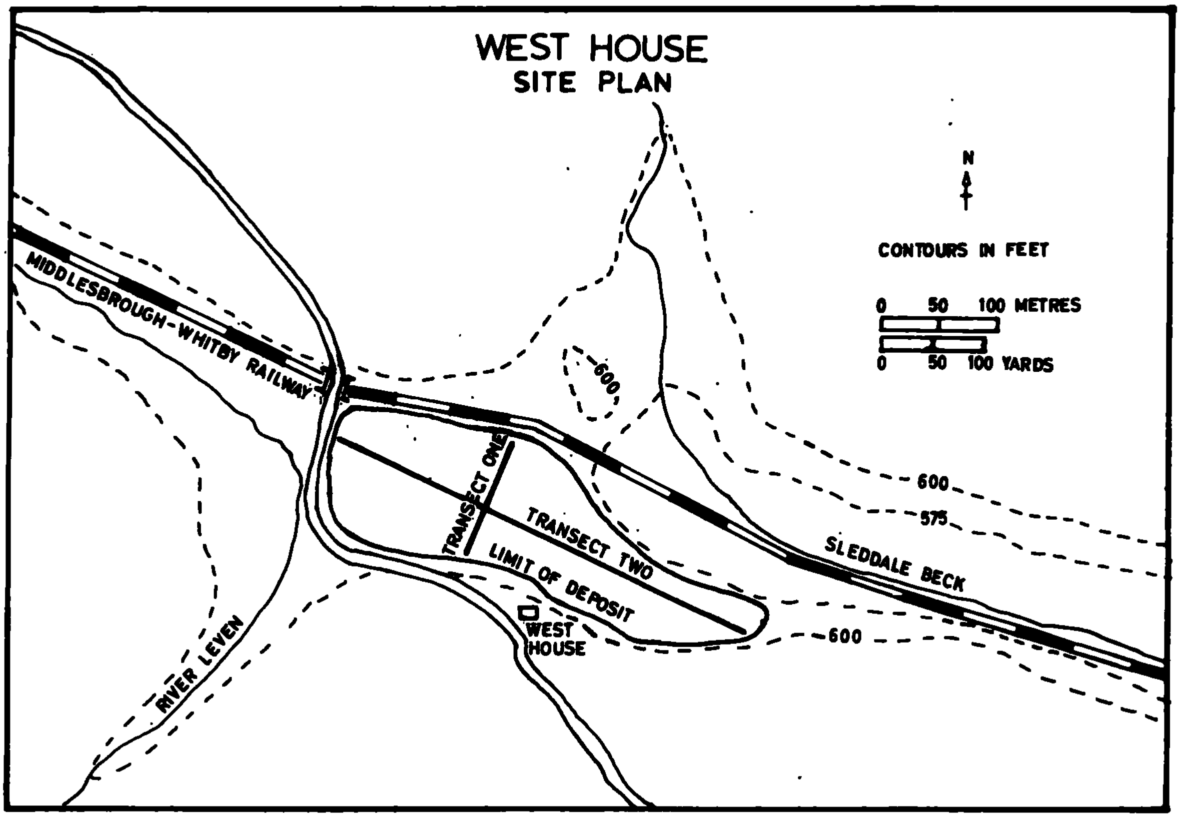

WEST HOUSE
SITE PLAN
N
CONTOURS IN FEET
0 50 100 METRES
0 50 100 YARDS
MIDDLESBROUGH-WHITBY RAILWAY
600
TRANSECT ONE
TRANSECT TWO
LIMIT OF DEPOSIT
WEST HOUSE
600
575
600
SLEDDALE BECK
RIVER LEVEN

FIGURE 14

Topography

The nature and origin of the West House watershed was first discussed by Kendall (1902, 1903), later being reaffirmed, (Kendall and Wroot, 1924). The broad, flat, peat covered area was thought to have originated on a mass of material laid down as a delta. The River Leven (flowing now westwards to join the Tees) formerly flowed eastwards to join the Esk via Sleddale. During the glaciation of the area, the Leven debouched into Lake Kildale near West House. Here it filled its former channel and built out a delta into the lake. A sudden flood probably caused it to change its course and scour out a new channel westwards down the steeper gradient. It was envisaged that there was 46 metres (150 feet) of water in this region at the maximum of lake systems, gradually draining until at 175 metres (575 feet) the West House watershed became visible, and Lake Kildale split from Lake Eskdale. Kendall made a series of augerings to investigate the sub-surface depth of non-organic matter, as did Hawell et al. (1902), who claim to have "bottomed" their borer, in Liassic shale and Oolitic sandstone a few metres apart.

Gregory (1962), also attributed the Leven's present course to capture, but not by the formation of a bridge delta or "corrom" as Kendall had suggested. Gregory regards the glacial deposits in this part of western Eskdale as largely sub-glacial in origin, associated with a greater maximum extension of Weichselian ice than that proposed by Kendall. While there is no direct borehole evidence to indicate the composition of the Esk/Leven watershed, Stitch Hill,

WEST HOUSE MOSS LOOKING EASTWARDS
TOWARDS ESKDALE AND THE MOORLAND PLATEAU

PLATE 3

immediately to its north, standing 12 metres (40 feet) above the valley floor has a distinct sub-glacial morphology and lithology, and it is probable that a similar mass of glacial sand and gravel comprises the West House divide. Erdtman (1927, 1928), considered the West House Moss itself to have originated in Boreal time, with moss peat underlain by birch wood peat, muddy detritus, and grey sandy clay, making up 6 metres (20 feet) of sediments, above impenetrable deposits. In contrast to other peat filled hollows, Gregory has no augering records for West House Carr.

The position of the bog at the constricted head of Kildale, with sharply rising ground to both north and south, means that natural drainage is restricted to west and east. It is bounded by a road on the west and south, and the Middlesbrough-Whitby railway line on the north, and has been subjected to drainage, cutting and grazing.

Vegetation

As a consequence of human activity, the hydrology and vegetation of the moss have been, and are in the process of, modification. However, it still retains a characteristically convex raised bog morphology, upon which two quite distinct vegetation units can be recognized.

The margins of the bog have been altered by drainage, here the peat is dry, and supports grasses such as Nardus stricta, Agrostis tenuis, Molinia caerulea, Deschampsia flexuosa, Anthoxanthum odoratum and Holcus lanatus. Calluna vulgaris, Erica tetralix, Rumex acetosa and Alchillea millifolium are also abundant.

In marginal drainage ditches and peat cuttings, Juncus squarrosus, J. effusus, Potentilla palustris, Potamogeton polygonifolius and Polytrichum commune flourish. The vegetation of the rand is more typical, consisting of Trichophorum caespitosum, Eriophorum angustifolium, E. vaginatum, Carex glauca, C. panicea, C. nigra, Nardus stricta, Molinia caerulea, Potentilla erecta, Galium saxatile, Calluna vulgaris, Erica tetralix, Vaccinium myrtillus, Narthecium ossifragum, Sphagnum papillosum, S. palustre, S. rubellum, Dicranum scoparium and Drosera rotundifolia. However, this area is also drying out, with grassland communities encroaching rapidly upon it. One specimen of Sorbus aucuparia in the north-western corner of the mire, remains as the only evidence of former tree growth on the bog surface.

Stratigraphy

The stratigraphy was investigated by means of two series of levelled boreholes, intersecting as shown (Figure 14). The results of the borings are indicated in Figure 15.

The basal deposit is everywhere a very tenacious grey clay with angular stones, over 20 cm. thick in all borings but nowhere penetrable with hand-boring equipment. This is succeeded in the central parts of the mire by about 30 cm. of bluish-grey clay mud containing Equisetum, Carex and Juncus remains. The interface with the stony clay is not sharp, and the clay mud disappears gradually laterally. Following this is a well developed Phragmites peat, usually over a metre thick and containing abundant Equisetum nodes and Menyanthes trifoliata seeds. This is covered by about

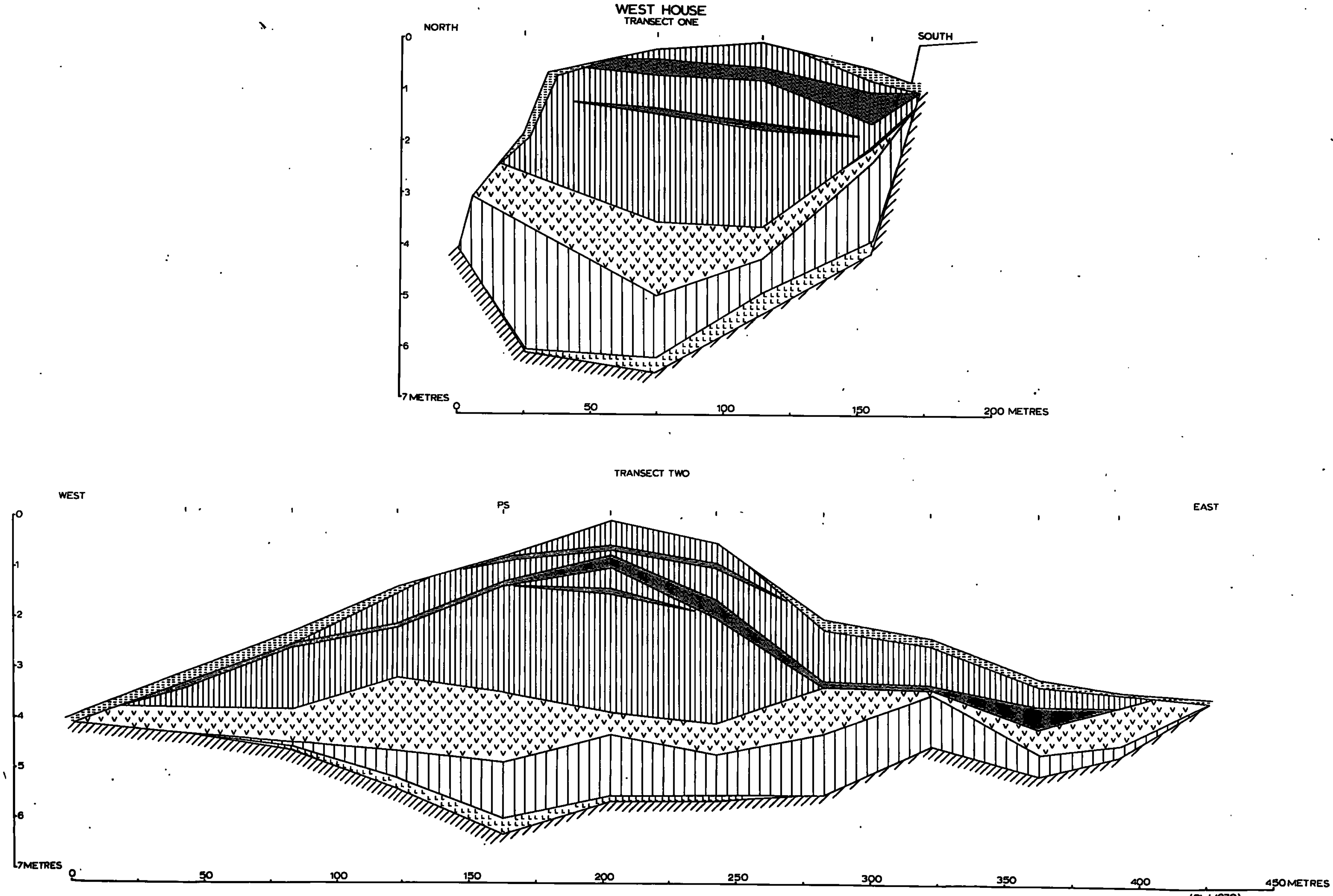

WEST HOUSE
TRANSECT ONE
NORTH
SOUTH
0
1
2
3
4
5
6
7 METRES
0
50
100
150
200 METRES
TRANSECT TWO
WEST
PS
EAST
0
1
2
3
4
5
6
7METRES
0
50
100
150
200
250
300
350
400
450 METRES
(R.L.J. 1970)

FIGURE 15

1½ metres of a damp wood peat, with *Pinus* and *Salix* in its lower parts, and *Betula* and *Alnus* nearer the upper boundary of the deposit. Overlying the wood peat is a *Carex* peat, well humified, with some *Eriophorum*, and *Betula* twigs. At the southern side of the bog 5 cm. of grey silty clay feathers out from the surrounding slopes into the mire, at the Wood-*Carex* peat junction. Within the 3½ metres of *Carex* peat, 3 distinct *Sphagnum* horizons are intercalated. The first occurs 1½ metres below the present surface, averaging 10 cm. in thickness. 30 cm. of mixed *Carex*-*Sphagnum* peat then gives way to a 25-30 cm. thick *Sphagnum* layer, 10-15 cm. more *Carex*-*Sphagnum* peat and 15 cm. of *Sphagnum* peat. The first and third horizons occur only in the central area, the second, major one, is found over the whole bog. The top 50 cm., to the present surface, is a mixed sedge-bryophyte peat, showing signs of desication, and being superceded by grassy sward at the margins.

The maximum depth of deposits encountered at West House was 6.1 metres (20 feet).

Pollen and Macrofossil Analysis and Chronology.

Samples for pollen and macrofossil analysis were secured in 1968 from the borehole indicated on Figure 15. The stratigraphy appropriate to the pollen diagram shows :-

0-10 cm. Dry *Carex* peat with *Molinia* stems, *Calluna* twigs, leaves of *Sphagnum rubellum*, *S. palustre*, *S. acutifolium* and *Dicranum scoparium*.

10-18 cm. Light brown pure *Sphagnum* peat with *S. cuspidatum*, *S. recurvum*, *S. rubellum* and *S. magellanicum*.

18-54 cm. Mid-brown fairly well humified *Carex* peat with some bryophyte remains. Leaves of Sphagnum cuspidatum 30-40 cm., S. rubellum at 35 cm., S. magellanicum at 40 cm., S. papillosum at 50 cm., Rhacomitrium lanuginosum at 35 cm., Dicranum scoparium 30-45 cm., Pleurozium schreberi at 45 cm. Calluna twigs throughout.

54-68 cm. Light brown pure Sphagnum peat, with S. cuspidatum dominant. Also S. tenellum, S. papillosum, S. palustre, S. acutifolia agg. Leaf of Dicranum scoparium at 60 cm. Calluna and other Ericaceous remains at 60 cm. Algal remains throughout.

68-278 cm. Mid-brown quite well humified Carex peat with bryophyte remains locally abundant 68-180 cm. and Eriophorum vaginatum remains 180-278 cm. Sphagnum cuspidatum, S. papillosum, S. recurvum, S. acutifolia agg. Rhacomitrium aciculare, Hypnum cupressiforme, Camptothecium nitens, Rhacomitrium lanuginosum the most common mosses. Carbonized Calluna at 90 and 145 cm. Sporangia of Pteridium aquilinum at 90 and 150 cm. Stems of Vaccinium oxycoccus at 150 cm.

278-422 cm. Mid-brown, damp wood peat, with a matrix of Carex spp. in the upper parts. Phragmites in lower parts. Remains of Betula and Alnus 278-370 cm., and Pinus, Salix and Betula 370-422 cm. Charcoal frequent 350-410 cm., with silt at 410 cm. Leaves of Sphagnum papillosum at 290 - 410 cm. Leaves of Polytrichum commune at 350 and 410 cm.

422-538 cm. Grey-brown Phragmites peat with Equisetum nodes and Menyanthes trifoliata seeds. Pinus and Salix fragments 422-440 cm. Sporangia of Thelypteris sp. at 430 and 530 cm. Seeds of Juncus effusus at 500 and 530 cm. Leaves of Drepanocladus fluitans 460-480 cm.

538-573 cm. Grey-brown clay mud with Phragmites, Equisetum, Menyanthes, Carex and Juncus remains.

573-610 cm. + Tenacious grey clay with angular stones. Cyperaceous and Ericaceous remains in the upper 20 cm., becoming very pure and impenetrable with depth.

The pollen diagram (Figure 16) shows the following zones to be present, and is based upon a total tree pollen sum :-

Zone III (610-572 cm.)

Herbaceous dominance, principally of Gramineae, Cyperaceae, Empetrum, Artemisia, Filipendula, Rosaceae, Rubiaceae, Saxifragaceae and Rumex acetosa. Salix, Betula nana and Juniperus present. Betula the most important tree, only Pinus otherwise represented. Aquatics and pteridophytes occur in significant frequencies. Armeria and Silene recorded.

Zone IV (572-458 cm.)

Slight increases in arboreal pollen with Betula most important. Corylus immigrates in mid-zone. Non arboreal pollen very significant making up 75% of total pollen in some cases. Salix, Gramineae, Cyperaceae, Tubuliflorae, Filipendula, Rosaceae, Rubiaceae and Rumex acetosa have high frequencies. Menyanthes, Typha latifolia, Equisetum, Thelypteris and Filicales also important. Calluna recorded.

Zone V (458-432 cm.)

Corylus rises sharply at the lower boundary. Arboreal pollen now 45% of total pollen with Betula and later Pinus important. Most non arboreal pollen types important in Zone IV decline, but Gramineae, Cyperaceae,


C
B
VIIb+VIII
A
VIIa
VIc
VIb
VIa
V
IV
III
HYDROCOTYLE
RHINANTHUS
STELLARIA HOLOSTEA

Filipendula and *Rumex acetosa* re-expand in mid-zone. *Ulmus* and *Quercus* recorded.

Zone VI (432-332 cm.)

The following sub-divisions can be recognized :-

VIa (432-412 cm.)

Lower boundary marked by a fall in *Betula* and an expansion of *Pinus* and *Corylus*. *Ulmus* exceeds *Quercus* in frequency. *Alnus* immigrates. *Melampyrum*, *Calluna*, *Ericales* and *Succisa* present. Trees and shrubs comprise 85% of total pollen.

VIb (412-375 cm.)

Pinus - *Corylus* dominance begins to receed late in the sub-zone. *Alnus* expands slightly and *Ulmus* and *Quercus* well represented. *Filipendula*, *Melampyrum* and *Succisa* present. *Pteridium* first appears and *Filicales* expand.

VIc (375-332 cm.)

Pinus - *Corylus* loses dominance, and *Betula*, *Quercus*, *Ulmus*, *Alnus* and *Tilia* increase in frequency. Herbs make up under 10% of total pollen, but a small extension of *Gramineae* occurs near the upper boundary.

Zone VIIa (332-198 cm.)

Lower boundary characterized by a fall in *Pinus*, *Corylus* and *Betula* and a rapid increase of *Alnus* (dated by Radiocarbon at a level just above the lower boundary to 6,650 $\pm$ 290 BP : 4,700 $\pm$ 290 B.C. (Gak 2706)). *Quercus*, *Ulmus*, *Tilia* and *Fraxinus* expand by mid-zone. *Lonicera* recorded.

Zones VIIb and VIII (198-0 cm.)

No division into a separate VIIb and VIII is made. Within the complex, 3 sub-zones can be characterized :-

Sub-Zone A (198-139 cm.)

Opening marked by an *Ulmus* decline and a slight fall and later recovery of arboreal pollen. *Corylus* expands slightly but herbs remain in low frequencies. *Gramineae*, *Calluna*, *Ericales* and *Filipendula* increase, *Plantago lanceolata* first appears and a *Melampyrum* peak occurs.

Sub-Zone B (139-43 cm.)

Lower boundary characterized by a decline and temporary disappearance of *Ulmus*, and a fall in *Tilia* values, together with most other trees. *Fagus* appears and *Fraxinus* establishes a continuous curve. *Corylus* expands. *Sorbus* and *Ilex* recorded. *Cerealia* first appear and *Gramineae*, *Calluna*, *Artemisia*, *Liguliflorae*, *Plantago lanceolata*, *Plantago major/media*, *Ranunculaceae*, *Rosaceae*, *Rubiaceae*, *Rumex acetosa* and *Urtica* increase in frequency, together with *Pteridium* and *Filicales*. *Spergularia* recorded. Arboreal pollen less than 30% of total pollen near zone's conclusion. *Sphagnum* increases steadily throughout.

Sub-Zone C (43-0 cm.)

Major increases in herbs commence at the lower boundary with trees and shrubs declining sharply in frequency. *Fraxinus* and *Fagus* only become better established and arboreal pollen values fall to about 10% of total pollen. *Gramineae*, *Cerealia*, *Cyperaceae*, *Calluna*, *Ericales*, *Tubuliflorae*, *Artemisia*, *Liguliflorae*, *Chenopodiaceae*, *Cruciferae*, *Plantago lanceolata*, Plantago major/media, Ranunculaceae, Rosaceae, Rubiaceae, Rumex acetosa, Umbelliferae, Urtica, Pteridium and Filicales frequencies increase sharply. Epilobium, Cirsium, Humulus - Cannabis T., Polygonum convolvulus, Vicia and Valeriana recorded. Sphagnum reaches its maximum of development. Non arboreal pollen constitutes over 90% of total pollen.

The Development of the Mire System

The foundations of West House Moss were laid by ice of the last glaciation, and exposed after that ice had become stagnant in western Eskdale and deglaciation was completed there. They took the form of an expanse of hummocky fluvio-glacial gravels at the head of Kildale, in which small sheets of open water existed throughout the following Late-glacial period.

The solifluction of Late Weichselian time produced here a stony grey clay which forms the basal deposit of the mire system. This clay is not stratified and probably represents the majority of Late-glacial time, having been subjected to erosion and re-deposition, especially in the last cold phase of the period (Zone III), which the pollen spectra of the lowest analysed levels indicate to be present. The vegetation then was fairly sparse with a largely treeless landscape, accompanied by a fairly impoverished mire system, with Cyperaceae and Gramineae dominating the margins of the open water, where Potamogeton was growing. At a time corresponding to the opening of the Post-glacial period, the stony clay is superceded by a clay mud with much more organic material and very little silt. Solifluction had, by now, ceased, and the pollen and macrofossil evidence shows that open water, with *Potamogeton* was surrounded by reedswamp and fen, with *Typha latifolia*, *Phragmites*, *Equisetum*, *Menyanthes trifoliata*, *Juncus*, *Carex*, *Hydrocotyle*, *Filipendula*, *Lychnis* and *Thelypteris* dominating. A fuller development of reedswamp soon ensued, with *Phragmites*, *Equisetum*, *Menyanthes* and *Thelypteris* spreading over the whole area, and remaining until early in Zone VI, when it passed into a base-rich, fen carr, dominated by *Salix* and *Betula*, quite damp and with patches of *Phragmites*, sedges and bryophytes. The later stages of this fen carr existed around the time of the Boreal/Atlantic Transition, when *Alnus* also began to grow around its fringes. The rise in the *Alnus* pollen curve to a maximum, (signifying the opening of Zone VIIa), has been dated by Radiocarbon here to 4,700 $\pm$ 290 B.C. (Gak-2706), when fen-carr was still in existence, but beginning to be influenced by a rising water table. This eventually led to swamping, and the rapid growth of a sedge - bryophyte, more acid community, supplied by precipitation as it grew upwards, forming a typical raised bog. This development continued throughout the 'climatic optimum', and into Zones VIIb and VIII, when the pollen diagram indicates quite intense anthropogenic activity in the area. Near the southern edge of the mire, a band of fine, grey silt is found at the interface of the fen-wood peat and the *Carex* peat, formed at a time of human interference with the surrounding landscape, and associated with charcoal in the peat. *Calluna* and *Molinia* macrofossils, and charcoal, indicate that by late Zones VIIb-VIII the bog had become treeless and quite dry at the surface; though the bryophytes present, show that formation was still active in places towards its centre. Three distinct moss horizons, dominated by various species, (principally of Sphagnum), occur at, and around what may be the opening of Zone VIII, (the Sub-atlantic period), and separated by mixed sedge-bryophyte associations. These are indicative of an increase in wetness, and renewed, widespread, active bog growth. Both pool and hummock forming species of Sphagnum were present, together with Rhacomitrium, Dicranum and Pleurozium, indicative of a quite acid environment. In the intervening periods, it seems to have been a little less damp, with Calluna and Molinia able to colonize again, Pteridium important, presumably on the surrounding slopes; a situation which is reflected in the immediately sub-surface layers, and also upon the present bog surface, both of which have suffered considerable disturbance in historic time.

Vegetational History of the West House Area

The initial vegetation type represented for the West House area was a shrub heath community of a very open nature, Betula nana, Salix and Juniperus dominated the shrub component. Betula and Pinus were the only trees present, the latters fluctuating percentage suggesting its presence some way from the site and transport to there through the very open vegetation. In any case, their combined contribution to the vegetation cover was not more than 10%. Dry heaths were present on the well drained slopes with Empetrum, Artemisia, Gramineae, Rumex acetosa and Armeria important constituents. The overall conditions were ones where solifluction was important, and communities generally were unstable, with large extents of bare ground, and Cyperaceae, Filipendula, Caryophyllaceae, Rubiaceae and Chenopodiaceae occupying the damper situations.

Similarly to Wildale Hall, the opening of the Post-glacial period did not provide a sufficient impetus around West House, for a major rapid enclosure of the landscape by trees. Here, throughout both Zones IV and V, while some development of closed birch woodland was evident, the major feature was a period of relatively luxuriant shrub and herb vegetation dominated by Salix, Rosaceae, Empetrum and Gramineae. The types characteristic of Late-glacial conditions declined sharply (e.g. Betula nana, Juniperus, Artemisia, Rumex acetosa and Rubiaceae).

While Betula, and by now almost certainly Pinus were present, Corylus immigrated and began to expand, obviously finding abundant suitable habitats. Late in Zone V Ulmus appeared, but it was not until later Boreal time, in Zone VI that the area first became closed woodland. Throughout Zone VI Pinus and Corylus dominated the spectrum taking over from Betula, and being much more widespread than either Quercus, Ulmus, Alnus or Tilia which were all present, but in no more than certain favoured localities such as patches of base rich soil or streamsides. A temporary opening of the forest is suggested twice within Zone VI. At the beginning of the Zone, Ericales expanded, along with Melampyrum and Pteridium, also Succisa and Chenopodiaceae were present, indicating some disturbance of the vegetation, and perhaps a temporary clearance near the zone's conclusion, Gramineae and Pteridium increased, suggesting a further temporary clearing in what was by now a closed woodland. This situation continued but its components effectively changed at about the time of the Boreal/Atlantic Transition, dated at this site to 4,700 B.C. (Gak-2706). Now the pine-hazel forests gave way quite quickly to a mixed deciduous forest in which Quercus, Betula, Ulmus, Tilia, Fraxinus and above all, Alnus were dominants in the landscape, which was now over 80% tree covered.

This situation persisted until Zones VIIb and VIII when the first reductions in forest cover were effected. Three quite distinct Sub-Zones are recognizable, and within these, several phases approaching a 'landnam' (Iversen,1941) can be discerned to have been approached. Sub-Zone A is characterized by seemingly selective attacks on certain tree species, particularly Ulmus and Tilia, and the extension of some open habitat plants such as Gramineae, Melampyrum and Pteridium. This suggests that clearance was small scale, but quite effective with pastoral activity dominant. Soon after the clearances, Corylus and Fraxinus expanded probably recolonizing cleared areas, to be succeeded by regeneration of trees, and very little overall reduction in tree cover at this early stage.

The second part of Zones VIIb and VIII, Sub-Zone B, saw a much more concerted attack on the forests. Now, apart from Ulmus and Tilia, other trees declined, especially Quercus and Alnus. The clearings thus created were used mainly for pastoral activity, with

Plantago lanceolata, Pteridium and Gramineae widespread. However, cultivation was being practised too, and Cerealia (mainly Triticum dicoccum and Hordeum T.) were being grown. Recolonization was still taking place; Fraxinus and Corylus fulfilling this function, Fagus and Sorbus appearing too in newly cleared areas.

Sub-Zone C (only the early part of which is represented) provided a continuation of Sub-Zone B, but once again, with increasing effectiveness. The shrub components, particularly Corylus now began to be cleared, as well as all types of trees, until they formed under 10% of the vegetation. A vast area of land was now in human use, both as pasture (Plantago spp., Gramineae, Pteridium values are high) and also as arable, (Cereals - mainly Hordeum T. and Avena T., Rumex acetosa, Chenopodiaceae, Artemisia, Compositae, Cruciferae, Humulus-Cannabis T., Urtica and Vicia are well represented). As well as this activity, a fairly new phenomenon was taking place, the colonization of large cleared areas by vast expanses of Calluna, other Ericales and Gramineae forming the forerunners of the present day vegetation of heather moorlands and poor acid pastureland in the area around West House.

3.4 Stratigraphy and Pollen Analysis at Ewe Crag Slack

Ewe Crag Slack (NZ 695110) is a broad depression of almost 1.5 kilometres (1 mile) length, crossing the North Cleveland watershed on Danby Low Moor at a height of 235 metres (770 feet) O.D., due north of the village of Danby. To the north it grades into the drift covered Cleveland Plateau, to the south it falls into Eskdale. It contains an infilling of peat, particularly

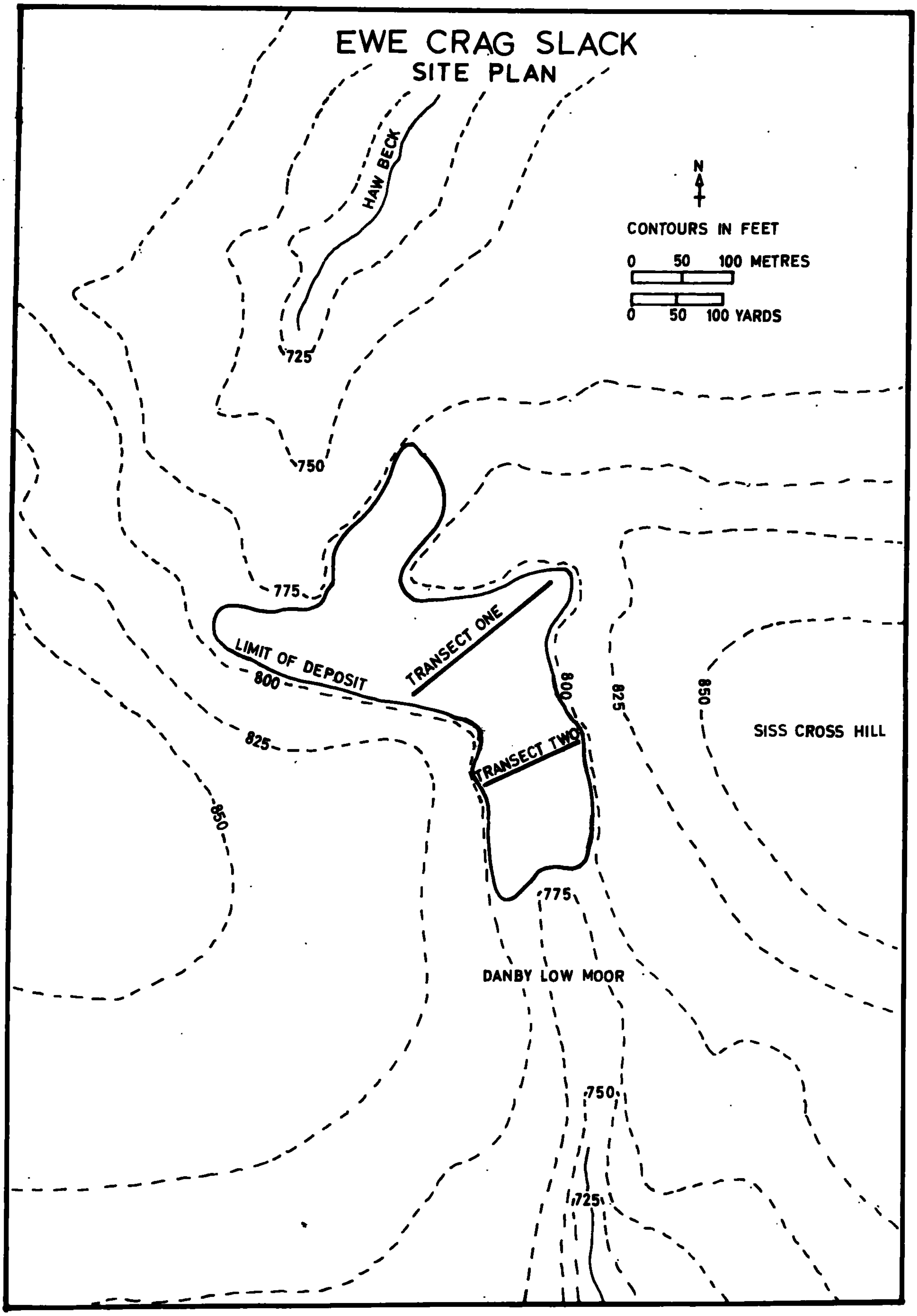

EWE CRAG SLACK
SITE PLAN
HAW BECK
N
CONTOURS IN FEET
0 50 100 METRES
0 50 100 YARDS
725
750
775
800
825
850
LIMIT OF DEPOSIT
TRANSECT ONE
TRANSECT TWO
SISS CROSS HILL
DANBY LOW MOOR

FIGURE 17

well developed in its central area (Figure 1) (Plate 4).

Topography

The whole feature is cut in solid rock, its depth ranging from 8 metres (26 feet) where it traverses the watershed to 23 metres (75 feet) in its southern part where it assumes a ravine-like form. Drainage is absent from the majority of the depression, but small streams issue from springs in the lower reaches. The breadth of the floor rarely exceeds 150 metres (492 feet) and its form is generally flat, being the surface of an infilling of sediment of varying thickness.

The earliest interpretation of its form and origin was offered by Kendall (1902), who suggested that it had formed sub-aerially in the Pleistocene, as the main drainage channel of ice-dammed Lake Moorsholm southwards into Lake Eskdale. This view has been challenged by Gregory (1962) who showed that Ewe Crag Slack had a 'hump profile' (formed by uphill movement of water across a divide) and breached a pre-glacial watershed, concluding that its origins were likely to have been sub-glacial rather than sub-aerial.

The accumulation of organic matter was noted first by Kendall (1902, 1903), who in a series of borings, recorded a maximum depth of 6.5 metres (21 feet) of peat "at a point where the bog slopes upstream as well as down". Elgee (1912) noted the presence of the deposits in the channel, and Erdtman (1927) produced outline sections and pollen diagrams for the site. He stated that the stratigraphy consisted of forest peat covered with decayed vaginatum peat, the latter with some clayey downwash in places, and attributed the earliest deposits to Boreal time. Gregory (1962) established a maximum

EWE CRAG SLACK LOOKING SOUTH-WESTWARDS
ACROSS THE CENTRAL PART OF THE MIRE

PLATE 4

depth of 5.7 metres (18 feet) comprising bedrock covered by a thin veneer of clay overlain by peat.

Vegetation

Elgee (1912, 1914) drew attention to the vegetation of Ewe Crag Slack as a typical example of that found in such depressions, and discussed earlier (page 31). At the ends of the depression Juncus communities prevail, dominated by Juncus effusus and Juncus conglomeratus with Sphagnum cuspidatum and Sphagnum palustre abundant. There swampy areas are fed by streams of peaty water emanating from the central morass, and providing ideal, mineral rich ecological conditions enabling them to flourish. Also, fairly extensive peat cutting has left hollows which have become waterlogged and initially occupied by a Junco - Sphagneta association. These are in various stages of replacement by Eriophorum - Calluna association as the humus becomes more solid. It is this solid humus formation which occupies the majority of the deep peat area. Calluna vulgaris, Erica tetralix, Empetrum nigrum, Eriophorum vaginatum, Eriophorum augustifolium, Molinia caerulea, Deschampsia flexuosa, Sphagnum acutifolium, Sphagnum rubellum and Sphagnum papillosum dominate the drier areas, while the surface is pitted with a complex of pools and very damp areas, where Sphagnum cuspidatum, Sphagnum recurvum, Sphagnum plumulosum and Polytrichum commune are found, with Carex nigra, Carex rostrata, Juncus squarrosus, Juncus effusus amd Juncus acutiformis. Bog formation is active here, with rafts of Sphagnum (principally S. recurvum) forming in hollows, and near the mire edges. The slopes of the channel are dominated by Pteridium aquilinum with Calluna vulgaris, Vaccinium myrtillus, Erica cinerea, Carex and Eriophorum. Potentilla erecta is abundant, colonizing burnt patches, where Cladonia rangifera is found in profusion. Trees and shrubs are virtually non existent, with a few scattered specimens of Ilex aquifolium, Sorbus aucuparia and Crataegus monogyna found in the sheltered, deeper ravine section.

Stratigraphy

The stratigraphy was investigated by means of two levelled transects of borings across the channel, the positions of which are shown (Figure 17). The results obtained are presented in Figure 18.

Initial tests indicatedthat the deepest sections lay in the relatively flat area where the watershed is breached. A transect here revealed a basin-like hollow, the lowest deposit of which is a tenacious blue clay with numerous angular stones, averaging over a metre in thickness, and not completely sampled with the coring devices. Overlying this is a dry wood peat with an amorphous matrix, and Betula, Pinus and Salix fragments, attaining some 1½ metres in places. Superceding this is a well humified Carex peat with Eriophorum bands, and Betula and Alnus fragments, of up to 4 metres in thickness. In the upper 50 cm. of this deposit two bands of fine grey silt, each about 10 cm. thick, wedge out from the eastern side of the mire for approximately 10 mëtres. The upper boundary of the youngest silt layer forms the junction between the Carex peat and a damp, compact, mid-brown Sphagnum peat with alternations of dominant pool and hummock forming species, such as Sphagnum cuspidatum and Sphagnum

EWE CRAG SLACK

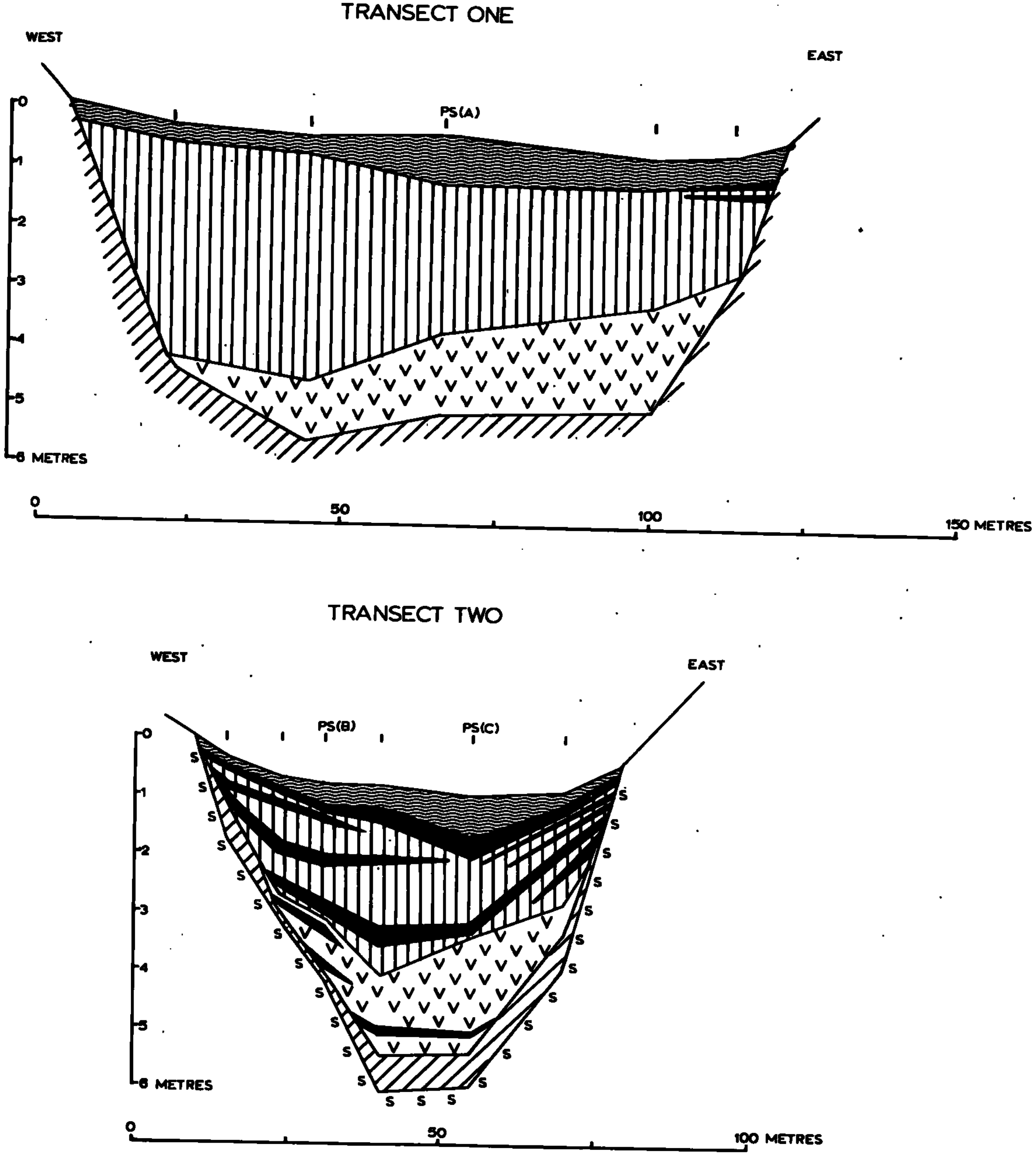


FIGURE 18

(RLJ. 1970)

papillosum and *Sphagnum rubellum*, together with monocotyledonous remains, (Carices and grasses), as well as *Calluna* twigs. The whole deposit is around $1\frac{1}{2}$ metres in thickness, with ericaceous material common only in the last metre, and the bog surface composed of an admixture of *Sphagnum* spp. *Eriophorum angustifolium* and Carices. The overall maximum thickness of the sediments in this transect was $5\frac{1}{4}$ metres (17 feet).

The second transect was made some 150 metres south of the first, in a narrower portion of the channel, and the gross stratigraphy proved almost identical. However, the basal clay was softer and penetrable to bedrock, its thickness not being in excess of 1 metre. The succession of Wood peat - *Carex* peat - *Sphagnum* peat is found, though in decreased thicknesses. The surface vegetation again is mainly composed of *Sphagnum* spp. with subsidiary *Carex*, *Eriophorum* and *Calluna*. The major feature of this transect is, however, a marked increase in the number and extent of silty bands intercalated with the deposit than in transect one, or than noted by Erdtman (1927). They are not confinedto the *Carex* peat as in the first transect; first occurring near the base of the wood peat, and thereafter at intervals throughout the succeeding deposits. Their form, extent and thickness is variable; some radiating from the west of the channel, some from the east, some continuous across the basin, others wedging out after several metres lateral extent, all varying in vertical thickness, from 5 to 35 cm. They do not occur in the *Sphagnum* peat, and the phenomena of the uppermost one being the best developed, and forming the boundary between *Carex* and *Sphagnum* peat is repeated.

The maximum depth of deposits encountered on this transect was 4.9 metres (16 feet).

Pollen and Macrofossil Analysis and Chronology

Samples for pollen and macrofossil analysis were collected in 1967 with the Soil Survey of Scotland sampler, and three profiles were secured. The first was from the deepest part of the first transect in order to provide a complete as possible stratigraphical and palynological record for the site and its environs. The second was taken on the second transect at a point where the intercalated silts showed their fullest development, to attempt an explanation of their form and origin. A final short, basal sample, was taken from the deepest point on the second transect to provide a comparison of time of the inception of peat formation between the two transect lines.

The stratigraphic descriptions and macrofossil identifications appropriate to the 3 Pollen Diagrams (Figures 19, 20, 21) are as follows :-

Ewe Crag Slack (A) (PS (A). Figure 18)

0-86 cm. Light brown Sphagnum peat, with Sphagnum cuspidatum, S. plumulosum, S. recurvum, S. palustre, S. papillosum, S. acutifolium, S. rubellum and S. tenellum. Occasional Carex, Eriophorum and Calluna remains, seeds of Juncus conglomeratus, stems of Molinia, sporangia of Pteridium and charcoal fragments.

86-334 cm. Mid-brown quite well humified Carex peat. Sphagnum quite frequent to 165 cm., especially S. cuspidatum, S. recurvum, S. sub-secundum, S. papillosum, S. tenellum and S. acutifolia agg. Leaf of Drepanocladus fluitans at 105 cm. Calluna abundant, with charcoal between 120-150 cm. Twigs of Betula and Alnus at 315 and 330 cm., and a fruit of Betula pubescens at 315 cm. Juncus and Eriophorum vaginatum present in small amounts, together with Molinia.

334-474 cm. Light brown, amorphous, dry wood peat with Betula twigs 334-400 cm., 440-474 cm., Betula charcoal and silt at 388 cm. Pinus and Salix fragments at 470 cm. Matrix of Carex spp. and Sphagnum, principally S. cuspidatum, S. plumulosum and S. palustre. Seeds of Juncus squarrosus and fern sporangia abundantly distributed throughout.

474-525 cm. Blue clay with angular stones. An admixture of Carex spp. in the upper 20 cm., becoming tenacious and pure at 5 metres.

525 cm. + No penetration of sampler.

Ewe Crag Slack (B) (PS (B) Figure 18)

0-40 cm. Little humified, light brown Sphagnum peat, with S. recurvum, S. papillosum, S. rubellum, S. tenellum, S. acutifolia agg. Infrequent remains of Carex, Molinia and Juncus.

40-60 cm. Light grey silt with seeds of Juncus effusus and J. conglomeratus, Carex stems and Calluna twigs.

60-62 cm. Dark brown silty peat, with Carex spp.

62-69 cm. Light grey silt with Carex spp., and seeds of Juncus effusus and J. conglomeratus.

69-121 cm. Mid-brown quite well humified Carex peat with Molinia and Calluna fragments throughout. Eriophorum vaginatum spindles at 88 cm. Seeds of Juncus effusus at 70 and 112 cm. Eroded leaf of Sphagnum cuspidatum at 72 cm. Charcoal at 72 cm.

121-135 cm. Light grey silt with Carex stems. Leaves of *Sphagnum papillosum* at 130 cm., seeds of *Juncus conglomeratus* at 126 and 130 cm.

135-212 cm. Mid-brown quite well humified *Carex* peat with *Eriophorum vaginatum*, *Juncus* and *Calluna* remains. *Betula* twigs at 166 and 206 cm., *Betula* charcoal at 221 cm.

212-232 cm. Brown silty peat with *Carex* spp. and eroded leaves of *Sphagnum cuspidatum*.

232-244 cm. Light brown, amorphous, dry wood peat with frequent *Betula* fragments and charcoal at 240 cm. *Carex* spp. and *Juncus* stems abundant.

244-264 cm. Light grey silt with *Carex* spp. and twigs of *Betula*.

264-310 cm. Light brown, amorphous, dry wood peat with *Betula* and *Alnus* twigs. Seeds of *Carex* spp. *Juncus effusus* and *J. squarrosus*. Leaves of *Sphagnum subsecundum* at 302 cm.

310-313 cm. Light grey silt with wood and charcoal. Leaf of *Sphagnum squarrosum* at 310 cm.

313-322 cm. Light brown amorphous dry wood peat with *Betula* and *Alnus* remains, *Carex* spp. and *Juncus* remains abundant. Leaves of *Sphagnum cuspidatum*, *S. squarrosum*, *S. palustre* at 315 cm. and *S. acutifolia* agg. at 318 cm.

322-337 cm. Soft blue clay with some angular stones.

337 cm. Bedrock.

Ewe Crag Slack (C) (PS (C) Figure 18)

400-416 cm. Light brown, amorphous, dry wood peat with *Betula* twigs, *Carex* spp. and *Juncus effusus* seeds.

416-430 cm. Light grey silt with *Carex* spp. and *Juncus* stems.

430-448 cm. Light brown amorphous, dry wood peat with fragments of *Betula*, *Alnus* and *Pinus*. Stems and leaves of Polytrichum commune 432-446 cm.

448-496 cm. Blue clay with wood remains to 460 cm., grading to more tenacious material with angular stones.

496 cm. Bedrock.

The pollen diagram for Ewe Crag Slack (A), (Figure 19), is based on a total tree pollen sum and indicates the following zonation :-

Zone III (525-475 cm.)

Herbaceous dominance, but up to 40% arboreal pollen at some levels. Betula and Pinus the only trees present. Betula nana, Juniperus, Salix and Hippophae the main shrubs. Gramineae, Cyperaceae, Empetrum, Artemisia, Liguliflorae, Rosaceae and Filipendula frequencies high.

Zone IV (475-448 cm.)

Characterized by a sharp rise in arboreal pollen principally tree birches, and a decline of non arboreal pollen Betula nana and Juniperus disappear, but in mid-zone increases in frequency of Empetrum, Rosaceae, Filicales and Sphagnum occur. Quercus, Corylus and Calluna first appear.

Zone V (448-438 cm.)

Betula dominant early in the zone, later Pinus becomes so. Quercus present and Ulmus immigrates. Corylus expands sharply; Salix still important but non arboreal pollen now less than 20% of total pollen.

Zone VI (438-340 cm.)

Can be sub-divided into :-

EWE CRAG SLACK (A)

VIa (438-402 cm.)

Pinus - *Corylus* dominance. *Ulmus* exceeds *Quercus* in value. *Alnus* immigrates. *Melampyrum* present, and *Salix*, *Gramineae*, *Cyperaceae* and *Rumex acetosa* frequencies increase near its conclusion.

VIb (402-368 cm.)

Pinus dominates, *Corylus* falls and *Betula* recovers slightly. *Quercus* exceeds *Ulmus* in value. *Alnus* expands slowly and *Tilia* appears.

VIc (368-340 cm.)

Pinus - *Corylus* lose dominance. *Quercus*, *Alnus*, *Tilia* and *Ulmus* increase in frequency. Trees and shrubs account for 85% of total pollen.

Zone VIIa (340-152 cm.)

Lower boundary characterized by a rapid expansion of *Alnus* and a further decline of *Pinus*, *Quercus*, *Ulmus*, *Tilia* and *Betula*, dominate the arboreal pollen sum and *Fraxinus* immigrates. *Corylus* less important than in Zone VI. *Sorbus* and *Hedera* recorded.

Zones VIIb and VIII (152-0 cm.)

A division into separate Zones VIIb and VIII is not made, but within the complex, 3 sub-zones can be characterized :-

Sub-Zone A (152-110 cm.)

A clear *Ulmus* decline marks the opening of this sub-zone, followed by a recovery. *Corylus* expands. Some other trees, especially *Tilia* show small declines but recover. *Fagus* immigrates and *Fraxinus* expands slightly. Herbs expand, *Cerealia* appear and increase in frequency together with *Plantago lanceolata*, *Rosaceae*, *Rumex acetosa*, *Pteridium* and *Calluna*.

Sub-Zone B (110-61 cm.)

A secondary *Ulmus* decline occurs at the lower boundary accompanied by a fall of *Tilia* and an expansion of *Fraxinus* and *Corylus*. *Quercus*, *Betula* and *Alnus* also decline and non arboreal pollen accounts for up to 70% of total pollen. *Sorbus* recorded. *Gramineae*, *Cerealia*, *Compositae* spp., *Plantago lanceolata*, *Rosaceae*, *Rumex acetosa* and *Pteridium* increase in frequency.

Sub Zone C (61-0 cm.)

Tilia becomes extinct near the lower boundary reappearing sporadically thereafter. *Ulmus*, *Quercus*, *Betula* and *Alnus* show substantial reductions. *Corylus* declines, *Fraxinus* and *Fagus* expand. *Hedera*, *Ilex* and *Sorbus* recorded.

Major increases in herb frequencies occur, especially of *Gramineae*, *Cerealia*, *Calluna*, *Ericales*, *Tubuliflorae*, *Artemisia*, *Centaurea*, *Liguliflorae*, *Chenopodiaceae*, *Cruciferae*, *Filipendula*, *Plantago* spp., *Ranunculaceae*, *Rosaceae*, *Rumex acetosa*, *Umbelliferae* and *Urtica*. *Spergularia*, *Succisa* and *Polygala vulgaris* recorded; *Pteridium*, *Filicales* and *Sphagnum* frequencies reach their maxima. Non arboreal pollen accounts for over 90% of total pollen at the highest levels.

The pollen diagram for Ewe Crag Slack (B) (Figure 20), also based on a total tree pollen sum, shows the following zonation :-

C
B
A
VIIb + VIII
VIIa
HERBS
SHRUBS
TREES
SPHAGNUM
FILICALES
PTERIDIUM
POTAMOGETON
SPERGULARIA
CALLUNA
CYPERACEAE
CEREALIA
GRAMINEAE
CORYLUS
FRAXINUS
FAGUS
ALNUS
TILIA
QUERCUS
ULMUS
PINUS
BETULA

Zone VIIa (322-265 cm.)

Quercus, Alnus, Ulmus, Betula, Tilia and Fraxinus dominate the arboreal pollen sum. Corylus important and Salix, Hedera, Ilex and Sorbus present. Herbs important near the upper zone boundary, where Gramineae, Filipendula, Potentilla, Rosaceae, Artemisia, Melampyrum, Plantago lanceolata, Rumex acetosa and Succisa increase in frequency together with Pteridium.

Zones VIIb and VIII (265-0 cm.)

Three major sub-zones can be delimited :-

Sub-Zone A (265-162 cm.)

Declines of Ulmus, Tilia and Fraxinus, followed by recoveries. Fagus immigrates and Corylus fluctuates in frequency. Salix, Hedera and Sorbus present. Herb values rise. Cerealia recorded and Gramineae, Calluna, Artemisia, Filipendula, Plantago lanceolata, Potentilla, Ranunculaceae, Rosaceae, Succisa and Umbelliferae increase in frequency. Non arboreal pollen over 60% of total pollen.

Sub-Zone B (162-42 cm.)

Ulmus, Tilia and Fraxinus fall again, also most other trees. Fagus expands and Corylus has high frequencies. Herbs increase in value markedly, especially Gramineae, Calluna, Artemisia, Cruciferae, Liguliflorae, Plantago lanceolata, Filipendula, Potentilla, Ranunculaceae, Rosaceae, Rumex acetosa and Succisa. Centaurea cyanus, Cirsium, Valeriana and Vicia recorded. Pteridium expands also Sphagnum. Potamogeton and Lycopodium selago recorded. Non arboreal pollen over

90% of total pollen by the upper boundary of the Sub-Zone.

Sub-Zone C (42-0 cm.)

Tilia finally declines and arboreal pollen falls to between 5 and 10% of total pollen. *Corylus* values decline sharply. *Fagus* and *Fraxinus* increase slightly. Massive extensions of herb percentages, especially *Gramineae*, *Cerealia*, *Calluna*, *Ericales*, *Tubuliflorae*, *Artemisia*, *Chenopodiaceae*, *Cruciferae*, *Filipendula*, *Plantago lanceolata*, *Plantago major/media*, *Potentilla*, *Ranunculaceae*, *Rosaceae*, *Rumex acetosa* and *Umbelliferae*. *Spergularia* and *Urtica* recorded. *Pteridium* and *Sphagnum* have high values.

The pollen diagram for Ewe Crag Slack (C) (Figure 21) (based upon a total tree pollen sum) shows that the following zones are present :-

Zone V (455-451 cm.)

Betula high but declining, *Pinus* increasing. *Ulmus*, *Quercus* and *Alnus* present. *Corylus* has high frequencies. Non arboreal pollen falls near the upper zone boundary.

Zone VI (451-404 cm.)

Can be sub-divided :-

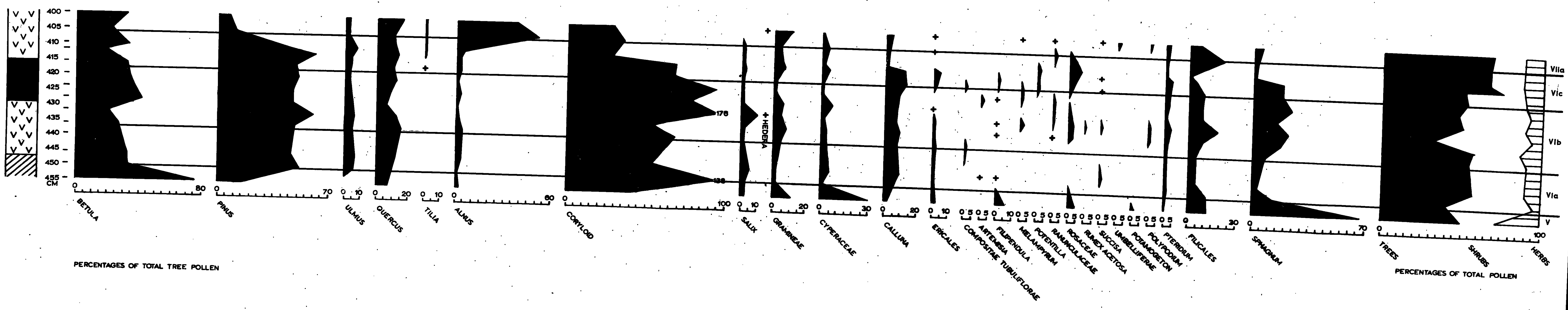
VIa (451-436 cm.)

Pinus - *Corylus* dominance. *Betula*, *Ulmus* and *Quercus* present in significant amounts.

VIb (436-417 cm.)

Still *Pinus* - *Corylus* dominance but *Betula*, *Quercus*, *Ulmus* and *Alnus* begin to be better represented.

EWE CRAG SLACK (C)



(RLJ 1970)

FIGURE 21

Salix, *Gramineae*, *Artemisia*, *Melampyrum*, *Rosaceae*, *Ranunculaceae*, *Succisa*, *Rumex acetosa* and *Pteridium* expand in mid sub-zone.

VIc (417-404 cm.)

Pinus - *Corylus* loses dominance. *Tilia* immigrates and *Quercus*, *Ulmus* and *Betula* become most important. Non arboreal pollen values fall.

Zone VIIa (404-400 cm.)

Pinus, *Corylus* and *Betula* decline. *Alnus* expands and *Quercus*, *Ulmus* and *Tilia* increase in frequency, Arboreal pollen values exceed 70% of total pollen.

The Development of the Mire System

Ewe Crag Slack ceased to operate as a glacial drainage channel as the surrounding moorland emerged from beneath the Weichselian ice. From this time onward it has carried no through drainage, and a mire sequence has been able to accumulate, especially in the flat hollow region where the North Cleveland watershed is breached by its course. The basal deposit, a stony grey clay of considerable thickness has a Late-glacial pollen flora. There is no stratification within it, and little organic matter. It may be referable to the last cold phase of the Late-glacial (Zone III) and contain eroded and redeposited earlier strata. The channel at this time must have been a poorly drained swamp with some areas of open water. Sedges, grasses and pteridophytes are the dominant macro-fossils. Together with pollen of *Potamogeton*, *Equisetum*, *Filipendula*, *Thalictrum* and *Salix* they suggest a fairly sparse flora. Solifluction gradually ceased however, and the Post-glacial period opened with the gradual expansion of birch forests on the surrounding slopes, and the development of a fen carr, dominated at first by Betula and Salix in the channel. Macrofossils of Carex, Juncus, Thelypteris, and intermediate fen species bryophytes (e.g. Sphagnum plumulosum, Drepanocladus fluitans), indicate the damp nature of the community, which was maintained throughout Boreal time. A significant change in the hydrosere did not come until around the time of the Boreal/Atlantic Transition, when first, a layer of fine grey colluvial silt was deposited into the basin from the surrounding slopes, and secondly the composition of the mire changed. A rapid rise in Alnus pollen, indicating on the Pollen Diagrams, the advent of Zone VIIa and the climatic optimum, was accompanied by the colonization of some parts of the fen carr by alder. This was only a temporary feature, because due to increased precipitation, water tables rose early in the Atlantic period, and rapid, widespread growth of sedge dominated swamp, began to choke tree growth in the mire. Pollen of Potamogeton and Callitriche at this time, indicate that pools of open water must have existed on the bog surface, and the increasing incidence of acid bog forming bryophytes such as Sphagnum, illustrate the trend towards acidification of the mire. The most important feature of the later stages of this sedge swamp, is the intercalation with it, of numerous bands of grey, colluvial silt, containing sedges, grasses, Juncus, charred Calluna and other woody fragments. Anthropogenic activity on a major scale is indicated for this time by the pollen diagrams, and these silt bands must represent a response to forest clearance and cultivation on the adjacent moorland. The final, and best developed layer of silt, is overlain by a very pure acid *Sphagnum* peat, which began accumulating at about the commencement of Sub-Zone C. This was no doubt a response to some climatic deterioration about this time. Prior to this, the mire surface must have been somewhat drier, with *Calluna* and *Molinia* macrofossils present in quantity. The *Sphagnum* peat has continued to form in favoured localities, with a minimum of disturbance by peat cutting. The presence of *Calluna*, *Molinia*, *Carex* spp. and charcoal, as well as a majority of pool and hummock forming *Sphagna*, and an absence of tree remains, shows that acid mire development has continued from this time, when the fringing slopes were clothed by *Pteridium* and *Calluna*, and human activity was reaching its climax in terms of forest clearance and agriculture. This is no evidence to suggest that a raised bog community is developing since the surface of the mire, even allowing for peat cuttings, is nearly flat and even slightly concave in places.

Vegetational History around Ewe Crag Slack

The last phases of Late-glacial time on the uplands around Ewe Crag Slack were ones where, once again, shrubs and herbs dominated a rather poorly developed and open plant community. *Betula nana*, *Salix*, *Juniperus* and *Hippophaë* formed the majority of the shrub component, and *Empetrum*, *Artemisia*, *Gramineae*, *Cyperaceae* and *Rosaceae* the herbaceous communities. The only trees present were *Betula* and *Pinus*, the former being quite well established in some favoured localities, the latter's representation more likely the result of long distance pollen transport. The presence of a fair amount of Betula was probably the reason for the fairly rapid but local establishment of birch forests in the early Post-glacial period. Throughout Zones IV and V the development of closed woodland continued, but there was still a considerable extent of open vegetation with Empetrum, Rosaceae and Filicales important in it. Corylus and Ulmus immigrated and managed to find suitable sites for expansion later in this pioneer period, when open habitats were reduced to a minimum. Later Boreal time (Zone VI) saw a marked and quite sudden change in forest composition with Pinus and Corylus taking over as dominants from Betula. At the same time, Quercus, Ulmus, and a little later on, Alnus and Tilia, were present in the forests but could not expand, with Pinus accounting for over 75% of the trees. Early in Zone VI, a layer of silt was deposited in the mire, and some slight, temporary opening of the forests nearby is suggested by a fall in trees and a rise in Corylus and certain herbs such as Melampyrum, Rosaceae, Rumex acetosa, Succisa, Artemisia and Ericales.

It was not until late Boreal time that Pinus and Corylus began to lose dominance and were replaced by Quercus, Alnus, Betula, Ulmus and Tilia, which later joined by Fraxinus, developed in Atlantic time to a closed deciduous forest covering 85% of the landscape. Later in Zone VIIa more silt was deposited into the mire, with the pollen record suggesting a slight temporary clearance of trees and the spread of patches of clearings dominated by Gramineae, Filipendula and Melampyrum. This activity continued sporadically until a distinct fall in Ulmus values, accompanied by another silt layer and a rise in a wide variety of herbs signified the opening of Zones VIIb and VIII which can be divided into Sub-Zones A, B and C. In Sub-Zone A a more accentuated form of the minor Zone VI and VIIa clearings took place. Now Ulmus, Tilia and Quercus were attacked by man; the destruction, erosion, deposition, clearance and regeneration cycle represented by silt bands with charcoal in the mire; Plantago lanceolata, Melampyrum, Gramineae, Ranunculaceae, Rosaceae and Pteridium being present suggesting a pastoral activity taking place, and some regeneration, first by Corylus and Fraxinus, later, but not very successfully, by other trees. Late in A, Fagus and Cerealia are found. The grains of Triticum dicoccum and Hordeum T. accompanied by Artemisia, Centaurea cyanus, Cruciferae and Chenopodiaceae indicating that cultivation was in progress, though likely on a quite small scale and very localized.

Sub-Zone B was very like A in overall characteristics, but with certain important differences. A major feature of this time was the concerted attack on all tree types, rather than more selective felling, a wider and more varied sphere of activity, both arable and pastoral in the area, and the failure of trees and shrubs to regenerate with any great effectiveness in the clearings produced. The earliest phase of B was predominantly pastoral, with Gramineae, Plantago and Pteridium expanding, to be followed by a dominantly cultivation period with Cerealia (mainly Hordeum T.) Rumex acetosa, Artemisia, Succisa and Cruciferae present, accompanied by more silty inwash in the mire, containing charred wood from the clearings. Tree cover neat the end of B must have been about 10% of the landscape; the failure of regeneration was leading to the colonization of cleared areas by Calluna, Ericales and Gramineae.

Sub-Zone C was again distinct, but with similar activities. Arable and pastoral farming was being carried on simultaneously, and clearing was now extended to what trees remained, and to shrubs, particularly Corylus. Cultivation, with cereals (still mainly Hordeum T. but with some Avena T.), Artemisia, Centaurea, Cirsium, Rumex acetosa, Liguliflorae, Spergularia and Cruciferae dominated early in C, later to be superceded in importance by pastoral activities. The deposits at Ewe Crag Slack may stretch into early historic, and perhaps Medieval times, when it seems that grazing activity was the main land use. Higher values of Plantago lanceolata, Gramineae, Pteridium and Filicales than of the Cerealia - Artemisia - Rumex group in the later phases indicates this. No further hillwash occurred in Sub-Zone C, when Calluna extended rapidly into cleared areas, and must have helped stabilise the surrounding slopes. The earlier correlation of this phenomenon with clearance and cultivation suggesting that neither was now of major importance and that the landscape had begun to look much like it does at present, a predominantly Calluna heathland used for pastoralism.

3.5 Stratigraphy and Pollen Analysis at Tranmire Slack

Tranmire Slack (NZ 766119) is situated on Roxby High Moor, about 13 kilometres (8 miles) west of Whitby, and was the most easterly of the sites investigated. Like Ewe Crag Slack, it is a depression trenched in

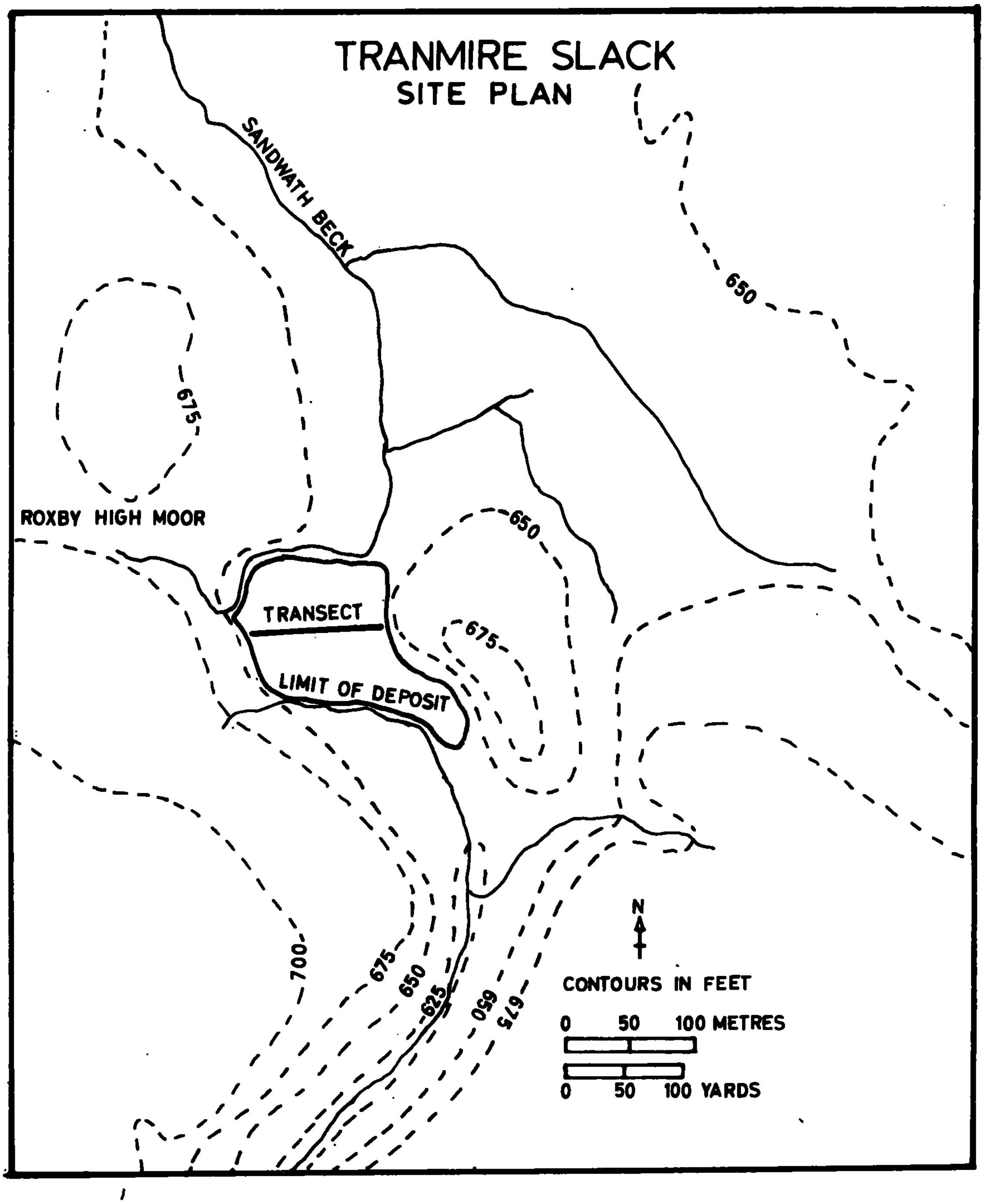

TRANMIRE SLACK
SITE PLAN
SANDWATH BECK
650
675
ROXBY HIGH MOOR
650
TRANSECT
675
LIMIT OF DEPOSIT
700
675
650
625
650
675
N
CONTOURS IN FEET
0 50 100 METRES
0 50 100 YARDS

FIGURE 22

solid rock crossing the North Cleveland watershed, eventually falling to lowland Cleveland on the north, and the Esk Valley to the south. (Figure 1) (Plate 5).

A peat deposit occurs in the broad, flat area where the watershed has been breached.

Topography

Tranmire Slack, according to Kendall (1902, 1903) was no more than "a mere gutter", developed to carry off water from the ice margin of the last glaciation of the area, when a glacial lake existed around Moorsholm to its west. The meltwater then entered Lake Eskdale via the Stonegate system of channels to the south of Tranmire. Jissons (1961), described the landforms of the Stonegate Valley, and took them to indicate there the former presence of a mass of stagnant ice. Gregory (1962) suggested that stagnant ice remained longest in eastern Eskdale during deglaciation, and that Tranmire Slack played a large part in the meltwater drainage of the area. The channel's hump profile and breaching of pre-glacial watershed mean that it must have developed either wholly or partly as a sub-glacial feature. The sides of the channel have three marked benches indicating the presence of former floors, and three stages of development, the two later ones corresponding with ice marginal drainage; at the head of the Stonegate Valley there are features which corroborate this hypothesis. The channel must therefore, have been developed partly sub-glacially, and partly sub-aerially, being initiated by a sub-glacial stream, and then exposed between ice margins to its north and south as deglaciation proceeded. Gregory conducted a series of augerings in the deposits of the

TRANMIRE SLACK LOOKING NORTHWARDS WITH THE SMALL FEN IN THE FOREGROUND AND THE MAIN MIRE AROUND THE AREA OF THE PEAT CUTTINGS

PLATE 5

channel and found a maximum depth of 3.3 metres (11 feet) consisting of peat underlain by a stiff whitish-grey clay, very tenacious and containing small boulders, "very similar to that found at Ewe Crag Slack underlying the peat". The present infill is obviously a remnant of a larger deposit. Active peat cutting is in progress, with only a small area retaining something near to its original dimensions. About 250 metres in a north-south direction contain some infill, all in the broad flat interfluve while the channel is not more than 150 metres wide at any point. The slopes around the mire are the source for several small streams; the headwaters of Sandwath Beck flowing northwards, and those of Hardale Beck southwards, at the edges of the deposits, which pass from peat to a thin layer of colluvium overlying a basal solifluction clay, in an upstream and a downstream direction.

Vegetation

The contemporary flora is indicative of considerable human interference with the bog and its regime. The slopes of the channel, cut in Grits, are covered mainly with well drained grassland with Molinia caerulea, Deschampsia flexuosa and Nardus stricta, as well as cultivated grasses. Occasional bushes of Sarothamnus scoparius and Ulex europaeus occur, together with increasing amounts of Pteridium aquilinum. The banks of the fringing streams, whose courses have, in some parts, been artificially altered, are dominated by Salix spp., Alnus glutinosa, Betula pubescens, Juncus effusus, Molinia caerulea and Alopecuris geniculatus.

The relatively undisturbed area of the bog has as its dominants, Eriophorum vaginatum, E. angustifolium, Molinia caerulea, Anthoxanthum odoratum, Poa pratensis, Calluna vulgaris, Vaccinium myrtillus, Rumex acetosa, Galium saxatile, Juncus effusus, Sphagnum recurvum, S. papillosum, S. compactum, Carex nigra, C. panicea. This is indicative of the fact that although a number of plants of wetland habitats are present, a fair number of species represent evidence of drying out and contraction of the mire, particularly at its margins.

The large hollow left by peat cutting shows an accumulation of drainage water, and a quite well developed fen community at its southern end. The cut area is dominated by Eriophorum vaginatum, E. angustifolium, Molinia caerulea, Carex rostrata, Carex panicea, Juncus effusus, J. squarrosus, J. conglomeratus, Vaccinum myrtillus, V. oxycoccus, Scabiosa succisa, Tussilago farfara, Dryopteris spinulosa, Polytrichum commune, P. strictum, Sphagnum papillosum and S. recurvum.

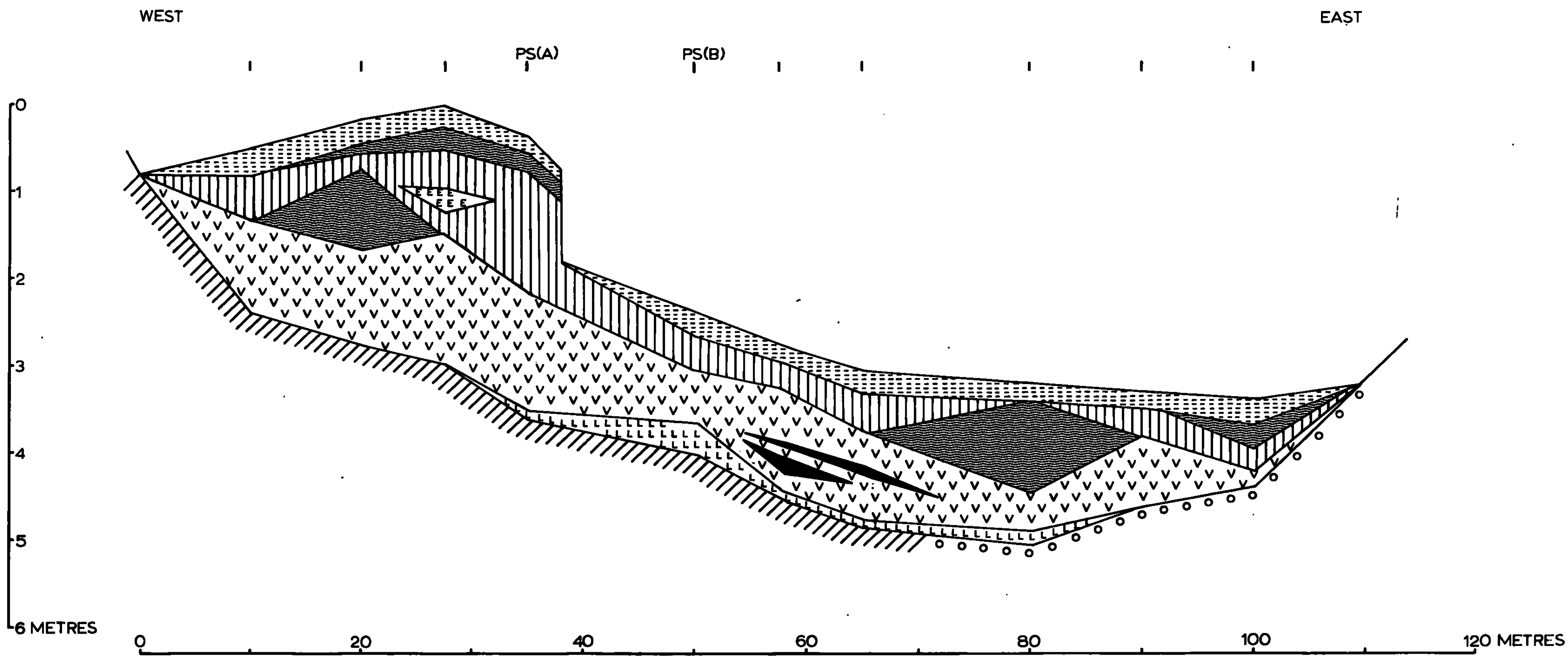
The fen has a small area of open water at its interior; and Salix spp., Alnus glutinosa and Betula pubescens at its margins, together with Potentilla erecta, P. palustris, Rumex acetosella, Valeriana dioica, Filipendula ulmaria, Dactylorchis incarnata, Sphagnum cuspidatum, S. recurvum, S. papillosum and Polytrichum commune. In the shallow water, Hydrocotyle vulgaris, Potamogeton polygonifolius, Equisetum palustre, Ranunculus flamula, Mentha aquatica and Sparganium emersum flourish.

Stratigraphy

The stratigraphy was investigated by means of a levelled transect of borings from west to east across the channel (Figure 22). The results are shown in Figure 23.

The first seven bores from the western edge bottomed in impenetrable grey clay with angular stones, while the remaining three encountered rounded gravels at their maximum penetration. In the centre of the channel, the concave surface of these deposits provides a hollow in which up to 45 cm. of light brown clay mud has accumulated, thinning and disappearing laterally as the slopes become steeper and more convex. A large expanse of dry wood peat covers this and stretches to the bog margins, being up to 1½ metres thick in places. Remains of *Pinus* and *Salix* are frequent near its base with *Betula* and *Alnus* higher up. In the central part of the wood peat about one metre from the present surface, are two bands of grey silt of colluvial form; the lower 25 cm. thick and extending laterally for 10 metres, the upper, 5 cm's. higher, about 10 cm. thick and extending 20 metres before petering out laterally. Two lenses of *Sphagnum* peat occur in depressions of the upper surface of the wood peat near the mire edges. The western one attaining 90 cm. in thickness, the eastern one 105 cm., both extending only short lateral distances. Overlying this over the whole area is a quite well humified *Carex* peat with *Calluna* and *Betula* twigs and seeds of *Menyanthes trifoliata*, up to 140 cm. thick in places. A small band of *Eriophorum* peat with small lateral dimensions and 25 cm. thick is found near the western side. Above the *Carex* peat a well defined *Sphagnum*

TRANMIRE SLACK



(RLJ. 1970)

FIGURE 23

TRANMIRE SLACK LOOKING NORTHWARDS WITH THE SMALL FEN IN THE FOREGROUND AND THE MAIN MIRE AROUND THE AREA OF THE PEAT CUTTINGS

PLATE 5

layer, about 25 cm. thick can be traced through the uncut western sector to near the surface in the cut eastern area. The superficial deposit in the succession is a mixture of dried peaty soil in the undisturbed area, while below the metre high peat cutting cut peat and soil are admixed to a depth of 15-30 cm. In the cut area the lower part of the Carex peat forms the first undisturbed sediment.

The maximum depth of deposits encountered at Tranmire was 3.67 metres (12 feet), though the possibility that deeper ones existed before the extensive human influence is very likely.

Pollen and Macrofossil Analysis and Chronology

Samples for pollen and macrofossil analysis were secured in 1969 from two sites. The first through the deepest and most complete succession (PS (A), Figure 24), and the second from near the centre of the deposit (PS (B), Figure 25), to provide a cross check on the inception of sediment formation in the channel.

The stratigraphy appropriate to PS (A) is as follows :-

0-15 cm. Dry peaty soil with contemporary roots, fragments of Calluna, Carices and Molinia; leaves of Sphagnum rubellum and S. compactum.

15-36 cm. Light brown Sphagnum peat with Sphagnum acutifolia agg., S. rubellum, S. cuspidatum, S. plumulosum, S. recurvum, S. tenellum, S. squarrosum, S. palustre. Leaves of Hypnum cupressiforme and Pleurozium schreberi at 35 cm. Occasional Carex stems and

Eriophorum vaginatum spindles. Annuli of Pteridium aquilinum at 15 cm.

36-178 cm. Mid-brown, fairly well humified Carex peat with Molinia stems and Calluna twigs throughout. Charcoal abundant 40-155 cm. Seeds of Juncus effusus 160-175 cm. Leaf of Trichophorum sp. at 130 cm. Eriophorum fibres 55-150 cm. Betula twigs at 120 cm. Bryophytes locally abundant 36-150 cm. particularly, Sphagnum recurvum, S. plumulosum, S. palustre, S. papillosum, S. rubellum, S. magellanicum, S. sub-secundum, S. acutifolia agg., Dicranum sp., Acrocladium cuspidatum. Sporangia of Pteridium aquilinum 160-178 cm.

178-322 cm. Mid-brown amorphous, dry wood peat with Carex remains throughout; with Juncus effusus, J. conglomeratus seeds and Sporangia of Thelypteris palustris. Alnus and Betula twigs frequent 178-310 cm. Pinus and Salix remains 310-322 cm. Leaves of Sphagnum acutifolium at 235 cm. Polytrichum commune at 300 cm. and Aulacomnium palustre at 290 cm. Some fine silt present.

322-341 cm. Light brown clay mud, with Carex spp. and seeds of Juncus squarrosus.

341-367 cm. + Tenacious grey clay with angular stones. Some Carex and wood remains in upper 20 cm., then becoming purer and impenetrable.

Profile PS (B) shows :-

0-30 cm. Disturbed sediment.

30-60 cm. Mid-brown, well humified Carex peat with Betula and Calluna remains.

60-135 cm. Mid-brown amorphous dry wood peat with Alnus and Betula remains in the upper part, Salix and

Pinus at lower levels. Some silt.

135-168 cm. Light brown clay mud with *Carex* stems, and seeds of *Juncus squarrosus*.

168-180 cm. + Grey clay with angular stones. *Carex* stems, *Juncus* seeds and wood in the upper 10 cm., thereafter tenacious, becoming impenetrable.

The pollen diagram for Tranmire Slack (A) (Figure 24) shows the following zones to be present :-

Zone VIc (350-328 cm.)

Pinus dominant at first, later *Alnus* and *Quercus* increase in frequency. Herbs rare. Aquatics - *Sparganium* and *Potamogeton* recorded.

Zone VIIa (328-227 cm.)

The lower boundary characterized by a rapid increase in *Alnus* frequencies, with *Quercus* and *Betula* expanding also. *Ulmus*, *Tilia* and *Fraxinus* appear at the zones commencement but each not exceeding 5-8% of total tree pollen. *Corylus* and *Salix* decline, to re-expand later. *Hedera*, *Ilex* and *Lonicera* recorded. Small frequencies of *Filipendula*, *Melampyrum*, *Plantago coronopus*, *Rumex acetosa*, *Succisa*, *Ranunculaceae* and *Rosaceae* present. Aquatics - *Hydrocotyle* and *Menyanthes* occur, and *Polypodium*, *Pteridium* and *Filicales* also.

Zones VIIb and VIII (227-0 cm.)

No division into separate Zones VIIb and VIII is made, but overall 3 sub-zones can be identified :-

Sub-Zone A (227-156 cm.)

Lower boundary marked by an *Ulmus* fall. Above and

C
B
VIIb + VIII
A
VIIa
VIc
HERBS
SHRUBS
TREES
SPHAGNUM
FILICALES
PTERIDIUM
POLYPODIUM
LYCOPODIUM CL
EQUISETUM
SPARGANIUM
POTAMOGETON
MYRIOPHYLLUM
MENYANTHES
VALERIANA
HYDROCOTYLE
URTICA
UMBELLIFERAE
SUCCISA
SPERGULARIA
SCROPHULARIACEAE
SAXIFRAGACEAE
RUMEX
RUMEX ACETOSA
RUBIACEAE
ROSACEAE
RANUNCULACEAE
POTENTILLA
POLYGONUM CONVOL
POLYGALA VULGARIS
POLYGONUM PERSICARIA
PLANTAGO MAJOR/ME
PLANTAGO CORONOPI
PLANTAGO LANCEOLATA
VICIA
PAPILIONACEAE
OXYRIA
MERCURIALIS
MELAMPYRUM
FILIPENDULA
DROSERA
EPILOBIUM
CRUCIFERAE
CHENOPODIACEAE
STELLARIA HOLOSTEA
CARYOPHYLLACEAE LYCH
CARYOPHYLLACEAE DIANT
COMPOSITAE LIGULIFLORAE
CIRSIUM
CENTAUREA CYANUS
ARTEMISIA
COMPOSITAE TUBULIFLORAE
ERICALES
EMPETRUM
CALLUNA
CYPERACEAE
CEREALIA
GRAMINEAE
SORBUS
LONICERA

below this level, Pinus, Corylus, Quercus and Alnus expand slightly, Fraxinus temporarily disappearing. Gramineae, Cyperaceae, Plantago spp., Liguliflorae, Chenopodiaceae, Melampyrum, Ranunculaceae, Rosaceae, Rumex acetosa and Succisa frequencies rise, as does that of Pteridium. Lycopodium clavatum recorded.

Sub-Zone B (156-36 cm.)

Ulmus and Tilia decline, also Fraxinus and other arboreal pollen frequencies. Fagus and Sorbus appear. Arboreal pollen no more than 10-12% of total pollen. Gramineae, Cerealia, Cyperaceae, Calluna, Tubuliflorae, Liguliflorae, Caryophyllaceae, Chenopodiaceae, Filipendula, Plantago spp., Potentilla, Ranunculaceae, Rosaceae, Rubiaceae, Rumex acetosa, Umbelliferae and Pteridium increase significantly. Lycopodium clavatum recorded.

Sub-Zone C (36-0 cm.)

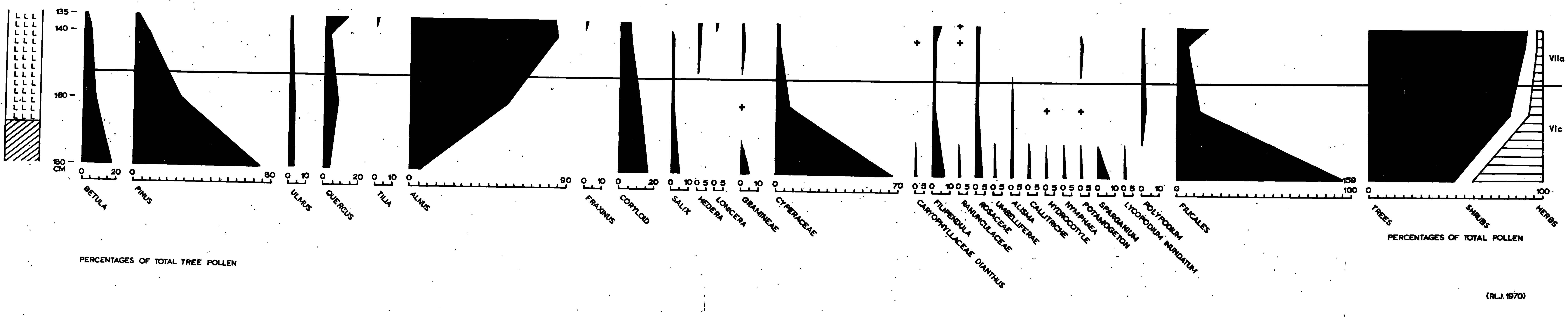
Arboreal pollen and shrubs decline to under 10% of total pollen, even Fraxinus and Fagus poorly represented. Herbaceous types of B increase sharply together with Succisa, Urtica, Spergularia, Valeriana, Vicia, Polygonum persicaria and Centaurea cyanus. Sphagnum has its maximum value.

The pollen diagram for Tranmire Slack (B) (Figure 25), based on a total tree pollen sum shows the following zones to be present :-

Zone VIc (180-152 cm.)

Pinus and Betula dominant. Quercus and Ulmus present, Alnus expanding steady. Corylus declines.

TRANMIRE SLACK (B)



PERCENTAGES OF TOTAL TREE POLLEN

(R.L.J. 1970)

FIGURE 25

Herb frequencies low, but aquatics quite high, especially *Alisma*, *Callitriche*, *Hydrocotyle*, *Nymphaea*, *Potamogeton* and *Sparganium*. *Lycopodium inundatum* recorded.

Zone VIIa (152-135 cm.)

Alnus expands, *Pinus*, *Corylus* and *Betula* decline. *Quercus*, *Ulmus*, *Tilia* and *Fraxinus* increase in frequency. Arboreal pollen values up to 85% of total pollen.

The Development of the Mire System

At the onset of deglaciation in the Weichselian, with the emergence of North Cleveland as a nunatak, and the presence of stagnant ice in eastern Eskdale, Tranmire Slack began its evolution. Solifluction processes, acting upon an area with few glacial deposits sensu strictu, gave rise to a stony grey clay with little admixture of organic matter. There is no evidence in the stratigraphy or macrofossils of any environmental changes during the accumulation of this clay, and the pollen analytical record dates from near the close of Boreal time (late Zone VI). The lithology of the clay, however, and the presence within it, of certain pollen types characteristic of Late-glacial deposits (*Tubuliflorae* and *Filipendula*, for example); when considered in relation to its close affinities to other almost identical clays, definitely ascribable by pollen content to the Late-glacial, at other sites in the region, makes it almost certainly of this origin. The eastern part of the channel is floored by rounded gravels, very like present day river bed deposits.

This indicates that, at this time, Tranmire Slack contained through drainage. At present, a small stream flows around the edge of the mire, and the gravels represent part of its former course. The ecological conditions in the channel during the Late-glacial and early Post-glacial periods, consisted of a stream meandering across the floor, and liable to flooding, inundating, eroding and redepositing any sediment which was accumulating. Apart from the stream, there were some areas of open water, represented by the clay mud above the solifluction deposit, and its pollen of Alisma, Callitriche, Potamogeton, Nymphaea, Sparganium, Hydrocotyle, Lycopodium inundatum and Filipendula, and macrofossils of Carex, Juncus, Salix and Betula. This suggests some fringing swamps and fen deposits, but nowhere with an uninterrupted succession, and an overall, complex hydroseral stage.

In late Boreal time a marked change took place. The importance of the stream, and other water bodies diminished and a fen carr became quite rapidly established in the channel. Birch, willow, and later, alder were important in this, together with sedges, Juncus, Thelypteris palustris and patches of fen mosses. Within this stage, which lasted through the climatic optimum, and into early Zones VIIb and VIII, pollen records for Menyanthes, Equisetum, Epilobium, Sparganium, Myriophyllum alterniflorum, Lycopodium clavatum and Filicales give a further indication as to the composition of the mire. Two small areas of fine grey silt are found within the wood deposits. These must have come from the surrounding slopes, and were the product of soil erosion there, at a time when the pollen diagram is indicative of some human influences in the neighbouring landscape.

Early in the Sub-boreal period, the fen carr decreased in importance, when a sedge peat, with Carex spp., Juncus, Molinia and bryophytes began to form. It quickly accumulated, choking tree growth, and no doubt having a major influence on the course of the stream, which by then must have been occupying something like its present marginal course. Increasing water availability, and a rising water table must have initiated this stage, when the acidification of the mire first began. As the swamp developed, drier conditions are indicated by the presence of Calluna and grasses in the macrofossil record. Charcoal is present too, and human activity must have extended very near to, if not upon, the site itself. Pteridium is well represented by macrofossils and pollen late in this stage, and probably occupied much of the surrounding slopes at this time.

The final stages of mire evolution were initiated, according to the pollen spectra, about the opening of Sub-Zone C (which may represent early Sub-atlantic time). The sedge swamp in its later phases, developed an increasingly acid flora, with bryophytes playing an important role in the community. Fairly sharply, the sedge-bryophyte deposit was succeeded by a pure moss peat, dominated by Sphagnum spp.. Both pool and hummock complexes can be deduced from macrofossil evidence, and the present shape of the mire, a slightly raised, convex feature, indicates the effectiveness of this active growth. It is difficult to estimate when this ceased, because the upper parts of the bog have been altered by contemporary human activities, and the widespread occurrence of Calluna, Molinia and Pteridium in the peat here, together with the driest hummock forming Sphagna (S. rubellum and S. compactum), is attributable in large measure to these.

Vegetational History of the Tranmire Black Area

Evidence for the vegetational developments on the moorlands around Tranmire is lacking until late Boreal time. The first pollen records show that the landscape was covered by a well developed closed forest, dominated by Pinus and Corylus. Betula, Quercus, Ulmus and Alnus were present but not of widespread significance in a 95% closed community. At the close of Zone VI, mixed deciduous forest replaced a pine-hazel spectrum. Alnus was especially important early in Zone VIIa later, Betula assumed this position, both perhaps the results of local dominance around the mire in the Atlantic period. The surrounding moors carried a vegetation dominated by Quercus, Ulmus and eventually also Tilia and Fraxinus, though it may have been quite open, with Corylus an important constituent. Pinus also expanded peculiarly late in Zone VIIa, soon to decline, around the time of the commencement of Zone VIIb. In the closing parts of the Atlantic period there appear to have been a few attempts to clear forest. Increases in shrubs, and Melampyrum, Rosaceae and Pteridium at some levels suggest that temporary clearances were made, soon to recover and become reforested.

The first effective and lasting clearances came though in Zones VIIb and VIII, and as at the other 3 sites, three major periods of activity are separable into Sub-Zones A, B and C.

Sub-Zone A showed characteristic attacks on Ulmus and Tilia, but also most other trees were subjected to a fairly effective clearance, and their percentage cover soon was reduced. The expansions of Gramineae, Plantago lanceolata and Pteridium indicate an early phase of pastoral activity which was quite well developed. However, Betula and Alnus, and to a lesser extent Ulmus and Corylus, were able to regenerate in the later stages of A, only to be soon subjected to further removal of a most effective nature.

Sub-Zone B illustrates the rapid efficiency of clearance at this time in this area. Ulmus and Tilia were decimated almost to total disappearance, and most other trees suffered declines from which they never recovered. Corylus was quite effective in extending into some cleared areas, Fraxinus less so, and it was Calluna, Gramineae and other heathland plants which spread into the open spaces. It is difficult to separate phases of pastoral and arable activity here. Gramineae, Plantago lanceolata, Melampyrum, Potentilla, Ranunculaceae, Rosaceae and Pteridium dominance of the herbaceous components early on suggest a pastoral phase; but Cerealia (mainly Triticum dicoccum and Hordeum T.), together with Artemisia, Fagus, Rumex acetosa, Chenopodiaceae, Cruciferae and Plantago coronopus show that cultivation was in progress too. Late in the Sub-Zone some regeneration, principally by Betula, occurred, human activity while still in progress, seems to have been less, and the massive extension of Calluna heathland which started right at the beginning of A was slowed down temporarily.

Sub-Zone C has as its main features, firstly a reduction of the regenerated woodland of late B, including a severe attack on the shrub components of the vegetation, leading to less than a 5% cover of trees and shrubs. This was followed by an agricultural phase, dominated by Cereals (Hordeum T., Avena T. and later Secale), Artemisia, Compositae, Liguliflorae, Cruciferae, Chenopodiaceae, Rumex, Centaurea cyanus, Cirsium and Spergularia. Later, dominance of Gramineae, Calluna, Empetrum, Plantago lanceolata, Pteridium and Filicales amongst the herbaceous vegetation shows that then, pastoral farming came to be the most important. The massive expansion of heath vegetation giving a community not unlike that of the present day over much of the moorland, with trees and shrubs confined to a very few localities. and subject to removal and replacement under human influences in what may have been Medieval times.

CHAPTER 4

THE ECOLOGICAL DEVELOPMENT OF CLEVELAND

The purpose of this chapter is to attempt an outline of the major ecological changes that have occurred in the landscape of Cleveland in Late Quaternary time, based mainly on the plant records from the sites investigated, while taking into consideration some of the problems involved in such interpretations.

The discussion is separated into two sections, dealing with the Late-glacial and the Post-glacial periods respectively; the latter sub-divided into (a) The Period of Forest Establishment and (b) The Period of Forest Reduction.

4.1 The Late-Glacial Period

In this section, vegetational history, and environmental changes with which it can be correlated, is considered from the time of the earliest floral evidence (sometime within pollen zone I) until the beginnings of the establishment of a tree covered landscape (about the conclusion of pollen zone III). The evidence is drawn mainly from Seamer Carrs and Kildale Hall, with West House and Ewe Crag Slack, providing information only about the later stages of development.

Chronology

The zonation of the pollen diagrams, independent for each, is based on a total pollen sum (excluding aquatic pollen; pteridophyte and bryophyte spores), overall thought to give the clearest indications of the relative importance of plants in what must have been a largely open, treeless landscape. For Cleveland, the zonation adopted may have some chronological significance, due to the relatively small size of the region. There is good synchroneity between Late-glacial boundaries within Britain and Europe (Godwin and Willis, 1959), as determined by radiocarbon assay. The radiocarbon date of 8,400 B.C. for late Pre-boreal time at Kildale Hall indicates that a broadly similar timescale is valid for Cleveland as far as the Late-glacial is concerned. As yet no absolute correlations with other Late-glacial sites in north-east England is possible, but developments at Neasham near Darlington (Blackburn, 1952); Lake Pickering near Scarborough (Godwin and Walker, 1954); Tadcaster on the Escrick moraine (Bartley, 1962); Romaldkirk in Teesdale (Bellamy et al., 1966); Thorpe Bulmer and South Wingate in eastern Durham (Bartley, personal communication) and Cranberry Bog in central Durham (Turner, personal communication) show certain affinities to the Cleveland ecological record. Diagrams from Aby Grange, Lincolnshire (Suggate and West, 1958), Bamburgh, Northumberland (Bartley, 1966) and Corstorphine, Edinburgh (Newey, 1970) also are relevant; while in northern Europe, the investigations in Denmark (Iversen,1954, Krog, 1954) and the Netherlands (Van der Hammen et al., 1967) provide important comparative detail.

In Cleveland, the Late-glacial period has been sub-divided into Lower Dryas (Zone I), followed by the Allerőd Interstadial (Zone II). No Bölling oscillation

(Zone Ib) is recognized, but Zone II is characterized by three divisions, a, b and c. The final phase of Late-glacial time was the Younger Dryas period, (Zone III).

The actual end of Full-glacial and the beginning of Late-glacial time is problematical. Gross (1957) defines the end of the Hauptwurm Stadial in Europe and the beginning of the Late-glacial there at the start of ice retreat from the Pommerian moraines and the opening of the oldest Dryas period, which Firbas (1949) called pollen analytical zone Ia. De Geer (1954) calculated by varve analysis that the Pommerian glacial stage ended before 14,000 B.C., and the oldest radiocarbon dates for Pollen Zone Ia do not exceed 13,800 ± 800 B.C. The beginning of the Late-glacial was probably therefore, around 14,000 B.C. Wolstedt (1956) divides the Mittel-Würm and the Late-glacial towards the end of the initial retreat from the Pommerian moraines, and both he and Gross (1957) include the Bölling and the Alleröd amongst Late-glacial interstadials.

Van der Hammen (1952b, 1957a, 1967) defines his Pleniglacial/Late-glacial boundary on palynological criteria, principally a rise in the Artemisia pollen curve, occurring at the Older-Younger Coversand interface in the Netherlands. Here the 'Main Würm' lasted from about 26,000 to 15,000 years ago, with what has been termed 'polar desert' vegetation and conditions in its latter stages (Van der Hammen et al., 1967). A radiocarbon date of 11,300 B.C. has been obtained by these workers for the Pleniglacial/Late-glacial boundary.

In northern England it is assumed, (Penny, Coope and Catt, 1969. Pennington, 1970) that Full-glacial conditions existed from about 25,000 to 15,000 years ago. Godwin (1956) stated that the Full/Late-glacial boundary lay somewhere within pollen analytical Zone I, but it was not precisely known where. Radiocarbon dates of 18,500 ± 400 B.P., and 18,240 ± 250 B.P., from what is regarded as an Upper Pleniglacial moss silt from Dimlington, east Yorkshire not of interstadial rank (Penny, Coope and Catt, 1969) and overlain by the Drab, Purple and Hessle Tills of Upper Pleniglacial (Weichselian maximum) age, are critical in the area. The site is outside the Late-glacial moraine limits, and the tills are overlain by pre-Alleröd sediments, for example at Star Carr, Aby Grange and at Tadcaster. The Weichselian ice had retreated from north Lancashire by about 14,000 B.P. (Godwin and Willis, 1964) and the south-west Scottish Lowlands by 13,000 B.P. (Moar, 1963). Between 18,000 B.P. and 13,000 B.P. therefore, the three divisions of the Weichselian maximum drift were deposited. Penny, Coope and Catt (1969) suggest one composite ice sheet with no time for three separate ice invasions, and Francis (1970) and Land (personal communication) support this scheme for Durham and north-east Yorkshire. The maximum Weichselian advance must have been reached just beyond 18,000 B.P., and as Dimlington is only 30 kilometres north of the Weichselian till limits the ice cannot have been far north of the site before 18,000 B.P., as the impoverished insect fauna and bryophyte habitats of the silts indicate.

At Seamer Carrs and Kildale Hall a full succession of Late-glacial deposits occurs. Godwin and Walker (1954), Suggate and West (1958) and Bartley (1962), all suggest that there is some evidence at their sites for a separate Bölling oscillation within Zone I, but radiocarbon assays are absent, and Godwin (personal communication), is disinclined to believe that a separate Bölling exists in Britain, a view which is becoming increasingly held amongst workers in the field of Late-glacial palynology. The Allerö́d is present and well defined at many sites in north-east England. Hewey (1970) and Bartley (personal communication) have reported an Allerö́d sequence divisable into three parts in south-east Scotland and eastern Durham respectively.

Iversen (1954) and Krog (1954) in Denmark suggest similar divisions of Zone II time, and both Cleveland sites (Seamer Carrs and Kildale Hall) appear to conform to such a pattern. If Van der Hammen's <u>Artemisia</u> rise criteria is adopted in order to determine a possible Full/Late-glacial boundary, both Cleveland sites can be regarded as having pre-Allerö́d sediments of Late-glacial age, with no evidence for Full-glacial conditions. However, the lack, as yet, of any clear and finite evidence from known interstadial and interglacial sites in the area makes only pollen analytical zones suitable for correlations, and in what follows they provide the basis for description and definition.

<u>Problems in the Interpretation of the Late-Glacial Pollen Record</u>

Assemblages of Late-glacial vegetation have been characterized for many areas, being synthesized notably by Godwin (1956) and Pennington (1969). There have been various approaches to the analysis of such vegetation. Walker (1966) attempted a classification into habitat types (viz. Dry land herbs and Damp land herbs) in order to separate communities. Community characterization, with analysis of habitats and tolerances is a desirable method of approach, and has been adopted by Proctor and Lambert (1961), Kirk and Godwin (1963), Moore (1970) and Pennington (1970).

Pennington (1970) suggests that while this approach is the best one, it does raise problems, particularly when marginal hydroseres of shallow basins are included in the analysis. Then, such taxa as Gramineae, Cyperaceae and Compositae are included in more than one community and are difficult to assign to a particular one with confidence.

The ratio of arboreal pollen to non arboreal pollen is also important in Late-glacial spectra. A higher arboreal/non arboreal pollen ratio, or a change to one, has been interpreted as indicating periods of climatic amelioration, and a reverse of this ratio a return to a poorer climatic regime. The possible long distance transport of pollen grains, especially of Pinus (which has no macro-fossil representation in the Cleveland Late-glacial) must be considered, particularly with reference to recent studies of pollen transport (Tauber, 1965). If Pinus arrives by long distance transport, and remains a constant amount yearly, then when local vegetation components (and their supply of pollen) are reduced, pine will increase in the spectrum. Such spectra need careful consideration if *Pinus* is a major contributor, (Jessen, 1949).

There is commonly one other tree type found in Late-glacial deposits, *Betula*, and this too presents problems. Typical grains of dwarf birch, *Betula nana*, have been distinguished by observation and measurement from those of tree birches, for example by Terasmae (1951), Walker (1955) and Bartley (1962). There is a large area of overlap, however, and even quantitative separation methods such as used by Birks (1968), based on the pore depth to grain diameter ratio of *Betula nana* and tree birches cannot be used where Hydrofluoric acid has been used in the preparation (distortion of grains results). Therefore, the proportion of *Betula* falling outside the accepted characteristics of *Betula nana*, may, according to Pennington, (1970) in fact be it, and it is inaccurate to regard a curve for percentage *Betula* pollen as indicative of the relative importance of merely trees in the vegetation. A rising *Betula* curve could be nearly all *Betula nana*, and to overcome this to some extent, the Cleveland Late-glacial diagrams have a separate *Betula nana* curve, but the grains have been included, where necessary, with the tree pollen sum.

The use of absolute pollen counting techniques in America (Davis and Deevey, 1964) and in north-west England (Pennington and Bonny, 1970), has produced two fresh theories on Late-glacial pollen diagram interpretation. Firstly, at times such as the early Late-glacial when absolute pollen frequency was low, changes in percentages of various tree pollens, previously interpreted as evidence of climatic oscillations may represent statistical artifacts rather than significant vegetational changes. Also, at the Late-glacial/Post-glacial boundary absolute counts give herbaceous pollen frequencies which do not diminish greatly, as they do with the percentage method when they are suppressed by massive increases in total yearly production of tree pollen which occurred when many trees spread in the early Post-glacial.

The Landscape

The retreat of the Weichselian ice left boulder clays and sands and gravels spread quite thickly over the Cleveland Plain and in the dales, the North Cleveland Moors being left with glacially eroded landforms by what was presumably "clean" ice. In the early stages of deglaciation there must have been a number of cold, freshwater lakes, dammed by the retreating ice margins or by material dumped from the glaciers. The climate would have been severe, with perhaps perennially frozen ground and a waterlogged soil, limiting the spread of plant growth; something perhaps close to Van der Hammen's concept of a 'polar desert'. The water bodies must have drained, water tables falling as a consequence, with the accentuation of habitat differences on the boulder clays and sands and gravels of the lowlands and the bare rock of the uplands. All this would have been accomplished gradually with the boulder clays the best areas in terms of available nutrients for plant growth. Even the lowland sand and gravel spreads, and the uplands with their soliflucted slopes must have been reasonable areas for plant colonization when compared to present day conditions with leaching at an advanced stage everywhere.

The relative positions of land and sea in eastern England at this time are reasonably well known. The majority of what is now the southern North Sea, (to a line about the Wash), was land, connecting Britain to Europe (Jelgersma, 1961). Thus a good avenue for plants recolonizing the glaciated areas after spending the cold periods of the Quaternary in refugia to the south of the ice sheets was afforded. For species which retreated immediately south of the last glacial limit, the broad lowland corridor between the western and eastern uplands of England was an important migratory route northwards for vegetation. The physical barriers of the Pennines, for example, may help to explain the somewhat differing Late-glacial environments of north-west and north-east England.

The lowland basins of Cleveland, after the gradual melting of the ice, accumulated a considerable depth of pure silty clay with little organic content and few aquatic pollen types. This suggests that a fair amount of solifluction was in progress and that the water bodies that existed were frozen over for quite long periods. The fresh, loose fluvio-glacial deposits of the lowlands were more conducive to mass-movements than the bare uplands with their siliceous bedrock. The upland mires, with deposits which must in part represent early Late-glacial time, have a much coarser solifluction clay with angular stones, indicative of more severe processes than those of the lowlands, where, in spite of a similar lack of vegetation cover, only the finer deposits were moved into the lakes. Solifluction is a variable phenomenon which can be caused by either a rise or a fall in mean temperature, or simply variation around a mean, giving temporarily or permanently frozen ground. The Cleveland kettle-holes and inter-drumlin hollows could have carried ice blocks for a considerable period at this time. In Denmark, Hartz (1912) reported some kettle-holes retaining 'dead' ice blocks for 2,000 years after deglaciation.

Both stratigraphically and palynologically it proved impossible to determine the Full-glacial/Late-glacial boundary in Cleveland. However, very little derived pollen (for example, of Carboniferous and Tertiary age) was encountered at the lowest analysed levels, and continuous curves for certain pollen types such as Artemisia and Rumex make it feasible to place the basal deposits of the lowland mires within Pollen Zone I. The upland channel mires, where presumably conditions of accumulation accompanied by intensity of periglaciation have prevented the delimitation of full and clear sequences, remain a problem in this respect.

Pollen Zone II saw a distinct change in conditions, with base-rich organic muds laid down in the mires of Seamer and Kildale. The absence of these deposits at the other sites may be explicable by their removal and redeposition by later solifluction, or simply that the climatic amelioration which caused their formation did not have sufficient effectiveness to do so at the higher altitudes. Very little silt is found in the organic deposits, (save in the middle of the sequence, where mass movement must have occurred again), and generally solifluction ceased while lake productivity increased. Pediastrum expanded, and at Kildale mollusca and bryophytes flourished in a very base rich marl, indicating considerable climatic amelioration during the 1,200 or so years duration of the Allerød interstadial (Godwin and Willis, 1959. West, 1968).

Pollen Zone III, with a time span of only around 500 years (Godwin and Willis, 1959. West, 1968) saw the accumulation of a considerable thickness of coarse sediment at all sites. It was a period of renewed solifluction and of mass movement into the mires, where organic productivity fell. Once again, the 200 metres altitudinal difference between the lowland and upland sites, and the effect of this upon processes active at the time is shown by the much coarser solifluction clays of the moorland mires. The presence of a variety of aquatic pollen in this zone indicates that while the climate was severe, the annual period of freezing over of the water bodies was not enough to inhibit plant growth, but it did reduce their frequency. The high base-status of the lake water was maintained by the inwashing of sediment, while the slopes marginal to the mires remained unstable and largely unvegetated. Toward the close of Late-glacial time, (around the Zone III/Zone IV boundary), the accumulation of inorganic matter in the mires ceased gradually, showing that solifluction was reaching an effective conclusion and that the slopes were becoming markedly more stable.

Hydrosere Development

Hydrosere development has been discussed separately for each site, but generally some trends can be deduced in their evolution.

At Seamer Carrs and Kildale Hall open water bodies existed throughout Late-glacial time. The flora was quite impoverished early on, but later, in Zones II and III Potamogeton was joined by Nymphaea, Nuphar and Alisma; Typha latifolia, Sparganium, Filipendula, Thalictrum and Hydrocotyle were added to Cyperaceae, Gramineae and Salix in the fringing swamps and poor fens. The unhindered evolution of these lakes throughout Late-glacial time points to the existence of two factors, (a) that the vegetation cover of the slopes was tolerant of instability and (b) that the lake flora was not adverse to renewed silting (cf. the aquatics and hypnoid mosses present). At Kildale Hall the extinct and very rare species, Paludella squarrosa and Camptothecium nitens amongst the bryophytes were joined by a variety of mollusca including Limnaea, Psidium and Planorbis in a base-rich and rapidly accumulating Zone II deposit. The lowland hydroseral succession can be contrasted with the situations at West House, Ewe Crag Slack and probably Tranmire Slack also. Here the Zone III hydroseres show that patches of fairly shallow open water existed with a quite poor aquatic flora and associated swamp and fen species, rather similar to the Zone I conditions of the lower sites. Nowhere does solifluction appear to have been severe enough to cut off all records of hydroseral change, as found, for example, in northern Northumberland, (Bartley, 1966).

Land Vegetation

The most obvious feature of the Cleveland Late-glacial pollen record is the dominance to a greater or lesser extent of herbaceous pollen over that of trees and shrubs. In view of the mechanics of the pollen sums (based on total pollen) this implies that for the majority of the time a predominantly open, almost treeless landscape existed, even during the Allerӧd interstadial, when Seamer and Kildale furnish evidence of slightly more abundant tree growth.

The absence of pre-Zone III sediments in the upland mires is to some extent compensated for by the fact that the pollen spectra for the basal clays there accord well with the Zone III lowland flora. Trees, shrubs and herbs available at Seamer and Kildale increased their frequency in Zone II indicating a lack of competition between the plants, all within the limits of their climatic tolerances, and available either from within the area or from outside it with relative ease.

During Zone I the vegetation appears to have been predominantly herbaceous with a wide variety of taxa represented on the pollen diagrams. The open nature of the landscape is clearly shown by the assemblage of heliophytes, for example, Artemisia, Chenopodiaceae, Cruciferae, Epilobium, Rumex acetosa, Helianthemum, Polemonium, Galium, Thalictrum and Saxifragaceae.

Grass and sedge pollen dominates the early spectra, together with Salix (probably S. herbacea) and Betula nana. Some tree birches must have existed, but it was Pinus which dominated the arboreal sector, its high and fluctuating percentages making it ascribable with some confidence to transport from distance. Overall, it must have been an open sward, dominated by short turf communities on the well drained slopes, with Helianthemum, Compositae, Rubiaceae, Botrychium and Lycopodium spp.; dwarf shrub-heath with Betula nana, Salix, Juniperus, Hippophäe and Empetrum and taller herbaceous communities with Caryophyllaceae, Filipendula, Rumex acetosa, Polemonium, Cyperaceae and Thalictrum in damper situations.

Rises in certain pollen frequencies near to the conclusion of Zone I, notably those of Juniperus and Hippophae, indicate a rise in temperature and the borderline between the sub-arctic, 'steppe-tundra' of the immediate post deglaciation period and the more temperate 'park-tundra' of Zone II (Iversen, 1954). For its existence, Hippophae needs a temperature of over 10°C and cannot tolerate more than a transient, thin snow cover (Gams, 1943), while also seeming to require climatic and edaphic dryness (Gams, 1952). Juniperus thrives on a snow cover, but flowers in profusion only when this is reduced and it can spread beyond the snow patches, becoming suppressed again when either increased snowfall or denser forest growth occurs.

The virgin soil of the Late-glacial period had as yet undergone very little leaching and was everywhere, even in the most acid environments, no more than neutral or slightly acidic in reaction. Indeed some areas, boulder clay tracts for example, must have been quite calcareous habitats.

At the opening of the Allerӧd interstadial, it was the drier communities which suffered most, giving way to patches of tree birches in favoured localities, with Pinus perhaps even making an isolated appearance. The absolute increase in pollen frequency in Zone IIa, especially of Betula, (even allowing for a Betula nana / tree birch overlap), must mean that there was an increase in tree birch cover. One of the most significant indicators of temperature increases in Late-glacial times is a rise in Filipendula values (Iversen, 1954), and this occurs in Zone II in Cleveland. Also in Zone II many of the herb communities of Zone I extended, becoming more well developed if somewhat less dominant as slopes stabilized, soil conditions improved and organic matter began to accumulate. Both Late-glacial diagrams show a double Betula maximum within Zone II (Zones IIa and IIc) indicating two ameliorations separated by a recession (IIb), when silt was moved once again into the mires. In the warmer periods the summer maximum temperature must have been about 12°C which is the minimum summer value for tree birch growth (Iversen, 1954). Manley (1953, 1959) has made estimates of Allerӧd temperatures for northern Britain, indicating a summer maximum of over 10°C for the Allerӧd. At the conclusion of Zone IIb, when there had been some extension, perhaps locally, of herbaceous communities again, rises in frequency of Juniperus and Hippophae suggest the passing of the tree line in the area and the start of Zone IIc. In this part of the Allerӧd birch woodland was best developed, with perhaps some pine also. The 'park-tundra' of Iversen (1954) must have been approached, patches of birch woodland growing close to the mires on sheltered, south facing slopes, a situation envisaged by Blackburn (1952) at Neasham, and Newey (1970) at Corstorphine. In the 1,200 or so years of the Allerød interstadial (Godwin and Willis, 1959), apart from extensions of tree growth, closed grassland occupied drier slopes and damp hollows while fen communities made up the majority of the remaining landscape.

This situation was effectively disrupted during the 500 or so years of the succeeding period, Zone III, (Godwin and Willis, 1959). The performance of Betula deteriorated, indicating a lowering of temperatures, sufficient to produce mass movement and frozen ground, with a return to unstable and rapidly changing plant communities. There is no evidence for any glacier formation and readvance in the region, such as occurred in north-west England in Zone III (Manley, 1959), where a fall in temperature of 9°F in areas with over 70 inches of rain per annum was sufficient to produce such conditions. The North Yorkshire Moors, never a centre of glaciation in the Pleistocene, could not have fulfilled these requirements (Gregory, 1962). Although conditions in Cleveland must have been a good deal less severe than around the Lakeland Fells, there is no doubt that the vegetation became open once again and that tree growth was not successful. High values for Pinus pollen can once again be attributed to movement over long distances in a landscape suited to such transport (Tauber, 1965). Dwarf shrub and heath communities dominated again with Betula nana, Salix, Juniperus, Hippophae, Empetrum, Artemisia and Rumex acetosa important; Gramineae and Cyperaceae expanding into areas formerly occupied by birch woodland and closed grassland. A single occurrence of *Ephedra distachya* with its liking for a steppe like climate and basic substrate, and records for *Armeria* and *Saxifragaceae* emphasize the instability and re-assortment of plant communities that took place. *Empetrum* heath was important, but localized on the sandier drift and thin upland soils which provided a suitable base-poor habitat for its extension.

The impoverished mire flora of this period was matched by that of their fringing swamps and fens. Near to the Zone IV transition, organic matter began to accumulate at all sites, but only at Seamer Carrs did *Juniperus* show its characteristic extension as the forerunner of closed forest. Elsewhere the Late-glacial components disappeared slowly as they became shaded out by recovering *Betula* woodland; or, more commonly, with the cessation of solifluction and the stabilization of slopes, a mosaic of communities rich in shrubs and herbs in a state of imbalance, and containing little closed woodland, sensu strictu, took over in the dales and on the moorlands, while a closed forest, mainly composed of *Betula*, began to colonize the lowlands

4.2 The Post-Glacial Period

(a) The Period of Forest Establishment

The purpose of this section is to describe the environmental changes that occurred from the time of the initiation of a forest cover (Zone IV), through its development and maximum extension (Zones V, VI and VIIa), until the first concerted attempts at its disruption (early Zones VIIb and VIII).

Chronology

The five sites provide evidence for these stages, but Tranmire Slack is restricted to information from later Boreal time onward. The pollen diagrams, independently zoned according to Godwin's (1956) scheme for England and Wales, are based on the relative abundance of all types of tree pollen, as a total tree pollen sum (page 62). Alnus and Betula are considered to have been likely to have played significant roles in hydrosere development and are interpreted with this in mind. A radiocarbon date of 4,700 B.C. for the Boreal/Atlantic transition at West House, has been obtained, and, when taken in conjunction with the radiocarbon assay from Kildale Hall of 8,400 B.C. for early Boreal time (assuming slight errors in each, due probably to sampling), a tentative 'normal' time scale for Boreal time in Cleveland can be assumed.

The Landscape

Over the majority of the region, the cessation of solifluction and the establishment of some form of continuous vegetation cover, reduced soil disturbance to a minimum and led to the gradual accumulation of organic matter and the development of soil profiles.

The relative positions of land and sea in eastern England remained fairly constant in early Boreal time, with the North Sea predominantly land south of a line extending from mid-way between the present Tees and Humber estuaries across to Scandinavia (Godwin, 1956. Jelgersma, 1961). An effective migratory route for plants was therefore maintained, and operated along with the lowland corridors until later Boreal time when eustatic rise in sea level and tectonic downwarping of the North Sea basin caused the submergence of the "land bridge" separating Britain from the Continent. The extension of oceans resulting from this must have been a factor in the humidity changes at the Boreal/ Atlantic transition; with many low lying areas flooded by the transgression along the north-east coast of England aiding the trend towards increasing wetness in the environment.

Hydrosere Development

The early Post-glacial period saw little parallelism in the hydroseral development of the sites, each being affected largely by local conditions. The large and deep Seamer Carrs lake was accompanied by a smaller, shallower one at Kildale Hall. Both had a high productivity and a quite luxuriant aquatic flora, together with reasonably well developed fringing reedswamp and fen communities. Eutrophic conditions were maintained at both, with open water at Seamer throughout the period, the Kildale lake drying up in the late Boreal to be replaced by a base rich fen carr, with *Pinus* upon it at one stage. West House too had open water in early Boreal time, but this was replaced by *Phragmites* swamp and later by a fen carr, again with *Pinus* as a constituent in the later stages of Boreal time. Similar situations existed in the channel mires, with Ewe Crag Slack dominated by a fen carr, and Tranmire Slack (once the stream course had been choked by bog growth) having patches of open water until the late Boreal. The opening of the Atlantic period saw a reversal rather than a logical progression of hydroseral succession at Ewe Crag Slack and at West House. Here Carex dominated reedswamps developed and became progressively more acidic. These must have been initiated by rising water tables (which led to a fen carr development at Kildale Hall and Tranmire). The amount of base-poor drainage water entering the mires increased as soil leaching on the surrounding slopes became well advanced.

Regional Vegetational History

The climatic amelioration which began towards the close of Late-glacial time is indicated by a number of factors. Apart from the end of inorganic matter accumulation in the mires indicating the conclusion of large scale mass movement and the establishment of more stable slopes; continuations in the rises of the Filipendula curves over the region, accompanied by varied rates of extension of birch dominated woodlands, show that for the first time since the Allerød interstadial temperatures had once again reached a summer maximum of 10°-12°C. Certain characteristic Late-glacial heliophytes were shaded out quickly by the colonizing birch forests, especially at lower altitudes. No evidence exists from macro-fossils to prove that Pinus was a forest component at this time, but its pollen curves are more consistent and the climate should not have been such as to preclude its extension. Some of the temperature 'indicator' curves (e.g. that for Filipendula) suggest that generally, climatic amelioration was so rapid that forest development could not keep pace with it. The Cleveland Plain, where a late Zone III

Juniperus maximum indicates the proximity of the tree-line, and its subsequent extinction the passing of the same, experienced a rapid and comprehensive colonization by closed Betula forests early in the Pre-boreal period. This emulates the pattern of change at Star Carr (Godwin and Walker, 1954) and at Tadcaster (Bartley, 1962), in the eastern English lowlands to the south of Cleveland.

Betula is an adaptable, pioneering species with a rapid dispersal rate due to its numerous, light seeds, and there is little doubt (from macroscopic remains evidence), that the most important species in the Post-glacial forest period was B. pubescens.

In the lowlands only in small areas between the edges of the forests and the mires did open communities remain, Salix doing well on the base-rich soils, together with Cyperaceae, Umbelliferae, Caryophyllaceae, Rubiaceae and Rosaceae.

In the dales, and on the moorland, the accumulated evidence from Kildale Hall, West House and Ewe Crag Slack indicates open conditions over much of the area during Zones IV and V. A time-lag in the arrival of colonizing species at the higher altitudes, together with local edaphic factors influenced the type of vegetation present here. Some closed Betula forest developed in favoured localities, but in other areas, around Kildale Hall, for example, Empetrum heath was important. The presence of Empetrum heath has been interpreted as an indication of an oceanic climate (Jessen, 1949. Smith, 1961a). In Cleveland, edaphic factors, particularly sandy soils must have contributed to the maintenance of such communities, into which birch trees were unable to expand. It may have been that in these situations the temperature was not sufficiently high to permit extensive colonization by birch. This factor may perhaps be extended to include Corylus, which immigrated in Zone IV, and also faced with open habitats which it likes to colonize, failed to do so. This implies that temperatures were below 15°C in the uplands at this time (the minimum summer mean needed for the rapid extension of Corylus). The delayed Filipendula maxima at Kildale Hall and West House may reflect similar conditions, the deep Kildale valley may have been susceptible to late frosts which inhibited good tree generation in a frost hollow situation. Bartley (1966) has invoked exposure to explain the persistence of open habitats in some parts of northern Northumberland at this time. The situation in upland Cleveland must have been quite similar, with open canopy birch woods with first Salix, later with Corylus along their margins, accompanied by Empetrum heaths on the acid soils and calcareous grassland communities on the base-rich and less stable slopes.

Behre (1967) has suggested that within Zone IV there was a climatic oscillation with forested conditions being replaced by more open habitats and these reverting to forests once again. The diagrams for upland Cleveland are complicated by the fact that conditions were generally open anyway in Zone IV, but Seamer Carrs does show a small expansion of herbaceous types, especially of Empetrum at this time, when birch forests had developed around that area.

The first records for Ulmus and Quercus (late

Zone IV and early Zone V), show that these trees immigrated early on and found suitable habitats in which to become established. The upland diagrams records probably represent grains of *Ulmus* and *Quercus* brought through the open canopy environment of the very early Post-glacial period. It is hardly likely that in the face of the failure of *Betula* to colonize, more ecologically demanding *Ulmus* and *Quercus* would form anything more than very isolated stands. Later in Zone V two significant trends took place in the vegetational succession. Now the overall dominance of *Betula* began to wane; the lowland forests being supplemented by increasing numbers of *Ulmus* and *Quercus* as well as *Pinus* and *Corylus*, the uplands becoming covered by a *Pinus* - *Corylus* association. The lowlands appear to have received their first complements of elm and oak at about the same time, with the former able to establish more rapidly than the latter.

The opening of Zone VI, around 7,000 B.C. (Godwin, Walker and Willis, 1957), saw these trends hastened, with the uplands becoming covered for the first time with a reasonably closed forest community. The behaviour of *Corylus* can be used as an index of climatic conditions at this time, Its great extension everywhere indicating a complete lack of climatic inhibition, and a summer maximum temperature of at least 15°C, as well as dry conditions and the absence of late spring frosts.

The expansion of *Ulmus* in Zone VIa corresponded with the reduction in *Betula* on the best soils of the lowlands; while in the uplands a much more powerful complex of factors were interacting to give an up to

80% Pinus dominated, forested landscape. There can be no doubt that Pinus was an important constituent of the lowland forests at this time (Godwin and Walker, 1954), taking up suitable sandy soils there. However, as shown at Seamer Carrs, throughout Zone VI there was a well established closed canopy forest of Ulmus, Quercus, Betula and Corylus with only minor readjustments taking place in community structure. Pinus is a pioneer species with wide climatic and edaphic tolerances, but most favouring a dry climate and an acid soil. It has mobile seeds and therefore advantages over slower seeding species such as Quercus, which too must have been attracted to the open conditions and sandy soils of the Cleveland moors in Boreal time. The extent of the Pinus forest was limited, with its lower boundary somewhere between Seamer (70 metres O.D.) and Kildale Hall (170 metres O.D.). The pollen diagrams and mire stratigraphy show that during Boreal time Pinus even extended across some of the bog surfaces. Pinus casts a deep shade, and is not easily replaced by an understorey, so the Corylus component of these forests must have occurred in marginal and perhaps more favoured habitats, such as damp hollows or valley sides. It is quite common at present to find Quercus robur, Ulmus and Betula at lower altitudes, succeeded by Pinus woods at around 350 metres and this replaced at higher elevations by Betula scrub (Tansley, 1939). Betula disappeared on the North Cleveland Moors because it was shaded out by Pinus stands, taking up a place peripheral to them together with Corylus and Quercus petreae as the most important forest components.

Zone VI saw *Alnus* become established in Cleveland. Erdtman (1928) correlated this with the tree's prominence in forest histories of countries along the southern shore of the North Sea at this time, and the continued presence of the "land bridge" between Britain and the Continent, leading to a more rapid and early spread of *Alnus* along the east coast of Britain than along the west. The maximum extension of *Alnus* did not begin until late in the Boreal (Zone VIc) and early in the Atlantic (Zone VIIa) when *Pinus* - *Corylus* dominance was disappearing on the uplands and *Quercus* and *Ulmus* had established as the most important constituents of the lowland forests. Erdtman also suggested that the *Alnus* rise contributed to the suppression of the *Pinus* curve at this time, but it is more likely that *Alnus* replaced *Betula* (which also declined) in the damper habitats as soils became waterlogged and acidic. Also *Alnus* must have been competitive in other habitats; the damper elements of the lowland oak and elm forests and the mire fringes, for example, would have been ideal sites for rapid colonization. The spread of *Alnus* in the early Atlantic, and the associated development of closed deciduous forests in both upland and lowland Cleveland, with *Quercus*, *Ulmus*, *Betula*, *Tilia* and *Fraxinus* dominating, can be explained largely by the climatic and edaphic requirements of these trees. *Alnus* cannot tolerate cold, especially late frosts, and needs abundant soil moisture for maximum extension (Mcvean, 1953, 1956a). *Quercus* must have a July mean of over 13°C, while the presence of *Hedera* indicates that winter means were above 1.5°C and oceanic conditions existed in the Atlantic period.

Godwin (1956) considers the early part of Atlantic time as the 'Climatic Optimum', with high temperatures and a moist climate supporting a 'climax' type deciduous forest cover. In Cleveland, temperatures had been ameliorating since the end of Late-glacial time, with the late Boreal period one of maximum dryness. Precipitation on the other hand does not seem to have increased until around the time of the Boreal/Atlantic transition (circa 4,700 B.C. at West House). Throughout Boreal time normal climatic elements were in operation, with soil leaching progressing; but it was the increased oceanity that resulted from Britain's separation from Europe about this time which most influenced the hydrological cycle. Increased precipitation caused rises in water tables with acidic soils developing, and at many higher localities this soon led to the inception of blanket peat formation and some destruction by this of forest cover. In Cleveland, while no blanket peat formed, the effects of these processes on the mixed oak forests of both lowland and upland must have been considerable.

Human Influence on the Landscape during the Boreal and Atlantic Periods

Until comparatively recently, the view was held that Mesolithic man was dominated by his environment (Iversen, 1949. Godwin, 1956). However, the findings in pollen analytical studies of pre Sub-boreal deposits of evidence of human activity (Dimbleby, 1962. Simmons, 1964, 1969a), has led to a rethinking of established concepts, notably by Smith (1970).

In north-east Yorkshire, Dimbleby (1962), Simmons (1969a) and Simmons and Cundill (1969), have outlined possible Mesolithic influences in the landscape of the higher moorland, relating this activity to the Atlantic period. This accords with archaeological evidence there of late Mesolithic artifacts (Radley, 1969), and has been related to forest clearances and blanket peat growth.

For Cleveland, Seamer Carrs shows no palynological or other evidence of such early man; not really surprising in view of the prevailing densely forested landscape of the lowlands at this time, a habitat which it is known Mesolithic peoples did not favour. At Star Carr near Scarborough (Clark, 1954), in a lowland situation with almost identical vegetation, a major cultural group existed in the early Boreal period. This culture has been ascribed to a form transitional between Upper Palaeolithic and Mesolithic, and the reasons for its existence may have been the presence of a favourable, large, open, lake-side camping site close to the coastal area to which they came from Scandinavia, across the "land bridge".

Stratigraphical and palynological evidence, together with a radiocarbon date of 8,400 B.C. for early Post-glacial activity at Kildale Hall, has provided some evidence of Mesolithic activities in Boreal time in Cleveland. The small lake and the open habitats surrounding it in Kildale must have served as a watering and browsing area for animals such as the Reindeer (Rangifer tarandus), Red-deer (Cervus elaphus) and the Aurochs (Bos primigenius), the remains of all of which have been recovered around the Kildale Hall site. The pollen record from the levels of the Bos bones and their associated charcoal, indicates an age of around late Zone IV or early Zone V. There appears to be some reduction in the tree cover, and expansions of Corylus, Gramineae, Rosaceae, Melampyrum, Artemisia and Rumex acetosa follow this, with a suggestion of the use of fire to flush out game or make small clearings.

Dimbleby (1962) points out that the effects of Mesolithic man could have been quite major in spite of his small numbers. His use of fire was bound to have been indiscriminate as he had no means of controlling it at a time when both vegetation (birch/pine) and climate (warm and dry) were conducive to its utilization. The Star Carr pollen diagram (Godwin and Walker, 1954) shows that at the occupation level (the Zone IV/V boundary), the Corylus curve began to rise and was followed by a temporary decline in Betula. Charcoal, flints, silt, birch bark and hazel nuts were found at these levels also.

A comparison of Star Carr with the Kildale site shows that even in the absence of artifacts at the latter, some similarities exist. Kildale Hall appears to have been a small focal point to which Mesolithic man either drove game by using firing techniques, or used the site as one where the products of hunting were killed and consumed at a temporary camp site. The mixed, open vegetation with scanty birch forests and grassy heathland was ideal for the co-existence of various ruminants and man himself. Bos and Cervus are the natural woodland habitat successors to *Rangifer* which prefers a tundra environment, and Mesolithic man is known to have favoured dry, sandy terrain with watering places and a balance of forested and open communities where he could hunt and gather food while effecting easy passages over quite wide areas (Pigott, 1965). There is no suggestion of any organization at Kildale as at Star Carr, but it does seem that Mesolithic man was present in Cleveland in Boreal time in favoured lowland localities. Pigott (1965) has calculated that the population of the Star Carr settlement would have ranged over at least 200 square miles along the easiest routes in their quest for food in spring and in summer, and it may be that some found their way up to Kildale, which appears to have been capable of supplying their needs in this respect.

No other site in the region indicates such an early or positive influence of Mesolithic man. With Seamer Carrs, itself a large lake site, not apparently one of the primitive hunters haunts, they seem, somewhat later in the Boreal, to have turned to higher altitudes where they appear to have effected small and temporary openings in the forest cover throughout this and the following period, the Atlantic. The Kildale activity may be reflected in the slight shifts in the pollen curves toward more open conditions in Zone V at West House and at Ewe Crag Slack. Here, accompanying the rising *Corylus* curves, *Gramineae*, *Melampyrum*, *Artemisia*, *Rumex acetosa*, *Ericales* and *Filicales* expand. Zone VI shows very similar, transient activity at both sites, while Zone VIb at Ewe Crag Slack has a layer of silt intercalated with peat in its stratigraphic sequence, a fall in arboreal pollen and an increase in Corylus and herb values. Apart from reworked sediment (there is no evidence of a hiatus in the pollen record), the most likely origin for this silt would have been the surrounding slopes, presumably laid bare by forest clearance and subjected to soil erosion either gradually by wind, water or a combination of both, or by one severe storm.

Evidence of Mesolithic activity has been reported from widely separated areas in England, notably Dartmoor (Simmons, 1962, 1964), the Pennines (Walker, 1956) and Kent (Dimbleby, 1963). At these sites it is considered that Mesolithic man cleared some woodland and created patches of generally unstable, quickly changing plant communities in these clearings. Smith (1970) has suggested that the decline of certain species and the expansion of others, (for example, Pinus and Corylus being superceded by Alnus near the Boreal/Atlantic transition), may be ascribable to human causes; while Tallis (1964) holds the view that records of pollen from open habitat species in diagrams showing mainly closed forest may simply represent the remnants of former montane vegetation which survived until finally secumbing to the forest cover. Clearly, with little supporting evidence, many Cleveland Boreal "clearance indicators" could be regarded in the latter category, particularly as it is envisaged that forest cover was never really as luxuriant and complete upon the uplands as upon the lowlands.

The Atlantic period was one of relative vegetational stability in Cleveland, with no major community changes reflected in the pollen curves to complicate the effects (or otherwise) of man on vegetation. It is to this period that the majority of the Mesolithic flints of the region have been ascribed (Radley, 1969). Many flint sites occur at the interface of a mineral soil and an overlying blanket peat, the tools themselves having mainly characteristic Tardenoisean form. Siss Cross Hill on Danby Low Moor, overlooking Ewe Crag Slack has been assigned to this category (Elgee, 1930. Radley, 1969). The fact that the pollen diagrams in the uplands indicate some possible activity in Boreal and Atlantic time suggests that the situation may have been a little different to that which has been previously held as occurring. In the Atlantic pollen records, a secondary Corylus maximum is present soon after the Boreal /Atlantic transition, but there are no other signs of human activity then. However, if it is accepted that Mesolithic people were in the region in Boreal time, what became of them early in Zone VIIa? Also, Corylus shows a late Boreal suppression, probably due to the growth of other trees which were more shade tolerant, therefore why did it reappear during what is assumed to have been a closed forest period? It could be that it recolonized areas formerly occupied by Pinus (Oldfield, 1965), or it may be an expression of Corylus stands marginal to the mires contributing increased amounts to the pollen rain when Pinus and Betula were excluded due to a rising water table, but before Alnus was fully established (Smith, 1970).

The problems of microlith layers below peat, including depositional intervals and downwashing of pollen in mineral soil have been recognized, (Dimbleby, 1957. Godwin, 1958. Davies, 1963. Tallis, 1964 and Smith, 1970). There seems to be no reason why Siss Cross and other sites could not represent much earlier settlement sites if these arguments are borne in mind. The upland plateau of North Cleveland, in later Atlàntic time, shows evidence of some quite distinct vegetational changes from the pollen diagrams at West House, Ewe Crag Slack and Tranmire Slack. Then, extensions of species such as Gramineae, Artemisia, Chenopodiaceae, Melampyrum, Plantago lanceolata and Pteridium temporarily at the expense of trees (but with no marked Corylus maximum, except at Tranmire Slack), are shown. Once again, Ewe Crag Slack provides stratigraphic evidence, with two silt horizons intercalated within the mire deposits almost certainly the result of forest destruction, soil erosion and run-off nearby. Declines in arboreal pollen frequencies and increasing ones for herbs at these levels support this contention.

What sort of activities Mesolithic man engaged himself in, is a really open question. The incidence of Plantago lanceolata pollen in pre Sub-boreal deposits (where it almost certainly had nothing to do with prehistoric farming practices) is of relevance. Later than the Atlantic period its presence was equally as certainly connected with agricultural practices, but it is the late Atlantic period itself which is important in this respect. Dimbleby (1963) considers that Mesolithic man may have been something of a farmer at this time, in particular, a stock rearer. The chronological significance of pollen zone boundaries is of vital importance in such assumptions, and for Cleveland, the radiocarbon dates to ensure this are not, as yet, available. In view of this, the most tenable explanation for the whole of the pre-Neolithic vegetational changes is probably that species colonizing the region entered clearings along with those species regarded as "human indicators" (for example, Artemisia and Melampyrum). These clearings either existed naturally, or were made by man or by the indigenous herbivores which he sought (Smith, 1958b). The role of indiscriminate firing as an aid to hunting must have been a major one, and such clearings, while of small areal extent, could have remained open for quite long periods when set against the 5,000 or so years spanning the Mesolithic period.

(b) The Period of Forest Reduction

This section describes and attempts to explain the general pattern of vegetational change from the time of the initial systematic reduction of closed canopy forest (early Zones VIIb and VIII), until the evidence from the last reliable pollen spectra of the mires (the later stages of Zones VIIb and VIII).

Chronology

From the start of Zone VIIb, about 3,000 B.C. (Godwin, Walker and Willis, 1957), the forests of northern England were progressively reduced, their place being taken by secondary woodland, shrub and herb communities (Godwin, 1956).

The contemporary landscape of Cleveland provides evidence of the results of the processes which brought about these changes, but the five mires investigated unfortunately have all been disturbed in their upper parts by human influences. This has led to the removal of the stratigraphic and palynological record from various stages in the Post-glacial; at Mildale Wall, for example, back to as early as the commencement of Zone VIIa. The uppermost analysed levels of the other four sites must be regarded with caution in view of the disturbance which has taken place there, in some cases since later Medieval time, (Mitchell, 1965). Furthermore, the absence of radiocarbon evidence makes any assumption of age all the more tenuous. A tentative chronological framework can be postulated though, by virtue of a series of unpublished radiocarbon dates made available by workers in closely adjacent areas, (Simmons and Cundill on the higher parts of the North York Moors, and Bartley in southern Durham). The proximity of many of these dated sites, (the high moorland ones only 8 kilometres distant), suggests that the time sequences cannot have been so radically different as to be totally unreliable, especially in view of the recent findings of Hibbert (unpublished) concerning the synchroneity of zone boundaries in various parts of Britain during the Post-glacial. A radiocarbon date of 2,817 B.C. from blanket peat at North Gill, Glaisdale Moor (Simmons, unpublished), and equated with the Zone VIIa/VIIb boundary, is near to one for late Zone VIIa of 3,440 B.C., from peat in a landslip at Saint Helena, Castleton Rigg (Cundill, unpublished). Further dates of 1,935 B.C. from blanket peat at Collier Gill, Egton

High Moor (Simmons, unpublished), equatable with Early or Middle Bronze Age activity; 1,410 B.C. from peat in the south Durham 'Carrs' at Bishop Middleham (Bartley, unpublished), and 1,236 B.C. from blanket peat at Wheeldale Gill, Wheeldale Moor (Cundill, unpublished), both roughly of Middle Bronze Age cultural time, add weight to strong palynological and archaeological evidence for intense human activity in this period in the region.

The post VIIa pollen record, (Zones VIIb and VIII), was zoned independently for each diagram, based upon a VIIb and VIII complex, rather than the delimitation of separate Zones VIIb and VIII. It was felt that insufficient evidence, both stratigraphical and palynological, was forthcoming to enable this to be done with confidence for all sites. A sub-zonation scheme A, B and C has been adopted for Zones VIIb and VIII, based on similar changes in pollen spectra at each site. There is no evidence to prove that A, B and C are synchronous at each site, but the consistency of the pollen record for each Sub-Zone and the relatively small region under consideration do not render this wholly impossible.

The Landscape

Throughout Zone VIIa the separation of Britain from the Continental mainland was fully realized, with the North Sea assuming something like its present dimensions at the conclusion of the Flandrian Transgression. Later sea-level changes which are known to have occurred along the coast of north-east England did not affect the area in consideration, being confined to areas below the present 50' O.D. contour, (Tooley, personal communication).

Therefore, by Zone VIIb, the easy migratory routes from the Continent were effectively cut off, and further immigration of plant species either took place from within Britain (especially from southern England), or by more hazardous routes across the surrounding oceans, especially the North Sea.

Hydrosere Development

The trend towards the acidification of what were generally eutrophic mires, started in Zone VIIa, everywhere continued throughout Zones VIIb and VIII, becoming more intensified in the last recorded stages of development.

Seamer Carrs became colonized by a slightly less basic, partial fen community, dominated by *Phragmites* and bryophytes, while at West House, Ewe Crag Slack and Tranmire Slack, the sedge/wood swamps acidified, with West House becoming an ombrogenous mire. The channel mires remained topogenous while showing high proportions of bryophytes, especially *Sphagnum* spp. in their stratigraphic record. Some evidence exists for alternate wetter and drier phases of bog development, *Calluna* and *Eriophorum* peat being intercalated with layers of almost pure bryophyte peat, dominated by *Sphagnum*. However, this whole problem is extremely complex and the stratigraphy was not studied in sufficient detail to ascertain whether retardation layers and recurrence surfaces existed, or indeed could be used to delimit an arid Sub-boreal and a more oceanic Sub-atlantic stage in bog development, as suggested by Godwin (1956). Some evidence of increased precipitation in the upper parts of the mire stratigraphies may be present in the form of the silt horizons, which at Ewe Crag Slack, Erdtman (1928) thought to be of Sub-atlantic age and caused by increased rainfall totals. Equally, high winds could have caused such accumulations, but it would first need disturbance of the vegetation cover for these to be initiated, and the charcoal associated with the silt indicates that anthropogenic factors were the main ones, at least at the outset.

Regional Vegetational History

Within this period the most significant changes in the composition of the land vegetation were in the relative frequencies of trees to shrubs and herbs. Human activity is assumed to have influenced landscape changes throughout, and once again, particular care must be exercised in the interpretation of pollen spectra, especially in the case of the contribution of hydrosere components such as Gramineae and Cyperaceae.

The general trend from the commencement of Zone VIIb was one of an overall reduction in high forest cover and its replacement by more open conditions, with some recolonization by trees.

The changing forest communities of this time were dominated by Quercus, Ulmus, Tilia and Fraxinus, with the lowlands having a better developed and less easily attackable closed community structure. Betula and Alnus must have made significant contributions too, but their relative positions are complicated by their presence in the hydroseres. Pinus was by now of little importance, except locally on acid substrates, (as around Tranmire Slack, for example). The basis of the percentage calculations (upon a total tree pollen sum) makes the variations in percentages of various tree species in the upper levels of diagrams purely relative to one other; the significant factor is the decline in total tree cover from up to 75% to less than 10% in the majority of cases.

Some species appear to have been removed at the expense of others, particularly Ulmus and Tilia in the early stages. Certain trees expanded, notably Fraxinus which had been present since Zone VI in the lowlands and since Zone VIIa in the uplands. It now became quite a significant component of the vegetation after the declines in Ulmus and Tilia, a feature encountered by other workers (for example, Oldfield, 1960. Birks, 1965b). Fraxinus is a pioneering tree which does well on moist, disturbed soils of quite high base-status (Wardle, 1961). It is less light demanding than Betula but cannot tolerate shade as well as Alnus can (Iversen, 1960). At this time the soils would have been either fairly basic and supporting mixed Quercus - Ulmus forest, or more acid and supporting a Betula - Alnus association. It is difficult to envisage how, in such situations, Fraxinus could expand into such environments without there being some disruptions of the existing ecological balance.

Fagus is first recorded in sufficient frequency to have been growing locally soon after the start of this period. Godwin (1956) states that Fagus was established in southern England by late Boreal time and persisted there throughout the Atlantic, spreading widely but sparsely only in the Sub-boreal, when human rather than climatic factors were in operation. The shifting densities of prehistoric populations and their clearance of natural mixed oak forest gave Fagus a chance to compete effectively in recolonization complexes with Fraxinus. The expansion of both trees in association with increases in herbaceous pollen frequencies supports this hypothesis, and has been noted by many investigators (for example, Godwin, 1956. Simmons, 1964, 1969a).

Corylus, which achieved a balanced position in the Atlantic forests, played an important role in the changing vegetational patterns of this period. High frequencies of this shrub are recorded in Zones VIIb and VIII in Sub-Zones A and B, suggesting that it was able to successfully colonize opened areas, while lower values in Sub-Zone C indicate that by this time it was itself subject to clearance on quite a large scale.

All plants involved in this complex of changing communities were within their climatic limits. Some species, Tilia and Ulmus, for example, may have been poised in a delicate ecological balance, but the high values for Tilia (up to 15% of total tree pollen at some sites) supports the contention of Simmons (1969a) that north-east Yorkshire was both climatically and edaphically suitable for its growth. Further north, at Bradford Kaims, Bartley (1966) reports percentages of 2 or less for Tilia at its maximum, suggesting a latitudinal threshold for its successful growth somewhere between the two areas. Ulmus too, probably grew best in suitable edaphic situations, being reduced in frequency partly by natural succession of elm woodland by that of oak under oceanic conditions and soil podsolization (Walker, 1966), and partly by a complex of causes amongst which human influence was one of the foremost (Smith, 1970).

Areas of open vegetation already existed in the region, either naturally or as a result of earlier forest clearances, and these must have been contributing to the pollen rain; consistent Calluna percentages suggesting heaths, probably upon the moorland summits. Many of the herbs encountered in increasing amounts from Zone VIIb onward (for example, Plantago lanceolata, Artemisia and Rumex acetosa) are not heath plants and must have been growing in places other than these. The alternative hypothesis of such occurrences is one which has for many years been widely accepted in Britain and Europe (for example, Iversen, 1941, 1949, 1960. Godwin, 1956. Troels-Smith, 1960. Smith, 1970). It is basically that human activity was the major factor in determining the direction of vegetational changes from Neolithic time onwards. The presence of archaeological evidence in support of palynological criteria is useful, and, as Figure 3 illustrates, Cleveland has no shortage of such information for a wide range of cultural types, whose influence upon ecological changes at individual sites has already been inferred.

The Phases of Forest Clearance

The sporadic but nevertheless quite effective activities of Mesolithic man in Cleveland during Boreal and Atlantic time were carried a stage further both in areal extent and intensity around the time of the commencement of the Sub-boreal period (circa 3,000 B.C.). Neolithic artifacts have not been widely discovered in the region, the few flint finds being mainly confined to the lowlands. Neolithic man undoubtedly inhabited the region, but seemingly not in large numbers. It is more likely that Mesolithic and Neolithic men lived in close proximity here at the same time, each in his preferred habitat, but with some cultural mixing and technological diffusion between the groups. The resulting population probably had a culture including traditional Mesolithic and Neolithic activities, such as hunting, food gathering and some agricultural practices.

The Earliest Clearances

The first phases of forest reduction in Zones VIIb and VIII seem to have been a concentration on the clearance of high forest trees on a selective basis, especially of Ulmus and Tilia which were either felled or defoliated. Troels-Smith (1960) suggested that such species were used as animal fodder. Fire was used in some instances, and locally upon the moorlands, clearances were quite effective; the silt and charcoal in the mire at Ewe Crag Slack at levels corresponding to this period indicate this. During this early phase (Sub-Zone A), selective clearances could have taken place over a wide area where the best specimens were available, more thorough destruction being confined to suitable localities, perhaps those with some open conditions already. Into these clearings Plantago spp., Gramineae, Rumex spp., and Pteridium spread and increased their percentage cover. The size of such clearings is difficult to ascertain, but they seem to have been used primarily for pastoral purposes. Only at Ewe Crag Slack late within Sub-Zone A do Cerealia and other herbs (for example, Artemisia, Chenopodiaceae and Rumex acetosa) indicative of arable farming appear.

The boulder clay lowlands around Seamer Carrs seem to have had very minor clearances followed by effective regeneration of trees, while the rather open woodlands around Tranmire Slack, supported by quite acid soils, did not fare nearly so well, Fagus and Fraxinus making little headway in cleared areas. The colonization complexes and abandonment of clearings indicates a shifting mode of existence for these agriculturalists, but clear 'landnam' sequences (Iversen, 1941) are not really discernable. Their uncertain technological capabilities may explain their diversity of activity which included, in all probability, cereal growing, pastoralism, stock rearing, hunting and food gathering.

Simmons (1969a) has placed the first phases of activity upon this scale over the central watershed of the North York Moors into the Neolithic, and it seems logical to extend this just a few kilometres northwards to Cleveland. Sub-Zone A is taken here as representing activity from the Mesolithic/Neolithic overlap through until the earliest parts of Bronze Age time. This is consistent with the archaeological record for these periods which suggest only slight activity in the region by a fairly sparse population.

The Main Clearances

Most of the region recovered quite reasonably from the first clearances, and it was not until the pollen diagrams indicate clear secondary declines in *Ulmus* and *Tilia* frequencies, that widespread, consistent and in many areas not easily reversible changes in the vegetational succession took place. Within Sub-Zone A it was limited areas of the upland plateau that were cleared and later cultivated, but in Sub-Zone B the most important single feature was a widespread, consistent decline in all types of arboreal pollen. Clearings now were much more numerous and larger, and arable farming is shown to be of importance. The tree cover of the uplands was reduced to around 10% of the landscape, that of the lowlands to around 35%. Herbs were spreading into cleared areas at ever increasing rates and the powers of recolonizing species, particularly *Corylus*, were checked. The whole of Sub-Zone B was one of high activity by what must have been quite a large population. The absence of radiocarbon dates and an insufficiently close sampling interval of the profiles (1-2 cm. intervals are needed), makes the separation of particular types of activity unwise (Turner, 1965, 1970). *Cerealia* (*Triticum* and *Hordeum*) are recorded from all sites, together with herbs such as *Artemisia*, *Chenopodiaceae*, *Cruciferae*, *Succisa*, *Liguliflorae*, *Spergularia*, *Centaurea* and *Urtica*, indicative of cultivation (Turner, 1965, 1970). However, values for *Plantago lanceolata*, *Gramineae* and *Pteridium* increase too, suggesting that pastoral activity was important, or that there were many areas of exhausted soils which were becoming clothed with ruderals after they had been left fallow. Removal of the vegetation cover must have greatly accelerated soil podsolization and erosion, the latter process being manifest in the mires in the form of silt bands and charcoal, moved in from the surrounding slopes.

Some areas most affected by tree removal began to revert to a heath formation with Calluna playing a dominant role, this being especially true of the moorlands.

Such activities can only be ascribed to a people who favoured the area as a dwelling place. If the earlier clearances are equated with Neolithic and Early Bronze Age people, it seems feasible to postulate that this period of high activity was a result of the occupation of the region by Middle Bronze Age folk, for their burial sites and settlements are found in Cleveland in great profusion, especially upon the uplands (Elgee, 1930). Elgee contended that it was these people who made the first serious attempts to settle what he regarded as heather moorlands and forested dales, being mainly cultivators with small herds. Dimbleby (1961, 1962) also concludes that Middle Bronze Age dwellers were responsible for the main deforestation of the North York Moors and the initiation of soil podsolization and heath formation on a large scale. While Dimbleby considers these people to have been mainly pastoralists, Fleming (1971) believes that their economy was more of a mixed nature. He suggests that clearings were made in the woodlands to obtain produce, especially cereals as well as for the keeping of grazing animals. The thin and acid soils probably rendered the usefulness of such clearances to a short duration, and when soil exhaustion set in moves were made to new areas, with the abandoned clearings left to become colonized by scrub and heath.

Palynological evidence supports much of this theory. It is now certain that the region as a whole was cleared of forest by human activity rather than being a progressively degenerating heath community as Elgee (1912) had envisaged. For Cleveland, Fleming's (1971) concepts of a mixed economy are supported, so are the ideas of effective clearance, soil exhaustion and erosion and the trend towards the establishment of vast expanses of Calluna heath. The pollen spectra associated with the radiocarbon dates quoted as Bronze Age (page 180), show many similarities to the overall form of the curves within Sub-Zone B, but such analogies cannot be carried far with confidence.

The Last Clearances Represented

Whatever small recoveries were made within Sub-Zone B by trees and shrubs were soon nullified after the commencement of the final recognizable clearance phase, delimited as Sub-Zone C. Seamer Carrs, West House, Ewe Crag Slack and Tranmire Slack provide evidence of further substantial reductions in woody vegetation, until trees covered less than 10% of the lowlands and well under 5% of much of the moorland. A significant factor was the decimation of shrub vegetation, particularly Corylus, and massive increases in Calluna heath and acid grassland, the former at higher altitudes, the latter upon the Cleveland Plain.

Once again it is difficult to determine phases of distinct farming activity within this period, major increases in the frequencies of all types of herbaceous pollen occurring. The lowlands, still with a little natural forest cover, appear to have been a centre of mixed farming, with cereal growing and pastoralism carried on simultaneously upon what must have been still quite fertile soils. The later stages of Sub-Zone C indicate that pastoralism was gaining the upper hand, at least around Seamer Carrs and West House.

The upland environment is slightly less difficult to reconstruct throughout this time. Initially there seems to have been an arable phase; with high frequencies of the pollen of Cerealia, (Hordeum and Avena), Artemisia, Chenopodiaceae, Cruciferae, Rumex, Centaurea and Spergularia; while later on, Gramineae, Plantago lanceolata and Pteridium, indicative of pastoral farming according to Turner (1965, 1970), dominate the upper spectra at Ewe Crag Slack and Tranmire Slack.

At all sites, the changes which occurred are more likely to have been shifts in the emphasis of one type of farming over another rather than a complete change from one type to another. None of the activity appears to have been able to have kept pace with the spread of Calluna heaths, which cannot have been very productive, and whose extension reflects the closing stages of the degradation of the ecological balance of much of the elevated land in the region. Very little true forest could have remained, save isolated patches in the dales and around the mires. Arable farming must have become increasingly difficult upon rapidly degenerating soils and extensive grazing remained the only feasible activity in the uplands. The lowlands too, while retaining a mixed farming economy will have experienced difficulties in coping with soil depauperation and the spread of poor pasture and heathland.

Once again there is a lack of radiocarbon dating evidence for this important period of activity, and it is purely by logical progression through the cultural groupings that causal effects can be assigned to particular inhabitants. Late Bronze Age folk did not settle widely in Cleveland, and until comparatively recently, the same was thought true of Iron Age dwellers. However, Hayes (1966) has shown that quite extensive Iron Age settlements existed in western Cleveland from about the fifth century B.C. to the first century A.D., and that they were active farmers. Elgee (1930) held the view that descendents of the Urn people of the Middle Bronze Age persisted in the uplands through until Roman times, carrying on a very marginal form of cultivation there. They may also have lived in the area contemporaneously with succeeding peoples, in a manner analagous to that envisaged for Mesolithic and Neolithic time.

The Romans and the following waves of Anglo-Saxon and Scandinavian settlers of the first few centuries A.D. confined their attentions mainly to the Cleveland Plain and the dales, where, according to Elgee (1930), they carried on mixed farming, cultivating wheat, barley and spelt whilst also keeping grazing animals. The uplands were used in Anglo-Saxon times as a refuge for the British; the Celtic Fields on Kildale and Commondale Moors evidence of their agricultural practices with foot ploughs or oxen.

Some or all of such activities may be reflected in the early stages of Sub-Zone C, when the landscape must have consisted of a mosaic of field systems, poor pasture and heath.

The first significant change in the economy of the region came with the spreading of monastic influences, especially in the thirteenth century A.D. (Waites, 1957). Monastic granges covered a large part of Cleveland with their emphasis on pastoral activities, arable agriculture assuming insignificant proportions. This farming system did not extend above 180 metres (600') O.D., (Farra, 1961), where the moorland plateau by now devoid of virtually all trees, served only as extensive pasture for sheep and cattle. The last parts of Sub-Zone C at Ewe Crag Slack and Tranmire Slack seem to indicate the transition to this Medieval farming economy. On the moorlands above the limits of the improved pastures of this time, the full effects of around 4,000 years of fairly intensive human activity were manifested in a barren and desolate landscape. The uppermost reliable palynological evidence from Seamer Carrs and West House reflect the relative prosperity of the Medieval lowland economy, also dominated by pastoralism, but with a fuller land utilization, a greater density of population and maybe even some remaining pristine vegetation.

CONCLUSION

This study which has been based primarily upon the analysis and interpretation of Quaternary stratigraphical and palynological records from five mires, has outlined the major ecological changes which have occurred in Cleveland in the Late-glacial period and in the majority of Post-glacial time which has so far elapsed.

Sequences examined range from the time of the earliest plant records in the Late-glacial (Zone I), until stages when either hydrosere development ceased or was affected by human activities and could no longer be considered a reliable indicator of ecological changes (normally during the later stages of Zones VIIb and VIII of the Post-glacial).

The main phases of landscape evolution in the region are summarized in Figure 26, and are set against the current terminological and chronological schemes for Late Quaternary events in England and Wales (Godwin, 1956. West, 1968).

Detailed results and the development of individual sites and their environs have been presented and discussed, and it remains to contrast summary evidence of these with that available for adjacent parts of north-east England, and to touch upon deviations from the established scheme for patterns of change in the British Quaternary flora (Godwin, 1956).

The period immediately following deglaciation in the region after the Weichselian maximum (circa 14,000 - 12,000 B.C.) was characterized by extremely cold conditions,

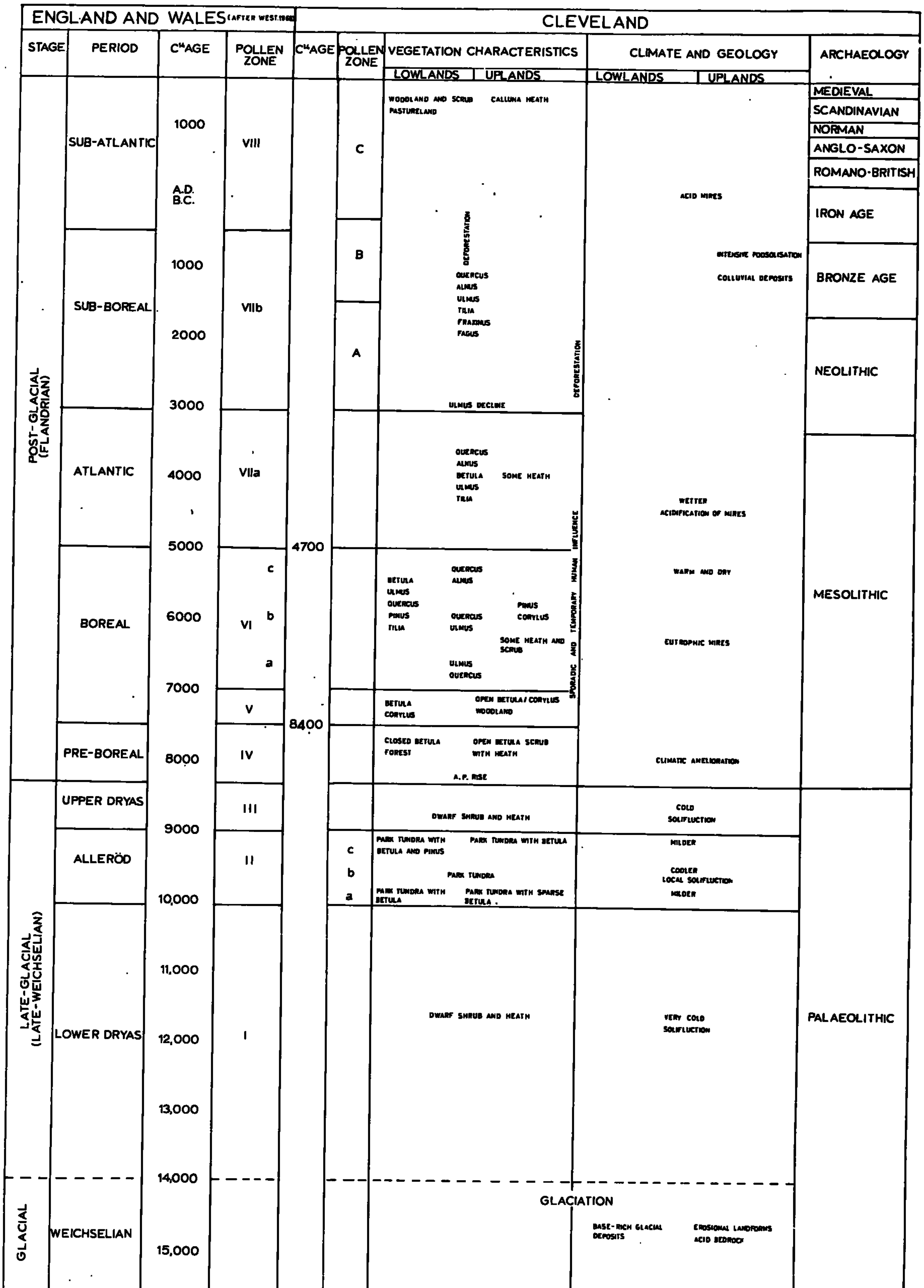

ENGLAND AND WALES (AFTER WEST 1968)
CLEVELAND
STAGE
PERIOD
C14 AGE
POLLEN ZONE
C14 AGE
POLLEN ZONE
VEGETATION CHARACTERISTICS
LOWLANDS
UPLANDS
CLIMATE AND GEOLOGY
LOWLANDS
UPLANDS
ARCHAEOLOGY
POST-GLACIAL (FLANDRIAN)
LATE-GLACIAL (LATE-WEICHSELIAN)
GLACIAL
SUB-ATLANTIC
SUB-BOREAL
ATLANTIC
BOREAL
PRE-BOREAL
UPPER DRYAS
ALLERÖD
LOWER DRYAS
WEICHSELIAN
1000
A.D.
B.C.
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
12,000
13,000
14,000
15,000
VIII
VIIb
VIIa
VI
a
b
c
V
IV
III
II
I
4700
8400
C
B
A
c
b
a
WOODLAND AND SCRUB
PASTURELAND
CALLUNA HEATH
DEFORESTATION
QUERCUS
ALNUS
ULMUS
TILIA
FRAXINUS
FAGUS
DEFORESTATION
ULMUS DECLINE
QUERCUS
ALNUS
BETULA
ULMUS
TILIA
SOME HEATH
SPORADIC AND TEMPORARY HUMAN INFLUENCE
BETULA
ULMUS
QUERCUS
PINUS
TILIA
QUERCUS
ALNUS
QUERCUS
ULMUS
PINUS
CORYLUS
SOME HEATH AND SCRUB
ULMUS
QUERCUS
BETULA
CORYLUS
OPEN BETULA / CORYLUS WOODLAND
CLOSED BETULA FOREST
OPEN BETULA SCRUB WITH HEATH
A.P. RISE
DWARF SHRUB AND HEATH
PARK TUNDRA WITH BETULA AND PINUS
PARK TUNDRA WITH BETULA
PARK TUNDRA
PARK TUNDRA WITH BETULA
PARK TUNDRA WITH SPARSE BETULA
DWARF SHRUB AND HEATH
ACID MIRES
INTENSIVE PODSOLISATION
COLLUVIAL DEPOSITS
WETTER
ACIDIFICATION OF MIRES
WARM AND DRY
EUTROPHIC MIRES
CLIMATIC AMELIORATION
COLD
SOLIFLUCTION
MILDER
COOLER
LOCAL SOLIFLUCTION
MILDER
VERY COLD
SOLIFLUCTION
GLACIATION
BASE-RICH GLACIAL DEPOSITS
EROSIONAL LANDFORMS
ACID BEDROCK
MEDIEVAL
SCANDINAVIAN
NORMAN
ANGLO-SAXON
ROMANO-BRITISH
IRON AGE
BRONZE AGE
NEOLITHIC
MESOLITHIC
PALAEOLITHIC

FIGURE 26

perennially frozen ground and water bodies, and extensive solifluction both on the drift covered lowlands and in the dales, as well as the elevated drift free plateau. This early Zone I landscape must have been akin to a 'polar desert' (Van der Hammen et al., 1967), gradually evolving to a poor 'park tundra' environment (Iversen, 1954) with heliophilous herbs and dwarf shrub communities dominant. This accords with the general vegetation pattern for north-east England and Britain generally at this time, when there were no closed woodlands and the vegetation was dominated by herbs, shrubs and a few trees (Godwin, 1956).

Around 10,000 B.C. these conditions gave way to a more equable period when the climate was considerably warmer, solifluction processes largely ceased, slopes stabilized and organic matter accumulated in the mires. Some soil development took place, and a more complete vegetation cover including Betula copses and perhaps isolated specimens of Pinus developed, along with luxuriant herb and shrub communities. A minor climatic oscillation within this Alleröd interstadial caused a slight recession in tree cover and some renewed mass movement (Zone IIb). The general trend of Zone II vegetation in Britain was one of birch woodland (especially in eastern England), with some pine. Northwards and westwards from Yorkshire and Lincolnshire however, only very few favoured localities had such a vegetation, and generally herb and shrub dominated communities were most important throughout Zone II (Walker, 1966). The sub-division of Zone II into a, b and c has been made by Newey (1970) in south-east

Scotland, and exists at sites in eastern Durham (Bartley, personal communication).

The final phase of Late-glacial time was marked by another period of cold climate and severe conditions with solifluction active and mineral matter deposited in the mires. Tree cover was reduced with shrubs and herb communities re-expanding, but not to their Zone I frequencies.

Zone III conditions, severe enough to lead to a minor glacial advance in some upland areas of Britain (see for example, Manley, 1959), saw a general extension of herbaceous communities with most or all elements of the Zone II flora persisting in a reduced condition.

About 8,000 B.C. solifluction processes ceased, slopes stabilized and organic matter accumulation began once again in the mires. Vegetational changes occurred in response to a rapid climatic amelioration. The basic soils of the Cleveland Plain quickly became clothed with closed Betula forest within which little heliophytic vegetation was able to survive. Consequently, many characteristic Late-glacial species either became extinct or took up restricted habitats (for example, Betula nana, Juniperus, Hippophae and Ephedra distachya among the shrubs, Polemonium, Helianthemum and Jasione montana among the herbs, and the bryophytes Paludella squarrosa and Camptothecium nitens).

Upon the poorer, more acid upland soils vegetational developments were not able to keep pace with the climatic amelioration. The 200 metres difference in altitude and their exposed nature, made them both climatically and edaphically less suitable than their neighbouring lowlands for uninterrupted hydrosere development, quick migration and full establishment of the pioneer species that took place at this time. Consequently, here open *Betula* woods, *Salix* and *Corylus* thickets as well as *Empetrum* heath and acid grassland persisted in early Boreal time (Zones IV and V). It was then, in such a relatively open environment that Mesolithic man found suitable hunting terrain and temporary camp sites around Kildale, as he had done on a much bigger scale in the Vale of Pickering (Clark, 1954).

The early Post-glacial period in Cleveland appears to have been similar to other areas of eastern England, particularly so to conditions near Bamburgh, Northumberland (Bartley, 1966) where the highest site in the area retained Late-glacial vegetation into Boreal time. This area was, however, unforested throughout the whole of Late-glacial time.

Zone VI (about 7,000 B.C.) saw the development of a forested landscape in the uplands and changes in the composition of the lowland forest communities. *Ulmus*, *Quercus*, *Corylus*, *Tilia*, *Alnus* and *Fraxinus*, together with substantial amounts of *Pinus*, joined *Betula* in the Boreal lowland forests. In the uplands, above about 150 metres O.D., a *Pinus* - *Corylus* forest in which deciduous components played only a small part developed and persisted throughout Zone VI, thriving upon the sandy soils and enjoying a lack of competition from an already closed woodland community. Areas of quite open, heathy vegetation still existed here, seemingly suited to the needs of small numbers of Mesolithic people who traversed the terrain making small clearings in what was a warm and dry climatic regime.

The composition of the Boreal forests, apart from the peculiarly high _Pinus_ frequencies is not unlike that reported for other areas in Britain (Godwin, 1956).

The importance of the Boreal/Atlantic transition (radiocarbon dated to around 5,000 B.C.) in the region, can be gauged by the events at the time approaching the 'climatic optimum', which caused quite widespread changes in forest composition. The _Pinus_ - _Corylus_ woodlands upon the moorlands were replaced quite quickly by a deciduous community in which _Quercus_, _Ulmus_, _Betula_ and _Alnus_ dominated. The Cleveland Plain, already covered with well developed deciduous forest, was subjected to extensions of _Alnus_ at wetter sites and _Tilia_ and _Fraxinus_ in favourable edaphic conditions. Also from early Zone VIIa onwards mire growth and acidification was accelerated, suggesting increased dampness and rising water tables which helped eliminate plants requiring neutral or alkaline soils of high base status which had managed to remain in suitable refuges since Late-glacial time. Mesolithic man appears to have continued his wanderings over the uplands perhaps enlarging slightly any small areas of open vegetation.

The general composition of the Atlantic forests of Cleveland when compared to the rest of the country, seems to fulfil the idea that the climatic optimum conditions reached this far north, but that the region was near to the threshold for such an environment, if the behaviour of such species as Tilia is examined.

Until the commencement of combined Zones VIIb and VIII (around 3,000 B.C.), there can be no doubt that in common with other parts of the country, climate, soils and physical geography (especially changing sea-levels) were almost solely responsible for the patterns of environmental change in Cleveland; though there seems to be support for Smith (1970) in his contention that Mesolithic man was more influential in modifying this environment than formerly thought possible. It was not until the migration of Neolithic farming cultures to Britain that this general subservience of man to the ecosystem began to change. Neolithic peoples had stone axes, cultivation techniques and domesticated animals, all able in some way to help in the destruction of the natural high forest vegetation. Their effects in Cleveland were not great, probably serving more to furnish Mesolithic survivors with new ideas. Classical 'landnam' sequences of Iversen (1941) are not seen; clearances were temporary, small and soon recolonized with emphasis mainly on selective felling of Ulmus and Tilia probably for foliage to use as animal fodder, and little use of cultivation techniques was made.

The first concerted attack on the Cleveland landscape, particularly the uplands, was made by Bronze Age folk, particularly those of the 'Collared Urn'

(Middle Bronze Age) period. Their very abundant remains indicating that they were responsible for deforestation, and that they carried on shifting arable and pastoral farming whose unmanaged nature eventually led to soil exhaustion, erosion and the spread of poor pasture and heathland. The transition to Calluna dominated heaths began earlier here than in many areas; but the lowlands were less affected, retaining a fair percentage cover of forest.

It is difficult to isolate the effects of succeeding cultural groups in the region, save to add that they saw the completion of deforestation of both uplands, and later on the lowlands, with further degenerations of the ecological balance. It is interesting to observe that the pollen record shows that Avena (first cultivated in the Iron Age) and Secale (found earliest in Romano-British times), according to Godwin (1956), are not encountered until Sub-Zone C of Zones VIIb and VIII. It is tentatively assumed that this Sub-Zone commenced about the time of the Iron Age occupation (circa 500 B.C.), but to what extent the climate deteriorated then, and if this really affected the general vegetational succession is not clear. There is, however, some evidence of renewed and ombrogenous mire growth and certain plant species, for example, Tilia, Ulmus and Hedera declined or disappeared; both these factors being considered by Godwin (1956) to support climatic changes at this time. Some authors, for example, Turner (1962) have placed anthropogenic factors on the decline of such plants, and the evidence seems equally strong on both sides in many instances, especially in the absence of radiocarbon dates.

Post-Roman and Pre-Medieval landscape evolution can be best summarized as a progressive accentuation of established trends. The uplands reverted to more and more acid heathland, of use only for extensive grazing, while the lowlands were cleared of most remaining forest cover by the Anglo-Saxons, Normans and Scandinavians who favoured arable and pastoral activities. Monastic influences began to dominate the economy in the thirteenth century A.D. Their predominantly pastoral economy led to the utilization of both upland and lowland for grazing, while they also cleared and improved land at lower altitudes.

Palynological evidence of changes between this era and the present day are lacking due to mire disturbance, but conditions must have looked in Medieval times not greatly dissimilar to those of the present as far as vegetation cover is concerned. Whatever woodland remained would have been progressively cleared for agricultural and later, industrial purposes, leaving a mixture of Calluna heathland and acid grassland in the uplands, and a mosaic of first, open fields and later, enclosures upon the Cleveland Plain and in the dales.

It is only within the last few decades that awareness of the delicate ecological balance which exists in the uplands and the need to correct, or at least maintain it has been forthcoming. Widespread peat erosion, mainly a result of indiscriminate moor burning, has led to vast areas of regolith being exposed, and the Calluna monoculture, used for grouse rearing mainly, is often badly managed. The planting of trees, mainly conifers, has taken place since 1950, only in areas too poor to be of use for any other purpose, but does indicate at least a partial appreciation of the problems and potentialities of the land use ecology of the uplands.

The lowlands are a prosperous agricultural area, no doubt serving a just purpose as they exist at present, and the careful management techniques employed to maintain both physical and economic well-being outweigh any case for land use changes here.

It can only be hoped that the remaining cultural groups within the present interglacial period will adhere a good deal more firmly than their predecessors to the basic principles of ecology and ecosystem management. If this is the case, the cumulative effects of the last 5,000 or so years need not be nearly as poor a starting point for future ecological changes in the region.

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