I

THE LATE QUATERNARY VEGETATIONAL HISTORY OF HOLDERNESS, YORKSHIRE

being a thesis submitted for the Degree of Doctor of Philosophy

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by

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CONTAINS PULLOUTS

II

'Winnow all my folly, folly, folly,
And you'll find
A grain or two of truth among the chaff ...

... When a jester is outwitted,
Feelings fester, heart is lead ...'

W.S. Gilbert

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LIST OF ABBREVIATIONS USED

km	kilometre (s)
m	metre (s)
cm	centimetre (s)
mm	millimetre (s)
ml	millilitre (s)
B.P.	Before Present
B.C.	Before Christ
A.D.	Anno Domini
O.D.	Ordnance Datum
r.p.m.	revolutions per minute
^{o}C	degrees Celsius
sp.	species (singular)
spp.	species (plural)

Notes

Nomenclature follows that of Clapham, Tutin and Warburg (1962) for vascular plants, and Warburg (1963) for mosses. Faunal nomenclature follows that of the relevant literature cited.

Scandinavian spelling has been anglicised.

GENERAL INTRODUCTION

This study was undertaken to reconstruct the regional vegetational history of Holderness, in south-east Yorkshire. It is an area with great potential for palaeo-ecological investigations and yet it has been largely ignored during the great increase of research in this field in recent years. Being on the east coast, Holderness is well placed to provide information on the migration of plants into this country, particularly in Late-glacial and early Flandrian times, when the region was joined to the continent by dry land. As a distinct and somewhat isolated region of low-lying land which must have been rather water-logged for much of Post-glacial time it would have provided a considerable challenge to prehistoric man. Therefore an exmination of the extent to which early man was able to emploit this difficult environment seems to be worthwhile.

Among the most interesting advances in the study of vegetational history have been the introduction of the evaluation of pollen concentration and absolute pollen frequencies in an attempt to give a more quantitative picture of past vegetational communities, and also the considerable reassessment of climatic conditions during the Late-glacial period. Consequently, in the elucidation of the vegetational history of Holderness, the intention has also been to throw some light on these current problems. The Late-glacial of Holderness has therefore been studied in terms of pollen concentrations and absolute pollen frequencies, and the results obtained compared with other recent evidence, much of which has come from north-western England, to try to establish to what extent conditions varied within northern England during this period. Somewhat more approximate estimates of absolute pollen frequencies in Post-glacial times have been made, and the value that this

information adds to the understanding of vegetational history of the area, has been considered.

SECTION I

INTRODUCTORY

CHAPTER 1

THE REFINEMENT OF THE POLLEN ANALYSIS TECHNIQUE - a literature survey

Since its introduction, the pollen analysis method has undergone considerable changes in application and has been continually refined to keep pace with this. Von Post (1916) undertook palynological investigations to add to the work of Blytt and Sernander (Sernander, 1908), who drew up a scheme of four Post-glacial periods of climate from studies of peat bog stratigraphy. They recognised a general pattern of two layers of dense woody peat with many Pinus and other tree stumps present. Lying above each of these layers was another of less dense sedge or Sphagnum peat. The tree stump layers were said to represent periods of continental climate - named the Boreal and Sub-Boreal periods, in which trees grew over the drying bog surfaces and peat formed only slowly. The less dense peats were thought to have formed more quickly under a more humid maritime climate. The earlier of these two periods was named the Atlantic and the latter the Sub-Atlantic.

Von Post's early work in Sweden, on the fossil tree-pollen spectra of peat bogs, supported this broad view of Post-glacial climatic changes. He found that peat deposits had similar pollen assemblages at the top and bottom - the terminokratic elements - which consisted largely of pollen of Pinus, Picea and other cold-tolerant trees. The central portion of the Post-glacial peats contained pollen of comparatively thermophilous trees, such as Quercus, Tilia, Ulmus and Alnus. These he termed the mediokratic elements. He considered these changes in the fossil pollen spectra to be due to climatic change from a cool, early Post-glacial time, through a warmer period, to a more recent deterioration in climatic conditions.

Many more pollen analyses were then completed throughout Europe and on a world-wide scale with the main purpose of elucidating climatic changes.

In Europe, for example, Von Post's scheme of Post-glacial climatic change came to be broadly accepted over a wide area, though more than the three basic zones were soon distinguished. In the British Isles a sequence of zones I to III to cover Late-glacial time and zones IV to VIII for the Post-glacial period, was drawn up (Godwin, 1940a, 1956). These zones were characterised largely by their arboreal pollen assemblages. Changes from zone to zone were, in the main, attributed to climatic causes and, in the Post-glacial peats, the apparent development from Pinus and Betula forest to mixed deciduous woodland, followed by the disappearance of some of the more thermophilous elements such as Ulmus and Tilia, seemed to coincide well with the idea of an ameliorating Post-glacial climate, with a subsequent deterioration.

In its early days, therefore, pollen analysis served chiefly as a climatic indicator. It was also an important means for the relative dating of archaeological finds, etc., discovered in peat. Such finds could be ascribed, by the pollen analysis of peats around them, to specific pollen zones, and thus given comparative ages. With the introduction of the radiocarbon dating technique (Libby, 1955) absolute ages could be estimated with a fair degree of accuracy, particularly as the technique was improved (e.g. Suess, 1970). This meant that, in some ways, pollen analysis was reduced to a dating tool of secondary importance, although it gained as an indirect means of dating, because the pollen zone boundaries themselves could now be effectively dated (Godwin, Walker and Willis, 1957; Godwin, 1960a; Hibbert, Switsur and West, 1971; Smith and Pilcher, 1973; Hibbert and Switsur, in the Press)

Further advances have tended to reduce the pre-eminence of pollen analysis for the understanding of past climate. These include the more direct palaeotemperature measurements obtained by the oxygen isotope

method (Emiliani, 1955), and results from other indirect methods, such as analyses of fossil Coleoptera, Foraminifera and Diatoms. Such studies as those of fossil Coleoptera (e.g. Coope, 1970) have suggested that there may be a time lag between climatic improvement and the arrival of new plant species, and hence deposition of pollen spectra which would be taken to indicate this improvement. This means that pollen analytical studies may not show climatic changes as soon as they occur. The length of time necessary for plants to migrate into newly suitable habitats does not seem to have been appreciated by early palynologists (Faegri, 1966). There may also be inertia in the vegetation during deteriorating climatic conditions. Faegri (1966) noted that soil development factors might influence vegetational development, and that changes interpreted as climatic might be primarily edaphic. As soil development is closely related to climate, however, this may not be very significant.

At first pollen analysts largely ignored the influence of early man on the natural vegetation, and hence on the deposition of pollen spectra. Man was thought to have had little effect on his environment before quite recent times, and so Von Post (1916) was able to attribute the revertence to pollen of more cold-tolerant plants in recent times to a deterioration of climate. Now, with the accumulation of more and more evidence of the great influence of early man on his surroundings it has been realised that vegetational changes cannot be regarded merely as a result of climatic change. Man's activities in clearing forest, burning, and rearing grazing animals have been found to extend much further back than was at first appreciated, and quite widely to around 3,000 B.C. when it is probable that Neolithic man cut elm branches to feed to cattle (Troels-Smith, 1960), and so contributed to the decline in Ulmus pollen seen in many north European pollen diagrams. Other explanations have been proposed for this change in the pollen spectra, however (see chapter 9).

More work has demonstrated the influence of earlier cultures on their environment, also reflected in the fossil pollen spectra of nearby deposition sites. At Star Carr (Clark, 1954) mesolithic hunters built a lakeside dwelling, and their small influence on the local vegetation was reflected by the presence of several weed species in the pollen spectra, although their effect on the general forest vegetation was probably insignificant.

Together, these advances have meant that pollen analysis has become of relatively less importance as a means of understanding climatic change, especially for the Post-glacial period when man has been actively affecting vegetational communities; and it has been reduced to secondary importance as a dating technique. The emphasis in fossil pollen analysis has therefore been slightly shifted to a more refined study of the past vegetation itself; and the technique is used now much more for palaeo-ecology than palaeo-climatology.

If pollen analysis is to be effective as a palaeo-ecological tool then it should give results comparable with those of modern floristic ecology. It should provide, in the first place, a comprehensive list of types present, including especially plants indicative of certain communities, human disturbance or cultivation, all identified to within the narrowest possible limits. It should give results explicable in terms of vegetation communities at known distances from the sampling point, and covering areas of known extent. Some estimate of the quantitative abundance of individual taxa within the plant communities should be made from the pollen frequencies obtained.

The limitations of pollen analysis for the description of past vegetation have been fully discussed (e.g. Fagerlind, 1952; Davis, 1963; Faegri and Iversen, 1964; Faegri, 1966). The main weaknesses of the

method include the following. Difficulty in distinguishing between the pollen of certain closely-related plants limits the ecological interpretations possible. The non-flowering of some plants, due to climate, human interference or even youth, will prohibit them from representation in deposited pollen spectra. Differential production, dispersive ability and deposition of pollen between various taxa or by one taxon at different times will distort the relative values in the pollen spectra, which will not, therefore, represent equal values of vegetation. Differential decay of pollen during or after incorporation into a sediment will also distort the spectra (e.g. Sangster and Dale, 1961; Cushing, 1967), as will redeposition of older pollen (e.g. H.J.B. Birks, 1970). The chemical treatments involved in the preparation of pollen samples may cause selective destruction of some pollen; and inadequate mixing or the counting of an insufficient number of pollen grains in the sample may distort the results. Even the mounting of fossil pollen onto the microscope slide for counting may have an effect on what types are missed in the count (Brooks and Thomas, 1967). The expression of the results has usually been as percentages of total arboreal pollen, and this gives only proportional values. Davis (1963) has shown that as the values for arboreal pollen, for instance, are usually taken to add up to 100%, and the individual values are therefore complementary, a rise in the value of one type, rather than representing an increase in the pollen production of that taxon, may be due to the decline of another type. The percentage method also gives no measure of absolute pollen frequency or of differences in pollen concentration between spectra.

Many of the problems confronting pollen analysts in their attempts to interpret vegetational changes had been seen quite early on. In 1916 Von Post had stated 'A number of questions remain to be investigated before the pollen analysis method can be considered entirely clear.

Among other things we must analyse the modern pollen rain in regions whose forest composition is to some degree well known. Perhaps by this method it might be possible to introduce a correction for the differences in magnitude of pollen production of the different tree species and for the different flight ability of the different kinds of pollen. Thus the question of the post-glacial's real forest composition will come closer to reality.' (in Davis, 1963).

These ideas were not pursued for some years, but Pohl (1937) calculated the amount of pollen produced by one hectare of pure forest. Taking into account frequency of flowering of different species, he arrived at the following relative figures:-

Alnus	17.7	Pinus	15.8	Corylus	13.7
Betula	13.6	Picea	13.4	Carpinus	7.7
Quercus	1.6	Fagus 1.0	1.0		

Iversen (1947; and in Faegri and Iversen, 1964) proposed a simplified correction for differential pollen production. He divided European tree species into three groups, A, B and C, according to pollen productivity, and then suggested that fossil pollen numbers from group A should be divided by four, but that groups B and C should not be changed.

These results are, however, of little use in interpreting fossil pollen diagrams as they are only a measure of what is produced, and not of the amount of pollen likely to accumulate in a sediment suitable for pollen analysis. Over- or under-representation is best measured at a depositional site, as heavy pollen producers may have their pollen poorly dispersed and therefore be under-represented in fossil pollen spectra.

Modern pollen spectra, for comparision with modern vegetation, have

been studied in a variety of ways. The pollen rain has been caught in various kinds of traps (e.g. Tauber, 1967; Flenley, 1973; Berglund, 1973) or the modern spectra examined directly from moss polsters (e.g. Birks, 1973; Rymer, 1973), the surface mud of lake deposits (e.g. Lichti-Federovich and Ritchie, 1968) or the surface layers of peat bogs (e.g. Turner, 1964) where pollen is being deposited at present.

Tree pollen percentages from surface samples of mud from Brownington Pond, Vermont, have been compared with the actual tree species content of the surrounding vegetation (Davis and Goodlett, 1960). Nearly all of the tree species growing in the area were represented in the pollen spectra, but for most types the percentage (of total tree pollen) in the sediments was quite unlike the percentage of total basal area in the forest stands. In the forest about 75% of the basal area total was represented by Acer spp., Thuja, Abies balsamea, Picea spp., Betula spp. and Populus. The most abundant types found in the pollen spectra were Betula, Fagus, Tsuga and Pinus. To estimate relative efficiencies of pollen production and dispersal from the data it was assumed that most (80-90%) of the pollen collected had its source within the local area of about 150 square miles. General evidence showed this to be a reasonable assumption.

Quercus rubra was found to be highly over-represented in the surface samples, suggesting that it is easily dispersed by the wind, as most European species of Quercus have been regarded as only moderate pollen producers. It is possible, however, that pollen productivity may vary between different species of thessame genus and between stands of the same species in different areas. Pinus was also found to be over-represented, and it was equally common in the surface samples at Brownington Pond, around which Pinus trees were infrequent, as in the nearby Spectacle Pond, bordered by stands of Pinus strobus and Pinus

resinosa. They suggested that Pinus pollen was easily dispersed and fell over a wide area in an even rain. Betula and Alnus were also over-represented in the pollen spectra, but not to the same extent as Pinus and Quercus.

The pollen percentages of Tsuga canadensis, Fagus grandifolia, Fraxinus spp., Ulmus americana, Picea spp. and Ostrya virginiana from the surface samples were found to fit fairly closely with the percentage basal area of these taxa in the actual vegetation. However, Acer spp., Thuja occidentalia, Abies spp., Populus and Larix spp. were all under-represented in the pollen percentages. Pollen production of the various Abies species varied.

Potter and Rowley (1960) also studied modern pollen spectra percentages and found them to relate reasonably well to basal area percentages of tree species. They found the average composition of arboreal pollen from all their sites to be Juniperus 61%, Pinus 26%, Quercus 9% and others 4%. The percentage basal area for forested areas was Juniperus 40%, Pinus 50%, Quercus 9% and others 1%. Thus Juniperus was over-represented here. In this study Pinus was under-represented in the pollen spectra, probably because Juniperus contributed such a high proportion of the total pollen rain.

In modern pollen spectra from moss polsters and surface deposits in Minnesota, Tilia was under-represented quite strongly although it is a fairly heavy producer of pollen (Janssen, 1966). Very little Tilia pollen seemed to be dispersed more than 200m from its source, probably because it is carried by insects. The better-dispersed Ulmus was under-represented, but less so than Tilia; and Fraxinus showed similar behaviour to Ulmus. Corylus avellana has a high pollen production (Pohl, 1937), and it is one of several pollen types with a low settling velocity (Dyakowska,

1937), however Janssen (1966) found it to be generally under-represented except actually under the Corylus bushes. The heavy, poorly-dispersed grains of Abies and Larix were strongly under-represented. Erdtman (1935) had reported the absence of pollen of Larix from Boreal forests of Canada where it grows abundantly. Janssen found Picea pollen to be abundantly produced but poorly dispersed, and Pinus to be only slightly over-represented here. Pinus pollen has been found in the tundra of Lappland at percentages as high as in the Pinus forest (Aario, 1940). Janssen (1966) suggested that as Pinus pollen is so easily dispersed it will fall in an even rain over a wide area and so be under-represented in surface pollen spectra where it occurs plentifully in the vegetation, and over-represented where its trees are scarce.

Janssen (1966) considered Quercus to be over-represented and considered that where it had been found to be under-represented there had been an over-abundance of heavily producing types - e.g. Juniperus in New Mexico (Potter and Rowley, 1960), or Pinus ponderosa in the Chuska mountains (Bent and Wright, 1963). Alnus was over-represented in the Minnesotan samples when it occurred locally and Salix was often under-represented because of poor dispersal. Herbs were strongly under-represented, the pollen being found under the forest canopy only where the plants grew close by. In open conditions their pollen dispersal may be much more efficient (e.g. Berglund, 1973; Birks, 1973b; Rymer, 1973).

Andersen (1967), working on moss polster samples from southern Jutland, compared the modern pollen percentages with the percentage basal area in the surrounding vegetation, and produced relative production values for each taxon. The percentage basal areas were from a circle of 30m radius around the sampling point. Pollen from outside this area would contribute to the pollen spectra at the sampling point, but this 'exotic' pollen rain

could be assumed to be fairly constant. He therefore calculated a 'truer' pollen productivity value from:

$$P = \frac{p - po}{a}$$

where P = pollen productivity

p = pollen frequency of a species

po = exotic pollen frequency of that species

a = percentage basal area of that species

From this regression equation the following pollen productivity ratios (related to Fagus = 1.0) were estimated:-

Betula	4.1	Quercus	4.1	Alnus	1.5
Fagus	1.0	Tilia	0.7	Fraxinus	0.6

He suggested correction by dividing fossil pollen values of Betula and Quercus by 4, Alnus by 2 and by multiplying Tilia and Fraxinus values by 2. He accepted that in more open areas of forest different correction factors might be needed. Andersen plotted these corrected pollen percentage values against percentage basal area and demonstrated the improved fit. Later work has refined this (Andersen, 1970, 1973).

These studies seem to be of local value only. One type, as shown for Pinus above, may be over-represented by the pollen spectra in one community and under-represented in another, depending on the pollen productivity of the other plants present. Davis (1963) avoided this problem of varying ratios of pollen percentages to vegetational percentages (her 'R' value) by using ratios of this 'R' value between the species present. She maintained that this value stayed constant even when the 'R' value changed. Thus, with productivity being equal in examples 1 and 2:-

	Veg %age	Pollen %age	'R' value	Ra:Rb:Rc
Example 1				
Species A	40	80	2	10
B	10	10	1	5
C	50	10	0.2	1
Example 2				
Species A	20	50	2.5	10
B	30	37.5	1.25	5
C	50	12.5	0.25	1

These correction values, evaluated by modern pollen rain studies for several species, were then used to reconstruct a fossil pollen diagram from the 'Pine zone' period of north-eastern U.S.A. Using such values as R Pinus: R Picea: R Betula: R Abies: R Larix of 24,000:70:680:17:1 she suggested that the so-called 'Pine zone' of about 8,000 B.P. was in fact dominated by Larix, Abies, Acer and Populus. Her correction factors were vastly different from those calculated by other workers, and as Janssen (1966) has shown, Pinus may be under-represented where it is plentiful.

Faegri (1966) considered some of Davis's calculations to be statistically inadmissable, and later work (Davis, 1967) suggested that the 'Pine zone' did represent a genuine peak of Pinus in the forest. Janssen (1970) and Andersen (1970) considered that the R values for any type might vary too much from site to site to be useful.

The variations in the suggested correction factors of different authors suggests that caution must be taken in using them. Birks (1973a) characterised a range of modern vegetation types in Scotland by means of contemporary pollen spectra and then compared the modern spectra with fossil pollen assemblages. Where there was a significant relationship

past changes in vegetation over time could be interpreted in terms of present vegetational changes in space. This seems to be a safer method of interpretation than the use of correction factors.

There are several reasons why comparison of recent plant communities with fossil pollen spectra might fail to be productive. (Janssen, 1970). Firstly, competition may have been different in the past with some species having not yet migrated in, and lack of competition in the Late-glacial might be the reason for the broad ecological amplitudes observed for many species at that time. Secondly, if differentiation of soils occurred late in the Holocene (Andersen, 1964) species now restricted to acid soils may once have grown on neutral soils. Thirdly, further back in time there is a chance that other ecotypes were involved.

Oldfield (1970) has pointed out that many of the problems with pollen analysis arise from the use of the technique for such a wide variety of purposes, from regional changes of vegetation throughout the Pleistocene down to the detailed history of a small tract of woodland over two or three centuries. He emphasised the need for objectives to be known when a pollen analytic study is begun. He considered that modern pollen spectra were only of use in interpretation when from the same site as the fossil spectra under consideration. This then necessitates translation in time only, not time and space, but is unfortunately rarely possible. He emphasised the importance of distance of a pollen source from the collecting point. A poor pollen producer near to the sampling site may contribute as much as an abundant pollen producer at some distance from it. This makes the application of correction factors from modern pollen studies rather dubious. Oldfield seems to be suggesting that, to obtain any meaningful average correction factors, many modern pollen rain studies must be carried out. These would have to be done at many sites in order to eliminate the bias at any one site, resulting from its vegetational

peculiarities. Yet only those contemporary studies from the fossil site under consideration can be realistically compared with the fossil spectra, which leaves the researcher on the horns of an insoluble dilemma. Oldfield also noted the value of absolute pollen counts in reducing the number of assumptions necessary.

Before any generalised correction factors for representation can be introduced comparative values and percentages need to be replaced by absolute values of deposition of pollen from vegetation stands, against time. There is also a need for more precise knowledge on what area is contributing pollen to a depositional site, and how this area might change with time.

To study pollen deposition against time pollen rain has been caught in various traps. Tauber (1967) used 100mm diameter traps with an aerodynamically shaped collar to demonstrate that pollen rain could be considered to have three components. The trunk space component, pollen transported horizontally through the forest below canopy level, was all that was caught by traps placed inside a stand of pure Fagus; the traps were roofed to prevent pollen from other components being washed into them by rainfall. Two traps were placed on a small lake surrounded by forest stands. One of these was roofed and so caught only the canopy component, that element of the pollen rain which moves just above canopy height and descends only at openings in the forest. The other, unroofed, trap caught both the canopy component and that washed down from higher levels by rain - the rainout component.

The evaluation of the relative importance of the three components at any site is of significance in understanding the pollen spectra, modern or fossil, that occur there. If the site is dominated by the receipt of the trunk space component it will contain largely local pollen. If the canopy and/or rainout components dominate at the site

the spectra will represent a more regional vegetation pattern. This information may be of limited value for interpreting fossil pollen diagrams, however, if the site in question now receives pollen mostly of a component different from that which it received in the past. Such a change may be caused by forest clearance or other vegetational change. By a study of modern pollen spectra Janssen (1973) distinguished four kinds of pollen deposition related to pollen dispersion: Local, Extralocal, Regional and Extraregional pollen deposition according to distance travelled by the pollen and distinguished by the abundance and regularity of values in the pollen assemblages.

The use of such traps as outlined above (Tauber, 1967, 1974) or other, similar ones (Flenley, 1973), ensures that pollen deposition over a set time can be measured. It does suffer from being an artificial technique and may not collect exactly what would be deposited on the ground surface, or in a lake basin (Peck, 1972).

Turner (1964) studied pollen dispersion from a strip Pinus plantation by examining the pollen spectra in surface samples of Sphagnum along a transect at right angles to the plantation. She found that almost all pollen released from the plantation was deposited within 500m of it. Similar measurements of pollen dispersion were made at various distances from an artifical source of Ambrosia pollen, and these also produced an exponential curve for dispersion (Raynor and Ogden, 1965). Such studies are of value in determining what sort of area of vegetation contributes pollen to any one point, but the simplified vegetation conditions under which they must be carried out means that pollen dispersion may be quite different from that within an extensive mixed forest stand.

Noting the similarity of pollen dispersion to that of smoke or any

other small particles, Sutton (1947) has produced formulae which allow an approximate prediction of the pollen concentration in the atmosphere at distances from point or line sources. In practice such formulae may be of limited use as area or volume sources of pollen are more often met with than point or line sources, and the parameters necessary for the calculations, such as source strength in number of pollen grains emitted per second, are impossible to measure accurately. However, much theoretical studies may give an idea of the order of magnitude to be expected.

Pollen rain has been trapped in special air samplers (Hirst, 1952) or on sticky slides (e.g. Van der Hammen, 1961). The conditions of capture in these cases are quite unnatural and probably selective (Tauber, 1965). Slides or traps (e.g. Flenley, 1973; Tauber, 1967; Peck, 1973) can operate over a strictly controlled time period, however, and they have enabled daily and seasonal changes in the pollen rain to be studied, and have also shown the relative rarity of long-distance dispersal, except in treeless areas where it may form an important proportion of the total pollen deposition (Tyldesley, 1973).

The pollen analysis method has been further refined by increasing exactness of identification. Understanding of Late-glacial vegetation in Europe has been advanced by the distinction of the fossil pollen of dwarf birch (Betula nana) from that of the various tree birch species. The distinction was made qualitatively (Terasmae, 1951) and later, more quantitatively (Walker, 1955; Birks, 1968) by measurements of the grain size and of the ratio of grain diameter to pore depth (see chapter 3). Other detailed studies of modern reference pollen have led to the identification of distinct genera within what seemed to be families with homogeneous pollen types (e.g. Oldfield, 1959). Phase contrast and

Electron microscopical studies have produced greater knowledge of pollen grain structure and of the finer differences between pollen of closely related taxa (e.g. Chambers and Godwin, 1971; Rowley, 1960; Grohne, 1957).

The zonation of pollen diagrams has been reconsidered. West (1970) has stressed the need to distinguish clearly between the pollen assemblage zone, defined as a body of strata characterised by a certain assemblage of fossils without regard to their ranges; and the chronozone, defined as a segment of a rock sequence adopted as a standard unit of chronostratigraphy with limits defined by such a method as radiocarbon dating; and the many other types of zone in use. West examined the problem of correlation of these zones from different parts of an area such as the British Isles, with a strong regional variation in vegetation.

Existing schemes of zonation (e.g. Godwin, 1940) have come to acquire inferred ecological, temporal and climatic connotations (Birks, 1973a). Pollen zone boundaries have frequently been regarded as synchronous stratigraphic horizons throughout their geographical extent, and there has been a tendency to equate the pollen zones with lithological units, even in the absence of evidence for such a correlation. Birks concluded that the zones used in the description, discussion and comparison of the data should be defined in a way that excludes any external implications. Several recent British pollen analyses have therefore been described in terms of local pollen assemblage zones and regional pollen assemblage zones rather than with reference to the Godwinian zones (e.g. Hibbert, Switsur and West, 1971; H.H. Birks, 1970, 1972; H.J.B. Birks, 1973a; Moore, 1972).

The requirement that criteria for zonation be precisely formulated, objective, and to a certain extent, standardised, has led to the use of numerical methods for zonation of pollen diagrams. Kershaw (1970) used

a chi-squared test of significance of difference between neighbouring samples as an aid to the exact location of a horizon first generally located by inspection. Dale and Walker (1970) agglomerated levels using information analysis, choosing zones from the groups near the end of the agglomerative procedure. They used no stratigraphic constraint on the levels, so that the revertence in the pollen sequence meant that levels separated by considerable distances vertically were often zoned together. Gordon and Birks (1972) used stratigraphic constraint in testing agglomerative and divisive procedures for zonation and such procedures have been used for the comparison of pollen data (Gordon and Birks, 1974; Birks, 1974). In general the results from these numerical methods produce the same zonation as is achieved by careful observation. They may be of most value where sequences of pollen spectra are too complicated for satisfactory visual zonation, as perhaps in tropical environments.

Moore (1973) computed diversity in the pollen spectra of a peat profile of recent date from Wales. He found a general tendency for total diversity to increase rapidly during human interference stages and to fall or remain steady during regeneration phases. Numerical analyses have also been used for further evaluation of past vegetational data (Birks and Deacon, 1973).

The value of the many refinements in the interpretation of basic pollen data is restricted while this data is presented in a relative form. The weaknesses of the percentage method have been highlighted by many of the modern pollen rain studies (Davis, 1963; Janssen, 1966). In 1916 (in Davis, 1963) Hesselman suggested that numbers of pollen per unit weight or volume of sediment would be of more value than percentages. Erdtman and Erdtman (1933) calculated an absolute pollen frequency of the total number of three pollen grains in 1 gm of dried peat. In the absence of a measure of sedimentation rates this was not of great value and

pollen data continued to be presented in terms of percentages. However, Livingstone and Estes (1967) calculated absolute pollen frequency per microlitre of wet lake sediment and produced an absolute diagram on the assumption that deposition of lake sediment had been at a constant rate since a date, obtained by radiocarbon assay, of about 9,000 B.P. The introduction of the radiocarbon dating technique enabled the calculation of sedimentation rates and of absolute pollen frequency against time to be made.

Three main methods have been used to determine absolute pollen frequencies. Benninghoff (1962) added a measured volume of a suspension of exotic pollen, of which the concentration was known, to a measured volume of the sediment under study. After standard fossil pollen preparation both fossil and exotic pollen were counted until a satisfactorily large number of fossil pollen and spores had been achieved. As a known quantity of exotic pollen was added to a known volume of sediment, the amount of fossil pollen per unit sediment was equal to:

$$a \times \frac{b}{c}$$

where a = number of exotic grains added

b = number of fossil grains observed

c = number of exotic grains observed

This method has been tested by estimates of the quantity of Corylus avellana pollen in a series of six homogenised gyttja samples (Matthews, 1969). None of the estimated concentrations of Corylus pollen in the samples was found to be significantly different from any other.

Davis (1965, 1966) suspended a known volume of the sample to be assayed in a measured quantity of liquid. Aliquots of the suspension were withdrawn for counting. The number of pollen grains in the original suspension was derived from the average number of grains found per aliquot.

The error involved in measuring small aliquots was reduced by diluting the samples with a volatile liquid to a size where aliquots could be taken more accurately. After the aliquots had been measured they were reduced in volume by evaporation to a practical size before counting.

Jorgensen (1967) estimated absolute pollen frequency per gram dry weight by counting pollen in sediment samples of known dry weight. To obtain pollen deposition rates from this last method sediment density measurements are necessary. This technique, however, avoids the difficulties of volume measurements of small samples, which is necessary with the other methods. The advantages and disadvantages of each method are discussed further below (see chapter 3).

Davis (1967) used her volume method to calculate pollen accumulation rates at Rogers Lake, Connecticut, during Late- and Post-glacial time. Pollen numbers per unit volume in 1 ml samples from the core were divided by the number of years represented by each sample. This latter variable was determined from twenty four radiocarbon dated levels within the core. The total pollen deposition rate was found to rise steeply from 1,000/cm^2/year 14,000 years ago to 10,000/cm^2/year in later late)glacial time, reaching a maximum of 40,000/cm^2/year 9,000 years ago during the 'Pine zone' period. Then the deposition rate fell to between 20,000 and 25,000/cm^2/year, at which level it has stayed stable for the last 8,000 years.

The deposition rate diagram, when compared with the percentage diagram, showed that general pollen deposition during Late-glacial times was scarce and that very little tree pollen was deposited, a fact masked by the percentage values. In the 'Pine zone' period a genuine peak of Pinus pollen occurred, refuting an earlier assertion (Davis, 1963) that high Pinus pollen percentages at this time resulted from low pollen

production by the rest of the vegetation. For most of the post-glacial period deposition of sediment in Rogers Lake was at a uniform rate and therefore the percentage diagram gave almost all the information about changes in individual types contained in the deposition rate diagram. The volume aliquot method has also been used in the study of vegetation history from lake sediment in Manitoba (Ritchie, 1969).

Pennington and Bonny (1970) have produced an absolute pollen diagram from the British Late-glacial, at Blelham Bog in the Lake District. The, modfied, exotic pollen method of Benninghoff (1962) (Bonny, 1972) was used in conjunction with a series of radiocarbon dates to calculate annual pollen deposition per unit surface area of lake mud.

Results showed a sudden increase in total pollen deposition from very low levels to about 4,000/cm^2/year between 11,000 and 10,750 B.C. This was interpreted as marking climatic amelioration. Juniperus accounted for most of this early increase, followed by an increase in the deposition of Betula pollen, to give the classical Allerod period. They suggested that climatic amelioration began in western Britain early in the eleventh millenium B.C. and that between this time and the height of the Allerod interstadial there was no general climatic recession of sufficient amplitude to deflect the plant succession. Above this, in the Younger Dryas period, total pollen deposition rates decreased markedly to about 1,000 - 2,000/cm^2/year. There was a steep fall in the deposition rates of Betula and Juniperus pollen, but an increase in the deposition of Artemisia pollen. These figures were taken as support for the generally held belief in climatic deterioration at this time.

Further studies of absolute pollen deposition include, for example, work in Post-glacial vegetational history in Alaska (Heusser, 1973), Minnesota (Craig, 1972), and on detailed investigations of special

features, such as the elm decline (Sims, 1973; Pennington, 1973).

This pioneer work in absolute pollen analysis has already demonstrated the potential of the method for throwing new light onto studies of past vegetation, and in adding accuracy to the investigations. To aid the interpretation of the absolute fossil pollen diagrams absolute studies of modern pollen rain are now being undertaken (e.g. Berglund, 1973; Davis, Brubaker and Webb, 1973; Flenley, 1973). Detailed studies of the nature of pollen influx and incorporation into lake sediments will also aid interpretation of the fossil pollen diagrams. Variations in pollen concentration in sediments in different parts of the same basin have been demonstrated (Davis, Brubaker and Webb, 1973), as have the differences in pollen influx between lakes of different morphometry (Pennington, Haworth, Bonny and Lishman, 1972; Pennington, 1973). Peck (1973) has shown how the character of the catchment area of a lake and the nature of drainage into it, affects pollen influx. She attributed very high influx values of pollen of Calluna and spores of Pteridium in a reservoir in the North York Moors to the flowering of these taxa at the time of the early winter floods which therefore carried disproportionately large amounts of the pollen and spores of these two taxa into the basin. The importance of streams in increasing the pollen influx into lakes has been noted elsewhere (e.g. Crowder and Cuddy, 1973).

The advances in the pollen analytic method have made it a more accurate technique for the understanding of past vegetation. The recognition of the need to consider factors of migration, soil development etc. in interpretation of the results has made such interpretations more valid. Radiocarbon dating and absolute pollen counting techniques have enabled changes in vegetation against time to be traced more clearly and in a more quantitative manner. More accurate identification of pollen

types has allowed narrower ecological interpretations to be made. Some advances in the understanding of the relationship between fossil pollen spectra and real vegetation, by modern pollen rain studies, has allowed more about communities and abundance of types in the vegetation to be estimated. The recognition of human disturbance of communities, by the distinction of pollen of crop plants or of weed species has meant that pollen analysis has developed as an archaeological tool.

Pollen analysis has been greatly refined but is still not an exact method of tracing past plant communities in a strictly quantitative manner. The weaknesses still remaining in the method must be appreciated if the advantages are to be fully exploited.

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CHAPTER 2

HOLDERNESS

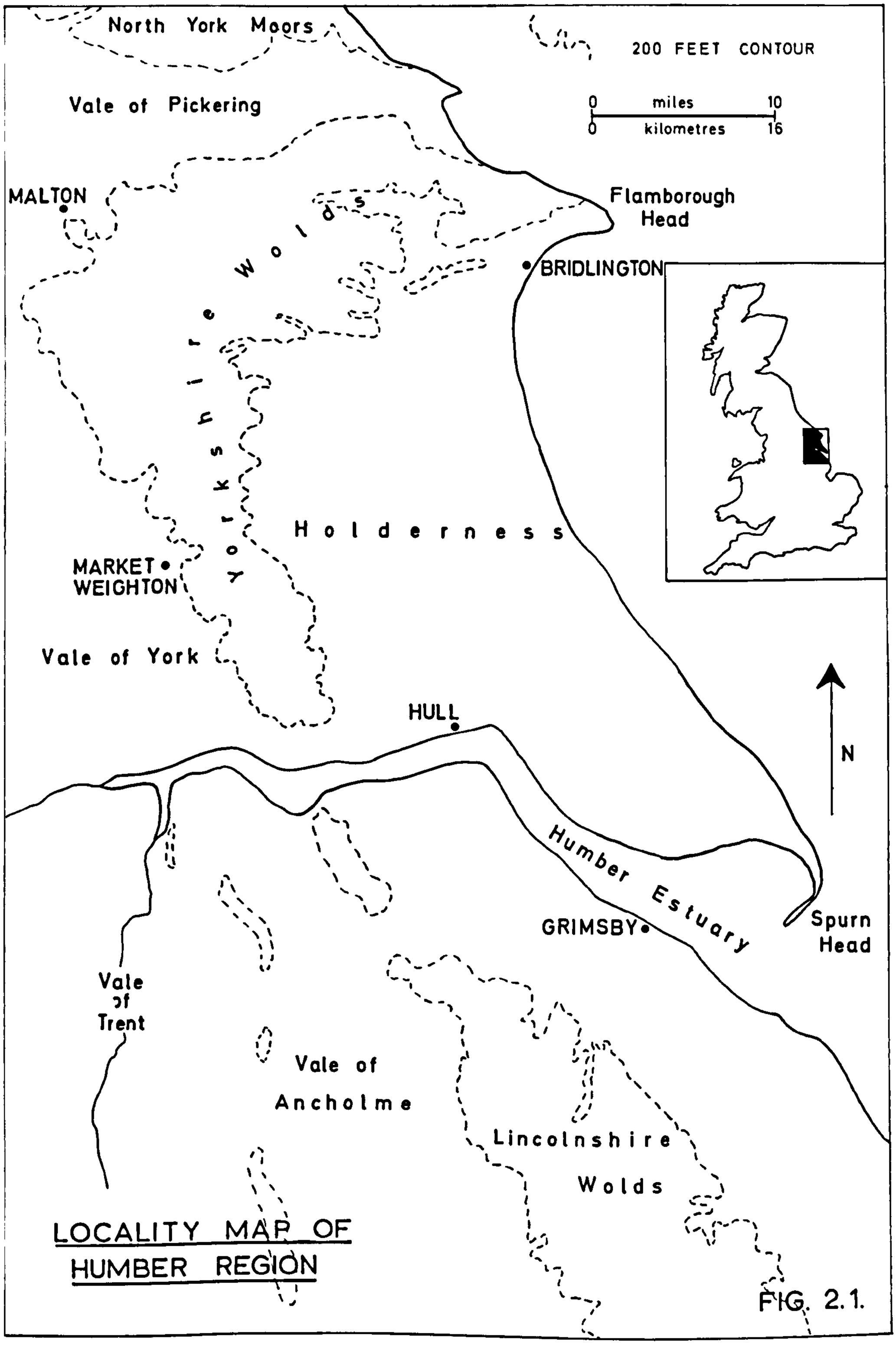
The Plain of Holderness (figure 2.1) may be taken to include all of the land between the Yorkshire Wolds, the Humber Estuary, and the North Sea, thus forming the south-eastern corner of Yorkshire. It is an area of low, undulating relief. In the valley of the River Hull, which drains the area southwards to the Humber, the land is generally below 10m O.D. and only at Dimlington High Land, on the coast, does it rise above 30m O.D. The whole plain is composed of unconsolidated Quaternary deposits which the sea erodes at the exceptional rate of 1-2 metres a year (Reid, 1885). At the southern end of the coast, guarding the mouth of the Humber estuary is Spurn Head, a sand spit considered to have had a cyclical history of growth and destruction (de Boer, 1963, 1964).

The climate of the area is the relatively dry one typical of eastern England, with annual rainfall generally below 650mm.

The freshwater lake of Hornsea Mere is the sole survivor of many such meres and carrs, which formerly covered the undrained land. Some of these may have silted up quite naturally but most disappeared as a result of drainage since medieval times (Sheppard, 1956). Away from the main towns of Hull, Beverley, and Driffield and the coastal resorts such as Hornsea and Withernsea, this drained land supports chiefly arable farming with very little planted woodland or waste ground where 'semi-natural' vegetation might survive.

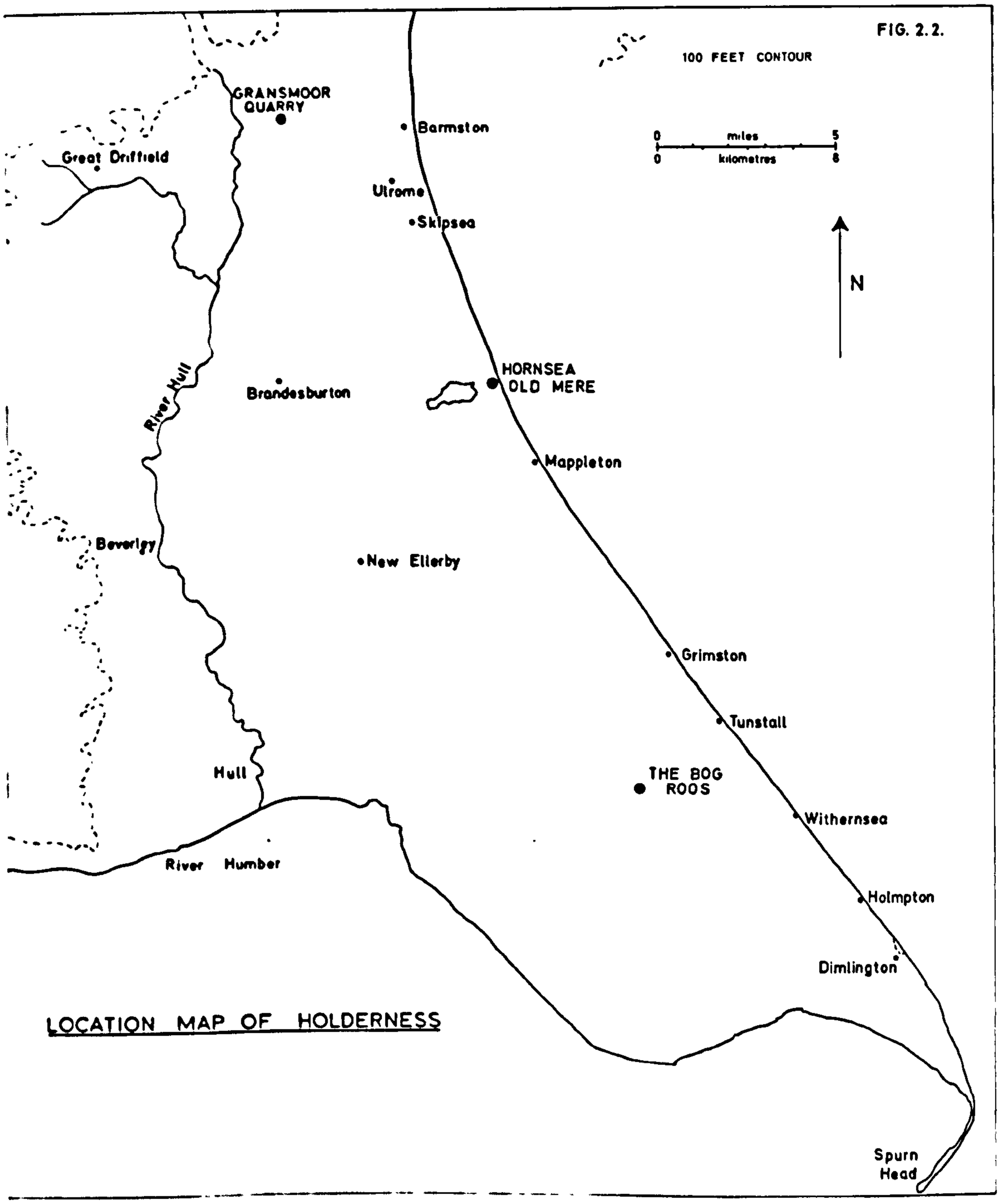
GEOLOGY

The Yorkshire Wolds, which border Holderness to both the north and west, form the northernmost part of the scarped chalk uplands which extend almost continuously from the south of England to Flamborough Head.



LOCALITY MAP OF HUMBER REGION

FIG. 2.1.



LOCATION MAP OF HOLDERNESS

They rise in one place to 250m O.D. and are a direct continuation of the Lincolnshire Wolds, south of the Humber. In Yorkshire the chalk is in the form of a shallow syncline plunging to the south-west so that to the west it forms a scarp running S.S.E. - N.N.W. overlooking the Vale of York, but northwards swings round to a W - E direction overlooking the Vale of Pickering and terminating at Flamborough Head. The change in slope along the foot of the Wolds, where the chalk dips beneath Quaternary deposits, marks the Pleistocene Buried Cliff and makes a distinct boundary between the Yorkshire Wolds and the Plain of Holderness.

Holderness is a natural region of Pleistocene deposition and its geology has been much studied. Wood and Rome (1868) made the first thorough stratigraphical study and noted a tripartite division of the boulder clays. Their sequence of Basement, Purple and Hessle clays has formed the basis of later work (e.g. Reid, 1885; Bisat, 1932). The description here largely follows the work of Catt and Penny (1966). They recognised four principal divisions of the boulder clays and demonstrated the importance of the Buried Cliff for the dating of Pleistocene events in Holderness.

The Pleistocene Buried Cliff extends from Sewerby by way of Driffield and Beverley, to Hessle on the north bank of the Humber estuary, and it continues into Lincolnshire. The chalk platform, which stretches away from the cliff, slopes to the east at about 2 or 3m per kilometre, and underlies Holderness. The Buried Cliff is concealed by later deposits but its course can be traced at the surface by a slight, but distinct, change in slope. The best exposure of the Buried Cliff is seen at Sewerby where the modern cliff cuts across it. The exposure has been described as having a deposit of beach shingle on a wave-cut platform of chalk, at the foot of the Buried Cliff. Chalky rain wash covered by blown sand overlies this and is banked against the cliff. Above this is a solifluction

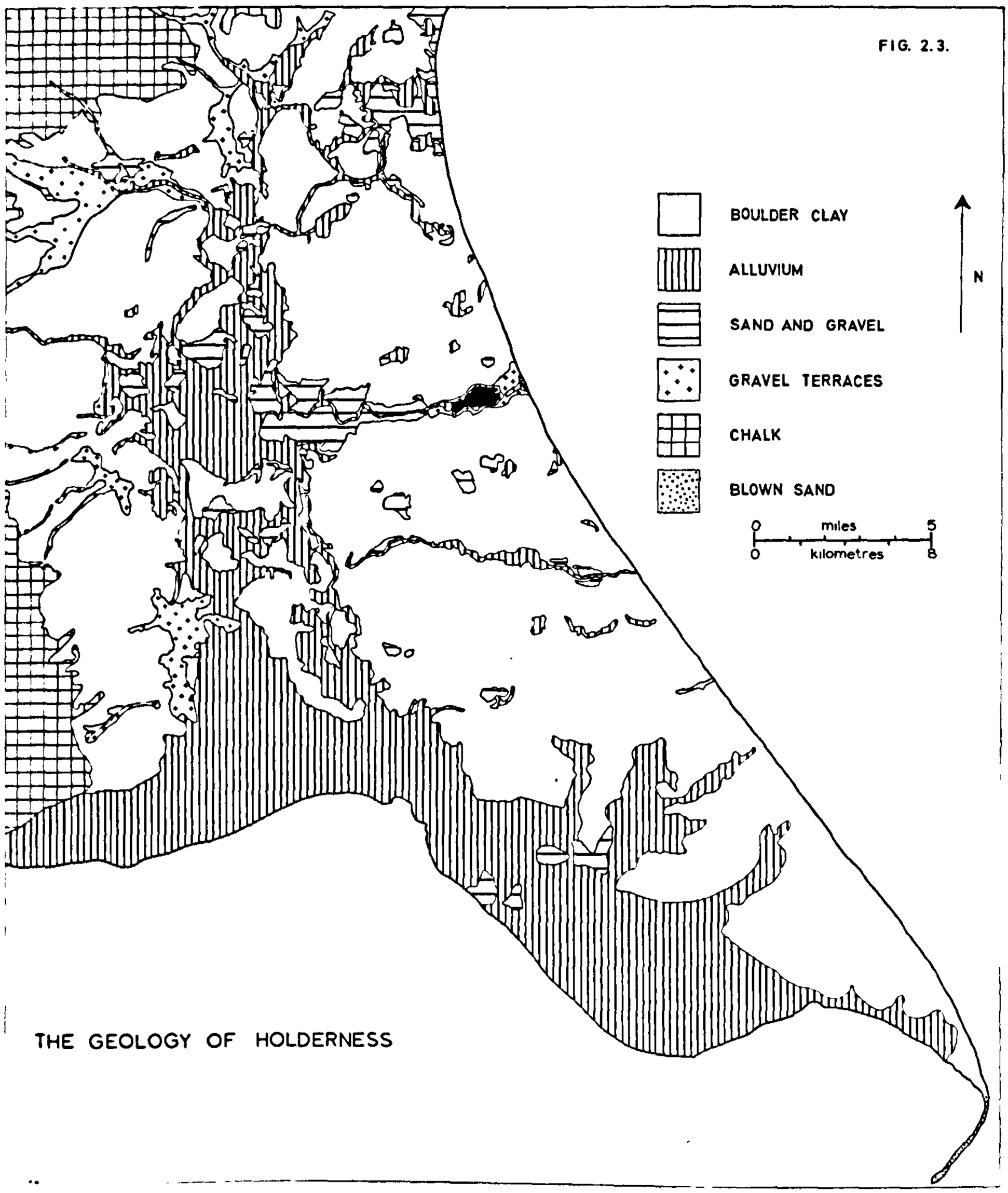


FIG. 2.3.
BOULDER CLAY
ALLUVIUM
SAND AND GRAVEL
GRAVEL TERRACES
CHALK
BLOWN SAND
N
0 miles 5
0 kilometres 8
THE GEOLOGY OF HOLDERNESS

deposit of chalk rubble, overlain by a till which covers the top of the Buried Cliff (Lamplugh, 1891). This till is the Drab till (Catt and Penny, 1966).

The beach shingle contains vertebrate remains (Lamplugh, 1891), which have been recently reinvestigated by Boylan (1967). The presence among these remains of the Straight-tusked Elephant (Palaeoloxodon antiquus) and Hippopotamus (Hippopotamus amphibius), both of which are indicators of warm conditions, showed that the fauna of the beach was interglacial rather than interstadial. Also present were remains of Hyaena (Crocuta crocuta) and Water Vole (Arvicola terrestris). Hyaena, Water Vole and Hippopotamus finds are common from known Ipswichian interglacial deposits in England, but rare in or absent from deposits of the Hoxnian interglacial. From this and other faunal evidence, Boylan (1967) concluded that the beach shingle dated from the Ipswichian (last) interglacial. If this is so then the Buried Cliff was also formed during this interglacial and must have constituted the shoreline of the Eem Sea (Catt and Penny, 1966). Any boulder clays that overlie the Buried Cliff are therefore of Devensian age, and any found to lie below the beach deposits must belong to the Wolstonian, or an earlier, glaciation.

The boulder clays are exposed in the cliffs along the Holderness coast. The complete sequence can be seen in the cliffs near Dimlington where the succession was described by Catt and Penny (1966) as (from the lowest upwards) Basement Till, Drab Till, Purple Till and Hessle Till. The Basement Series which consisted mainly of the Basement Till was considered to be the lowest of the Holderness succession, resting more or less directly on the chalk. This lies below the beach deposits of the Buried Cliff and was considered to be pre-Ipswichian. The Basement Till is a stiff, homogeneous, grey-brown boulder clay. It contains in places a blue clay and a glauconitic sand, both holding a rich marine fauna

indicative of cold climatic conditions, which were termed 'Bridlington Crag'. Catt and Penny (1966) envisaged two periods of erosion associated with the Buried Cliff: planation of the chalk surface followed by deposition of the Basement Series; then marine planation of the Basement Series during the Ipswichian interglacial and formation of the Buried Cliff and beach deposits followed by a lowering of sea level and deposition of the blown sand and chalk rubble before the advance of the Devensian ice.

In the modern cliffs at Dimlington fossiliferous silts and sands (the Dimlington Silts) are exposed, lying on the surface of the Basement Till and below the Drab Till. These have been described and dated (Penny, Coope, and Catt, 1969). The silts contain the remains of a moss Pohlia wahlenbergii cf. var. glacialis, a calcifuge found in cold water habitats such as meltwater from snow beds and glaciers. Two separate radiocarbon dates on the moss gave values of:-

18,500 ± 400 years B.P. (I - 3372)

and 18,240 ± 250 years B.P. (Birm - 108)

The silts were deposited, therefore, during the Upper Pleniglacial, which is the period of maximum Weichselian glaciation on the European continent. The Dimlington Silts also contain insect remains, chiefly Coleoptera. These indicate that the silts were deposited in a pond with little aquatic vegetation, surrounded by open expanses of sand and silt with a patchy covering of moss. The fauna, of an impoverished Devensian type, demonstrates that climatic conditions within Holderness at this time must have been extremely severe.

The Drab Till is the lowest of the three upper tills of Holderness (Catt and Penny, 1966); it is a dark chocolate-brown boulder clay. It is exposed along most of the Holderness coast and lies above the

Dimlington silts and Sewerby Buried Cliff. Its thickness varies from 6 to 12 or more metres. The overlying Purple Till, dark reddish-brown in colour, is less variable than the Drab. A 'Pennine and Trias' till, it reaches its greatest thickness, of over 20m, at Dimlington, but is of more restricted occurrence than the Drab, forming a lenticular mass along the coast from Easington to Mappleton. The uppermost till is the Hessle Till, deep reddish-brown in colour and varying in thickness from 2 - 5 m. The Hessle Till may represent merely the weathered surface of the underlying boulder clays rather than a distinct till itself (Madgett, 1975). Within and between these tills are local beds of sands and gravels. Their lack of indigenous fossils suggests that they are of en-glacial, rather than interstadial or interglacial, origin.

The evidence for the lateral extent of these tills inland is fairly scanty. The Hessle Till covers more or less the whole area, the Purple Till seems to thin out westwards from the coast, and in much of the inland area the Hessle Till lies directly on the Drab Till.

Within Holderness distinction has been made between the tills of the eastern and western parts, the surface of the western part of the plain having a much less pronounced relief than the 'Newer Drift' topography of the eastern half, with its kettle holes. Charlesworth (1929) considered that the end moraine of the 'Newer Drift' ran down the centre of Holderness along the line Kelk-Frodingham-Brandesburton; and Valentin (1957) placed the eastern part within the limit of the last glaciation, leaving the western part as pre-Weichselian (pre-Devensian). The uppermost till on both sides of this line has been described as the Hessle till (Catt and Penny, 1966) though, as above, this is now doubted. However the difference in topography between eastern and western halves of the plain may be due to flooding of the low-lying western part in post-

glacial times, and erosion in the Hull valley. The limit of the 'Newer Drift' has been placed at the Flamborough moraine and all of Holderness considered to have an 'Older Drift' topography (Farrington and Mitchell, 1951), but since the Drab Till overlies the Buried Cliff and the Dimlington Silts, the three top tills must be of Devensian Age.

The Drab, Purple and Hessle Tills, post-date the Dimlington Silts and are older than the pre-Allerod deposits which lie above them - as at Roos where the lowest organic deposits give a radiocarbon date of 13,045 ± 270 B.P. (Birm - 317) (see chapter 4). They were deposited, therefore, in Upper Pleniglacial times and within a period of only about 5,000 years. The short time period available for the deposition of the tills supports the conclusion of Catt and Penny (1966) that they were deposited from a composite ice sheet made up of superimposed tributary glaciers from the Tees, Cheviot and other sources.

Several patches of sands and gravels occur at or near the surface in Holderness but chiefly around Kelsey Hill in the south of the area, and between Brandesburton and Hornsea. The Kelsey Hill gravels (Smith, 1821; Prestwich, 1861) form a low ridge running N.N.E. - S.S.W. for about 3 km., and south of this spread out into a broader shallower deposit underlying the villages of Thorngumbald, Ryhill and Keyingham. They are a complex of light yellowish-brown water-lain gravels with sand and silt, often strongly current bedded. The ridge seems to be an esker and material is thought to have been transported along its axis mainly in a southerly direction (Catt and Penny, 1966). The gravels contain fossils of 50 species of marine mollusca of mainly temperate type; and remains of vertebrates which range climatically from Mammoth (Mammuthus primigenius) Reindeer (Rangifer tarandus) and Bison (Bison priscus) to the much more thermophilous Straight-tusked elephant (Palaeoloxodon antiquus) and

Dicererhine Rhinocerus (Dicerorhinus hemitoechus) (Penny, 1963). Catt and Penny (1966) concluded that, although the fauna was probably Ipswichian to mid-Devensian in age, the gravels were deposited under glacial conditions in a late stage of the Devensian glaciation. They suggested that the advancing ice sheet picked up the fossils from deposits of the preceding interglacial, but noted the unusual deposition of these fossils in just one small area.

Between Brandesburton and Hornsea is what Valentin (1957) regarded as a sub-glacial valley. At Kelk and Brandesburton are gravel deposits which Valentin described as eskers associated with an outwash fan at Leven, further west. Sand and gravel deposits here have been termed the 'Brandesburton Kame' (Phemister, 1922).

Along the north bank of the Humber, and in the Hull valley the glacial deposits are obscured by later deposits of alluvium or 'Warp'. Much of this was deposited naturally before medieval times by estuarine flooding of the low-lying areas. Within and below the warp are thin deposits of peat, such as the 'submerged forest' along the shores of the Humber (Reid, 1885), and the fen carr peats of the upper Hull valley. In its natural state parts of this valley were flooded for much of the year, and meres and carrs formed leaving extensive areas of thin peat cover (Sheppard, 1956). On the higher ground of eastern Holderness alluvial and/or peaty deposits are found above the boulder clay at the sites of former meres which occupied hollows in the irregular surface of the drift (Sheppard, 1957) or kettle-holes as at Roos and New Ellerby.

The surface left after the retreat of the Devensian ice from Holderness was therefore one of a fresh topography, largely covered by stiff boulder clays with occasional patches of sands and gravels. It was on this newly-formed, immature, and nutrient-rich substratum that

Late- and Post-glacial colonisation by plants commenced.

SOILS

The characteristics of the soils of Holderness are linked to the nature of the underlying deposits. Soils developed on the uppermost boulder clay occur in eastern Holderness and on the eastern edge of the Wolds. They are imperfectly drained clay loams with a coarse prismatic structure, and, in sub-soil horizons, with deep-reaching fissures. The soil is generally decalcified to a depth of about one metre. In the ploughed layer all erratics except the most resistant have been weathered, disaggregated and mixed with other soil material. Weathering has resulted in the eluviation of clay particles etc. from the top layers to lower horizons.

The warplands of the Hull valley and Humber banks, as mentioned above, were formed by flooding from the Humber, Since about 1750 the process has been accelerated by the practice of warping. At flood tide water carrying clay and silt in suspension was allowed through sluice gates into an area enclosed by banks, and then slowly drained off after the mud had been deposited. In suitable sites over 0.5m a year could be added by this process.

Warp is a highly calcareous and micaceous fluviatile or alluvial deposit which may be of a fine sandy or silty nature, but lacks coarse sand (Heathcote, 1951). The texture is determined by the speed of movement of water from which the warp is deposited; the slower the water movement, the finer-textured the warp will be. Many of the soils formed on these warplands are still naturally calcareous but surface horizons on older deposits are generally decalcified. Groundwater is permanently close to the surface in many of them, but the better-drained soils are very fertile.

Strongly organic soils are found on the carr lands of the upper Hull valley, north of Beverley. These low-lying soils are poorly drained.

The gravel lands form isolated patches in Holderness, but there is very little true gravel soil. Most of the gravel has loam 300 - 600 mm deep over it, and is therefore a well-drained light soil. Some of the gravel-capped hills have a loamy soil and some boulder clay hills carry lightish soils. Reid (1885) suggested that this was due to rainwash and wind deposition of fine-textured material. In general the soils of Holderness have been little eroded because of the lack of relief.

Much of the eastern slope of the Wolds is covered with patches of boulder clay and gravel and these form a well-drained, light or variable, loamy soil which is easy to work (Heathcote, 1951).

VEGETATION

Intensive cultivation of Holderness leaves little space for natural or semi-natural vegetation. The rampant erosion of the east coast precludes the development of coastal plant communities there. The sand of Spurn Head supports dune communities, now being overrun by the spread of Hippophae rhamnoides. In the slack water of the Humber estuary behind Spurn Head salt marsh has developed, although much of this has been reclaimed for cultivation. Plants that must have been associated with the formerly extensive wetlands of Holderness were probably destroyed by the drainage of these areas. Calamagrostis stricta, a rare marshland grass, grows on the banks of the Leven canal and may have survived there from pre-drainage days when it probably would have been much more common in the damp carr lands of the Hull valley (Crackles, 1933, 1968).

The history of the vegetation of Holderness has been traced to some

extent by pollen analyses of peats at Skipsea (Godwin and Godwin, 1933), Brandesburton (Clark and Godwin, 1956) and Faxfleet (Hulme and Beckett, 1973). The results of these analyses will be discussed below.

THE PRESENCE OF MAN

Post-glacial Holderness could hardly have been less attractive for settlement by prehistoric man. In general he avoided the heavy clay lands and the low-lying flooded carrs and settled on the lighter, drier soils of the adjacent Wolds.

Although Palaeolithic implements have been recorded from Holderness (e.g. Elgee and Elgee, 1933) in places such as the Kelsey Hill gravels, these implements are not very diagnostic and quite possibly derived. The first settlers of whom we have certain knowledge were Mesolithic people with a Maglemose culture. These were fishers and hunters living on raft-like structures in shallow meres. Their implements, such as antler harpoons, have been found in silt below peat at Skipsea (Godwin and Godwin, 1933), on Hornsea foreshore (Clark and Godwin, 1956) and at Ulrome. Bone harpoons of a later type have been discovered at Brandesburton (Clark and Godwin, 1956), while Maglemose flints have been unearthed at Skipsea (Armstrong, 1923). Around the Ulrome site (Smith, 1911) bones of red deer, wolves, boars, beavers and domestic animals such as horses, pigs, goats, sheep and oxen have been found. The presence of bones of domesticated animals suggests that these people raided the flocks of their more advanced neighbours (Sheppard, 1956).

These advanced neighbours were the Neolithic peoples, who had settled on the Wolds by about 3,000 B.C. Their pastoral activities probably kept them to the chalk lands but they may have made hunting excursions into Holderness as flint axes have been found at several sites, although these may be of a later date (Elgee and Elgee, 1933). The

discovery of a Neolithic lake dwelling at Ulrome (Smith, 1911) demonstrated some settlement, if only seasonal, in Holderness at this time.

In early Bronze Age times Beaker people probably mingled with the earlier Neolithic inhabitants of the Wolds to evolve the food vessel culture, still largely dependent on flint implements, bronze being known of, but rare. They were largely pastoralists and probably grew some cereals, possibly only entering Holderness for hunting or to obtain oakwood for coffins (Elgee and Elgee, 1933). The region therefore remained sparsely inhabited and less affected by man than the comparatively densely-settled Wolds, apparently.

Late Bronze-Age peoples, possibly related to the lake-dwellers of Switzerland, settled in Holderness. They had bronze axes (Smith, 1911) but seem to have preferredtthe gravel areas; finds have been made on the gravel hills at Bilton, Sproatley and Skirlaugh (Elgee and Elgee, 1933). They probably grazed sheep and cattle and grew a small amount of cereals. Others of the settlers built lake-dwellings. Six of these have been found, one of which is at Ulrome 0.6m above the Neolithic lake dwelling. Pottery found here suggests that the site was occupied until during the Roman period (Smith, 1911). There were other Bronze Age lake-dwellings at Barmston (Varley, 1968) and Gransmoor and there is evidence of still more elsewhere (Smith, 1911). Almost all were in northern Holderness where gravels are widespread and would have provided lighter soils, suitable for cultivation (Sheppard, 1956). The finds of sewn boats, dated to around 1,100 to 1,500 B.C. from North Ferriby (Wright and Churchill, 1965) and the discovery of the wooden 'model' artifact known as the Roos Images in peaty land near to the Bog at Roos (Sheppard, 1912) point to some Bronze Age activity in southern Holderness.

Iron Age people of the La Tene culture settled on the Wolds in the third century B.C. but do not seem to have entered Holderness except for a little trading with the Bronze Age people (Elgee and Elgee, 1933). The Romans seem to have had an influence on the people of Holderness but built no settlements except on the boundary of the region with the Wolds. The Hull valley may well have been a considerable barrier to movement (Sheppard, 1956).

The Germanic invaders of the fifth century A.D. settled on both the clay and the chalk. They introduced the mouldboard plough, capable of turning over heavier ground and so were able to spread out onto the clay lands of Holderness from early settlements, such as at Keyingham and Ottringham. These Angles must have absorbed or driven away all earlier settlers.

Danish invaders of the ninth century began to settle and, needing more land, turned their attention to the marshy areas ignored by the Angles. Sheppard (1956) noted that this marks the true beginning of man's attempt to drain the marshland. She considered that the Danes probably built some embankments along the Humber, though this is not certain. They seem to have indirectly improved drainage in Holderness by cutting boundary ditches between townships and, in at least one case, diverting a stream to drive a water-mill.

Sheppard (1956, 1957) has made a detailed study of the meres in existence in Holderness in medieval times, and of their drainage. The sites of former meres were traced by various lines of evidence including studies of relief, distribution of silt and peat deposits, flood-time conditions temporarily recreating former meres, place names such as those ending in 'mere', 'Mar', or 'sea', and medieval documentary evidence. These meres were easier to trace in the claylands of eastern Holderness,

where the distinction between mere and surrounding land was clear, than in the peatlands of the Hull valley where the separation between mere and carr would rarely be distinct. Figure 2.4 is taken from Sheppard (1956) and shows the distribution of these meres in Holderness.

On the claylands Anglian and Danish ploughing and clearance may well have provided material to accelerate the silting up of some meres before 1066. The Domesday Book described the area as closely settled with much land already reclaimed and in use. Many smaller meres may have been drained by the improving and scouring of streams, which began at this time. The larger meres, such as Hornsea, Lambwath, Skipsea and Pidsea were important fisheries and so were kept cleared of excessive weed growth.

The peatlands of the Hull valley were probably still in a naturally waterlogged state in 1066. Most of the medieval drainage was an indirect result of the activity of Monks, especially around Meaux Abbey. Water-courses were dug for navigational purposes and as boundary ditches, but must have indirectly aided the drainage. Between 1210 and 1220 A.D. for example, the monks of Meaux cut a new dike, to take water from Lambwath Mere, to the east of the Hull valley, through their abbey grounds and into the River Hull, to power water-mills and to act as a navigation channel. By about 1400 A.D., however, this channel was dry in the summer months and Lambwath Mere had disappeared. Where the monks had influence the peatlands must have become seasonally dry and so provided peat, reeds, wildfowl and summer grazing for sheep. Away from the Abbey the peatlands probably remained wet.

Much of the siltland of the lower Hull valley and north bank of the Humber was reclaimed by the embanking of saltmarsh, and drainage, between 1066 and 1300. In 1256 Spurn Head was probably breached near

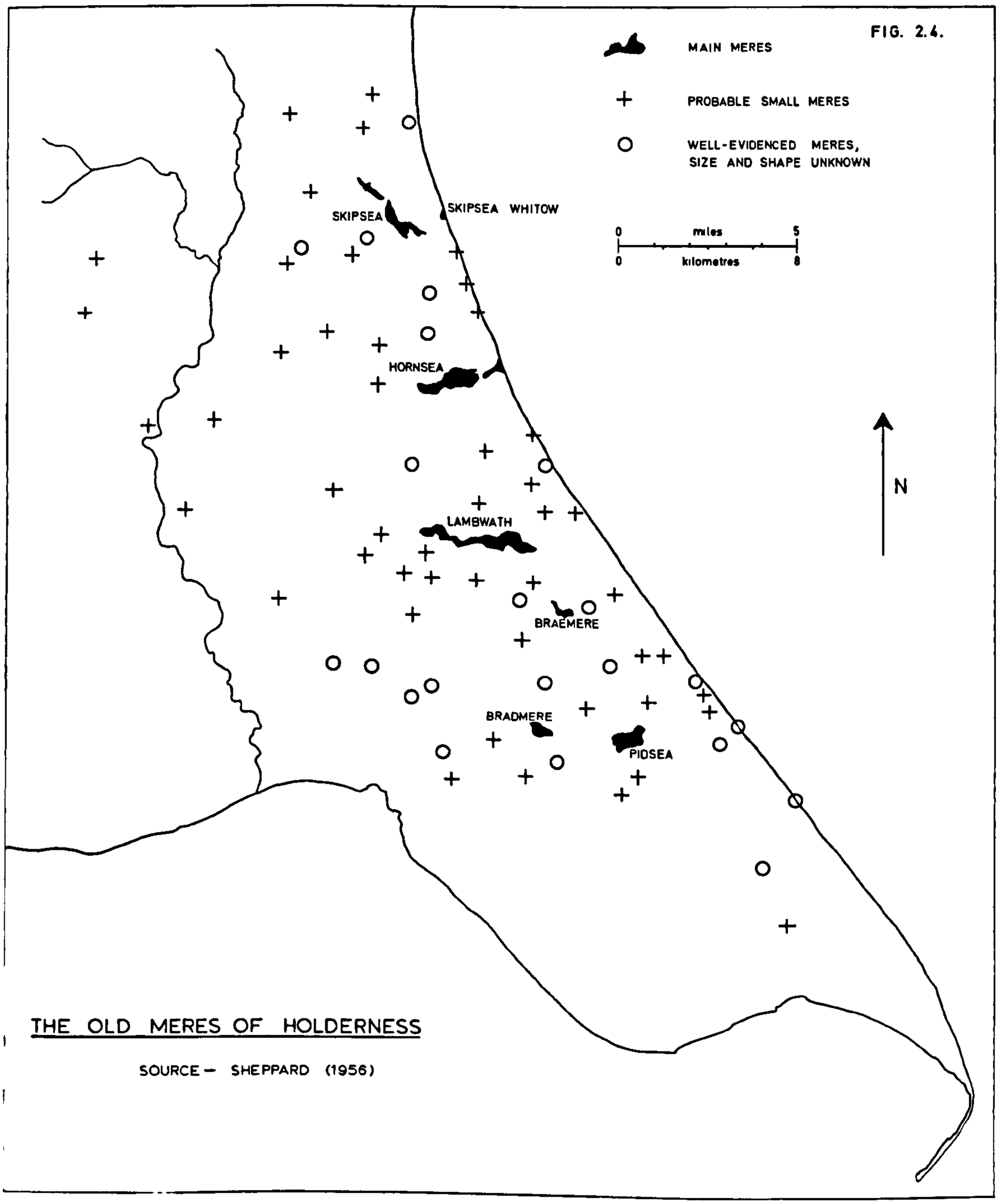


FIG. 2.4.
MAIN MERES
PROBABLE SMALL MERES
WELL-EVIDENCED MERES, SIZE AND SHAPE UNKNOWN
0 miles 5
0 kilometres 8
N
SKIPSEA
SKIPSEA WHITOW
HORNSEA
LAMBWATH
BRAEMERE
BRADMERE
PIDSEA
THE OLD MERES OF HOLDERNESS
SOURCE – SHEPPARD (1956)

its northern end by the sea and the resulting stronger tides in the Humber in the years following this caused some loss of previously reclaimed lands. Because of this and perhaps also as a result of the Black Death, little drainage was achieved in the succeeding centuries. A decrease in the importance of freshwater fisheries also probably meant that the larger meres were allowed to become overgrown with weeds.

In the seventeenth and eighteenth centuries most of the meres on the drift were drained, often by merely deepening and widening of the outflow streams. No details of the drainage of a mere are known but by 1800 almost all meres on the claylands had disappeared, their demise attracting little attention owing to their overgrown condition. Only two meres survived through the nineteenth century, Hornsea Mere and, possibly, Burton Agnes Mere of which the exact position and history are not clear but which seems to have been filled in about 1900.

Little drainage of the peatlands of the Hull valley was undertaken between 1300 and 1760. Apart from the cutting of some north-south channels to rreplace the east-west ones cut by the monks, and a little private enterprise, much of the earlier drainage work fell into neglect. After the establishment of the drainage authorities in 1760 the Hull valley was at last efficiently drained into the River Hull, and, via the Holderness Drain, directly into the Humber. The carr lands of southern Holderness such as the Winestead, Keyingham and Roos Carrs probably became wetter in the eighteenth century as silting and some reclamation in the Humber estuary impeded drainage. Efficient drainage of the Keyingham area and the reclamation of Sunk Island was largely accomplished around 1800.

CHAPTER 3

THE METHODS USED

FIELD METHODS

The choice of site

To establish the regional vegetational history of Holderness several criteria were considered in the choice of sites. Firstly, it was necessary to analyse the pollen from at least two deposit sequences which both covered the whole of the Late-glacial and Post-glacial period. These could be used as a basis against which to fit other, incomplete sequences. To separate those effects of pollen deposition caused by local site characteristics from those due to changes in the regional vegetation, distinctly different sites were chosen. The choice of the Bog, a probable kettle-hole, at Roos, and the much larger Old Mere at Hornsea gave sites of different genesis, size and margin characteristics. This enabled a picture of regional vegetational changes in and around the meres of Holderness to be drawn up.

The position of the Bog at Roos in southern Holderness, and the Old Mere at Hornsea in eastern central Holderness, meant that they, together with the shorter time-span pollen profile from Gransmoor in north-western Holderness, and also the published pollen diagrams from Skipsea (Godwin and Godwin, 1933) in the north-east, Brandesburton (Clark and Godwin, 1956) in the centre of the region, and North Ferriby (Wright and Churchill, 1965) and Faxfleet (Hulme and Beckett, 1973), on the bank of the Humber estuary, gave a good spread of sites over the area - and so could give a more valid regional picture of vegetational history.

The Gransmoor Quarry site was chosen to give some information on the north-western corner of Holderness, and hopefully to throw some light on the vegetational history of the calcareous Yorkshire Wolds,

close to this site. While this proved to be largely unsuccessful, the site yielded information on rather different habitats to the other sites.

The existing Hornsea Mere might have given a regional picture of vegetational change up to the present day and therefore have been of more value than the Old Mere site in which pollen deposition ceased some time ago. However, access to Hornsea Mere was initially restricted, and the uppermost horizons of the deposit have, in any case, probably been somewhat disturbed.

Stratigraphic work

To trace the basim characteristics, and to find the most suitable points for pollen analysis, a transect of borings was made across the deposits of the two major sites. For most of this work a 'Russian' peat sampler (Jowsey, 1966) was used. This gave half-metre length semi-cylindrical cores. Less often, both a 'Thomas' type of peat borer, and a 'Livingstone' piston sampler (Livingstone, 1955) were used. The surface of the deposits was levelled at the Hornsea Old Mere site. This was unnecessary at the Bog, Roos, where the surface was either open water or peat at a level very close to this water level. The results of these investigations are shown in figures 4.2 and 5.2. At Gransmoor Quarry the stratigraphy was examined in a cleaned face at the pollen sampling point.

The deposits were described according to the methods of Troels-Smith (1955). The physical properties identified, classified on the five-point scale, were as follows:-

Nigror	- the degree of darkness	-	abbreviated as	nig
Stratificatio	- the degree of stratification	-	- do -	strf
Elasticitas	- the degree of elasticity	-	- do -	elas
Siccitas	- the degree of dryness	-	- do -	sicc
Humositas	- the degree of humicity	-	- do -	humo

The deposit components noted included the following:-

Turfa bryophytica	- the basis of moss peat	- symbol Tb
Turfa lignosa	- the basis of wood peat	- symbol Tl
Turfa herbacea	- the basis of herbaceous peat	- symbol Th
Detritus lignosus	- coarse woody detritus	- symbol Dl
Detritus herbosus	- coarse herbaceous detritus	- symbol Dh
Detritus granosus	- fine detritus mud	- symbol Dg
Limus detrituosus	- very fine lake mud	- symbol Ld
Argilla steatodes	- clay (grains $<$0.002 mm)	- symbol As
Argilla granosa	- silt (grains 0.002 - 0.06 mm)	- symbol Ag
Grana arenosa	- fine sand (grains 0.06 - 0.6 mm)	- symbol Ga
Grana saburralia	- coarse sand (grains 0.6 - 2 mm)	- symbol Gs
Grana glareosa	- gravel (grains 2 - 20 mm)	- symbol Gg
Substantia humosa	- homogeneous humous substance	- symbol Sh

During the stratigraphic investigations macroscopic finds, such as leaves, seeds and moss remains were noted and identified where possible. Bulk samples were removed from the cleaned face at Gransmoor Quarry for a more detailed search for macroscopic remains.

The stratigraphic symbols used in the construction of subsequent diagrams do not necessarily correspond to those of Troels-Smith (1955).

Sampling for pollen analysis

At Roos and Hornsea cores were removed for pollen analysis from near to the centre of the sites, where a full, deep stratigraphic sequence

was represented. Cores were extracted from the deposits with a 'Russian' peat sampler, which gave undisturbed semi-cylindrical cores of 0.5 m length and 40.0 mm diameter. Alternate half-metre cores were removed from separate, but immediately adjacent holes to avoid vertical contamination from the head of the borer. Cores were taken to the laboratory intact, kept in cold storage to prevent fungal growth or excessive drying, and then sub-sampled for pollen analysis.

At Hornsea the deepest deposits could not be removed satisfactorily in an undisturbed condition by hand-boring methods. These lowest sediments were sampled with a 'Pilcon' piston sampler which extracted 0.5 m length cylindrical cores of 100 mm diameter.

From Gransmoor Quarry, where there was an exposed peat face, samples for pollen analysis were removed directly from this cleaned face and placed into specimen tubes.

Sampling for radiocarbon dating

Material was removed from the half-cylinder cores of the Late-glacial deposits at Roos. Other cores were extracted from these lowest deposits, very closely (less than 1 m) adjacent to the cores used for pollen analysis. For radiocarbon assay, sediment was taken from the same horizons, stratigraphically aligned, of from two to four of these cores, including the actual pollen-analysis cores.

At Hornsea, material for dating was taken from the centre of one of the 100 mm diameter cores used for pollen analysis. From Gransmoor Quarry 20 mm thick slices of peat were removed from the exposed face immediately behind the pollen analysis samples.

Radiocarbon dating of samples from the Bog, Roos, and the Old Mere, Hornsea, was carried out at the Department of Geology, Birmingham

University, while samples from Gransmoor Quarry were dated at the Scottish Universities Research and Reactor centre, East Kilbride, Scotland.

LABORATORY METHODS

Absolute pollen analysis

The theory behind this technique, and the three basic methods currently in use have been outlined above (chapter 1). These three main methods are the 'exotic pollen' method (Benninghoff, 1962; Matthews, 1969; Waddington, 1969; Bonny, 1972), the 'volume aliquot' technique (Davis, 1965, 1966), and the weight method (Jorgensen, 1967).

A very slightly modified weight method was used in this study. This technique was considered most suitable because almost the only measurements that have to be made are of weight and can therefore be made accurately on a balance. The 'volume aliquot' method entails the measurement of precise volumes, which must make accuracy difficult to achieve, and is also dependent on homogeneous mixing. The 'exotic pollen' method introduces a further possible source of error if the added exotic pollen suspension is not homogeneous or thoroughly and evenly mixed with the fossil preparation.

The weight method yields results in numbers of pollen grains and spores per gram dry weight. It is necessary, therefore, to carry out density measurements on the deposit to convert this data into pollen grains and spores per ml. Some such sediment volume measurement is necessary in all of the techniques. The advantage of the weight method is that these volume (and density) measurements can be taken more accurately from larger segments of the deposit cores extracted from a borer of known cross-sectional area. Although the 'exotic pollen' method has been considered quick and easy (Bonny, 1972) the weight method was not found unduly time-consuming. Jorgensen (1967) considered

it safer to prepare just one sample at a time, but this was not found to be necessary.

Preparation of samples for pollen analysis

The preparation used was essentially the basic method with treatment with caustic potash, Erdtman's acetolysis, and hydrofluoric acid where necessary (Faegri and Iversen, 1964; West, 1968). To this was added the weighings at several stages for the absolute pollen frequency information. Throughout the preparation great care was needed in decanting after each centrifugation, on transference to small tubes, etc. to ensure the minimum possible loss of pollen. For example when the hydrofluoric acid treatment was used each sample was always returned to its original glass centrifuge tube to minimise loss.

The procedure was as follows (with centrifugation after washings, etc. for about 4 minutes at 3000 r.p.m.):-

Approximately 1 - 2 ml of sediment was removed from core or sample tube and dried for 24 hours at 90°C (to remove weight anomalies due to water content).

The dry weight of the sample was measured and noted.

The sample was boiled in 10% caustic potash for 5 to 10 minutes, or until well broken up.

The sample can be sieved at this stage if necessary. In this case it was rarely necessary, which was an advantage in avoiding a potential cause of pollen loss. Any sieving done must be thorough.

The sample was washed in distilled water.

The sample was washed in 10% acetic acid.

The sample was washed in glacial acetic acid.

The sample was then subjected to Erdtman's acetolysis - 2.5 ml of a fresh mixture of 9 parts acetic anhydride and 2 parts concentrated sulphuric acid were added to the sample in its centrifuge tube,

which was placed in a boiling water bath for 4 or 5 minutes. The action was then stopped by the addition of glacial acetic acid.

The sample was washed in 10% acetic acid.

The sample was washed in distilled water.

Where necessary to remove silicates the following treatment was carried out at this stage.

The sample was washed in 5% hydrochloric acid and transferred to a nickel crucible. 40% hydrofluoric acid was added, and the sample was boiled in a fume cupboard for a period of between 5 minutes and an hour, depending on the nature of the sediment.

More hydrofluoric acid was added during this period when necessary.

At the end of this treatment the sample was added to hot 5% hydrochloric acid in a polypropylene centrifuge tube, capped and centrifuged.

The sample was washed in distilled water and returned to its original glass centrifuge tube.

The sample was washed in 80% alcohol.

The sample was washed twice in absolute alcohol.

The sample was washed in a 50:50 mixture of absolute alcohol and benzene.

The sample was washed in benzene.

A small glass vial (3.5 ml), labelled and with a glass stirring rod, was weighed, and the weight noted.

The sample was transferred completely in benzene, to this small vial and centrifuged.

A little fresh benzene and silicone oil (viscosity 2000 centistokes) was added.

The glass stirring rod was replaced in the tube with the sample, which was left overnight in a slightly warm oven to allow the

benzene to evaporate.

After the benzene had completely evaporated the labelled vial and stirring rod and sample in silicone oil was weighed and the weight noted. By subtracting the weight of the empty labelled tube and stirring rod from this the weight of the prepared sample and the silicone oil containing it was calculated and noted.

The sample was then thoroughly stirred.

Some of the stirred sample suspension was mounted onto (usually four) microscope slides.

The labelled tube and stirring rod and remaining sample suspension was then re-weighed, to give the weight of sediment suspension in silicone oil mounted onto the microscope slides. This weight was noted.

When a known weight of the sample suspension had been placed onto the microscope slides any quantity of additional silicone oil (2000 centistokes viscosity) could be added and thoroughly mixed with the sample suspension to aid mounting and dilute the suspension.

The sample was mounted on microscope slides under 40 x 22 mm no 0 coverslips and sealed with nail varnish. When necessary further slides could be made from weighed amounts of the prepared sample suspension removed from the stored small tubes.

Counting procedure

Pollen identification and counting were carried out on a Zeiss photomicroscope at a magnification of x 400. Where pollen was scarce, as in the Late-glacial clays, the slides were scanned for pollen and spores at a magnification of x 160, each grain or spre being identified at x 400. Pollen and spores were identified and recorded until, generally, at least 300 arboreal pollen grains or a total of 500 'dry land' pollen grains had been counted. Where one type was overwhelmingly abundant

(e.g. Corylus or Ericaceae at Roos) much larger total pollen counts were made. In some of the Late-glacial deposits, particularly at Hornsea, pollen was very scarce. Some of the total pollen counts from these deposits were very small - despite the fact that up to twelve slides for each sample were examined for pollen and spores. The actual numbers of pollen and spores counted also varied somewhat as it is essential to count an equal number of evenly-spaced traverses on each of the slides, to give the absolute data. Jorgensen (1967) recommended counting all pollen and spores on each slide prepared, but it was considered as reliable to count a large and equal number (usually between 10 and 20) of evenly-spaced traverses on each slide. The area of each slide covered for pollen counting could therefore be calculated.

Numbers of pollen and spores of each taxon per gram dry weight of sediment were calculated from the measurements made by the following formula:-

$$\text{no. of grains of taxon counted} \times \frac{\text{total area of coverslips}}{\text{area of coverslips examined}} \times \frac{\text{total weight of sample in silicone oil}}{\text{weight of sample in silicone oil placed on slides}} \times \frac{\text{1 gram}}{\text{dry weight of sediment used in preparation}}$$

Calculation of pollen deposition/cm^2/year

To convert the values of pollen grains/gram dry weight to pollen grains deposited/cm^2/year it was necessary to measure the sediment density in grams dry weight/cm^3 of fresh sediment, and thus to obtain a value for pollen numbers/cm^3 of fresh sediment. Sedimentation rates were then calculated and the results converted into pollen deposition/cm^2/year.

The density measurements could be made at the very start of the preparation, by preparing a sample of measured volume, as has been

done in the other absolute methods. Density measurements of larger volumes of sediment were thought to be more accurate. Therefore the density measurements from Roos and Hornsea were obtained by cutting lengths of 30 or 50 mm from the half-cylinder cores taken with the 'Russian' peat sampler. Since the internal cross-sectional area of the peat sampler was known (6.286 cm^2) the volume of these cores could be calculated easily. These volumes of sediment were taken from the pollen analysis cores, where possible, and from between the levels sampled for pollen analysis. These samples of known volume were then dried for 24 hours at 90°C, and weighed. From the measurements the density of the sediment could be calculated.

For the Late-glacial deposits at Hornsea half-cylindrical slices 10 mm thick from the 100 mm diameter cores were treated in exactly the same way to obtain density values, although absolute values of pollen deposition were not subsequently computed for these horizons.

From the Gransmoor Quarry site a monolith was removed from immediately behind the 'pollen-sampled' face. Density measurements were taken from this by measuring the dry weight of a known volume of sediment. This volume was obtained by pushing an aluminium tube of 44 mm internal diameter, 30 mm into the face of the monolith, cleaning any excess off the end of the tube, and then drying and weighing the amount (of volume 45.63 cm^3) held in the tube. This last method did not seem ideal, but yielded consistent results.

The density of the sediments from all of the sites was then calculated and expressed as:-

grams dry weight / cm^3 of fresh sediment

for a series of levels throughout the profiles. This measure of dry weight over wet volume may not be a true measure of density, but is

referred to as such for convenience. The pollen values in numbers/gram dry weight were then converted to:-

no. of pollen grains / cm^3 of fresh sediment

The sedimentation rates for the Late-glacial deposits at Roos, and the deposits at Gransmoor, were calculated by reference to the radiocarbon dates obtained from these profiles. The actual radiocarbon dates, without regard to the stated errors, were applied to the mid-points of the samples assayed. Sedimentation rates were then calculated for the intervals between adjacent radiocarbon dates, assuming that the rate was constant between these two dates. By dividing the number of pollen grains/cm^3 by the number of years taken for 1 cm depth of deposit to accumulate, a value of numbers of pollen grains deposited/cm^2/radiocarbon year could be calculated (see chapters 4, 5 and 6 for actual rates).

The calculation of actual sedimentation rates for the Flandrian deposits at the Bog, Roos and the Old Mere, Hornsea was impossible as there was insufficient finance for radiocarbon dates from these profiles. An approximate estimate of sedimentation rates was calculated by assigning assumed dates to certain pollen horizons in the deposits (see chapters 4, 5 and 6).

The percentage pollen diagrams (see below) were examined and the levels of marked changes of pollen representation were assigned dates. The pollen assemblage horizons chosen were ones which occur throughout northern England, and the rest of the country, and which have been dated elsewhere with a fair degree of synchroneity. Estimated dates could therefore be applied with some confidence. The pollen horizons chosen, and the dates attributed to them, were as follows:

Expansion of tree species of Betula	- at Hornsea an estimate of 10,000 B.P.
	at Roos, actual radiocarbon date
Expansion of Corylus	- 9,000 B.P.
Expansion of Alnus	- 7,500 B.P.
End of decline of Ulmus	- 5,000 B.P.

The actual depths to which these dates were applied are given in the relevant site chapters (4 and 5), together with some discussion of their validity.

These estimated dates were then used in the same way as the radiocarbon dates from the Late-glacial horizons at Roos to calculate sedimentation rates, and ultimately pollen deposition rates in terms of numbers of pollen grains deposited/cm^2/year.

This whole technique is admittedly far from satisfactory. Although five radiocarbon dates were obtained for the Late-glacial deposits at Roos, it is evident that a really reliable outline of pollen deposition would require a greater number of closely-spaced dates.

The estimates of pollen deposition for the Flandrian period, based on estimated dates, can only give an approximate idea of the order of absolute pollen numbers involved. The validity of some of the assumed dates may be questioned. That for the expansion of Betula pollen of tree species is from an actual radiocarbon date from Roos and therefore acceptable. The estimate of the rounded-off date of 10,000 B.P. for the base of the Flandrian deposits at Hornsea may also be considered fairly reliable. The Flandrian/Late-Weichselian boundary has been shown to be quite synchronous at low altitudes, at about 10,300 B.P., right across north western Europe (Hibbert, Switsur, and West, 1971), and the lowest levels of the Hornsea Flandrian deposits analysed probably lie

just above this boundary.

The start of the expansion or rational limit of Corylus has been dated close to 9,000 B.P. throughout the British Isles (Hibbert, Switsur and West, 1971; Hibbert and Switsur, in the press; Smith and Pilcher, 1973), although the dates for this phenomenon have shown a little variation. The estimation of a date for the beginning of the expansion, or rational limit, of Alnus is the most difficult. There seems to have been a diachroneity of this expansion across Europe covering about 1,500 years (Hibbert, Switsur and West, 1971). Dates for this within the British Isles have normally lain between 7,500 and 6,700 B.P. The radio-carbon date of 8,507 ± 55 B.P. (SRR-230) from Gransmoor Quarry lies not far below the Alnus pollen expansion, which may, therefore, have been fairly early in Holderness. For these reasons a date of 7,500 B.P. was applied to the rational limit of Alnus at the Roos and Hornsea sites. Because of the apparently rather different behaviour of Alnus at these two sites and the consequent uncertainty attached to this date further absolute pollen deposition diagrams were produced with the Alnus expansion date omitted.

The date of 5,000 B.P. could be applied to the end of the decline of Ulmus pollen at both Hornsea and Roos with a fair degree of certainty. The decline of Ulmus pollen was dated at Gransmoor to 5,099 ± 50 B.P. (SRR-229) and throughout north western Europe the prominent elm decline feature has been dated close to 5,000 B.P., and is the most synchronous of Flandrian vegetational changes (Hibbert, Switsur and West, 1971; Hibbert and Switsur, in the press; Smith and Pilcher, 1973).

Rounded-off dates have been used in these estimates to emphasise their approximate nature. It was realised that they could give no

more than a rough idea of absolute pollen deposition. They may be of some value in comparison of pollen deposition values between separate, whole zones. The small number of estimated dates and their approximate nature makes the identification of changes in absolute pollen deposition within individual zones impossible. Their value in the interpretation of a feature such as the elm decline is therefore strictly limited. Although the 'absolute' data have been used in the discussion of this phenomenon (chapter 9) they provide only indirect evidence of what actually happened. However, in instances where the values for one taxon change abruptly while all other types do not change, for example, even these approximate calculations of pollen deposition will demonstrate a real change in the vegetation without percentage constraints. It was therefore considered worthwhile to attempt to construct these absolute pollen diagrams.

Construction of the pollen diagrams

From the data obtained both 'percentage' and 'absolute' pollen diagrams were constructed. For the percentage diagrams the pollen sum was, in most cases, total arboreal pollen i.e. tree species of *Betula*, and *Pinus*, *Quercus*, *Ulmus*, *Tilia*, *Alnus*, *Fraxinus*, *Fagus* and *Carpinus*. All other, non-arboreal, taxa were expressed as percentages of this sum.

For the Late-glacial percentage diagrams the pollen sum used was total dry land pollen. This was used because of the general scarcity of tree pollen types, and to demonstrate the nature of the vegetation of this period more clearly.

For figure 6.3 from Gransmoor Quarry, the pollen sum used was total arboreal pollen excluding *Tilia* - to remove the effect of the over-abundance of this taxon on the other arboreal percentages, as occurs

in figure 6.2.

The pollen sum used is indicated on each of the percentage pollen diagrams.

Absolute pollen deposition rates were estimated by the method outlined above, and the figures for the most abundant and/or significant taxa were drawn up on the pollen diagrams with values for each taxon, and total pollen deposition expressed as pollen grains deposited/cm^2/year.

Because the pollen deposition rates in the absolute pollen diagrams for the Flandrian period were largely based on estimated dates the basic absolute data in terms of grains/gm dry weight of sediment has also been presented in diagrammatic form.

Pollen identification

Pollen and spores were identified and counted, generally at a x400 magnification, on a Zeiss automatic photomicroscope. Critical identification was effected under oil immersion at x640 magnification. Pollen and spore types were identified as narrowly as possible by comparison with preparations of reference pollen, using a Wild comparison eyepiece. Reference was also made to the pollen identification key of Faegri and Iversen (1964) and to Erdtman, Berglund and Praglowski (1961), Hyde and Adams (1958), and Knox (1951).

Where identification was uncertain the limits of certainty were defined by the standard terms 'sim' and 'comp', (Benninghoff and Kapp, 1962) where

sim = strong similarity to indicated taxon

comp = compares favourably with material from living representatives of indicated taxon

In some cases several different taxa were identified together as

one 'type' - e.g. Sparganium type, abbreviated on the pollen diagrams to Sparganium T. The 'types' identified are listed below. Unless otherwise stated they represent the 'types' of Erdtman, Berglund and Praglowski (1961).

Aster T.	Aster type - includes Aster, Bellis, Erigeron and Solidago
Matricaria T.	Matricaria type (equals Anthemis type of Erdtman, Berglund and Praglowski, 1961) - includes Matricaria, Achillea, Anthemis, Chrysanthemum and Cotula.
Rumex acet. T.	Rumex acetosa type - includes Rumex acetosa, Rumex acetosella, and Oxyria digyna
Sparganium T.	Sparganium type - includes Sparganium and Typha angustifolia.

Other abbreviations for taxa on the pollen diagrams are as follows:

Compositae Lig.	- includes all types in the sub-family Liguliflorae, such as Taraxacum, Tussilago, Crepis, Hieracium, Leontodon and Sonchus.
Filicales undiff.	- undifferentiated Filicales spores
Plantago lanc.	- Plantago lanceolata
Myriophyllum alt.	- Myriophyllum alterniflorum
Myriophyllum spic.	- Myriophyllum spicatum
Myriophyllum vert.	- Myriophyllum verticillatum

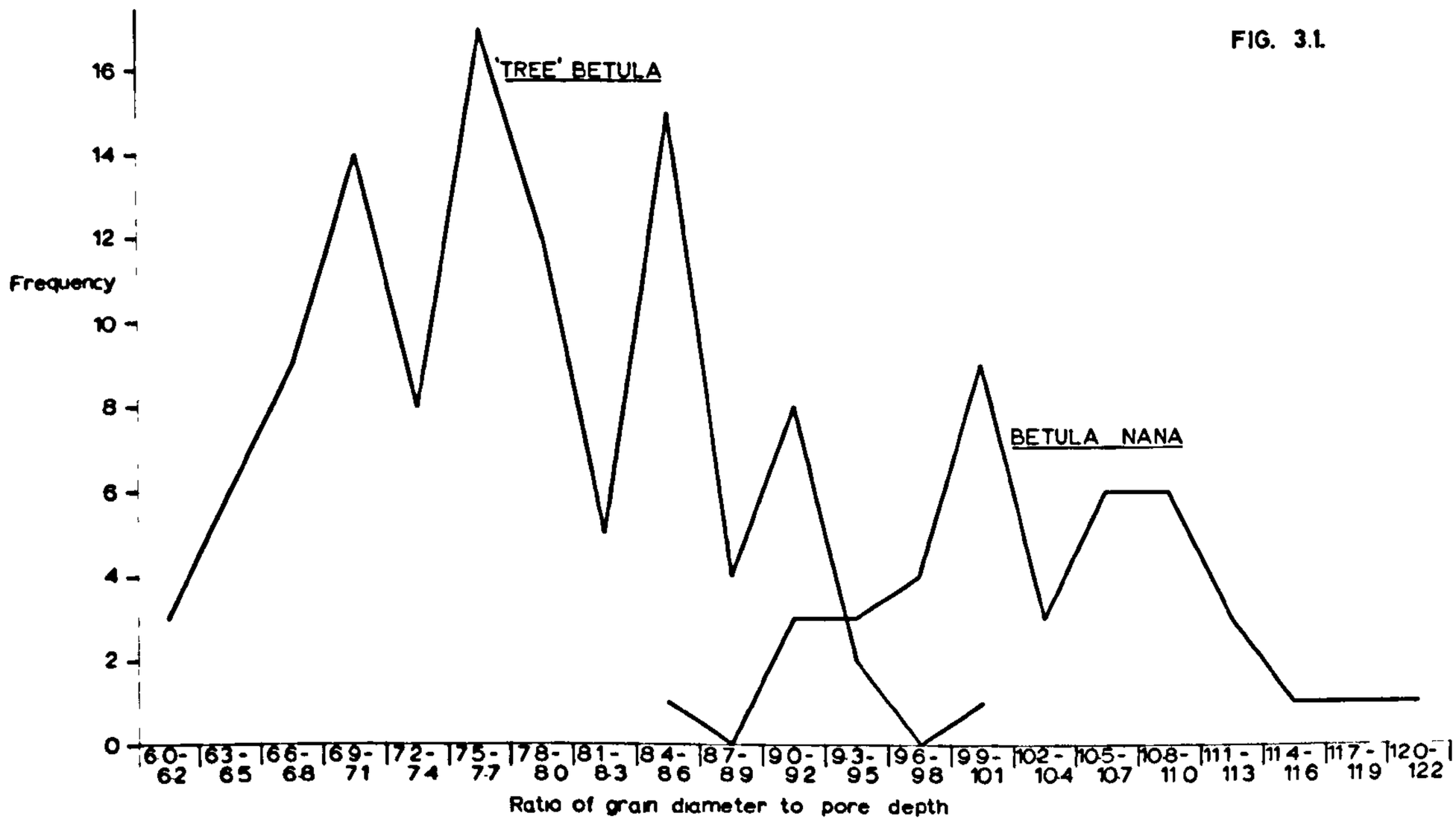
Identification of Betula nana - As described in Chapter 1 the pollen of the dwarf birch, Betula nana has been distinguished from that of the tree species of Betula on several criteria. Qualitatively, Betula nana pollen has been distinguished from pollen of other Betula species by its thinner exine, its more rounded and slightly smaller form, and its less-pouting pores (Terasmae, 1951; Praglowski, 1962). It has

also been separated from Betula pubescens and Betula tortuosa by measurements of the ratio of grain diameter to pore depth (Walker, 1955; Birks, 1968). Mean ratios for reference material of these three species gave values of between 7.3 and 7.93 for B.pubescens, 9.24 and 9.42 for B.tortuosa and between 10.0 and 11.5 for Betula nana. However, this statistical separation has been considered invalid for fossil material treated with hydrofluoric acid (Pennington, 1970), as were the Late-glacial samples from Roos and Hornsea.

To establish whether statistical separation was possible or not, fossil pollen was classified as either Betula nana or as 'tree' species of Betula on qualitative criteria, and measurements of the ratio of grain diameter:pore depth were made. Frequency values of this ratio were plotted for each, qualitatively identified taxon (figure 3.1). In all, 41 pollen grains of Betula nana and 104 of 'tree' Betula were measured. This graph (figure 3.1) shows that the two taxa are separable, both qualitatively and quantitatively, despite hydrofluoric acid treatment, but with a small amount of overlap between the two. The mean ratios were found to be 7.6 for pollen of the tree species of Betula and 10.3 for that of Betula nana. This suggests that the 'tree' Betula was largely Betula pubescens. To aid further identification, therefore, both quantitative and qualitative observations were made on doubtful grains. Any Betula pollen which appeared to be intermediate between the two types was recorded as 'tree' Betula pollen. The Betula nana pollen values expressed are therefore probably minimum values.

Preparation for macroscopic analysis

Some bulk samples from Gransmoor Quarry were prepared for a search for macroscopic remains. Samples were placed in 10% nitric acid and left in a fume cupboard for 24 hours, and occasionally stirred to aid



FREQUENCY OF GRAIN DIAMETER : PORE DEPTH RATIOS IN QUALITATIVELY-IDENTIFIED FOSSIL POLLEN OF BETULA, PREPARED WITH HF TREATMENT.

the break up of the material. The samples were then sieved and the residue examined.

INTERPRETIVE METHODS

Zonation of pollen diagrams

Something of the theory behind zonation has been outlined above (chapter 1). The percentage pollen diagrams from Roos, Hornsea and Gransmoor were each zoned quite independently into local pollen assemblage zones (sensu West, 1970), purely on the basis of the percentage assemblages of fossil pollen present at that site alone. These zones were numbered from the base of the deposits upwards, and each zone was prefixed by an abbreviation of the site name, as follows:-

The Bog, Roos	RB
The Old Mere, Hornsea	HO
Gransmoor Quarry	GQ

The basal pollen assemblages at the sites were all named (site prefix) 1., however different they might be in pollen content, age, etc., and written as RB.1., HO.1., and GQ.1. These zones established for the percentage diagrams were then applied directly to the absolute pollen diagrams to aid comparison.

These local pollen assemblage zones from the various sites were then correlated, and broadly similar zones were grouped into regional pollen assemblage zones for Holderness. The regional pollen assemblage zones were named after the two or three most characteristic pollen types present in them, and prefixed by the abbreviated name - HLD. Thus, for example, the local pollen assemblage zones RB.6, HO.6 and GQ.2 all represent the regional pollen assemblage zone HLD. Alnus/Ulmus. For each regional pollen assemblage zone a type locality was selected, and the limits of the zone defined.

This procedure largely follows that of H.H. Birks (1972). However in this study a regional name (HLD) has been used for the regional pollen assemblage zones, as it was felt that such a regional zone must apply to a defined region.

Zonation is not overemphasised in this study. It is regarded simply as an aid to the understanding and comparison of pollen diagrams, not the be all and end all of pollen analysis. In the subsequent discussion of the results the traditional 'Godwinian' zones are referred to as they were utilised at many of the other sites brought into the discussion. As a result, the relation of these zones, and of the Post-glacial divisions of Blytt and Sernander (Sernander, 1908) to the regional pollen assemblage zones for Holderness is briefly discussed to aid the comparison of results. Any attempt at a precise correlation is avoided.

Form of presentation of results and discussion

Data from each of the three sites is presented separately in section II. The results from each site are discussed in these chapters without reference to other sites, mainly to separate the local vegetational sequences at the individual sites from the regional pattern of vegetational history.

In section III the discussion is split into three chapters, each covering a different time period, namely Late-glacial, early Flandrian and late Flandrian. For each period the regional pattern of vegetational history is established for Holderness by comparison of the sites investigated, together with other published information. These sequences for Holderness are then compared with other data from north-eastern England, largely from the lowland area east of the Pennines, between Lincolnshire and the Scottish border. Finally, features of special note are discussed in a wider context.

SECTION II

THE SITES INVESTIGATED

CHAPTER 4

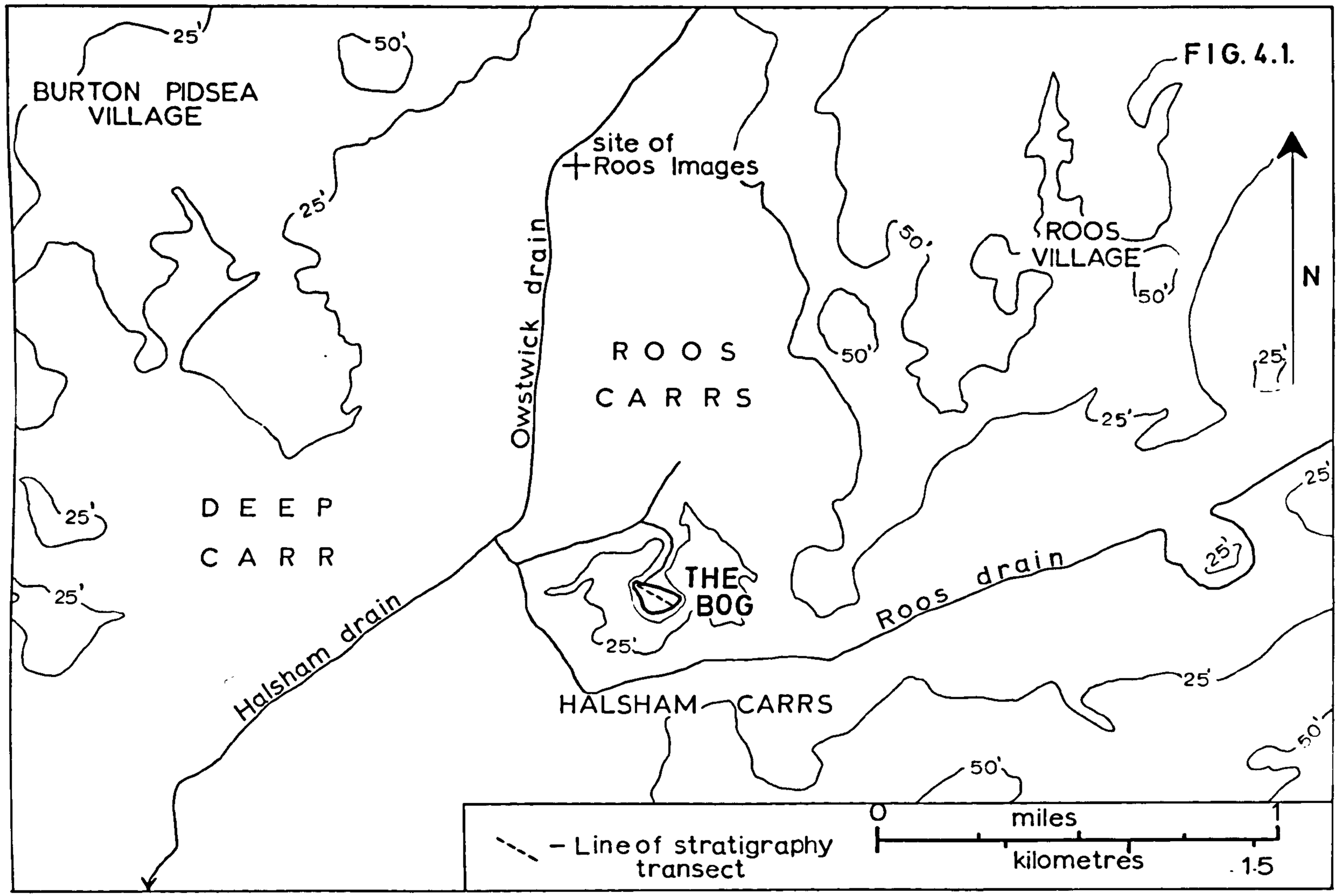
THE BOG, ROOS

INTRODUCTION

The Bog lies at Grid reference TA.273288, 1½ miles (2km) south west of the village of Roos and 4 miles (6 km) inland from the coastal town of Withernsea in southern Holderness. It is a hollow in the Devensian tills, slightly isolated from the surrounding Halsham Carrs, Roos Carrs and Deep Carr by a rim of higher ground (figure 4.1). The valley and the carrs are an extensive area of rather peaty land lying generally below 3 m O.D. Drainage work on Roos Carrs in the last century revealed a wooden artifact, probably of the Bronze Age, of figures in a boat, known as the Roos Images, from a ditch just to the north of the Bog (Sheppard, 1912).

The Bog is an approximately oval basin about 220 m along its longest axis, from north-west to south-east and about 120 m across its widest point. It is almost completely surrounded by a rim of higher ground of between 8 and 15 m O.D. The basin contains up to 11.5 m of infilling deposits of peats, organic muds and clays. The sides slope fairly steeply so that much of the hollow has a depth of over 6 m. This feature has been described as a basin excavated by moving ice (Valentin, 1957). However, its considerable depth is strong evidence for an origin as a kettle-hole formed during the retreat of the Devensian Ice. The feature might represent a pingo, the rim of higher ground being the 'rampart' of such a feature. Pingos rarely occur singly (Watson, 1972) but then neither do kettle-holes. The distinction between the landforms resulting from these two modes of origin is, in any case, not totally clear.

Before 1968 the surface of the Bog was comparatively dry, being drained by a series of ditches, via an outflow pipe to the north, and



MAP OF AREA SURROUNDING THE BOG, ROOS.

PLATE I Aerial view of the Bog, Roos

PLATE II Surface of the Bog, Roos

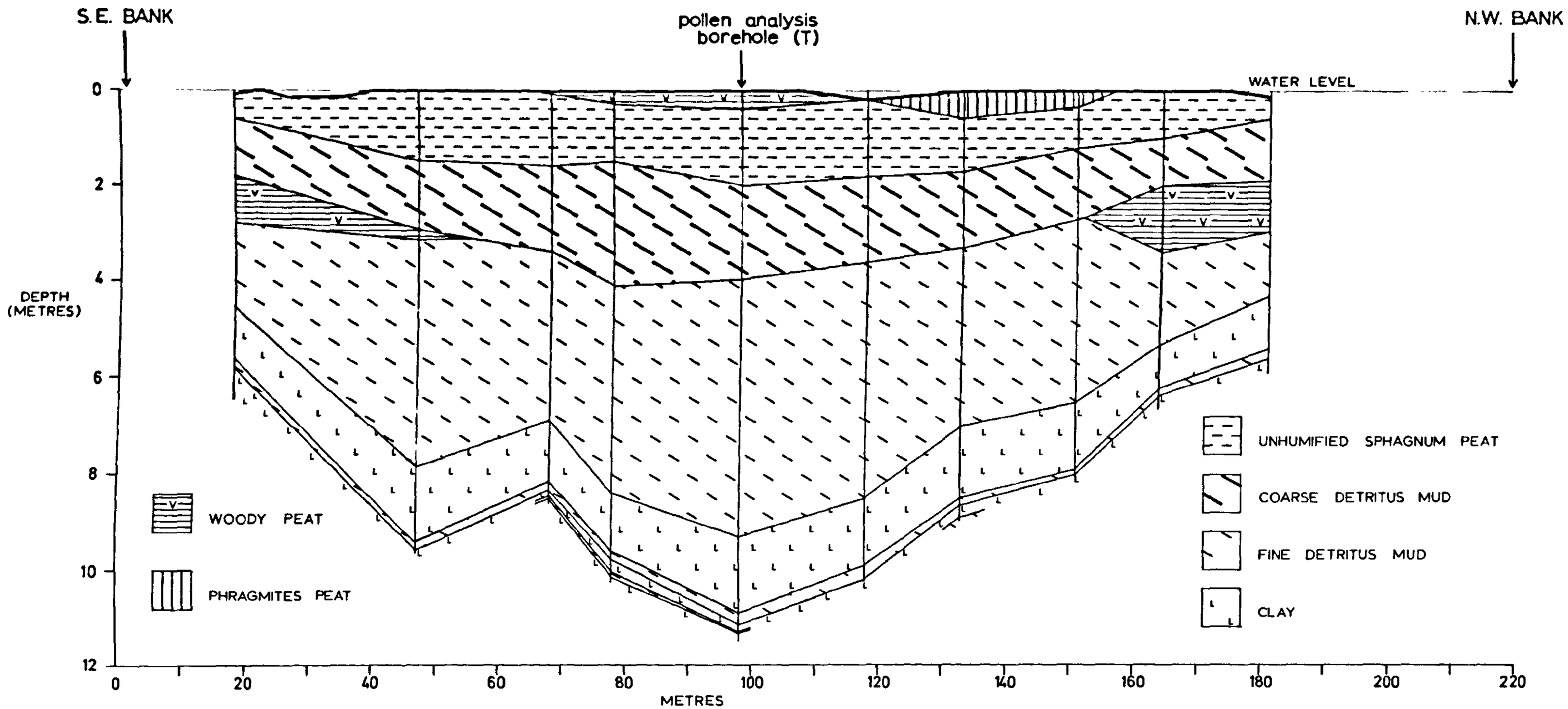
eventually into the Keyingham Drain. This surface supported numerous Betula pubescens, a few Quercus robur trees and a patch of planted Larix sp. with a damp woodland flora. Some pools on the Bog's surface contained Lemna minor, Mentha aquatica and Typha latifolia besides other species (Crackles, personal communication). The basin was then deliberately flooded to provide water for irrigation. It is now completely waterlogged, with a depth of up to 1 m of water in places. Only in the centre does the peat surface lie at, or slightly above water level. There is no natural inflow or outflow stream, but still some drainage of water through the outflow pipe, keeping the water level more or less constant. The flooding has killed the trees, and Salix is now vigorously colonising the waterlogged area. Phragmites communis, uncommon here in 1967, now forms an extensive patch near the centre, and Typha latifolia and Sparganium erectum flourish.

STRATIGRAPHY

A transect of borings across its longest axis (figure 4.2) shows the basin to be fairly steep-sided and flat-bottomed and to contain a series of deposit types.

At the base are two layers of clay separated by an organic layer. A thinner organic band occurs in places within the lower clay. Both clays are pinkish-grey in colour and contain little plant matter. The lower clay which is often gravelly at its base, does however contain fragments of the moss Leptodictyum sp. The upper clay includes patches of the moss Fontinalis antipyretica.

Separating the two clays is an organic layer, generally 0.15 - 0.30 m thick, of a fine detritus mud, dark in colour and well humified, with very little recognisable macroscopic plant material. A similar detritus mud occurs in the thin organic layer sometimes found within the lower clay.



THE BOG, ROOS. STRATIGRAPHY OF DEPOSITS ALONG S.E.- N.W. TRANSECT. FIG. 4.2.

Above the uppermost clay is a thick layer of dark, humified detritus mud, similar to that between the clays. Few macroscopic plant remains are present but some leaves of Quercus robur, Betula pubescens and Salix sp. are preserved, and occasional seeds of Menyanthes trifoliata occur.

At the edges of the basin, above this detritus mud, are lenses of up to one metre in thickness, of a reddish, poorly humified peat with quantities of wood fragments, particularly of Alnus. Above this peat, and lying on the detritus mud in the centre of the basin, is a moderately humified, rather coarser detritus mud, containing leaves of aquatic species of Sphagnum.

Over most of the site the top two metres of the deposits is represented by a comparatively unhumified peat with plentiful Sphagnum leaves, Menyanthes trifoliata seeds and rootlets of Ericales, notably Calluna vulgaris, as well as occasional patches of the moss Polytrichum sp. and a few fragments of Betula wood. In places the surface deposit is of a more woody peat, with chiefly Betula twigs. There is also a patch of Phragmites peat immediately below the area colonised by this plant.

The sequence of the deposits is shown by the stratigraphy of borehole T, from which a core was removed for pollen analysis and radiocarbon dating. This is as follows:-

0 - 0.40 m	Humified woody peat with Betula twigs nig 2, strf 0, elas 1, sicc 2, humo 3. Tl 3, Th 1, Tb +.
0.40 - 2.0 m	Less humified peat with plentiful Sphagnum, Menyanthes trifoliata seeds, Ericales rootlets, and Polytrichum sp. (particularly at around 1.80 m). nig 2, strf 0, elas 1, sicc 2, humo 2. Tb 3, Th 1.

2.0 - 3.90 m Humified coarse detritus mud, with Sphagnum leaves. nig 2, strf 0, elas 1, sicc 2, humo 3. Dg 4.

This grades into -

3.90 - 9.30 m Fine detritus mud, dark brown in colour. Well humified with some leaves of Betula pubescens, Quercus robur and Salix sp. Becoming darker and more humified below. nig 3, strf o, elas 0, sicc 2, humo 3-4. Ld 4, Dh +.

9.30 - 10.90 m Pinkish grey clay, with occasional fragments of the moss Fontinalis antyipyretica. nig 1, strf 0, elas 0, sicc 2. Ag 4, Ga +.

10.90 - 11.16 m Dark, humified fine detritus mud. nig 3, strf 0, elas 0, sicc 2, humo 3-4. Ld 4, Ag +.

11.16 - 11.33 m Slightly organic grey clay. nig 2, strf 0, elas 0, sicc 2. Ag 3, Ld 1, Ga +.

11.33 - 11.36 m Dark, humified fine detritus mud, with a little clay. nig 3, strf 0, elas 0, sicc 2, humo 3. Ld 3, Ag 1, Ga +.

11.36 - 11.50 m Grey clay. Gravelly at base only. nig 1, strf 0, elas 0, sicc 2. Ag 4, Ga + (Gg +).

POLLEN ANALYSIS

Pollen analysis was carried out on material from a core removed at borehole T, since this was considered to give the most complete sequence. Preparation of the samples was by the method outlined in chapter 3. It was necessary to treat some of the lowermost samples by boiling in 40% hydrofluoric acid to remove silicates.

Results of the analysis are presented in two percentage pollen diagrams. In that for the Late-glacial deposits (figure 4.3) all values

PLATE III Double organic band of the Late-glacial deposits at the Bog, Roos

are expressed as percentages of total dry land pollen. Values on the Post-glacial pollen diagram (figure 4.4) are expressed as percentages of total arboreal pollen (i.e. excluding Corylus).

For ease of description these diagrams have been zoned into local pollen assemblage zones, numbered from the base upwards, and prefixed with the site initials RB (see chapter 3).

Absolute pollen deposition calculations are dealt with below, and after the percentage diagrams have been described.

THE LATE-GLACIAL PERCENTAGE POLLEN DIAGRAM (figure 4.3)

All percentages given below are of total dry land pollen.

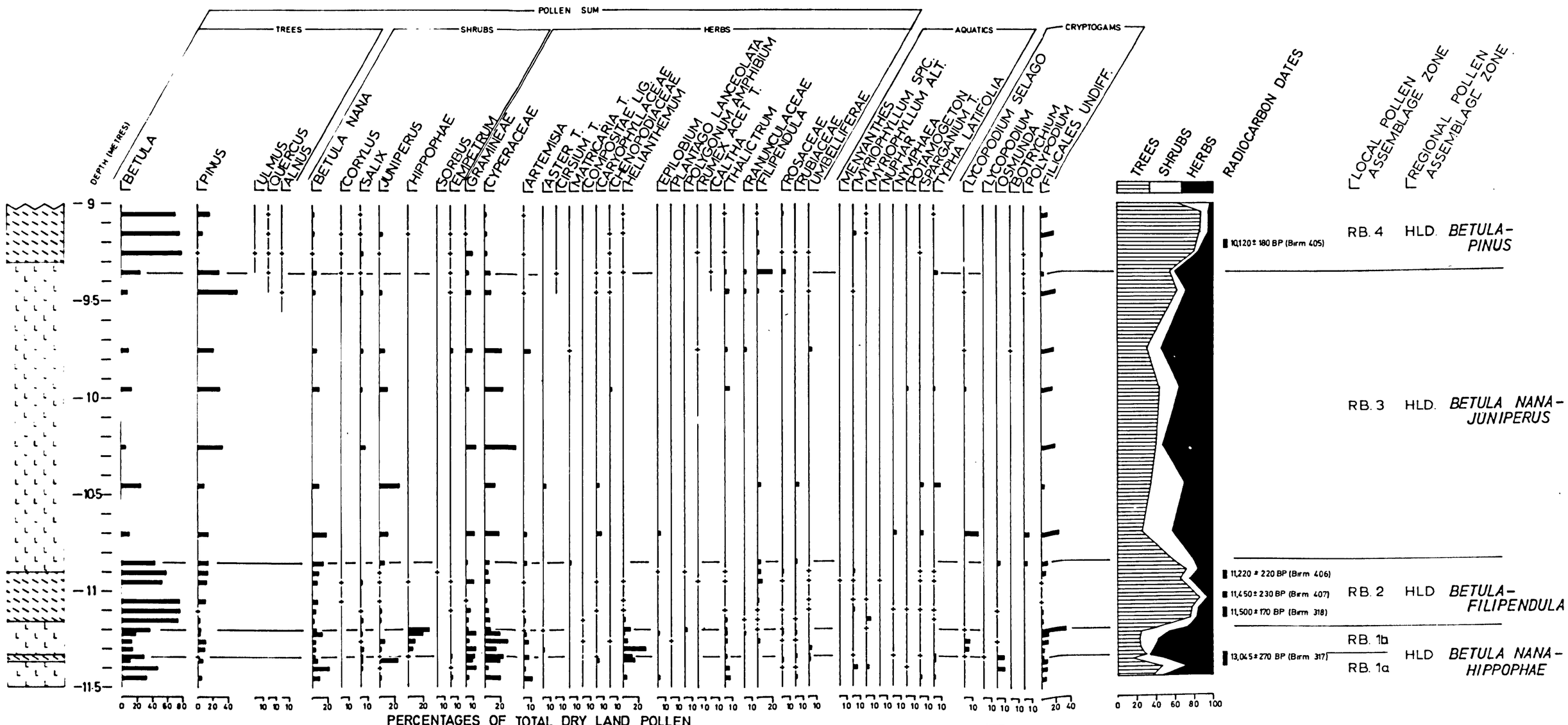
Zone RB.1 11.45 - 11.20 m

The pollen deposition is dominated by that of herbs, tree and shrub pollen values being low. The tree pollen present is dominated by that of Betula, at 10-25%, with about 5% of Pinus pollen. Pollen of Betula nana contributes about 5% and Salix pollen is present in only small amounts. Juniperus pollen is present but scarce. Hippophae pollen percentages exceed 20% at the top. Cyperaceae pollen contributes 25%, Gramineae 10%. Artemisia, Helianthemum, Rubiaceae and Thalictrum pollen is present throughout.

There is some evidence for division into two subzones.

RB.1a 11.45 - 11.34 m - Tree Betula pollen values at about 30%, Betula nana pollen at 10%, while Juniperus pollen contributes generally less than 5%. Pollen of Helianthemum is scarce, and that of Hippophae is absent.

RB.1b 11.34 - 11.20 m - Tree Betula pollen contributes less than 20% and Betula nana pollen about 5% Values of Helianthemum and Hippophae pollen increase to over 20% in this sub zone.



THE BOG, ROOS. POLLEN DIAGRAM OF LATE-GLACIAL DEPOSITS.

FIG. 4.3

Zone RB.2 11.20 - 10.85 m

Tree pollen values increase to about 60 - 80% of total dry land pollen. Most of this is of Betula (50-75%), but Pinus pollen contributes 10-15% towards the top of the zone. Betula nana pollen values lie at around 10%, increasing above 11.0 m. Pollen of Juniperus and Salix contribute less than 5%, while Hippophae pollen is almost absent. Gramineae and Cyperaceae pollen values are generally below 5%. Filipendula pollen is present and increases to 5% at the top of the zone. Pollen of other herbs, such as Helianthemum and Thalictrum is present but scarce. Pollen of a range of aquatic plants occurs.

Zone RB.3 10.85 - 9.35 m

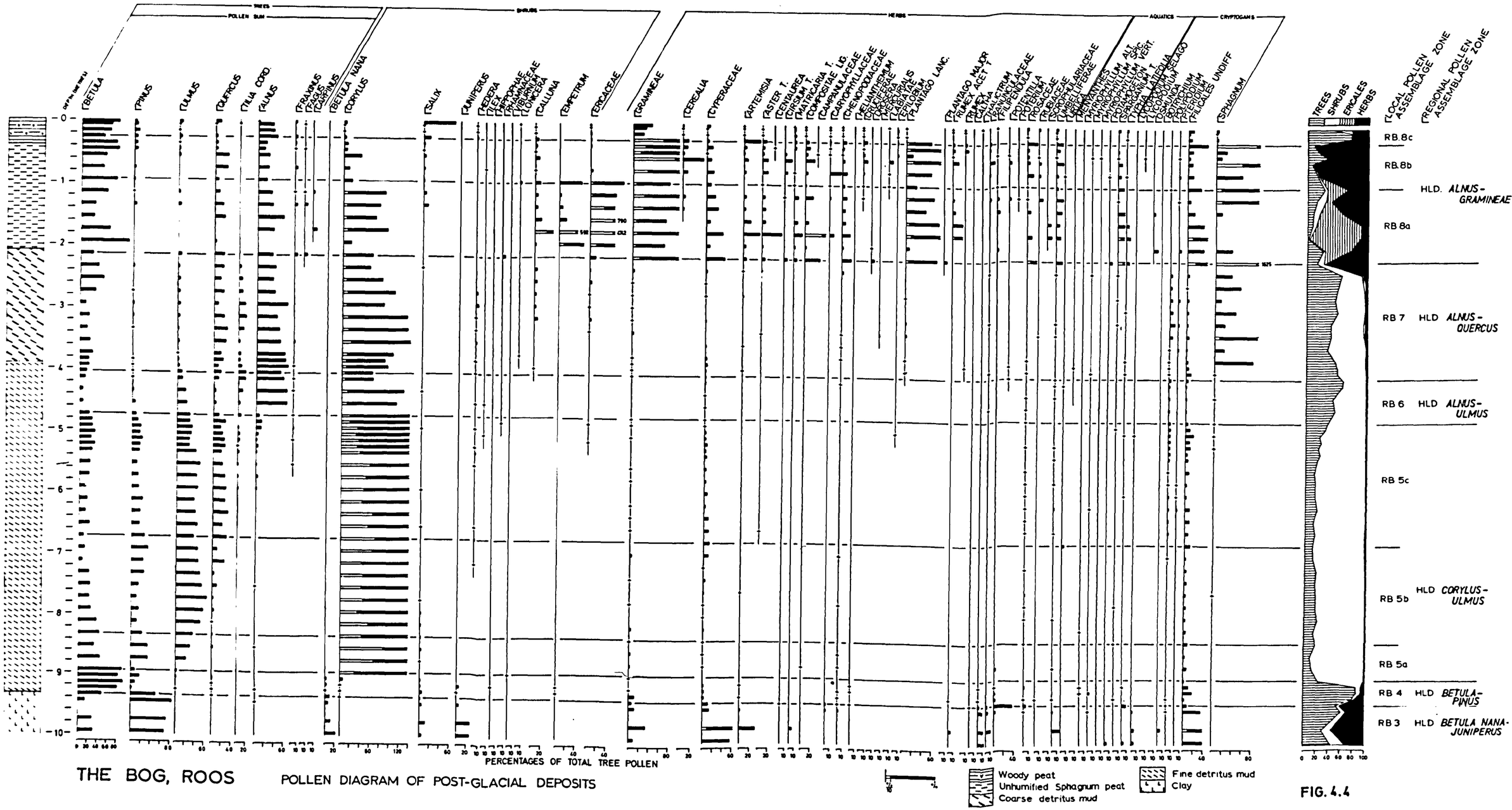
Total tree pollen values fall and herb pollen is dominant. Pollen of tree species of Betula represents from 5 to 20%, Pinus pollen contributes 10-30%. Betula nana pollen values are variable at between 5 and 20%. Juniperus pollen generally exceeds 10%. Cyperaceae pollen reaches up to 30%, and Gramineae pollen to about 10% but few other types of herb pollen are present. Filicales spores contribute about 10%, and very little of all types of pollen is present throughout this zone.

THE POST-GLACIAL PERCENTAGE POLLEN DIAGRAM (figure 4.4)

Percentage values referred to below are percentages of total arboreal pollen, unless otherwise stated.

Zone RB.4 9.35 - 8.95 m

Tree pollen represents up to 80% of total dry land pollen. Most of this is Betula pollen with up to more than 70% of arboreal pollen. Pinus pollen values decrease during the zone to below 20%. Pollen of Ulmus and Quercus is scantily present. Betula nana pollen values fall from 10% at the base of the zone, and it is absent above 9.05 m. Juniperus pollen also declines in values and disappears. Corylus pollen is consistently



THE BOG, ROOS POLLEN DIAGRAM OF POST-GLACIAL DEPOSITS

FIG. 4.4

present at less than 5%. Total herb pollen values are fairly low with Gramineae and Cyperaceae each contributing less than 10%. Filipendula pollen values increase to 35% in mid-zone, but are less above this. Pollen of aquatics such as Myriophyllum, Typha latifolia and Sparganium type occurs here in small amounts.

Zone RB.5 8.95 - 4.75 m

This zone is dominated by very high values of Corylus pollen, generally over 300% arboreal pollen, and reaching almost 900%. Of the trees, Betula pollen represents 10 to 40%, Pinus pollen also up to 40% variably, Ulmus pollen contributes not less than 25% and up to 60% and Quercus between nothing and 20% at the top of the zone. Hedera pollen is present and herbs are only sparsely represented by pollen of Gramineae, Cyperaceae, Rosacene and Umbelliferae at generally below 5% each and often below 1%. Pollen of aquatics is only sporadically present.

The zone can be divided into sub-zones according to variations in the tree pollen values.

RB.5a 8.95 - 8.35 m - Tree pollen is dominated by Betula (about 40%), Pinus (about 40%) and Ulmus pollen which increases from under 10% to 40% during the zone. Quercus pollen is sporadically present in small amounts. Corylus pollen values rise to between 400 and 900%. Salix pollen contributes less than 5%.

RB.5b 8.35 - 6.75 m - Ulmus pollen dominates the tree pollen at values of 40 - 60%. Pollen values of Betula and Pinus lie generally at or below 20%. Quercus pollen is present, and contributes up to 5% towards the top of the zone. Corylus pollen values generally lie between 400 and 700%. Hedera pollen occurs while that of Salix is scarce.

RB.5c 6.75 - 4.75 m - Pollen values for Betula and Quercus lie at around 20%, Ulmus pollen at 40% and Pinus pollen values are generally below 20%. The pollen of Tilia cordata and Alnus occurs but each type generally represents less than 5%. Corylus pollen holds values predominantly in excess of 400%. The spores of Polypodium contribute 5 - 10%.

Zone RB.6 4.75 - 4.05 m

The pollen of Alnus varies from values of 5% at the base of the zone to about 60% for the greater depth of it. Betula pollen contributes between 5 and 20%, and Quercus pollen less than 10%. Pinus pollen represents less than 5%, while pollen values of Ulmus decline from 20% at the base of the zone to about 10% at the top. Tilia cordata pollen contributes over 10% at the top of the zone. Fraxinus pollen is present but represents less than 1%. Corylus pollen values lie at 50 - 100% and herbs are sparsely represented by pollen.

Zone RB.7 4.05 - 2.15 m

Ulmus pollen contributes less than 5%, as does Pinus pollen, which is sometimes completely absent. Alnus pollen is still dominant at 40 - 60%. Betula and Quercus pollen values both vary between 10 and 30%. Pollen of Tilia cordata contributes up to 15%, but rather less at both the base and the top of the zone. Corylus pollen values lie at between 50 and 100%. Hedera pollen contributes about 1%, and Calluna and other Ericales each about 5%. Gramineae, Cyperaceae and other herbs such as Artemisia, Chenopodiaceae, and Plantago lanceolata are all represented by their pollen but total herb pollen values do not exceed 5% of total dry land pollen. Sphagnum spores occur in variable, but considerable, amounts, generally between 20 and 80%.

Zone RB.8 2.15 - 0 m

In this zone the pollen assemblages are characterised by the importance of numerous herbs and/or dwarf shrubs, which together contribute a majority of the total dry land pollen. The zone can be divided into three subsidiary zones.

Zone RB.8a 2.15 - 0.95 m - Tree pollen contributes 20% or less of the total dry land pollen. Of arboreal pollen Betula contributes between 20 and 90%, and Alnus about 40%. Quercus pollen values are variable, and up to 20%. Pollen of Pinus and Ulmus is almost absent, while that of Tilia is absent. Fagus and Carpinus pollen is sporadically present, generally at less than 5%. Corylus pollen holds steady values at about 50%. The pollen of Ericales, including Calluna and Empetrum exceeds 100%, often abundantly so. Of the herbs Gramineae pollen often exceeds 100%. A great range of herb pollen types appear. Pollen of Plantago lanceolata is the most abundant of these, at 30-60%. Other pollen types present include various Compositae, Chenopodiaceae (5-20%), and Rosaceae, Rumex acetosa type and Umbelliferae, each with pollen values of up to 20%. Cereal pollen is present at the top of the sub-zone at less than 10%. Drosera pollen occurs at the base of the zone. Of the aquatics Sparganium type pollen contributes over 20% and Typha latifolia 5-10%. Filicales spores often exceed 30% while spores of Sphagnum are scarce at the base of the zone and exceed 100% at the top.

RB.8b 0.95 - 0.25 m - Betula pollen (60%) and Alnus pollen (10-40%) dominate the scarce arboreal pollen. Pollen of Pinus and Ulmus reaches about 5% at the top of the sub-zone but is less below. Quercus pollen values vary between 5 and 30%, with smaller values at the top. Corylus pollen contributes only 5-40%, and Calluna

only 5% with other Ericales very scarce. There is some, less than 5%, Salix pollen. Gramineae pollen exceeds 200% and dominates the herb pollen values. The pollen values for cereals, Caryophyllaceae, Cruciferae and Rumex acetosa type reach up to 10%, while other herb values are as for RB.8a. Filicales spores contribute 10-20% and spores of Sphagnum are variably abundant.

RB.8c 0.25 - 0 m - In this zone arboreal pollen is once again dominant and is largely represented by Betula pollen (60-80%) and Alnus (20-40%), with other arboreal pollen types present in small amounts. Corylus pollen contributes less than 10% but Salix pollen values reach 60% in the surface sample. Gramineae pollen represents 30-40%. Nearly all of the herb pollen types present below 0.25 m occur here, but at much smaller percentage values. Aquatic pollen is absent except for that of Sparganium type and Typha latifolia in the surface sample. Filicales and Sphagnum spores are also scarce (less than 10%).

RADIOCARBON DATING

Radiocarbon dates were obtained for five horizons within the deposits. Material for assay was taken either solely from the core used for pollen analysis or from this and closely adjacent additional cores. Where one sample was taken from several cores these were carefully aligned by their stratigraphy to ensure that material of the same horizon was removed from each. The assays were completed in the radiocarbon dating laboratory of Birmingham University.

The radiocarbon ages obtained were as follows:

Birm - 405	9.20 - 9.25 m	10,120 ± 180	Radiocarbon years B.P.
Birm - 406	10.91 - 10.95 m	11,220 ± 220	- do -
Birm - 407	11.02 - 11.05 m	11,450 ± 230	- do -
Birm - 318	11.10 - 11.15 m	11,500 ± 170	- do -
Birm - 317	11.33 - 11.40 m	13,045 ± 270	- do -

The standard errors quoted were calculated by combining one standard deviation of the sample count rate and the background count rate.

When these dates are plotted on a graph (fig. 4.5) they do not fall on a straight line or smooth curve. This is not entirely surprising since sharp changes in sedimentation rate are to be expected when there are rapid changes in sediment type. Nevertheless Birm - 318 and Birm - 317 seem remarkably discordant. The possibility that Birm - 317 is too old has been considered but it is difficult to see how it could be contaminated by 'old' carbon on a freshly glaciated landscape. The possibilities of coal being incorporated, and old carbonate error were eliminated by the selection of vegetable fragments for dating. Birm - 318 is surprisingly close in date to Birm - 407 above it. The possibility of Birm - 318 being slightly contaminated with younger material from above, either shortly after deposition, or during core collection, cannot be ruled out. This date has therefore been omitted in the calculation of rates.

ABSOLUTE POLLEN DEPOSITION - THE LATE-GLACIAL

Values of absolute pollen deposition in terms of grains deposited/ cm^2/year were calculated for selected taxa of the Late-glacial deposits. This was achieved by the methods outlined in chapter 3.

Sediment accumulation rates were calculated from the radiocarbon dates obtained from the deposits. The date from 11.10 - 11.15 m

(11,500 ± 170 B.P.) was not used as it is only slightly older than the date for 11.02 - 11.05 m (11,450 ± 230 B.P.) yet approximately 0.09 m below it. Taking the other dates into consideration, the date from 11.02 - 11.05 m seems the more reliable.

An estimated date of 12,000 B.P. was applied to 11.20 m for the calculation of accumulation rates. This can only be taken as an approximation but does seem to fit satisfactorily with the other dates. If the accumulation rate from 11.03 - 11.20 m is taken as constant, with 11.20 m as 12,000 B.P., then the estimated date for 11.12 m is at about 11,750 B.P., a date which still lies only just outside the error quoted for the radiocarbon date of 11.10 - 11.15 m. Figure 4.5 is an age/depth graph for the lowest deposits at the Bog, and shows the relationship of the radiocarbon dates.

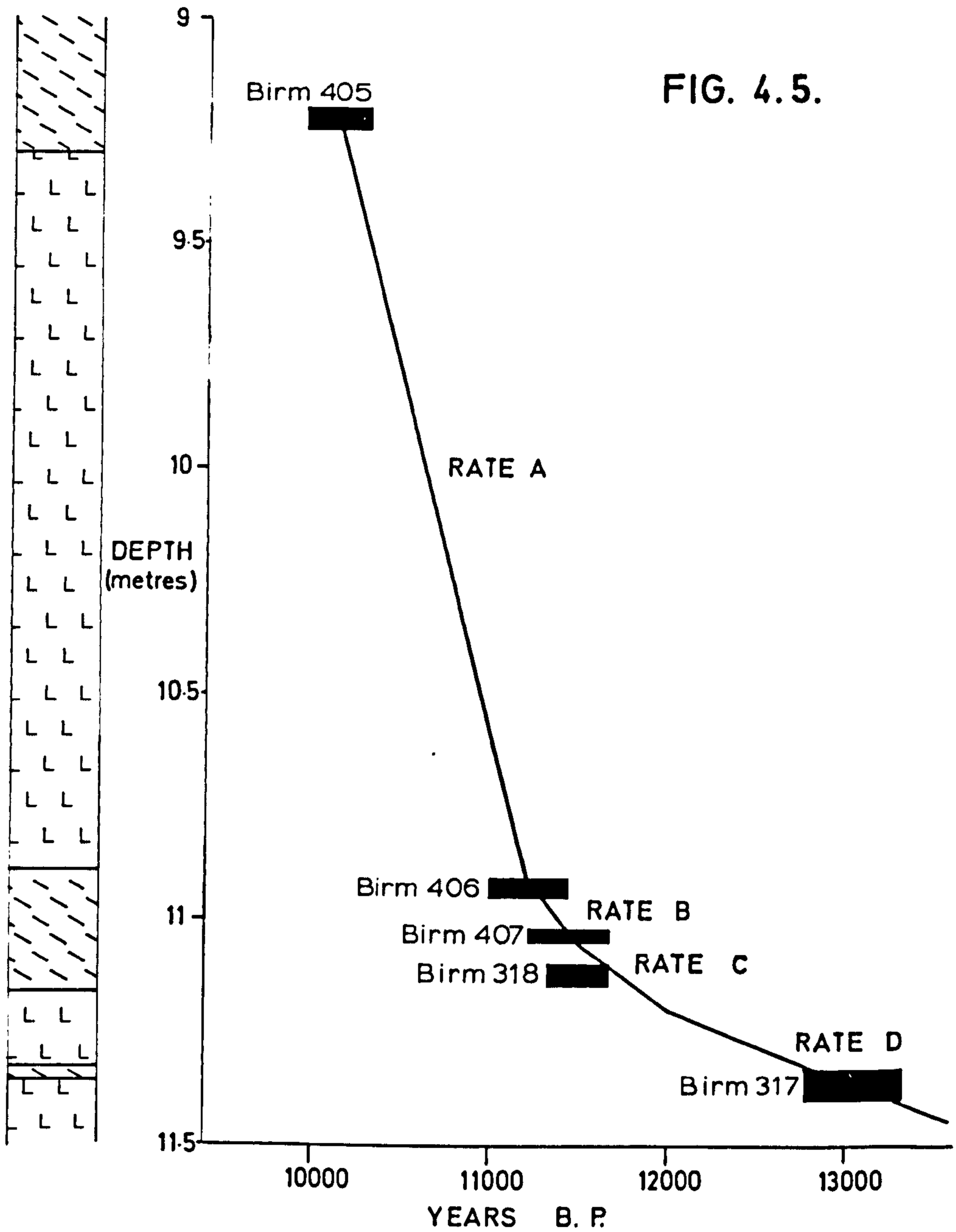
The sediment accumulation rates used for the constructions of the Late-glacial absolute pollen diagram (figure 4.6) were as follows:

Sample at 9.25 m - rate A - 0.2 mm/year - rate based on date for 9.20 - 9.25 m and an estimate of 9,000 B.P. for 9.0 m (see below) - assuming a constant deposition rate.

9.35-10.85 m inclusive - rate B - 1.55 mm/year - rate calculated from dates for 9.20 - 9.25 m and 10.91 - 10.95 m - assuming a constant deposition rate.

10.90-11.05 m inclusive - rate C - 0.43 mm/year - rate calculated from dates for 10.91 - 10.95 m and 11.02 - 11.05 m - assuming a constant deposition rate.

FIG. 4.5.



THE BOG, ROOS.
RADIOCARBON DATES AND SEDIMENTATION RATES USED TO CALCULATE LATE-GLACIAL POLLEN DEPOSITION.

11.05-11.20 m inclusive - rate D - 0.31 mm/year - rate calculated from dates for 11.02 - 11.05 m and the estimated date for 11.20 m - assuming a constant deposition rate.

11.20-11.45 m inclusive - rate E - 0.15 mm/year - rate calculated from the estimated date for 11.20 m and the date for 11.33 - 11.40 m, assuming a constant deposition rate. This rate was extrapolated back for the samples below 11.36 m.

Pollen deposition rates for the samples at 11.05 m and 11.20 m were both calculated twice, using the rates for the sediment accumulation both above and below these levels. On the diagram (figure 4.6) both values are shown for these samples by splitting the bar horizontally. The variation in these two samples gives some idea of the adequacy, or otherwise, of the calculations.

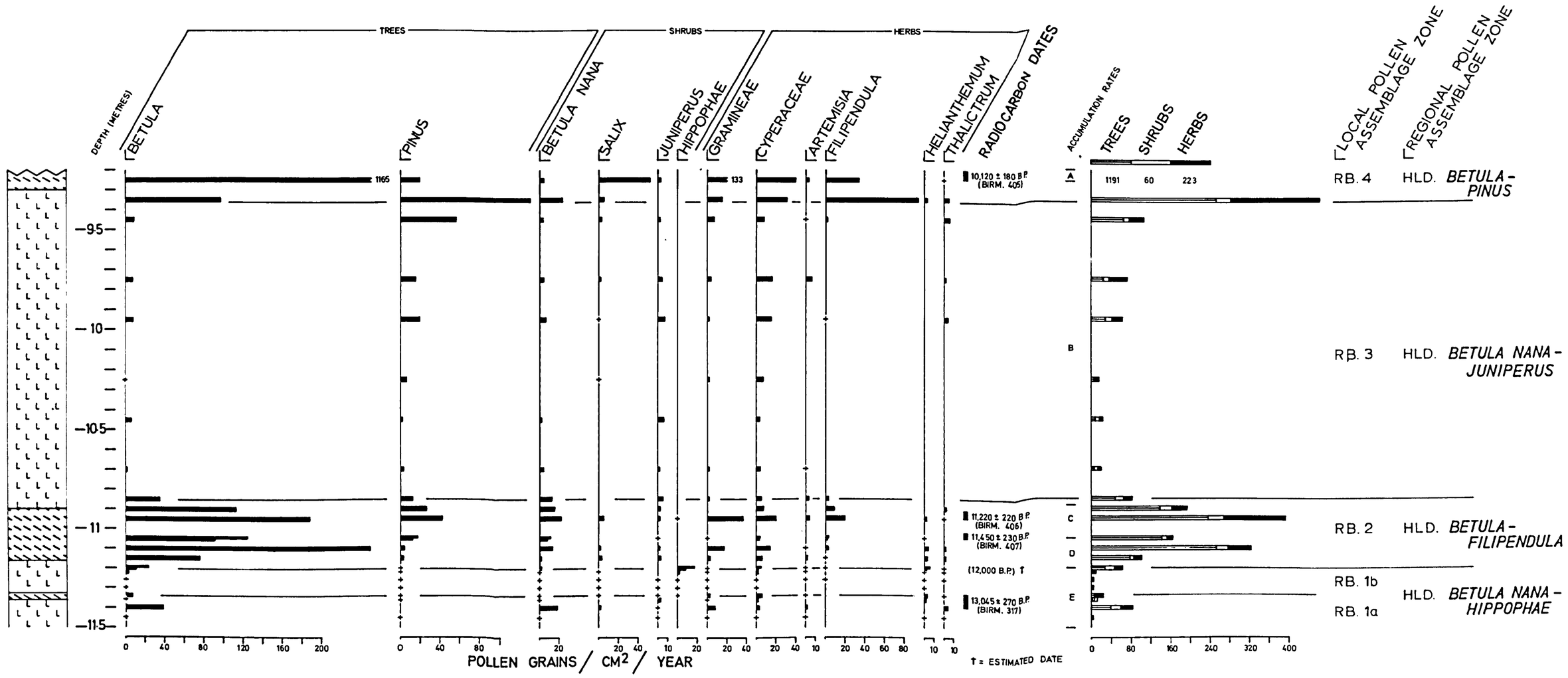
THE ABSOLUTE POLLEN DIAGRAM OF THE LATE-GLACIAL DEPOSITS (figure 4.6)

To simplify description of this diagram the pollen assemblage zones applied to the percentage diagram (figure 4.3) are used here. Undefined figures quoted are for pollen deposition in grains/cm^2/year.

Zone RB.1 11.45 - 11.20 m

Total dry land pollen deposition is extremely low - generally under 50, and falling as low as 4. The pollen of tree species of Betula is comparatively important, although present in small amounts. Betula nana pollen is less abundant. Gramineae, Cyperaceae and Helianthemum pollen form a major part of the remainder, but all are represented by very low values, generally under 10.

There is some evidence for the division into the two sub-zones



THE BOG, ROOS ABSOLUTE POLLEN DEPOSITION IN LATE-GLACIAL DEPOSITS. (OF SELECTED TAXA ONLY)

FIG. 4. 6.

described for the percentage diagram. The lowest sample has very little pollen present, but samples from 11.40 - 11.34 m have higher values of total deposition than those directly above. Between 11.34 and 11.20 m pollen deposition values are extremely low. Deposition of pollen from both tree and dwarf species of Betula is less than below. While deposition of Hippophae pollen increases towards the top Juniperus, Helianthemum and Thalictrum pollen values decline.

Zone RB.2 11.20 - 10.85 m

Total pollen deposition rises to values of 300 or over. Tree, shrub and herb values are all higher than in zone RB.1, particularly tree pollen values. Pollen deposition of tree species of Betula reaches a peak of 250 at 11.10 m but decreases above this level. Pinus pollen deposition exceeds 20 only at the top of the zone. Values for Betula nana pollen lie at around 20. Although arboreal pollen values reach a peak at 11.10 m, herb values peak at 10.95 m. Hippophae pollen is almost absent. Gramineae (40), Cyperaceae (20) and Filipendula (20) all peak towards the top of the zone whereas Helianthemum pollen deposition declines throughout the zone. Artemisia and Thalictrum pollen values remain below 5.

Zone RB.3 10.85 - 9.35 m

Total pollen deposition decreases markedly at the base of the zone for almost all types, but most dramatically for pollen of the tree species of Betula. Pinus pollen values exceed 50 only at the top. Values for Betula nana pollen lie at 5 to 10. Juniperus alone shows a slight increase in pollen deposition values from zones RB.1 and RB.2 but still contributes less than 10. Cyperaceae pollen values are at about 10. Filipendula pollen is almost absent. The pollen of Thalictrum is absent from the lower half of the zone but increases in the top half. At the

very top of the zone pollen deposition of all types increases; and particularly of the tree species of Betula and Salix, Gramineae, Cyperaceae and Filipendula.

ABSOLUTE POLLEN DEPOSITION - THE POST-GLACIAL

As outlined in chapter 3 an attempt was made to estimate absolute pollen deposition rates during the Post-glacial period. Because there was no finance available to obtain radiocarbon dates for these deposits, deposition rates have been estimated by applying dates to the more distinct pollen assemblage zone boundaries. The dates used for these boundaries are discussed in chapter 3.

The dates used at Roos to calculate Post-glacial pollen deposition rates, and the horizons to which they were applied, were as follows:-

9.22 m - 10,120 B.P. (Radiocarbon date) (Birm - 405)

9.00 m - 9,000 B.P.

4.80 m - 7,500 B.P.

4.00 m - 5,000 B.P.

0.00 m - Present Day

The placing of the Alnus expansion date (7,500 B.P.) at 4.80 m suggests a surprisingly slow deposition rate between 4.80 m and 4.00 m. This may, of course, be the case, but the behaviour of Alnus might also be rather abnormal here, and the date cannot be applied to this level with any certainty. For this reason absolute pollen deposition values for the period between the Corylus pollen increase and the elm decline have also been calculated on the basis of a constant sediment deposition rate between the two estimated dates of 9,000 and 5,000 B.P. (figure 4.9).

The rates used were based on constant sediment deposition rates between adjacent estimated dates (given above), and were as follows:-

0.0 - 4.0 m - rate X - 0.80 mm/year

4.0 - 4.8 m - rate Y - 0.32 mm/year

4.8 - 9.0 m - rate Z - 2.80 mm/year

9.0 - 9.35 m - rate A - 0.20 mm/year

The sedimentation rate used to construct figure 4.9 was -

4.0 - 9.0 m - 1.25 mm/year

ABSOLUTE POLLEN FREQUENCY IN THE POST-GLACIAL SEDIMENTS

Figure 4.7 shows the absolute pollen frequency per gram dry weight of sediment for the Post-glacial deposits at the Bog, Roos. This diagram provides the basic absolute pollen data unbiased by the application of sedimentation rates. It is zoned in the same way as the percentage pollen diagram; and is presented without a written zone-by-zone description. The pollen frequency diagram may be regarded as a basis for the construction of the absolute pollen deposition diagrams and a straight written description of the pollen frequencies is therefore omitted.

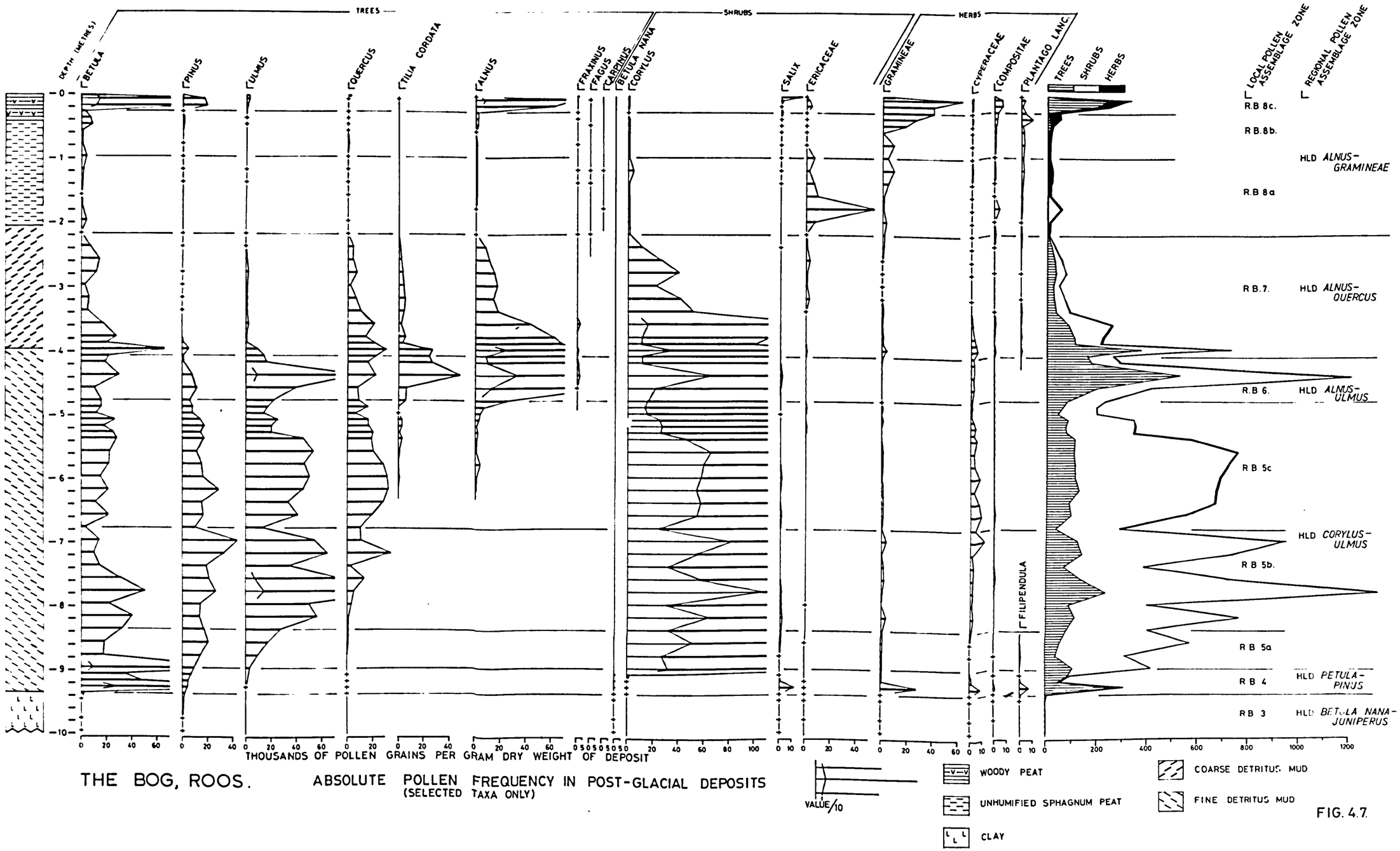
THE ABSOLUTE POLLEN DEPOSITION DIAGRAMS OF THE POST-GLACIAL SEDIMENTS

(figures 4.8 and 4.9)

The pollen assemblage zones applied to the percentage diagram (figure 4.4) are used here. Any unqualified figures given below are for pollen deposition in grains/deposited/cm^2/year.

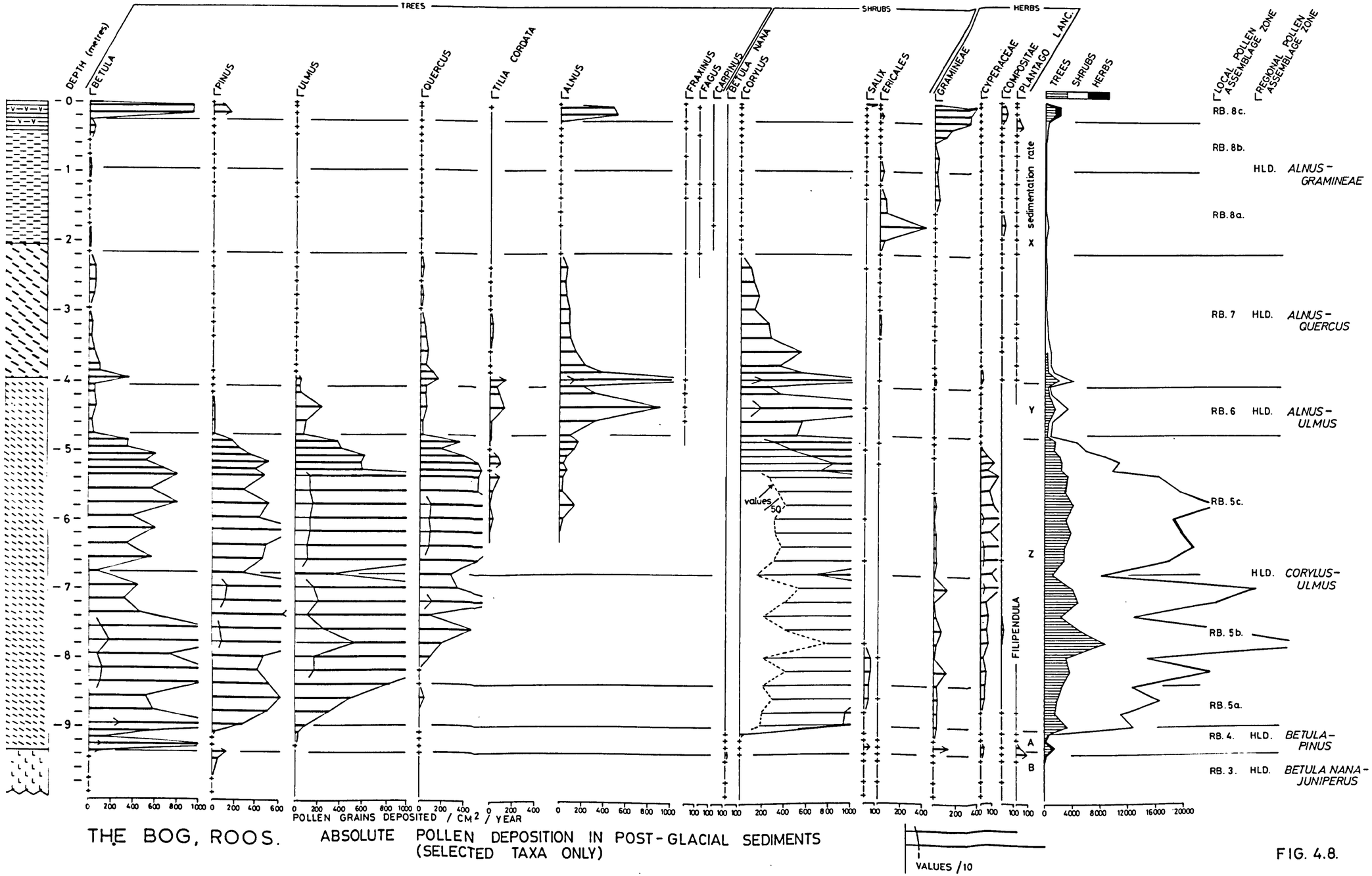
Zone RB.4 9.35 - 8.95 m

Total pollen deposition is low but variable - generally below 300. Pollen of the tree Betula, especially, varies greatly, between 100 and 1300. Pinus pollen values decline from over 100 to below 20 at the top of the zone. Quercus, Alnus and Ulmus pollen is present in negligible amounts, with deposition values less than 20. Betula nana pollen is also present in small quantity, as is that of Corylus, Salix and Juniperus.



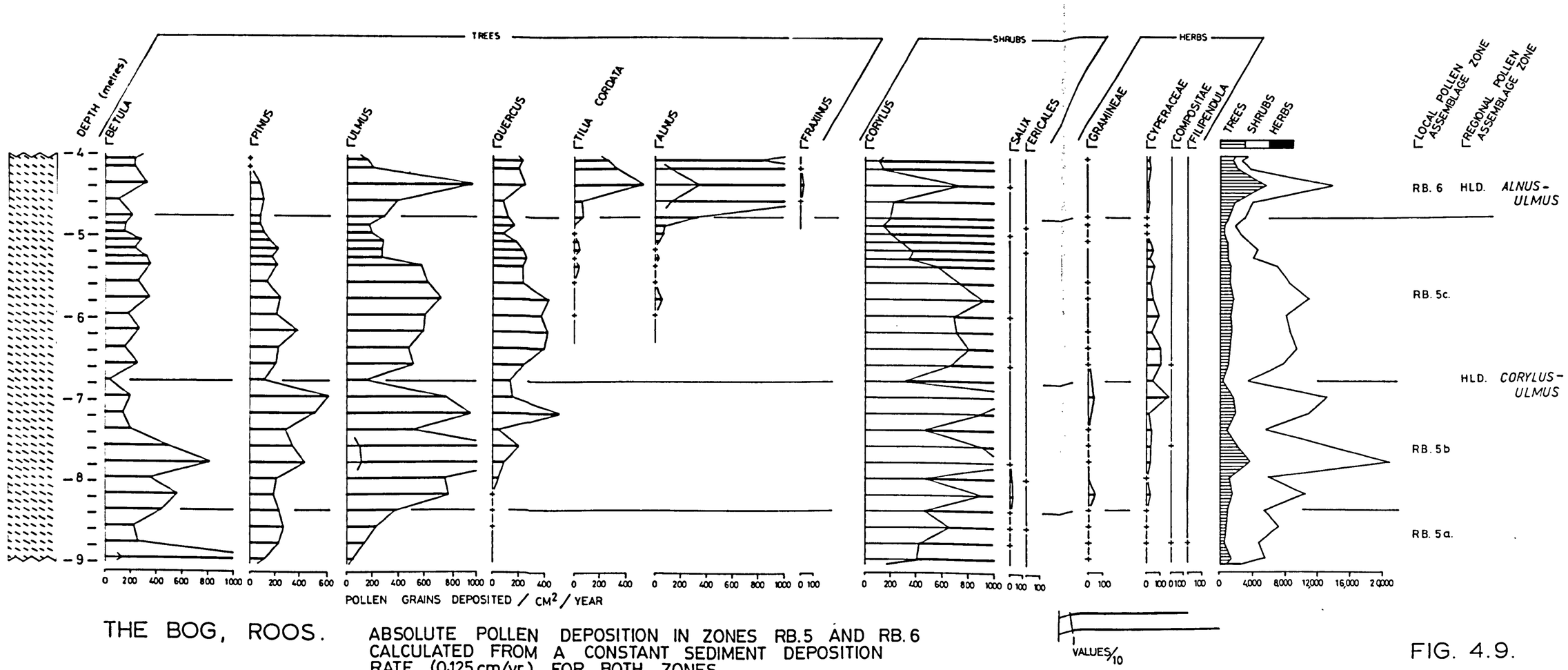
THE BOG, ROOS. ABSOLUTE POLLEN FREQUENCY IN POST-GLACIAL DEPOSITS (SELECTED TAXA ONLY)

FIG. 4.7.



THE BOG, ROOS. ABSOLUTE POLLEN DEPOSITION IN POST-GLACIAL SEDIMENTS (SELECTED TAXA ONLY)

FIG. 4.8.



THE BOG, ROOS.

ABSOLUTE POLLEN DEPOSITION IN ZONES RB.5 AND RB.6 CALCULATED FROM A CONSTANT SEDIMENT DEPOSITION RATE (0·125 cm/yr.) FOR BOTH ZONES.
(SELECTED TAXA ONLY)

FIG. 4.9.

All herbs present are represented by small pollen deposition values, but pollen deposition of Filipendula reaches over 50 at the base of the zone.

Because the accumulation rate of sediments here was probably changing rapidly, the pollen deposition values tend to vary greatly, and cannot be taken as highly accurate estimates.

Zone RB.5 8.95 - 4.75 m (figure 4.8 - sedimentation rate - 2.80 mm/year)

RB.5a 8.95 - 8.35 m - Total pollen deposition values increase markedly at the base of the sub-zone - to about 12,000. Pollen values of tree Betula and of Pinus lie at about 500. Ulmus pollen increases from 200 to 800 during the sub-zone but Quercus pollen is poorly represented. Pollen of Betula nana is absent. Pollen deposition values of Corylus increase sharply to values of 10,000 - 15,000. Only a few herbs are represented. Pollen of Gramineae and Cyperaceae is present in very small amounts.

RB.5b 8.35 - 6.75 m - Total pollen deposition varies considerably but in general lies at around 20,000. Arboreal pollen contributes about 4,000 of this. Betula pollen values decline slightly. Pinus pollen values rise to over 1,000 and Quercus pollen increases from 200 to 400. Pollen deposition values of Ulmus reach over 1,500. Corylus pollen values are generally higher than in RB.5a and peak at almost 39,000. Little herb pollen is present.

RB.5c 6.75 - 4.75 m - Total pollen deposition values remain high in the lower half of the sub-zone but decline to around 6,000 at the top. Arboreal pollen holds steady values of

about 3,000. Pinus pollen values fall somewhat. Ulmus pollen deposition decreases at the top of the sub-zone from 1000 to 500. Quercus pollen deposition reaches a peak of around 900 but declines higher up to about 400. Tilia, Alnus and Fraxinus pollen is present in small amounts. Corylus pollen holds values of 15,000 - 20,000 in the lower half of the sub-zone, and then declines to around 3,000 at the top. Herbs contribute an insignificant amount of pollen.

Zone RB.5 8.95 - 4.75 m (figure 4.9 - sedimentation rate - 1.25 mm/year)

RB.5a 8.95 - 8.35 m - Total pollen deposition values increase markedly at the base of the sub-zone to about 6000. Pollen values of tree Betula and of Pinus lie at about 250. Ulmus pollen increases from 100 to 400 during the sub-zone but Quercus pollen is poorly represented. Pollen of Betula nana is absent. Pollen deposition values of Corylus increase sharply to values of 4000 - 7000. Only a few herbs are represented. Pollen of Gramineae and Cyperaceae is present in very small amounts.

RB.5b 8.35 - 6.75 m - Total pollen deposition varies considerably but in general lies at around 10,000. Arboreal pollen contributes about 2000 of this. Betula pollen values decline slightly. Pinus pollen values rise to over 500 and Quercus pollen increases from 100 to 200. Pollen deposition values of Ulmus reach over 750. Corylus pollen values are generally higher than in RB.5a and peak at over 17,000. Little herb pollen is present.

RB.5c 6.75 - 4.75 m - Total pollen deposition values remain high in the lower half of the sub-zone but decline to around 3000 at the top. Arboreal pollen holds steady values of about 1500. Pinus pollen values fall somewhat. Ulmus pollen

deposition decreases at the top of the sub-zone from 500 to 250. Quercus pollen deposition reaches a peak of 400 but declines higher up to around 200. Tilia, Alnus and Fraxinus pollen is present in small amounts. Corylus pollen holds values of 6000 - 9000 in the lower half of the sub-zone, and then declines to around 2000 at the top. Herbs contribute an insignificant amount of pollen.

Zone RB.6 4.75 - 4.05 m (figure 4.8 - sedimentation rate - 0.32 mm/year)

Total pollen deposition is about 1000, and half of this is represented by arboreal pollen. That of Betula has values of about 50, but pollen values of Pinus decline to negligible amounts. Ulmus pollen increases from 70 to 250 near the base of the zone but above this it decreases to less than 50. Pollen of Quercus contributes about 50. Tilia pollen values increase to around 100, while those of Alnus, increase markedly to 300 or more. Fraxinus pollen values are insignificant. Pollen deposition of Corylus is variable and decreases. Herbs still contribute little pollen.

Zone RB.6 4.75 - 4.05 m (figure 4.9 - sedimentation rate - 1.25 mm/year)

Total pollen deposition is about 4000, and half of this is represented by arboreal pollen. That of Betula holds values of about 200, but pollen values of Pinus decline to negligible amounts. Ulmus pollen increases slightly from the base of the zone, but then decreases more drastically. Pollen of Quercus contributes about 200. Tilia pollen values increase to about 250, while those of Alnus increase markedly to exceed 1000. Fraxinus pollen values are insignificant. Pollen deposition of Corylus is variable, and decreases. Herbs still contribute little pollen.

Zone RB.7 4.05 - 2.15 m

Total pollen deposition falls dramatically from 4000 to under 300.

Values for Betula, Ulmus, Quercus and Tilia all decline to very small amounts, often less than 20. Ulmus and Tilia pollen deposition values decline abruptly, those of Betula and Quercus more gradually. Pinus pollen values do not recover. Alnus pollen declines to less than 100. Pollen of Fraxinus is only sporadically represented. Corylus pollen values decline steadily from 500 - 100. Herb pollen values are insignificant and less than in RB.6.

Zone RB.8 2.15 - 0.0 m

RB.8a 2.15 - 0.95 m - Total pollen deposition values are generally very low, often below 200. Betula, Quercus and Alnus values are insignificant. Pinus, Ulmus and Fraxinus pollen is often absent, that of Tilia is absent. Fagus and Carpinus contribute insignificant amounts of pollen, and Corylus pollen is not plentiful. There is a temporary increase in the deposition of Ericales pollen, reaching a maximum of 400. The herbs together contribute slightly more pollen than in RB.7.

RB.8b 0.95 - 0.25 m - Total pollen deposition remains small until the top half of the sub-zone when it increases to about 500. All tree pollen values, and those of Corylus, remain insignificant. Total herb pollen values increase to 200. About a half of this is contributed by the Gramineae. Plantago lanceolata pollen reaches a peak value of about 50.

RB.8c 0.25 - 0.0 m - Total pollen deposition increases to about 2000. Betula pollen (900) and Alnus pollen (500) increase dramatically. Pinus pollen values increase to over 100. Pollen of the other trees, and Corylus, remains at low values. Salix pollen deposition only increases in the surface sample. Total herb pollen deposition increases to about 500. Gramineae pollen

constitutes over half of this. Various Compositae increase. Cyperaceae pollen deposition remains insignificant and that of Plantago lanceolata declines to below 20.

DISCUSSION

The history of the basin itself

The basin apparently formed before 13,000 B.P., perhaps by the melting of a block of Devensian Ice. Throughout the Late-glacial period the Bog was open water. Both of the clay layers and the organic detritus mud that lies between them are demonstrative of deposition in open water. The moss, Leptodictyum, present in the lower clay, favours open habitats near to water. Fontinalis antipyretica, of which fragments occur in the upper clay, is a moss which grows submerged in open water (Dickson, 1973). The finely comminuted plant remains of the organic layer of the Late-glacial deposits have clearly been transported from their source and deposited in lake conditions. The pollen spectra of these deposits contain a range of aquatics typical of fairly deep water, such as Nymphaea, Nuphar, Myriophyllum and Potamogeton in addition to that of Sparganium type and Typha latifolia, representing plants growing at the edge of the lake in rather shallower water.

That open water persisted in the basin for a considerable part of the Post-glacial period, certainly until the time of the elm decline, is demonstrated by the homogeneous deposits of fine detritus mud. The finely broken up material could not have formed in situ and must have been deposited in a lake. Only a few leaves are preserved intact in these horizons. In the very early Post-glacial deposits pollen of the same aquatics as occurred in the Late-glacial is found. Later, in the pre-elm decline period, very little aquatic pollen is present, only

occasional pollen grains of Myriophyllum, Potamogeton and Sparganium type. However pollen provides no evidence for a distinct shallowing of water depth, but it may well have ceased to be deep enough for Nymphaea and Nuphar to thrive, as pollen of these types was not found.

At about the time of the elm decline there seems to have been a distinct decrease in water depth. The deposits laid down at the edge of the basin are of a woody peat, largely of Alnus; while in the centre a coarser detritus mud with plentiful Sphagnum remains was deposited. There was probably shallow water with much aquatic Sphagnum floating on or near to the water surface, with a fen carr in the still shallower water of the margins.

Later there appears to have been a complete infilling as a true unhumified peat was deposited, and a raised bog formed. The abundance of Sphagnum and the Ericales is demonstrated by macroscopic remains and by spores and pollen. Patches of the terrestrial moss Polytrichum, occurred. A few Betula wood fragments occurred in the peat. Mire plants such as Filipendula and Drosera grew as well as shallow water types such as Sparganium or Typha angustifolia and Typha latifolia.

At the surface there is a more woody peat, and the expansion in the pollen representation of Betula and Alnus, particularly noticeable in the absolute pollen deposition diagram (figure 4.7), shows that parts of the Bog had become dry enough to support these trees on its surface. The digging of ditches in the surface peat will have artificially dried out the site and aided tree growth. Several Larix trees were planted and thrived, and indeed still stand on the site together with many Betula, though they have all been killed by the recent flooding. The dry period might have resulted in a hiatus of peat formation for an unknown length of time.

Pollen incorporation into the lake sediments

Throughout Late-glacial and early Post-glacial time the site at Roos was an open water lake in a closed basin with only a very small catchment. Aerial deposition of pollen onto the water surface would therefore have been the major pollen-contributing factor. There was no inflow stream to bring in pollen from outside, but a very small amount of pollen may have been washed into the basin from its immediate surrounds by overland flow.

In later Post-glacial time the lake became infilled and the site developed into a raised bog, later to become tree-covered. Pollen from outside the immediate surrounds of the Bog could still only reach the site by aerial transport to it, but the vegetation of the Bog was now contributing its own pollen to the spectra in its deposits.

History of the vegetation of the surrounding area

The regional pattern of vegetational history is described below (Section III). Here some idea of possible vegetational sequences in the surrounding area is discussed, on a very provisional basis, from the Roos pollen and radiocarbon data alone, without comparison to other published material and without consideration of edaphic, climatic or anthropogenic factors. This provides a basis for the interpretation of the regional vegetational history, described in Section III.

The Late-glacial period - In the early part of the Late-glacial period (Zone RB.1), dated here to around 13,000 B.P., the fairly inorganic clay deposits and the extremely low total pollen deposition values suggest, but do not prove, a sparse vegetation cover. The surrounding land may have carried a few Betula trees, unless the pollen of this genus was blown from a very long distance. There cannot have been a great deal of shade as the dwarf birch, Betula nana, was present, as well

as a little Juniperus, and light-demanding herbs, notably Gramineae, Cyperaceae, Artemisia and Thalictrum.

Later, but still before about 12,000 B.P. the vegetation appears to have become more open, as deposition of tree Betula pollen declined, both as a percentage and in absolute terms. Although Pinus pollen is represented in the deposits of this time, whether it grew locally is not clear. Betula nana as well as the tree Betula, seems to have declined at this time. The open vegetation was dominated by the shrub, Hippophae, and Helianthemum in addition to the herbs previously present. Juniperus was perhaps scarce because of competition from Hippophae.

At some time between about 12,000 and 11,500 B.P., at the opening of pollen zone RB.2, a more closed Betula woodland developed around the Bog. Hippophae disappeared, but in absolute terms Betula nana and some herbs, notably Filipendula also increased at this time. Juniperus and Helianthemum do not seem to have been reduced by a spread in Betula forest, so the woodland must still have been comparatively open and unshady. Higher in the zone, at perhaps around 11,200 B.P., Pinus pollen values show a real increase. It may have been at this time that Pinus began to grow locally. There is some evidence from both pollen diagrams that there was a slight opening up of the woodland, some time before the beginning of zone RB.3, in which Betula nana and various herbs spread somewhat.

During pollen zone RB.3, roughly between 11,000 and 10,000 B.P., little pollen accumulated in the inorganic clay of the kettle-hole. Vegetation around the site was perhaps sparse and patchy, and virtually treeless. Juniperus and low-growing herbs were probably dominant. Juniperus seems to have been the only plant to expand after the reduction of the Betula woodland.

The Post-glacial period - At just before 10,000 B.P. vegetation conditions around the site changed markedly. The deposits in the lake are suddenly almost entirely of organic material. Total pollen deposition at this level seems to vary, but suggests a total increase in vegetation cover. Absolute data from these deposits is probably rather unreliable because of rapidly changing sedimentation rates.

The percentage diagram shows that tree species of Betula quickly became dominant, soon shading out such shrubs as Betula nana and Juniperus, which declined and disappeared. That conditions were fairly open, particularly early on in zone RB.4 is shown by the wide range of herbs present. Filipendula, in particular, showed a marked increase at just about 10,000 B.P. but, like Gramineae, Cyperaceae, Chenopodiaceae, Helianthemum and Thalictrum, was rapidly shaded out by the spreading Betula trees. Ulmus, Quercus and Corylus made their first appearance in the Betula woods soon after the opening of the Post-glacial period but could not have been plentiful.

During the time represented by pollen zone RB.5a total pollen deposition appears to have increased dramatically. Dense woodland developed. There were probably fewer Betula trees at this time as Pinus and Ulmus (which expanded throughout the zone) were perhaps co-dominants with Betula. Corylus dominates the pollen spectra of this zone, but its status in the vegetation is not clear. It is likely that it was replaced as a major forest component as Ulmus and Quercus migrated in. It may well have formed a bushy fringe immediately around the Bog, whose steep sides would have given the site a fairly dry rim on which Corylus might well flourish in conditions of fair light intensity. If Corylus bushes were overhanging the lake they would tend to contribute an inordinately large amount of pollen to the deposits. Herbs cannot

have been abundant; those that survived under the trees would produce little, poorly-dispersed pollen. Chenopodiaceae, Rosaceae and Umbelliferae grew scantily in a few open patches, perhaps on the bank of the lake itself.

Later, while the pollen assemblages which constitute zone RB.5b were being deposited, the more thermophilous trees began to expand in the woodland. Betula was partly superseded by Pinus early on, but then the forest was dominated by Ulmus. The rim may still have been covered by Corylus, perhaps. The high and very variable values for pollen production of this taxon, being strong evidence that it was growing very close to the lake.

As time progressed the forest became more diverse. Pinus showed a real decline, Betula a comparative one, at least in pollen production. Ulmus still dominated a woodland in which Quercus was increasing. Later Tilia, Alnus and Fraxinus appeared in small amounts.

The difficulty of establishing the true sedimentation rate while the pollen spectra which comprise zone RB.6 were being deposited, makes the evidence from the absolute pollen diagrams of rather less value here. If the 7,500 B.P. date is applied at 4.8 m the sedimentation rate is very low, and total pollen deposition values consequently lie at very low levels as well (figure 4.8). Using this sedimentation rate the pollen values for RB.6 exhibit some alarming discontinuities with the values for the adjacent parts of the zones below and, especially, above. When the 7,500 B.P. date is not applied, and a constant sedimentation rate used for the calculation of pollen deposition values for zones RB.5 and RB.6 (figure 4.9) most taxa show an increase in absolute values. This is a pattern similar to that displayed by the pollen frequency diagram (figure 4.7) and may safely be taken as considerably nearer to

the truth than when the very low sedimentation rate is applied. Using the absolute data from the zone 5-6 constant-rate diagram (figure 4.9) and the percentage results an idea of the regional vegetation during the zone can be built up.

Tree pollen deposition appears to have increased slightly during RB.6 while that of Corylus declined somewhat. Since herbs contributed very little pollen, woodland conditions must have persisted in the area. Alnus was dominant, but its high pollen values suggest that it was growing close to the site. Perhaps shallowing water allowed it to occupy a damp stretch on the edge of the site; more woody detritus or peat does occur at the edge of the basin. Ulmus and Quercus, together with Alnus dominated the surrounding woodland. Tilia became more frequent, but Pinus may have more or less disappeared from the local area. Corylus seems to have declined; it may just have ceased to overhang the basin or its pollen may have been precluded from reaching the basin by closer Alnus.

At about four metres depth in the deposits, the percentage and absolute pollen diagrams show something of a conflict. The percentage values imply that, while most of the forest trees continued as before, Ulmus became more scarce. However the absolute diagram suggests that total pollen deposition declined at this level, and implies that all of the trees declined dramatically.

Calculation of absolute pollen deposition after the elm decline cannot be achieved with great accuracy here. The accumulation rate of sediment must have changed considerably as the basin changed from open water to bog; and these values are only based on the two estimated dates of 5,000 B.P. and the present day. However, since these two estimates are fairly reliable it is evident that, in general, after 5,000 B.P.

total pollen deposition was much lower than before; unless there was a considerable period of time when no peat was formed - as has been alluded to above. The different accumulation rates used to calculate pollen deposition values before and after the elm decline may accentuate the apparent differences somewhat. If the same sediment accumulation were used both below and above the level of the elm decline, however, there would still be a marked decline in total pollen deposition at the time when Ulmus values fell.

There certainly seem to have been less Ulmus trees in the area at this time, and possibly less of the other trees and Corylus. Tilia was perhaps a more significant sufferer than the rest. Artemisia, Chenopodiaceae and Plantago lanceolata, in addition to occasional other herbs grew locally. These types are associated with open conditions. However herbs could not have been common during zone RB.7. Alnus, Quercus and Betula dominated a slightly open woodland. There is slight evidence of a recovery of Tilia later on; and of a real, but minor, decrease of herbs at the same time, presumably as a result of increased tree growth.

During the time represented by zone RB.8a the pollen diagrams imply that trees declined drastically, and herbs spread. Such a rapid change in the vegetation of the surrounding area probably did not occur. The change in the pollen spectra is largely due to bog formation at the site. The absolute pollen deposition values show that herbs increased to a small extent, though perhaps a small increase in herb pollen represents a large increase in herb growth. A much wider range of herbs appeared and cereals were grown.

Later, as cereal cultivation, increased, the area became almost treeless; even Alnus was scarce. Of the herbs Gramineae and Plantago

lanceolata expanded greatly, while Caryophyllaceae, Cirsium, Cruciferae and Labiatae appeared in addition to the types already present.

In most recent times, represented by the pollen spectra of zone RB.8c there is no clear evidence for changes in the surrounding vegetation. The changes of the percentage diagram represent the growth of Betula and Alnus on the surface of the Bog itself, and later of Salix on the flooded site. The apparent decline of herbs is a percentage artifact. They probably increased continuously towards the present day but their pollen was under-represented in the completely changed conditions of the Bog, now a wooded 'island' in an expanse of tree-less land where it had formerly been a small patch of open water surrounded by a 'sea' of forest.

CHAPTER 5

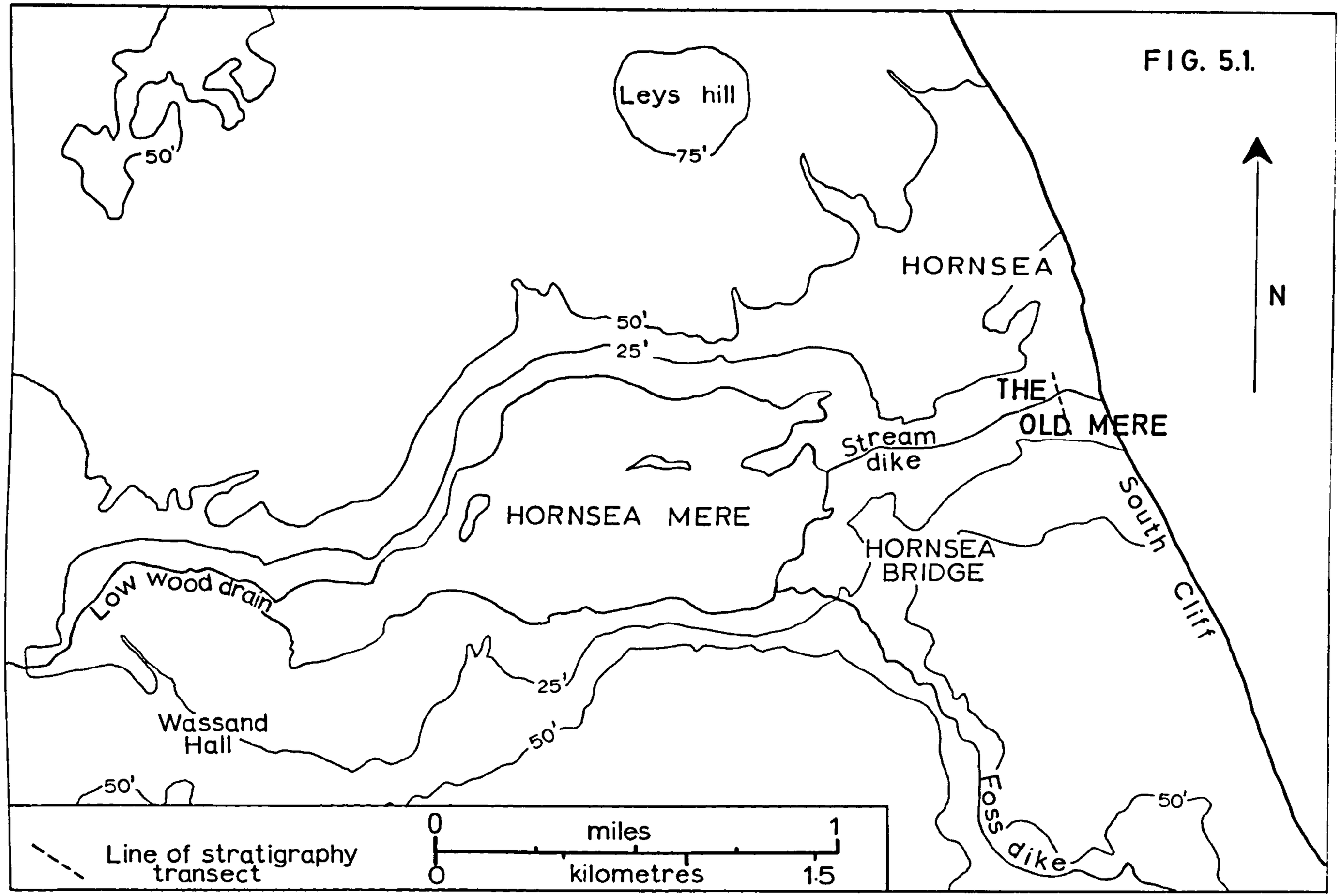
THE OLD MERE, HORNSEA

INTRODUCTION

The Old Mere site (Grid reference TA209475) lies directly on the coast just to the south of the town of Hornsea. It is a dry depression of landscaped ground at about high tide level, separated from the sea by a sea wall. The Old Mere occupies the eastern end of the pre-glacial valley which extends westwards to Brandesburton, and includes the surviving Hornsea Mere, immediately inland from the Old Mere site. The large existing mere (2½ km long and up to 1 km wide) is drained by the Stream Dike, which runs through the centre of the Old Mere basin. A low gravel ridge separates the Old Mere basin from the present Mere and this gravel rim also forms distinct north and south shorelines to the basin.

When open water the Old Mere must have been up to 300 m in width. Its length would have exceeded 500 m by some measure, but to what extent it is not clear, because highly active coastal erosion has destroyed the eastern end of the basin. It seems quite feasible that the lake occupied a basin considerably greater in length than that which remains today. The presence of a terrace around the existing Hornsea Mere, at about 3 m above the present water level, suggests a previously higher water surface. This may well have been sufficiently high to join the Old Mere and the present one into one lake of considerable size (Reid, 1885).

Before construction of the sea wall lacustrine deposits were exposed for some distance along the foreshore, representing an eastern extension of the Old Mere. All of the fossils removed from parts of this exposed bed have been listed by Reid (1885). No precise location for each find could be given, and it is possible, therefore, that some do not originate from the lacustrine deposits but have been derived from



MAP OF AREA SURROUNDING THE OLD MERE, HORNSEA.

PLATE IV Aerial view of the Old Mere, Hornsea from the west

the boulder clays or gravels.

The fossil finds included:-

Chara sp. Pinus sylvestris Potamogeton sp.

Alnus glutinosa (leaves and cones) Quercus robur (leaves and cups)

Salix sp (leaves) Prunus padus (fruit stones)

Cypris compressa C. gibba C. reptans Cypridopsis obesa

Candona detecta C. albicans C. lactea C. candida

Limnicythere inopinata Cytheridea lacustris

Anodonta anatina Cyclas cornea Pisidium pusillum Limnaea peregra

Planorbis contortus P. nautileus Bithynia tentaculata

Valvata piscinalis Perca fluviatilis Fish scales

Bos primigenius Cervus elaphus C. megaceros Elephas primigenius

Equus sp. Felis spelaea

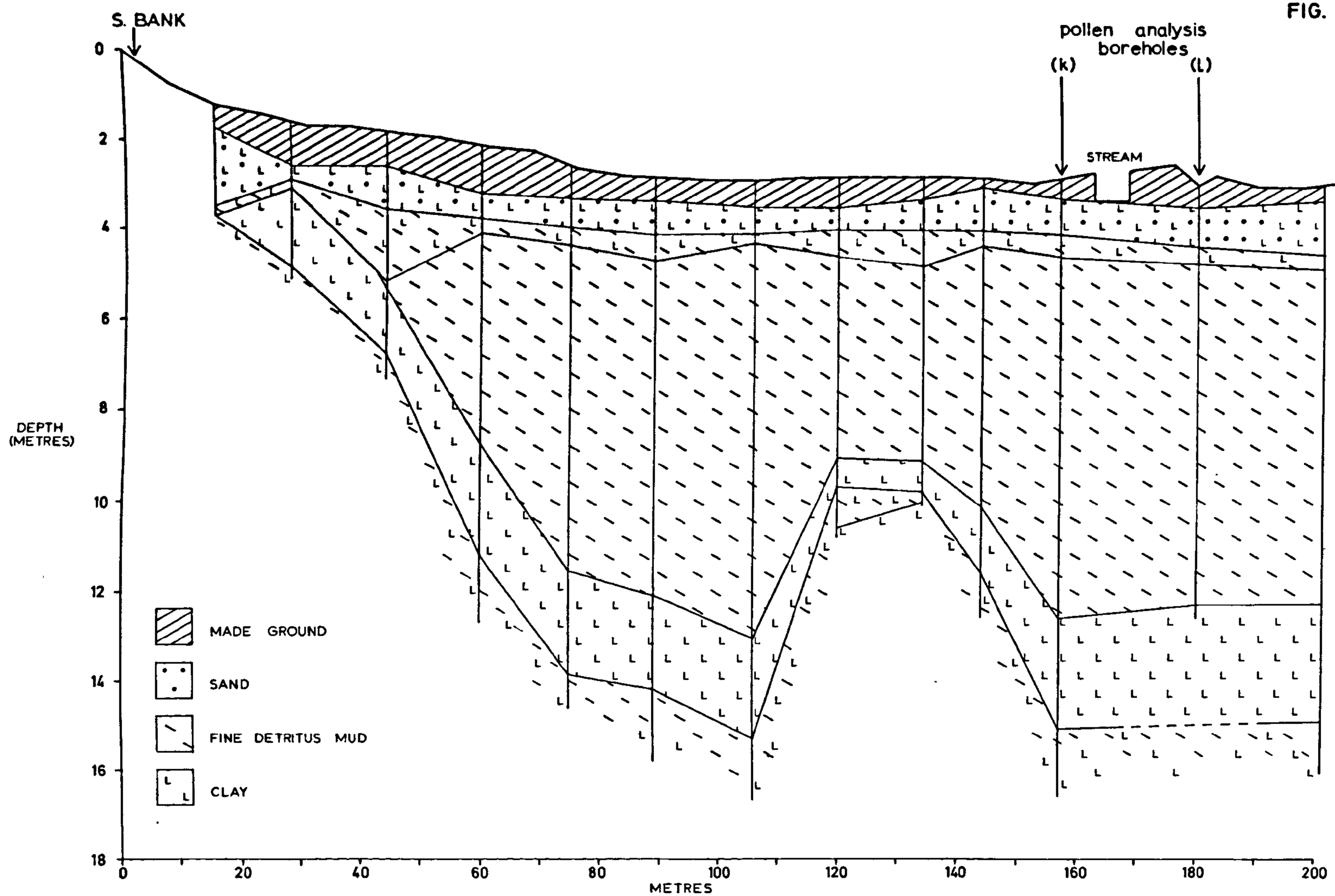
STRATIGRAPHY

A transect of borings north to south across the widest part of the basin show lake deposits to lie in a depression up to 14 m deep. Figure 5.2 shows the stratigraphy of most of this transect. The floor of the depression falls fairly gently, apart from a ridge just to the south of the Stream Dike's position, which rises to within 8 m of the surface.

The lowest deposit traced is a clayey, fine detritus mud, very dark and compact but not very organic and containing few macroscopic plant remains. Only on the top of the ridge could this deposit be penetrated, and there a pinkish clay, gravelly at the base, was discovered underneath. Above the detritus mud is a layer, often 2 m thick, of pinkish inorganic clay containing no macroscopic plant remains.

This clay is overlain by a considerable thickness of fine detritus mud, which extends to within about 2 m of the surface. The organic mud is extremely homogeneous, containing finely comminuted plant

FIG. 5.2.



THE OLD MERE, HORNSEA. STRATIGRAPHY OF DEPOSITS ALONG S.-N. TRANSECT.

remains and occasional shells, notably of the duck mussel, Anodonta anatina. This lacustrine deposit is dark brown in colour, becoming darker and more compact below.

Nearer to the surface the mud becomes increasingly clayey. These clays contain a consistent fauna of the Ostracods Candona cf. compressa, Candona sp. and Cytherissa lacustris, the last-named being numerically dominant (Robinson, personal communication). In places the clay becomes sandy; lenses of blown beach sand occur within and above the clay. At the surface is a top soil and refuse deposit of 'made ground'.

The sequence of the deposits is illustrated by those of the boreholes used for pollen analysis. For reasons outlined below, pollen analysis was completed on the upper deposits of borehole L, and on the lower deposits of borehole K, the base of borehole L being impenetrable for reliable sampling. The stratigraphy of these two boreholes, just less than 20 m apart is described below, the upper part from L and the lower part from K, as follows:-

Borehole L

0.0 - 0.50 m	Made ground
0.5 - 1.40 m	Sandy clay, becoming more clayey below nig 1, strf 0, elas 0, sicc 3. Ag 4, Gs +
1.40 - 1.75 m	Clayey detritus mud, becoming more organic below. Organic matter highly humified. nig 2-3, strf 0, elas 1, sicc 2, humo 3. Ld 3, Ag 1.
1.75 - 9.30 m	Dark brown fine detritus mud, no recognisable plant fragments, but occasional shells of Anodonta anatina. A small amount of silt present, particularly at base. nig 3, strf 0, elas 1, sicc 2, humo 3-4. Ld 4, Ga +.

9.30 - 9.50 m Slightly silty pinkish clay

nig 1, strf 0, elas 0, sicc 2. Ag 4, Ga +.

below 9.50 m - impenetrable for reliable sampling

Borehole K

Very similar sequence in upper deposits to L (see figure 5.2)

above 9.85 Fine detritus mud, as in borehole L

9.85 - 12.30 m Slightly silty pinkish grey clay with occasional thin, more organic bands.

nig 1, strf 0, elas 0, sicc 2. Ag 4, Ga +.

12.30 - 12.60 m Darker silt and clay with some highly humified and comminuted organic matter (i.e. a very clayey fine detritus mud)

nig 3, strf 0, elas 0, sicc 2, humo 3-4. Ld 2, Ag 2, Ga +.

12.60 - 13.80 m Rather gravelly clay

nig 1, strf 0, elas 0, sicc 2. Ag 4, Gg +.

POLLEN ANALYSIS

As described above a core was removed from borehole L, to be near the centre of the basin but away from the ridge, for pollen analysis of the top 9.5 m. The deposits below this level were extremely compacted and undisturbed material could not be extracted manually. To remove reliable cores from the lower deposits in the centre of the basin a rig with a 100 mm diameter piston sampler was used. It could only be used at borehole K, just to the south of the stream. The cores so removed were not ideal for pollen analysis, their stratigraphy being slightly distorted in places.

Since the two cores were taken close together and one lay stratigraphically above the other, pollen analysis of the two could be considered to give togther a complete sequence through the deposits of the site.

Preparation of the pollen samples was by the method outlined in chapter 3. It was necessary to treat many of the samples with boiling 40% hydrofluoric acid to remove silicates.

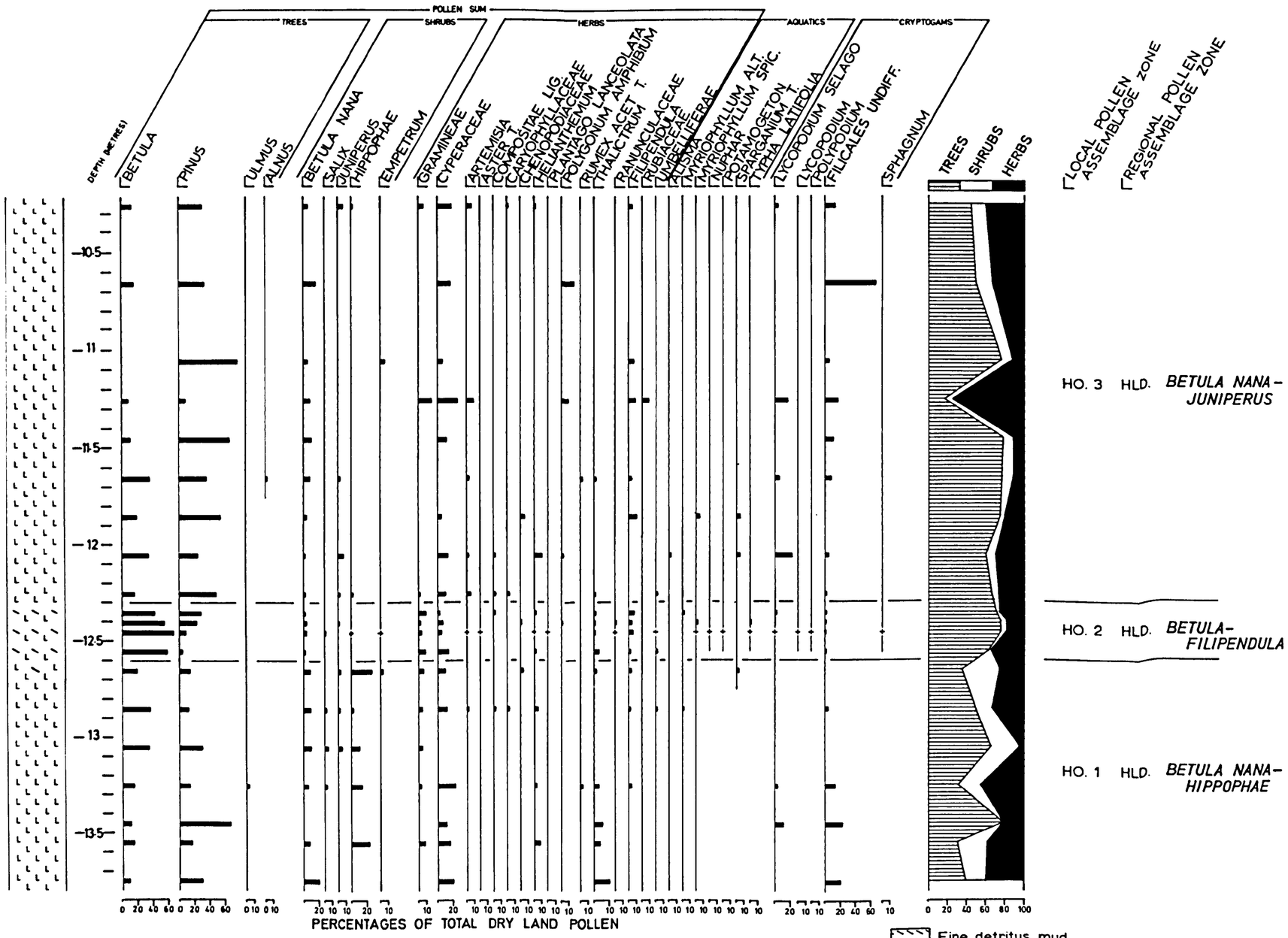
Results of the pollen analysis are presented in two percentage diagrams. In that for the Late-glacial deposits of borehole K (figure 5.3) all values are expressed as percentages of total dry land pollen. Values in the Post-glacial pollen diagram, from borehole L (figure 5.4) are expressed as percentages of total arboreal pollen.

For ease of description these diagrams have been zoned into local pollen assemblage zones, numbered from the base upwards, and prefixed with the site initials HO.

Absolute pollen deposition at the site is dealt with below, after the percentage pollen diagrams have been described.

The Late-glacial percentage pollen diagram (figure 5.3)

Zonation of this pollen diagram is difficult as the deposits contain very little pollen. Only the rather more organic band around 12.50 m contains really adequate amounts of pollen. The ratios of trees/shrubs/herbs are not described below as there is no noticeable change in these throughout. However, there is evidence for the distinction of three zones. All percentage values expressed below are given as percentages of total dry land pollen.



HORNSEA, OLD MERE POLLEN DIAGRAM OF LATE-GLACIAL DEPOSITS

FIG. 5.3

Zone HO.1 below 12.60 m

Pollen values of tree species of Betula increase throughout the zone from 10-40%. Pinus pollen values are variable but generally represent over 20% of total dry land pollen. Pollen of Betula nana contributes 10-20%. Salix and Juniperus pollen is only sporadically present but Hippophae pollen values lie at 10-30%. Gramineae, Cyperaceae, and Thalictrum are consistently represented by their pollen but Helianthemum is only occasionally so. The only aquatic type present is Aliama. Lycopodium selago spores occur.

Zone HO.2 12.60 - 12.30 m

Pollen is slightly more plentiful than in the zone below. Pollen of the tree species of Betula contributes 40-60% of total dry land pollen. Pinus pollen percentages rise from 5 at the base to about 30 at the top of the zone. Betula nana pollen only represents 2-3%. Pollen of Salix, Juniperus and Hippophae is scarce. Empetrum pollen occurs. A wide range of herb pollen is present in small amounts, including that of Gramineae, Cyperaceae, Thalictrum, Helianthemum and Compositae. Filipendula. consistently contributes about 5% of total pollen. The pollen of several aquatics occurs, usually at values of less than 1%, including Myriophyllum alterniflorum and M. spicatum, Nuphar, Potamogeton, Sparganium type and Typha latifolia.

Zone HO.3 above 12.30 m

The lower zone boundary is not very clear as tree Betula values vary and Betula nana pollen is present in fairly small amounts at the base. Pinus pollen is dominant with values of 30-70%. Above 11.50 m tree Betula pollen values decrease to about 10% or less, and above 12.0 m Betula nana pollen percentages increase to about 10. Juniperus, Salix and Hippophae pollen is scarce or absent. Gramineae pollen is occasionally

present but that of Cyperaceae represents 10-20%. Artemisia pollen values lie at 5-10% where this herb is represented at all. Pollen of Polygonum amphibium and Filipendula is sporadically present. Pollen of aquatics only occurs at the base of the zone. Spores of Lycopodium selago are found.

THE POST-GLACIAL PERCENTAGE DIAGRAM (figure 5.4)

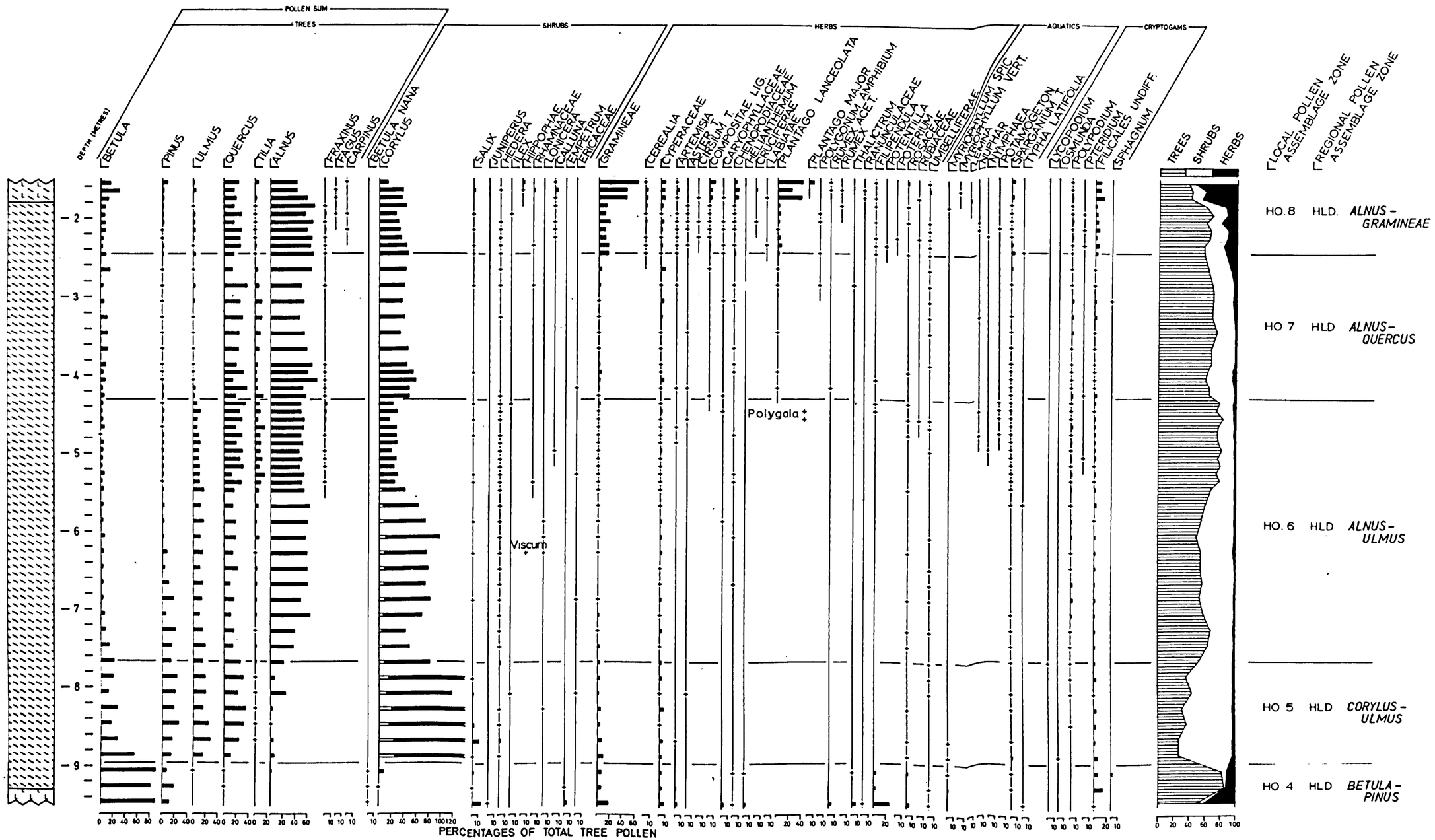
Any unqualified figures given below are as percentages of total arboreal pollen.

Zone HO.4 9.45 - 8.95 m

Tree pollen increases from 50 - 80% of total dry land pollen during this zone. The tree pollen is dominated by that of Betula (80%) with Pinus pollen contributing much of the remainder. Quercus, Ulmus and Alnus pollen occurs in small amounts. Betula nana pollen is present at values of below 1% and is absent from the top of the zone. Corylus pollen is scantily present. Pollen values of Gramineae decline from 20 to 10% during the zone. The pollen of other herbs, such as Filipendula, Artemisia, Helianthemum and Thalictrum, is plentiful at the base, Filipendula pollen values reach 30% but it is much more scarce at the higher levels within the zone.

Zone HO.5 8.95 - 7.65 m

The zone is dominated by very high values of Corylus pollen, up to 250% of arboreal pollen, and reaching a maximum in the lower half of the zone. Betula and Quercus pollen values lie at 20 - 30% while Pinus and Ulmus pollen each contribute about 20%. Alnus pollen values generally lie at around 5 - 10%. Up to 2% of the arboreal pollen is represented by that of Tilia cordata. Gramineae and Cyperaceae pollen values fall to below 5% and pollen of other herb types is more or less absent.



HORNSEA, OLD MERE POLLEN DIAGRAM OF POSTGLACIAL DEPOSITS

FIG. 5.4

Zone HO.6 7.65 - 6.30 m

Alnus pollen values increase from the base of the zone to 50% or more of arboreal pollen. Betula and Pinus pollen percentages fall below 5. Quercus pollen values fall to less than 20% as Alnus pollen increases, but higher in the zone Quercus again contributes between 20 and 30%. Pollen values of Ulmus decline steadily from 20% at the base of the zone to about 10% at the top, whilst pollen representation of Tilia cordata increases to 10% higher in the zone. Fraxinus pollen is sparsely present in the top half of the zone. Corylus pollen values lie at between 50 and 100% of arboreal pollen, and at values below 50% at the top of the zone. Hedera pollen is regularly present. Herb pollen is sparse, but a few types are represented at the top of the zone, such as Artemisia and Filipendula. Some pollen of aquatics occurs: that of Sparganium type is consistently represented and that of Nymphaea and Nuphar sporadically so.

Zone HO.7 4.30 - 2.45 m

At the base of the zone pollen values of Ulmus decline to very low amounts, generally less than 1%, as also do values of Pinus pollen. Betula pollen contributes about 10%, Quercus 30% and Alnus 50%. Tilia cordata pollen values vary within the zone, dropping to under 5% in the lower part but increasing to 10% higher in the zone. Fraxinus pollen is only present at the base and the very top levels of the zone. Fagus pollen is present at the top of this zone. Corylus pollen represents 40-60%. There is a slight increase in herb pollen values at the base of the zone. Gramineae pollen contributes up to 5% of arboreal pollen and Plantago lanceolata pollen occurs in small amounts. This increase in herb pollen representation is not maintained at higher levels of the zone.

Zone HO.8 2.45 - 1.55 m

This zone is characterised by the expansion of herb pollen values from

10% at the base to 50% of total dry land pollen at the top of the zone. Of the arboreal pollen, that of Betula represents less than 10%, but reaches slightly higher values at the top. Pollen values of Pinus and Ulmus are extremely low, recovering slightly at the highest levels. Tilia cordata pollen contributes less than 1%, generally; Quercus about 20-30% and Alnus about 60%. Fraxinus pollen is consistently present in small amounts, while that of Fagus and Carpinus occurs sporadically. Corylus pollen contributes about 40% of arboreal pollen while Salix and Hedera pollen values lie regularly below 1%. Hippophae pollen is present in the topmost sample. Pollen of Gramineae increases in abundance throughout the zone to exceed values of 50% at the top. Cerealia pollen is present. Pollen values of Cyperaceae show a slight increase. The pollen of a range of herbs is present, generally in fairly small amounts. Plantago lanceolata pollen values increase from 5% to 40% from the base of the zone upwards. At the top of the zone Chenopodiaceae and Liguliflorae pollen each contribute about 5 to 10%. Pollen of various aquatics is occasionally present, as are spores of Pteridium and of other Filicales, which contribute up to 10 - 20% of the arboreal pollen sum.

RADIOCARBON DATING

One radiocarbon date was obtained from the deposits at the Old Mere, Hornsea. Material for assay was taken from the actual 'pollen core', and the assay was completed in the radiocarbon dating laboratory of Birmingham University.

The material assayed was taken from the most organic layers of the Late-glacial deposits, but a considerable amount of sediment was needed to produce enough carbon. The date was as follows:-

Birm - 444 12.52 - 12.73 m 10,720 ± 480 radiocarbon years B.P.

The standard error quoted was calculated by combining one standard deviation of the sample count rate and the background count rate.

ABSOLUTE POLLEN DEPOSITION

Because of the scarcity of pollen in the Late-glacial deposits at this site no attempt was made to estimate absolute pollen deposition for these sediments. The small numbers of pollen present, and the complete absence of reliable radiocarbon dates would render such an attempt of little value.

The method outlined in chapter 3 was used to estimate absolute pollen deposition for the Post-glacial period. As there was no finance for radiocarbon dating of these deposits deposition rates have been estimated by applying dates to the more distinct pollen assemblage zone boundaries. The dates used are explained in chapter 3.

The dates used at Hornsea Old Mere to calculate Post-glacial sediment accumulation rates, and hence pollen deposition rates, and the horizons to which they were applied were as follows:-

9.35 m	10,000 B.P.
8.95 m	9,000 B.P.
7.65 m	7,500 B.P.
4.30 m	5,000 B.P.

Pollen deposition did not continue until the present day at Hornsea Old Mere, and so a date was estimated for the upper limit of pollen deposition of:-

1.55 m	2,000 B.P.

Of these dates, that of 10,000 B.P. at the base of the Post-glacial deposits is related to an actual date at Roos (chapter 4) for a similar pollen horizon. As no Late-glacial deposits were analysed from this

actual core it is not easy to locate the Late-glacial/Flandrian boundary precisely. General palynological and stratigraphic evidence suggests that this estimated date is fairly reliable.

The elm decline has been widely dated to around 5,000 B.P. (see chapter 9), as at Gransmoor (chapter 6), and it is a well-marked feature here, so that this date should be fairly accurate.

The estimate of 9,000 B.P. for the Corylus pollen increase is probably fairly reasonable, but the estimate for the Alnus increase of 7,500 B.P. cannot be regarded as more than a rough estimate. The differing behaviour of Alnus at this site and at Roos (see chapter 8) makes the estimation of a date for its expansion, based on dated horizons from elsewhere in northern England, quite hazardous. For this reason absolute pollen deposition values for the period between the Corylus pollen increase and the elm decline have also been calculated on the basis of a constant sediment deposition rate between the two estimated dates of 9,000 and 5,000 B.P. (figure 5.7).

The estimate for the top of the pollen-bearing sediments of a date of 2,000 B.P. is another of loose accuracy, and the true date may lie well to either side of this figure.

The likely accuracy of these dates is discussed further below (chapters 8 and 9). Here it may be said that without some initital estimate no calculation of pollen deposition rates could be made for this site. In interpreting the results the weaknesses of the method must be borne in mind.

The actual sedimentation rates used were based on the assumption of constant deposition rates between each adjacent pair of estimated dates. The rates used were as follows:

1.55 - 4.30 m - rate P - 0.92 mm/year

4.30 - 7.65 m - rate Q - 1.38 mm/year

7.65 - 8.95 m - rate R - 0.80 mm/year

8.95 - 9.45 m - rate S - 0.40 mm/year

The sedimentation rate used to construct figure 5.7 was:

4.30 - 8.95 m - 1.16 mm/year

ABSOLUTE POLLEN FREQUENCY IN THE POST-GLACIAL SEDIMENTS

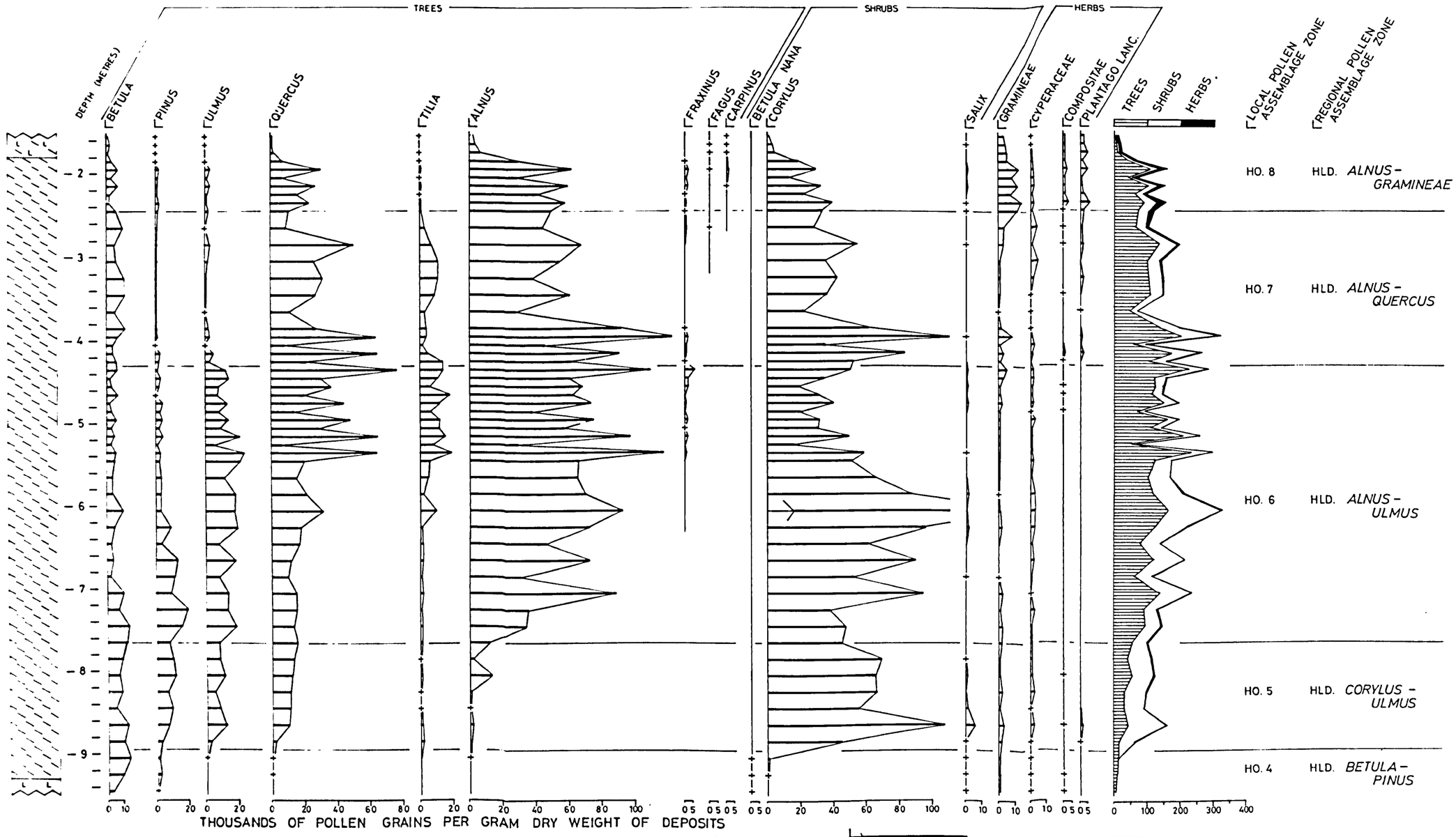
Figure 5.5 shows the absolute pollen frequency per gram dry weight of sediment for the Post-glacial deposits at the Hornsea Old Mere site. This diagram provides the basic absolute pollen data unbiased by the application of sedimentation rates. It is zoned in the same way as the percentage pollen diagram; and is presented without a written zone-by-zone description. The pollen frequency diagram may be regarded as a basis for the construction of the absolute pollen deposition diagrams, and a straight written description of the pollen frequencies is therefore not given.

THE ABSOLUTE POLLEN DEPOSITION DIAGRAMS OF THE POST-GLACIAL SEDIMENTS (figures 5.6 and 5.7)

The local pollen assemblage zones applied to the percentage diagram (figure 5.4) are used here. Any unqualified figures for pollen deposition given below are in pollen grains deposited/cm^2/year.

Zone HO.4 9.45 - 8.95 m

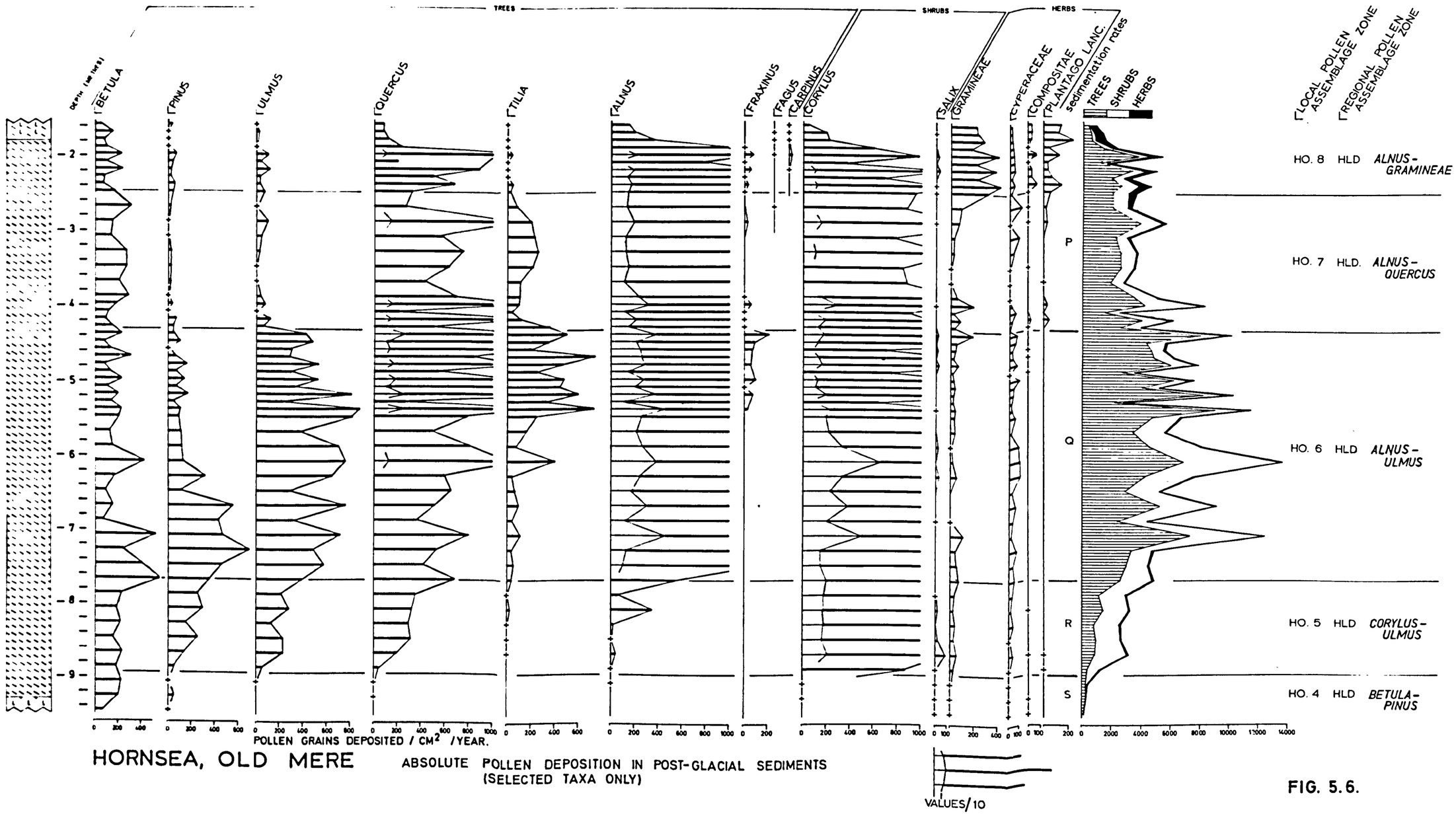
A zone of low total pollen deposition values, rising from 200 to 3000 at the top of the zone. Pollen of tree species of *Betula* contributes about 200, *Pinus* pollen is less plentiful. *Ulmus* and *Quercus* contribute little pollen at the base of the zone, but up to 200 at the top. *Alnus* pollen is present but scarce. Pollen of *Betula nana* and *Juniperus* show only low values at the base of the zone and are absent from the top.



THE OLD MERE, HORNSEA.

ABSOLUTE POLLEN FREQUENCY IN POST-GLACIAL DEPOSITS
(SELECTED TAXA ONLY)

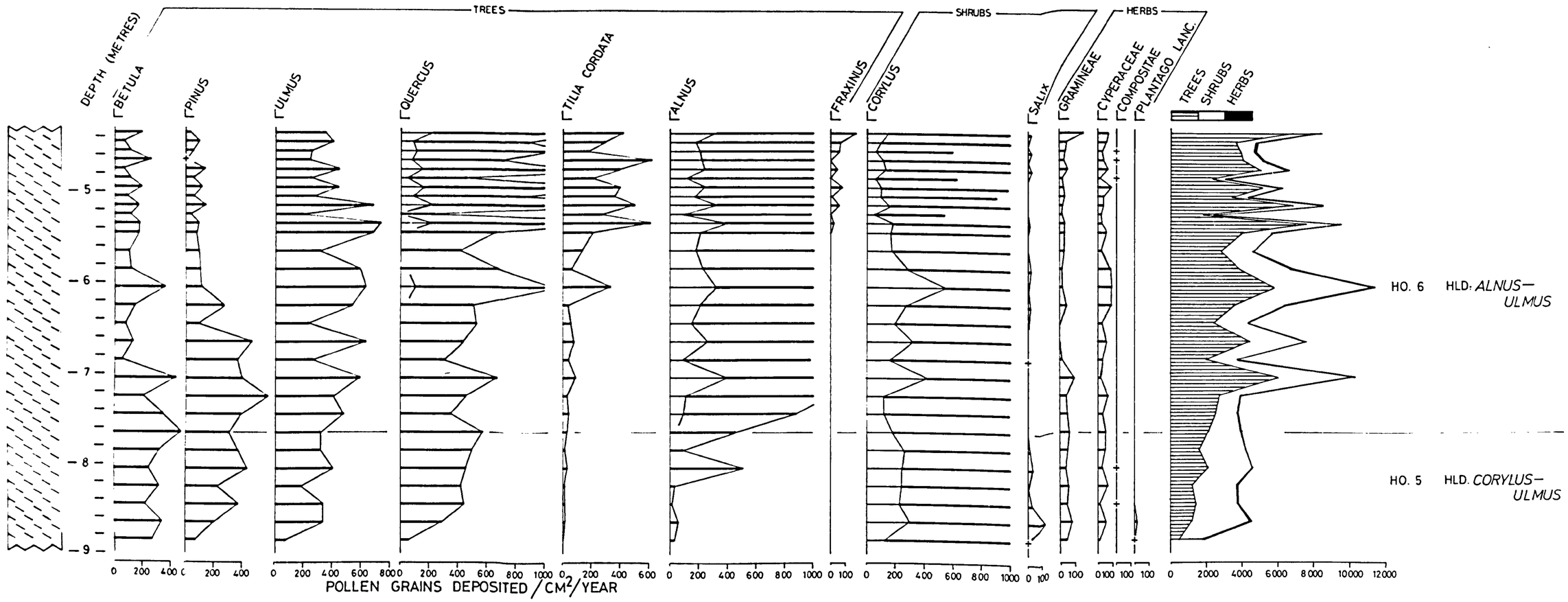
FIG. 5.5.



HORNSEA, OLD MERE

ABSOLUTE POLLEN DEPOSITION IN POST-GLACIAL SEDIMENTS (SELECTED TAXA ONLY)

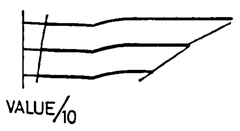
FIG. 5.6.



HORNSEA, OLD MERE

ABSOLUTE POLLEN DEPOSITION IN ZONES HO.5 and HO.6 CALCULATED FROM A CONSTANT SEDIMENT DEPOSITION RATE (0·116cm/yr) FOR BOTH ZONES

(SELECTED TAXA ONLY)



FINE DETRITUS MUD

FIG. 5. 7.

Corylus pollen is scantily present. Herbs do not contribute a great deal of pollen, but they represent a fair proportion of the total. The probably rapidly changing conditions of this zone make these estimates of limited reliability.

Zone H0.5 8.95 - 7.65 m (figure 5.6 - sedimentation rate - 0.80 mm/year)

Total pollen deposition increases from 3000 to 5000, and that of trees increases throughout the zone from 1000 to 2000. It is largely of Pinus (about 250), Ulmus (200 to 400) and Quercus (300 to 700?). Betula pollen deposition values stay at around 250. Pollen of Alnus and Tilia occurs consistently in small amounts. Corylus pollen deposition increases dramatically at the base of the zone to between 1500 and 2000. Total herb pollen values lie at about 100, chiefly represented by Gramineae and Cyperaceae.

Zone H0.5 8.95 - 7.65 m (figure 5.7 - sedimentation rate - 1.16 mm/year)

Naturally enough, all values are 45% higher than for zone H0.5 with a sedimentation rate of 0.80 mm/year.

Zone H0.6 7.65 - 4.30 m (figure 5.6 - sedimentation rate - 1.38 mm/year)

Total pollen deposition values are somewhat variable in this zone, but in general increase from the base to reach values around 7000, with a slight fall in the top metre of the zone. It is arboreal pollen which accounts for most of this increase. Betula pollen values, above a small increase, fall to between 100 and 200. Pinus pollen deposition reaches values of 400 to 500 but higher in the zone declines to similar values to Betula. Ulmus pollen values increase to a peak of about 800, but decline at the top of the zone. Quercus pollen values increase to generally over 500, and up to 2500. (the oddly alternating values in the top part of this zone, particularly noticeable for Quercus, may be due to the fact that the earliest samples prepared were taken from this

zone, and some error or loss of material has produced the lower set of values). Tilia pollen has consistent but low representation, until it increases at the top of the zone. Alnus pollen dominates the zone, values rising rapidly to between 2000 and 4000. Fraxinus pollen appears in the top half of the zone. Pollen values of Corylus generally lie between 2000 and 5000, but fall a little at the top. Little herb pollen is present; what there is is largely of Gramineae and Cyperaceae.

Zone H0.6 7.65 - 4.30 m (figure 5.7 - sedimentation rate - 1.16 mm/year)

All values are 15.94% lower than for zone H0.6 with a sedimentation rate of 1.38 mm/year.

The effect of using the constant sedimentation rate for these two zones is to slightly increase their similarity. When based on different sedimentation rates, however, the two zones are quite similar in nearly all respects, except for the differences in Alnus pollen deposition. The use of a constant sedimentation rate therefore makes very little difference to the picture of pollen deposition during the passage of these two zones.

Zone H0.7 4.30 - 2.45 m

Total pollen deposition values are erratic at the base of the zone, but in general fall to between 3000 and 4000. Ulmus pollen shows a marked decline at the base of the zone to values below 20, and higher up recovers only slightly. Pinus pollen values decline. Quercus pollen deposition remains at about 500, while that of Tilia cordata declines rapidly to about 100, but increases to about 200 at the same depths (3.50 - 3.00 m) as Ulmus pollen shows its minor recovery, but its values decline to insignificance again at the top of the zone. Alnus pollen values decline just above the base of the zone to between 1000 and 1300. Fraxinus pollen is sparsely present lower down and more or less absent

above. Corylus pollen maintains values of 750 - 1000. Herb pollen values vary, declining in the central part of the zone (where Ulmus and Tilia pollen increase), and increasing at the top of the zone.

Zone HO.8 2.45 - 1.55 m

The amount of pollen deposited varies around 3000 grains/cm^2/year and declines below this in the top half metre. This later change is largely due to a decline in tree pollen values. Betula pollen contributes about 100, Pinus generally less than 50, and Ulmus up to 100. Quercus pollen values are again variable but fall at the top to less than 100. Tilia cordata pollen is only sporadically present. Alnus pollen values increase at the base but, like that of all types, decline at the top of the zone. Fraxinus, Fagus and Carpinus pollen is occasionally present. Corylus pollen values are at about 500 to 1000, but decline in the top half metre. Herb pollen values peak in this zone. Gramineae pollen deposition expands to about 250, Cyperaceae and Compositae pollen hold steady values of about 50 and Plantago lanceolata deposits 50 to 100 grains/cm^2/year in general throughout the zone.

DISCUSSION

The history of the basin itself

Stratigraphical and palynological evidence suggests that changes within the Old Mere throughout much of Late- and Post-glacial times were only of a minor character.

The clay deposits and finely-comminuted clayey organic layer of the Late-glacial period all appear, from the species present, to have been deposited in a fair depth of open water. All pollen is scarce in these deposits, but that of a range of aquatics is present in the richer, more organic layer. Evidently Myriophyllum, Nuphar and Potamogeton grew at this time, and they are plants of submerged or floating-leaved habit in

quite deep water. Sparganium and/or Typha angustifolia, and Alisma probably grew close to the edge of the lake. The considerable depth of Late-glacial deposits, and their silty nature suggests that there was a considerable amount of deposition from an inflow stream.

That the Old Mere was open water throughout the greater part of the Post-glacial period is demonstrated by the very homogeneous, finely broken up, lake muds which comprise up to 7.5 metres of deposits in the centre of the basin. For much of early Post-glacial time (when sedimentation was at a slow rate) almost no aquatics appear to have been present, from the pollen record, except for Sparganium or Typha angustifolia at the edge of the mere, and some Myriophyllum at the opening of the Flandrian period. Since the stratigraphy clearly reflects open water conditions it is likely that there was a considerable depth of water at this time, or that movement of water through the mere was at a sufficient pace to keep its centre free from floating or submerged aquatics. What depth the water may have attained is not clear. The terraces that surround the Old Mere and the surviving Hornsea Mere suggest that at some time the surface of the water was at least 3 m above the present surface deposits (Reid, 1885).

From the mid Post-glacial (when sedimentation was at its most rapid) onwards occasional deep-water aquatics, such as Nuphar, Nymphaea, and Potamogeton were able to grow in the lake. Perhaps the speed of water through the mere decreased at this time or infilling reduced the water depth such that it was suitable for these plants.

In later Flandrian time the Old Mere seems to have dried out fairly rapidly. A gradual shallowing by infilling would probably have produced a vegetation succession to bog and/or dry land, yet there is no evidence of this. Possibly the lake was drained suddenly by a breach in the

eastern end caused by coastal erosion allowing much, or all of the water to drain away rapidly. If the lake was drained by a breach of the cliff, perhaps at the date of 2,000 B.P. estimated for the cessation of pollen accumulation in the site (see above), some measure of the former length of the mere may be postulated. If coastal erosion has continued during the last two millenia at the current rate of about 1 - 2 metres a year (Reid, 1885) the Old Mere basin may have extended 2 or 3 km to the east of the present coastline. This can only be taken as a very rough possible estimate.

The topmost deposits in the basin contain successively more inwashed clay with a fauna of freshwater Ostracods (Robinson, personal communication), so the site was not flooded by the sea for any long period of time. The floods of 1953 did temporarily inundate the area, and earlier floods may have done so also. The clay was in turn succeeded, and the infilling completed, by deposits of dune sand blown onto the site from the advancing beach which now lies across what formerly must have been part of the bed of the mere.

Pollen incorporation into the lake sediments

During the Late-glacial period and for much of Post-glacial time the Old Mere at Hornsea appears to have been a fairly extensive, open-water lake. Pollen will have been incorporated into the sediments from two distinct agencies. Firstly from the aerial pollen rain, precipitating pollen directly onto the surface of the mere; and secondly pollen will have been brought from the catchment into the lake by the inflow stream.

Several authors have emphasised the importance of the contribution which streams may make to the pollen influx into lakes (e.g. Peck, 1973; Crowder and Cuddy, 1973), and it may well have been a significant factor at this site. The stream water would have carried the pollen that fell

directly onto it, and may therefore have contained much pollen of stream-side taxa such as Alnus. It will also have included pollen washed from the surface of the catchment in the course of overland flow and soil erosion. On occasions it may also have held pollen in material resuspended from earlier deposition upstream, perhaps in the existing Hornsea Mere. The stream will therefore probably have considerably increased pollen influx into the lake and, by bringing pollen from all over the catchment, will have increased the extent to which the pollen spectra in the lake reflect regional rather than local vegetational patterns.

The importance of the 'stream component' may be enhanced in the centre of the lake, where the core for pollen analysis was removed, as here the aerial contribution of pollen will have been least (Davis, 1967a; Waddington, 1969). Towards the centre of a largish lake, such as this one, the 'rainout component' will have tended to increase in importance in comparison with the canopy and especially the trunk-space components (Tauber, 1965) and the pollen spectra will consequently reflect the regional, rather than local, vegetation.

Differential deposition of certain pollen types may have occurred here, and this might have distorted the composition of the fossil pollen spectra. Elsewhere conflicting ideas have been expressed on this subject. Pinus pollen has been found to accumulate more in the shallows, especially on the side of the lake receiving the offshore wind (Kabailiene, 1966), presumably because of its buoyancy (Hopkins, 1950). But Pinus pollen has also been described as being more concentrated in the central deposits of the north basin of Windermere (Pennington, 1947); and as being evenly distributed in sediments right across some lakes (Davis, Brewster and Sutherland, 1969). If is therefore

impossible to suggest what effect differential deposition may have had here. Possibly the more buoyant pollen types will have been carried out from the lake by the current of water to the outflow stream, and might therefore be under-represented in the sediments. However these buoyant types may have been readily carried into the lake by the inflow stream, and so the two factors may balance each other out.

The relevance of the comparative contributions of the various pollen rain components, and of differential pollen deposition in different parts of the mere may have been minimised by the considerable amount of mixing of sediments which occurs in most lakes. This is effected by the resuspension and redeposition of material during the seasonal water circulation (Tutin, 1955; Davis, 1967a, 1968). The pollen spectra in sediments at the Old Mere site should, on balance, be expected to represent a fairly regional picture of vegetational changes because of the probably strong influence of the stream, rainout and canopy components.

Because of coastal erosion nothing can be known of the nature of the outflow stream, but presumably one existed, and would have removed suspended pollen from the mere. This may have slightly negated the effect of the inflow stream in increasing pollen influx into the mere. Removal of pollen and erosion of deposits from the lake bottom by the outflow stream may have occurred chiefly at the lower end of the mere, now completely lost, and was perhaps not of great significance at the sampling point.

<u>The history of the vegetation of the surrounding area</u>

As in chapter 4, only a provisional idea of vegetational sequences is given below. No reference is made to published material, and climatic, edaphic and anthropogenic factors are not considered. The

intention below is to outline possible vegetationssequences and provide a basis for the compilation of the regional vegetational history, described in Section III.

The Late-glacial period - The zone HO.1 pollen assemblage represents the earliest pollen deposition at the site. The radiocarbon date from the top of this zone of 10,720 ± 480 B.P. (Birm - 444) places it in the Late Devensian period but is of doubtful reliability. The difficulty in obtaining this date from so inorganic a deposit is good reason for its probable inaccuracy.

During the time represented by this pollen assemblage zone the inorganic nature of the deposits and the scarcity of pollen points to a sparse vegetation cover on the surrounding dry land. Arboreal pollen represents a fair proportion of the total, but only because *Pinus* pollen is comparatively so abundant. This may well be due to long-distance dispersal of *Pinus* pollen which consequently preponderates in a sediment with little local pollen to contribute to it. *Pinus* trees need not have been present in the vicinity. The genus *Betula* may have been represented locally, both in the form of trees and as the dwarf birch, *Betula nana*, perhaps in roughly equal amounts. Light demanding shrubs such as *Hippophae* and *Juniperus*, and herbs, notably Gramineae, Cyperaceae, *Helianthemum* and *Thalictrum* were probably important constituents of a very open vegetation.

While the pollen of zone HO.2 was being deposited tree species of *Betula* probably expanded locally, partly shading out *Betula nana* and *Juniperus* and completely shading out *Hippophae*. A wide range of herbs seems to have been growing in an open *Betula* woodland.

Few remarks can be made about the vegetation conditions of pollen

assemblage zone HO.3 since so little pollen was found in the clay. This fact again probably explains the dominance of Pinus pollen, the high values of which may be attributable to long-distance dispersal. Vegetation was presumably of a very open sparse type with Betula nana comparatively more important than the tree Betula than was the case in zone HO.2. Juniperus may have been more abundant in the area than is suggested by its pollen values. The pollen of this shrub is weak, thin-walled and presumably easily destroyed.

The Post-glacial period At the opening of the Post-glacial period deposition in the mere changed from clays to richly organic lake mud, reflecting an increase in vegetation cover and a consequent anchoring of soil material. The absolute pollen diagram (figure 5.5) shows that total pollen deposition may have increased only slightly. However, trees seem to have become much more important. A light Betula forest with some Pinus now perhaps present locally, may have been the dominant vegetation form. Ulmus, Quercus and Alnus were present but could not have been abundant. The vegetation was open enough for many herbs to survive, but their importance quickly declined.

While pollen assemblage zone HO.5 was forming the vegetation became more diversified. The absolute pollen diagram shows that while Betula did not expand, it was as abundant as before, but Ulmus, Pinus and Quercus expanded to become co-dominant. Alnus and Tilia trees were present but not plentiful. Corylus seems to have been an important, probably pioneer, woodland constituent, while most of the herbs must have been shaded out by the increasingly dense tree cover.

Forest development seems to have reached its peak during the deposition of pollen zone HO.6. Alnus dominated the pollen deposition. The high values may suggest that it was abundant rather close to the

mere and on the banks of the inflow stream, from where the stream would carry much Alnus pollen into the lake. A succession seems to have taken place in the surrounding vegetation. At first Pinus and Betula were important, but were later succeeded as dominants by Alnus, with, as secondary dominants, first Ulmus and then Quercus. Where each type grew is not, of course, clear from the pollen diagrams themselves, but is discussed below (chapter 8). Corylus maintained its abundance but became comparatively less important. There could have been little open space for light-demanding herbs at this time. Any woodland herbs present would produce very little, poorly dispersed, pollen. Gramineae and Cyperaceae were unimportant and other types, such as Chenopodiaceae, Rosaceae and Umbelliferae must have survived in just a few places.

Ulmus seems to have declined in importance as a forest constituent throughout the later parts of the time represented by this zone, and at the base of zone HO.7 both percentage and absolute pollen diagrams show its pollen to suffer a marked decline. There seems to have been a real decrease in the number of Ulmus trees present. Tilia was probably also reduced. It appears from the absolute diagram that most tree types suffered a decline. Betula may have expanded into some of the newly open areas and Alnus was perhaps still abundant in places. There was no decline in the proportion of total pollen which the trees contributed, so the apparent decline may in some measure be an artifact of the calculations. Fraxinus was present in small amounts at about the time of the elm decline, perhaps growing in the opened-up woodland as a secondary tree. Several ruderals appeared in the area at the time of the elm decline, notably Plantago lanceolata and various Compositae. Gramineae may have spread somewhat but no great numbers of herbs were present.

At some time after the elm decline there seems to have been some regrowth of the forest. Ulmus and Tilia both increased temporarily while Gramineae, Plantago lanceolata and other herbs became scarce again. The evidence suggests that this was only a slight regeneration of woodland. In general after the elm decline Alnus and Quercus became the two most abundant trees.

The beginning of cereal cultivation here marks the opening of zone HO.8. Ulmus and Tilia declined again at this time, while Quercus and Alnus were probably also reduced. The ruderals showed a marked increase in the now presumably fairly unshaded vegetation. Particularly important were Gramineae, Plantago lanceolata, various Compositae, such as Artemisia, Cirsium, Aster type and Liguliflorae, as well as Chenopodiaceae and a range of other herbs in less abundance.

By the time pollen deposition ceased at the site trees were probably quite scarce in the area, perhaps most of them being fringing Alnus. The proximity of the eroding sea in these more recent times is demonstrated by the deposits of blown dune sand, and the occurrence once more of Hippophae, this time in its 'modern' coastal environment, after an absence of perhaps ten thousand years.

CHAPTER 6

GRANSMOOR QUARRY

INTRODUCTION

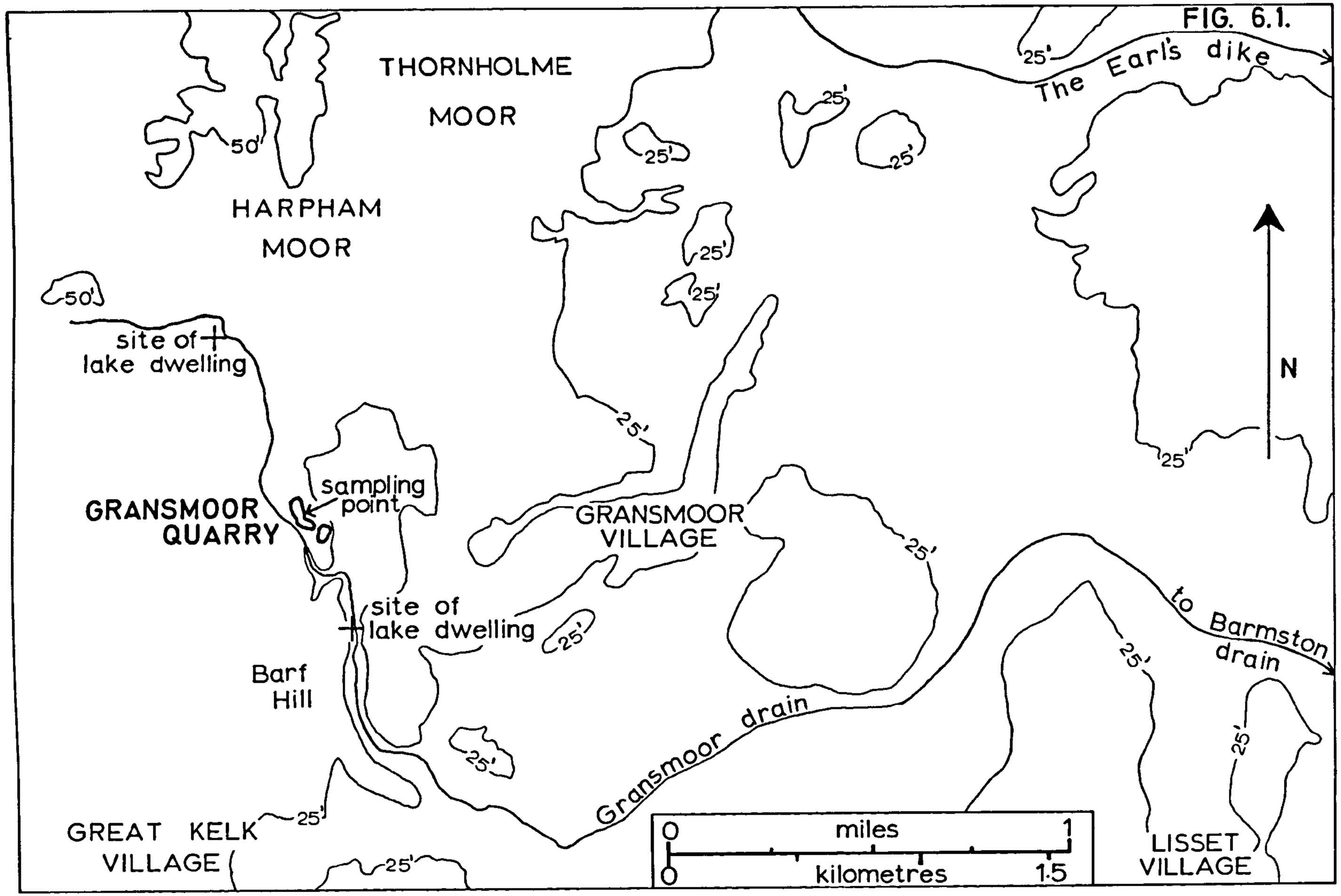
Gransmoor Quarry lies 1.5 km west of Gransmoor village and 8 km east-north-east of Great Driffield, at National Grid reference TA111596. It is in a small valley, the stream of which drains the area to the sea at Barmston. A ribbon of alluvium follows the course of this stream and alluvium occurs elsewhere in the surrounding area of flat, low-lying land, chiefly composed of boulder clay surface deposits, with occasional sand and gravel patches. About 3 km to the north-west the chalk of the Yorkshire Wolds is exposed, as these hills curve round to a west-east orientation to meet the sea at Flamborough Head.

The area is now wooded only sparsely and is intensively cultivated. Less than 1 km to the south of the quarry, and within the valley, remains of a Bronze Age lake dwelling, and a Roman urn, were uncovered (Smith, 1911). Somewhat further away from the site other such lake dwellings have been found at Barmston (Varley, 1968) and at Ulrome (Smith, 1911). There is much evidence of early human activity to the north and west of the site, on the chalk Wolds (Elgee and Elgee, 1933).

Quarrying for sand and gravel at the site has revealed several small peat beds now exposed in the walls of a flooded pit. The four or five exposed faces are all of thin peaty deposits and of limited extent. The largest is less than a metre thick and exposed over a length of about 30 metres.

STRATIGRAPHY

The most extensive and deepest exposure of peat was chosen for pollen analysis, and the stratigraphy was examined in a cleaned face.



MAP OF AREA SURROUNDING GRANSMOOR QUARRY

At the base of the section a rather gravelly deposit is exposed. Immediately above this is an inorganic layer of sand with a little clay. This becomes rather more clayey above. The peat lies above this. At the base it is silty, humified, and very compact. The only macroscopic remains are occasional fruits of Corylus. Higher up, the peat, which is still compact and humified, becomes less silty and contains a few wood fragments. Above the peat is clayey, disturbed ground.

The stratigraphy at the sampling site was as follows:-

0.0 - 0.2 m Overburden of clayey sand and disturbed ground

0.2 - 0.9 m Dark brown, compact humified peat, with a few wood fragments

nig 3, strf 0, elas 1, sicc 3, humo 3. Th 3, Tl 1, Tb +

0.9 - 1.15 m Slightly silty, compact, dark brown, humified peat with occasional Corylus fruits.

nig 3, strf 0, elas 1, sicc 3, humo 3. Th 4, Tl +, Ga +.

1.15 - 1.50 m Sand, with a little clay, especially towards the top.

nig 1, strf o, elas 0, sicc 3. Gs 3, Ag 1.

below 1.50 m Gravelly clay

nig 1, strf 0, elas 0, sicc 2. Ag 4, Gg +.

POLLEN ANALYSIS

Samples were taken from the exposed face for pollen analysis. These were prepared by the method outlined in chapter 3. As some of the samples were rather silty they were treated with boiling hydrofluoric acid to remove silicates.

Results of the pollen analysis are presented in a percentage diagram with values expressed as percentages of total arboreal pollen (figure 6.2). Because of the overabundance of Tilia pollen another percentage diagram was constructed for tree pollen types with values expressed as percentages

of total arboreal pollen, excluding Tilia (figure 6.3). For ease of description the diagrams have been zoned into local pollen assemblage zones, numbered from the base upwards, and prefixed with the site initials GQ.

Absolute pollen deposition at the site was calculated and is dealt with below, after the description of the percentage diagrams.

The Percentage pollen diagram (Pollen sum = total arboreal pollen) (figure 6.2)

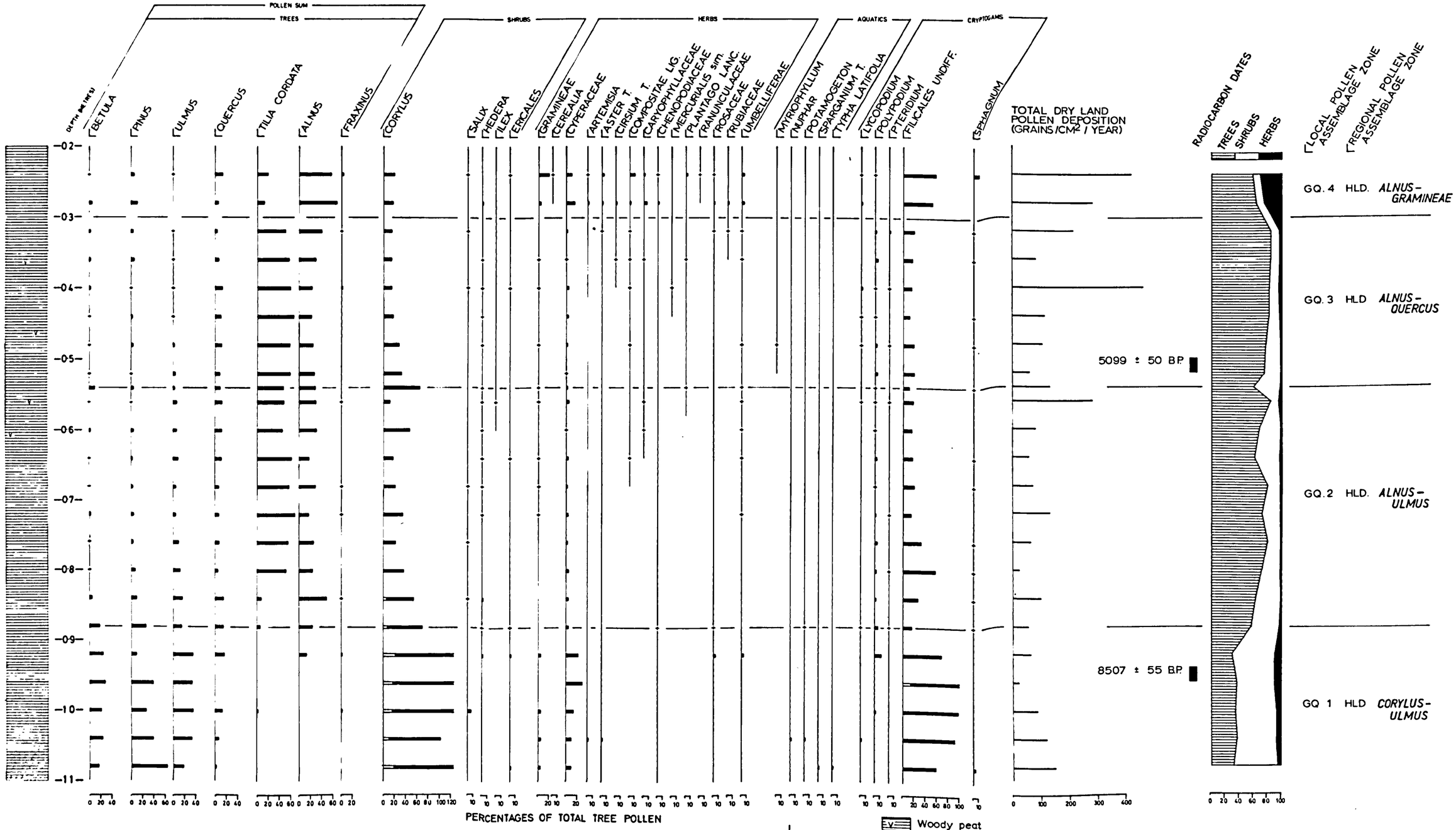
Unqualified percentages given below are percentages of total arboreal pollen.

Zone GQ.1 1.08 - 0.88 m

Tree pollen contributes 30% of total dry land pollen, and is itself dominated by pollen of Pinus (20 - 40%), Ulmus (30 - 40%) and Betula (about 20%). Quercus pollen values lie at about 10%. Corylus pollen contributes about 150 - 200% of arboreal pollen. Cyperaceae pollen values are between 10 and 20% but other herb pollen is scarce. Gramineae pollen is consistently present in small amounts and there are only occasional grains of other herbs and aquatics. Filicales spores occur in considerable quantities of up to 100%.

Zone GQ.2 0.88 - 0.54 m

Tree pollen is dominant, contributing about 70% of the total dry land pollen, and is dominated by the pollen of Tilia cordata, values of which rise at the base of the zone to 50% arboreal pollen or more. Alnus pollen values increase to around 20%. Pollen of Ulmus and Quercus represents between 5 and 10% for each type. Pollen values of both Betula and Pinus decline at the base of the zone to very low percentages. Fraxinus pollen is sporadically present. Corylus pollen values decline to 50% at the base



GRANSMOOR QUARRY POLLEN DIAGRAM

FIG. 6. 2

of the zone, and to lower values at the top. Salix pollen is intermittently present and Hedera pollen occurs. Herb pollen is only sparsely represented, only Cyperaceae pollen being consistently present. Gramineae, Tubuliflorae, Caryophyllaceae and Umbelliferae pollen is only sporadically present at the top of the zone. There is no pollen of aquatics. Polypodium spores are regularly present, and there are traces of Sphagnum and Pteridium spores. Spore values of undifferentiated Filicales decline to around 20%.

Zone GQ.3 0.54 - 0.30 m

At the base of the zone Ulmus pollen values fall from between 5 and 10% to generally below 1%. Tilia cordata pollen (about 50%) and Alnus pollen (between 20 and 40%) dominate the arboreal pollen, with Quercus pollen contributing about 10%, and that of Betula, Pinus and Fraxinus is scarce. Corylus pollen values, above a temporary increase at the base of the zone, decline to about 20%. Herb pollen is sparse, but several types are represented, including Plantago lanceolata, Liguliflorae, Caryophyllaceae and Umbelliferae.

Zone GQ.4 0.30 - 0.24 m

The uppermost two samples are characterised by a slight decline in the importance of tree pollen to about 60% of total dry land pollen. Tilia cordata pollen values decrease markedly to less than 20% and Alnus pollen values show a corresponding increase to about 60%. Pinus pollen values also increase slightly. Corylus pollen contributes up to 20%. Herb pollen values increase to over 20% of total dry land pollen, and a wide range of herbs is represented. Gramineae and Cyperaceae each contribute between 10 and 20% of arboreal pollen. Pollen of various Compositae, Caryophyllaceae, Chenopodiaceae, Rosaceae, Umbelliferae, and other herbs is present in small amounts. Filicales spore values reach 50% of arboreal pollen and some Sphagnum spores occur in the top sample.

The adapted percentage pollen diagram (figure 6.3)

The pollen sum used was total arboreal pollen excluding *Tilia*. The pollen assemblage zones of the complete percentage diagram (figure 6.2) have been applied to the adapted one. The pollen assemblages described for the standard diagram (figure 6.2) can also be traced in the adapted one, except that in the latter, with *Tilia* pollen outside the pollen sum, the percentages of other tree pollen types is enhanced, notably in zones GQ.2 and GQ.3. The importance of *Alnus* and *Quercus* pollen is seen more clearly here, and the fall of *Ulmus* pollen values between these two zones can be more easily discerned.

RADIOCARBON DATING

Material was removed from the exposed face for radiocarbon dating. Thin slices of peat were taken from immediately behind that sampled for pollen analysis. The assay was completed in the Scottish Universities Research and Reactor centre, East Kilbride, Scotland.

The dates obtained were as follows:-

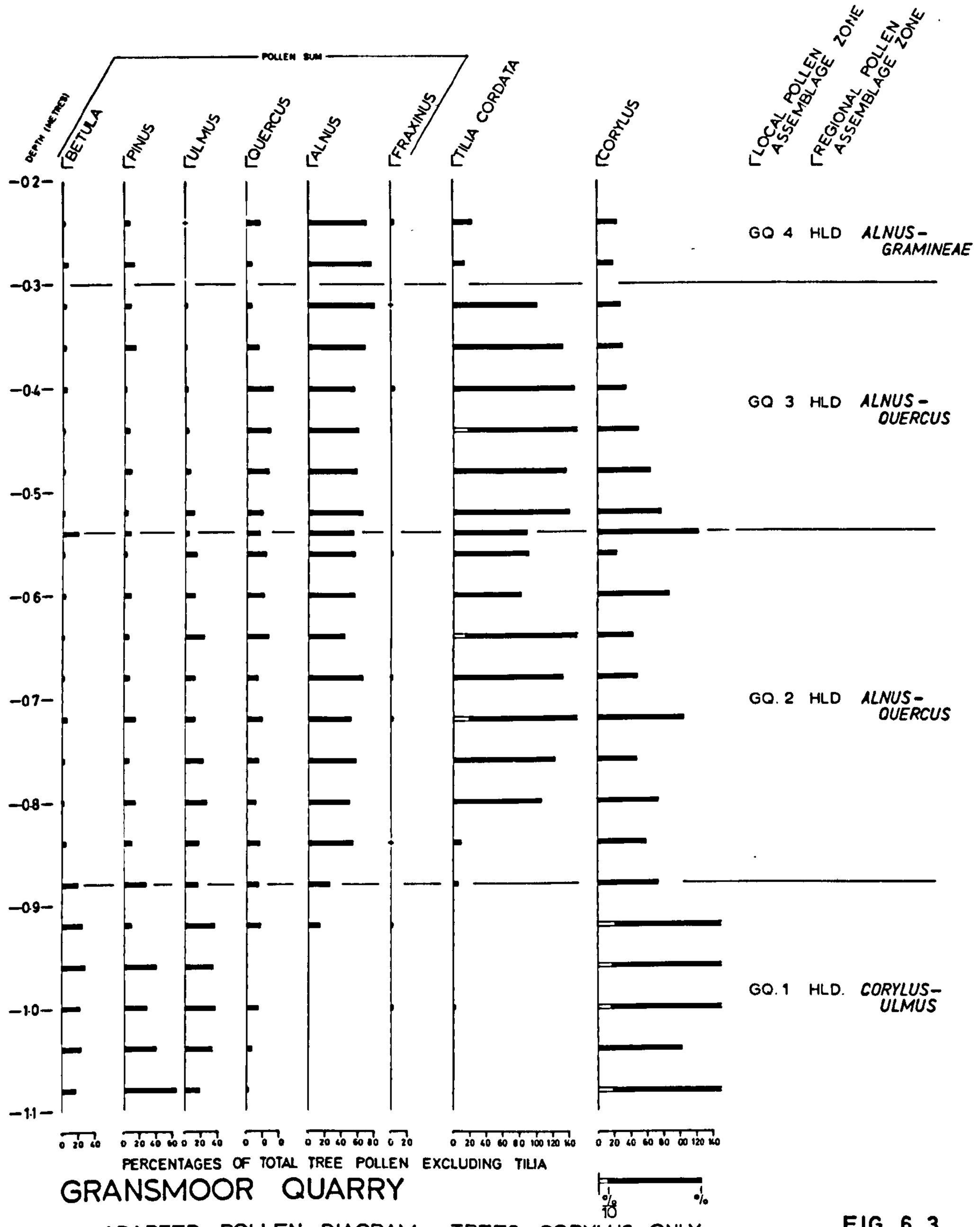
SRR - 229	0.50 - 0.52 m	5099 ± 50	radiocarbon years B.P.
SRR - 230	0.94 - 0.96 m	8507 ± 55	radiocarbon years B.P.

The standard errors quoted were calculated by combining one standard deviation of the sample count rate and the background count rate.

ABSOLUTE POLLEN DEPOSITION

Values for absolute pollen deposition were calculated for this site by the method outlined in Chapter 3. Density measurements were taken from a monolith removed from immediately behind the face from which pollen analysis samples were taken.

A sediment accumulation rate was calculated from the two radiocarbon dates. This rate, of 0.13 mm/year, was the sole rate used, and the rate



ADAPTED POLLEN DIAGRAM - TREES + CORYLUS ONLY

FIG. 6.3

was extended for use both below the lower date and above the upper one. The justification for this was that the density of the peat was very similar throughout the profile, suggesting fairly consistent deposition. Only at the extreme ends did density vary widely and here calculated values of pollen deposition may be of only limited value.

Results

Because the calculated pollen deposition rates were so low no separate 'absolute' pollen diagram has been drawn up. It would show very little. Total pollen deposition values have been added to the basic percentage diagram (figure 6.2).

Throughout, total pollen deposition appears to have been at very low levels, generally below 200 grains/cm^2/year. Many of the tree pollen types, for example, have values below 10 grains/cm^2/year in most samples. As a result no conclusions can be drawn from these figures. No Ulmus pollen decline, for instance, can be described in quantitative terms, since values for this type are so low, even in pollen assemblage zone GQ.2. Values for Tilia cordata pollen, the most abundant tree type, only exceed 60 grains/cm^2/year in one sample.

DISCUSSION

The history of the site itself

The peat section studied is one of a series of separate beds of peat which lie in a small area within alluvial valley deposits, together with patches of sand. The peat is itself quite silty. These peat beds were therefore probably formed in silting-up meanders of abandoned stream courses, hence their shallowness and silty nature. The peats are probably partly allocthonous in nature. Single pollen grain occurences of Nuphar, Potamogeton, Typha latifolia and Sparganium type in the very lowest peat deposits are scant evidence of local open water early on. Terrestrial,

slightly woody peat then developed, and as peat formation ceased a little Sphagnum grew locallyl

Total pollen incorporation was very poor, and peat accumulation very slow. This may well have been due to periodic, perhaps seasonal, drying out of the peat beds. An error in the radiocarbon dates might be a possible reason for the very low pollen deposition rates here. However, the upper date is strongly supported by the fact that it applies to the widely synchronous elm decline (Hibbert, Switsur and West, 1971). Even if the time period between the two dates were only half the 3,400 years postulated (i.e. if the lower date were 6,800 B.P. instead of 8,500 B.P.), the pollen deposition rates at this site would be doubled but would still be very small (and still only equal to about one tenth of the pollen deposition rates at Roos and Hornsea).

History of the vegetation of the surrounding area

As in chapters 4 and 5 only a very provisional picture of vegetational sequences is given below, without regard to other factors. Some of the problems of interpretation of the vegetational history of the area around this site are mentioned, but are more fully discussed in chapters 8 and 9.

Pollen deposition commenced sometime before 8,500 B.P., when the surrounding area was probably already densely wooded. Pinus, Ulmus and Betula were the dominant trees, with Corylus an important component. The presence of some Corylus fruits in the deposits may imply that it was growing close to the site, however these may have been washed in from further upstream by occasional flooding.

After 8,500 B.P. Alnus seems to have expanded and Betula and Pinus were more or less replaced by Quercus. From the pollen evidence Tilia

cordata appears to have been the dominant tree.

At 5,100 B.P. the widely recognised elm decline occurred here. The adapted pollen diagram (figure 6.3) shows this phenomenon fairly clearly. After the elm decline, however, fairly dense woodland seems to have prevailed, with Alnus and Tilia apparently dominant, and few herbs present.

As pollen deposition ended at the site the woodland became more open. Cereal cultivation evidently began, and ruderals appeared in greater range and quantity; of the trees only Alnus seems to have spread at this time.

The chief problem in interpretation of the vegetational history of this area is the status of Tilia cordata. Its pollen is comparatively abundant and yet quite scarce in absolute terms. An extensive search for fruits of this plant in the peat revealed none. This might suggest that Tilia did not grow locally. However, as very few other macroscopic remains occurred in the peats, the possibility of locally abundant growth of Tilia cannot be ruled out. A possible explanation for the abundance of Tilia cordata pollen in deposits with, in general, very little pollen present, is that periodic drying out and rather neutral or alkaline conditions has caused much pollen to be destroyed while Tilia pollen, which is resistant to decay, has been preferentially preserved. In the topmost borizons, however, a wide range of herb pollen types is represented and pollen destruction does not, therefore, seem to have been significant. Though less abundant than below, Tilia cordata pollen values are still comparatively high. It is, therefore, not impossible that Tilia cordata has, at sometime, formed an important constituent of the vegetation of this area. The possible status of Tilia within Holderness is discussed more fully in chapter 8.

SECTION 111

DISCUSSION

CHAPTER 7

THE LATE-GLACIAL PERIOD OF HOLDERNESS

INTRODUCTION

From the evidence outlined above (chapters 4 and 5), from a pollen diagram from Brandesburton (Clark and Godwin, 1956), and from other sources (e.g. Reid, 1885), an attempt is made to build up a synthesis of Late-glacial conditions in Holderness. The type site for this is taken as the Bog, Roos, from which a radiocarbon-dated pollen diagram in both percentage and absolute terms has been constructed. With the pollen diagram from Roos the other information is compared and contrasted to produce a more complete picture of vegetational and climatic conditions in the region.

The sequence established for Holderness is compared with other Late-glacial data from north-eastern England, and elsewhere. Certain aspects of the Late-glacial period of Holderness are also discussed in a wider context.

THE OPENING OF THE LATE-GLACIAL PERIOD

Pollen assemblages

Late-glacial pollen deposition began at Roos sometime before 13,000 B.P. The lowest pollen assemblage zone (RB.1) can be equated with the lowermost zone (HO.1) at Hornsea. Both contain very little pollen, particularly at Hornsea, but also at Roos where absolute pollen deposition values lie below 50 pollen grains/cm^2/year. Tree pollen is insignificant, the spectra being dominated by shrub and herb pollen. Of the arboreal pollen *Betula* is dominant, though *Pinus* pollen is fairly abundant in zone HO.1 at Hornsea. *Betula nana* pollen is present at both sites while pollen of *Salix* and *Juniperus* is scarce. Both show high values of *Hippophae* pollen, particularly in the upper parts of the zones, and lesser values of *Helianthemum*. Of the herbs Gramineae, Cyperaceae and Thalictrum pollen

dominates this basal zone at both sites. Artemisia pollen is present in RB.1 but absent from HO.1. The other main differences are the relative abundance of Pinus pollen at Hornsea, and the absence of the Old Mere site of a lower sub-zone with more pollen of tree and dwarf Betula, as occurs at Roos. This sub-zone (RB.1a) at Roos seems to represent a real increase in total pollen deposition, followed by a decline. These two pollen assemblage zones at Hornsea and Roos also occupy a similar stratigraphic position in rather inorganic clays at the base of their lake deposits, those at Roos being somewhat more organic.

Similar pollen assemblages have been described from elsewhere within Holderness. At Brandesburton, in basal deposits of a silty clay mud, pollen of Gramineae, Cyperaceae, Artemisia, Thalictrum, and Rubiaceae, with less Salix and Juniperus, was found to dominate a pollen spectrum in which arboreal types represented less than 30% of total dry land pollen. Betula pollen was the main arboreal type, but much of this was considered attributable to Betula nana. Hippophae pollen was not found in this spectrum (Clark and Godwin, 1956) (see figure App.1)

At Holmpton on the Holderness coast, pollen spectra from a thin peaty bed and underlying 'freshwater loam' contained pollen of Betula nana, Juniperus, Gramineae and Artemisia, and were assigned to the early Late-glacial period (Price, unpublished). In the peaty layer macroscopic remains of Betula nana have been found, while from the 'freshwater loam' shells of the mollusca Perca fluviatilis, Planorbis, Limnaea peregra, Cyclas carnea and Pisidium were described (Reid, 1885).

These local pollen assemblages may be grouped into the regional pollen assemblage zone HLD, Betula nana/Hippophae. The type locality and zone is the Bog, Roos, zone RB.1 11.45 - 11.20 m. The regional pollen assemblage zone may be described briefly as dominated by the pollen

of herbs, notably Gramineae, Cyperaceae and Helianthemum, and of shrubs, especially Betula nana and Hippophae. Arboreal pollen, mainly of Betula, contributes less than 50% of total pollen. The zone is the basal pollen deposition zone in Holderness; its upper limit is defined by the increase of arboreal pollen to over 50% of total dry land pollen, and by the decline of Hippophae pollen values.

Vegetation

This regional pollen assemblage zone may be taken to represent the vegetation of an early part of the Late-glacial period, dated at Roos to around 13,000 B.P. The vegetation throughout Holderness at this time must have been very open, with few trees. Tree birches were probably present in sheltered places only, but throughout the plain. Betula pubescens may have been the main species involved, as suggested by the pollen grain diameter and pore depth measurements (see chapter 3). It is possible, but perhaps unlikely, that all tree Betula pollen was contributed by long-distance dispersal, and that tree birches were absent from Holderness at this time (see below). Pinus pollen occurred, relatively more abundantly at Hornsea than elsewhere because of scarcity of other pollen types. Pinus pollen is easily dispersed long distances, is preserved well, and may not have grown locally at this time. The extremely low absolute deposition values for Pinus pollen at Roos support this idea.

The shrubs must have formed an important constituent of the vegetation. The dwarf birch, Betula nana was present throughout the area, macroscopic remains proving its presence at Holmpton (Reid, 1885). It is possible that this low-growing shrub hybridized with the tree birches in the region. This has been observed where both occur at the present day (Elkington, 1968). Hippophae rhamnoides was a major component of the vegetation, especially towards the end of the time represented by the first

pollen zone. Intolerant of shade, like Betula nana and Juniperus, it thrived in the open conditions and on the unleached boulder clay soils which would still have been somewhat calcareous. Although now found as a coastal plant on sand dunes or, in Europe, associated with streams and morainic detritus in alpine situations, Hippophae does grow on Gault clay cliffs at Folkestone, and competes successfully with Salix elsewhere (Pearson and Rogers, 1962). It was a pioneer plant on chalky boulder clay during the Hoxnian interglacial (West, 1956). Its presence as pollen, in considerable amounts, in the Late-glacial therefore is not surprising. As an aggresive pioneer it would have competed successfully with Salix and Juniperus, neither of which appear to have been abundant in Holderness at this time.

Between the sparse trees of Betula, and the more plentiful shrubs grew a range of herbs. Cyperaceae may have been over-abundant close to the damp pollen-collecting sites, but Gramineae and the shade intolerant Helianthemum, Artemisia and Thalictrum were probably widespread. Other notable plants included Chenopodiaceae, Epilobium, Plantago lanceolata, Rubiaceae and Umbelliferae, all of which are light-demanding. It would probably be unprofitable to attempt to attribute these plants to definite communities.

The only evidence for significant vegetational change within this zone is from Roos. Around this site tree and dwarf birches seem to have spread at about 13,000 B.P., at which time the shade-intolerant plants were scarce. Hippophae and Helianthemum spread later when the trees probably suffered a setback of some kind. Whether this variation occurred elsewhere in Holderness is uncertain; the lowest deposits at Hornsea contain so little pollen that such a fairly minor variation can neither be proved nor disproved. Whatever the case, the higher values of arboreal

pollen in zone RE.1a could not have represented a very closed vegetation as herbs were dominant and Betula nana important. Conditions may not have been shady enough to exclude Hippophae, which may just not have migrated into the area at this early date. From the Roos evidence the vegetation appears to have become more scanty towards the end of the zone, with less trees and more shrubs and herbs. This depletion of vegetation was soon corrected over much of the area by a vigorous expansion of Hippophae at the close of the zone.

The vegetation of Holderness during the opening of the Late-glacial period reflected the climatic conditions of the area. It was also a result of other factors such as soil stability and maturity, and the migration rates of the plants involved. Though there has been some evidence of activity by Palaeolithic man in Late-glacial times elsewhere (e.g. Hammen, Van der, 1952) he probably had only a very minor effect on the vegetation. In the absence of local evidence for early human activity the anthropogenic factor can be ignored here.

Climate

The absence of an extensive tree cover during the opening of the Late-glacial period has been used to imply severe climatic conditions. This absence may however be attributable to a lack of time for many plant types to migrate in. Climatic conditions can only be deduced from the plants that were actually present at the time in the area.

The tree that was present, Betula, is the most hardy of deciduous trees and the genus has a very wide climatic tolerance. Of the shrubs the dwarf birch, Betula nana is an arctic-alpine plant with a relict distribution in the British Isles at the present time. It is found in the Scottish mountains and at one locality in upper Teesdale (Hutchinson, 1966).

There is some evidence that it is intolerant of temperature above a certain level, but this is not clear (Conolly and Dahl, 1970). Juniperus can exist in very severe conditions in a prostrate form, hardly flowering (Iversen, 1954). It is not clear what species of Salix was present, so no precise climatic conclusions can be drawn from it.

The Sea Buckthorn, Hippophae rhamnoides has a present day range extending from 67°56'N in Norway southwards to the northern Mediterranean shore, where the southern limit more or less coincides with the 10°C January isotherm. It reaches altitudes of 5,000 m in the Himalayas (Pearson and Rogers, 1962). This shrub has therefore often been assumed to be widely tolerant of temperature. However, it is not now found in the arctic or alpine zones and where it occurs near to the tree limit in Norway it is sterile (Iversen, 1954). According to Game (1943) Hippophae never reaches the tree limit in the Alps and fails to flower long before the sub-alpine zone is reached. It can tolerate only a thin snow cover (Nordhagen, 1943), but is very resistant to frost and drought. The main controlling factor seems to be the shade of trees.

The three British species of Helianthemum are calcicoles, resistant to frost and drought, though perhaps poorly tolerant of winter damp (Procter and Griffiths, 1956). The other herbs present at the beginning of Late-glacial times yield little climatic evidence. Most are widely tolerant, and present in Holderness today. Light rather than temperature, seems to have been their main control, as they cannot tolerate shading.

It may also be noted that almost all the types of Mollusca discovered in Late-glacial deposits at Holmpton were still represented by living forms in Hornsea Mere, in the nineteenth century A.D. (Reid, 1885).

The pollen evidence for the period around and before 13,000 B.P., therefore, gives little guide to climatic conditions. At face value the

almost tree-less conditions and the many light-demanding plants present are suggestive of low temperatures. However their presence may equally well represent a pioneer vegetation in mild climatic conditions. The low absolute deposition values of pollen as much as the taxa represented, suggest a fairly poor climate, good enough to support some tree birches. The possibility remains that more thermophilous trees might have been able to survive had they been able to migrate in.

Since the trees seem to have suffered a real decline after 13,000 B.P. at Roos, and therefore possibly throughout Holderness, there does seem to have been some sort of climatic recession. As the tree birches declined it was Hippophae that expanded, so that temperatures cannot have been excessively low. Helianthemum also became more abundant, and it, like Hippophae is resistant to drought. It seems quite possible, therefore, that this recession was not one of lowered temperature but of lessened rainfall, limiting tree growth and allowing the aggressive Hippophae, which can spread by vegetative propagation, to expand markedly.

Soils

The recently deposited boulder clays, fairly chalky in nature, could not have had time to become leached at this stage and so would still be fairly rich in nutrients. The presence of the aquatic Polygonum amphibium at Roos demonstrates that the lake water was rich in nutrients (Seddon, 1954). Growing on the boulder clay were the moderate calcicoles Hippophae rhamnoides and Helianthemum sp. The aquatic Myriophyllum spicatum, also present, is a pronounced alkaphile (Iversen, 1964).

In the early Late-glacial the soils of Holderness were probably unstable and immature, limiting tree growth. These soils supported pioneer plants, such as Lycopodium selago, many ruderals and Hippophae

rhamnoides, which can withstand considerable changes in soil level, surviving as long as the plant is not buried completely (Pearson and Rogers, 1962). Hippophae rhamnoides also had the competitive advantage of being a nitrogen fixer. This must have aided its spread on these immature, and probably nitrogen-deficient, soils.

THE 'INTERSTADIAL' PERIOD

Pollen assemblages

The pollen assemblage zone RB.2 at Roos is, in brief, characterised by an increase in pollen deposition of most types when compared with RB.1. The pollen spectra are dominated by pollen of trees, preponderantly Betula which contributes between 50 and 80% of total dry land pollen. Pinus pollen values increase towards the top of the zone. Betula nana pollen values are greater in absolute terms than in RB.1, but represent lower percentage values. Hippophae pollen is absent, while pollen of other shrubs and herbs is relatively scarce. The pollen of Filipendula, however, is present in significant amounts. The same features occur in the pollen assemblage zone HO.2 at Hornsea. There is slightly more tree Betula pollen at Roos than at Hornsea, and a wider range of taxa are represented by their pollen in the better-preserved deposits at Roos, but otherwise the pollen spectra from both sites are very similar.

At Brandesburton (Clark and Godwin, 1956) Late-glacial values were expressed as percentages of arboreal pollen so the spectra cannot easily be compared. However, less herbs occur in deposits above the zone which corresponds to HLD, Betula nana/Hippophae. The tree pollen is dominated by Betula. Gramineae, Cyperaceae, Artemisia and Thalictrum still represent high values as percentages of arboreal pollen. Their values here are probably higher than at Roos and Hornsea, but these spectra may still be likened to RB.2 and HO.2.

These local pollen assemblage zones may be grouped into the regional pollen assemblage zone HLD. (tree) Betula/Filipendula. The type locality and zone is at the Bog, Roos, zone RB.2 11.20 - 10.85 m. The regional pollen assemblage zone may be briefly described as containing over 50% arboreal pollen, predominantly of Betula, with pollen of shrubs and herbs relatively unimportant, but with Filipendula pollen consistently present in small amounts. The lower limit of the zone is the increase of tree Betula pollen values to about 50% of total dry land pollen, and the upper limit is the decline of Betula pollen values to below this figure.

Age

Radiocarbon dates for this zone at Roos place its upper limit at just after 11,220 ± 220 B.P. (Birm-406). The date for the lower part of the zone is not clear. A mid-zone dateof 11,450 ± 230 (Birm-407) has been obtained. The date of 11,500 ± 170 B.P. (Birm-318) seems too close a date to Birm-407 to be reliable, and is, in any case, well above the base of the zone. A radiocarbon date from the base of zone HO.2 at Hornsea of 10,720 ± 480 B.P. (Birm-444) does not concur with the dates from RB.2, and seems much too young. Since so little carbon was present and much material was needed for assay, this date is of limited value and quite probably incorrect. A peat bed from the Holderness coast at Hooks, near to Grimston Hall, containing macroscopic remains of Phragmites at its base, and of the mosses Helodium blandowii, Aulocomnium palustre andAcrocladium giganteum above (Dickson, 1973), has been dated (Penny - personal communication). An assay from just below the top of the peat yielded a date of 11,250 ± 170 B.P. (Birm-301), which is very close to the date for the top of zone RB.2 at Roos. From towards the base of the peat at Grimston a date of 12,230 ± 120 B.P. (Birm-298) was obtained. The position of this date with regard to any

pollen spectra is not clear, but the bulk of the peat at Grimston seems to occupy a similar stratigraphic position and time period to pollen assemblage zone RB.2. As a rough estimate therefore the base of the regional pollen assemblage zone HLD. (tree)Betula/Filipendula may be taken as approximately 12,000 B.P.

Vegetation

All the evidence points to a spread of Betula forest in Holderness at about 12,000 B.P. The apparently denser woodland around Roos may be due to over-representation in the pollen spectra from birch trees growing around the rim of the site, while the Hornsea pollen spectra represent a more regional picture of vegetation, which at this time was probably of rather light birch woodland. The distinct increase in percentage and absolute Pinus pollen values in mid-zone RB.2 at Roos suggests that, if Pinus, did not grow locally before this time, it may have arrived at about 11,500 B.P. There is no evidence for this from the other sites. As birch woodland and Pinus spread, Betula nana, Juniperus, Hippophae, Helianthemum and light-demanding herbs became comparatively less significant. However, several of them may have flowered more profusely, only Hippophae, Helianthemum and Thalictrum being much reduced. The birch woodland must have been quite open to allow Betula nana, Salix, Juniperus, Gramineae, Cyperaceae and Filipendula to survive in some quantities. It was apparently shady enough to exclude Hippophae.

Climate

Pinus may have been the only new component of the vegetation, but the absolute increase in pollen deposition and the spread of birch woodland points to an amelioration of climate. Filipendula was able to spread, and is quite a thermophilous plant, its present northern limit coinciding with the 14°C July isotherm (Seddon, 1962).

Since Hippophae, itself quite thermophilous, was abundant before the birch woodland spread, it seems unlikely that there was a significant increase in temperature at the beginning of the tree Betula/Filipendula zone. If tree growth had been limited previously by drought, as seems possible, then it may have been an increase in wetness which allowed the spread of Betula woodland at about 12,000 B.P. The precise dating of any climatic change is difficult because of the different response of the various plants. The increase of Hippophae followed by that of the tree Betula may have been in response to the same climatic change, Hippophae responding by a rapid expansion and Betula only spreading much more slowly to finally replace the Hippophae. Since tree Betula seems to have been present in Holderness before even the Hippophae expansion, it was presumably restricted by some climatic factor before its expansion, at about 12,000 B.P. Increasing wetness at this date after a dry period might explain this satisfactorily.

There is some evidence from Roos that the tree birches reached their maximum spread soon after 12,000 B.P. and then declined in the later parts of RW.2. Betula nana and several of the herbs probably reached their peak later in the zone. This perhaps demonstrates an opening up of the woodland in response to a deteriorating climate some time before the close of this pollen assemblage zone, possibly after 11,450 B.P.

Soils

There is little to suggest a decline in the base status of the soils. The aquatics Polygonum amphibium and Myriophyllum spicatum, both requring water rich in nutrients, still occurred. The vegetation must have formed a more complete soil cover, and thus helped further to stabilise the maturing soils.

THE END OF THE LATE-GLACIAL PERIOD

Pollen assemblages

Local pollen assemblage zones RB.3 and HO.3 correspond with this time. Both zones contain very little pollen, demonstrated by the absolute pollen diagram from Roos (figure 4.6). Tree pollen represents a small proportion of the total, except that at Hornsea much Pinus pollen is present - presumably contributed largely by long-distance dispersal or by derived pollen. Much less tree Betula pollen is present than in the regional zone HLD. (tree) Betula /Filipendula. Betula nana pollen is fairly abundant. Juniperus pollen is sparsely represented in RB.3 and almost absent from HO.3, but it alone increases in absolute terms from RB.2 at Roos. Pollen of Hippophae is absent from both sites. The herbs contribute a fair proportion of the total pollen and the most abundant types represented by their pollen are Gramineae, Cyperaceae and also Artemisia and Thalictrum. Few herb pollen types are preserved in the zone HO.3 at Hornsea. Lycopodium selago spores occur at both sites.

At Brandesburton it is again difficult to trace a similar zone because of the method of presentation. However at the top of zone 'a' (The Late-glacial) pollen values of Gramineae, Cyperaceae, Artemisia, Helianthemum (absent from most of RB.3 and HO.3) and Thalictrum are substantial, and so seem to represent a similar pollen zone to RB.3 and HO.3. At Brandesburton, however, small amounts of Hippophae pollen occur at the top of the zone, at which levels Juniperus pollen reaches values of 100% arboreal pollen (Clark and Godwin, 1956).

These local pollen assemblage zones may be grouped into the regional pollen assemblage zone HLD. Betula nana/Juniperus. The type locality and zone is at the Bog, Roos, zone RB.3 10.85 - 9.35 m. The regional pollen assemblage zone may be briefly described as generally containing very little pollen, with herb pollen dominating what does occur. Juniperus

and Betula nana pollen are relatively important. The basal limit of the zone is the decline of tree Betula pollen values to below 50% of total dry land pollen, and the upper limit is the increase of tree Betula pollen values to exceed 50% of total dry land pollen.

Age

Both zones at Roos (RB.3) and Hornsea (HO.3) occupy a similar stratigraphic position, in water-deposited clay overlying the more organic horizon bearing the regional pollen zone HLD, (tree)Betula/Filipendula. Pollen zone RB.3 has been dated at Roos, where it lies between 11,220 ± 220 B.P. (Birm-406) and 10,120 ± 180 B.P. (Birm-405). This may therefore be taken as the time span for the regional pollen assemblage zone HLD, Betula nana/Juniperus.

Vegetation

The birch woodland present up to some time after 11,200 B.P. must have been drastically reduced and the vegetation opened up. Betula trees probably only persisted during this zone in the most sheltered places. Pinus was doubtless scarce, and possibly absent from the region, its pollen probably being contributed by long distance dispersal. The shrubs Betula nana and Juniperus became comparatively more important, but do not appear to have been dominant. Indeed, an incomplete vegetation cover may have prevailed, since the lake deposits are quite inorganic. Juniperus was uncommon around Roos and Hornsea, but appears to have been dominant in the Brandesburton area. It is possible that, in the absence of other trees and shrubs, Betula nana and Juniperus covered a fair area in prostrate form, flowering only sporadically. Hippophae only seems to have grown near to Brandesburton, or at least to have flowered only there. Helianthemum also grew near to this site, but scantily elsewhere. Herbs must have dominated the very open, sparse

vegetation of this millenium, particularly Gramineae and Cyperaceae, but also Artemisia and Thalictrum.

Climate

At about 11,000 B.P. the decline of woodland must represent a climatic deterioration of some kind. Betula nana and Juniperus, which increased comparatively (and absolutely in the case of Juniperus) are both hardy arctic tundra plants (Iversen, 1954), while conditions were presumably too severe for extensive birch woods. The herbs represented can all tolerate cold conditions, though they thrive in unshaded situations at higher temperatures, too. A few pollen grains of Filipendula, the plant of which is fairly thermophilous, occur in HO.3 but this zone contains so little pollen that nothing can reliably be deduced from this.

Hippophae was just about present in Holderness during the previous zone, being represented by pollen in zone HO.2 at Hornsea, but it was evidently unable to expand into the open vegetation of zone HLD. Betula nana/Juniperus. It must therefore be concluded that the climate was too severe for it, presumably because temperature was too low. As noted above, Hippophae does not flower above the tree line, which may therefore have passed during the early part of the zone. Hippophae is also intolerant of a heavy snow cover, and possibly increased precipitation at this time prevented its expansion. Perhaps it was present but sterile. However, it may be dangerous to try to establish the climate from a plant type which is absent.

A small amount of Hippophae and Helianthemum did grow near to Brandesburton. Bartley (1962) suggested that Helianthemum was inhibited by severe climatic conditions. It may be that while the climate was in general very severe at this time, a rather milder local climate

prevailed around Brandesburton enabling these plants to survive and flower there.

Soils

A decline in trees, in the range of herbs, and notably of Helianthemum might be evidence for declining base status of the soils, but climatic deterioration seems to have been the main cause. The soils of Holderness may well have become less stable, with an incomplete vegetation cover and under a severe climatic regime, probably with considerable frost action. If this was the case then new soil material would be continually exposed and the nutrient status maintained. The growth of some Helianthemum and Hippophae close to Brandesburton may reflect a rather different vegetation type on the drier sand and gravel patches of this area.

THE LATE-GLACIAL OF HOLDERNESS - A SUMMARY

After deposition of the Devensian tills, Holderness first developed a very open vegetation of tree birch, dwarf birch and a wide range of herbs, in uncertain climatic conditions on unstable soils. The very earliest vegetation successions may not have been found. At somewhat later than 13,000 B.P. a brief decline in woodland and comparative increase in some shrubs, notably Hippophae, and herbs followed perhaps as a result of drought rather than lowered temperatures. An open birch woodland spread later, perhaps as rainfall increased again. Low growing shrubs and many herbs grew with the birch on stable soils in a fairly equable climate. At some time around 11,000 B.P. there was the culmination of a climatic deterioration, which may really have begun a few centuries earlier. The woodland was reduced to leave an open, perhaps incomplete, vegetation dominated by the low shrubs and herbs with the climate apparently too severe for some of the plants previously present.

Throughout the Late-glacial period the meres of Holderness, including the Bog, Roos, Hornsea Old (and present) Mere, Tunstall (Gilderson Mere), Bitternboom Mere (at New Ellerby), and Mappleton Mere were all open water. Only the 'lake' at Grimston seems to have hada more terrestrial character at this time.

The Late-glacial period ended at just before 10,000 B.P. with an increase in tree growth in response to climatic amelioration (see below, chapter 8).

THE LATE-GLACIAL OF HOLDERNESS - ITS GEOGRAPHICAL SETTING

In broad outline the Late-glacial sequences within Holderness can be seen in resemble the threefold division of this period which has now been traced throughout north-western Europe. Such a succession was first discovered at Allerod in Denmark (Hartz and Milthers, 1901) where lake muds with cool temperature plant remains were found lying between clays with remains of the arctic-montane plant Dryas octopetala. The two clay layers, named the Older and Younger Dryas, were regardedas being formed during a severe climatic regime. The intervening organic layer, the 'Allerod' horizon, was thought to represent a milder period of climate, an interstadial within the Late-glacial time span. Similar deposits were found elsewhere on the continent (e.g. Van der Hammen, 1952; Krog, 1954; Muller, 1954).

This tripartite sequence was soon recognised at many sites within the British Isles (e.g. Jessen and Farrington, 1938; Conolly, Godwin and Megaw, 1950; Walker and Godwin, 1954; Kirk and Godwin, 1963) and the 'Godwinian' pollen zones I, II and III were, in general, taken to represent the British equivalent of the Older Dryas, Allerod and Younger Dryas respectively.

Since much variation has been observed between Late-glacial conditions at different sites in the British Isles it is most convenient to compare the Late-glacial of Holderness with that at other places within north-eastern England alone. Then some of the main features will be discussed in a wider context.

To ease the discussion, the Late-glacial is dealt with in three stages, referred to as Pre-interstadial, Interstadial and Post-interstadial. This is preferable to a possibly misleading, undefined use of either the Godwinian zones or the continental terminology. The Pre-interstadial represents the time before the main birch wood phase. It approximately corresponds to the Godwinian zone I, and the continental Older Dryas, and includes all Late-glacial time before about 12,000 B.P. The Interstadial represents the main birch wood phase, and may be compared with the Godwinian zone II, or the Allerod. It covers approximately 12,000 to 11,000 B.P. The Post-interstadial stage includes the last millenium of the Late-glacial, the period of sparse tree growth that followed the interstadial. It corresponds roughly to the Godwinian zone III, or the Younger Dryas. These three headings are not intended to be too strictly defined or limited.

The Pre-interstadial period

The very earliest Late-glacial deposits seem to be absent from Holderness. They were found at Tadcaster, in the Vale of York (Bartley, 1962) where tree birches were thought to have been absent at the opening of the Late-glacial, but to have expanded early on. Gramineae, Cyperaceae and other herbs dominated the pioneer vegetation. Bartley's pollen zone 'Ib' - above the earliest deposits, is strongly reminiscent of the RB.1a pollen spectra at Roos, with tree *Betula* pollen values at about 20% of total pollen, and *Betula nana* pollen contributing about 5%. At

Tadcaster a spread in birch woodland and a decrease in grassland was concluded to have occurred during better climatic conditions. This milder, more forested, period within the Pre-interstadial times is represented elsewhere in the north-east. At Star Carr, in the Vale of Pickering, at two sites examined a mild fluctuation was noted (Walker and Godwin, 1954), but here tree birches were thought to have been rare throughout this period. At Romaldkirk, in the lower Tees basin, no mention of vegetational change within the Pre-interstadial was made (Bellamy et al., 1966) but the pollen diagram produced shows a decrease in pollen values of Betula nana and herbs within the earliest zone, and suggests a similar oscillation to that further south. At Aby, in Lincolnshire, there was also a proportionate decrease in herbs in 'mid-zone I' (Suggate and West, 1959).

The decline of tree birch within Holderness after this milder period, and before the opening of the main interstadial (i.e. between 13,000 and 12,000 B.P.) is echoed at Tadcaster, Star Carr, Romaldkirk and Aby. If the milder period at these sites was synchronous it seems to have been followed by some sort of a climatic deterioration, perhaps only of a minor nature. In the rest of north-eastern England Juniperus expanded to dominate the vegetation at the end of the Pre-interstadial phase, although its pollen was not distinguished at Aby. In Holderness it was Hippophae which became dominant. The expansion of Juniperus at the close of the pre-interstadial phase at Tadcaster was mirrored by the spread of Hippophae within Holderness. It is the importance of Hippophae in Holderness rather than of Juniperus elsewhere, which points to a fairly dry climate with temperatures maintained at a level suitable for tree growth. It is possible that temperatures were rather higher or conditions somewhat drier in Holderness than elsewhere in north-eastern England at this time.

There is, therefore, much evidence for a fairly widespread vegetation and climatic oscillation within north-eastern England in Pre-interstadial times. At Roos it occurred at around 13,000 B.P. The lack of dates for the oscillation from other parts of the region makes its synchroneity unproven.

The Interstadial

Organic layers above the basal deposits containing pollen assemblages similar to those of the HLD. (tree) Betula/Filipendula zone occur throughout the north-eastern region. They have been assigned by their authors to the Godwinian zone II. Few radiocarbon dates are available for this zone outside Holderness, but at Aby the top of the zone was dated to 11,205 ± 120 B.P. (Q-279, Suggate and West, 1959). This is a very similar date to that from the top of the zone RB.2 at Roos, and to that obtained from the top of the peat at Grimston (Penny - personal communication). This assemblage zone can be taken to lie between 12,000 and 11,000 B.P. approximately.

At all of the sites mentioned above the vegetation became more wooded with Betula, and at most sites shrubs and herbs declined in comparison. This has generally been considered to be in response to a climatic improvement. This improvement may have been an increase in precipitation, and may be represented by the culmination of the expansions of Hippophae or Juniperus which possibly survived in dry late Pre-interstadial conditions, and then perhaps luxuriated in damper conditions for a short time before the slower expansion of tree Betula finally shaded them out.

The vegetation at this time varied somewhat from north to south, and with altitude. At the southernmost site, Aby, total Betula contributed about 50% of total pollen. It was considered to have represented a more significant woodland than these figures suggest because of local abundance

of Cyperaceae pollen. Further north, in the Plain of Holderness, tree Betula pollen represented over 50% and up to 80% of total dry land pollen, so birch woodland must have been extensive, if fairly open. At Tadcaster birch woodland was similarly dominant to that of Holderness. It is difficult to estimate the importance of the tree birches at Star Carr during the interstadial, as results were expressed as percentages of arboreal pollen, but they seem to have been quite significant.

Still further north, in the lower Tees basin, birch wood was less well-established, contributing only about 20% of the total pollen deposited at this time. At Cranberry Bog, County Durham, birch woods were barely developed by the end of the zone, all types of Betula contributing only 10 to 15% of total pollen (Turner and Kershaw, 1973). In Northumberland a lowland site near Bamburgh had birch woodland poorly developed at this time, and trees were thought to have been fairly scarce. Even less trees were present at a nearby site 200 feet (60 m) higher, and at this altitude the zone was contracted in time (Bartley, 1966).

The behaviour of Pinus demonstrates the same trend. It was considered to be locally present at Aby, probably so at Tadcaster and within Holderness; but the low pollen values of this taxon in all sites north of the North Yorkshire Moors suggests that it may have been quite absent in these more northerly parts.

Juniperus, able to withstand more severe conditions than Betula and Pinus, was more abundant further north, where Hippophae, always scarce in this zone, occurred sporadically in the more open conditions to the north of Holderness. There was also a corresponding increase in the importance of herbs at higher latitudes and altitudes.

The possibility of a climatic deterioration before the end of the interstadial, as suggested at Roos, with less, or more open, birch woodland and more shrubs and herbs, is given some support from the other sites. This is particularly so at Aby, where climatic deterioration before the end of the zone was thought to have caused a sharp decline of Pinus (Suggate and West, 1959). Such a demise of Pinus cannot be traced elsewhere, often because the Pinus pollen curve is confused by derived grains and long-distance dispersal. However at some sites, notably Roos, Tadcaster and Bamburgh, tree Betula pollen peaked early on during the interstadial and the herbs expanded later. At the higher sites near Bamburgh Juniperus reached its maximum spread at the end of the interstadial (Bartley, 1966). Without radiocarbon dates from these other sites it is difficult to decide how early the deterioration set in. The positioning of the pollen zone boundary itself will determine whether tree pollen values fall in the Godwinian zone II or III.

The Post-interstadial

The thinning out of birchwoods and the expansion of herbs within Holderness, dating from around 11,000 B.P. at Roos was attributed to climatic deterioration. The event and the ensuing cold period extending to about 10,000 B.P. in Holderness, has been noted elsewhere in north-eastern England.

Cyperaceae, Artemisia and Thalictrum increased in the Vale of York as tree Betula declined, while Betula nana held its importance. Juniperus, as in Holderness, was insignificant but Gramineae did not increase. This led to the conclusion that the tree line did not pass to the south of this area, though the birch woods must have been considerably thinned out (Bartley, 1962). At Aby, to the south, conditions were milder than in Yorkshire. Although the birch woods were opened up, and herbs expanded,

the presence of trees was established by macroscopic remains of tree Betula as well as of Betula nana, well after the dated horizon of 11,200 B.P. (Suggate and West, 1959).

To the north conditions were worse. The proximity of the tree line was suggested for the lower Tees basin (Bellamy et al., 1966) while in County Durham the herbs, especially Gramineae and Cyperaceae were very dominant components of the open vegetation (Turner and Kershaw, 1973). Further north no pollen was preserved in the deposits presumed to represent the last phase of the Late-glacial in Northumberland (Bartley, 1966).

Throughout the Late-glacial period the vegetation and climatic conditions in Holderness are seen to fit into the gradation of conditions from south to north in eastern England. The vegetation of Holderness must have been highly comparable with that of the Vale of York, to the west, throughout the Late Devensian, except for the substitution of Juniperus by Hippophae in Holderness. Woodland grew more luxuriantly in the somewhat milder conditions to the south, but only to a limited extent to the north of the North Yorkshire Moors, even during the milder periods of the Late-glacial.

FEATURES OF THE LATE-GLACIAL OF HOLDERNESS

The Pre-interstadial oscillation

The apparent oscillation of climate and vegetation of north-eastern England in pre-interstadial times is an intriguing feature of the Late-glacial. Such a phase occurred at Roos, Tadcaster, Star Carr, and possibly at Aby and Romaldkirk. Bartley (1962) tentatively correlated this oscillation at Tadcaster with a similar event within the Older Dryas on the continent. Such an early variation in pollen spectra, with an increase in pollen of tree Betula, has been demonstrated at Bollingso

and elsewhere in Denmark (Iversen, 1942, 1954), where a July mean temperature of a little over 10°C was postulated. It has also been recognised in Holland (Van der Hammen, 1952), in Belgium (Mullenders, Gullentops, and Crevecoeur, 1958), and Germany (Muller, 1953). It has generally been called the Bolling oscillation, and has been assigned dates of about 12,700 B.P. in southern Norway (Chanda, 1965) and about 12,450 B.P. in Holland and Denmark (Van der Hammen et al., 1967).

Where this phase occurred on the continent it was followed by a recession in tree growth, and therefore apparently of climate before the opening of the Allerod interstadial. In Denmark Iversen (1954) stated that tree Betula and Hippophae disappeared after the Bolling, and that in the ensuing tundra conditions the July mean fell below 10°C.

The pre-interstadial oscillation at Roos has a date of approximately 13,000 B.P. If, as seems likely, this represents the optimum of the oscillation found over much of north-eastern England, it cannot be easily equated with the Bolling, being 500 or so years earlier than this oscillation on the adjacent parts of mainland Europe. It is the 'Hippophae period' of Holderness which corresponds in date to the Bolling of Denmark, in which Hippophae was also fairly abundant (Iversen, 1954). If the Hippophae expansion of Holderness represents the Bolling oscillation then there was no deterioration of climate before the opening of the 'Allerod' period, just a shading out of Hippophae or Juniperus as the trees responded to increased wetness. In Denmark there does seem to have been a climatic deterioration after the Bolling, and the opening of the main interstadial, or Allerod, was probably quite sudden, with a marked increase in tree growth. The Allerod and Bolling oscillations thus appear to have been quite distinct on the continent, less so in eastern England.

This would leave the oscillation of 13,000 B.P. as a separate rather mild, possibly damp, period without correlation on the continent, and followed by drought rather than temperature decline. In the absence of other radiocarbon dates from eastern England it is unwise to try to correlate these oscillations too precisely.

In north-western England Late-glacial vegetation has been studied extensively. Pollen began to accumulate before 14,000 B.P. at Blelham, Lancashire (Evans, 1970) where pollen, diatom and cladoceran evidence supported a picture of cold conditions and an oligotrophic lake. Pre-interstadial oscillations have been identified in north-western Britain at some sites. The earliest was at Blelham where less open vegetation with more Betula occurred temporarily around 14,000 B.P. (Evans, 1970), a much earlier date than that for the first Betula expansion at Roos, or for the continental Bolling. Other fluctuations in vegetation, and presumably in climate, have been found at Haweswater (Oldfield, 1960) and possibly Cumberland (Walker, 1966) but both phases are undated. There is some evidence for an early temporary increase in both tree Betula and Betula nana at Dalton-in-Furness, Lancashire, thought possibly to represent the Bolling oscillation 'at 12,200 to 12,700 B.P.' (Johnson et al., 1972). A similar pre-interstadial oscillation has also been noted in central Wales (Moore, 1970).

Pennington (1970) has doubted the validity of many of these supposed pre-interstadial oscillations, agreeing with Davis and Deevey (1964) that many rely on flimsy evidence and may be the result of statistical artifacts rather than real vegetational changes. For one of the 'Kettle-holes' at Blelham an absolute pollen deposition diagram for the Late-glacial has been produced (Pennington and Bonny, 1970). At this site there was a very small amount of pollen deposited before 13,000 B.P., and the little

that was contributed was mainly of Gramineae, Rumex, and other ruderals. At about 13,000 B.P., when pollen incorporation began at Roos, there was a tenfold increase in pollen deposition at Blelham. As at Roos, most types expanded, but especially Betula. The expansion at Blelham was not followed by a decrease prior to the main interstadial, as happened at Roos, where birchwoods were thinned out just after 13,000 B.P. At Blelham Betula increased to dominance after an early expansion of Juniperus, which was quicker to respond to the climatic amelioration. The warmest temperatures are thought to have been during the earliest part of the 'main interstadial'. The idea of the 'interstadial' comparable to the Allerod comes to mean very little now. It was suggested that in the West the amelioration began before the Bolling and that the Bolling and Allerod of the continent were merged into one interstadial event, because of the more oceanic conditions of western Britain.

At both Roos and Blelham sediment accumulation proceeded at a very slow rate during the Pre-interstadial phase. In both cases the rate was slower than that during the Interstadial and Post-interstadial periods. In Holderness the Late-glacial sediment accumulation rate seems to have been greatest during the Post-interstadial phase when frost action was important and ground cover sparse, allowing much inorganic material to be washed into the basin. In the Interstadial period there was a considerable organic contribution to the sediments. During Pre-interstadial time both of these contributions seem to have been smaller - a state of affairs which would add weight to the idea of limited erosion by solifluction etc., because temperature was too high, and yet a limited expansion of vegetation, due to drought.

Evidence from the occurrence of fossil Coleoptera in Late-glacial

deposits of the north-west has tended to support this latest evidence. Coope (1970), and Coope and Brophy (1972) have studied Coleoptera fossils from North Wales, the Isle of Man, and the west Midlands. By comparing the modern distribution of types present as fossils they have estimated Late-glacial temperature changes. These Coleoptera are not selective eaters, and can migrate into new areas much faster than trees, and so respond very quickly to a change in climate. In the pre-interstadial pollen zone several Coleoptera occurred which today have a range in southern Europe. Coope and Brophy therefore suggested an early climatic amelioration, at or before 13,000 B.P., to warm conditions with a July mean temperature of up to 16 or 17°C in lowland Britain. They found no evidence for a deterioration of climate before the main interstadial, or birchwood phase.

Thus the evidence supports the idea of amelioration in both north-western and north-eastern England at about 13,000 B.P. In the eastern part of the country woodland was then checked, while its expansion continued in warm conditions in the West. If the Coleopteran evidence that there was no temperature decline is taken to apply to eastern England as well as western Britain, this check of Betula expansion can best be explained by dryness. Coleoptera might not be as adversely affected by a drought as the trees were and so the apparently conflicting Coleoptera and pollen evidence may not be paradoxical at all. Conditions on the continent and in eastern England, with much of the North-Sea dry land, would have been far more 'continental' than in western England where a moister 'oceanic' climate did not check tree growth at all. The Bolling amelioration of the continent may have been contained within the dry period of eastern England, but obscured by the constantly oceanic climate of western England. Perhaps the still more continental conditions of mainland Europe compared with eastern, and

especially western Britain meant that a further temporary climatic deterioration before the opening of the Allerod period (Iversen, 1954), could only be traced on the continent. Less extensive, local oscillations of vegetation and climate may have occurred sporadically in several places at different times. The main, regional changes, however, seem to have been most marked on the European mainland and to have been weakened or obscured by the more oceanic climates further west.

Climatic change during the main Interstadial

The main interstadial period was probably one of generally similar vegetation throughout north-western Europe, and was broadly synchronous. On the continent it has been termed the Allerod period, and this name has been used for similar pollen assemblages in British deposits. In Denmark, as in north-eastern England, there was a vegetation dominated by tree birch, thermophilous aquatics and shade-tolerant plants such as Solanum dulcamara grew. A July mean temperature of 13 to 14^{0}C was considered likely (Iversen, 1954).

In western Britain the opening of the main interstadial has been dated to about 11,900 B.P. at Windermere (Pennington, 1970), and it was a period dominated by birch woodland in lowlands of the West (e.g. Johnson et al., 1972; Oldfield, 1960). As in eastern England there was a decrease in the dominance of tree birches from south to north and with increasing altitude (Pennington, 1970).

Pennington (1970) suggested that the temperature reached a maximum early on during the zone, as may have been the case in Holderness. However the spread of Betula trees at most sites, maintained until around 11,000B.P. or 10,800 B.P. in Denmark (Krog, 1954), has usually been taken to demonstrate moderately high temperatures during this whole period.

Coope (1970) found the same Coleoptera as occur in northern Britain today in deposits dated to 12,000 B.P. At higher levels within deposits of the interstadial phase he identified Coleoptera of a decidedly more northern range at the present time. He considered that the temperature declined throughout the interstadial period from a July mean maximum of 16 to 10^{0}C at the close of the interstadial, at about 11,000 B.P. He concluded that only during the later half of the interstadial would temperatures have been low enough to suppress the birch woods.

There is some scanty pollen evidence to support this hypothesis. A possible deterioration of climate at Roos has been alluded to above, from the steady decline of birchwood and increase in herbs after about 11,500 B.P. As noted above (Pennington, 1970) maximum temperatures were thought to have occurred early in the zone. Climatic decline during the main interstadial has also been described from Aby, Lincolnshire (Suggate and West, 1959) where Pinus suffered (see above), and in the Netherlands where the Allerod was represented by a 'birch forest time' followed by a 'pine forest time'. The change was thought to be due to a rise in sea level and consequent increased oceanicity (Van der Hammen, 1952).

Some factors of inertia may have delayed the suppression of the birch woodland during a decline of temperatures in interstadial times. Such a deterioration of climate, if not as marked everywhere as suggested by the Coleopteran evidence, seems to have been a real phenomenon over a widespread area, and is given mild support by pollen evidence.

The Post-interstadial

Whatever variations in conditions occurred during the pre-interstadial and interstadial phases of the Late-glacial, it is quite clear that vegetation and climate were very similar throughout north-western Europe during its last millenium -from about 11,000 B.P. to 10,000 B.P. This

post-interstadial period was termed the Younger Dryas on the continent, and was represented by severe climatic conditions in which a sparse tundra-like vegetation covered most areas. Conditions may have remained oceanic enough for Empetrum (Brown, 1971) and Sphagnum in the Netherlands (Van der Hammen, 1952), while some tree Betula probably survived in southern Denmark and Pinus survived on Bornholm (Iversen, 1954).

In western England absolute pollen deposition decreased greatly after 11,000 B.P. (Pennington and Bonny, 1970), as was the case in Holderness. At all western sites investigated trees declined in importance, and the herbs formed an open, perhaps incomplete, vegetation cover (e.g. Pennington, 1970). There is some evidence of a temporary amelioration at Blelham (Evans, 1970) but this has not been observed elsewhere. It has been suggested that trees and shrubs persisted through this cold period only in sheltered valleys (Oldfield, 1960).

Many of the fossil Coleoptera extracted from post-interstadial deposits in western Britain were of an alpine or tundran nature. From these a mean July temperature for the middle of the period of 10°C has been estimated (Coope, 1970; Coope and Brophy, 1972).

Thus all the evidence points to severe climatic conditions and sparse vegetation on unstable soils at the end of the Late-glacial period over a very wide area. Coleoptera appear to pre-date the vegetation in their response to ameliorating climate at the close of the Late-glacial (Coope, 1970; Coope and Brophy, 1972). Their more rapid response is to be expected, and serves as a herald to the ensuing Flandrian period.

CHAPTER 8

THE EARLY FLANDRIAN PERIOD OF HOLDERNESS

INTRODUCTION

The early Flandrian period is regarded here as occupying the time between the opening of the Post-glacial period and the decline of Ulmus pollen in the analyses from Holderness. In other words it covers the approximate time span from just before 10,000 B.P. to about 5,000 B.P.

The pollen assemblages

Zone RB.4 at Roos is characterised by arboreal pollen values of up to 80% of total dry land pollen. It is dominated by Betula (tree species) pollen, with low values of Pinus. Ulmus, Quercus and Corylus pollen is present in small amounts, values of Betula nana and Juniperus decline to zero. Many herbs are represented by small, declining, amounts of pollen. Filipendula pollen values reach a peak within this zone, but the values decline above this peak. Absolute pollen deposition and pollen frequency seems to be low during this zone, as it is in the corresponding zone HO.4 at Hornsea, in which the pollen percentages of the trees and Corylus are very similar to those at Roos. However at Hornsea Alnus pollen is also present in small amounts. Juniperus pollen is very poorly represented here. Herb pollen values decrease during the zone, as at Roos, but the brief peak of Filipendula pollen values occurs at both sites.

At Brandesburton (Clark and Godwin, 1956) a somewhat similar pollen assemblage occurs in the lower half of the described 'zone b', with much Betula, little Pinus and Corylus pollen, and a wide range of herb pollen types with Filipendula abundant for a part of the zone. At this site pollen of Ulmus and Quercus is absent from the zone while a little Alnus occurs. Juniperus pollen values decline sharply and a trace of Hippophae pollen is present (see figure App. 1.).

These local pollen assemblages may be grouped into the regional pollen assemblage zone HLD, Betula/Pinus with its type locality and zone at the Bog, Roos zone RB.4 9.35 - 8.95 m. The assemblage zone may be briefly described as being dominated by arboreal pollen, preponderantly of Betula with a little Pinus. A range of herb pollen type occurs, notably Filipendula. The lower limit of the zone is where tree Betula pollen values rise above 50% of total pollen, the upper limit is the base of rapid increase of Corylus pollen values. Absolute pollen deposition during the zone is at a low level.

Pollen assemblage zone RB.5 at Roos is distinguished by very high values of Corylus pollen with Betula, Ulmus, Pinus, Quercus, and at higher horizons Alnus and Tilia pollen present in varying amounts, and with herb pollen scarce. Absolute pollen deposition appears to increase dramatically at the base of the zone and then hold fairly high values. This applies whichever of the two sedimentation rates is chosen. Local pollen assemblage zone HO.5 at Hornsea can be seen to correspond, but only in the broad outlines. Absolute pollen deposition increases during the zone, but to values considerably lower than at Roos. Pollen frequency in HO.5 is at only about one sixth of the values for Roos. Hθ.5 has high pollen values of Corylus, but these are generally much lower than at Roos, both in percentage and absolute terms. Absolute values of Corylus in HO.5 are between one third and one seventh of the values in RB.5 (depending on the sedimentation rate chosen for Roos). Absolute deposition of total tree pollen is similar to that at Roos (when the lower sedimentation rate is used), but whereas RB.5 can be divided into sub-zones dominated by different arboreal pollen types of a) Betula, Pinus and Ulmus; followed by b) Ulmus; and then c) Ulmus and Quercus; HO.5 shows a less clear succession of Betula, Pinus, Ulmus and Quercus pollen. At Hornsea Alnus pollen is present, generally at values below 5% of arboreal

pollen, throughout this zone, whereas at Roos Alnus and Tilia pollen are absent except in the very top horizons of RB.5. At both sites herbs are scarcely represented by pollen.

Zone GQ.1 at Gransmoor corresponds to RB.5 and HO.5. It contains quite high values of Corylus pollen, with Pinus, Betula, Ulmus and Quercus as the main arboreal types. Alnus pollen is absent except at the top. Pollen of Gramineae and Cyperaceae and spores of Filicales are more abundant than at the other sites. The very low values of absolute pollen deposition here can be explained by local characteristics (chapter 6).

A similar assemblage is scarcely represented at Brandesburton. Corylus pollen values begin to rise at the top of 'zone b' but do not reach very high percentages. Pinus pollen values increase as those of Betula decline. As Quercus and Tilia pollen appears and Alnus pollen values increase there is an apparent stratigraphic non-conformity, thought to be due to drying out of the site and erosion of some of the deposits. This makes it more or less impossible to identify a similar zone here. The lowermost couple of samples from the small Skipsea Whitow mere, now exposed in the low cliffs of northern Holderness, probably represent a similar zone to RB.5 and HO.5. Betula, Pinus and Ulmus, with lower values of Pinus pollen and little or no pollen of Alnus and Tilia occurs. Corylus pollen values lie at around 200% of arboreal pollen. No herb pollen was described (Godwin and Godwin, 1933) (see figure App.2).

These local pollen assemblage zones may be grouped into the regional pollen assemblage zone HLD. Corylus/Ulmus with its type locality and zone at the Bog, Roos, zone RB.5 8.95 - 4.75 m. The regional zone may be briefly described as being dominated by high values of Corylus

pollen; plentiful Ulmus, Pinus, Quercus and Betula pollen, and very little herb pollen. Its lower limit is the rapid rise of Corylus pollen to values over 100% of arboreal pollen, and its upper limit is the base of the expansion of Alnus pollen values (usually coupled with a decline of Corylus percentages). Absolute values of pollen frequency and deposition vary considerably between sites.

The percentages of Alnus pollen increase markedly in both zones RB.6 at Roos and HO.6 at Hornsea. Both zones also show great similarity in many other features. The percentage values of the other arboreal pollen types decline as Alnus pollen increases; this is notably so for Betula and Pinus. Quercus pollen suffers to a lesser extent, while Ulmus pollen values decline steadily throughout the zone at both sites. Tilia pollen values increase and Fraxinus pollen appears for the first time. Corylus pollen values decline to between 50 and 100% of arboreal pollen; while Hedera pollen occurs consistently, herb pollen is scarce.

The absolute pollen deposition values, however, show considerable differences between Roos and Hornsea. Which of the two sedimentation rates is chosen for HO.6 makes little difference to the absolute pollen deposition values. At Roos there is a great variation in pollen deposition values for RB.6, depending on the sedimentation rate chosen. The higher sedimentation rate seems to be closer to the truth (see chapter 4). Applying this higher sedimentation rate at Roos total pollen deposition is lower in RB.6 than in RB.5, while at Hornsea it is higher in HO.6 than in HO.5. Total pollen deposition is similar in RB.6 and HO.6, but frequency is higher in RB.6. At both sites the deposition of arboreal pollen appears to increase. At Hornsea Corylus pollen values remain as in HO.5 but at Roos the decrease of absolute pollen values of this genus in RB.6 accounts for all of the decrease in total pollen deposition.

Absolute deposition of Corylus pollen is similar for both sites (between 2000 and 4000 grains/cm^2/year). Alnus pollen deposition is greater in the 'extended' zone HO.6 at Hornsea than in the stratigraphically short zone RB.6 at Roos. In absolute terms, as in percentage terms Betula and Pinus pollen decline somewhat. Quercus pollen shows a slight increase at Hornsea, but a slight decrease at Roos. The absolute values also suggest that Ulmus pollen values decline throughout zone RB.6 but only at the top of HO.6. Tilia pollen increases in absolute terms. If the lower sedimentation rate is applied to RB.6 total pollen deposition values are much lower than in HO.6 at Hornsea. Even Corylus values are reduced to about a quarter of those in HO.6.

The pollen assemblage zone GQ.2 at Gransmoor corresponds to RB.6 and HO.6 in that it is the zone in which Alnus pollen expands, in that Betula, Pinus, Ulmus and Quercus pollen hold somewhat smaller values and Fraxinus pollen appears. As elsewhere Corylus pollen percentages fall and herb pollen is scarce. However it differs drastically in that it is dominated by the pollen of Tilia cordata, which increases from the base of the zone to hold values of 50% of arboreal pollen, or more. Absolute pollen deposition values are still very low in this zone.

'Zone d' at Brandesburton also has arboreal pollen dominated by Alnus to a similar extent to RB.6 and HO.6. Betula and Pinus pollen values decrease while Quercus pollen is only sparsely represented, but that of Ulmus is almost absent. Corylus pollen declines, some Hedera pollen occurs and only a few herb types are represented. Here also Tilia pollen is an important arboreal constituent, increasing to 20 - 40% of arboreal pollen. The zone resembles GQ.2 at Gransmoor in this respect, and also in the abundance of Filicales spores.

A similar pollen assemblage is represented by most of the lower half

of the pollen diagram from Skipsea Whitow (Godwin and Godwin, 1933), where Alnus represents about 50% of arboreal pollen. Quercus pollen percentages are secondary, Ulmus pollen is common but that of Betula and Pinus is scarce. Here Tilia pollen is poorly represented. Corylus values lie at 50 to 100% of arboreal pollen. This assemblage is more comparable to RB.6 and HO.6 than to the similar zones at Gransmoor and Brandesburton.

A somewhat similar pollen assemblage has been described from a peat bed at Barmston, at the site of a Bronze Age crannog (Varley, 1968). The results of this analysis, however, are not very clear, and so have been excluded from this discussion.

These local pollen assemblages may be grouped into the regional pollen assemblage zone HLD. Alnus/Ulmus with its type locality and zone at the Bog, Roos, zone RB.6 4.75 - 4.05 m. The regional zone may be briefly described as being dominated by arboreal pollen, chiefly of Alnus but also with fairly abundant pollen of Ulmus and Quercus and quite plentiful Corylus pollen. Herb pollen is scarce. The lower limit of the zone is the base of the expansion of Alnus pollen values and the upper limit is the decline of Ulmus pollen percentages to below 5% of arboreal pollen.

Age

Only three radiocarbon dates have been obtained for this period within Holderness. They do serve to delimit the extent of these pollen zones. The date of 10,120 ± 180 B.P. (Birm-405) from Roos lies towards the base of RB.4. Of the two dates from Gransmoor the earlier, 8507 ± 55 B.P. (SRR-230) lies just below the top of pollen zone GQ.1, while the later date, 5099 ± 50 B.P. (SRR-229) lies at the top of zone GQ.2 and marks the close of the early Flandrian period.

Sedimentation and pollen incorporation

For the whole of the early Flandrian period the sedimentation rate at Hornsea and Roos, both of which were open water, was fairly similar. During the Betula/Pinus pollen zone sedimentation was slow, but it was twice as fast at Hornsea as at Roos. At Hornsea the stream would have contributed inorganic matter from erosion within the incompletely vegetated basin. At both sites the sedimentation rate may have varied during this zone, but on average it was less than later on, so erosion cannot have been very great at this time. However, the higher 'density' of the sediments of this Betula/Pinus zone demonstrates their partly inorganic mature.

It is difficult to be certain about the sedimentation rates for the rest of the early Flandrian period, because of the lack of radiocarbon dates. The rate as a whole as greater than during the Betula/Pinus zone because of the increased contribution of organic matter. In the Old Mere at Hornsea sedimentation was probably fairly consistent for this period. At Roos the position is far less clear. Local pollen assemblage zone RB.6 is limited in depth, and therefore sedimentation may have been much slower than in HO.6, but it is possible that RB.6 was also of shorter duration than HO.6. At Roos the lake was shallowing at this time and so the sedimentation rate was probably changing somewhat. If the sedimentation rate had shlowed down a lot the pollen frequency in the sediments might be expected to be very high, but the frequency is fairly similar to that in RB.5 (except for one exceptional sample). Therefore RB.6 possibly covered a shorter time span than HO.6.

Despite the overall sedimentation rate for the early Flandrian being comparable, and the pollen deposition values being fairly similar (apart from Corylus and Alnus) at the two sites, pollen frequency per gram dry weight was much higher at Roos than at Hornsea. This is a result of the

greater density of the Hornsea sediments (about double that of those at Roos), which reflects their more inorganic nature, with erosion products being brought into the lake from the catchment by the stream. At Roos there was no inflow stream and consequently very little inorganic material was introduced into the sediments.

The main difference in the pollen deposition values between these two sites is the amount of Corylus during the Corylus/Ulmus zone, much more Corylus pollen being deposited at Roos. Apart from this pollen deposition was fairly similar - so there was no great advantage to pollen incorporation by stream influx of pollen at Hornsea, except in the case of Alnus which presumably grew on stream-sides and contributed much pollen to them. Rather the smaller lake (Roos) gained by having a massive aerial contribution of pollen of Corylus, which perhaps was growing so as to overhang the lake.

The low sedimentation and pollen deposition rate during the early Flandrian period at Gransmoor, is probably a reflection of the rather allocthonous, and possibly intermittent nature of the deposits there.

Vegetation

The pollen evidence demonstrates the development of closed forest throughout Holderness, from the opening of the Flandrian period.

At some time before 10,100 B.P. the open vegetation of the Late-glacial was replaced by spreading birch woodland throughout the area. Although this woodland shaded out the lower growing shrubs and herbs fairly quickly, Filipendula was able to accomplish a widespread, but temporary expansion. Before the trees spread Juniperus was not an important component of the vegetation, but it and Betula nana were soon shaded out by the tree Betula. Juniperus was only abundant around

Brandesburton where Hippophae also grew, perhaps on rather sandy or gravelly patches. While Betula dominated the woodland, other trees appeared. Pinus was doubtless present with some Ulmus and Quercus which arrived soon after 10,000 B.P. They may not have reached the immediate vicinities of Brandesburton and Hornsea until some time later, but close to Roos they were present from this early date. As Ulmus and Quercus appeared at Hornsea Alnus also arrived, probably growing on the damp margins of the mere and on the banks of streams draining into it. It appeared early on at Brandesburton also, where damp marginal conditions would have prevailed. The absence of a marshy edge to the steep-sided site at Roos may well have precluded Alnus from the immediate vicinity of the site until much later. This would explain the absence of its pollen from these deposits.

Very early in the Flandrian period absolute pollen deposition was possibly only in small amounts. As pointed out above it is difficult to estimate absolute pollen deposition for this time when sedimentation rates were probably changing rapidly. If the low figure is valid it perhaps suggests fairly open woodland conditions. Pollen frequency and deposition values are more variable for this zone at Roos than at Hornsea. This may be because the more regional contribution of pollen to the sediments at Hornsea removed the effects of local variations, evident at Roos.

Absolute pollen deposition increased as Betula lost its dominance of the woodland, which became more diversified, closed and dense. Betula did not decline in real terms for some time as Pinus and Ulmus spread. Quercus was more abundant around Hornsea than around Roos early on. In the area of Roos Ulmus became dominant as Pinus and Betula declined somewhat, before Quercus became really significant. Such a clear succession in forest development cannot be traced so easily from the

Hornsea pollen diagram, and in this area Pinus, Ulmus and Quercus seem to have spread more or less simultaneously. Alnus was also present around the edge of the Old Mere, yet still absent from the kettle-hole rim at Roos. The Betula, Pinus and Ulmus woodland, with some Quercus surrounded Gransmoor well before 8,500 B.P. Here Alnus was absent until after this date, despite the fact that it might be expected to have been locally abundant here as early as it was at Hornsea. The damp valley conditions which probably prevailed would have suited it well. The poor preservation of the lowermost pollen assemblages at Gransmoor may mean that some Alnus pollen was destroyed, but there is no evidence for its presence before 8,500 B.P.

This period of forest succession was characterised throughout Holderness by the considerable growth of Corylus. It was abundant all over the plain, including the area around Brandesburton, where the period is only scantily represented by pollen deposition. The beginning of pollen deposition at Skipsea Whitow was at a time when Corylus was an important constituent of Betula, Pinus, Ulmus and Quercus woodland. The contrast in the amounts of Corylus pollen at this time between Roos and the other sites yields evidence of its behaviour. At Roos absolute deposition of Corylus was massive. It must have grown very locally, and in abundance. At Hornsea, Gransmoor, and where this zone (HLD, Corylus/Ulmus) is represented at Brandesburton and Skipsea, Corylus contributed less pollen, but still a considerable amount, to the assemblages. It was probably able to thrive on the drier ground of Holderness, and therefore especially on the higher rim around the Bog at Roos. Although abundant throughout Holderness, Corylus was prevented from growing close to the other pollen-collecting sites by the dampness of their margins, where Alnus was more suited to the conditions. If Corylus only formed an understorey to the forest it is surprising that it should have contributed

so much pollen. It is perhaps more likely that it grew on land as yet uncolonised by the taller trees, and immediately around the rim of the site at Roos.

The percentage diagrams from both Roos and Hornsea show the spread of Alnus to be after the Corylus maximum and during (or towards the end of) the part of the diagram with high percentages of Quercus; Pinus and Ulmus. The absolute diagrams (both pollen frequency and deposition), however, suggest that the behaviour of Alnus might have been different at the two sites and that the apparent similarity of the percentage diagrams could be merely a result of the constraints of percentage calculations. At Hornsea, in absolute pollen deposition terms, Alnus spread during the Corylus maximum and before the peak values of Quercus, Pinus and Ulmus. At Roos, the absolute diagram shows the Alnus expansion to be after the Corylus maximum and after the maximum deposition values of pollen of Quercus, Pinus and Ulmus. This applies whichever sedimentation rate is chosen.

In addition to this the sedimentation and pollen frequency evidence support the idea of a later Alnus expansion at Roos (see above). The date of the Alnus expansion cannot be fixed with certainty for these two sites, but was probably at or just before 7,500 B.P. at Hornsea, and well after that date at Roos. If the constant sedimentation rate is applied to zones RB.5 and RB.6 at Roos, as seems appropriate, then the Alnus expansion is dated at around 5,600 B.P. This seems extremely late when compared with Hornsea. It may be very much a local phenomenon. If the rim of ground around Roos was covered by dry-land trees, Alnus pollen might be prevented from reaching the site. If Alnus was growing abundantly around Hornsea as early as 7,500 B.P. it seems highly unlikely that it should not grow on the low lying carr-lands close to Roos soon after this date. Its pollen may only have appeared abundantly in the

spectra at Roos when Alnus grew on the shallowing margins of the Bog itself, and later when there was some clearance of the surrounding rim to allow pollen from a greater area to contribute to the deposits at the site.

Throughout Holderness as a whole, therefore, it seems possible that Alnus expanded considerably earlier than is apparent from the Roos pollen spectra. Whereas it was formerly restricted to a few damp watersides it became more widespread, being well represented around all of the other pollen deposition sites. It was probably still most abundant on the damper land. The absolute pollen values of Alnus at Hornsea are much higher even than those during the short peak of Alnus at Roos. This must represent the result of the combination of several factors. At Hornsea Alnus grew abundant on the margin of the mere, the inflow stream contributed pollen from riparian Alnus in the catchment, and the aerial pollen contribution, being of a more regional nature than that at Roos, brought more Alnus pollen from other damplands within the plain.

The forest composition showed other changes as Alnus became a dominant tree in the landscape. Betula and Pinus grew less abundantly throughout. Ulmus and Quercus seem to have been scarce around Brandesburton, but the drying out of the deposits here may have confused the issue. Absolute pollen values of Quercus seem to have been greater at Hornsea than at Roos. If it grew very close to Roos, as seems likely, it is odd that this should be so. The difference may be due to the different pollen-collecting character of the sites, with more Quercus pollen entering the Old Mere deposits because of stream influx, and from the large regional aerial pollen contribution. In the now closed forest the light-demanding Fraxinus was only rarely present.

Tilia cordata spread at the same time as Alnus pollen values expanded

at Roos, but well after the spread of Alnus at Hornsea (and presumably elsewhere). It became a fairly important forest constituent, probably on rather drier, richer soils. While not being excessively significant in the vegetation of eastern Holderness, considerable quantities of Tilia pollen were deposited at Brandesburton; and at Gransmoor pollen of this tree dominates the spectra. What this means in terms of vegetation is not altogether clear.

As discussed in chapter 6 Tilia pollen is resistant to decay, and at both Gransmoor and Brandesburton selective destruction of other pollen types may have occurred. The very low values of total pollen deposition in absolute terms may reflect this but may just be due to inconsistent deposition in the valley site. More Tilia pollen was deposited per year at Roos and Hornsea than at Gransmoor, but this is so for all pollen types and may be a result of the different pollen-collecting character of the site rather than poor preservation of pollen. Since, apart from Tilia, the pollen diagrams for this zone from Gransmoor and Brandesburton coincide with those from elsewhere in Holderness, pollen destruction was probably not too important. If destruction had occurred one would expect it to have been selective and therefore for all of the tree pollen types to have responded differently and so to have produced very abnormal percentages. Here it is only the Tilia percentages which seem distorted. Percentages of Ulmus and Quercus pollen are somewhat more distorted at Brandesburton than at Gransmoor, so some pollen destruction may have occurred at this more southerly site.

It may perhaps be assumed that Tilia cordata was a more important component of the vegetation near to these two sites than elsewhere in Holderness. Since Gransmoor and Brandesburton lie in the more western parts of the plain, and the former site lies very close to the Wolds it

is conceivable that the pollen values at these sites represent Tilia cordata growing on the calcareous Wolds. However, Tilia pollen is generally poorly dispersed (Janssen, 1966) and unlikely to be transported the distances from these hills in such numbers. It seems likely, therefore, that Tilia was present locally around Gransmoor and, perhaps, Brandesburton, probably within the valleys enclosing these sites. This problem is discussed more fully below.

Hedera was present in Holderness during the 'Hazel period' but occurred more widely and consistently after the expansion of Alnus. Although it contributed little pollen its position below the tree canopy would depress pollen dispersal from it. It was probably quite a frequent plant of the diverse forests.

In such dense woodland conditions herbs must have been severely restricted; with sedges, grasses and a few ruderals surviving in openings at the edges of the meres, or close to the Humber estuary in the south. Towards the end of the early Flandrian period, that is just before 5,000 B.P., a few herbs of open habitats, such as Chenopodiaceae, appeared in very small quantities. They were not abundant enough to signify any substantial opening up of the forest.

Climate

The development of rich and varied forest in place of the sparse, open tundra-like vegetation at the close of the Late-glacial period reflects a distinct amelioration of climate. A rise in average and winter temperatures must have occurred as cryoturbation and solifluction ceased, with lake deposits becoming richly organic. This increase in temperature allowed birch woodland to expand quickly and extensively. How sudden and how marked this increase was, is not clear. Tree species of Betula were probably already present in a few sheltered places and so

able to respond fairly quickly. Conditions may have been suitable to support the more warmth-demanding trees from a very early time, but such trees could not have migrated in as quickly as Betula did in response to the amelioration. Of these types Corylus soon expanded, as did Pinus. Quercus and the more thermophilous Ulmus arrived fairly early and expanded. Alnus was present quite early in some places, but expanded later at somewhat variable times. The later presence of Tilia, in particular, demonstrates the mildness of the climate. It is the most thermophilous of native British trees (Godwin, 1956). The drying out of deposits at Brandesburton has been interpreted as demonstrating a dry climate for at least a short period of time (Clark and Godwin, 1956). Evidence for this is not really forthcoming from elsewhere in Holderness, unless in comparison with later times, probably at or after 7,500 B.P., when Alnus increased dramatically around Hornsea and possibly throughout much of the area. It may be that the last two millenia of this early Flandrian period suffered increased rainfall and a rise in ground-water levels, providing wide expanses of damp land in the low-lying plain for Alnus to thrive on.

That temperatures were maintained at fairly high levels at this time is shown by the increase of Tilia and by the widespread presence of Hedera. Iversen (1944) reasoned that this climber does best in oceanic conditions and is sensitive to the low winter temperatures of a continental climate. Its northern and eastern limits at the present time for normal growth in northern Europe are set by mean temperatures for the coldest month being above - 1.5°C.

Soils

As outlined above, lake deposits became organic at the opening of the Flandrian period, as major frost disturbance ended. The more stable soils

were able to support a tree cover as they matured. Expansion of many tree types may have been initially limited not only by migration but by the early immaturity of the soils. The calcareous nature of the boulder clay soils may perhaps be part of the explanation for the abundance of Corylus. Leaching of soil nutrients must have begun as the soils matured but there is no vegetational evidence for a decline in soil base-status before 5,000 B.P. Nutrient-demanding species such as Ulmus and Tilia were able to thrive. Most of the area was covered by soils formed on boulder clay, with occasional lighter soils on the patches of gravel. Some western valleys, as at Gransmoor, may have been rather more calcareous due to their proximity to the Wolds, and these richer alluvial soils may have supported Tilia in some abundance. Low-lying soils may have become waterlogged later in the period as deposition in newly water-filled depressions began in some places, for example at Skipsea and Gransmoor, and Alnus spread as a result.

The influence of man

There has been some evidence for the presence of Mesolithic man in Holderness. Spear heads of a Maglemosian culture have been found at Brandesburton, Skipsea, and on the foreshore at Hornsea (see chapter 2). The antler spear from Hornsea was thought to be of an earlier date than the bone spears of Brandesburton and Skipsea (Clark and Godwin, 1956).

These Mesolithic people were probably hunters and fishers, and the pollen diagrams show little evidence for any great influence on the vegetation. Perhaps immediately before 5,000 B.P. a steady decline in Ulmus and the rare appearance of a few ruderals may reflect the presence of man in small numbers. The decline of Corylus pollen values at an earlier date at Roos might reflect some clearance by Mesolithic man of the immediate rim of the site, but there appears to have been no complementary

expansion of herbs, to support this idea. On the whole, therefore, man had little effect on the early Flandrian vegetation of Holderness, unless Rawitscher's (1945) assertion that the abundance of Corylus was due to the burning of forest by Mesolithic man to aid hunting, is upheld (see below).

THE EARLY FLANDRIAN OF HOLDERNESS IN ITS REGIONAL SETTING

The early post-glacial development of forest showed a general uniformity throughout the British Isles (Godwin, 1940a, 1956) and Western Europe (e.g. Iversen, 1960; Van Zeist, 1955; 1958). For the British Isles Godwin described four zones for this period from IV to VIIa, demonstrating the succession of species in the increasingly diverse and thermophilous forest. In very brief outline zone IV was characterised by Betula dominance and the survival and temporary increase of many Late-glacial plants such as Juniperus, Filipendula and other herbs. This zone roughly corresponds to the Pre-Boreal period of Blytt and Sernander (Sernander, 1908). Zone V showed increases in Pinus and Corylus, while zone VI, often subdivided, was characterised by high Corylus values, a succession of Pinus, Ulmus and Quercus, and the later arrival of Alnus and Tilia. These zones V and VI together more or less correspond to the Boreal period. The Atlantic period of Blytt and Sernander is equivalent to the Godwinian zone VIIa with high pollen values of Alnus, Quercus and a range of mixed deciduous forest types, and generally considered to represent the Flandrian climatic optimum.

The vegetational sequences in Holderness can be seen to fit into this general pattern, and more particularly into that outlined for north-eastern England. The forest development has been traced within this north-eastern region at Tadcaster, in the Vale of York (Bartley, 1962), at Star Carr in the Vale of Pickering (Walker and Godwin, 1954), on the North Yorkshire Moors (Simmons, 1969), in the Tees basin (Bellamy et al., 1966), at

Cranberry Bog in County Durham (Turner and Kershaw, 1973) and at Bamburgh (Bartley, 1966) and Din Moss (Hibbert and Switsur, in the press) in Northumberland.

Few radiocarbon dates are available from the region, making precise comparison difficult. At Din Moss the Flandrian period opened at about 10,300 B.P. a date similar to that from Roos. We may take a date of just before 10,000 B.P. as a generalised one for the opening of the Post-glacial in the region. The rise in temperature at this time was marked at all sites by a temporary expansion of Filipendula, which is considered to respond to increased warmth (Iversen, 1954). Only in the north of the region, in Northumberland and parts of Durham, did Juniperus expand widely as temperatures rose. Further south, in the Tees basin, and the Vale of York, as in Holderness, tree species of Betula, already sporadically present, must have expanded sufficiently quickly to shade out the Juniperus before it had time to expand.

Betula formed the first Flandrian woodland throughout north-east England. Soon Pinus, Ulmus and Quercus appeared as minor forest constituents. Ulmus and Quercus generally arrived at the same time; only at Star Carr did Quercus begin to grow a little after the first appearance of Ulmus. Corylus expanded everywhere, but nowhere so quickly or to such an extent as at Roos. At Tadcaster it increased steadily to produce very high pollen values, but elsewhere, as at Hornsea, it was important during the early part of the Godwinian zone VI, which roughly corresponds to the HLD. Corylus/Ulmus assemblage, but it rarely contributed more than 300% of arboreal pollen. Corylus pollen did reach quite high values at Cranberry Bog, Durham, which, like the Bog, Roos, is a small basin, so that this abundance may be a local effect in both cases.

Pinus became most abundant while Corylus was at its maximum, but was

never important on the soils of Holderness. It seems to have had a variable status in northern England, reaching abundance at Flixton (Star Carr) and Tadcaster, but never being extensive in Northumberland or the lower Tees basin. In general Pinus was perhaps less plentiful than in other parts of the country, as for example, in East Anglia (Godwin, 1940b) or Lancashire (Hibbert, Switsur and West, 1971; Pennington, 1964). This difference may be due in part to soil characteristics, the boulder clay soils of Holderness and some other areas being unsuitable for Pinus.

Corylus declined somewhat, at least comparatively, as first Ulmus and then Quercus spread, and then as Alnus and Tilia appeared. The variation in behaviour of Alnus within Holderness is repeated all over the larger region. At Tadcaster Alnus appeared in small amounts as early as around 9,000 B.P., perhaps. Near one of the Star Carr sites, Flixton, Alnus was established early on, while Corylus was still at its maximum, but at the adjacent site, Seamer, Alnus did not grow locally till much later. Further north Alnus grew sporadically from the early Flandrian. At all sites Alnus spread extensively to define the opening of the Godwinian zone VIIa or the Atlantic period. There is a dearth of dates for Alnus expansion in this region. Whilst the diagrams suggest that this was a fairly synchronous event, only percentage diagrams have been produced and, as shown above, these can be deceptive in relation to this feature. This expansion occurred irrespective of whether Alnus had long been present locally or had just arrived. It seems that throughout the region Alnus grew at an early date in favourable localities, perhaps damp, sheltered sites, and then expanded, possibly at sometime before 7,000 B.P., to cover wide areas as conditions became more suitable for it. This may have been an increased precipitation/evaporation ratio or an extended area of damplands as water table rose and/or as the climate became more oceanic as the North Sea formed and cut the British Isles off from the

continent. Whatever the cause, Alnus came to dominate wide areas throughout the region. The very late expansion of Alnus values at Roos seems to be an exception to the rule, but several more dates would be needed to confirm this.

The mildness of climatic conditions during the Atlantic period is demonstrated by the presence of the thermophilous Tilia cordata and Hedera. Tilia probably varied a great deal in abundance from place to place, and its status in the vegetation will be discussed more fully below. In general, however, it was clearly more abundant in the southern half of this region than in Durham and Northumberland. Simmons (1969) considered Tilia to have been fairly plentiful on the North York Moors during the Atlantic period and suggested that the Tees basin formed a latitudinal threshold for the tree at this time. To the north climate was too cold for such a thermophilous tree. In the same way Hedera, though never represented abundantly by pollen, occurred more frequently, and at an earlier date in the southern part of this region. In Holderness and the Vales of York and Pickering it grew during the Corylus maximum. Further north Hedera was much less abundant and restricted to the Atlantic period apart from sporadic early occurrences near Cranberry Bog, Durham.

The presence of Mesolithic man in Holderness has been demonstrated by the artifacts found, rather than by pollen evidence. Mesolithic man may have burnt some forest on the North York Moors and thus encouraged Corylus and Betula and a small amount of Gramineae and Ericales to spread (Dimbleby, 1961). A lakeside occupation site at Star Carr has yielded most information on the behaviour of Mesolithic man in north-eastern England (Clark, 1954). This occupation site, dated to around 9,500 B.P., probably represented a seasonal hunting settlement. Despite the clear

local presence of man at this early date, pollen diagrams from the vicinity showed that he could have had only a minimal effect on the vegetation. Just a few pollen grains of nitrophilous plants, such as Urtica, Stellaria and Chenopodium, suggested man's presence. Similar harpoons to those found within Holderness occurred at Star Carr, and it may be assumed that the same culture was present in Holderness, perhaps only seasonally descending from the Yorkshire Wolds.

Vegetational sequences during the early Flandrian appear to have been fairly uniform throughout north-eastern England. Although there is a little evidence for a cooler climate towards the north, such a deterioration with latitude is nowhere nearly so marked as it was during the Late-glacial period.

SOME ASPECTS OF THE EARLY FLANDRIAN PERIOD

The behaviour of Corylus

Corylus first appeared throughout north-western Europe at close to 10,000 B.P. (Hibbert, Switsur and West, 1971; Smith and Pilcher, 1973). Such a date is the likely one for the arrival of Corylus in Holderness, immediately above the Late-glacial/Post-glacial boundary, and dated to about 10,000 B.P. at Roos. There is therefore no evidence for diachroneity in the first appearance of Corylus despite the contention that Corylus migrated from the West (Moore, 1972). A marked diachroneity has been noted for the 'rational limit', or beginning of the expansion, of this genus across Europe. It increased to abundance first on the continent at about 9,500 B.P., and later across Britain (Hibbert, Switsur and West, 1971). No precise date can be applied to the Corylus expansion in Holderness, but it probably occurred quite early, perhaps at about 9,000 B.P., and certainly it expanded very rapidly.

The status of Corylus as an apparent dominant of the forest of Boreal times is rather uncertain. If it formed just an undershrub it is surprising that it should have produced so much pollen. It is more likely that it was capable of fast migration and so outstripped the other trees and formed something of a pioneer community, only gradually replaced by the taller trees (Iversen, 1960).

The abundance of Corylus has been equated with the presence of Mesolithic man (Smith, 1970). Though for many years Pre-Neolithic man was considered to have had little effect on vegetation and to have been dominated by his environment (e.g. Godwin, 1956; Iversen, 1949), this idea is now being reviewed. Mesolithic man certainly collected hazel nuts (Godwin, 1956) and used hazel wood (Smith, 1970) but it is possible that his use of fire to aid hunting had a greater effect, and encouraged the spread of Corylus. Rawitscher (1945) put forward this idea on the basis of the resistance to firing of its strong root system. Corylus pollen is abundant at the known levels of mesolithic occupation sites in Europe (Jessen, 1935; Jorgensen, 1963) as well as at Star Carr (Walker and Godwin, 1954). Dimbleby (1961) considered that Mesolithic man encouraged C orylus by burning on the North York Moors, as noted above, and found charcoal at these levels. However Corylus was also abundant at many sites where other evidence for Mesolithic activity is quite absent. It may be concluded that the expansion of Corylus was a natural process, perhaps slightly encouraged or maintained in a few places by the activity of early man (Smith, 1970). The super-abundance of Corylus at Roos might imply more intense Mesolithic activity close to the Bog, but the topographical explanation outlined above is probably more feasible. The variation in percentages of Corylus pollen between marginal and central portions of the same lake, or between sediments of different-sized lakes may be due to the character of Corylus pollen

transport rather than the actual number of bushes present (Pennington, 1970).

The first decline of Corylus, which appears to have occurred more or less synchronously over much of the country was probably due either to forest succession or increasing dampness rather than to any anthropogenic factor. Smith (1970) noted that prehistoric settlements in the Atlantic period at Stump Cross, Yorkshire (Walker, 1956) and Muckel Moss, Northumberland (Pearson, 1960) among other sites, were accompanied by a secondary, temporary increase in Corylus pollen values. Whether this represented a real increase in Corylus or just a decline in production or arboreal pollen is not clear. In absolute terms Corylus showed little decline at Hornsea, but a marked decline from the much higher values at Roos, while other trees increased at both sites. The widespread 'decline' of Corylus may therefore be in reality more of a relative decline, as the other tree species spread. Corylus may have been reduced to an undershrub at this stage, and consequently produced less pollen.

The arrival and expansion of Alnus

Alnus has been considered to have first appeared in the British Isles at coastal or lowland sites (Smith and Pilcher, 1973). Much evidence suggests that this was not the case. Within Holderness local conditions were probably responsible for the diachroneity of Alnus appearance at the different sites investigated. The difference in date of arrival at two adjacent sites near Star Carr of Alnus has been mentioned above. At Tregaron, in Wales, Alnus was absent before 7,500 B.P. (Hibbert and Switsur, in the press) whereas at Gwarllyn, 7 km distant and overlooking Tregaron, Alnus was present much earlier, well within the 'Corylus maximum' period (Moore, 1972). It seems that Alnus appeared much earlier, as early as 9,000 B.P. at Nant Ffrancon (Hibbert and

Switsur, in the press), where local conditions were favourable, perhaps in the form of damp or waterlogged soils.

The earliest expansion of Alnus occurred before 8,500 B.P. in southern Sweden, and progressively later westwards across northern Europe with many dates close to, or just before, 7,000 B.P. for much of England and Wales (Hibbert, Switsur and West, 1971; Hibbert and Switsur, in the press). At upland sites in Northern Ireland the rational limit of Alnus has been dated to almost as late as 5,000 B.P. (Smith and Pilcher, 1973) but this seems to be exceptional. At lower altitudes the expansion of Alnus seems to have been a moderately synchronous event, occurring as early as 7,500 B.P. in Southern England (Clark and Godwin, 1962) and between that date and 7,000 B.P. further north. In parts of the Lake District Alnus spread because of hydroseral changes resulting from a flooding of estuaries in a period of marine transgression (Oldfield, 1960). At Seamere, in East Anglia, the late expansion of Alnus was considered to be the result of local conditions (Sims, 1973). It may be concluded that Alnus spread moderately synchronously except where exceptional conditions existed locally, as at Roos.

The expansion of Alnus has been widely attributed to increasing oceanicity of climate after a comparatively dry Boreal period (e.g. Godwin, 1956; Oldfield, 1965). Smith (1970) suggested that human activity at this time (the Boreal-Atlantic transition) may have been more important than previously thought, and that man may have accelerated the otherwise autogenic spread of Alnus. The expansion seems to have been due largely to some climatic change.

The importance of Tilia

Tilia platyphyllos has been identified by both pollen and fruits as a native English tree, growing during the Atlantic period (Burchell and

Erdtman, 1950; Clark and Godwin, 1962; Godwin, 1968). However, Tilia cordata was probably more abundant, as at Gransmoor, and the hybrids doubtless occurred. In general, British pollen diagrams show low values of Tilia pollen and the tree has been regarded as a minor constituent of the 'climatic optimum' forest in most of England, limited by temperature in the very north. However quite high values of Tilia cordata pollen occur at Gransmoor and Brandesburton (Clark and Godwin, 1956) within Holderness, and at widely scattered sites elsewhere - e.g. at Shustoke, Warwickshire (Kelly and Osborne, 1964); at Shippea Hill, Cambridgeshire (Clark and Godwin, 1962); at Cardiff (Hyde, 1936); and in Zealand, Denmark (Iversen, 1960). This unusual abundance of Tilia pollen, generally under-represented because of its poor dispersive qualities (Janssen, 1966; Anderson, 1967), in a few sites has often been attributed to selective destruction of other, less-resistant pollen types (e.g. Clark and Godwin, 1956; Smith, 1958a). Kelly and Osborne (1964) considered that this was not the case at Shustoke. They suggested that the abundance of poorly-dispersed Tilia and of macroscopic remains of both species of Tilia could only be explained if Tilia had formed an important, or even dominant, constituent of the local forest in Atlantic times. It may have grown on the alluvial valley sides where the soils were enriched by drainage water from calcareous rocks exposed higher up. Tilia could probably compete successfully with Ulmus and Quercus on well-drained, fertile soils (Iversen, 1960). It seems likely, therefore, that, despite the lack of macroscopic remains, Tilia cordata was indeed locally abundant at Gransmoor, growing on the valley sides which, just as at Shustoke, lie close to, and at a lower altitude than, exposed calcareous rocks to the west.

Piggot (1969) regarded both Tilia cordata and Tilia platyphyllos as native on the Derbyshire limestone. If this was the case it is possible

that the high values of Tilia pollen, with no macroscopic remains present, at Gransmoor represented native Tilia on the Yorkshire Wolds, only about 2 km to the west. The poor dispersive qualities of this pollen make this unlikely. Tilia, especially Tilia cordata may well have been common on the Wolds in the Atlantic period, but it was probably also common on the sides of alluvial valleys within Holderness, besides forming a minor constituent of the more widespread mixed forest.

Man

Much of the possible influence of man in the early Flandrian period has been discussed above, particularly in relation to the behaviour of Corylus. In conclusion it may just be said that although Mesolithic man was widely present in small numbers in Britain in Boreal and Atlantic times, pollen analysis has rarely demonstrated his presence convincingly. At several sites where pollen sequences were not considered to demonstrate interference by Mesolithic people (e.g. Clark and Godwin, 1962; Piggot and Piggot, 1963), evidence of human disturbance has been identified on re-examination of the data (Smith, 1970). Smith (1970) concluded that Mesolithic man accelerated otherwise autogenic vegetational changes in some places, rather than drastically affecting them. Fire may have been his chief weapon. Clearly direct archaeological investigations yield more information on Mesolithic man's activities than do pollen-analytic methods at present. The possibility that more advanced absolute pollen analysis methods mightyield more evidence on this has been demonstrated by the identification of a minor Mesolithic clearance in East Anglia by such techniques (Sims, 1973).

CONCLUSIONS

The early Flandrian period was characterised by the development of

mixed deciduous forest in response to climatic amelioration over much of the British Isles. The apparently slow increase of absolute pollen deposition of tree taxa in the early Post-glacial period of Holderness, followed by a later acceleration of pollen deposition, if valid, demonstrates the course of migration of the forest trees. The response to improved climate in terms of dense, thermophilous forest was delayed by the comparatively slow migration rates of the tree species involved.

Within Holderness, as doubtless elsewhere, this forest was not completely homogenous. Marked differences in its composition must have occurred in response to local conditions of moisture, soil nutrients and soil type. Though Mesolithic man was present he probably did little more to the vegetation than slightly accelerate the otherwise autogenic processes.

The estimated absolute pollen deposition values have proved useful in clarifying the vegetational changes in Holderness during this period, especially with regard to the behaviour of Alnus. As yet there is a lack of similar evidence from elsewhere to compare with this.

CHAPTER 9

THE LATE FLANDRIAN OF HOLDERNESS

Introduction

This period is taken to include all of the time between the major decline of Ulmus and the present day. That is approximately the last 5,000 years.

The pollen assemblages

The correlation of pollen assemblage zones from these sites is not easy as many of the changes in pollen spectra were due to local effects rather than alterations in regional vegetation. An attempt is made to distinguish two broad zones for the period without consideration of local effects.

The base of this period is the major or final decline in the values of Ulmus pollen. This 'elm decline' is a marked feature of northern European pollen diagrams (see below). At Roos Ulmus pollen values fall steadily throughout zone RB.6 but at about 4.0 m depth they drop below 5% of arboreal pollen and do not recover higher in the profile. On the Hornsea Old Mere pollen diagram the decline of Ulmus pollen occurs at 4.25 m depth, and it holds very low values above this horizon. The decline of Ulmus is also shown in the frequency and pollen deposition diagrams for both of these sites. At Gransmoor Quarry the abundance of Tilia pollen obscures the decline of Ulmus pollen percentages, but the characteristic decline can be seen clearly at around 0.52 m depth in the adapted pollen diagram (figure 6.3) with Tilia excluded from the pollen sum. In Skipsea Whitow mere (Godwin and Godwin, 1933) Ulmus pollen percentages decline over a fair depth of sediment and a definite 'elm decline' horizon cannot be marked clearly, but probably lies at just above 1.0 m depth, where Ulmus values fall to just below 5% for the first time. At Brandesburton (Clark

and Godwin, 1956) Ulmus pollen is scarce throughout, and no such decline feature can be distinguished.

Pollen assemblage zone RB.7 at Roos lies immediately above the elm decline and corresponds to HO.7 at Hornsea Old Mere. In percentage terms both show continued dominance of arboreal and shrub pollen. Values of Ulmus pollen remain low, and Pinus pollen is scarce. Betula pollen is more abundant at Roos than at Hornsea, but at both sites the arboreal pollen is dominated by Alnus and, secondarily, by Quercus. At both sites Tilia pollen is scarce in the lower part of the zone, and slightly more plentiful higher up. Fraxinus pollen, scantily present at the base of the zones RB.7 and HO.7, is absent from the top of both zones. Corylus pollen is more abundant at Roos than at Hornsea, but in both cases it is less plentiful than in the zones below. Hedera pollen is occasionally present. Little herb pollen occurs, but a few types appear at the base of these zones for the first time since the close of the Late-glacial period, e.g. the pollen of Plantago lanceolata, Chenopodiaceae and Rumex spp. Gramineae pollen occurs consistently, but in small amounts. The absolute pollen frequency and deposition diagrams from Roos (figures 4.7 and 4.8) are affected by major stratigraphic changes during this zone, and so the apparently dramatic decline of all pollen types at the level of the elm decline can be attributed to an alteration of pollen-collecting characteristics of the site. At Hornsea the absolute pollen deposition diagram is probably more reliable for this period, and (like the frequency diagram) shows Ulmus, Pinus and Tilia pollen suffering a 'real' decline at the base of this zone while Quercus and Alnus pollen deposition values do not decline at all markedly at the level of the elm decline. Their values fall at slightly higher levels in the zone. Betula pollen maintains its values throughout. Herb pollen shows only a very minor 'real' increase, and an apparent decrease higher in the zone.

Zone GQ.3 at Gransmoor differs from the other two sites in that Tilia pollen is dominant. Apart from Tilia pollen, however, it is directly comparable with RB.7 and HO.7. Alnus then becomes the dominant arboreal pollen type, with Quercus pollen secondary and Ulmus, Pinus and Betula of little significance. Corylus pollen is not abundant, except at the base of the zone - as in HO.7. Herb pollen is not at all plentiful, but Plantago lanceolata, Compositae (Liguliflorae), and Caryophyllaceae pollen appears in this zone.

Although no elm decline can be distinguished at Brandesburton a zone 'e or VIIb' was described (Clark and Godwin, 1956) which corresponds with the above-mentioned zones in Holderness. Alnus dominates the tree pollen, while Tilia pollen, quite abundant below, declines steadily during the zone. Betula, Pinus and Ulmus pollen all occur in small percentages as does Quercus pollen here. Corylus pollen is not abundant but a little Salix pollen is present. Hedera pollen is only present at the base of the zone. Pollen of herbs, including that of Chenopodiaceae, Plantago and Artemisia, appears in the zone. Gramineae pollen and other herbaceous pollen increases in abundance higher up in the zone 'e', more than in RB.7 or GQ.3, and it may be that only the lowermost part of this Brandesburton zone is comparable with the others (see figure App. 1).

Above the elm decline at Skipsea Whitow (Godwin and Godwin, 1933) a similar pollen assemblage can also be distinguished - for the arboreal pollen only as no herb pollen was described. Alnus pollen is dominant here with Quercus pollen subsidiary to it. Tilia pollen here holds low values but shows no decline. Betula, Pinus and Ulmus pollen is scarce, with Corylus pollen values moderate, as elsewhere (see figure App.2).

These local pollen assemblage zones may be grouped into the regional pollen assemblage zone HLD. Alnus/Quercus, with its type locality and

zone at the Bog, Roos zone RB.7 4.05 - 2.15 m. The zone may be briefly described as dominated by arboreal pollen, predominantly of Alnus and secondarily Quercus. Ulmus pollen is scarce. Small amounts of herb pollen occur, notably Plantago lanceolata and other ruderals, such as Chenopodiaceae. The lower limit of the zone is the decline of Ulmus pollen percentages to values consistently below 5%. The upper limit is the expansion of several herb pollen types, notably of Gramineae and Plantago lanceolata to consistently significant percentages; of Gramineae to over 20% of arboreal pollen. No real generalization can be made concerning absolute pollen deposition during this zone.

The uppermost zone at Roos, Hornsea and Gransmoor is characterised by increasing herb pollen frequencies, but local effects make exact correlation impossible.

Zone RB.8 at Roos has been shown to reflect the changes within the Bog itself (chapter 4), particularly the pollen values of Betula, Ericales and Sphagnum. If these local effects in the pollen assemblages are ignored the zone can be regarded as broadly similar in other points to HO.8 at Hornsea, and the very top of the Gransmoor sequence, zone GQ.4. There is little change in the relative values of all types of arboreal pollen at the three sites. Alnus and Quercus pollen is still generally dominant. Ulmus, Pinus and Betula pollen is scarce (except for the abundant Betula pollen at the top of RB.8). Tilia pollen is almost absent from RB.8; its values decline during HO.8, as they do in GQ.4, but Tilia pollen is still more abundant at Gransmoor than elsewhere. Fraxinus pollen is consistently present in small amounts at Roos and Hornsea. The pollen of Fagus and Carpinus occurs within RB.8 and HO.8 The absolute deposition decreased during the zone, particularly in the top part. Corylus pollen declines in importance in these zones. The

expansion of percentages of herb pollen is shown to be a 'real' expansion by the absolute pollen deposition information. Gramineae pollen is a major component of this expansion, particularly at Roos. At Hornsea it expands more gradually. Herb pollen types already present in the zone below, such as that of Chenopodiaceae, Plantago lanceolata, Caryophyllaceae and Rumex, expand steadily in the zones RB.8, HO.8 and GQ.4, especially towards the top of the zones at Roos and Hornsea. A great range of other herb pollen types occur at all three sites - pollen of various Compositae, Rosaceae, Cruciferae and Rubiaceae, etc. Cerealia pollen occurs for the first time within this uppermost zone.

At Brandesburton a similar zone is probably represented by all of 'zone f' (Clark and Godwin, 1956). Arboreal pollen percentages vary somewhat here, Alnus pollen values increasing below a decline. Pinus pollen values increase at the very top, as they do to a lesser extent at Roos. Other trees are represented by low pollen percentage values. Carpinus pollen appears here. Corylus pollen increases in values somewhat at the top. Gramineae, and other herb pollen types expand as new types appear. Both Gramineae and Plantago pollen is less abundant than at the other sites, pollen of Compositae contributing much of the herb pollen expansion at Brandesburton. Here, as at Gransmoor, the spores of various Filicales are quite abundant.

Since no herb pollen types were distinguished at Skipsea Whitow no similar zone can be identified here. The arboreal pollen evidence perhaps suggests that pollen deposition at this site ended during the previous zone.

At Faxfleet, on the Humber shore line to the west of Hull, two Phragmites peats were analysed for pollen (Hulme and Beckett, 1973). These lay on, and were separated by, estuarine clay and were covered by

this clay and a sandy warp higher up. Within the warp a Roman rubbish level was discovered. The pollen assemblages from these two peats are comparable with RB.8, and HO.8 and GQ.4 and the top of the Brandesburton sequence. The tree pollen percentages are dominated by Alnus and Quercus. Betula, Ulmus, Tilia, Fraxinus and Fagus pollen is poorly represented, Pinus pollen moderately so. Corylus pollen is not abundant. A few herb pollen types are quite plentiful, notably pollen of Gramineae, increasing from about 50 to over 500% or arboreal pollen at the top of the upper peat. Compositae and Chenopodiaceae pollen is fairly abundant. Plantago lanceolata pollen is absent, in contrast to the other sites, but Plantago maritima pollen occurs.

Also on the bank of the Humber, at the foot of the Yorkshire Wolds, at North Ferriby, Bronze Age boats have been found (Wright and Churchill, 1965) (see below). A single pollen analysis from this site has Alnus and Quercus pollen contributing most of the arboreal pollen. Corylus pollen is quite abundant. Pollen of several herb types is well represented - notably pollen of Gramineae, Plantago lanceolata, Plantago maritima, Chenopodiaceae and Artemisia. This assemblage is strongly comparable with that at Faxfleet and in HO.8, RB.8 etc.

A further thin peat bed at Elloughton Beck, Brough, lying close to the Humber estuary, and within estuarine clays, has a pollen assemblage of tree pollen again dominated by Alnus, and, secondarily, Quercus, with very low values of Betula, Pinus, Ulmus and Tilia pollen. Corylus contributes about 50% of total arboreal pollen, rather more than at Faxfleet, but less than at North Ferriby. Herb pollen is abundant, notably of Gramineae, Plantago lanceolata, Compositae, Carophyllaceae and Chenopodiaceae (Beckett, unpublished). This assemblage is strongly comparable with the other Humber bank sites, and in general, to the

uppermost zone at the other sites within Holderness.

These local pollen assemblages may be grouped into the regional pollen assemblage zone HLD. Alnus/Gramineae, with a type locality and zone at the Bog, Roos RB.8 2.15 - 0.0 m. The zone may be briefly described as containing much herb pollen, which may predominate in the spectra. Of the arboreal pollen Alnus is dominant, Betula and Quercus pollen occurs in small amounts. Many herb pollen types are present, notably of Gramineae, Plantago lanceolata, other ruderals and Cerealia. The lower limit is the general increase of herb pollen values; and of Gramineae pollen in particular, to more than 20% of arboreal pollen. In Holderness this zone is the uppermost pollen deposition zone. The pollen spectra of this zone are, at Roos, rather obscured by the abundance of pollen of Betula and Ericales and spores of Sphagnum, due to local effects. It might therefore have been more satisfactory to chose zone HO.8 at Hornsea as the type zone as its pollen assemblages are not confused by local over-abundance. On balance, however, as the type localities and zones for the other seven regional pollen assemblage zones were taken as the Bog, Roos, it was thought best to follow suit for the uppermost regional zone. No generalizations can be made about absolute pollen deposition during this zone.

Age

The date for the elm decline of 5,099 ± 50 B.P. (SRR-229) at Gransmoor fixes the opening of this late Flandrian period. Other dates were obtained from the Bronze Age boats discovered at North Ferriby (Wright and Churchill, 1965). From Taxus stitches of one boat a date of 3,433 ± 110 B.P. (Q.837), and from a small branch of Alnus near a higher boat a date of 3,120 ± 105 B.P. (Q-715) were obtained. The peat at Elloughton Beck, Brough, yielded a date of 3,905 ± 105 B.P. (IGS-C14/59) (Gaunt, personal communication).

Sedimentation and pollen incorporation

Sediment accumulation during the post-elm decline period at Roos and Hornsea is not really comparable because the two sites were distinctly different. The Old Mere was a lake which dried out; the Bog suffered a shallowing water depth and then the development of raised bog, followed by a growth of trees on its surface.

The calculation of sediment accumulation rates for the Roos site is highly problematical. It is not known to what extent drainage in recent centuries has affected the deposits. It is also possible that there may have been an hiatus in deposition due to a natural drying out, or even from medieval peat cutting. There is no strong evidence for either possibility. There is no really sharp break in the stratigraphy. The great expansion of herb pollen percentage values at around 2.0 m depth, coinciding with the beginning of the raised bog development, could represent a period of drying out and poorer preservation of the sediments, and consequently a break in pollen accumulation. There is no evidence to support this from the pollen frequency or deposition diagrams which show no sharp changes at this level. Therefore, these percentage changes may merely be the result of local seral progress.

If a hiatus did occur its duration cannot be estimated. Assuming no hiatus occurred and that there was constant sediment accumulation for five thousand years from the elm decline to the present day, a sediment accumulation rate of 0.80 mm/year has been used to calculate the pollen deposition rate. With the changing nature of the deposits the accumulation rate is unlikely to have been constant throughout this long time period, and so the estimated sedimentation rate is not likely to be of much relevance. If there was a hiatus, the true sediment accumulation rate (or rates) would be quite different, though to what extent cannot be known while the length of such a hiatus in deposition remains a mystery.

Pollen frequency and pollen deposition values at the Bog, Roos are extremely low during the late Flandrian period. Total pollen deposition values decline at around the level of the elm decline, even when compared with the figures calculated from the lower sedimentation rate for RB.6. If a hiatus were considered to occupy as much as a half of this late-Flandrian period (i.e. 2,500 out of 5,000 years) then the sediment accumulation rate would, of course, be doubled and pollen deposition rates would be increased by the same amount. They would still be only a fraction of the pollen deposition values for the early Flandrian period.

Clearly, the pollen-collecting character of the site changed dramatically as it developed into bog. Why there should be such a decline in pollen influx is not clear. The earlier pollen influx into the lake was not enhanced by contributions from an inflow stream, the Bog would still be surrounded by vegetation contributing pollen, and the raised bog developed on the site itself would add its own pollen production to the deposits. Some woodland clearance occurred throughout this period and therefore a slight diminution in pollen influx might be expected, but it is very surprising that all tree values should decline so dramatically. Pollen deposition into the Roos basin may reflect largely the vegetation of the immediately surrounding rim of land, which perhaps cut off the basin from much of the influence of the regional vegetation. If this is so clearance of a few trees close to the site might produce a drastic reduction in pollen influx into the deposits. On the other hand it might open the site up to a more regional contribution of pollen.

With all these uncertainties over pollen incorporation into the deposits at Roos in the last 5,000 years it would be quite wrong to jump to any conclusions about the vegetation based on evidence from the absolute pollen values. This temptation has been avoided and no

conclusions have been drawn from these figures.

The pattern of the sedimentation sequence at the Old Mere site at Hornsea after the elm decline is somewhat more straightforward, but there is no certainty as to the time period covered by these sediments. The lake seems to have shallowed and been infilled by clay washed in from the surrounding land. A fairly sudden drainage of the mere, caused by coastal erosion, might have occurred (see chapter 5).

The sediment accumulation rate calculated (0.92 mm/year) is based on an estimated date for the cessation of pollen incorporation of 2,000 B.P. This is undoubtedly an approximation. The true sedimentation rate may therefore lie somewhat either side of this figure. If the uppermost levels analysed for pollen are assumed to date from 3,000 B.P., which seems the earliest possible date judging from the amount of clearance that had already occurred, the sedimentation rate would be increased to 1.38 mm/year (identical to the higher sedimentation rate for H0.6). If the pollen influx is considered to have ended at 1,000 B.P. (which seems far later than is likely) the sedimentation rate would be reduced to 0.69 mm/year.

The processes of pollen influx into the deposits of the mere would be the same as those operating during the early Flandrian period (see chapter 8).

At the chosen rate total pollen deposition is slightly lower than that for H0.6. At the higher sedimentation rate (taking the cessation of pollen incorporation at 3,000 B.P.) total pollen deposition would be slightly greater than in H0.6. The absolute total pollen frequency seems to hold consistent values throughout zones H0.6, 7 and 8, only declining as the lake dried up.

Despite the (limited) uncertainty of the true sediment accumulation rate it is clear that absolute pollen values of Ulmus and Tilia, in particular, declined at the opening of zone HO.7 and that the opening of zone HO.8 is marked by an increase in absolute pollen deposition of the herbs, especially of the weed types.

Sedimentation rates during the last 6,000 years have been measured, but not discussed, for Lough Neagh, Ulster (O'Sullivan, Oldfield and Battarbee, 1973). Sedimentation occurred in deep water throughout and therefore is not directly comparable with sedimentation at Roos or Hornsea during this period.

Vegetation

Just before 5,000 B.P. Holderness was covered by a dense, mixed forest of Quercus, Ulmus, Tilia and Betula with, in places, a little Pinus. Alnus was probably dominant on the lower, damper, ground, particularly at the margins of the meres, which must have been numerous at this time. Elsewhere, on the drier ground, Corylus was still quite abundant. Few herbs were able to flower in such densely shaded conditions.

At about 5,100 B.P. a change in forest composition occurred. Ulmus certainly declined comparatively as a forest constituent over a fairly short time period. The absolute pollen deposition data from Hornsea suggests that Tilia and possibly Pinus also declined at this time, along with Ulmus. Tilia seems to have decreased generally in Holderness at this time. Betula, Quercus, less certainly, and Alnus seem not to have suffered; and the Hornsea absolute diagram shows that the total arboreal pollen deposition remained at values almost as high as in the preceding zone. If the true sedimentation rate was a little higher then pollen deposition values would be as great as in HO.6. Thus, although some trees declined, notably Ulmus and Tilia, the forest remained quite closed. This

is demonstrated by the small amounts of pollen of only a few herb types in the pollen assemblages. Light-demanding weeds such as Plantago lanceolata, Chenopodiaceae and Artemisia occurred but were apparently limited to the few openings in the forest. The most light-demanding of the trees, Fraxinus, was unable to expand significantly.

There is evidence from both Roos and Hornsea that after this slight opening up of the woodland there was some regeneration and a closing of the forest canopy once more. The pollen diagrams from the two main sites are so alike in exhibiting this feature that it may be taken as a regional regeneration of forest. Ulmus, though not regaining its former abundance, recovered somewhat, and Tilia increased again. Fraxinus seems to have been shaded out to a considerable extent, while the ruderals, notably Plantago lanceolata and the Chenopodiaceae largely disappeared, presumably for the same reason.

At the opening of the Alnus/Gramineae pollen assemblage, the forests of Holderness began their final decline, leading to their non-existence at the present day. The date for the opening of this pollen assemblage zone cannot be accurately determined from the evidence available. It was probably not much before 4,000 B.P. If the sedimentation rate of 0.92 mm/year is assumed to have occurred throughout the late Flandrian at Hornsea Old Mere this zone boundary would be placed at close to 3,000 B.P. Since the dated pollen spectra from North Ferriby and Brough seem to belong to the regional pollen assemblage zone HLD. Alnus/Gramineae the true date for the opening of this zone may well lie fairly early in the fourth millenium B.P. This forest decline was at first a gradual, then an accelerating demise. Most types of trees decreased; although Fraxinus reappeared to a limited extent in the more open woodland. In the increased open area a wider range of herbs grew. An expansion of Gramineae occurred

throughout Holderness, perhaps over-exaggerated by local effects at Roos. With it, grassland herbs such as Plantago lanceolata spread. Weeds of disturbed ground began to appear again; these included Artemisia and other Compositae, Chenopodiaceae and Rumex spp.

In the second millenium B.C. dated pollen analyses from North Ferriby and Brough show that forest was no longer completely dominant. Alnus and Quercus were still abundant but ruderals became increasingly plentiful. From North Ferriby alone there is evidence for the growing of cereals at this time. In this Bronze Age period the forests were far from complete over all of Holderness, yet plenty of woodland persisted. There is some evidence for the presence of Fagus at the time of the deposition of the Humberside peats, but this is rather doubtful as only a few isolated pollen grains were found.

Vegetational changes during the last 3,000 years are difficult to trace effectively, because little pollen evidence covers this time period, and because none of the vegetational sequences recorded have been dated. Fagus and Carpinus probably arrived or became properly established in the area during this time, perhaps the first millenium B.C. for Fagus. However, in general the trees continued to decline. Tilia was locally absent at Roos throughout the uppermost regional pollen assemblage zone time period of about the last 4,000 years, but it was present in the Hornsea area probably until the Iron Age. Marked expansions of the Gramineae and other herbs occurred as peat formation ceased at Faxfleet and Gransmoor, and as the Old Mere at Hornsea dried up, all at rather uncertain dates. The Hornsea Old Mere may have continued to collect pollen for a little while longer than the Faxfleet and Gransmoor sites, and finally dried up at perhaps about 2,000 B.P. Therefore, the only evidence for vegetational changes within the historic period in Holderness comes from Roos, and here the local effect of developing bog

masked the regional picture. The regrowth of Betula and possibly of Alnus, as well as of Ericales, Sphagnum, some Gramineae and Cyperaceae, and most recently of Salix may be attributed to the very local seral changes (see chapter 4). If the Betula and Alnus pollen of the assemblages represented local trees, then little woodland can have been present in the surrounding area for most of the historic period. Ulmus and Tilia virtually disappeared. Quercus persisted for some time before it also declined. Fagus and Carpinus trees could never have been more than occasional. As the trees disappeared grassland and its associated weed flora, especially Plantago lanceolata spread extensively. Cereals were more extensively grown and their concomitant weed flora became significant in the open conditions.

While the general pattern for Post-Neolithic times in Holderness is one of decreasing tree cover it is clear that several, locally distinct, vegetation types occurred.

The infilling of the Bog, at Roos, with the development of raised bog supporting Sphagnum, Calluna and other Ericales, later to be succeeded by Betula, provided a contrast to the rest of the plain. A similar sequence no doubt occurred at Bitternboom Mere, New Ellerby, which also probably had a kettle-hole origin. Here stratigraphical investigations demonstrated the development from open water to raised bog followed by Betula. A cover of woodland, albeit largely of planted aliens, still persists. A silting up or later deliberate drainage of the many more extensive meres provided local open habitats where discrete vegetational changes would occur where man did not immediately intervene.

The identification of pollen of Plantago maritima at North Ferriby (Wright and Churchill, 1965) demonstrates the probable presence of patches of coastal vegetation along the shores of the Humber estuary.

Although Plantago maritima may not formerly have been restricted to coastal or mountainous areas (Gregor, 1930) it was surely in a coastal situation here. Chenopodiaceae pollen at Faxfleet (Hulme and Beckett, 1973) and Brough (Beckett, unpublished), and some of the Gramineae present, may represent salt marsh weeds such as Suaeda and various grasses. The reappearance of Hippophae pollen at the top of the Hornsea sequence, after an absence of perhaps 8,000 years points to a coastal vegetation type here. The eroding cliffs would not have allowed for much development of coastal vegetation on the east coast, except for local patches, as on sand dunes at Hornsea. It is, however, fascinating to consider whether Hippophae could have survived throughout the Post-glacial forest period on the sand banks at the mouth of the Humber, on Spurn Head and its precursors.

Climate

There is no conclusive evidence for major climatic change during the late Flandrian episode from within Holderness itself. The elm decline has been attributed to climatic deterioration (see below), but this is not now widely supported. Hedera, which is sensitive to winter cold and will not survive January mean temperatures of below -1.5°C (Iversen, 1944) continued to grow at Roos and Gransmoor, though it was temporarily absent from Hornsea. Van Zeist (1959) maintained that a climatic deterioration can hardly have caused the elm decline where Hedera continued to flourish.

Although nearly all of the trees declined in abundance after the elm decline, a climatic cause is unlikely. Fagus and Carpinus appeared in Holderness during this period, and are more thermophilous than most of the other trees already present. Although many of the herbs present in these more recent times occurred in the Late-glacial period, most of them have a wide tolerance of climatic conditions and so imply little, except

that the shade which drastically reduced them in early and middle Post-glacial times was itself severely reduced.

The development of raised bogs over an extensive area has been attributed to increasing wetness or oceanicity (e.g. Conway, 1954; Godwin, 1948). In Holderness raised bogs developed on the two probable kettle holes at Roos and New Ellerby and also at Rimswell (Flenley, personal communication). They were the result of the infilling of these basins and a normal part of the hydrosere. There is no need for a hypothesis of climatic change to explain them. In a similar, but reverse way, the disappearance of most of the more extensive meres of Holderness within the last 5000 years need not be due to a drier climate. Many must have silted up quite naturally. Man may have encouraged this process in some places and deliberately drained other meres (Sheppard, 1956).

Soils

It is unlikely that soil deterioration caused the elm decline and that of the other trees later on, since Fagus grew at a later date, and requires a fairly rich soil. It may be that leaching increased after the decline of forest and caused a soil deterioration which may have prevented later forest regeneration. Such a marked deterioration clearly has not occurred as most trees would thrive on the soils of Holderness today. Drainage of the lower-lying areas and warping during historic times has improved most of the soils to their intensive agricultural status of today.

Man

Archaeological evidence has demonstrated man's presence in Holderness during the last five thousand years (chapter 2). He was scantily, perhaps only seasonally, present in Neolithic times. The appearance of some herbs in the vegetation for the first time since the Late-glacial,

including Plantago lanceolata, Artemisia and Chenopodiaceae may well be due to a limited amount of clearance. Plantago lanceolata, in particular, has been associated with Neolithic activity, and it appeared widely in Holderness immediately after the elm decline. It seems likely, therefore, that Neolithic man may have been responsible for the demise of Ulmus. This possibility is discussed more fully below. Just as the archaeological evidence suggests that Neolithic settlement in Holderness was only very sparse, with more concentrated habitation on the lighter soils of the Wolds, which would have been drier and easier to cultivate, so also the pollen evidence shows that Neolithic man had a fairly minor effect on the vegetation of the plain. His influence may well have lessened in later Neolithic times, allowing the temporary regeneration of Ulmus and Tilia which to some extend shaded out the herbs and Fraxinus.

In contrast, Bronze Age man was much more numerous in Holderness. The lake dwellings testify to his presence in fair numbers in the northern part of the plain while the North Ferriby boats (Wright and Churchill, 1965) demonstrate his activity on the Humber at 3200 to 3500 B.P. The Roos Images show that he ventured inland in southern Holderness. This increase in population corresponds with a reduction of woodland and an increase in quantity and variety of the herb flora. It seems most likely, therefore, that Bronze Age man was responsible for this more marked clearance. Grassland weeds, especially Plantago lanceolata, expanded, reflecting a pastoral economy. There is limited evidence of a little cereal cultivation from North Ferriby and possibly Hornsea. Arable activity probably did not become very important until later times, possibly not until the Roman era.

As noted in chapter 2 Iron Age man was not thought to have been very active in Holderness (Elgee and Elgee, 1933), and the Hull Valley may

still have been a major barrier to communications between the densely settled Wolds and Holderness. The Romans had great influence on the area but did not settle in Holderness itself. It was the Germanic invaders of the fifth century A.D. who introduced the mouldboard plough and settled on the clay lands. From this time onwards man's dominance over the vegetation of the region is undoubted. The Saxons accelerated the woodland clearance, pastured livestock, and cultivated cereals. This activity probably contributed much to the final silting up of many meres, as perhaps at the Old Mere Hornsea, and Skipsea Whitow.

The medieval drainage of many meres, such as that of Lambwath by the monks of Meaux, and of the peatlands of the Hull valley may have reduced Alnus considerably where these areas were immediately used for agriculture. The drainage of many wetlands, such as the carrs surrounding the Bog, Roos, was not completed until much later. Reclamation of the low-lying area on the shores of the Humber estuary was continued by warping and embankment until about 1800 A.D. This would have reduced considerably the natural development of salt marsh communities. By this date all of the meres, except the extant Hornsea Mere had been drained or encouraged to silt up. Thus the earlier variety of the vegetation of Holderness, with forest, Carr-land, salt-marsh, and differing hydroseral stages, had been reduced to the open, almost treeless, farmed landscape that characterizes the region at the present time.

It is unfortunate that there is little pollen analytical evidence to trace these more recent changes in the vegetation. What there is demonstrates the fairly late clearance of forest and spread of cereal cultivation in an area fairly hostile to early settlement.

Sea-level changes

The dated peat beds of the north shore of the Humber estuary give

some idea of the sequences of marine incursion and regression during the Flandrian period. A peat bed from about 15 m below the centre of Hull has been dated to about 6,900 B.P. (Gaunt and Tooley, 1974), and lies below estuarine deposits. The two peat beds at Faxfleet were thought to represent pauses in a marine transgression during the Bronze Age period (Hulme and Beckett, 1973). The pollen analysis from the Bronze Age boats at North Ferriby (Wright and Churchill, 1965) suggests that this peat bed is of the same age as the upper Faxfleet peat, placing this later pause in transgression to the second half of the fourth millenium B.P. That from Brough, dated to 3,900 B.P. (Gaunt, personal communication) may represent the same phase as the lower Faxfleet peat, although the pollen assemblages differ somewhat, more herbaceous pollen being present at Brough. The lower peat from Faxfleet was considered to date from about 4,000 B.P., which is a likely date if it corresponds to that from Brough.

THE LATE FLANDRIAN OF HOLDERNESS IN ITS REGIONAL SETTING

The pollen sequences of the late Flandrian of the British Isles have been placed into two main zones (Godwin, 1956). Zone VIIb followed the elm decline and was characterised by abundant *Alnus* and *Quercus* pollen, with that of other deciduous forest types, such as *Tilia*, but with low values of *Ulmus*. Some herb pollen also characteristically occurred. The zone corresponded to the Sub-Boreal of Blytt and Sernander (Sernander, 1908) and approximately spanned the Neolothic and Bronze Ages. Pollen zone VIII was the most recent, and typified by a fall in *Tilia* pollen values and an increase in pollen representation of *Betula*, *Pinus* and many herbs. It represented the Sub-Atlantic period. The separation of these two zones has proved to be extremely difficult. The decline of *Tilia*, for example, has been shown to exhibit a marked diachroneity in this country (Turner, 1962). As a result these zones have,

in the past, been loosely applied, if at all. This was particularly the case in the very north of England where Tilia was never plentiful.

Comparing the vegetational changes of Holderness with those from the rest of the north-east region is not easy as there is a surprising lack of data for post-elm decline vegetational history in this part of England.

The elm decline has been identified at several sites in this region. It has been dated to about 5,400 B.P. at Din Moss, Northumberland (Hibbert and Switsur, in the press) and to 5,100 B.P. at Gransmoor Quarry, both dates which lie close to the majority of those obtained for this synchronous feature. In Northumberland (Hibbert and Switsur, in the press; Blackburn, 1953; Bartley, 1966) and on the North York Moors (Simmons, 1969), as in Holderness the decline was immediately followed by the appearance of several herbs associated with human activity, notably Plantago lanceolata. On the North York Moors some clearance indicators appeared just before the elm decline and were attributed to Mesolithic activity (Simmons, 1969). Except in the far north of this region, where Tilia was never abundant, the decline of Ulmus was accompanied by a decrease of Tilia. The phenomenon has been considered to be due to Neolithic clearance (e.g. Simmons, 1969).

Following the elm decline the regeneration of woodland, notably of Ulmus and Tilia, that occurred in Holderness, seems to have occurred elsewhere in north-eastern England. Again, this is not clear in the very north because of the scarcity of Tilia and because the pollen profiles at Bamburgh and Din Moss ceased soon after the elm decline, while there was a cessation of peat formation at Cranberry Bog, in County Durham, during much of this time (Turner and Kershaw, 1973). On the North York Moors both Ulmus and Tilia increased after their initial decline, and the ruderals suffered a slight setback at most of the sites investigated (Simmons, 1969).

The slight clearances were thought to represent the low level of activity of Neolithic man, making only small, temporary clearings. The population was thought to have been small during Neolithic times in Lincolnshire where pieces of charcoal found at clearance horizons were taken as evidence of the use of fire by Neolithic man to aid forest clearance (Smith, 1958a).

The length of the regeneration period on the Moors was not clear, but it was succeeded by more extensive Bronze Age clearances, possibly related to early Bronze Age settlements to the south of the North York Moors. More archaeological evidence exists of middle Bronze Age settlements, all over these Moors, which led to increased clearance, a second elm decline and a final decrease in abundance of Tilia. These clearances may have led to podsolization and other irreversible soil changes with a consequent development of heath vegetation over much of the Moors (Dimbleby, 1962).

At Thorne Waste, near Doncaster, Bronze Age activity in a diverse woodland vegetation has been demonstrated. Some woods were probably dominated by Tilia and Corylus, some had much Ulmus and Fraxinus, while still others had more Quercus. The mosaic of forest was selectively exploited by Bronze Age man (Turner, 1962). Gramineae, Plantago lanceolata, Rumex and Pteridium occurred but were not plentiful, so there could have been no great disturbance, possibly rather less than on the north bank of the Humber at the same time. Clearance increased in the late Bronze Age at Thorne Waste and Tilia was drastically reduced at around 3,000 B.P.

There is some evidence for cereal cultivation on the North York Moors during the Bronze Age (Simmons, 1969) and also at North Ferriby (Wright and Churchill, 1965). This last-named site is at the foot of the Wolds and may reflect cereal cultivation on their calcareous slopes

rather than in southern Holderness. There does not seem to have been widespread growth of cereals in the north-east until Iron Age or even later times.

It was during the Iron Age culture that Tilia finally declined on the North York Moors, as it did in Holderness. Fagus appeared at this time but was even more sporadic on the North York Moors (Simmons, 1969) than in Holderness, and Carpinus did not grow on the Moors. On these higher lands clearance increased during the Iron Age, as in Holderness. Unfortunately there is a dearth of palynological evidence for the changes in vegetation during the historic period, for the whole of the north-eastern region.

Sea level changes in the Humber estuary - a peat bed at Immingham, on the Lincolnshire bank of the estuary has been dated to about 6,700 B.P. (Wright and Churchill, 1965). It is overlain by clays of brackish water origin, corresponding to the rising sea level that submerged the peat bed of similar date under Hull. At Ingoldmells, near Chapel Point in Lincolnshire, two Bronze Age peat beds, the lower one dated to 3,945 ± 100 B.P. (Q-685) (Smith, 1958a; Wright and Churchill, 1965), seem to be of the same period as the two Faxfleet peats, and that from Brough. All probably represent the same pair of pauses in a general marine transgression during the Bronze Age. In the Flandrian stage as a whole, sea level fluctuations in the Humber estuary have been found to be similar in direction and magnitude to those recorded for other parts of northern England (Gaunt and Tooley, 1974).

SOME ASPECTS OF THE LATE FLANDRIAN

The elm decline

The marked decline of percentages of Ulmus pollen in pollen diagrams from throughout north-western Europe is the main feature of the

Atlantic/Sub-Boreal transition. It has been shown to be a remarkably synchronous feature, certainly across the belt from southern Sweden, Denmark and the Netherlands, to England, Wales and Northern Ireland, where it has been widely dated to within a century or two either side of 5,000 B.P. (Hibbert, Switsur and West, 1971; Hibbert and Switsur, in the press; Smith and Pilcher, 1973). The majority of dates lie close to 5,100 B.P., and this is the date for the elm decline at Gransmoor, in Holderness (5,099 ± 50 B.P. (SRR-229)).

In Europe the elm decline has often been described as a double feature (e.g. Iversen, 1941), but in England one elm decline only has usually been identified (Sims, 1973). Only at a few English sites has a dual feature been noted (Oldfield, 1963; Simmons, 1969). However the distinction of a single or double elm decline is rather arbitrary and depends on what is regarded as a regeneration of forest. The decline of Ulmus pollen is accompanied by a fall in the values of Hedera pollen in Denmark (Iversen, 1941). In north-eastern England this is not so clear (e.g. Hibbert, Switsur and West, 1971; Smith, 1958b) but at Thrang Moss in the Lake District a temporary decline of Tilia was noted (Oldfield, 1963). No comparable decline of Tilia has been noted from East Anglia (e.g. Godwin and Tallantire, 1951; Sims, 1973; Godwin, 1956), but in other southern areas, for example in Somerset, the behaviour of Tilia varied at the time of the elm decline (e.g. Godwin, 1948; Dewar and Godwin, 1963; Coles and Hibbert, 1968). In parts of Norway it was Viscum that declined most notably with Ulmus (Hafsten, 1957). Everywhere the elm decline was followed by an increase, often only a minor one, of weed types such as Plantago lanceolata, Chenopodiaceae and Artemisia.

The cause of the elm decline has been a matter of contention for some time. In the absence of much data on the activity of Neolithic man

this change in forest composition was at first attributed to climatic deterioration (Iversen, 1941; Godwin, 1956). This hypothesis was based on the decline of the frost-sensitive Hedera in Denmark (Iversen, 1944), and the decline of the thermophilous Tilia in parts of England. Other evidence has been presented for a brief period of colder climate in mountainous areas of central Europe where the anthropogenic factor at this time could be considered negligible (Frenzel, 1966), and for increased precipitation in Scotland (Pennington, 1973). In England and the Netherlands there was no decline of Hedera with Ulmus and a climatic deterioration, or increased continentality, has therefore been considered invalid by some workers (Van Zeist, 1959).

The possibility that soil deterioration was a major cause has been ruled out by the observation that Ulmus was often partly replaced by Fraxinus, an equally demanding tree as far as soil nutrients are concerned (Godwin, 1956).

Disease has been suggested as a possible cause of the elm decline (Watts, 1961). Heybroek (1963) considered Dutch Elm disease and Phloem Necrosis to be of quite recent origin, and to be considerably aggravated by the intense activity of man at the present time. He suggested that if one of these diseases had been long-established then the elm would have developed more resistance to it by now. It is also noteworthy that in Warwickshire, where a rich beetle fauna was described from the same level as the elm decline pollen record, the insects responsible for transmitting Dutch Elm diseas (Scolytus spp.) were quite absent (Kelly and Osborne, 1964).

It has been suggested that the decline of Ulmus pollen values did not represent a change in forest composition at all, but that the fairly heavy pollen grains of Ulmus were merely prevented from reaching the

pollen-collecting sites by being filtered out by abundant growth of Salix surrounding these basins (Tauber, 1965). Since in many places, including Holderness, the decline of Ulmus pollen was not accompanied by any abundance of Salix pollen this hypothesis seems rather unlikely.

As dates for Neolithic settlements were pushed back to that of the elm decline, and as evidence for substantial activity by Neolithic man accumulated he has increasingly been held responsible for the elm decline. Neolithic artifacts have been found at the level of the elm decline at Shippea Hill, Cambridgeshire (Clark and Godwin, 1962). Many Neolithic trackways dated to a similar time as the elm decline have been unearthed in the peat of the Somerset Levels (e.g. Coles and Hibbert, 1968; Coles, Hibbert and Clements, 1970; Coles, Hibbert and Orme, 1973). In Denmark the appearance of 'weed' herbs, especially of Plantago lanceolata, immediately after the elm decline has been taken as strong evidence for temporary clearance by man (Iversen, 1941, 1949). Throughout north-western Europe these herbs appeared after the elm decline and they are strongly suggestive of human interference. In the British Isles Plantago lanceolata has been found in Late-glacial deposits, so it was probably not introduced here, as in Denmark. Nevertheless, its presence after the elm decline can only have occurred if there was some sort of forest clearance. The growth of the light demanding Fraxinus, notable in Holderness at the time of the fall of Ulmus, is further evidence for the opening up of the woodland. Fraxinus and some weed herbs did grow during the Atlantic period, but these may well represent some earlier, Mesolithic activity (e.g. Sims, 1973).

Troels-Smith (1960) has proposed that the lopping of Ulmus, Fraxinus and Hedera to feed to stalled cattle was the main cause of the elm decline. Certainly there can have been few open grasslands for stock

to graze and only a limited amount of tree felling may have been possible. The feeding of Ulmus branches, as well as those of Fraxinus and a range of other trees, including Salix, has continued until very recent times in the more remote parts of Europe, and is still practised in the Himalayas today, where Ulmus is even deliberately planted for this purpose (Heybroek, 1963).

That there was some forest clearance for cultivation at or just after the elm decline is demonstrated by the presence of cereal pollen at some sites - as at Hockham Mere, Norfolk (Sims, 1973). In Ireland the elm decline has been considered to mark the beginning of Neolithic cultivation with lopping of elm for fodder followed by selective clearance of Ulmus because it grew on the better soils (Mitchell, 1965).

The widespread synchroneity of the elm decline is almost 'too good' for a human cause, as there is perhaps insufficient range in the dates to suggest the spread of a new culture from one centre. This synchroneity is more reflective of a climatic cause. The percentage pollen diagrams do not make it clear whether Ulmus alone declined or whether other trees suffered as well. This is an important point in determining whether climatic deterioration was responsible or whether rather selective felling by man occurred. The detailed, absolute pollen analyses of Hockham Mere and Sea Mere, in East Anglia (Sims, 1973) showed that Quercus and Fraxinus declined as well as Ulmus, and that there was a fall in total tree pollen production at the elm decline. The 'approximate' absolute pollen information from Hornsea supports the idea of a drop in total arboreal pollen production which is notably of Ulmus, Tilia, Quercus and Fraxinus. Oldfield (1963) has observed a fall in tree pollen frequency after the elm decline, in the Lake District, where truly absolute pollen analyses have demonstrated a decline of Betula and Pinus as well as of Ulmus, and the importance of fire in the elm decline has been considered (Pennington, 1973).

Despite some conflicting evidence the anthropogenic cause of the elm decline is, on balance, the most likely explanation. This is most likely to be the cause of the phenomenon in Holderness. Neolithic man was present in the region, if only sparsely (Elgee and Elgee, 1933), and there is no clear evidence for a climatic, edaphic or disease factor as the major cause.

It may well be that the real cause was a combination of factors (Smith, 1961). Some slight climatic deterioration may have begun a decline which was vastly accelerated by early man, which in turn may have caused soil deterioration in some places. Although disease can probably be rejected as the main cause (Heybroek, 1963), the lopping of Ulmus for fodder may have provided numerous 'wounded' trees through which disease of some sort could spread rapidly. The spread of an insect vector over a few years might be caused by some climatic change, or even some other type of human activity, and in turn lead to a temporary decline of elm (Smith, 1961). While there is evidence for an anthropogenic cause to the elm decline in much of Britain, such a link between Neolithic activity and the clear decline of elm in northern Scotland is absent (Pennington, 1973). It is not known why man began lopping and clearing, but some widespread climatic change may have been behind his new activity. Sims (1973) has proposed that a climatic deterioration in the continental climate of central Europe caused a spreading of the Neolithic cultures to more favourable areas. This hypothesis satisfies the synchroneity of the elm decline if the spread of this culture was fairly rapid, as is likely.

The Neolithic period

In Holderness the Neolithic period, which probably opened with the elm decline, was one in which man had a noticeable but fairly small effect on the vegetation. Some forest openings were made and in these herbs

flourished, but there could have been no widespread clearance. Doubtless Holderness, with its dense forest, heavy soils and considerable areas of waterlogged ground, was inhospitable to Neolithic man. Access from the more densely settled Wolds would have been restricted by the Hull valley.

Elsewhere in northern England the presence of Neolithic man has been shown to have a fairly small effect on the vegetation. In the southern Lake District there was sufficient clearance to allow Fraxinus to spread, and a little cereal cultivation was attempted (Oldfield, 1963). In south-western Cumberland there was considerable and permanent Neolithic clearance allowing Gramineae, Ericales and Pteridium to expand (Walker, 1966). Yet it was in southern England that Neolithic man was most active. Settlement and agriculture were probable mainly on the calcareous slopes, so there is little palynological evidence. On the Somerset levels the construction of trackways may represent the movement of Neolithic peoples from settlements on the Mendip and Polden Hills, and possibly on the patches of interglacial sands within the levels. Pollen analysis has shown that on the slopes, and on the lighter sandy soils of the Burtle beds, forest clearance and cultivation was well under way (Godwin, 1960b; Coles and Hibbert, 1968; Coles, Hibbert and Clements, 1970; Coles, Hibbert and Orme, 1973). In the Cambridgeshire fens there was some clearance associated with a Neolithic settlement (Clark and Godwin, 1962). In the Breckland of East Anglia clearance and cereal cultivation has been demonstrated close to the Neolithic flint mines of Grimes Graves. This area of light sandy soils being very suitable for settlement, the clearance of forest was more or less permanent as Gramineae, Plantago lanceolata and Ericales spread over the cleared ground and soil deterioration began on the easily leached soils (Godwin and Tallantire, 1951).

Perhaps the most typical feature of the Neolithic is the 'Landnam' temporary clearance, first described from Denmark (Iversen, 1941). A small area of forest was felled and a primitive form of cultivation carried out until the soil fertility deteriorated, when the area was left to regenerate. The whole phase might last only fifty years. In the British Isles somewhat longer, but still temporary, clearances have been described from East Anglia (Sims, 1973) and Northern Ireland (Morrison, 1959; Smith, 1958c; Pilcher et al., 1971). These clearance phases, lasting about two hundred years, opened with a period of pastoralism. This was followed by some cultivation and was in turn succeeded by more pastoralism as the soil fertility declined, before the area was abandoned and scrub woodland was allowed to regenerate.

Within Holderness the regeneration of the woodland seems to have occurred on a regional scale long after the elm decline, and perhaps up to a thousand years later. This extended period of clearance followed by a regional regeneration of woodland therefore probably represents a whole series of small, temporary, clearances by nomadic, largely pastoral peoples followed by a regional decrease of human activity in Holderness in later Neolithic times.

The Post-Neolithic period

The Bronze Age saw an increase in forest clearance in the plain of Holderness, and more abundant crannog, or lake-village, settlement than before. A few cereals may have been cultivated for the first time here. Nevertheless the Wolds and the North York Moors were still more attractive to settlement and clearance. The extension of clearance at this time has been demonstrated from much of the British Isles, such as the Lake District (Oldfield, 1960, 1963; Pennington, 1970), north-west Yorkshire (Piggot and Piggot, 1963), Scotland (Turner, 1965, 1970), Somerset (Dewar and Godwin, 1963) and Ireland (Mitchell, 1965). It was on the

southern chalklands, however, that clearance was most complete. In Kent much chalk downland had been deforested by 3,600 B.P., when there was an extensive weed flora. Tilia was almost completely cleared by 3,200 B.P. (Godwin, 1962), much earlier than further north (Turner, 1962, 1965). The Breckland was probably less completely cleared than the chalk (Turner, 1970). It is likely that most clearance was still of a fairly temporary nature. These may have led to soil impoverishment on the higher and lighter soils (e.g. Dimbleby, 1962; Pennington, 1970), but this did not occur on the heavier soils, as those of Holderness, where much woodland remained in spite of Bronze Age activity.

During the Iron Age period there was further clearance in Holderness, but still no great activity. Such a minor influence of Iron Age man has also been noted in north-western England (Oldfield, 1960; Pennington, 1964; Walker, 1966). At Malham, however, there was a major clearance (Piggot and Piggot, 1963), and elsewhere in England and Wales deforestation advanced considerably (e.g. Sparks and Lambert, 1961; Turner, 1970). In Somerset much land was cleared close to the Glastonbury and Meare lake villages, which date from about 2,300 B.P. (Godwin, 1960).

After the end of the Iron Age period there is little palynological evidence for vegetational change within Holderness. From other data, however, it seems likely that there was little further clearance until about 400 A.D. when the introduction of the mouldboard plough facilitated cultivation of the heavy soils (Elgee and Elgee, 1933). Pollen analyses have demonstrated more extensive clearance at this later date in other parts of northern England, as in Cheshire (Birks, 1965) where clearances similar to those of the Iron Age occurred; and in the Lake District (e.g. Smith, 1959) where clearance at about 400 A.D. has been attributed

to the Brigantian culture (Pennington, 1965). What pollen evidence there is from Roos, though possibly confused by local effects, supports the idea of much increased clearance at, possibly, around this time.

As has been noted, there is no evidence for climatic deterioration in late Bronze Age and/or early Iron Age times in Holderness. Elsewhere, many of the features taken as evidence for such a climatic change (e.g. Godwin, 1948) now seem to have been caused by early man. The climatic deterioration hypothesis was largely based on the recurrence surfaces and development of raised bogs, the decline of the thermophilous Tilia, and the increase of Betula, apparently in response to increased oceanicity. It was from the Iron Age onwards that the warmth demanding Fagus and Carpinus spread, however. The decline of Tilia was not synchronous and was most likely to have been caused by man (Turner, 1962) who also may have initiated the increase of Betula. In Wales the spread of blanket bog has been considered a result of human activity (Moore, 1973). Therefore it is now difficult to hold a view of recent climatic deterioration, and the pollen analyses from Holderness do not support such an idea. However, the vegetational changes were not necessarily caused solely by man. Small temporary changes in climate presumably did occur, but their effect on the vegetation would have been swamped by the increasing dominance of man over his environment.

Conclusions

The late Flandrian period of Holderness was characterised by the increasing influence of man as he gradually cleared the mixed forest and began cultivation. This is the main feature of the period throughout the rest of the country and north-western Europe. Compared with the lighter and drier soils of much of the rest of England, notably the chalk downlands of the south, and the sandy Breckland of East Anglia, but also the uplands of the North York Moors, for example, Holderness must have been

inhospitable for prehistoric man. The extensively waterlogged areas would have made access difficult. The Hull valley, not finally drained until the eighteenth century A.D., together with the Humber estuary, must have more or less cut off Holderness from the rest of the country. Although Neolithic, Bronze Age, and Iron Age clearance was carried out the dense, mixed deciduous forest and the heavy clay soils must have put cultivation largely beyond the capabilities of these cultures. As a result prehistoric clearance of the vegetation of Holderness rather lagged behind that of much of the rest of England. It was not until the historic period, when the heavy land could be more easily ploughed, and later when serious drainage began, that the vegetation of the region approached the almost total artificiality which it exhibits today.

GENERAL CONCLUSIONS

Some of the main features to emerge from this study are outlined below.

Late-glacial vegetation The sequences displayed in the Late-glacial vegetational history of Holderness seem to fit into place along a gradient of oceanicity, which decreased from west to east across north-western Europe. In Holderness an amelioration of climate, allowing some birchwood development, has been demonstrated at around 13,000 B.P. This coincides with what seems to have occurred in north-western England at the same time (Pennington and Bonny, 1970). In the north-west this open woodland development was maintained right through to the main interstadial. In Holderness birch woodland seems to have been suppressed between the early amelioration of climate and the main interstadial expansion of trees. This is postulated to be due to drought rather than a significant drop in temperature, chiefly because of the spread of Hippophae at this time. On the continent of Europe, for example in Denmark and the Netherlands, evidence has tended to suggest that there was a decrease in temperature between an early amelioration, the Bolling oscillation, and the main interstadial, or Allerod (e.g. Iversen, 1942, 1954; Van der Hammen, 1952). Thus, the effects of a climatic deterioration appear to have increased further away from the ameliorating effect of the Atlantic Ocean. The Pennines may have formed a significant barrier to this oceanic influence, and consequently the Late-glacial vegetation of Holderness was rather more akin to that of the adjacent parts of mainland Europe than to that of north-western England.

The use of absolute pollen analysis methods in tracing Late-glacial vegetational history has enhanced the demonstration of the marked changes

in climate during this period of time. Total annual pollen deposition varied considerably, peaking during the phases of milder climate, and reaching a minimum during the climatically severe Post-interstadial phase. The absolute pollen values have demonstrated that during the main interstadial, not only did woodland spread, but the growth and spread of many herbs was also enhanced. This phenomenon of the expansion of both woodland and herb growth has been noted for the main interstadial where absolute pollen analysis has been carried out elsewhere, in north-west England (Pennington and Bonny, 1970) and in North America (Davis, 1967).

Post-glacial vegetation The development of the vegetation of the Flandrian Stage in Holderness mirrors the general pattern for the rest of England, and indeed for most of north-western Europe. A few notable features stand out, however.

Alnus appears to have shown a markedly varied behaviour within Holderness. In the British Isles as a whole its early spread does not seem to have been a steady migration across the country. Rather, it became established in locally favourable situations such as lake shores or damp valleys and remained restricted to these sites for a considerable period of time. In Holderness it was established close to Hornsea Mere at a very early date, yet it was not represented in the pollen spectra at Roos until much later. This tree presumably did not grow very close to the Bog early in the Flandrian. It seems unlikely that it did not grow in the carr-lands fairly close to Roos at an early date, and therefore its poor representation in the pollen spectra at this site may be due, in some measure, to the character of pollen deposition in the basin. There also seems to have been a marked diachroneity in the great expansion of Alnus, at the two sites. This may be due largely to local topographic features and the much more local nature of the pollen rain contribution

to the Bog at Roos.

The status of Tilia cordata in Holderness during the Flandrian is not totally clear. The abundance of its pollen in the spectra of some sites may be partly the result of poor preservation of the pollen of other types. However, it does seem likely that this tree was a more important constituent of the mid Flandrian deciduous forest in Holderness than in many other parts of the country. This may be due to the fairly calcareous nature of the boulder clays on which the soils of the plain formed. Tilia cordata may have been especially abundant on the more calcareous soils of the valley sides in western Holderness, closer to the influence of the chalk Wolds.

Because of the lack of radiocarbon dates available and the possibly inconsistant nature of sediment accumulation at the Roos site it has been considered unwise to draw too many conclusions about the later Flandrian changes in vegetation from the absolute pollen deposition values. Together, the percentage and absolute evidence suggests that the elm decline, which occurred at around 5,000 B.P. throughout much of north-western Europe, was not merely a decrease in the importance of Ulmus in Holderness. Other trees, notably Tilia, but possibly some of the other dry-land forest types also suffered somewhat. Elsewhere much evidence has pointed to clearance by Neolithic man as the main cause, and this was probably the case in Holderness. In this low-lying, rather damp area of heavy clay soils clearance was probably only rather slight, and a later regeneration of the forest suggests that there was a significant abandoning of the plain by Neolithic peoples.

Pollen accumulation A notable feature has been the nature of pollen accumulation at the two major sites. For the first half of the Flandrian, for example, total pollen accumulation at the Old

Mere, Hornsea and at the Bog, Roos was roughly the same - at values around 6,000 pollen grains deposited/cm^2/year. However at Hornsea Alnus pollen was deposited in the sediments from a much earlier date, and in much greater quantity than at Roos. Quercus pollen was also somewhat more plentiful at Hornsea. Annual deposition values of Corylus pollen at Roos were double those at Hornsea. These differences have been attributed partly to the varying contribution of the different pollen rain components (Tauber, 1967) (see chapter 8).

Both sites were open water at this time. At Hornsea the inflow stream brought in much Alnus pollen, and the aerial pollen deposition represented a fairly regional pattern of vegetation - possibly explaining the large contribution of Quercus. The Bog at Roos had no inflow stream, and the canopy and rainout components of aerial pollen deposition into it were probably dwarfed by the massive amount of pollen of the trunk space component from the overhanging vegetation around this small lake. This would explain the great amounts of pollen from the comparatively low-growing Corylus in the sediments at this site.

Pennington (1973) has shown that pollen deposition into lakes is directly comparable with the size of the lake, smaller lakes trapping considerably greater quantities of pollen than large ones. The full size of the Old Mere at Hornsea cannot be properly gauged but has been estimated at perhaps two to three miles long. This would make it of comparable size to Loch a'Chroisg, in north-west Scotland, for which pollen deposition just before the elm decline has been calculated at 6,036 grains/cm^2/year (Pennington, 1973). This figure is very similar to that for the Old Mere at Hornsea for most of the mid-Flandrian. The relationship between lake size and pollen deposition would therefore seem to be borne out thus far.

The smallest site of Pennington (1973) was Blea Tarn, with a surface area of 31 hectares. It yielded figures of 23,815 pollen grains deposited/ cm^2/year just before the elm decline. The Bog is smaller than Blea Tarn and therefore one might expect even greater annual pollen deposition figures than at Blea Tarn, and certainly much greater pollen deposition values than at Hornsea. Yet, The Bog, like the Old Mere site, trapped only about 6,000 pollen grains/cm^2/year in mid-Flandrian times. Both Blea Tarn and the Bog, Roos would have large quantities of trunk space component pollen deposited in them. At Blea Tarn the inflow stream also probably added much pollen, and the lack of such a stream at Roos accounts for the lower values of pollen deposition.

In general small lakes may trap more pollen than large ones where, although both have the pollen contribution from an inflow stream, the smaller lake has a greater aerial pollen contribution from the more adjacent surrounding vegetation. At the two sites in Holderness annual pollen deposition was similar, probably because the larger lake (Hornsea Old Mere) had a large stream component of pollen influx, despite a comparatively small aerial (especially trunk space) component. The Roos site could have trapped much trunk space component pollen, but received no stream component. The effect of these two different enhancing factors at the two sites was to give them the same total annual pollen deposition values.

The relationship between increasing lake size and decreasing pollen deposition (Pennington, 1973) would therefore seem to be valid only where all the lakes considered either do or do not have an inflow stream. This emphasises the importance of the 'stream component' in contributing pollen to limnic deposits.

The use of absolute pollen analysis methods The two main potential advantages of absolute pollen analysis have been outlined by Pennington (1973). Firstly, the absolute pollen deposition rates for each taxon are advantageous over percentage figures as a basis for comparison of diagrams from many sites, when one or more high pollen producers vary from site to site. Secondly, the elimination of the need to use judgement in selecting a pollen sum as a basis for percentage calculation makes comparison more objective. The extensive calculation of absolute pollen frequencies should eventually allow the quantitative evaluation of the regional pollen component (Janssen, 1966) - that component of the pollen rain that is constant throughout a region.

The disadvantages of the technique include the fact that the characteristics of pollen influx into lake sediments are not yet adequately understood. The total pollen deposition values in sediment may vary at the same level within a single lake (Davis, Brubaker and Webb, 1973). Lake size and morphometry also has a considerable influence on the absolute numbers of pollen grains deposited (Pennington, 1973). Thus the absolute frequency of pollen in lake sediments is not a direct reflection of the local or regional vegetation pattern. The calculation of pollen deposition rates relies heavily on the accuracy of the measurement of sedimentation rates. This latter is made difficult by the variability of sedimentation in lake basins and by the inherent uncertainties of radiocarbon dating.

These current weaknesses in the absolute pollen analysis method may, in time, be removed to some extent by more quantitative studies of pollen influx into lakes, along the lines of the work of Peck (1973), for example. In the meantime the calculation of absolute pollen frequencies and deposition rates makes its greatest contribution to the understanding

of past vegetation not through the comparison of absolute numbers of pollen grains deposited, but through the comparison of the changes in the absolute figures within and between sites.

The reliability of the absolute pollen deposition rates calculated for the Late-glacial period at the Bog, Roos is somewhat reduced by the small number of radiocarbon dates. For such a phase of rapidly changing sediment type, sedimentation rate may also have changed rapidly and therefore a considerable number of radiocarbon dates are required for a really accurate assessment of absolute pollen deposition rates. Nevertheless the pollen deposition rates calculated do show up several features, as outlined above. The differences in total pollen deposition values between the cold and mild climatic phases and the expansion of the absolute values of most taxa in response to climatic amelioration, have been noted above and elsewhere (Pennington and Bonny, 1970; Davis, 1967), and they represent a distinct gain on the information derived from the percentage diagram alone.

The calculation of absolute pollen deposition for the Flandrian of Holderness has been based on estimated dates, and therefore on rather uncertain sedimentation rates. These statistics are consequently of rather less value than 'true' calculations of absolute pollen deposition. For this method to be effective there is a need for the site under consideration to have a consistent sediment type and, therefore, the high probability of a fairly constant sedimentation rate. The Old Mere at Hornsea serves better for this purpose than the Bog at Roos which underwent change from open water to raised bog. At this latter site the absolute pollen values of the late-Flandrian were not comparable with those of the early Flandrian or Late-glacial because pollen deposition occurred under completely different circumstances.

The clearly-marked pollen zone boundaries have had to be used to fix the estimated dates for the calculation of sedimentation rates. One is looking chiefly for changes in absolute values between adjacent zones, but it is at the zone boundaries that the sedimentation rates, necessarily, change. The pollen deposition rates tend to change across the zone boundaries, but this may frequently be a result of the, possibly erroneous, change in sedimentation rate, rather than a result of a vegetational change. Where the deposition values for pollen of all taxa change in the same direction and to the same degree as the alteration in sedimentation rate, then the pollen deposition values can be regarded as the result of an incorrect calculation of sedimentation rate, and they probably do not portray a vegetational change. Where the values of one or two taxa change in a different direction to the change in sedimentation rate, or in a distinctly different way to the majority of the other taxa a real change in the vegetation may be deduced.

In other words, it is in the comparison of the behaviour of the absolute values of the individual taxa, rather than in the changes of total pollen deposition, that the real value of this 'semi-absolute' pollen analysis method lies. The very uncertainty of the dates and sedimentation rates does, in itself, bring advantages. It necessitates the application of various, different sedimentation rates to the same data, and this can produce considerably more information than can come from the use of just one 'certain' sedimentation rate, or from the percentage diagrams.

This is demonstrated well by the problem of Alnus (see chapter 8). Percentage diagrams show the Alnus expansion to be after the Corylus maximum and during the peaks of Quercus, Pinus and Ulmus percentages at both Hornsea and Roos. The absolute diagrams from Hornsea show the spread of Alnus to occur during the Corylus maximum and before the peak

values of Quercus, Pinus and Ulmus. At Roos the absolute diagrams show Alnus values expanding after the Corylus maximum and after the peak deposition values of pollen of Quercus, Pinus and Ulmus. This suggests that the Alnus expansion was later at Roos than at Hornsea. When the same date for this feature is applied to both sites the sedimentation rates are such as to produce very erratic results at Roos. So the absolute data here give some evidence to the diachroneity of Alnus expansion at the two sites. This is obscured to a considerable extent by the percentage diagrams because of the interdependent nature of their values.

The absolute pollen data, whether used in terms of pollen frequency, or pollen deposition based on actual radiocarbon dates or estimated dates, has been a useful aid in the unravelling of the vegetational history of Holderness. Because of the several weaknesses of these methods they yield little conclusive evidence themselves. Used in conjunction with the percentage results of pollen analysis they serve to establish a considerably clearer picture of past vegetation.

REFERENCES

AARIO, L (1940) Waldgrenzen und subrezenten pollenspektren in Petsama, Lapland.
Helsinki, Ann. Acad. Sci. Fenn. 54(8), 1-120.

ANDERSEN, S. Th. (1964) Interglacial plant successions in the light of environmental changes
Rep. Vith int. Quat, Congr. 2, 359-368.

ANDERSEN, S. Th. (1967) Tree pollen rain in a mixed deciduous forest in South Jutland.
Rev. Palaeobot and Palynol. 3, 267-275.

ANDERSEN, S. Th. (1970) The relative pollen productivity and pollen representation of north European trees, and correction factors for tree pollen spectra.
Danm. Geol. Unders. II, 96, 99pp.

ANDERSEN. S. Th. (1973) The differential pollen productivity of trees and its significance for the interpretation of a pollen diagram from a forested region.
In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 109-115. Blackwell Scientific Publications, Oxford.

ARMSTRONG, A. L. (1923) The Maglemose remains of Holderness and their Baltic counterparts.
Proc. Prehist. Soc. East Anglia. 6(i), 57-70.

BARTLEY, D. D. (1962) The stratigraphy and pollen analysis of lake deposits near Tadcaster, Yorkshire.
New Phytol. 61, 277-287.

BARTLEY, D. D. (1966) Pollen analyses of some lake deposits near Bamburgh, in Northumberland.
New Phytol. 65, 141-156.

BELLAMY, D. J., BRADSHAW, M. P., MILLINGTON, G. R. and SIMMONS, I. G. (1966) Two Quaternary deposits in the lower Tees basin.
New Phytol. 65, 429-442.

BENNINGHOFF, W. S. (1962) Calculation of pollen and spore density in sediments by addition of exotic pollen in known quantities. Pollen et Spores 4, 332-333.

BENNINGHOFF, W. S. and KAPP, R. O. (1962) Suggested notations to indicate identification stature of fossil pollen. Pollen et Spores 4, 332.

BENT, A. and WRIGHT, H. (1963) Pollen analysis of surface materials and lake sediments from the Chuska mountains, New Mexico. Bull. Geol. Soc. Amer. 74, 491-500.

BERGLUND, B. E. (1973) Pollen dispersal and deposition in an area of southeastern Sweden - some preliminary results. In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 117-129. Blackwell Scientific Publications. Oxford.

BIRKS, H. H. (1970) Studies in the vegetational history of Scotland. I. A Pollen diagram from Abernethy Forest, Iverness-shire. J. Ecol. 58, 827-846.

BIRKS, H.H. (1972) Studies in the vegetational history of Scotland. II. Two pollen diagrams from the Galloway Hills, Kirkcudbrightshire. J. Ecol. 60, 183-217.

BIRKS, H. J.B. (1965) Pollen analytical investigations at Holcroft Moss, Lancashire, and Lindow Moss, Cheshire. J. Ecol. 53, 299-314.

BIRKS, H. J. B. (1968) The identification of Betula nana pollen. New Phytol 67, 309-314.

BIRKS, H. J. B. (1970) Inwashed pollen spectra at Loch Fada, Isle of Skye. New Phytol. 69, 807-820.

BIRKS, H. J. B. (1973a) Past and Present vegetation of the Isle of Skye: a Palaeoecological study.
Cambridge University Press, London.

BIRKS, H. J. B. (1973b) Modern pollen rain studies in some arctic and alpine environments.
In: Quaternary Plant Ecology (ed. by H. J. B. Birks and R. G. West) pp 143-168 Blackwell Scientific Publications. Oxford.

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

BIRKS, H. J. B. and DEACON, J. (1973) A numerical analysis of the past and present flora of the British Isles.
New Phytol. 72, 877.

BISAT, W. S. (1932) On the sub-division of the Holderness boulder clays.
The Naturalist, Hull, 215-219.

BLACKBURN, K. B. (1953) A long pollen diagram from Northumberland.
Trans. Nth. Nat. Union 22, 40-43.

de BOER, G. (1963) Spurn Point and its Predecessors.
The Naturalist, Hull, 113-120.

de BOER, G. (1964) Spurn Head: its history and evolution
Trans. and Papers, Inst. Brit. Geogr., No. 29, 115-128.

BONNY, A. P. (1972) A method for determining absolute pollen frequencies in lake sediments.
New Phytol. 71, 393-405.

BOYLAN, P. J. (1967) The Pleistocene Mammalia of the Sewerby-Hessle buried cliff.
Proc. Yorks. Geol. Soc. 36, 115-125.

BROOKS, D. and THOMAS, K. (1967) The distribution of pollen grains on microscope slides.
Pollen et Spores, 9, 621-629.

BROWN, A. P. (1971) The Empetrum pollen record as a climatic indicator in the Late Weichselian and early Flandrian of the British Isles. New Phytol. 70, 841-849.

BURCHELL, J. P. T. and ERDTMAN, O. G. E. (1950) Indigenous Tilia platyphyllos in Britain. Nature, London. 165, 411.

CATT, J. A. and PENNY, L. F. (1966) The Pleistocene deposits of Holderness, East Yorkshire. Proc. Yorks. Geol. Soc. 35, 375-420.

CHAMBERS, T. C. and GODWIN, H. (1971) Scanning electron microscopy of Tilia pollen. New Phytol. 70, 687-692

CHANDA, S. (1965) The history of vegetation of Brondmyra, a late-glacial and early post-glacial deposit in Jaeren, South Norway. Arbok. Univ. Bergen Nr. 1. pp 17.

CHARLESWORTH, J. K. (1929) The South Wales end-moraine. Q. Jl. Geol. Soc. Lond. 85, 335-358.

CLAPHAM, A. R., TUTIN, T. G. and WARBURG, E. F. (1962) Flora of the British Isles, 2nd edn. Cambridge University Press, London.

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

CLARK, J. G. D. and GODWIN, H. (1956) A Maglemosion site at Brandesburton, Holderness, Yorkshire. Proc. Prehist. Soc. 22, 6-22.

CLARK. J. G. D. and GODWIN, H. (1962) The Neolithic in the Cambridgeshire fens. Antiquity 36, 10-23.

COLES, J. M. and HIBBERT, F. A. (1968) Pre-historic roads and tracks in Somerset, England. I Neolithic.
Proc. Prehist. Soc. 34, 238-258.

COLES, J. M., HIBBERT, F. A. and CLEMENTS, C. F. (1970) Prehistoric roads and tracks in Somerset, England. 2 Neolithic.
Proc. Prehist. Soc. 36, 125-151.

COLES, J. M., HIBBERT, F. A. and ORME, B. J. (1973) Prehistoric roads and tracks in Somerset: 3 The Sweet track.
Proc. Prehist. Soc. 39, 256-293.

CONOLLY, A. P. and DAHL, E. (1970) Maximum summer temperature in relation to the modern and Quaternary distributions of certain arctic-montaine species in the British Isles.
In: Studies in the vegetational history of the British Isles (ed. by D. Walker and R.G. West) pp 159-223.
Cambridge University Press, London.

CONOLLY, A. P., GODWIN, H. and MEGAW, E. M. (1950) Studies in the post-glacial history of British vegetation, XI Late-glacial deposits in Cornwall.
Phil. Trans. Roy. Soc. B 234, 397.

CONWAY, V. M. (1954) Stratigraphy and Pollen Analysis of Southern Pennine blanket peats.
J Ecol. 42, 117-147.

COOPE, G. R. (1970) Climatic interpretations of late Weichselian coleoptera from the British Isles.
Revue de Geographie physique et de Geologie dynamique XII, Fasc 2, 149-155.

COOPE, G. R. and BROPHY, J. A. (1972) Late glacial environmental changes indicated by a coleopteran succession from North Wales.
Boreas 1, 97-142.

CRACKLES, F. E. (1953) Calamagrostis stricta in S.E. Yorkshire.
Bot. Soc. Brit. Is. Year Book, 54.

CRACKLES, F. E. (1968) Some Plant associations of the River Hull valley.
East Yorkshire Field Studies, 1, 13-24.

CRAIG, A. J. (1972) Pollen influx to laminated sediments: a pollen diagram from north eastern Minnesota.
Ecology 53, 46-57.

CROWDER, A. A. and CUDDY, D. G. (1973) Pollen in a small river basin: Wilton Creek, Ontario.
In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 61-77. Blackwell Scientific Publications, Oxford.

CUSHING, E. J. (1967) Evidence for differential pollen preservation in Late-Quaternary sediments in Minnesota.
Rev. Palaeobotan. Palynol. 4, 87-101.

DALE, M. B. and WALKER, D. (1970) Information analysis of pollen diagrams I.
Pollen et Spores 12, 21-37.

DAVIS, M. B. (1963) On the theory of pollen analysis.
Am. J. Science, 261, 897-912.

DAVIS, M. B. (1965) A method for the determination of absolute pollen frequency.
In: Handbook of Palaeontological techniques (ed. by B. Kummel and D. Raup) pp. 674-686. Freeman San Francisco.

DAVIS, M. B. (1966) Determination of absolute pollen frequency.
Ecology 47, 310-311.

DAVIS, M. B. (1967) Pollen accumulation rates at Rogers Lake, Connecticut during late- and post-glacial time.
Rev. Palaeobotan. Palynol. 2, 219-230.

DAVIS, M. B. (1967a) Pollen deposition in lakes as measured by sediment traps.
Bull. Geol. Soc. Am. 78, 849-858.

DAVIS, M. B. (1968) Pollen grains in lake sediments: redeposition caused by seasonal water circulation.
Science, 162, 796-799.

DAVIS, M. B. and DEEVEY, E. S. JR. (1964) Pollen accumulation rates: Estimates from Lake-glacial sediment of Rogers lake.
Science, 145, 1293-1295.

DAVIS, M. B. and GOODLETT, J. C. (1960) Comparison of the present vegetation with pollen spectra in surface samples from Brownington Pond, Vermont.
Ecology 41, 346-357.

DAVIS, M. B., BRUBAKER, L. B. and WEBB, T. III (1973) Calibration of absolute pollen influx.
In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 9-25. Blackwell Scientific Publications. Oxford.

DAVIS, R. B., BREWSTER, L. A. and SUTHERLAND, J. (1969) Variation in pollen spectra within lakes.
Pollen et Spores, 11, 557-571.

DEWAR, H. S. L. and GODWIN, H. (1963) Archaeological discoveries in the raised bogs of the Somerset Levels, England.
Proc. Prehist. Soc. 29, 17-49.

DICKSON, J. H. (1973) Bryophytes of the Pleistocene.
Cambridge University Press, London.

DIMBLEBY, G. W. (1961) The ancient forest of Blackamore.
Antiquity 35, 123-128.

DIMBLEBY, G. W. (1962) The development of British heathlands and their soils.
Oxford, Forestry Memoirs No. 23.

DYAKOWSKA, J. (1937) Researches on the rapidity of the falling down of pollen of some trees.
Bull. Acad. Polon. Sci. Lett. Ser. B: 155-168.

ELGEE, F. and ELGEE, H. W. (1933) The Archaeology of Yorkshire.
Methuen. pp 272.

ELKINGTON, T. T. (1968) Introgressive hybridization between Betula nana and Betula pubescens in N.W. Iceland.
New Phytol. 67, 109-118.

EMILIANI, C. (1955) Pleistocene temperatures.
J. Geol., 63, 538-578.

ERDTMAN, G. (1935) Pollen statistics.
In: Pollen grains, by R.P. Wodehouse pp. 110-125 Mcgraw Hill book company, New York.

ERDTMAN, G. and ERDTMAN, H. (1933) The improvement of the Pollen-analysis technique.
Svensk. Botanisk. Tidskrift 27, (3) 347-357.

ERDTMAN, G., BERGLUND, B. E. and PRAGLOWSKI, J. (1961) An introduction to a Scandinavian pollen flora.
Grana palynol. 2, 1.

EVANS, G. H. (1970) Pollen and Diatom analyses of Late-Quaternary deposits in the Blelham Basin, North Lancashire.
New Phytol. 69, 821-874.

FAEGRI, K. (1966) Some problems of representativity in pollen analysis.
The Palaeobotanist, 15, 135-140.

FAEGRI, K. and IVERSEN, J. (1964) Textbook of pollen analysis.
Munksgaard, Copenhagen.

FAGERLIND, F. (1952) On the real signification of pollen diagrams.
Bot. Notiser, V, 185-224.

FARRINGTON, A. and MITCHELL, G. F. (1951) The end-moraine north of Flamborough Head.
Proc. Geol. Ass. 62, 100-106.

FLENLEY, J. R. (1973) The use of modern pollen rain samples in the study of the vegetational history of tropical regions. In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 131-141. Blackwell Scientific Publications. Oxford.

FRENZEL, B. (1966) Climatic change in the Atlantic/Sub-Boreal transition on the Northern Hemisphere: botanical evidence. In: World Climate from 8000 to 0 B.C. (ed. by J.S. Sawyer) pp 89-123. Royal Met. Soc., London.

GAMS, H. (1943) Der Sanddorn (Hippophae rhamnoides L.) in Alpengebiet. Beih. z. Bot. Central bl. 62B, 1.

GAUNT, G. D. and TOOLEY, M. J. (1974) Evidence for Flandrian sea-level changes in the Humber estuary and adjacent areas. Bulletin of the Geological Survey of Great Britain, No. 48, 1974, pp. 25-41.

GODWIN, H. (1940a) Pollen analysis and Forest History of England and Wales. New Phytol. 39, 370-400.

GODWIN, H. (1940b) Studies of the Post-glacial History of British Vegetation. III Fenland pollen diagrams. IV Post-glacial changes of relative land- and sea-level in the English Fenland. Phil. Trans. R. Soc. Lond., B, 230, 239-303.

GODWIN, H. (1948) Studies of the post-glacial history of British vegetation. X. Correlation between climate, forest composition, prehistoric agriculture and peat stratigraphy in Sub-Boreal and Sub-Atlantic peats of the Somerset Levels. Phil. Trans. Roy. Soc. B 233, 275-286.

GODWIN, H. (1956) History of the British Flora. Cambridge University Press, London.

GODWIN, H. (1960a) Radiocarbon dating and Quaternary history in Britain.
Proc. Roy. Soc. Lond., B, 153, 287-320.

GODWIN, H. (1960b) Prehistoric Wooden Trackways of the Somerset Levels: their construction, age and relation to climatic change.
Proc. Prehist. Soc. 26, 1-36.

GODWIN, H. (1962) Vegetational History of the Kentish Chalk Downs as seen at Wingham and Frogholt.
Veroff, Geobot. Inst. Zurich, 37, 83-99.

GODWIN, H. (1968) Studies of the Post-glacial history of British vegetation. XV. Organic deposits of Old Buckenham Mere, Norfolk.
New Phytol. 67, 95-107.

GODWIN, H. and GODWIN, M. E. (1933) British Maglemose harpoon sites.
Antiquity 7, 36-48.

GODWIN, H. and TALLANTIRE, P. A. (1951) Studies in the Post-glacial history of British vegetation. XII Hockham Mere, Norfolk.
J. Ecol. 39, 285-307.

GODWIN, H., WALKER, D. and WILLIS, E. H. (1957) Radiocarbon dating and post-glacial vegetational history: Scaleby Moss.
Proc. Roy. Soc. Lond., B, 147, 352-366.

GORDON, A. D. and BIRKS, H. J. B. (1972) Numerical methods in Quaternary Palaeoecology. I Zonation of pollen diagrams.
New Phytol. 71, 961-979.

GORDON, A. D. and BIRKS, H. J. B. (1974) Numerical methods in Quaternary Palaeoecology. II Comparison of pollen diagrams.
New Phytol. 73, 221-249.

GREGOR, J. W. (1930) Experiments on the Genetics of Wild Populations, I *Plantago maritima*.
J. Genetics 22, 15-25.

GROHNE, U. (1957) Die bedeutung des phasenkontrast-verfahrens fur die pollenanalyse, dargelegt am beispiel der Gramineen-pollen vom Getreidetyp.
Photographie Forsch. 7, 237-48.

HAFSTEN, U. (1957) Om mistelteinens og bergflettens historie i Norge
Blyttia 15, 43-60.

HAMMEN, TH. VAN DER (1952) Late-glacial flora and periglacial phenomena in the Netherlands.
Leidse Geologische Mededilingen 17, 73-185.

HAMMEN, Th. VAN DER (1961) Deposicion reciente de polen atmosferico en la Sabana de Bogota y Alrededores.
Boletin Geologico (Servicis Geologico National de Colombia) 7, No. 1-3, 183-194.

HAMMEN, Th. VAN DER, MAARLEVELD, G. C., VOGEL, J. C. and ZAGWUN, W. H. (1967) Stratigraphy, climatic succession and radiocarbon dating of the last glacial in the Netherlands.
Geol. en Mijnbouw, 46, 79-95.

HARTZ, N. and MILTHERS, V. (1901) Det senglaciale Ler i Allerod Teglvaerksgrav.
Meddel. Dansk Geol. Foren, 8, 31.

HEATHCOTE, W. R. (1951) A soil survey on Warpland in Yorkshire.
J Soil Sci. 2, 144-162.

HEUSSER, C. J. (1973) Postglacial vegetation on Umnak Island, Aleutian Islands, Alaska.
Rev. Palaeobotan. Palynol. 15, 277-285.

HEYBROEK, H. M. (1963) Diseases and lopping for fodder as possible causes of a Prehistoric decline of Ulmus.
Acta. Bot. Neerl. 12, 1-11.

HIBBERT, F. A. and SWITSUR, V. R. (in the press) Radiocarbon dating of Flandrian pollen zones in Wales and Northern England.

HIBBERT, F. A., SWITSUR, V. R. and WEST, R. G. (1971) Radiocarbon dating of Flandrian pollen zones at Red Moss, Lancashire. Proc. Roy. Soc. Lond., B, 177, 161-176.

HIRST, J. (1952) An automatic volumetric spore trap. Ann. Appl. Bot. 39, 257-265.

HOPKINS, J. S. (1950) Differential floatation and deposition of coniferous and deciduous tree pollen. Ecology, 31, 633-641.

HULME, P. D. and BECKETT, S. C. (1973) Pollen Analysis of the Faxfleet Peats. East Yorkshire Field Studies 4, 15-24.

HUTCHINSON, T. C. (1966) The occurrence of living and sub-fossil remains of Betula nana in Upper Teesdale. New Phytol. 65, 351-357.

HYDE, H. A. (1936) On a peat bed at East Moors, Cardiff. Trans. Cardiff Nat. Soc. 69, 39-48.

HYDE, H. A. and ADAMS, K. F. (1958) An atlas of airborne pollen grains. Macmillan London.

IVERSEN, J. (1941) Landnam i Danmarks Stenalder. Danm. Geol. Unders. IIR, 66, 68pp

IVERSEN, J. (1942) En pollenanalytisk Tidsfaestelse of Ferakvandslagene ved Norre Lyngby. Medd. fra D.G.F. 10(2), 130.

IVERSEN, J. (1944) Viscum, Hedera and Ilex as climatic indicators. Geol. For. Stockh. Forh. 66, 463-483.

IVERSEN, J. (1947) Diskussionsindlaeg i: Norkiskt Kvartargeologiskt note den 5-9 nov. 1945. Geol For. Stockh. Forh. 69, 241-242.

IVERSEN, J. (1949) The influence of prehistoric man on vegetation. Danm Geol. Unders. IVR, 6, 1-25.

IVERSEN, J. (1954) The late-glacial flora of Denmark and its relation to climate and soil.
Danm. Geol. Unders. IIR, 80, 87.

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

JANSSEN, C. R. (1966) Recent pollen spectra from the deciduous and coniferous-deciduous forests of N.E. Minnesota: a study in pollen dispersal.
Ecology 47, 804-825.

JANSSEN, C. R. (1973) Local and regional pollen deposition.
In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 31-42. Blackwell Scientific Publications. Oxford.

JESSEN, K. (1935) The composition of the forests in Northern Europe in Epipalaeolithic time.
Kg Danske Videnskab. Selskab., Bid. Medd. 12, 1-64.

JESSEN, K and FARRINGTON, A. (1938) The bogs at Ballybetagh, near Dublin, with remarks on late-glacial conditions in Ireland.
Proc. Roy. Irish Acad. XLIV B no. 10, 205-260.

JOHNSON, R. H., TALLIS, J. H. and PEARSON, M. (1972) A temporary section through late-Devensian sediments at Green Lane, Dalton-in-Furness, Lancashire.
New Phytol. 71, 533-544.

JORGENSEN, S. (1963) Early Post-glacial in Aamosen.
Danm. Geol. Unders. IIR, 87, 1-36.

JORGENSEN, S. (1967) A method of absolute pollen counting.
New Phytol. 66, 489-93.

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

KABAILIENE, M. (1966) On distribution of pollen in lakes.
In: Palynology in geological research in the Baltic Soviet Republics. Institute of Geology, Vilnius, pp. 113-119.

KELLY, M. and OSBORNE, P. J. (1964) Two Faunas and Floras from the alluvium at Shustoke, Warwickshire.
Proc. Linn. Soc. Lond. 176, 37-65.

KERSHAW, A. P. (1970) A pollen diagram from Lake Euramoo, North East Queensland, Australia.
New Phytol. 69, 785-805.

KIRK, W. and GODWIN, H. (1963) A late-glacial site at Loch Broma, Ross and Cromarty.
Trans. Roy. Soc. Edin. 65, 225-249.

KNOX, E. M. (1951) Spore morphology in British ferns.
Tr. Bot. Soc. Edinb. 35, 437-449.

KROG, H. (1954) Pollen analytical investigation of a C^{14} - dated Allerod Section from Rude Vedby.
Danm. Geol Unders. IIR, 80, 120-139.

LAMPLUGH, G. W. (1891) Final report of the committee appointed for the purpose of investigating an ancient sea-beach near Bridlington Quay.
Rep. Br. Ass. (for 1890), 375-377.

LIBBY, W. F. (1955) Radiocarbon Dating.
University of Chicago Press.

LICHTI-FEDEROVICH, S. and RITCHIE, J. C. (1968) Recent pollen assemblages from the western interior of Canada.
Rev. Palaeobot and Palynol. 7, 297-344.

LIVINGSTONE, D. A. (1955) A light-weight piston sampler for lake deposits.
Ecology 36, 137-139.

LIVINGSTONE, D. A. and ESTES, A. H. (1967) A carbon-dated pollen diagram from the Cape Breton plateau, Nova Scotia. Can. J. Bot. 45, 339-359.

MADGETT, P. A. (1975) Re-interpretation of Devensian Till stratigraphy of eastern England. Nature, London, 253, 105-107.

MATTHEWS, J. (1969) The assessment of a method for the determination of absolute pollen frequencies. New Phytol. 68, 161-166.

MITCHELL, G. F. (1965) Littleton Bog, Tipperary: an Irish Agricultural Record. J Roy. Soc. Antiq. Ireland 95, 121-132.

MOORE, P. D. (1970) Studies in the vegetational history of Mid-Wales II The late-glacial period in Cardiganshire. New Phytol. 69, 363-375.

MOORE, P. D. (1972) Studies in the vegetational history of Mid-Wales III Early Flandrian pollen data from west Cardiganshire. New Phytol. 71, 947-959.

MOORE, P. D. (1973) The influence of prehistoric cultures upon the initiation and spread of blanket bog in upland Wales. Nature, London 241, 350-353.

MORRISON, M. E. S. (1959) Evidence and interpretation of 'Landnam' in the north-east of Ireland. Bot. Notiser 112, 185-203.

MULLENDERS, W., GULLENTOPS, F. and CREVECOEUR, E. (1958) L'Oscillation de Bolling a Lommel (Campine, Belgique). Bull. Acad. Belg. 90, 315.

MULLER, H. (1953) Zur spat und nacheiszeitlichen vegetaticnsgeschichte des mittel deutschen Trock-engebietes. Nova Acta Leopoldina Carol. (n.F.) 16, 1-67.

NORDHAGEN, R. (1943) Sikilsdalen og Norges Fjellbeiter.
Bergens Museums Skrifter, 22, pp 607.

OLDFIELD, F. (1959) The pollen morphology of some of the west European Ericales.
Pollen et Spores 1, 19-48.

OLDFIELD, F. (1960) Studies in the Post-glacial history of British vegetation: Lowland Lonsdale.
New Phytol. 59, 192-217.

OLDFIELD, F. (1963) Pollen analysis and man's role in the ecological history of the south-east Lake District.
Geogr. Annlr. 45, 23-40.

OLDFIELD, F. (1965) Problems of mid-Post glacial pollen zonation in part of north-west England.
J. Ecol. 53, 247-260.

OLDFIELD, F. (1970) Some aspects of scale and complexity in pollen-analytically based palaeoecology.
Pollen et Spores 12, 163-171.

O'SULLIVAN, P. E., OLDFIELD, F. and BATTARBEE, R. W. (1973) Preliminary studies of Lough Neagh sediments. I. Stratigraphy, chronology and pollen analysis.
In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 267-278. Blackwell Scientific Publications, Oxford.

PEARSON, M. C. (1960) Muckle Moss, Northumberland. I. Historical.
J. Ecol. 48, 647-666.

PEARSON, M. C. and ROGERS, J. A. (1962) Hippophae rhamnoides L.
Biological Flora of the British Isles.
J. Ecol. 50, 501-513.

PECK, R. M. (1972) Efficiency tests on the Tauber trap used as a pollen sampler in turbulent water flow.
New Phytol. 71, 187-198.

PECK, R. M. (1973) Pollen budget studies in a small Yorkshire catchment.
In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 43-60. Blackwell Scientific Publications. Oxford.

PENNINGTON, W. (1947) Lake sediments: Pollen diagrams from the bottom deposits of the north basin of Windermere.
Phil. trans. Roy. Soc. B 233, 137.

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

PENNINGTON, W. (1965) The interpretation of some Post-glacial vegetation diversities at different Lake District sites.
Proc. Roy. Soc. B, 161, 310-323.

PENNINGTON, W. (1970) Vegetation history in the north-west of England: a regional synthesis.
In: Studies in the vegetational history of the British Isles (ed. by D. Walker and R.G. West), pp 41-79. Cambridge University Press, London.

PENNINGTON, W. (1973) Absolute pollen frequencies in the sediments of lakes of different morphometry.
In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 79-104. Blackwell Scientific Publications. Oxford.

PENNINGTON, W. and BONNY, A. P. (1970) Absolute pollen diagram from the British late-glacial.
Nature, London, 226, 871-873.

PENNINGTON, W., HAWORTH, E. Y., BONNY, A.P. and LISHMAN, J. P. (1972) Lake sediments in northern Scotland.
Phil. trans. Roy. Soc. B 264, 191-294.

PENNY, L. F. (1963) Vertebrate remains from Kelsey Hill, Burstwick and Keyingham.
Hull. Mus. Publs. No. 214, 5-14.

PENNY, L. F., COOPE, G. R. and CATT, J. A. (1969) Age and insect fauna of the Dimlington Silts, East Yorkshire.
Nature, London 224, 65-67.

PHEMISTER, J. (1922) Notes on the Brandesburton Kame, Yorkshire.
Geol. Mag. 59, 323-326.

PIGGOT, C. D. (1969) The status of Tilia cordata and Tilia platyphyllos on the Derbyshire limestone.
J. Ecol. 57, 491-504.

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

PILCHER, J. R., SMITH A. G., PEARSON, G. W. and CROWDER, A. (1971) Land clearance in the Irish Neolithic: new evidence and interpretation.
Science, N.Y. 172, 560-562.

POHL, F. (1937) Die polleneizevgung der Windbluter.
Beih. bot. Centralblatt, 56A, 365-470.

POST, L. VON (1916) Om Skogstradpollen i sydsvenska torfmosslagerfoljder.
Geol. For. Stock. 38, 384.

POTTER, L. D. and ROWLEY, J. R. (1960) Pollen rain and vegetation, San Augustin Plains, New Mexico.
Bot. gazette 122, 1-25.

PRAGLOWSKI, J. R. (1962) Notes on the pollen morphology of Swedish trees and shrubs.
Grana palynol. 3, 45.

PRESTWICH, J. (1861) On the occurrence of Cyrena fluminalis, together with marine shells of recent species, in beds of sand and gravel over beds of boulder clay near Hull.
Q. Jl. Geol. Soc. Lond. 17, 446-456.

PROCTER, M. C. F. and GRIFFITHS, M. E. (1956) Helianthemum Mill.
Biological Flora of the British Isles.
J. Ecol. 44, 675-692.

RAWITSCHER, F. (1945) The Hazel Period in the Post-Glacial Development of Forests.
Nature, London. 156, 302-303.

RAYNOR, G. S. and OGDEN, F. C. (1965) Twenty-four hour dispersion of ragweed pollen from known sources.
Brookhaven National Laboratory, Publ. 957, (T-398).

REID, C. (1885) The geology of Holderness, and the adjoining parts of Yorkshire and Lincolnshire.
Mem. Geol. Surv. 177pp London.

RITCHIE, J. C. (1969) Absolute pollen frequencies and carbon - 14 age of a section of Holocene Lake sediment from the Riding Mountain area of Manitoba.
Can. J. Bot. 47, 1345-1349.

ROWLEY, J. R. (1960) The exine structure of 'cereal' and 'wild' type grass pollen.
Grana Palynologica 2, 9-15.

RYMER, L. (1973) Modern pollen rain studies in Iceland.
New Phytol. 72, 1367-1373.

SANGSTER, A. G. and DALE, H. M. (1961) A preliminary study of differential pollen grain preservation.
Can. J. Bot. 39, 35-43.

SEDDON, B. (1962) Late-glacial deposits at Llyn Dwythwch and Nant Ffrancon, Caernarvonshire.
Phil Trans. Roy. Soc. B 244, 459-481.

SEDDON, B. (1964) Aquatic plants of Welsh lakes.
Nature, Wales 9, 3.

SERNANDER, R. (1908) On the evidence of Post-glacial change of climate furnished by the peat mosses of northern Europe.
Geol. Foren. Stockholm. 30, 465-478.

SHEPPARD, J. A. (1956) Draining of the Marshlands of East Yorkshire.
PhD. thesis, University of Hull.

SHEPPARD, J. A. (1957) The Medieval Meres of Holderness.
Trans. Inst. Brit. Geog. 75-86.

SHEPPARD, T. (1912) The Lost towns of the Yorkshire coast.

SIMMONS, I. G. (1969) Pollen diagrams from the North York Moors.
New Phytol 68, 807-827.

SIMS, R. E. (1973) The anthropogenic factor in East Anglian vegetational history: an approach using A.P.F. techniques.
In: Quaternary Plant Ecology (ed. by H.J.B. Birks and R.G. West) pp 223-236. Blackwell Scientific Publications. Oxford.

SMITH, A. G. (1958a) Post-glacial Deposits in South Yorkshire and North Lincolnshire.
New Phytol. 57, 33-54.

SMITH, A. G. (1958b) Two Lacustrine deposits in the south of the English Lake District.
New Phytol. 57, 363-386.

SMITH, A. G. (1958c) Pollen analytical investigations of the mire at Fallahogy Td., Co. Derry.
Proc. Roy. Irish Acad. 59B, 329-343.

SMITH, A. G. (1959) The mires of south-western Westmorland: stratigraphy and pollen analysis.
New Phytol. 58, 105-127.

SMITH, A. G. (1961) The Atlantic Sub-Boreal Transition.
Proc. Linn. Soc. Lond. 172, 38-49.

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

SMITH, A. G. and PILCHER, J. R. (1973) Radiocarbon dates and vegetational history of the British Isles.
New Phytol. 72, 903-914.

SMITH, R. A. (1911) Lake-dwellings in Holderness.
Archaeologia 62, 593-610.

SMITH, W. (1821) New geological atlas of England and Wales: Part IV, Geological map of Yorkshire.
Cary, London.

SPARKS, B. W. and LAMBERT, C. A. (1961) The Post-glacial deposits at Apethorpe, Northamptonshire.
Proc. Malac. Soc. Lond. 34, 302-315.

SUESS, H. E. (1970) Bristlecone pine calibration of the radiocarbon timescale. 5200 B.C. to the present.
Proc. Nobel Symposium XII.

SUGGATE, R. P. and WEST, R. G. (1959) On the extent of the Last Glaciation in eastern England.
Proc. Roy. Soc. B 150, 263-283.

SUTTON, O. (1947) The problem of diffusion in the lower atmosphere.
Quart. J. Roy. Met. Soc. 73, 257-276.

TAUBER, H. (1965) Differential pollen dispersion and the interpretation of pollen diagrams.
Danm. Geol. Unders. IIR, 89, pp 69.

TAUBER, H. (1967) Investigations of the mode of pollen transfer in forested areas.
Rev. Palaeobotan. Palynol., 3, 277-286.

TAUBER, H. (1974) A static non-overload pollen collector.
New Phytol. 73, 359-369.

TERASMAE, J. (1951) On the pollen morphology of Betula nana.
Svensk. Botanisk. Tidskrift. Bd45H2, 358-361.

TROELS-SMITH, J. (1955) Characterisation of unconsolidated sediments.
Danm. Geol. Unders. IVR, 10, 38-74.

TROELS-SMITH, J. (1960) Ivy, Misletoe and Elm: Climatic indicators - fodder plants.
Danm. Geol. Unders. IVR, 4, pp32.

TURNER, J. (1962) The Tilia decline: An anthropogenic interpretation.
New Phytol. 61, 328-341.

TURNER, J. (1964) Surface sample analyses from Ayrshire, Scotland.
Pollen et Spores 6, 583-592.

TURNER, J. (1965) A contribution to the history of forest clearance.
Proc. Roy. Soc. B 161, 343-354.

TURNER, J. (1970) Post-Neolithic disturbance of British vegetation.
In: Studies in the vegetational history of the British Isles (ed. by D. Walker and R.G. West) pp. 97-116. Cambridge University Press, London.

TURNER, J. and KERSHAW, A. P. (1973) A late- and post-glacial pollen diagram from Cranberry Bog, near Beamish, County Durham.
New Phytol. 72, 915-928.

TUTIN, W. (1955) Preliminary observations on a year's cycle of sedimentation in Windermere, England.
Mem. Ist. Idrobiol suppl. 8, 467-484.

TYLDESLEY, J. B. (1973) Long range transmission of tree pollen to Shetland. I Sampling and trajectories. II Calculation of pollen deposition.
New Phytol. 72, 175-190.

VALENTIN, H. (1957) Glazialmorphologische Untersuchungen in Ostengland. Abh. Geogr. Inst. Freien Universitat Berlin, 4, 1-86

VARLEY, W. J. (1968) Barmston and the Holderness Crannogs. East Riding Archaeologist 1, 11-26.

WADDINGTON, J. C. B. (1969) A stratigraphic record of the pollen influx to a lake in the Bag Woods of Minnesota. Geol. Soc. Am. Special Paper 123, 263-282.

WALKER, D. G. (1955) Studies in the post-glacial history of British vegetation. XIV Skelsmergh tarn and Kentmere, Westmorland. New Phytol. 54, 222-254.

WALKER, D. G. (1956) A site at Stump Cross, near Grassington, Yorkshire, and the age of the Pennine microlithic industry. Proc. Prehist. Soc. 22, 23-28.

WALKER, D. G. (1966) The late Quaternary history of the Cumberland Lowland. Phil. Trans. Roy. Soc. B 251, 1-210.

WALKER, D. G. and GODWIN, H. (1954) Lake stratigraphy, pollen analysis, and vegetational history. In: Excavations at Star Carr (by J.G.B. Clark) pp 25-69. Cambridge University Press, London.

WARBURG, E. F. (1963) Census Catalogue of British Mosses, 3rd edn. Ipswich.

WATSON, E. (1972) Pingos of Cardiganshire and the latest ice limit. Nature, London, 236, 343-344.

WATTS, W. A. (1961) Post-Atlantic forests in Ireland. Proc. Linn. Soc. Lond. 172, 33-38.

WEST, R. G. (1956) Quaternary deposits at Hoxne, Suffolk. Phil. Trans. Roy. Soc. B 239, 265-356.

WEST, R. G. (1968) Pleistocene Geology and Biology.
Longmans, London.

WEST, R. G. (1970) Pollen zones in the Pleistocene of Great Britain and their correlation.
New Phytol. 69, 1179-1183.

WOOD, S. V. and ROME, J. L. (1868) On the glacial and post-glacial structure of Lincolnshire and south-east Yorkshire.
Q. Jl. Geol. Soc. Lond. 24, 146-184.

WRIGHT, E. W. and CHURCHILL, D. M. (1965) The boats from North Ferriby, Yorkshire, England.
Proc. Prehist. Soc. 31, 1-24.

ZEIST, W. VAN. (1955) Pollen analytical investigations in the northern Netherlands.
Acta Bot. Neer, 4, 1-81.

ZEIST, W. VAN. (1958) Some radiocarbon dates in the post-glacial vegetation history of the northern Netherlands.
Veroff, Geob. Inst. Rubel, 34, 160-165.

ZEIST, W. VAN. (1959) Studies on the post-Boreal vegetational history of south-eastern Drenthe (Netherlands).
Acta Bot. Neer 8, 156-184.

APPENDIX

Pollen and spore counts from the Bog, Roos, the Old Mere, Hornsea and Gransmoor Quarry are tabulated below. Figures given are actual numbers of pollen grains of each taxon counted at each level sampled.

Key to pollen taxa

1. *Betula*(arboreal)
2. *Pinus*
3. *Ulmus*
4. *Quercus*
5. *Tilia cordata*
6. *Alnus*
7. *Fraxinus*
8. *Fagus*
9. *Carpinus*
10. *Betula nana*
11. *Corylus*
12. *Salix*
13. *Juniperus*
14. *Hedera*
15. *Ilex*
16. *Hippophae*
17. *Sorbus*
18. Rhamnaceae
19. *Viburnum*
20. *Lonicera*
21. *Calluna*
22. *Empetrum*
23. Ericaceae (undiff.)
24. Ericales
25. Gramineae
26. Cerealia
27. Cyperaceae
28. *Artemisia*
29. *Aster* T.
30. *Centaurea*
31. *Cirsium* T.
32. *Matricaria* T.
33. Compositae Lig.
34. Campanulaceae
35. Caryophyllaceae
36. Chenopodiaceae
37. *Helianthemum*
38. Cruciferae
39. *Drosera*
40. *Mercurialis*
41. Labiatae
42. *Epilobium*
43. *Polygonum amphibium*
44. *Plantago lanceolata*
45. *Plantago major*
46. *Rumex acet* T.
47. *Rumex*
48. *Caltha*
49. *Thalictrum*
50. Ranunculaceae

51. Filipendula
52. Potentilla
53. Poterium
54. Rosaceae
55. Rubiaceae
56. Scrophulariaceae
57. Umbelliferae
58. Urtica
59. Polygala
60. Viscum
61. Menyanthes
62. Alisma
63. Myriophyllum alterniflorum
64. Myriophyllum spicatum
65. Myriophyllum verticillatum
66. Myriophyllum (undiff.)
67. Lemna
68. Nuphar
69. Nymphaea
70. Potamogeton
71. Sparganium T.
72. Typha latifolia
73. Lycopodium selago
74. Lycopodium
75. Osmunda
76. Botrychium
77. Polypodium
78. Pteridium
79. Filicales undiff.
80. Sphagnum

THE BOG, ROOS

Sample depth (metres)	TAXA 1	2	3	4	5	6	7	8	9	10	11
0.0	114	5	10	15		1	4				6
0.5	562	64	7	2	2	279		1			2
0.15	436	73	3			235					3
0.25	32	4		3		27	3				2
0.35	90	8	1	4		22	2				8
0.45	192	16	4	9		33		1			15
0.55	13			7		6					9
0.75	43	3		24		20	5				11
0.95	56	2		5		14					13
1.15	40	1	2	7		21	1	1	2		66
1.35	10	2	2	6		11	2	2			26
1.55	4			3		8					10
1.75	7					4			1		11
1.95	4			1							7
2.15	4	1	1	3		5	1	1			9
2.35	48	2	3	24	5	49					72
2.55	81		8	23	12	60					148
2.75	84	1	12	53	22	100					289
2.95	19	2	7	13	22	104					141
3.15	38	3	7	42	31	85					270
3.35	15	1	2	29	11	50					146
3.55	42		6	52	4	103	4				393
3.75	74		2	37	12	165					301
3.85	44	2	3	46	7	150					220
3.95	94	5	13	43	37	335	1				485
4.05	39	2	25	39	42	140					175
4.15	33	1	29	46	174	1					196
4.35	32	8	96	24	52	353	2				716
4.55	33	33	119	24	19	373					664
4.75	51	20	68	28	16	77	1				478
4.85	28	14	30	28		13					241
4.95	37	26	45	20	2	14	2				482
5.05	48	26	47	30	5	5					477
5.15	39	37	44	38	7	3	1				606
5.25	41	23	34	33	1	4					438
5.35	45	27	72	30	5	2					731
5.55	35	17	80	31	2	2					989

The Bog, Roos (continued)

Sample depth (metres)	TAXA 12	13	14	15	16	17	18	19	20	21	22
0.0	94								1		
0.5	6		2							2	
0.15	1		3							5	
0.25	9	1								4	
0.35	2									3	
0.45	1									2	
0.55	1									2	
0.75	2			1						1	
0.95	1								2	8	35
1.15	4									4	2
1.35	3									2	2
1.55										2	2
1.75										31	71
1.95										1	42
2.15						1					
2.35	1									7	
2.55										9	
2.75			7							8	
2.95			9							5	
3.15			1							14	
3.35			1								
3.55			3								
3.75									1		
3.85			1								
3.95										2	
4.05			1								
4.15											
4.35	1										
4.55			2	1							
4.75											
4.85								1			
4.95			1								
5.05				2							
5.15											
5.25	1										
5.35	2										
5.55	1										

The Bog, Roos (continued)

Sample depth (metres)	TAXA 23	25	26	27	28	29	30	31	32	33	34
0.0	1	56	2	9	1				2	2	
0.5	5	235	6	3	1	1			18	3	
0.15	12	151	5	4	2	5			14	4	
0.25	1	423	8	2	23	5			2	4	
0.35	2	319	12	14	6	4	1		4	11	
0.45		396	7	2	4	7		7		10	1
0.55		219	11	2	2	3		6		5	
0.75	4	278	9	12	3	10		5	1	4	
0.95	52	57		6		1			1	1	
1.15	39	169	4	13	3	4		1	6	12	
1.35	103	80	1	8	1						
1.55	118	10		1	2	1			1	1	
1.75	569	12		4	4	5			2	42	
1.95	28	29		3	2	.1			1	1	
2.15	2	23		6	1	1		1	1	5	
2.35	2	4		3	1	2					
2.55	9	1		1							
2.75	3	2		2	3						
2.95	1	2									
3.15	8	1		3							
3.35	1	3					1				
3.55				3	2						
3.75		2		9							
3.85		2		10							
3.95		6	1	8	1						
4.05		1		4							
4.15				5							
4.35				2							
4.55				7							
4.75		1		3							
4.85	1	1		1							
4.95				3							
5.05		1		5							
5.15	2			9							
5.25				4							
5.35				8							
5.55		1		5							

The Bog, Roos (continued)

Sample depth (metres)	TAXA 35	36	37	38	39	40	41	42	43	44	45
0.0	1	2		1			1			1	
0.5	7	4		1				15		11	
0.15	7	1		5				2		3	
0.25	1	5		5				1		35	
0.35	1	3		1						110	
0.45	2			7	1			5		32	
0.55		1		2			2			37	
0.75	22	9		2			1			48	
0.95	1	3		1			1			16	
1.15	1	7		1						43	
1.35		2								14	
1.55		1								10	
1.75	1	2								14	
1.95		1			4					3	
2.15		3			1					10	1
2.35		4									
2.55											
2.75	2									1	
2.95											
3.15										3	
3.35		1				2				3	
3.55		1									
3.75		1								2	
3.85											
3.95										1	
4.05											
4.15		1									
4.35											
4.55											
4.75											
4.85											
4.95								2			
5.05											
5.15											
5.25											
5.35											
5.55											

The Bog, Roos (continued)

Sample depth (metres)	TAXA 46	47	48	49	50	51	52	53	54	55	56
0.0	1	1		1		1			4	3	
0.5	1	1									
0.15									1		
0.25	2	3			2				12		
0.35	6	9			2				4		
0.45	3					1	1		7	1	
0.55	3				3			1	1	1	
0.75	1				2				11	3	
0.95						1			1		
1.15	2				2	2	2	1	1	6	
1.35	2					2			1		
1.55	3										1
1.75	5								1		1
1.95	1					1					
2.15									10		
2.35					1						
2.55											
2.75											
2.95											
3.15					1						
3.35										1	
3.55											
3.75									3		
3.85							2				
3.95					1				1		
4.05							1				
4.15					1						
4.35									1		
4.55					1				1		
4.75									1		
4.85											
4.95											
5.05											
5.15									1		
5.25											
5.35											
5.55									1		

The Bog, Roos (continued)

Sample depth (metres)	TAXA 57	58	61	63	64	65	68	69	70	71	72
0.0	5									4	3
0.5	6										
0.15	8										1
0.25	23										
0.35	9									2	
0.45	3				1	1				2	
0.55	4									2	
0.75	4	1							1	5	1
0.95	2									9	
1.15	10									1	
1.35	4									7	
1.55	1									2	1
1.75	1									6	1
1.95											
2.15	2									15	1
2.35	1										
2.55					1					1	
2.75										2	
2.95											1
3.15	1									1	
3.35	1										
3.55											
3.75											1
3.85				3							
3.95					1						1
4.05	1										
4.15	1										
4.35	2	1									
4.55					1						
4.75											
4.85											1
4.95											1
5.05											
5.15	1										
5.25											
5.35	1										
5.55											

The Bog, Roos (continued)

Sample depth (metres)	TAXA 73	74	75	76	77	78	79	80
0.0							15	5
0.5							22	7
0.15							50	18
0.25							27	612
0.35							11	25
0.45		1				1	10	25
0.55							2	134
0.75						2	11	53
0.95						1	22	71
1.15						1	4	92
1.35			1				1	4
1.55							5	
1.75							12	
1.95			4			2	14	15
2.15							25	260
2.35					5		2	15
2.55					7		7	61
2.75					14	7	10	141
2.95					10		6	20
3.15					22	4	4	88
3.35					7		6	22
3.55					3	5	11	195
3.75					2		9	56
3.85					2		12	198
3.95					7		51	1
4.05					10		10	
4.15					7		4	
4.35					12		6	3
4.55					9		6	
4.75					8		9	2
4.85					4		9	
4.95	1				6		24	1
5.05					7		12	
5.15					4		17	2
5.25					5		4	
5.35					3		9	
5.55					2		12	

The Bog, Roos (continued)

Sample depth (metres)	TAXA 1	2	3	4	5	6	7	8	9	10	11
5.75	30	20	62	37		5					795
5.95	24	25	79	49	2	2					901
6.15	34	46	74	52							884
6.35	16	23	50	41							854
6.55	39	31	78	35							1024
6.75	6	19	25	20							499
6.95	12	37	46	9							694
7.15	14	49	93	50							870
7.35	17	23	42	3							387
7.55	48	32	112	20		1					890
7.75	73	38	218	8							1556
7.95	44	28	101	6							627
8.15	46	15	64	1							729
8.35	73	38	62	2							745
8.55	63	72	61	5		1					1795
8.75	47	40	25								761
8.95	155	15	5								514
9.05	150	34		2						4	11
9.15	160	15		1						4	1
9.25	851	14	1	3		1				3	1
9.35	46	51		1						9	1
9.45	13	80				1				5	
9.75	5	13								2	
9.95	7	16								5	
10.25	1	5									
10.45	6	2								2	
10.70	3	4								5	1
10.85	21	7								7	
10.90	52	12								7	3
10.95	213	48								25	1
11.05	159	14								14	1
11.10	229	4								12	
11.15	140	5								4	
11.20	83	8								11	
11.22	13	2								8	
11.26	9	7								2	
11.30	8	5								2	

The Bog, Roos (continued)

Sample depth (metres)	TAXA 12	13	14	15	16	17	18	19	20	21	22
5.75											
5.95	1										
6.15											
6.35											
6.55	1		1								
6.75			1								
6.95											
7.15			1								
7.35											
7.55											
7.75	1										
7.95	3		1								
8.15	2										
8.35	3										
8.55	5										
8.75	1										
8.95						1					
9.05	2										
9.15	2				2						1
9.25	38										1
9.35	2										1
9.45	4	5									1
9.75	2	5									2
9.95	1	6									
10.25	1										
10.45		6									
10.70		3									
10.85		3									
10.90		1				1					
10.95	6	2			1						1
11.05		1									
11.10	2	7									1
11.15	6	3									
11.20					61						
11.22	1				13						
11.26	1	5			6						
11.30	2	1			3						

The Bog, Roos (continued)

Sample depth (metres)	TAXA 23	25	26	27	28	29	30	31	32	33	34
5.75		1		5							
5.95				13							
6.15		2		5							
6.35		1		11							
6.55		2		17		1					
6.75				8							
6.95		3		10							
7.15				2							
7.35		1		3							
7.55		3		3	1						
7.75		1		3							
7.95				2							
8.15		4		2							
8.35		2		2							
8.55		5		1							
8.75		2		1						1	
8.95		1									
9.05				4	1						
9.15		2		5							
9.25		97		29	1						
9.35		6		12				1			
9.45		10		12	2						
9.75		6		16	6				1		
9.95		2		13							
10.25		2		6							
10.45				3		1					
10.70		3		5	1						
10.85		1		3	2				1		
10.90				3							
10.95		41		23	4						
11.05		2		5							
11.10		16		13	1						
11.15		5		11	3					1	
11.20		6		16	2	1					
11.22		9		13	2						
11.26		3		21	4					1	
11.30		7		8		1					

The Bog, Roos (continued)

Sample depth (metres)	TAXA 35	36	37	38	39	40	41	42	43	44	45
5.75											
5.95											
6.15											
6.35											
6.55											
6.75											
6.95				1							
7.15											
7.35											
7.55											
7.75				2							
7.95											
8.15											
8.35											
8.55				1							
8.75				1							
8.95											
9.05					2						
9.15				1	1						
9.25				1							
9.35		2		1	1						
9.45		2		1							
9.75											
9.95				1							
10.25											
10.45		1									
10.70		1							1		
10.85											
10.90								1	1		
10.95		2			2						
11.05					1						
11.10		1			4						
11.15					5						
11.20					20				7		
11.22					1			1			
11.26				1	4					1	
11.30					16						

The Bog, Roos (continued)

Sample depth (metres)	TAXA 46	47	48	49	50	51	52	53	54	55	56
5.75									1		
5.95					1				1		
6.15									1		
6.35									1		
6.55									1		
6.75											
6.95											
7.15									2		
7.35											
7.55									3		
7.75									3		
7.95									2		
8.15											
8.35									1		
8.55											
8.75				3							
8.95											
9.05				1					3		
9.15						3					
9.25	1			1		25			1	1	
9.35			1	2	3	37			5		
9.45				8	4	3			1		
9.75	1			2	2						
9.95				3							
10.25											
10.45						1				1	
10.70											
10.85						2				1	
10.90				1		4			2		
10.95		1		1		23			1		
11.05						4					
11.10				2		3			1		
11.15				4	1	1				1	
11.20				4		2			1		
11.22				2	1				1	1	
11.26				2		2			1	1	
11.30											

The Bog, Roos (continued)

Sample depth (metres)	TAXA 57	58	61	63	64	65	68	69	70	71	72
5.75	1										
5.95	1										1
6.15	3				1						
6.35											
6.55	1										
6.75		3									
6.95											
7.15											
7.35											
7.55										1	
7.75											
7.95	2										
8.15				1							
8.35										1	
8.55											
8.75	1										
8.95											
9.05				1							1
9.15				1	8						
9.25	5									10	
9.35											9
9.45	1				1						
9.75	3										
9.95									1		1
10.25											
10.45										1	2
10.70								1		1	
10.85											
10.90	1				2					1	1
10.95	1		2		1		1			4	1
11.05	1			3	1						
11.10	1				5			1	1	2	1
11.15				11							1
11.20				1							
11.22											
11.26											
11.30	2										

The Bog, Roos (continued

Sample depth (metres)	TAXA 73	74	75	76	77	78	79	80
5.75					1	1	4	
5.95					3	1	6	
6.15					3	3	19	
6.35					2		12	
6.55					3		11	
6.75							8	
6.95					1		2	
7.15							9	
7.35							3	
7.55							7	1
7.75							13	
7.95							6	
8.15							4	
8.35							14	
8.55							5	
8.75							8	
8.95							3	
9.05							22	
9.15							31	
9.25						1	21	
9.35						1	8	
9.45		2				1	33	
9.75		1			1		10	
9.95		1					9	
10.25							3	
10.45							1	
10.70		5				2	7	
10.85			2			2	4	
10.90							4	
10.95							3	
11.05							1	
11.10							10	
11.15							3	
11.20		2					77	
11.22							7	
11.26		5		1			6	
11.30		3					2	

The Bog, Roos (continued)

Sample depth (metres)	TAXA 1	2	3	4	5	6	7	8	9	10	11
11.34	36	1								4	
11.36	4	3								3	
11.40	44									4	
11.45	15	2								20	

Sample depth (metres)	TAXA 12	13	14	15	16	17	18	19	20	21	22
11.34	3	1			1						2
11.36	1	11									
11.40	2	1									1
11.45		1									1

Sample depth (metres)	TAXA 23	25	26	27	28	29	30	31	32	33	34
11.34		14		30	8						
11.36		4		9							
11.40		12		4	2						
11.45		2		9	5						

Sample depth (metres)	TAXA 35	36	37	38	39	40	41	42	43	44	45
11.34	1			14							
11.36	2			7							
11.40											
11.45					2				1		

The Bog, Roos (continued)

Sample depth (metres)	TAXA 46	47	48	49	50	51	52	53	54	55	56
11.34				3						3	
11.36									1		
11.40				5					1	1	
11.45				3						1	

Sample depth (metres)	TAXA 57	58	61	63	64	65	68	69	70	71	72
11.34	2				1			1		1	3
11.36	1										1
11.40				3	5				1		
11.45										1	1

Sample depth (metres)	TAXA 73	74	75	76	77	78	79	80
11.34	2	1	11				4	
11.36							4	
11.40			9				7	
11.45							3	

THE OLD MERE, HORNSEA

Sample depth (metres)	TAXA 1	2	3	4	5	6	7	8	9	10	11
1.55	12	7	2	18	4	34			1		10
1.65	38	3	6	21		55		1	3		48
1.75	13	3		21	2	62		1	2		37
1.85	24	7	3	53	2	224	2				136
1.95	23	7	10	101	4	203	7	1	2		97
2.05	23	11	9	52	2	211	4				95
2.15	28	3	13	104	2	224	6		1		122
2.25	12	4	5	81	2	212	2				110
2.35	8	7	4	79	5	193	3				132
2.45	23	6	10	45	4	199	1				134
2.65	54	4	2	47	15	235		1			153
2.85	16	2	11	157	23	209	3				168
3.05	22	3	7	94	38	194					127
3.25	39	4	4	110	38	172					149
3.45	56	5	3	132	45	293					176
3.65	38	4	2	79	20	201					159
3.85	48	3	7	118	18	393	1				263
3.95	20	4	8	175	11	340	6				306
4.05	23	2	1	42	8	233	3				181
4.15	7	5	9	111	9	156	1				144
4.25	16	5	7	56	39	164	1				139
4.35	11	2	20	129	24	184	10				84
4.45	7	9	40	89	29	176	7				101
4.55	12	6	27	120	19	227	6				64
4.65	28	1	26	77	67	234					117
4.75	6	12	39	129	35	216	4				119
4.85	17	9	39	71	33	187					98
4.95	15	9	34	119	31	185	6				77
5.05	11	7	33	104	44	206	1				109
5.15	14	12	58	181	43	272	5				137
5.25	22	7	36	43	53	189					103
5.35	16	8	64	181	53	329	2				162
5.45	16	7	63	61	19	198					151
5.65	10	9	30	40	13	169					169
5.85	10	8	47	55	5	181					226
6.05	19	6	34	57	18	171					293
6.25	15	28	57	54	4	220					288
6.45	10	11	29	65	7	173					232
6.65	11	39	54	37	7	217					270

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 12	13	14	15	16	18	20	21	22	23	25
1.55					2					1	49
1.65	3		1		1	2				6	57
1.75										1	48
1.85										1	41
1.95	2			1							40
2.05			2					1			55
2.15	3		5					1			43
2.25			3					1			37
2.35	1		4			1					48
2.45	2		3								44
2.65			1								16
2.85	1		1			1					8
3.05											5
3.25			1								4
3.45											3
3.65											1
3.85											10
3.95	1										21
4.05											6
4.15										1	6
4.25			1								4
4.35	1		2	1							9
4.45			5								5
4.55	2		3								4
4.65											3
4.75	2		2								5
4.85			4								3
4.95			1					1			2
5.05			5								4
5.15			1								2
5.25	1		2							1	4
5.35	1		4			1					3
5.45			1								3
5.65			3								3
5.85	2		2				1				1
6.05			2				1				1
6.25	2		1				1				5
6.45			3								
6.65			1								

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 26	27	28	29	31	33	35	36	37	38	41
1.55	1	5	1			7		3			
1.65	5	7	4			5		9		2	
1.75	3	6	1		1	4	1	6			1
1.85	7	10		1		3		2			
1.95	1	5	3	1		3		2			
2.05	6	13	1	1	1	1	2	3		1	
2.15	7	1	1	1		1	1	3			
2.25	4	4	1		1	3					
2.35	1	6	2	1		5	2	2			1
2.45	1	3	1				1	6			
2.65		23				1					
2.85		3	1					2			
3.05		17					1	2			
3.25		7									
3.45		1		1							
3.65		2						1			
3.85		2						1			
3.95		3						1			
4.05		14									
4.15		2	1	1							
4.25						1	1				
4.35		4									
4.45		6					1				
4.55		3		1							
4.65		4	1								
4.75		6						1			
4.85		2	1								
4.95		7									
5.05		5									
5.15		3									
5.25		4						1			
5.35		2						1			
5.45		5									
5.65		2									
5.85		7					1				
6.05		5						1			
6.25		10									
6.45		3									
6.65		5						1			

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 43	44	45	46	47	49	50	51	52	53	54
1.55		31	6	1				1			
1.65		29		1	1		1				2
1.75		40					1	1			
1.05		9			1			1			1
1.95	1	12									
2.05	3	8						1			1
2.15		4									
2.25		10						2		1	
2.35	1	16						1	1		
2.45	1	7						1			3
2.65		4									
2.85	1	3				1					
3.05											
3.25											
3.45											
3.65		1									
3.85											
3.95		3		1							1
4.05								1			
4.15		3		1							
4.25											
4.35											1
4.45											
4.55											1
4.65											
4.75											1
4.85											
4.95											
5.05											
5.15											
5.25											
5.35											
5.45											
5.65											2
5.85											
6.05											
6.25						1					1
6.45											
6.65											

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 55	57	59	60	62	63	64	65	67	68	69
1.55		1									
1.65		3						1			
1.75	1								2		
1.85							1				
1.95											
2.05		2								1	
2.15		1								1	
2.25	1	2									1
2.35		2									
2.45		2									
2.65		1									
2.85		1									
3.05		1									
3.25		1								1	
3.45		1									
3.65											
3.85		3									
3.95											
4.05		1									
4.15											
4.25											
4.35											
4.45			2							1	
4.55	2	2	1								
4.65		1									
4.75										1	
4.85											
4.95		1									
5.05											
5.15											
5.25											
5.35	1										
5.45											
5.65											
5.85											
6.05		1									
6.25				1							
6.45		3									
6.65		1									

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 70	71	72	73	74	75	77	78	79	80
1.55		4					1		7	
1.65							1		10	
1.75		3					2		14	
1.85		1					1		8	
1.95		2					5	1	12	
2.05		4					6		13	
2.15	1	3					4	1	23	
2.25		1					5		6	
2.35		5					1	1	17	
2.45		12	1				2		10	
2.65		6					1		4	
2.85		3					3		5	
3.05							10		8	1
3.25		1					11		9	
3.45		2					16		4	
3.65		1					2		3	
3.85		1					8		5	
3.95		3					5		5	
4.05		2					2		1	
4.15		2					2		3	
4.25		2					6	1	8	
4.35	1	2					4		8	
4.45	1	1					5		4	
4.55	3	3					2		7	
4.65		1					11		8	
4.75	1	4					3		7	
4.85		2					7		6	
4.95		1					3		6	
5.05		2					7	1	9	
5.15		3					4		6	
5.25		1					7		9	
5.35		2					6		7	
5.45		1					6		6	
5.65		3	1				3		8	
5.85							5		4	
6.05							5		6	
6.25							2		8	
6.45		1					4		6	
6.65							10		6	

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 1	2	3	4	5	6	7	8	9	10	11
6.85	12	72	352	62	8	194					328
7.05	24	22	33	37	5	215					230
7.25	32	89	63	69	5	168					182
7.45	55	62	78	57	7	142					198
7.65	74	48	52	91	5	72					280
7.85	37	42	36	57	2	10					296
8.05	26	45	42	48	3	52					254
8.25	44	30	25	58	2	4					338
8.45	27	45	41	54	2	1					280
8.65	42	25	42	36	2	7					372
8.85	94	25	26	20		9					443
9.05	261	22	1	4		5				3	22
9.25	155	36		1						1	1
9.45	71	10								1	
10.25	6	14								3	
10.65	1	2								1	
11.05		13								1	
11.25	1	1								1	
11.45	1	6								1	
11.65	13	13				1				3	
11.85	4	11								1	
12.05	14	10								1	
12.25	7	20								1	
12.35	18	12								1	
12.40	44	18								3	
12.45	258	33								17	
12.55	27	2								1	
12.65	7	5								3	
12.85	15	5								4	
13.05	7	6								2	
13.25	5	4	1							2	
13.45	1	6									
13.55	2	2								1	
13.75	1	3								2	

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 12	13	14	15	16	18	20	21	22	23	25
6.85	1		2							2	3
7.05			3								5
7.25			1								6
7.45			2								8
7.65			6								10
7.85	2										6
8.05	4			1						1	4
8.25			2				1				8
8.45	4		2								6
8.65	16		3								10
8.85	1		2								16
9.05	7										16
9.25	2								1		11
9.45	11								3		15
10.25		3			1						3
10.65											
11.05									1		
11.25											2
11.45											
11.65		1									
11.85											
12.05		3									
12.25		1			1						1
12.35											4
12.40		1									2
12.45	7				1				1		12
12.55											4
12.65		1			9				1		2
12.85	1	1			1						2
13.05	1	1			2						1
13.25	1				4						1
13.45											
13.55					3						
13.75											

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 26	27	28	29	31	33	35	36	37	38	41
6.85		6									
7.05		1									
7.25		11									
7.45		5									
7.65		8									
7.85		5									
8.05		3		1							
8.25		9									
8.45		2									
8.65		7	1								
8.85		4									
9.05		8						1	1		
9.25		7	3								
9.45		6	3				2	1	2		
10.25		8	3				1		1		
10.65		1									
11.05		1									
11.25		3	1								
11.45		1									
11.65			1								
11.85		1						1			
12.05		5	1			1		1	4		
12.25		4	2			1	1				
12.35		1				1			1		
12.40		5						1			
12.45		18	1	2					3		
12.55		6							1		
12.65		3						1			
12.85		5	1			1	1		2		
13.05											
13.25		7							1		
13.45		1									
13.55		2							1		
13.75		2									

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 43	44	45	46	47	49	50	51	52	53	54
6.85											1
7.05											
7.25											2
7.45											1
7.65											
7.85											
8.05											
8.25											2
8.45											
8.65		2									1
8.85		1									1
9.05						1		9			4
9.25								5			
9.45				3		5		20			3
10.25								2			
10.65	1										
11.05								1			
11.25	1							1			
11.45											
11.65					1	1		1			
11.85								2			
12.05	1										
12.25						1					
12.35						1		3			
12.40	1					1	1	3			
12.45		1		3		5		20			
12.55						3		1			
12.65						1		1			
12.85								1			
13.05											
13.25				1		2		1			
13.45						1					
13.55						1					
13.75						2					

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 55	57	59	60	62	63	64	65	67	68	69
6.85		1									
7.05											
7.25		1									
7.45											
7.65		1									
7.85		1									
8.05		2									
8.25											
8.45											
8.65							1				
8.85							1				
9.05							2				
9.25		1					3				
9.45		1									
10.25											
10.65											
11.05											
11.25	1										
11.45											
11.65											
11.85							1				
12.05					1						
12.25		1									
12.35						1					
12.40							2				
12.45		1					2				
12.55		1									
12.65											
12.85		1				1					
13.05											
13.25											
13.45											
13.55											
13.75											

The Old Mere, Hornsea (continued)

Sample depth (metres)	TAXA 70	71	72	73	74	75	77	78	79	80
6.85							12		9	
7.05		1					6		6	
7.25		1					2		8	
7.45		2					3		9	
7.65		1		1			1		8	
7.75							1		8	
8.05		2					1		3	
8.25		1							7	
8.45							1		5	
8.65		1							3	
8.85		3					1		10	
9.05		3							19	5
9.25		2							26	
9.45		1							1	
10.25				2					6	1
10.65									4	
11.05									1	
11.25				2					2	
11.45									1	
11.65				2					3	
11.85		1								
12.05		2		1					2	
12.25									1	
12.35				1					1	
12.40			1						1	
12.45	1		1	1	2		1		5	2
12.55									1	
12.65		1								
12.85									2	
13.05										
13.25				1					4	
13.45				1					2	
13.55										
13.75									2	

GRANSMOOR QUARRY

Sample depth (metres)	TAXA 1	2	3	4	5	6	7	11	12	14	15
0.24	3	14	2	35	49	147	9	48	2		
0.28	3	6		3	7	37		9		1	
0.32	4	10	3	8	130	102	1	36	1		
0.36	6	21	2	24	217	111		51		1	
0.40	10	4	6	75	349	132	11	83	4	2	
0.44	2	8	4	37	238	78		64		1	
0.48	2	10	7	34	172	73		80		1	
0.52	2	3	9	17	125	58		68			
0.54	17	7	4	15	82	50		113		1	
0.56	4	5	24	43	165	102	4	40		2	1
0.60	4	9	14	24	93	63		97		1	
0.64	1	5	20	23	133	38		37		2	
0.68	1	6	11	13	126	62	2	45	1	1	
0.72	5	12	11	17	186	47	1	97		1	
0.76	2	5	18	12	104	48		40	1		
0.80	1	8	15	6	63	29		43			
0.84	7	14	25	23	12	78	1	86	1	3	
0.88	24	35	20	19	7	35		96		1	
0.92	13	5	19	9		7	1	113		1	
0.96	5	7	6					31			
1.00	10	13	17	6	1		1	76	3		
1.04	11	19	16	3				50			
1.08	9	36	10	1				105			

Gransmoor Quarry (continued)

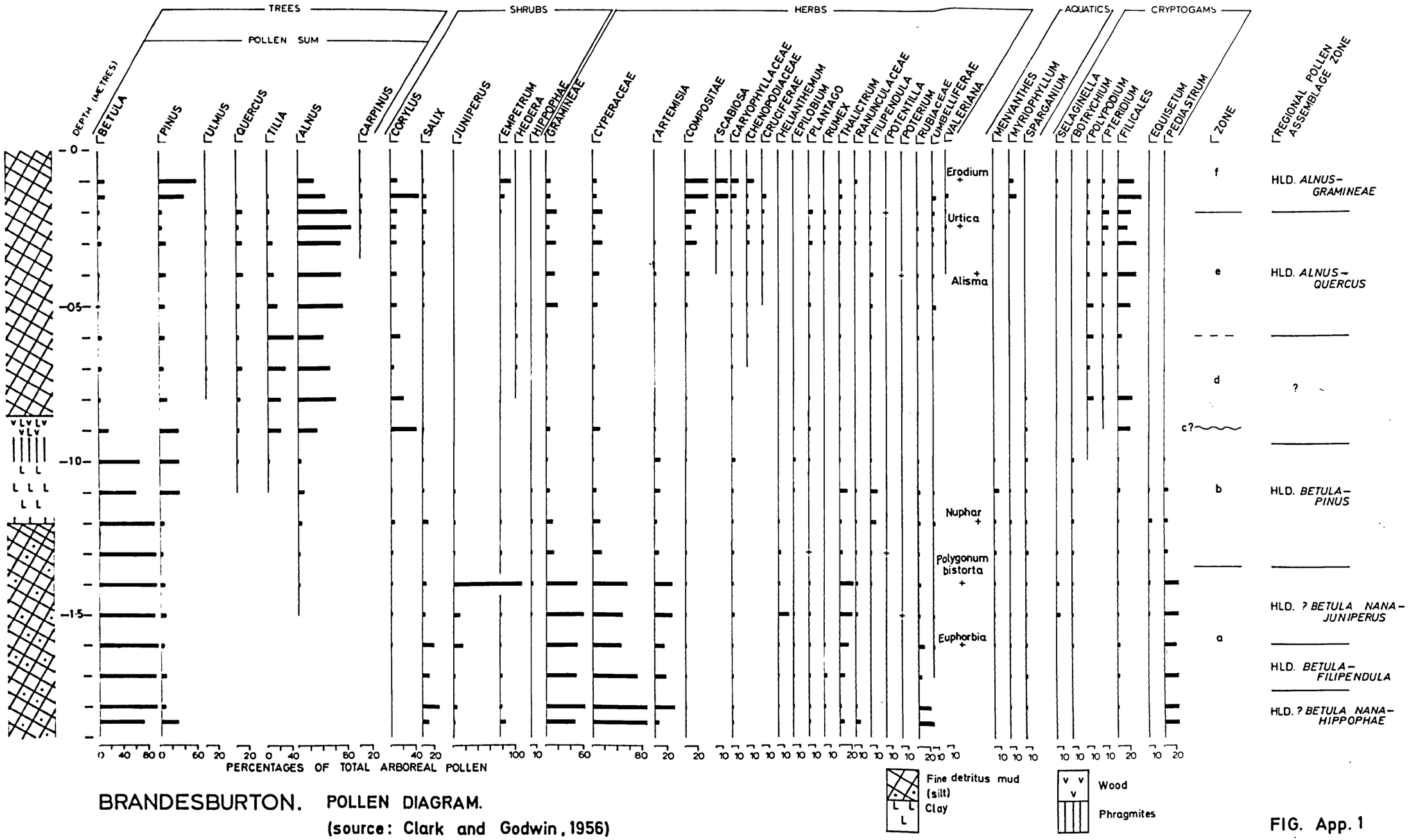
Sample depth (metres)	TAXA 24	25	26	27	28	29	31	33	35	36	40
0.24	1	50	1	23	3	8		23	4	2	
0.28		2		8	1	1	1	1	3	1	
0.32				4		1		1			
0.36		4		5			1	2	2		
0.40	4	6		22				3			1
0.44				10							
0.48		3		5				1			
0.52				3							
0.54		1		3					1		
0.56		2		17							
0.60				2					2		
0.64	1	1		7				1			
0.68		1		4							
0.72		2		8							
0.76				4							
0.80				5							
0.84				5							
0.88	1			5						1	
0.92	1	2		11							
0.96				5							
1.00		2		6							
1.04		2		4	1	1					
1.08	1	2		5							

Gransmoor Quarry (continued)

Sample depth (metres)	TAXA 44	50	54	55	57	66	68	70	71	72	74
0.24	7	5	2		10						2
0.28			1	1	2						1
0.32			1	1	1						
0.36	1				1						
0.40											11
0.44											2
0.48					1	1					2
0.52											
0.54	1				1						
0.56					1						3
0.60					2						
0.64					2						
0.68											
0.72					1						
0.76											
0.80											
0.84											
0.88			1				1				2
0.92			2	2							
0.96											
1.00											
1.04						1	1				1
1.08								1	1		

Gransmoor Quarry (continued)

Sample depth (metres)	TAXA 77	78	79	80
0.24	3		149	27
0.28			29	
0.32	5	5	48	2
0.36	18		60	3
0.40	8	3	83	
0.44	5		40	1
0.48	8	3	55	1
0.52	8		40	
0.54	1		18	1
0.56	3	4	61	
0.60	3		31	
0.64	6		37	1
0.68	2		44	2
0.72	3	2	40	
0.76	7		61	1
0.80	3	1	70	1
0.84	3		43	1
0.88	7	1	21	1
0.92	6		37	
0.96			25	
1.00	1		47	
1.04			45	
1.08			33	2



BRANDESBURTON. POLLEN DIAGRAM.
(source: Clark and Godwin, 1956)

FIG. App. 1