The vegetational history of Teesdale

Chambers, Carl

THE VEGETATIONAL HISTORY OF TEESDALE

CARL CHAMBERS

A Thesis presented for the Degree of
Doctor of Philosophy in the Faculty
of Science in the University of Durham.

Carl Chambers
Dept. of Plant Sciences,
University of Leeds.

March, 1974.

a) No part of this thesis has been previously submitted for a degree at this or any other University.

b) The work presented is wholly my own except where due reference is given.

ABSTRACT

Three radiocarbon dated pollen diagrams have been constructed from different locations within Teesdale. These diagrams provide some interesting regional variations in the vegetational history of the dale. Evidence suggests that a Late-glacial type of vegetation persisted in Upper Teesdale after its replacement in more lowland areas of northern England. In the early Post-glacial pioneer birch and pine woodland spread more quickly in the lowlands than in the uplands of the dale. Similarly, the expansion of the thermophilous trees was slower at the higher altitudes, where pine continued to remain a dominant element of the upland woods. Of particular note was a late pine expansion in Upper Teesdale which occured some 6,800 years ago. During the early Post-glacial the trees migrated up the dale along the sheltered valley of the Tees. Once established the upland woods were less dense than those of the lowlands.

There is some evidence for the presence of Mesolithic man on the Moor House National Nature Reserve some 5,900 years ago. From this time onwards it is clear that the vegetational history of Teesdale can only be considered in the light of human interference. All diagrams indicate that during the late Post-glacial period woodland clearance became an ever increasing feature of the vegetational history.

ACKNOWLEDGEMENTS

I would like to start by thanking the Teesdale Trust for a most generous grant. I am indebted to people of the Gakushuin Radiocarbon Laboratory in Japan and Dr. D.D. Harkness of the Scottish Research Reactor Centre who carried out the radiocarbon assays. Professor D. Boulter receives my thanks for providing me with the use of facilities in the Department of Botany, University of Durham. At various times during this investigation friends and colleagues have given considerable help and advice and I would like to thank Mr. J.P. Doody, Dr. A. Jones, Dr. M. Tooley, Dr. R.H. Squires and Mr. M. Rawes, Officer in Charge of the Moor House National Nature Reserve. Lastly, I am indebted to Dr. J. Turner, who supervised this project, Dr. D.D. Bartley, who let me examine and use some of his pollen diagrams and Kathleen, my wife, who provided much encouragement in getting this research work written up.

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CHAPTER I

AN INTRODUCTION

When this research project was begun quite a number of pollen diagrams had already been constructed from various sites scattered throughout Teesdale. In the lowlands there were diagrams from Burtree Lane, Romaldkirk (Bellamy et al, 1966) and Neasham Brick Pit (Blackburn, 1952). Farther up the dale, in the Cronkley Fell region, other diagrams had just been completed from Dufton Moss and Fox Earth Gill (Squires, 1970). Several diagrams were also available from deposits in the Cow Green Reservoir Basin, on Widdybank Fell (Turner et al, 1973) and on the Moor House National Nature Reserve (Johnson and Dunham, 1963). With so many diagrams available from Teesdale why was it thought that more were needed?

Firstly, there was a regional variation in the pattern of woodland development in the Boreal and Atlantic periods. Birch was much more abundant in the lowlands than in the uplands. In these uplands pine flourished and appeared to have been growing long after its replacement in the lowlands, consequently delaying the expansion of alder. Secondly, only one diagram, that from Tinklers Sike (Turner et al, 1973), was accompanied by radiocarbon dates. Therefore, it was felt that there was a need for a full radiocarbon dated pollen diagram from each of these regions. The radiocarbon dates could then be used to clarify any regional variations in the timing of major vegetational changes.

The actual choice of sites for investigation depended upon two essential factors. Firstly each site would have to provide, as near as possible, a continuous record of the Post-glacial vegetational history. Secondly, the deposits had to be suitable for radiocarbon dating. With these requirements in mind Neasham Fen was chosen as a lowland site. Weelhead Moss, in the Cow Green Reservoir Basin was decided upon as the second site. It was hoped that this diagram would cover those periods which were absent on the radiocarbon dated diagram from Tinklers Sike Moss, on nearby Widdybank Fell. Unfortunately, time allowed for only three sites to be investigated and choosing the third was a difficult matter. Eventually, Valley Bog, on the Moor House National Nature Reserve, was decided upon, even though it had previously been investigated by Johnson and Dunham (1963). There were several reasons for the decision. Firstly, this site is farther up the dale than Weelhead Moss and lies close to the head of the Tees. Secondly, the original diagram seemed to have a late maximum of Pinus pollen. Thirdly, this diagram had a double elm-decline which was of great interest.

The author has included in an Appendix some pollen diagrams from the Cow Green Reservoir Basin and Widdybank Fell (Turner et al, 1973). The reason for this is one of convenience as these diagrams are constantly referred to when interpreting the radiocarbon dated Weelhead Moss diagram.

As this project is primarily concerned with regional variation of the Post-glacial woodlands the Late-glacial clays at Neasham Fen have not been analysed for pollen content. However, some mention of Late-glacial vegetation and climate is made where it is thought that they have direct influence on early Post-glacial events.

SKETCH MAP OF TEESDALE

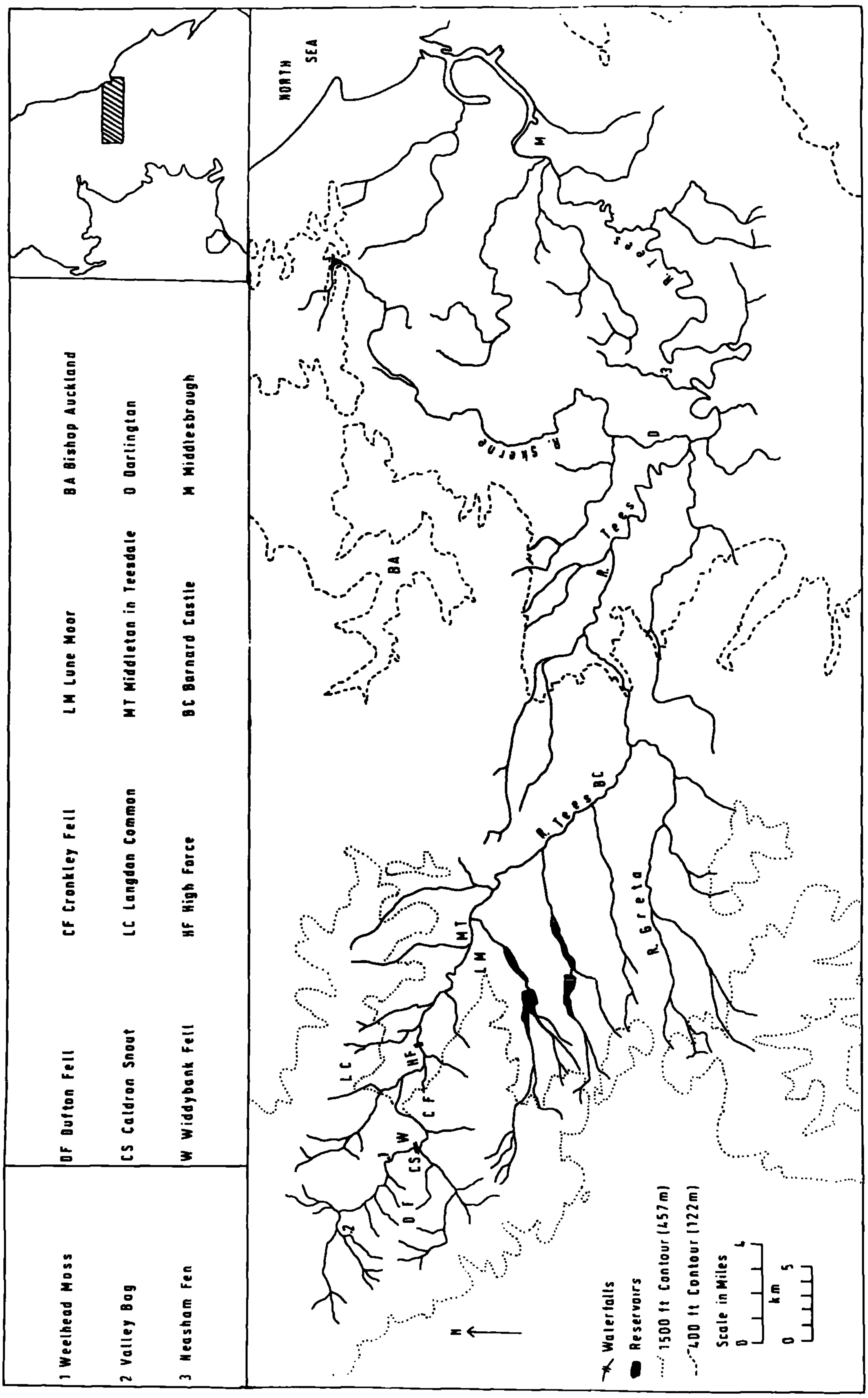


Fig. 1

CHAPTER 2

AN INTRODUCTION TO TEESDALE

Teesdale consists of two topographic regions, one where the Tees flows through the uplands of the northern Pennines, and the other where the river emerges from the Pennines and flows across the lower Tees basin (Fig. 1, p. 3). Between these regions lies the site of Romaldkirk, at an altitude of 660 ft. (200m) O.D. The geology and climate of these two topographic regions are quite different. As geology and climate are important factors influencing soil formation and plant distribution they will be discussed so that the vegetational history can be more fully understood.

Pre-Pleistocene History

The area known as the northern Pennines is composed of two major blocks, the Alston and Askrigg Blocks, which are Carboniferous in origin. Beneath these Carboniferous rocks lie the older Palaeozoic deposits which may continue almost without interruption under the northern Pennines (Woolacott, 1923). Separating the Carboniferous and the older rocks there is an unconformity. Within the older Palaeozoic deposits there is much folding and faulting (Shotton, 1935). In the northern Pennines there are only two outcrops of the Lower Palaeozoic deposits. One, the Cross Fell Inlier, lies immediately to the west of the Inner Pennine Fault and part of it occurs on the western margins of the Moor House National Nature Reserve. This Inlier has been extensively studied e.g. Shotton (1935) and consists of Ordovician and Silurian deposits separated by a faulted junction. The other outcrop of lower Palaeozoic rocks can be seen below Cronkley Scar, in Upper Teesdale (Fig. 2, p.6).

The Carboniferous Alston Block has been studied by Dunham (1948) who sub-divided the deposits as follows :-

'local Millstone Grits	)	Upper Carboniferous
Upper Limestone Group	)	
Middle Limestone Group	)	
Lower Limestone Group	)	Lower Carboniferous
Basement Group	)	

The Basement Group which consists mainly of conglomerates and sandstones can be seen outcropping below Cauldron Snout and by Cronkley Scar (Fig. 2, p. 6). In the Cow Green area it is the Lower Limestone Group which is exposed but in Upper Teesdale as a whole it is the middle and Upper Limestone Groups which outcrop most extensively.

These Carboniferous rocks are richly mineralised and form part of the North Pennine Ore Field (Dunham, 1934). There is some suggestion that the orefield may have been worked during the Romano-British period (Raistrick, 1968). However, from the reign of Henry I onwards there is actual documented evidence of mining in the northern Pennines.

Structural movements towards the end of the Carboniferous caused uplift, compression and doming of the Upper Teesdale region. At about this time the volcanic, Great Whin suite of quartz-dolerite penetrated the Carboniferous succession at various depths. In fact, the Great Whin Sill now presents the two major obstacles along the course of the River Tees. These are the Cauldron Snout and High Force waterfalls. The heat of intrusion of the sill was so intense that the rocks with which it came into contact were metamorphosed.

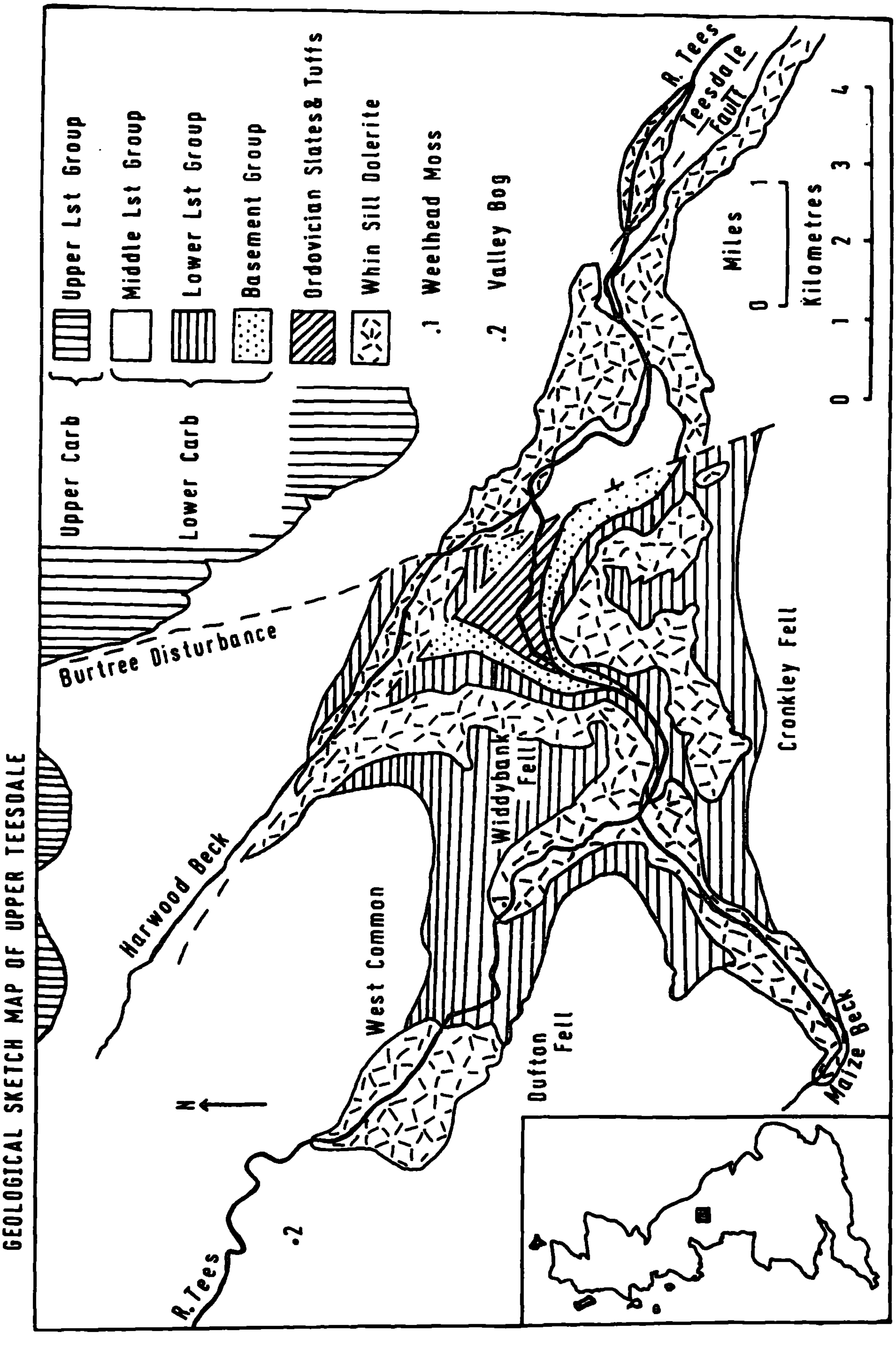

GEOLOGICAL SKETCH MAP OF UPPER TEESDALE
Upper Carb
Lower Carb
Upper Lst Group
Middle Lst Group
Lower Lst Group
Basement Group
Ordovician Slates& Tuffs
Whin Sill Dolerite
.1 Weelhead Moss
.2 Valley Bog
Burtree Disturbance
Harwood Beck
West Common
Widdybank Fell
Dufton Fell
Cronkley Fell
Maize Beck
R.Tees
R. Tees
Teesdale Fault
N
.2
.1
Miles
0 1
Kilometres
0 1 2 3 4

Fig. 2

Shales were converted into hard porcellaneous rocks (whetstones) and the pure Melmerby Scar Limestone was recrystallised into a marble. Weathering of this saccharoidal marble by subsurface ground water has given rise to the 'sugar-limestone' which is peculiar to Widdybank and Cronkley Fells, in Upper Teesdale (Johnson et al, 1971). This 'sugar-limestone' is an unconsolidated calcite and its presence at the surface today is the result of recent erosion of the overlying drift and soil. Soils incorporating the weathered 'sugar-limestone' are to be found on both Widdybank and Cronkley Fells. These two areas are of immense botanical interest because associated with these soils are the Teesdale rarities, plants which belong to widely differing phytogeographical groups and are a relict of the late-glacial vegetation (Pigott, 1956; Squires, 1971).

Younger rocks, which are absent in Upper Teesdale because of erosion, outcrop eastwards in an orderly sequence. This is due to the carboniferous doming of Upper Teesdale which caused all subsequent deposits to be laid down dipping to the east. Between Middleton-in-Teesdale and Barnard Castle the Millstone Grits of the Upper Carboniferous are exposed. North of the Staindrop Fault the Upper Carboniferous Coal Measures may be seen. Although these deposits outcrop in much of lowland County Durham, only a south-west extension reaches into Lower Teesdale. West of Darlington, which is situated on a narrow south-west to north-east strip of Upper Permian Marls, the Permian Magnesian Limestone is exposed. To the east Triassic Sandstones and Keuper Marls together with Lower Jurassic rocks complete the depositional sequence. The lowland geology of County Durham and Teesdale is well described by Johnson (1970) and a sketch map shows the position of all the outcrops mentioned in this paragraph.

Pleistocene History

During the Pleistocene ice sheets advanced and retreated across northern England. The deposits left behind by these glacial periods have in the past been variously interpreted. Woolacott (1921) believed that they represented four glacial periods whilst more recently Carruthers (1953) thought that they were the result of only one glacial period. However, it is now widely accepted that these glacial deposits of north east England belong in general to the last two glacial episodes, the Wolstonian and the Devensian (Francis, 1970; West, 1968; Spark and West, 1972).

Early Pleistocene deposits in the north-east are scarce, probably because of the severity of the last glacial period (Devensian). However, clays found in fissures near Blackhall Colliery, County Durham (Trechmann, 1919) may have Lower or Middle Pleistocene origins (Francis, 1970). The Warren House Till, formerly known as the Scandanavian Drift (Trechmann, 1915), is thought to be of Wolstonian age. A peat raft exposed at Hutton Henry is believed to have belonged to the Ipswichian interglacial, which followed the Wolstonian glacial episode (Beaumont, Turner and Ward, 1969).

The majority of glacial deposits in lowland Teesdale are of Devensian age. This is the last glacial period following the Ipswichian interglacial. Although these deposits have not been extensively studied they are thought to be very similar to those which cover much of County Durham. If this is correct, then the lowest deposits are the Lower Boulder Clays. These rest upon the bedrock and may be up to 9m in thickness. Above these there are the Middle Sands, up to 30m thick, which themselves are covered by the Upper Boulder Clays. It is very interesting that similar glacial deposits cover the Dimlington Silts, in east Yorkshire. A moss bed preserved in these silts has been radiocarbon dated to 18,500 $\pm$ 400 and 18,240 $\pm$ 250 radiocarbon years B.P. (Penny, Coope and Catt, 1969). As the Yorkshire glacial deposits are similar to those of County Durham, it may be assumed that they are both of similar age. The Dimlington Silts lie close to the limit of maximum Devensian ice cover and one can postulate that maximum cover must have occurred not long after 18,000 years ago. Lowland Teesdale could not have been covered by ice for a long period because it has been shown that by 14,000 years ago ice had already retreated from north Lancashire (Godwin and Willis, 1964).

In Upper Teesdale the glacial drift is restricted mainly to the floor and U-shaped valley of the Tees which possibly reflects the severity of the Late-glacial climate in these upland regions. Lateral moraines are present in the Cow Green Reservoir Basin and just below Cronkley Scar. Drumlins have also been left undisturbed where Harwood Beck joins the Tees. Farther up the dale, on the Moor House National Nature Reserve, stoney and gravelly deposits in the form of moraines and kames are present. There is also evidence for the existence of boulder clays as high as 2,200 ft (670 m) O.D. on Cross Fell (Raistrick and Blackburn, 1932) and 2,000 ft (610 m) O.D. on Mickle Fell (Trotter, 1929).

During the glacial maximum it is probable that all of Teesdale was covered by ice. A Lake District erratic boulder found on the western escarpment of the northern Pennines indicates that the ice was piled up as high as 2,200 ft (670m) O.D. (Trotter, 1929). On the crest of Knock Ridge at 2,400 ft (732m) O.D. and even as high as 2,800 ft (853m) O.D. on Cross Fell, sandstone boulders have been turned in a uniform manner, indicating glacial action. At the height of glacial activity the north east of England was severly congested with different ice flows (Eastwood, 1953). Ice from the Southern Uplands converged with the Lake District ice and together flowed eastwards through the Tyne Gap. The Cheviot Massif ice moved south whilst yet more from the Lake District came through the Stainmore Depression. Ice from local glaciers, on the eastern slopes of the Pennines , also caused further congestion in this region.

Climate

The most noticeable feature of the climate of Teesdale is its extreme severity in the upland Pennine region. In fact it has been said that the northern Pennine moorlands are the most constantly elevated and chilly part of England (Manley, 1936). The three factors which primarily contribute to this situation are; heavy precipitation, low temperatures and high wind speeds.

Manley's (1943) estimated rainfall figures for six years at Moor House clearly indicate this heavy precipitation which occurs in Upper Teesdale (Table 1).

Table 1 - Estimated average monthly rainfall for 6 years at Moor House in inches

J	F	M	A	M	J	J	A	S	O	N	D	Total
6.5	6	5.75	4	3.75	4	6	7	4.5	7.5	6.5	8.5	70

These figures are by no means unusual because the annual mean rainfall from 1916 to 1950 at Moor House was over 70 ins. (178 cm). A comparison of the mean monthly rainfall figures from 1961 to 1963 (British Rainfall, 1967 + 1971) for nine stations scattered throughout Teesdale (Fig. 3 p.11) clearly demonstrates the regional differences. For example, the March figures for Middlesbrough and Moor House are 1.5 ins (3.8 cm) and 5 ins (12.7cm), respectively, whilst the September values are 2 ins (5.1 cm) and 6 ins (15.2cm), respectively. Although these figures cover only a short period they do illustrate regional rainfall variations. When the mean yearly rainfall values are plotted against altitude these differences become most striking (Fig. 4 p.12).

TEESDALE — MEAN MONTHLY RAINFALL 1961-3

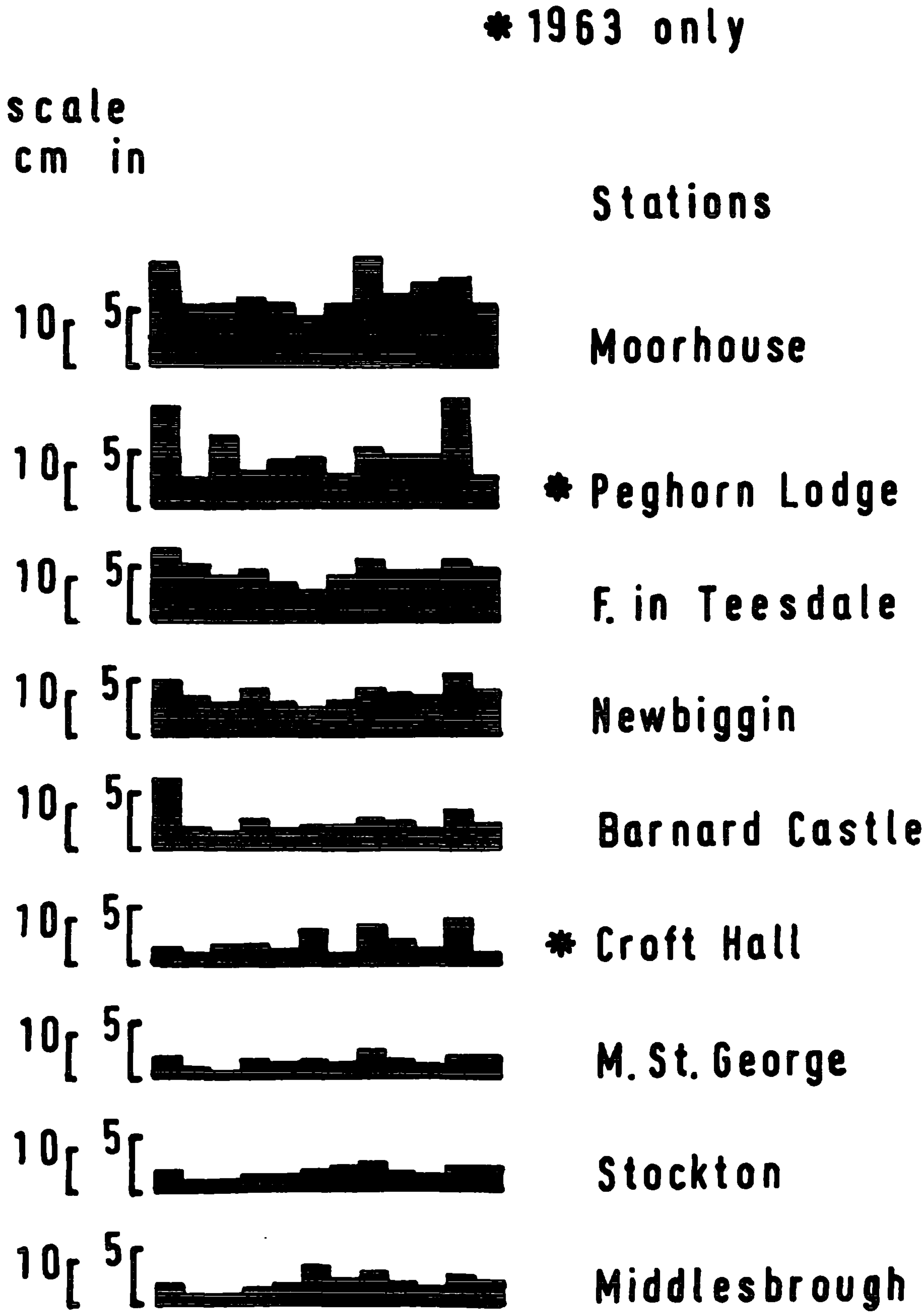


Fig. 3

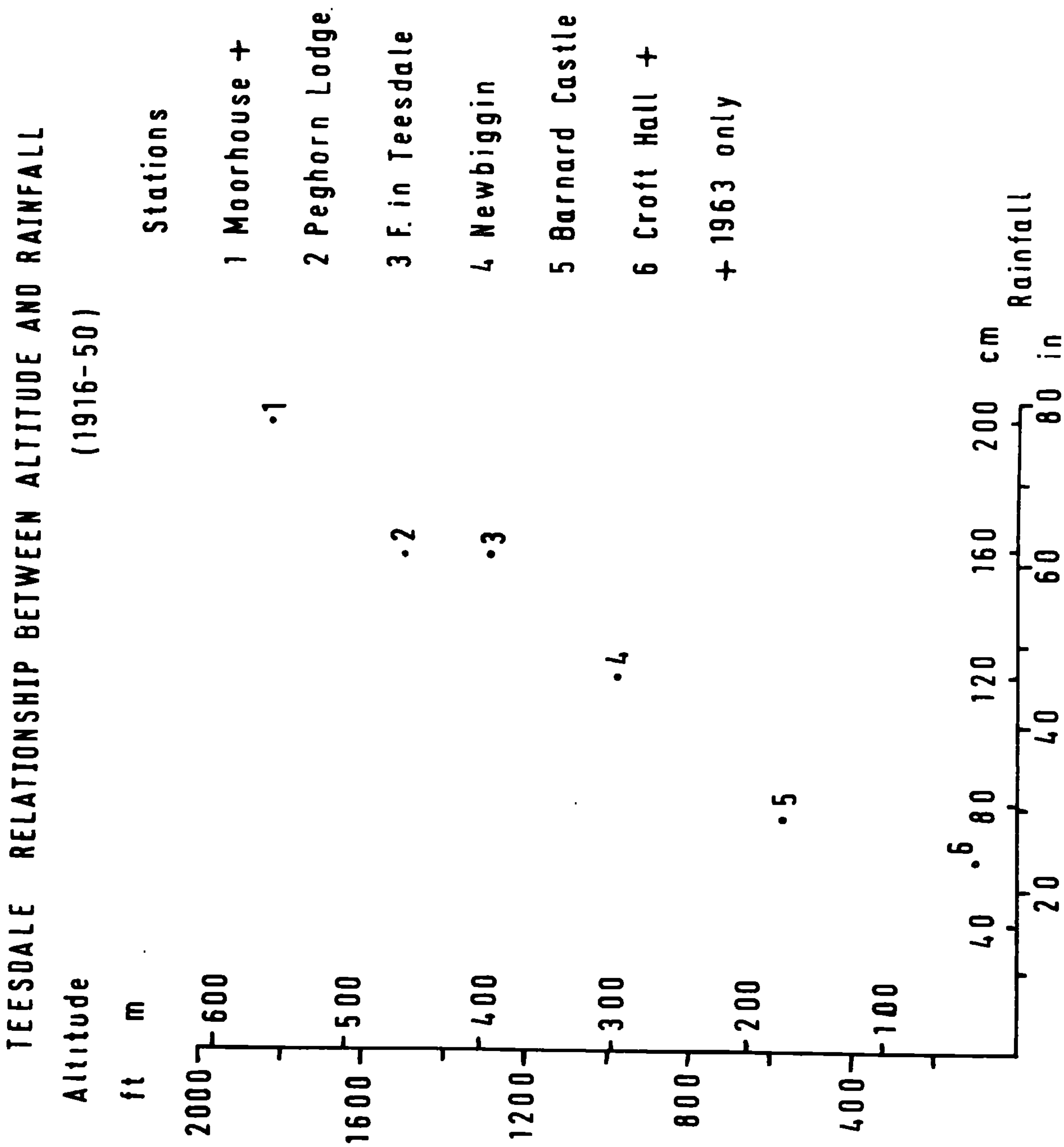

TEESDALE RELATIONSHIP BETWEEN ALTITUDE AND RAINFALL
(1916-50)
Altitude
ft m
2000 600
1600 500
1200 400
800 300
400 200
100
Stations
1 Moorhouse +
2 Peghorn Lodge
3 F. in Teesdale
4 Newbiggin
5 Barnard Castle
6 Croft Hall +
+ 1963 only
Rainfall
40 80 120 160 200 cm
20 40 60 80 in

Fig. 4

For example, Croft Hall received under 25 ins (63.5 cm) compared with over 70 ins (178 cm) at Moor House (British Rainfall, 1967).

Temperatures also show marked regional differences in Teesdale. In the uplands winter conditions are much more severe, than in the lowlands, with mean monthly temperatures just above freezing for much of the year (Table 2).

Table 2 - Mean monthly temperatures (°F) for 1906-1935 at Moor House (Manley, 1943).

J	F	M	A	M	J	J	A	S	O	N	D	Year
33.0	32.6	34.1	38.0	44.7	49.4	52.8	52.3	48.3	42.3	36.4	33.9	41.5

Consequently the growing season in Upper Teesdale is quite short and the continuation of freezing conditions into April is well illustrated by Table 3.

Table 3 - Average number of 'ice-days' (maximum temperature of 32°F or less) per month for 1938-1940 on Great Dun Fell (Manley, 1942).

J	F	M	A	M	J	J	A	S	O	N	D	Year
19	17	12	2	0	0	0	0	0	1	7	16	74

The third factor contributing to the regional climatic differences in Teesdale is wind speed. A meterological report for the year 1952, a so-called windy year, states that over lowland County Durham gale force winds were experienced on only 5 days. This compares most favourably with Moor House and Great Dun Fell where there were no less than 49 and 127 days, respectively, on which winds reaching gale force were recorded (Smith K., 1970).

Rainfall, temperature and wind speed are the three factors, which taken together have given rise to marked climatic regional variation in Teesdale. In order to emphasise the variation it should be mentioned that Moor House has an overall thermal similarity to places at sea level some 10^{o} latitude farther north.

Soils

In lowland Teesdale the most important soil determining factors are the texture of the parent soil material and topography (Stevens and Atkinson, 1970). Both these factors directly affect the water content of the soil. Within this region there is a wide variation of parent soil materials including glacial deposits, fluvioglacial sediments, lacustrine deposits, alluvium and aeolian (wind blown) sands.

The predominant soils of the lowlands are the poorly drained surface-water gleys. These are usually associated with the non-porous heavy tills derived fromargillaceous carboniferous deposits (fine grained shales and siltstones) or areas where the topography allows only slight water run-off. In limited areas, under more favourable topographic conditions, where there is good drainage, brown earths of low base status have developed on those tills derived from arenaceous carboniferous deposits (course sandstones). Where the internal drainage is supplemented by topographical drainage, these brown earths become imperfectly drained. Some brown earths of a high base status are to be found on mixed tills derived from Permian Magnesian limestone and Triassic sediments. In these soils, although the surface horizons may be carbonate free, the subsoil has a high carbonate content, often in the form of limestone fragments. The total area covered by all of the brown earths is only a fraction of that covered with surface-water gleys. Within the region there are also some limited areas of peat at Bradbury and Morden Carrs, which have formed on top of poorly drained lacustrine deposits. The alluvium along the banks of the Tees, because of its non-porous nature has given rise to waterlogged soils. Although this is by no means a complete survey of the soils of lowland Teesdale it does indicate that surface-water gleys are the most common soil types and that various others are present in limited areas.

In the upland regions of Teesdale, climate and topography have been the two most important soil determining factors. The excessive precipitation (Table 1, p.10) has resulted in waterlogging in many areas and the overall soil forming process has been; brown earth - podsol - peaty podsol - blanket peat. Low temperatures (Table 2, p.13) have also contributed to the formation of blanket peat by aiding the retention of water in the soils. This is brought about by reducing evaporation and decreased transpiration of the plant cover. The effects of topography on soil development, first stressed by Muir (1956), has been demonstrated by Johnson and Dunham (1963) on the Moor House National Nature Reserve where they carried out an extensive soil survey.

About 70% of the Reserve is at present covered by blanket peat. The blanket peat is not continuous but, particularly in the eastern parts of the Reserve, is dissected by areas of erosion, known as eroded blanket peat soil complexes. In these complexes small areas of blanket peat, bare eroded peat, bare gleyed soil and peaty gleyed soil repeatedly occur over wide tracts of ground . On the more western parts of the Reserve and the upper slopes of the summit ridge peaty gleys, with a thin superficial layer of peat, are present on level and gently sloping ground which impedes water drainage. Under deep peat gleyed mineral soils are to be found. These are permanently waterlogged and are not evident on Johnson and Dunhams soil map because the areas have been designated areas of blanket peat

Other soil types are also present in the Reserve, generally in the western parts, but in terms of area are far less important than the blanket peats, blanket peat soil complexes and peaty gleys. These include the peaty gleyed podsols and fell top podsols that have formed on ground which has sufficient slope to allow some water run off. Isolated areas of normal podsols are situated on Great Dun Fell, Little Dun Fell, Cross Fell, Knock Fell, Hard Hill and the summit ridge. They have been formed on flat sandstone outcrops where there is no drift, only a thin layer of solifluxion deposits. Shattered sandstone, much of it rotten, incorporated into these soils has made them light, sandy and therefore porous. Other soils worthy of a mention are the brown earths, which have developed on steep slopes where drainage is free.

Blanket peats and peaty gleyed soils with a superficial peat layer are also the most extensive soils in the Cow Green and Widdybank Fell region of Upper Teesdale. In the U-shaped valley of the Tees, e.g. Weelhead Moss, valley plants have developed over alluvial deposits which have been permanently waterlogged by topographical drainage water. It is clear that the soils of this region are very similar to those of the Moor House National Nature Reserve but with an additional group of very interesting soils. These are the soils derived from the 'sugar-limestone' present on Widdybank Fell and the most important factors in their development have been the presence or absence and the thickness of drift overlying the crystalline marble. Where the drift is deep, over 60 cm in thickness, the limestone has little effect upon drainage in the upper layers ; this remains poor, and consequent waterlogging produces peats and peaty gleyed podsols. However, where there is less drift, 30 to 60 cm, the limestone maintains free drainage and influences the soil chemistry causing brown earths and brown calcareous soils to be formed. Where the drift if only a thin covering, less than 30 cm, rendzinas incorporating the 'sugar-limestone' have developed. Johnson et al, (1971) have described three types of rendzinas and it is these which are the most outstanding soils of the area because of their supposed responsibility for the survival of the Teesdale rarities.

CHAPTER 3

NEASHAM FEN AND THE TEES LOWLANDS

Neasham Fen (Nat. Grid. Ref. 332116) is situated about 3.25 miles (5.2km) south-east of Darlington in the Tees lowlands (Fig. 5, p.19). To the east, a narrow ridge of high ground above 150 ft (45.7m) O.D. separates it from the River Tees. Boulder clays are present throughout the region and the general undulating topography is typical of glacial deposition. The fen itself has all the characters of an infilled kettle hole. It is circular, quite small, with a diameter of only 394 ft (120m) and surrounded by steeply sloping ground on all sides.

A wide selection of plants are to be found growing on the fen and a list of the more common is as follows :

- *Angelica sylvestris*
- *Betula pendula*
- *Callitriche palustris*
- *Caltha palustris*
- *Cardamine pratensis*
- *Carex flacca*
- *C. nigra*
- *Cerastrium holosteoides*
- *Cirsium palustre*
- *Deschampsia caespitosa*
- *Epilobium hirsutum*
- *Equisetum fluviatile*
- *Festuca rubra*
- *Galium saxatile*
- *Glyceria fluitans*
- *Hydrocotyle vulgaris*
- *Juncus inflexus*
- *Lathyrus sylvestris*
- *Lemna minor*
- *Luzula multiflora*
- *Pedicularis sylvatica*
- *Potentilla erecta*
- *P. palustris*
- *Ranunculus flammula*
- *Ranunculus repens*
- *Rumex acetosa*
- *R. conglomeratus*
- *Salix* sp.
- *Valeriania officinalis*

A SKETCH MAP TO SHOW THE LOCATION OF NEASHAM FEN

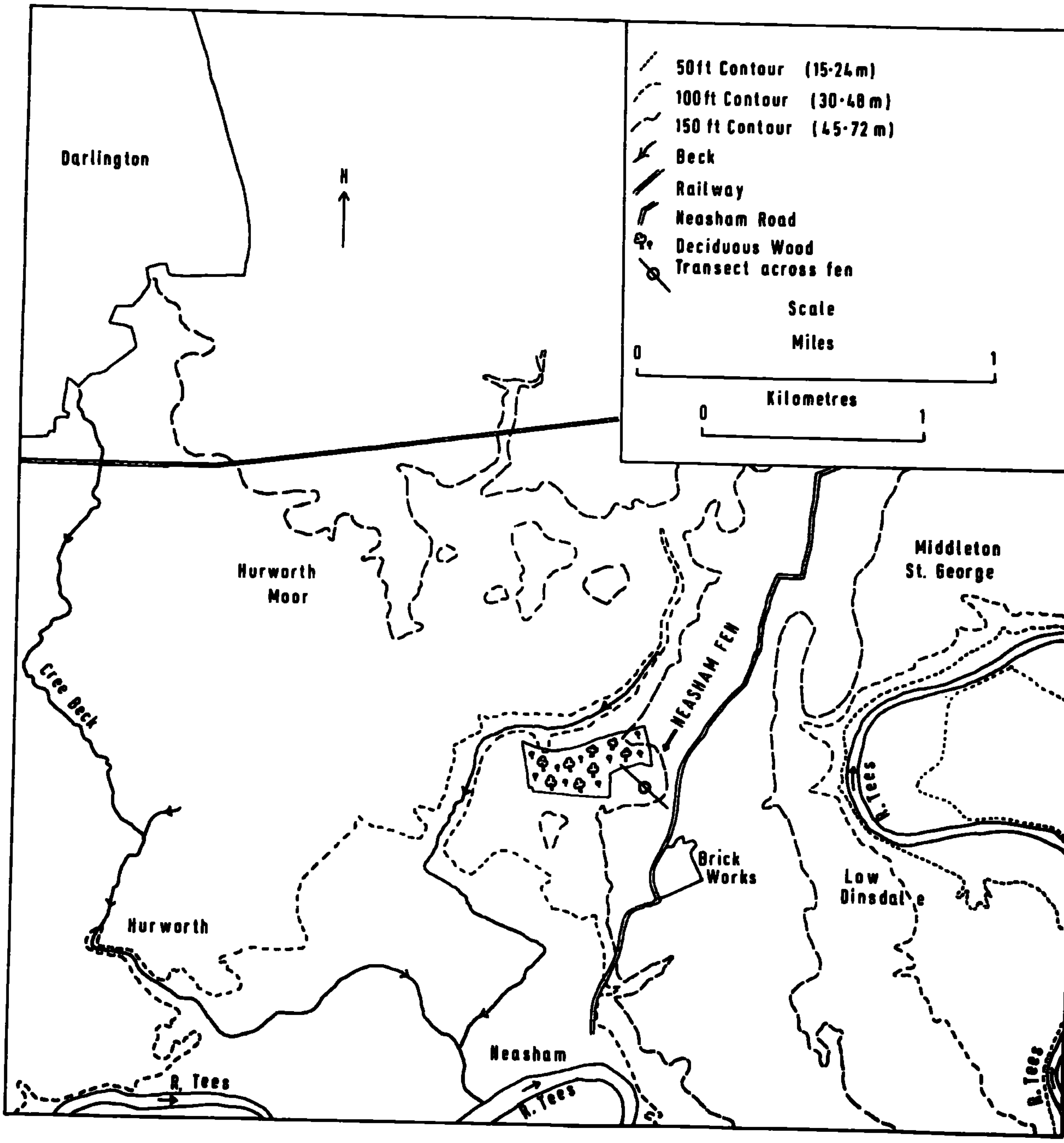


Fig. 5

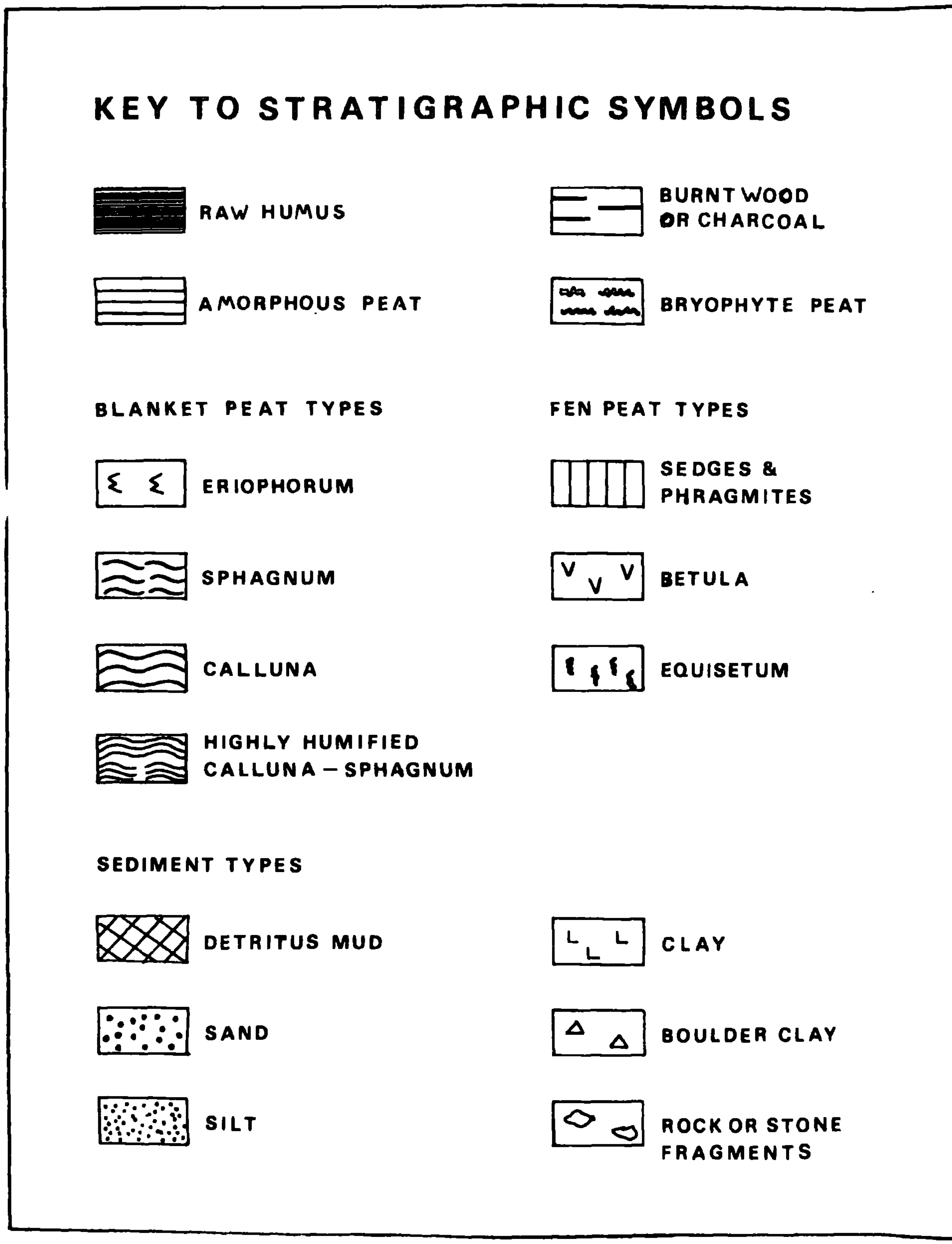

KEY TO STRATIGRAPHIC SYMBOLS
RAW HUMUS
BURNT WOOD OR CHARCOAL
AMORPHOUS PEAT
BRYOPHYTE PEAT
BLANKET PEAT TYPES
FEN PEAT TYPES
ERIOPHORUM
SEDGES & PHRAGMITES
SPHAGNUM
BETULA
CALLUNA
EQUISETUM
HIGHLY HUMIFIED CALLUNA – SPHAGNUM
SEDIMENT TYPES
DETRITUS MUD
CLAY
SAND
BOULDER CLAY
SILT
ROCK OR STONE FRAGMENTS

Fig. 6

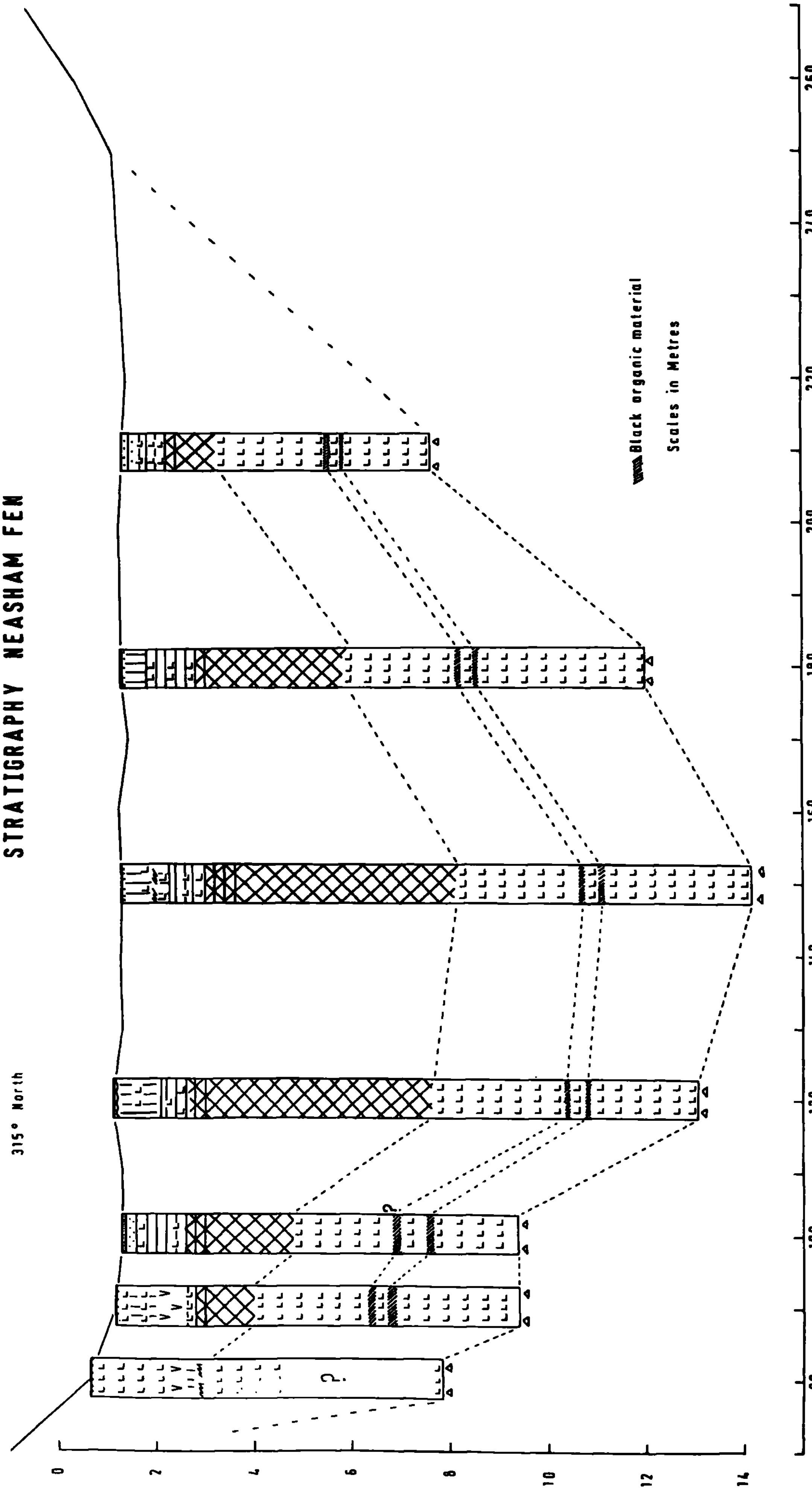

STRATIGRAPHY NEASHAM FEN
315° North
Black organic material
Scales in Metres
0
2
4
6
8
10
12
14
80
100
120
140
160
180
200
220
240
260

Fig. 7

Stratigraphy

A line transect, consisting of stakes placed at 10m intervals, was laid across the fen along a compass bearing of 315^{o}N and extended in both directions up the surrounding slopes. A Dumpy level and staff were used to level the surface of the ground along the transect and the stratigraphy of the fen was investigated using a Hiller borer.

The boulder clay at the bottom of the kettle hole is at least 13m below the surface of the fen (Fig. 7, p.21). It is red in colour which suggests that it has been derived from the underlying red Triassic sandstones and marls. Above this boulder clay the lower deposits consist of fine textured pink and pink-grey clays which are up to 6.2m thick in the centre of the kettle hole. Two black bands of organic material are present in the middle of these clays, which are of Late-glacial origin. Fine detritus muds occur above the clays, except near the margins of the fen, where there are stiff mottled orangy-brown clays. On top of the fine detritus muds there are muddy amorphous peats which themselves are overlaid by wood peats, sedge peats and some bryophyte peats. Potamogetom and Menyanthes seeds are present in the deposits down to the depth of some 3m. Small leaf fragments occur in the detritus muds and modern roots together with Equisetum stems are present in the top 40 to 50 cm.

Collection of Radiocarbon and Pollen Samples

It was previously decided that material to be radiocarbon dated should be sent to the Scottish Research Reactor Centre, East Kilbride, where a scintillation counter is in service. As samples of less than 10 gm dry weight can be assayed it was possible to collect sufficient material using a Russian borer and multiple shot boring.

Altogether five cores, one for pollen counting and the rest for radiocarbon dating material, were collected from an area of 1 sq.m at the 160m mark along the transect. Each 50cm vertical section removed was stored in marked half cylindrical plastic containers. These containers, each 51cm long, were sealed in polythene tubing and stored in a deep freeze, to prevent fungal and bacterial contamination, until they were further required.

Laboratory Techniques

Material for pollen analysis was prepared by the standard method of sodium hydroxide treatment followed by acetolysis (Faegri & Iversen, 1964). Macro remains retained on the sieve after sodium hydroxide treatment were kept for future investigation. Bottom samples, which contained relatively large amounts of silica, were treated with hydrofluoric acid. This process was incorporated into the standard preparation, after sodium hydroxide treatment, and carried out thus :

(a) The sample was taken up in 10% HCl and centrifuged.

(b) Then the residue was transferred to a platinum crucible, using a small quantity of 10% HCl, and HF was added.

(c) This mixture was then boiled carefully for a few minutes.

(d) The mixture was then poured into 10ml of 10% HCl and centrifuged.

(e) The resultant residue was heated with 10% HCl to dissolve the white precipitate.

If some silica still remained then the whole hydrofluoric acid process was repeated until all had been removed. Once this was achieved the normal acetolysis was carried out. On completion of the preparation the samples were stained and mounted in a medium of glycerine jelly which contained safranin. This method provides semi-permanent slides with the advantage that pollen grains can be turned, if necessary, using a hot needle.

A standard method of counting was employed and each count was terminated when either 150 tree pollen grains, excluding Corylus, or 500 land pollen grains, excluding aquatic, pteridophyte and bryophyte pollen and spores, had been counted. The actual pollen identification was facilitated by the pollen type collection, in the Department of Botany, and the keys of Faegri & Iversen (1964). All pollen percentages on the finished diagram are expressed as percentages of the total tree pollen, excluding Corylus. The tree - shrub - herb ratios, however, are calculated as percentages of the total land pollen, excluding aquatic pollen and bryophyte and pteridophyte spores.

The completed diagram (Figs. 8,9, and 10, p. 26-28) was examined in order to locate those levels which required radiocarbon dating. By matching up the pollen spectra very carefully each of these levels was identified on each of the four radiocarbon cores. Once this was completed 5cm vertical sections of peat were removed from each core at the required levels and dried in an oven at 100°C for 24 hours before being sent to the Scottish Research Reactor Centre. The levels which were sent and the results of the assay in radiocarbon years B.P. are as follows :

1. SRR - 96, peat from 55-60cm, increased herb pollen frequencies, 1,213 ± 60.
2. SRR - 97, peat from 100-105cm, declining herb pollen values, 2,804 ± 80.
3. SRR - 98, peat from 105-110cm, the same vegetational changes as SRR - 97, 2,850 ± 60.
4. SRR - 99, peat from 135-140cm, level with increasing herb pollen frequencies, 2,538 ± 50.
5. SRR - 100, peat from 140-145cm, the same vegetational changes as SRR - 99, 2,488 ± 75.

6. SRR - 101, peat form 245-250cm, peak of Gramineae and _Plantago_ pollen percentages, 3,242 ± 70.

7. SRR - 102, peat from 335-340cm, decline of _Ulmus_ pollen frequencies, 5,468 ± 80.

8. SRR - 103, peat from 410-415cm, lowest sample with high _Ulmus_ values, 6,972 ± 90.

9. SRR - 104, peat from 530-535 cm, increasing _Quercus_ pollen percentages, 8,202 ± 95.

10. SRR - 105, peat from 580-595cm, lowest level with high _Ulmus_ pollen frequencies, 8,829 ± 120.

11. SRR - 106, peat from 590-595cm, lowest level with high _Corylus_ values, 9,082 ± 90.

The two levels 105-110cm and 135-140cm were assayed later as a check on the two dates of 2,804 ± 80 and 2,488 ± 75 for levels 100-105cm and 140-145cm respectively, which are in reverse order.

Examination of the macro remains, retained after sodium hydroxide treatment, and the counting core indicated that the stratigraphy at 160m along the transect is :

cm	
0 - 5	Raw humus.
5 - 15	Amorphous muddy peat with hillwash and modern roots.
15 - 37	Amorphous muddy peat with modern roots.
37 - 47	Bryophyte peat.
47 - 180	Amorphous muddy peat with _Potamogeton_ and _Menyanthes_ seeds.
180 - 220	Transition.
220 - 623	Detritus mud with leaf fragments, _Potamogeton_ and _Menyanthes_ seeds in the top metre. The bottom 5cm slightly clayey.

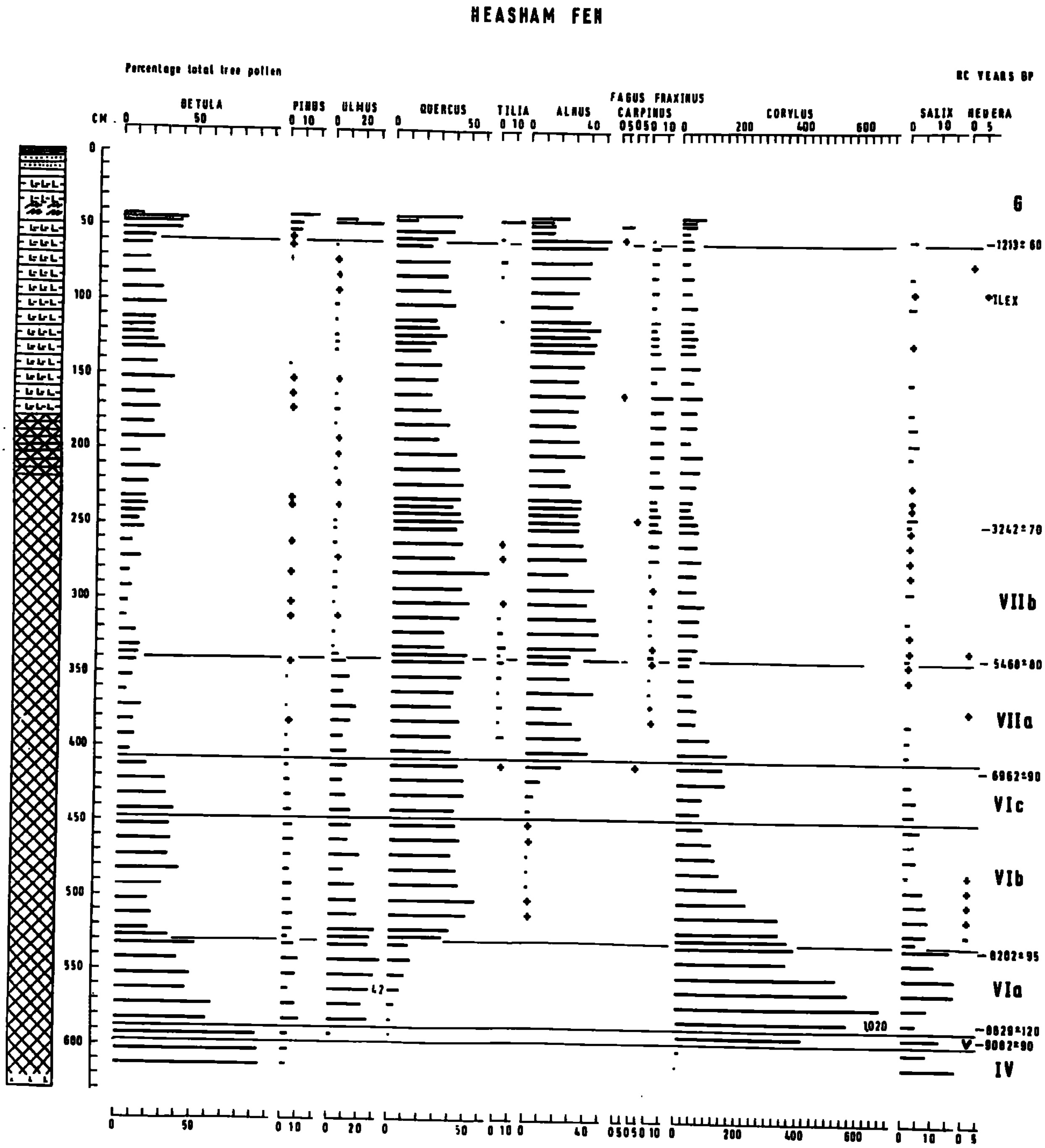

HEASHAM FEN
Percentage total tree pollen
RC YEARS BP
CM.
BETULA
PINUS
ULMUS
QUERCUS
TILIA
ALNUS
FAGUS
FRAXINUS
CARPINUS
CORYLUS
SALIX
HEDERA
ILEX
G
VIIb
VIIa
VIc
VIb
VIa
V
IV
-1213±60
-3242±70
-5460±80
-6962±90
-8202±95
-8829±120
-9002±90
1020
42

Fig. 8

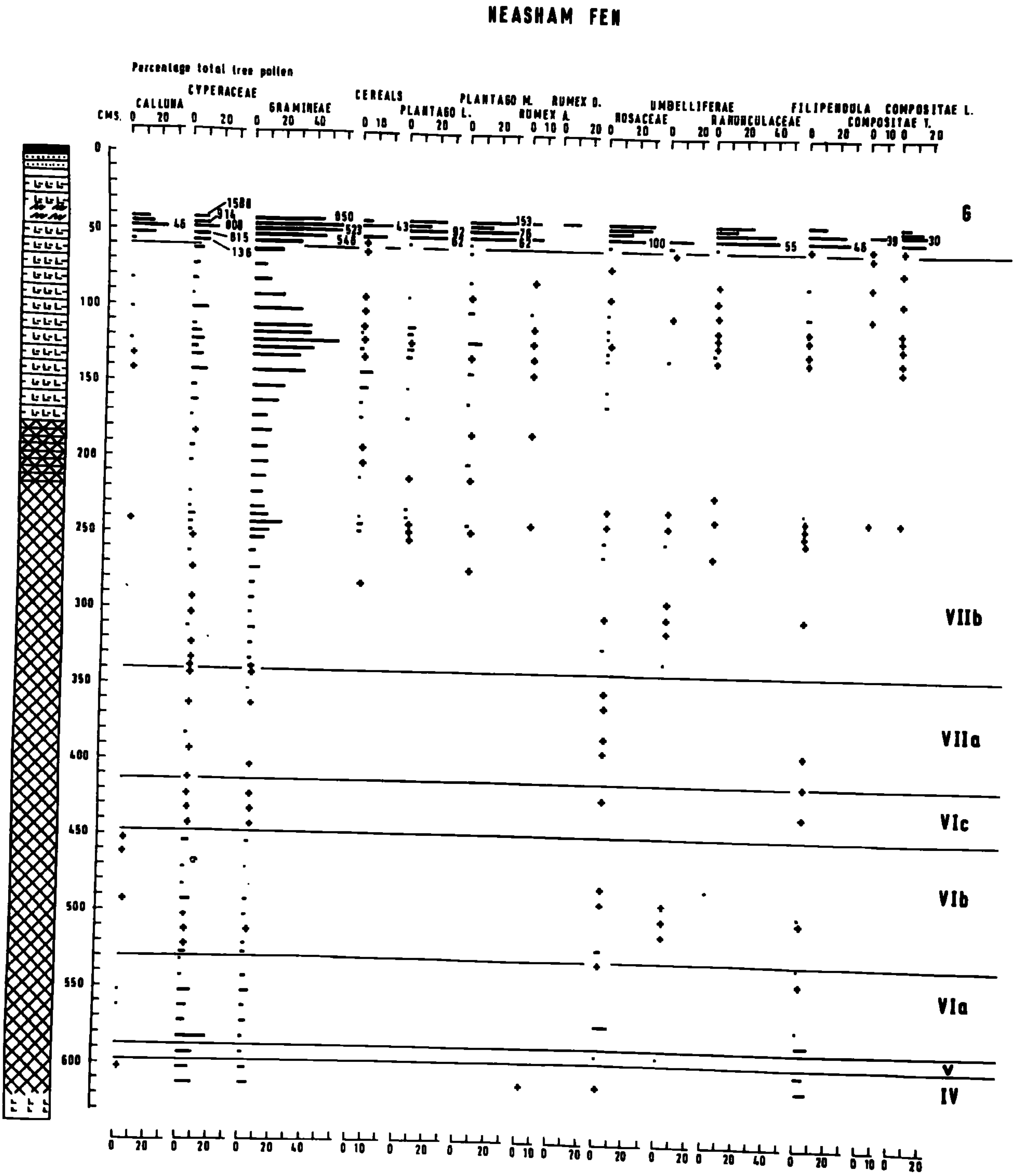

NEASHAM FEN
Percentage total tree pollen
CALLUNA
CYPERACEAE
GRAMINEAE
CEREALS
PLANTAGO L.
PLANTAGO M.
RUMEX A.
RUMEX O.
ROSACEAE
UMBELLIFERAE
RANUNCULACEAE
FILIPENDULA
COMPOSITAE T.
COMPOSITAE L.
CMS.
G
VIIb
VIIa
VIc
VIb
VIa
V
IV

Fig. 9

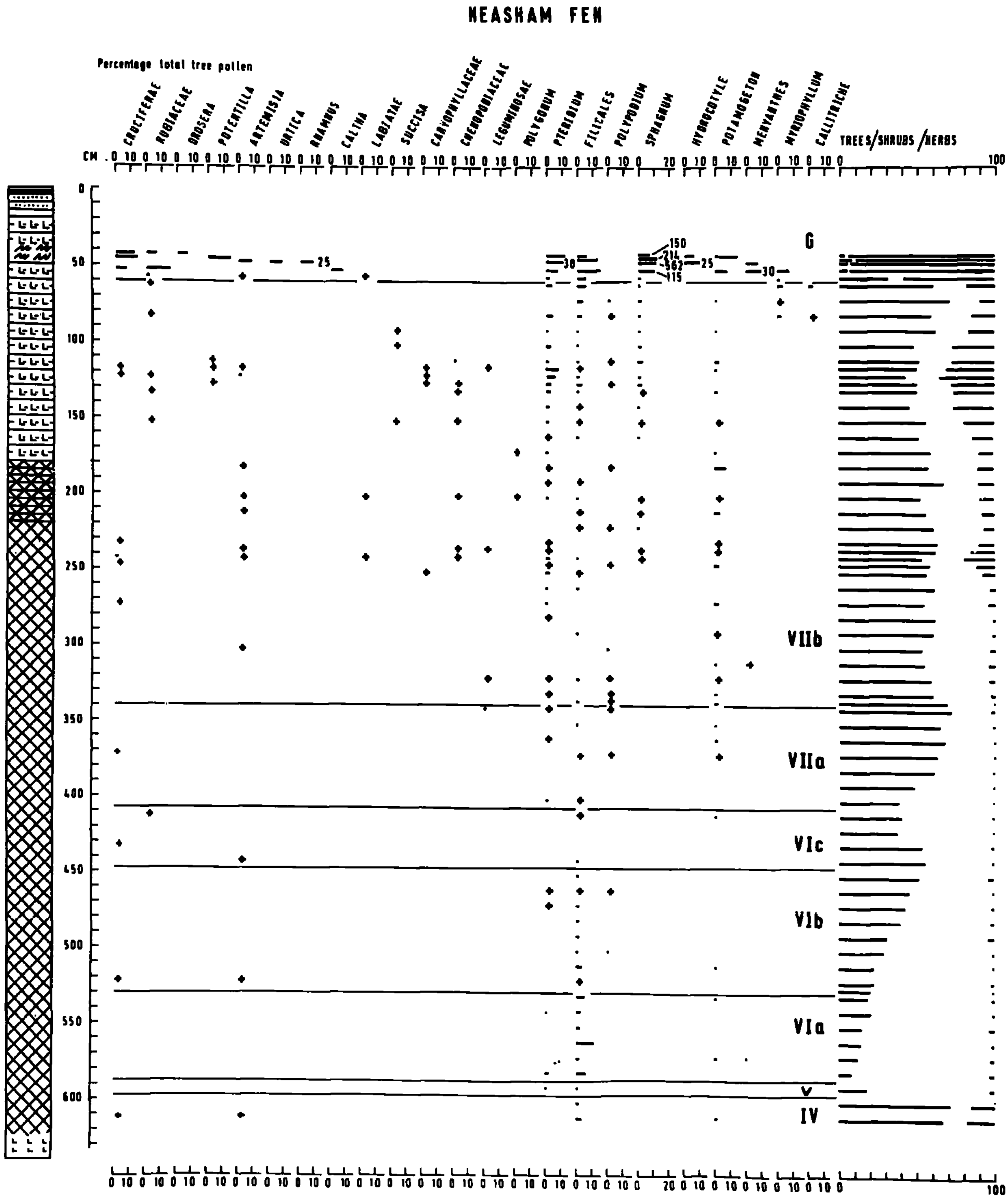

NEASHAM FEN
Percentage total tree pollen
CRUCIFERAE
RUBIACEAE
DROSERA
POTENTILLA
ARTEMISIA
URTICA
RHAMNUS
CALTHA
LABIATAE
SUCCISA
CARYOPHYLLACEAE
CHENOPODIACEAE
LEGUMINOSAE
POLYGONUM
PTERIDIUM
FILICALES
POLYPODIUM
SPHAGNUM
HYDROCOTYLE
POTAMOGETON
MENYANTHES
MYRIOPHYLLUM
CALLITRICHE
TREES/SHRUBS /HERBS
CM
0
50
100
150
200
250
300
350
400
450
500
550
600
G
VIIb
VIIa
VIc
VIb
VIa
V
IV
25
30
150
214
562
115
100

Fig. 10

cm	
623 - 630	Transition.
630 -	Fine pink clay.

Interpretation of the stratigraphy and pollen diagram

Six pollen assemblage zones were recognised on this Neasham Fen diagram, which are so similar to the zones proposed by Godwin (1940) for England and Wales that it was decided to use his symbols , IV to VIIb. However, the highest pollen assemblage zone (40-60cm) has been denoted by the letter G because it is purely local feature.

Late-glacial

Although the Late-glacial deposits at Neasham Fen have not been investigated by pollen analysis (see Chapter 1) a brief summary of the Late-glacial vegetational history of lowland Teesdale is presented below. Blackburn (1952), Bellamy et al (1966) and Bartley (unpublished) have constructed diagrams from Late-glacial deposits at Neasham Brick Pit (Nat. Grid Ref. 334112) Romaldkirk (Nat. Grid Ref. 992230) and Thorpe Bulmer (Nat. Grid. Ref. 465355), respectively. These diagrams indicate the following sequence of events.

In zone I herb pollen values are high and plants now found growing in open habitats, such as Artemisia, Rumex, Thalictrum and Chenopodiaceae, are well represented in the herb pollen spectra. It is quite clear that much of the region supported open herbaceous plant communities of a park tundra nature on unstable soils. Betula nana, Salix and Juniperus pollen frequencies indicate that dwarf birch - willow - juniper scrub grew in the area, probably in scattered stands. Towards the end of zone I with the gradual improvement in climate juniper began to spread. Soon after the start of zone II tree birch began to flourish and quickly shaded out the light demanding juniper (Iversen, 1954). It is not altogether clear exactly how much tree birch grew, but with pollen values representing some 50% of the total pollen om the Thorpe Bulmer diagram it may have been fairly abundant. With the return to more severe climatic conditions towards the latter part of zone II the birch woods became less abundant. This allowed juniper to flourish briefly before its eventual disappearance, in zone III. In this zone there was a return to the more open herbaceous type of vegetation with the soils again becoming unstable (Mackereth, 1966). The unstable nature of the soils may have given rise to a variety of different habitats because these three pollen diagrams present a wide selection of herbaceous pollen taxa.

Early Post-glacial

Zone IV (597.5 - 612.5 cm) on the Neasham Fen diagram (Figs. 8, 9 and 10 p. 26-28) has high Betula pollen frequencies, - about 90% of the total tree values. The arboreal pollen itself accounts for 65 to 75% of the total land pollen. These figures indicate that pioneer birch woodland responded very quickly to the amelioration of climate at the start of the early Post-glacial and rapidly spread in this region to form nearly closed forests. However, the presence of Gramineae, Cyperaceae, Artemisia, Rumex and Filipendula pollen shows that some areas of open vegetation still persisted despite the rapid spread of pioneer woodland. Pinus pollen only represents some 10% of the total arboreal pollen and one must assume that these pioneer woodlands consisted almost solely of birch, a tree which grows quickly and has a rapid dispersal, because of its high production of light seeds.

In zone V (587.5 - 597.5 cm) Corylus pollen frequencies increase very sharply. Correspondingly the herbaceous pollen declines from between 15 and 20%

to under 3% whilst the tree pollen values fall to about 18% of the total land pollen. Low Ulmus and Quercus pollen frequencies are present but it is believed that they can be attributed to long distance transport since it is extremely unlikely that they had migrated into the region at this time. The shape of the Corylus pollen curve and the high percentages attained indicate the rapid manner in which it had immigrated and spread and the enormous abundance in which it must have been growing. There has always been some confusion as to whether hazel grew as an under shrub below a woodland canopy or in pure hazel woods. However, the decline of herb pollen values and the disappearance of some herbaceous taxa might be taken to indicate that hazel was now growing where grassland existed before. If this is so, then surely hazel may have been growing as pure woods as well as an under shrub. The middle of zone V and the expansion of hazel is dated at 9,082 ± 90 radiocarbon years B.P., which agrees most favourably with the date of 8,809 ± 192 radiocarbon years B.P. for the top of the same zone at Scaleby Moss (Godwin, Walker & Willis, 1957).

Zone VI (417.5 - 587.5cm) has been divided into three sub-zones; VIa (530 - 587.5cm), VIb (447.5 - 530cm) and VIc (417.5 - 447.5cm). In VIa Corylus pollen frequencies are very high, up to 1,020% of the total tree pollen. Pinus values continue to remain low whilst those of Ulmus rise. Following the continued expansion of hazel, elm spread quickly into the region and by 8,829 ± 120 radiocarbon years B.P. this, the first of the thermophilous trees, had become truely established. In the course of VIb it is apparent that hazel was being partially replaced by the broad leaved trees, which now included oak. The spread of oak is dated at 8,202 ± 95 radiocarbon years B.P., some 600 years later than the elm expansion. During VIc Betula pollen values continue to decline whilst Alnus percentages start to increase and it is clear that by 6,962 ± 120 radiocarbon years B.P. alder had also migrated into the area and was expanding quickly. Therefore, in the course of

1,800 years elm, then oak and lastly alder spread into the area around Neasham Fen.

Other diagrams from the lowland Teesdale e.g. Romaldkirk, Burtree Lane (Bellamy et al, 1966), Thorpe Bulmer (Bartley, unpublished) and Morden Carr (author, unpublished) also indicate the presence of early birch woodlands. All of these diagrams, with the exception of that from Burtree Lane, have low herb pollen values and it is evidence that these woodlands must have been quite extensive. Those diagrams from Thorpe Bulmer, Morden Carr and Romaldkirk suggest that in these parts of the lowland Teesdale the early Post-glacial vegetational history was almost identical to that which occurred in the vicinity of Neasham Fen. Despite the lack of radiocarbon dates the similarity of all of these diagrams leads one to assume that the major vegetational changes occurred more or less simultaneously in each of these areas. Like the Neasham Fen diagram, those from Thorpe Bulmer, Morden Carr and Romaldkirk have low <u>Pinus</u> pollen values indicating that pine was never an important part of the woodland communities.

However, at Burtree Lane, Bishop Middleham (Bartley, unpublished) and Neasham Brick Pit (Blackburn, 1952) <u>Pinus</u> pollen frequencies increase with those of <u>Corylus</u>. <u>Betula</u> values decline and <u>Ulmus</u> and <u>Quercus</u> percentages rise only slowly. When the pine pollen values rise on these diagrams they attain much higher percentages than are to be found on those diagrams which are so similar to that from Neasham Fen (see above paragraph). It now becomes apparent that all of the lowland diagrams can be placed within two categories. There are those with low <u>Pinus</u> pollen percentages and the rest with high. It must now be decided whether these different amounts of <u>Pinus</u> pollen represent apparent or actual variations in the abundance of local pine woods at each of the sites mentioned.

Such differences of pollen frequency cannot be attributed to variations in the amount of Pinus pollen brought in by long distance transport because some of the sites which appear to be different, e.g. Neasham Fen and Neasham Brick Pit, are situated very close to one another. There is, however, the possibility that the amount of Pinus pollen present in the various deposits may have been affected by the nature of the deposits. At Neasham Fen, Romaldkirk, Thorpe Bulmer and Morden Carr low Pinus pollen frequencies are present in open water deposits whilst at Burtree Lane and Bishop Middleham high values are found in peats. It is therefore feasible that Pinus pollen, with its two large air sacs, may have floated on open water. Any wave action would then have transported them to the edges of the areas of open water where they may have then become incorporated into the marginal sediments. Such a process would cause over representation on marginal deposits and under-representation in more central sediments. In order to test such a hypothesis two marginal cores were collected from Neasham Fen, one 18m along the original transect and the other 7.5m in from the western edge ofthe fen. Only a part of the early Post-glacial sediments were analysed for pollen content and the results (only the tree pollen was counted) obtained, expressed as percentages of total A.P. are as follows :

First core (18m)

cm	Betula	Pinus	Ulmus	Quercus	Alnus
300	55.3	7.0	30.7	7.0	-
308	63.1	12.3	23.1	1.5	-
316	74.4	14.3	13.0	1.3	-
324	76.7	11.6	8.1	3.5	-

Second core (7.5m)

cm	Betula	Pinus	Ulmus	Quercus	Alnus
102	30.7	4.0	6.6	40.0	16.0
110	53.4	9.7	10.4	13.2	4.8
118	79.6	11.1	6.5	1.9	0.9
126	91.3	5.3	2.0	0.7	-
134	93.3	4.7	1.3	0.7	-
142	94.0	5.3	-	0.7	-

These percentages of Pinus pollen are almost identical to those on the pollen diagram (Figs. 8,9 and 10, p.26-28), which was constructed from a central core. In the light of these results it is probably safe to assume that there was no differential deposition of pine pollen in open water. Therefore the Pinus pollen percentages reflect actual variations in the abundance of local pine at each of these lowland sites. Thus, the high values in peat deposits and the low in open water sediments is only coincidence.

As all of the sites, with the exception of Romaldkirk, are from a relatively small area climatic variation can be excluded as a possible cause for the differences in the abundance of local pine. Therefore, one must conclude, as Pennington (1970) did, that edaphic factors were largely responsible for this local variation in the abundance of pine.

In zone VI on the Burtree Lane and Bishop Middleham diagrams peaks of Pinus pollen seem to occur at different times. On the former diagram there is one in the middle of the zone whilst on the latter there are two, - one in the middle and another towards the end. This may imply that pine was responding to different edaphic conditions. In the middle of zone VI it spread with drying out of the soils whilst towards the end of the zone it expanded as water table levels were recovering (Oldfield, 1965). This latter suggestion is not wholly hypothesis because at Bishop Middleham pine remained fairly abundant after the B.A.T. However, without radiocarbon dates the precise nature of the response of pine to edaphic factors cannot be stated with any certainty. Nevertheless,this whole question of the response of pine will be dealt with more fully when discussing the behaviour of pine growing on the Moor House National Nature Reserve (see Chapter 6).

Wherever pine grew in lowland Teesdale it is clear that it had replaced the pioneer birch woodland although elm and oak were present in the region they were always less abundant where pine flourished. When pine eventually decreased in abundance it was largely replaced by alder, which in the vicinity of Bishop Middleham was a gradual process. Throughout the early Post-glacial the composition of the woodlands of lower Teesdale must have been continually changing as new trees and shrubs migrated into the region. The whole pattern of woodland development would have been one of continued adjustment. During all this time the woodlands around Neasham Fen, Morden Carr, Romaldkirk and Thorpe Bulmer provided a closed tree canopy. However, those diagrams from Neasham Brick Pit, Bishop Middleham and Burtree Lane all have reasonably high herbaceous pollen values. Much of this pollen can be attributed to local cyperaceous pollen and areas of more open vegetation were probably less extensive than these diagrams suggest. In which case almost the whole of lowland Teesdale supported closed woodland communities.

Low Tilia pollen frequencies on all of the lowland diagrams suggest that this region was beyond the natural growth range of lime, the most warmth demanding of the thermophilous trees.

Late Post-glacial

At 340cm on the Neasham Fen diagram (Figs. 8,9 and 10, p. 26-28) the elm-decline marks the beginning of sub-zone VIIb, in the course of which herb pollen frequencies rise very gradually. There is no direct evidence which indicates that the elm-decline was caused by anthropogenic activity a topic which has always stimulated much discussion and interest (Iversen, 1949; Troels-Smith, 1960; Smith A.G., 1970). However, an unpublished diagram from Hartlepool foreshore (Tooley), only some 18 miles (28.9km) distance from Neasham Fen, has human remains closely associated with an elm-decline. These remains include three finger bones and a skull. Close to where these remains were found there is a distinct layer of charcoal. All of these finds together with increased frequencies and variety of herbs associated with pastoralism strongly indicate that the elm-decline was indeed caused by human action. It is therefore probably safe to assume that at Neasham Fen anthropogenic activity was responsible for the elm decline.

At Neasham Fen the elm-decline is dated at 5,468 $\pm$ 80 radiocarbon years B.P., which is earlier than the majority of such dates. There is, however, other evidence for an early elm-decline in lowland Teesdale. On the Bishop Middleham diagram the elm-decline is 10cm below a level dated at 5,180 $\pm$ 110 radiocarbon years B.P.

Following the elm-decline Ulmus pollen values remain low and it is clear that elm was unable to re-establish itself in the region. This was probably caused by a lack of base rich soils which are essential for the growth of elm (Pennington, 1965). During the Atlantic the high precipitation gave rise to rapid leaching of the soils beneath the woodland canopy which allowed only a slow rate of erosion (Mackereth, 1966). To-day there is a distinct lack of base-rich soils in lowland Teesdale. This in itself may be the result of leaching in the past.

In sub-zone VIIb oak and alder were the two most dominant trees of these lowland forests. However, above 270cm Betula and Fraxinus pollen values increase.

As birch and ash respond quickly to woodland clearance, colonising clearings there, pollen increases suggest that some clearance activity was undertaken prior to 3,300 years B.P. The herbaceous pollen values do not rise substantially and it would appear that these clearances were small and of a temporary nature. This may well account for the lack of early Bronze Age archaeological finds from the region (Harding, 1970).

At 242cm (Figs. 8,9 and 10, p. 26-28) herbaceous pollen values increase from 5% to 20% of the total land pollen. This increase is mostly accounted for by a rise of Gramineae pollen frequencies. However, the number of herb pollen taxa also increases and of particular interest is the first appearance of Plantago, Rumex and cereal pollen. This peak of herb pollen is dated at 3,242 ± 70 radiocarbon years B.P. It was at this time that the forests were first seriously altered by human interference. At Bishop Middleham a larger peak of herbaceous pollen has been dated to 3,360 ± 80 radiocarbon years B.P. The similarity of these two dates suggest that Bronze Age settlements may have been numerous in lowland Teesdale. In the vicinity of Neasham Fen this clearance phase was only temporary and regeneration of the forests soon took place. Pioneer birch and ash quickly colonised the vacated clearings. At Bishop Middleham a date of 3,660 ± 80 radiocarbon years B.P. indicates that the clearing of the woodlands had begun some 300 years earlier than in the area around Neasham Fen.The very high Gramineae, Plantago, Rumex and cereal pollen values show that the extent of woodland destruction was much more pronounced than in the vicinity of Neasham Fen.

It is very intriguing that there is an almost total absence of archaeological evidence (Harding, 1970) of Bronze Age occupation in Teesdale. Some unassociated axes and weapons have been found. Even burial sites are relatively few. However, there is a most remarkable late Bronze Age site at Heathery Burn Cave near Stanhope, in Upper Weardale. Here many items have been discovered, including a sheet bronze bucket and pieces of pottery, all of which have been ascribed to the seventh century B.C.

With the Heathery Burn Cave finds in mind it is very interesting that at Neasham Fen there is a peak of herbaceous pollen, dated above (100-105cm) and below (140-145cm) at 2,804 ± 80 and 2,488 ± 75 radiocarbon years B.P., respectively. It would seem that people were clearing the woodlands in lowland Teesdale when late Bronze Age settlers were present in Upper Weardale. At this point on the Neasham Fen diagram Gramineae, *Plantago*, *Rumex* and *Pteridium* pollen all increase. These pollen curves suggest that the anthropogenic effects upon the forests were more pronounced than those of the earlier occupation some 3,200 years ago. Quite extensive areas of the forest around Neasham Fen must have been felled during this last phase of settlement.

An enigmatic feature of the two radiocarbon dates for levels 100-105cm and 140-145cm is that they are in the reverse order. As a check the two levels 105-110cm and 135-140 were radiocarbon dated. Again the dates were in the reverse order (see p. 25). At present no plausible explanation is offered. Neither the stratigraphy nor the pollen curves show any peculiarity of deposition and a comparison between the radiocarbon dates and bristle cone pine dates offers no solution (Olsson, 1970).

Zone ς (40-60cm), the herb pollen assemblage, is characterised by high Cyperaceae, *Calluna*, *Sphagnum*, Gramineae, cereal, *Plantago*, *Rumex*, Rosaceae, Umbelliferae, Ranunculaceae, *Filipendula* and Compositae pollen frequencies. There are also high *Hydrocotyle*, *Menyanthes*, *Myriophyllum*, *Potamogeton* and Callitriche values. The high Cyperaceae, *Calluna* and *Sphagnum* frequencies reflect the change from open water to peat forming conditions and each of the above mentioned aquatic genera includes species which flourish in shallow water or wet peaty conditions. The rise of Gramineae and ruderal pollen frequencies represents yet another phase of woodland clearance. The massive increase of these pollen types illustrates the extent of modification to these lowland forests. Even if the cyperaceous pollen, most of which is of purely local origin, is disregarded the herb pollen values, still rise from 26% (57.5cm) to 91% (52.5cm) of the total pollen. This increase of herbaceous pollen together with the date of 1,213 $\pm$ 60 radiocarbon years B.P. (Figs. 8,9 and 10 p. 26-28) clearly shows that much of the woodland around the fen had been cleared by Anglo-Saxon times. The large increase of cereal pollen values demonstrate the importance of arable farming to the economy of these people.

It is very interesting to note that there is no palynological evidence of middle Iron Age - Romano-British clearance activity at Neasham Fen. A radiocarbon date for a level a few centimetres below that dated at 1,213 $\pm$ 60 radiocarbon years B.P. (55-60cm) would indicate if the rate of deposition had slowed down in this part of the fen. Such a phenomenon would contract that part of the pollen diagram and hence obscure any middle Iron Age - Romano-British clearance phases.

At present little is known of the Iron Age occupation of north-eastern England (Harding, 1970). An overall paucity of archaeological sites has in the past given rise to the popular belief that this region was a cultural backwater. However, Scottish sites indicate new fashions, if not new immigrants, by the fifth century B.C. (Mackie, 1969) and many scholars would now agree that this region was more advanced culturally than was at first thought.

Bartley's unpublished diagram from Thorpe Bulmer provides some evidence of the vegetational history of the Romano-British period. Increased Gramineae and Plantago frequencies have been dated at 1,730 ± 120 radiocarbon years B.P. At this level there is also a peak of Cannabis/Humulus pollen which demonstrates an impetus towards arable farming at that time after the Roman occupation. Evidence suggests (Dobson, 1970) that Roman troops first advanced this far north whilst Petillius Cerealis was governor (A.D. 71-74). Shortly afterwards (A.D. 78-84/5) a fort was built at Piercebridge to guard a river crossing on the Tees. Although the occupation probably lasted until the last quarter of the fourth century A.D. very little is known of how the civilian population lived and worked.

Following the withdrawal of the Romans people of mixed Germanic origins invaded and settled in the region in the fifth and early sixth centuries. The River Tees then became the southern boundary of Bernicia and it has been suggested that the region became a meaningless cultural and political unit until A.D. 995, when the Community of St. Cuthbert ruled part of it (Cramp, 1970). However, the Neasham Fen diagram clearly shows that by about A.D. 740 settled communities were present in the lowlands of Teesdale. These people may have been the same as those who erected stone crosses at Northallerton, Hurworth and Croft, following the foundation of Jarrow in A.D. 682.

CHAPTER 4

WEELHEAD MOSS AND THE COW GREEN REGION OF UPPER TEESDALE

Weelhead Moss (Nat. Grid Ref. 807304) was situated in the peat filled valley of the Tees, above Cauldron Snout and upstream of the glacial moraine (Fig.11, p.43). The southern, eastern and north-eastern margins of the moss were bounded by the lower slopes of Widdybank Fell and Cow Green. The River Tees flowed beside the western and south-western limits of the Moss (Fig. 12, p.44).

The Moss sloped gently to the north-west, becoming more fen-like in character and in parts the peat had eroded leaving peat haggs (Fig. 11 p A list of the more common plants found growing on the Moss is as follows :

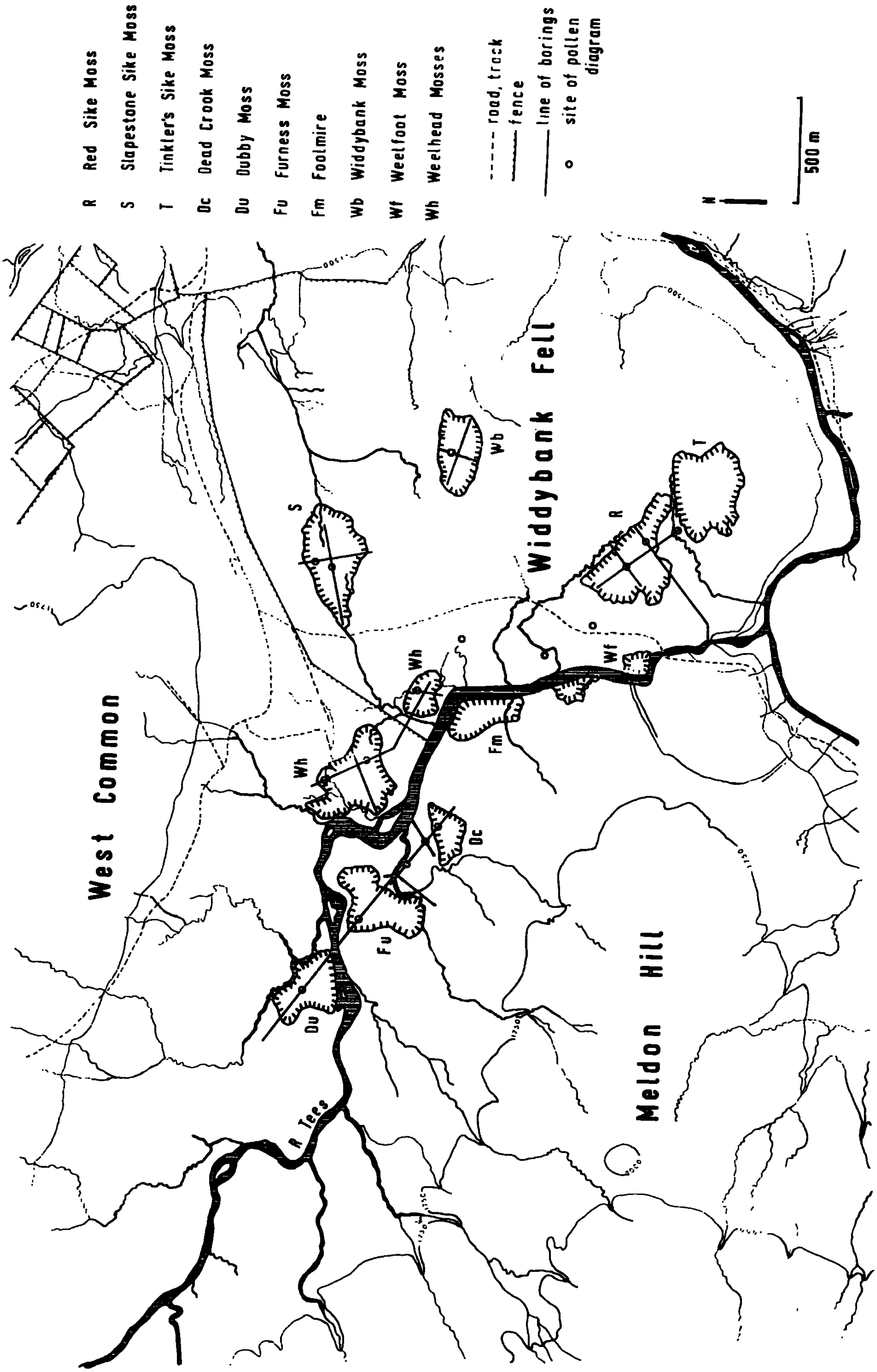
Calluna vulgaris	Narthecium ossifragum
Carex nigra	Potentilla erecta
Deschampsia flexuosa	Rubus chamaemorus
Empetrum nigrum	Trichophorum spp.
Erica tetralix	Vaccinium oxycoccus
Eriophorum angustifolium	Polytrichum sp.
E. vaginatum	Sphagnum capillaceum
Festuca ovina	S. papillosum
Juncus squarrosus	S. rubellum
Molinia sp.	Cladonia spp.
Nardus spp.	

STRATIGRAPHY

The stratigraphy of the moss was examined along two line transects that were laid across the moss at right angles to one another. Each transect consisted of stakes set at 10 or 20m intervals. A Dumpy level and staff were used to level the surface of the moss along each transect. The stratigraphy was determined at different points along the transects (Figs. 13 & 14, pages 46,47) by means of a Hiller borer.

These borings indicated that the peat had formed in a depression on alluvial deposits which consisted of fine blue and coarse grey silts. The depth of peat varied in different parts of the moss. For instance, in some places it was 2.5 to 4m deep whilst near the top of the moraine it was reduced to only a few centimetres. The lower peats were found to consist of sedge or sedge-Sphagnum remains, sometimes with a muddy transition zone separating them from the underlying silts. In other parts a well humified Sphagnum peat was present beneath sedge peats. In all of these lower peats some Eriophorum and Culluna remains were found together with pieces of Betula wood. Overlying these lower peats were less humified sphagnum peats with Eriophorum and Calluna remains. To illustrate the different layers the detailed stratigraphy at 140m along transect II was as follows :

cm	
0 - 7	dry, light-brown soily peat penetrated by modern roots.
7 - 35	dark-brown moderately humified Eriophorum-Calluna peat with sedge remains.
35 - 140	mid-brown highly humified Sphagnum-Eriophorum peat with some Culluna.
140 - 165	dark-brown highly humified Sphagnum-Eriophorum peat with sedge remains.
165 - 200	light-brown highly humified sedge peat with Sphagnum.
200 - 235	dark-brown moderately humified sedge peat with Calluna.



R Red Sike Moss
S Slapestone Sike Moss
T Tinkler's Sike Moss
Dc Dead Crook Moss
Du Dubby Moss
Fu Furness Moss
Fm Foolmire
Wb Widdybank Moss
Wf Weelfoot Moss
Wh Weelhead Masses
road, track
fence
line of borings
site of pollen diagram
N
500 m
West Common
Widdybank Fell
Meldon Hill
R Tees

Fig. 11

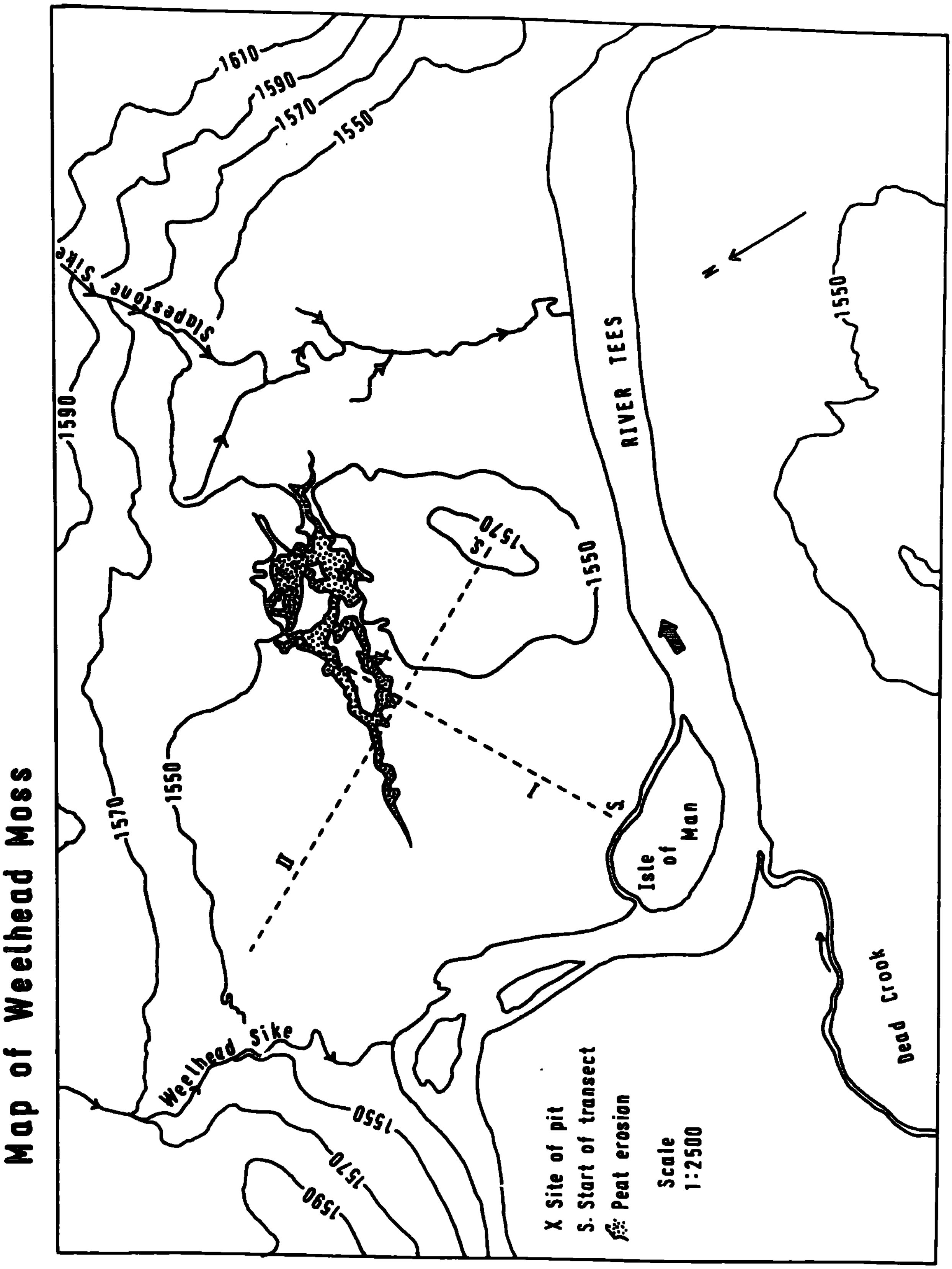

Map of Weelhead Moss
1610
1590
1570
1550
Slapestone Sike
RIVER TEES
1590
1570
1550
1570
1550
1550
S
I
II
S
Isle of Man
Weelhead Sike
1550
1570
1590
Dead Crook
X Site of pit
S. Start of transect
Peat erosion
Scale 1:2500

Fig. 12

cm	
200 - 248	light-brown sedge peat with some <u>Betula</u> wood.
248 - 250	<u>Sphagnum cuspidatum</u> peat.
250 - 270	light-brown <u>Sphagnum</u>-sedge-birch peat with a layer of birch at 270 cm.
270 - 300	light-brown sedge-birch peat.
300 - 330	light-brown <u>Sphagnum</u>-sedge peat.
330 - 350	light-brown sedge peat with bands of <u>Sphagnum cuspidatum</u>.
350 - 360	dark-brown highly humified peat.
360 - 380	dark-brown peat with bands of <u>Sphagnum cuspidatum</u>, and carbonised fragments.
380 - 394	stiff dark-brown peat with sedges and <u>Sphagnum cuspidatum</u>.
394 - 397	band of white clay.
397 - 430	dark-brown stiff sedge peat with band of clay between 403 and 406 cm.
430 - 450	light grey silty sand with round pebbles.

WEELHEAD MOSS TRANSECT I

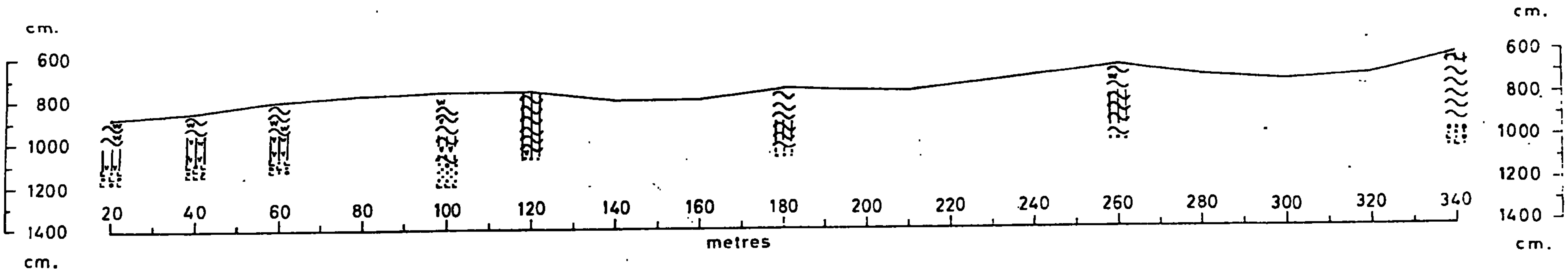
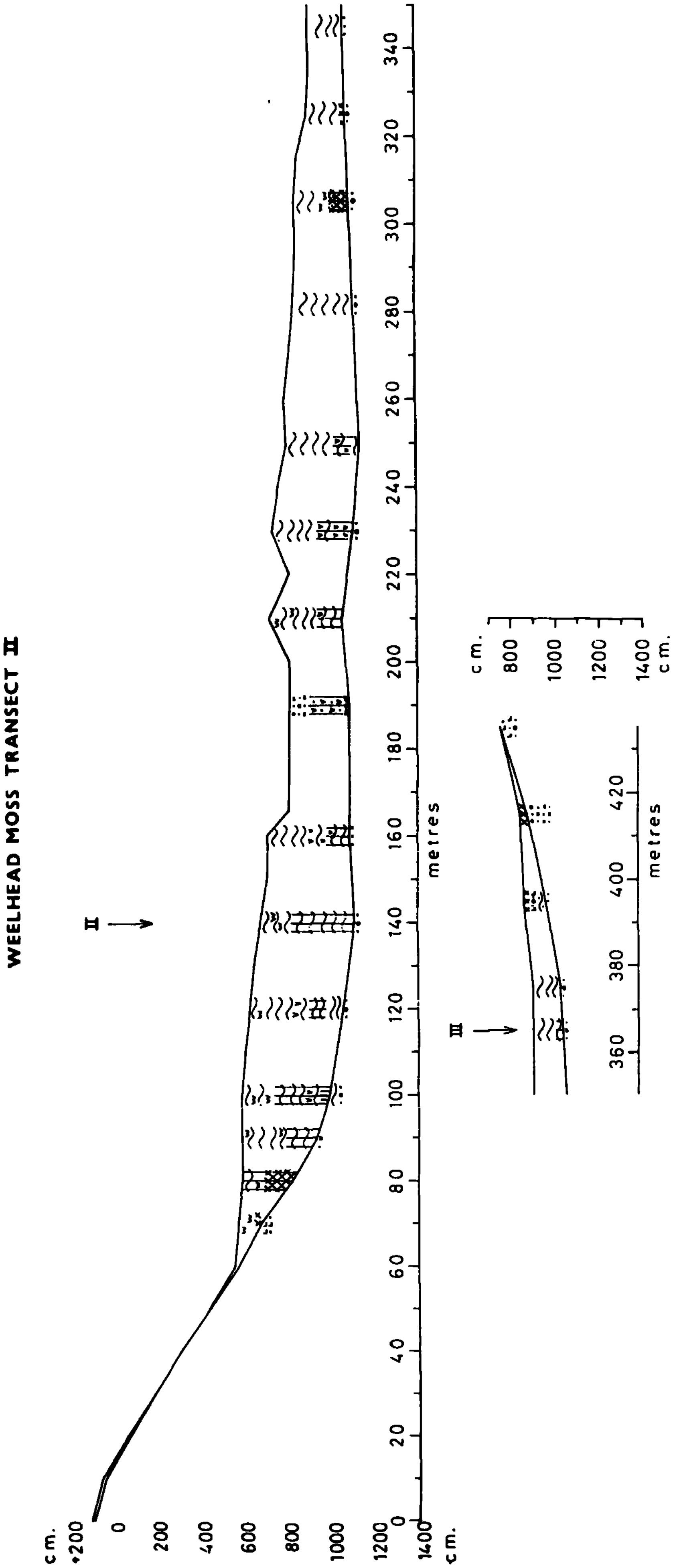


Fig. 18



WEELHEAD MOSS TRANSECT II
II
III
metres
c m.
+200
0
200
400
600
800
1000
1200
1400
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420

Fig. 14

Collection of Samples for Pollen Analysis and Radiocarbon Dating

Where possible, the best way of collecting peat samples is to take a complete vertical monolith. This method was decided upon for two reasons. Firstly, the presence of peat haggs on Weelhead Moss would make the task relatively easy and secondly, at least 20 gm of dry weight peat was required by the Gakushuin Radiocarbon Laboratory in Japan for radiocarbon analysis. The collecting was carried out after a period of relatively dry weather, on the assumption that the water table would be low. An exposure of 1.75m of peat at the side of the hagg, in the dissected area of the moss proved an ideal site (Fig. 12, p.44). The side of the hagg was cut back and a pit dug at its base, thus exposing a complete vertical section. When the complete monolith was removed it was sliced into 2cm thick horizontal sections and from each of these sections a sample for pollen analysis was taken. The slices were sealed in polythene bags and stored in a deep freeze, to prevent fungal and bacterial growth, until required for radiocarbon dating. The stratigraphy of this monolith was as follows :

cm	
0 - 65	Sphagnum peat of low humification (H-3) with sedge and Calluna remains.
65 - 74	Sphagnum - sedge peat of low humification (H3-4) with some Calluna.
74 - 240	sedge peat of medium humification (H5-6) with Sphagnum, Eriophorum and Calluna. Pieces of Betula wood at 180cm.
240 - 360	sedge peat of low humification (H2) with Sphagnum, Eriophorum and Calluna. Some small pieces of Betula wood and a Scirpus seed at 361cm.
360 - 383	sedge peat of low humification (H2) with abundant Eriophorum remains.

cm		
383 - 399		sedge peat of medium humification (H4-5).
399 - 417		sedge peat of medium humification (H4-5) with some silica, particularly in the bottom 7cm.
417 - 425		grey silty clay with pebbles up to 8mm in diameter.

Because of the necessity to collect samples and record the stratigraphy before the Cow Green Reservoir Basin was flooded the above mentioned field work, with the exception of the monolith stratigraphy, was carried out by my Supervisor, Dr. J. Turner, before I took up my appointment.

Laboratory Techniques

Standard methods of sample treatment, pollen preparation and pollen counting were used (see CHAPTER 3). Examination of the macro-remains, retained after pollen preparation, resulted in the identification of a Scirpus seed at 361cm and pieces of Betula wood at 180cm and between 240 and 260cm leaves of Rhacomitrium were found between 337 and 345cm and Sphagnum recurvum remains at 80cm. In general, the Sphagnum remains were poorly preserved and it was with difficulty that they were assigned to either the Acutifolia or Cuspidata series.

When the pollen diagram from Weelhead Moss (Figs. 15,16 and 17, pages 50,51 and 52) was constructed (all percentages expressed as a percentage of total tree pollen) and examined it was decided that seven levels should be radiocarbon dated. These levels were then dried (see Laboratory Techniques, CHAPTER 3) and sent to the Gakushuin Radiocarbon Laboratory in Japan. The levels and the results of the analyses, expressed in radiocarbon years B.P. are :

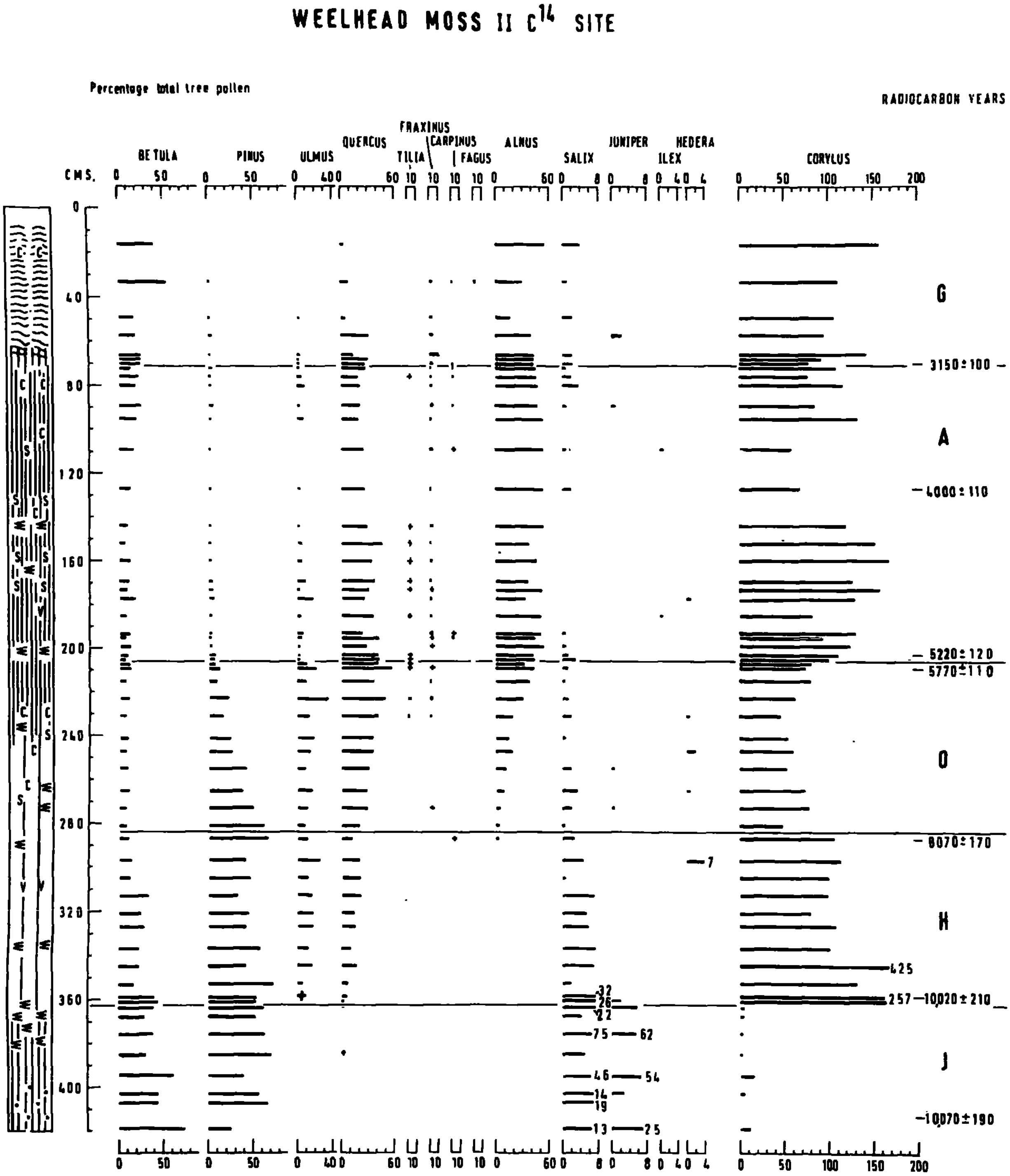

WEELHEAD MOSS II C14 SITE
Percentage total tree pollen
RADIOCARBON YEARS BP
BETULA
PINUS
ULMUS
QUERCUS
TILIA
FRAXINUS
CARPINUS
FAGUS
ALNUS
SALIX
JUNIPER
ILEX
HEDERA
CORYLUS
CMS.
3150±100
4000±110
5220±120
5770±110
8070±170
10020±210
10070±190
G
A
D
H
J

Fig. 15

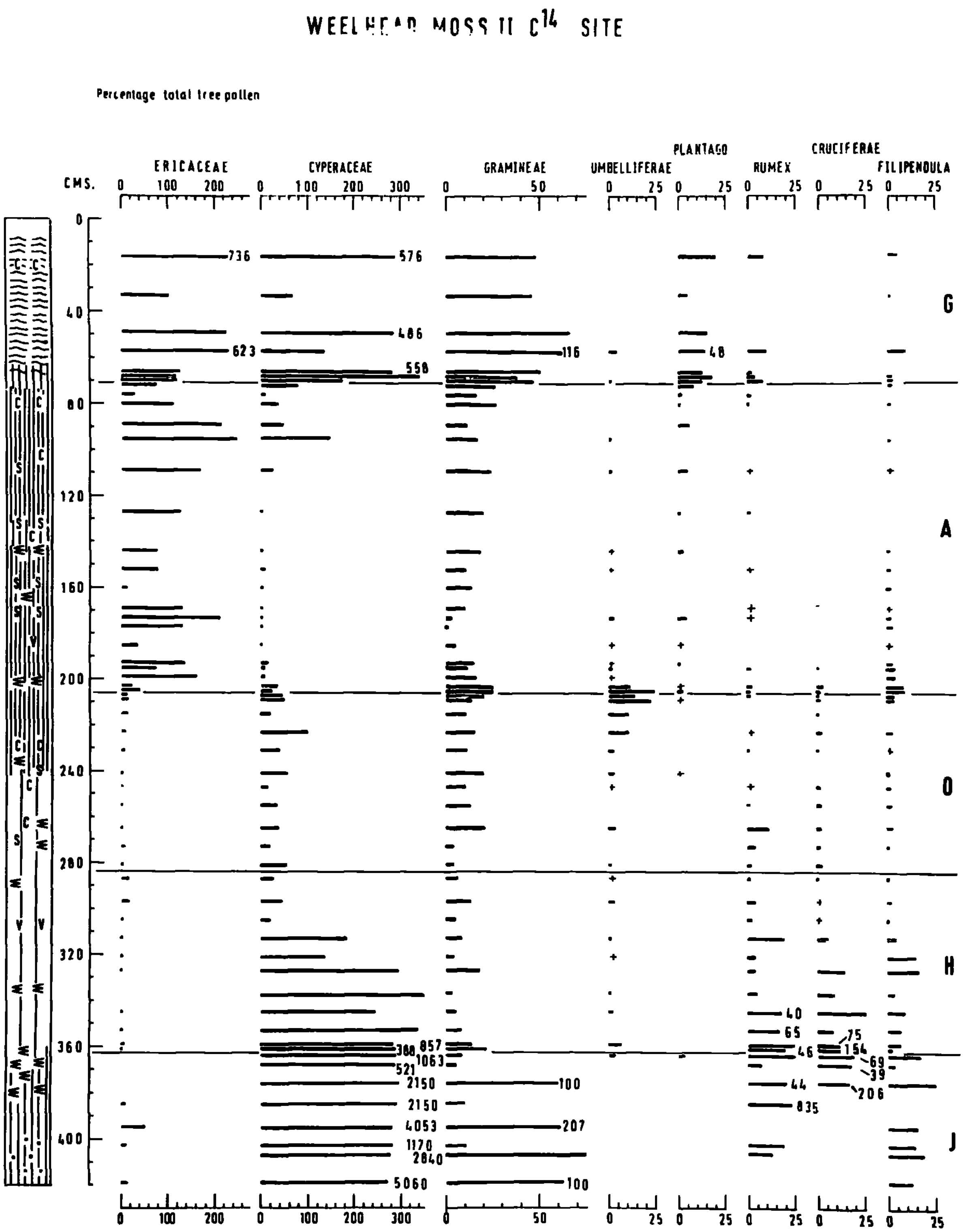

WEELHEAD MOSS II C14 SITE
Percentage total tree pollen
CMS.
ERICACEAE
CYPERACEAE
GRAMINEAE
UMBELLIFERAE
PLANTAGO
RUMEX
CRUCIFERAE
FILIPENDULA
G
A
O
H
J

Fig. 16


WEELHEAD MOSS II C^{14} SITE
Percentage total tree pollen
P = POLYGONUM C = CENTAUREA S = SCROPHULARIACEAE
A = PAPILLIONACEAE B = BOTRYCHIUM L = LYCOPODIUM
Se = SELAGINELLA E = EMPETRUM
CARYOPHYLLACEAE
CHENOPODIACEAE
ARTEMISIA
COMPOSITAE
RANUNCULACEAE
ROSACEAE
POTENTILLA
SUCCISA
CALTHA
THALICTRUM
SAXIFRAGACEAE
RUBIACEAE
CEREALS
FILICALES
POLYPODIUM
PTERIDIUM
SPHAGNUM
TREES/SHRUBS/HERBS
CMS.
G
A
O
H
J

Fig. 17

1. Gak - 2913, peat from 70cm, lowest sample with high Gramineae, *Plantago* and *Rumex* pollen percentages, 3,150 ± 100.

2. Gak - 2914, peat from 127cm, level with falling *Quercus* and rising *Betula* pollen frequencies, 4,000 ± 110.

3. Gak - 2915, peat from 203cm, lowest sample with low *Ulmus* pollen percentages, 5,220 ± 120.

4. Gak - 2916, peat from 209cm, highest sample with high *Ulmus* pollen percentages, 5,770 ± 110.

5. Gak - 2917, peat from 287cm, the level at which *Pinus* values fall and *Alnus* percentages increase, 8,070 ± 170.

6. Gak - 2918, peat from 359cm, the level where *Corylus* pollen frequencies increase, 10,020 ± 210.

7. Gak - 2919, peat from 413cm, a sample from near the bottom of the pollen diagram, 10,070 ± 190.

Sometime after examining these dates it was decided that a further two levels should be dated. These levels were sent to the Scottish Research Reactor Centre, East Kilbride, for assay. These two levels and the results, expressed in radiocarbon years B.P. are:

1. SRR - 107, peat from 239cm, 6,202 ± 70.

2. SRR - 108, peat from 337cm, the level with first low *Corylus* pollen frequency, 8,057 ± 85.

Interpretation of the Stratigraphy and Pollen Diagram

The pollen diagram has been divided into five clearly recognisable pollen assemblage zones (Figs. 15,16 and 17, pages 50,51 and 52). These assemblage zones do not correspond with those used by Godwin (1940) for England and Wales and have been assigned local names, already used for other diagrams from the Cow Green Reservoir Basin and Widdybank Fell region (Turner, Hewetson, Hibbert, Lowry and Chambers, 1973). These pollen assemblage zones are :

a juniper - willow - herbaceous assemblage zone, Zone J.

a pine - hazel assemblage zone, Zone H.

an oak - elm - hazel assemblage zone, Zone O.

an oak - alder assemblage zone, Zone A.

a grass - heather - plantain assemblage zone, Zone G.

All of the diagrams from the Cow Green Reservoir Basin and Widdy Bank Fell come from a relatively small area of peat deposits (Fig. 11, page 43.) It has therefore been assumed that a substantial proportion of the pollen rain, at each site, must have come from the same area, a regional upland source. In such circumstances these major pollen assemblage zones may be taken to represent chronological periods.

Not all of these pollen assemblages are necessarily present on every diagram from this region because some of the peats began forming earlier than others. Some diagrams also have more than five assemblages because peat was forming in these places whilst in other areas there was a 'hiatus period'.

The five major pollen assemblage zones are not identical on all diagrams e.g. Zone O can be sub-divided on some but not on others. As all the diagrams come from a relatively small area these minor assemblages are thought to represent local vegetational diversities, which need not necessarily be synchronous.

Late-glacial

Zone J (363-419cm) on the Weelhead Moss Radiocarbon diagram

(Figs. 15,16 and 17, pages 50,51 and 52) is one with high herbaceous pollen values, Cyperaceae, Gramineae and Filicales percentages are very high. Filipendula, Plantago, Cruciferae, Rumex, Caryophyllaceae, Thalictrum and Caltha frequencies also contribute to these high herb pollen percentages. Other herb pollen taxa present include Chenopodiaceae, Artemisia, Compositae, Ranunculaceae, Rosaceae, Selaginella and Lycopodium. In all, the herb pollen represents some 90% of the total land pollen present in the assemblage zone.

Other diagrams which have a zone J pollen assemblage are those from Tinklers Sike Moss (Appendix Figs. 1 and 2), Red Sike Moss (Appendix Figs. 3 and 4), Foolmire Sike Moss (Appendix Figs. 5 and 6) and Dead Crook Moss (Appendix Figs. 7 and 8). On each of these diagrams herbaceous pollen values are high. Included in the herb pollen taxa are such Late-glacial types as Artemisia, Filipendula, Helianthemum, Rumex and Thalictrum. However, both the Weelhead Moss and Tinklers Sike (135cm) dates of 10,070 ± 190 and 9,900 ± 190 radiocarbon years B.P., respectively, are not typical Late-glacial dates (Hibbert, Switsur and West, 1971; Pennington, 1969; Godwin, 1961). These dates suggest, although each has a high standard deviation, that a Late-glacial vegetation continued to flourish in Upper Teesdale after its replacement in more lowland parts of northern England.

Such a large number of herb pollen taxa in zone J on all of these diagrams must indicate that a wide variety of habitats were present. On Widdybank Fell there were those soils which were developing on the 'super-limestone' areas. These soilsdiffered in their degrees of permeability and carbonate content according to the absence, presence and thickness of drift overlying the 'sugar-limestone' (see CHAPTER 2). There were also those areas in the reservoir basin which were becoming increasingly waterlogged due to topographical drainage and the non-porous nature of the alluvial deposits. Areas which eventually became covered with blanket peat must also have provideda variety of habitats. Soil instability, as indicated by the presence of *Artemisia* pollen, would continually cause new habitats to be formed and thus add to the variety of ecological niches.

On the Weelhead Moss Diagram both *Juniperus* and *Salix* frequencies are high and together with *Betula nana* are present on other diagrams from the region which have a zone J pollen assemblage. This suggests that juniper, willow and birch scrub were growing locally in the area at that time. It is interesting to note that *Salix* values are considerably lower on the Tinklers Sike (TSI) and Red Sike (RS II) diagrams from Widdybank Fell than on the reservoir basin diagrams. Bartley (1967) has demonstrated that *Salix* pollen is deposited close to its source of origin and it therefore seems probable that willow was less abundant on the well drained soils of the fell than in the wetter areas of the reservoir basin.

The low arboreal pollen values on the Weelhead Moss and other diagrams from the vicinity suggest that trees were not growing in the region at this time. That *Betula* and *Pinus* pollen which has been recorded can probably be attributed to long distance transport into this region of park tundra vegetation. This open herbaceous vegetation is similar to that found in other upland regions at this time.

Early Post-glacial

Zone H (285-363cm) has high *Corylus* and *Pinus* pollen frequencies. *Ulmus* and *Quercus* pollen ~~is~~ are also present. At the Zone H pollen assemblage boundary the pollen curves change very markedly. The type of deposit also changes from a highly to a more lowly humified peat. Both these features indicate that there had been a 'hiatus-period'. Diagrams from Tinklers Sike Moss and Red Sike Moss also show that there had been a gap in peat deposition.

There is only a little palaeobotanical evidence of the vegetional history during the 'hiatus-period'. Some peat was forming at Foolmire Sike and an assemblage zone (HJ), intermediate between zone J and H, is present on the diagram from this Moss (Appendix Figs. 5 and 6). This pollen assemblage is characterised by rising *Corylus* values, up to 80% of the total tree pollen, and *Juniperus* frequencies of between 10 and 20%. These figures suggest that hazel scrub was invading and spreading into the region, but not to such an extent as to shade out juniper. The high *Salix* pollen values indicate that willow was growing locally, most probably in the wetter areas. Increasing *Filipendula* percentages point to a rising of temperatures. However, some Late-glacial pollen taxa such as *Thalictrum*, *Artemisia* and *Rumex* are still present. The low arboreal pollen values suggest that birch and pine were only present in very small amounts.

The only other source of evidence of the vegetation during this 'hiatus-period' is provided by Dead Crook Moss (Appendix Figs. 7 and 8).. On the diagram from this site the pollen assemblage (P) is one with high *Pinus* and low *Corylus* values. *Juniperus* pollen is all but absent and *Salix* frequencies never rise above 10%. In contrast to Foolmire Sike, it would seem that hazel, willow and juniper did not flourish in this part of the reservoir basin. It is difficult to ascertain whether the high arboreal pollen values represent an actual spread of pine because the peat is a sedge peat and the predominant herbaceous pollen is cyperaceous in origin. The high arboreal values might only be a reflection of local changes on the surface of the bog e.g. diminished cyperaceous pollen production.

No definite date can be given for the general resumption of peat deposition after the 'hiatus-period'. The Weelhead Moss date of 10,020 ± 210 radiocarbon years B.P., for the first high *Corylus* frequency is totally misleading because it is far too old. During the 'hiatus-period' erosion of peat at the surface caused some of the old peat to become incorporated into the newer deposits as soon as they began to form. However, two radiocarbon dates from above the hiatus do provide some information regarding the time at which the resumption of peat growth occurred. A level from Weelhead Moss (337cm) is dated at 8,057 $\pm$ 85 radiocarbon years B.P. and another from Tinklers Sike (115cm) at 8,250 $\pm$ 280 radiocarbon years B.P. Both these dates show that peat was being redeposited well before 8,000 years ago. The pollen spectra at the bottom of Zone H are very similar to those of Godwin's early Zone VI and it may be that the 'hiatus-period' finished some 8,800 years ago. If this is correct, then the 'hiatus-period' lasted for about 1,200 years.

At the start of Zone H arboreal pollen values are slightly higher on the Weelhead Moss radiocarbon diagram and other diagrams than they are in the previous zone(s). This suggests that some pine with a little birch had migrated into the region during the 'hiatus-period'. However, it is clear that these woods did not expand until after some 8,800 years ago. This expansion did not happen at the same rate everywhere. In the reservoir basin the tree pollen percentages risemore sharply and reach higher values than on thetop of Widdybank Fell. For example, the tree pollen values represent some 20 to 40% of the total land pollen at Weelhead Moss (Figs. 15,16 and 17, pages 50,51 and 52) compared with 15 to 25% at Red Sike (Appendix Figs. 3 and 4). These percentages suggest that the woodlands spread in the reservoir basin before migrating up onto the higher ground of Widdybank Fell. For this situation to have occurred the woods must have migrated up the dale along the valley of the Tees and up and over Cauldron Snout into the Cow Green Reservoir Basin. This certainly appears to be a quite logical conclusion as one would expect the migration of these pioneer woods to have been along the sheltered valley of the Tees rather than across the exposed fell tops. Once these woods became established in the reservoir basin the gradually rising temperatures would then have made the circumstances right for an expansion up onto Widdybank Fell.

An examination of the relative frequency of each tree pollen type on the various diagrams from the region, shows that they differ quite markedly, particularly the <u>Pinus</u> values. For example, the mean <u>Pinus</u> pollen percentages, with their standard deviations, for Zone H at six sites are as follows :

Tinklers Sike	TS I	73.1 ± 2.3
Red Sike	RS II	51.0 ± 8.0
Foolmire Sike		35.8 ± 7.5
Dead Crook Sike	CD I	67.0 ± 11.7
Weelhead Moss	WM I	78.8 ± 0.8
Weelhead Moss	WM II	49.9 ± 11.3

These figures provide an indication of the relative abundance of pine at the different sites within the region. Pine was well established near to Tinklers Sike, Dead Crook Sike and the larger part of the Weelhead Moss complex but not in the vicinity of Foolmire Sike. On this last diagram <u>Betula</u> pollen frequencies are higher than those on any other diagram from the region and one cannot but conclude that birch was growing locally by Foolmire Sike. This diagram is also the only one with <u>Alnus</u> pollen in Zone H. The absence on the other diagrams indicates that this alder pollen must have come from a local source. Therefore alder was growing close to Foolmire Sike, probably on the flatter, wet areas which previously supported willow shrub.

On the Weelhead Moss Radiocarbon diagram (Fig. 15 page 50) <u>Corylus</u> pollen values are high. They are also high on the Red Sike (Appendix Fig.3) and Tinklers Sike (Appendix Fig.1) diagrams but not on the Foolmire Sike (Appendix Fig.5) and Dead Crook (Appendix Fig.7) diagrams. Thus hazel appears to have been growing in more abundance on the eastern and northern areas of this region than elsewhere. These areas are close to where the limestone soils predominate and hazel presumably preferred these well drained soils to the wetter soils down by the Tees which supported alder.

During Zone H the high herb pollen values on all diagrams show that the woodlands were never closed. Pine and birch, with some alder by Foolmire Sike, were the dominant trees of these woods. Whether elm and oak were present is more difficult to ascertain but it is suggested that they may have been growing in the more sheltered parts of the reservoir basin.

The top of Zone H, on the Weelhead Moss diagram, is dated at 8,070 ± 170 radiocarbon years B.P. A level 46cm below the top of this zone has a date of 8,057 ± 85, radiocarbon years B.P. which indicates that after the 'hiatus period' peat deposition was proceeding quite rapidly. However, on Widdybank Fell at this time peat growth was much slower than in the Cow Green Reservoir Basin where topographical drainage would have resulted in an accumulation of ground water.

At Weelhead Moss _Pinus_ pollen values decline from 60% to under 10% in Zone O (205-285cm), the oak - elm - hazel assemblage zone. _Betula_ percentages are low and _Ulmus_ pollen frequencies are only slightly higher than in the previous zone. _Quercus_ values are high and _Alnus_ percentages increase steadily in the lower two-thirds of the zone before rising sharply. _Tilia_ and _Fraxinus_ pollen is present for the first time. It is in the course of this zone that the arboreal pollen percentages reach their highest values. However, the herb pollen still contributes up to 50% of the total land pollen and it is clear that at their maximum extent of cover the woods were never completely closed. Extensive areas of open grassland must always have been present throughout the forest maximum.

Pollen assemblage Zone O on other diagrams from the region is different from that on the Weelhead Moss Radiocarbon diagram. On these diagrams Zone O is sub-divided into minor pollen assemblage zones; Oa, Ob and Oc, which reflect local vegetational changes.

Pinus pollen values decline in Zone O on all diagrams from the region. This reduction in the abundance of pine with the spread of the thermophilous trees did not, however, take place everywhere at the same time. The centre from which the thermophilous trees spread appears to have been close to Foolmire Sike. The diagram from the site shows that the hazel was less well represented in Zone O than in the previous zone, although it had never been a major component of the vegetation. Alder still flourished in the wetter areas of the Reservoir Basin by the side of Foolmire Sike. On this diagram it is the tree - shrub - herb ratios that are really interesting. They indicate that the woodlands reached their maximum extent of cover early in sub-zone Oa, not much later than 8,000 years B.P. Examination of the diagrams from Weelhead Moss (Appendix Fig.9), Dead Crook Moss (Appendix Fig.7) and Weelfoot Moss (Appendix Fig.11) shows that at these sites the woodlands had expanded early in Zone O. All of these areas, particularly Dead Crook, must have been reasonably sheltered. During this woodland maximum the composition of the woods was continually changing. At Weelhead Moss, for instance, pine was being replaced by oak early on in Zone O. The same changes were also taking place in the area around Weelfoot Moss but not, apparently, in the vicinity of Dead Crook.

On Widdybank Fell the situation was altogether different from that in the reservoir Basin. Diagrams from Tinklers Sike (Appendix Figs. 1 and 2) and Slapestone Sike (Appendix Figs. 13 and 14) suggest that on the fell the woods were less extensive in early Zone O. Not only were these woods less extensive but pine continued to flourish. At this time the thermophilous trees had not yet migrated onto the higher ground of the fell. This situation must reflect the effects of increased altitude upon the woodland vegetation.

By 6,202 ± 70 radiocarbon years B.P. in the vicinity of Weelhead Moss the replacement of pine by oak was well under way. At Foolmire Sike the same situation is also evident at the Oa/Ob boundary. However, on the top of Widdybank Fell pine still continued to flourish. The Tinklers Sike diagram has high Pinus pollen frequencies throughout sub-zone Ob. At only one place in the reservoir basin was pine able to withstand the spread of the thermophilous trees. This was in the area around Dead Crook.

In sub-zone Oc reduced Pinus pollen frequencies are present on all diagrams from the region as oak and alder spread. In the reservoir basin the local alder by Foolmire Sike began a sudden expansion phase at the start of sub-zone Oc. The only area in the reservoir basin where pine continued to flourish was by Dead Crook. On the diagram from this site Pinus pollen values remain high until the top of sub-zone Oc. On the top of Widdybank Fell the fall in Pinus pollen percentages is dated on the Tinklers Sike diagram to 6,150 ± 160 radiocarbon years B.P. Thus pine continued to grow on the fell some 2,000 years after its replacement in the reservoir basin. It is also apparent that the woodlands at these higher altitudes did not reach their maximum extent of cover until late in Ob and early Oc.

During the period 8,000 to 5,770 years B.P. pine was replaced by elm, oak and alder at all sites in this region of Upper Teesdale. Alder first grew locally close to Foolmire Sike before spreading over the rest of the reservoir basin and then up onto Widdybank Fell. Oak followed alder into the reservoir basin although there is some evidence for it growing locally near Weelhead Moss when alder flourished by Foolmire Sike. The late arrival of these thermophilous trees on the upper areas of Widdybank Fell suggests that their route of immigration was along the sheltered Tees Valley round by Falcon Clints and not over the high ground surrounding the reservoir basin.

There may have been two possible reasons for pine woods persisting up on

Widdybank Fell after they had been replaced in the reservoir basin. Firstly the fell is more exposed than the reservoir basin and the climatic conditions on the fell may have favoured pine but not the thermophilous trees. Secondly, edaphic factors may have been of considerable impotance. In Zone H pine was more abundant by Tinklers Sike, which lies close to the free draining limestone soils on Widdybank Fell. The continued presence of pine woods on the fell until 6,150 $\pm$ 160 radiocarbon years B.P. might indicate that these limestone soils remained free draining for sometime after the B.A.T., unlike those soils in the reservoir basin which soon became waterlogged. It is extremely interesting that there is still some evidence for the existence of these pine woods. Carex ericetorum, which today grows on Widdybank Fell, is thought to be an indicator of past pine woods.

Elm appears to have spread with oak at each of these upland sites, with the possible exception of Foolmire Sike, where it grew early on in the Post-glacial. The Ulmus pollen percentagesvary on the different diagrams. They are consistently above 10% of the total tree pollen on those diagrams from Weelhead Moss (radiocarbon dated diagram), Red Sike Moss, Foolmire Sike Moss and Weelfoot Moss but not on the diagrams from Tinklers Sike and Weelhead Moss (WH I). It is extremely difficult to ascertain where elm grew. For example, Ulmus is plentiful on the Weelhead Moss radiocarbon diagram but not on the other Weelhead Moss diagram. The same situation is also apparent on the Tinklers Sike and Red Sike diagrams from sites on Widdybank Fell. One can only assume that elm grew on the base rich soils of Widdybank Fell or on the soils of the slopes surrounding the reservoir basin which would not be so prone to waterlogging as the soils of the reservoir basin.

On the Weelhead Moss diagram (Fig. 15, page 50) two radiocarbon dated levels, one either side of the O/A boundary, indicate a most interesting feature of peat deposition. The two levels, 209 and 203cm, are dated at

5,770 ± 110 and 5,220 ± 120 radiocarbon years B.P. respectively. Therefore in some 550 years only 6cm of peat was laid down. Another level 30cm below 209cm dated at 6,202 ± 70 radiocarbon years B.P. shows that earlier peat deposition was quicker and only towards the end of Zone O did it slow down and may even have stopped altogether. A similar situation is also evident on diagrams from Tinklers Sike and Red Sike (Appendix Figs. 1,2,3, and 4) where there is a change in stratigraphy at the O/A boundary. On the former diagram two radiocarbon dates of 6,150 ± 160 and 3,390 ± 90 radiocarbon years B.P. which date the beginnings of sub-zone Oc and Zone A, respectively also indicate a slow rate of peat growth towards the end of Zone O. However, there is one important difference between peat deposition at Weelhead Moss and Tinklers Sike. At the former site peat started to reform about 5,200 years B.P. but at the latter, redeposition did not take place until 3,400 years B.P., some 1,800 years later.

There is evidence that the blanket peats of the southern Pennines also underwent a retardation phase during the Atlantic period (Conway, 1954). The most likely cause appears to have been climate. It is extremely doubtful if the climate was too dry. Indeed, this phenomenon occurred during the Atlantic period when blanket peat spread in many areas of Upper Teesdale e.g. Widdybank Moss and Slapestone Sike Moss (Appendix Figs. 15,13 and 14) One must assume that the climate infact became too wet , a theory first put forward by Kulczynski (1949) and later adopted Bellamy and Bellamy (1966) to explain certain features of the lowland mires of Ireland. They found that in the warmer wetter regions of western Ireland the peats are restricted in growth compared with those of the drier central regions. The warmer and wetter climate caused surface erosion and so the peats in the western parts are less high above the mineral substrate than those of the central regions, where erosion has been less severe. A similar type of erosion could easily have caused the Upper Teesdale peats to become retarded during late Zone O.

Late Post-Glacial

The retardation of the peat development in the latter part of Zone O at Weelhead Moss makes it difficult to give a precise date for the elm decline. It obviously occurred between 5,770 ± 110 and 5,220 ± 120 radiocarbon years B.P. The former date is much too early and it seems most probable that it happened in the region of 5,200 years B.P., which would be an acceptable date.

Above the elm-decline on the Weelhead Moss diagram (Figs. 15,16 and 17 pages 50,51 and 52) Zone A, the oak-alder pollen assemblage zone is characterised by high Alnus and slightly lower Quercus pollen frequencies. Pinus pollen has all but disappeared and Betula percentages rise. As with other diagrams from the region e.g. Foolmire Sike (Appendix Figs. 5 and 6), Weelhead Moss (WH I, Appendix Figs. 9 and 10) and Red Sike (Appendix Figs. 3 and 4) the tree pollen values decline in this zone. This reduction in the extent of tree cover and any other vegetational changes can only be considered in the light of possible human activity in the region.

The Plantago and Gramineae pollen curves rise and fall together unlike the Ericaceae pollen values which change independantly. The plantain and grass pollen curves are thought to reflect changes in the extent of grassland whereas the Ericaceae pollen curve represents a spread of blanket peat. Unlike the plantain and grass values, which rise and fall, the Ericaceae curve remains high after the initial rise. This suggests that woodland to grassland was a reversible process but woodland to blanket peat was not.

The spread of blanket peat, as indicated by the Ericaceous pollen curves, did not occur simultaneously in areas of this upland region. In the area around Weelhead Moss blanket peat began to spread early in Zone A compared with a middle Zone A spread in the vicinities of Dead Crook and Weelfoot Moss. At

As the beginning and middle of Zone A are dated at 5,220 ± 120 and 4,000 ± 110 radiocarbon years B.P., respectively, on the Weelhead Moss diagram it follows that the spread of blanket peat at Crook and Weelfoot occurred some 1,200 years later than at Weelhead Moss. On the Foolmire Sike diagram the Ericaceae pollen curves do not rise until the A/G pollen Zone boundary, which is dated at Weelhead Moss to 3,150 ± 100 radiocarbon years B.P. Therefore in the area around Foolmire Sike blanket peat did not spread until 1,800 years later than in the vicinity of Weelhead. At Tinklers Sike blanket peat had begun to spread in Zone O but it is in Zone G that the Ericaceae pollen curves really rise to reach high values. Therefore the major expansion of blanket peat must have taken place at about the same time that it had done in the area around Foolmire Sike.

Gramineae and _Plantago_ pollen frequencies increase slightly in Zone A on the Weelhead Moss and all other diagrams from the region. Thus it can be seen that up until some 3,200 years ago the effects of human activity were only slight.

However, pollen assemblage Zone G is marked by large increases of _Plantago_, Gramineae and other herb pollen percentages. Examination of the Weelhead Moss diagram (Figs 15,16 and 17, pages 50,51 and 52) shows that _Plantago_ values rise from under 5 to over 15% and Gramineae frequencies from 25 to 50% of the total tree pollen. All other diagrams from the region have similar increases of herbaceous pollen values. On the Weelhead Moss diagram this increase of herb pollen is dated at 3,150 ± 100 radiocarbon years B.P. This date is Middle Bronze Age and marks the first really distinct clearance phase. Once again the Tinklers Sike Moss appears to have stopped growing at that time because the first high herb pollen frequencies are dated at 2,570 ± 80 radiocarbon years B.P. This date marks the time at which peat started to grow again and agrees with the dates for peat regeneration in other parts of the Pennines.

From the middle Bronze Age onwards anthropogenic activity was clearly an important factor in the changing vegetation of this upland region of Teesdale. On those diagrams from Weelhead Moss, Tinklers Sike Moss and Slapestone Sike Moss alternating high and low Plantago and Gramineae frequencies reflect varying intensities of clearance activity. The grazing of domesticated animals must have also contributed to the woodland destruction and the revertance to grassland. As previously mentioned the change from woodland to grassland was a reversible process which partly depended upon grazing pressure. The removal of such grazing pressure would probably allow woodland regeneration. Blanket peat began to spread in many areas at that time, presumably on those soils which impaired drainage. Although man did not initiate the spread of peat he may have contributed to the expansion because of the effects of grazing of his domesticated animals.

CHAPTER 5

VALLEY BOG AND THE MOOR HOUSE NATIONAL NATURE RESERVE

The third site, Valley Bog, lies in a channel at an altitude of 1,800 ft. (549m) O.D. on the Moor House National Nature Reserve. There are two valley bogs in the channel and it was the upper and larger of the two which was studied. To the north, east and west of the bog there are glacial deposits which form part of a series of moraines. The southern edge of Valley Bog is bordered by House Hill, a ridge of bedrock shales and sandstone. To the south and west of the bog the land rises up to 2,512 ft. (766m) O.D. on Dufton Fell and 2,250 ft. (686m) O.D. on Hard Hill, respectively. Northwards Bellbeaver Rigg reaches up to an altitude of 2,035 ft. (620m) O.D. whilst to the east Viewing Hill rises up to 2,099 ft. (640m) O.D. Much of the area surrounding Valley Bog is covered by blanket peat or eroded blanket peat-soil complexes. The actual depth of peat varies in different parts of the Reserve e.g. on Knock Ridge and Bog Hill the peat is quite shallow (1.5m to 1.75m) whilst on Hard Hill and Knock Fell it is much deeper (2.5m and 3.5m, respectively).

A list of the more common plants found growing on Valley Bog is as follows :

Calluna vulgaris	*Rubus chamaemorus*
Drosera rotundifolia	*Scirpus cespitosa*
Empetrum nigrum	*Sphagnum cuspidatum*
Erica tetralix	*Sphagnum papillosum*
Eriophorum angustifolium	*Sphagnum recurvum*
Eriophorum vaginatum	*Cladonia arbuscula*
Narthecium ossifragum	

SKETCH MAP TO SHOW VALLEY BOG

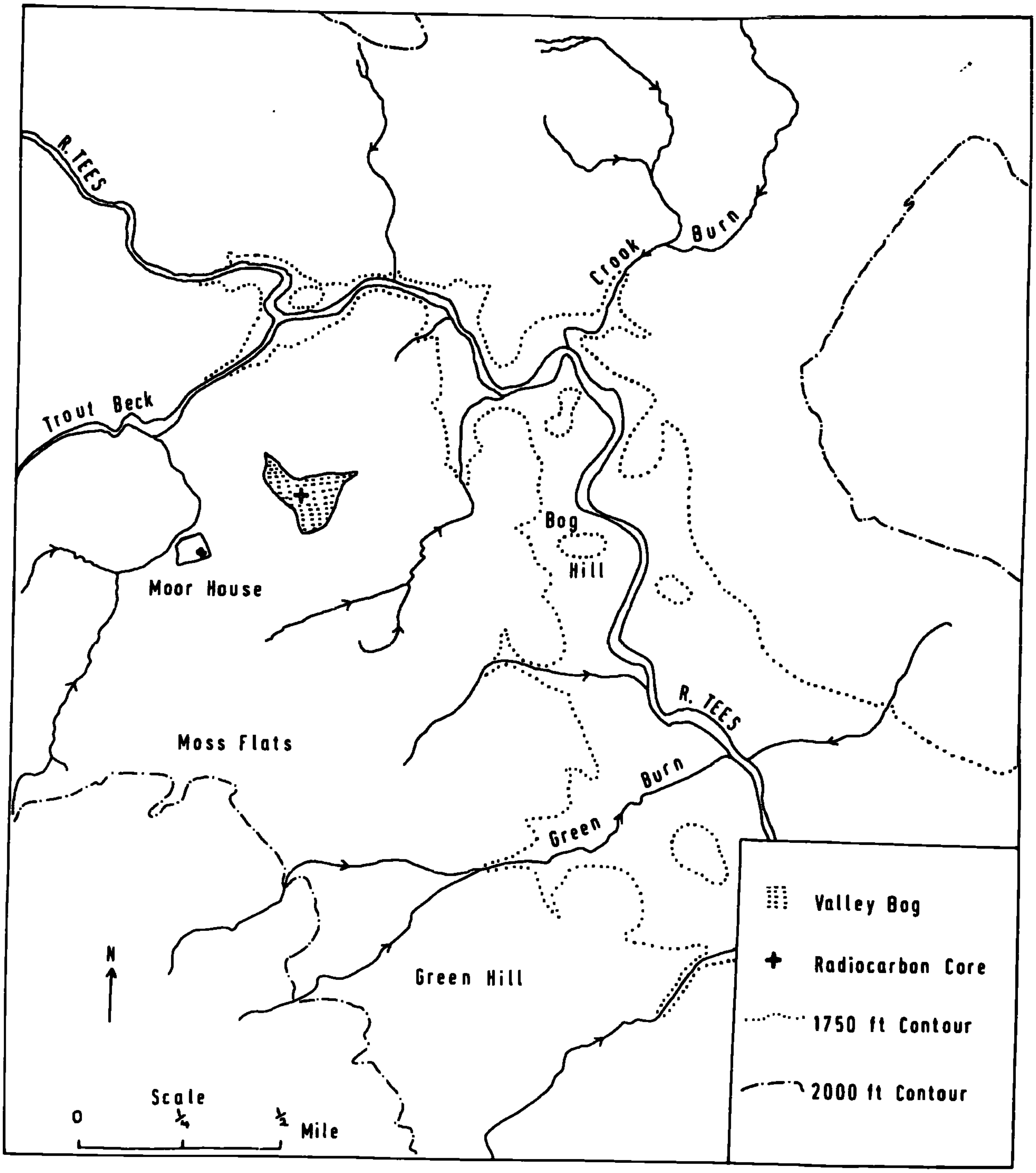


Fig. 18

Collection of Radiocarbon Samples

Authorisation could not be obtained to investigate the stratigraphy of Valley Bog at various points. However, permission was granted by the Warden to collect sufficient material for pollen analysis and radiocarbon dating. Fortunately, the radiocarbon assays were to be carried out at the Scottish Research Reactor Centre with the result that only relatively small amounts of peat were required. Four cores were collected by multiple shot boring, using a Russian borer, from near the centre of the bog (Fig. 18 page 69) However, it was not physically possible to get the borer below the depth of 6m and so the bottom deposits were not collected. These cores were packed and stored in exactly the same manner as those from Neasham Fen (see CHAPTER 3).

Laboratory Techniques

Exactly the same laboratory methods were used for this Valley Bog material as had been used for the Neasham Fen deposits. A slight difference in proceedure was that in this case one of the four cores was used for both pollen analysis and radiocarbon assay. After examination of the completed diagram (Figs. 19,20 and 21 pages 71-73) it was decided to date eight levels. These levels and the dates expressed in radiocarbon years B.P. are :

1. SRR - 88, peat from 152.5 to 157.5cm, lowest sample with high <u>Plantago</u> and Gramineae pollen frequencies, 2,212 ± 55.
2. SRR - 89, peat from 157.5 to 162.5cm, highest sample with low <u>Plantago</u> and Gramineae pollen percentages, 2,175 ± 45.
3. SRR - 90, peat from 302.5 to 307.5cm, lowest sample with low <u>Ulmus</u> pollen frequencies, 4,596 ± 60.
4. SRR - 91, peat from 312.5 to 317.5, highest sample with high <u>Ulmus</u> pollen frequencies, 4,794 ± 55.

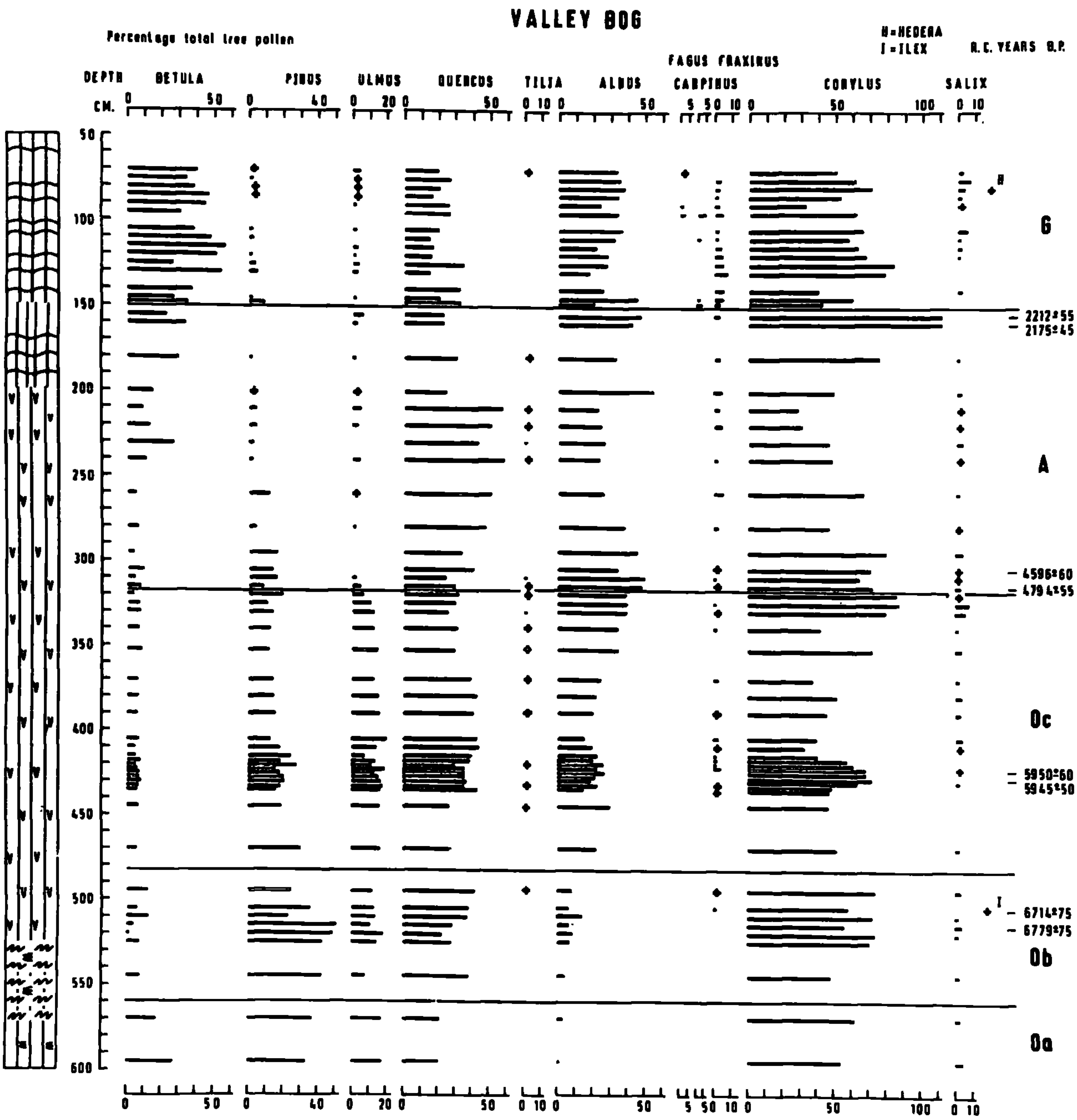

VALLEY BOG
Percentage total tree pollen
H=HEDERA
I=ILEX
R.C. YEARS B.P.
DEPTH CM.
BETULA
PINUS
ULMUS
QUERCUS
TILIA
ALNUS
FAGUS FRAXINUS
CARPINUS
CORYLUS
SALIX
G
A
Oc
Ob
Oa
2212±55
2175±45
4596±60
4794±55
5950±60
5945±50
6714±75
6779±75

Fig. 19

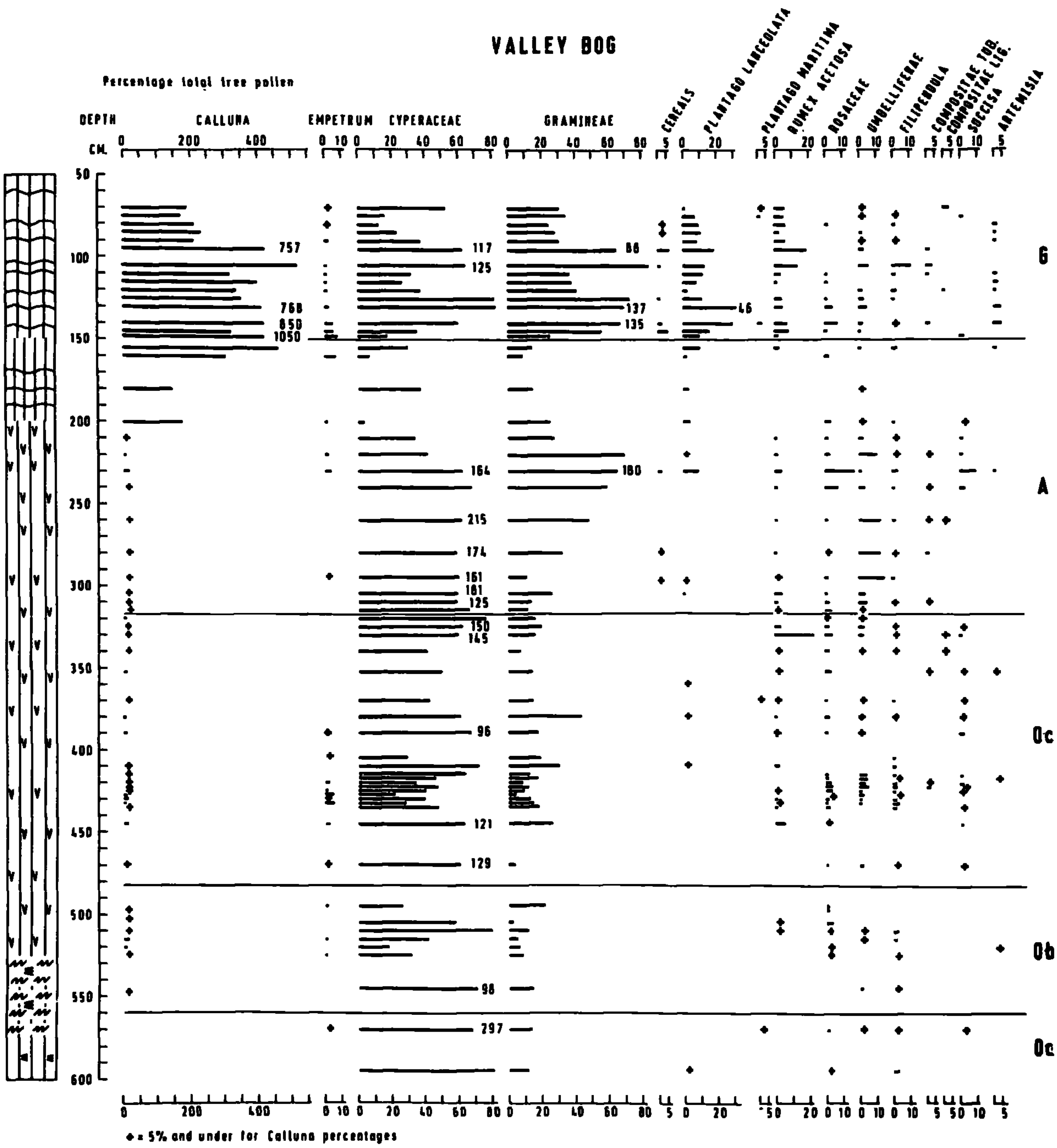

VALLEY BOG
Percentage total tree pollen
DEPTH CM.
CALLUNA
EMPETRUM
CYPERACEAE
GRAMINEAE
CEREALS
PLANTAGO LANCEOLATA
PLANTAGO MARITIMA
RUMEX ACETOSA
ROSACEAE
UMBELLIFERAE
FILIPENDULA
COMPOSITAE TUB.
COMPOSITAE LIG.
SUCCISA
ARTEMISIA
G
A
Oc
Ob
Oa
◆ = 5% and under for Calluna percentages

Fig. 20

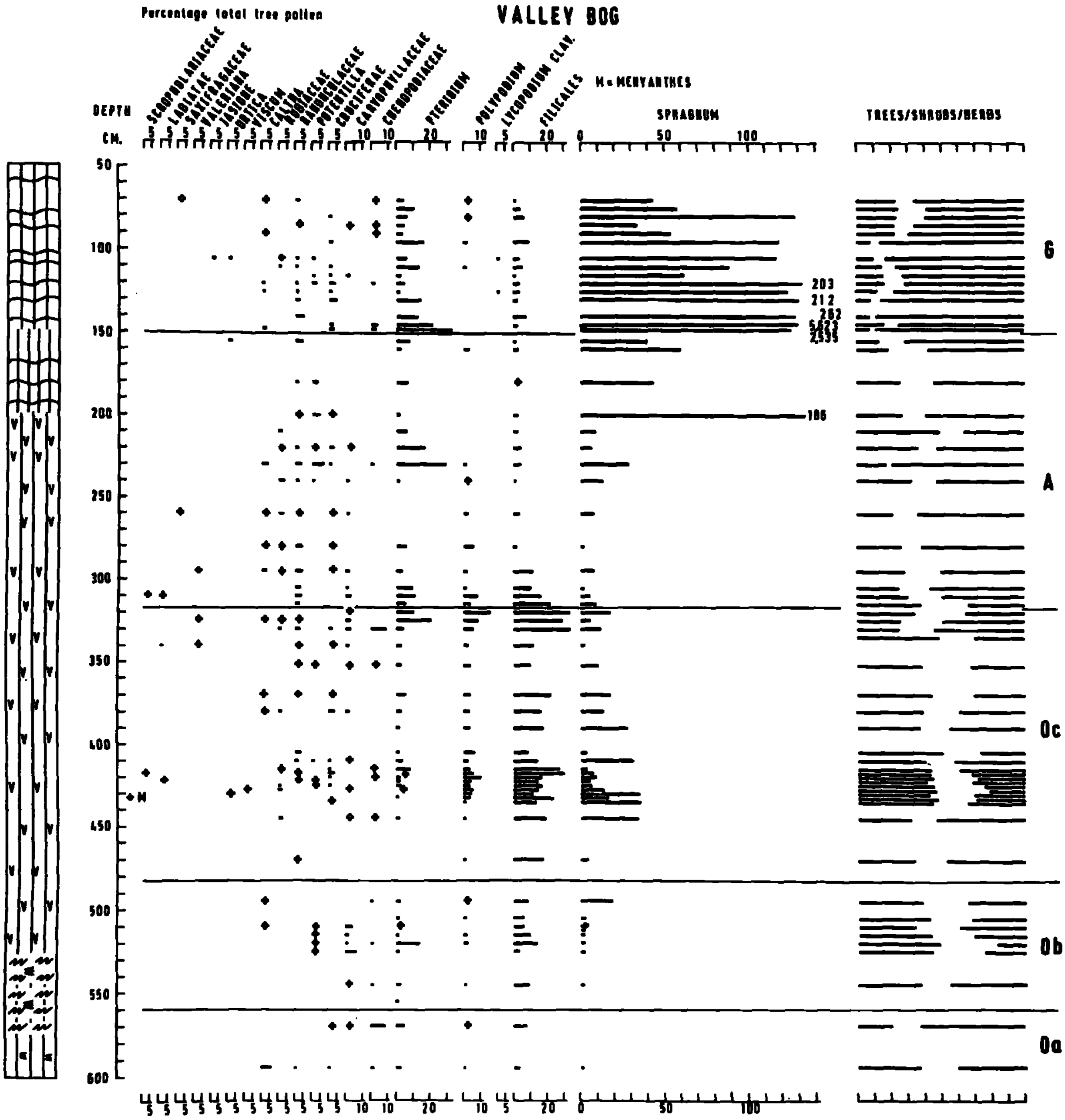

Percentage total tree pollen
VALLEY BOG
DEPTH CM.
SCROPHULARIACEAE
LABIATAE
SAXIFRAGACEAE
VALERIANA
JASIONE
URTICA
VISCUM
CALTHA
RUBIACEAE
RANUNCULACEAE
POTENTILLA
CRUCIFERAE
CARYOPHYLLACEAE
CHENOPODIACEAE
PTERIDIUM
POLYPODIUM
LYCOPODIUM CLAV.
FILICALES
M = MENYANTHES
SPHAGNUM
TREES/SHRUBS/HERBS
203
212
282
186
G
A
Oc
Ob
Oa

Fig. 21

5. SRR - 92, peat from 421 - 426cm, sample with decreased *Ulmus* pollen percentage 5,950 ± 60.

6. SRR - 93, peat from 426 - 431cm, sample with high *Ulmus* pollen percentage 5,945 ± 50.

7. SRR - 94, peat from 502.5 to 507.5cm, lowest sample with low *Pinus* pollen frequency, 6,714 ± 75.

8. SRR - 95, peat from 512.5 to 517.5cm, highest sample with high *Pinus* pollen percentage, 6,779 ± 75.

Stratigraphy

The only stratigraphy examined was that of the counting core which it is thought is fairly representative of the centre of the bog. The stratigraphy is as follows :

cm	
0 - 50	not sampled
50 - 75	sedge peat of low humification (H4) with some *Calluna*.
75 - 100	sedge peat of low humification (H3) with some *Calluna*.
100 - 150	sedge peat of low humification (H4) with more *Calluna*.
150 - 200	sedge peat which is slightly muddy and of a medium humification (H5-6) with *Calluna*.
200 - 250	sedge peat of low humification (H3-4) which is slightly muddy with *Betula* wood present.
250 - 290	sedge peat of low humification (H3-4), slightly muddy with a little *Betula* wood present.
290 - 525	sedge peat of low humification (H3-4), slightly muddy with abundant pieces of *Betula* wood.
525 - 580	Bryophyte peat of low humification (H3) made up of *Paludella squarrosa* with some sedges and *Eriophorum*.

580 - 600 sedge peat of low humification (H3-4) with Eriophorum.

Interpretation of the Stratigraphy and Pollen Diagram

The pollen diagram is divided into three major pollen assemblage zones, which reflect local vegetational changes. These zones are as follows :

an oak-elm assemblage Zone O

an oak-alder assemblage Zone A

a grass-plantain assemblage Zone G

Zone O has been further divided into three sub-zones; Oa, Ob and Oc based on changes in the oak, alder and birch pollen frequencies (Figs. 19, 20 and 21, pages 71-73).

Early Post-glacial

As it was not physically possible to collect peat from below 6m this dated diagram does not cover the earlier periods which are present on Johnson and Dunham's (1963) original Valley Bog diagram. In sub-zone Oa *Betula* pollen values decline as *Pinus* frequencies rise. *Ulmus* and *Quercus* pollen is present with each contributing about 20% to the total A.P. values. *Alnus* pollen is present in only small amounts and *Corylus* values are not exceedingley high. A comparison between the two Valley Bog diagrams indicates that sub-zone Oa correlates with that part of the older diagram between 640cm and 660cm in depth. There is also some stratigraphic evidence for such a correlation. The bryophyte, *Paludella squarrosa* is present in the upper peat of sub-zone Oa and just above 640cm on the original stratigraphic diagram. Although the pollen and stratigraphic correlations do not coincide exactly, they are very close together.

It is the mud and peat deposits at Valley Bog and Hard Hill (Johnson and Dunham, 1963), respectively, which provide the earliest information regarding the vegetational history of the Moor House National Nature Reserve. Both of these deposits were formed in permanently waterlogged areas. A barrier of boulder clay at the eastern end of Valley Bog caused a small lake to form in a hollow and inorganic and organic muds soon accumulated in the early Post-glacial. Up on Hard Hill peat began to develop in Zone V. This early start of peat formation is thought to have been caused by springs coming from the base of the Quarry Hazle sandstone above this site (Johnson and Dunham, 1963).

Betula pollen is present on diagrams from both Valley Bog and Hard Hill in Zone V. This together with the presence of Betula wood in the bottom layers of the blanket peat on Hard Hill suggests that birch grew locally on the Reserve in Zone V. Pinus pollen frequencies represent some 20% to 30% of the A.P. which indicates that it too grew in the region. However, these woodlands were never extensive. This is reflected by the herbaceous pollen values which remain high. Included in the herb pollen are such taxa as Gramineae, Filipendula, Compositae, Umbelliferae and Ranunculaceae. These high herb frequencies together with the presence of Juniperus pollen suggests that relatively large areas of open vegetation still existed on the Reserve. It is interesting that the herb pollen values are higher on the Hard Hill diagram, which is from a site some 450ft. (137m) above Valley Bog and considerably more exposed. If one assumes that the herb pollen frequencies reflect the amounts of open vegetation then it is clear that there was more open vegetation in the vicinity of Hard Hill than around Valley Bog. The most likely cause for such a situation appears to have been the effects of increased altitude and exposure upon climate. On Hard Hill the more severe climate restricted woodland development whilst in the sheltered area of Valley Bog the climatic conditions were more favourable to woodland growth. Towards the end of Zone V *Corylus* pollen values rise on the Valley Bog diagram as hazel spread into the area. The continued amelioration of climate which helped the spread of hazel also allowed more woodland to grow on Hard Hill. This is reflected in the A.P./N.A.P. ratios on the diagram from this site.

The beginning of Zone VI is marked by a sudden increase of *Corylus* pollen values on both diagrams. At Valley Bog the maximum value attained is 390% of the total tree pollen compared with 560% on the Hard Hill diagram. Although the A.P./N.A.P. ratios are difficult to interprete there is some indication in the above percentages that hazel grew more abundantly in the vicinity of Hard Hill, where there is a local occurrence of limestone soils. Soon after the hazel expansion elm and then oak migrated onto the Reserve and began to replace birch which was unable to compete with these longer-lived thermophilous trees. At Hard Hill tree pollen percentages continue to rise as more woodland spread up onto the higher ground. With the consequent decrease in available open habitats certain herb pollen taxa such as Gramineae, Ranunculaceae, Umbelliferae, Compositae, Cruciferae and Chenopodiaceae all but disappear. However, the Valley Bog diagram does not provide such clear evidence of continued woodland expansion and it is only the decline of Gramineae, Ranunculaceae and Cruciferae pollen frequencies which suggest that it was occurring in this part of the Reserve. Although *Salix* pollen values are low they persist longer at Valley Bog indicating that willow was growing locally, most probably on the wetter soils beside the small stretch of open water. One very interesting feature of the Hard Hill diagram is the *Empetrum* pollen curve which rises sharply at the start of Zone VI. *Empetrum* pollen is deposited close to its source of origin and crowberry must have been present on the hill to quite a large extent.

In early Zone VI Valley Bog was still an expanse of open water and detritus muds continued to be deposited. High *Myriophyllum* and *Potamogeton* pollen percentages indicate that these two aquatic plants were growing locally in some abundance. Filipendula pollen frequencies are also high and it is clear that it too grew locally, probably on the wetter soils, by the side of the small lake. However, above 740cm depth the sediment changes from an organic mud to a sedge peat as a fen developed where there had once been open water. The pollen of aquatic herbs diminish whilst that of cyperaceous plants and 'horse-tails' rises sharply. This Carex - Phragmites - Equisetales period was the first of a succession of fen communities which culminated in the formation of Valley Bog.

Following the immigration of elm and oak Corylus pollen frequencies decline on both the Valley Bog and Hard Hill diagrams. The tree pollen curves suggest that hazel decreased in abundance at the same time in both areas. However, hazel appears to have remained more abundant on Hard Hill. The Betula and Pinus frequencies indicate that at that time pine was replacing birch. Alnus pollen is present but in subh small amounts that it is doubtful if alder grew locally.

As previously stated sub-zone Oa on the dated Valley Bog diagram correlates with the 640cm to 660cm part of the original diagram. From this point onwards it is now possible to discuss the vegetational history of the region in the light of the new diagram with its radiocarbon dated levels.

Sub-zone Oa (560-600cm) has declining Betula pollen frequencies which fall from 27% to 17% of the total tree pollen. Pinus values increase slightly whilst Ulmus and Quercus frequencies remain steady, each contributing some 20% to the tree pollen values. Alnus pollen is present in small amounts together with Corylus which represents a substantial portion of the land pollen, about one fifth. There is a great deal of similarity between this sub-zone and the corresponding part of the original diagram. It is apparent that pine continued to replace birch and elm and oak flourished in the region, on the better drained soils.

However, there is one difference between the two diagrams. The new diagram has a greater variety of herbaceous pollen taxa, which includes Gramineae, Plantago, Rosaceae, Umbelliferae, Filipendula, Caltha, Cruciferae and Chenopodiaceae. The presence of these herbs indicates that there were extensive areas of open vegetation in the region and the woods therefore did not cover all parts of the Reserve. The most obvious reason for this state of affairs would have been the general severity of the climate in this upland region of Teesdale. It is difficult to give a precise indication of the area actually covered by woodland because the tree-shrub-herb ratios must be examined with extreme caution. The greater part of the herb pollen is cyperaceous and the stratigraphy indicates that sedges were the dominant peat-forming plants at this time. Therefore the tree-shrub-herb ratios reflect purely local changes on the surface of the fen as well as changes in the surrounding vegetation. If one ignores the cyperaceous pollen it becomes clear that the area of woodland was greater than is first apparent by examining the tree-shrub-herb ratios.

In sub-zone Ob (482.5 - 560cm) Betula pollen values are low, less than 15% of total tree pollen. Pinus frequencies reach a maximum in the middle of this sub-zone whilst Ulmus percentages are slightly lower than in the previous sub-zone. Quercus values are high at the beginning and end of Ob and lower in the middle. Alnus pollen is more plentiful than in Oa. It is clear that birch woodland became very much reduced in abundance as pine and oak replaced it. The pine then continued to expand at the expense of oak and possibly elm. This expansion of pine into existing birch and oak-elm woodland is similar to the situation described in Lonsdale (Oldfield, 1965), north-west England. Oldfield suggested that pine spread during a period of recovering water-table levels, probably some time later than its expansion in southern and eastern England. The evidence from Valley Bog supports this theory. Firstly it is clear that alder, a tree which flourishes on wet soils, began to grow in the region at this time. Secondly, the stratigraphy of the dated diagram from Valley Bog (Figs. 19,20 and 21, pages 71-73) from 525 to 580cm consists of a bryophyte peat with plentiful Paludella squarrosa remains. Today Paludella squarrosa is a relatively rare British moss only found in predominantly wet conditions. Thirdly, and most importantly, the pine maximum is dated to 6,779 ± 95 radiocarbon years B.P. This date indicates that this maximum occurred in the Atlantic period, a markedly wet period. All of these three sources of evidence suggest that the pine maximum occurred at the time of recovering water-levels and much later than the maximum in southern and south-eastern England.

On the new Valley Bog diagrams levels 512.5cm and 502.5cm are dated to 6,779 ± 75 radiocarbon years B.P., respectively. Both these levels still have low Alnus pollen values, less than 10% of the total tree pollen. The main increase of Alnus pollen values occurrs above level 502.5cm. Therefore, if Godwin's VI/VII pollen zone boundary were to be placed on this diagram it would not be synchronous with that on other diagrams from England e.g. Scaleby Moss (Godwin, Walker and Willis, 1957). The VI/VII boundary on Johnson and Dunham's original diagram (1963) also exhibits this diachroneity with other diagrams but without the radiocarbon dates this is not so apparent. Oldfield (1965) suggested the possibility of such a delay in the increase of alder in lowland Lonsdale and more recently the diachronous nature of the VI/VII pollen zone boundary has been demonstrated by Hibbert, Switser and West (1971) with the aid of radiocarbon dates.

There is also some evidence for a similar expansion of pine into existing birch and oak-elm woodland up on Hard Hill. However, the Pinus pollen values never rise above 30% of the total arboreal pollen. As Hard Hill and Valley Bog are less than 2 miles (3.2km) apart the proportion of _Pinus_ pollen which can be attributed to long distance transport would be the same for both sites. Therefore, one must conclude that these different pine pollen frequencies reflect local variation in the abundance of pine. It has already been demonstrated that the pine maximum occurred at Valley Bog in a time of increased precipitation. Because these two sites are situated in totally different topographical areas one would expect the effects of increased rainfall to be different. The water-table levels would be raised more at Valley Bog, which is in a hollow, than on Hard Hill. If pine responds to the raising of water levels then the effects would be greater at Valley Bog than on Hard Hill.

Sub-zone Oc (319.5 - 482.5cm) is characterised by gradually rising _Alnus_ pollen fréquencies and a decline of _Pinus_ values in the first half of the sub-zone. The _Ulmus_, _Quercus_ and _Corylus_ pollen curves exhibit distinct fluctuations. These tree and shrub pollen percentages indicate that birch had become almost totally replaced by pine and the thermophilous trees by some 6,500 years B.P. Although alder was growing in the area some 300 years earlier it was unable to expand to its full extent. It is clear that when it started its expansion it was replacing pine and possibly some oak. The pine maximum was a response to rising water levels and it is apparent that at this time with the gradual increase of temperature alder was now able to compete more favourably than pine on the wetter soils. _The Alnus_ pollen values suggest that it was growing equally abundantly on all parts of the Reserve.

The shape of the _Alnus_ pollen curves is not the same on all diagrams, however, at Valley Bog the pollen frequencies rise slowly whilst on Hard Hill they rise very quickly. This difference is in fact not due to different rates of migration and expansion of alder but to varying rates of peat deposition during this period. At the former site, peat was forming very quickly but on Hard Hill it was very slow. Again the reason for these differences appears to have been the nature of the topography at the two sites. Drainage water collected by Valley Bog in the hollow but not on Hard Hill to such an extent.

Immediately above the increase of Alnus pollen values the Ericoid frequencies also increase on the Hard Hill diagram. The lack of Calluna in the peat suggests that these pollen frequencies do not reflect a succession on the growing surface of the peat but on actual spread of blanket peat in the area. Hard Hill was not the only place on the Moor House National Nature Reserve where blanket peat began to form at this time. The pollen spectra of the basal layers of the blanket peat on Bog Hill (Johnson and Dunham, 1963) clearly indicates that this too began to develop soon after the spread of alder. This general spread of blanket peat was due to the waterlogging of areas on the Reserve caused by the high precipitation. Today, under the extensive areas of blanket peat on the Reserve can be seen the peaty gley mineral soils which are still permanently waterlogged.

Between 415cm and 430cm on the dated diagram (Figs. 19, 20 and 21, pages 71-73) Ulmus pollen percentages decrease in an unsteady manner. Associated with this decline there are small peaks of Rosaceae, Umbelliferae, Filipendula and Cruciferae pollen percentages. There is also an increase in the number of herb pollen taxa present, including Plantago, Rumex and Artemisia. Distinct peaks of Pteridium, Filicales and Polypodium are also present. Two radiocarbon dates of 5,950 ± 60 and 5,945 ± 50, radiocarbon years B.P. for levels only 5cm apart indicate that peat deposition was rapid and that the decline of elm and its re-establishment was only a temporary phenomenon. It is felt that such a temporary vegetational change could only have been caused by anthropogenic activity. Supporting this theory there is the sound archaeological evidence of human occupation on the Reserve. Altogether eighteen fragments of worked flint have been discovered at six scattered localities. In the vicinity of Hard Hill, Upper Moss Flats and Teeshead Microlithic tools have actually been found in the peat. Pollen analysis of the peat on Hard Hill has demonstrated that the finds were laid down in the Atlantic period (Johnson and Dunham 1963). This correlates remarkably well with the two radiocarbon dates which also suggest that this temporary vegetational change took place in the Atlantic, some 6,000 years ago.

The fact that the pieces of worked flint come from scattered sites and the temporary nature of the vegetational changes infer that these Mesolithic people did not settle in the region. It therefore seems very probable that the area was only used for brief hunting expeditions. An abundance of finds in peat on Hard Hill led Johnson and Dunham to the conclusion that this may have been a resting place for the hunters. What is very interesting is the association of microliths and the remains of <u>Bos</u>, the indigenous wild cattle, found in two sites on the Reserve. Therefore wild cattle may well have been the hunters prey. An examination of the Valley Bog (Figs. 19,20 and 21, pages 71-73) and other upland pollen diagrams (see CHAPTER 4) provides a reason for the presence of wild cattle and hence their possible hunters in these upper regions of Teesdale. All the diagrams indicate that large areas of open vegetation were in existance which would have provided ideal conditions for the grazing cattle. In the lowlands, however, closed woodland grew almost everywhere (see CHAPTER 3) so the cattle together with their Mesolithic hunters had no choice but to roam these upland regions.

<u>Corylus</u> pollen values show a very interesting peak at the level of the temporary elm-decline on the radiocarbon dated Valley Bog diagram. Walker (1956) investigating at a site at Stump Cross, near Grassington, Yorkshire discovered a Mesolithic flint close to where he was sampling. This diagram indicated a peak of <u>Corylus</u> pollen values close to the level at which the 'in situ' flint

was found. The diagram also exhibited a peak of Polypodium frequencies and traces of Artemisia and Rosaceae pollen which Walker interpreted as the reflection of anthropogenic activity. This situation is remarkably similar to that found on the Reserve. Thus, there is the possibility that man may have helped hazel to spread, for as Smith (A.G. 1970) concludes, the effects of Mesolithic man cannot be ruled out when discussing the spread of hazel in the early Post-glacial.

Late Post-glacial

Zone A (150 - 317.5cm) begins with the elm-decline for which there are two radiocarbon dates of 4,596 ± 60 and 4,794 ± 55 radiocarbon years B.P. These dated levels are only 10cm apart which suggests that peat growth was slower than it had previously been in the Atlantic period. Both these elm-decline dates are rather late e.g. the elm-decline is dated at Scaleby Moss (Godwin, Walker and Willis, 1957) to 4,925 ± 134 radiocarbon years B.P. Associated with the elm-decline there are distinct peaks of herbaceous pollen values which include Rumex pollen. These vegetational changes are typical of those brought about by anthropogenic activity. Following the elm-decline cereal pollen is present for the first time in small amounts. This pollen was probably blown in from lower down the Tees rather than derived from a local source. The rising Gramineae pollen frequencies reflectthe increase of woodland clearance to provide suitable grazing land for domesticated livestock. This woodland clearance activity continued into the middle of zone A which unfortunately has not been radiocarbon dated. However, both the top and bottom of the zone has been dated and if one assumes that there had been a steady rate of peat deposition then the peak of clearance activity must have been reached some 3,400 years ago. After this time grass pollen percentages decline as the grazing and anthropogenic pressures were removed. Consequently, the woodlands were able to regenerate. Birch, which had once been an important element of the pioneer wood of these upland regions, together with some ash began to flourish. Both trees, which are light demanding and grow quickly, quickly colonised the vacated clearings. Birch probably grew on the poorer soils whilst ash flourished on the small areas of limestone soils on the Reserve.

Between 210cm and 200cm Calluna values rise from 10% to 200% of the tree pollen. Whether these figures are a true reflection of the spread of blanket peat in the vicinity of Valley Bog is not altogether clear because the deposits change at this point from a sedge peat to a sedge peat with Calluna remains. The decline of Cyperaceae pollen values also indicates a vegetational change on the surface of the growing bog. However, the pollen diagrams from Bog Hill and Hard Hill both provide information regarding the spread of blanket peat on the Moor House National Nature Reserve (Johnson and Dunham, 1963). On the Bog Hill diagram Ericaceae pollen frequencies increase at 100cm depth in peat which contains little or no Calluna remains. As there was no local increase of ericaceous pollen production on the surface of the peat the increased values represent an increase in the area of blanket peat. The Hard Hill diagram also has increased Ericaceae percentages at 60cm depth in peat which contains Calluna remains. There is no change in the stratigraphy at this level and the rising Ericaceae pollen values once again reflect the spread of blanket peat. Examination of the Valley Bog, Bog Hill and Hard Hill pollen diagrams indicates that on all three the ericaceous frequencies rise as the Betula pollen percentages increase. Therefore, it is probably safe to assume that at each site the ericaceous values increase at the same time and that at Valley Bog the rising Calluna frequencies represent a spread of blanket peat. Although this spread is not dated the top of Zone A is and this phenomenon must have occurred before 2,200 years ago, probably about 2,700 B.P.

Zone G (50 - 150cm), the grass-plantain pollen assemblage, has high

Gramineae, Plantago, Rumex, Pteridium and Sphagnum pollen values. The start of this period of clearance activity is dated as 2,212 $\pm$ 55 and 2,175 $\pm$ 45 radiocarbon years B.P. The Gramineae, Plantago and Rumex pollen curves suggest that there were in fact two distinct periods when the woodlands were felled. During the first intensity of clearance activity was more pronounced than during the second. Between these two periods the relaxation of anthropogenic pressures allowed some regeneration of the woods, particularly birch and ash which thrived in the clearings. The pollen curves clearly demonstrate the marked effects which Iron Age man had upon the environment in these upland areas, particularly the ratio of grassland to woodland areas. He may also have been partly responsible for helping the spread of blanket peat. At the start of zone G Calluna pollen values rise once again and reach very high percentages. Although the increased precipitation would have been the initial cause for the blanket peat spread this does not mean that Iron Age man with his herds of animals did not speed up the process. After this period blanket peat must have covered very large tracts of the Moor House National Nature Reserve. Much of this blanket peat is still present over large areas of the Reserve today.

CHAPTER 6

THE VEGETATIONAL HISTORY OF TEESDALE.

In the course of the last three chapters the vegetational histories of three regions of Teesdale have been dealt with in some detail. Using all this information the vegetational history of the whole dale can now be discussed and comparisons made with other parts of Britain.

Late-glacial

During the Late-glacial period it is evident that the vegetation was more open and the climate more severe at the higher altitudes. There is also some indication that the climate continued to be severe in the uplands after a general amelioration had taken place in more lowland areas.

In lowland Teesdale during the first cold period (Zone 1) open park tundra vegetation flourished almost everywhere. As the climate became more amenable birch woodland spread into the region. Although it is difficult to assess the actual area covered by these woods the Thorpe Bulmer and Neasham Brick Pit pollen diagrams suggest that tree birch grew fairly abundantly in Zone II. More evidence for the presence of birch was found by Blackburn (1952) at Neasham Brick Pit in the form of actual macro-remains of Betula pubescens. It is interesting that similar finds of macro-remains have been discovered from Allerød deposits in Northumberland (Bartley, 1966). At the end of the Allerød these woods were replaced by open park tundra vegetation as the climate deteriorated and the soils again became unstable. Juniper was able to flourish briefly after the woods decreased in abundance and before the climate became too cold.

In upland Teesdale there is no palaeobotanical evidence of the vegetation which grew in the first two Late-glacial periods. There are, however, some geological features which indicate the severity of the upland climate following the Allerød oscillation. Moraines which are present on the Moor House National Nature Reserve show that corrie glaciation was active on the Cross fell range and that glaciers existed in the Middle Tongue Beck and Knock Ore Gill valleys (Johnson and Dunham, 1963). It has also been suggested by Johnson and Dunham that glaciers may have been active in other large valleys on the Reserve. This post Allerød glaciation was not only restricted to the Upper Teesdale region of Northern England. Manley (1959) has associated moraines found in the Lake District with corrie glaciation whilst Rowell and Turner (1952) have found evidence of glacial action in the Upper Eden Valley.

On the Moor House National Nature Reserve solifluxion caused stone stripes to be formed on sloping ground. This solifluxion may also have been responsible for the removal of much of the unconsolidated drift from the higher Fell tops. It is very interesting that cryoturbation structures are well preserved below peats which began to form in the late Boreal and early Atlantic periods. The good state of preservation has been taken to indicate (Johnson and Dunham, 1963) that a relatively short time elapsed between the end of peri-glacial conditions and the onset of peat development. If this is so then a severe climate continued to exist well after the normal date for the Late-/Post-glacial boundary. This geological evidence agrees well with the botanical indications (see CHAPTER 4) for the persistance of a Late-glacial flora in Upper Teesdale after its replacement in lowland areas.

The Late-glacial vegetational history of Teesdale is similar to that of other northern regions of England (Evans, 1970; Pennington, 1964), where in some circumstances the effects of increased altitude upon climate and vegetation can also be seen (Bartley, 1966).

Early Post-glacial

Following the Zone III/IV transition birch soon migrated and spread into the lowlands of Teesdale and in the vicinities of Neasham Fen, Romaldkirk, Thorpe Bulmer and Morden Carr formed extensive areas of pioneer woodland. The Neasham Fen radiocarbon date of 9,082 $\pm$ 90 radiocarbon years B.P. shows just how quickly this process took place. The area covered by these pioneer woods appears to have been similar to that found in other regions of England (Pigott and Pigott, 1963; Godwin and Tallantire, 1951; Oldfield, 1965). However, those pollen diagrams from Neasham Brick Pit, Bishop Middleham and Burtree Lane indicate that in these areas the woods were much less dense than those in other parts of lowland Teesdale and similar to those of lowland Northumberland (Bartley, 1966). Thus it becomes apparent that dense woodland flourished in some areas but not in others. However, it has already been suggested (see CHAPTER 3) that the more typical lowland Teesdale vegetation consisted of the dense woodland rather than the more open type.

Towards the end of Zone V hazel began to expand rapidly in lowland Teesdale and together with birch formed a closed tree/shrub canopy in the areas around Neasham Fen, Morden Carr, Thorpe Bulmer and Romaldkirk. Those diagrams from the Moor House National Nature Reserve (Johnson and Dunham, 1963) together with that from Foolmire Sike, in the Cow Green region, suggest that hazel was also spreading up in the Pennine parts of Teesdale. This hazel expansion would appear to have been synchronous with that of the lowlands. The palynological record and the presence of <u>Betula</u> wood in the basal layers of the peat on Hard Hill indicates that some birch and pine were already growing in Upper Teesdale by the time of the hazel expansion. Exactly when birch and pine first grew in the Cow Green region is difficult to ascertain because of the general lack of peat belonging to the period 10,000 to 8,800 years B.P. (see CHAPTER 4). It is certain, however, that the extent of woodland in Upper Teesdale must have been considerably less than that of more lowland areas. The small amounts of pine which managed to grow in the uplands may have migrated from areas in the lowlands such as Bishop Middleham and Burtree Lane, where pine had become quite abundant by the time that hazel began to spread.

At Neasham Fen the first high Corylus pollen value is dated at 8,829 ± 120 radiocarbon years B.P. This date agrees with that of 8,809 ± 192 radiocarbon years B.P. from Scaleby Moss (Godwin, Walker and Willis, 1957) and one may assume that the spread of hazel must have been simultaneous in both north-eastern and north-western regions of England. It is also worth noting that on almost all of the Teesdale pollen diagrams the Corylus pollen values rise very sharply. Such a rapid expansion of hazel seems to have been a constant feature of northern and western regions of Britain (Oldfield, 1960; Walker, 1965; Mitchell, 1942; Simmons, 1964; Pigott and Pigott, 1963). This contrasts with south-eastern England where the spread of hazel was much slower (Clapham and Clapham, 1939; Godwin and Tallantire, 1951).

It has been suggested (Moore and Chater, 1969a) that the rapid expansion of hazel in these northern and western regions may be correlated with a predominantly maritime type of climate. In Teesdale, however, other factors may also have influenced the spread of hazel. For instance, in Upper Teesdale hazel expanded with a minimal amount of competition from birch and pine which only grew in small amounts. In such areas as Widdybank and Cronkley Fells the continuation of cryoturbation (see Late-glacial) may have contributed to the spread of hazel by continuously providing fresh calcereous soils (Squires, 1970). After its establishment it is clear that hazel flourished more on the calcereous soils of Widdybank than on the less calcareous soils of the Cow Green Reservoir Basin (see CHAPTER 4). Squires has also indicated that burning could have been beneficial to the hazel expansion, particularly in the vicinity of Dufton Moss. The other Teesdale diagrams provide no other evidence for such an occurance, but as Smith A.G. (1970) points out 'There is no reason, however, for discarding the possibility that the expansion of hazel may be connected in some way with human activity.'

By 8,829 ± 120 radiocarbon years B.P. elm had spread into the lowlands of Teesdale, replacing some of the pioneer birch woodland around Neasham Fen (see CHAPTER 3). Within the next 600 years oak had also migrated into the area and expanded. This type of woodland development is typical of that which occurred in many other parts of England (Bartley, 1966; Oldfield, 1960). Those pollen diagrams from the Cow Green region of Upper Teesdale are, however, not so easy to interpret. Even so, it is suggested that some elm and oak may have been growing in this region during the period 8,800 to 8,000 years B.P. Those diagrams from the Moor House National Nature Reserve would appear to support such a suggestion.

The pollen diagrams from Moor House indicate that elm migrated into the region before oak. Farther down the dale, however, in the Cow Green region the diagrams suggest that elm and oak arrived at the same time (start of Zone H). If elm arrived before oak on the Moor House National Reserve and these trees migrated along the valley of the Tees then elm must have preceded oak in the Cow Green region. For elm to have reached Moor House first and not Cow Green it must be assumed that these trees came to Moor House via another route e.g. from the west. However, it is already known that these trees migrated from the lowlands to the Cow Green region by following the course of the River Tees (see CHAPTER 4). Therefore, it might be reasonable to assume that the route of migration continued to follow the valley of the Tees above Cow Green and that these trees did not come from the west onto the Moor House National Nature Reserve. To have come from the west elm and oak would have had to migrate up the steep western slopes of the

Pennines and cross over the high ground to the west of the Reserve. It would probably be right to suggest that elm preceded oak in the Cow Green region but this situation is not clearly visible on the diagrams from the region.

A regional variation between the lowland and upland vegetational history now becomes apparent. Around Neasham Fen, Morden Carr and Romaldkirk elm and oak spread quickly and soon flourished. In Upper Teesdale, however, elm and oak grew only in small amounts, probably in the more sheltered areas. In the vicinity of the Cow Green Reservoir Basin the expansion of elm and oak was very slow. This regional variation was most probably caused by the effect of altitude upon climate which favoured the non thermophilous trees.

By 6,772 $\pm$ 90 radiocarbon years B.P. alder woods had spread over large areas of lower Teesdale replacing most of the remaining pioneer birch woods (see CHAPTER 3). In the Cow Green Reservoir Basin, however, alder was unable to expand until some 6,202 $\pm$ 70 radiocarbon years B.P. (see CHAPTER 4), although it had grown locally around Foolmire Sike since early zone H. Such an early establishment of alder in the vicinity of Foolmire Sike is not a feature peculiar to Upper Teesdale but is also found in other northern and more western parts of Britain (Jessen, 1949; Mitchell, 1951; Fraser and Godwin, 1955, Donner, 1957). Up on the Moor House National Nature Reserve alder did not become abundant until some 6,200 years ago for a level dated at 6,779 $\pm$ 75 radiocarbon years B.P. still has low <u>Alnus</u> pollen values. This delay in the expansion of alder in Upper Teesdale is similar to that found in north-eastern Scotland (Moar, 1969) and parts of northern Ireland (Pilcher, 1969).

The expansion of alder in Teesdale appears to have been controlled by several factors. Climatic changes, which Firbas (1949) thought were of extreme importance, were not the only reasons for the alder spread. However, the increased precipitation at the B.A.T. must have been partly responsible in determining when alder increased in abundance. The exact nature of all these factors is not known, but there seems to have been a variety, interdependant upon one another (McVean, 1956). What is clear is that the timing of the spread of alder in Teesdale is closely related to altitude and the behaviour of local pine woodland. It isbecause of the relationships between alder and pine that the history of Teesdale's pine woods has been conveniently left until this point in the chapter.

In lowland Teesdale it is clear that pine grew abundantly during the early Post-glacial in such areas as Burtree Lane, Bishop Middleham and Neasham Brick Pit (see CHAPTER 3). It would appear that pine grew in these areas in Zone V and spread, together with hazel, some 8,800 years ago, replacing part of the pioneer birch woodland. This contrasts with south-western England, where pine was already abundant in Zone IV (Seagrief and Godwin, 1960). Around Neasham Fen, Morden Carr and Romaldkirk, however, pine was never an important constituent of the early Post-glacial woodlands. This again contrasts with south-eastern England where, once pine had become established, it flourished practically everywhere (Godwin, 1940: Godwin and Tallantire, 1951; Seagrief, 1959; Clark and Godwin, 1962).

Prior to 8,800 years B.P. only small amounts of pime grew in Upper Teesdale (see earlier in this Chapter). After 8,800 years B.P. pine became more abundant but, as in the lowlands, here too there was variation in the abundance of pine from one site to another (see CHAPTER 4). There was, however, one major difference between the lowlands and the uplands. In the former region pine only grew abundantly in isolated areas but in the uplands it flourished almost everywhere and was a dominant feature of the woodlands.

A similar variation in the amount of local pine woodland from one site to another can be seen in north-western England (Pennington, 1964; Walker, 1965). This situation lead Pennington to conclude (1970) that the spread of pine must have been edaphically controlled. She was, however, unable to determine the precise situations in which pine flourished. Likewise in lowland Teesdale edaphic factors must have been largely responsible for the spread and abundance of pine. Climatic changes brought about by altitudinal variations must have been important in the initial spread of pine. For example, when pine migrated into the Cow Green region it grew first in the Cow Green Reservoir Basin and then moved up onto the higher and more exposed slopes of Widdybank Fell. Once established on the higher slopes pine grew more abundantly than in the Reservoir Basin.

On many of the Teesdale pollen diagrams peaks of Pinus pollen occur when both Ulmus and Quercus pollen is present. This suggests that pine expanded into elm-oak woodland. On those diagrams from Burtree Lane and Bishop Middleham there are such peaks in Zone VI. At Weelhead Moss a similar peak of Pinus pollen values is dated at 8,070 ± 170 radiocarbon years B.P. It is of extreme interest that a pine peak on Johnson and Dunham's (1963) original pollen diagram has been dated on the new Valley Bog diagram to 6,779 ± 75 radiocarbon years B.P. Similar phenomena can be seen on diagrams from north-western England (Oldfield, 1965) and parts of Wales (Hyde, 1940; Godwin, 1955; Seddon, 1962). In southern and eastern England an expansion of pine has always been associated with dry 'continental' climatic conditions. Similarly, in mid Wales Moore and Chater (1969a) correlate a pine maximum with lowering water levels and suggest that pine began to grow on bog surfaces which were drying out. Pennington (1970) combining the pollen record and iodine curves, which are used as an index of precipitation (Mackereth, 1966), also proposed that in the north-eastern parts of England pine responded to a phase of drying out. Oldfield (1965), on the other hand, suggested that the pine maximum occurred during a 'moist' period in lowland Lonsdale. Squires

(1970), working in Teesdale, has also put forward a similar explanation by suggesting that pine was able to complete more successfully with increased water in the soils.

On the Valley Bog diagram the pine peak does not occur until some 6,779 ± 75 radiocarbon years B.P. This would seem to point to the fact that pine was able to respond positively to the increase of precipitation which followed the B.A.T. Oldfield (1965) has stated that Scots pine (*Pinus sylvestris* spp. *scotica*), which today grows in areas of Scotland with heavy rainfall, would be capable of responding to wet climatic conditions. This would then possibly account for a late pine maximum on Moor House National Nature Reserve. On Widdybank Fell pine remained abundant until about 6,150 ± 60 radiocarbon years B.P. In this area, however, the local abundance of pine has been correlated with the free draining limestone soils of the fell (see CHAPTER 4). The continued presence of pine on the fell after its replacement in the Reservoir Basin can be accounted for by the resistance of these soils to waterlogging and the exposed nature of the fell top when compared with the Reservoir Basin. Thus it can be seen that pine seems to behave in two contrasting ways with respect to water requirements, and one can only assume that two biotypes grew in Teesdale. It is interesting that Moar (1969) has demonstrated the ability of pine to flourish until some 6,150 years ago in a remarkably wet region of Britain. Therefore pine could tolerate wet soils.

Around Neasham Brick Pit and Bishop Middleham alder and oak replace pine in the early Post-glacial forests in late zone VI and early VII. Although there was only a minimal amount of pine growing locally by Neasham Fen it was declining in abundance before 8,200 years ago. Farther up the dale, in the Cronkley Fell region (Squires, 1970), the amount of pine woodland diminished towards the end of VIa at Dufton Moss and late in sub-zone VIc at the higher site of Fox Earth Gill. In the Cow Green region pine was replaced by oak and then alder soon after 8,000 years B.P. Up on Widdybank Fell, however, pine continued to flourish until some 6,200 years ago and consequently delayed the alder expansion. On the Moor House National Nature Reserve pine was not replaced and alder did not spread until after 6,700 years B.P., probably at about the same time that these changes occurred on Widdybank Fell. This delay in the expansion of alder clearly adds considerable weight to Oldfield's (1965) statement that'the suggestion of a late pine maximum would carry with it the possibility of a delayed alder increase.' In all instances alder was present before its expansion, a situation which is typical of many parts of Ireland and some other northern sites (Birks, 1964).

Following the expansion of alder the woodlands of Teesdale became more 'stable'. Previously, there had been continual adjustment to the immigration of new trees and shrubs (Walker, 1965). Though the woods were more 'stable' competition between oak and alder was intense, as oak and alder alternately became the woodland dominant. The diagram from Hard Hill (Johnson and Dunham, 1963) indicates that these oak-alder woods grew locally at an altitude of at least 2,250 ft. (688m) in these upper reaches of Teesdale. In other parts of England there is also evidence for oak-alder woods reaching similar altitudes (Godwin, 1955; Pennington, 1964 & 1969).

After 9,000 years B.P. closed forests flourished in most parts of lowland Teesdale, with the exceptions of such areas as Burtree Lane and Bishop Middleham. Here the tree cover was more open. In some areas there were still stretches of open water e.g. Morden and Bradbury Carrs.

In the Cow Green region and on the Moor House National Nature Reserve it is clear that the woodlands remained relatively open throughout the whole of the Post-glacial . The pollen record from Upper Teesdale contains a wide variety of herbaceous pollen types and it would seem that there had always been a wide variety of different habitats in these upland areas of the dale. One must imagine the vegetation as consisting of a mosaic of woods, areas of peat and grassland vegetation. It is extremely difficult to ascertain with certainty where the upper limit of closed woodland lay in Teesdale. The main difficulty lies in the fact that all of the Upper Teesdale diagrams are from peat deposits, which contain an abundance of purely local pollen. Squires (1971), however, has suggested that the upper limit of closed woodland occurred at about 1,200 ft (368m) O.D. This would appear to be a reasonable estimate for the maximum altitudinal limit of closed woodlands in the valley of the Tees. Within Upper Teesdale there was considerable variation in the actual amount of woodland. For instance, the Cow Green Reservoir Basin was more wooded than the more exposed slopes of Widdybank Fell. Squires (1970) has also found a similar situation between sites at different altitudes near to and on the top of Cronkley Fell.

In the Lake District closed forests became established over the whole of the region up to an altitude of 2,500 ft. (760m) O.D. (Pennington, 1970). This contrasts with Teesdale, where the lower limit of closed woodland was most probably brought about by a more severe climate. This is emphasised by Manley's (1936) statement that the 'northern Pennine moorlands are the most constantly elevated and chilly parts of England'.

Not only did the extent of tree cover in Teesdale diminish with altitude but the time at which maximum tree cover occurred also became progressively later at the higher altitudes. In the lowlands closed woodlands were present in most areas by 9,000 years ago. Around Dufton Moss (Squires, 1970), however, the trees did not reach their maximum degree of cover until the end of VIa. In the vicinity of Weelhead Moss the full spread of woodland has been radiocarbon dated to 6,202 ± 70 radiocarbon years B.P., some 2,800 years later than the maximum spread in the lowlands. There is also a similar lag between sites at different altitudes within Upper Teesdale. For instance, the trees achieved their maximum extent of cover in the Cow Green Reservoir Basin in sub-zone Oa, compared with Oc on the top of Widdybank Fell. A similar situation is also evident in the Cronkley Fell region (Squires, 1970). It is clear that when these woods were migrating up the dale the climate was such to prevent the trees from moving over the fell tops. Instead the woods followed the more sheltered route along the banks of the Tees (see CHAPTER 4).

Once the oak-alder woods became established in Upper Teesdale there is some evidence of Mesolithic human activity on the Moor House National Nature Reserve (see CHAPTER 5). It is very interesting that another diagram from Fox Earth Gill (Squires, 1970) should also indicate a similar phenomenon. A peak of Gramineae and ruderal pollen, on this diagram, in VIIa suggests that man was beginning to clear the woods prior to the elm-decline. It is felt that these activities may in fact be contemporary with those indicated in other regions of Britain (Dimbleby, 1962; Durno and McVean, 1959; Simmons, 1964 and 1969; Walker, 1956). Although, there is only a limited amount of palaeobotanical and archaeological evidence for Mesolithic man being present in Upper Teesdale, one cannot exclude the fact that man may have had quite a marked effect upon the vegetation of this region prior to the Neolithic revolution.

Late Post-glacial

The elm-decline, which marks the beginning of the late Post-glacial, is dated on a diagram from each of the three regions of Teesdale. In the lowlands, at Neasham Fen, it is dated at 5,468 ± 80 radiocarbon years B.P. In Upper Teesdale, at Weelhead Moss, the elm-decline occurred between 5,770 ± 110 and 5,220 ± 120 radiocarbon years B.P. The later date is probably closer to the time of the elm-decline because of a hiatus in peat development which took place towards the end of Zone 0 (see CHAPTER 4). On the Moor House National Nature Reserve, at Valley Bog, the elm-decline occurred between 4,794 ± 55 and 4,596 ± 60 radiocarbon years B.P. An examination of these dates indicates that the elm-decline took place progressively later in the upland regions than in the lowlands. This relationship between the time of the elm-decline and altitude strengthens the proposal that the elm-decline was brought about by selective anthropogenic activity. If a fall in temperature or leaching of the base rich soils were the cause one would expect the dates to be in the reverse order.

This relationship between the time at which the elm-decline occurred and altitude may be explained in two possible ways. Firstly, it might be explained in terms of an actual migration of new peoples up the dale. Various pressures due to an expanding lowland population would have possibly given rise to such a migration. Secondly, there may have been a lag in an indigenous development of new food collecting techniques among a more or less sedentary populations (Smith, A.G. 1970).

Within Teesdale there is only a small amount of archaeological evidence which supports an anthropogenic interpretation of the elm-decline. Tooley (see CHAPTER 3) has found human remains and a charcoal layer associated with an elm-decline, at Hartlepool. Squires,(1970), working in the Cronkley Fell area, discovered a charcoal layer just below the level of the elm-decline at Long Crag. The presence of quartz particles, which had been blown onto the bare soil following the destruction of the vegetation cover, suggests that the burning was fairly extensive. However, it must be remembered that the effect of burning could have been completely out of proportion to the number of people in the area because of fires becoming uncontrolable. For example, a small number of people using fire to drive game might easily have a pronounced effect upon the vegetation. On the Moor House National Nature Reserve there is both archaeological and palaeobotanical evidence for the presence of Mesolithic hunters on the Reserve some 6,000 years ago (see CHAPTER 5). It therefore seems quite probable that these people continued to use the area for the next 1,200 years until Neolithic peoples or influences arrived.

All of these Teesdale dates for the elm-decline fall within the range of other dates from various sites within Britain. The early one from Neasham Fen (5,468 ± 80 radiocarbon years B.P.) is comparable to Irish radiocarbon dated elm declines e.g. 5,335 ± 120 radiocarbon years B.P. at Fallahogy, County Derry (Smith and Willis, 1961-2). The late Valley Bog dates (4,794 ± 55 and 4,596 ± 60 radiocarbon years B.P.) are very similar to that of 4,770 ± 110 radiocarbon years B.P. from Hipper Sick, on the East Moor of Derbyshire (Hicks, 1971) and another of 4,570 ± 120 radiocarbon years B.P. for a level only 2 cm above the elm-decline at Flanders Moss, in the Forth Valley (Turner, 1965).

Several of the Teesdale pollen diagrams provide evidence which suggests that at the time of the elm-decline man may have had some effect upon the abundance of hazel. Diagrams from the Moor House National Nature Reserve, Cow Green Reservoir Basin, Widdybank Fell and Neasham Fen all have increased Corylus pollen values at the elm-decline. It is possible that the collecting of hazel nuts (Godwin, 1956) by these Neolithic people contributed to the spread of hazel. The use of fire may also have had a similar effect because of hazel's resistance to burning (Rawitscher, 1945).

After the decline of Ulmus pollen it is evidence that elm was unable to regenerate in the oak-alder woods. This might have been caused by the effects of leaching upon the base rich soils or the continuation of anthropogenic selective activity. Fluctuations of the herb pollen frequency on the Cow Green Reservoir Basin and Widdybank Fell diagrams suggest that small temporary clearings were being made during the Neolithic period and early Bronze Age. Birch and ash were beginning to spread in the lowlands at that time and it seems likely that they were invading vacated clearings, which were too small to show on the tree-shrub-herb ratios of the Neasham Fen diagram.

At Neasham Fen a small clearance phase is dated at 3,242 ± 70 radiocarbon years B.P. However, at nearby Bishop Middleham (Bartley, unpublished) large areas of woodland had been cleared by 3,360 ± 80 radiocarbon years B.P. in a phase of deforestation which began some 300 years earlier. On the Weelhead Moss radiocarbon diagram a massive increase of Gramineae and Plantago pollen values occurs at the A/G boundary, which is dated at 3,150 ± 100 radiocarbon years B.P. It is evidence that very large areas were cleared in this region of Teesdale. The Valley Bog diagram has a distinct peak of Gramineae and Plantago pollen values at 230 cm which unfortunately has not been radiocarbon dated. However, levels 155 cm and 305 cm have been dated at 2,175 ± 45 and 4,596 ± 60 radiocarbon years B.P. If one assumes that peat deposition between these two dates was occurring at a steady rate then the peak of clearance activity must have taken place some 3,300 years ago. The pollen curves indicate that the amount of deforestation was extensive but not as great as that of the Cow Green area, farther down the dale.

It is evident that areas of woodland were being cleared in all parts of Teesdale in the middle Bronze Age. The diagrams also indicate that there was considerable variation in the actual amounts of woodland felled in different areas of the dale. For example, deforestation was much more extensive by Bishop Middleham than in the vicinity of Neasham Fen, only 13 miles

(20.9 km) away. Similarly, in the Pennines, clearance activity was much more pronounced in the Cow Green area than on the Moor House National Nature Reserve. This variation can be seen in other parts of Britain, particularly on the chalk downs of South Eastern England (Godwin, 1962; Kerney, Brown and Chandler, 1964).

All of the Teesdale pollen diagrams indicate that there was an overall intensification of forest clearance during the Bronze Age. This is in agreement with a general statement made by Turner (1970) with reference to the whole of Britain. In North-western Scotland there is evidence that a policy of deliberate forest clearance was undertaken soon after 3,690 ± 110 radiocarbon years B.P. (Moar, 1969). Similarly, to the south, in Ayrshire, a pollen diagram from Bloak Moss (Turner, 1965) has increased Gramineae, <u>Plantago</u> and <u>Pteridium</u> values dated at 3,320 ± 105 radiocarbon years B.P. (Godwin, Willis and Switsur, 1965). In north-east England pollen diagrams from south of the Lake District (Oldfield 1960; Oldfield and Statham, 1963) clearly indicate a period of increased deforestation which Turner (1970) suggests occurred in the Bronze Age. Dickinson (personal communication) has also found a similar situation at Rusland Moss, in the Furness district of north Lancashire. South of Teesdale, at Leash Fen, on the East Moor of Derbyshire Hicks (1971) found clearance activity which is dated at 3,450 ± 100 radiocarbon years B.P. At Holme Fen, Norfolk; Whixall Moss, Shropshire and Thorne Waste, south of the Humber clearance phases have been dated at 3,390 ± 120, 3,227 ± 115 and 3,160 ± 115 radiocarbon years B.P., respectively (Turner, 1962). Simmons (1964) has also found evidence of Bronze Age deforestation on Dartmoor whilst Turner (1964), Thomas (1965) and Moore and Chater (1969 a and b) have all discovered similar findings in Wales.

Cereal pollen is sparce on all of the Teesdale diagrams at those levels which indicate Bronze Age clearance activity. This emphasis upon pastoralism agrees with Turner's (1970) suggestion that 'the Bronze Age saw only an extension and intensification of a basically Neolithic way of life'. These people may also have been partly nomadic because the clearances were only temporary and woodland soon regenerated after the removal of farming pressures. A general lack of Bronze (Childe, 1950) partly explains this continuation of a Neolithic life-style which gradually became more advanced with new farming techniques.

In the lowlands the Neasham Fen diagram indicates another period of deforestation in the first millenium B.C. (see CHAPTER 3). In the vicinity of the fen the extent of woodland clearance was greater that at any previous time. The pollen curves show that these people still depended upon pastoralism which agrees with the view held by Piggott (1961). Following this period of deforestation in the lowlands another is evident on the radiocarbon dated Valley Bog diagram, from the Moor House National Nature Reserve. Gramineae, Plantago, Rumex and Pteridium pollen values all increase at the A/G pollen zone boundary, which is dated at 2,175 $\pm$ 45 and 2,212 $\pm$ 55 radiocarbon years B.P. This late Iron Age phase of clearance activity was more extensive than any previous one in this part of Teesdale. It was infact on the same scale as the Bronze Age clearances of the Cow Green area some 1,100 years before. There are, two possible reasons for such extensive deforestation. Firstly, an expanding population would have required more pasture land for the necessary larger herds of grazing animals and secondly, wood was essential for the charcoal which was used in the smelting of the iron ore.

Similar Iron Age clearances have been demonstrated from many other sites within Britain. In Derbyshire Hicks (1971) found an intensification of deforestation in the Iron Age. In the region of Leash Fen this activity began

2,290 ± 100 radiocarbon years B.P. and continued for some 200 years. Thus a policy of deliberate deforestation was undertaken in both Derbyshire and Upper Teesdale at about the same time. In both regions the emphasis was upon pastoralism and there had been no significant change in methods of farming since the Bronze Age. This lack of change would seem to be a constant feature of northern England (Walker, 1966; Pennington, 1964; Smith, 1959; Birks, 1965). The evidence of clearance activity on the Valley Bog diagram clearly indicates that Iron Age clearances were not restricted to the lowlands as Squires (1970) supposed.

From the Iron Age onwards there is only a small amount of palynological evidence regarding the vegetational history of Teesdale. At Thorpe Bulmer (Bartley, unpublished) increased Graminaae and Plantago pollen frequencies and a peak of Cannabis/Humulus pollen are dated at 1,730 ± 120 radiocarbon years B.P. It is very interesting that this date corresponds with another from Bollihope, Upper Weardale, (Turner, unpublished) of 1,730 ± 100 radiocarbon years B.P. which dates a similar clearance phase. This activity in upper Weardale strongly indicates that the same thing may have been happening in Upper Teesdale, just the other side of the watershed. In the lowlands the Cannabis/Humulus pollen peak shows that arable farming was becoming an important agricultural practise. This agrees with the findings of Hicks (1971) who also discovered Cannabis/Humulus pollen from Romano-British deposits. This would suggest that these crops were grown in the north long before they were cultivated in Norfolk (Godwin, 1967).

In other parts of northern England there is also evidence of deforestation during Romano- British times. In north-western England, Smith (1959), Birks (1965) and Oldfield and Statham (1963) have all found evidence for a clearance phase which occurred about 400 A.D., some 200 years later than in lowland Teesdale. It has been suggested (Turner, 1970) that the extent of clearing was comparable to that undertaken in the southern parts of England during the

Iron Age (Godwin, 1960 and 1967).

The Neasham Fen diagram clearly shows that by 1,213 ± 60 radiocarbon years B.P. large areas of woodland in the vicinity of the fen had been felled. The increased Gramineae, Plantago and cereal pollen values and radiocarbon date indicate that by the mid eighth century farming communities had been established in lower Teesdale. It has been suggested by Roberts (in Squires, 1970) that these communities may even have been formed by the mid seventh century. Some of todays place-names e.g. Billingham, Bishop Middleham, Neasham and Hardwick (near Sedgefield) have obvious Anglo-Saxon origins and testify to these seventh and eighth century settlements. It has been generally thought that these people did not farm the upper reaches of Teesdale but only used the more accessible slopes for summer pastures. Interestingly, this practise of using summer pastures and consequently herdman's shelters is reflected by place-names that contain 'shiel' e.g. Carp Shiel (Muggleswick) in the uplands of County Durham (Watts, 1970).

In Teesdale the palynological record clearly shows how the forests and woodlands have been progressively destroyed because of human requirements. At first the clearings were small and of a temporary nature and the woodlands soon recolonised the vacated clearings with birch and ash as pioneers. During the Bronze Age deforestation became more intensive in all parts of the dale, particularly in the Cow Green Reservoir Basin and Widdybank Fell region. By the late Iron Age large tracts of woodland in Teesdale had already been cleared. In the Romano-British period there was an added impetus to arable farming and rye was probably grown for the first time (Helbaek, 1964) together with hemp/hops. By the mid eighth century A.D. farming communities were well established in the lower regions of the dale and a lot of the remaining woodland in this region came under the axe. As the demand for wood and suitable land for arable and pastoral farming increased so the woodlands became even more depleted throughout the following centuries.

The Blanket Peats of Upper Teesdale

During the last ten millenia peat began to form in various places at different times in Upper Teesdale. About 10,000 years ago some peat had already started to accumulate in waterlogged areas of the Cow Green Reservoir Basin e.g. Weelhead Moss and on Widdybank Fell e.g. Tinklers Sike Moss. However, soon after the initial development of peat a 'hiatus-period' set in which lasted from 10,000 years B.P. until 8,800 years ago. By the end of the 'hiatus-period' blanket peat had begun to spread on Hard Hill (Johnson and Dunham, 1963). This was about the time when blanket peats started to form on the Grampian Highlands of Scotland (Durno and Romans, 1969). About 1,000 years later more blanket peat spread on the Moor House National Nature Reserve as peat began to accumulate in many areas of the Southern Pennines (Woodhead and Erdtmann, 1926; Conway, 1947 and 1954).

Then some 5,000 years ago blanket peat began to form in the vicinities of Weelhead and Dead Crook Mosses, in the Cow Green Reservoir Basin. This spread of peat followed another 'hiatus-period' which can be seen in many of the peats of the region. It is suggested that the hiatus was caused by an excess of rainfall (see CHAPTER 4), the effects of which must have been similar to those which have been operative more recently (Bower, 1962; Conway, 1954; Tallis, 1964). About 3,150 years ago the most extensive period of blanket peat development began. This brief survey of the blanket peats of Upper Teesdale shows that they began to form at different times even over small areas as in the Southern Pennines (Tallis, 1964).

Examination of the soils under the blanket peats clearly indicate that a gradual accumulation of water caused the peat to develop. The process was one of brown earth - podsol - peaty podsol - blanket peat. However, the major spread of blanket peat occurred in the Cow Green region some 3,150 years ago, in the middle of the Bronze Age. One cannot but conclude that anthropogenic activity must have contributed to this spread. Successive clearings of the woodlands gave rise to open grassland areas. However, on those soils already prone to water-logging this clearing activity may have resulted in the formation of blanket peats. With the removal of human pressure the grasslands were able to revert to woodlands but the blanket peats could not (see CHAPTER 4.) The grazing of domesticated animals would have had very similar effects upon the more water-logged areas (Ratcliffe, 1959). It is very interesting that Moore (1973) has recently stressed the importance of anthropogenic activity and the grazing of animals upon the initiation and spread of blanket peat in the uplands of Wales. Burning may also have contributed to the spread of blanket peat. In the Cow Green area there is no evidence to this effect and it is doubtful if burning had the significance in this area that Squires (1970) suggests that it had in the Cronkley Fell region. It must be remembered that anthropogenic activity was not the sole cause for the spread of blanket peat and that the gradual worsening of climate must have been an important factor. Peat may have encroached into the woods in a similar manner to which peat now grows in the high oak woods of the Lake District (Yapp, 1953) today because the remains of woods can be seen in the basal layers of many of the blanket peats.

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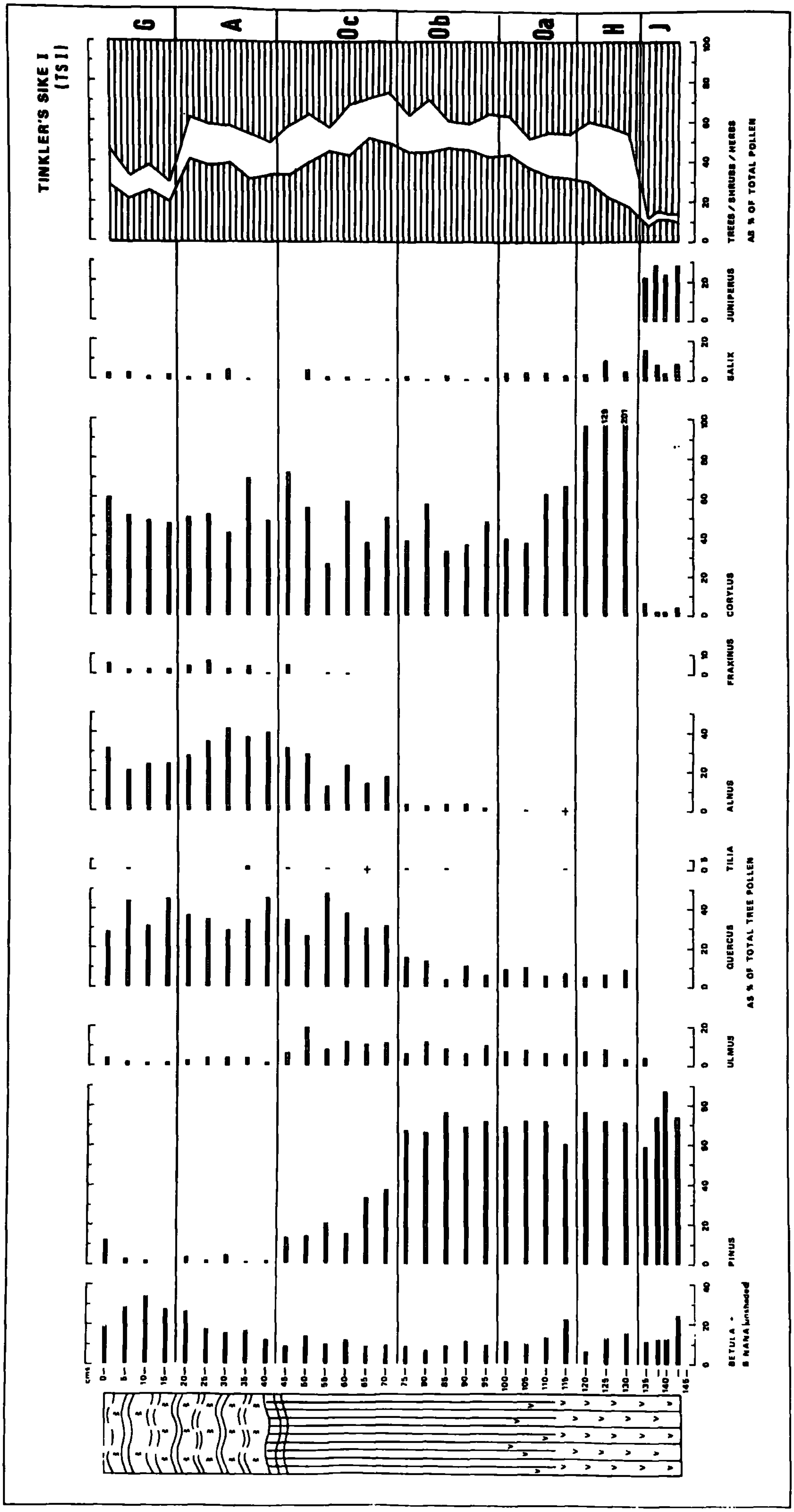
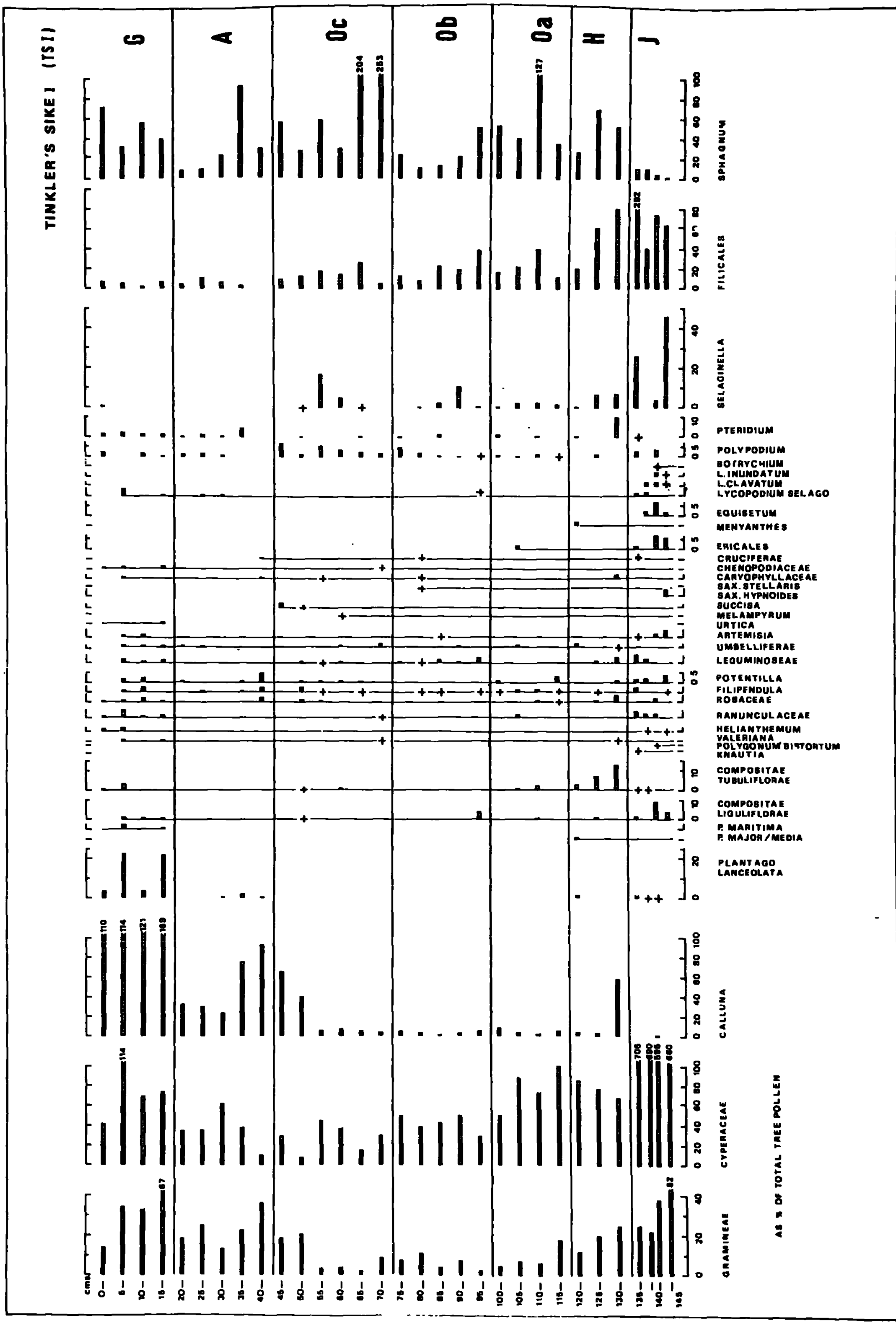
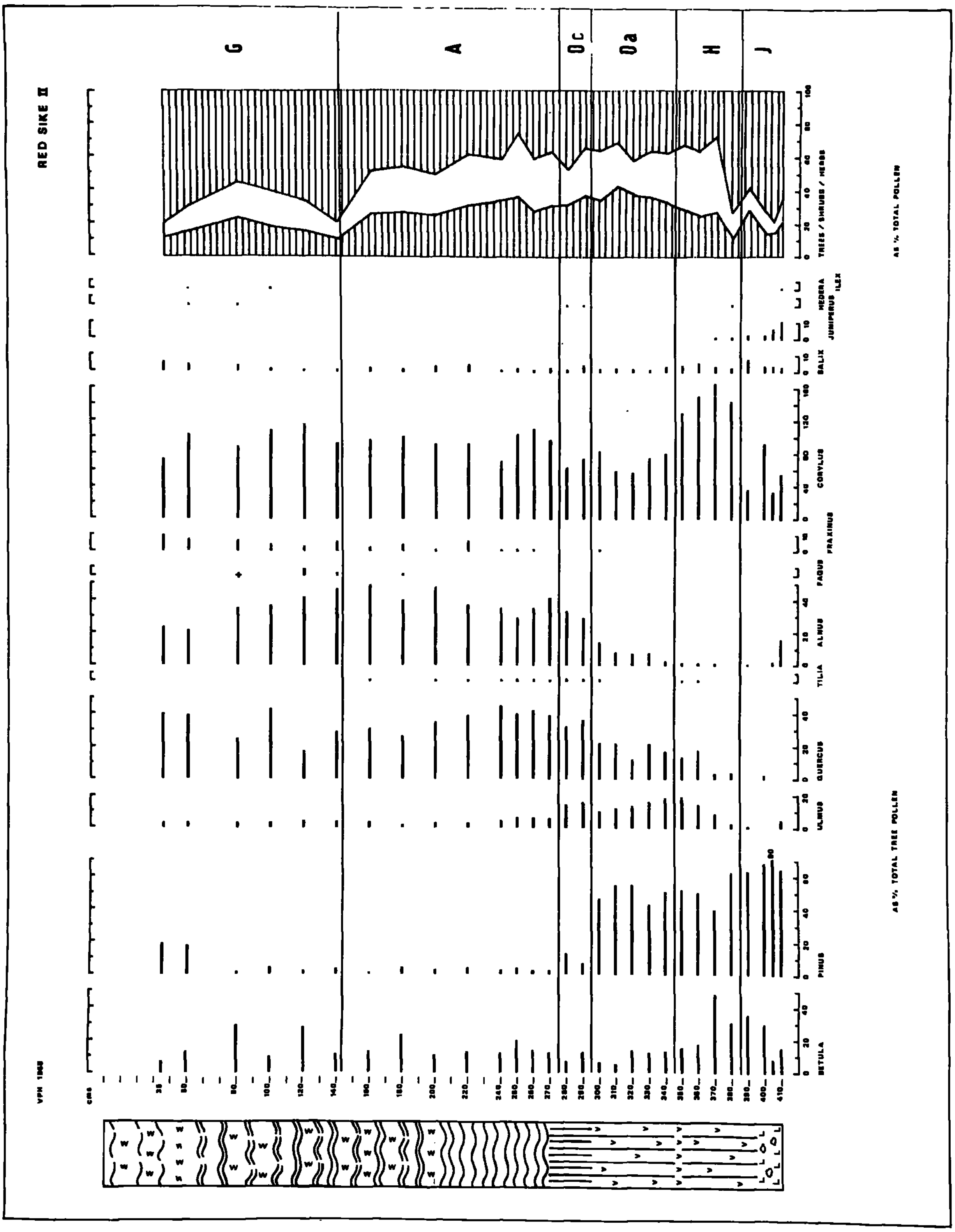


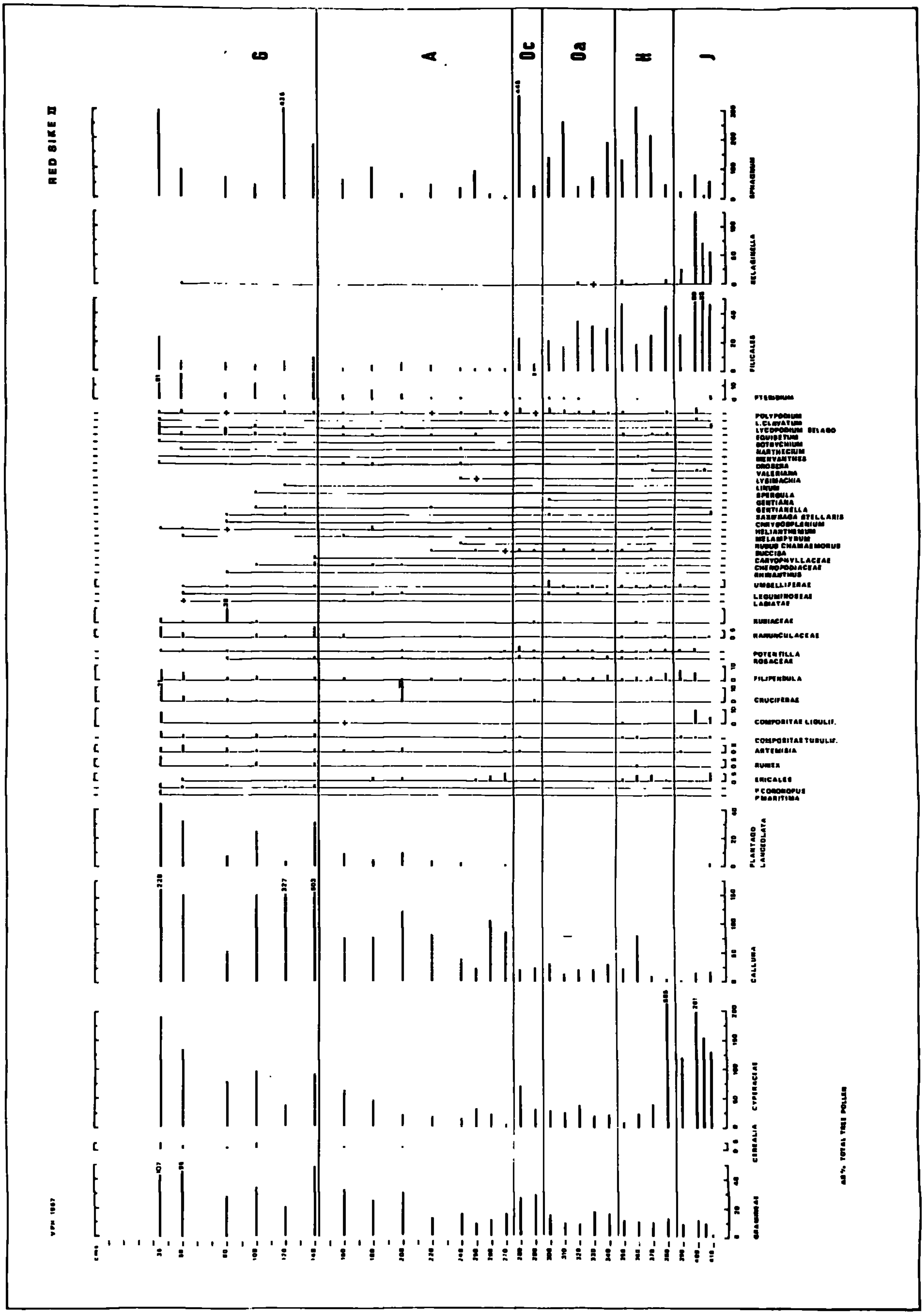
Appendix Fig. 1



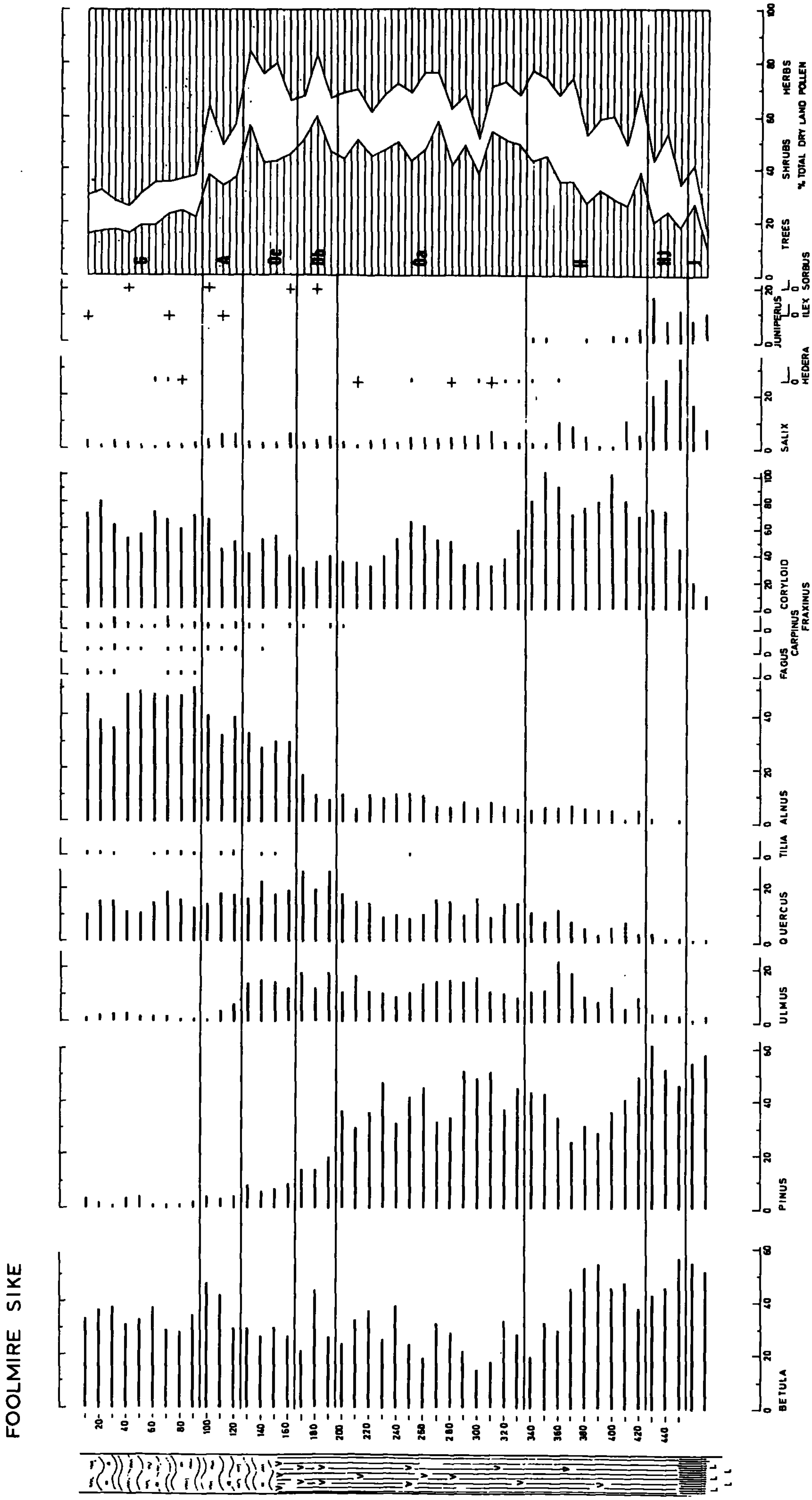
Appendix Fig. 2



Appendix Fig. 3

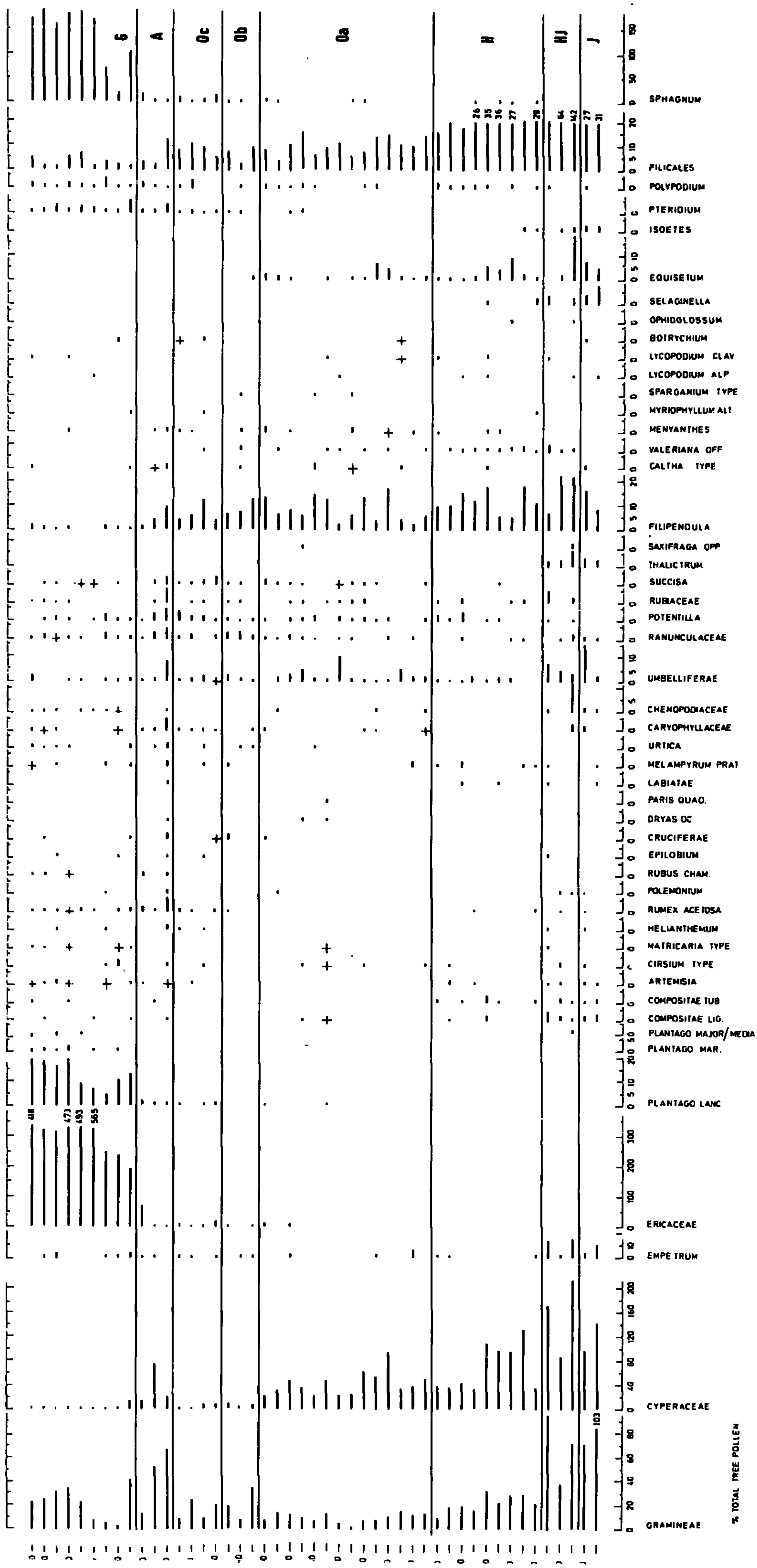


Appendix Fig. 4

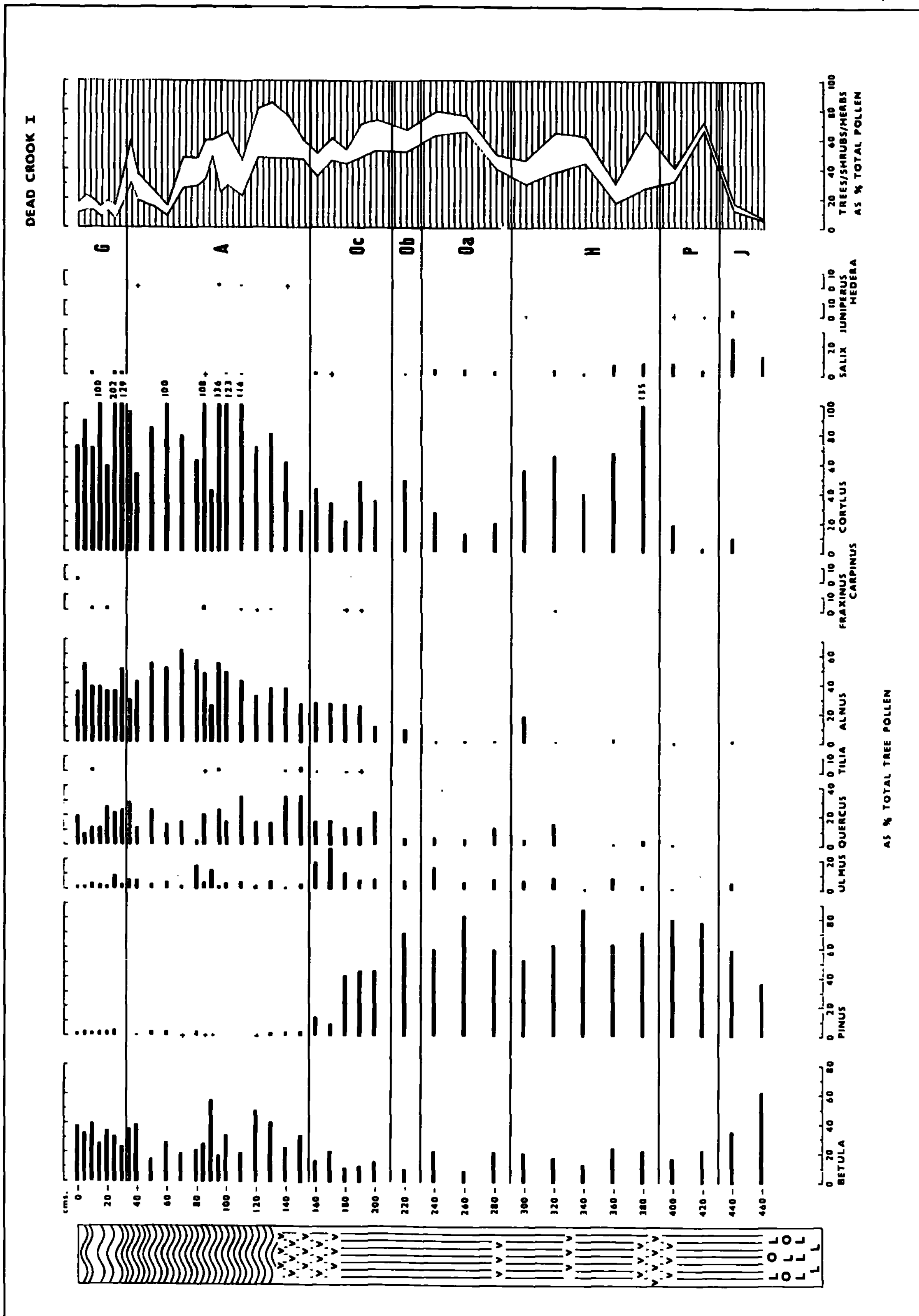


Appendix Fig. 5

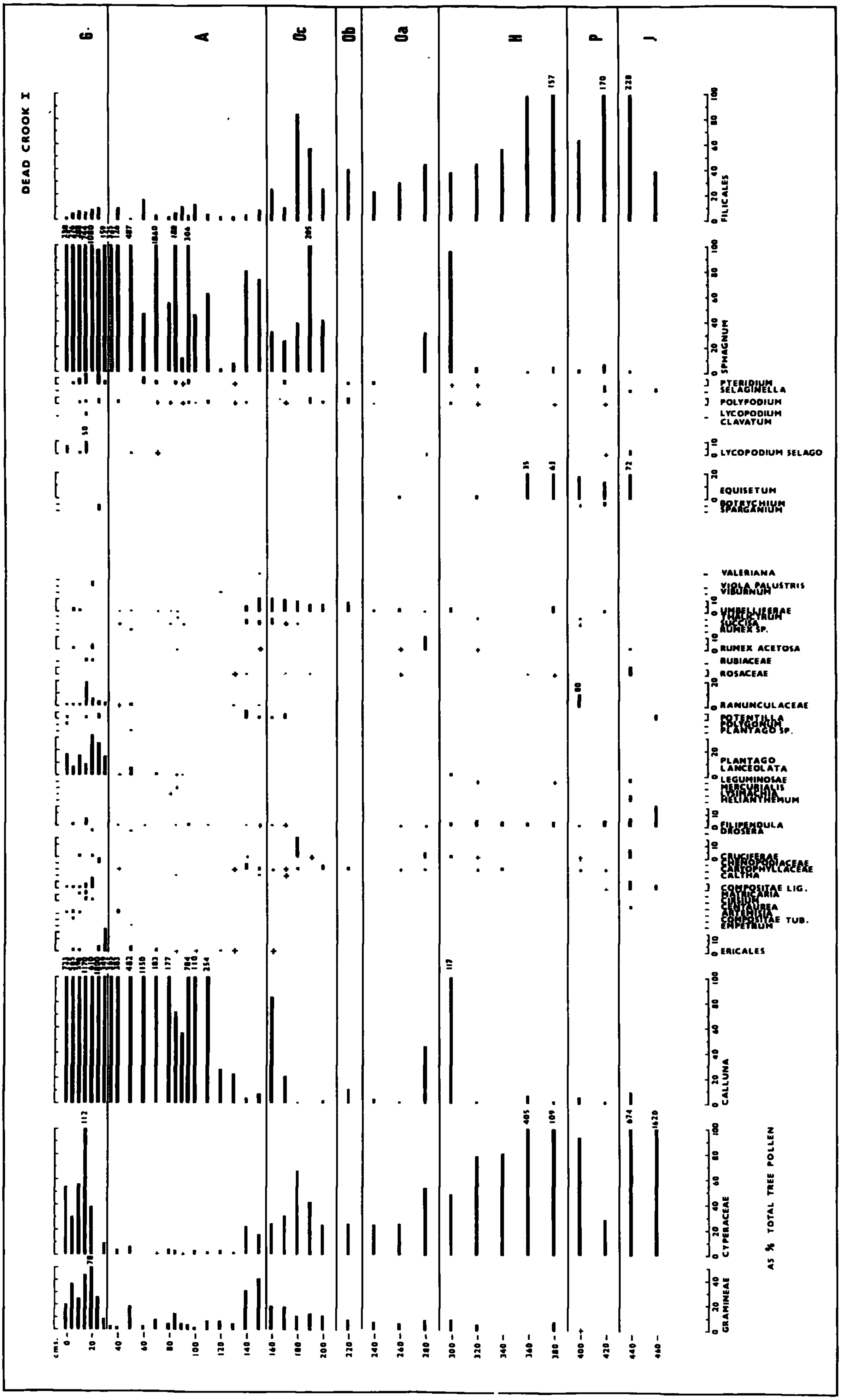
FOOLMIRE SIKE



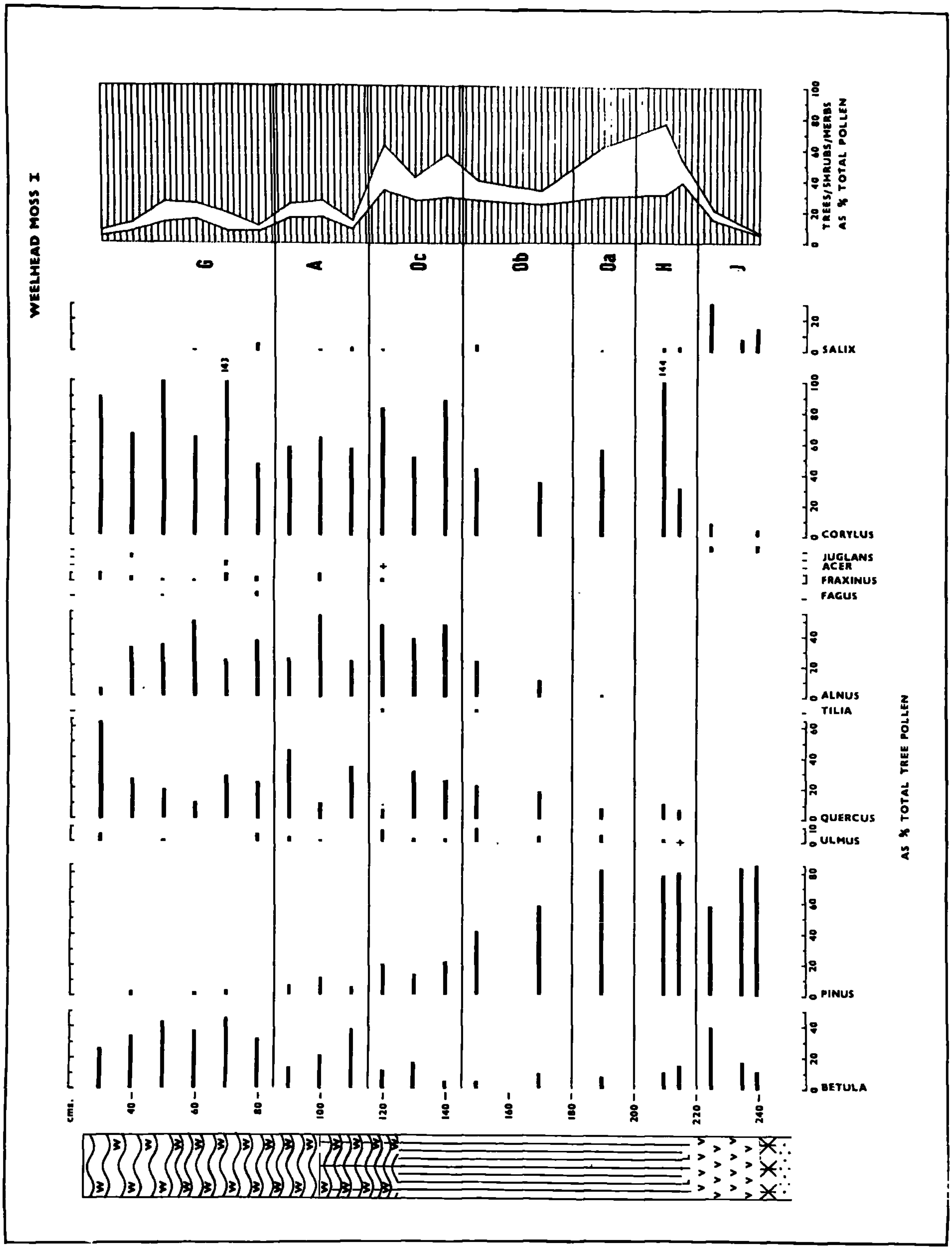
Appendix Fig. 6



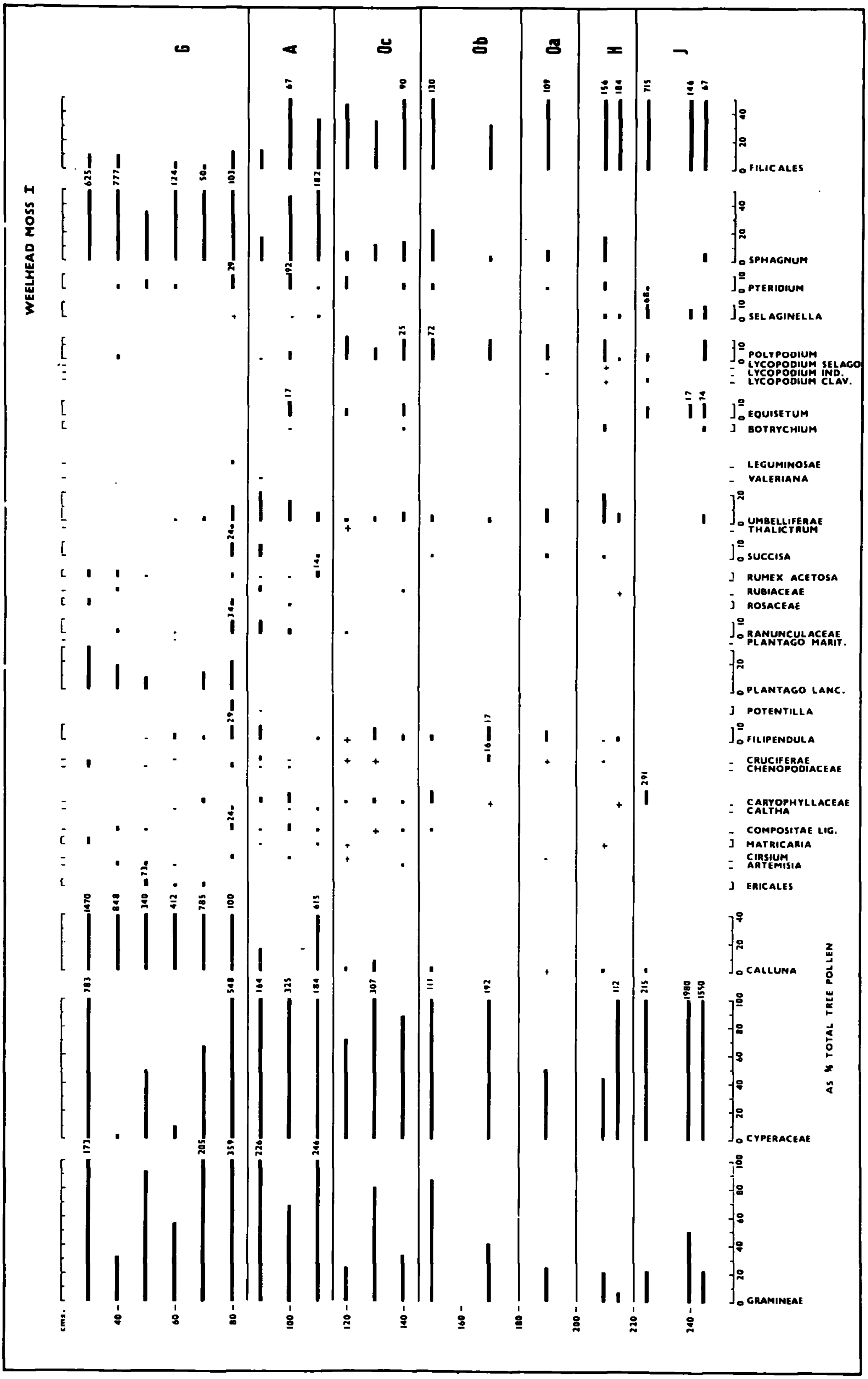
Appendix Fig. 7



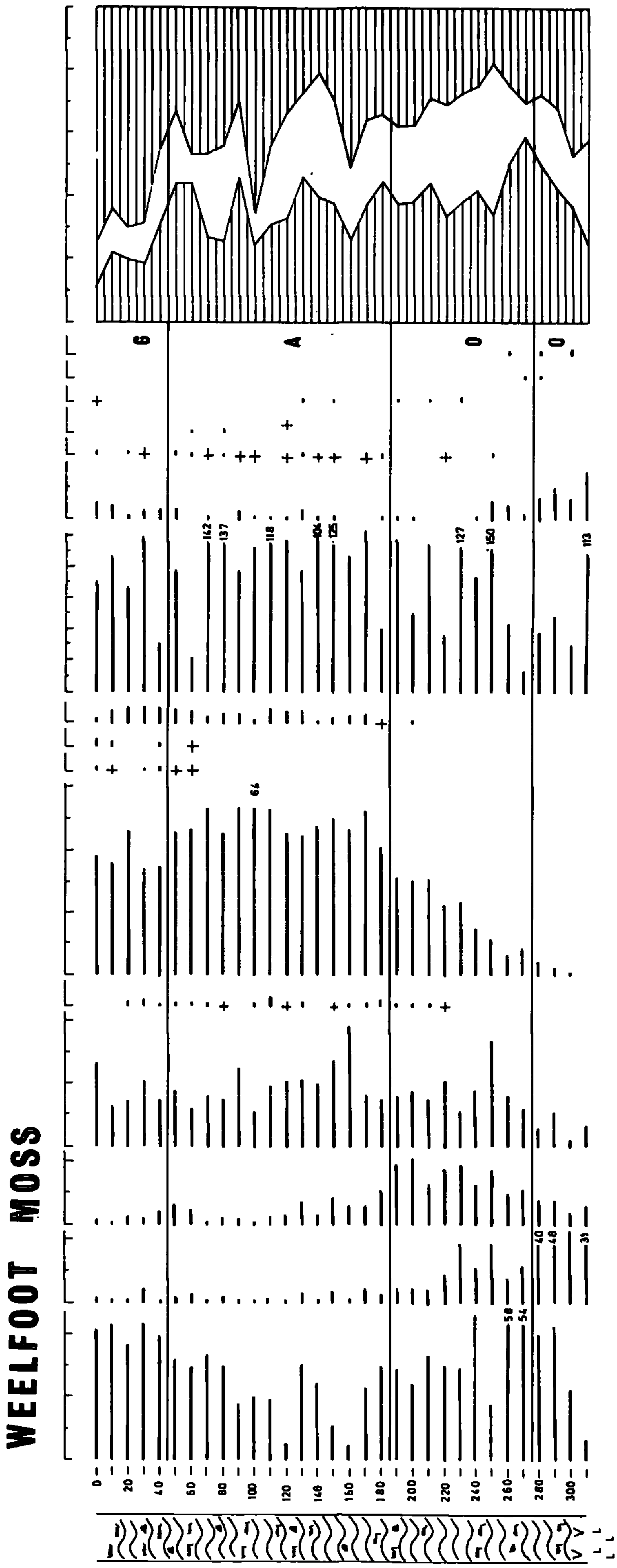
Appendix Fig. 8



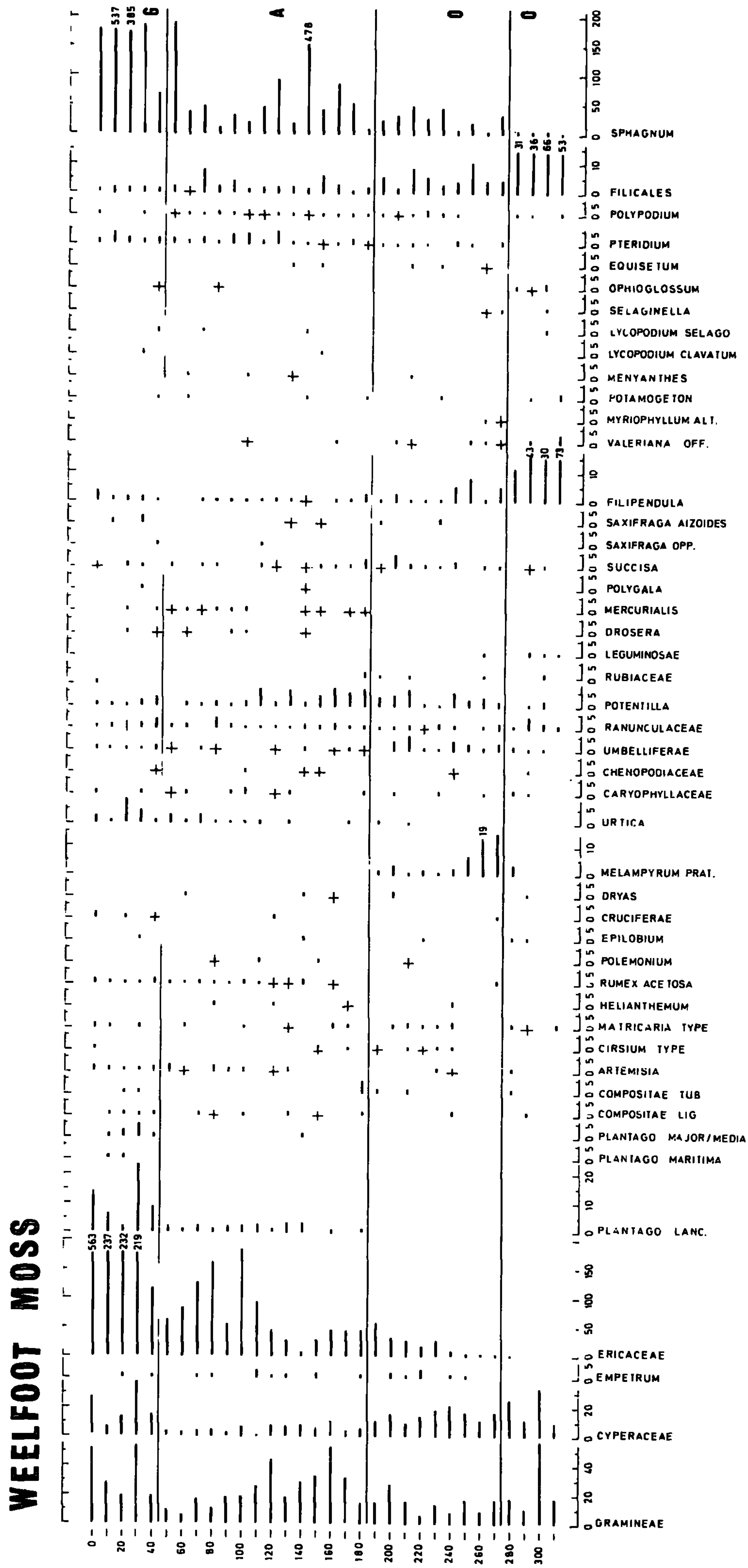
Appendix Fig. 9



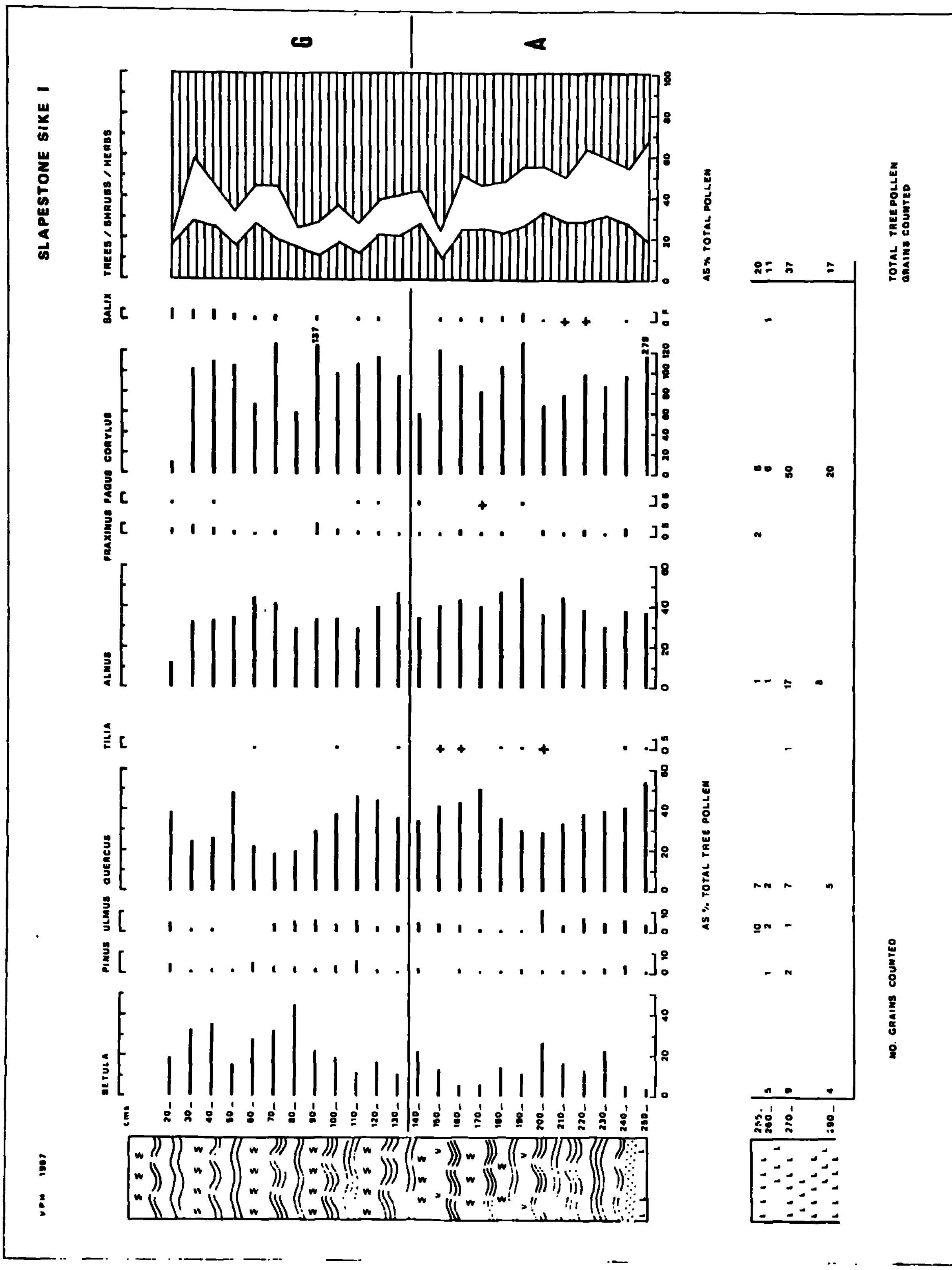
Appendix Fig. 10



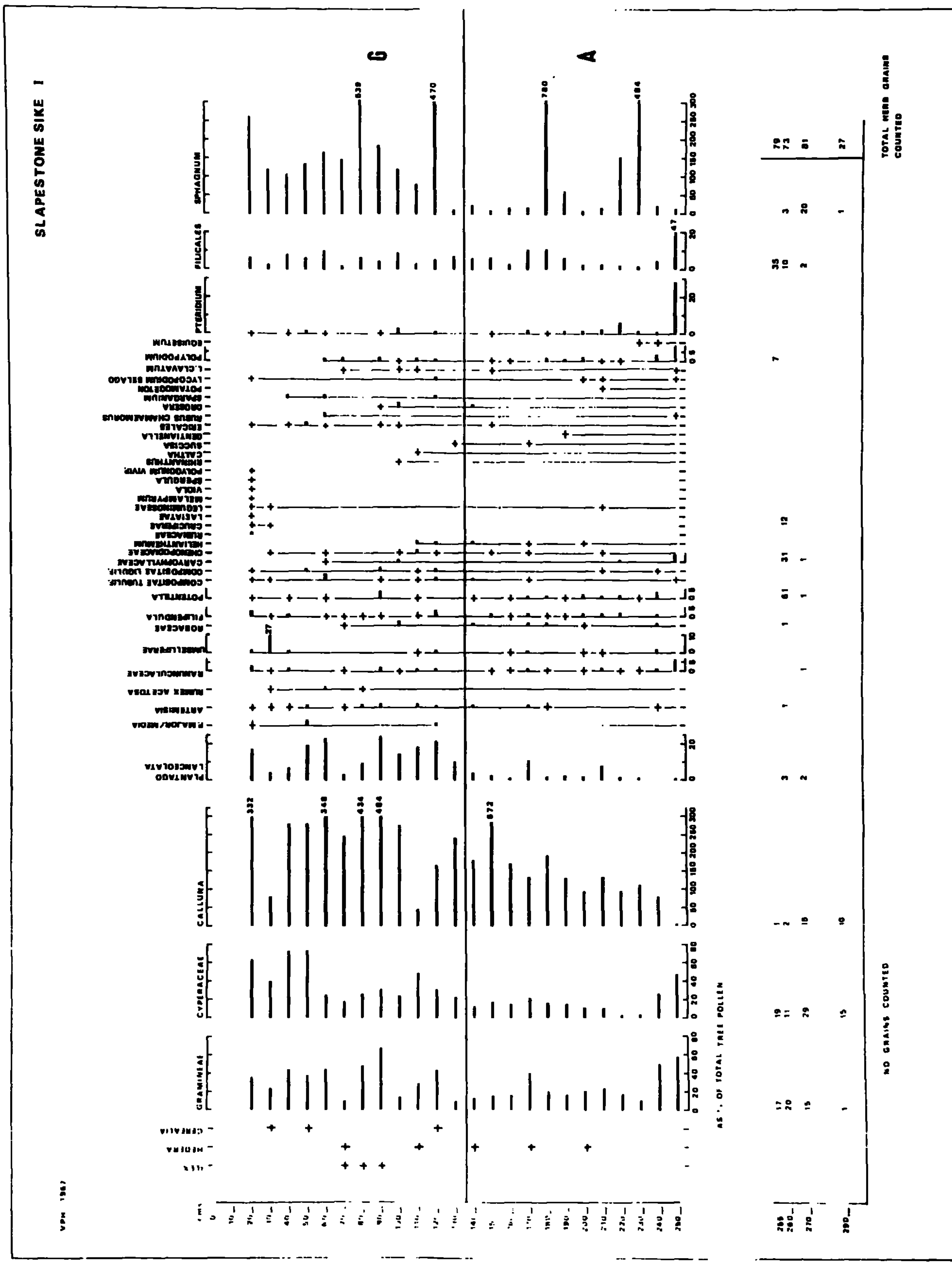
Appendix Fig. 11



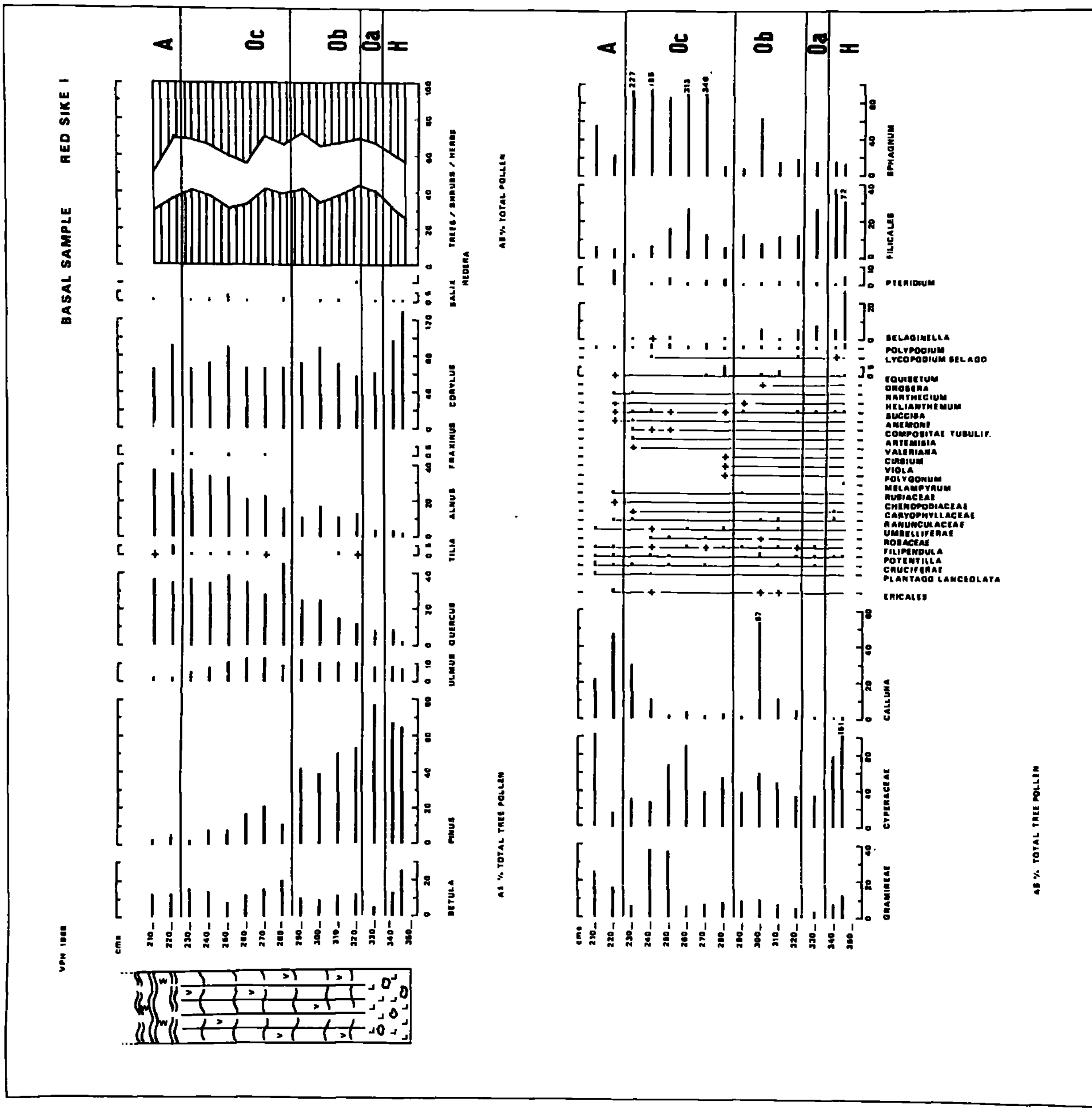
Appendix Fig. 12



Appendix Fig. 13



Appendix Fig. 14



Appendix Fig. 15