The distribution of pine in the North-East of England during the boreal period

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THE DISTRIBUTION OF PINE IN THE NORTH-EAST OF ENGLAND DURING THE BOREAL PERIOD

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INTRODUCTION

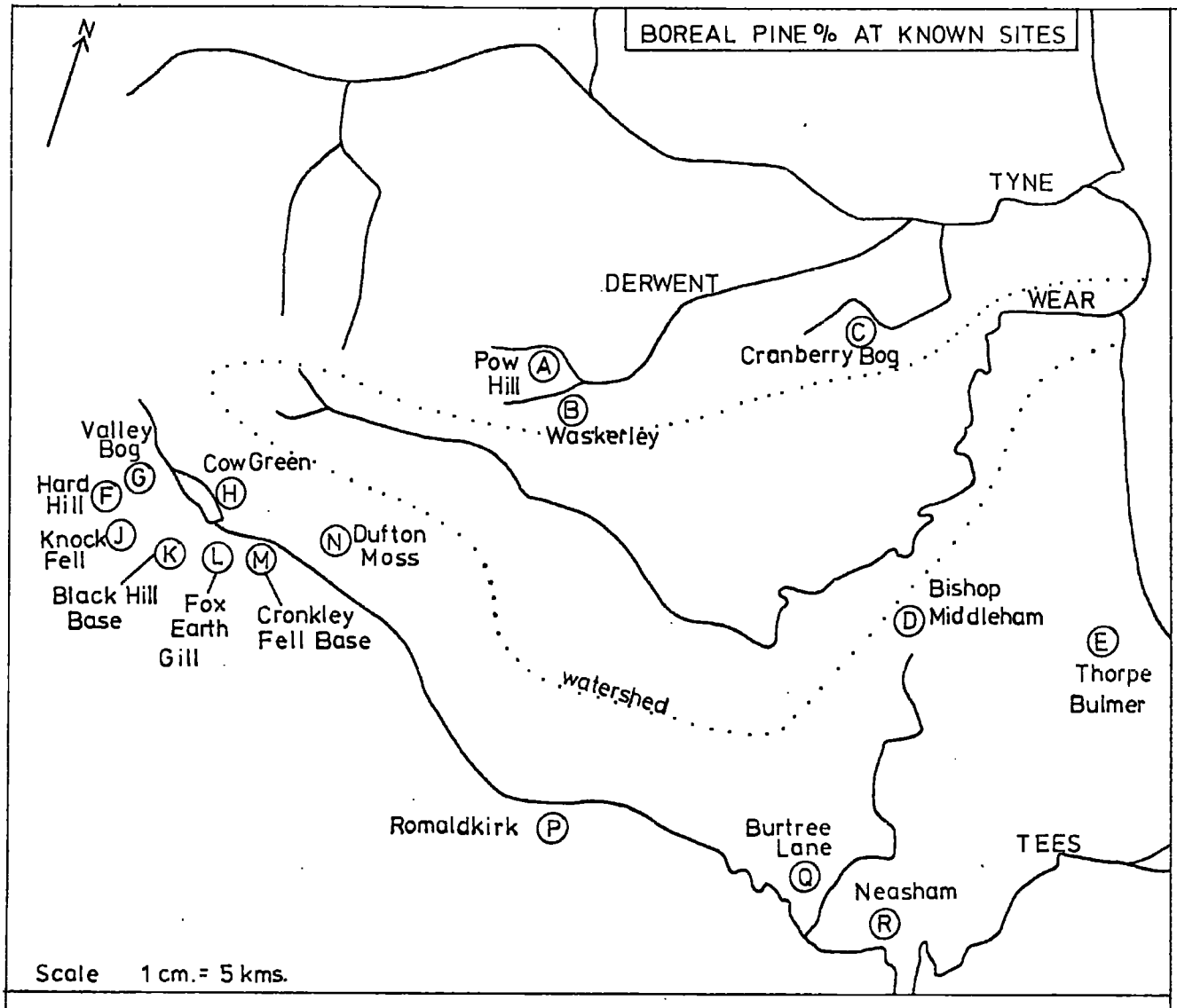
During the boreal period which in Britain lasted from about 7500 B.C. to 5500 B.C., the climate was thought to have been warmer and drier than now. The Devensian ice had long since retreated and the sea-level was rising. Immigration of tree species to Britain across the shrinking continental land bridge from the warmer regions in the south had begun earlier and forest development was proceeding rapidly.

The beginning of the boreal is characterised by the replacement of the native birch forest by hazel and pine spreading northwards on the lowlands and up into the valleys. Soon however thermophilous trees like oak, elm and lime migrated rapidly north and proved to be very strong competitors for the pine, particularly where the soil had reached an advanced stage of development i.e. the lowlands. Subsequently as the boreal advanced, the pine forests became less and less extensive and the distribution of pine more complex. The microfossil record of this period is preserved in peat deposits which formed at this time. Pollen analysis of boreal peat yields evidence about the relative abundance of the species present in the area. (Figs. 1 and 2)

Early work in the County of Durham provided clues that the pine frequency was probably very variable, pollen diagrams up to and including 1966 giving the following results:-

	% frequency range
Raistrick and Blackburn (1932), Waskerley	up to 78
Blackburn (1954), Neasham Brick Pit, lower Teesdale	5-45
Johnson and Dunham (1963), Upper Valley Bog, Moor House	18-50
" " " Hard Hill " "	10-22
Bellamy et al (1966), Romaldkirk, mid-Teesdale	2-6
" " Burtree Lane, lower Teesdale	10-70

FIG. 1



SITE	% RANGE OF PINUS	SITE	% RANGE OF PINUS
A	25 - 87	J	10 - 22
B	< 78	K	38 - 60
C	1 - 33	L	10 - 52
D	16 - 52	M	3 - 26
E	< 5	N	3 - 70
F	10 - 22	P	2 - 6
G	18 - 50	Q	10 - 70
H	< 90	R	3 - 10 Fen
			5 - 45 Brick Pit

Bellamy et al's results were surprising in that while a high pine frequency at a lowland site could be ascribed to a mosaic distribution, a very low pine frequency half way up the dale was apparenty inexplicable.

Later work by Squires (1970) in the Cronkley Fell area of Upper Teesdale and of Turner et al (1973) in the Cow Green area of Upper Teesdale and also by Casiker (1972) at Pow Hill near the Derwent reservoir all revealed very high pine percentages indeed:

Black Hill Base	maximum of	60%
Red Sike RS II		90
Pow Hill		87

The Upper Teesdale results from over 15 sites however showed occasional lower percentages viz. Foolmire Sike 35.8% (Turner et al) and Cronkley Fell Base 26% (Squires), but the most surprising result of all was that of Chambers (1974) at Neasham Fen in lower Teesdale. His values are very low indeed, contrasting sharply with those obtained by Blackburn at the nearby Neasham Brick Pit.

As the distribution of pine in County Durham appeared to have been so uneven, Dr. Turner suggested that to search for more boreal peat deposits and to plot the resulting percentages on a map would probably help to build up a more complete picture of the distribution of boreal pine and perhaps give a hint as to the factor controlling it.

The area searched was that enclosed by the Rivers Tyne and Tees, linked by the Pennine watershed to the west. Emphasis was placed on Weardale, where no boreal site had been found (and which lies in

a key position between the two areas specified) and on the mid-altitude ranges for which little information existed.

The results of the investigation have been linked together with data from previous work and are presented in the form of a sketch map which indicates the probable distribution of pine during the boreal period in the area selected.

ABSTRACTED DATA

Site	Nat.Grid Ref.	Alt.(m.)	% frequency range boreal pine	
Cranberry Bog	NZ 232 545	90	1 - 33	TYNE
Pow Hill	NZ 012 516	230	25 - 87	
Waskerley	NZ 025 442	338	78	
Burtree Lane	NZ 267 185	80	10 - 70	TEES
Dufton Moss	NY 872 293	368	3 - 70	
Fox Earth Gill	NY 842 282	538	52	
Black Hill Base	NY 817 281	425	60	
Cronkley Fell Base	NY 855 290	400	26	
Hard Hill, Moor House	NY 727 331	692	10 - 22	
Upper Valley Bog	NY 763 331	554 (J.&D.)	18 - 50	
		(C.C.)	25 - 50	
Neasham Fen	NZ 325 105	15	3 - 10	
Neasham Brick Pit	"	"	5 - 45	
Romaldkirk	NY 995 222	240	2 - 6	
Red Sike, Cow Green	NY 815 290	501	I 78 II 90	
Tinkler's Sike	"	"	88	
Foolmire Sike	NY 811 298	469	62	
Dead Crook	NY 803 303	475	86	
Weelhead	NY 806 306	469	I 85 II 70	
		No data available		WEAR

METHODS

A) The search for new sites

1", 2½" and 6" Ordnance Survey maps were consulted and all indications of possible peat deposits noted. In the brief period available for collection and working of samples, it was considered more practical to look at as great a number of sites as possible, thus the area over which work was done can be enclosed by the Rivers Tyne and Tees, together with the Pennine chain in the west. Tracings of 6" maps helped to locate the more obscurely-situated sites. Place names, topographical features indicating slow or impeded drainage, drift and solid geology were taken into account as well as altitude when developing the list of about 20 sites from which samples were to be collected.

B) Collection of samples

Peat cores were taken mainly with a Russian borer which gives a very clean core, a scew auger being used on occasion to test depth or to penetrate compact layers. An attempt was made to strike the deepest part of the deposit. This was usually taken to be central, judging by means of the extent of the surface vegetation. Ideally, line transects could be done and a series of borings made to develop a better knowledge of each site. 50 or 100 cms. of peat were taken, depending upon the depth of the deposit.

Cores were carefully placed in labelled, protective plastic liners of 5 cms. diameter and these in turn were wrapped in polythene bags for easy transport. Great care was taken to label each one with the site name, depth, date, and where appropriate, the

borehole number. It was found that with help on the borer, up to four sites could be located and sampled in one day. Preparation of further slides where necessary, was found to occupy most of the rest of the week leaving aside half a day for map-work and route-planning for the next field outing.

C)Preparation of slides

1 cm^3 of peat was removed from the inner region of the core by means of a sharp knife. The first sample was taken generally from just above the transition between the organic and inorganic portions so that tha bottom of the bog could be zoned according to Godwin's pollen assemblages (1956). The sample was divided into two, half being kept in a closed, labelled 5 x $2\frac{1}{2}$ cms. specimen bottle for use as required, the other half being subjected to that series of chemical processes required to remove the organic and inorganic matrix, leaving the pollen grains free for staining and mounting.

Details: a) Organic matter was dissolved out with hot 10% NaOH over about 30 minutes and poured off through a very fine metal sieve after centrifuging. It was important to wash in distilled water, stir and re-centrifuge the filtrate until the supernatant wasclear. Macrofossils withheld by the sieve were washed and retained for examination.

b) If the remains looked whitish and felt gritty, then silica had to be removed by means of hot hydrofluoric acid, taking full safety precautions. One sample could be dealt with in 10 - 15 minutes. Of the 114 samples prepared, 44 needed this treatment.

c) Acetolysis with a mixture of acetic anhydride and concentrated sulphuric acid completed the removal of extraneous matter and the pollen grains could then be mounted in glycerin jelly mixed with safrannin.

D) Pollen analysis

A binocular Vickers microscope with integral lighting and vernier stage was used and most identification and counting was done with x8 eyepieces and a x40 objective lens, giving a total magnification of x320. Difficult grains were examined under the x100 oil immersion lens (total = x800). Rapid scanning was done with a x10 objective lens (total = x80).

An overall total of more than 25 000 tree pollen grains were counted. On each slide, a minimum of 150 tree pollen grains were counted, but if the pollen was sparse then the whole slide was fully counted, following traverses at 2 mm. intervals. The frequency of all tree, shrub and herb species was then estimated by percentaging their score against the total tree count. Where possible the percentage frequency of each species was plotted on to the pollen diagram. The relative amounts of tree, shrub and herb pollen were also indicated on the diagram along with an outline of the stratigraphy.

E) Assessment

For each site, the bottom sample was first made up to see if peat had begun to form as early as the boreal. Where the Alnus value was found to be high, indicating that the peat was post-boreal (i.e. zone VII or later), generally no further slide was made. 30 - 40% frequencies were considered a normal indication of the Atlantic period. Where Alnus had not risen, several more slides

were prepared at 5 or 10 cms. intervals up the core to give a diagram for the boreal period.

This pattern of work was pursued for 6 weeks and 22 sites were examined: about half of these were in the Wear and a quarter each in the Tyne and Tees catchments.

Note

1974 was particularly dry until mid-summer, therefore the boring was done under ideal conditions in May and June, the bog surfaces being dry except on the Juncus-covered sites.

A LIST OF THE 21 NEW SITES

Clearly, not all the sites examined could be expected to reveal a boreal deposit. It is impossible to judge the age of a deposit by depth, topographical position, present drainage pattern or surface features and thus, although much interesting data was amassed and is included, only 6 out of the 21 sites will be considered in detail as they are of boreal age. These are:

1. Mown Meadows
2. Moss Mire North and Moss Mire South
3. Fortherley Moss
4. Green Swang
5. Stanley Moss
6. South Cornsay.

Data from the other sites, mainly in the form of data sheets, is included in the appendix. The names of these sites are:

POST-BOREAL

GROUP A
7. Seven Hills
8. Long Moss
9. Goose Tarn Beck
10. Hedleyhope Burn

GROUP B
11. Wolsingham Park Moor
12. White House
13. Woodland
14. Bellow Moss

GROUP C
15. Cuthbert's Hill
16. Shivery Hill
17. Sikehead
18. Thornhope Sikes
19. Wanister Bog
20. Black Mire
21. Coal Gate

The sites are described in the sequence given above.

NEW DATA

DATA SHEET

Site	Nat.Grid Ref.	Alt. (metres)	% frequency range pine	Catchment
Bellow Moss	NZ 081 338	231	31	Wear
Black Mire	NZ 048 255	368	0	
Cuthbert's Hill	NY 863 600	505	0	
Green Swang	NY 813 432	523	9 - 19	
South Cornsay	NZ 127 399	284	- 29	
Stanley Moss	NZ 150 385	277	22 - 62	
Thornhope Burn	NZ 030 404	400	1	
Wanister Bog	NZ 253 494	85	16	
Wolsingham Park Moor	NZ 042 414	400	12	
Woodland	NZ 077 268	338	8	
Hedleyhope Burn	NZ 139 412	230	0	
Coal Gate	NZ 042 486	235	-	Tyne
Fortherley Moss	NZ 018 576	206	6 - 48	
Long Moss	NY 863 600	293	2	
Mown Meadows	NZ 075 472	308	50 - 81	
Sikehead	NY 962 469	428	5	
Shivery hill	NY 816 457	538	0	
Goose tarn Beck	NZ 015 235	335	4	Tees
Moss Mire North	NZ 026 215	285	7 - 21	
South	NZ 027 210	283		
White House	NZ 025 238	358	9	
Seven Hills	NY 038 414	400	1	

BOREAL SITES

1. MOWN MEADOWS

The site was selected from the 2½" O.S. map, sheet NZ 04. It is easily accessible from the Moor Cock Inn on Goldhill Lane, being 1.5 km. N. of Waskerley and it occupies a shallow depression fanning out from the bed of a narrow stream on the 1000' (308m.) contour. Drainage is impeded on the downstream end where the peat depth is less than 20 cms. There are a number of springs and wells in the area. The position of the pilot bore is shown (Fig. 4).

The surface vegetation is Juncus effusus and the bog can be wet. The bottom of the deposit is a fine pale grey silt overlaid by a darker grey silt containing narrow streaks of orange-yellow sand. There is a narrow transition region (2 cms.) above which the well-humified dark brown peat was found to contain fragments of wood. These are particularly plentiful at 167 and 180 cms.

The samples prepared showed that the pollen is well-preserved except at the bottom of the deposit. Counts at 10 cms. intervals, the results of which are shown (Fig. 5), were plotted on a pollen diagram (Fig. 7) and they reveal an excellent boreal sequence with a full zone VI. The VI/VIIa boundary occurs between 158 and 168 cms. where values for falling Pinus and rising Alnus curves coincide at about 20%. The bottom of the deposit (198 cms.) shows the high Corylus value characteristic of VIa with the Pinus frequency at the same level, being 50%.

At 188 cms., the pine frequency rises to a substantial 81% then slowly drops to 16% at 158 cms.

FIG. 4

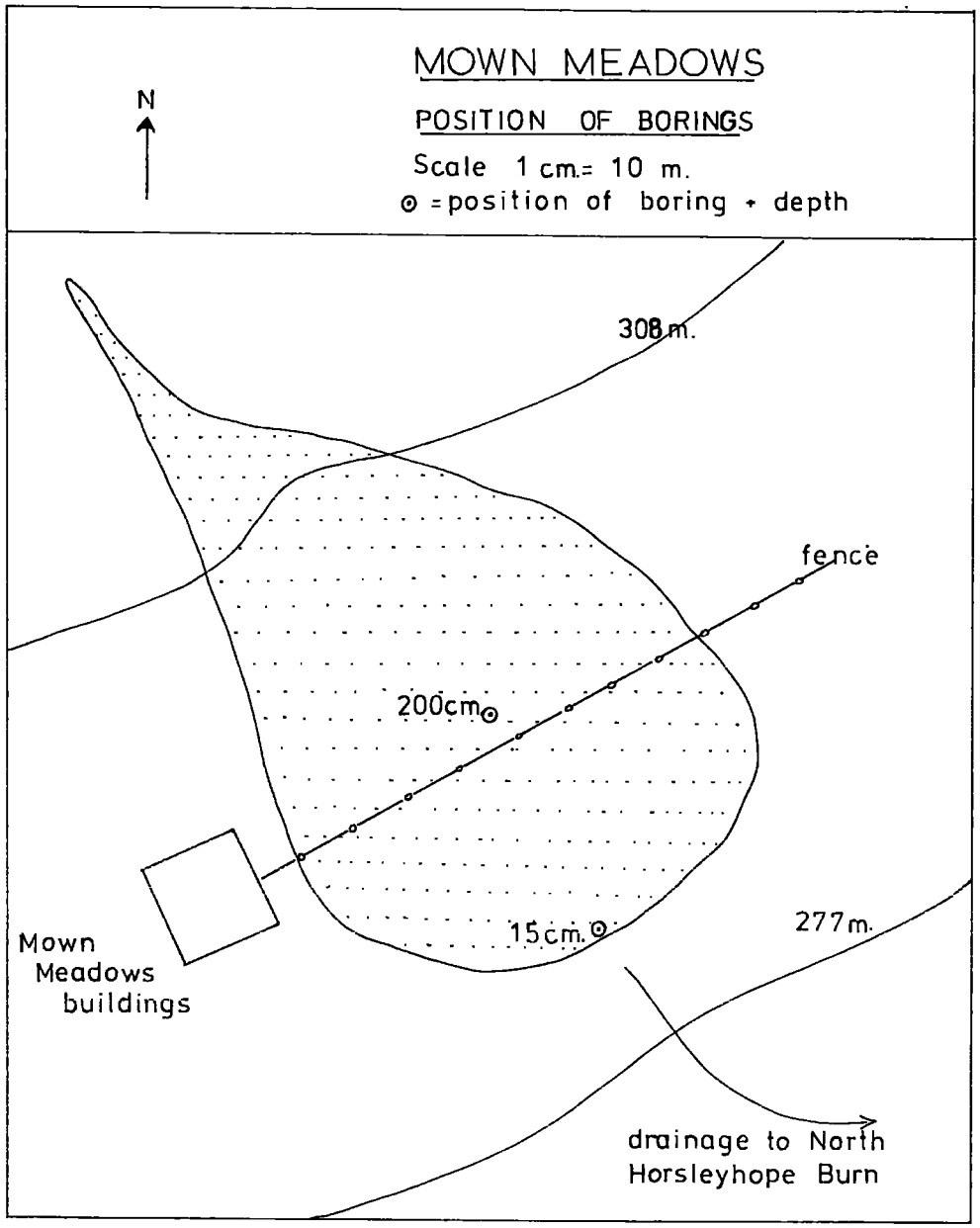

MOWN MEADOWS
POSITION OF BORINGS
Scale 1 cm.= 10 m.
⊙ = position of boring + depth
N
308 m.
fence
200cm.⊙
15cm.⊙
277m.
Mown
Meadows
buildings
drainage to North
Horsleyhope Burn

FIG. 5

INDIVIDUAL SITE DATA

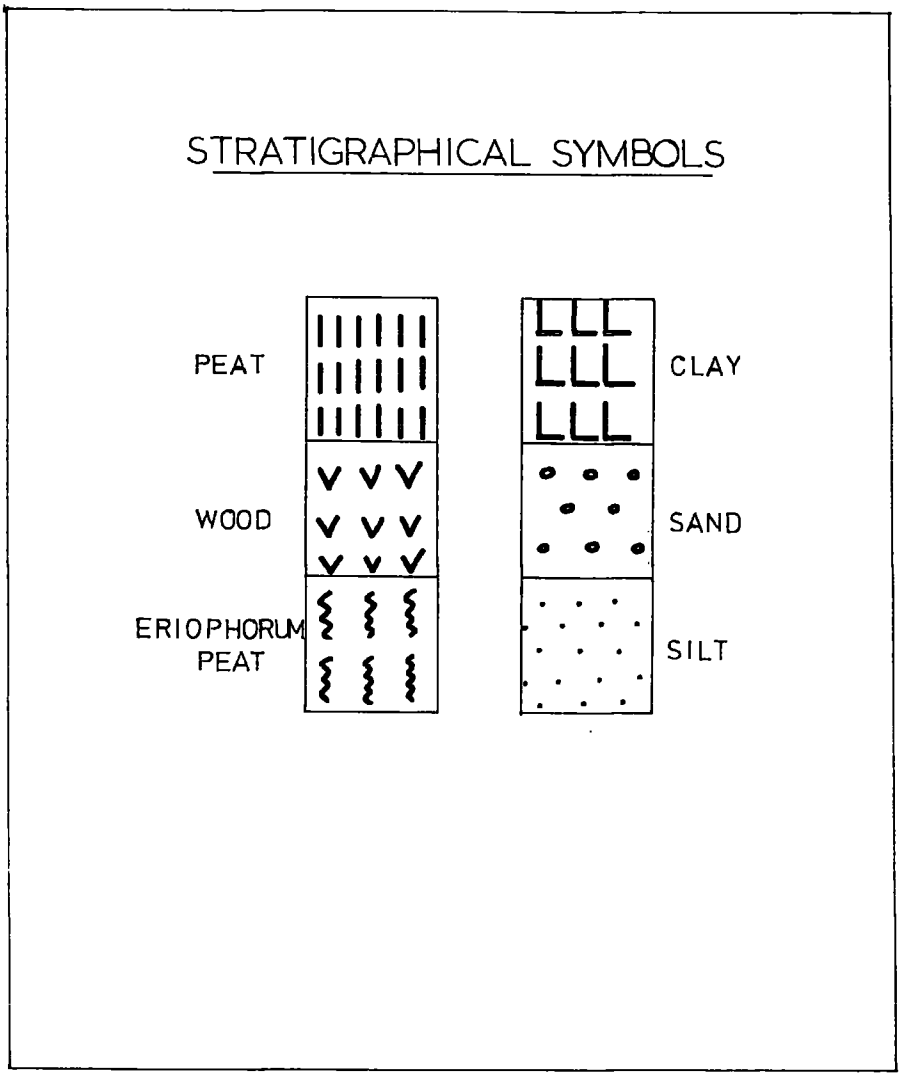
SITE: MOWN MEADOWS

	Number of grains							As % total tree pollen						
Depth cms.	B	P	U	Q	T	A	C	B	P	U	Q	T	A	C
158	53	24	0	24	0	49	11	35	16	0	16	0	33	7
168	33	68	1	14	2	22	37	22	45	+	9	1	15	25
178	38	198	0	15	0	5	28	15	77	0	6	0	2	11
188	14	121	0	12	1	2	56	9	81	0	8	+	1	37
198	9	11	1	1	0	0	47	41	50	5	5	0	0	214
Total	147	322	2	66	3	78	179							

= 797 grains

	Tree	Shrub	Herb %
158 cms.	84	8	7
168	76	20	4
178	67	20	13
188	54	24	22
198	24	58	18

FIG. 6


STRATIGRAPHICAL SYMBOLS
PEAT
WOOD
ERIOPHORUM PEAT
CLAY
SAND
SILT

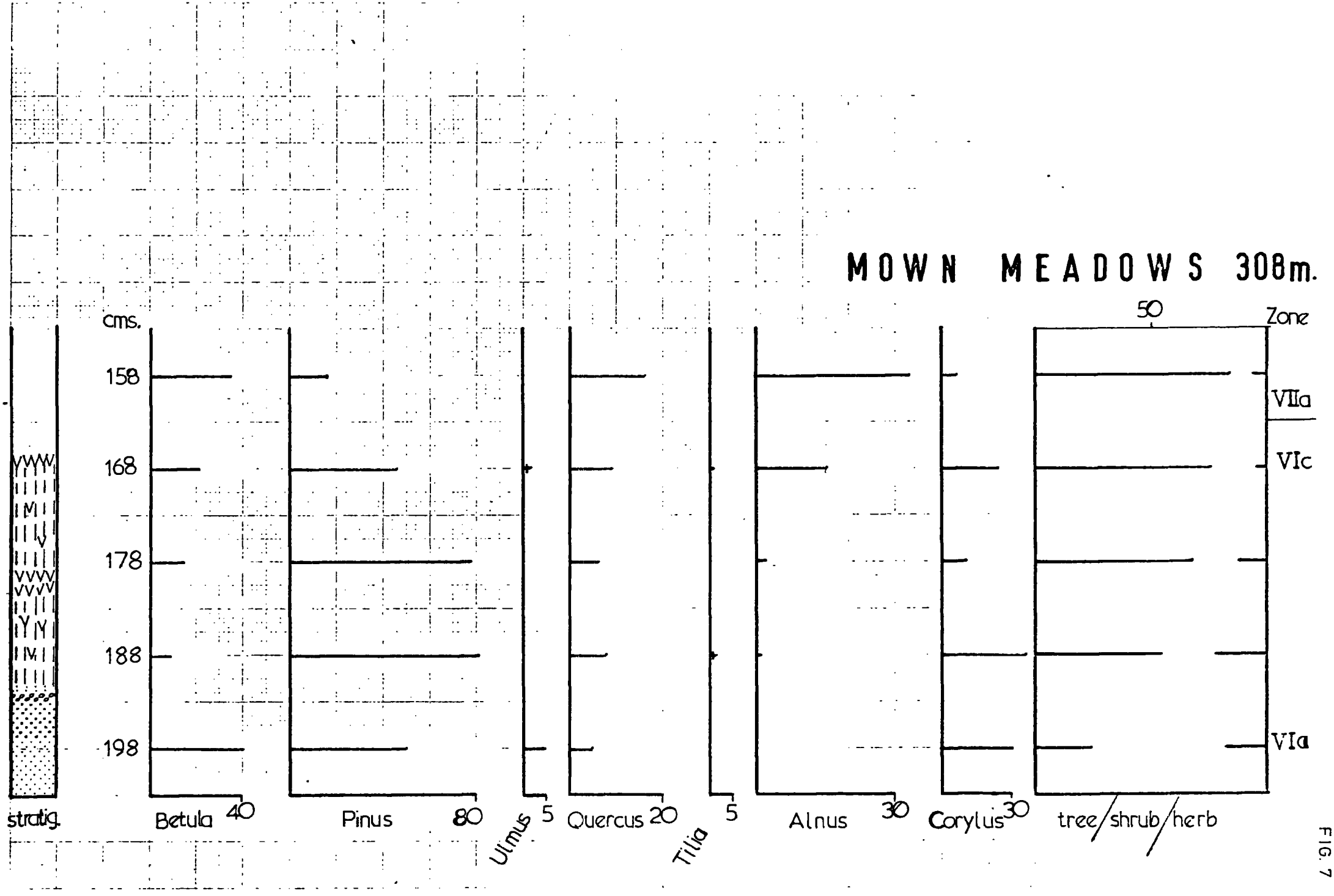

MOWN MEADOWS 308m.
cms.
158
168
178
188
198
strat.g.
Betula 40
Pinus 80
Ulmus 5
Quercus 20
Tilia 5
Alnus 30
Corylus 30
50
Zone
VIIa
VIc
VIa
tree/shrub/herb

FIG. 7

Associated with the massive rise in the pine frequency is a parallel decrease in birch, the value for which drops to 9% at 188 cms. The decrease in pine values following the maximum is matched by an increasing frequency of mixed oak forest species:

Depth (cms.)	Pine %	Mixed oak % (Ulmus+Quercus+Tilia)
158	16	16
168	45	10
178	77	6
188	81	8

Bearing in mind Andersen's correction factor (see Discussion), the height of the maximum nevertheless indicates a dense cover of pine in the boreal and this is substantiated by the low herb pollen frequency and the low *Corylus* values following the peak in early VI. Thus the full boreal forest in the Mown Meadows area appears to have been composed mainly of pine with a little oak. The birch values are particularly low (maximum = 41% in early VI).

2. MOSS MIRE NORTH AND MOSS MIRE SOUTH

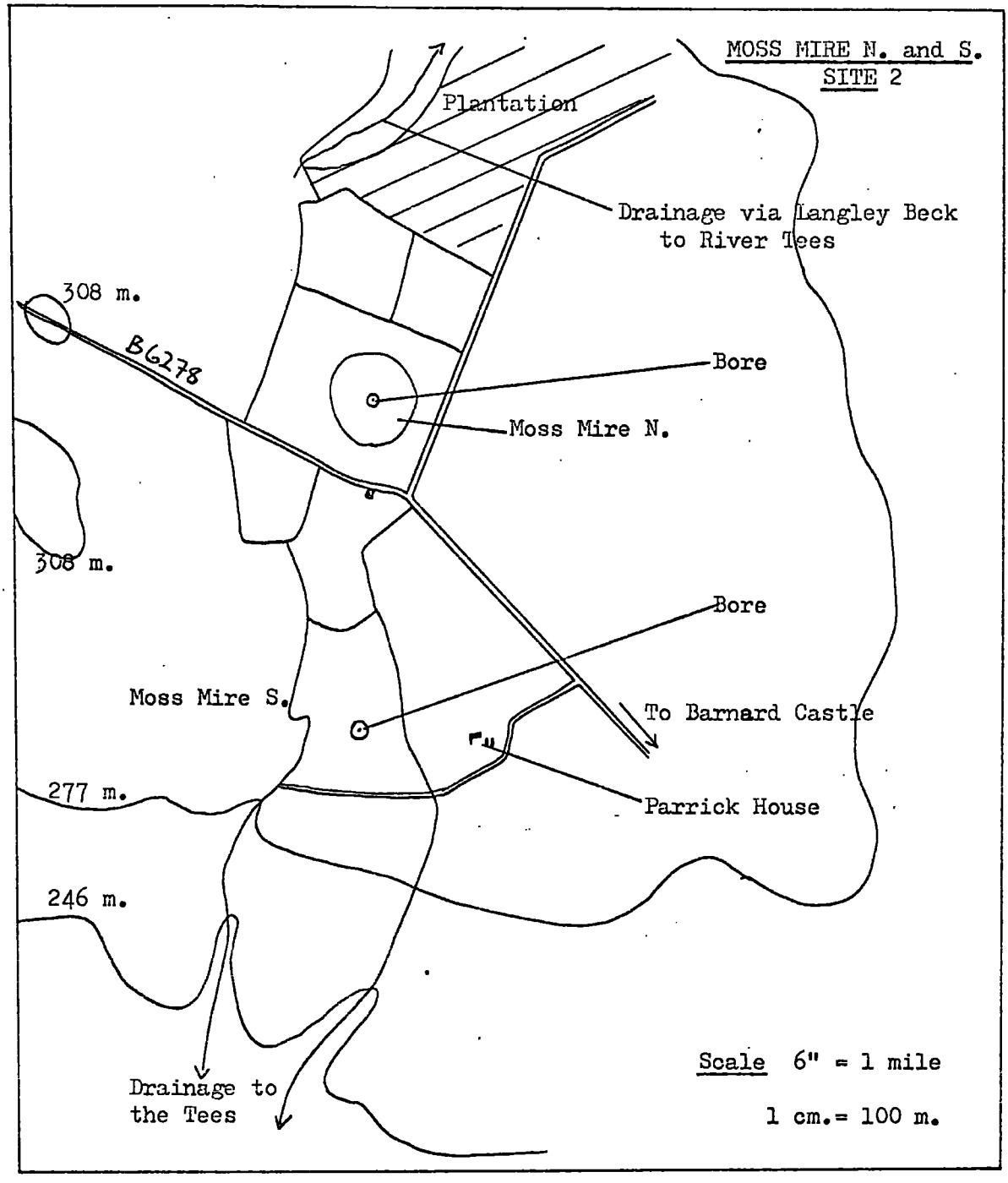
These sites were recommended for study by Dr. Turner and had been reported to be strikingly visible with their cover of fruiting Eriophorum vaginatum. They are easily accessible from the B6278 road near Parrick House which is 4.8 kms. N.W. of Barnard Castle (Fig.8).

At first, only Moss Mire South was considered, being the larger and deeper of the two as the screw auger revealed. As pollen analysis proceeded (Figs.9,10), it became evident that the peat was not yielding a clear picture of forest development, although there was pine present (17% at 302 cms. and 13% at 322 cms.). It was therefore decided to bore Moss Mire North 200 m. away, hoping that the sequence of forest development would become clearer.

Happily this was the case. There was however a complication at Moss Mire North, namely an over-representation of birch which seems to have been growing on or very near the bog surface. Using the Faegri and Iversen correction method for over-representation (1964), it is first of all necessary to estimate the probable true value for birch. In order to do this, data from Moss Mire South and other sites was used as follows:

i) birch frequency throughout the deposit at Moss Mire South varies mainly from 48 to 70%: the average of these figures is 59% which indicated a possible value for birch.

ii) comparison was made with values at other boreal sites for which pollen diagrams were available:


MOSS MIRE N. and S.
SITE 2
Plantation
Drainage via Langley Beck
to River Tees
308 m.
B6278
Bore
Moss Mire N.
308 m.
Bore
Moss Mire S.
To Barnard Castle
277 m.
Parrick House
246 m.
Drainage to
the Tees
Scale 6" = 1 mile
1 cm.= 100 m.

INDIVIDUAL SITE DATA

SITE: MOSS MIRE SOUTH

	Number of grains						As % total tree pollen						
Depth cms.	B	P	U	Q	A	C	B	P	U	Q	A	C	
302	81	29	3	10	47	146	48	17	2	6	28	86	
306	95	8	2	5	40	51	63	5	1	3	27	34	
310	38	4	0	2	13	20	67	7	0	4	23	35	
312	79	8	6	13	50	48	51	5	4	8	32	31	
314	62	20	3	21	61	78	37	12	2	13	36	47	
318	82	11	3	15	44	59	53	7	2	10	28	38	
322	16	3	0	3	1	3	70	13	0	13	4	13	
326	10	2	1	0	3	4	63	12	6	0	19	25	
333	39	3	0	2	16	24	65	5	0	3	27	40	
347	8	2	0	0	0	5	80	20	0	0	0	50	omitted
Total	510	90	18	71	275	438							

= 1402 grains

	Tree	Shrub	Herb %
302cms	38	45	18
306	36	21	43
310	40	23	37
312	45	20	36
314	56	32	12
318	54	23	23
322	28	6	66
326	19	8	72
333	48	20	32
347	16	25	59

MOSS MIRE SOUTH 280m.

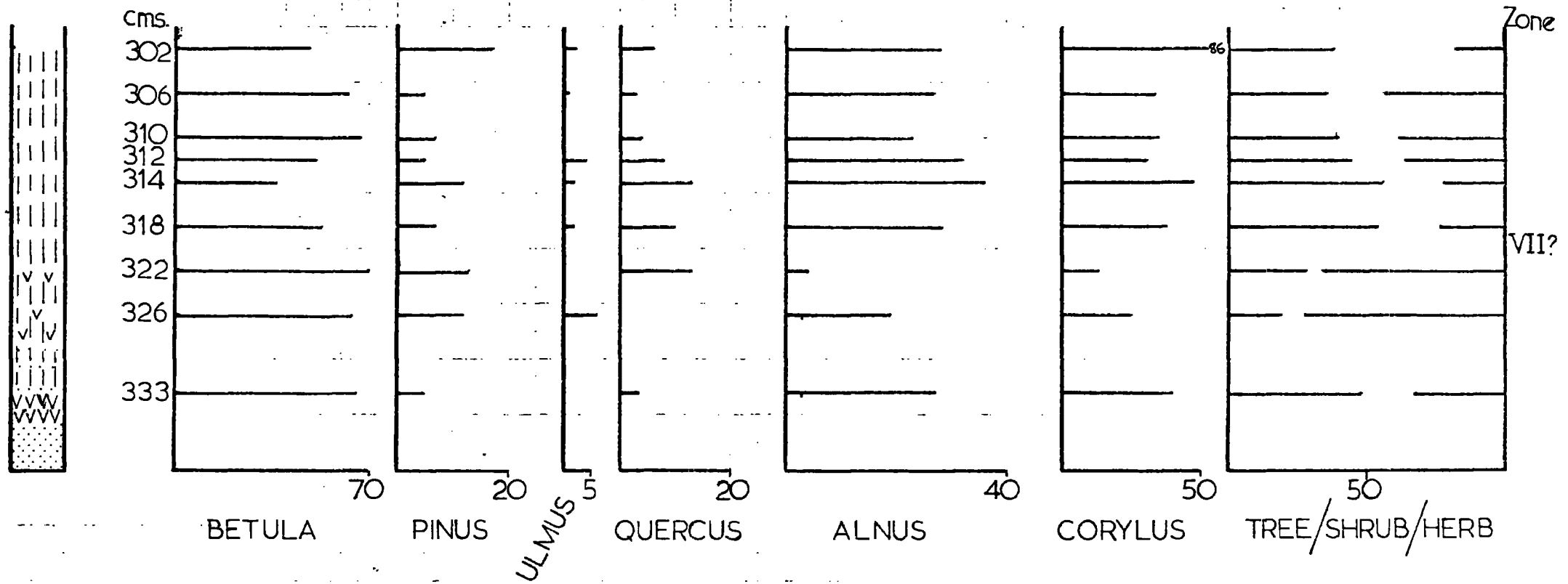


FIG. 10

Burtree Lane	maximum birch value	76%
Dufton Moss		70
Hard Hill		90
Neasham Brick Pit		10
Neasham Fen		95
Romaldkirk		45
Upper Valley Bog	(Johnson & Dunham)	80
	(Chambers)	28
	Total=	494
	Average =	61.75%

Thus taking the two average figures, 59% and 61.75% it was considered that a reasonable value to use for birch in the Faegri and Iversen correction would be 60%.

The Faegri and Iversen correction formula was then applied in calculating the percentage frequency of other tree species at Moss Mire North, taking the birch value to be 60% throughout.

Formula: $$P_i = ap \frac{100 - r_i}{S - a_r}$$

where P_i = corrected percentage for the species

ap = no. grains of that species in the count

r_i = the fixed percentage of the over-represented species

S = total of all grains in the sum

a_r = no. of grains of the species.

The corrected results are plotted on Fig. 12 . It was found that pollen preservation was poor towards the bottom of the peat and for this reason the pollen count at 180 cms. is not shown on the pollen diagram.

INDIVIDUAL SITE DATA

SITE: MOSS MIRE NORTH

	Number of grains							As % total tree pollen						
Depth cms.	B	P	U	Q	T	A	C	B	P	U	Q	T	A	C
155	513	15	12	51	0	30	123	60	6	4	22	0	11	46
160	616	26	25	30	0	15	226	60	11	10	12	0	8	94
165	1277	20	45	42	0	4	492	60	7	16	15	0	1	177
170	1017	16	8	6	0	1	306	60	21	10	8	0	1	395
175	76	1	1	0	0	0	31	60	20	20	0	0	0	620
180	23	2	0	0	0	0	12	60	40 omitted	0	0	0	0	240
total	3522	80	91	129	0	50	1190							

= 5062 grains

Over-representation of birch corrected for assuming frequency to be 60%

	Tree	Shrub	Herb %
155cms	75	21	4
160	71	24	5
165	45	49	6
170	47	46	7
175	28	14	58
180	9	2	89

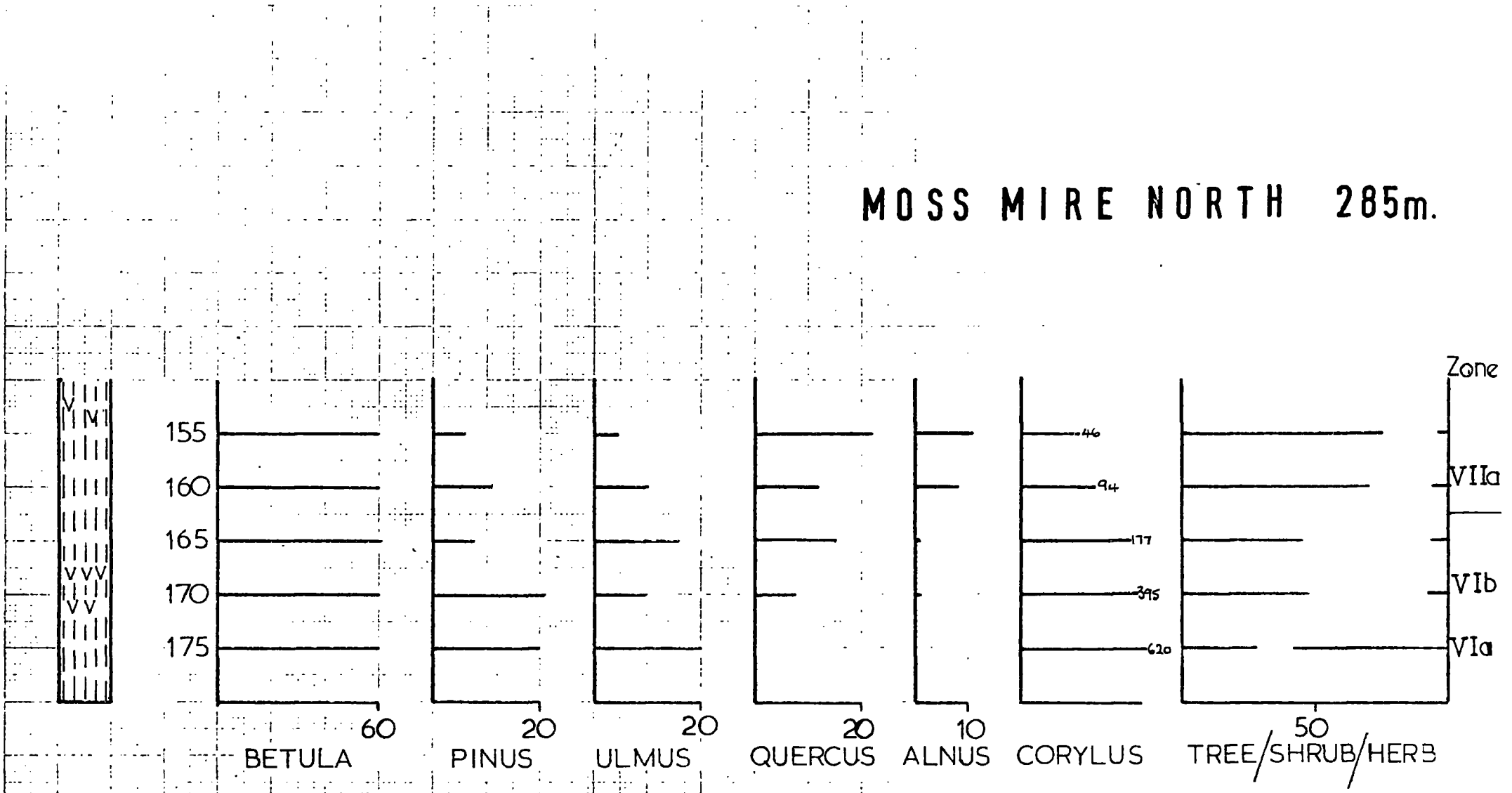

MOSS MIRE NORTH 285m.
V
M
V V V
V V
155
160
165
170
175
60
BETULA
20
PINUS
20
ULMUS
20
QUERCUS
10
ALNUS
46
94
177
395
620
CORYLUS
50
TREE/SHRUB/HERB
Zone
VIIa
VIb
VIa

FIG. 12

Zonation is difficult at Moss Mire South. Possibly the whole peat deposit belongs to zone VII as the Alnus value is so high (c.30%), but if this is the case it is difficult to understand why the Pinus persists at values of up to 17% at 302 cms. At Moss Mire North the VI/VIIa boundary can best be positioned between 160 and 165 cms., where the Alnus frequency rises sharply. Samples at 165, 170 and 175 cms. are clearly zone VI. The lowest sample at 180 cms. is rather problematic and may well be as early as zone V.

The sequence of forest development, based on Moss Mire North thus seems to have been:

a) at 180 cms., open birch forest with some pine, a small scrub but large herb component. There were no doubt large glades amongst the well-spaced trees and plenty of light would have been able to penetrate to the ground.

b) by 175 cms. invasion of the birch by pine and elm had taken place and there was a dense shrub layer of hazel. The light to the herb layer had thus been drastically reduced and the herb pollen count is low. It is interesting to note that the Pinus and Corylus values peak together, a characteristic usually found at lowland sites. As elm is present but not oak this level is judged to belong to VIa.

c) by 170 cms. oak has arrived to complete the mixed oak forest which continues to the VI/VIIa boundary when the wetter climate increased the competitive success of Alnus.

The total depth of boreal peat at Moss Mire North is 30 cms. which is slight and indicates a relatively dry situation.(see Fig.12)

3. FORTHERLEY MOSS

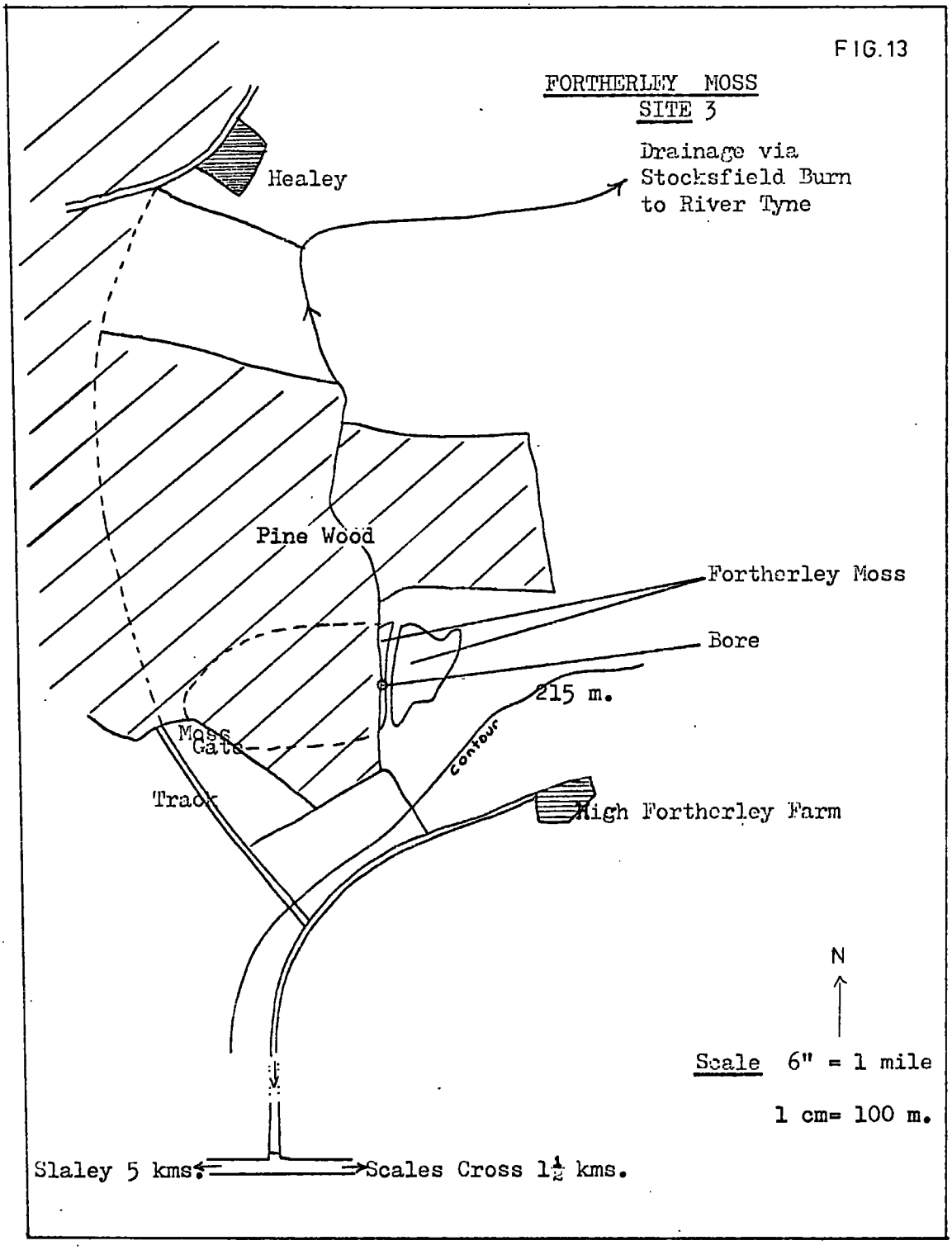
The Moss lies 1.5 km. W. of the A68 road at a point 5 kms. S. of Riding Mill. Access is via the gated entrance to High Fortherley Farm (Fig.13). "Fortherley" is the spelling used by Bartholomew's ½" map of Tyneside, sheet 39 and by the original investigators of the site, Raistrick and Blackburn (1932), but both the Ordnance Survey and the G.P.O. favour "Fotherley".

Raistrick and Blackburn thought the lower part of the Moss to be boreal but unfortunately the deposit was so soft that the borer sank under its own weight and they were obliged to curtail their investigations. It was felt that 42 years later the Moss might well have dried out sufficiently to make possible both a boring and the construction of a pollen diagram. A depth of 4 m. was reached at the E. edge of the Moss and well-humified peat was removed from the bottom of the deposit.

During the last 40 years, a natural pine forest has developed on the bog, replacing the original heather cover remembered by the local farmer. The surface vegetation under the pines includes large eroding Eriophorum tussocks, Oxycoccus quadripetala, Vaccinium myrtillus, some Erica cinerea and Calluna vulgaris, together with large Sphagnum hummocks of varying species. Some deep pools remain at the centre of the Moss so for safety reasons, the area is fenced off. Some Juncus effusus and a line of 4 m. high birches marks the outer edge of the strip investigated. There is a wider expanse of peat nearer High Fortherley farm covered by grasses and sedges. The whole Moss well-deserves detailed study.

The Russian borer penetrated two layers of wood at 320 and 400 cms., the latter being very distinct and in order to avoid damage to the sampler, the fine screw auger was used to obtain the material below

FIG.13


FORTHERLEY MOSS
SITE 3
Drainage via
Stocksfield Burn
to River Tyne
Healey
Pine Wood
Fortherley Moss
Bore
215 m.
Contour
Moss
Gate
Track
High Fortherley Farm
N
Scale 6" = 1 mile
1 cm= 100 m.
Slaley 5 kms
Scales Cross 1½ kms.

below 400 cms. At 440 cms., the auger entered a coarse lumpy white sand, in contrast to the "fine grey silt" discovered by Raistrick and Blackburn. There was no effervescence with dilute HCl although the initial appearance was reminiscent of the Teesdale sugar limestone. The clear rough granules are thus probably quartz brought by ice-movement from the west during the Devensian.

About 50 cms. of boreal peat was found in this boring which represents a slow rate of growth (Fig.15). Results of pollen analysis are presented in figs.14 a,14 b,15 .

The peat examined appears to belong entirely to zone VI because, even though Pinus values drop fairly sharply from 48% at 385 cms. to 8% at 355 cms., there is no matching rise in the Alnus frequencies, which remain fairly steady at 8-19% between 305 and 375 cms. despite a brief rise from 3% at 385 cms. to 14% at 375 cms. It would seem therefore that the VI/VIIa boundary lies above 305 cms. Raistrick and Blackburn had commented previously that the Alnus rise was very slow.

The Pinus values reach their maximum after those of Corylus which is interesting, as this feature is characteristic of upland sites like Upper Valley Bog (Johnson and Dunham 1963). Fortherley lies at 206 m. which can scarcely be termed "upland" however and this point will be discussed in more detail later.

A minor feature of the pollen counts is the apparent correlation between the small decrease in the Pinus frequency at 400 cms. and the peak in values for the Ericaceae: 30% at 408 cms. 75% at 404 cms. and 109% at 400 cms. (Figs.15,16). This may possibly

INDIVIDUAL SITE DATA

SITE: FORTHERLEY MOSS

	Number of grains							As% total tree pollen						
Depth	B	P	U	Q	T	A	C	B	P	U	Q	T	A	C
305	83	31	0	28	0	16	28	52	20	0	18	0	10	18
325	275	28	0	91	2	93	52	56	6	0	19	+	19	11
335	486	79	14	112	1	82	46	63	10	2	14	+	10	6
345	156	26	2	35	0	18	30	66	11	1	15	0	8	13
355	176	22	8	37	0	36	34	63	8	3	13	0	13	12
365	135	47	4	41	0	38	47	51	18	1	15	0	14	18
375	135	54	1	19	0	33	64	56	22	+	8	0	14	26
385	59	72	2	12	0	5	22	39	48	1	8	0	3	15
395	81	58	0	4	0	12	55	54	39	0	3	0	8	37
400	39	4	2	11	0	10	37	70	7	4	20	0	18	66
404	39	15	1	16	0	12	27	42	18	1	19	0	14	33
408	34	10	3	16	0	8	8	48	14	4	23	0	11	11
412	45	8	3	8	0	13	29	60	10	4	10	0	17	38
Total	1743	454	40	430	3	376	479							

= 3525 grains

FIG. 14 b

Fortherley Moss continued

Depth	Tree	Shrub	Herb %
305 cms.	70	27	3
325	85	10	2
335	90	6	4
345	85	11	4
355	82	13	5
365	79	20	1
375	62	17	21
385	45	17	38
395	38	46	16
400	28	19	53
404	39	15	46
408	60	12	28
412	50	22	28

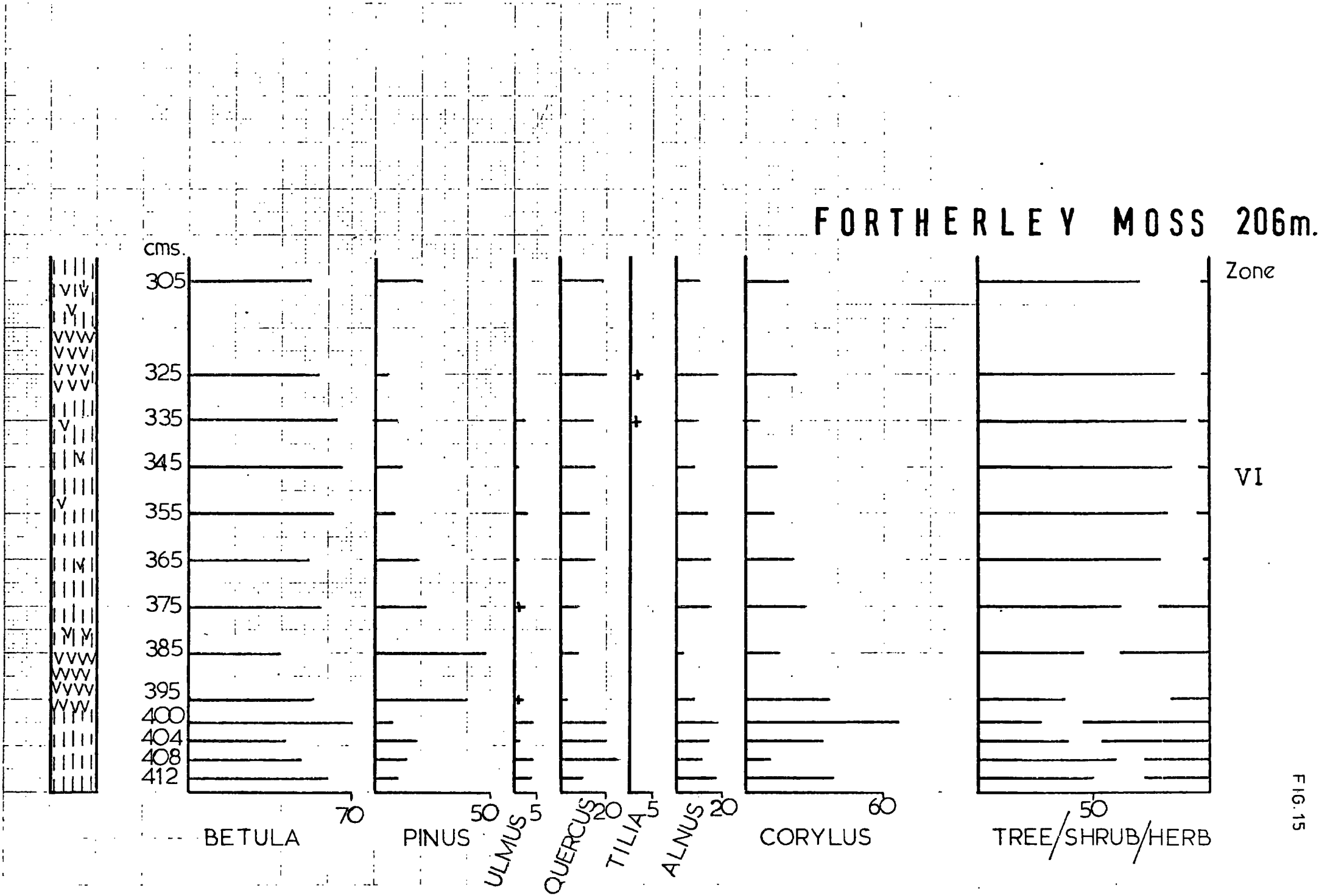

FORTHERLEY MOSS 206m.
cms.
305
325
335
345
355
365
375
385
395
400
404
408
412
Zone
VI
70
50
5
20
5
20
60
50
BETULA
PINUS
ULMUS
QUERCUS
TILIA
ALNUS
CORYLUS
TREE/SHRUB/HERB

FIG. 15

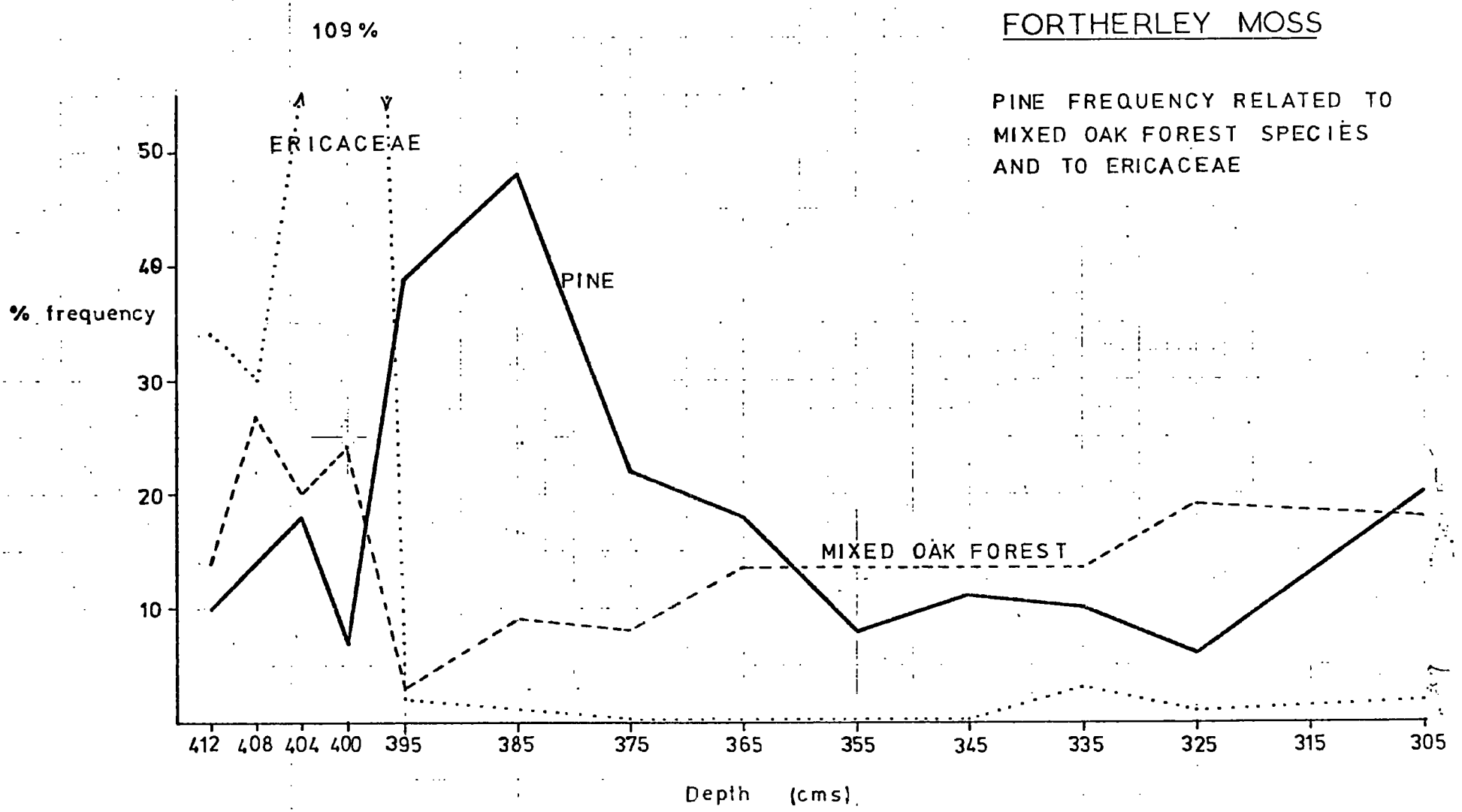

FORTHERLEY MOSS
PINE FREQUENCY RELATED TO MIXED OAK FOREST SPECIES AND TO ERICACEAE
109 %
ERICACEAE
PINE
MIXED OAK FOREST
% frequency
50
40
30
20
10
412 408 404 400 395 385 375 365 355 345 335 325 315 305
Depth (cms)

FIG.16

be of interest in the context of Handley's work (1964), quoted by McVean and Lockie (1969), which refers to the mycostatic effect of the heather root mycorrhiza on those of the roots of pine seedlings. However, the pollen frequencies cannot be considered firmly-enough established for a deduction of this nature to be drawn.

It is perhaps also worth mentioning that whereas Raistrick and Blackburn found pollen infrequent in the upper part of the deposit, there was no lack of perfectly-preserved pollen between 300 and 400 cms.: the only inconvenience to counting was the large number of fungal hyphae present.

4. GREEN SWANG

Green Swang was selected from the 2½" O.S. map, sheet NY 84 as an obvious site at the head of Weardale where material might contain evidence of boreal forests. The Wear is easily crossed from the A689 road and the raised shelf of Green Swang, approximately 500 m. long by 70 m. wide becomes more obvious.

Surface vegetation consists of Erica tetralix, Eriophorum vaginatum, Calluna vulgaris, Polytrichum and Sphagnum species. The deposit where bored was under 2 m. deep and appears to lie directly on bedrock. The single core taken at 115-165 cms. consists of a homogeneous dark brown, well-humified peat containing tiny fragments of wood.

The data obtained are presented on figs.17 and 18 .

The VI/VIIa boundary can be firmly fixed where the relatively low Pinus frequency falls from 15% at 145 cms. to 3% at 135 cms. as it is here that the Alnus values rise from 12% to 24% and the two curves cross. These low values for pine will be referred to again. However, there are two other points which require consideration: firstly, the Pinus curve is not easy to interpret with great confidence as the peat examined gave two low peaks, one of only 19% at 160 cms and seemingly a second at 145 cms. of 15%.

The second interesting feature is the unexpected rise in Corylus values with Alnus at the VI/VIIa boundary. Corylus frequencies between 163 and 155 cms average 35% but suddenly rise to 70% at 145 cms. and it is unlikely that this represents the main zone VI rise in Corylus frequencies because the Ulmus/Quercus ratio indicates VIb or later. The familiar early zone VI maximum

INDIVIDUAL SITE DATA

SITE: GREEN SWANG

	Number of grains							As % total tree pollen						
Depth cms.	B	P	U	Q	T	A	C	B	P	U	Q	T	A	C
135	89	5	5	17	1	36	91	58	3	3	11	+	24	60
145	101	31	20	29	0	24	144	49	15	10	14	0	12	70
155	94	17	11	26	0	2	41	63	11	7	17	0	1	27
158	101	19	12	13	0	5	62	67	13	8	9	0	3	41
160	92	28	9	20	0	1	71	61	19	6	13	0	+	47
163	118	15	14	24	0	4	43	67	9	8	14	0	2	25
Total	595	115	71	109	1	72	452							

= 1415 grains

	Tree	Shrub	Herb %
135 cms.	57	35	8
145	45	33	22
155	55	17	28
158	53	23	24
160	40	20	40
163	40	11	49

GREEN SWANG 523m.

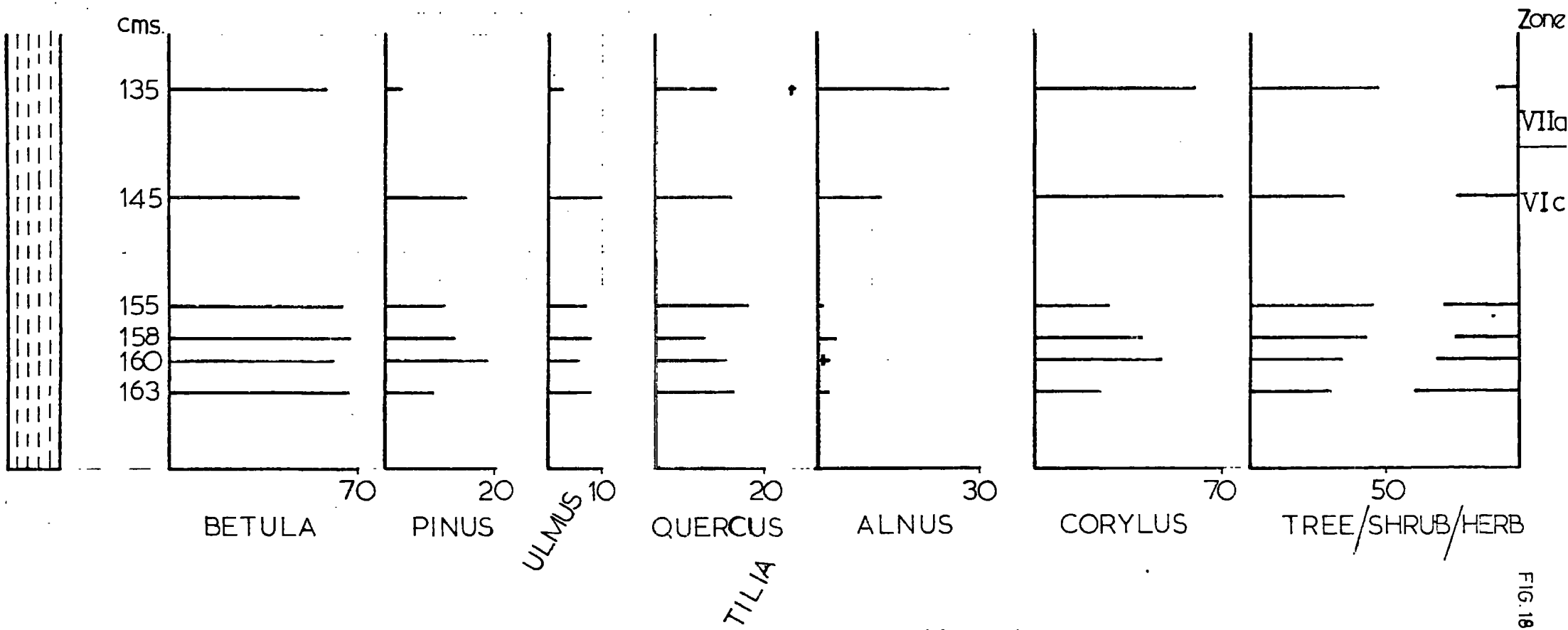


FIG. 18

is simply not represented at this site due to the fact that no peat was forming. The diagram is showing a late pine peak which is more frequently seen at upland sites eg. Moor House. Green Swang lies at 523 m.

The frequency of herb pollen at 163 cms is 49%, falling to 22% at 145 cms. which is again characteristic of upland sites where the forest does not necessarily develop a closed cover. At Green Swang, the relatively open boreal forest was composed of as much Quercus as Pinus, showing that at this site, Pinus established itself less successfully than one might expect in relation to data from Upper Teesdale (Turner et al 1973) and it is fairly easily invaded and overtaken by the mixed oak forest as the following table shows:

Depth (cms.)	Pinus%	Mixed oak %
135	3	14
145	15	24
155	11	24
158	13	17
160	19	19
163	9	22

The depth of the boreal peat is 30-40 cms. here, which may represent a slow rate of growth but it must also be borne in mind that only part of the boreal period is represented in the one core taken.

5. STANLEY MOSS

This large Moss, 371 m. x 84 m., is clearly marked on the 2½" O.S. map sheet NZ13 and is just visible from the B6299 road at a point 1.5 km. E. of Sunniside where a rise overlooks the plantation which otherwise hides it from view. The easiest access is from the minor road which runs parallel to the N. side of the Moss.

The particularly well-developed surface vegetation includes Eriophorum vaginatum, with Calluna vulgaris, Erica tetralix and Vaccinium myrtillus. There are several small pools, a perfectly circular one of about 3 m. diameter at the east end of the Moss is full of half-submerged Sphagna. A considerable area of Stanley Moss now lies under plantations to the E. and S.

In order to solve the problem of finding the deepest part of the peat, two lines of stakes were put out, the N/S line intersecting with the E/W line at a point exactly 40 m. from the fence on the N. side, and in line with two small trees visible against the horizon beyond the fence (Fig.19). Five borings were made at the places indicated on the sketch map. The surface of the bog is relatively even, so levelling was considered unnecessary. The bottom profile is shown on the scale diagram, fig.20.

The bottom of each core shows about 10 cms. of a compact pale creamy-grey silt, bearing streaks of yellow and pink. The extent of the transition varies slightly from 0-5 cms. Above this, the peat is extremely uniform, being dark brown and well-humified. There were some wood fragments concentrated mainly around 370 cms.

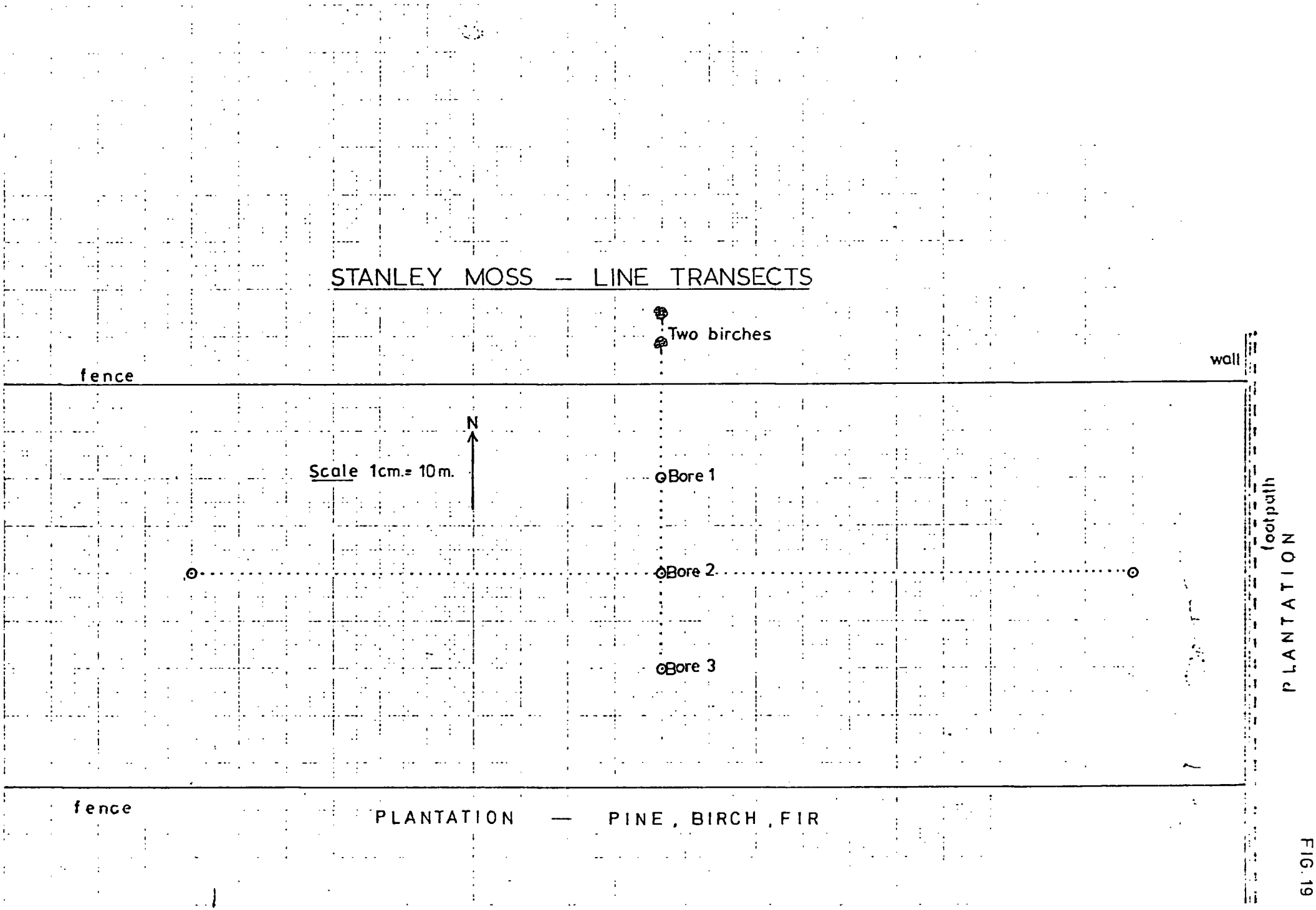
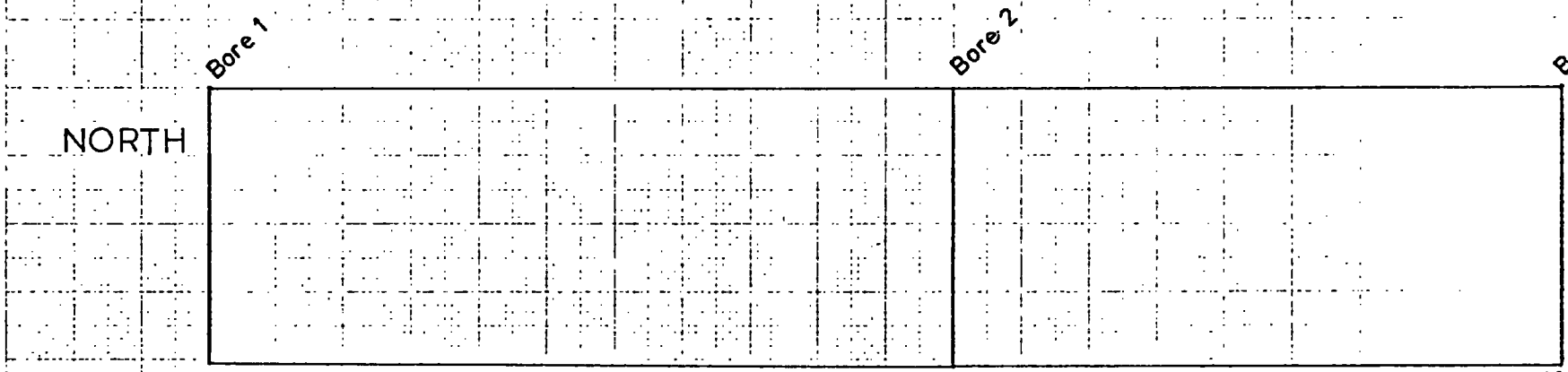

STANLEY MOSS — LINE TRANSECTS
Two birches
wall
fence
N
Scale 1cm.= 10m.
Bore 1
Bore 2
Bore 3
footpath
PLANTATION
fence
PLANTATION — PINE, BIRCH, FIR

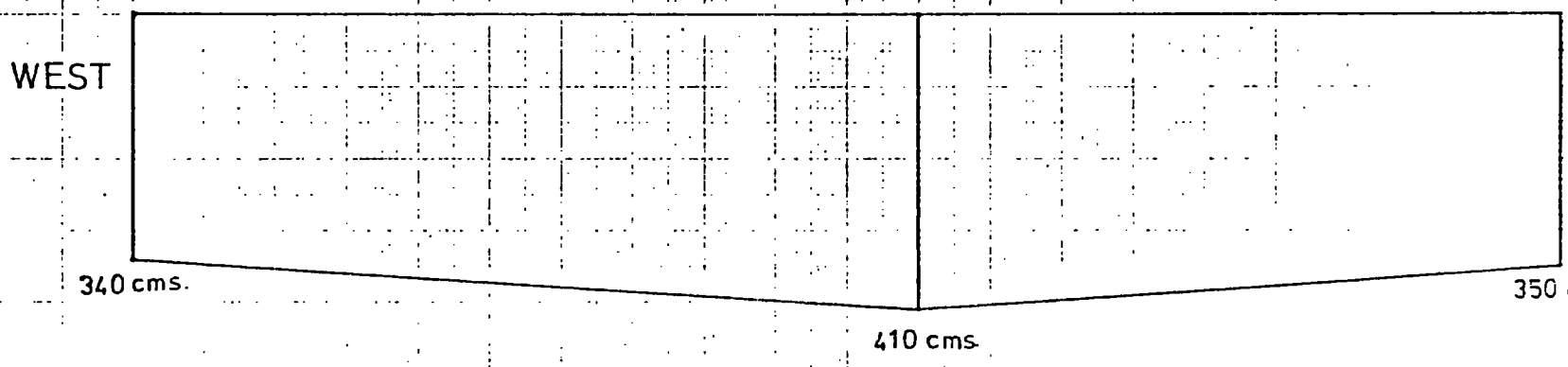
FIG. 19

STANLEY MOSS - BOTTOM PROFILES



SCALES

horizontal 1cm. = 2m.
vertical 1cm. = 1m.



SCALES

horizontal 1cm. = 10m.
vertical 1cm. = 1 m.

FIG.20

Bore 2, at the intersection of the two transect lines was used for analysis, being from one of the deeper borings.

When this core was analysed, the four samples taken at 10 cms. intervals were all found, rather disappointingly, to belong to zone VII. However an indication by Raistrick and Blackburn (1932) concerning the presence of high Pinus values in the clay and silt immediately below their Waskerley peat led to a similar investigation being made on Bore 2. The results obtained from the whole core are given (Fig.21) and the diagram constructed from them is shown on Fig. 22.

As clay and silt deposits are not built up in the same way or at the same speed as peat deposits, it would be quite wrong to over-emphasise the sequential nature of the information presented on Fig.22. However insofar as there is an indication of the presence of pine prior to zone VII, in which it is hardly represented at all, is of significance in the context of this work and is the only justification for placing Stanley Moss with the Boreal Sites.

In order to check more closely on the presence of pine in the top 10 cms. of silt, two slides were made up from Bore 3, at 404 and 408 cms. The counts are given at the bottom of Fig.21 and are plotted on a separate diagram, Fig.23. It is interesting that although the high value of 62% pine obtained from Bore 2 at 408 cms is not repeated at either 404 or 408 cms in Bore 3, there is nevertheless 22% pine at 408 cms. in this core.

INDIVIDUAL SITE DATA

SITE: STANLEY MOSS

Core Two

Depth cms.	Number of grains B	P	U	Q	T	A	C	As % total tree pollen B	P	U	Q	T	A	C
360	84	2	0	20	1	61	37	50	1	0	12	+	36	22
370	285	3	0	46	3	547	55	32	+	0	5	+	62	6
380	102	1	3	15	0	189	27	33	+	1	5	0	61	9
390	118	3	5	60	1	412	42	20	+	+	10	+	69	7
400	32	30	8	53	0	442	26	6	5	1	9	0	78	5
408	17	168	0	6	0	83	103	6	62	0	2	0	30	38
410	52	33	0	9	0	56	89	35	22	0	6	0	37	59
Total	690	240	16 = 3790	209	5	1790	379							

Core Three

404	5	22	1	28	2	98	28	3	14	+	18	1	63	18
408	11	46	1	40	1	120	22	5	21	+	18	+	55	10
Total	16	68	2 = 425	68	3	218	50							

		Tree	Shrub	Herb %
Core 2	360 cms	78	19	4
	370	92	6	2
	380	85	8	7
	390	85	6	9
	400	83	7	10
	408	66	28	6
	410	59	38	3
Core 3	404	73	15	12
	408	83	9	7

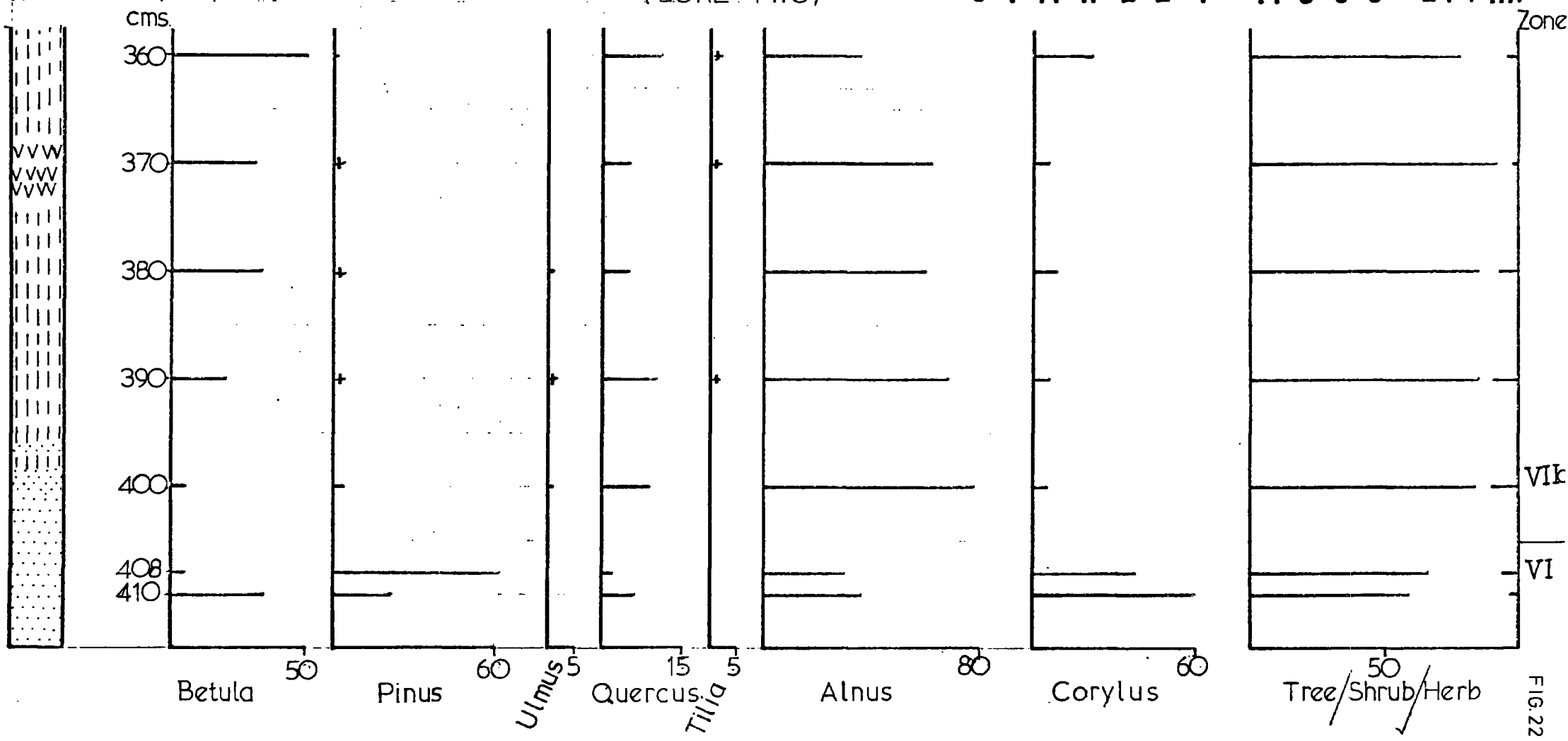

STANLEY MOSS 277m.
(BORE TWO)
cms.
360
370
380
390
400
408
410
Zone
VIb
VI
50
60
5
15
5
80
60
50
Betula
Pinus
Ulmus
Quercus
Tilia
Alnus
Corylus
Tree/Shrub/Herb

FIG. 22

(BORE THREE)

STANLEY MOSS 277m.

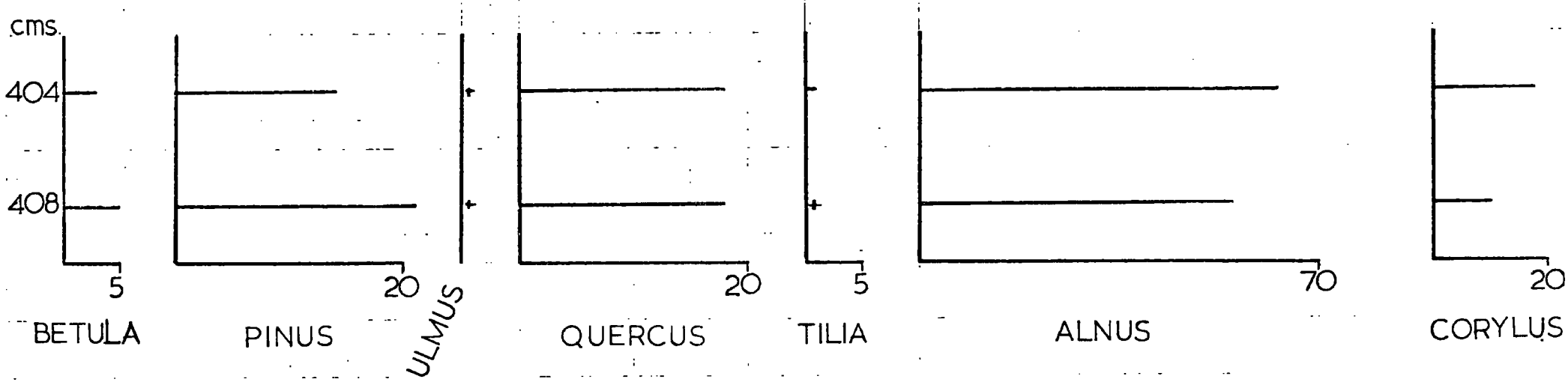


FIG. 23

Any imaginative picture of forest development at Stanley Moss using the scanty information available from these pilot bores must be viewed with discretion, but it would appear from figs.21,22 that the boreal forest was composed mainly of pine with hazel, alder and some oak. The proportion of pine to mixed oak forest as shownat 408 cms. in Bore 2 is about 30:1. But the proportion of pine to hazel at the same level is approximately 2:1, and the ratio to alder is very similar. From these figures, supported by information at other depths, two deductions can be made:

i) The mixed oak forest species had great difficulty in competing with other species in this area (maximum value for pooled mixed oak forest species = 12%).

ii) The alder values are high (30%) at the pine maximum and rise from this frequency at 408 cms. to a very substantial 78% by 400 cms.

6. SOUTH CORNSAY

The site lies on common land to the W. of the B6301, about 3 kms. N.N.E. of Tow Law. It is a wide area, 100 m. x 70 m., partly affected on the N.W. side by the effects of open-cast coal-mining. In early June it is covered with fruiting cotton grass which is easily visible from the road.

Closer examination shows a good cover of Calluna vulgaris, Erica tetralix and Vaccinium myrtillus too, while the edges of the bog have extensive areas of Juncus effusus.

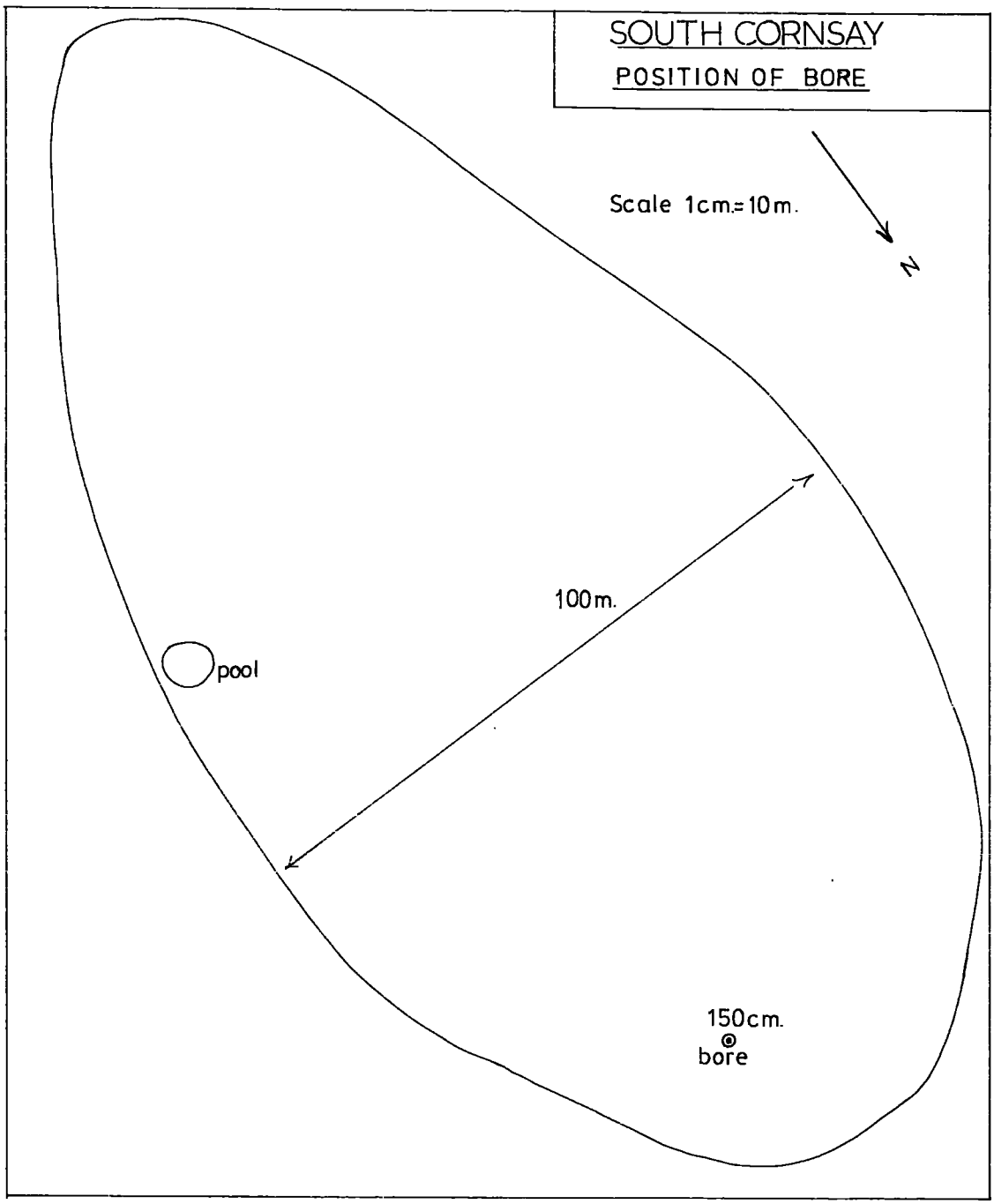
The bottom of the deposit is a soft yellowish-grey clay which was easily penetrated by the borer to a depth of 40 cms.

Pollen analysis of the rather wet peat produced an interesting series of results shown on Figs. 25 and 26. It is felt that, owing to their close proximity, South Cornsay and Stanley Moss might well be expected to give similar results.

Despite its relative shallowness (107 cms), the peat at South Cornsay does in fact contain more information about the boreal than the deeper peat (400 cms.) at Stanley Moss, and the VI/VIIa boundary line can be drawn between 95 and 98 cms. over which depth a perfect rise in Alnus frequency from 27 to 72% is matched by a fall in the Pinus percentage from 29 to 13%.

Points of special interest are first of all that the pine frequency is still 29% when Alnus has reached 27% at 98 cms. This places the pine value in the region of that found in the silt at Stanley Moss after the maximum of 62% so it is possible that the pine curve at South Cornsay is falling from a value somewhat less than its maximum. It is unfortunate that the

FIG. 24


SOUTH CORNSAY
POSITION OF BORE
Scale 1cm.=10m.
N
100m.
pool
150cm.
bore

INDIVIDUAL SITE DATA

SITE: SOUTH CORNSAY

Depth cms.	Number of grains							As % total tree pollen						
	B	P	U	Q	T	A	C	B	P	U	Q	T	A	C
90	22	0	0	6	0	79	20	21	0	0	6	0	74	19
91	27	1	1	38	1	332	40	7	+	+	10	+	83	10
93	43	8	0	21	0	274	49	12	2	0	6	0	80	14
95	23	21	0	0	0	114	36	14	13	0	0	0	72	23
98	65	44	0	0	0	41	186	43	29	0	0	0	27	124
Total	180	66	1	65	1	840	331							

= 1484 grains

	Tree	Shrub	Herb %
90 cms.	84	20	0
91	87	9	3
93	86	13	1
95	82	36	0
98	44	56	0

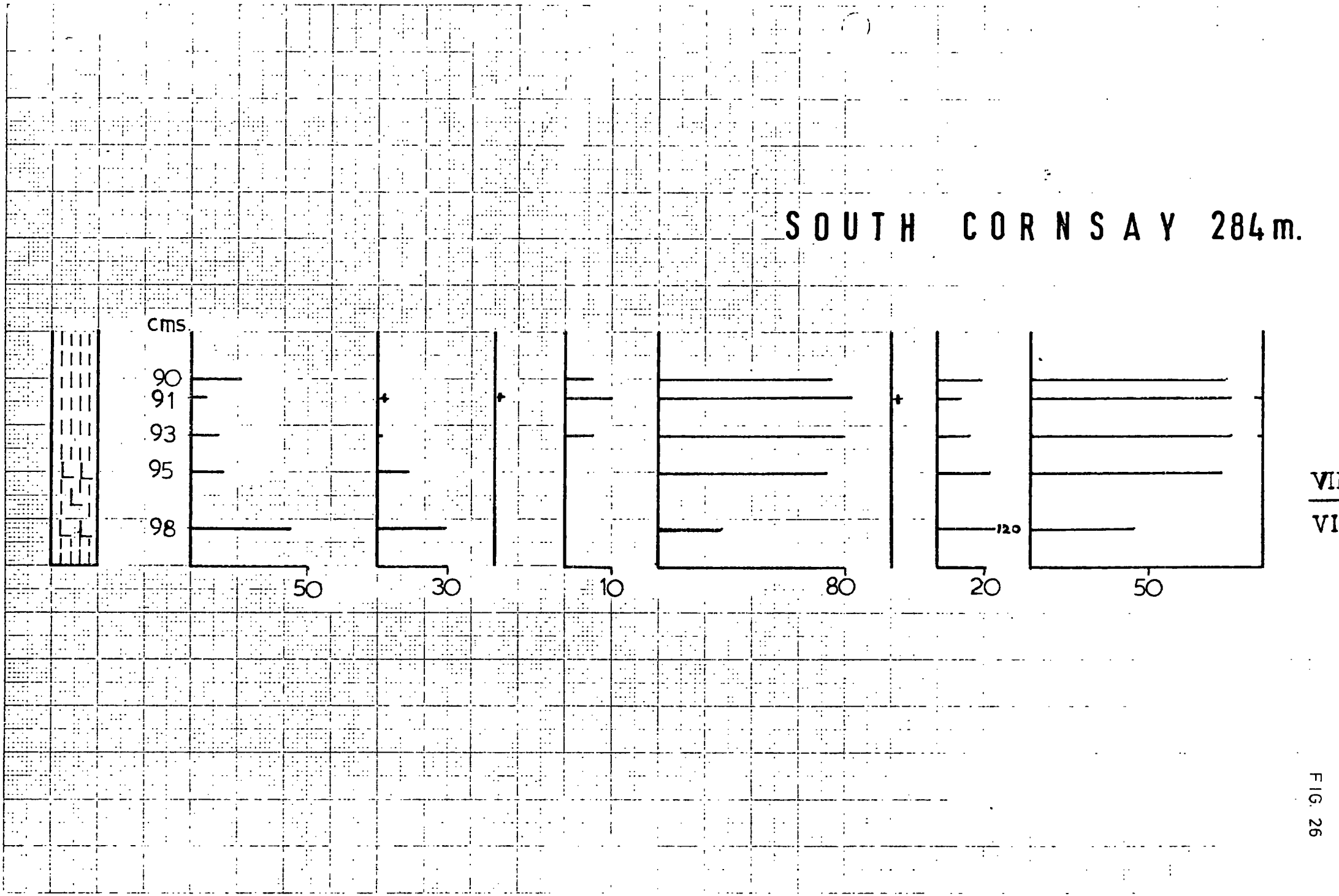

SOUTH CORNSAY 284m.
cms
90
91
93
95
98
50
30
10
80
120
20
50
VIIc
VI

FIG. 26

pollen preservation is less good in silt and clay than it is in peat, but analysis to greater depths at South Cornsay might well prove interesting from the point of view of attempting to find evidence concerning the true pine maximum.

Secondly, the Alnus frequency rises from 22% at the VI/VIIa boundary to 83% within 7 cms. of deposit. This exceptionally high value matches that found at Stanley Moss and opens up the whole question of the status of Alnus in Weardale during the Atlantic period. Unfortunately this tantalising issue can only be treated in rather general terms at this moment, but well deserves closer inspection, as high values like these restrict the expression of the mixed oak forest, especially at South Cornsay as shown below:

Site	Depth (cms.)	% frequency Pine	oak	elm	alder
South Cornsay	90	0	6	0	74
	91	+	10	+	83
	93	2	6	0	80
	95	13	0	0	72
	98	29	0	0	27
Stanley Moss	360	1	12	0	36
	370	+	5	0	62
	380	+	5	1	61
	390	+	10	+	69
	400	5	9	1	78
	408	62	2	0	30

Woodland at South Cornsay seems therefore to have been controlled by Alnus from the VI/VIIa boundary. Immediately before that time, Betula predominated, with Pinus and Alnus present in equal amounts. The mixed oak species seem to

have established themselves only with the greatest difficulty in the face of the massive development of Alnus and do not appear until well into zone VII. Betula and Corylus values are also very much suppressed by Alnus as shown below:

Depth (cms.)	% frequency: Betula	Corylus	Alnus
95	14	23	72
98	43	124	27

Note

Throughout this series of 6 sites, the rôle of elm is not obvious. An important component of the mixed oak forest, its representation on the pollen diagrams is slight relative to oak because it produces only half as much pollen (Andersen 1970).

FURTHER SUBDIVISION OF THE NEW SITES INTO GROUPS

BOREAL SITES

a) Full Boreal : Mown Meadows, Moss Mire North, Fortherley Moss.

b) Late Boreal : Green Swang, Stanley Moss, South Cornsay.

POST-BOREAL SITES

These are divided into three groups according to their Alnus frequencies. Exceptionally high Atlantic Alnus frquencies have already been noticed at South Cornsay and Stanley Moss, so it was considered worthwhile to group the Post-Boreal sites with this in mind. In this way, other areas in which the Atlantic forest was dominated by Alnus could be clearly seen.

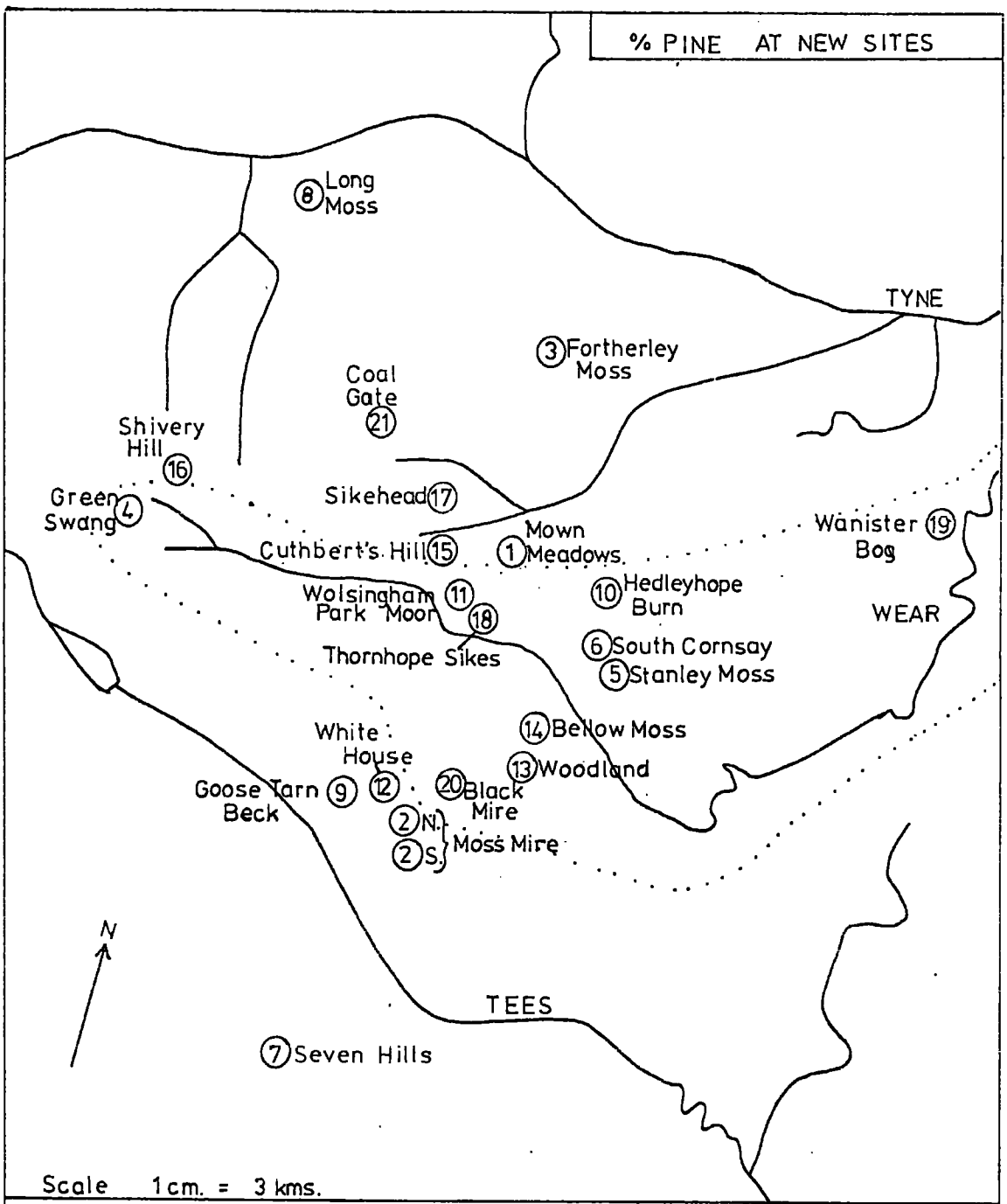
Group A: Very high Alnus%: Seven Hills
Long Moss
Goose Tarn Beck
Hedleyhope Burn

Group B: Normal or low Alnus%: Wolsingham Park Moor
White House
Woodland
Bellow Moss

Group C: Sites which for some reason do not fit into the above groups:
Cuthbert's Hill
Shivery Hill
Sikehead
Thornhope Sikes
Wanister Bog
Black Mire
Coal Gate.

As the sites in Groups A,B and C do not contribute directly to the subject of this dissertation but show a great deal of new and interesting data, their description has been tabulated as far as possible and is included in the Appendix.

FIG. 27



	SITE	% PINE		SITE	% PINE
BOREAL	1	50 - 81	POST-BOREAL GROUP B	11	< 12
	2	7 - 21		12	< 9
	3	6 - 48		13	< 8
	4	9 - 19		14	< 31
	5	22 - 62	GROUP C	15	0
	6	< 29		16	0
POST-BOREAL GROUP A	7	< 1		17	< 5
	8	< 2		18	< 1
	9	< 4		19	< 16
	10	0		20	0
				21	?

CORRELATION OF RESULTS AND DISCUSSION

The pilot borings were made in the area enclosed by the River Tyne to the N., the Pennine watershed to the W., and the River Tees to the S. Added to the information already available the results, as hoped, do provide a fuller picture of the distribution of *Pinus* in the boreal forests of the area.(Figs. 27, 28)

Altogether six new boreal sites were located and the microfossil evidence has been set out in the form of short pollen diagrams. The significance of this data with respect to published diagrams is evaluated for three of the valley systems in the area since it was by way of these that the pine spread to the uplands.

In interpreting pollen frequencies, it must be remembered that tree species differ in their capacity to produce pollen to an extent which must be reckoned with when building up a visual image of the forest cover. Andersen (1970), working on present-day pollen rain trapped in the ground layer of Danish forests has shown that if *Fagus sylvatica* is used as the standard because it flowers well on a variety of soil types, then other species are over-represented by their pollen, relative to the number of actual trees, in the ratio:

Quercus, Betula, Alnus, Pinus	1:4
Carpinus	1:3
Ulmus, Picea	1:2
Fagus, Abies	1:1
Tilia, Fraxinus	1:2

Reference has been made to Andersen's correction where this has a direct bearing on the interpretation of results. As the main species dealt with are all over-represented to the same degree except for *Ulmus*, this is the only species for which adjustment must be made while interpreting the diagrams here.

THE COMPOSITION OF THE BOREAL FORESTS OF THE NORTH-EAST OF ENGLAND

SITE		% FREQUENCY						
		BETULA	PINUS	ULMUS	QUERCUS	ALNUS	CORYLUS	ALT(m.)
Full Boreal represented								
Cranberry Bog	TYNE	30-80	1-33	5-20	2-30	0-15	45-710	90
Mown Meadows (new)		9-41	45-81	0-5	5-9	1-15	11-214	308
Pow Hill		5-58	25-87	6-24	1-13	0-10	12-120	230
Fortherley (new)		38-70	6-48	1-4	3-23	3-19	6-66	206
Burtree Lane	TEES	12-76	10-70	0-5	0-5	0-50	30-200	80
Dufton Moss		10-70	3-70	1-22	1-35	1-10	40-326	368
Hard Hill		30-90	10-22	0-25	0-20	0-30	120-562	692
Moss Mire N. (new)		60	7-21	10-20	0-15	0-1	177-620	285
Neasham Brick Pit		5-10	5-45	0	0-2	0-5	5-25	15
Neasham Fen		20-63	3-10	8-42	1-58	0-22	75-1020	"
Romaldkirk		5-35	2-6	8-25	3-45	0-5	30-450	240
Upper Valley Bog (J.&D.)		10-70	18-50	10-20	0-38	0-25	30-380	554
(C.C.)		1-28	25-50	8-20	20-42	0-15	48-72	"
Late Boreal only								
Waskerley	TYNE	10-22	40-78	20	20	5-30	18-190	338
Fox Earth Gill	TEES	3-52	10-52	5-30	12-50	1-42	44-190	538
Black Hill Base		8-32	38-60	17	5-12	2-5	146-224	425
Cronkley Fell Base		25-62	3-26	10-22	2-35	1-41	160-409	400
Red Sike RS I	Cow Green Sites	8-25	40-78	8-12	2-25	2-18	50-125	501
Tinkler's Sike TS I		8-28	60-88	0-10	0-40	0-30	2-201	501
Foolmire Sike		12-58	25-62	2-23	2-25	2-30	10-100	469
Dead Crook DCI		10-60	38-86	0-30	0-35	0-30	1-425	475
Weelhead WH I		5-40	58-85	0-10	0-30	0-50	5-144	469
Green Swang (new)	WEAR	48-68	9-19	6-10	9-17	1-11	25-70	523
South Cornsay (new)		44	29	0	0	29	120	284
Stanley Moss (new)		6-36	22-62	0-2	2-6	30-79	4-60	277

A) The Derwent Valley

The sites in the upper Derwent valley are ones which all show very high boreal pine maxima:

Pow Hill	87%
Waskerley	78
Mown Meadows	81

indicating that these reaches of the Derwent valley system were clothed in forests in which pine was the major species.

The ratio of tree/shrub/herb pollen indicates also that the forest, although rich in Pinus was not closed, but had many light-filled glades:

Site	Tree	Shrub	Herb	pollen %
Mown Meadows	54	24	22	
Pow Hill	65	23	12	

This situation resembles that found by Turner et al (1973) in Upper Teesdale except that there, the forest was even more open. The herb pollen frequency at the latter is high, averaging 35% as seen at Red Sike RS II.

It is interesting that the composition of the boreal forests in these two valley heads was similar in zone VI, even though the altitude is quite different.

Valley	Site	Alt. (m.)	Maximum % frequency of major tree species during the boreal					
			B	P	U	Q	A	C
Derwent	Pow Hill	230	58	87	24	13	10	120
	Mown Meadows	308	41	81	5	9	15	214
Teesdale	Tinkler's Sike I	501	28	88	10	40	30	201
	Weelhead II	469	75	70	30	40	30	425

A species which emerges as being more successful in Upper Teesdale than it was in the upper Derwent valley during the boreal is oak. This is difficult to understand. One would expect as

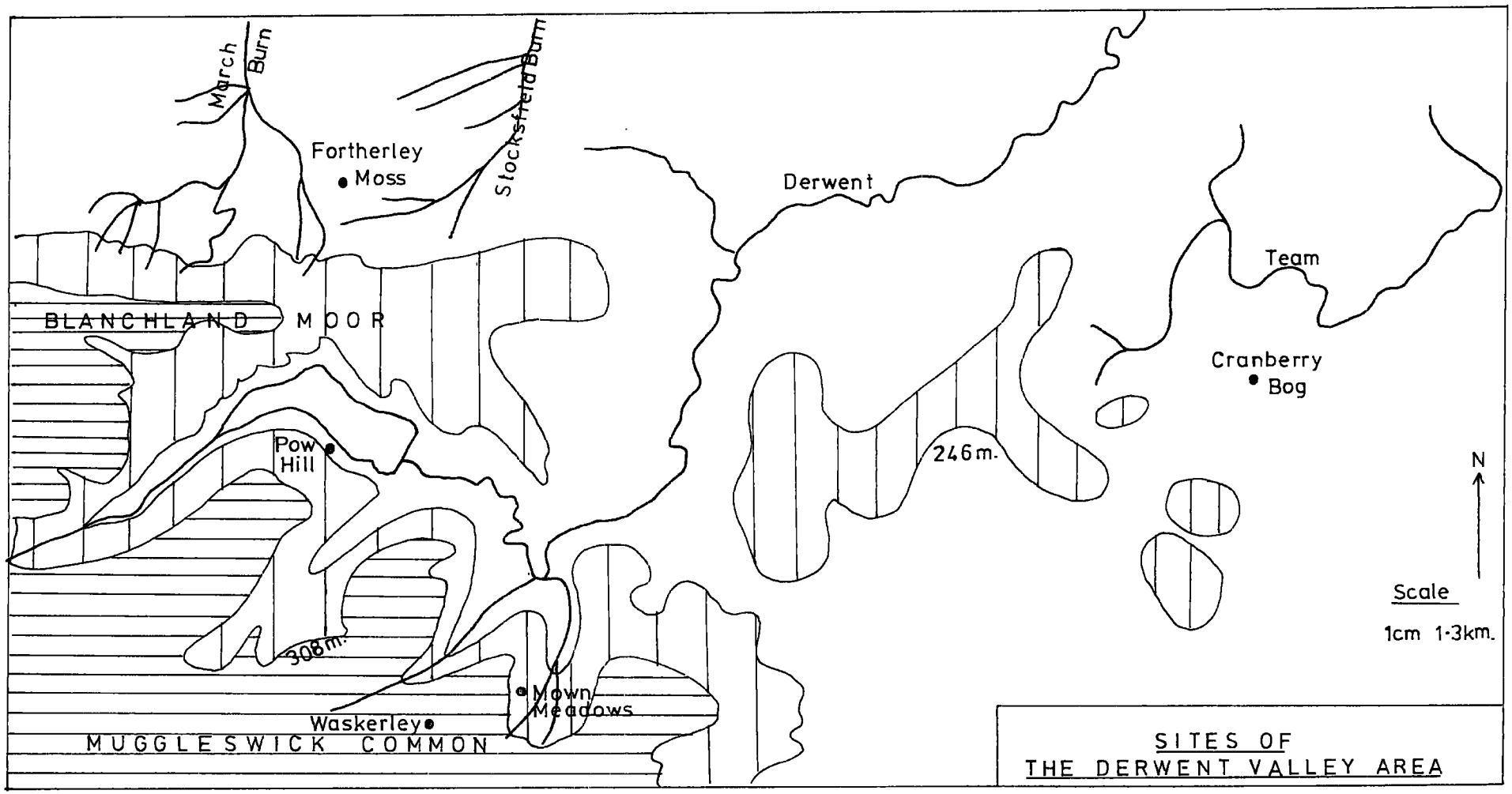

March Burn
Stocksfield Burn
Fortherley
Moss
Derwent
Team
Cranberry
Bog
BLANCHLAND MOOR
Pow Hill
246m.
N
Scale
1cm 1·3km.
308m.
Mown Meadows
Waskerley
MUGGLESWICK COMMON
SITES OF
THE DERWENT VALLEY AREA

FIG. 29

much oak or more in the Derwent valley as at the higher altitudes of Teesdale. The full expression of oak must have been depressed in the Derwent area by some specific factor, possibly a biotic one such as the feeding of herds of wild boar and deer. These animals would have found the climate of Upper Teesdale less congenial than that of the Derwent valley.

Alnus values are higher in Upper Teesdale too, but this is not so surprising as this species is very successful on wetter ground. Also, in the late boreal, Alnus frequencies are rising rapidly and there are differences in the speed at which the maximum is reached at different sites.

11 kms. N.N.W. of Mown Meadows and 100 m. lower is Fortherley Moss which lies just over the watershed of Blanchland Moor. Here the pollen counts have indicated a much lower pine maximum (48%), the boreal forest including more birch and oak than at the Derwent sites.

18 kms. E.N.E. of Mown Meadows and 200 m. lower is Cranberry Bog where the boreal pine maximum is only 33% but the birch, elm, oak and hazel are much more important components of the forest than at any of the sites so far mentioned. Cranberry Bog may thus be considered as a typical lowland site for the area. (Fig. 29)

These five sites, enclosed in a rectangular region measuring approximately 23 x 13 kms., show the increasing success of pine with altitude and the gradual change in forest composition from that at Cranberry Bog where the forest is fairly dense but is mainly deciduous (the pine maximum = 33%), through mid-altitude sites typified by Fortherley Moss where the forest is more open

but pine is more important than any other tree species, to higher sites like Pow Hill and Mown Meadows where the pine is by far the most successful tree species.

Raistrick and Blackburn's results at Waskerley indicate that this pine forest, the presence of which has now been demonstrated at the upper valley sites of Pow Hill and Mown Meadows, also spread across the intervening spurs at about 300 m. altitude. If this were to be true for all similar spurs in the area, the Derwent Forest may have extended over the whole of Muggleswick Common and Blanchland Moor, thinning only on the more exposed hilltops a little further W. and giving way to deciduous forest gradually below 200 m.

B) Upper Weardale and Upper Teesdale

As only one boreal site, Green Swang, was discovered in Upper Weardale, this part of the discussion is based on slender evidence. Nevertheless, an attempt is made to see the boreal forest development at this site against the background provided by Turner et al (1973), Johnson and Dunham (1963) and Chambers (1974) for Upper Teesdale.

With respect to altitude and siting, Green Swang (523 m.) is quite closely paralleled by Upper Valley Bog (554 m.) which is 12 kms. away to the S.W. in Teesdale and therefore it might be expected that forest development at the two sites would have followed roughly the same course. But comparison of the percentage frequency ranges for major species in zone VI brings to light some unexpected differences which show that Green Swang with its low pine percentages is more like Hard Hill (692 m.), the highest boreal site in the area for which a full pollen diagram is available (Johnson and Dunham).

		% frequency ranges in zone VI					
Site	Alt(m.)	B	P	U	Q	A	C
U. Valley Bog	554	1-28	25-50	8-50	20-42	0-15	48-72 (C.)
" " "	"	10-70	18-50	10-20	0-38	0-25	30-380(J.&D.)
Green Swang	523	48-68	9-19	6-10	9-17	1-11	25-70
Hard Hill	692	30-90	10-22	0-25	0-20	0-30	120-562(J.&D.)

Another important point is that both sets of figures for Upper Valley Bog indicate a very successful development of oak and elm, the percentage sum rising to a maximum of about 60% of the total tree pollen (and it must be remembered that elm is always less well represented than oak) , whereas at Green Swang these were found in

considerably smaller quantities: a total of 27% at maximum in the core taken.

Bearing in mind the question of over-representation and taking the results at their face value, it would seem that the forest at Green Swang was most probably a very sparse development mainly of birch and hazel similar to that seen at Hard Hill which is 169 m. higher. It may well be that closeness to the windswept Pennine ridge rather than actual altitude is the factor determining the upper limit of pine growth in the area. Hard Hill is $2\frac{1}{2}$ kms. E. of the ridge and Green Swang a mere $1\frac{1}{2}$ kms. Upper Valley Bog on the other hand has a high pine percentage and is situated further E. at a lower altitude in a relatively more sheltered position.

If there is a parallel between events in Upper Teesdale and those in Upper Weardale during the boreal, then the poor development of pine in the exposed parts next to the Pennine watershed should give way in both cases to extensive pine forests in the more sheltered upland sites further east and being sporadic in the lowlands. In Weardale therefore, it might be profitable to search more closely in the St. John's Chapel and Westgate areas for peat deposits likely to contain a record of the boreal forests.

C) The middle and lower reaches of Weardale and Teesdale

The valleys will be considered in turn and an attempt made to establish the pattern of Pinus distribution in each, then any points which arise in comparison between the two valleys can be discussed.

i) Weardale

The two peat bogs which have yielded boreal information are Stanley Moss and South Cornsay, both of which are new sites near Tow Law. They have proved to be problematic due to the fact that there is such a small depth of boreal deposit at the bottom and this is for the most part silt, rather than peat which began to form properly in Zone VII.

From the record which is preserved, the forests of mid-Weardale appear to have been fairly dense (herb pollen frequency range 0-6%) and with quite a lot of pine. Tree pollen amounts to between 40 and 65% of the total pollen rain and of this, most pollen apart from pine is of alder and birch with variable oak (0-18%). The pine frequency reaches a maximum of 29% at South Cornsay and 62% at Stanley Moss which is a considerable difference for two sites considering they are only 3 kms. apart.

ii) Teesdale

A good deal of information is available for the mid and lower reaches of Teesdale and diagrams have been published from the following sites: Romaldkirk and Burtree Lane (Bellamy et al 1966), Neasham Brick Pit (Blackburn 1954) and Neasham Fen (Chambers 1974). The newly-discovered site at Moss Mire North is about 4 kms. from Romaldkirk (see sketch map fig.30 for all these sites).

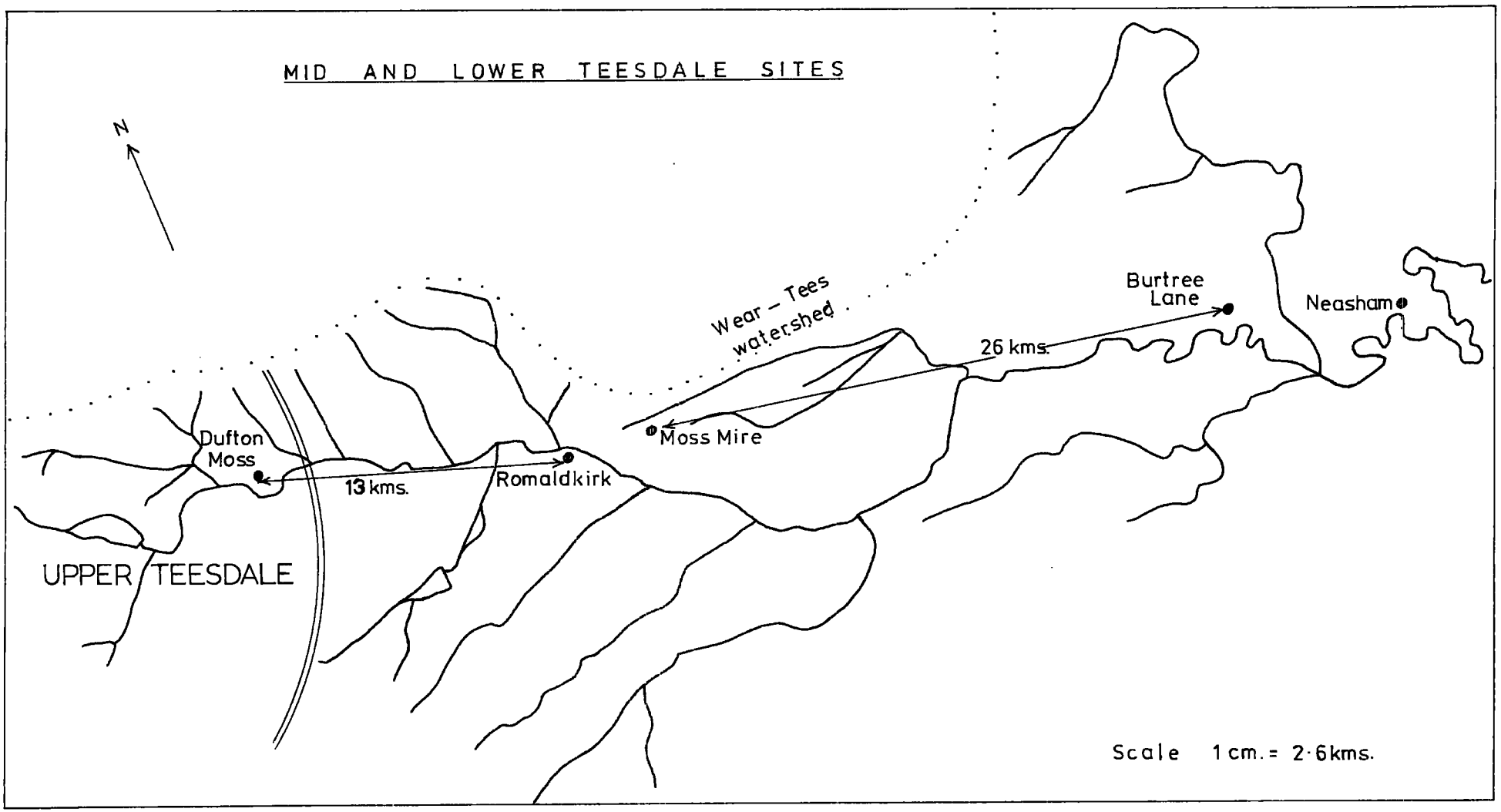

MID AND LOWER TEESDALE SITES
N
Wear – Tees watershed
Burtree Lane
Neasham
26 kms.
Moss Mire
Dufton Moss
13 kms.
Romaldkirk
UPPER TEESDALE
Scale 1 cm. = 2·6 kms.

FIG. 30

In lower Teesdale the pattern is complex. Results at the three sites are startlingly different and therefore indicate a mosaic pattern of distribution:

maximum pine frequency	Burtree Lane	70%
	Neasham Fen	10
	Neasham Brick Pit	45

Mid-Teesdale shows what appears to be a simpler pattern of distribution, judging by the evidence available so far from Romaldkirk and Moss Mire North. Both of these sites have low pine values as has Moss Mire South, although this latter was a difficult site.

maximum pine frequency	Romaldkirk	6%
	Moss Mire North	21
	Moss Mire South	17

D) <u>The distribution of pine in the whole of Teesdale and Weardale</u>

i) <u>Teesdale</u>

To be added to the picture of pine distribution which is being built up is the detailed account by Turner et al for the Cow Green area of Upper Teesdale. Here, frequencies are very high in the main (fig.28) yet at the same time showing a surprising amount of local variation in the mean values at the closely-positioned sites:

Foolmire Sike	35.8%	difference = 43%
Weelhead Moss L	78.8	

This type of variation seems to have been noticed by Squires (1970) in the Cronkley Fell area of Upper Teesdale although his sites are further apart than the two above:

Fox Earth Gill	52%
Black Hill Base	60
Cronkley Fell Base	26

Thus the overall pattern of pine frequemcies for Teesdale, beginning with the lower reaches and working upwards to the west is

a) a mosaic distribution with some areas of very high pine in lower Teesdale

b) low pine in mid-Teesdale

c) higher pine in most of the Cronkley area of Upper Teesdale

d) very high pine in most of the Cow Green area

e) intermediate pine values at Upper Valley Bog

f) low values again at Hard Hill, the highest Teesdale site.

This reasonably clear picture of pine distribution in Teesdale contrasts very strongly with that already drawn for the Derwent valley (with Cranberry Bog) where pine frequencies increased regularly with altitude. Because Weardale lies between these two areas, it is now very important to find out how its pine distribution compares with the patterns established for Teesdale and the Derwent valley.

ii) Weardale

At the head of the valley, pine values at Green Swang bear a distinct resemblance to those at Hard Hill in Teesdale, but in Mid-Weardale, the moderately high pine frequencies of Stanley Moss and South Cornsay seem more closely to resemble those of the Derwent area 10 kms. away than they do the mid-Teesdale ones from twice that distance. It is interesting to note that the altitudes of the sites in the Derwent area, mid-Weardale and in mid-Teesdale are very similar:

Derwent	eg.	Mown Meadows	308 m.
Wear		South Cornsay	284
Tees		Moss Mire North	285

As to the lower reaches of the Wear, very little information is so far available. Wanister Bog near Chester-le-Street has indicated 16% pine but the zonation is confused at this site and a more detailed analysis is needed. No other site has been discovered. There are some figures (D.Bartley, unpublished) from sites outside the Wear catchment which hint at extension of the lowland mosaic found in Teesdale:

Bishop Middleham (21 kms. N. of Neasham)	52% pine in zone VI
Thorpe Bulmer (Hart, near Hartlepool)	5

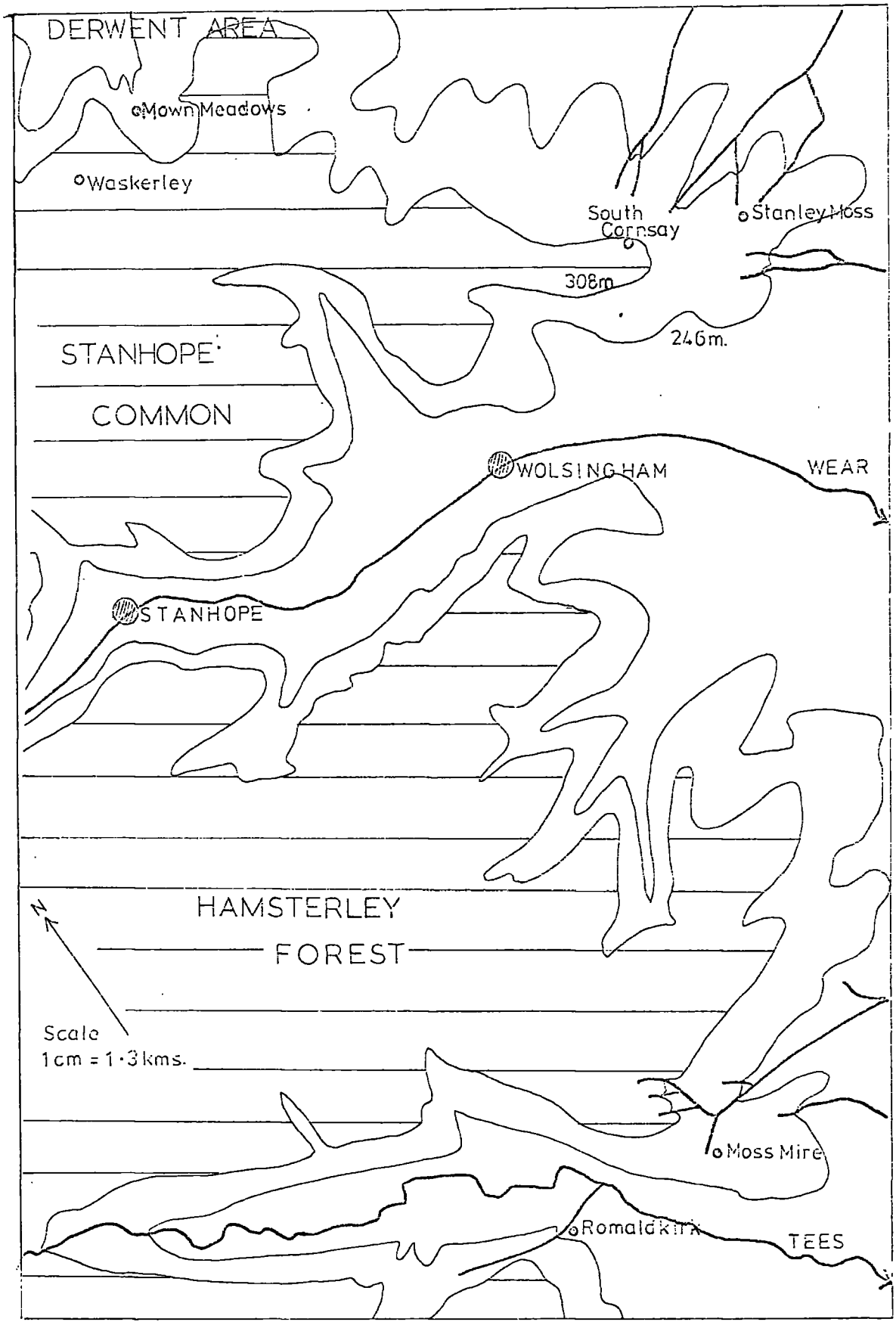
and the pine maximum at Cranberry Bog (River Team catchment) is given as 33% by Turner and Kershaw (1973).

OVERALL SUMMARY

Interpreting what has so far been established about pine distribution in this area of N.E. England during the boreal, it therefore seems likely that the lowlands to the east were mainly covered by deciduous forest in which patches of intensive pine development remained whereas, over major portions of the hilly country rising to the west, pine was much the most important species until conditions very near the Pennine watershed caused its frequency to drop quite sharply.

It is just possible that the rather dense pine forest stretching across Blanchland Moor and Muggleswick Common also reached into mid-Weardale via Stanhope Common and Wolsingham Park Moor (where there was still 12% pine in zone VII). Whether it could have extended yet further and S.W. to the higher reaches of Teesdale is a matter for Conjecture. Perhaps the splendid pine forest of Cow Green

FIG. 31



THE POSITION OF MID-WEARDALE SITES
WITH RESPECT TO THE DERWENT AND MID-TEESDALE

was directly connected to it over the Wear/Tees watershed. How exciting it would be in this context to find a boreal deposit with high pine on Bollihope Common for example, and to make really sure of the connection, one on Langdon Common (see Fig.32)

The attempted distribution map answers the question "where?" up to a point, but it poses the question "why?" and it is very difficult to find a satisfactory reason for the particular pattern of distribution of Pinus which is proposed above.

Published works on the ecology of Pinus sylvestris are mainly concerned with the characteristics of the species as seen from the following two points of view:-

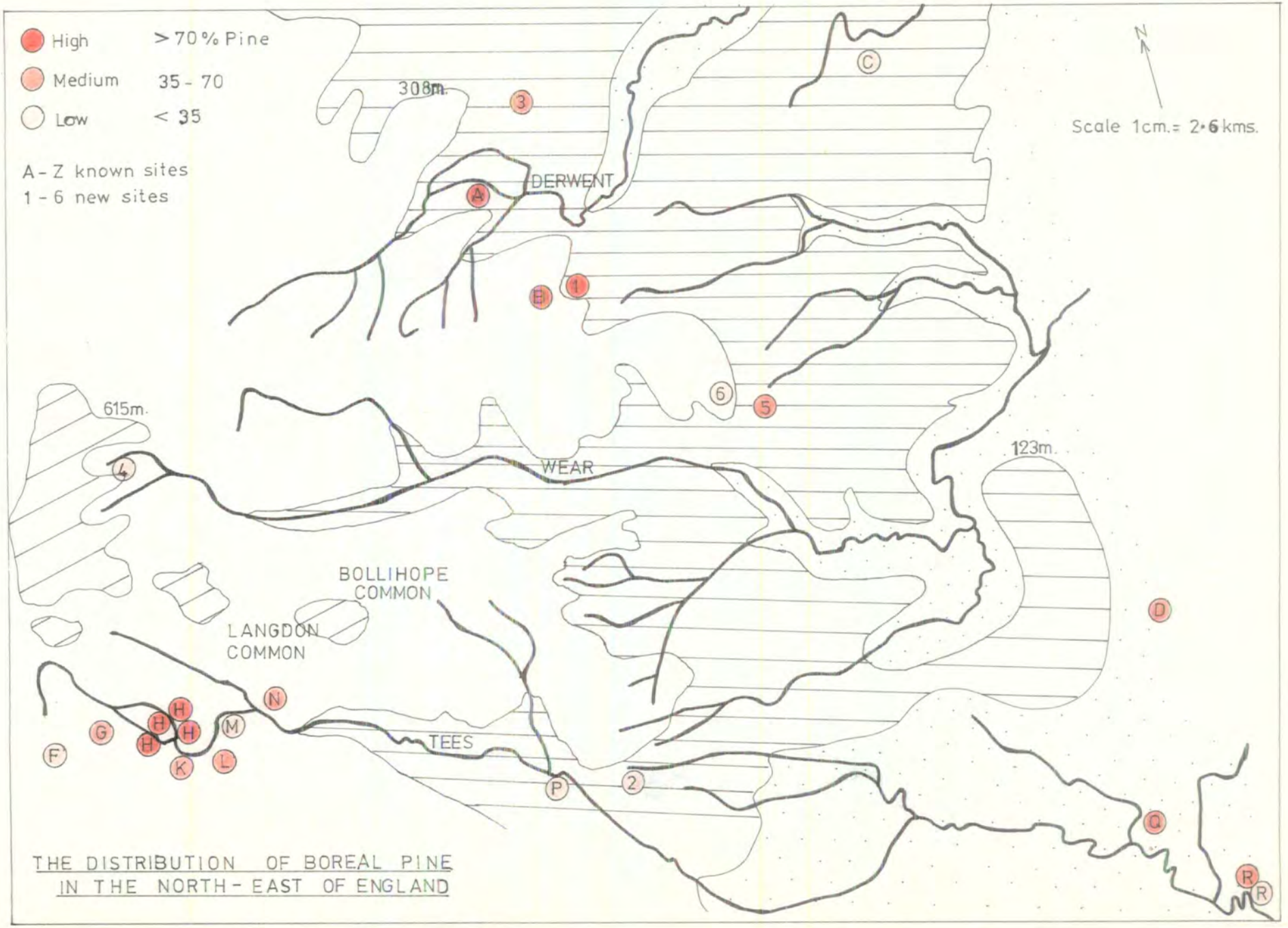
a) the regeneration of pine forest in the present-day context

b) pine as a relict species in restricted areas of Scotland.

Unfortunately, neither of these aspects can give enough information about the competitive power of pine in the conditions found during the boreal in the area studied.

Pine is said to prefer light sandy soils which are acid. These it found in the Derwent area, but it has been shown to have been equally successful on the sugar limestone of Upper Teesdale. It was also the major species to colonise the limestone hills of Greece while Northern Europe was covered with ice during the Devensian. Thus attempts to correlate high pine with any particular soil type seem doomed to failure.

As there also seems to be no really clear correlation between pine frequency and altitude (with its related climatic features),



THE DISTRIBUTION OF BOREAL PINE IN THE NORTH-EAST OF ENGLAND

FIG. 32

it becomes more and more difficult to discover reasons behind the patterns which are emerging from this study. Carlisle and Brown (1968) qoute Wright and Baldwin (1957) who describe Pinus sylvestris as exhibiting a number of "geographic ecotypes". Apparently there is continuous variation in morphological and anatomical features throughout the species and this may well extend to physiologocal features. It may be on this basis that the distribution of the species will be finally understood.

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My especial thanks go to Dr. Judith Turner who suggested this particular project and who followed its progress with such interest throughout. Her expert guidance and encouragement have been greatly appreciated.

APPENDIX

DATA CONCERNING POST-BOREAL SITES

Site	Approx. size	Surface vegetation	peat depth	probable zone
Group A				
7. Seven Hills	800x400m.	Calluna, Eriophorum, Sphagnum	382cms.	VIIa or b
8. Long Moss	1500x50	" " "	213	VIIb
9. Goose Tarn Beck	80x20	Juncus	235	VIIa or b
10. Hedleyhope Burn	10m. diam.	Eriophorum, Calluna, Vaccinium	33	VIIb
Group B				
11. Wolsingham Park	150x150	Eriophorum, Sphagnum	160	VIIa
12. White House	100x70	Juncus	160	VI or VIIa
13. Woodland	100m. diam.	Calluna, Eriophorum	31	"
14. Bellow Moss	100x60	Juncus, sedges, herbs, thistles	150	"?
Group C				
15. Cuthbert's Hill	blnkt. peat	Calluna, Eriophorum, Sphagnum	220	VIIa
16. Shivery Hill	150m. diam.	" " "	27	VIIb
17. Sikehead	10m. diam.	Sphagnum, Juncus	150	VIIb
18. Thornhope Sikes	patches	Calluna, Sphagnum, Eriophorum	90	VIIb
19. Wanister Bog	300x75	Grasses, thistles, herbs	170	late glacial to VIIb
20. Black Mire	100x65	Calluna	235	-
21. Coal Gate	100x50	Juncus	120	-

ACCESS AND POSITION OF BORINGS POST-BOREAL SITES GROUP A

Site 7.Seven Hills

5 kms. west of Bowes on the Gilmonby to Sleightholme road the group of low hills is seen to the S. Although very big, the site is hidden between the trigonometrical survey point on Citron Seat and Bow Hills Head, being nearer the latter. It is reached from the road by following the wall marked on the 1" O.S. Sheet 84 (Teesdale).

The boring was made roughly in the middle of the bog on an imaginary line joining Citron Seat and Bow Hills Head. The peat was deeper here (382 cms.) than at the N. end where only 200cms were found.

Site.8 Long Moss

Long Moss if parallel to Stublick Sike, 1.5 km. due S. of Low Stublicck Farm which is reached from the B6305 road midway between Hexham and Allendale Town.(1" O.S. Sheet 77 Hexham) Stublick Sike is easily crossed. Long Moss is vast. The boring was made 5 m. in from the N. edge at a point due S. of Low Stublick Farm. Deeper peat may well be found elsewhere, but this bore went to 293 cms.

Site 9. Goose Tarn Beck

Almost 7 kms. S.W. of Woodland on the B6282, the site is easily reached on foot from the road. The scew auger was used at a point c. 25 m. from the plantation edge and on a Sphagnum patch in the middle of the Juncus - coverdd channel.

Site 10. Hedleyhope Burn

A small circular site, noticeable when travelling from Lanchester to Tow Law on the B6301, provided the Eriophorum is fruiting. Just above the bed of Hedleyhope Burn on the S. bank, it faces a tributary coming in from the W. Open cast mining has occured between the site and the road. The peat in the centre of the bog was found to be shallow (33cm)

ZONE VII SITES

Group A

WITH UNUSUALLY HIGH ALNUS LEVELS

SEVEN HILLS - SITE 7

Depth cms.	Number of grains							As % total tree pollen						
	B	P	U	Q	T	A	C	B	P	U	Q	T	A	C
375	29	1	0	9	0	111	54	19	+	0	6	0	74	36
380	32	2	3	7	0	106	69	21	1	2	5	0	71	46
384	58	1	4	5	0	39	40	54	1	4	5	0	36	37
	119	3	7	21	0	256	163							
	= 569 grains													

LONG MOSS - SITE 8

270	37	1	1	25	0	365	16	9	+	+	6	0	85	4
280	25	6	0	19	0	262	18	8	2	0	6	0	84	6
290	12	1	0	18	0	219	10	5	+	0	7	0	88	4
	74	8	1	62	0	846	44							
	= 1035 grains													

GOOSE TARN BECK - SITE 9

185	10	1	0	27	0	40	12	13	1	0	35	0	51	15
187	4	1	0	10	0	47	15	6	2	0	16	0	76	24
195	33	6	3	27	2	92	27	20	4	2	17	1	56	17
	47	8	3	64	2	179	54							
	=357 grains													

HEDLEYHOPE BURN - SITE 10

33	47	0	0	29	1	67	60	31	0	0	19	+	43	40
35	51	0	0	16	2	92	49	32	0	0	10	1	57	30
	98	0	0	45	3	159	109							
	= 414 grains													

Group A (cont.)

	Depth cms.	Tree	Shrub	Herb %
Seven Hills	375	63	28	9
	380	61	30	10
	384	65	25	10
Long Moss	270	85	5	10
	280	86	5	9
	290	80	8	12
Goose Tarn Beck	185	67	17	16
	187	53	22	25
	195	61	13	26
Hedleyhope Burn	33	68	27	5
	35	65	21	14

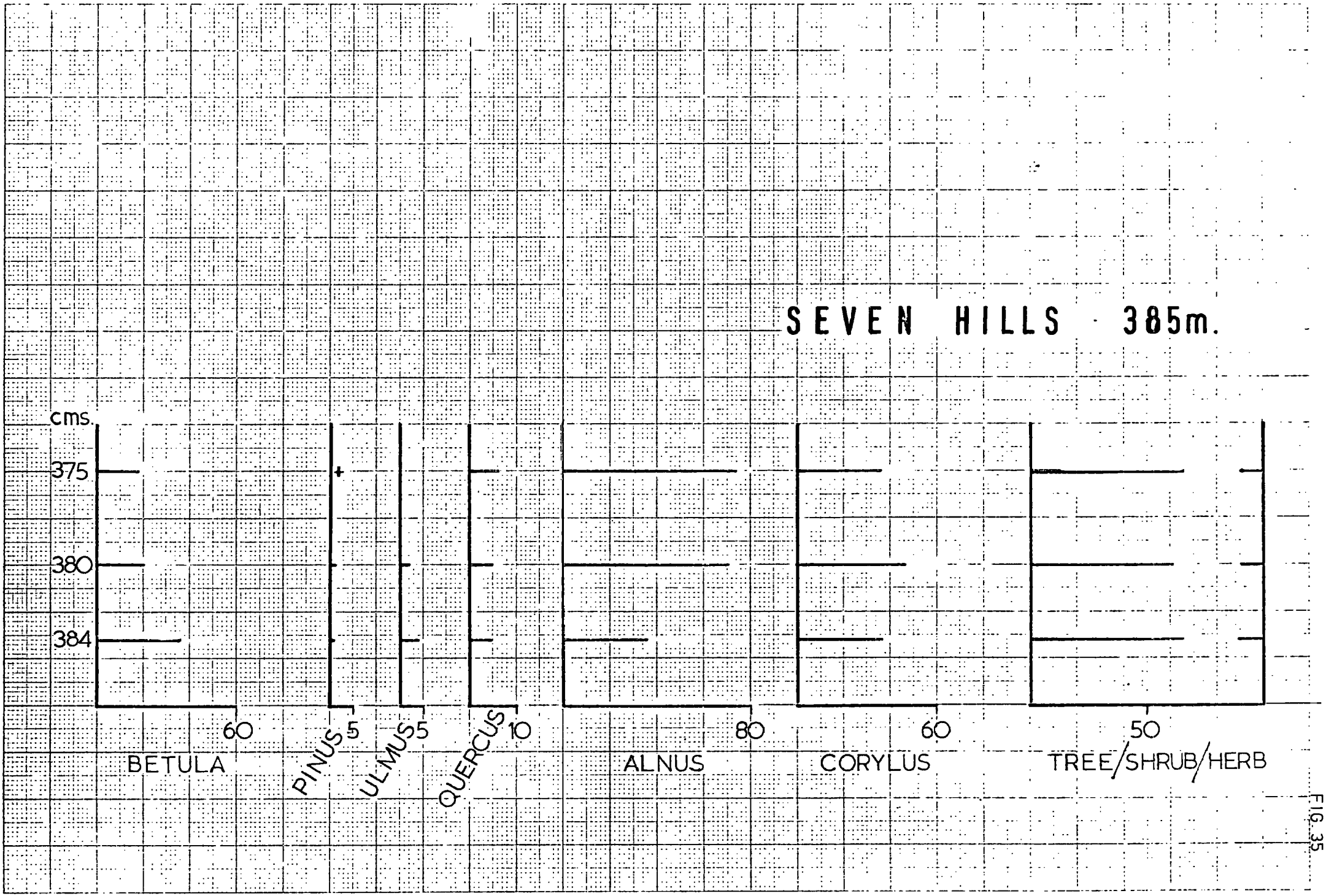
SEVEN HILLS · 385m.
cms.
375
380
384
60
BETULA
PINUS 5
ULMUS 5
QUERCUS 10
80
ALNUS
60
CORYLUS
50
TREE/SHRUB/HERB

FIG. 35

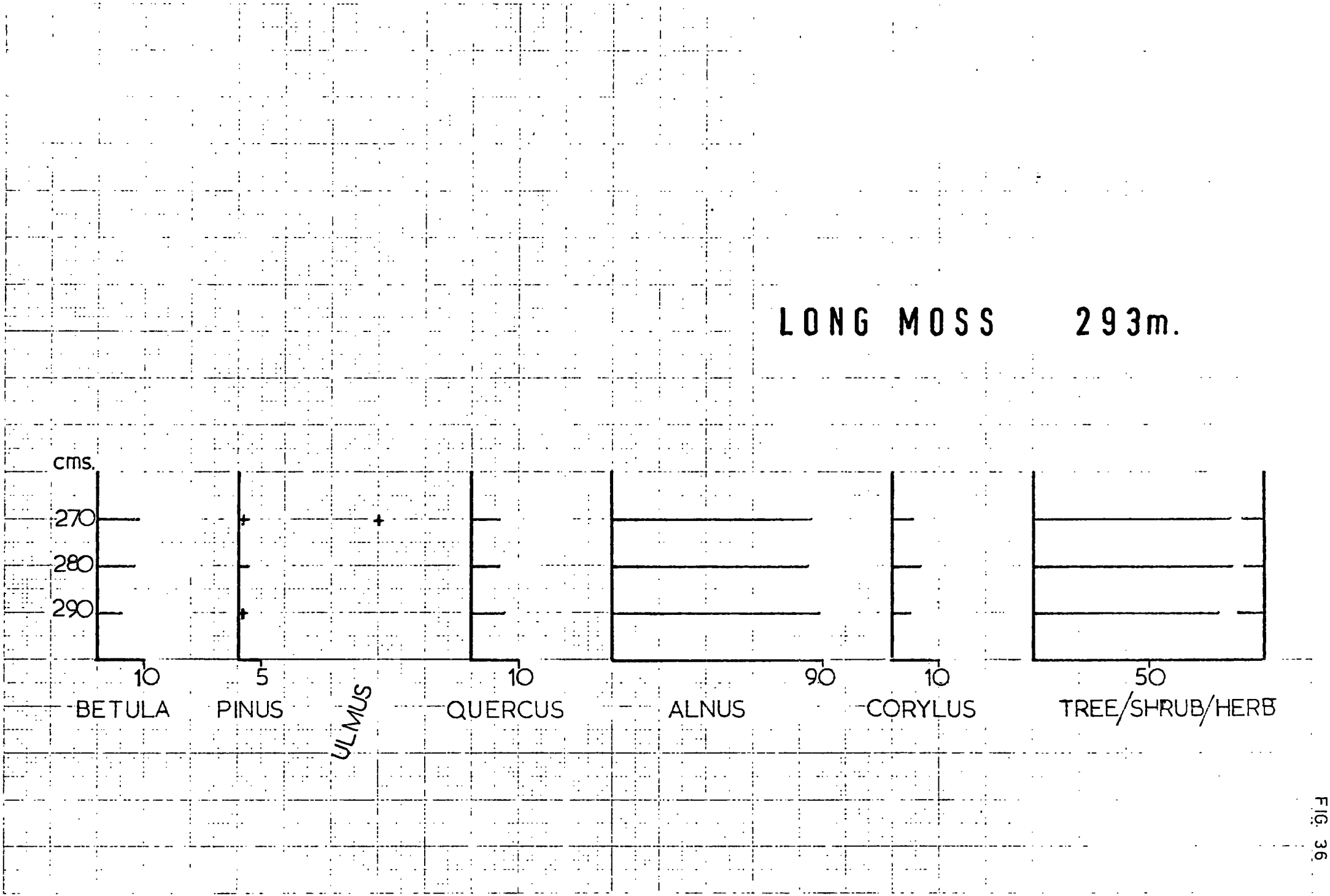
LONG MOSS 293m.
cms.
270
280
290
10
BETULA
5
PINUS
ULMUS
10
QUERCUS
90
ALNUS
10
CORYLUS
50
TREE/SHRUB/HERB

FIG. 36

GOOSE TARN BECK 335 m.

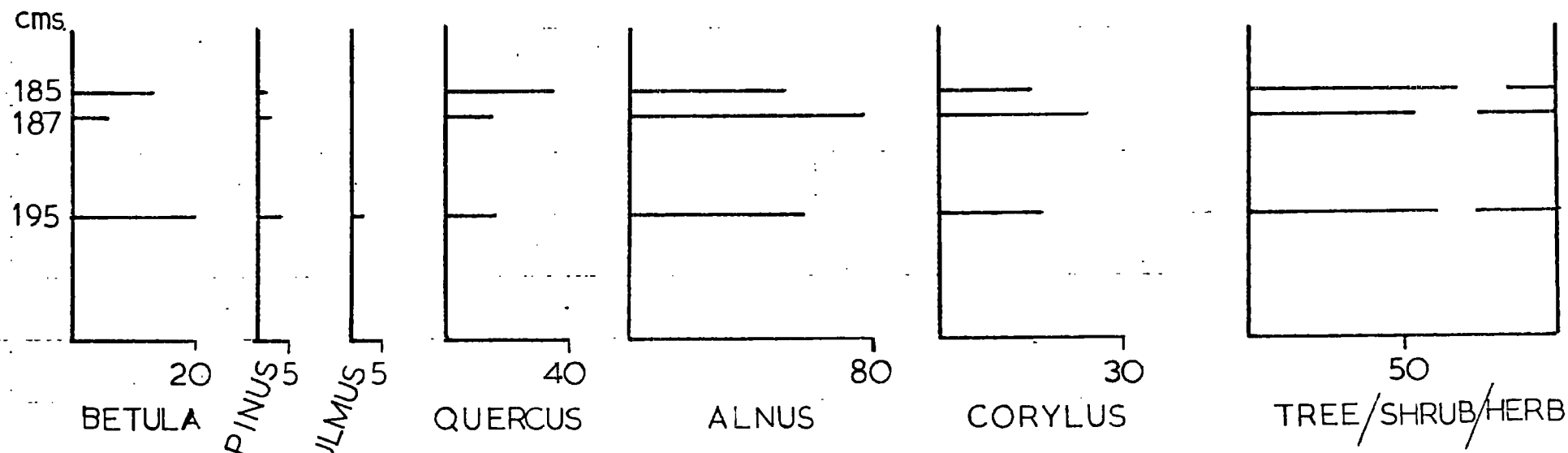

FIG. 37

HEDLEYHOPE BURN 260m.

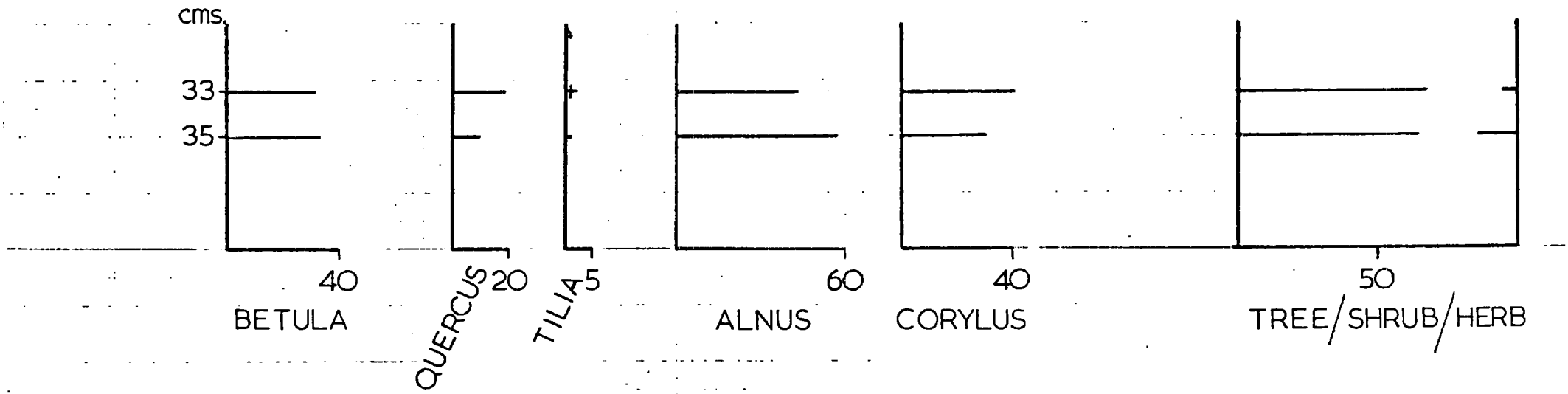

FIG. 38

ACCESS TO POST-BOREAL SITES, GROUP B

Site 11. Wolsingham Park Moor

Most easily accessible from the Tunstall reservoir, this beautiful site is enclosed by a dry stone wall to the W. and S. (gates) and is on a managed grouse moor. Permission for access may be sought from Mr. T.R. Fenwick, Bishop's Oak, Wolsingham. Tel. 435.

Site 12. White House

Very near Goose Tarn Beck but in a dip to the N., immediately by the roadside. Permission is needed to bore the site from the Teesdale Warden.

Site 13. Woodland

The site is seen immediately on the left when leaving Woodland on the minor road to the N.E. The landowner may refuse permission to bore. About seven places in the N.E. sector were tested, but none were deeper than 50 cms.

Site 14. Bellow Moss

In the dip 100 m. N.E. of Ruddy Carr. There is no access by Dryderdale estate. The estimated middle of the bog gave a peat depth of 150 cms. The owner lives at St. John's nearby.

ZONE VII SITES

Group B

WITH MEDIUM ALNUS

WOLSINGHAM PARK MOOR - SITE 11

Cms.	Number of grains B	P	U	Q	T	A	C	As % total tree pollen B	P	U	Q	T	A	C
150	14	4	1	5	0	8	18	44	12	3	16	0	25	56
158	36	4	3	35	2	33	62	32	4	3	31	2	29	55
	50	8	4	40	2	41	80							
	= 225													

WITH LOW ALNUS

WHITE HOUSE - SITE 12

140	335	5	4	51	1	21	75	82	1	11	12	+	5	18
145	139	2	9	33	0	16	53	69	1	4	16	0	8	27
163	215	12	24	91	1	19	274	59	3	7	25	+	5	76
168	80	14	9	31	0	22	392	51	9	6	20	0	14	250
	769	33	46	975	2	78	869							
	= 2772													

WOODLAND - SITE 13

28	68	2	8	11	0	7	84	71	2	8	11	0	7	87
30	101	12	2	21	0	14	95	67	8	1	14	0	9	63
32	32	0	3	1	0	5	12	78	0	7	2	0	12	29
	201	14	13	33	0	26	191							
	= 478													

WITH NO ALNUS

BELLOW MOSS - SITE 14

120	33	1	0	0	0	0	9	97	3	0	0	0	0	26
130	37	5	0	0	0	0	13	88	12	0	0	0	0	31
138	42	1	0	0	0	0	5	98	2	0	0	0	0	12
148	11	5	0	0	0	0	33	69	31	0	0	0	0	206
	123	12	0	0	0	0	60							
	= 195													
Depth cms.	B	P	U	Q	T	A	C	B	P	U	Q	T	A	C
	Number of grains							As % total tree pollen						

Group B (cont.)

	Depth	Tree	Shrub	Herb %
Wolsingham Park Moor	150 cms.	39	22	38
	158	43	24	33
White House	140	91	8	1
	145	77	21	2
	163	55	42	3
	168	26	67	7
Woodland	28	45	44	10
	30	51	35	15
	32	62	21	17
Bellow Moss	120	19	66	27
	130	49	36	15
	138	57	33	10
	148	14	46	40

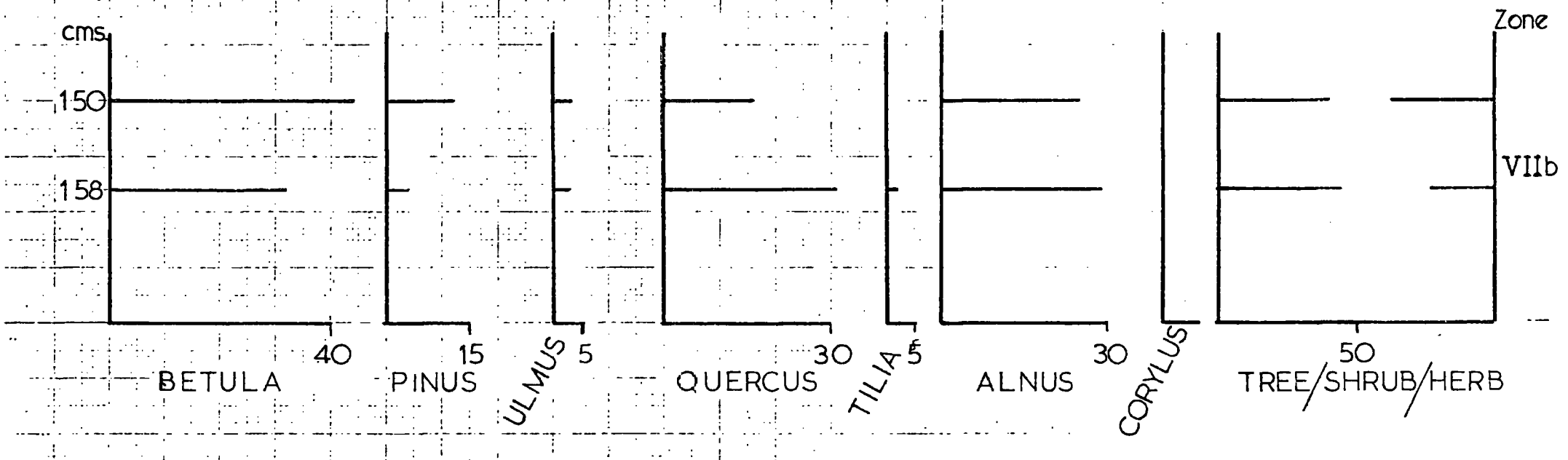
WOLSINGHAM PARK MOOR 400m.
cms
150
158
Zone
VIIb
40
15
5
30
5
30
50
BETULA
PINUS
ULMUS
QUERCUS
TILIA
ALNUS
CORYLUS
TREE/SHRUB/HERB

FIG. 40

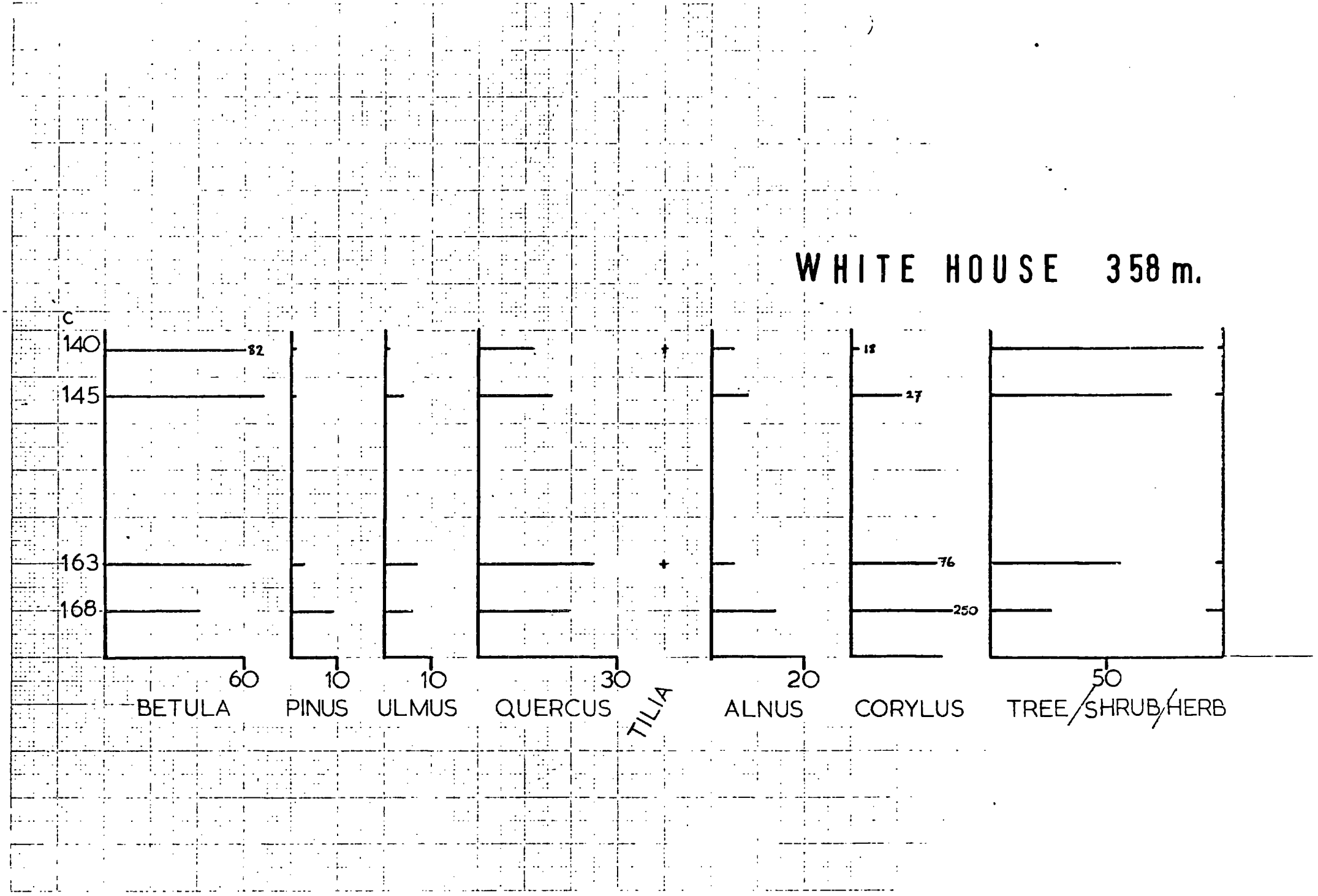
WHITE HOUSE 358 m.
C
140
145
163
168
82
18
27
76
250
60
10
10
30
20
50
BETULA
PINUS
ULMUS
QUERCUS
TILIA
ALNUS
CORYLUS
TREE/SHRUB/HERB

FIG. 41

WOODLAND 338m.

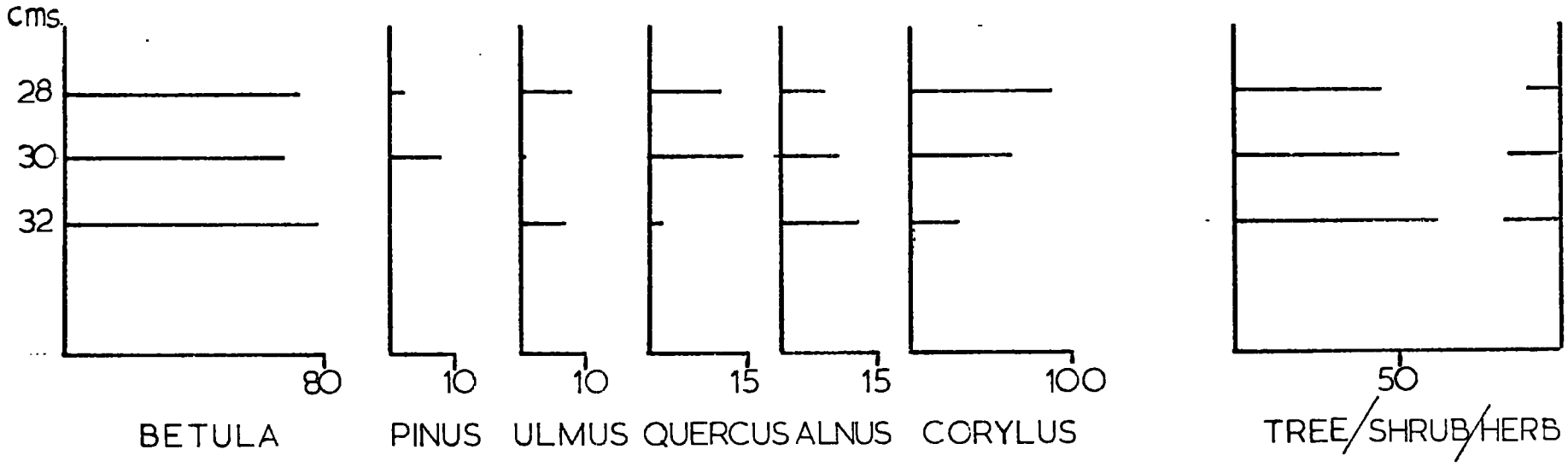

FIG. 42

BELLOW MOSS 231m.

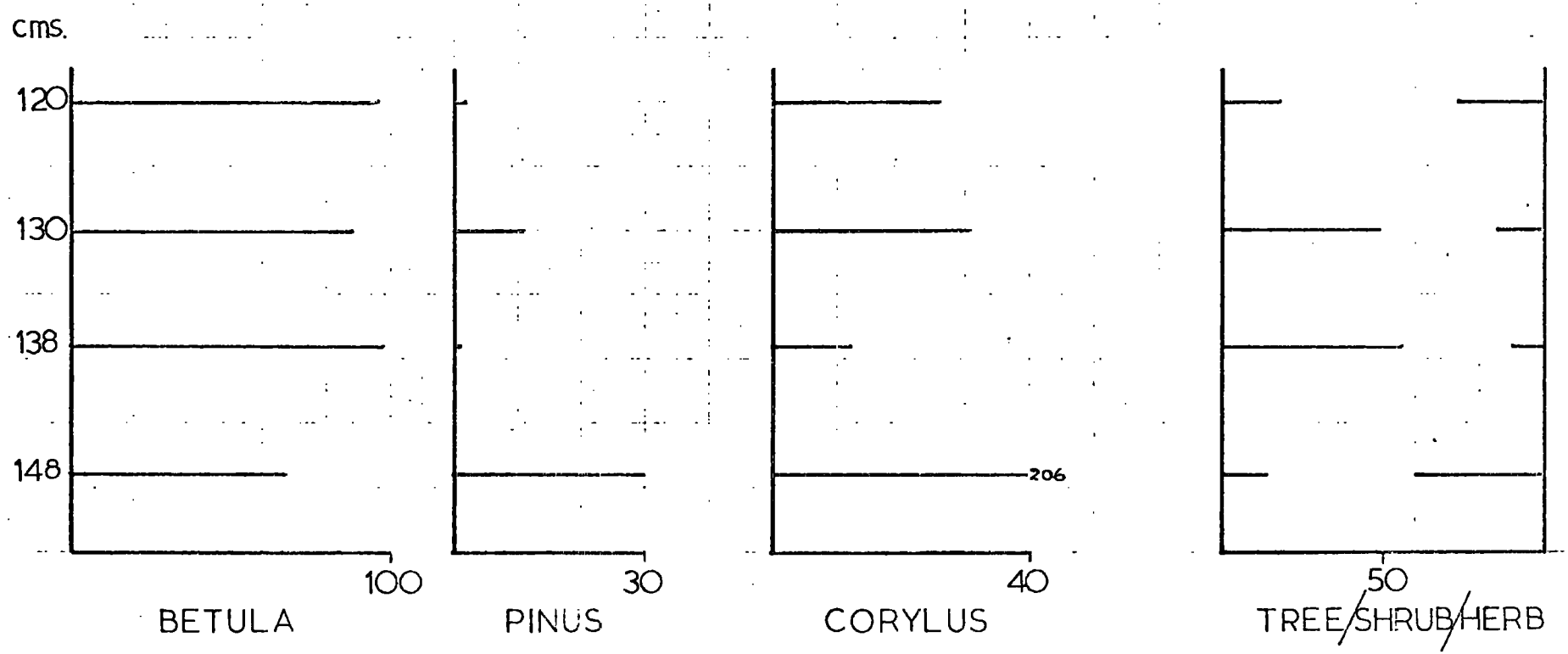

FIG. 43

ACCESS TO POST-BOREAL SITES, GROUP C

Site 15. Cuthbert's Hill

On common land 3 kms. N.N.W. of Rookhope. A boring was made about 100 m. W. of Paclet's Gate. It reached 220 cms.

Site 16. Shivery Hill

On common land 30 m. S. of the Allenheads to Coalcleugh road at the point where this crosses the watershed between E. and W. Allendale.

Site 17. Sikehead

By Sikehead Dam at the head of Burn Hope. The auger was used to bore at the stream head about 80 m. E. of the Chimney and 150 cms. was reached.

Site 18. Thornhope Sikes

Difficult of access and as far as can be judged, scarcely worth the effort. Perhaps least toil is involved when this site is approached from Fatherley Hill (1½ kms. of determined heather-bashing). The heads of various Sikes were examined but the peat rarely exceeded 90 cms.

Site 19. Wanister Bog

Wanister Bog lies just to the W. of where the road from Chester Moor to Waldridge crosses South Burn. The peat under the Menyanthes patch to the S. is only about 50 cms. deep but the cores used for analysis were taken from a point midway between this patch and the fenced-off pool towards the centre of the deposit. There is 170 cms. of peat, including a band of clay at about 150 cms. The whole deposit rests on deep soft clay.(Fig.46)

Site 20. Black Mire

A strange site on top of a rise W. of Hindon Hill. Accessible via the B6282 road 2 kms. S.W. of Woodland, then through a gate by Dale Terrace. At a point very roughly in the middle of the deposit, 235 cms. of peat were bored.

Site 21. Coal Gate

3½ kms. W.of Castleside, the farm is reached on minor roads. Permission from the farmer is needed to bore. The very black deposit (120cms.) was bored but proved impossible to deal with. HF treatment had no effect and one can only assume that the blackness of the sample is indeed due to the presence of coal. Investigation of the stream higher up revealed Cuudy's Stables, a terraced sequence of marshy downfalls, hinting at variation in the hardness of the rocks beneath. Coal outcrops on the surface at many places nearby.

POST-BOREAL SITES GROUP C

Depth cms.	Numbers of grains B	P	U	Q	A	C	As % total tree pollen B	P	U	Q	A	C	Zone
CUTHBERT'S HILL SITE 15													
220	17	7	8	38	30	89	17	7	8	38	30	89	VIIa
			= 189										
SHIVERY HILL SITE 16													
27	8	0	1	8	23	69	20	0	2	20	58	172	VIIb
			=109										
SIKEHEAD SITE 17													
100	33	5	1	18	47	96	32	5	1	17	45	92	VIIb
			= 200										
THORNHOPE SIKES SITE 18													
88	66	2	3	45	35	69	44	1	2	30	23	46	VIIb
			= 220										
WANISTER BOG SITE 19													
	B	P	U	Q	T	A	C	B	P	U	Q	T	A	C	
75	17	8	2	48	6	69	33	11	5	1	32	4	46	22	VIIb
100	0	8	0	1	0	2	3	0	16	0	2	0	4	6	VIc?
115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
125	0	0	0	0	0	0	0								
145	1	0	0	0	0	0	0								
160	0	0	0	0	0	0	0	Shrubs 15%, Herbs 85%. Late Glacial?							
			= 195												
BLACK MIRE SITE 20 no count															
COAL GATE SITE 21 " "															

Group C (cont.)

	Depth	Tree	Shrub	Herb %
Cuthbert's Hill	220 cms.	29	27	44
Shivery Hill	27	16	27	57
Sikehead	100	18	18	64
Thornhope Sikes	88	32	17	51
Wanister Bog	75	57	15	27
	100	44	36	20
	115	0	22	78
	125	0	0	present
	145	1	0	present
	160	0	15	85

STRATIGRAPHY OF POST-BOREAL SITES

SITES 9, 17 &21, no core

SITE 19 on separate sheet

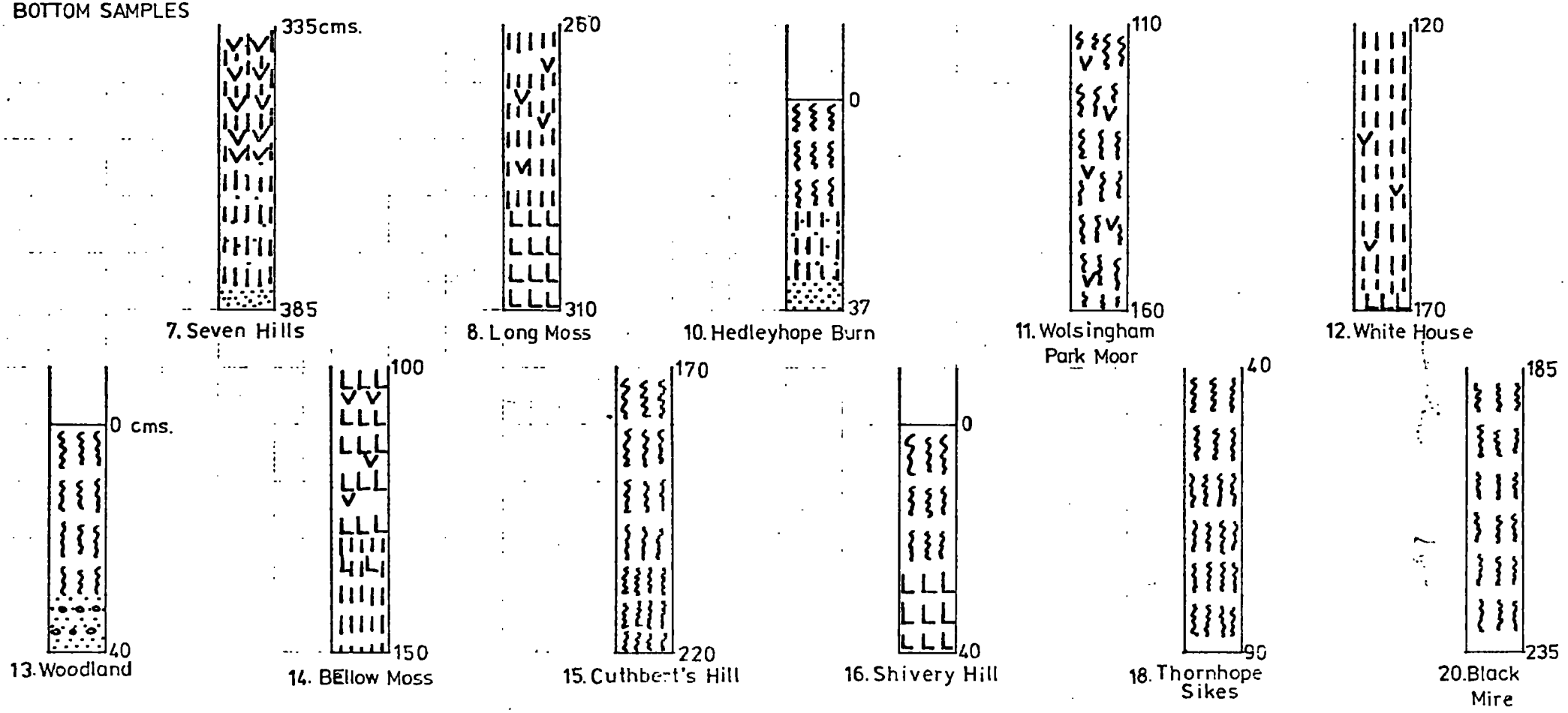

FIG. 45

STRATIGRAPHY OF WANISTER BOG