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A COMPARISON OF VARIATIONS IN FOREST COMPOSITION IN THE NORTH PENNINES BETWEEN THE SUB-BOREAL AND ATLANTIC PERIODS

By

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CONTENTS.

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ABSTRACT.

The aim of this investigation was to test whether the patterns of latitudinal variation observed in the Atlantic forests of the North Pennines were maintained in the Sub-Boreal. Nine Sites were selected along a north-south transect. Pollen analyses of the Sub-Boreal at these sites were compared with analyses for the Atlantic. The results show that *Tilia* and *Fraxinus* maintain significant clinal variations during both periods. During the Atlantic elm was more abundant to the south. This pattern was not observed in the Sub-Boreal. *Alnus* showed distinct clinal variation in the Sub-Boreal but not the Atlantic. No clinal variations were seen in *Quercus*, *Betula*, *Corylus* or *Salix* in either period. *Quercus*, *Betula*, *Alnus* and *Corylus* contributed most to within-site variation during the early Sub-Boreal. The results indicate that during the Sub-Boreal *Corylus*, *Betula*, and *Quercus* were influenced by local conditions, *Tilia* and *Fraxinus* by regional conditions and *Alnus* by some combination of both.

INTRODUCTION.

The work of Birks etal. (1975), concerning the arboreal flora after the elm decline, emphasized the comment that Godwin made in 1940 that the Flandrian pollen record convincingly indicates the ancient and permanent character of regional vegetational differentiation within the British Isles. It showed that pine and birch predominated in the north and east of Scotland and in western Ireland and that elm and hazel had their highest frequencies in central and eastern Ireland. In England and in lowland Wales, alder and hazel were more abundant than any of the other taxa. Oak had its greatest representations in the north and west of England, whilst lime was commonest in the south and east.

A more detailed study by Turner and Hodgson (1981 unpublished data) on the variations in the composition of North Pennine forests during the Atlantic period came to the conclusion that the major source of variation in the data was associated with latitude. Betula, Pinus and Salix frequencies were higher in the north whereas Tilia, Fraxinus and Corylus were more abundant in the south.

The present project was undertaken to study whether this latitudinal variation was maintained in the subsequent Sub-Boreal period, after the elm decline.

To test this hypothesis sites were selected along a north-south transect of the North Pennines. All nine sites selected were within the confines of the Turner-Hodgson area so that a comparison could be made of the changes, if any, between the Atlantic and Sub-Boreal tree and shrub frequencies.

METHODS

Samples of peat for pollen analyses were collected from Harthope Moss (site 4), Fleet Moss (9), Fog Close (7) and White Beacon Hags (8). Peat previously collected by Dr. J. Turner from Low Stublick and Staple Mosses (Sites 1 and 6) were sampled and prepared for slides. Data on the pollen assemblage for Pollen Zone VIIb, the Sub-Boreal period, from the three remaining sites (Grahms, Quick and Dufton Mosses), was made available from the work of Dr. J. Turner and Dr. R.H.Squires. The location of each site is shown in Fig. 1 and details of position, geology and altitude are listed in Table 1.

SELECTION OF SITES.

The sites were selected after searching the Ordnance Survey 1:50,000 First Series map, Sheets 77, 84 and 90 for areas marked either as marsh, bracken heath or rough grassland. The criteria for site selection were primarily that it should be on the 77 km. north-south transect and secondly that all sites should be at a similar altitude. The first criterion was fulfilled in that all sites were enclosed within a strip of land, 4 kms. wide, between the Tyne valley in the north to Wensleydale in the south. However the second criterion was not attained. Although the majority of sites were above 500 m, Low Stublick, Grahms and Dufton Mosses were not. These three sites were situated at 292m, 396m. and 364m respectively.

The presence of hillpeat was confirmed from the Geological Survey of Great Britain Drift map (scale 1 inch = 1 mile). The solid geology of each site was checked from the Geological Survey Solid map (scale 1 inch = 1 mile) Sheets 8, 13, 18, 19 and 25. Four of the sites were chosen where the pollen catchment area of the peat would appear to be from vegetation growing on soil derived from limestone strata. Four sites were in Millstone Grit areas and the remaining one was surrounded by Whin Sill.

All sites were visited and a general description of the site, its' peat face and present vegetation were obtained. Samples were taken as necessary.

COLLECTION OF SAMPLES.

Samples for analysis were collected from sites 4,7,8 and 9 by cutting steps into the sloping peat hag to expose a vertical profile. As a precaution against contamination between levels, the peat profile was scraped clean by using a horizontal cut with a flat trowel edge. A tape measure was then placed at the side of the profile to calibrate the depth of the samples. Samples were taken from below the Grenz-horizont, which is usually at or above the top of zone VII b, if it was observed. Otherwise samples were removed directly from the profile by working from the top surface of the peat downwards taking samples at either 5 or 10 cm intervals (Sites 7,8,9 and 4 respectively). Samples were removed from the profile by pressing glass specimen tubes into the peat and withdrawing a small quantity in the tube. To prevent contamination from present day pollen the specimen tubes were sealed by a plastic stopper immediately upon withdrawal. Labelling with site name and sample depth was done by using a waterproof ink pen.

PREPARATION OF SAMPLES.

As all the samples were from ombrotrophic peats the matrix was entirely organic. The digestion of the humic acids by boiling a sample of peat in dilute (10%) NaOH was followed by an acetolysis to remove cellulose. The above method was originally devised by Langerheim and later adapted by Von Post (Faegri and Iversen.1964: 67). This process was used by Conway (1947) and later workers on Pennine blanket peats. The digested samples were then mounted in glycerol jelly stained with safranin.

The prepared slides were counted using a Watson Microsystem 70 binocular microscope fitted with a X10 eyepiece lens. Rapid scanning was done using a magnification of X100. Counting was done under high power (X400) for easy identification of the pollen grains. Difficult grains were examined under the X100 oil immersion lens. At each level pollen counting stopped when at least 150 arboreal pollen grains, excluding Corylus and Salix, had been recognized. When Sphagnum spores swamped the slide, counting of such spores was halted at 50 arboreal pollen grains and the total obtained was multiplied accordingly.

Initially the pollen counts were made from levels at 20-30 cm. intervals to locate the lower boundary of pollen assemblage zone VII b (Sub-Boreal). This boundary was easily recognized by the marked decline in the frequency of Ulmus pollen. The elm decline throughout the north-south transect was at approximately the same depth for six of the sites. At two of the low altitude sites, Grahms and Dufton Mosses the VIIa /VIIb boundary was at 300 and 51 cms. respectively. If a double or triple elm decline was observed the VIIa/VIIb boundary was drawn at the final Ulmus decrease. Once the elm decline was established further samples were taken from levels directly above it at intervals of 5 or 10 cms depending on the individual site. These samples were taken as close to the elm decline as possible before any major clearance by man had occured. To validate the comparison between Sub-Boreal and Atlantic forest compositions, 5-7 post elm decline samples were taken from each site in order to obtain a sufficiently statistically sound mean for each tree taxon. Of the 92 samples counted, only 52 were from the Sub-Boreal period and used in the subsequent anaylses.

TREATMENT OF RESULTS.

The pollen counts for each site are listed in the Appendix (tables 1 and 2). This also includes values for the levels used to determine the lower limit of Zone VII b. Subsequently these values were discarded from each site's data leaving only the results of post elm decline levels. It was these results that were then used in the statistical analyses. The results are presented in two ways, graphically and statistically.

(a) Graphic Representation.

Pollen diagrams were drawn for each site in order to establish the elm decline and to provide a graphic representation of any variation in the frequency of pollen taxa within that time span. The pollen diagrams have been drawn using the values for the percentage of total arboreal pollen excluding the frequencies of *Corylus* and *Salix*.

(b) Statistical Analyses.

All statistical results were obtained by using the University computer to analyse the raw data. The procedure was as follows:-

(i) Tree Pollen data, including *Corylus* and *Salix* values, from all the sites were stored on a computer file named MONTEDATA.

(ii) A program called MONTECHI written by Dr. T. Gleaves was used to analyse the data, stored in MONTEDATA. The program calculated chi-squares. This analysis tested for the significance of both within-site and between-site variation in arboreal pollen taxa.

(iii) The MONTECHI program also applied the Montecarlo test to determine whether or not the between-site variation is separate from the within-site variation rather than a function of it.

(iv) Using a program written for the purpose by Dr. Turner the means for each tree taxon, including *Corylus* and *Salix*, were calculated for each site from the rawdata in file MONTEDATA. This information was checked against calculator derived means to validate the data. Once this was done the information was stored in a computer file appropriately called MEANS.

(v) Using statistical package *MIDAS the data from file MEANS was fed into the package at three different times and commanded as follows:-

(a) 1st. time - SCATTER.

(b) 2nd. time - REGRESSION.

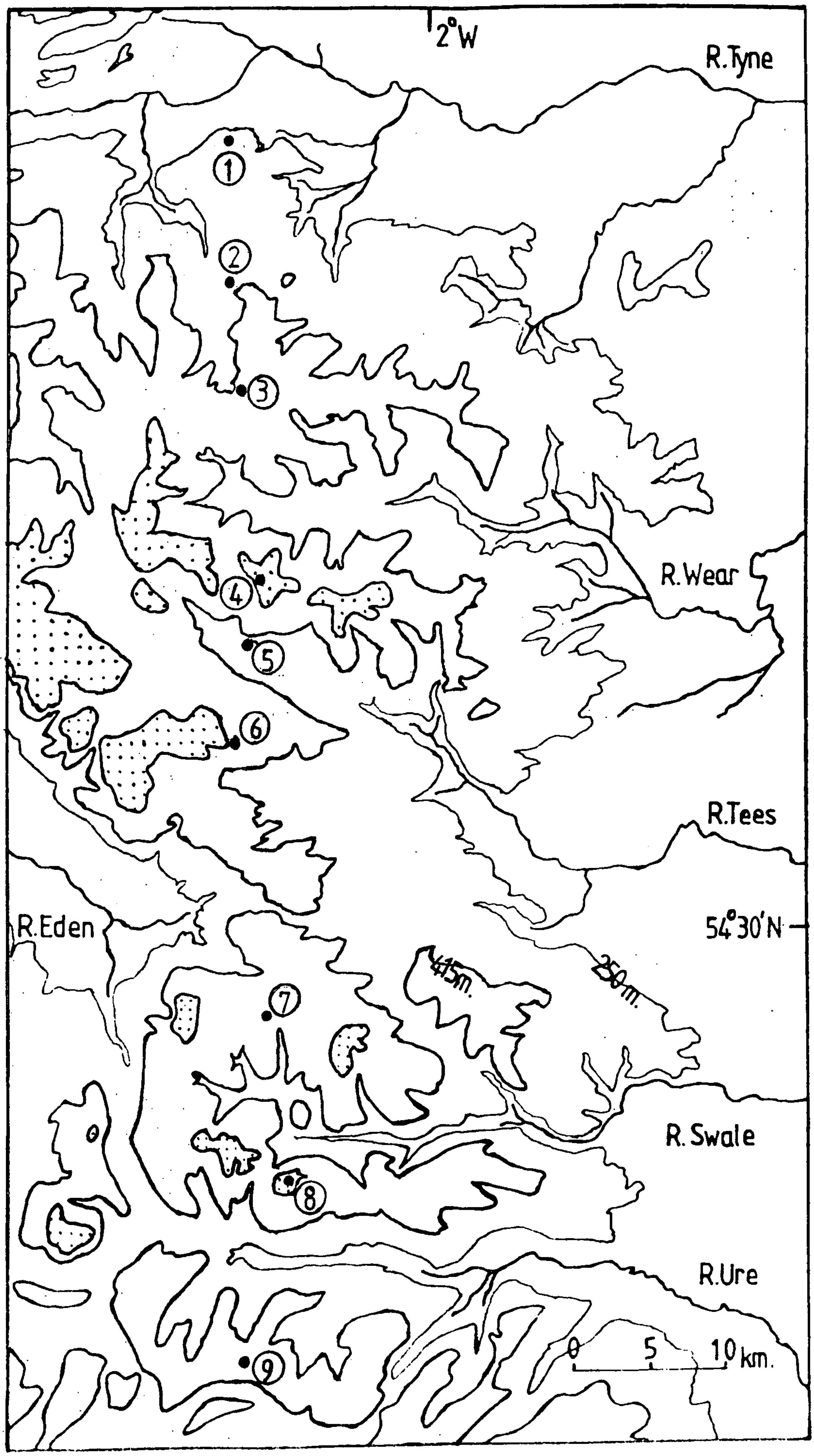
(c) 3rd. time - POLY.

(a) The SCATTER command produced a graphical representation of percentage frequency of pollen versus latitude for each tree taxon. Therefore nine graphs in all were obtained. Once these graphs were obtained, lines of closest fit were drawn through the points where felt appropriate.

(b) The REGRESSION command carried out bivariate linear analysis to fit the best least-squares line, through the data points, and then tested the significance of this line.

(c) It was felt that curves could be drawn through some of the points on the graphs. To test this hypothesis the POLY (polynomial) command was given. This command fitted quadractic curves to the data points using a least-squares criterion and then tested the significance of the curves.

Fig.1 Sketch map of the Northern Pennines, showing the location of the nine pollen sites mentioned in the text.



▨ above 615m.

TABLE 1 DETAILS OF SITES SHOWN IN FIG.1

SITE	NATIONAL GRID REFERENCE	GEOLOGY	ALTITUDE (M.O.D.)
1.Low Stublick.	NY 865604	Millstone Grit	292
2.Grahms Moss.	NY 860531	Millstone Grit	396
3.Quick Moss.	NY 876467	Limestone	518
4.Harthope Moss.	NY 868341	Limestone	654
5.Dufton Moss.	NY 871293	Whin Sill	364
6.Staple Moss.	NY 853240	Limestone	609
7.Fog Close.	NZ 870062	Millstone Grit	540
8.White Beacon Hags.	SE 893951	Millstone Grit	590
9.Fleet Moss.	SE 862834	Limestone	560

N.B. The geology is the solid geology immediately surrounding the site.

DESCRIPTION OF SITES.

1. LOW STUBLICK MOSS.

Low Stublick is the most northerly of the sites and is in a shallow depression on the low lying ground of Stublick Moor. The bog is sheltered by a small hillock towards its' eastern end. Drainage water from the bog collects eastward towards the hillock whereupon it is diverted northwards by man-made ditches. The bog is approximately 0.3 x 0.1 Km (0.03 Km^2) in area and the hillpeat is 4m at its' greatest depth. Unlike the majority of sites there are no signs of gully erosion at Low Stublick, the general impression being of a typical hummock-hollow forming community with a margin of Juncus. The hummocks supported a vegetation cover of Calluna vulgaris, Eriophorum vaginatum with occasional Erica tetralix and Empetrum nigrum. The lichen Cladonia was abundant. Sphagnum spp were confined to the pool margins.

Stublick Moor is formed upon Millstone Grit which overlies what is described as the Upper Limestone Series. Directly north of the bog the main Stublick fault bisects the Millstone Grit at 61°N.

2. GRAHMS MOSS.

Grahms Moss is situated, at an altitude of OD 396m, in a small depression between the sandstone outcrops of Green Hill and Sinderhope Carr to the north and south. The area of the bog is 0.01 Km^2 with a maximum peat depth of 4m. The Moss drained eastwards down through Westburnhope Moor onto Hexhamshire Common. Grahms Moss has a similar vegetation to Low Stublick in that the bog was encircled by marshy ground dominated by Juncus. The plant association was of the Calluna - Eriophoretum type on the high ground, with the wetter areas to the south dominated by pools of Sphagnum.

The soils on the hills surrounding the bog were derived from Millstone Grit which covers an expanse of approximately 90 Km^2

extending from Hexham in the north-east to Hexhamshire Common in the south.

3. QUICK MOSS.

Quick Moss (Quickcleugh Moss) describes the expanse of blanket peat 2Km. north-east of Allenheads. This bog is a tragic example of Pennine blanket peat erosion. The whole site was highly dissected by gullies that measured up to 18m across the top and over 3m in depth. Ironically due to such erosion the stratigraphy of the mire was easily observed. Quick Moss lies upon sandstone above limestone of the Upper Limestone Group. The peat was underlain by a layer of greyish-blue boulder clay. Immediately above this sediment was a recognisable tree layer which contained large ammounts of fossilized roots and bark of birch. The Grenz-horizont was observed at about one metre down from the bog surface. The peat above the horizon was highly humified in comparison to the *Eriophorum* peat below. The deep peat was supporting heather, cotton grass, some deer sedge and crowberry. There were more lichens present at Quick Moss than any other site which is probably an indication of the high atlitude of 518m O.D.

4. HARTHOPE MOSS.

The site at Harthope Moss is situated on the gradual sloping, south west face of Chapelfell top. Drainage water from the Moss collects south-westwards into Harthope and West Beck, thence to Langdon Beck that empties into the River Tees. The highly dissected peat supports a vegetation type of *Calluna-Eriophoretum* association.

The Moss is immediately above an area of upper felltop limestone a region of limestone in the Upper Limestone Group. Boulder clay overlays the limestone around Harthope and Langdon Becks and extends over the watershed towards Burnhope resevoir.

5. DUFTON MOSS.

Dufton Moss occupies a small depression some 100m south of the

B6277 Middleton/Alston road, and is situated at the foot of the Whin Sill exposure at Force Garth. The Moss is approximately 0.1 Km x 0.1 Km (0.01 Km^2) in area and the hillpeat is deep being 5m. at the centre of the bog. The general appearance is of a convex-surfaced heather-dominated area within a Juncus infested meadow. The vegetation is dominated by Calluna vulgaris and Eriophorum vaginatum. Also present were : Trichophorum cespitosum, Erica tetralix, Eriophorum angustifolium, Narthecium ossifragum, Empetrum nigrum, Sphagnum spp. and Cladonia spp

Dufton Moss is situated upon Whin Sill formed in the Carboniforous Permian periods (A.C. Dunham 1970). The bedrock is overlain by a blue-grey solifluxion material which supports the peat. The stratigraphy of the peat is described by Dr. R.H. Squires (1970). He observed that plant remains including Betula, Salix and Pinus were plentiful at the base of the peat.

6. STAPLE MOSS.

Staple Moss lies on the gently sloping limestone plateau of Lunedale, 3Km due west of the triangulation point on Mickle Fell. Like Quick Moss, Staple Moss was highly dissected by erosion gullies that ran from the northwest to the southeast draining into the Lunedale valley. Although the erosion was extensive and cut into the peat to a depth of 2-3m, regeneration of the bog was apparent on the bottom and sides of the gullies. The primary coloniser was Eriophorum angustifolium. At a later stage of bog regeneration a definite zonation was observed on a tussock. Calluna vulgaris occupied the upper-most zone above E.vaginatum and E.angustifalium. The peat hags were covered by a Calluna- Eriophoretum association. The pools that were present contained Sphagnum spp.

7. FOG CLOSE.

Fog Close is situated in a shallow depression on the plateau west of Tan Hill at an altitude of 540 m O.D. The area described is approximately 0.5 Km x 0.25 Km. (0.125 Km^2) situated at the water-shed of gills descending north to join the River Greta at Bowes and becks descending southwards to join the River Swale. To the north are disused mine workings. The southern part of the mire was deeply dissected by erosion gullies which were at a depth of up to 3.2m. The peat was underlain by a yellowish-grey silt which was above exposed bedrock. The dominant plants on the peat were *Calluna vulgaris* and *Eriophorum vaginatum*. *Vaccinium myrtillus* and *Erica tetralix* occurred occasionally on the peat surface.

The peat was developed on Tan Hill Grit, the most recent of the Millstone Grit strata, and overlays a sandstone.

8. WHITE BEACON HAGS.

White Beacon Hags describes a large area of hillpeat 1Km x 0.5 Km (0.5 Km^2) in extent situated 1.5 Km. east of the hill summit called Lovely Seat. The peat is on a flat shelf of land which is the water-shed for Muker Common with streams running northward to Swaledale and southward to Wensleydale. In the lowest part, west of the Beacon, the peat hags are 3.5 m high with almost perpendicular sides rising from bedrock above a layer of greyish silt 5 cm. thick. Large tree branches of pine and birch protrude from the base of the peat.

The present-day vegetation on the top of the hags is mainly composed of *Calluna vulgaris*, *Eriophorum vaginatum*, *Vaccinium myrtillus*, *Erica tetralix* and *Empetrum nigrum*. A similar plant community covered the fell tops, together with *Trichophorum cespitosum*, *Nardus stricta*, *Molinia caerulea* and the cloud-berry *Rubus chamaemorus*.

The peat has developed on Tan Hill Grit which is a shale having a very thin limestone in it. The surrounding peaks are also of the Millstone Grit Series.

9. FLEET MOSS.

Fleet Moss is the most southerly of the sites at an altitude of

560 M.O.D. The peat is situated in a shallow depression between the lower slopes of Dodd Fell Hill to the west and Jeffrey Pot Hill to the east. Drainage water from the Moss collects northwards into Bardale Beck, thence to Wensleydale and Wharfedale. The Moss is approximately 0.75 x 1.25 Km (0.94 Km^2) in area and the hillpeat is deep, rising nearly 3m above the base of the erosion gullies, where bedrock is exposed. Plant remains are abundant at the base of the peat hags, twigs and large branches of birch and pine being exposed. The peat hags support a vegetation cover of Calluna vulgaris, Eriophorum vaginatum with Vaccinium myrtillus and occasional Erica tetralix and Empetrum nigrum.

The slopes of the surrounding hills lie on Main Limestone of the Yoredale Series and the Moss has developed on Underset Limestone beneath which is a sandstone layer. A layer of light grey clay lies between the bedrock and the peat. The grassland on the Main Limestone is typical of a calcareous soil and provides a rich pasturage for sheep.

RESULTS AND DISCUSSION

(a) WITHIN-SITE VARIATIONS IN THE TAXA RECORDED

Refer to Tables 2 (i) and 3, pollen diagrams Figs. 2-10 and to tables 1 and 2 in the Appendix for the pollen counts.

At seven sites the value of P. was 0.001 whereas at site 6, Staple Moss, and site 9, Fleet Moss the values were 0.025 and 0.005 respectively. Thus the chi-squared test of the pollen counts at each level of a site showed that the within-site variation was significant at all nine sites. To investigate further the cause of this variation a pollen diagram was constructed for each site. The upper limit of Zone VIIa is shown on the right hand side of each pollen diagram. There was some difficulty in determining the elm decline precisely at Quick and Dufton Mosses (Figs.4 and 6 respectively). Quick Moss shows a triple elm decline with a decrease in Ulmus at 189, 196 and 212 cms. The decline has been drawn between 188 and 180 cms just after the final decline. At Dufton Moss the Ulmus decline has been drawn between the 55 and 51 cm level.

Pinus, Ulmus, Tilia, Fraxinus and Salix pollen frequencies changed little after the elm decline, and it was obvious from the pollen diagrams that variations in the values of Betula, Quercus, Alnus and Corylus pollen were the cause of the great within-site variation. To explore further the causes of this variation the mean and variance of the frequencies of the above four taxa were calculated at each site and tabulated along with the maximum and minimum values (See Table 3). Using the results from this analysis and the pollen diagrams a description was written to underline the major changes, if any, that occurred in representation of arboreal taxa after the elm decline.

Of all the arboreal taxa, Corylus has much the highest variance values in relation to its means and hence must make the greatest contribution to the within-site variation. The pollen diagrams show that the cause of the large variance (σ^2) values is great fluctuations in the Corylus pollen representation after the elm decline. This clearly results from a general trend at five of the nine sites in the Sub-Boreal. Whereas at Grahms, Dufton, Low Stublick and Fleet Mosses it is due to the wide range of the Corylus frequencies.

Another apparent trend is that Corylus frequencies decrease immediately after the elm decline. This occurred at six sites the remaining three showing an increase in Corylus pollen representation.

Just after the elm decline, unlike Corylus (see above), the pollen frequencies of Alnus increase greatly. This trend was observed at the majority of sites but not at Low Stublick and Dufton Mosses which showed a decline in Alnus pollen frequencies.

After this general trend of rise in alder pollen frequencies at the VIIa/VIIb boundary three of the nine sites show a decrease in Alnus pollen. Despite this there is little overall trend that can be recognized at all the sites. This apparent lack of any considerable variation in Alnus frequencies indicates that at the sites investigated, alder representation was effected by local rather than regional influences in the Sub-Boreal period.

At six sites Betula showed a decrease in pollen representation immediately after the Ulmus decline whereas at Fog Close, Low Stublick and Quick Mosses an increase was recorded.

Three sites investigated showed little variation of birch pollen frequencies in early zone VIIb. Of the variation observed three sites show an increase in Betula representation. A fourth site shows an increase in birch followed by a decline. In contrast the remaining two sites show a decrease followed by an increase in the pollen representation.

Betula is similar to Alnus in the sense that although trends can be recognized at a few sites these are not sufficiently consistent to be seen as overall trends occurring throughout the transect.

For Quercus there is a recognizable overall trend demonstrated at five of the sites investigated. This is best seen as an increase in pollen representation followed by a decline towards the upper samples. This is more pronounced at some sites compared to others.

Four sites show an increase whilst three show a decrease in Quercus pollen immediately following the elm decline. The two remaining sites show little variation in Quercus pollen frequencies.

As already noted little within-site variation occurs in the representation of the minor woodland components. Despite this certain features of these components are observed at the individual sites.

Pinus has a very low representation in the Sub-Boreal at the sites investigated. Quick Moss has the highest representation of pine. Two sites, Grahms and Quick Mosses, show a greater decrease in Pinus after the elm decline, more so than the other Pennine sites.

Tilia is absent from the Sub-Boreal samples at Grahms Moss and is notable for its almost complete absence throughout at the other sites.

At four sites Fraxinus reappears or increases in its representation at the upper levels of the Sub-Boreal profile. At Quick, Staple and Fleet Mosses ash increases slightly after the elm decline.

At three sites Salix declines or is lost altogether after the elm decline. At White Beacon Hags it shows a slight increase immediately following the decline.

For the nine sites investigated the within-site variation caused by the arboreal taxa can be summarized as follows:

Of the ten species investigated only Betula, Quercus, Alnus and Corylus contribute significantly to the within-site variation.

Immediately following the elm decline Corylus and Betula show a decrease in representation of pollen at six sites and an increase at three sites. By contrast alder shows an increase in frequencies at seven sites and a decrease at two. Quercus shows an increase in representation

TABLE 2

THE VALUES OF CHI-SQUARED FOR:

(i) WITHIN-SITE VARIATION
(ii) BETWEEN-SITE VARIATION.

(i) WITHIN-SITE VARIATION.

SITE	CHI-SQUARED	DEGREES OF FREEDOM	VALUE OF P
1	97.608	48	0.001
2	118.834	48	0.001
3	84.182	48	0.001
4	125.925	40	0.001
5	100.156	40	0.001
6	48.377	32	0.025
7	83.256	40	0.001
8	87.655	40	0.001
9	71.932	40	0.005
Total	817.886	376	

(ii) BETWEEN-SITE VARIATION.

Chi-squared = 1500.410 with 64 degrees of freedom

TABLE 3. **MINIMUM, MAXIMUM, MEAN ($\bar{X}$) AND VARIANCE (σ^2) VALUES OF BETULA, QUERCUS, ALNUS AND CORYLUS (EXPRESSED AS % A.P. EXCLUDING CORYLUS AND SALIX FREQUENCIES)**

SITE	BETULA				QUERCUS				ALNUS				CORYLUS			
	MIN	MAX	$\bar{X}$	σ^2	MIN	MAX	$\bar{X}$	σ^2	MIN	MAX	$\bar{X}$	σ^2	MIN	MAX	$\bar{X}$	σ^2
1	16.6	35.5	22.7	36.7	26.6	42	35.7	31.4	25.2	48	36.7	53.3	38.1	55.8	47.7	62.4
2	49.7	67.5	57.3	47.6	7.8	22	14.1	18.5	17.7	36.4	26.9	60.8	15.2	38.6	24	82.8
3	17.3	26	21.5	12.9	24.6	43.3	34.3	42.3	26.6	44.6	33.4	43.6	46	88	64.7	269.9
4	10	41.3	22.7	110.3	21.3	32.6	27.1	18.5	25.3	56.6	41.8	106.1	40	98.6	73.2	556.9
5	15.9	37	27.2	54.8	21.6	44.5	29	73.4	35	45.5	39.4	20.2	50.8	81.8	66.7	204.5
6	12.6	20.6	17.8	9	17.3	30	26.2	25.9	44.6	54	48.9	19.4	64	104	82.8	342.3
7	11.3	25.3	17.7	22.1	25.3	34	32	10.9	38	50	43.9	17.6	58	101.3	70	359.9
8	11.3	28.7	18.75	33.9	20.6	32.6	26.7	17.6	32	54	45.3	57.8	30.6	83.3	57.4	388.1
9	6.6	18.0	13.3	14.4	15.3	37.3	28.2	62.4	35.3	60.6	51.6	73.9	55.3	78	65.7	102.01

Fig. 2 Low Stublick Moss

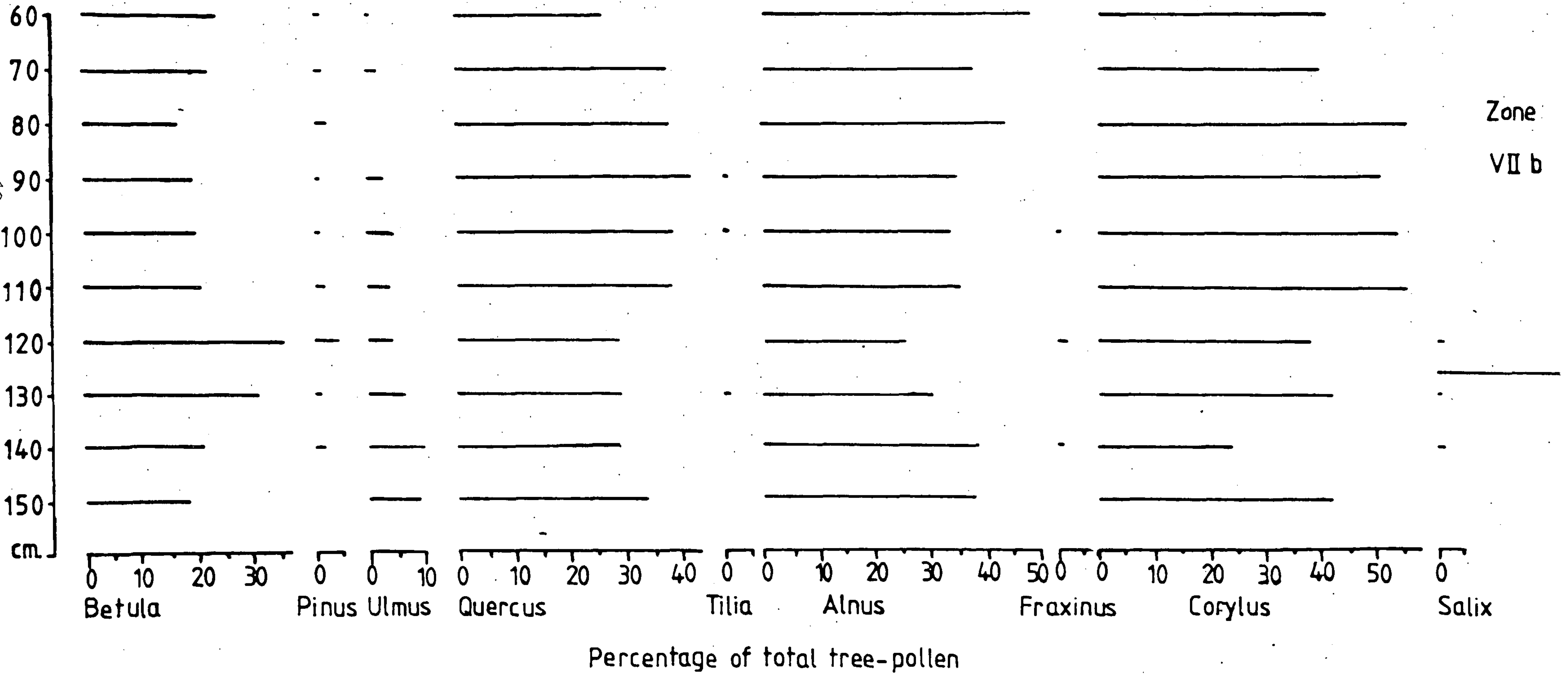


Fig. 3 Grahms Moss

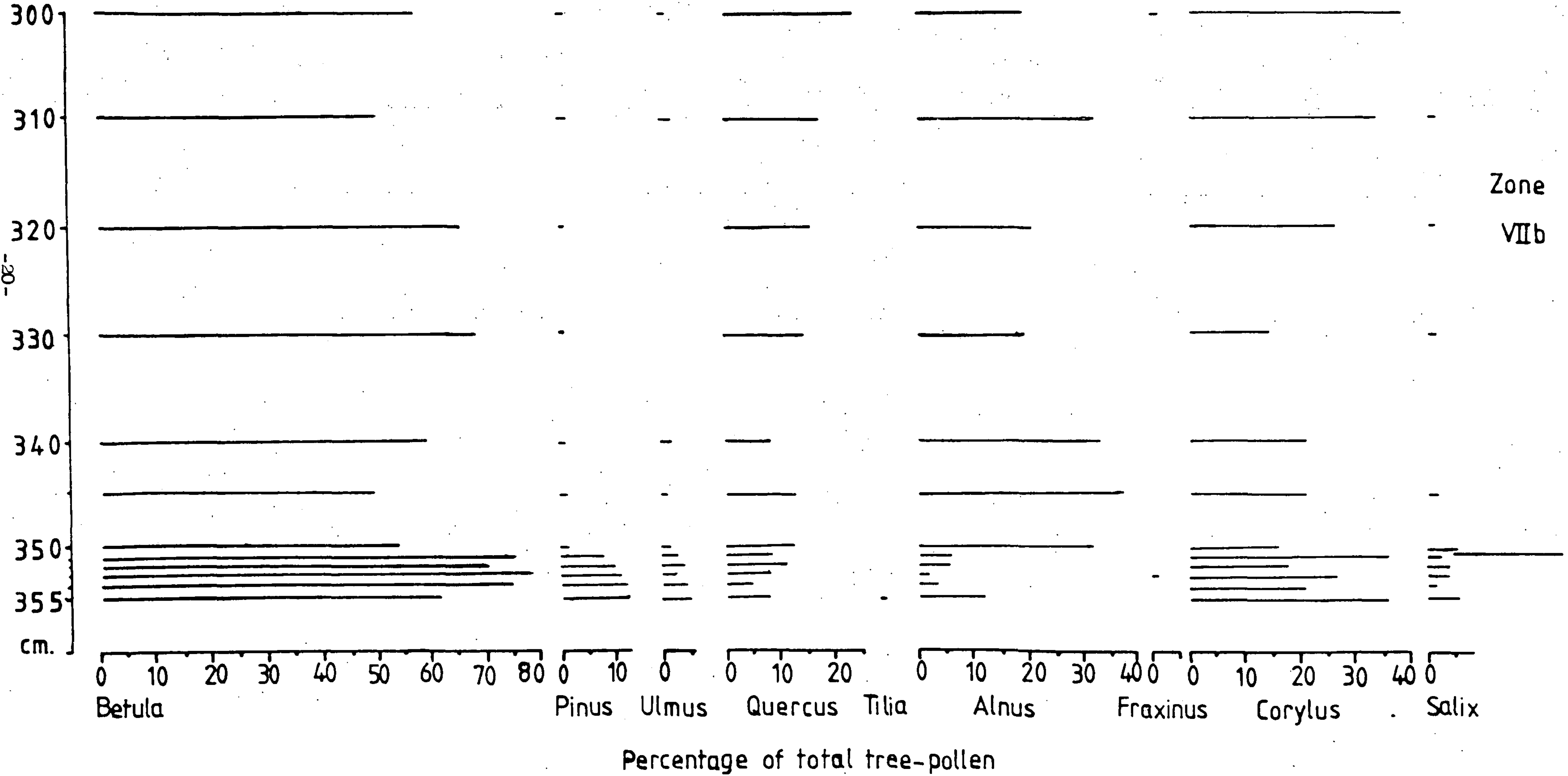
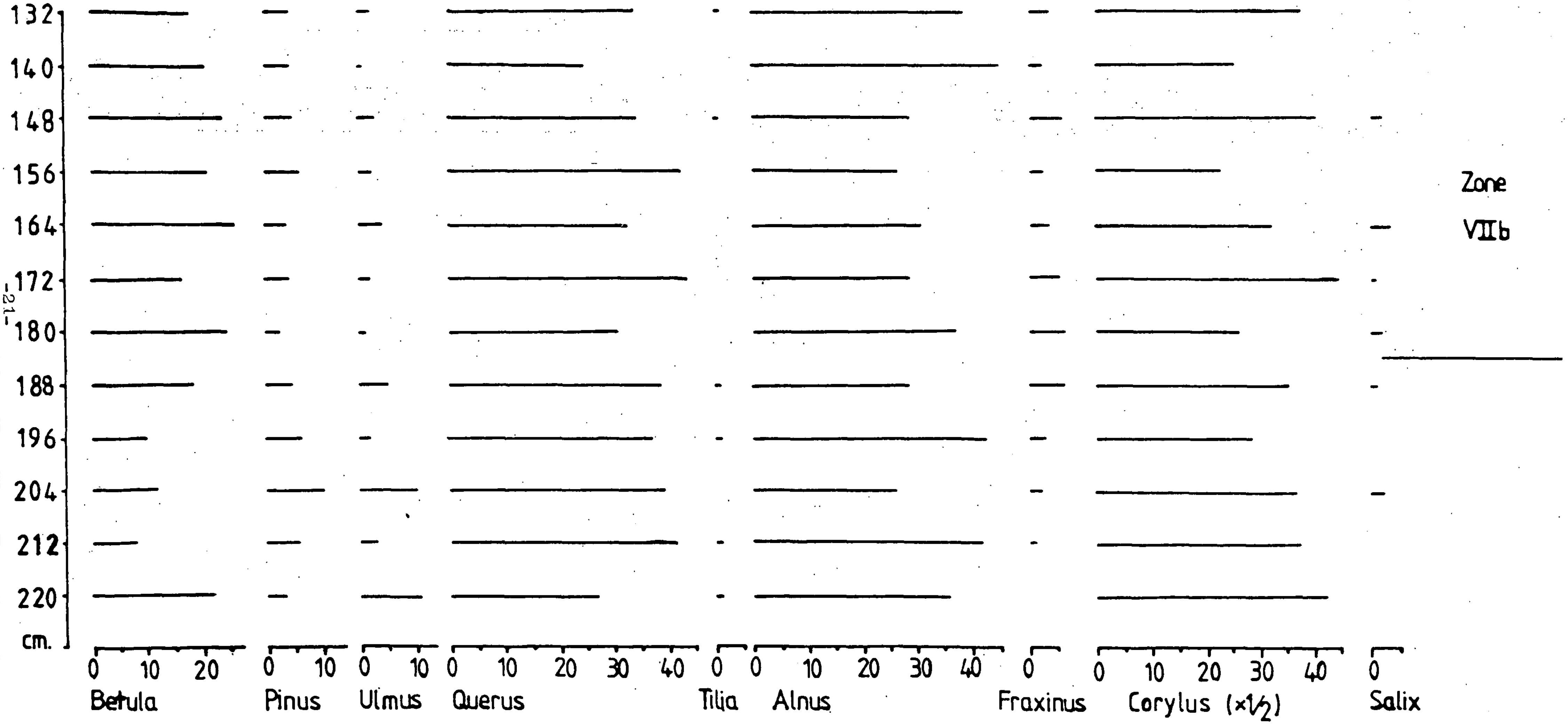


Fig. 4 Quick Moss



Percentage of total tree-pollen

Fig. 5 Harthope Moss

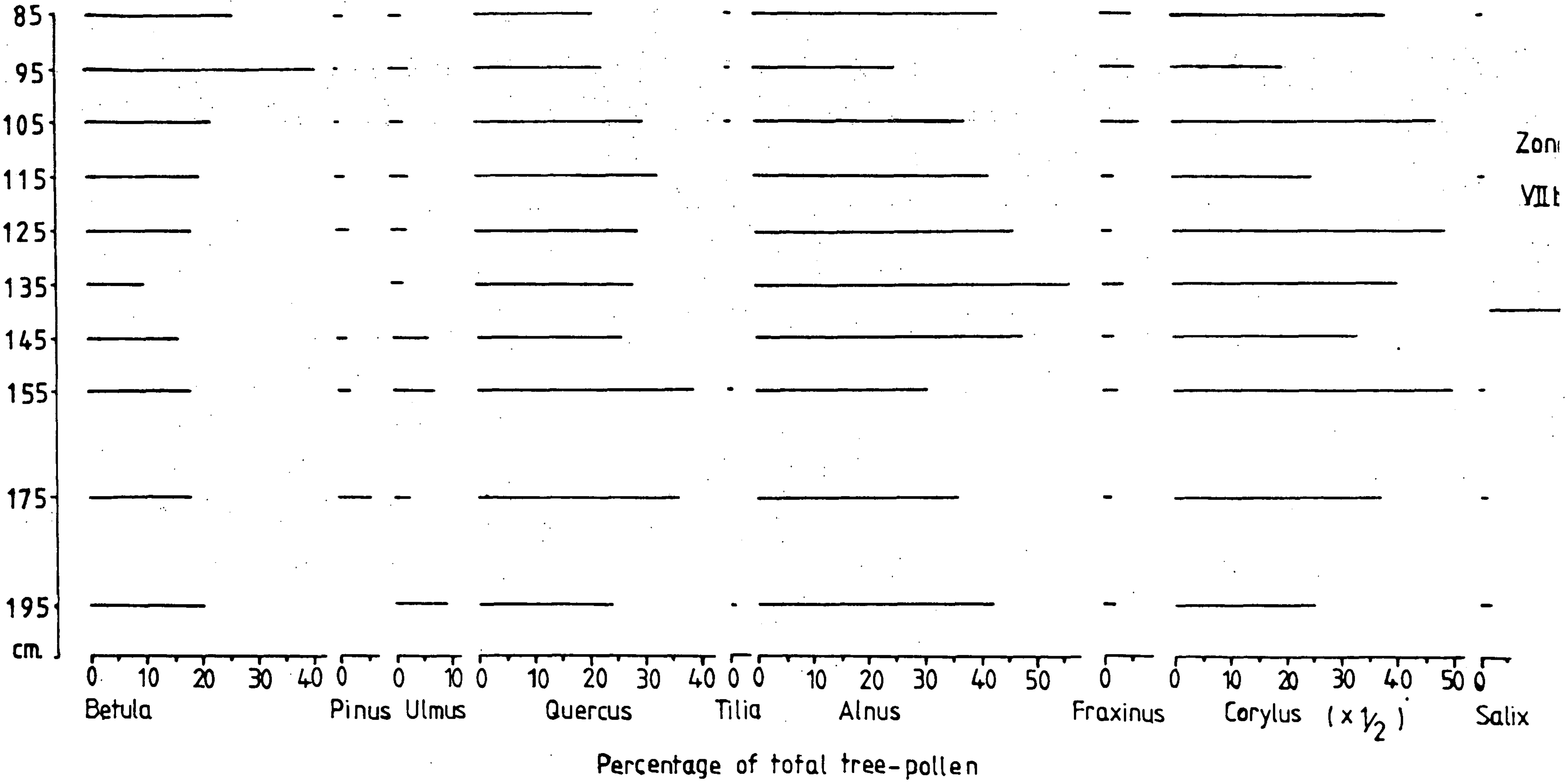


Fig. 6 Dufton Moss

Fig. 6 Dufton Moss

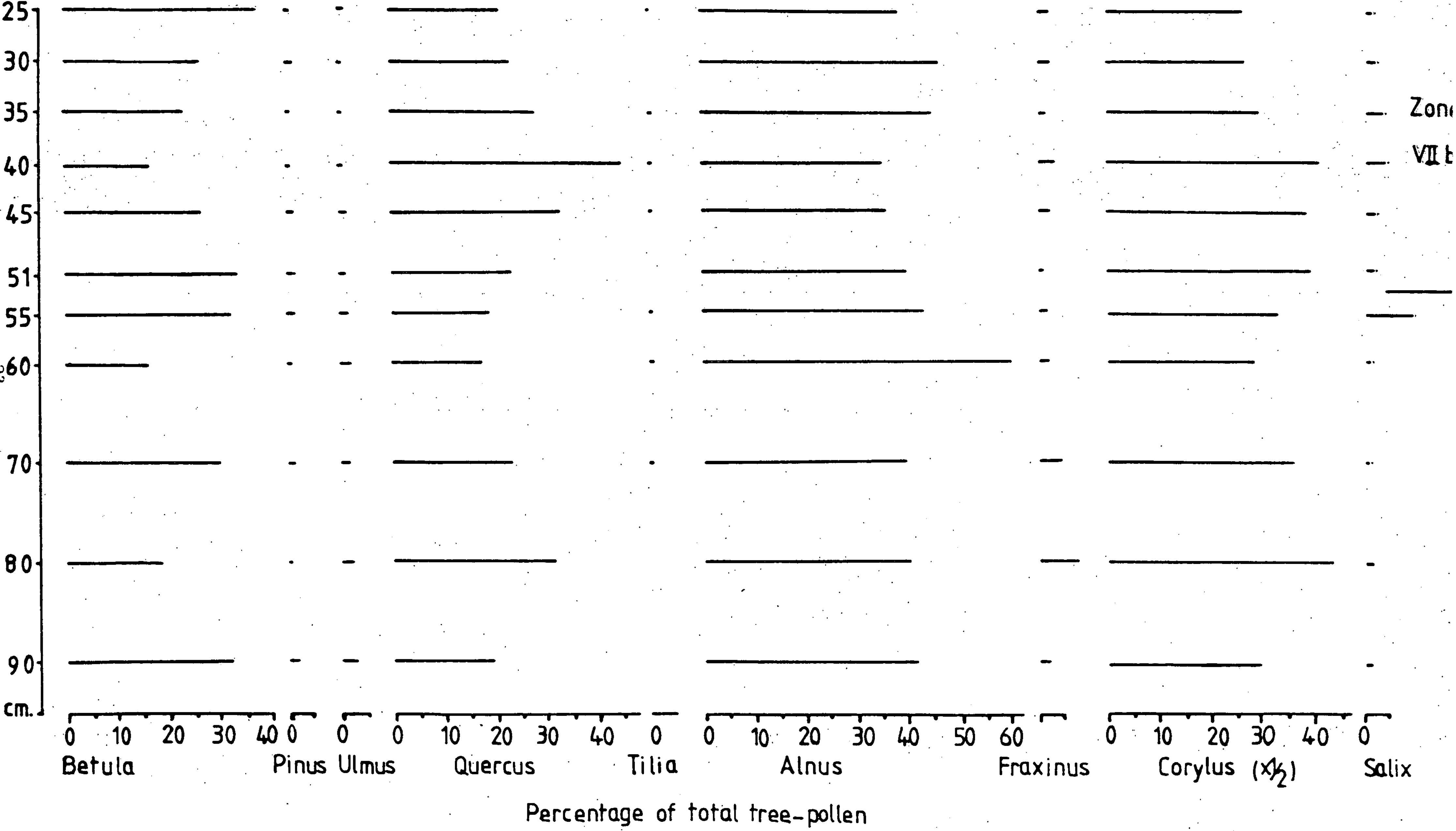


Fig. 7 Staple Moss

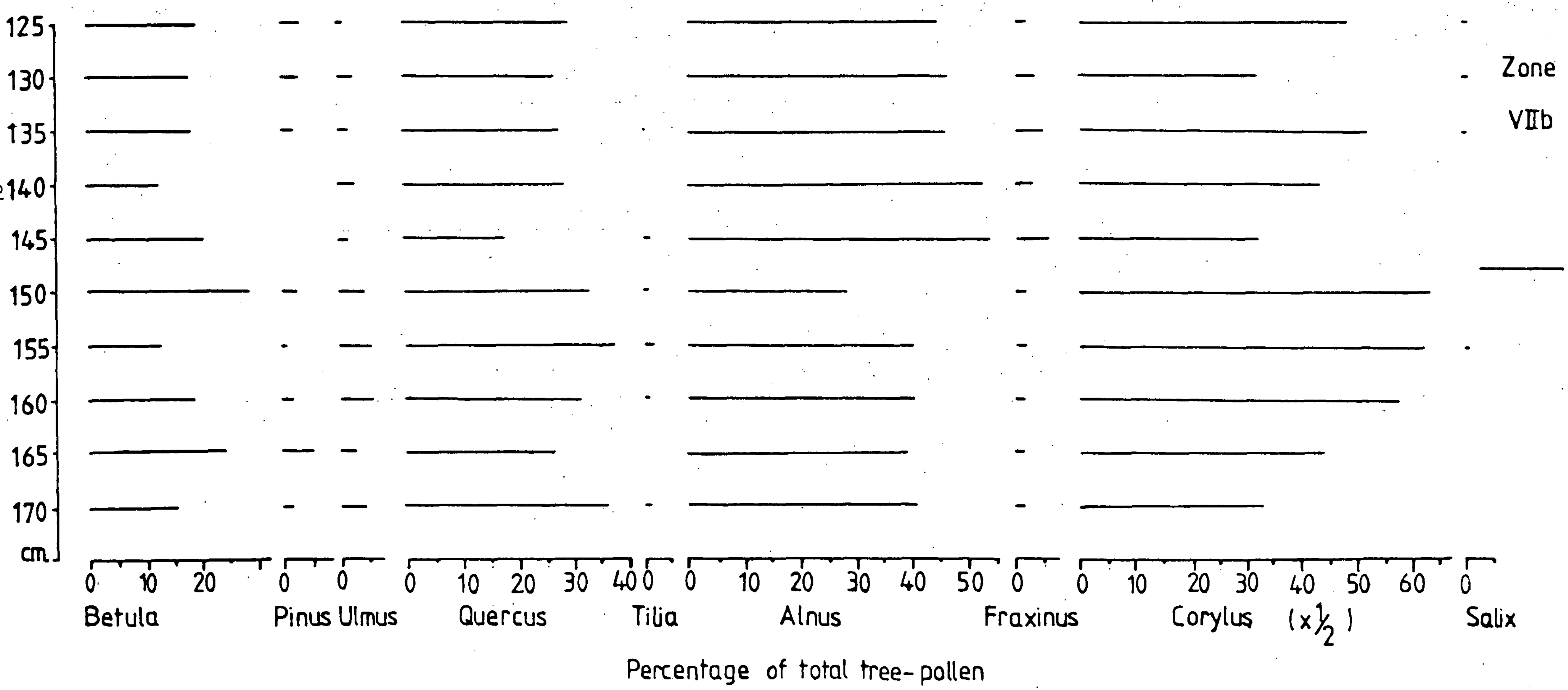


Fig. 8 **Fog Close**

Fig 8 Fog Close

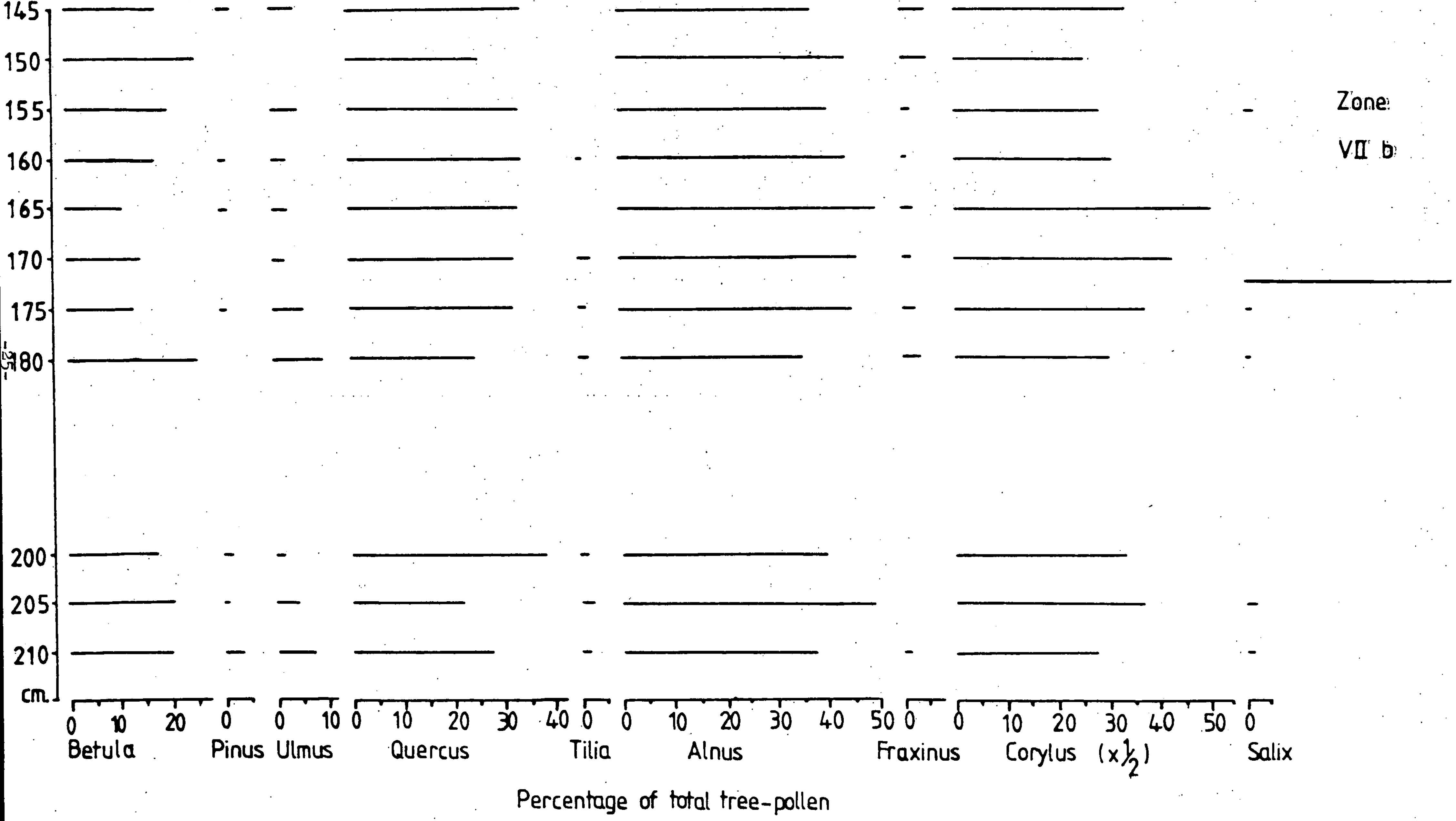


Fig. 9 White Beacon Hags

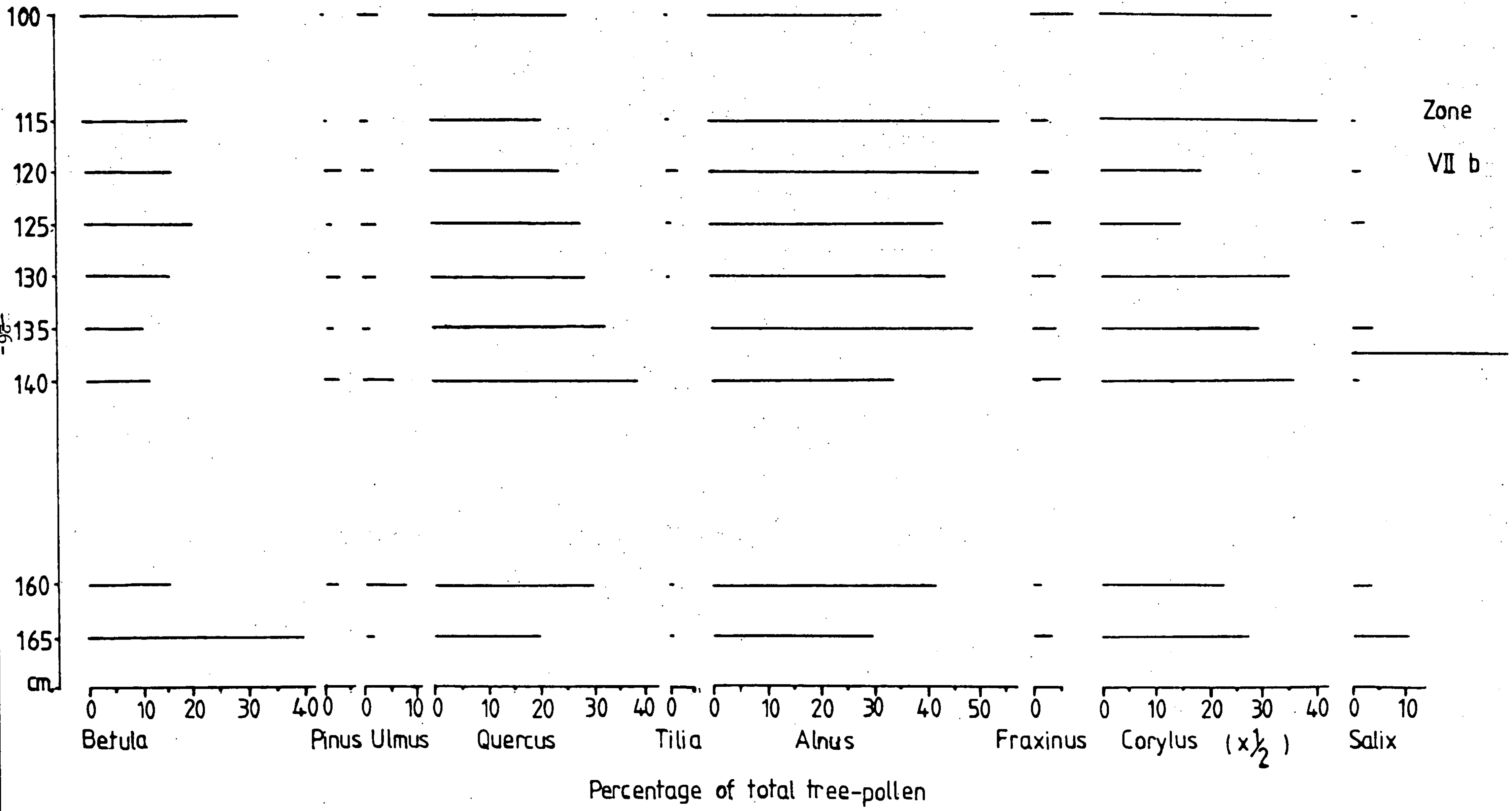
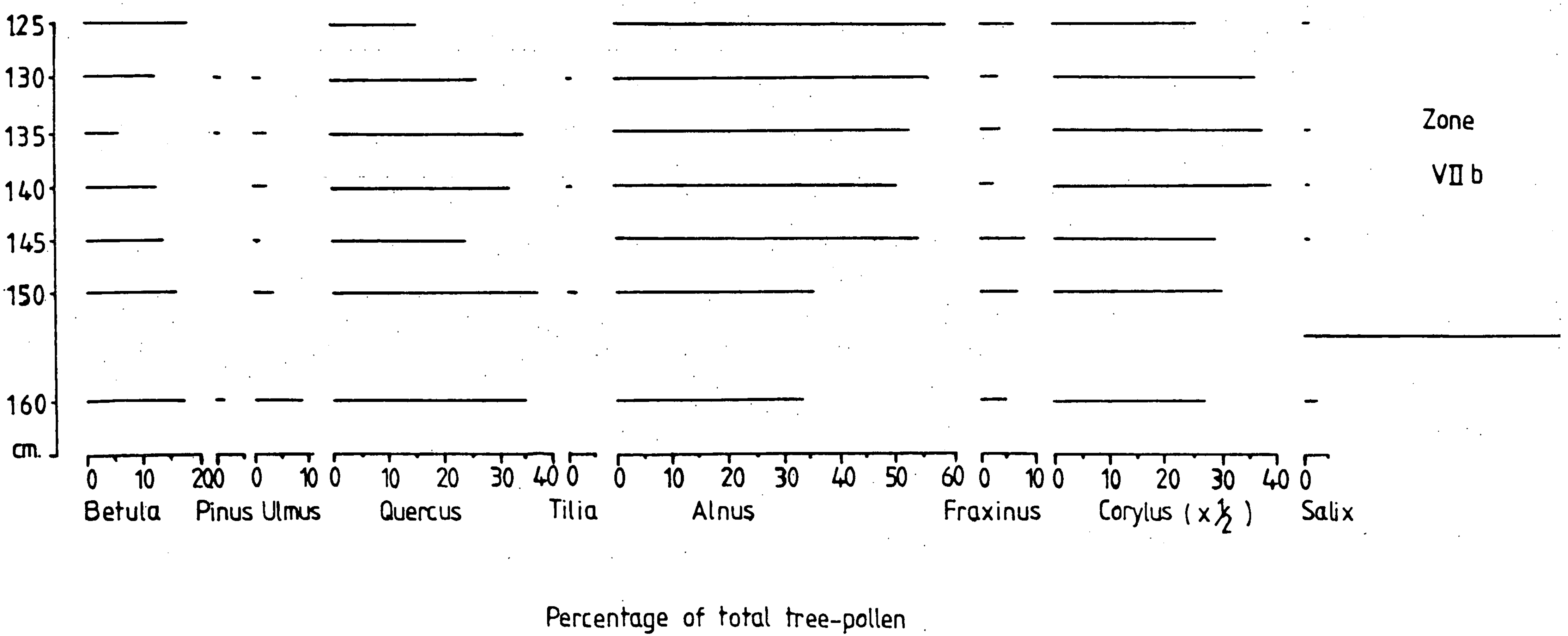


Fig. 10 Fleet Moss



at four sites, a decrease at three sites and little or no change at two sites.

Corylus and Quercus show overall trends in representation at five or more sites after the elm decline. Corylus shows great fluctuations in the pollen frequencies whilst Quercus shows a trend of increase followed by a decrease in representation after the elm decline. Although Alnus and Betula show trends at two or three sites, these variations do not represent an overall trend.

The minor arboreal components of the woodland show very little within-site variation but do show various features at one or more sites.

(b) BETWEEN-SITE VARIATIONS IN THE TAXA RECORDED ALONG THE NORTH-SOUTH TRANSECT DURING THE SUB-BOREAL PERIOD.

Refer to Tables 2 (i) and (ii) and 4

The chi-squared value for the variation between the sites using the total pollen count for each taxon at each site is 1500.41 with 64 degrees of freedom and is highly significant. However, both the chi-squared results and the pollen diagrams demonstrate that there is significant variation within each of the nine sites. It is therefore necessary to demonstrate that the apparent between-site variation is distinct from and not resultant from the within-site variation. This demonstration was made using a form of Montecarlo test which has been designed to establish the validity of the chi-squared value for the between-site variation, notwithstanding the significant within-site variation.

The program used for the test calculated a chi-squared value for the between-site variation 999 times. Before each calculation the fifty-six samples were rearranged in a random manner into nine groups having the same numbers of samples as the nine sites. The 999 chi-squared values were then placed in arbitrary, but equal-interval classes as represented in Table 4 to show their probability distribution. The highest chi-squared value based on a random rearrangement is 598.11, and this falls into class four, with a probability value of 0.05. The chi-squared value

TABLE 4 MONTECARLO DISTRIBUTION OF PROBABILITY BASED ON 999 RANDOM SAMPLES.

CLASS	CHI-SQUARED VALUE	NUMBER IN CLASS
1	0.00 - 150.04	5
2	150.04 - 300.08	479
3	300.08 - 450.12	465
4	450.12 - 600.16	50
5	600.16 - 750.20	0
6	750.20 - 900.24	0
7	900.24 - 1050.28	0
8	1050.28 - 1200.32	0
9	1200.32 - 1350.36	0
10	1350.36 - 1500.41	0
11	1500.41 - 1650.45	1

Montechi, ie. highest chi-squared value on a random number was 598.11. It falls in class 4. The probability value is 0.05.

for the actual data is 1500.41 and this falls into class eleven with a probability value of 0.001. Thus it can be concluded that the between-site variation apparent in the data is significant and independent of the variation within each site.

Having established that there was a significant variation between the sites, mean values were calculated for each taxon at every site (Table 6). Thereafter the between-site variation of taxa was further explored by means of scatter plots (Figs.11-19), regression and polynomial analyses (Table 9) as described in the methods.

COMPARISON OF THE ATLANTIC TO THE SUB-BOREAL FOREST COMPOSITION.

Refer to Atlantic and Sub-Boreal scatter plots Figs.11-28 and to Tables 5-9 inclusive.

Mean Values, for each taxon at every site, from the immediately preceding Atlantic period were obtained from the work of Dr.J.Turner (Table 5). These results underwent a scatter plot, regression and polynomial analysis before being compared with the Sub-Boreal data.

BETULA

The Sub-Boreal, and more so the Atlantic, regression results indicate an almost significant between-site variation with Betula frequencies higher in the northern than the southern sites. However this is not the case. It is the exceptionally high Betula frequency at Grahms Moss that is the cause of the great between-site variation observed during both periods.

The results that show the difference in Betula representation between the periods (Table 8) indicate an actual decrease at three of the northern sites and an increase at three of the southern sites. Therefore moving from the Atlantic to the Sub-Boreal we observe a see-sawing effect whereupon Betula, although showing little change in representation, has descreased in the north whilst increasing in the south.

PINUS

Like Betula, Pinus appears to show a general trend of increase along the transect with lower values of pine in the south. This trend is more pronounced in the Atlantic period than the following Sub-Boreal period. However neither the regression nor the polynomial analyses results for Pinus were significant in either of the periods.

ULMUS

The regression analysis for the Ulmus representation in the forest prior to the elm decline gave very significant results ($P=0.008$) Apparently in the Atlantic period, Ulmus was more abundant in the southern reaches showing a steady trend of decline moving northwards along the Pennine transect. This clinal variation observed in the Atlantic is totally lost after the elm decline as might be expected. This is clearly seen from the Sub-Boreal scatter plot and regression analysis. Here it is seen that Ulmus records the most insignificant result of all the taxa indicating virtually no between-site variation.

These results show that not only was the Ulmus representation reduced to less than a couple of percent after the elm decline but this decrease was greatest in the southern sites.

QUERCUS.

It is apparent from the scatter plot that in the Atlantic period Quercus frequencies decreased moving from the south to the centre of the transect and increased thereafter. To check this trend the polynomial test was run to see if a curve could fit this variation. However the results indicated that the variation was not sufficient for such a curve to be fitted. This was undoubtedly due to the exceptional low values for Quercus at Grahms Moss (see Betula paragraph).

In contrast the variations of Quercus between the sites in the Sub-Boreal showed little ,if any trends. Here again the regression and polynomial analyses recorded insignificant results.

What is clearly a feature of Quercus is that at six sites it increases in frequency when moving from the Atlantic to the Sub-Boreal.

TILIA

Although all the mean values of Tilia frequencies were below 0.8% the scatter graphs do indicate a clinal variation in both the Atlantic and Sub-Boreal periods with higher values of lime in the southern sites.

This variation is confirmed for both periods with a highly significant regression analysis result. Whether this trend is vegetationally significant with such a low representation of lime will be discussed later.

As Table 8 indicates Tilia decreased in frequency after the elm decline. Like Ulmus this decrease was greatest in the southern sites where Tilia was previously most abundant.

ALNUS.

Three points arise when comparing the Atlantic representation of Alnus to that during the Sub-Boreal.

One is that Alnus increased greatly after the elm decline and that the increase was the highest recorded of any of the tree taxa.

The second point is that this increase in frequency is greatest in the south.

The final point is that whereas there is no clinal variation in the Atlantic there is in the Sub-Boreal. As was seen in Ulmus frequencies in the Atlantic period and Tilia frequencies in both periods, Alnus shows a decline in representation moving northwards along the transect.

This third point is a direct consequence of the second, the clinal variation is due to increased values of Alnus in the south.

FRAXINUS

The variation between the sites was sufficient to pick up a clinal variation with the greater frequencies of Fraxinus in the south. This trend was highly significant and like Tilia it was originally present in the Atlantic and maintained in the Sub-Boreal period.

CORYLUS

Corylus pollen frequencies were the highest recorded of all the arboreal taxa in both periods. As seen previously Corylus decreases after the elm decline. It is now apparent that this decline was greatest in the southern sites.

In the Atlantic period a trend is observed whereby hazel is more abundant in the southern than the northern sites. In the Sub-Boreal it appears that Corylus increased towards the centre of the transect and decreased thereafter. The respective regression and polynomial results indicated that the variation was not sufficient to satisfy either of these models.

SALIX

Salix is a minor component of the forest with its highest proportion recorded in the Atlantic woodland. The regression and polynomial results are highly insignificant in both periods indicating a lack of pattern in the between-site variations

It is clear from the results that the trees that cause the greatest amount of between-site variation, with a greater representation to the south, are Ulmus (Atlantic only), Alnus (Sub-Boreal only), Tilia and Fraxinus (both periods). For each of these four species this clinal variation will be discussed in a little more detail below.

TABLE 5 ATLANTIC PERIOD MEAN VALUES OF EACH ARBOREAL TAXON(EXPRESSED AS % AP) RECORDED AT SITES 1-9 ALONG THE TRANSECT

SITE	BETULA	PINUS	ULMUS	QUERCUS	TILIA	ALNUS	FRAXINUS	CORYLUS	SALIX.
1	18.39	2.76	4.16	20.41	0.12	22.02	0.16	31.79	0.16
2	54.76	8.37	2.98	5.87	0.10	4.33	0.10	20.98	2.50
3	11.16	4.90	5.89	19.68	0.12	12.51	0.55	44.51	0.67
4	15.53	2.80	7.76	18.03	0.24	13.98	0.82	38.77	2.07
5	14.23	0.98	7.91	12.73	0.37	17.83	0.61	45.06	0.28
6	11.03	2.20	5.89	13.04	0.23	17.01	0.37	49.86	0.37
7	5.55	2.61	7.45	15.33	0.38	13.76	0.60	53.53	0.47
8	6.82	1.99	7.61	17.69	0.72	17.03	0.97	46.44	0.72
9	2.36	2.72	9.06	22.64	0.27	19.66	1.45	40.49	1.36

TABLE 6. SUB-BOREAL PERIOD MEAN VALUES OF EACH ARBOREAL TAXON(EXPRESSED AS % AP) RECORDED AT SITES 1-9 ALONG THE TRANSECT

SITE	BETULA	PINUS	ULMUS	QUERCUS	TILIA	ALNUS	FRAXINUS	CORYLUS	SALIX
1	15.44	1.15	1.72	24.12	0.13	24.76	0.26	32.29	0.13
2	45.70	0.58	0.58	11.30	0. 0	21.28	0.15	19.24	1.17
3	13.04	2.47	1.26	20.85	0.11	20.22	2.30	39.06	0.69
4	13.12	0.58	1.47	15.69	0.19	24.14	2.43	42.19	0.19
5	16.24	0.62	0.50	17.07	0.12	23.55	1.20	39.33	1.37
6	9.75	0.80	0.95	14.34	0.07	26.71	1.97	45.20	0.22
7	10.44	0.33	1.63	18.85	0.26	25.83	1.37	41.16	0.13
8	11.80	0.83	1.46	16.79	0.49	28.38	2.91	36.22	1.11
9	8.02	0.13	0.87	16.98	0.27	31.08	2.81	39.57	0.27

TABLE 7 THE OVERALL TRANSECT MEAN FOR EACH TAXON IN THE ATLANTIC AND SUB-BOREAL PERIODS

ARBOREAL	OVERALL MEAN VALUES (% AP.)	
TAXON	ATLANTIC	SUB-BOREAL
BETULA	15.51	15.95
PINUS	3.25	0.83
ULMUS	6.25	1.16
QUERCUS	16.15	17.13
TILIA	0.28	0.18
ALNUS	15.34	25.1
FRAXINUS	0.62	1.7
CORYLUS	41.3	37.14
SALIX	0.95	0.58

Where 'overall transect mean' is the mean of the nine mean values obtained for each taxon in both periods.

TABLE 8 CHANGE IN THE FOREST COMPOSITION BETWEEN THE ATLANTIC AND SUB-BOREAL PERIODS (SUB-BOREAL MEAN - ATLANTIC MEAN POLLEN FREQUENCIES)

ARBOREAL TAXA EXPRESSED AS % AP.

SITE	BETULA	PINUS	ULMUS	QUERCUS	TILIA	ALNUS	FRAXINUS	CORYLUS	SALIX
1	-2.95	-1.61	-2.44	3.71	0.01	2.74	0.1	0.5	-0.03
2	-9.06	-7.79	-2.4	5.43	-0.1	16.95	0.05	-1.74	-1.33
3.	1.88	-2.43	-4.63	1.17	-0.01	7.71	1.75	-5.45	0.02
4.	-2.41	-2.22	-6.29	-2.34	-0.05	10.16	1.61	3.42	-1.88
5.	2.01	-0.36	-7.41	4.34	-0.25	5.72	0.59	-5.7	1.09
6.	-1. 28	-1.4	-4.94	1.3	-0.16	9.7	1.6	-4.66	-0.15
7.	4.89	-2.28	-5.82	3.52	-0.12	12.07	0.77	-12.67	-0.34
8.	4.98	-1.16	-6.15	-0.9	-0.23	11.35	1.94	-10.22	0.39
9.	5.66	-2.59	-8.19	-5.66	0	11.42	1.36	-0 .92	-1.09

TABLE 9 COMPARISON OF THE REGRESSION AND POLYNOMIAL ANALYSES BETWEEN THE ATLANTIC AND SUB-BOREAL PERIODS.

ARBOREAL TAXA	DEGREE OF SIGNIFICANCE			
	REGRESSION		POLYNOMIAL	
	ATLANTIC	SUB-BOREAL	ATLANTIC	SUB-BOREAL
BETULA	0.064	0.138	0.702	0.621
PINUS	0.190	0.148	0.340	0.990
ULMUS	0.008**	0.997	0.358	0.788
QUERCUS	0.383	0.653	0.399	0.431
TILIA	0.035*	0.019*	0.426	0.674
ALNUS	0.412	0.004**	0.549	0.211
FRAXINUS	0.004**	0.034*	0.473	0.594
CORYLUS	0.101	0.218	0.100	0.131
SALIX	0.817	0.853	0.719	0.782

SIGNIFICANT PROBABILITIES.

0.05 to 0.01 *

0.01 to 0.001 **

Fig 11 Betula Atlantic

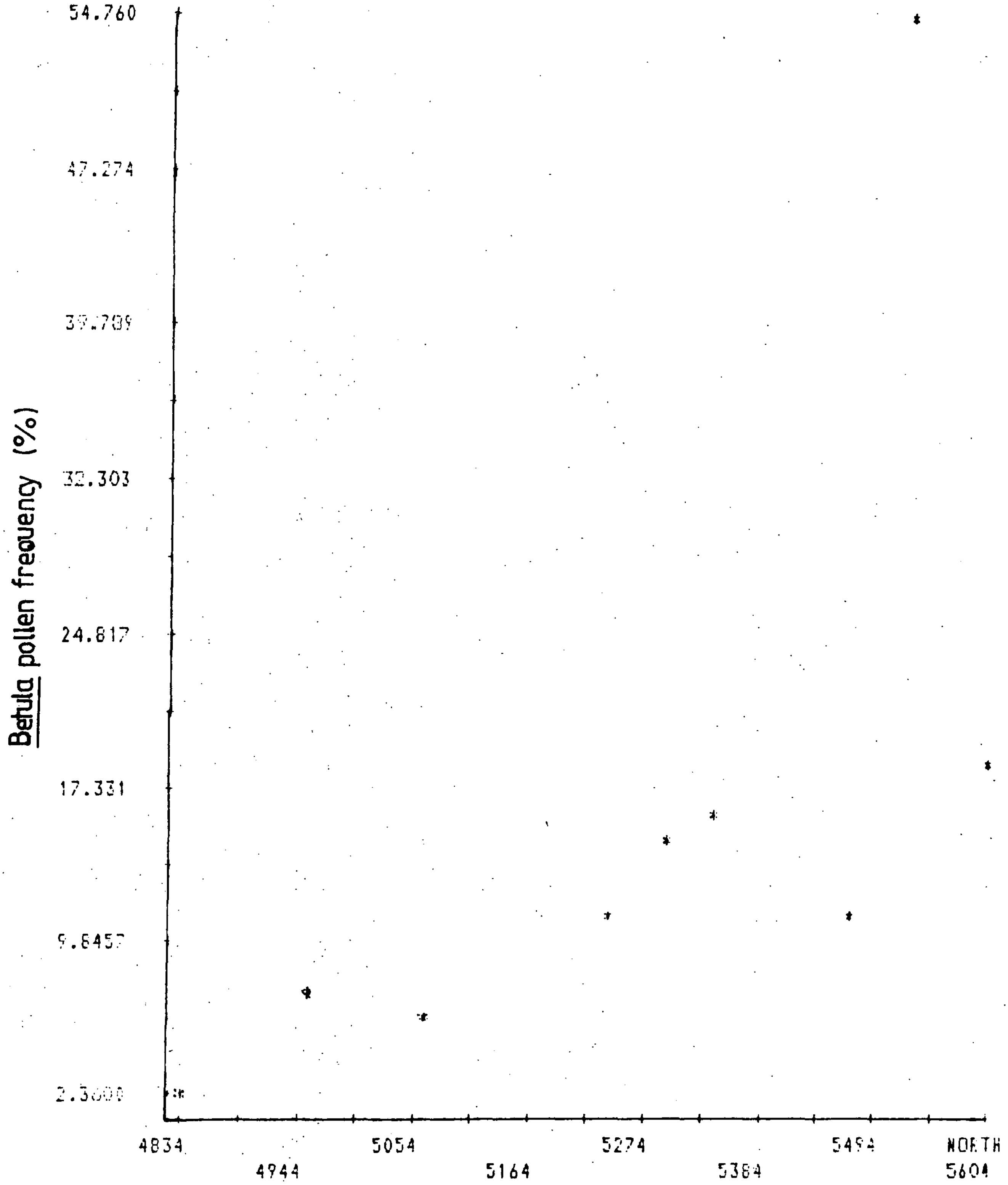


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Fig.12 Betula Sub-Boreal

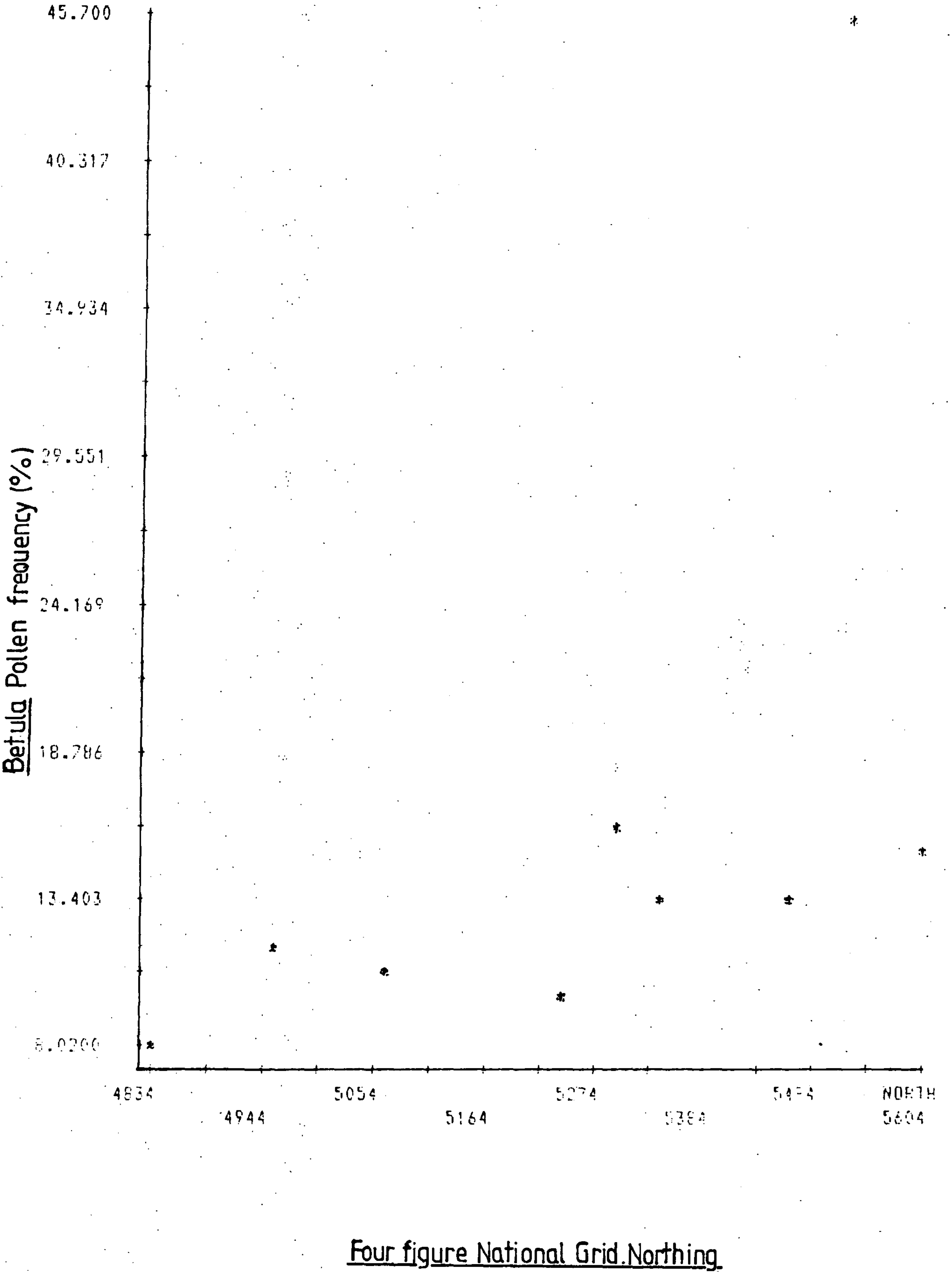

Fig.13 Pinus Atlantic

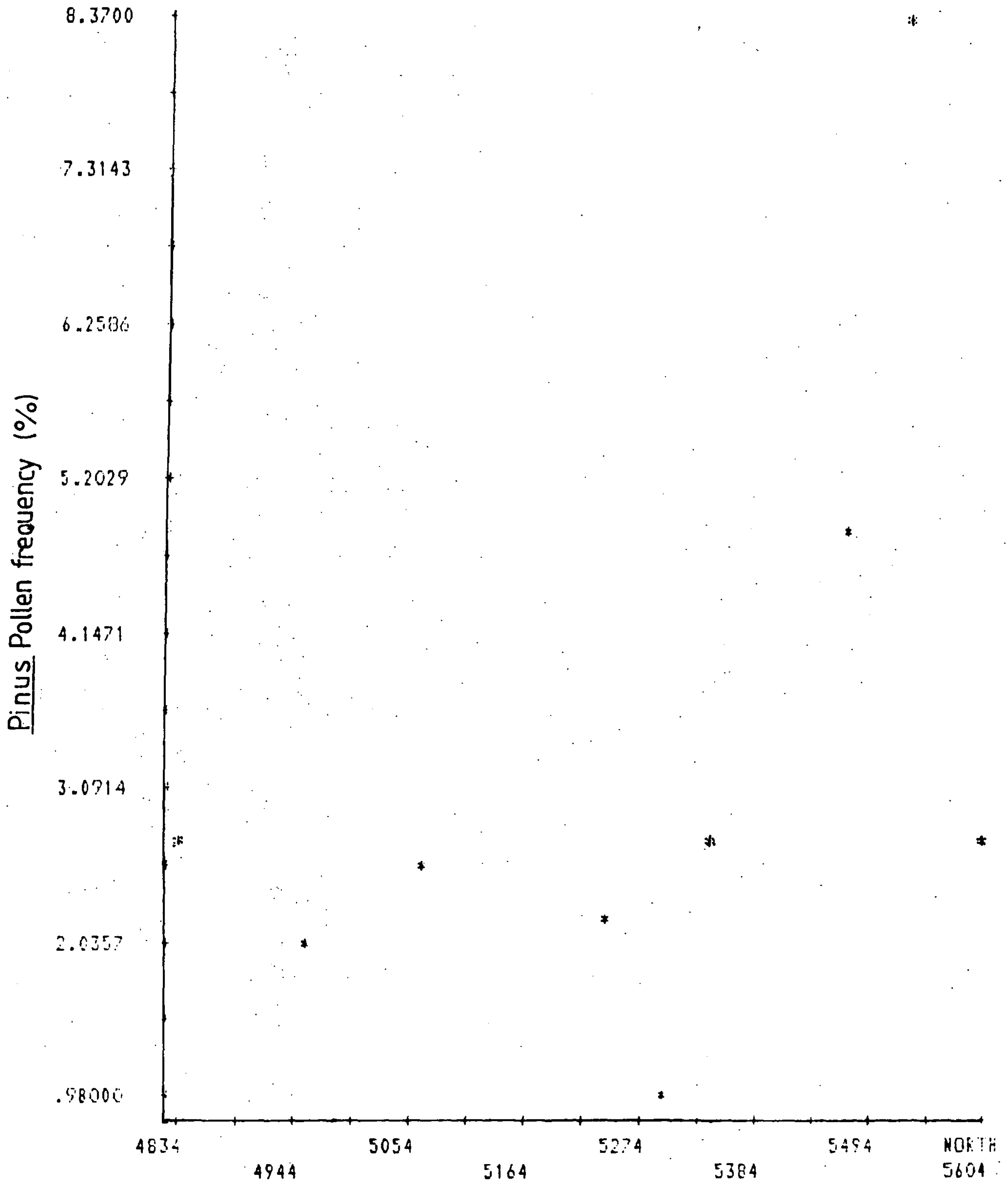

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Fig. 14 Pinus Sub-Boreal

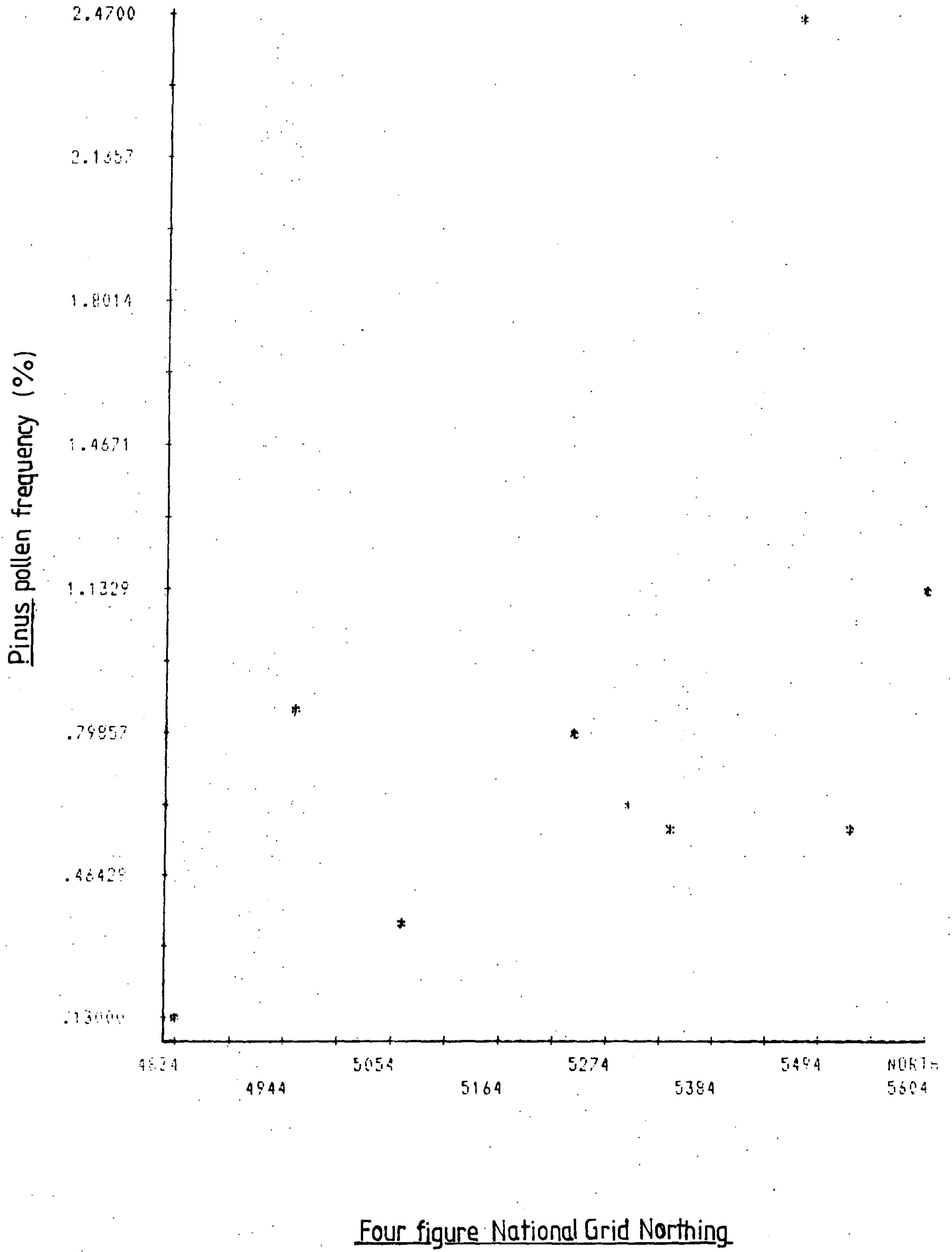

Fig 15 Ulmus Atlantic

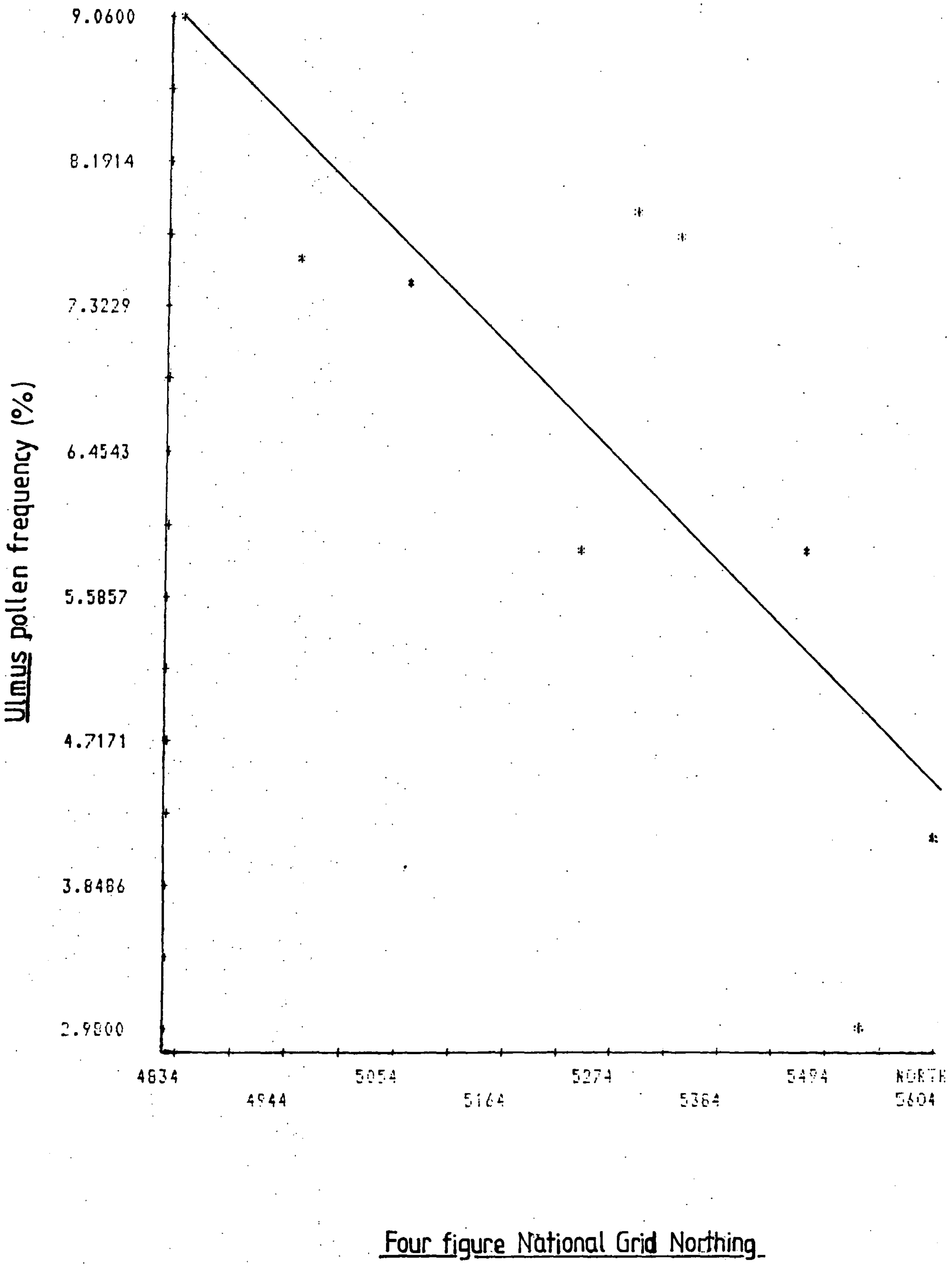

Fig 16 Ulmus Sub-Boreal

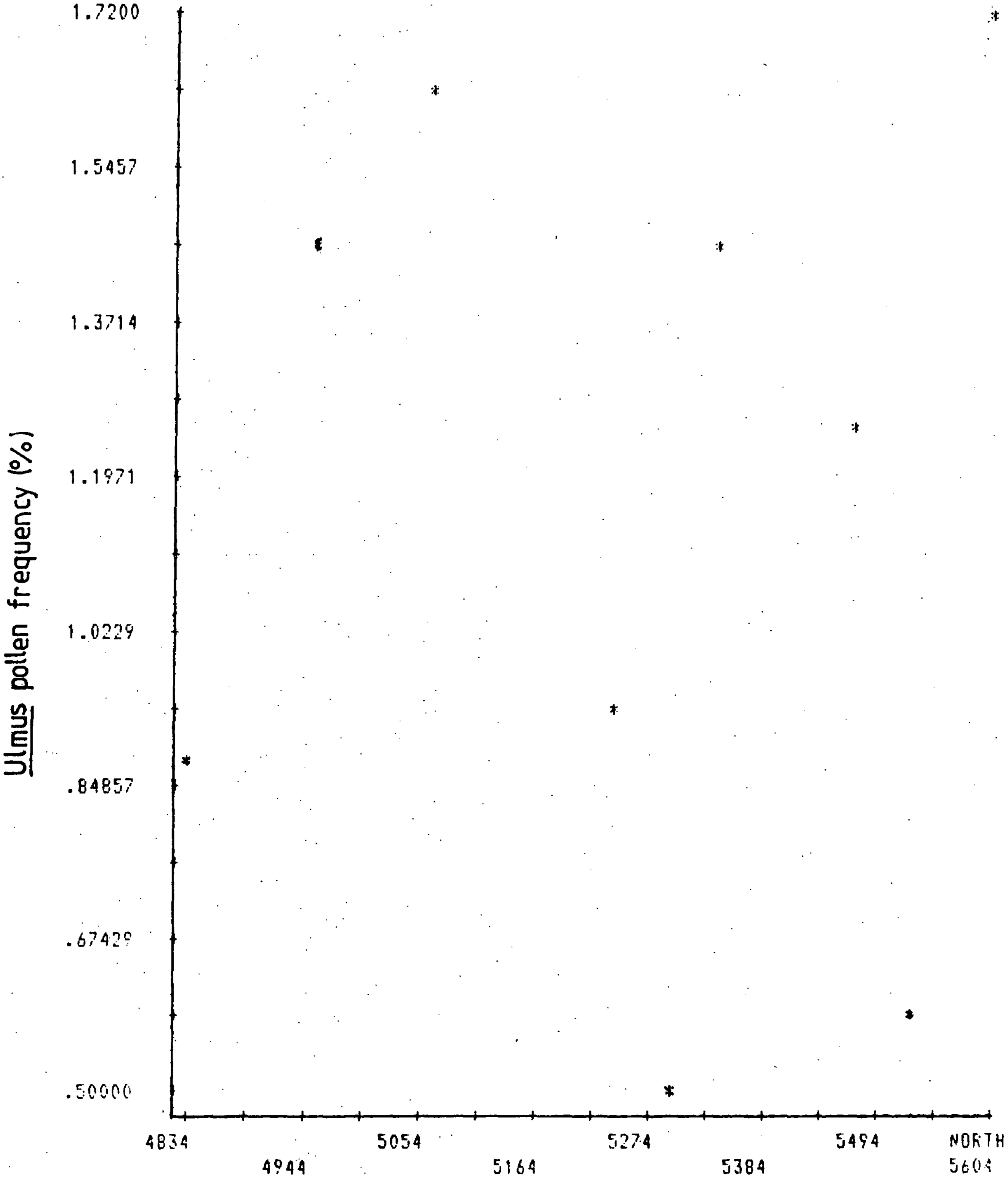

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Fig.17 Quercus Atlantic

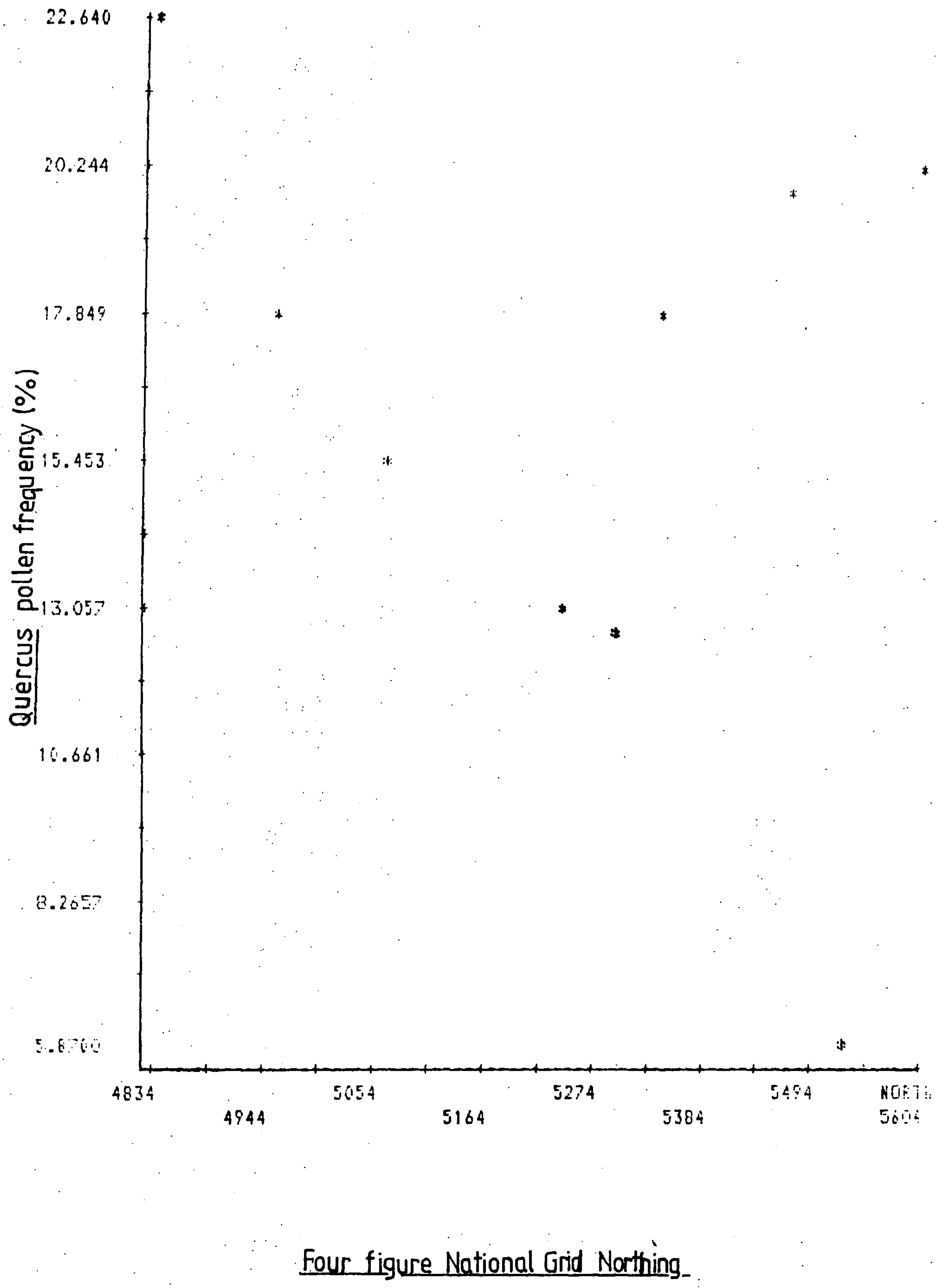

Fig.18 Quercus Sub-Boreal

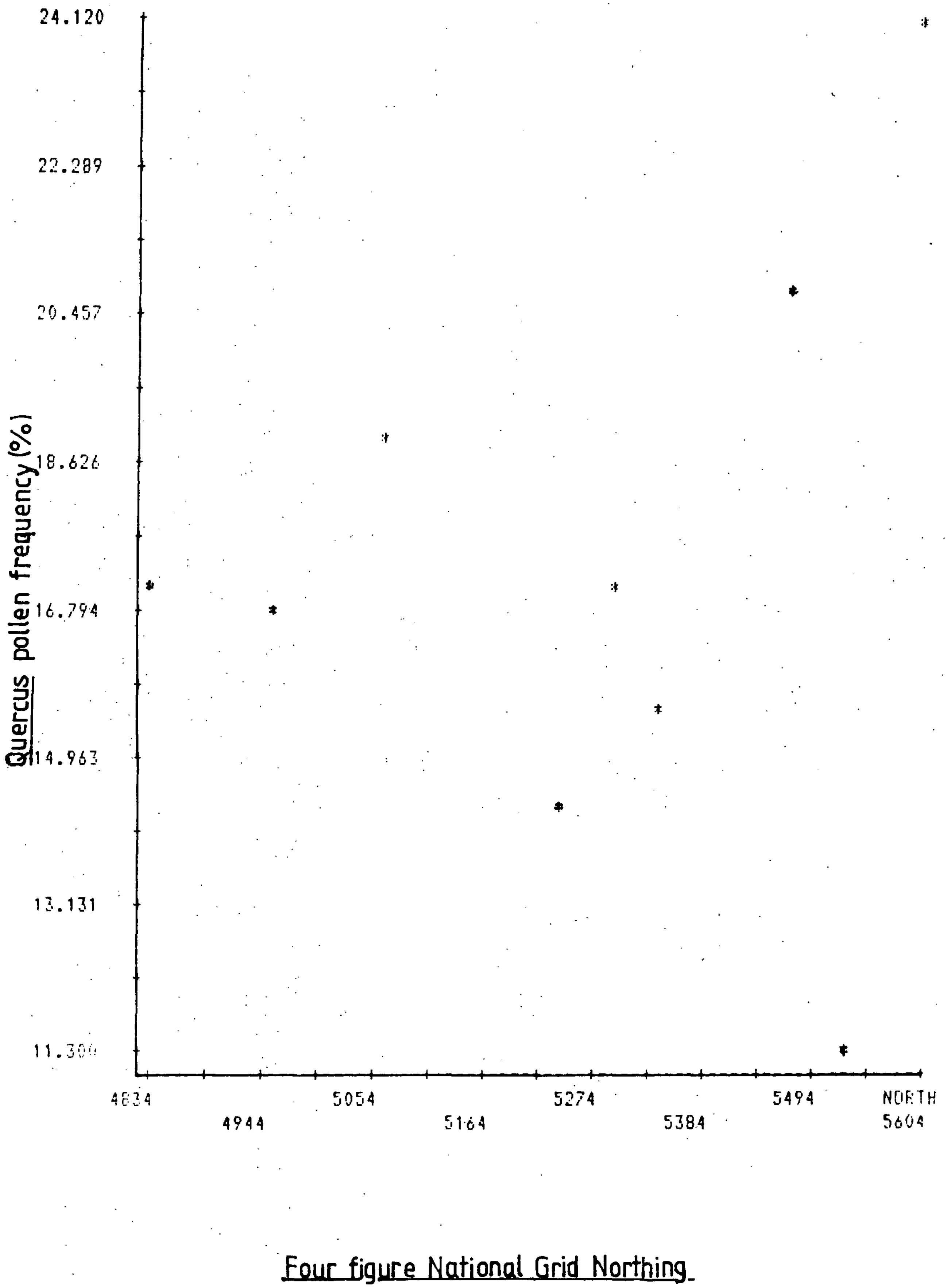

Fig. 19 *Tilia* Atlantic

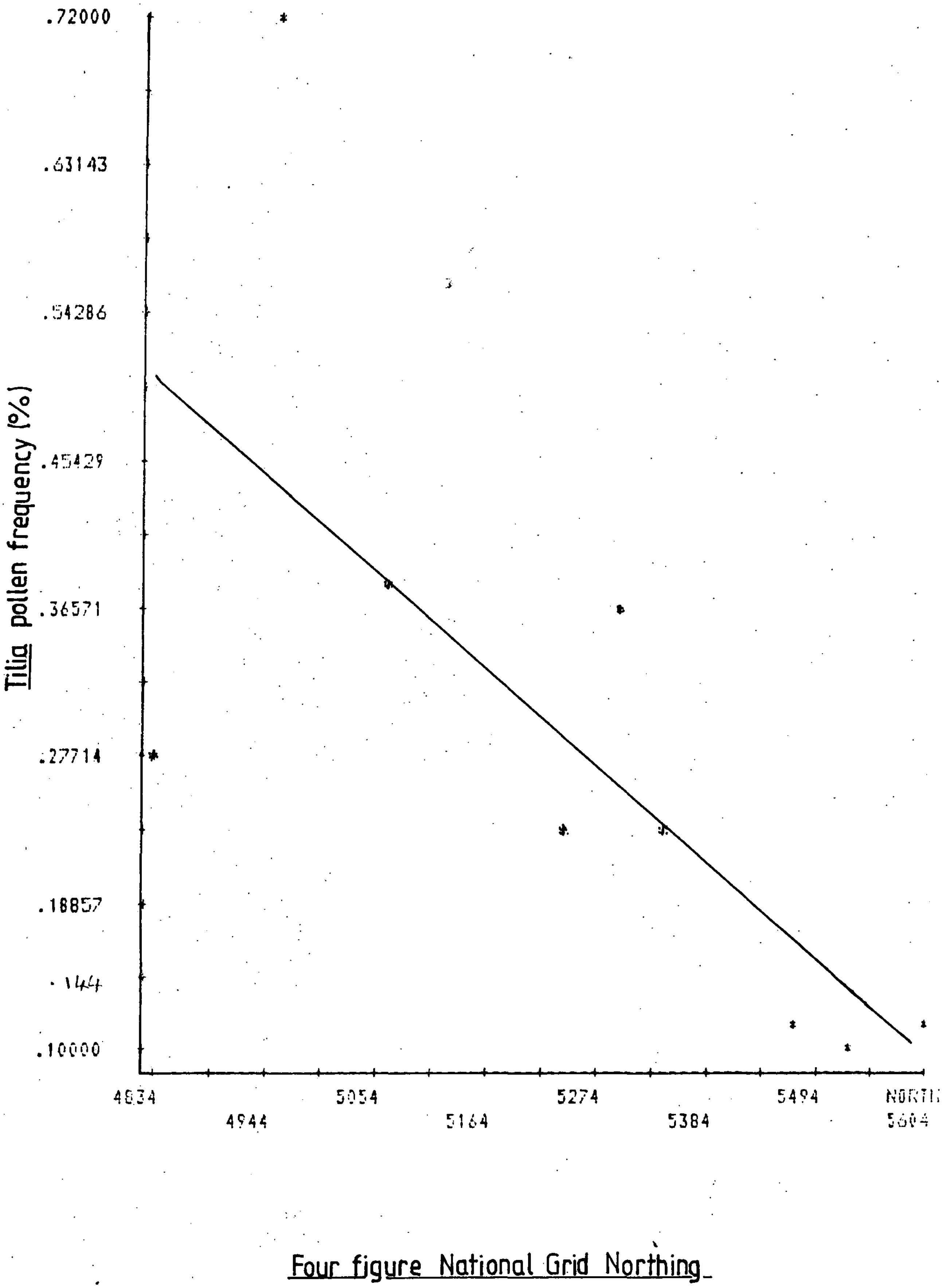

Fig. 20 Tilia

Sub-Boreal

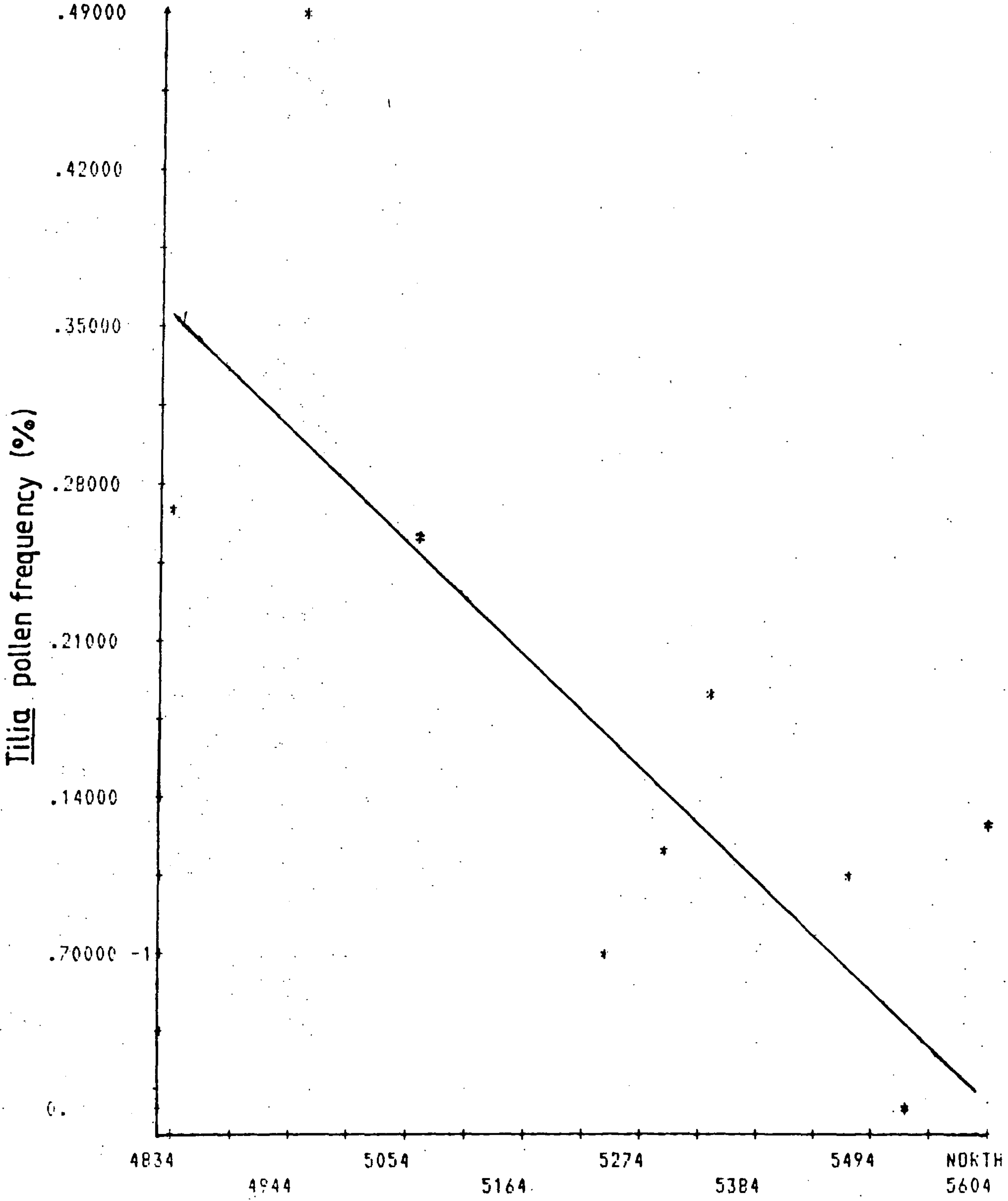

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Fig. 21 Alnus Atlantic

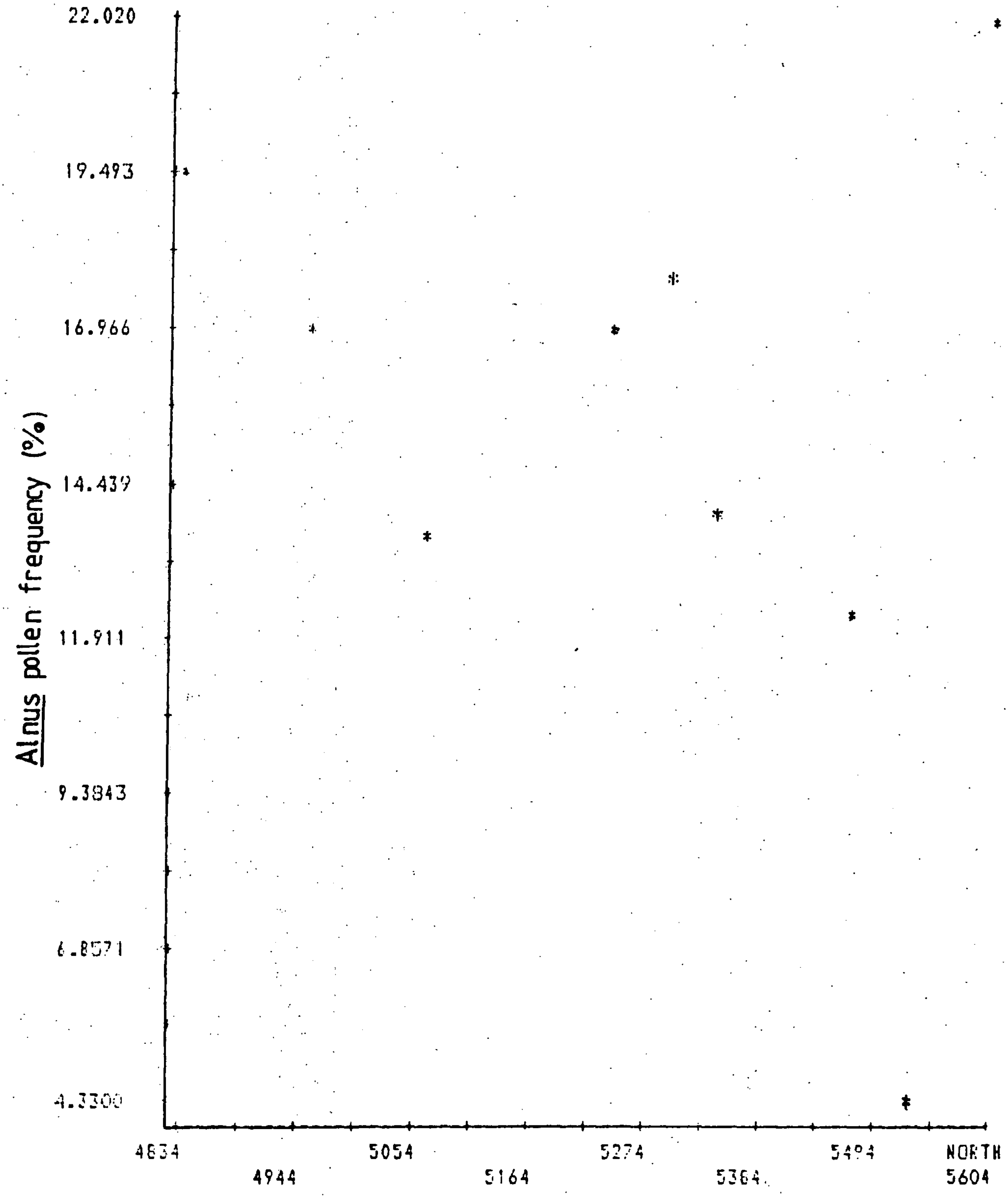

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Fig.22 *Alnus* Sub-Boreal

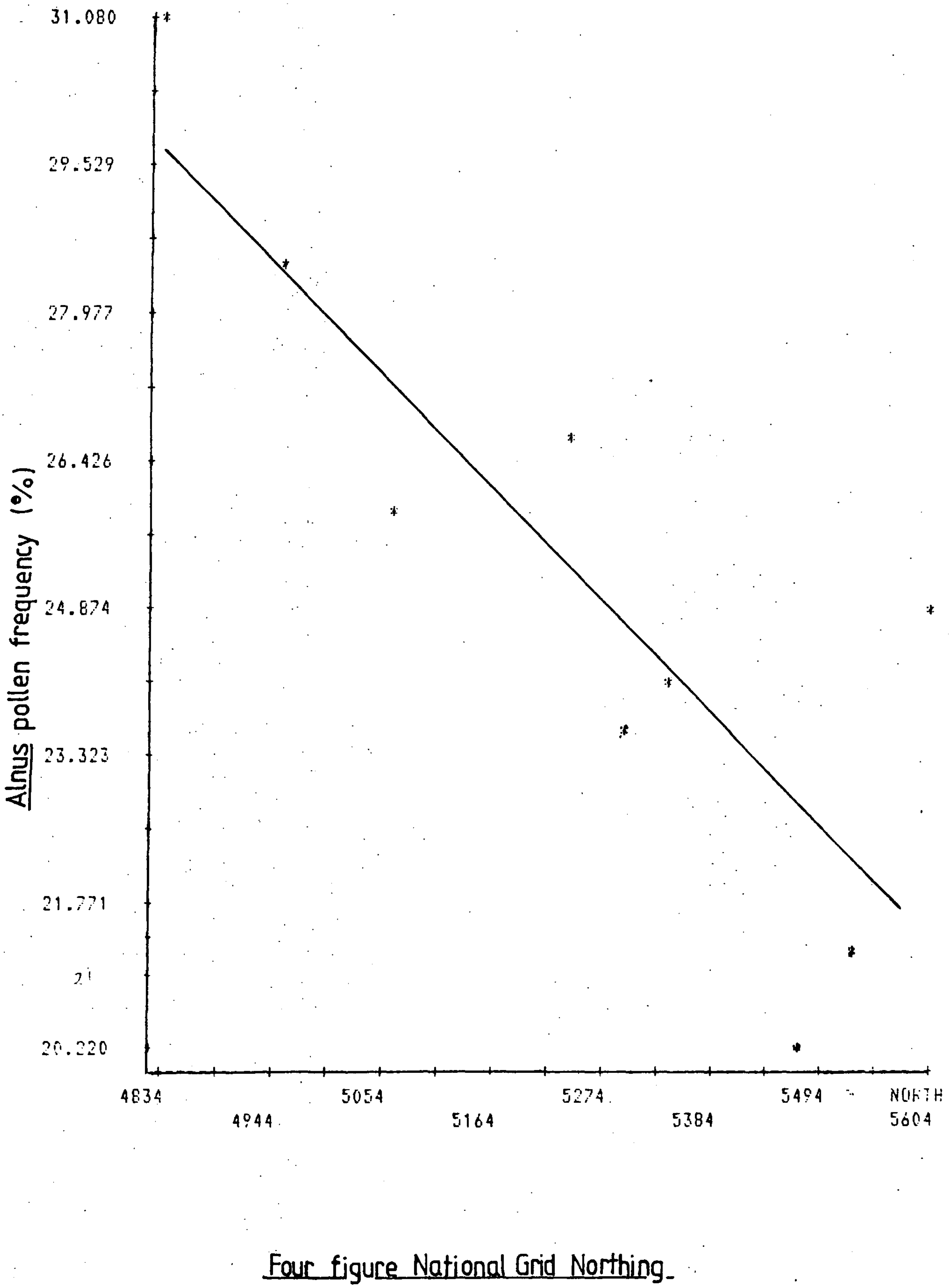

Fig. 23 Fraxinus Atlantic

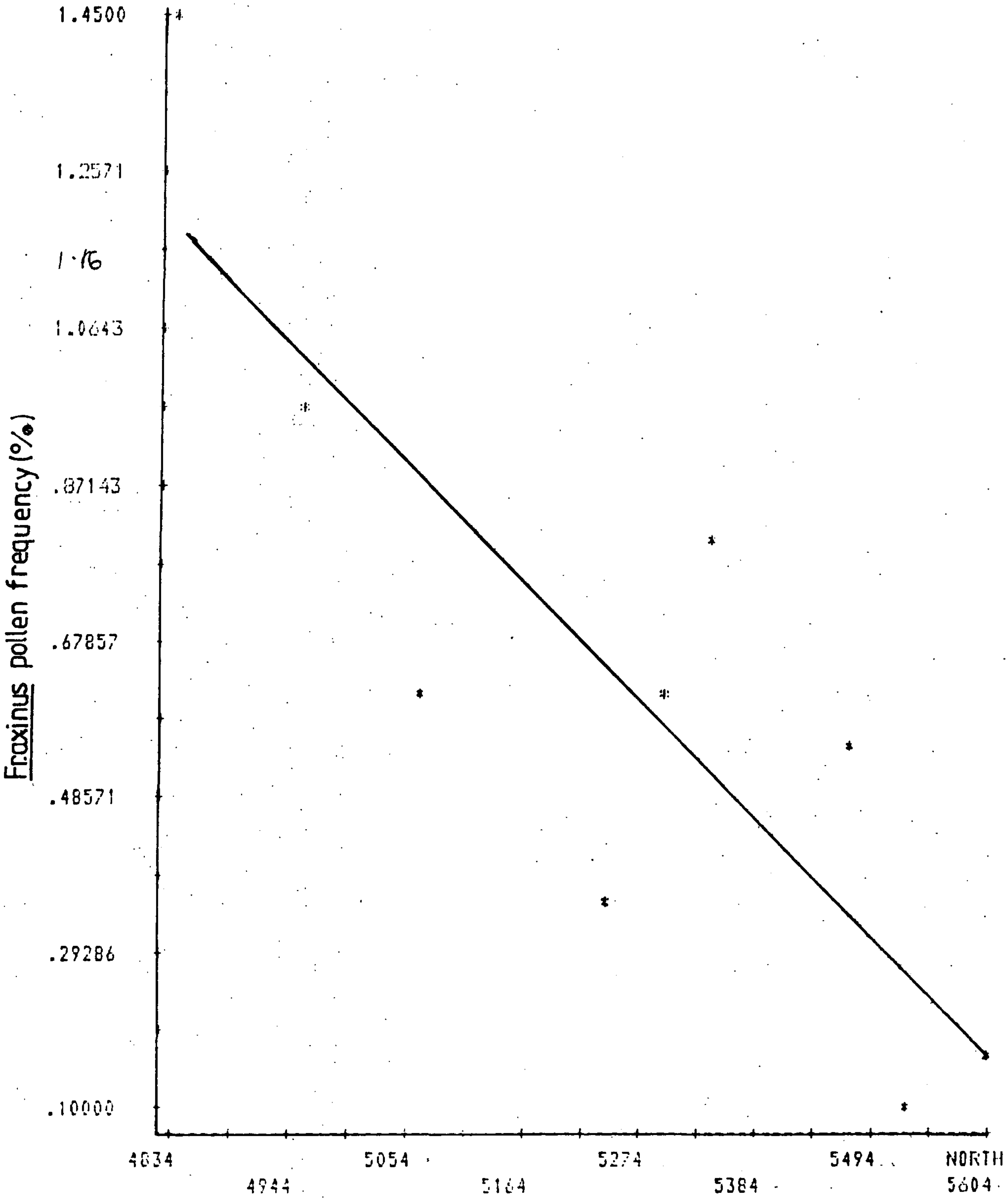

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Fig. 24 Fraxinus Sub-Boreal

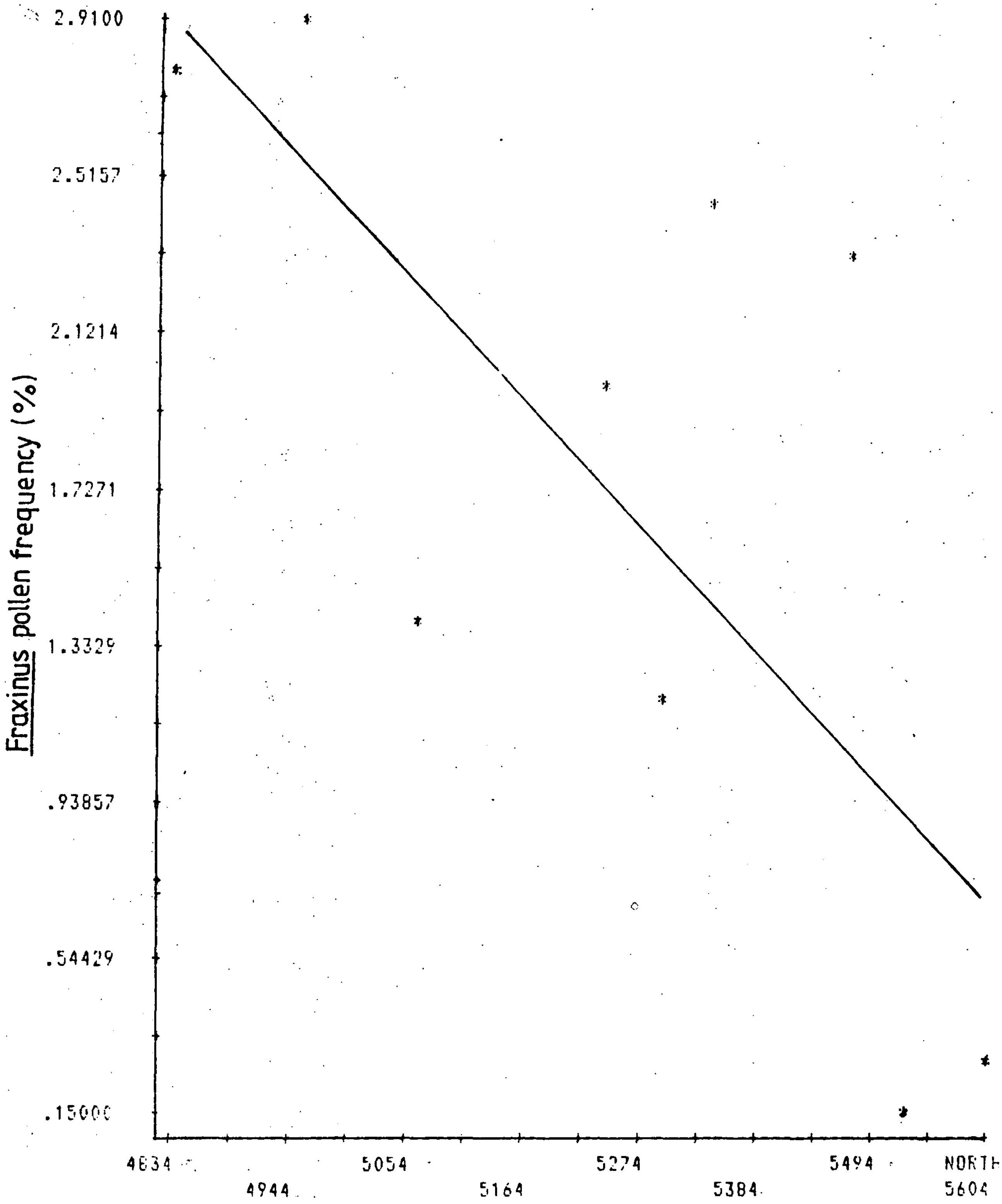

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Fig. 25 Corylus Atlantic

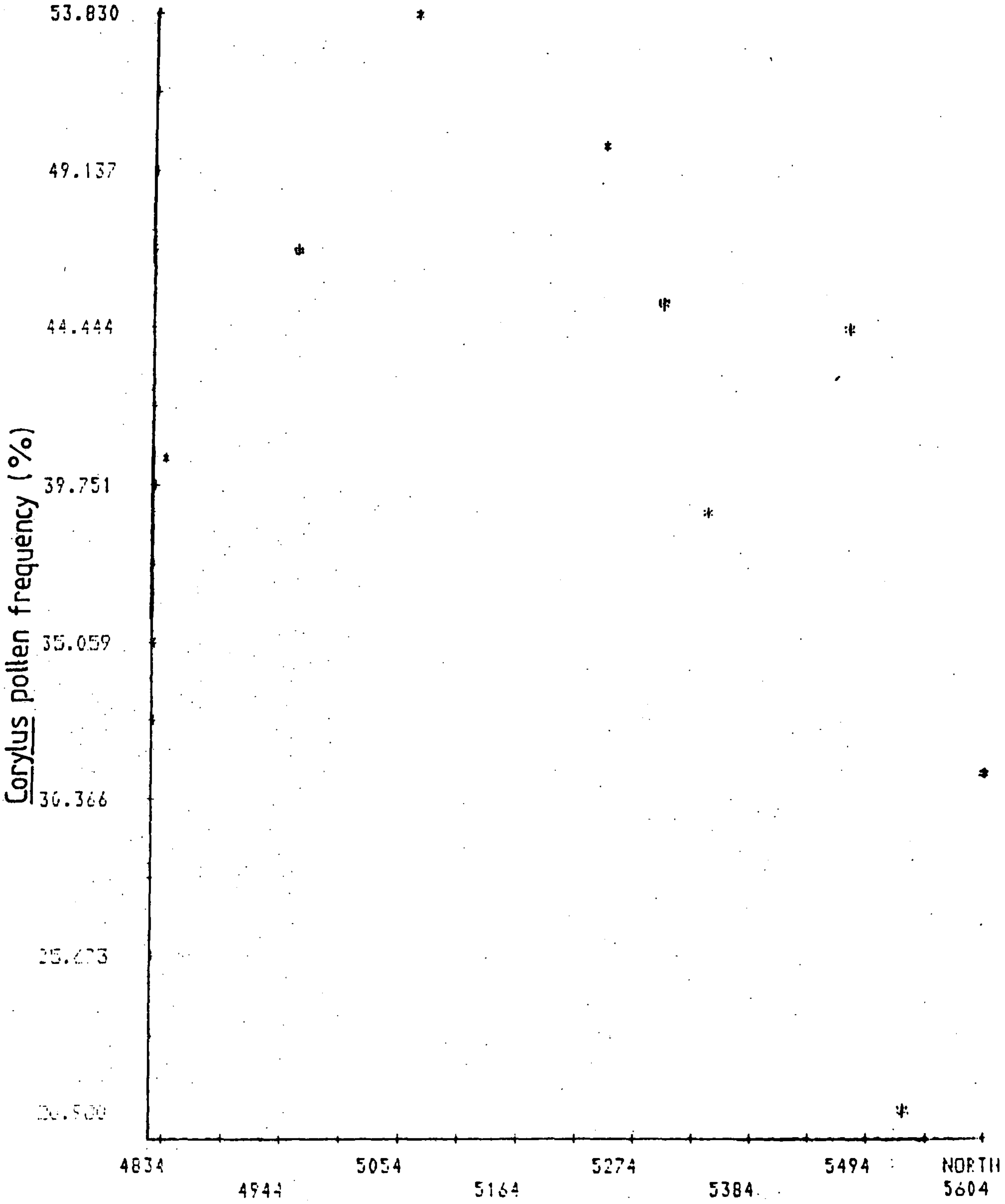

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Fig. 26 Corylus Sub-Boreal

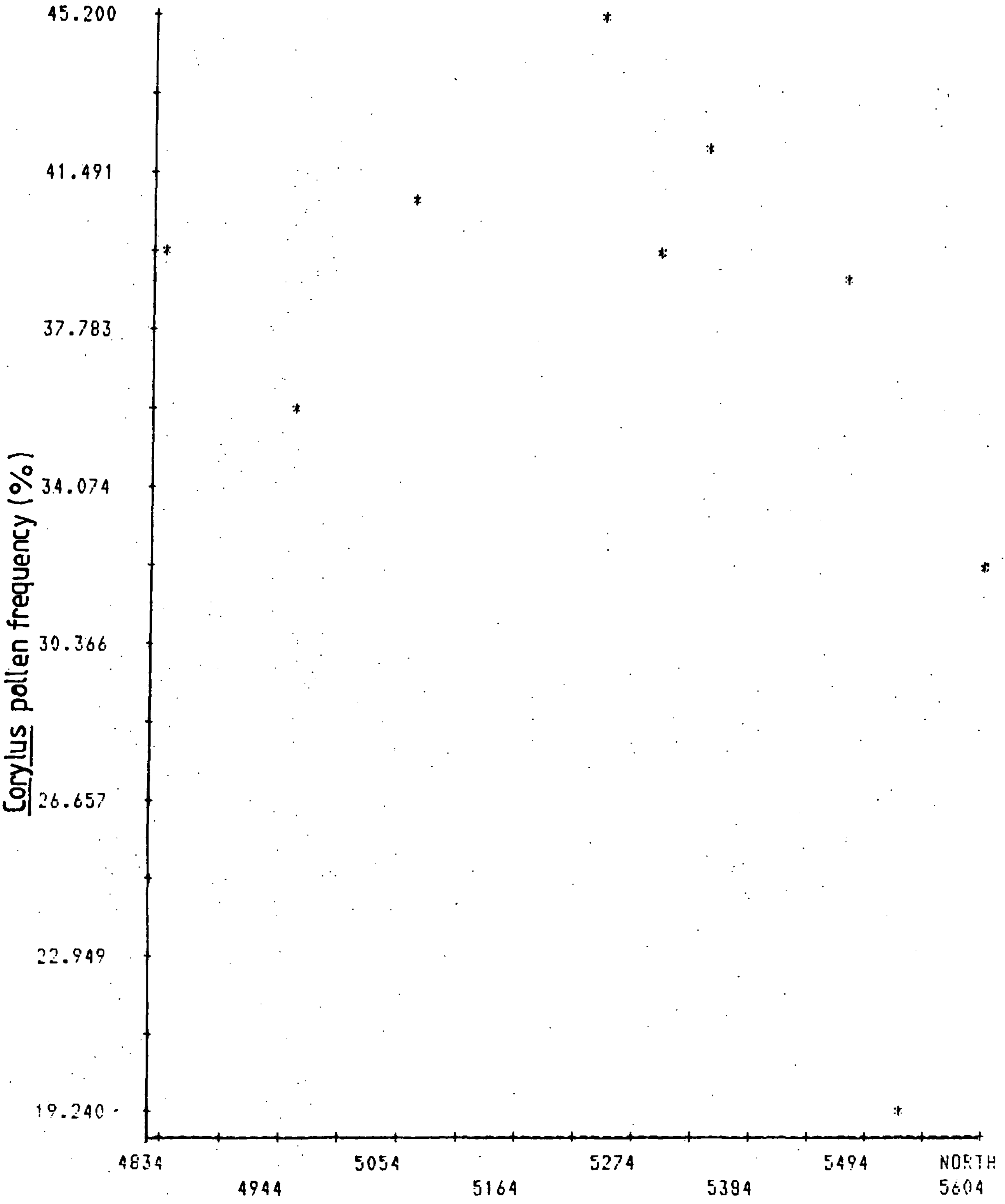

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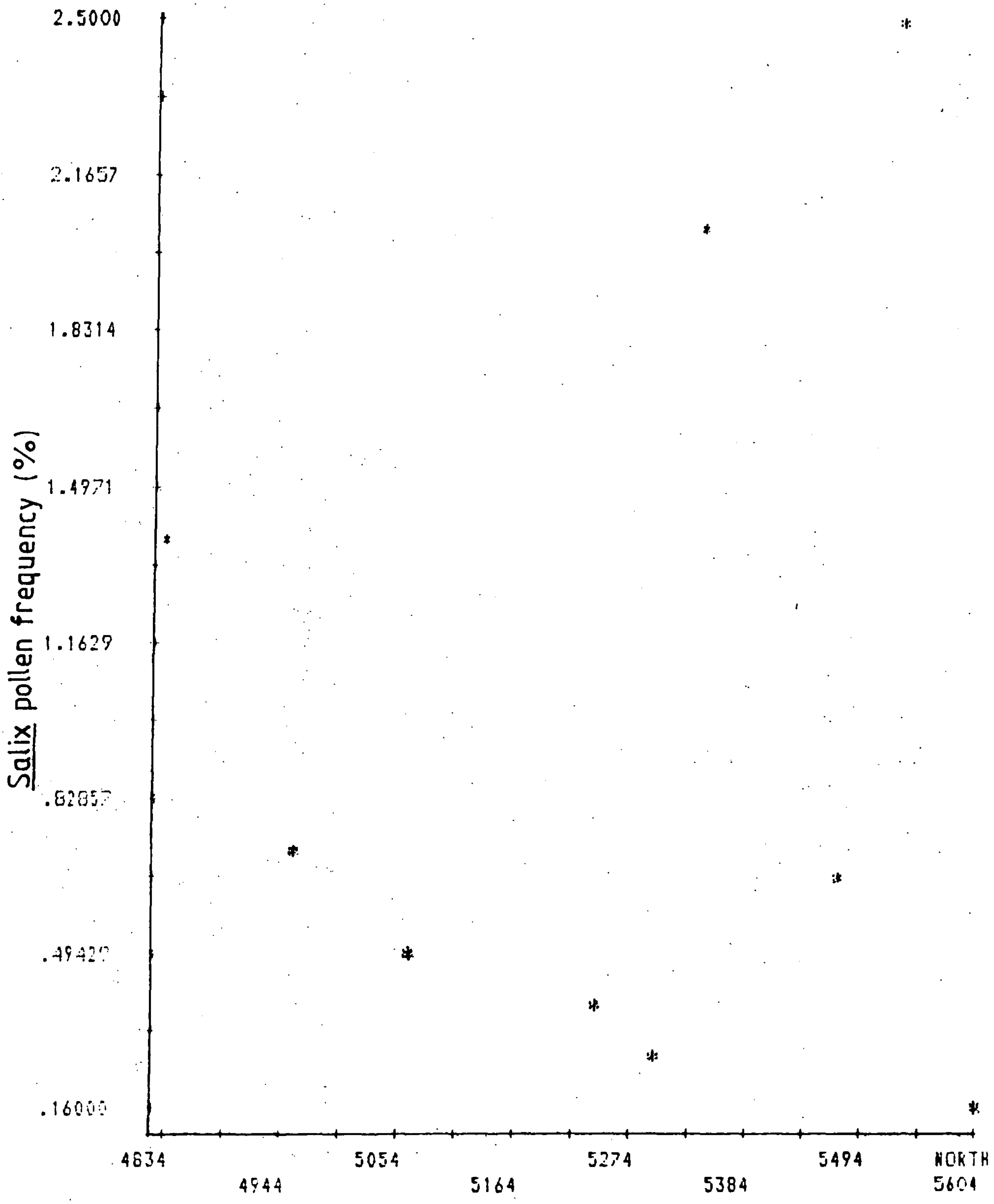
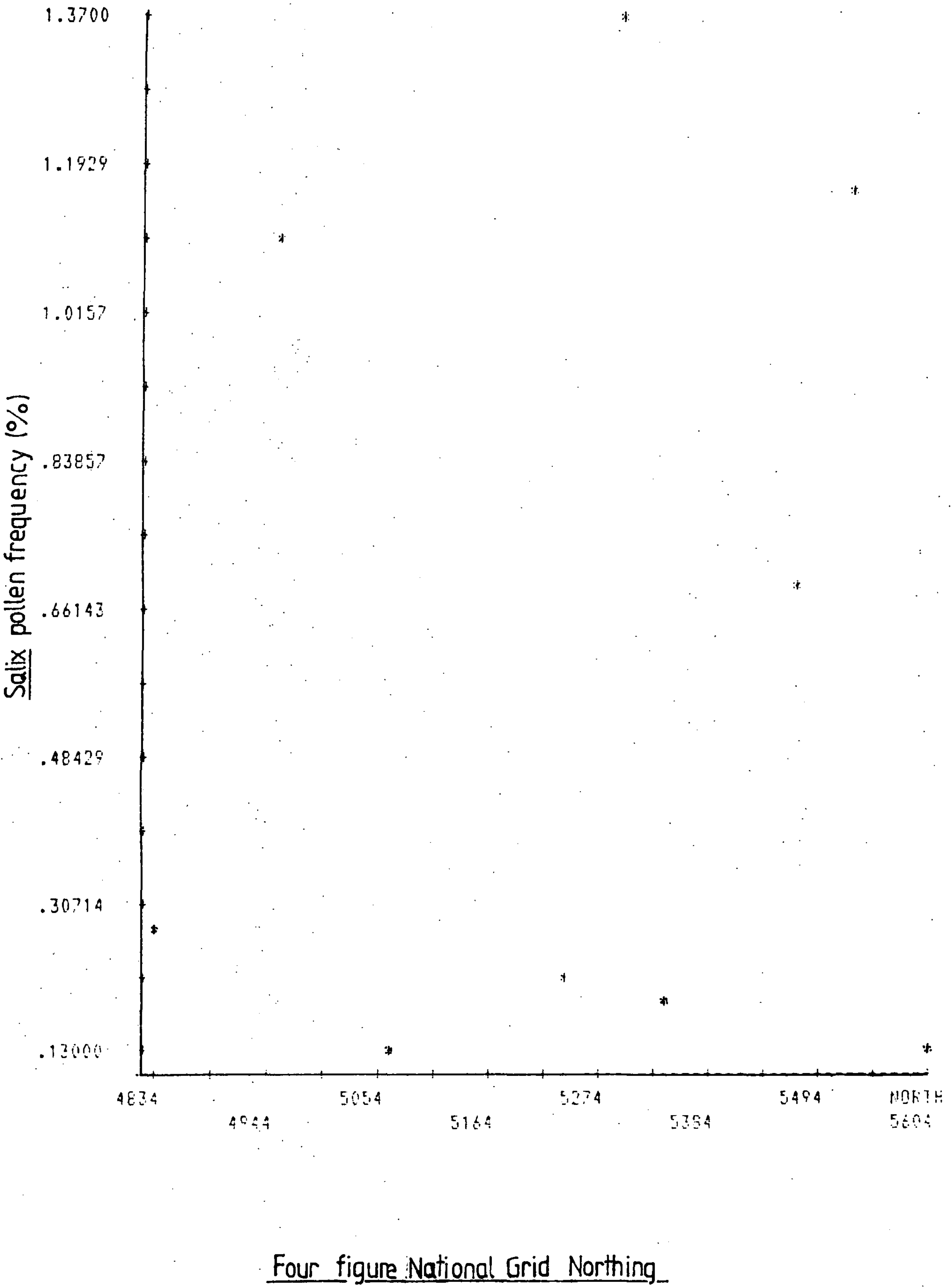
Fig. 27 Salix

Atlantic



Four figure National Grid Northing

Fig 28. Salix Sub-Boreal



ULMUS

The pollen counted is thought to represent the native U. glabra Huds.

The North Pennine work of Turner and Hodgson (1981 unpublished data), in the Atlantic period, indicated correlations between altitude, bedrock and Ulmus distribution. They showed that the frequency of Ulmus pollen varied with different bedrocks, being lower on the slow-weathering, base-poor Millstone grits and higher on the shales, sandstones, and limestones of the Carboniferous Limestone Series. This edaphic correlation accords well with elm's present day soil preferences in that it is more abundant on calcareous soils. These workers also demonstrated that Ulmus was more abundant at higher altitudes, but pointed out that this may simply reflect the distribution of the major bedrocks. Such correlations were not so readily apparent in the re-examined Turner-Hodgson Atlantic data for the nine transect sites. It was evident from these data that Ulmus was least represented at low altitude sites on Millstone Grit with greater values at Carboniferous Limestone sites at higher altitudes. Despite this, high frequencies of Ulmus were observed on Millstone Grit sites to the south of the transect. Unlike the northern Millstone Grit sites these two sites are however at higher altitudes. These interrelations between altitude, bedrock and Ulmus frequency are obviously complex, but no such correlations were observed in my own work from the Sub-Boreal period.

Comparing the Atlantic with Sub-Boreal frequencies of Ulmus it is clear that elm declined most in the south where it was initially more abundant.

ALNUS

Only one species of alder, Alnus glutinosa (L) Gaertn., is now native in the British Isles, and it is probably safe to presume that all sub-fossil remains of Alnus in the Flandrian period belong to this species.

Godwin (1975) emphasising the great flexibility of response of Alnus discussed factors which might have affected the spread and distribution of this species during the Flandrian and urged caution in interpreting its history since several climatic and edaphic parameters could be involved. In the North Pennines, Turner and Hodgson (1981 unpublished data) found that Alnus frequencies were significantly higher to the west. They then proceeded to correlate this with the present day levels of precipitation across the North Pennines and concluded that this was the major factor affecting alder's mid-Flandrian distribution. Obviously a north to south transect would not pick this variation up. Indeed in both the Atlantic and Sub-Boreal periods the Alnus frequencies along the transect do not apparently correlate either with altitudinal or edaphic factors.

What is apparent is that alder increased immediately after the elm decline and maintained high values into the Sub-Boreal period. Also that this increase was greatest in the south where elm decreased most of all the woodland trees and Betula showed an increase. This is comparable to Iversen's (1941) description of the forest composition immediately after the elm decline. In Iversen's words "at this level the elements of the high forest, Quercus, Tilia, Fraxinus and Ulmus undergo a distinct but temporary decline, while Betula reveals a transitory, Alnus a more lasting increase in pollen frequency, and at the same time the Corylus curve reaches a very pronounced maximum". He takes these shifts to express the local vegetational changes in an area where land tilling people had occupied territory and had cleared the dense primeval forest by felling and burning. Neolithic man is known to have been present in the North Pennines at this time (Smith, 1970) and evidence of increase in grasses, plantains and bracken obtained at all nine sites after the elm decline indicates clearance of the forest and subsequent cultivation.

FRAXINUS

The pollen is thought to represent the native Fraxinus excelsior(L.)

There is much in the detailed pollen analyses as well as in the generalized pollen record to suggest that the expansion of the ash in the later Flandrian primarily reflects human clearance of the climax forest, and the ash tree's strong invasive response. This is clearly shown by Conway's (South Pennines) and Godwin's (Somerset) pollen diagrams in which Fraxinus was apparently favoured by prehistoric forest clearance. Pennington (1964) reaches a similar conclusion concerning upland tarns in the English Lake District in that she proposed that the decline of the elm provided an opportunity for ash to enter the upland woods, and it is difficult to postulate a climatic change that would account for this. Such an increase in Fraxinus after the elm decline was recorded at all of the nine sites investigated. However this increase was not as great as previous workers have recorded.

The North Pennine work of Turner and Hodgson (1981 unpublished data) in the Atlantic period has indicated that the higher values of Fraxinus were in the south of the region. The transect results from the Atlantic period confirm this variation. More significantly it is seen that this variation is continued and maintained in the sub-Boreal period. Although the greatest representation of Fraxinus in the Sub-Boreal was recorded at a Millstone Grit site, the highest values of ash occurred predominantly on the Carboniferous Limestone. Moreover the greatest increases in Fraxinus , after the Elm decline, occurred at these sites. It is suggested therefore that after the elm decline Fraxinus benefited most on the Carboniferous Limestone. This is in accord with Pigott's (1969) observations that ash has a competitive advantage on Limestone cliffs where forest has been cleared.

TILIA

It is possible to distinguish the pollen of T.cordata Mill., T.Platyphyllos Scop. and T. X europea L. (Andrew 1971) but this was not done in the routine counts. It is unlikely that the grains encountered during this investigation were other than those of T. cordata.

Only at Fog Close in the Atlantic and Sub-Boreal periods is the mean representation of Tilia above o.5%. However these results are mean values obtained at each site for both periods and it can be seen from the pollen diagrams that the Tilia frequency ranges from o.7% - 2% of the total arboreal pollen (excluding Corylus and Salix frequencies). Work of Pigott and Huntley (1980) concludes that for sites of small surface extent which are or were surrounded by forest the occurence of Tilia pollen at values that rarely exceed 1% does seem to be evidence that trees were growing within 100-500m of the site. Thus taking this into account it can be concluded that the Tilia pollen recorded is an indication that lime grew near some of the sites but not others.

These values for lime are low when compared to Conway's (1954) 10% proportions obtained from Southern Pennine sites at equivalent altitudes. What the results do indicate is a decrease in Tilia after the elm decline at the majority of sites. This is in total accord with Pigott and Huntley's (1978) conclusion that after 5500 B.P. the frequency of pollen of Tilia declined and, by 3,700 B.P., fell to less than 1/20th of its maximum value, which is evidence that clearance of forest resulted in a disproportionate reduction of Tilia.

It is apparent from the results obtained however that even in the Atlantic, the so called climatic optimum, Tilia's presence was little felt on the North Pennine uplands. This is not surprising as Tilia, considered the most thermophilous of our native trees, is unlikely to inhabit and compete successfully upon the North Pennine fell tops.

It is interesting that with such a low representation of Tilia recorded a clinal variation was nonetheless observed showing higher frequencies of lime to the south. This was also observed by Turner and Hodgson (1981 unpublished data) in the Atlantic and as the results indicate this variation was obtained in the Sub-Boreal. This again is undoubtedly due to the thermophilous nature of lime with its most northerly limit in Britain during the Atlantic period being 54° 47N. Northerly extension of <u>Tilia</u> in Britain today is limited by its failure to produce viable seed in all but exceptionally hot summers (Pigott and Huntley 1978) and its Atlantic and Sub-Boreal distribution may have been similarly affected by summer temperatures.

CONCLUSIONS.

The primary aim of this study was to test whether the clinal variations that Turner and Hodgson (1981 unpublished data) observed in Atlantic pollen frequencies of arboreal taxa in the North Pennines were continued and maintained in the following Sub-Boreal period. Turner and Hodgson found that the major source of variation in the Atlantic period was associated with latitude, with Betula, Pinus and Salix frequencies being higher in the north and frequencies of other taxa higher to the south. For the nine site North Pennine transect used in this investigation it was found that Quercus, Betula, Pinus and Salix did not conform to these variations. This was the case in both the Atlantic and Sub-Boreal periods. Tilia and Fraxinus did however conform, showing a significant clinal variation with higher frequencies to the south of the region during the Atlantic period. More significantly, this observed clinal variation was continued into the early part of the Sub-Boreal period prior to any major forest clearance by man. It is suggested that the clinal variation observed in the Tilia frequencies is due to the thermophilous nature of lime limiting its northerly extension.

Fraxinus not only has higher pollen frequencies to the south of the transect in both periods, but these frequencies increase slightly after the elm decline. It is proposed that ash benefitted by the decrease in Ulmus proportions and this was best seen at sites on Carboniferous Limestone.

Ulmus frequencies from the north-south transect during the Atlantic period indicate that elm was more abundant to the south. This clinal variation was not observed in the Sub-Boreal period. Correlations between Ulmus frequency, bedrock and altitude, during the Atlantic, were not so readily apparent as seen in the overall Turner-Hodgson data for this period. Ulmus data from the Sub-Boreal period shows no such correlations. Nonetheless the Sub-Boreal period results do indicate that elm declined most in the south where it was initially more abundant.

Alnus shows a distinct clinal variation in the Sub-Boreal, unlike the preceding Atlantic period, with higher pollen frequencies observed to the south. No correlations were found between altitude, bedrock, climate and *Alnus* frequencies to explain this observation. It is suggested that the increase in *Alnus* frequencies immediately after the elm decline is due to alder benefitting from this clearance.

The results of this project also indicate that, at the nine sites investigated, *Betula*, *Quercus*, *Alnus* and *Corylus* contributed most to the within-site variation in forest composition during the early Sub-Boreal period. The minor forest components contributed little to the within-site variations observed.

Combining the two sets of data obtained, it is apparent that in the Sub-Boreal period, *Corylus*, *Betula* and *Quercus* contribute greatly to within-site variation but show no significant trend between the sites. This suggests that these taxa are influenced by local rather than regional conditions. On the other hand *Tilia* and *Fraxinus* contribute little to within-site variation but show a trend of increase towards the south of the transect, indicating that regional influences determine the abundance of these two species. *Alnus* shows great within-site and between-site variations thus it is apparent that although alder is influenced by local conditions, some as yet undetermined regional influence is also acting.

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APPENDIX.

TABLE 1 POLLEN SAMPLE COUNTS: TREES AND SHRUBS

SITE	Level in cm.	Betula.	Pinus.	Ulmus.	Quercus.	Tilia.	Alnus.	Fraxinus.	Corylus.	Salix.
1. Low Stublick	60	36	1	1	40	0	72	0	62	0
	70	33	2	3	56	0	56	0	59	0
	80	25	3	0	57	0	65	0	83	0
	90	29	1	4	63	1	52	0	76	0
	100	31	2	7	58	1	50	1	81	0
	110	33	2	6	59	0	54	0	86	0
	120	55	7	6	45	0	39	3	59	2
	130	47	1	10	44	2	46	0	64	1
	140	33	3	15	44	0	61	1	39	2
	150	28	0	14	51	0	57	0	63	0
2. Grahms Moss.	300	91	1	1	35	0	28	2	61	0
	310	78	2	2	26	0	48	0	52	1
	320	108	1	0	24	0	33	0	42	1
	330	102	1	0	20	0	28	0	21	2
	340	89	0	2	12	0	50	0	32	2
	345	75	1	1	19	0	55	0	32	0
	350	84	2	2	19	0	50	0	24	10
	351	113	12	5	13	0	8	0	55	4
	352	107	15	6	16	0	8	0	26	5
	353	122	18	4	11	0	2	1	42	5
	354	121	20	7	8	0	7	0	34	2
	355	106	22	9	13	1	20	0	61	10

APPENDIX TABLE 1 Contd.

SITE	Level in cm.	Betula.	Pinus.	Ulmus.	Quercus.	Tilia.	Alnus.	Fraxinus	Corylus.	Salix.
3.QUICK MOSS	132	26	7	4	50	1	57	5	112	0
	140	31	7	1	40	0	67	3	74	0
	148	37	6	4	51	1	43	8	119	3
	156	32	9	3	63	0	40	3	67	0
	164	39	5	6	49	0	46	5	97	5
	172	25	6	3	65	0	43	8	132	1
	180	37	3	1	45	0	56	8	77	3
	188	27	6	8	57	1	42	9	106	1
	196	15	9	3	55	1	64	3	88	0
	204	19	15	16	58	0	39	3	110	4
	212	12	8	4	62	1	62	1	112	0
	220	33	5	17	41	1	53	0	124	0
4.HARTHOPE MOSS.	85	39	2	3	32	1	65	8	114	2
	95	62	1	5	34	1	38	9	60	0
	105	33	1	4	45	1	56	10	142	0
	115	29	2	4	49	0	63	3	75	1
	125	27	3	4	43	0	70	3	148	0
	135	15	0	3	42	0	85	5	120	0
	145	24	0	10	39	0	72	3	100	0
	155	27	3	11	58	1	46	4	152	1
	175	27	9	4	54	0	54	2	109	1
	195	31	0	14	36	1	65	3	75	3
5. DUFTON MOSS.	25	89	2	3	52	0	89	5	122	2
	30	68	4	2	60	0	117	6	136	4

APPENDIX TABLE 1 Contd.

SITE.	Level in cm.	Betula.	Pinus.	Ulmus.	Quercus.	Tilia.	Alnus.	Fraxinus.	Corylus.	Salix.
5.DUFTON MOSS	35	58	1	2	71	1	109	4	144	10
	40	35	1	1	98	1	77	7	180	9
	45	63	3	3	75	1	82	5	179	4
	51	78	4	1	55	0	93	2	186	4
	55	83	4	5	48	2	110	5	169	25
	60	47	3	7	52	2	176	7	169	2
	70	77	3	5	63	1	104	12	194	2
	80	42	1	5	72	0	91	18	201	3
	90	78	4	7	47	0	101	5	143	2
6.STAPLE MOSS.	125	29	5	2	45	0	67	2	144	1
	130	27	4	3	41	0	70	5	95	1
	135	28	2	2	42	0	69	7	156	1
	140	19	0	4	43	0	80	4	130	0
	145	31	0	2	26	1	81	9	96	0
	150	43	4	7	50	1	43	2	190	0
	155	19	1	8	57	2	61	2	187	1
	160	28	3	8	48	1	60	2	176	0
	165	36	8	4	40	0	59	3	131	0
	170	23	2	6	54	1	62	2	99	0
7. FOG CLOSE.	145	27	3	6	51	0	57	6	99	0
	150	38	0	0	38	0	67	7	76	0
	155	30	0	7	50	0	61	2	87	2
	160	26	1	4	51	1	66	1	91	0

APPENDIX TABLE 1 Contd.

SITE	Level in cm.	Betula.	Pinus.	Ulmus.	Quercus.	Tilia.	Alnus.	Fraxinus.	Corylus.	Salix.
7.FOG CLOSE.	165	17	1	4	50	0	75	3	152	0
	170	22	0	4	49	3	70	2	126	0
	175	19	1	8	48	2	68	4	110	1
	180	38	0	15	37	2	53	5	90	1
	200	26	2	2	57	2	61	0	99	0
	305	30	1	7	34	4	74	0	111	3
	210	30	5	11	42	2	58	2	85	2
8.WHITE BEACON HAGS.	100	44	1	6	40	1	49	12	99	2
	115	29	1	2	31	1	81	5	125	1
	120	24	4	3	36	3	75	5	58	3
	125	31	1	4	42	1	65	6	46	4
	130	25	3	4	44	1	66	7	105	0
	135	17	2	2	49	0	73	7	89	6
	140	19	4	10	58	0	51	8	109	1
	160	23	3	11	45	1	64	3	69	5
	165	67	2	2	30	1	45	5	83	16
9.FLEET MOSS.	125	27	0	0	23	0	91	9	80	1
	130	19	1	1	40	1	84	4	108	0
	135	10	1	3	51	0	80	5	111	1
	140	19	0	3	48	1	76	3	117	1
	145	21	0	1	36	0	81	11	86	1
	150	24	0	5	56	2	53	10	90	0
	160	26	2	13	53	0	50	6	81	3

APPENDIX TABLE 2

POLLEN SAMPLE COUNTS FOR ERICALES AND HERBS.

SITE:	Level in cm.	Gramineae.	Cyperaceae.	Calluna.	Ericales.	Chenopodiaceae.	Compositae (Lig.)	Filipendula.	Plantago lanc.	Ranunculaceae.	Rumex.	Succisa.	Myriophyllum.	Polypodium.	Pteridium.	Sphagnum.	Filicales
1. Low Stublick.	60	5	3	36	0		0	1	0	0	0	0		0	3	30	5
	70	1	4	27	2		1	0	1	1	0	0		6	1	228	0
	80	3	5	16	0		0	1	1	1	1	1		1	3	49	2
4. Harthope Moss.	85	74	13	349	7	2		0	12				0	2	21	92	5
	95	2	2	78	0	0		4	2				0	0	0	8000	4
	105	8	18	182	0	1		1	1				0	0	2	173	8
	115	31	20	251	0	0		0	5				0	0	8	161	7
	125	17	11	136	0	0		1	5				0	3	16	621	7
	135	9	24	122	4	0		0	0				0	1	0	558	3
	145	7	8	93	0	0		0	0				0	0	4	220	5
	155	13	16	131	0	0		0	0				1	2	0	31	4
	175	4	5	212	1	0		0	0				0	1	0	28	4
	195	6	13	101	1	0		0	0				0	1	0	4	7

NB. The counts for Grahms and Quick Mosses (Sites 2 and 3) were not obtained.

APPENDIX TABLE 2 contd.

SITE.	Level in cm.	Gramineae.	Cereal.	Cyperaceae.	Calluna.	Ericales.	Artemisia.	Chenopodiaceae.	Compositae (Lig.)	Compositae (tub.)	Cruciferae.	Filipendula.	Polemonium.	Plantago lanc.	Ranunculaceae.	Rosaceae.	Rumex.	Succisa.	Umbelliferae.	Potamogeton.	Myriophyllum.	Polypodium.	Pteridium.	Sphagnum.	Filicales.
5. Dufton Moss (After R.H.Squires 1970)	25	37	1	24		107	0	0	0	1	0	0	0	6	1	1	1	0	0	0					
	30	58	0	38		81	1	2	0	0	0	13	0	8	1	3	0	0	2	1					
	35	95	0	100		44	2	2	0	1	0	6	0	28	1	1	0	0	0	0					
	40	167	1	121		59	2	4	1	1	0	5	0	44	1	2	6	0	1	0					
	45	79	1	86		23	4	3	0	0	0	2	0	25	0	1	2	0	0	0					
	51	92	0	124		26	0	1	0	0	0	2	1	24	1	0	9	2	0	0					
	55	24	0	0		44	0	0	0	0	0	2	0	2	0	1	0	0	0	0					
	60	45	0	0		145	0	0	0	0	1	1	0	8	0	2	1	0	0	0					
	70	25	0	48		37	0	0	0	0	0	2	0	2	1	2	1	0	0	1					
	80	52	0	159		20	0	1	0	0	0	1	0	1	0	0	2	0	0	0					
	90	55	2	140		14	0	0	0	0	0	0	0	6	6	0	0	0	0	0					
6. Staple Moss.	125	48		11	412	1		4	1	1		1		18			1	0	0		1	1	6	47	9
	130	14		6	250	0		0	0	0		0		0			0	0	0		0	0	2	78	6
	135	12		23	172	0		0	0	0		1		1			0	0	1		0	3	3	80	4
	140	22		67	106	0		0	0	0		0		5			0	0	0		1	0	4	10	2
	145	5		8	158	0		0	0	0		0		0			0	0	0		0	0	2	19	3
	150	6		11	33	0		0	1	0		0		0			0	0	0		0	3	0	19	6
	155	4		11	195	3		0	0	0		1		0			0	0	0		0	2	1	149	5
	160	1		17	159	4		0	0	0		0		0			0	1	0		0	2	1	13	5
	165	2		6	126	2		0	1	0		0		0			0	0	0		0	1	5	36	4
	170	3		13	198	0		0	0	0		0		0			0	0	0		0	1	0	86	7

APPENDIX TABLE 2 contd.

SITE	Level in cm.	Gramineae.	Cyperaceae.	Calluna.	Ericales.	Caryophyllaceae.	Chenopodiaceae.	Compositae (Lig.)	Filipendula.	Plantago lanc.	Ranunculaceae.	Rubiaceae.	Rumex acet.	Rumex.	Succisa.	Umbelliferae.	Urtica.	Myriophyllum.	Polypodium.	Pteridium.	Sphagnum.	Filicales.
7. FOG CLOSE.	145	10	9	249	0		0		0	0	0			0		0		0	0	0	15	8
	150	15	1	165	0		0		1	2	0			0		0		0	1	0	13	6
	155	11	13	128	1		1		1	5	1			0		2		0	0	6	17	1
	160	9	1	264	0		1		0	3	0			0		0		0	4	6	53	1
	165	5	1	66	0		0		2	0	0			1		0		0	2	0	4	5
	170	3	2	156	0		0		0	0	0			0		0		0	2	0	8	5
	175	6	3	116	1		0		1	0	2			0		0		0	0	0	25	6
	180	1	7	76	1		0		0	0	0			0		0		0	1	0	62	2
	200	18	2	223	0		0		0	1	0			1		0		1	1	0	58	4
	205	6	12	162	0		0		1	0	1			3		0		0	3	3	68	6
	210	12	6	123	0		0		1	0	0			0		0		1	0	0	101	9
8. White Beacon Hags.	100	105	99	71	0	0	0	0	4	6	7	0	0	52	0	5	0		3	2	69	13
	115	100	16	452	0	0	0	2	11	1	6	0	5	0	14	0	0		3	1	74	7
	120	175	48	66	3	0	0	1	36	12	8	0	0	9	13	0	0		1	7	222	6
	125	75	20	35	3	1	1	0	7	2	2	0	0	1	0	0	0		0	4	525	1
	130	93	47	39	2	0	0	0	12	8	0	0	3	2	0	0	1		2	9	133	4
	135	210	15	56	0	0	0	0	39	0	1	0	12	0	0	0	0		0	2	52	10
	140	146	31	33	1	0	0	0	58	3	1	0	26	0	0	0	1		0	5	215	2
	160	110	9	13	0	0	0	0	10	0	6	1	11	0	0	2	0		1	0	31	6
	165	65	2	9	1	0	0	0	10	0	3	0	0	0	0	0	0		2	2	8	4

APPENDIX TABLE 2 contd.

SITE	Level in cm.	Gramineae.	Cyperaceae.	Calluna.	Ericales.	Compositae (Lig.)	Filipendula.	Plantago lanc.	Ranunculaceae.	Rubiaceae.	Polypodium.	Pteridium.	Sphagnum.	Filicales.
9. Fleet Moss.	125	12	8	58	0	0	0	2	0	0	0	0	14	3
	130	16	14	56	0	1	1	0	0	0	1	1	37	4
	135	16	3	127	3	0	1	5	1	5	0	3	38	7
	140	17	12	110	9	0	2	0	2	0	1	3	217	8
	145	15	3	66	0	0	0	3	1	0	0	1	13	5
	150	7	7	34	0	0	0	1	0	0	0	1	45	3
	160	8	9	127	4	0	0	0	0	0	2	0	5	4