An investigation into differential lateral dispersion of fossil forest tree pollen

PARKIN, M. J.

AN INVESTIGATION INTO DIFFERENTIAL LATERAL DISPERSION OF FOSSIL FOREST TREE POLLEN

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ABSTRACT.

Pollen rain phenomena with particular reference to forest pollen are discussed with evidence from FAEGRI.K and IVERSON.J , TAUBER.H, TURNER.J, and DAVIS.M.B. The existence of fossil tree pollen rain in raised bogs is postulated. The problem of local bog pollen in the peat against which to count a varying forest pollen rain is seen as the major statistical problem, relating to even distribution both vertically and horizontally in the peat.

Bolton Fell is described as an ideal zone VIb bog to illustrate fossil tree pollen dispersion. Preliminary investigation of peat showed this bog to contain VIIb peat and the N. margin of the bog proved most suitable. A 500m transect was laid out and levelled with depth measurements every 10m. Thirteen profile samples were taken at intervals.

From eight replicatesamples taken over the centre metre of each profile, pollen slides were prepared and all grains counted until 150 tree grains had bean recorded. The varying numbers of bog plant pollen were used to compute the actual change in forest pollen frequency. The figures obtained are plotted against distance. A real reduction in forest pollen frequency is clearly shown from 0-100m with differences between values statistically valid, so confirming the work of TAUBER and TURNER on extant forest pollen dispersion.

Anomolously higher values for fores pollen further out on transect are discussed, and an explanatory hypothesis outlined of a slowly growing bog with trees possibly growing in it on 'islands' of shallow peat.

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INTRODUCTION.

It is now a well established fact in the field of Quaternary Ecology, that during the later stages of the Post-Glacial Period, much of Europe including the British Isles was covered with mixed deciduous forest. The evidence for this vegetational history comes from two forms of plant fossil remains. These are firstly, the macroscopic fragments of leaves, fruits, seeds, wood, and secondly. pollen grains which have the highest resistance of all plant parts to bacterial and fungal decay. These fossil remains occur in peat deposits and in fresh water and marine sediments. Much of the evidence for forest distribution during the late Post Glacial Period comes from pollen preserved in peat bogs which began their growth during this time.

A great deal has been written on local and regional vegetation deduced from pollen grains preserved in these peat bogs. One important problem in making these deductions is that pollen falling onto a peat bog may have come from a close 'local' source or from a 'regional', i.e, far distant place of origin, depending on whether the parent plants producing the pollen are entomophilous or anemophilous, small herbaceous plants near the ground, or large forest trees.

Many native forest trees are anemophilous producing large quantities of pollen freely dispersed into the atmosphere forming a 'pollen rain' which eventually falls to earth up to considerable distances from the point if origin. Much work has been carried out during the past fifty years on the production and dispersal of tree pollen. an outline of which is illustrated by the following examples.

FAEGRI and IVERSON [1] (1964 p33) quote several early workers as follows. POHL 1937, estimated average figures for pollen production from ten year old branch systems of various tree species; beech 28 million, larch spruce and oak about 100 million, and pine up to 350 million. HESSELMAN 1919, concluded that the spruce forests of S and Mid Sweden produced annually, about 75,000 tons of pollen. ANDERSON 1955, FEDORA 1959, and EISENHUT 1961, quoted by FAEGRI and IVERSON concluded that there is a consistent effect in the dispersion of pollen across border lines between different vegetational types. At the border between forested and non forested areas the quantity of forest tree pollen in the atmosphere and in surface samples was always found to decline rapidly. The following are average figures -

Distance from forest edge	% Forest tree pollen
0m	100%
100	30
200	10
300	3

From 300m to about 4Km the figure remains almost constant. These workers concluded that this value represented pollen rain of a whole region and not solely from the stand being investigated.

H. TAUBER[2] in 1965 and 1967 published results of some very detailed investigations into the theoretical dynamics, followed by a practical demonstration in the field, of pollen movement through and out of the three dimensional complex of a stand of forest trees. To this he added the fourth dimension of time by measuring pollen dispersion at various times of the year for several successive years. TAUBER was able to demonstrate that pollen falling on to land surfaces within a few hundred metres of a forest edge consists of varying proportions of three elements - 'regional' pollen rain made up of all the pollen carried by winds and air currents from a large area of countryside, and 'local' pollen rain variable in density, produced by local stands of vegetation, in this case forest. These two components had been recognised by earlier workers. TAUBER however went further and separated 'local' pollen rain into a 'canopy' component being blown diagonally upwards and eventually outwards from the forest edge, plus a 'trunk space' component blowing out laterally at the forest edge below the crown area of the main canopy forming trees.

He set up long term trapping experiments on a lake in Zeeland which was surrounded by mixed deciduous forest. Pollen traps were set up on the forest floor in the'trunk space', and also on rafts floating on the lake at varying distances from the forest edge. The pollen traps were in duplicate sets, one set being roofed and the other open to vertically dropping pollen. The roofed traps had a lateral gap for pollen to enter. This difference distinguishes between pollen floating in the air and pollen brought straight downwards trapped in rain drops.

Different species of tree were found to have varying efficiencies of pollen dispersal, beech, alder, hazel having grains which tend to settle quickly within the canopy. These are then subsequently removed in conditions of high wind. This TAUBER termed 'refloatation'. He found these grains predominantly in open pollen traps concluding that 'refloatation' grains are brought down in rain. 'Refloatation' effects were hugher in the August-November period of each year due to storm washing of leaves plus the fact that pollen release from flowers would end by late Summer.

The twigs and branches of the trees at the edge of the forest form an effective filtering system. TAUBER found up to 40,000 tree pollen grains on a single twig of hazel at the forest edge. Most forest trees flower before leaf development so that considerable wind speeds measured in the 'trunk space' enable the pollen that gets through the twig and branch filter system to carry for considerable distances from the forest margin. An empirical experiment demonstating this was carried out by lighting fires at the forest edge on the windward side of the forest ringed lake, and noting that the smoke carried horizontally low over the lake for several hundred metres.

TAUBER concluded from this work that the composition of the'local' pollen rain measured up to several hundred metres from a forest edge does not necessarily reflect the exact composition of the forest itself. Trees at the edge will be over-represented and over one year some species may be inaccurately represented due to refloatation effects.

J.TURNER[3] 1964 carried out a similar investigation on dispersion of forest pollen from an existing forest edge outwards over a non forested raised bog. This study arose from a desire to know whether the depth of a forest stand behind the margin had any influence on the dispersion spectrum across the neighbouring bog. TURNER carried out surface sampling on two raised bogs, one of which was traversed by a narrow, 90 metre wide strip of pine plantation, and the other which lay to the East of a much larger block of pine about 300 metres wide. The graphs of pine pollen/distance from the forestedge from surface samples on the bogs to the East of each pine stand were found to be very similar. The conclusion drawn from this is that the area of a stand of forest makes little difference to the pollen rain fall off close to the edge of that forest.

In view of the evidence on pollen dispersion from present day forests, it would appear that the site of boring on a bog in relation to distance from the edge becomes very important,if the bog at the time of its development, was likely to have been surrounded by thick undisturbed forest. It might be expected that within about 300 metres from the bog edge 'local' pollen rain effects from the free flowering trees of the forest, particularly those at the open edge would show up on pollen diagrams, the characteristics of the regional pollen rain being demonstated in samples taken further out on the bog.

The following study was undertaken in an attempt to verify the supposition outlined above; that indeed by sampling over several hundred metres from the present edge of a suitable bog, the dispersion pattern of forest tree pollen can be demonstated in the pollen diagrams obtained from these samples.

It was decided that a bog containing peat formed in time zône VIIb would be most suitable, as though the previous zone VIIa is considered as the time of optimum forest development, peat bogs were only beginning to develop at this time. In the later zone VIII the ideal fully formed raised bog is accompanied in its development by a deterioration in forest cover due to man's activities.

Determining the relative pollen frequencies of the various species present in peat samples has been a major problem for palynoligists. The most accurate method is to count the absolute numbers in a known volume of peat. This in itself poses a problem as invariably one has to count many samples from one core and to compare their contained pollen frequencies. This is only valid if it can be proved that separate samples of the same volume represent the same interval in time during which the pollen was being dispersed and trapped in the peat being tested. M. DAVIS[4] (1967) has demonstrated this successfully with fresh water inorganic sediments whose rate of settlement was accurately calculated. Peatformation however is very variable, depending both on the climate and the particular peat forming plants of the bog surface at any one time. Thus for peat analysis one has to fall back on percentage rather than absolute pollen counts.

Traditionally, with percentage counting, the total number of forest tree grains has been taken as the basic unit and all species expressed as a percentage of this total. This is the method employed in this study, which was aimed to demonstrate a varying quantity of tree pollen falling into peat which itself willcontain, in theory, a fixed quantity of local bog plant pollen derived from species of Ericales, Eriophorum, and spores of Sphagnum. If the tree pollen rain is changing, this will be reflected in percentage tree pollen counts as a variation in the percentage of local bog species pollen. Thus if the tree pollen rain is dense, the local bog pollen as a percentage will be low and vice versa. So with the knowledge of this varying ratio it should be possible to compute the change in forest pollen frequency at different distances from the bog edge.

However the constancy of the local bog pollen rain cannot be relied on due to one important factor. This is the possible none random dispres-ion of the local bog pollen. Ericales species are entomophilous liberating their pollen in tetrads, so that there is a possibility that this pollen would be left in high density clumps in the peat. Sphagnum growing very near to the peat surface is even more likely to give rise to aggregations of spores. This possible error is in fact investigated later on in the discussion sction. A second factor which might effect the local pollen rain is time. The vertical profile of the peat bog represents a period of time of growth which, due to varying climatic conditions may have experienced changes in the composition of the local bog flora.

Without an accurate dating method it would be impossible to take syn--chronous samples at different distances from the bog edge. Consequently the local bog pollen rain should be measured by replicate samples taken both at varying depths and over a horizontal area of the bog at each distance from the edge. In view of the time factor involved it was impossible to carry out the large amount of pollen analysis required by both horizontal and vertical replicate sampling. It was finally decided to concentrate on vertical replicates hoping that these would average out any variations in the bog pollen rain.

2. FIELD WORK

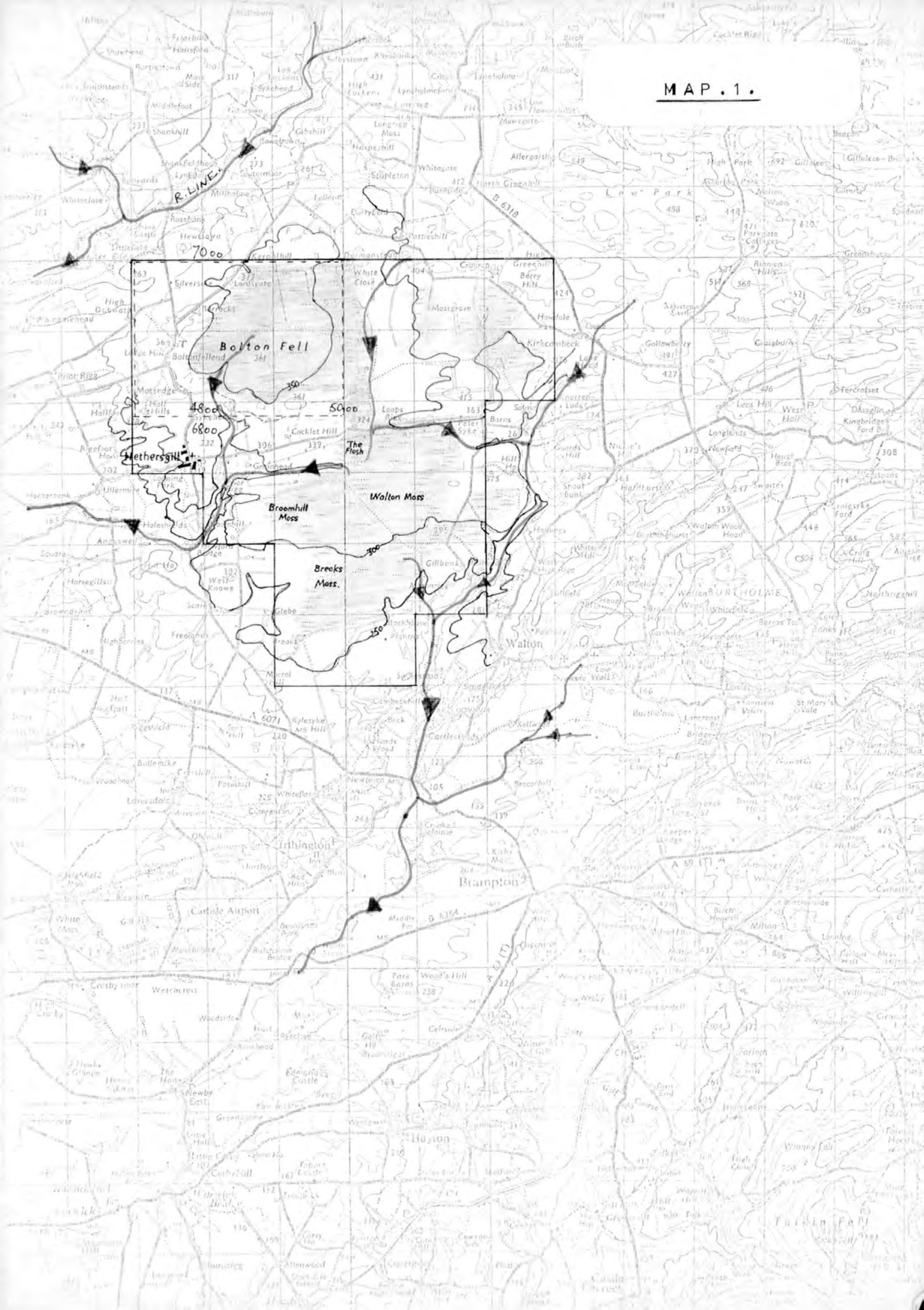
2.a. Choice of bog.

In view of the evidence discussed a zoneVIIb bog was thought to be suitable providing that it satis fied two requirements. Firstly it should be at least 600 metres wide, and secondly it should have avery clearly defined edge where peat meets mineral soil, so that the extinct forest edge could be clearly established. Bogs of this type and size are rare in N. England. Various sites were identified from O.S. 1" maps and inspected. The only one of the size desired was Bolton Fell close to the village of Hethersgill, about 12 miles N.E. of Carlisle - O.S. 1" sheet 76, grid ref - 4800-5000 E; 6800-7000 N. Most of the bog is situated in the area formed by these reference numbers.

This bog is part of a complex of raised bogs extending over several square miles - see map 1. The complex is separated into two fairly distinct areas; Bolton Fell to the N.W., and Walton Moss, Broomhill Moss, and Breaks Moss to the S.E. These two areas are connected by a narrow isthmus of bog called the Flush. If the bog complex is looked at in relation to altitude it can be seen that Bolton Fell lies largely within the 350 ft contour, whilst the three other mosses lie on a shallow slope dropping from 324ft at the Flush to 250ft on the S.E. margin of Breaks Moss. The whole complex is situated on a shallow watershed between the valley of the river Line to the N.W., and the valley of a small stream the Cambeck to the S.E., which in turndrains into the river Irthing. Bolton Fell is drained to the S.W. by a small stream running into the R. Line, and to the East by a stream running into the Flush, Then along the N. edge of Walton Moss, and further East into the Cambeck.

Bolton Fell was first investigated, permission being readily granted

MAP . 1.

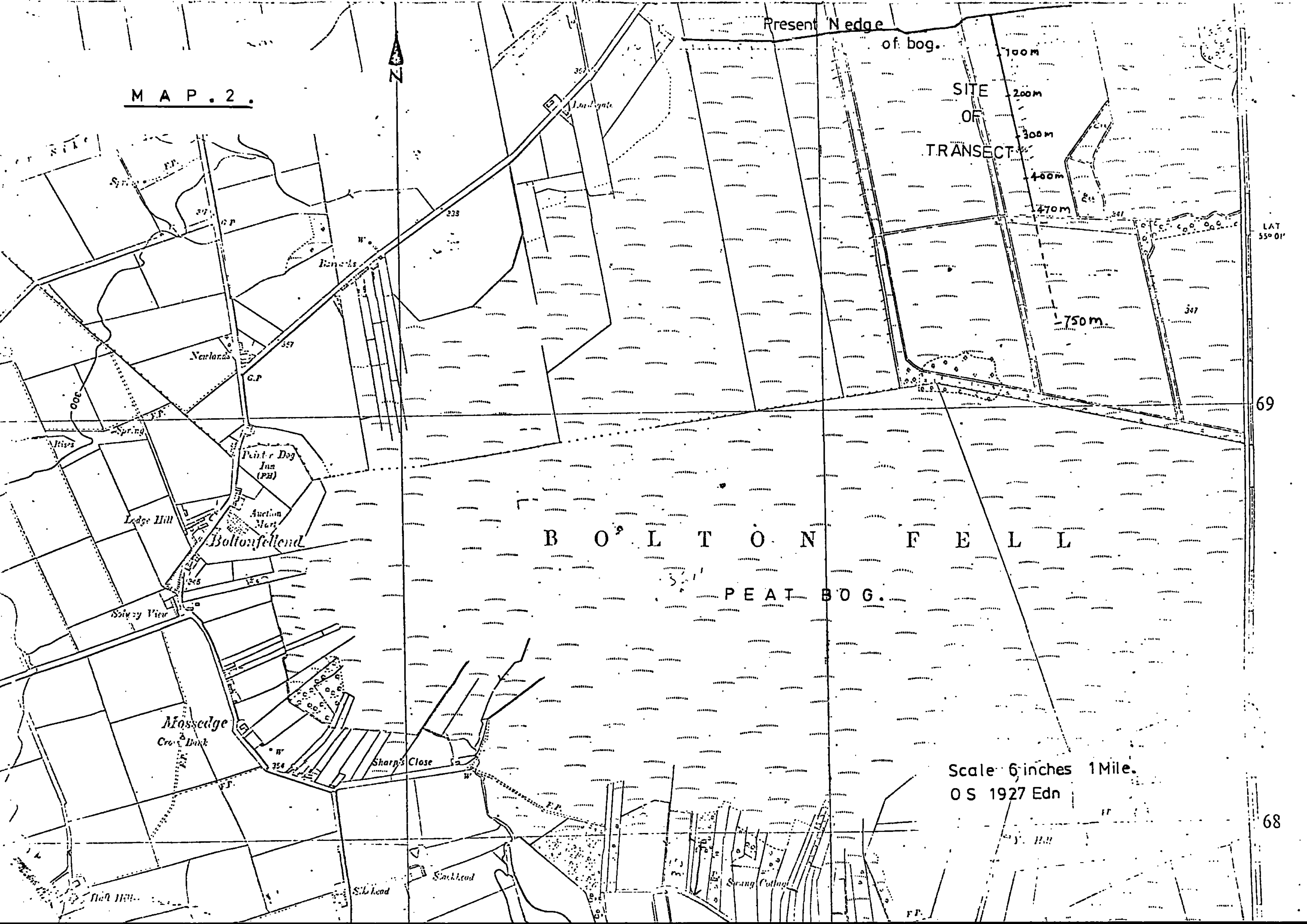


Bolton Fell
Walton Moss
Broomhill Moss
Breaks Moss.
The Flosh
R. LINE.
Nethersgill
7000
4800
5000
6800
350
361
300
250

by the management of the Boothby Peat Company, which latter concern is currently exploiting the northern half of the bog for horticultural peat. On first examination the bog appeared to be suitable from the points of view of size and definition of edge. However as will be seen from the discussion, it became clear by the end of the project that the apparent uniformity of the present day bog surface may be concealing islands of shallow peat. The island of woodland in the bog centre at about 800 metres from the N.edge was cosidered far enough away to give an uninterrupted bog surface of the required distance. Map 2 shows the present state of the bog surface and surroundings whilst it can be seen from map 3 - O.S 6" Ist Edn 1850, that much of the N.E. corner of the bog was divided into small areas by narrow strips of mixed forest growing in the peat. On inspection, much of the West and Northern margins of the bog showed evidence of peat cutting in past times with the surface now regenerated. It was discovered that most of the old freehold properties in Hethersgill and Bolton Fell-End villages possessed cutting rights on the bog. In addition to this the N. half of the bog has been for the last twenty years and still/is, being cut commercially by the company mentioned earlier. This gave an added complication to the final inter--pretation of the profile along the transect, in that the original domed profile of the intact bog is now missing and it was impossible to make an initial comparison of the quantities of zones VIIb, and VIII peats. However only the zone VIII peat suitable for burning and for horticultural purposes had been removed, leaving the earlier peat intact, and from which all the subsequent samples were taken.

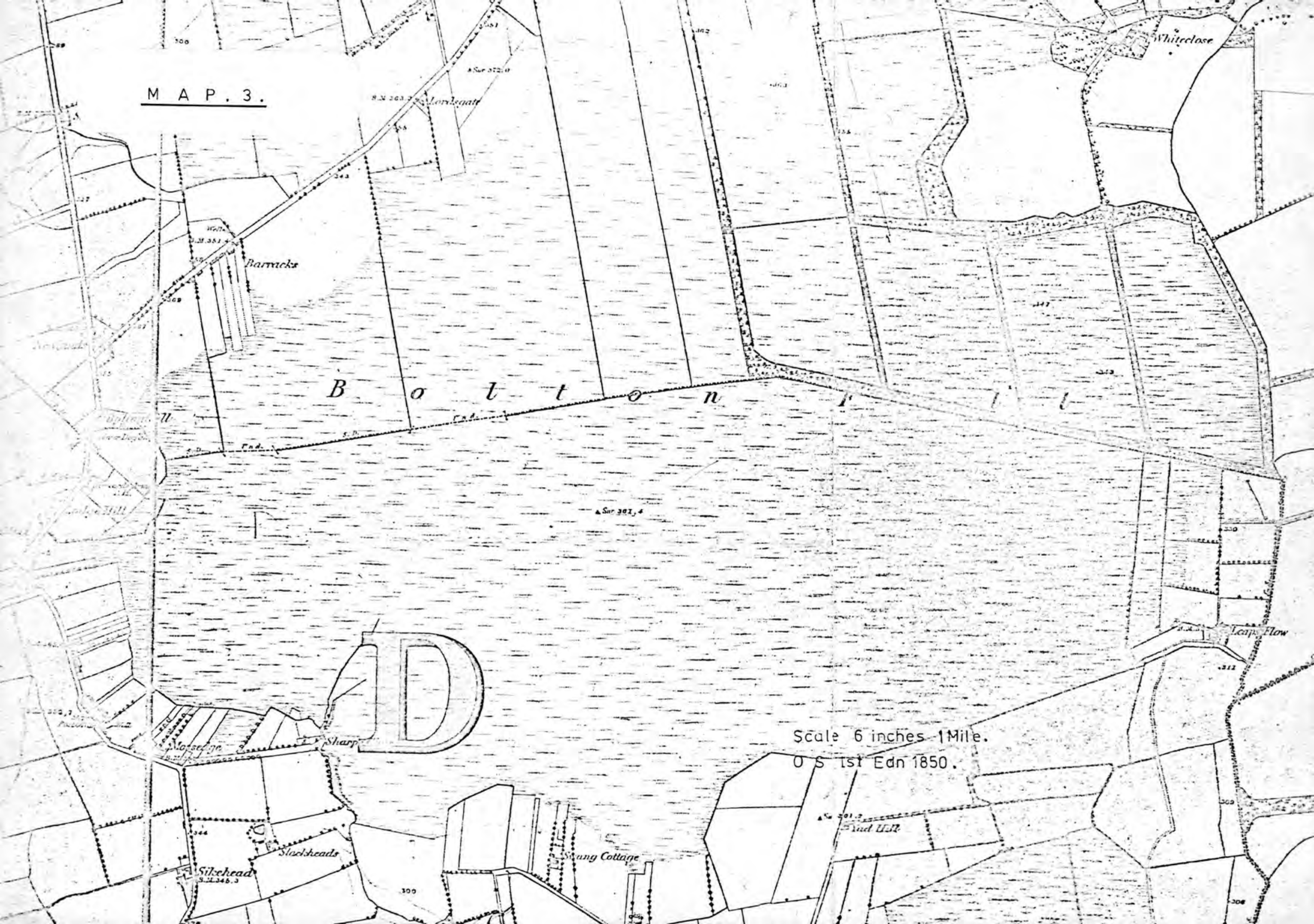
2. b. Site of transect and bores.

From tho map, both the S.W., and N. margins of the bog appeared to be suitable. The former part was investigated initially as this would have



MAP.2.
N
Present N edge of bog.
SITE OF TRANSECT
100m
200m
300m
400m
470m
750m.
BOLTON FELL
PEAT BOG.
Boltonfellend
Mossedge
Newlands
Sharp's Close
Painter Dog Inn (P.H.)
Auction Mart
Ledge Hill
Scale 6 inches 1 Mile.
OS 1927 Edn
69
68
LAT 55°01'

MAP. 3.



Scale 6 inches 1 Mile.
O S 1st Edn 1850.

provided a transect parallel to the likely prevailing wind direction during zone VIIb time, and with the open bog surface to leeward of the forest. This, it was thought, would provide good dispersion of tree pollen over the bog. However it proved to be very difficult to establish a clear edge in this area. The N. margin was then investigated and a clear edge with rapid increase in peat depth was discovered for over one quarter of a mile along the edge.

An experimental pilot sample was taken from this area at the base of the peat about thirty yards from the bog edge. Subsequent examination of a pollen preparation from this sample gave a high percentage of Betula, Quercus and Alnus, with Ulmus below four percent. The ratio of tree and shrub pollen to local bog pollen made up of Ericales, Cyperaceae, and Sphagna was high. Gramineae and ruderal species pollen were below ten percent. From these results it was judged that the peat was zone VIIb and that intact forest was present surrounding the bog during this period. The size of the bog, and the nature of the peat being satisfactory, it was decided to use this area of Bolton Fell as the experimental site.

The transect shown on map 2 was therefore set up at right angles to the bog edge. It was staked out at 10metre intervals and the top surface levelled out to 470 metres from the edge. The depth of peat was measured every 20 metres using a screw auger. Twelve full profiles were collected at intervals along the transect using a Russian borer. A thirteenth part profile at 750 metres in line with the main transect was collected on a later visit to the site. The details of the transect and profiles are shown in Fig 1.

2. c. Sampling.

As discussed in the Introduction it was decided to take replicate samples from each profile at varying depths only. Eight samples at 10cm intervals were taken from approximately the centre metre of each peat core. The outer exposed face of each hemispherical core from the Russian borer was carefully removed so that each sample came from the central uncontaminated part of the core. About two cubic centimetres of peat were removed at each sample depth and placed in sealed tubes. From each of these about one half cubic cetimetre was used in each pollen preparation.

3. LABORATORY WORK

3. a. Pollen Preparation.

The method employed is as follows. The peat was first boiled in 10% NaOH for up to 30 min to break down the larger fragments. The now liquid mixture was filtered through fine wire gauze and the retained fragments washed in water to remove NaOH. the remains were kept for examination for macroscopic plant material. The fine material filtered through the gauze was centrifuged and the supernatant containing much dissolved humic material discarded. The sediment was mixed with approx--imately 5cc of glacial acetic acid, centrifuged and the supernatant again discarded. This was done to dehydrate the sediment which was then boiled for one minute with a mixture of 10cc of acetic anhydride and 1cc of concentrated H_2SO_4. This acetolysis process had the effect of dissolv--ing humic material and reducing the sediment by about 50% , resulting in an increase in the ratio of pollen grains to plant debris. The acid mixture was discarded after again centrifuging, the sediment made alkaline by addition of dilute NaOH, and the pollen mounted on slides in about twice its volume of glycerine jelly containing safranin to stain the pollen.

3. b. Pollen Counting.

For each sample a total of one hundred and fifty tree grains were counted against a varying background count of local bog pollen consisting of Ericaceae, Cyperaceae, and Sphagna. No attempt was made to identify individual species. The pollen grains were counted at 400X magnification making vertical traverses from one side of the square coverslip to the other. The author considered that there might be a statistical error in slides containing very high tree pollen frequencies where only a few local bog pollen grains were counted per 150 tree grains, and these commonly were counted in one traverse or less. To test whether the number counted in one traverse was in fact near to the mean for the whole sample, local bog pollen counts were taken over several traverses of the slide and a mean value obtained. This was done for several slides showing high tree pollen percentages, and in all cases the number of local bog pollen grains per traverse was close to the mean value per traverse over the whole slide.

4. RESULTS AND DISCUSSION.

4. a. Stratigraphy.

The whole length of each core was examined and in all cases only the top 50 - 100cm was found to consist of zone VIII lightly humified peat. This is at least partly explained by the fact that up to two metres of peat have been cut from the top surface. The lower parts of each core were found to consist of greasy well humified peat of a red-brown colour which oxidised rapidly to dark brown on exposure to air. As shown in the profile diagram Fig 1, interspersed at intervals in the peat were coarse fibres of Eriophorum stems and leaves, small pieces of Calluna stem, unidentified well humified fragments of wood, and small twigs with identifiable silver bark of Betula. No clearly identifiable plant remains were found on examination of the peat residues remaining after NaOH treatment and sieving.

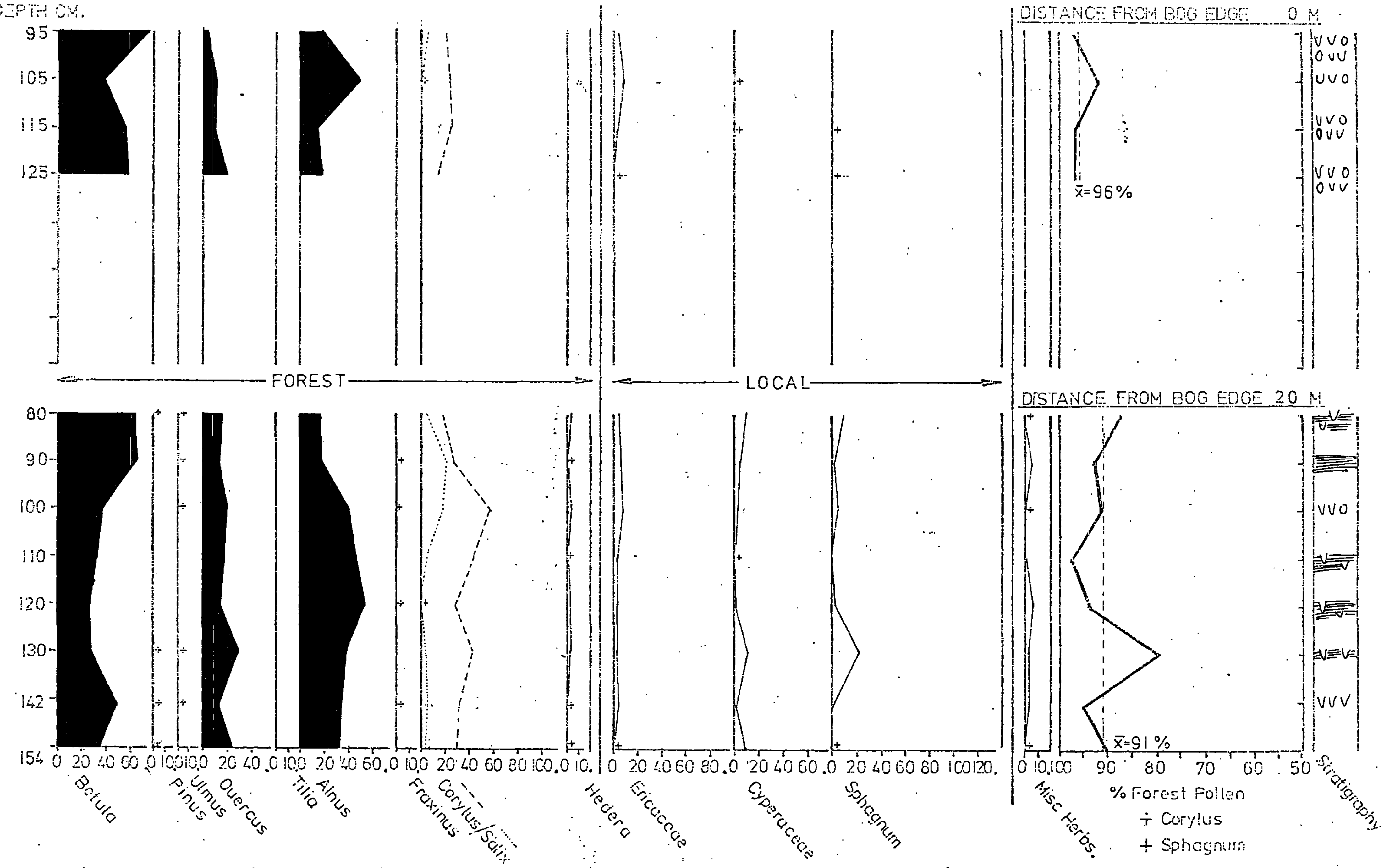
4. b. Pollen preservation.

The replicate sample slides at each site showed some variation in appearance and nature of the background material as follows. Those from areas of peat containing wood fragments showed large amounts of fungal hyphae. Both these and the contained pollen grains were stained a reddish brown with the safranin. Preparations from areas lacking any wood fragments were low in fungal material and were stained rose-pink. This would indicate possible variations in the degree of humification of the peat. As they occurred in all the cores it might be taken as indicating varying conditions near the bog surface during its growth. This in turn could fit in with the possibility, discussed later on, that the bog may have experienced variations in the surface plant cover .

4. c. Pollen Diagrams.

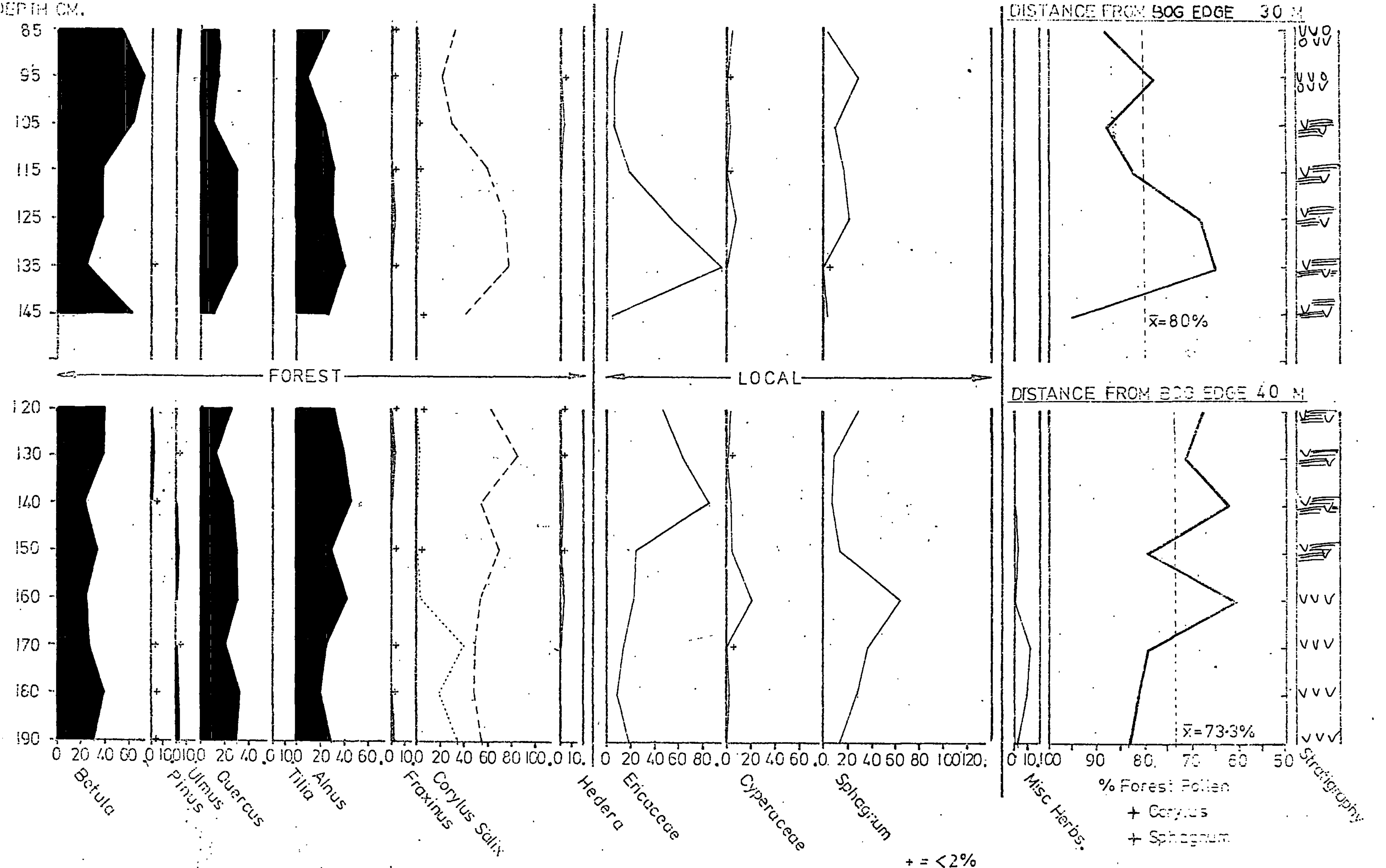
The figures obtained for the pollen percentages from the thirteen

FIG 2.



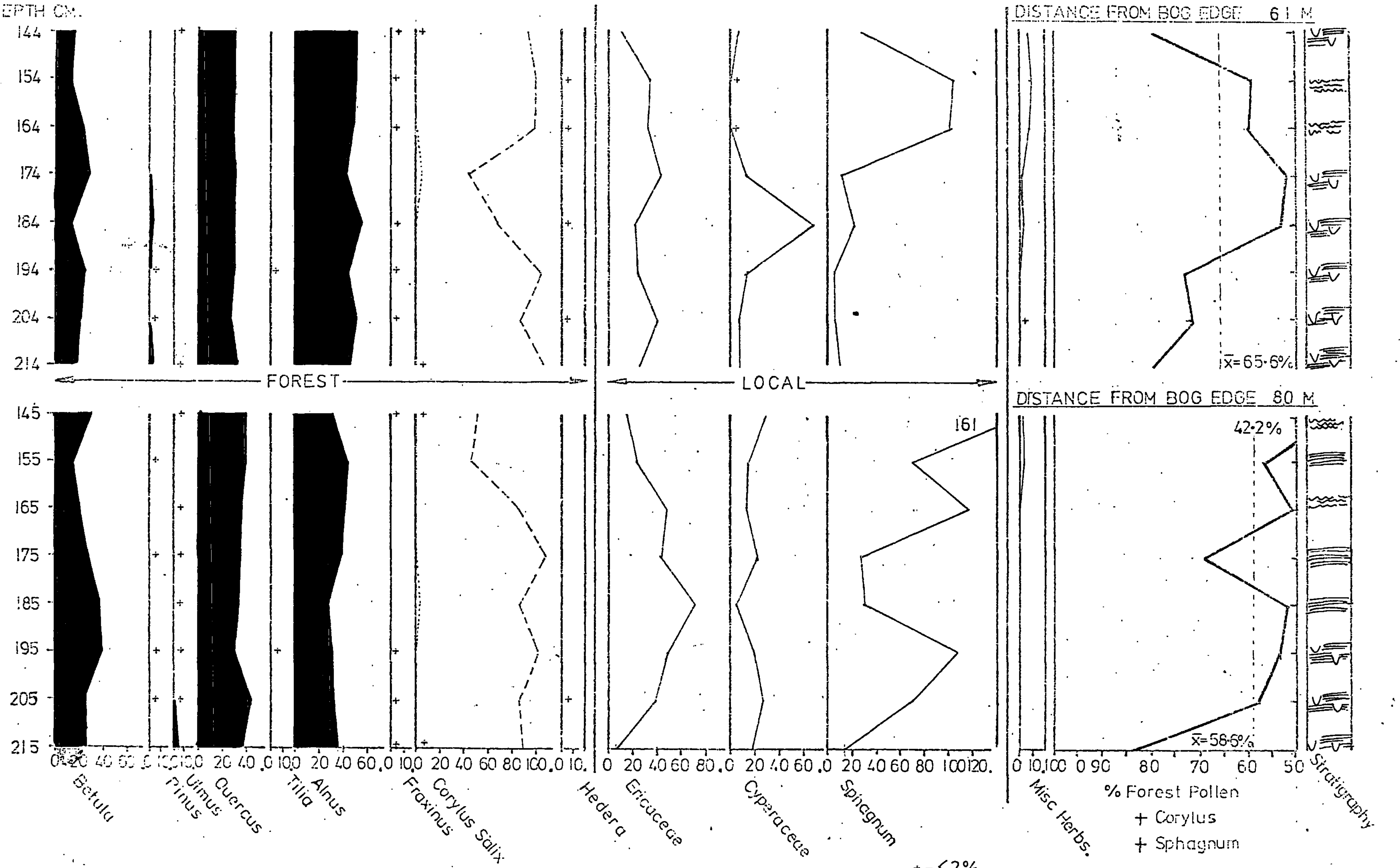
ALL POLLEN AS % TOTAL TREE POLLEN.

FIG 3.



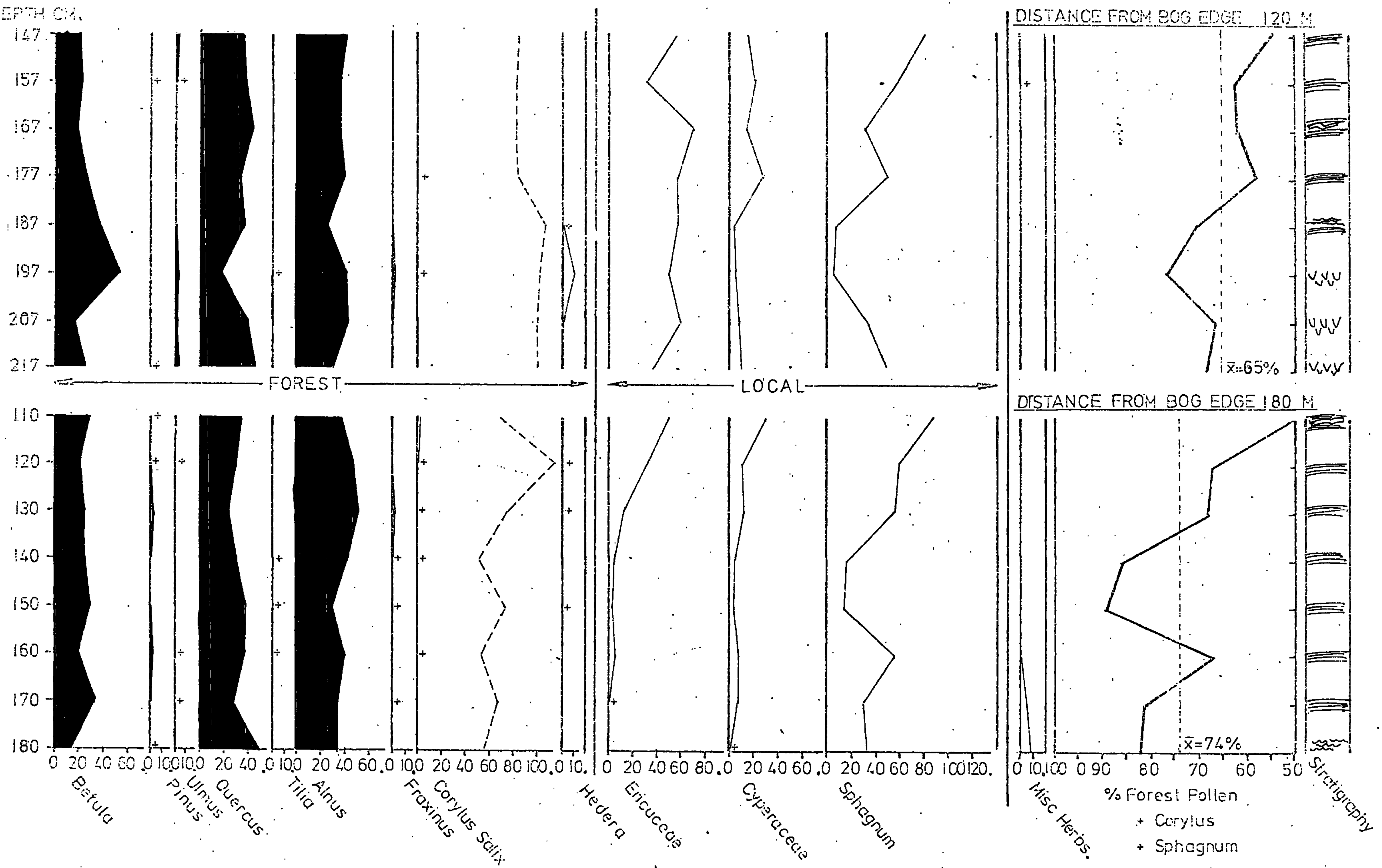
ALL POLLEN AS % TOTAL TREE POLLEN.

FIG 4.



ALL POLLEN AS % TOTAL TREE POLLEN.

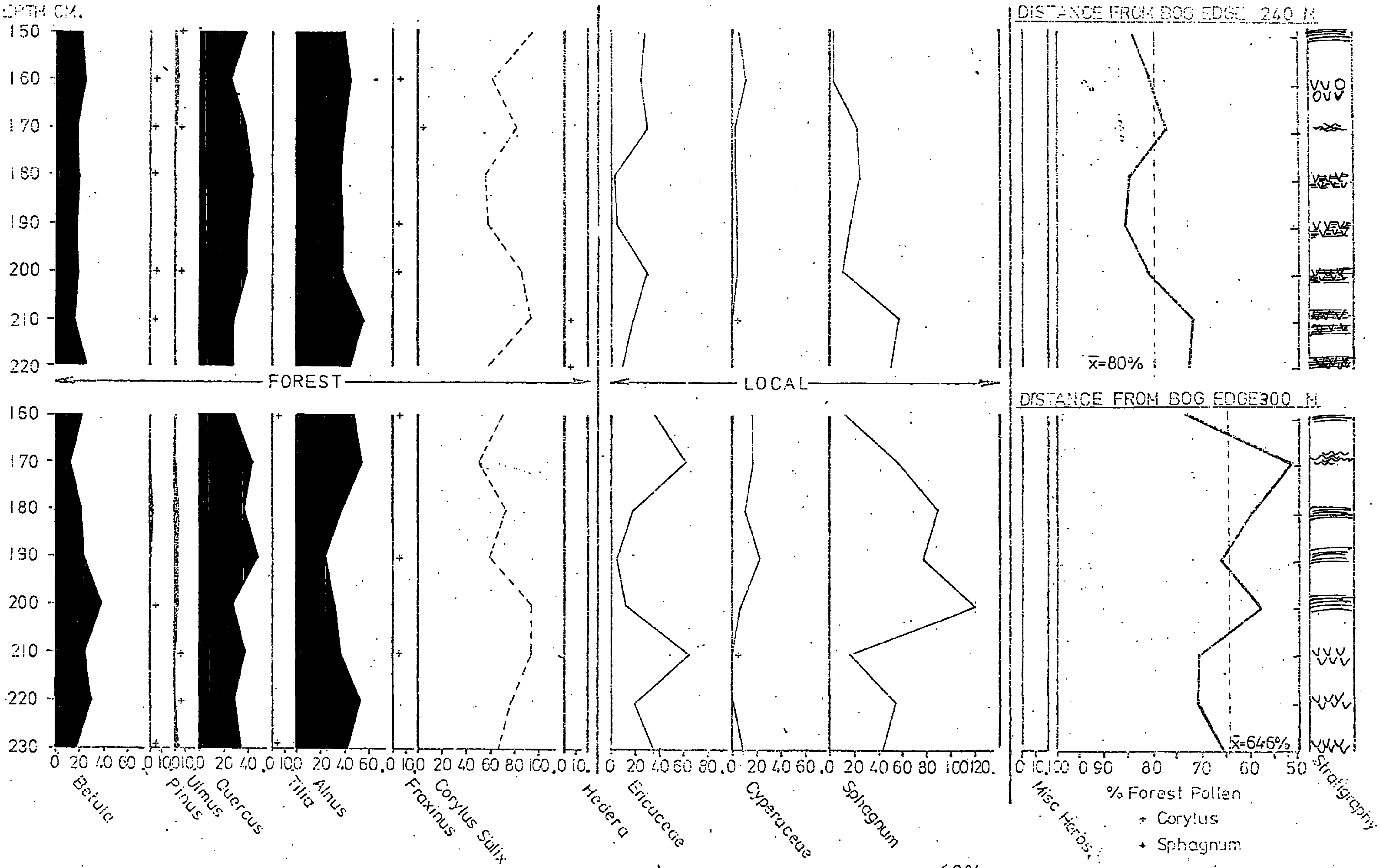
FIG 5.



ALL POLLEN AS % TOTAL TREE POLLEN.

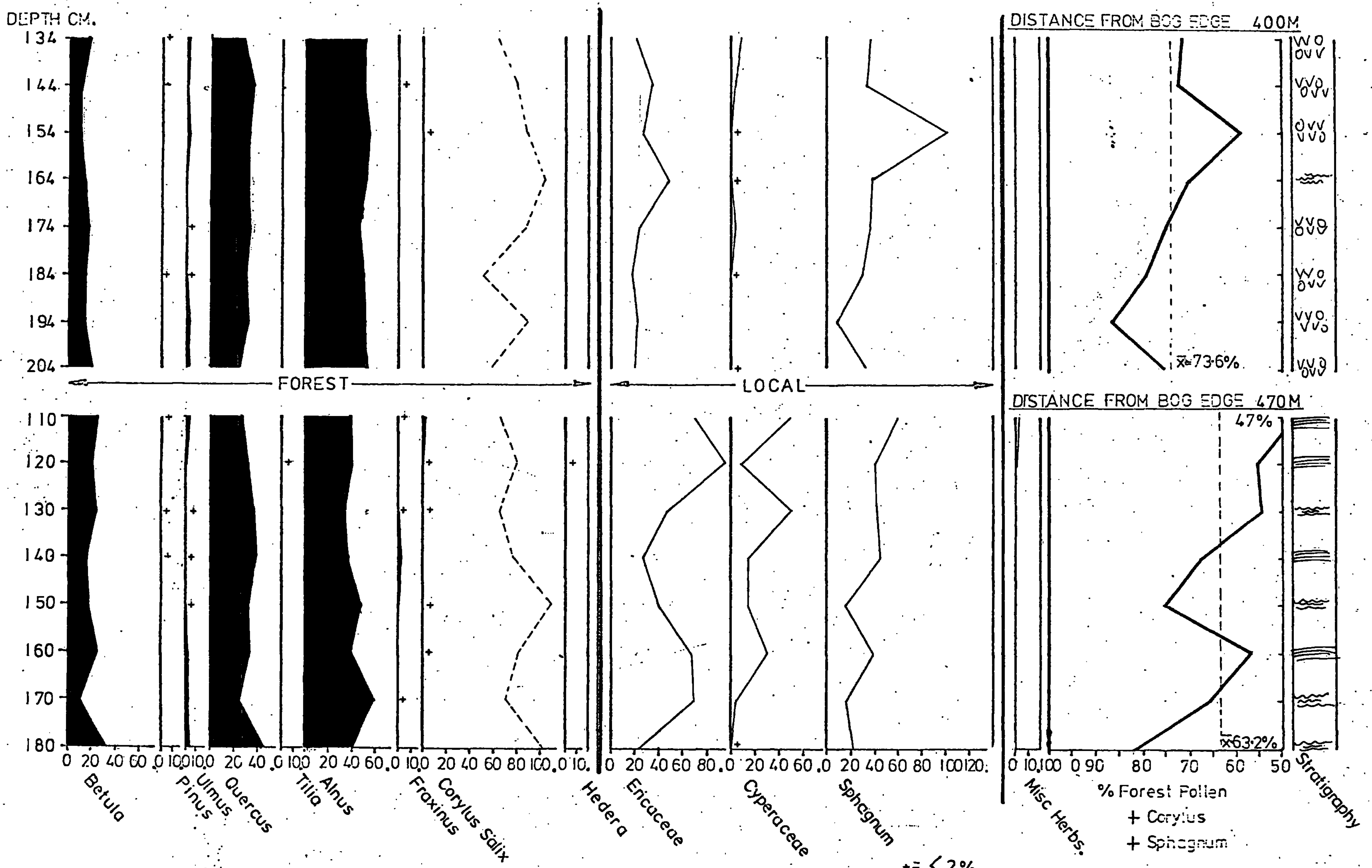
+=<2%

FIG 6.



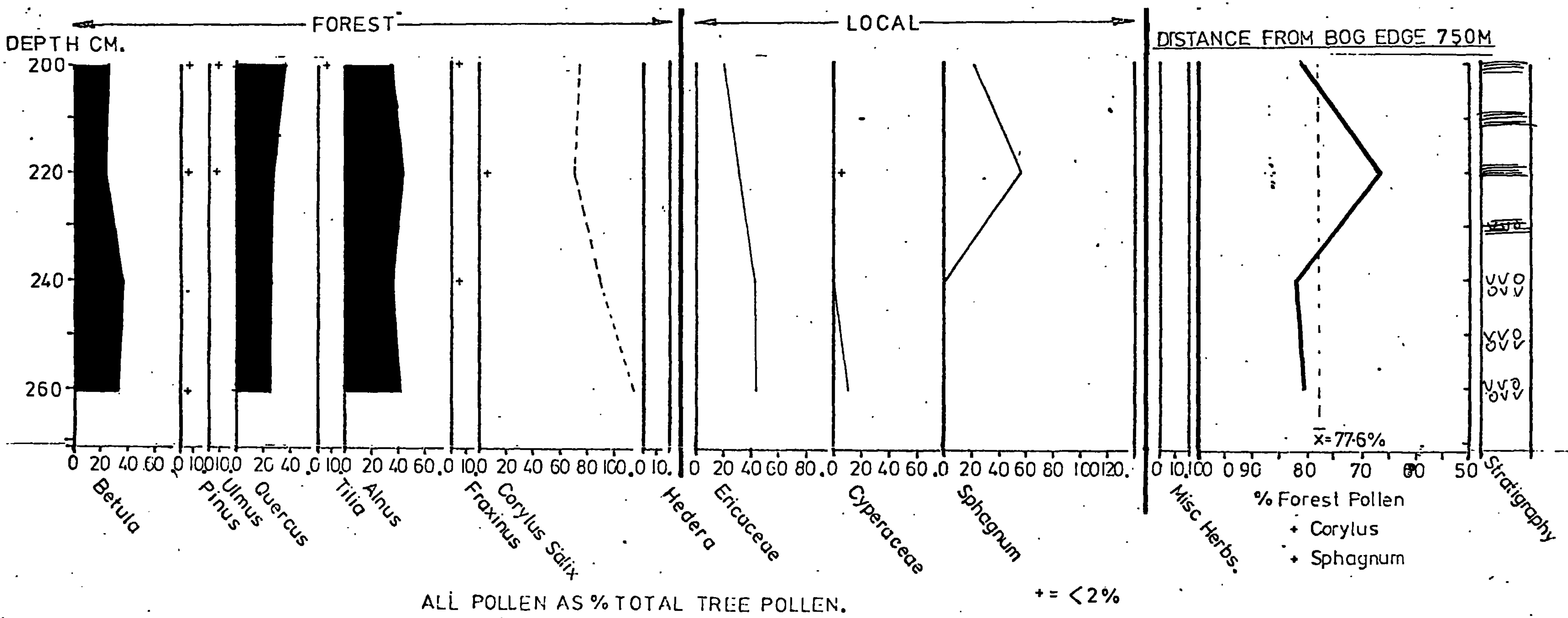
ALL POLLEN AS % TOTAL TREE POLLEN.

FIG 7.



ALL POLLEN AS % TOTAL TREE POLLEN.

FIG 8.



FOREST
LOCAL
DEPTH CM.
DISTANCE FROM BOG EDGE 750M
Betula
Pinus
Ulmus
Quercus
Tilia
Alnus
Fraxinus
Corylus
Salix
Hedera
Ericaceae
Cyperaceae
Sphagnum
Misc Herbs.
% Forest Pollen
+ Corylus
+ Sphagnum
Stratigraphy
x̄=77·6%
+ = <2%
ALL POLLEN AS % TOTAL TREE POLLEN.

profiles are presented in tables 1 - 5 of the appendix. Table 1 shows the percentages for all the species identified, each expressed as a per--centage of thr total tree pollen.

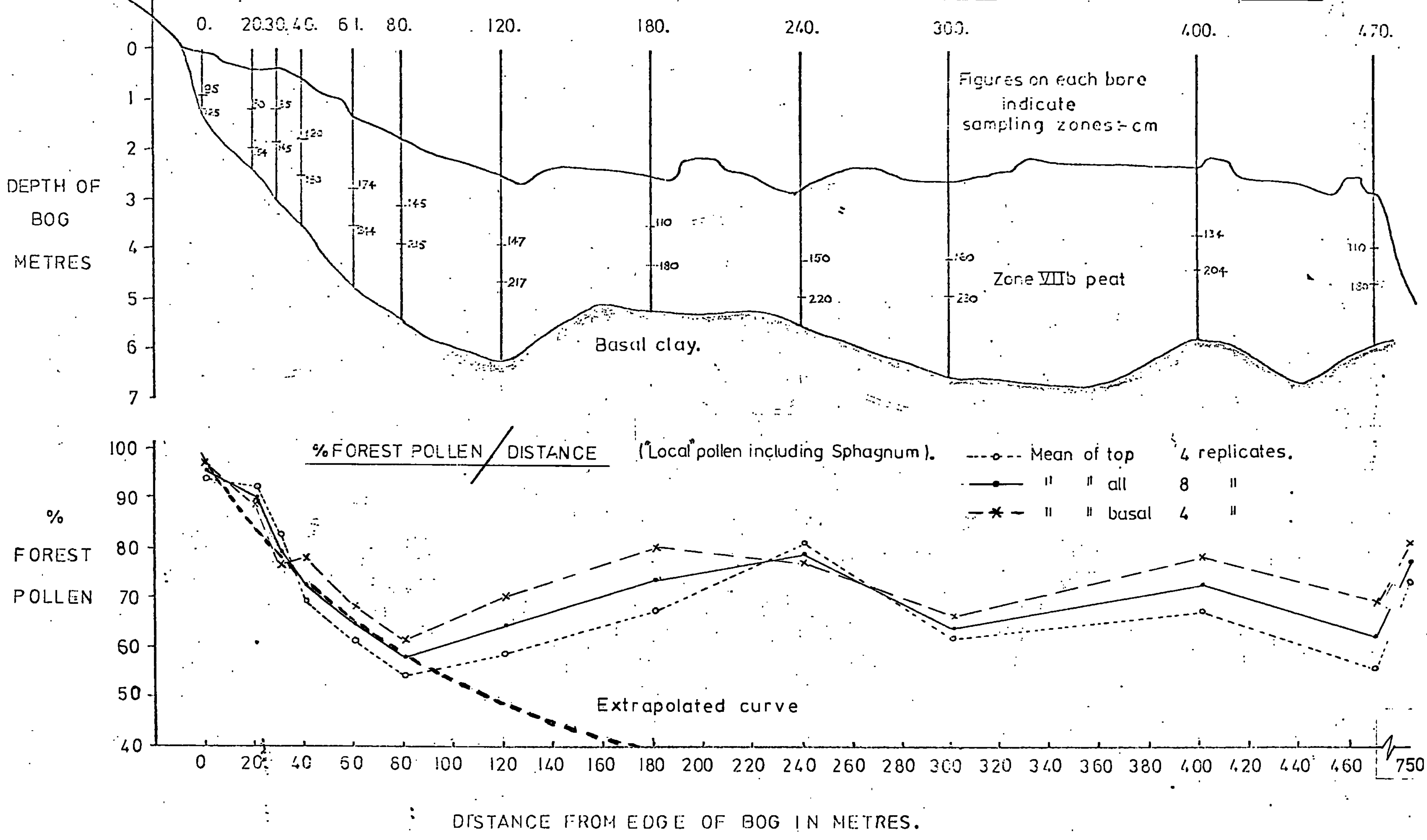
Pollen diagrams (Figs 2-8) were drawn for the depth replicates from each profile. Shown on the right hand side of each profile is a graph of forest pollen percentage containing the value for each replicate and the mean for the whole profile of 8 replicates. Grass pollen was omitted from the diagrams but is included in Table 1. In most profiles the grass percentage begins to rise in the upper replicates, particularly in those taken near the bog margin where the peat tends to be shallow. This would indicate the zone VIIb - VIII boundary. The topmost replicate at 30 metres contained a very high percentage of grass pollen, and was omitted from the results. The second replicate in the sample still showed 47% grass pollen, but as the forest pollen percentage was high, within the range of the lower replicates, it was decided to retain this one and to calculate the mean values at 30 metres on 7 replicates instead of 8.

4. d. Tree Pollen Percentages.

The forest tree pollen percentage was calculated from $\frac{\text{Tree Pollen} \times 100}{\text{Tree+Local pollen}}$

This was done for each sample and the means for each profile calculated, (see Tables 2 and 3-appendix). The mean values for the top and bottom four replicates in each profile were also calculated and all three sets of values plotted against distance in Fig 9. Taking the curve for all 8 replicates it can be seen that from 0-80 metres there is a well defined reduction in the forest pollen frequency. This was extrapolated by eye (thick dotted line in Fig 9) indicating that the initial curve would suggest a value of about 30% at 300metres. This agrees well with the results

FIG 9.

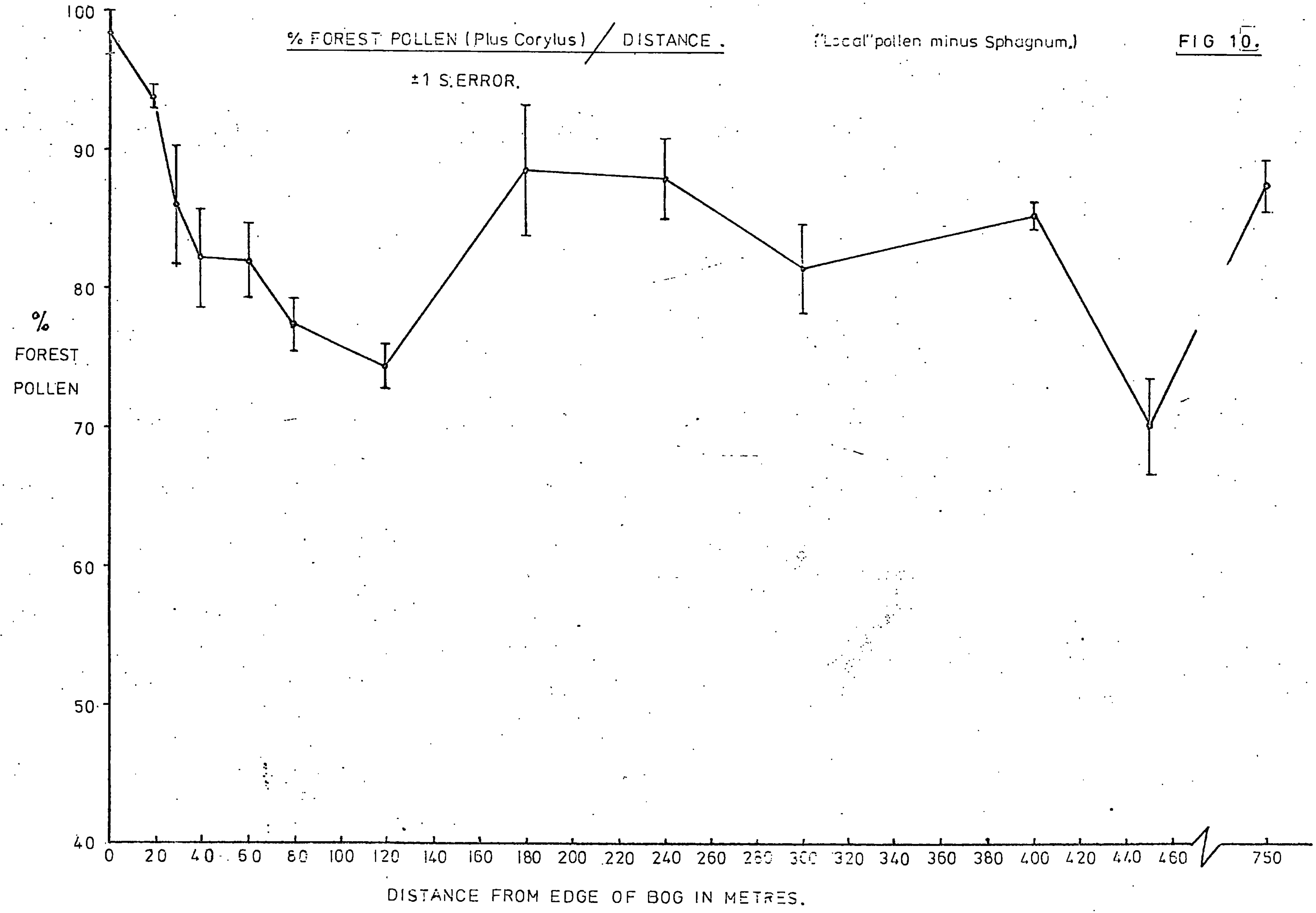

BOLTON FELL — PROFILE SHOWING SITES OF BORES.
0. 20.30.40. 61. 80. 120. 180. 240. 300. 400. 470.
DEPTH OF BOG METRES
0 1 2 3 4 5 6 7
Figures on each bore indicate sampling zones:- cm
Zone VIIb peat
Basal clay.
%FOREST POLLEN / DISTANCE
("Local" pollen including Sphagnum).
Mean of top 4 replicates.
" " all 8 "
" " basal 4 "
% FOREST POLLEN
100 90 80 70 60 50 40
Extrapolated curve
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 750
DISTANCE FROM EDGE OF BOG IN METRES.

of TAUBER and TURNER.

One possible source of error already discussed is in the degree of randomness in the distribution of local bog pollen in the peat. Sphagnum particularly, with its prostrate habit might be liable to leave spores in aggregated masses in the peat. In addition, Corylus pollen was found to form a very high proportion of the forest pollen and this posed an interesting speculation as to the change in forest pollen per-centage with distance for tree species only. In order to show the effects of Corylus on the forest pollen rain and Sphagnum on the local bog pollen distribution, each of these in turn was extracted from the data and the resulting forest pollen percentages calculated using the same formula already explained. The results for the following combin-ations are shown in table 2.

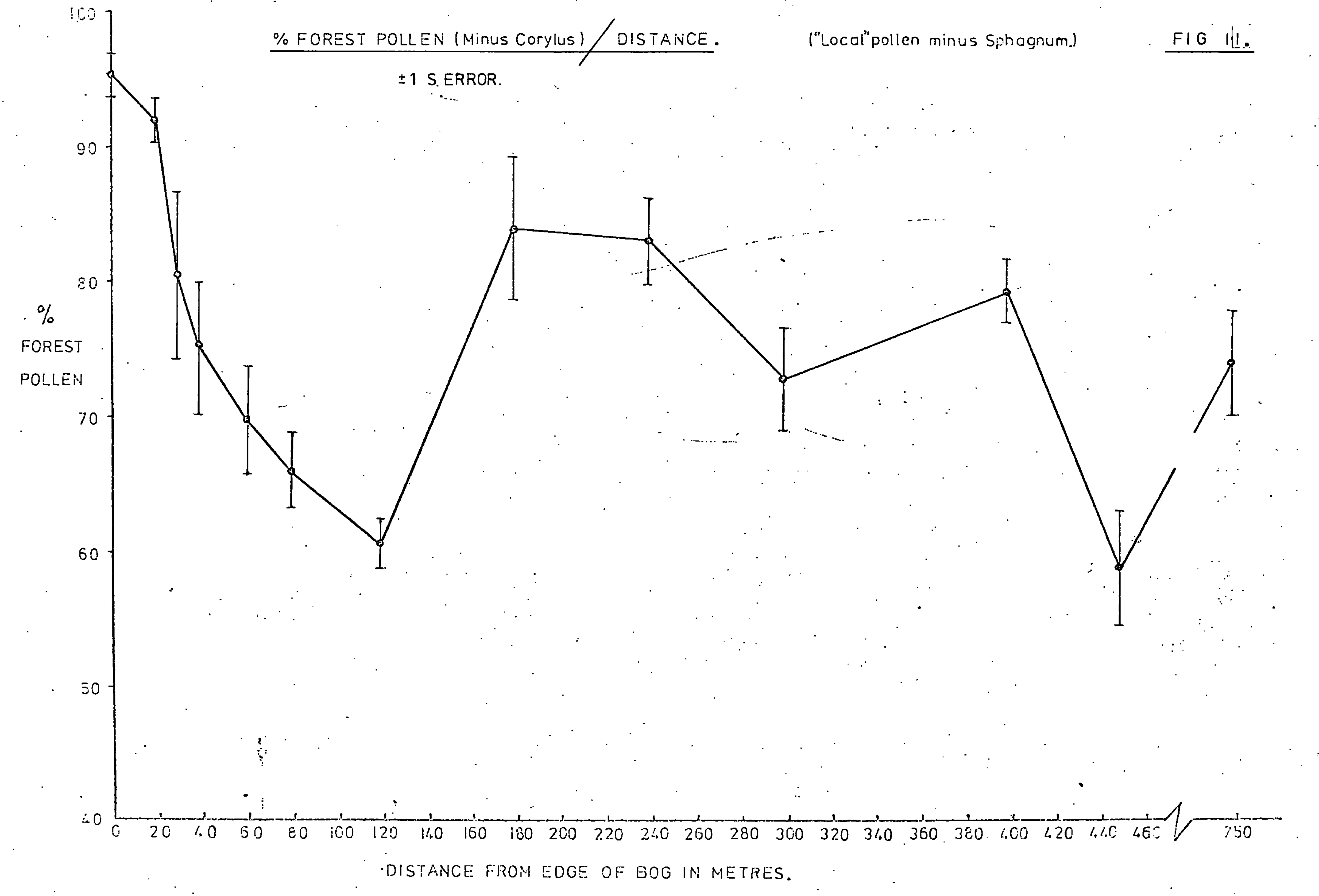
Forest	pollen	including	Corylus	/	Local	pollen	minus	Sphagnum
"	"	excluding	"	/	"	"	"	"
"	"	including	"	/	"	"	plus	"
"	"	excluding	"	/	"	"	"	"

These figures were plotted on four separate graphs as forest pollen percentage against distance, (Figs 10-13). In all four cases the shape of the graph remains essentially similar with a sharp drop in forest pollen from 95% at 0m, to 58.6% at 80m. This is followed by a rise to an average of about 71% from 120m-750m. These are the figures for plus Corylus and plus Sphagnum. As might be expected the graph for plus Corylus and minus Sphagnum gives the highest, and that for minus Corylus and plus Sphagnum the lowest overall forest pollen percentage over the whole transect. Less obvious but possibly more interesting is the fact that in the different plots the values for forest pollen in the 'low' parts of the graphs appear to change disproportionally to those in the higher value areas. This is particularly striking in the two graphs mentioned above for the values round 80-120m and 470m.



% FOREST POLLEN (Plus Corylus) / DISTANCE.
("Local" pollen minus Sphagnum.)
±1 S.ERROR.
%
FOREST
POLLEN
100
90
80
70
60
50
40
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
750
DISTANCE FROM EDGE OF BOG IN METRES.

FIG 10.


% FOREST POLLEN (Minus Corylus) / DISTANCE.
("Local" pollen minus Sphagnum.)
FIG 11.
±1 S. ERROR.
%
FOREST
POLLEN
100
90
80
70
60
50
40
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
750
DISTANCE FROM EDGE OF BOG IN METRES.

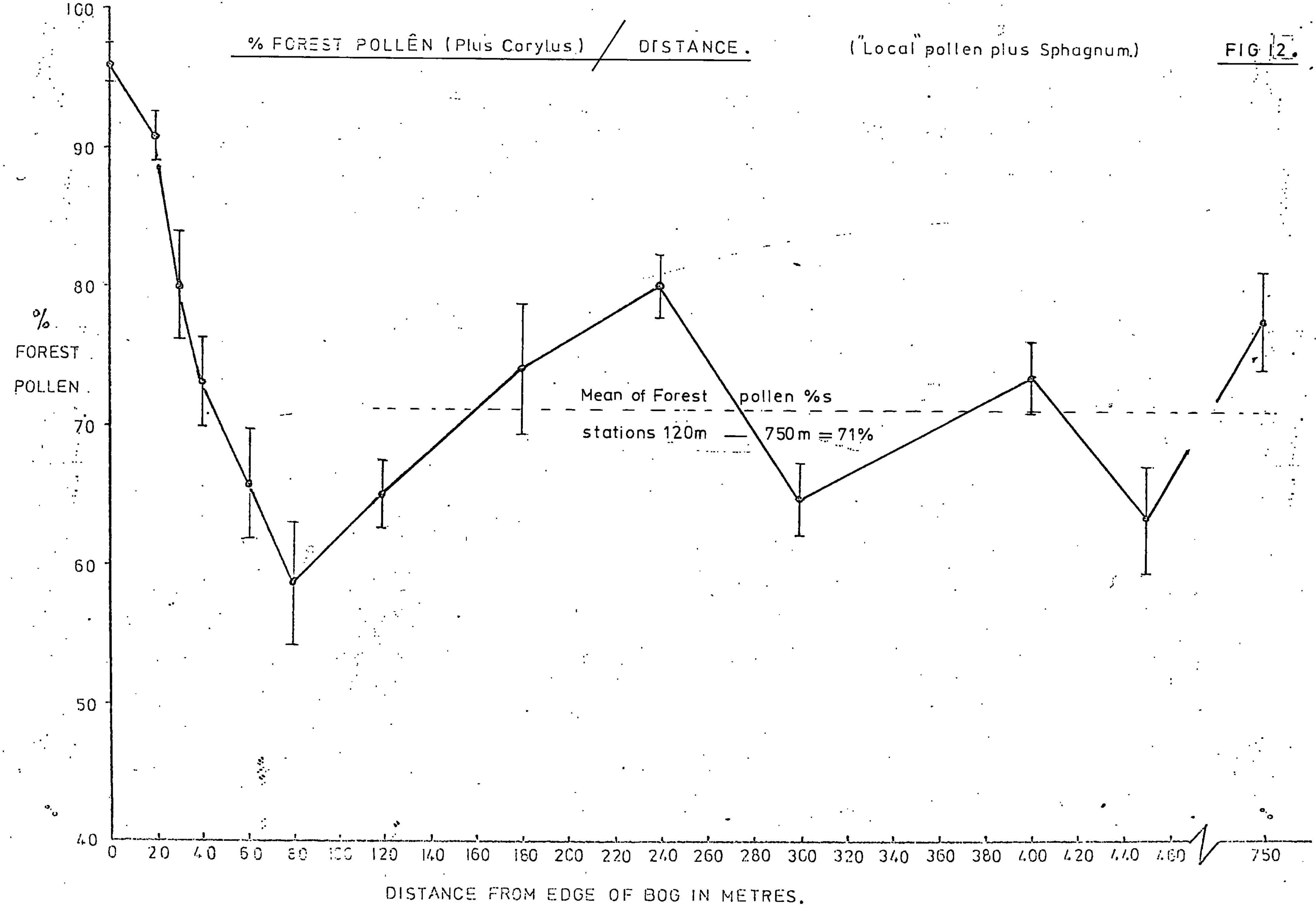
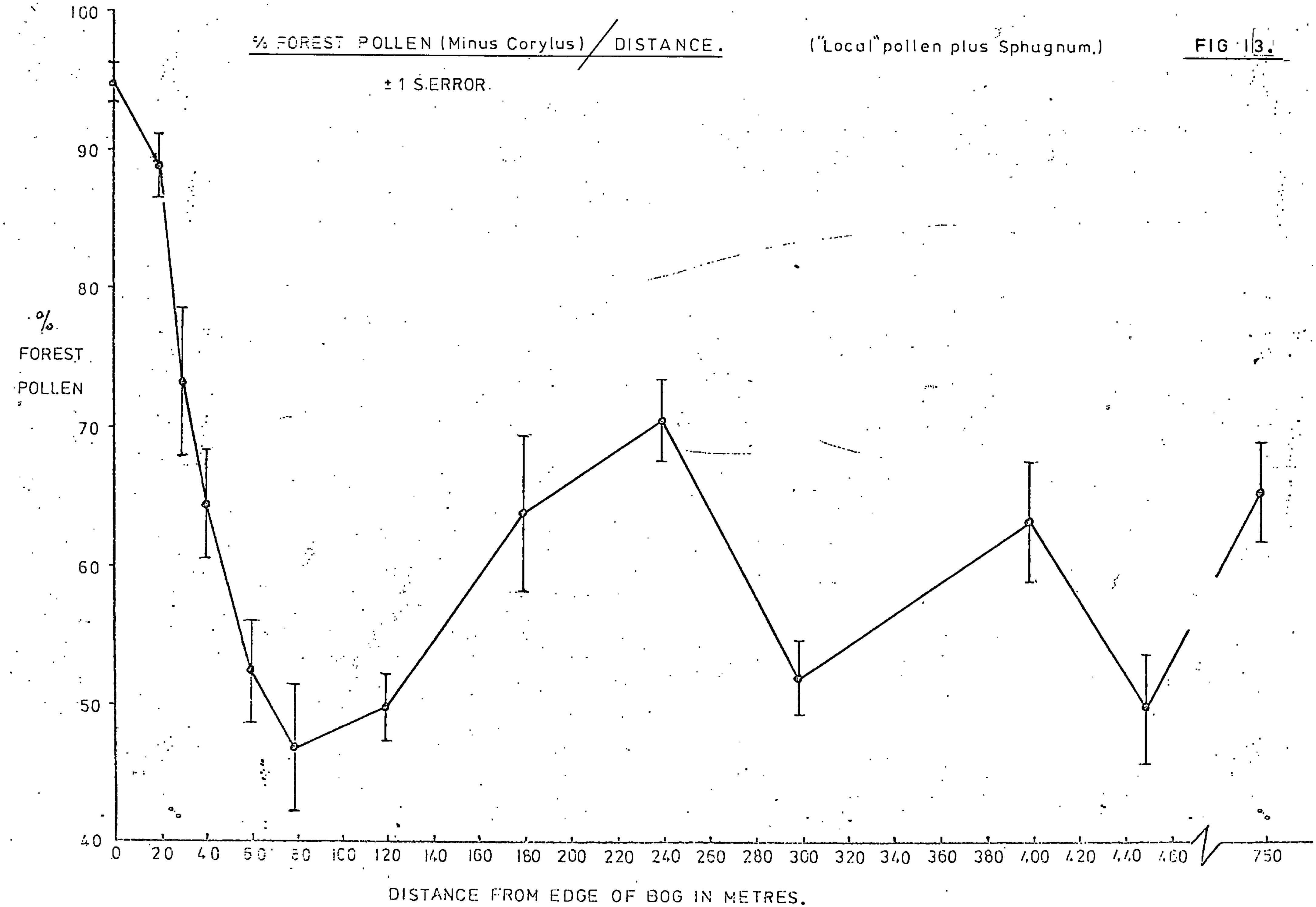

% FOREST POLLEN (Plus Corylus) / DISTANCE.
("Local" pollen plus Sphagnum.)
FIG 12.
% FOREST POLLEN
100
90
80
70
60
50
40
Mean of Forest pollen %s
stations 120m — 750m = 71%
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 750
DISTANCE FROM EDGE OF BOG IN METRES.

FIG 13.


% FOREST POLLEN (Minus Corylus) / DISTANCE.
("Local" pollen plus Sphagnum.)
± 1 S.ERROR.
% FOREST POLLEN
100
90
80
70
60
50
40
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 750
DISTANCE FROM EDGE OF BOG IN METRES.

The means of the forest pollen percentages for the first seven stations out to 120m were examined ststistcally for significance of difference. The standard deviation and variance were calculated for each and +/- 1 S.E. is plotted on the graphs (Figs10-13). As some of the standard errors were close or overlapping 't' tests were carried out to calculate the degree of real difference between them. The results of these tests are given in Table 4. In only two cases was 't' non significant with the probability level at 0.05 .

In the light of this firm statistical evidence the conclusion put forward at the beginning of this section can be taken as quite valid. The drop in forest pollen frequency from 0-80m is real thus proving beyond doubt that intact forest did indeed exist up to the edge of the growing bog.

4. e. High Tree Pollen frquency in the centre of the bog.

The problem remains of the higher forest pollen percentages further out in the bog beyond 100metres. The apparent peaks and troughs from 120m-750m cannot be taken as hard evidence of large variations in forest pollen frequency. Many more samples would have to be taken before it could be proved that these were not statistical variations. However it remains clear that the average forest tree pollen percentage appears to be maintained at around the 71% level in contrast to the extrapolated value of round about thirty per cent discussed earlier.

To investigate this situation further the means of replicates at each station for the individual tree and shrub species were plotted against distance. These graphs are shown in Figs 14 and 15, and in detail in figs 16 to 19. From these it can be seen that the relative

FIG 14.

BOLTON FELL — PROFILE SHOWING SITES OF BORES.

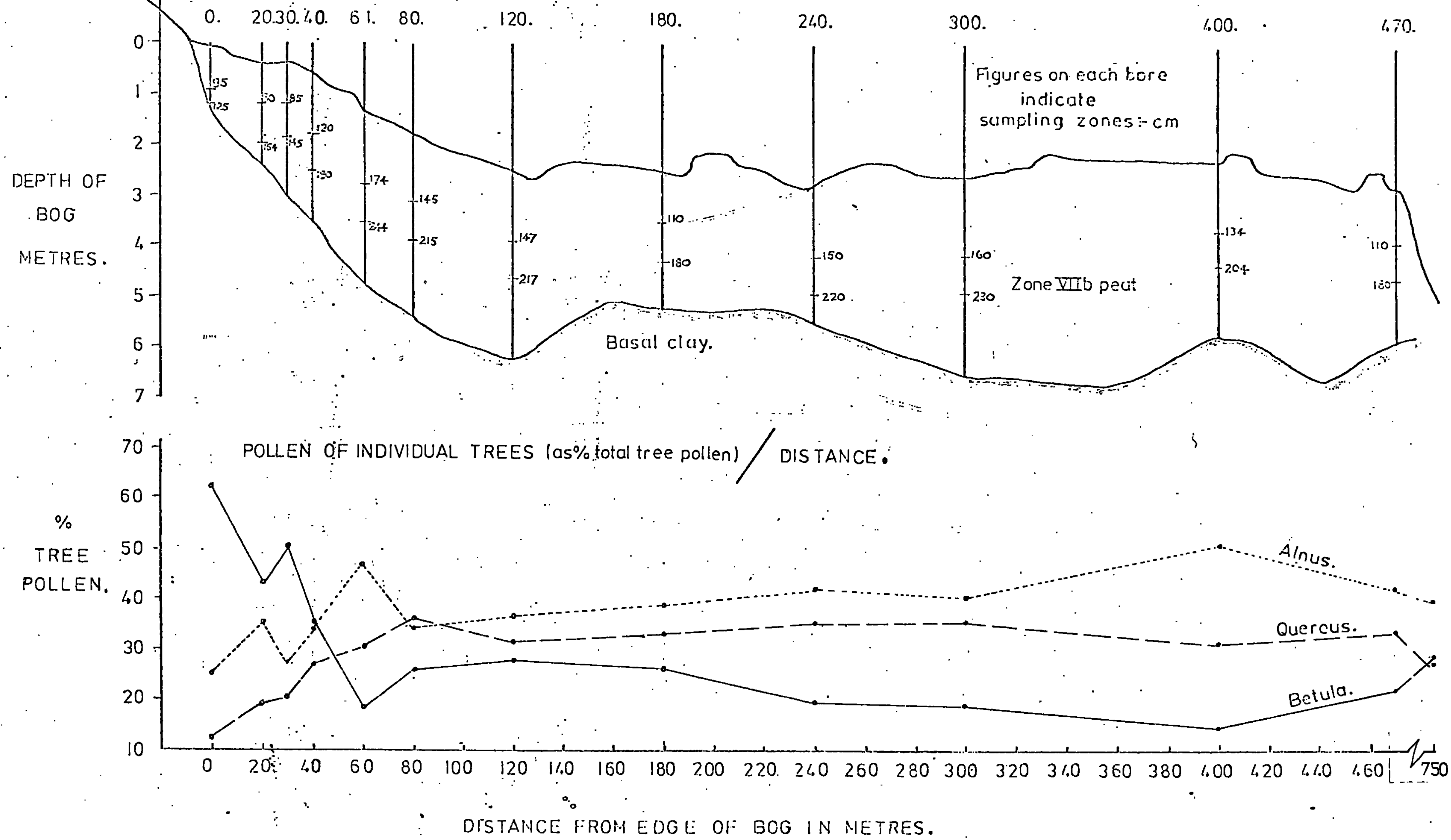


FIG 15.

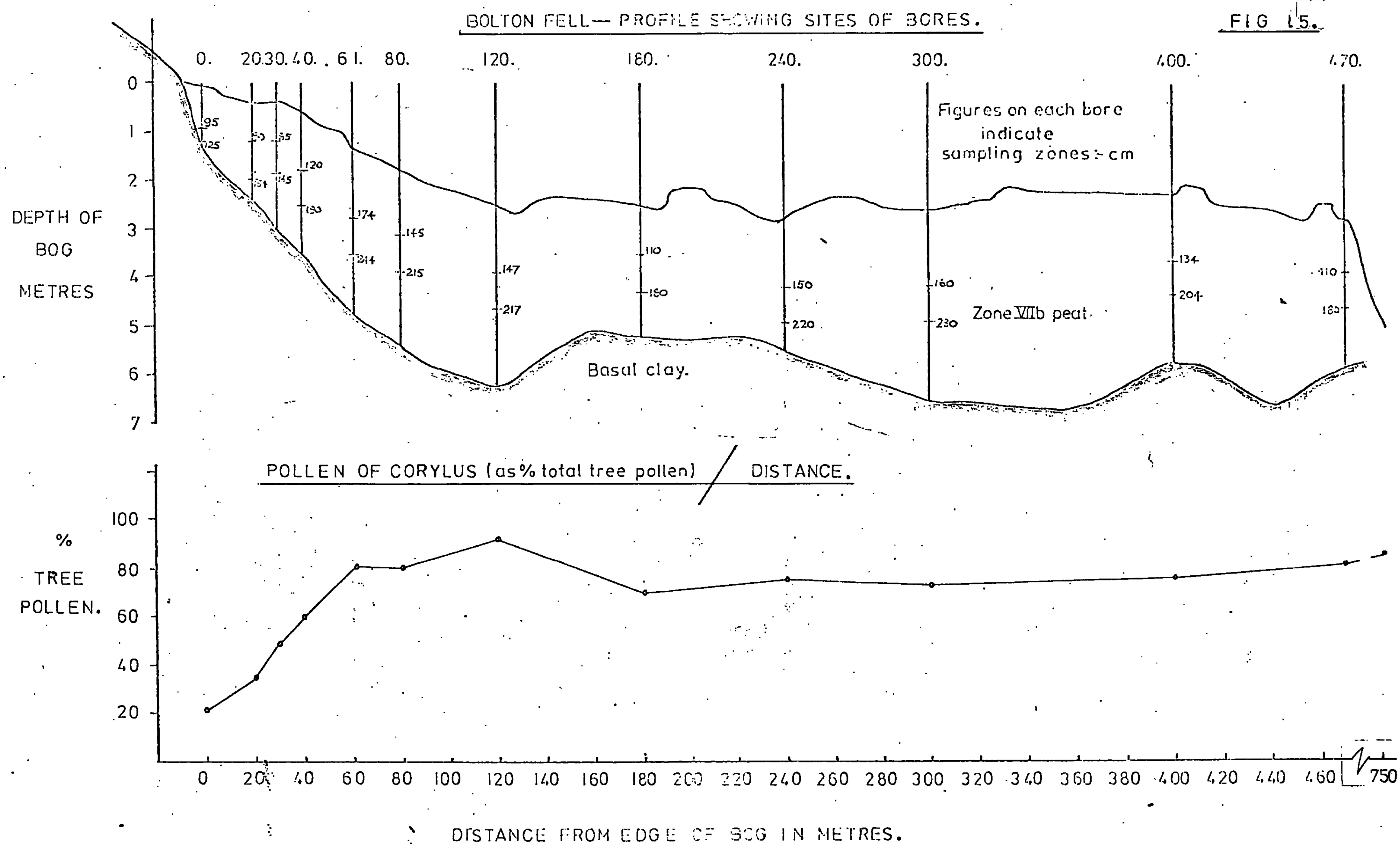
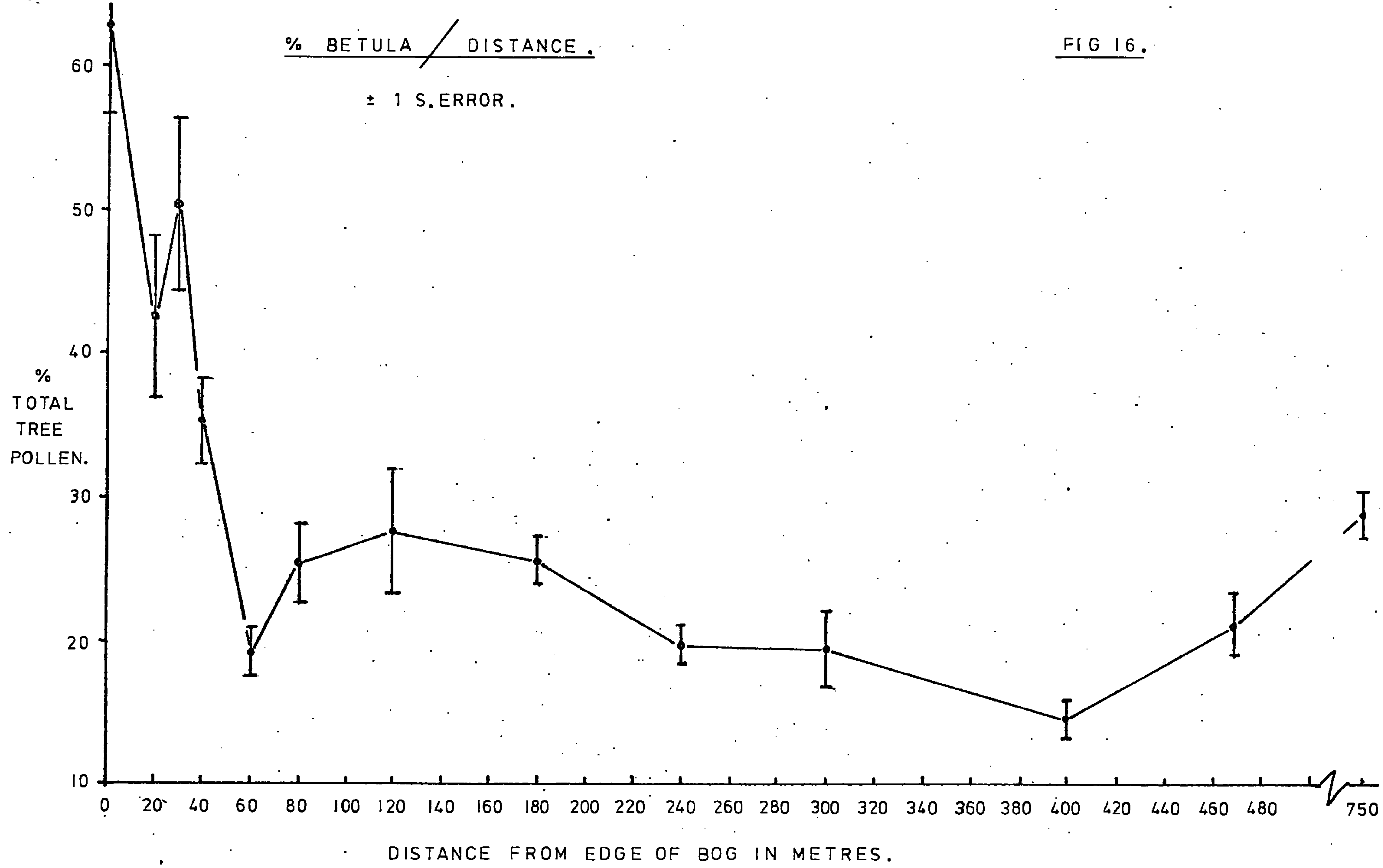
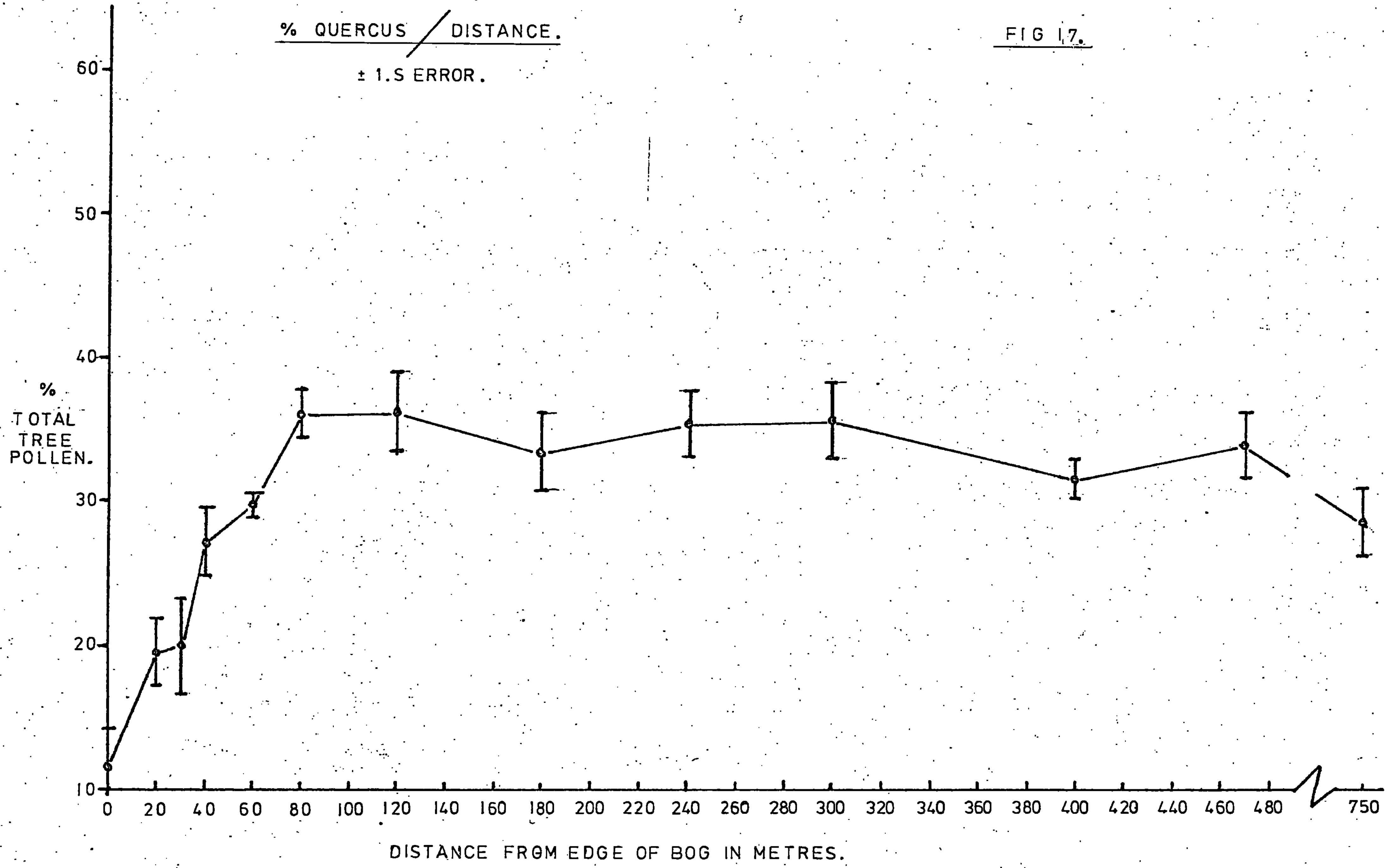

BOLTON FELL— PROFILE SHOWING SITES OF BORES.
Figures on each bore indicate sampling zones - cm
DEPTH OF BOG METRES
Basal clay.
Zone VIIb peat
POLLEN OF CORYLUS (as % total tree pollen) / DISTANCE.
% TREE POLLEN.
DISTANCE FROM EDGE OF BOG IN METRES.

FIG 16.



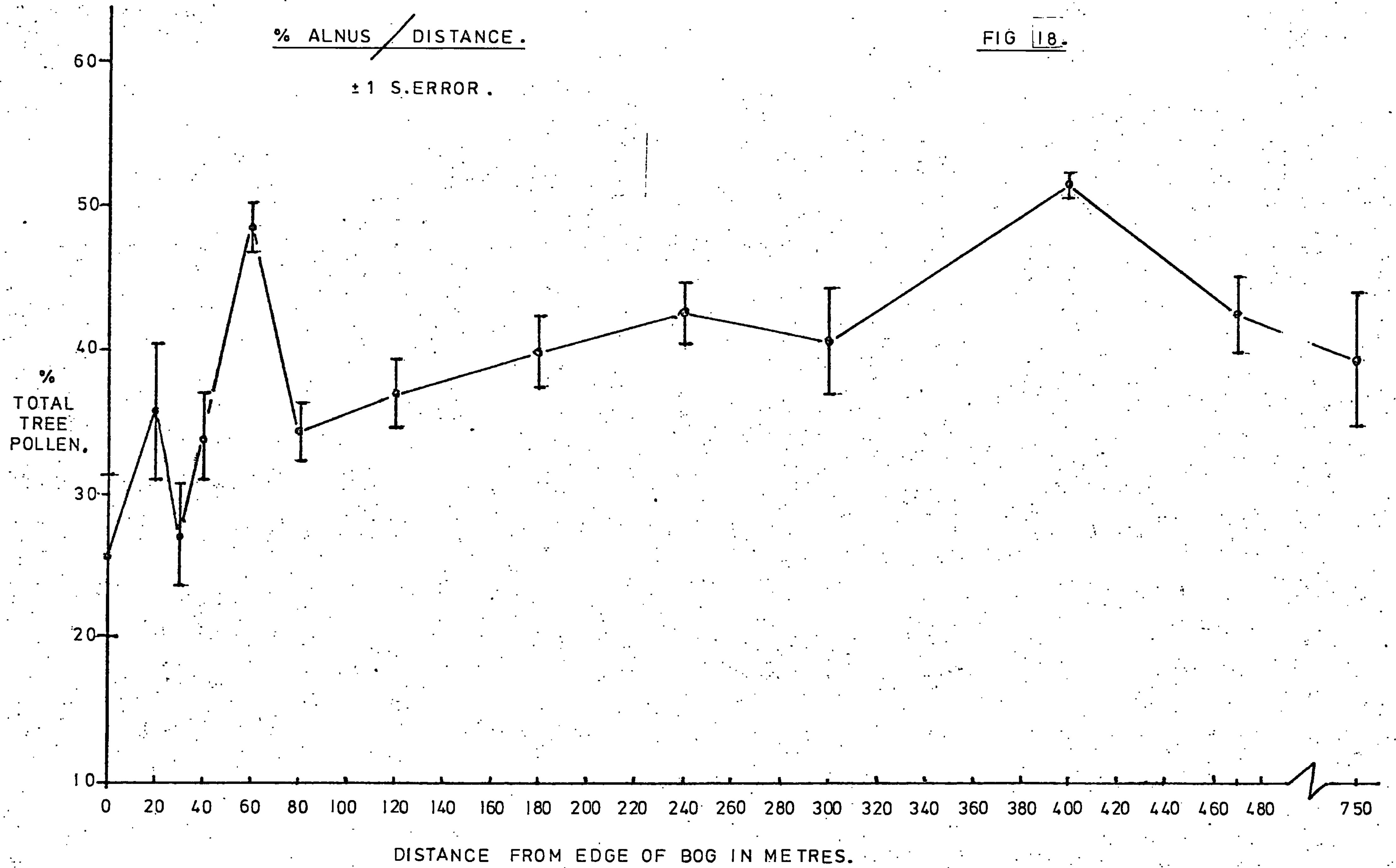
% BETULA / DISTANCE.
± 1 S.ERROR.
%
TOTAL
TREE
POLLEN.
60
50
40
30
20
10
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 750
DISTANCE FROM EDGE OF BOG IN METRES.

FIG 17.

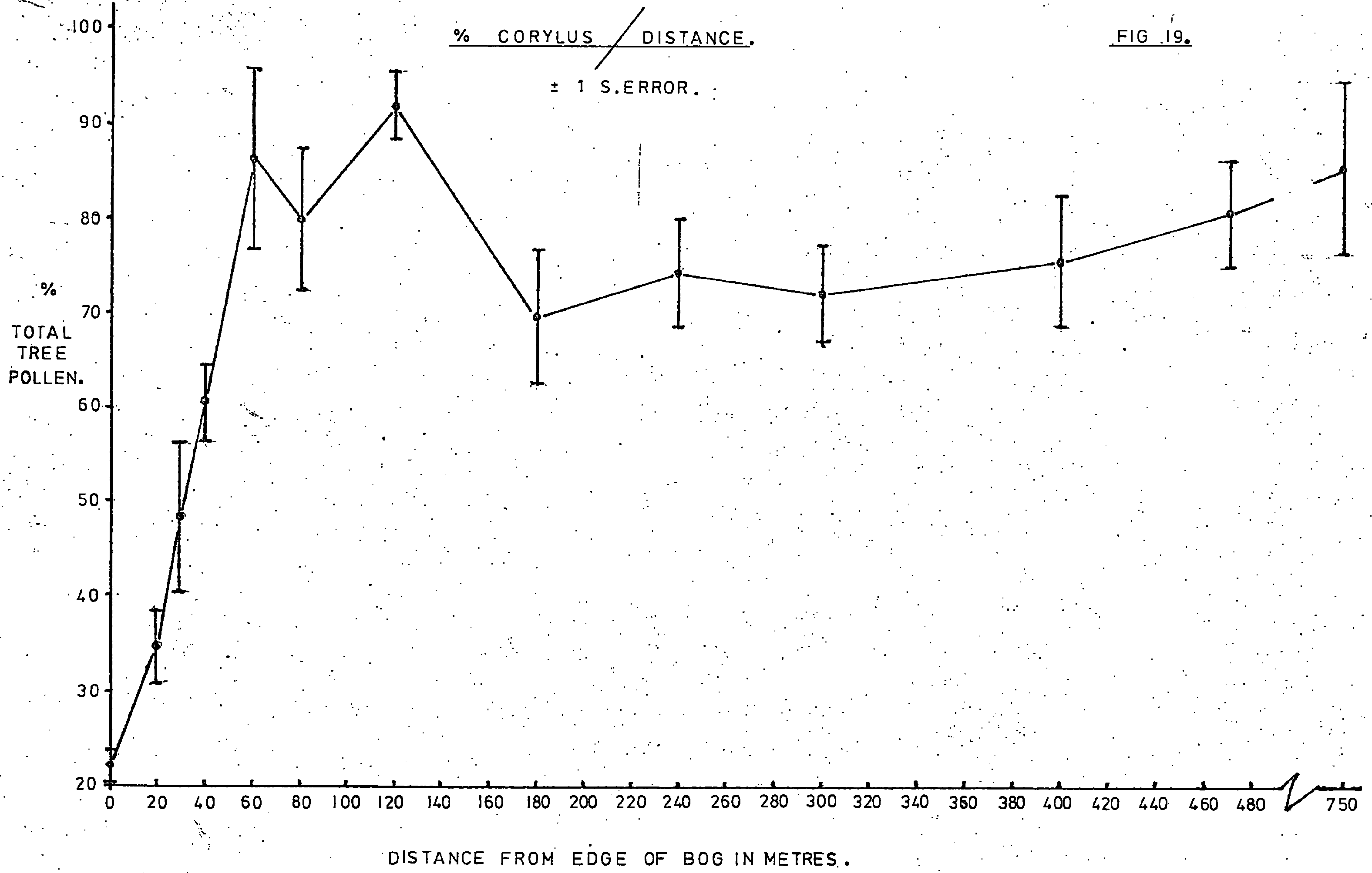


% QUERCUS / DISTANCE.
± 1.S ERROR.
%
TOTAL
TREE
POLLEN.
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
750
DISTANCE FROM EDGE OF BOG IN METRES.

FIG 18.



% ALNUS / DISTANCE.
±1 S.ERROR.
%
TOTAL
TREE
POLLEN.
60
50
40
30
20
10
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
750
DISTANCE FROM EDGE OF BOG IN METRES.



% CORYLUS / DISTANCE.
± 1 S.ERROR.
%
TOTAL
TREE
POLLEN.
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
750
DISTANCE FROM EDGE OF BOG IN METRES.

FIG 19.

frequency of the various species alters with distance from the bog edge. The Betula percentage rapidly drops from 0-80m, then maintains approximately the same value out to 750m, whilst the frequencies of Alnus, Quercus, and Corylus rise from 0-80m, and these in turn are maintained at a fairly steady level out to 750m. This would seem to suggest that at the original forest edge there was a thick stand of Betula with the other species present further back in the forest stand. The Betula at the edge would give a high representation of its own pollen close to the bog edge whilst acting as a filter to the pollen of the other tree species blowing through the trunk space. Consequently the pollen of the other tree species, coming out of the top of the canopy only achieves a high relative frequency further out on the bog where the Betula frequency is beginning to drop.

There remains the final problem of explaining the average forest pollen percentage out on the bog of 71% after dropping to 58% at 80m. One piece of evidence shown in the stratigraphy was the discovery of scattered wood fragments in the peat. Some of this was identified from the bark as Betula. So it seems possible that the bog at various times during its growth, may have experienced conditions dry enough for scattered Betula to have invaded the growing surface. However the Betula component of the forest pollen rain is low away from the bog edge so there must be at least one other factor involved in the high percentages of the other tree species. As explained earlier the forest pollen percentage at most sites on the transect was found to rise towards the base of each of the 1m sections sampled. If we assume that the total local bog pollen rain remains reasonably constant with time then the explanation must be that there was a higher total forest pollen rain earlier on in the bog's development. This might conceivably be due to a higher density of forest round the bog margin initially though there is no other pollen evidence to support this. There is another possible explanation for which unfortunately the author was unable in the time involved, to obtain sufficient stratigraphical evidence. This is that the bog, during its growth and in the time zone from which the samples taken was in fact not as complete a raised bog as would appear from its present surface topography, and that there may have been isolated 'islands' of woodland growing on very shallow peat, contributing a mosaic of tree pollen dispersion to the pollen rain over the whole bog surface. Thus ,if this were true, the bog is not quite as ideal as first anticipated, for the most clear cut demonstration of the 'Tauber effect' over long distances. However, for the effect of dispersion from the immediate bog edge, and for the demonstration of individual tree pollen effects up to nearly 100m out from the original forest edge, the bog proved to be highly satisfactory.

ACKNOWLEDGMENTS.

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TABLE .1.

POLLEN PERCENTAGES. (% Total Tree Pollen)

DISTANCE FROM BOG EDGE METRES.	LEVEL cm	Betula	Pinus	Ulmus	Quercus	Tilia	Alnus	Fraxinus	Corylus	Salix	Hedera	Misc Herbs	Ericaceae	Cyperaceae	Gramineae	Sphagnum
	95	78	0.0	0.0	2.9	0.0	19.0	0.0	21	6.7	0.0	0.0	4.8	0.0	28.0	0.0
	105	39	0.0	0.0	11.0	0.0	50.0	0.0	24	1.2	0.0	0.0	9.0	1.1	49.0	0.0
0	115	76	0.0	0.0	10.0	0.0	14.0	0.0	26	0.0	0.0	0.0	3.0	0.6	0.0	0.6
	125	59	0.0	0.0	21.5	0.0	20.0	0.0	15	0.0	0.0	0.0	1.9	0.0	11.0	1.9
	80	65	0.5	0.5	16.2	0.0	17.8	0.0	19	4.7	3.7	0.5	3.7	9.4	14.7	5.2
	90	66	0.0	0.6	13.9	0.0	18.1	1.8	27	22.9	0.6	5.4	5.4	4.2	14.5	1.8
	100	37	0.0	0.6	20.8	0.0	40.5	1.2	57	18.4	2.5	1.6	7.0	3.8	20.0	5.1
20	110	32	0.0	0.0	18.0	0.0	47.0	2.6	44	5.8	0.6	0.0	2.6	1.3	9.9	0.0
	120	27	0.0	0.0	15.3	0.0	55.8	1.4	29	1.9	3.7	5.6	3.3	2.3	1.9	3.3
	130	28	0.6	1.7	30.0	0.0	39.8	0.0	43	3.4	3.4	2.3	3.4	10.4	9.2	23.7
	142	49	0.4	0.4	14.0	0.0	35.0	0.3	32	6.0	0.3	2.6	3.5	2.0	9.5	0.0
	154	37	0.9	0.0	28.6	0.0	33.2	0.0	28	4.5	1.8	1.8	0.9	10.5	6.8	1.8
	85	54	0.0	3.8	14.0	0.0	27.0	1.2	32	0.0	0.0	0.0	13.0	5.0	47.0	2.5
	95	74	0.0	0.0	16.0	0.0	8.5	1.4	23	3.5	0.7	0.0	6.3	1.4	10.0	29.0
	105	64	0.0	0.0	11.0	0.0	24.0	0.0	31	0.8	3.3	0.0	6.5	3.2	17.0	10.6
	115	38	0.0	0.0	29.5	0.0	32.0	1.0	60	1.0	0.0	0.0	18.0	1.0	3.8	17.0
30	125	37	0.0	0.0	29.0	0.0	31.0	2.0	74	3.0	0.0	0.0	54.0	8.0	5.0	22.2
	135	25	1.6	0.0	31.0	0.0	41.0	1.6	79	0.0	0.0	0.0	96.0	0.0	3.2	1.1
	145	62	0.0	0.0	11.0	0.0	27.0	0.0	41	1.0	0.0	0.0	4.7	0.0	1.2	3.7
	120	40	0.0	0.0	26.8	0.0	32.5	0.6	63	1.0	1.3	0.3	48.0	3.0	14.0	30.0
	130	39	2.0	0.6	13.3	0.0	41.3	2.7	85	2.0	1.3	0.0	64.0	1.3	14.7	9.3
	140	24	1.1	0.0	27.0	0.0	47.2	0.0	55	0.0	2.2	0.0	85.0	3.4	8.9	7.0
	150	35	0.0	2.0	31.3	0.0	30.7	0.6	71	1.3	0.6	3.0	25.3	5.3	5.3	15.3
40	160	25	0.0	0.0	32.0	0.0	43.3	0.0	55	3.9	3.4	0.0	22.5	21.3	10.1	64.6
	170	48	0.6	1.9	21.7	0.0	26.8	0.6	49	40.0	0.0	14.0	14.0	0.6	13.4	37.5
	180	40	0.7	2.0	34.6	0.0	21.6	1.3	49	20.3	0.0	10.0	8.5	2.6	5.2	28.8
	190	32	1.8	2.4	31.4	0.0	30.2	2.4	57	34.3	0.0	3.0	18.9	0.0	13.0	14.0
	174	27	0.0	0.0	31.1	0.0	41.6	0.0	24	4.3	0.0	3.0	23.6	13.6	11.2	44.0
	184	12	2.0	0.0	29.8	0.0	55.6	0.7	68	0.0	0.6	5.0	21.9	68.9	21.3	59.0
	194	23	1.1	0.0	29.6	0.5	44.0	0.5	103	0.0	0.0	0.0	23.8	12.7	5.8	38.6
	204	20	1.3	0.0	26.1	0.0	51.6	0.7	85	0.0	0.7	0.7	39.9	6.5	5.9	29.6
61	214	16	2.0	0.6	32.6	0.0	47.3	0.6	105	0.6	0.0	0.0	25.3	7.3	9.3	22.7
	144	15	0.0	1.8	30.5	0.0	51.0	0.9	93	1.8	0.0	8.0	11.8	6.4	5.4	30.5
	154	20	0.0	0.0	29.0	0.0	50.0	1.2	99	0.0	1.2	9.0	33.0	1.2	7.0	104.0
	164	22	0.0	0.0	28.0	0.0	48.0	1.2	97	0.0	1.2	7.0	32.0	1.2	4.7	100.0
	145	28	0.0	1.9	39.7	0.0	30.1	0.6	49	0.7	0.0	2.0	14.7	28.2	1.9	161.5
	155	13	0.5	0.0	39.7	0.0	43.1	2.9	45	0.0	0.0	0.0	23.5	14.2	8.8	69.1
	165	19	0.0	0.7	35.1	0.0	40.5	4.6	84	0.0	0.0	0.0	46.4	13.1	8.5	116.3
	175	25	0.7	0.7	33.6	0.0	38.0	2.7	106	0.0	0.0	4.0	43.0	22.0	11.4	26.8
80	185	36	0.0	1.9	32.7	0.0	26.9	5.2	85	2.6	0.0	0.0	70.5	4.5	17.3	30.0
	195	37	0.6	0.6	29.3	0.6	30.5	1.1	99	0.0	0.0	0.0	47.7	19.0	13.8	105.0
	205	23	1.3	1.3	43.4	0.0	30.8	0.6	84	0.0	1.3	0.0	37.7	26.4	13.8	69.8
	215	24	0.0	2.9	36.3	0.0	36.3	0.9	87	1.5	0.0	0.0	5.9	16.2	8.3	13.7
	147	20	0.0	2.0	36.7	0.0	41.3	0.0	84	0.0	0.0	0.0	56.0	15.3	8.7	80.0
	157	23	0.6	1.3	38.0	0.0	37.0	0.0	83	0.0	0.0	0.6	31.0	21.0	3.0	57.0
	167	19	0.0	0.0	44.0	0.0	37.0	0.0	82	0.0	0.0	0.0	70.0	14.0	3.0	27.0
	177	26	0.6	0.0	33.0	0.0	41.0	0.0	83	1.3	0.0	0.0	57.0	27.0	6.0	49.0
120	187	37	0.0	0.0	37.0	0.0	26.0	0.0	106	0.0	1.3	0.0	67.0	3.3	0.6	7.0
	197	54	0.0	2.0	18.2	1.0	42.5	2.0	101	1.0	10.0	0.0	50.0	4.1	5.1	4.7
	207	17	0.0	0.0	39.3	0.0	43.3	0.0	99	0.0	0.0	0.0	59.0	7.0	0.0	33.0
	217	26	0.7	3.3	45.0	0.0	29.0	0.0	100	0.0	0.0	0.0	36.0	8.3	5.0	48.0

TABLE.1.(cont/d).

POLLEN PERCENTAGES. (% Total Tree Pollen)

DISTANCE FROM BOG EDGE METRES.	LEVEL cm	Betula	Pinus	Ulmus	Quercus	Tilia	Alnus	Fraxinus	Corylus	Salix	Hedera	Misc Herbs	Ericaceae	Cyperaceae	Gramineae	Sphagnum
180	110	28	0.8	0.0	34.0	0.0	38.0	0.0	67	2.3	0.0	0.0	49.0	29.0	13.0	88.0
	120	20	0.9	0.9	29.0	0.0	48.0	0.0	114	0.9	0.9	0.0	32.0	14.0	10.0	60.0
	130	24	2.0	0.0	22.0	0.0	51.0	2.0	75	1.0	1.0	0.0	13.0	12.0	9.0	56.0
	140	25	0.0	0.0	30.0	0.7	43.0	0.7	52	0.7	0.0	0.0	4.8	3.4	4.0	16.5
	150	29	0.0	0.0	38.0	0.9	30.0	1.9	73	0.0	0.9	0.0	3.7	2.8	5.6	14.0
	160	19	2.4	1.6	37.0	0.8	40.0	0.0	53	0.8	0.0	0.0	4.8	6.5	0.8	56.0
	170	34	0.0	1.8	27.5	0.0	35.0	1.8	67	0.0	0.0	5.0	1.0	6.2	1.0	30.0
	180	15	1.9	0.0	48.0	0.0	35.0	0.0	57	0.0	0.0	7.0	0.0	0.9	3.9	33.0
240	150	21	0.0	0.9	39.0	0.0	39.9	0.0	96	0.0	0.0	0.0	27.0	5.0	5.0	3.3
	160	25	1.4	2.1	26.0	0.0	45.0	1.4	64	0.0	0.0	0.0	24.0	11.0	4.3	3.5
	170	18	0.9	1.8	39.0	0.0	41.0	0.0	82	0.9	0.0	0.0	29.0	2.7	0.9	21.0
	180	19	0.7	0.0	44.0	0.0	37.0	0.0	57	0.0	0.0	0.0	2.8	2.8	3.5	23.0
	190	18	0.0	0.0	41.0	0.0	39.0	1.0	59	0.0	0,0	0.0	4.2	4.2	0.8	17.0
	200	18	1.7	0.8	40.0	0.0	39.0	0.8	86	0.0	0.0	0.0	29.0	5.0	5.0	10.0
	210	15	0.7	0.0	28.0	0.0	56.0	0.0	94	0.0	0.7	0.0	18.0	0.7	4.4	56.0
	220	25	0.0	0.0	28.0	0.0	46.0	0.0	58	0.0	0.9	0.0	9.0	0.0	2.7	50.0
300	160	21	0.0	0.0	29.0	0.9	48.0	0.9	70	0.0	0.0	0.0	35.0	16.0	7.0	11.0
	170	12	0.0	0.0	44.0	0.0	54.0	0.0	51	0.0	0.0	0.0	61.0	16.0	12.5	57.0
	180	21	2.3	3.3	37.0	0.0	38.0	0.0	72	0.0	0.0	0.0	16.0	10.0	5.9	88.0
	190	24	0.0	2.7	48.0	0.0	24.5	0.9	59	0.0	0.0	0.0	3.6	22.0	2.7	56.0
	200	38	1.0	3.0	23.0	0.0	32.0	0.0	93	0.0	0.0	0.0	11.0	7.0	3.0	120.5
	210	23	0.0	0.9	38.0	0.0	37.0	0.9	92	0.0	0.0	0.0	63.0	0.9	0.9	16.3
	220	29	0.0	1.0	29.0	0.0	52.0	0.0	75	0.0	0.0	0.0	18.0	0.0	1.0	53.5
	230	19	0.9	2.7	34.0	0.9	42.0	0.0	66	0.0	0.0	0.0	35.0	8.0	0.0	43.0
400	134	17	0.9	2.2	28.0	0.0	52.0	0.0	53	0.0	0.0	0.0	20.0	7.0	2.2	36.5
	144	10	0.8	0.0	37.0	0.0	51.0	0.8	79	0.0	0.0	0.0	33.0	3.3	0.8	33.0
	154	9	0.0	2.5	33.0	0.0	55.0	0.0	88	0.8	0.0	0.0	26.0	1.6	0.0	100.0
	164	14	0.0	0.0	33.0	0.0	53.0	0.0	102	0.0	0.0	0.0	48.0	0.7	2.0	38.0
	174	18	0.0	0.9	34.0	0.0	47.0	0.0	87	0.0	0.0	0.0	23.0	2.9	2.9	36.0
	184	15	0.8	1.6	31.0	0.0	51.0	0.0	50	0.0	0.0	0.0	17.0	1.6	1.6	29.0
	194	15	0.0	2.0	33.0	0.0	51.0	0.0	88	0.0	0.0	0.0	21.0	0.0	1.0	8.0
	204	20	0.0	3.0	25.0	0.0	53.0	0.0	58	0.0	0.0	0.0	19.0	1.0	2.0	33.0
470	110	25	0.7	2.0	27.0	0.0	39.0	1.4	65	2.0	0.0	2.0	70.0	49.0	15.0	60.0
	120	21	0.0	0.0	32,4	1.9	41.5	0.0	80	0.9	0.9	0.0	94.0	8.3	9.3	40.0
	130	24	1.0	1.0	38.0	0.0	35.0	1.0	65	1.0	0.0	0.0	46.0	50.0	14.0	42.0
	140	16	0.9	1.8	39.0	0.0	38.0	3.6	76	0,0	0,0	0,0	26.0	14.0	4.5	45.0
	150	17	0.0	0.8	33.0	0.0	49.0	0.0	108	1.0	0.0	0.0	39.0	14.0	5.6	16.0
	160	25	0.0	2.0	34.0	0.0	39.0	0.0	81	1.0	0.0	0.0	67.0	30.0	10.0	39.0
	170	11	0.0	2.1	25.0	0.0	60.0	1.1	71	0.0	0.0	0.0	69.0	4.1	2.1	15.0
	180	31	0.0	4.5	45.0	0.0	41.0	0.0	102	0.0	0.0	0.0	23.0	0.9	0.9	21.0
750	200	25	0.8	0.8	36.0	0.8	35,0	1.5	73	0.0	0.0	0.0	19.0	0.0	1.5	22.0
	220	23	0.9	1.8	28.0	0.0	45.0	0.0	70	1.0	0.0	0.0	29.0	0.9	7.3	55.0
	240	36	0.0	0.0	26.0	0.0	36.5	2.1	88	0.0	0.0	0.0	41.0	0.0	2.1	0.0
	260	32	1.0	0.0	25.0	0.0	42.0	0.0	112	0.0	0.0	0.0	42.0	9.7	3.9	0.0

TABLE.2.

FOREST POLLEN PERCENTAGES. Derived from F = Forest, L = Local grain Nos.

DISTANCE FROM BOG EDGE METRES.	− Sphagnum						+ Sphagnum						Level
	+ Corylus			− Corylus			+ Corylus			− Corylus			cm
	F	L	%	F	L	%	F	L	%	F	L	%	
	133	5	98.0	111	5	95.7	133	5	97.0	115	5	96.6	95
0	111	9	92.0	90	9	90.9	111	9	92.0	90	9	90.9	105
	212	6	97.0	168	6	96,6	212	7	96.8	168	7	96.0	115
	131	2	98.5	115	2	93.3	131	4	97.0	115	4	96.6	125
	Mean = 96.3			Mean = 95.4			Mean = 96.0			Mean = 94.8			
	SD=2.9 SE=1.4			SD= 3.2 SE=1.6			SD= 2.7 SE=1.4			SD= 2.6 SE=1.3			
	244	25	90.7	207	25	89.2	244	35	87.5	207	25	85.5	80
	251	16	94.0	205	16	92.8	251	19	93.0	205	19	91.5	90
	281	17	94.3	191	17	91.8	281	25	91.8	191	25	88.4	100
20	235	6	97.5	166	6	95.4	235	6	97.5	166	6	95.4	110
	281	12	95.9	217	12	94.8	281	19	93.7	217	19	91.9	120
	259	24	91.5	185	24	38.6	259	65	80.0	185	65	74.0	130
	324	13	95.5	245	13	94.9	324	13	95.5	245	13	94.9	142
	297	29	92.2	235	29	89.0	297	33	90.0	235	33	87.7	154
	Mean = 93.8			Mean = 92.1			Mean = 91.0			Mean = 88.7			
	SD=2.3 SE= 0.8			SD= 2.9 SE=1.0			SD= 5.4 SE=1.9			SD= 6.9 SE=2.4			
	104	14	88.0	79	14	84.9	104	16	86.7	79	16	83.2	85
	180	11	94.0	148	11	93.1	180	52	77.6	148	52	74.0	95
	166	12	93.0	128	12	91.4	166	25	87.0	128	25	83.7	105
30	159	20	89.9	106	20	84.3	169	38	81.6	106	38	73.6	115
	176	62	76.0	102	62	62.2	176	84	67.7	102	84	54.8	125
	168	90	65.0	94	90	51.1	168	91	64.9	94	91	50.8	135
	151	5	97.0	108	5	95.6	151	9	94.4	108	9	92.3	145
	Mean = 86.1			Mean = 80.4			Mean = 80.0			Mean = 73.2			
	SD=11.5 SE= 4.4			SD=17.0 SE=6.4			SD=10.7 SE=4.1			SD=15.4 SE=5.4			
	262	80	76.6	162	80	66.9	262	127	67.4	162	127	56.0	120
	283	96	74.7	155	96	61.8	283	110	72.0	155	110	58.5	130
	139	79	63.8	90	79	53.3	139	85	62.1	90	85	51.4	140
40	260	46	85.0	153	46	79.9	260	69	79.0	153	69	68.9	150
	288	70	80.4	191	70	73.2	288	185	60.9	191	185	50.8	160
	297	23	92.8	220	23	90.5	297	82	78.4	220	82	72.8	170
	259	18	93.5	184	18	91.1	259	62	80.7	184	62	74.8	180
	324	32	91.0	227	32	87.7	324	54	85.7	227	54	80.8	190
	Mean = 82.2			Mean = 75.2			Mean = 73.3			Mean = 64.3			
	SD=10.4 SE=3.7			SD=14.0 SE=5.0			SD= 9.1 SE=3.2			SD=11.5 SE=4.1			
	219	21	91.3	111	21	84.1	219	55	79.9	111	55	66.9	144
	163	28	85.3	82	28	74.5	163	113	59.1	82	113	42.1	154
	168	28	85.7	85	28	75.2	168	113	59.8	85	113	42.1	164
61	207	134	77.5	168	134	55,6	207	205	50.2	168	205	45.0	174
	255	137	65.1	152	137	52,6	155	226	53.0	152	226	40.2	184
	384	69	84.8	189	69	73.3	384	142	73.0	189	142	57,1	194
	286	71	80.1	156	71	68.7	286	116	71.1	156	116	57.4	204
	308	49	86.3	151	49	75.5	308	83	78.8	151	83	64.5	214
	Mean = 82.0			Mean = 69.9			Mean = 65.6			Mean = 51.9			
	SD= 8.0 SE= 2.8			SD=10.7 SE=3.8			SD=11.7 SE=4.1			SD=10.8 SE=3.8			
	233	67	77.6	157	67	70.1	233	319	42.2	157	319	33.0	145
	296	77	79.4	204	77	72.6	296	218	57.6	204	218	48.3	155
	282	91	75.6	153	91	62.7	282	269	51.2	153	269	36.0	165
80	309	97	76.1	150	97	60.7	309	137	69.3	150	137	52.3	175
	293	117	71.5	160	117	57.8	293	164	52,3	160	164	49.4	185
	347	116	74.9	174	116	60.0	347	299	53.7	174	299	36.8	195
	295	102	74.3	161	102	61.2	295	213	58.1	161	213	43.0	205
	385	45	89.5	207	45	82.1	385	73	84.1	207	73	73.9	215
	Mean = 77.4			Mean = 65.9			Mean = 58.6			Mean = 46.6			
	SD= 5.4 SE= 1.9			SD= 8.3 SE=2.9			SD=12.8 SE=4.5			SD=13.1 SE=4.6			

TABLE. 2.(cont/d).

FOREST POLLEN PERCENTAGES. Derived from F = Forest, L = Local grain Nos.

DISTANCE FROM BOG EDGE METRES.	− Sphagnum						+ Sphagnum						
	+ Corylus			− Corylus			+ Corylus			− Corylus			Level cm
	F	L	%	F	L	%	F	L	%	F	L	%	
	275	107	72.0	150	107	58.4	275	228	54.7	150	228	39.7	147
	274	79	77.6	150	79	65.6	274	165	62.4	150	165	47.6	157
	209	97	68.3	115	97	54.3	209	128	62.0	115	128	47.3	167
120	277	126	68.7	152	126	54.7	277	199	58.2	152	199	43.3	177
	301	106	73.9	142	106	57.3	301	116	70.5	142	116	55.0	187
	200	54	79.0	100	54	64.9	200	60	76.9	100	60	62.5	197
	298	99	75.1	150	99	60.2	298	149	66.6	150	149	50.2	207
	300	67	81.7	150	67	69.1	300	139	68.3	150	139	51.9	217
	Mean = 74.5			Mean = 60.6			Mean = 65.0			Mean = 49.7			
	SD= 4.8 SE= 1.7			SD= 5.4 SE=1.9			SD= 7.1 SE=2.5			SD= 7.1 SE=2.5			
	231	38	86.0	118	38	75.6	231	42	84.6	118	42	73.8	150
	228	50	72.0	139	50	73.5	228	55	80.6	139	55	71,6	160
	200	35	85.0	110	35	75.9	200	58	77.5	110	58	65.5	170
240	223	8	97.0	142	8	94.7	223	39	85.1	142	39	78.5	180
	190	10	95.0	169	10	94.4	190	31	86.0	169	31	84.5	190
	221	40	84.0	119	40	74.8	221	52	81.0	119	52	69.6	200
	266	25	91.0	137	25	84.6	266	103	72.1	137	103	57.1	210
	173	10	95.0	109	10	91.6	173	65	72.7	109	65	62.6	220
	Mean = 88.1			Mean = 83.1			Mean = 80.0			Mean = 70.4			
	SD= 8.2 SE= 2.9			SD= 9.3 SE=3.3			SD= 5.4 SE=1.9			SD= 8.8 SE=3.1			
	216	102	67.5	130	102	56.0	216	211	50.6	130	211	38.1	110
	234	50	83.5	109	50	68.6	234	115	67.0	109	115	48.7	120
	177	25	88.0	102	25	80.3	177	81	68.6	102	81	55.7	130
180	222	12	94.0	146	12	92.4	222	35	86.4	146	35	80.7	140
	185	7	97.0	107	7	93.9	185	22	89.4	107	22	82.9	150
	181	14	93.0	115	14	89.2	181	87	67.5	115	87	56.9	160
	189	8	95.9	113	8	93.4	189	42	81.8	113	42	72.9	170
	163	1	99.4	104	1	99.0	163	35	82.3	104	35	75.4	180
	Mean = 89.8			Mean = 84.1			Mean = 74.2			Mean = 63.9			
	SD=10.3 SE= 3.7			SD=14.9 SE=5.3			SD=13.0 SE=4.6			SD=16.3 SE=5.8			
	201	60	77.0	118	60	66.3	201	73	73.4	118	73	61.8	160
	179	96	65.0	122	96	55.9	179	166	51.9	122	166	42.4	170
	205	31	86.0	119	31	79.3	205	136	60.1	119	136	46.7	180
300	175	27	87.0	110	27	80.3	175	89	66.3	110	89	55.3	190
	195	18	92.0	102	18	85.0	195	141	58.0	102′	141	42.0	200
	211	70	75.0	110	70	61.1	211	88	70.6	110	88	55.6	210
	176	18	91.0	101	18	84.9	176	72	71.0	101	72	58.4	220
	184	48	79.0	111	48	69.8	184	96	65.7	111	96	53.6	230
	Mean = 81.5			Mean = 72.8			Mean = 64.6			Mean = 52.0			
	SD= 9.2 SE= 3.3			SD=11.1 SE=3.9			SD= 7.4 SE=2.6			SD= 7.4 SE=2.6			
	178	30	85.0	115	30	79.3	178	72	71.2	115	72	61.5	134
	217	44	83.0	121	44	73.3	217	84	72.1	121	84	59.0	144
	225	34	84.0	122	34	78.2	225	155	59.2	122	155	44.0	154
400	293	71	80.0	146	71	67.3	293	127	69.8	146	127	53.5	164
	196	27	87.0	105	27	79.6	196	65	75.1	105	65	61.8	174
	181	23	89.0	220	23	90.5	181	45	79.4	220	47	82.4	184
	189	21	85.0	101	21	82.8	189	29	86.7	101	29	77.7	194
	158	19	89.0	100	19	84.0	158	52	75.2	100	52	65.8	204
	Mean = 85.3			Mean = 79.4			Mean = 73.6			Mean = 63.2			
	SD= 3.1 SE= 1.1			SD= 7.0 SE=2.5			SD= 7.9 SE=2.6			SD=12.4 SE=4.4			

TABLE.2.(cont/d).

FOREST POLLEN PERCENTAGES.Derived from F = Forest, L = Local grain Nos.

DISTANCE FROM BOG EDGE METRES.	- Sphagnum						+ Sphagnum						Level
	+ Corylus			- Corylus			+ Corylus			- Corylus			cm
	F	L	%	F	L	%	F	L	%	F	L	%	
	221	165	57.0	131	165	44.2	221	249	47.0	131	249	34.5	110
	192	110	62.8	106	110	49.1	192	152	55.8	106	152	41.1	120
	167	96	63.0	102	96	51.5	167	138	54.8	102	138	42.5	130
	197	45	80.0	112	45	71.3	197	95	67.5	112	95	54.1	140
470	221	56	79.8	107	56	65.6	221	73	75.2	107	73	59.4	150
	181	97	65.0	100	97	50.8	181	136	57.1	100	136	42,4	160
	166	71	70.0	97	71	57.7	166	86	65.9	97	86	53.0	170
	221	25	85.0	109	25	81.3	221	48	82.2	109	48	69.4	180
	Mean = 70.3 SD=10.1 SE= 3.6			Mean = 58.9 SD=12.7 SE=4.5			Mean = 63.2 SD=11.7 SE=4.1			Mean = 49.6 SD=11.5 SE=4.1			
	224	25	90.0	130	25	83.9	224	53	80.9	130	53	71.0	200
	187	33	85.0	110	33	76.9	187	93	66.8	110	93	54.2	220
750	176	38	82.0	90	38	70.3	176	38	82.2	90	38	70.3	240
	219	53	80.5	103	53	66.0	219	53	80.5	103	53	66.0	260
	Mean = 84.4 SD= 4.2 SE= 2.1			Mean = 74.3 SD= 7.8 SE=3.9			mean = 77.6 SD=7.2 SE=3.6			Mean = 65.4 SD= 7.8 SE=3.9			

TABLE.3.

FORESS POLLEN PERCENTAGES. 'Means' of All 8,Top 4, Base 4 replicates.

DISTANCE FROM BOG EDGE METRES	- Sphagnum						+ Sphagnum					
	+ Corylus			- Corylus			+ Corylus			- Corylus		
	All 8	Top 4	Base 4	All 8	Top 4	Base 4	All 8	Top 4	Base 4	All 8	Top 4	Base 4
0	96.3	95.0	97.8	95.4	93.3	97.5	95.4	95.0	96.9	94.8	93.3	96.3
20	93.9	94.1	93.9	92.1	92.3	91.8	91.0	92.5	89.6	88.7	90.2	87.1
30	86.1	91.2	79.3	80.4	88.4	69.6	80.0	83.2	77.3	73.2	78.6	66.0
40	82.2	75.0	89.4	75.2	45.5	85.6	73.3	70.1	78.4	64.3	58.7	69.8
61	82.0	85.0	79.1	69.9	72.4	67.6	65.6	62.3	69.0	51.9	49.0	54.8
80	77.4	78.1	77.6	65.9	68.5	65.3	58.6	55.1	62.1	46.6	42,4	50.8
120	74.5	71.9	77.4	60.6	58.3	62.9	65.0	59.3	70.6	49.7	44.5	54.9
180	89.8	83.3	96.3	84.1	74.3	93.9	74.2	68.2	80.3	63.9	55.8	72.0
240	88.1	85.0	91.3	83.1	79.9	86.4	80.0	82.0	78.0	70.4	72.4	68.5
300	81.5	78.8	84.3	72.8	70.5	75.2	64.6	62.9	66.3	52.0	51.6	52.4
400	85.3	83.0	87.5	79.4	74.5	81.7	73.6	68.1	79.1	63.2	54.5	71.9
470	70.3	57.0	75.0	58.9	54.0	62.3	63.2	56.3	70.1	49.6	43.1	56.1
750	84.4	87.5	81.3	74.3	80.4	68.2	77.6	73.9	81.4	65.4	62.6	68.2

TABLE.4.

't' TEST ON DIFFERENCE BETWEEN THE MEANS OF FOREST POLLEN PERCENTAGES.

m	- Sphagnum						+ Sphagnum					
	+ Corylus			-Corylus			+ Corylus			- Corylus		
		t	p		t	p		t	p		t	p
0	96.3			95.4			95.4			94.8		
		9.30	0.001		5.6	0.001		7.9	0.001		7.3	0.001
20	93.9			92.1			91.0			88.7		
		10.5	0.001		12.5	0.001		10.7	0.001		11.3	0.001
30	86.1			80.4			80.0			73.2		
		2.5	0.05		2.5	0.05		3.8	0.01		2.9	0.02
40	82.2			75.2			73.3			64.3		
		0.2	0.1		3.2	0.01		5.6	0.05		5.1	0.001
61	82.0			69.9			65.6			51.9		
		5.2	0.001		2.5	0.05		4.3	0.002		3.3	0.01
80	77.4			65.9			58.6			46.6		
		4.3	0.001		6.0	0.001		3.9	0.002		1.9	0.1
120	74.5			60.6			65.0			49.7		

TABLE.5.

MEANS OF INDIVIDUAL TREE/SHRUB SPECIES AS % TOTAL TREE POLLEN.

DISTANCE FROM BOG EDGE IN METRES.		Betula.	Quercus	Alnus	Corylus
0	$\bar{x}$	63.0	11.4	25.8	21.5
	S.D	18.1	7.7	16.4	4.8
	S.E	6.4	2.7	5.8	1.7
20	$\bar{x}$	42.7	19.6	35.9	35.0
	S.D	15.7	6.4	13.1	12.0
	S.E	5.5	2.3	4.6	4.2
30	$\bar{x}$	50.6	20.2	27.2	48.6
	S.D	17.6	9.2	9.9	22.4
	S.E	6.2	3.3	3.5	7.9
40	$\bar{x}$	35.4	27.3	34.2	60.7
	S.D	8.3	6.9	8.8	12.4
	S.E	2.9	2.4	3.1	4.4
61	$\bar{x}$	22.1	29.6	48.6	84.3
	S.D	6.0	2.0	4.4	27.1
	S.E	2.1	0.7	1.6	9.6
80	$\bar{x}$	25.5	36.2	34.5	80.1
	S.D	8.0	4.5	5.7	22.0
	S.E	2.8	1.6	2.0	7.8
120	$\bar{x}$	22.7	36.4	37.0	92.2
	S.D	12.1	8.3	6.4	10.2
	S.E	4.3	2.9	2.3	3.6
180	$\bar{x}$	24.3	33.2	40.0	69.8
	S.D	6.1	7.9	7.0	19.9
	S.E	2.2	2.8	2.5	7.0
240	$\bar{x}$	19.9	35.6	42.8	74.5
	S.D	3.6	7.0	6.2	16.7
	S.E	1.3	2.5	2.2	5.9
300	$\bar{x}$	19.7	35.9	40.9	72.3
	S.D	7.7	7.4	10.1	14.6
	S.E	2.7	2.6	3.6	5.2
400	$\bar{x}$	14.8	31.8	51.6	75.6
	S.D	3.8	3.7	2.3	19.4
	S.E	1.3	1.3	0.8	6.8
470	$\bar{x}$	21.3	34.2	42.8	81.0
	S.D.	6.3	6.5	8.0	16.0
	S.E.	2.2	2.3	2.8	5.7
750	$\bar{x}$	29.0	28.6	39.6	85.8
	S.D.	6.1	5.0	4.6	19.2
	S.E	1.5	2.5	2.3	9.6

TRANSECT ON N END OF "BOLTON FELL" BOG FIG 1.

showing– sites of bores and statigraphy.