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RECONSTRUCTION OF HOLOCENE VEGETATION HISTORY IN THREE DIMENSIONS AT WAUN-FIGNEN-FELEN, AN UPLAND SITE IN SOUTH WALES

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[Pullouts 1–8]

CONTENTS

Sixteen sites in and around a small upland bog in South Wales were investigated by means of pollen analysis and radiocarbon dating. Most of the sites have ombrogenous (blanket) peat overlying a thin basal mor with abundant charcoal. A Devensian Late-glacial basin filled with muds and reedswamp deposits is shown to underlie the blanket peat in part of the area. It is concluded that the outlet of the basin was

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probably blocked by the development of ombrogenous peat, perhaps around 6500 years BP (though not closely dated), which spread across the basin and later up its western shore.

The pollen diagrams are divided into a series of pollen assemblage zones. The zone boundaries appear synchronous within the limits of the methods. Hazel played an important role in the woodland vegetation of the pre-peat mineral soils. This woodland had generally been replaced by heath and blanket peat by about 6000 years BP. Nevertheless, some woodland apparently persisted locally in areas where peat or mor accumulation had not yet begun. Alder appears to have been established in the basin area by *ca.* 7000 years BP and to have spread more widely some 500–1000 years later, possibly taking advantage of environmental damage caused by Mesolithic man, evidence of whose occupation is found in the area. It is concluded that Mesolithic man was probably responsible for making a small clearing in the woodland at *ca.* 8000 years BP when the first mor deposit began to accumulate. Heath vegetation first came into existence at about this time and there is circumstantial evidence of maintenance by burning. Heath conditions lasted in some areas until *ca.* 5500 years BP and on the more permeable soils podsolization took place. It is argued that the accumulation of relatively impermeable mor soils under heath was a major factor in the initiation of ombrogenous peat growth. This most generally began in the period *ca.* 5500–5800 years BP though it was both earlier (*ca.* 7600 years BP) and later (*ca.* 4000 years BP) in some areas.

A comparison is made of the behaviour of certain pollen curves at the major sites in which it is found that sites with common features fall into spatially coherent groups. It is concluded, therefore, that the pollen diagrams often reflect vegetational changes taking place in relatively small areas. A reconstruction of the vegetational changes in the 4000 years after *ca.* 8000 years BP is made by means of a series of maps.

The classical elm decline of the Atlantic–Sub-boreal transition (*ca.* 5000–5500 years BP) is variably represented and there follows a series of three other declines or minima dated to *ca.* 4600 years BP, *ca.* 4000 years BP and *ca.* 2850 years BP (though again with some possible variability). The Bronze Age appears to have been a time of major human impacts on the local vegetation with some woodland regeneration taking place in the earlier Iron Age before a renewed period of clearance that persisted through Romano-British times.

1. INTRODUCTION

The site investigated at Waun-Fignen-Felen, Powys, is an area of blanket peat much dissected and partly destroyed by erosion. The erosion has gone on to such an extent that it was relatively easy to examine sections, and to take samples for both pollen analysis and radiocarbon dating. The opportunity was taken to secure samples from a number of sites in differing topographic and stratigraphic contexts. The aim was to discover whether or not local differences exist in the history of the vegetation and, if possible, to reconstruct the vegetational history in three dimensions. The site has the added interest of Mesolithic remains found at the base of the peat.

The site (see figure 1) lies in the Black Mountain range some 50 km north of Swansea (National Grid Reference SS825179) on the limestone escarpment to the north of the South Wales Coalfield. The main bog, which proved to overlie a Late-Devensian lake basin, occupies an area of about 0.25 km^2.

The bog lies in a depression bordered to the north by the dip slope of the Old Red Sandstone of Fan Hir, which rises to *ca.* 800 m Ordnance Datum (O.D.) and drains mainly via the River

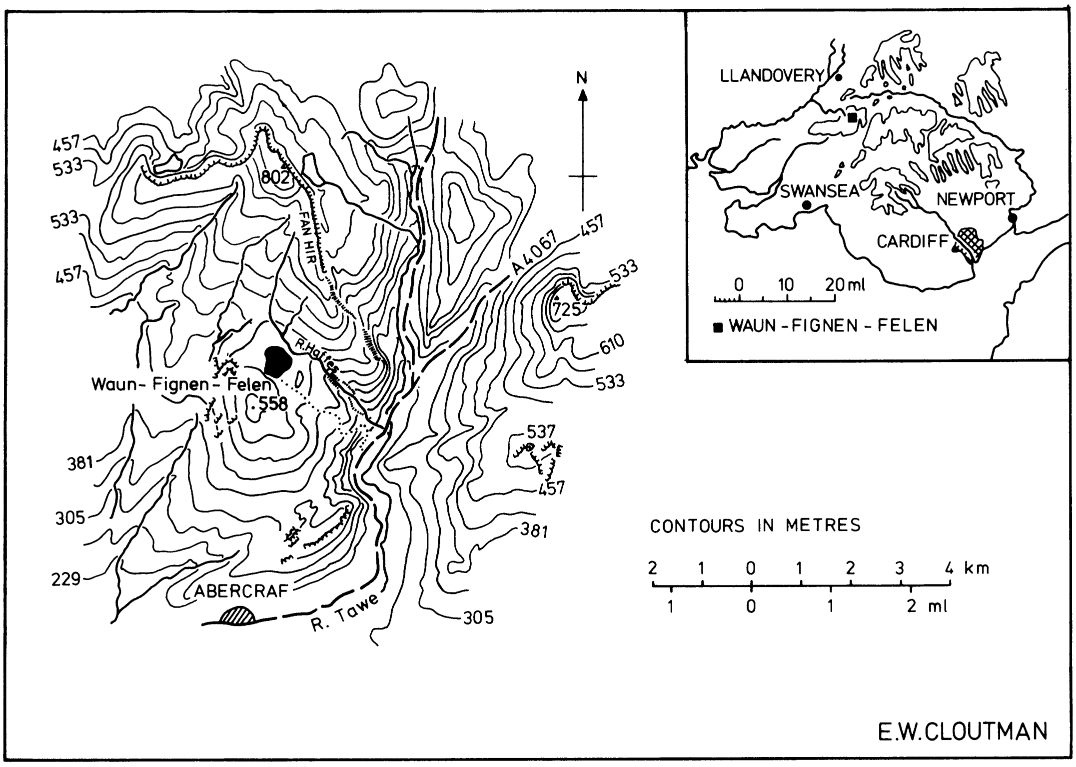

Figure 1. Maps showing the location of the site at Waun-Fignen-Felen in the Black Mountain range of South Wales.

Haffes, whose valley forms the northeastern boundary of the bog. The northwest and southeast sides are bounded by limestone hills reaching altitudes of about 500 m. To the south rises the limestone of Carreg-goch, capped by Millstone Grit, which rises to an altitude of *ca.* 550 m o.d. Beneath the bog itself boulder clay is encountered. The eroded areas reveal a landscape strewn with pebbles of conglomerate, limestone and Old Red Sandstone.

Much of the area around the bog, whether sandstone or limestone, is covered by blanket peat, again often much eroded. The limestone hills are beset with dolines, some dry and acting as drainage holes and others in the process of infilling with peat. The major drainage of the bog is southwards into a gorge (probably a collapsed cave) ending with a sink hole. There are also sink holes receiving drainage to the northwest.

A total of thirteen sites was investigated in the main bog area. With three exceptions these were entirely blanket peats, though often overlying a basal mor. The exceptions were sites from the centre of the bog where a basin was discovered containing reedswamp peats and muds below the blanket peat. The oldest basin deposits investigated were of early Flandrian age. In addition, three blanket peat sites at some distance from the main bog, and at higher altitude, were investigated in outline. The locations of the sites and their code names (their positions on the stratigraphic sections) are shown in figures 2 and 3.

Additional pollen diagrams (see Appendixes 3 and 4) have been lodged with the British Library as a supplement to this paper†.

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† Copies of the material deposited may be purchased from the British Library Documents Supply Centre, Wetherby, West Yorkshire LS23 7BQ, U.K. (reference SUP 10050).

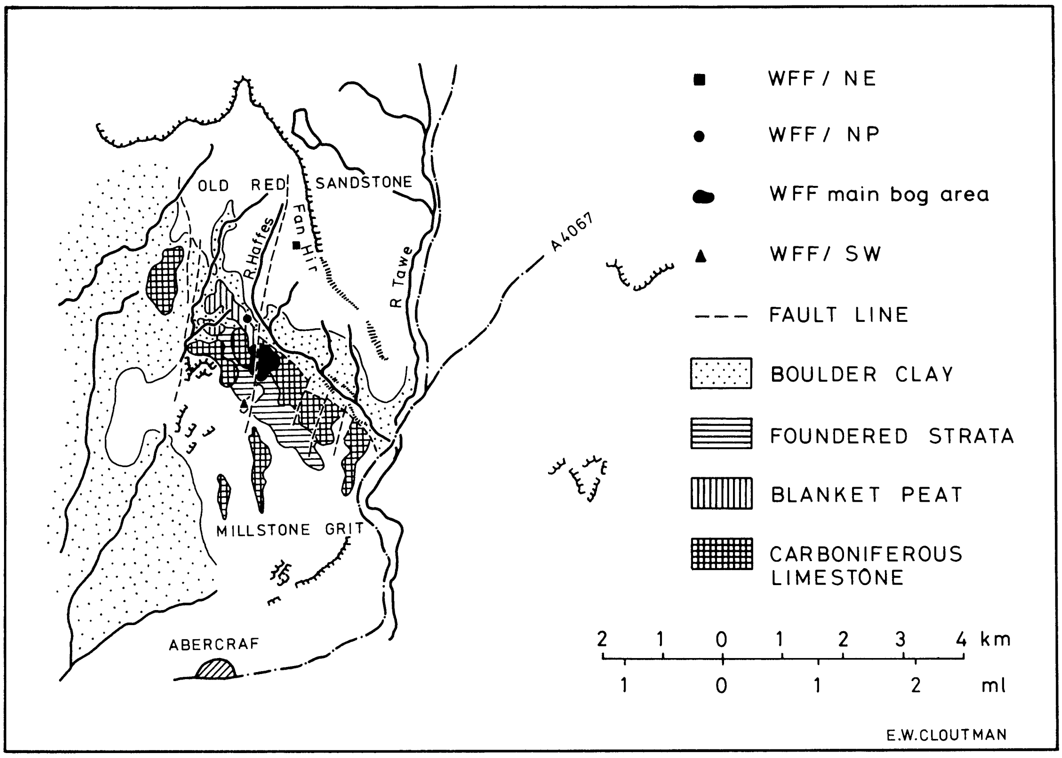


Figure 2. Map of the geological setting of the bog at Waun-Fignen-Felen and the locations of the three sites investigated at some distance from the main bog area, which was investigated intensively.

2. Techniques

Field stratigraphy was recorded from exposed peat faces and by use of Russian and Hiller borers. Samples were taken in aluminium monolith boxes or (for the deepest site, G00) with the large peat sampler described by Smith *et al.* (1968). The monoliths and cores were subsampled in the laboratory for pollen analysis and ^{14}C dating.

Peat was prepared for analysis by using standard techniques and (with a few exceptions) with a total of 500 land-plant pollen grains counted per sample. The pollen diagrams are generally based on this total as the pollen sum. Diagrams employing total tree pollen as the pollen sum are given in the Supplement (see also Appendix 4). Data were accumulated for the production of influx diagrams by using a suspension of *Lycopodium* spores as an exotic marker (see Appendix 3 for details of methods). The influx diagrams are among the first to be produced for upland peats in Britain and their significance is somewhat imponderable. For this reason only one example is given in the text. The remainder have been placed in the Supplement. Brief descriptions are given in Appendix 3.

Certain figures are included in which the pollen curves are drawn on a radiocarbon timescale. The same timescales were used in the preparation of the influx diagrams. Each timescale is derived from a deposition rate curve (see Appendix 2). From inspection of the curves decisions were made as to points at which the deposition rates changed, and regression lines calculated from which the ages of the samples were interpolated. The interpolated dates are subject to an inaccuracy related to the precisions of the radiocarbon age determinations and the method of calculation. The major reservations held about the dating and the individual timescales (which are discussed further in Appendix 2) are as follows.

Sites A16W and A78E: the basal samples appear too young, and have been ignored.

Sites B125N and E1N: in each case the basal sample may be too young.

Site B90S: the timescale is extrapolated into the mineral soil and may thus be unreliable at the base. It does, however, compare well with other sites.

Sites B32S and D7E: the ^{14}C dates are more erratic than at other sites. Redeposition of eroded peat may have taken place at D7E and some caution is required in the use of the timescales.

3. STRATIGRAPHY

The stratigraphy of the main bog area was investigated by means of seven levelled transects along lines shown in figure 3. The lines were set out in an intersecting pattern according to the microtopography so as to give as complete a coverage as possible of the area. Transects A, B and C meet at a point at which Mesolithic artefacts were first discovered. The intersection of transects C and E is at a point where erosion by the main drainage channel provided a high peat face which proved to be at the margin of a deep basin lying in the western half of the main bog area. To the east of this intersection the ground is generally higher, and covered by mor and blanket peats overlying sandy clays and boulder clay.

The basin deposits may be seen in transects A, C, D, E and G (figure 4). The minerogenic deposits underlying the organic deposits of the basin have not been investigated in detail. It is clear, however, that a Devensian Late-glacial sequence is present at A270W where a clay-mud was encountered between two layers of grey-blue clay. At the base of the organic infilling there are coarse detritus muds, which become woody at the western margin, overlain by *Phragmites* reedswamp peats. At the eastern side of the basin there is an initial layer of reedswamp peat separate from the main expanse. This is best seen in transects A (66–108W) and F, the latter of which runs across the natural outfall of the basin. This original drainage was apparently into the gorge, as now.

In two locations (around A66W and C62W) the base of the deposits was levelled at close intervals. The levels confirmed the impression gained in the field that there is a distinct, if low, bank to the basin. Presumably this was cut by wave-lap in the early stages of development. The basal deposit at site E1N, which is at this margin, is an unusual dark-brown sandy detritus mud.

The basin deposits are capped by blanket peat with frequent remains of *Eriophorum* and *Calluna*. In certain places at the eastern side of the basin this acid peat occurs at a relatively low level, below the level of the reedswamp peats. These low points may have been the foci of development of the acid peats. Further discussion is given later (§ 5 *b*). In a few places, where the original surface of the bog is intact, a thin superficial layer (30–40 cm) of pale-brown unhumified *Sphagnum* peat could be observed.

The blanket peats themselves showed little structure or differentiation. In many cases, however, the base of the peat was greasy and amorphous, with such a high charcoal content as to be almost black in colour. This type of peat is distinguished as a mor deposit. It occurred at the following sites: B125N, B90S, EE17E, F117S, B32S and to a lesser extent at E188S and A78E. In transect B the mor layer was particularly strong, overlying a distinct but shallow and variable iron pan podsol (B90–120S). The podsol was developed on a clayey sand overlying the

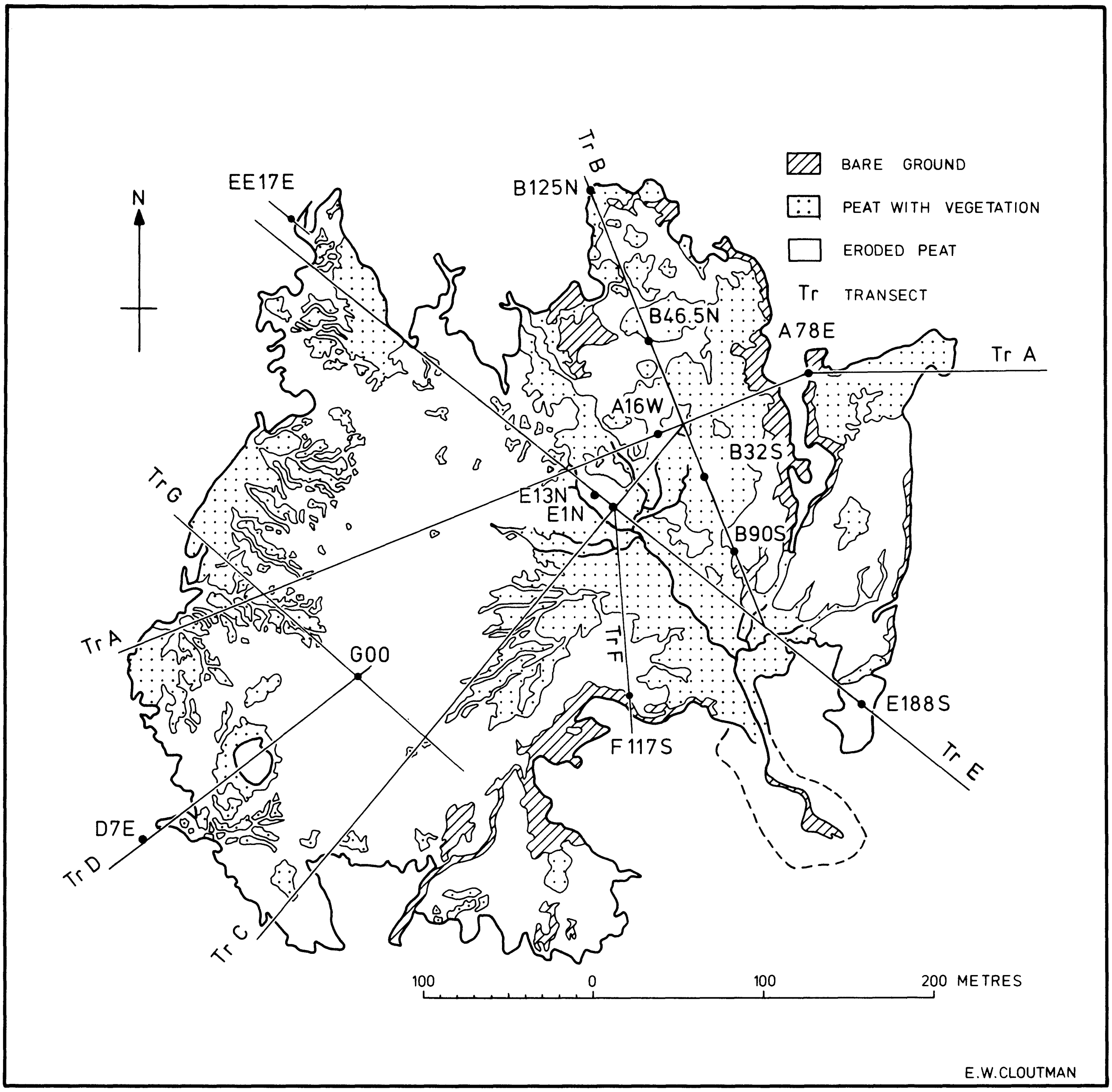


Figure 3. Map showing the surface condition of the main bog area studied at Waun-Fignen-Felen. The transects A–G were investigated by boring and recording from exposed peat faces. The labelled points mark the positions from which pollen diagrams were constructed. Broadly stated, the extensive eroded peat area to the west (now virtually devoid of vegetation), shown white, is a basin with sediments dating back to the Late-Devensian period. The area to the east, shown stippled and shaded, is generally speaking an area previously covered by blanket peat. The main drainage of the bog is to the south into a vast swallow hole, the margins of which are shown by a broken line.

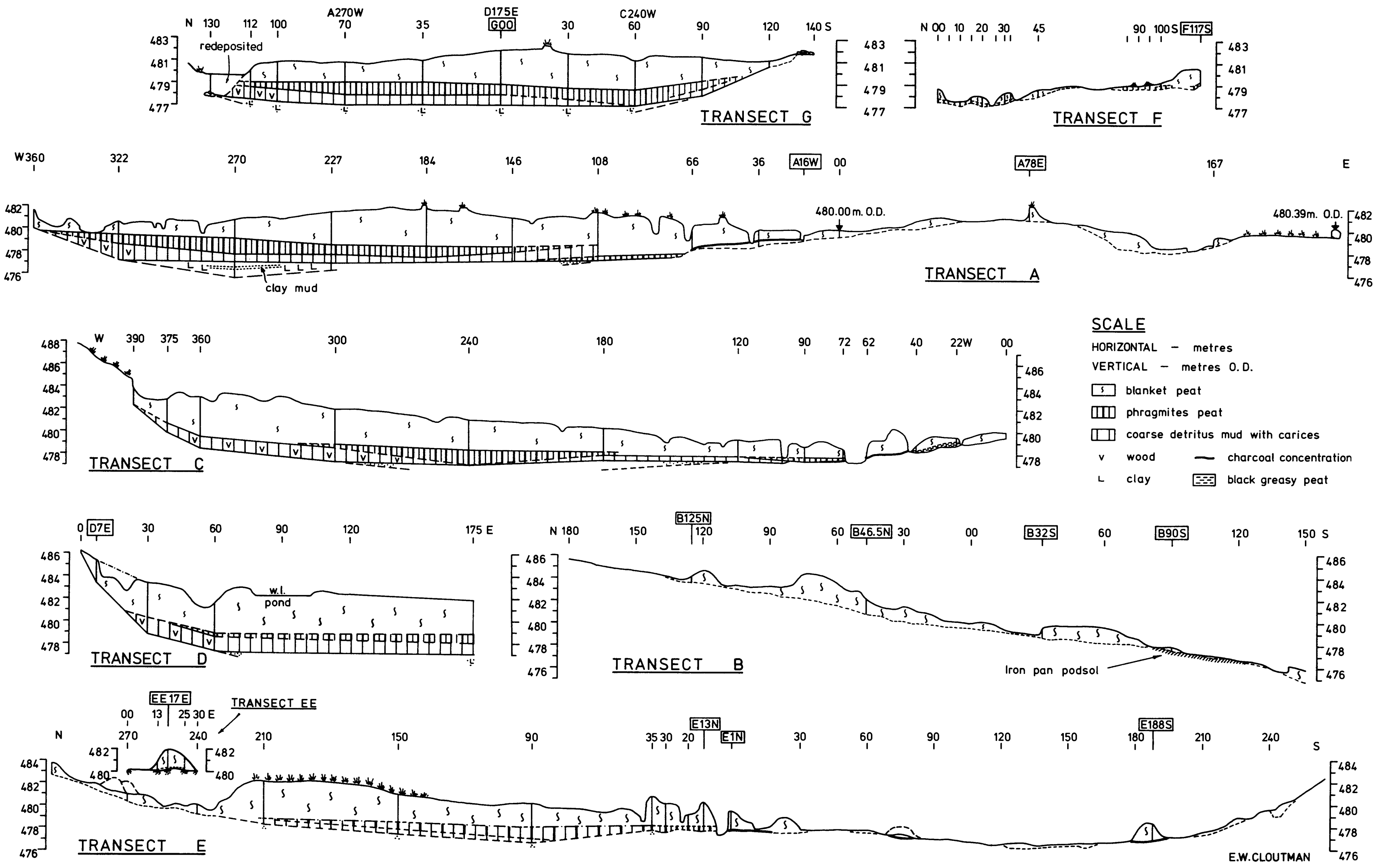


FIGURE 4. Stratigraphic sections from Waun-Fignen-Felen constructed from borings and recording of exposed peat faces. The lines of the transects are given in figure 3. The relation with Ordnance Datum is estimated from a spot height. Points from which pollen diagrams were constructed are indicated by a boxed label composed of the transect letter, distance in metres, and compass direction from the origin of the transect (marked 00).

boulder clay in an area some 100 m in diameter to the east of site B90S (figure 3). The mor layer was generally 10–15 cm thick and thus difficult to represent in the stratigraphic sections (figure 4) although indicated in the stratigraphic column of the pollen diagrams. Charcoal was observed, not only in the mor, but frequently as a concentration in the base of the peat. The concentration was particularly well developed in transect A (20–66 W), transect C (45–62S), and transect E (5N–20S). Records of the stratigraphy of the individual sites used for pollen analysis are given in Appendix 1.

4. The pollen diagrams

(a) *Zonation and dating*

For ease of comparability the pollen diagrams are presented with columns for the full suite of taxa encountered in the study as a whole. It should be noted, therefore, that occasionally a labelled column contains no value.

The pollen diagrams from the main bog area have a number of features in common and are sub-divided into a uniform set of pollen assemblage zones (PAZs) as follows.

6. *Betula–Fraxinus–Narthecium*.
5. *Quercus–Alnus–Plantago*.
4. *Quercus–Alnus*.
3. *Quercus–Ulmus–Alnus*.
2. *Corylus–Calluna–Ulmus–Pinus*.
1. *Betula*–Gramineae–*Salix*.

The PAZ boundaries are based on the following characteristics.

5–6. Rise of *Fraxinus* and *Narthecium* curves; *Ulmus* minimum.
4–5. Rise of *Plantago lanceolata* curve and decline of *Ulmus* curve.
3–4. Decline of *Ulmus* curve.
2–3. Rise of *Alnus* curve.
1–2. Rise of *Corylus* and fall of *Betula* curves.

In addition to the major pollen assemblage zones the pollen diagrams exhibit individual features. These features appear to reflect local episodes of vegetation history and are accommodated by subdivision of the major zones.

A comparison of the dates for the zone boundaries, interpolated from the deposition rate curves (see Appendix 2), is given in table 1. The most consistent of the boundaries is zone 4–5, at *ca*. 3800–3900 years BP. The other boundaries appear somewhat less consistent. In addition to the inaccuracies attendant on interpolation, an uncertainty arises from the fact that the zone boundaries cannot be drawn with precision. It should be noted that the time interval between any two samples either side of a zone boundary may be as much as 200 years. In the light of these considerations, the dates of the zone boundaries as a whole do not strongly oppose the idea that they are synchronous across the site. There are, however, two large discrepancies. In these two cases we must consider whether or not the real time differences exist between similar vegetational developments at different sites.

(i) *The rise of Corylus and decline of Betula (zone 1–2)*

The pollen zone boundary 1–2 is found only at two sites, G00 in the centre of the basin and B125N on the ridge to the northeast. The dates of the zone boundary at the two sites are

TABLE 1. INTERPOLATED ^{14}C DATES (BP) FOR POLLEN ASSEMBLAGE ZONE BOUNDARIES

(For deposition rate curves see Appendix 2 and figures A1–A3.)

	pollen assemblage zone boundaries				
sites	1–2	2–3	3–4	4–5	5–6
G00	9300	7500	5100	—	—
B125N	8000	6600	5350	—	—
B90S	—	?7300	5200	—	—
EE17E	—	7300	4950	3800	—
F117S	—	6200	5200	3900	—
E1N	—	6500	4900	—	—
B32S	—	6200	4850	—	—
A16W	—	—	?5200	—	—
E13N	—	—	5500	4050	2950
E188S	—	—	—	3750	2650
A78E	—	—	—	3800	2800
B46.5N	—	—	5350	3950	2800
D7E	—	—	—	3850	3150

ca. 9300 years BP and *ca.* 8000 years BP respectively. From the deposition rate curve for B125N (Appendix 2, figure A1) it appears possible that the basal date, CAR-509, may be slightly too young. However, any such discrepancy is unlikely to approach 1300 years. The trend of the curve suggests a century or two at the most. There is reason to believe, therefore, that a real time difference exists between the zone boundary at the two sites.

(ii) *The rise of the Alnus curve* (*zone* 2–3)

The dates for the zone 2–3 boundary range from *ca.* 7500 to *ca.* 6200 years BP. (Note, however, that the date at B90S may be unreliable because the boundary lies within the mineral soil which could not be used for ^{14}C dating, although the projected date does agree broadly with those from EE17E and G00.) The expansion of alder is thus apparently early, before 7000 years BP, at two of the sites. One is the basin-centre site G00, and the other (EE17E) is close to the margin of the basin. It would be logical to suppose that alder would first have gained a foothold in the basin area, but the question is whether the pollen dispersal could have been so local that it did not reach nearby sites. There is evidence from modern samples that the dispersal of alder pollen may, indeed, be quite local. Goddard (1971) shows, for instance, a fall from 28% (of total pollen) to 3% over a distance of 15 m at a transition from alderwood to birchwood. Within the (mixed) alderwood values of 45% and 51% were obtained, but in a very small clearing, *ca.* 10 m × 15 m, the *Alnus* value was merely 13%. In view of this evidence we take the view that alder was in fact established in the basin area earlier than on the surrounding higher, drier ground, and that the age differences in the rise of the *Alnus* curves are real.

The zone boundaries 3–4, 4–5 and 5–6 all have a decline or minimum of the *Ulmus* curve. These declines are sometimes more clearly seen in the diagrams based on tree pollen only (Supplement figures S13–S25). The first decline is dated to *ca.* 4950–5500 years BP on the basis of the interpolated dates and is undoubtedly the classical 'elm decline' between the Atlantic and Sub-boreal periods (pollen zones VIIa and VIIb) of Godwin (1940). The frequency of indicators of agricultural activity such as *Plantago lanceolata* is rather low, however, and the impact of Neolithic farming appears to be slight. The zone 3–4 boundary is rather obscure at E188S and A78E. Further consideration of the elm curves is given in the Discussion (§5*d*).

In the brief accounts of the individual sites that follow, emphasis is placed on special features or departures from the norm, and their interpretation in terms of vegetational history. Additional detail relating to some of the sites may be found in Cloutman (1983).

(*b*) *Sites in the main basin and blanket peat area*

Abbreviations used: AP, arboreal pollen; AP+S, total tree plus shrub pollen; NAP, non-arboreal pollen.

Site G00 (*figure* 5, *pullout* 1)

Between depths of 300 and 450 cm, where reedswamp conditions prevailed, the quantity and preservation of the pollen was poor. It was not always possible to count 500 grains. Where less than this the actual numbers counted are given in the diagram. It must be noted that the spectrum at 448 cm is particularly unreliable.

The high *Betula* values of zone 1 (amounting to *ca*. 90 % on a tree-pollen basis) may be taken as representing early Flandrian birchwoods. From the high *Empetrum* and other NAP values it appears unlikely that these were closed forests. There are, however, relatively few taxa representative of typical Late-Devensian plants of open habitats and broken ground. The occurrence of *Myriophyllum* pollen indicates at least some open water, and *Filipendula* suggests marsh or fen conditions.

Successive peaks of *Sphagnum*, Cyperaceae and Filicales in the lower part of the diagram are undoubtedly connected with the reedswamp conditions. Zone 2 contains the only record in this study of the vegetational history of the classical Boreal period (Godwin 1940) and the poor pollen preservation is thus doubly unfortunate. Nevertheless the usual rise of the *Corylus* curve can be distinguished before the appearance of pollen of the thermophilous forest trees. The occurrence of Chenopodiaceae pollen at the transition between zones 2 and 3 is likely to reflect the presence of broken ground and may be connected with the activities of the Mesolithic population of the area.

Site B125N (*figure* 6, *pullout* 2)

The two basal samples have a total NAP value of over 60 %; this signifies a relatively open habitat. Much of the NAP is accounted for by grasses, but other open-habitat plants are represented. The high *Empetrum* value at the base invites comparison with the early Flandrian at site G00. The pollen of *Artemisia*, *Thalictrum* and *Epilobium* might also be taken as indicating a vegetation cover containing relicts of the Late-Devensian flora. We have already seen reason to believe, however, that the lowest deposit at B125N does not belong to the earliest Flandrian, but dates from *ca*. 8000 years BP. The question is raised, then, as to whether the site was ever completely afforested in the early Flandrian. As the record is incomplete the answer can only be speculative. We may note that an early Mesolithic working floor was discovered close to this site at the base of the peat. It would be easy to conceive of a small area as having been cleared by man, or perhaps even by grazing pressure. The abundance of Compositae pollen in the basal samples, together with *Filipendula* and *Succisa*, Chenopodiaceae, *Plantago major*/*media* type, *Pteridium* and fern spores (in addition to the possible Late-Devensian relicts) gives the impression of a damp, grassy, somewhat disturbed area such as might have been quite intensively grazed by wild herbivores. In these circumstances it could have been kept open since early Flandrian times. Alternatively a clearing may have been created by prevention of woodland regeneration. It is recognized, however, that an open area in birchwood may have been part of the natural regeneration cycle (cf. McVean 1964*a*). Another possibility is that the local vegetation was akin to the possibly natural high-altitude herb and fern meadows in Scotland today (McVean 1964*b*).

From the rise of the *Corylus* curve in zone 1, which is accompanied by a fall in total NAP and fern spores, it appears that the open area was colonized by hazel. The *Corylus* curve continues to rise in zone 2 after a dramatic decline of the *Betula* curve and a marked rise of *Calluna*.

Zone 2 is subdivided so that zone 2a contains the very high *Corylus* values. This division is most obvious in the diagram based on total arboreal pollen (see Supplement). During zone 2a the *Corylus* influx values reached some 2000 grains $\text{cm}^{-2}\ \text{a}^{-1}$ (see Appendix 3 and Supplement) and hazel was undoubtedly locally dominant. Presumably there would have been a hazel-dominated scrub at, or very close to, the site. The *Calluna* values of over 20 % of total pollen, by comparison with modern spectra (Goddard 1971; Evans & Moore 1985), suggest that heather was actually growing on the mor deposit, and contributing to its formation. It must be noted, however, that *Juncus* seeds were abundant in the mor of zones 1 and 2a, so that rushes were almost certainly a strong contributory factor in the initiation of organic soil accumulation (cf. Mitchell 1972). The mor deposit was black with charcoal and it must be supposed that burning was frequent during its accumulation. The density of the charcoal certainly appears too great for it to have originated from occasional natural fires and we are strongly inclined to connect this apparently frequent burning with Mesolithic man. It is likely that the decline of birch, which can be wiped out by burning (as a recent example on Goole Moors, Humberside, demonstrates) is also probably to be attributed to this cause. Both hazel and heather are resistant to frequent light burning and we take this to be the reason for their abundance in zone 2a.

Blanket peat accumulation began in zone 2b but, from the low Cyperaceae values, cotton grasses must have been relatively unimportant in its initiation. From the relative abundance of their pollen, grasses and heather were probably the most important local constituents of the ground vegetation. The total AP + S in zone 2b amounts to over 75 %. Thus we must envisage nearby woodland. By this stage *Quercus* and *Ulmus* are well represented, presumably having to some extent displaced or overgrown the previously dominant *Corylus*. *Pinus* is now also more substantially represented.

Zone 3 is subdivided at the end of the rise of the *Alnus* curve; after the boundary the *Pteridium* values rise and the total AP + S curve begins to rise. There is also a change from *Calluna* to Gramineae dominance among the NAP. There were thus clearly changes in the ground flora but some regional effects cannot be ruled out.

Site B90S (*figure* 7, *pullout* 2)

A proportion of the pollen record at this site is contained in the mineral soil forming the leached horizon of an iron pan podsol. The pattern of the pollen curves within the mineral soil is comparable with the sequences within mor and peat at other sites. For this reason we consider the record to be a true time-sequence. The date of the beginning of the record is problematic in the absence of radiocarbon dates. For purposes of discussion, the timescale derived from the overlying mor and peat has been extrapolated (Appendix 2, figure A1). The dating so obtained appears reasonable by comparison with other sites but it must be regarded as tentative.

The lowest spectrum in the diagram is totally dominated by *Corylus*, leaving little doubt that the first vegetation recorded at the site was hazel scrub. Thereafter we see a substantial rise of the *Calluna* curve to values of 20% which, as argued above, signifies the presence of heather on the site. The reduction of hazel and its apparent partial replacement by heath could be due to progressive soil acidification as podsolization began to have an effect. Podsolization under the hazel cover appears unlikely, however, because of the mineral recycling that would have been taking place. It is conceivable, then, that hazel was removed by man and that the podsolization took place under heath. Indeed the phase of high *Calluna* values persists throughout the mor layer of zone 3a. Unless there is a lacuna in the sequence, the radiocarbon dates from the base and the top of the mor layer show that it accumulated very slowly, persisting for approximately 1000 years before being replaced by blanket peat. During the deposition of the mor, the AP+S values are 60–70% so that there is no indication of generally open conditions. Nevertheless it appears likely that the mor itself supported *Calluna* heath. From the long persistence of this community and the abundance of charcoal in the deposit it is likely that the heath was maintained by burning. Indeed, charred fragments of *Calluna* were found in the 18 cm sample, and characteristically crinkled pollen, which may be associated with burning (Cloutman 1983), at 16 cm. It would be natural to suppose that the fires were originated, either deliberately or accidentally, by the Mesolithic inhabitants. It is during this period of burning that the *Alnus* curve rises. As discussed by Smith (1984) alder may well have been able to take advantage of forest damage to establish itself in new habitats.

Zone 3 is subdivided by using criteria similar to those employed for B125N. The boundary between sub-zones 3a and 3b again comes close to the transition from mor to ombrogenous peat, but at B90S we have the additional feature of an increase in the *Sphagnum* spore curve which suggests an increase in the soil moisture. In zone 3b the total AP+S rises to over 80% indicating the nearby presence of woodland. The zone 3–4 elm decline is visible only in the diagram based on tree pollen (see Supplement) from which the level of the zone boundary is derived.

Site EE17E (*figure* 8, *pullout* 2)

The AP+S curve in this diagram barely rises above 65%, suggesting that woodland never grew particularly close to the site during the time period represented. The depositional sequence starts with mor, in which the *Corylus* values are relatively low compared with other sites, although this is still the most abundant pollen type. At the beginning of accumulation, at *ca*. 7000 years BP, the *Calluna* values are already high and soon reach 30%. We can thus envisage the initial vegetation of the organic deposits as heath. This persisted for a long time, the curve not declining until *ca*. 5400 years BP. During the life of the heath, deposition changed from mor to peat.

The steep rise of the *Alnus* curve of the zone 2–3 transition occurs between the two basal samples, and *Alnus* already has a value of *ca*. 20% of the total tree pollen (excluding shrubs) in the 68 cm sample. From the ^{14}C date at that level it appears to have been established near the site, which is marginal to the basin, as early as 7000 years BP.

Site F117S (*figure* 9, *pullout* 3)

As with site EE17E above, accumulation began with mor having relatively high *Calluna* values. A similar local vegetational history must therefore be envisaged. The date of the initiation is younger by some 200–300 years, however, and we do not see the rise of the *Alnus* curve until even later (*ca.* 6500 years BP). This may appear surprising, as F117S is also fairly close to the basin. The discrepancy may be taken, however, as further evidence of local distribution of alder pollen. In zone 3 the AP+S curve rises to almost 80%, suggesting that woodland then existed in closer proximity to the site.

Site E1N (*figure* 10, *pullout* 3)

Site E1N, which is at the actual margin of the lake basin, is one of the more interesting – if problematic – sites. Deposition began with a sandy mud which is assigned to zone 3. The four radiocarbon dates from this mud form a conformable sequence, the oldest (from just above the base) being *ca.* 6300 years BP. According to the extrapolated date, deposition began about 6600 years BP (see Appendix 2 where some reservations about the dating are given.)

Fern spores are abundant in the sandy mud and fern sporangia were also found in it, together with *Juncus* seeds. These plants must have been growing quite locally. Surprisingly, pollen of aquatic and littoral plants is lacking. The relative abundance of *Filipendula* and *Valeriana* is a possible indication of marshy conditions but the abundance of *Sphagnum* spores suggests that conditions were becoming less basic. The depositional environment of the mud is thus likely to have been relatively unvegetated open water, perhaps with aquatic *Sphagna*. The sand content suggests that some erosion was taking place on the shoreline, or possibly more generally with sand reaching the basin in the marginal input streams. Erosion, or soil disturbance, could have been due to natural causes but might equally be related to activities of the Mesolithic population. The start of accumulation of an aquatic deposit at this point indicates a hydrological change: either a rise in water level, or a reduction in seasonal fluctuations. It is notable that the *Alnus* curve rises soon after the commencement of deposition at around 6300–6400 years BP. Indeed, the basal sample could be regarded as belonging to zone 2. If, as we have argued, dispersal of *Alnus* pollen may be quite local, we may be seeing here the establishment of alder closer to the site and exploiting a newly created habitat.

Corylus is the dominant pollen type throughout the deposition of the sandy mud, amounting to between 40% and 60% of the total. Of the 100 modern pollen spectra analysed by Goddard (1971), we find that values for *Corylus* above 30% occur only within hazel-dominated woodland. We can hardly doubt, then, that the site was very close to hazel-dominated scrub or woodland. Such a community presumably clothed the slopes around the shore of the basin.

From the behaviour of the pollen curves, there was a distinct environmental change at the beginning of zone 4, at *ca.* 4900 years BP. This is also demonstrated by the lithological change to a more organic mud containing occasional *Phragmites* rhizomes, and leaves and wood of *Betula* and *Salix*. Further, at this point, the total pollen influx rises (Supplement, figure S6). This might have been expected with the development of a carr on the deposit, but the increase in pollen influx is universal and not restricted to carr species. It seems more likely, therefore, that the increase is due to an improvement in conditions of pollen preservation or entrapment.

It is notable that the species diversity increases markedly at the zone 3–4 boundary. No doubt this is a reflection of the establishment of fen and carr conditions at the site and possibly also of disturbances further afield caused by Neolithic farming activities. A fine sand layer at the opening of zone 4 may indeed be related to soil disturbance in the vicinity of the site.

Zone 4 is subdivided into subzones 4a and 4b at 29 cm (*ca.* 4600 years BP) where there is an elm decline. Thereafter, there is an increase of possible agricultural indicators including *Plantago*, *Pteridium*, *Rumex* and *Urtica*, and a decrease of *Filipendula* and other taxa possibly connected with local fen conditions. The very high grass-pollen values in the early part of zone 4 may reflect a *Molinia* phase as the peat at that level was extremely fibrous. There is a marked decline of elm at *ca.* 4600 years BP. Such a decline can be seen at a number of other sites and is discussed later (p. 203).

At 10 cm, where zone 4b has been subdivided, the *Calluna* curve rises to over 30%; the Gramineae curve declines and other herbaceous taxa become virtually unrepresented. By *ca.* 4200 years BP, then, the bog surface in the vicinity would have been dominated by *Calluna*; other heath taxa – *Empetrum* and *Vaccinium* – are also represented.

Site B32S (*figures* 11 *and* 12, *pullouts* 3 *and* 4)

Zone 2 has *Corylus* values around 60% and total AP+S values around 70%. For the reasons advanced above these features must betoken the nearby presence of hazel-dominated scrub or woodland. *Calluna* values are around 20% and the ground flora was probably dominated by this plant. From the slope of the graph in Appendix 2, figure A2, the high *Calluna* values persist for about 500 years during zone 2 and continue for another 200–300 years after the basal mor has given way to ombrogenous peat in zone 3.

Zone 3 is subdivided at 39 cm where there is an *Alnus* maximum and *Corylus* decline. At the zone 2–3 boundary there is an initial decline of the *Corylus* and *Quercus* curves, and subsequent increase of *Calluna*. Hazel and oak appear to have been replaced by heather. From the deposition rate curve (Appendix 2, figure A2) the duration of the tree-pollen decline is no more than *ca.* 55 years. There are no taxa indicative of forest clearance at this level but the deposit is full of charcoal and it seems likely that the changes are due to local burning. Support for this interpretation is provided by the pollen influx values (figure 12). The rising percentage and influx of *Betula*, *Quercus* and *Alnus* above 48 cm suggest regeneration of the woodland. As at site E1N, we see that the *Alnus* curve rises after an episode of disturbance. Expansion of alder thus appears to have been facilitated by the opening of the woodland canopy (cf. Smith 1984). From the high AP+S values in the later part of zone 3, the woodland must have been close to the sampling point. From the fall of the *Calluna* curve in zone 3a and the rise of Cyperaceae and Gramineae in zone 3b, the local heath was replaced by damp blanket bog communities.

The influx diagram (figure 12, pullout 4) shows a general increase of values for all curves in the first part of zone 3b. Thus either pollen productivity as a whole increased, or there is an undetected reduction of deposition rate. It is noteworthy that the samples at 36 cm had concentrations of microscopic charcoal and the sample at 38 cm had pollen with a characteristically crinkled appearance that may be connected with a burning of the bog surface (Cloutman 1983). It is possible, then, that the deposition rate was reduced in that way.

Zone 4 is subdivided at 12 and 20 cm so that a grass pollen maximum is included in zones 4a and b(i) and a heath pollen maximum in 4b(ii). These features presumably in the main reflect the bog vegetation. The bog near the site was thus probably heath-covered for the second time by about 4000 years BP, the first heath phase having ended some 1200 years earlier. The decline of the *Ulmus* curve at the zone 4a–b transition (best observed in the AP diagram given in the Supplement) is also evident at the nearby site A16W and elsewhere.

Site A16W (*figure* 13, *pullout* 4)

There is a high *Corylus* value in the basal mineral soil suggesting the existence of hazel scrub at the site before peat accumulation started at about 5800 years BP. The initial decline of *Corylus* in zone 3 may be a reflection of the displacement of hazel due to the accumulation of acid peat. Unlike other sites the *Calluna* values are not particularly high at the base, though there is a decline above 40 cm (where the zone has been subdivided). The lack of high *Calluna* values may be connected with the absence of a basal mor deposit. Peat initiation began directly as ombrogenous peat though the basal 12 cm contains some mineral material. This is suggestive of soil disturbance in the vicinity, which tends to be confirmed by the presence of *Artemisia* and Chenopodiaceae pollen. The continuing high AP + S values in zone 3a suggest that hazel, and possibly other tree species, may have continued to grow on the deposit. The increases of Cyperaceae and *Sphagnum* in zone 3b suggest damper surface conditions. The date of the zone 3*a*–*b* transition (*ca.* 5700 years BP) is similar to that at the nearby site B32S, where we also saw reason to believe that there was an increase in wetness.

The zone 3–4 boundary is drawn at 32 cm (5235 ± 75 years BP (CAR-326)) based on the decline of elm seen in the tree pollen diagram (Appendix 1; Supplement figure S24). The subdued representation of the primary elm decline at this site may be connected with the sampling interval, or may alternatively reflect local persistence of elm as compared with other areas. Small amounts of pollen of *Plantago*, Chenopodiaceae and *Urtica* do indicate, however, that there was some agricultural activity.

Zone 4 is subdivided at 12 and 19 cm. At 19 cm there is a decline of the *Ulmus* curve and general fall of AP. At 12 cm these trends are reversed. In zone 4b, starting at *ca.* 4500 years BP, a local clearance may be represented, because *Plantago* values increase. The *Calluna* curve rises at 14 cm where large pieces of charcoal were noted (see Appendix 1) and by *ca.* 4100 years BP (the end of zone 4b) the *Calluna* values exceed 20% of the total pollen indicating (as argued above) the probable existence of *Calluna* heath at the site.

Site E13N (*figure* 14, *pullout* 5)

The high values for Cyperaceae and Filicales in zone 3, together with relatively high species diversity, are no doubt a reflection of the fen conditions prevailing at the time. These features persist into the first part of zone 4 even though ombrogenous peat had begun to form. It must be assumed that fen conditions continued nearby.

Zone 4 is subdivided at 200 cm where the Gramineae curve falls and the *Calluna* curve rises. By this time (*ca.* 4500 years BP) the earlier high species diversity has come to an end; acid peat bearing much *Calluna* must have prevailed around the site. *Calluna* roots were visible in the peat between 165 and 196 cm.

In the middle of zone 5, around 3500 years BP, the *Calluna* curve rises to a value of over 30%. The *Plantago lanceolata* and *Pteridium* curves rise, and *Artemisia* pollen appears. These changes follow declines of the *Quercus* and *Corylus* curves in the earlier part of the zone, starting at *ca.* 4000 years BP. The high *Calluna* values indicate local heath conditions. The other features suggest woodland clearance and agricultural activity in the Bronze Age.

The E13N diagram contains the longest representation of zone 6 of all the diagrams, ending at about 800 years BP. The zone is remarkably uniform but there is a decline of *Corylus* pollen at 80 cm (*ca.* 2200 years BP) followed by a maximum for the *Plantago* and *Rumex* curves. These features presumably represent increased human pressures on the environment during the Iron Age (see also §5).

Site E188S (*figure* 15, *pullout* 5)

There is no strong indication of a primary elm decline at this site in any of the differently calculated diagrams although there is a decline dating to *ca.* 4300 years BP (for absolute and AP diagrams see Supplement).

The basal sample – at the interface between the mineral soil and the mor – has high values for both *Corylus* and *Calluna*. The total NAP value is relatively high at *ca.* 40% and is maintained at about this value throughout most of the diagram. This presumably indicates generally more open conditions near site E188S than at other sites (see also § 5). The initial ground vegetation appears to have been *Calluna* heath. The high Gramineae values that follow (subzones 3b and 4a) suggest a change in the ground flora in the initial stages of ombrogenous peat accumulation. From the relatively high *Calluna* values from zone 4b onwards (after *ca.* 4200 years BP), however, the site appears to have again become dominated by heath, which persisted for over 2500 years. The reversion to heath may have been encouraged by burning, as charcoal occurs frequently in the peat. It is also notable that this change to heath dominance follows an elm decline (108 cm). This is accompanied by a rise of the *Fraxinus* curve and the appearance of *Plantago* pollen. The site may thus be reflecting particular local land use on the limestone slopes to the southeast of the bog, to which it is in close proximity.

In zone 5 heath-burning is confirmed by the identification of carbonized remains of both *Calluna vulgaris* and *Erica tetralix* (G. Hillman *det.*). From the substantial values of *Plantago lanceolata* and *Pteridium*, this period (*ca.* 3800–2600 years BP), which substantially covers the Bronze Age, appears to have been one of sustained human pressure on the environment.

Zone 6 is subdivided at 16 cm. In the earlier part (zone 6a) there are relatively high values for *Fraxinus* and a *Betula* maximum. The *Plantago lanceolata* curve falls. This period (*ca.* 2600–2200 years BP) – the earlier part of the Iron Age – was then perhaps a time of reduced human pressures, allowing secondary woodland with a good deal of ash and birch to develop on the limestone slopes near the site.

In zone 6b the AP curve declines and quite substantial values are reached by the Gramineae, *Plantago* and *Pteridium* curves. There is also a stronger representation of taxa (including Chenopodiaceae and Compositae) that could be related to farming activity. Woodland clearance is thus likely to have taken place. From the ^{14}C timescale this started in late Iron Age times (*ca.* 2200 years BP) and resulted in a more open habitat.

The top sample contains some 2% of *Pedicularis* pollen that has been identified to *P. sylvatica* (L.). This pollen type is only sporadically represented at the other sites, and the plant was probably, therefore, actually growing on the peat at E188S. *P. sylvatica* pollen has also been recorded in mid-Wales (Chambers & Cloutman 1981).

Site A78E (*figure* 16, *pullout* 6)

As at certain other sites the basal sample, in the peaty mineral soil, is dominated by *Corylus* and *Calluna* pollen and these species must have been major components of the local vegetation. *Alnus* pollen is sparse in the basal sample, but in view of the high *Corylus* values (and high *Betula*) among the tree pollen it is unlikely that the rise of the *Alnus* curve represents the zone 2–3 boundary (the AP diagram is given in Supplement figure S23).

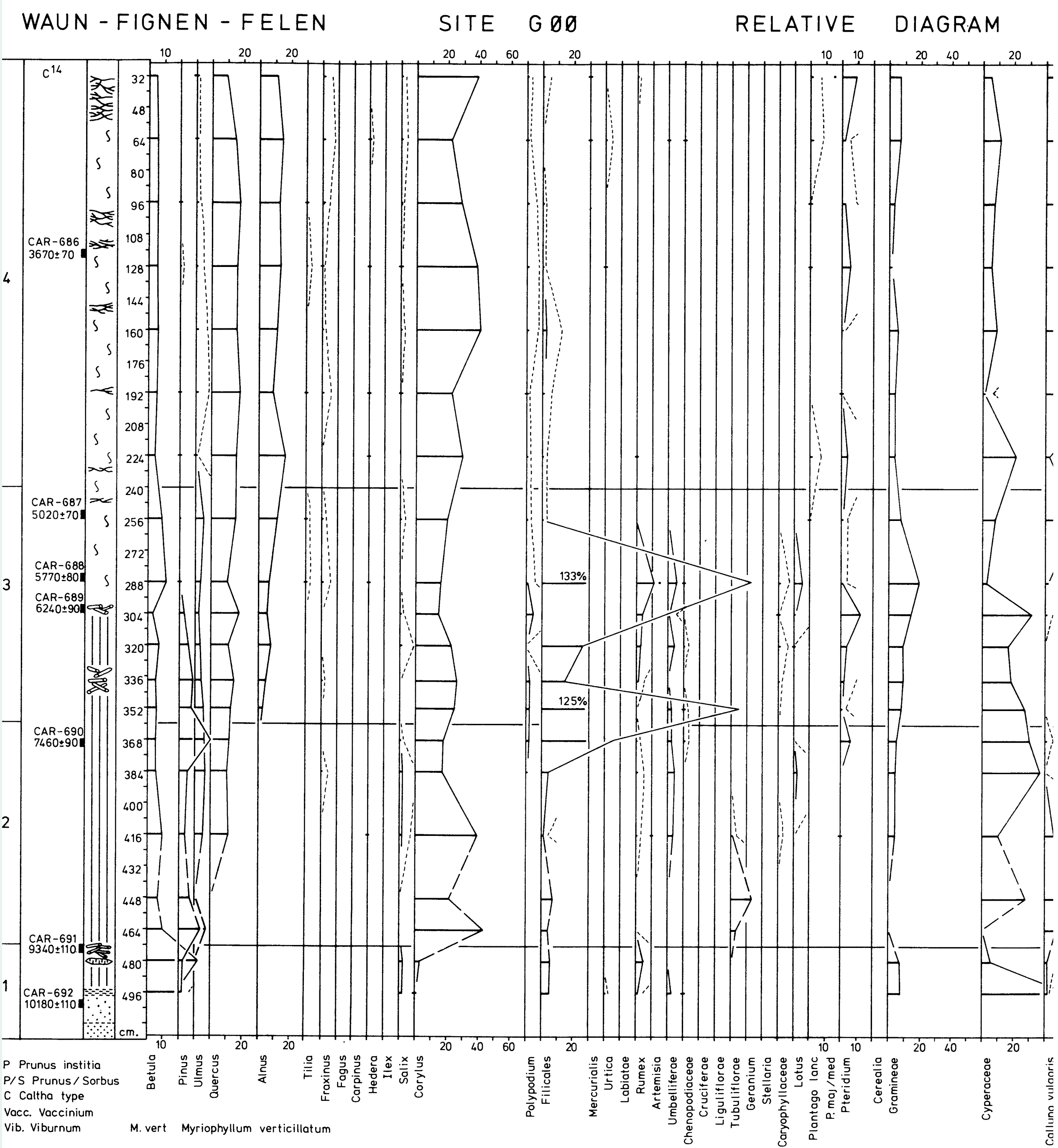
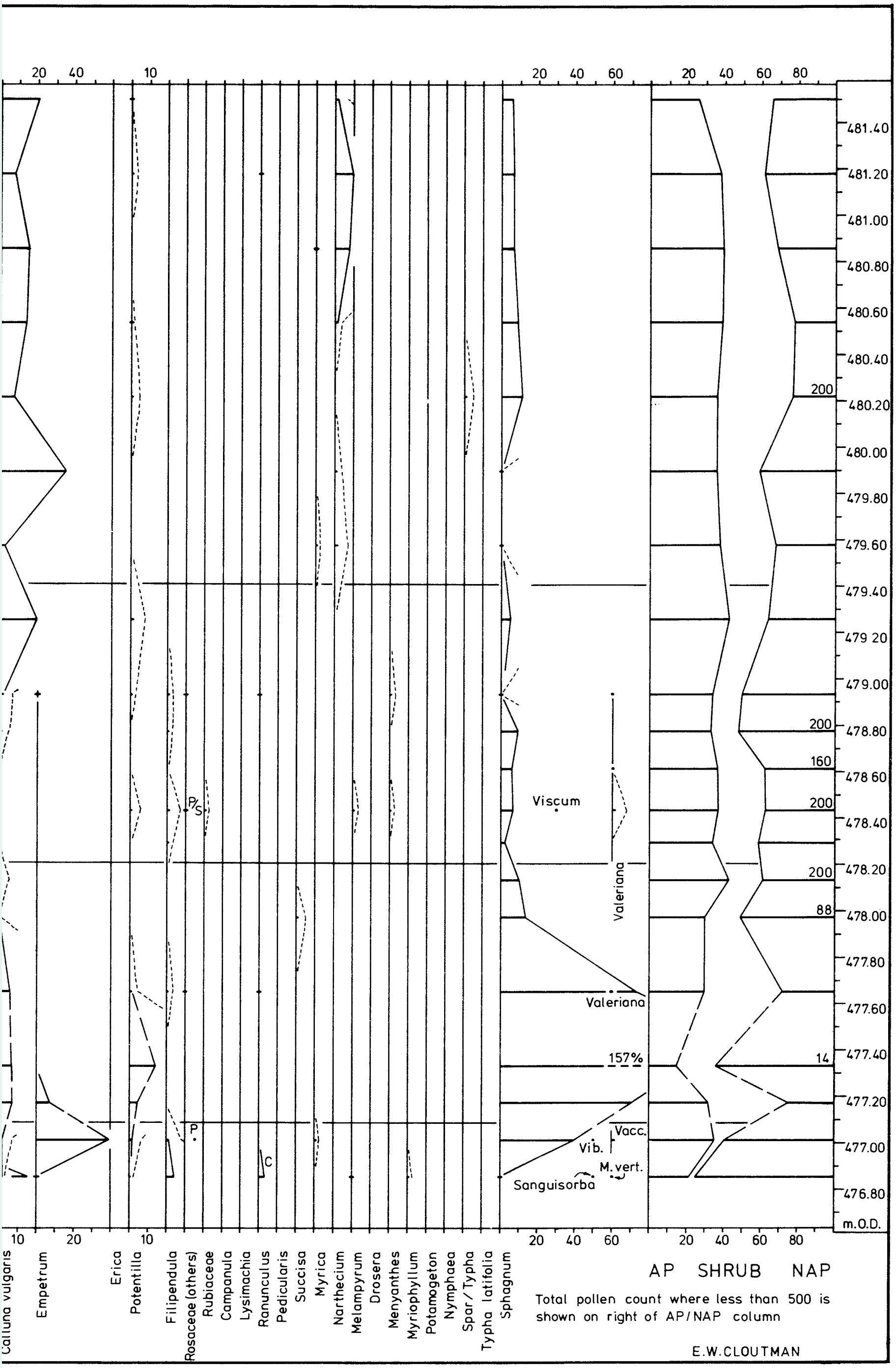


FIGURE 5. Relative total pollen diagram from the deepest part of the basin at Waun-Fignen-Felen (site G00). S
figures 3 and 4. (A pollen influx diagram from the site, together with a relative pollen diagr



Stratigraphic symbols are given in figure 4 and the location of the site in
ram based on tree pollen only, is given in the Supplement.)

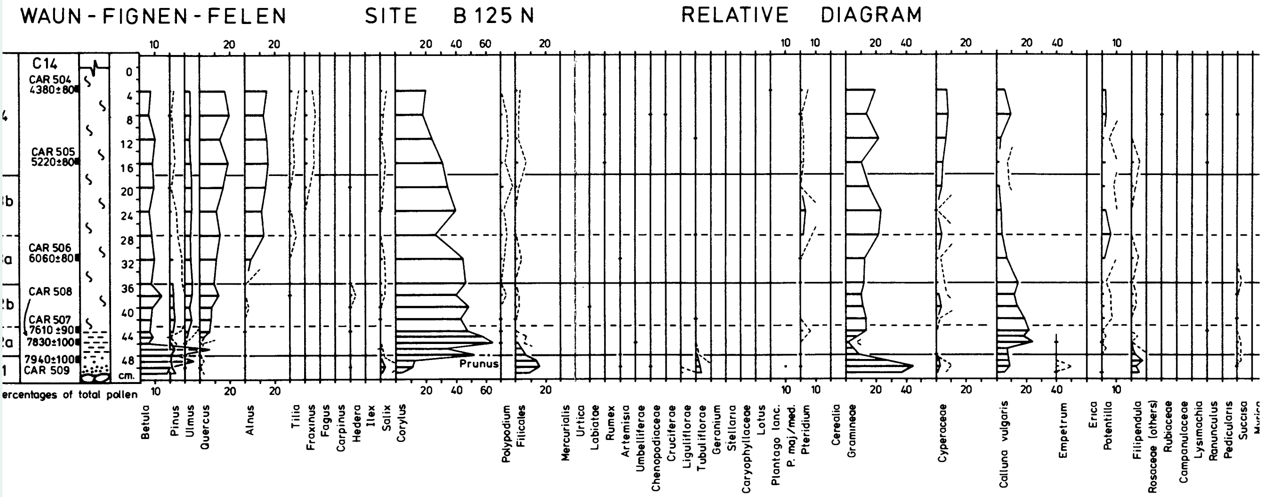


FIGURE 6. Relative total pollen diagram from the oldest mor and blanket-peat site (B125N) at Waun-Fignen-Fe

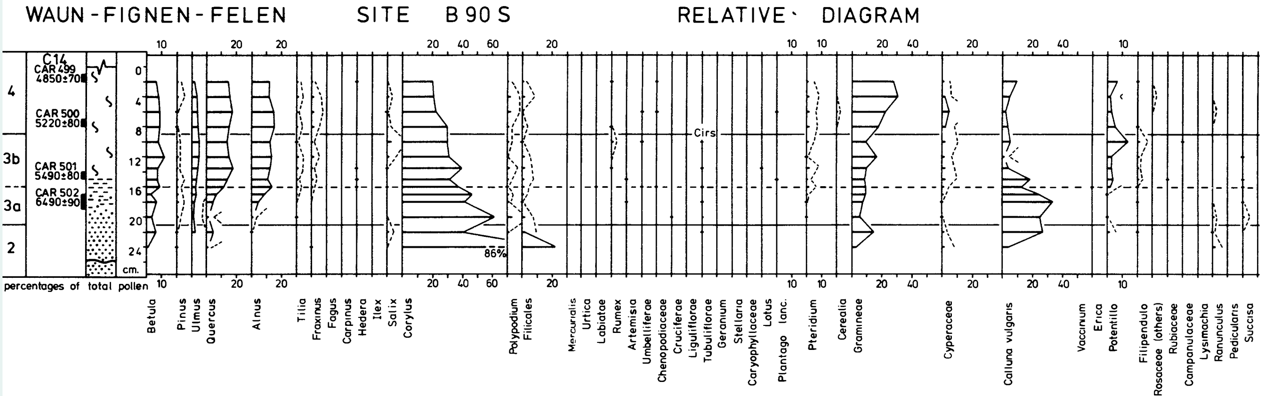


FIGURE 7. Relative total pollen diagram from a site with blanket peat above an iron pan podsol at Waun-Fignen-Fele

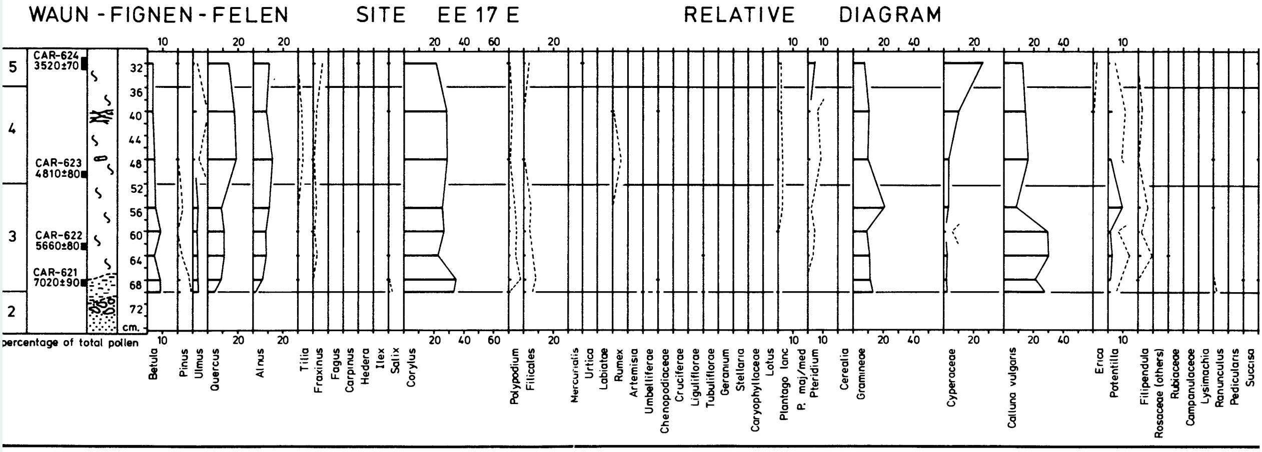
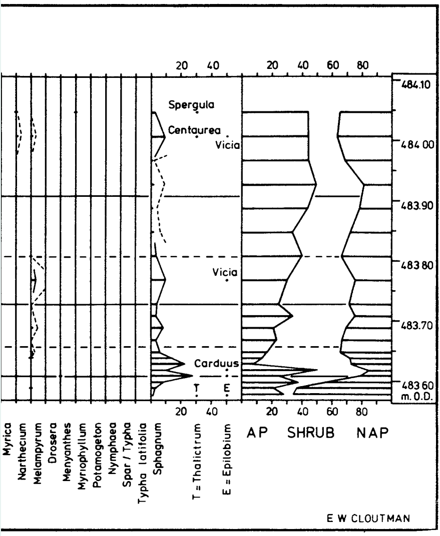
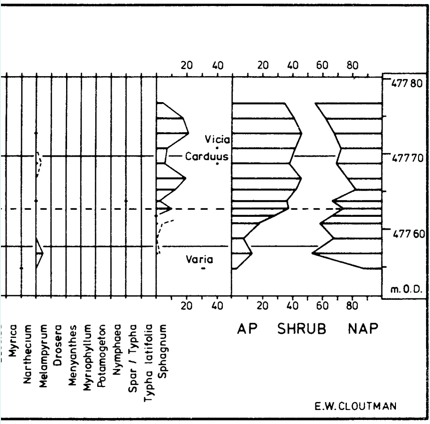


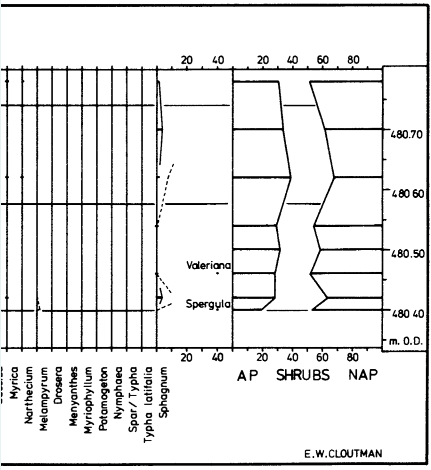
FIGURE 8. Relative total pollen diagram from one of the oldest mor and blanket peat sites (EE17E) found at Waun-Fi



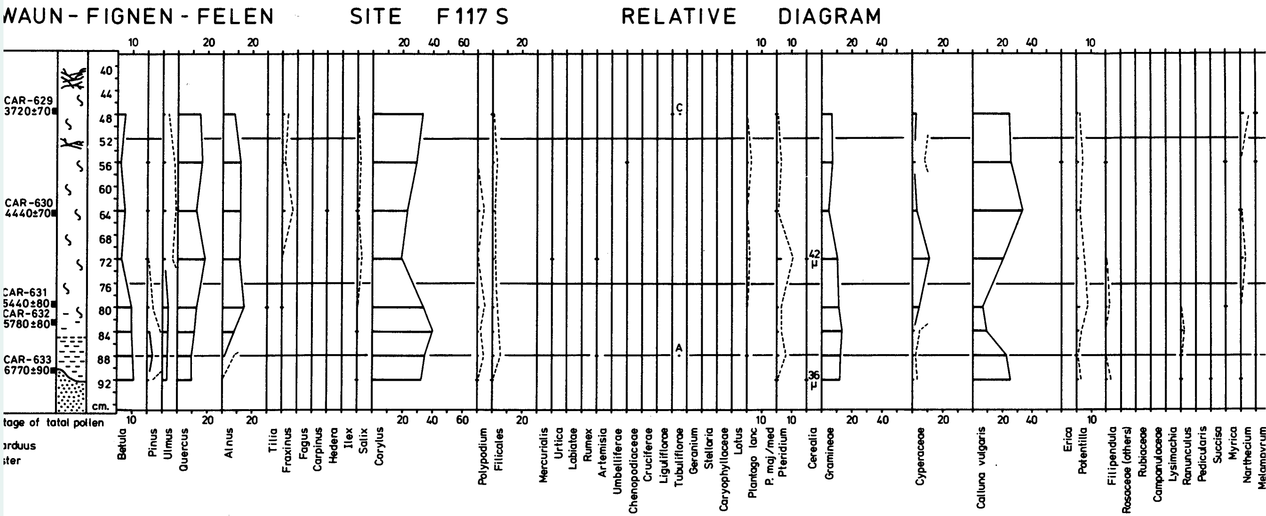
'elen. (Details as for figure 5.)



en (B90S). (Details as for figure 5.)



ignen-Felen. (Details as for figure 5.)



GURE 9. Relative total pollen diagram from a mor and blanket peat site (F117S) to the south of the basin area at Waun-Fig

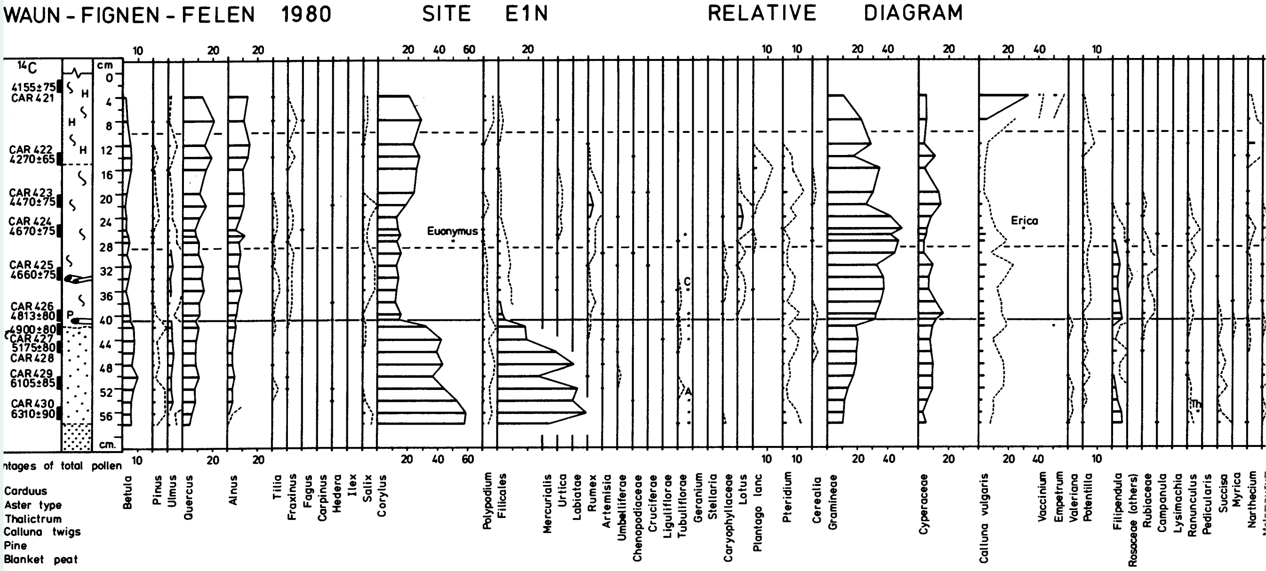


FIGURE 10. Relative total pollen diagram from a basin-margin site (E1N) at Waun-Fignen-Felen. (Details

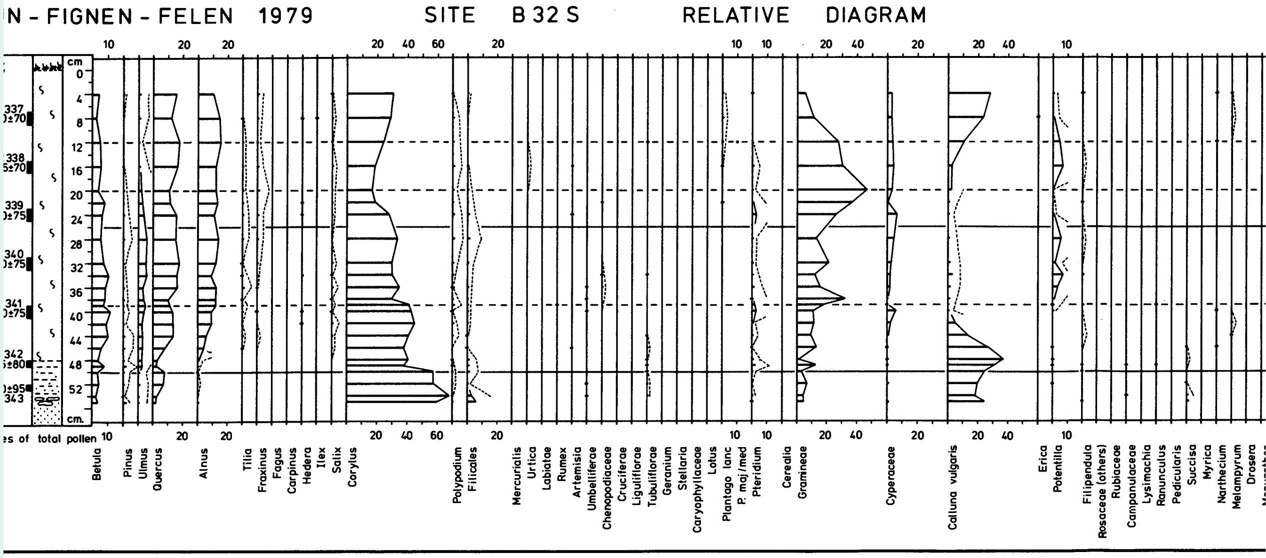
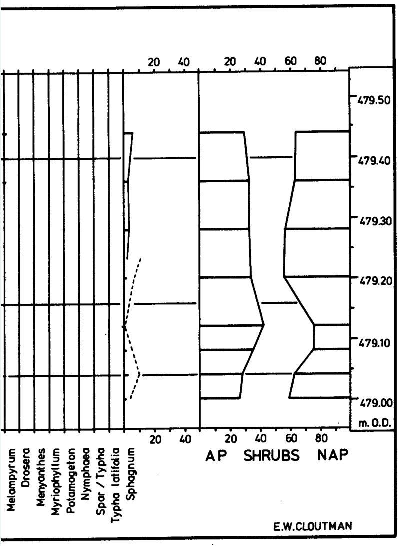
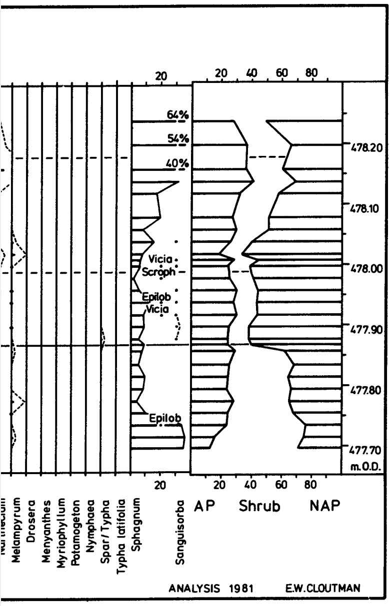


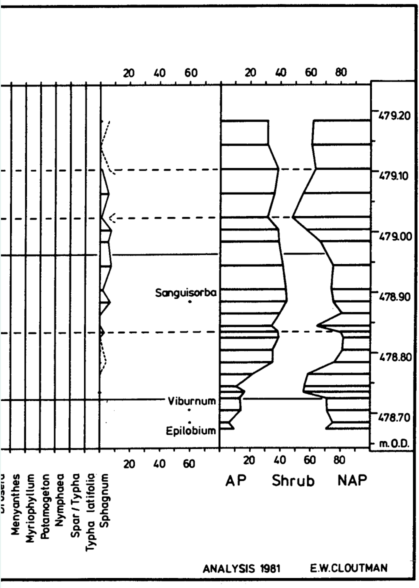
FIGURE 11. Relative total pollen diagram from a central site (B32S) in the blanket-peat area at Waun-Fignen-Felen from the site is given in figure 12. (Details as for figure 5.)



ignen-Felen. (Details as for figure 5.)



ls as for figure 5.)



n. A pollen influx diagram

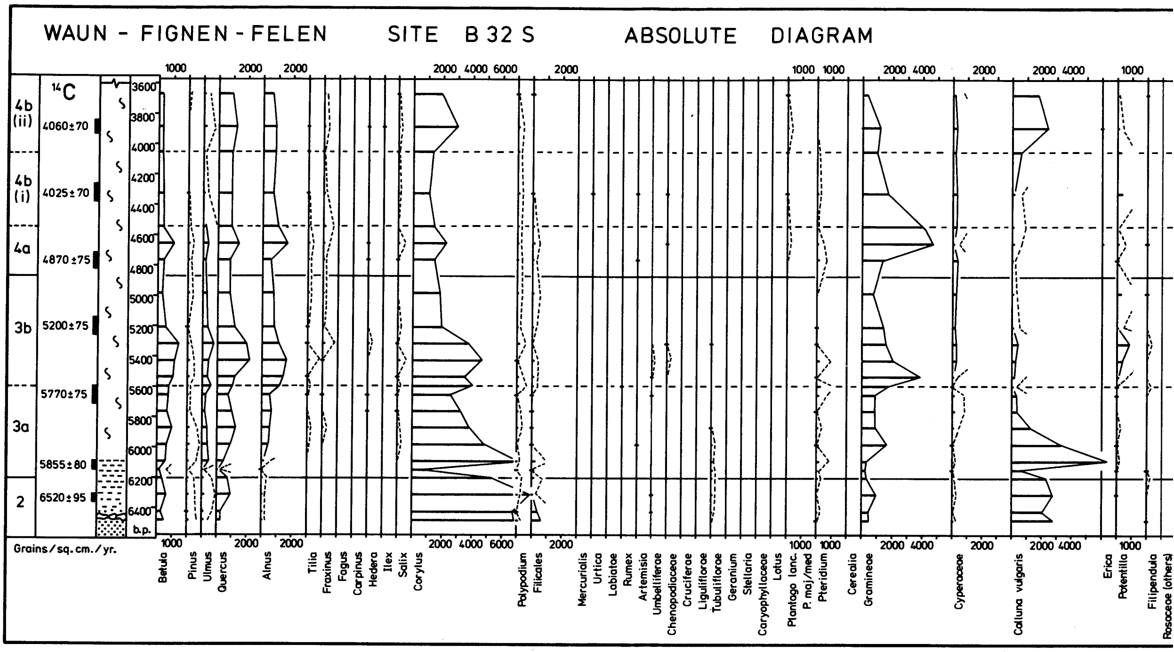


FIGURE 12. Pollen influx diagram from site B32S at Waun-Fignen-Felen. Se

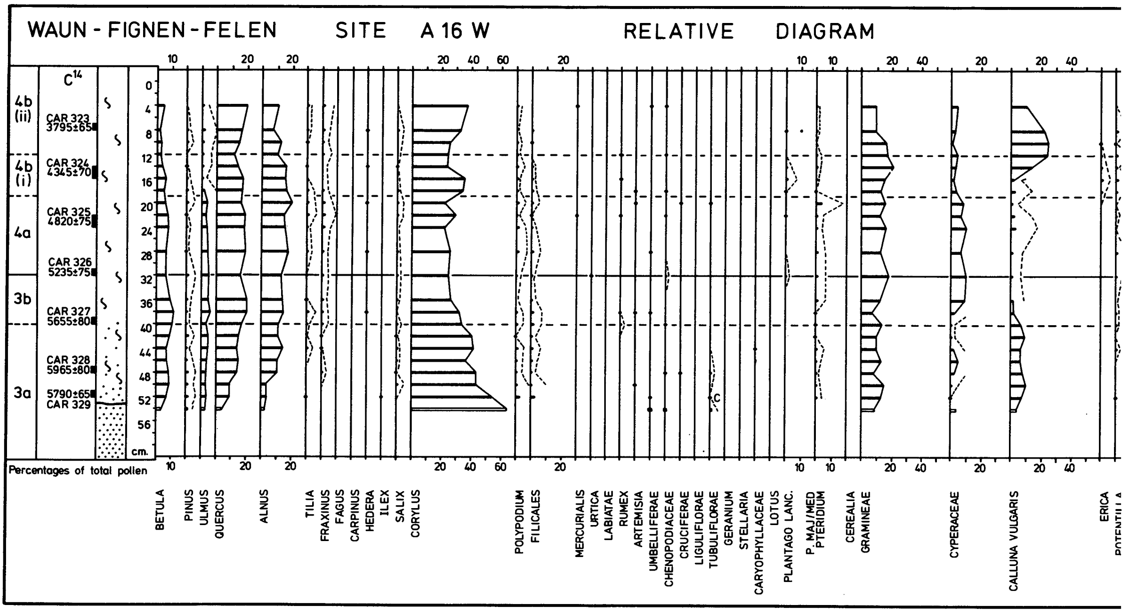
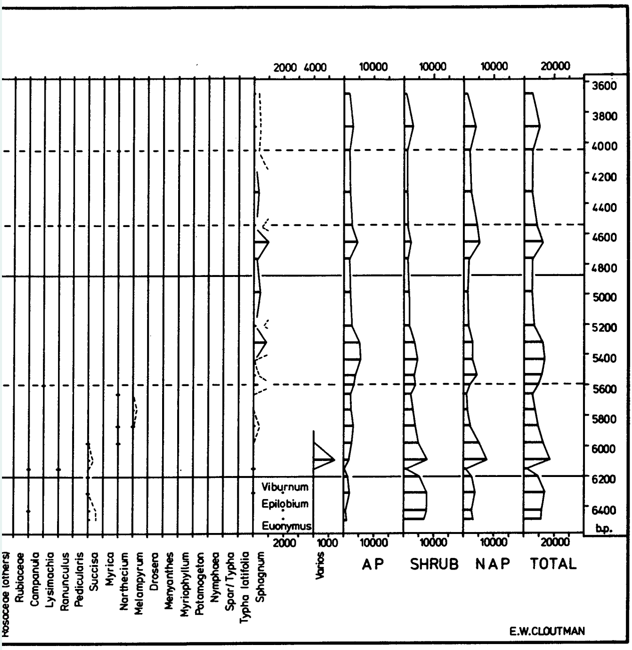
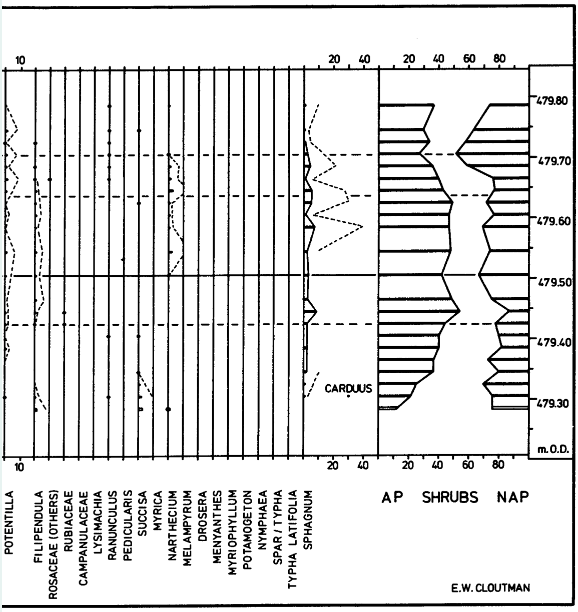


FIGURE 13. Relative total pollen diagram from the central part of the blanket peat area at Wa
no distinct basal mor layer was visible. (Details as for figure



ee legend to figure 11.



aun-Fignen-Felen (site A16W) where
5.)

Zone 3 is subdivided at 78 cm. At the boundary between the subzones 3a and 3b the Gramineae and Cyperaceae curves rise, presumably reflecting a change in the ground flora as mor-like peat began to accumulate. *Calluna* and *Corylus* values decline as the zone 3a–b boundary is approached and the curves for *Quercus* and *Alnus* rise. There is no effective diminution of the total AP+S curve, so oak and alder must have replaced hazel to some extent near the site.

As at site E188S there is no *Ulmus* decline at *ca*. 5000 years BP. Local persistence of elm could again be the explanation. The two sites are, of course, the most easterly of the group and the closest to the limestone slopes (see map, figure 3).

Site B46.5N (*figure* 17, *pullout* 7)

At the base of the peat the *Corylus* values are relatively low compared with other sites, and there are substantial values for *Betula*, *Ulmus*, *Quercus* and *Alnus*. The NAP totals little more than 20%. The site must, therefore, have been close to mixed woodland, which may indeed have been the local vegetation type on the mineral soil immediately before peat initiation.

The *Ulmus* decline of the zone 3–4 boundary is not particularly strong and *Plantago lanceolata* pollen is absent. It is of interest, however, to note the presence of Chenopodiaceae pollen and that, subsequently, the *Fraxinus* values increase. Clearly, some disturbance of the woodland cover was taking place in the vicinity.

Zone 4 is subdivided at 152 cm where there is a minor elm decline dating to about 4500 years BP. In zone 4b there are a few indicators of disturbance and the levels of the curves for *Quercus*, *Corylus* and *Alnus* change. There appears, therefore, to have been some alteration in woodland composition.

Plantago pollen is again absent from the level of the elm decline used to define the zone 4–5 boundary. Major changes do, however, take place in zone 5 (at 112–116 cm), including the appearance of *Plantago lanceolata*, where the zone has been subdivided. There is also a major decline of tree pollen. Among the NAP curves, dominance of Gramineae is replaced by dominance of Cyperaceae and *Calluna*. Charred ericaceous fragments were found at this level, which dates to *ca*. 3600 years BP. Without the evidence of the increase of *Plantago* these features could be interpreted as indicating a change in the ground flora. It is more likely, however, that we are again seeing evidence of human pressures on the landscape during the Bronze Age. It is notable that in zone 5b the *Quercus* curve declines and the *Corylus* curve initially rises. These changes may betoken the conversion of oak woodland to hazel scrub. Late in zone 5b there is a substantial further decline of AP+S, particularly of *Quercus* and *Corylus*, which signifies yet more opening of the woodland cover. This episode took place at *ca*. 3000 years BP, still within the Bronze Age. Disturbance is well indicated by the presence of pollen of Chenopodiaceae, *Artemisia*, and *Rumex*, and by high values for *Pteridium* spores.

Zone 6 has been subdivided at 44 cm where the *Fraxinus* curve declines and the curves for *Plantago lanceolata* and *Pteridium* rise. In zone 6a we see rising curves for *Fraxinus* and *Betula* and there is a minimum of *Plantago lanceolata*. These features parallel those of zone 6a at site E188S and belong to a similar period. Again we are apparently seeing evidence of development of secondary woodland in a period of reduced human pressure. The features of zone 6b suggest increased agricultural activity beginning at *ca*. 2100 years BP (approximately the same time as the renewed human pressure in zone 6b at site E188S). Above 18 cm there is a reversal of these trends, suggesting a further relaxation of agricultural pressures. The date of this horizon is *ca.* 1600 years BP, coinciding with the end of Romano-British times. The higher values of *Narthecium* that characterize zone 6 are discussed later (p. 203).

Site D7E (*figure* 18, *pullout* 8)

D7E provides the youngest date for peat initiation in the main blanket bog area at *ca.* 4000 years BP. The site is marginal to the basin area and this young date shows that the peat must have spread out progressively from the deeper part of the basin which, of course, started to fill with organic material in the early Flandrian period. Compared with the transition to blanket peat at site G00 in the centre of the basin, which took place at *ca.* 6200 years BP, peat initiation at D7E was considerably delayed.

The basal samples, from mineral-rich peat, belong to the end of zone 4. *Calluna* values of *ca.* 20% suggest that the ground flora was dominated by heath at the time of peat initiation. The decline of the *Ulmus* curve with which zone 5 opens is accompanied by a temporary decline of the *Corylus* and fern curves, and a temporary rise of the *Potentilla* curve. The latter two features appear to represent changes in the local ground flora. As the *Corylus* curve falls at the same time, hazel appears to have been locally present. In addition to *Plantago lanceolata* in zone 5 there are a number of disturbance indicators such as *Urtica*, Chenopodiaceae and *Spergula*. These must reflect Bronze Age agricultural activity in general, but it may be that the initial *Ulmus* and *Corylus* declines are attributable to local human activity. This elm decline has parallels at other sites (see §5).

Zone 6 is subdivided so that subzone 6b (56–80 cm) includes a tree-pollen minimum with a *Plantago lanceolata* maximum. Indicators of disturbance such as *Urtica*, *Rumex* and *Artemisia* are well represented; there is also a cereal pollen grain. Subzone 6b begins with a marked elm decline in the tree-pollen diagram (Supplement figure S25). It seems likely to represent a period of clearance and agriculture which, from the deposition rate curve (see Appendix 2), falls between *ca.* 2850 and *ca.* 2500 years BP, in the late Bronze Age.

Although all the sites covering the Bronze Age show evidence of human pressures in some form, site D7E is unique in having this apparently stronger agricultural phase in the late Bronze Age. This suggests that there might have been local activity on the western hill slopes. Indeed, there are several pollen records from site D7E that suggest the local limestone flora is represented. These include *Sanguisorba*, *Helianthemum* and *Centaurea*, all confirming that some open areas must have existed.

(*c*) *Outlying sites*

For comparative purposes the basal deposits at three sites away from the main basin and blanket peat area were studied. The locations of the sites are given in figure 2.

Site NE (*figure* 19, *pullout* 8)

The site is shallow blanket peat, with a basal mor layer containing charcoal lying in between rocks, just below the summit of Fan Hir some 1.5 km northeast of Waun-Fignen-Felen at an altitude of *ca.* 660 m O.D.

The basal amorphous peat had poor pollen preservation but yielded a radiocarbon date of 5940 ± 90 years BP (CAR-625). Three samples were analysed across the junction between the amorphous and blanket peat. The samples at 46 and 48 cm contained much charcoal. The total herb pollen amounts to almost 50%, suggesting a relatively open habitat. There is a good representation of open-habitat plants and ferns, which could well have been growing on the local scree. From the Gramineae values of over 30 %, the ground flora is likely to have been grass-dominated although the rising *Calluna* curve does suggest the beginning of heath development. The *Alnus* curve is rising. Bearing in mind the radiocarbon date this invites comparison with the early part of zone 3 at the Waun-Fignen-Felen sites.

Site NP (*figure* 19)

The site is in an area of eroded blanket peat with a basal mor-like layer. It is on a low plateau about 0.5 km to the north, and some 15–20 m higher than the main bog area investigated at Waun-Fignen-Felen. A basal sample yielded a ^{14}C date of 5100 ± 80 years BP (CAR-628). Save for D7E this is the youngest date for the peat initiation in or near the main blanket peat area. The total AP + S values of *ca.* 60 % suggest that there may have been some local woodland cover. Nevertheless, from the basal *Calluna* values of *ca.* 30 % the accumulation of mor must have begun under heath. Later, the Gramineae and Cyperaceae curves rise and the *Calluna* curve declines, suggesting that conditions became damper. It is notable, though, that this change takes place above a thin horizon with much charcoal at the peat–mineral interface which corresponds with the 36 cm sample. The occurrence of Chenopodiaceae pollen indicates the presence of broken ground. The radiocarbon date and basal elm decline show that initiation of organic soil accumulation did not begin until the end of zone 3. It is likely that the plateau area north of the Waun-Fignen-Felen site remained as an area of mineral soil throughout the Mesolithic period.

Site SW (*figure* 19)

The site is at *ca.* 530 m O.D., roughly halfway up the limestone slope to the southwest of Waun-Fignen-Felen and *ca.* 0.5 km distant. There is a thin (0.5–1.0 cm), black, greasy layer containing macroscopic charcoal at the base of the blanket peat which is some 1.3 m thick. This black layer yielded a ^{14}C date of 4370 ± 80 years BP (CAR-627) and the blanket peat 2 cm above it a date of 4250 ± 80 years BP (CAR-626). The peat rests on gravelly sand from which two pollen spectra were obtained.

Throughout the short pollen diagram the AP + S values are between 60 % and 70 %. According to Goddard's (1971) studies of modern pollen rain, such values are likely to represent the presence of scrub woodland or even greater woodland cover. It is unlikely that woodland grew on the peat but the nearby scree would have provided a suitable habitat.

Field observations of eroded peat faces showed that the basal charcoal-rich layer became very thick (20–25 cm) at the bottom of the scree. The charcoal appears likely to have resulted from the burning of woodland on the scree. From the course of the pollen curves no permanent damage to the woodland appears to have occurred, but it is nevertheless interesting to note that the peat initiation is associated with burning, just as it is in the main blanket peat area at Waun-Fignen-Felen at a much earlier date.

5. DISCUSSION

(*a*) *Comparison of sites*

A series of diagrams is presented in figures 20–25 in which the percentage curves for selected taxa from all the sites (with the exception of the outliers) are drawn together on a radiocarbon timescale. The timescales for the individual sites are derived from the regression lines shown on the deposition rate curves included in Appendix 2 (figures A1–A3). Bearing in mind the various possible errors in addition to the inherent uncertainty of the radiocarbon method, differences in ages between sites of a few hundred years can hardly be regarded as significant. The taxa selected are those that appear likely to have contributed to the local vegetation. Discussion of the diagrams is restricted to numbered points, which are given both in the figures and in the text.

Examination of the figures reveals that there are both broad similarities and clear differences between the sites. This implies that some features of the diagrams have local significance only and that changes in the plant communities growing at, or close to, the sampling points are represented. Where a consistent pattern emerges of the behaviour of a particular taxon, an attempt has been made to give a pictorial representation by means of a map showing the grouping of sites with common features. The fact that in very many cases sites with common features prove to occur in groups, and are not randomly distributed, is a compelling argument in support of the contention expressed above that local events are recorded.

(i) *Betula* (*figure* 20)

1. The central basin site (G00) alone shows the high *Betula* values typical of the early Flandrian period. The highest value, calculated on the basis of the total land-plant pollen, is only *ca*. 30%, but on the basis of tree pollen alone the two basal samples have over 90% *Betula* showing that the local woodlands were certainly dominated by birch (see Supplement figure S13). The decline of *Betula* took place between *ca*. 10100 and *ca*. 9800 years BP according to interpolated dates, though somewhat later if reliance is placed on a single determination.

2. High *Betula* values also occur at B125N, rising to an even higher value (*ca*. 48%) than at G00. A comparison with modern pollen samples is instructive. Of three modern samples from the Craigellachie birchwood on Speyside, Goddard (1971) obtained *Betula* values of 76%, 60% and 50% of total pollen, with 35% in a small clearing. By comparison, the basal high *Betula* values at B125N suggest that birch may well have been growing at the site, and certainly very close to it. Birch dominance of the local woodland in general is indicated by *Betula* pollen values rising to over 90% of the total tree pollen in the basal samples (see Supplement figure S14).

The apparent age difference of the period of high *Betula* values at G00 and B125N is approximately 1500 years, according to the radiocarbon dates. As discussed elsewhere (p. 167 and Appendix 2) there is some possibility that the basal radiocarbon determinations from B125N are too young, but the preferred interpretation is that they are substantially correct. In that case the basal phase of high *Betula* values at B125N would represent a phase of local birchwood development after the early Flandrian birchwoods had generally disappeared from the landscape.

(ii) *Corylus* (*figure* 21)

1. Taking the preferred interpretation of the date of the base of the profile at B125N, there appears to have been an expansion of hazel around 8100–8000 years BP. The values reached are higher than those at site G00, rising to over 60% of total land-plant pollen. By comparison with modern spectra, this appears to represent hazel growing at the site. Birks (1973), for instance, records a modern *Corylus* pollen value of 60% of total local pollen in a woodland in which hazel had a cover-abundance of 90%. Lower values were obtained where birch was

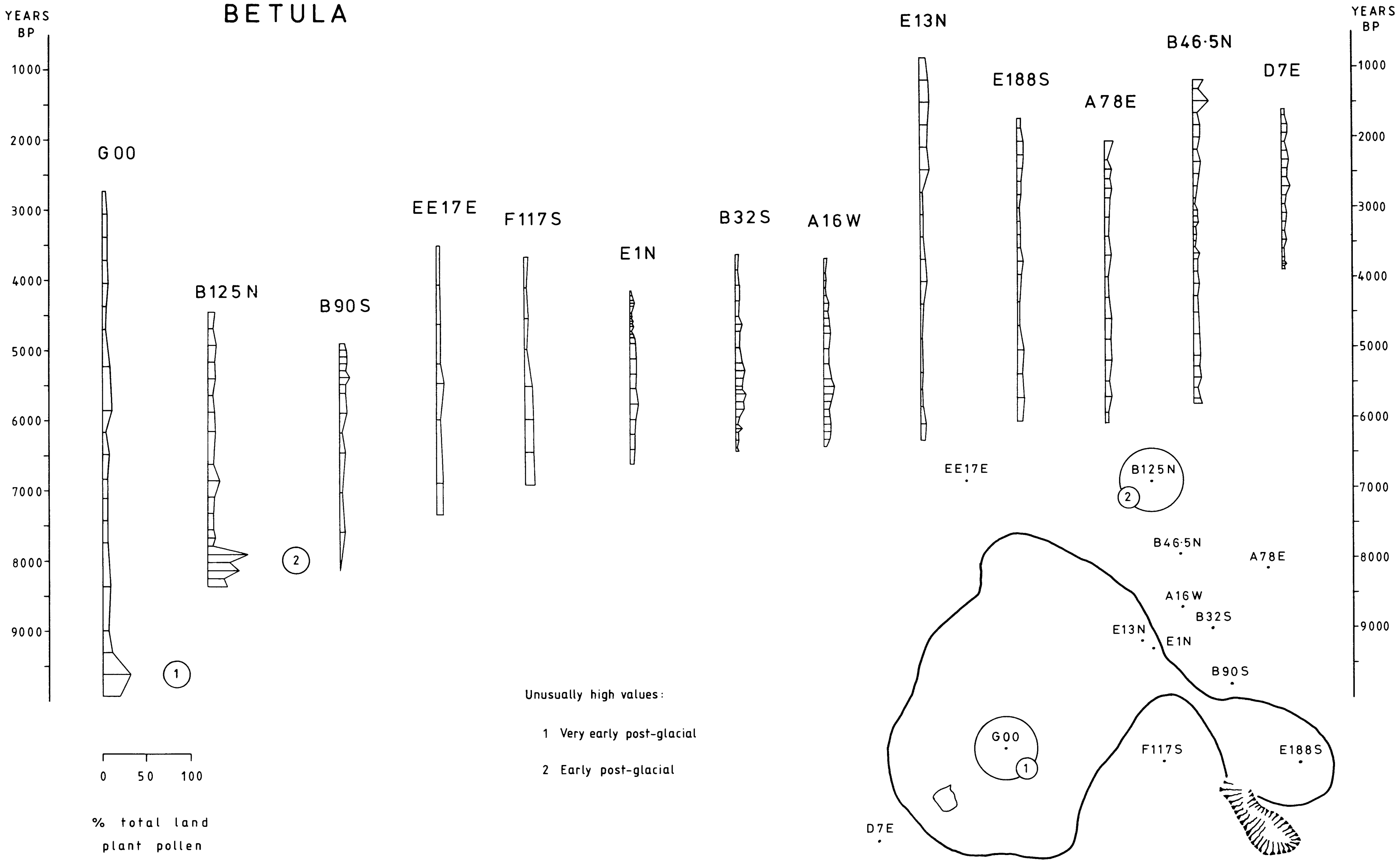


Figure 20. Pollen curves for *Betula* based on percentages of total pollen for thirteen sites in the main bog area at Waun-Fignen-Felen. The vertical scale is in radiocarbon years. This timescale is derived from deposition rate curves (see Appendix 2) based on the radiocarbon dates given in the relative pollen diagrams for the individual sites (figures 4–11 and 13–19). The timescale for site B90S may be unreliable at the base (see text and Appendix 2). The major features are numbered 1 and 2. A brief key to the numbered features is included in the figure. The numbers are used in the discussion in the text. The sketch map (cf. figure 3) gives outlines (again using the same numeration) that include the sites at which the features occur.

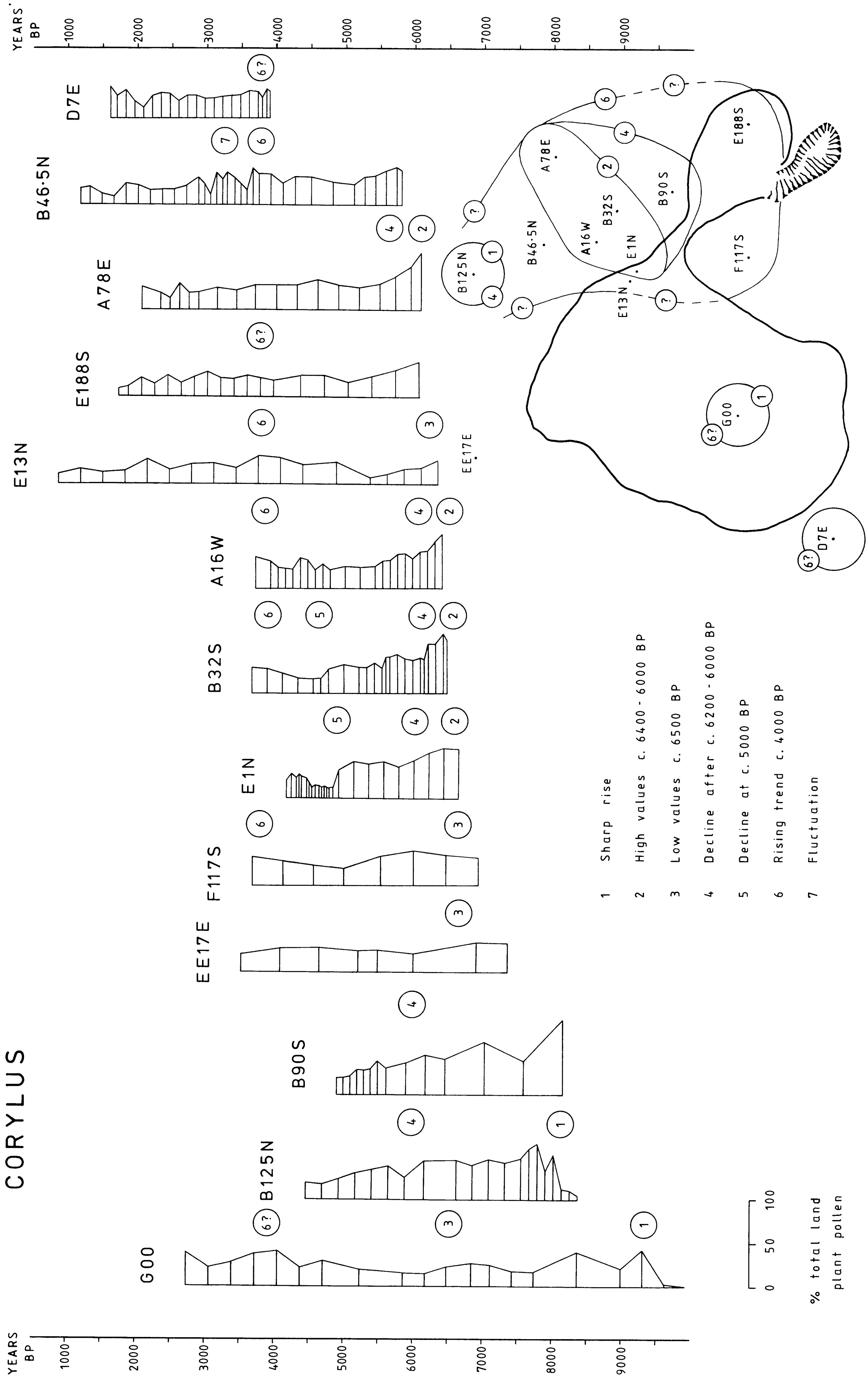


FIGURE 21. Pollen curves for *Corylus*. The major features are numbered 1–7. (Details as for figure 20.)

more strongly represented in the woodland. Local presence of hazel at site B125N is confirmed by the finding of hazel nuts in the area of eroded peat between the site and site B46.5N.

2. Similar high *Corylus* values, presumed again to indicate local presence, are found at a number of sites. These are E1N, B32S, A16W and A78E. The phases with high *Corylus* values all come to an end before *ca.* 6000 years BP.

It is striking that these sites fall together in a group in the main blanket peat area. This area is close to site B46.5N, at which peat did not begin to accumulate until after 6000 years BP. The soils around this site were thus probably not acid before this time, and are likely to have been the focus of the supposed local hazel growth. The high *Corylus* values at the base of the B90S diagram are actually in the mineral soil, and there can be little doubt that hazel was actually growing there before *ca.* 6400 years BP when mor began to accumulate.

3. By contrast, the *Corylus* values before *ca.* 6000 years BP at sites away from the main blanket bog area are relatively low (less than *ca.* 30%). The sites concerned are EE17E, F117S, E13N and G00. The appearance of the basin-centre site G00 in this group suggests that the hazel values reflect a more regional picture, or at least that hazel was not growing in the vicinity of the sites.

4. At a number of sites there is a marked decline of *Corylus* values after *ca.* 6000 BP. These are: B125N, B90S, E1N, B32S, A16W and A78E. It is again striking that, with the exception of B125N, these sites are adjacent to one another (see map in figure 21). B125N is separated from the rest of the group by B46.5N, where peat accumulation had not yet begun and where it must be presumed the hazel was actually growing.

5. Relatively high *Corylus* values (40% as compared with less than 30% at other sites) persist at E1N alone until *ca.* 5000 years BP. At sites E1N and B32S there is a decline of *Corylus* at about 5000 BP. These are adjacent sites and again a local event is indicated.

6. At all the sites represented at *ca.* 4000 years BP (save for EE17E, A78E and, questionably, D7E, E188S and G00) there is a rising trend in the *Corylus* curve. This suggests a rather widespread increase but the exceptions again indicate local variations.

7. At B46.5N there are very marked fluctuations of the *Corylus* curve as compared with other sites from which there is a record after *ca.* 3700 years BP. These unique fluctuations could indicate some hazel remaining in the vicinity. As hazel would have been unlikely to have been growing on the acid peat, such an explanation would perhaps demand that some of the mineral soils remained without peat cover.

(iii) *Alnus* (*figure* 22)

1. At G00 and EE17E *Alnus* pollen is present in some quantity before 7000 years BP.

2. At several other sites the actual rise of the *Alnus* curve can be seen: B125N, E1N, B32S and A78E. These rises all come after *ca.* 6500 years BP.

Of the two sites with an apparently early rise of the *Alnus* curve, G00 is in the centre of the basin and EE17E is close to its margin. There is thus a distinct possibility that alder became established first in the basin area. The later rise of the curve at other sites suggests that there was a delay before alder spread out from the damp areas that it initially colonized. Certainly the lack of *Alnus* pollen in the basal sample from the lake margin site E1N strongly suggests that alder was not present there as early as it was in the north of the basin near EE17E (see also p. 167).

3. Almost all the sites show a general rise of the *Alnus* curve at *ca.* 6000 years BP. The

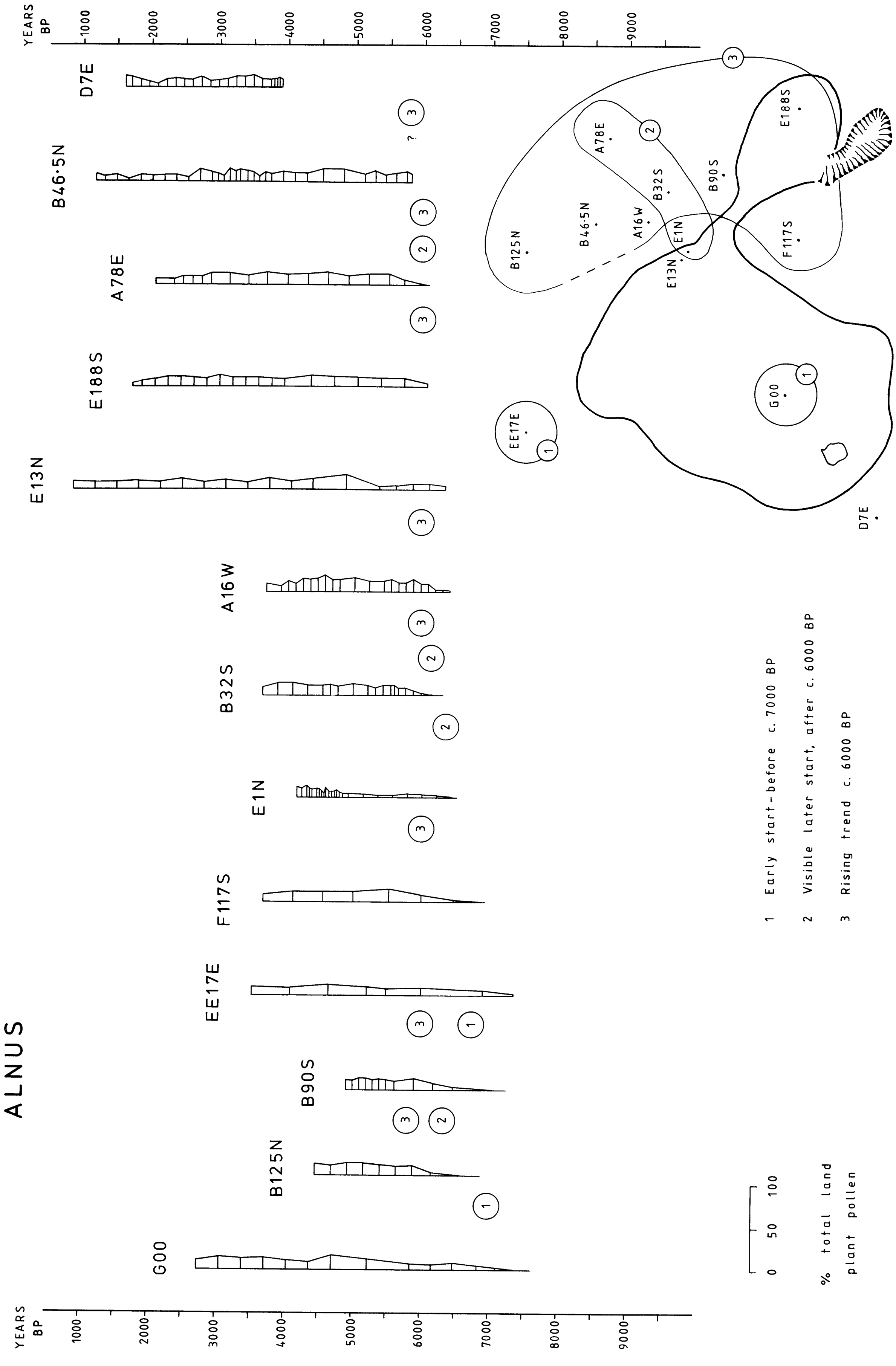


FIGURE 22. Pollen curves for *Alnus*. The major features are numbered 1–3. (Details as for figure 20.)

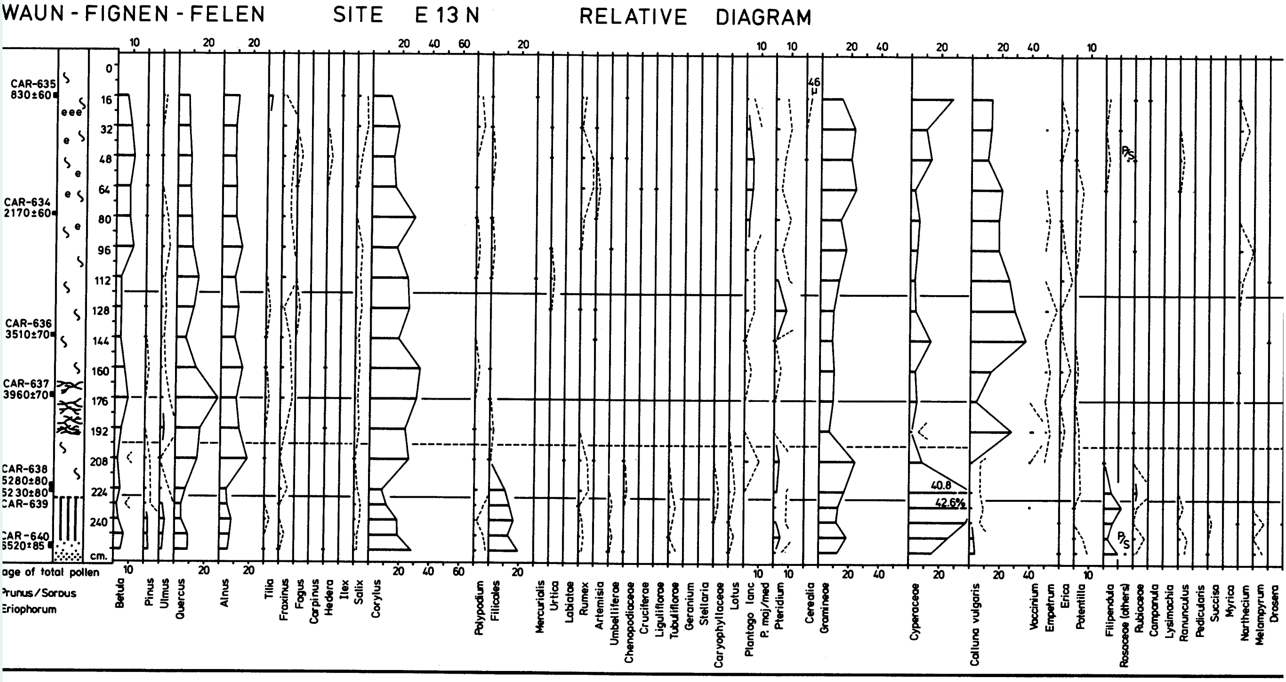


FIGURE 14. Relative total pollen diagram from a site (E13N) marginal to the basin at Waun-Fignen-Felen. H
sequence begins with reedswamp peats. (Details as for figure 5.)

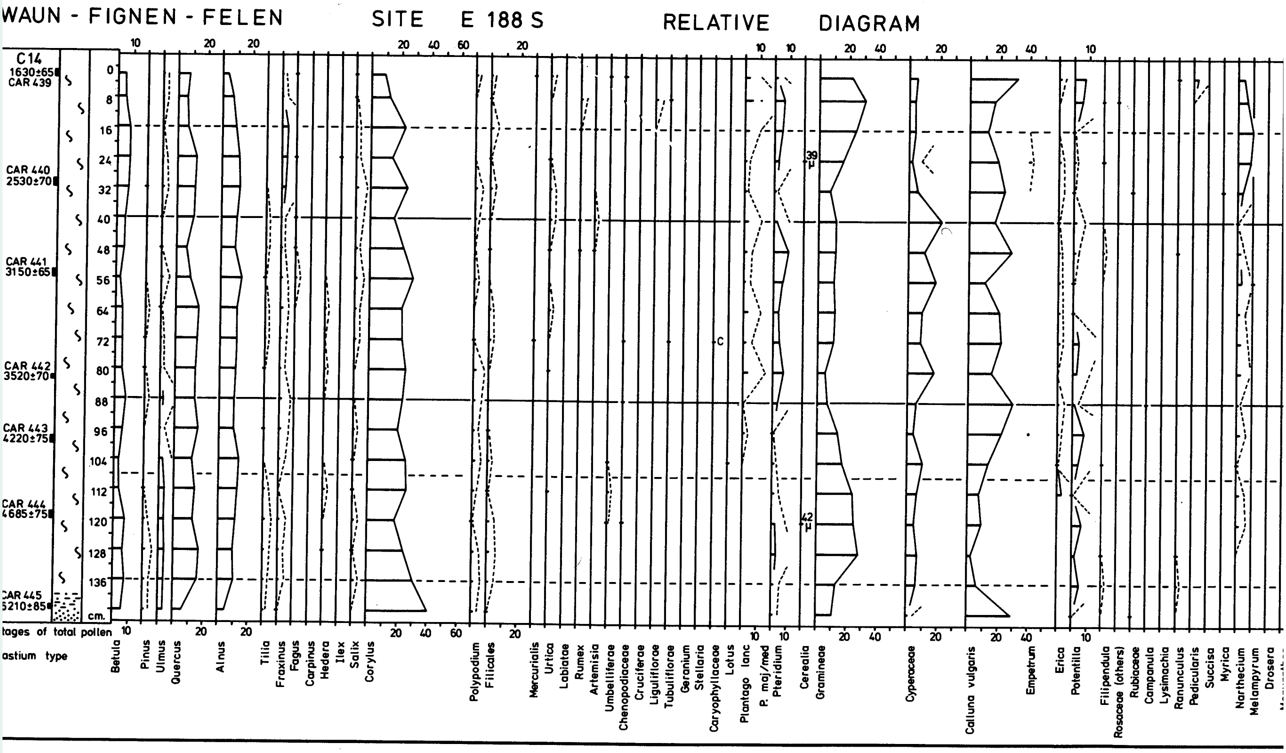
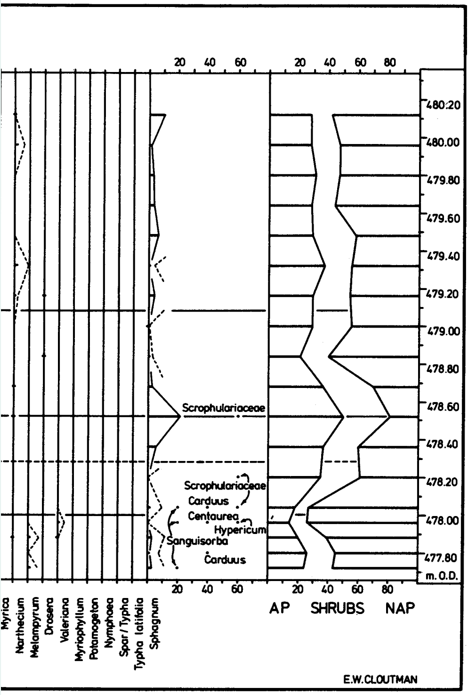
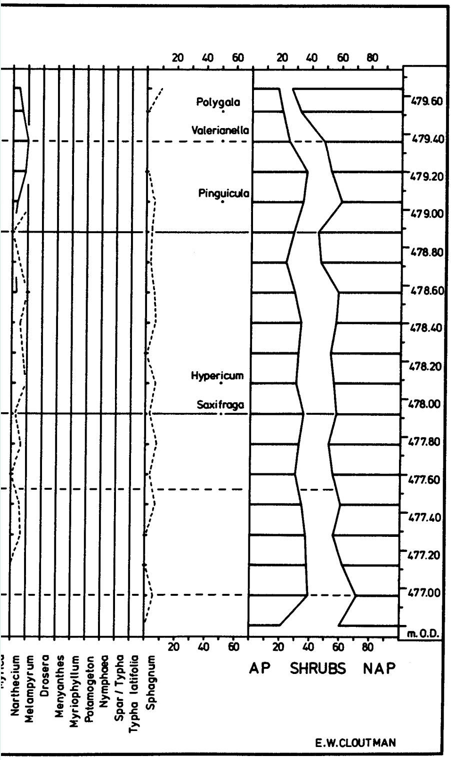


FIGURE 15. Relative total pollen diagram from the southern edge of the blanket peat area at Waun-Fignen-Felen (site E18



len. Here the depositional



te E188S). (Details as for figure 5.)

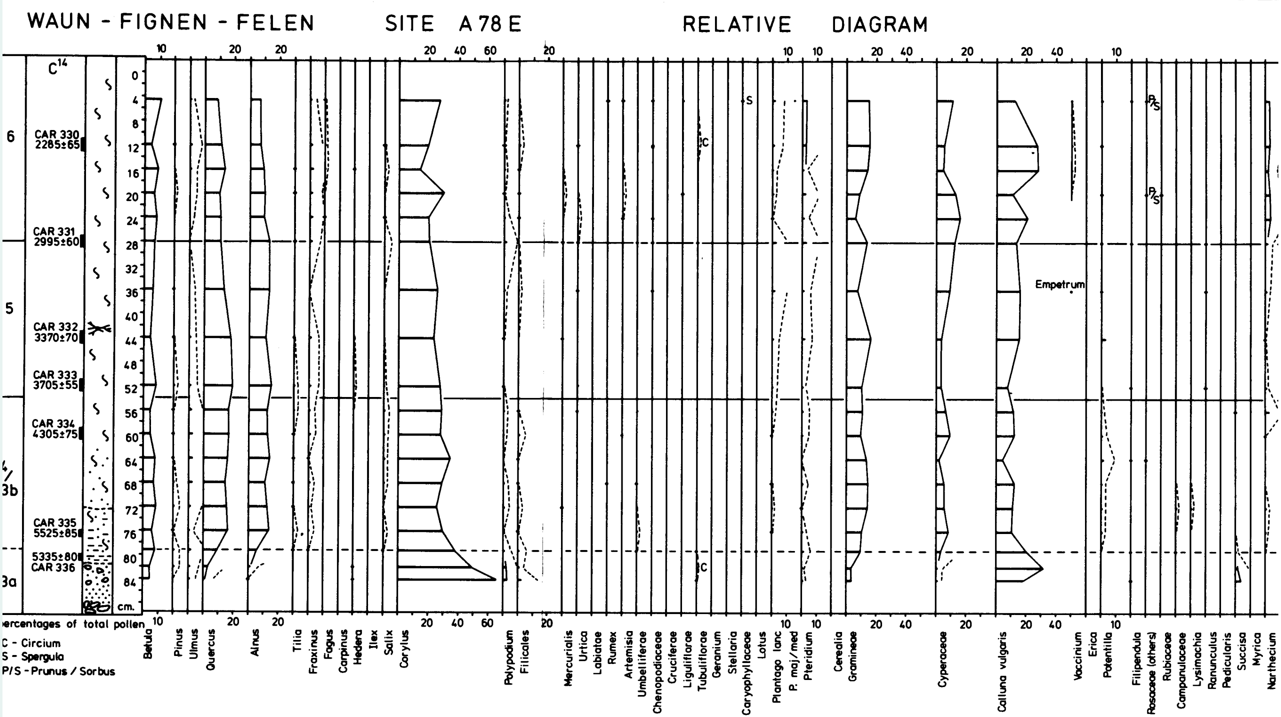
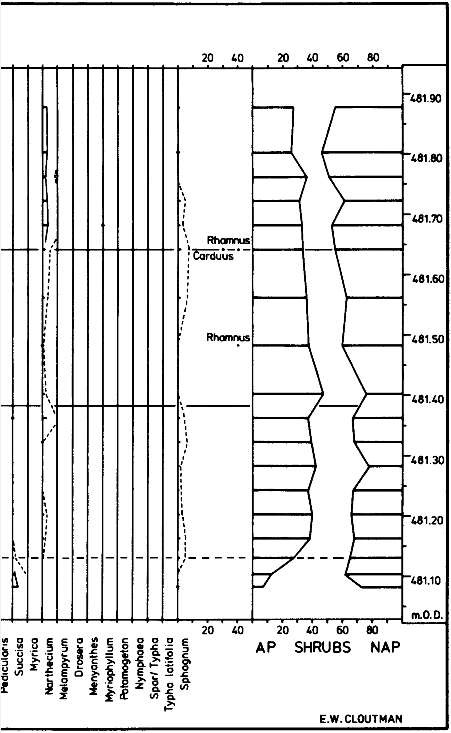


FIGURE 16. Relative total pollen diagram from the western edge of the blanket peat area at Waun-Fignen-Felen (site



(site A78E). Details as for figure 5.)

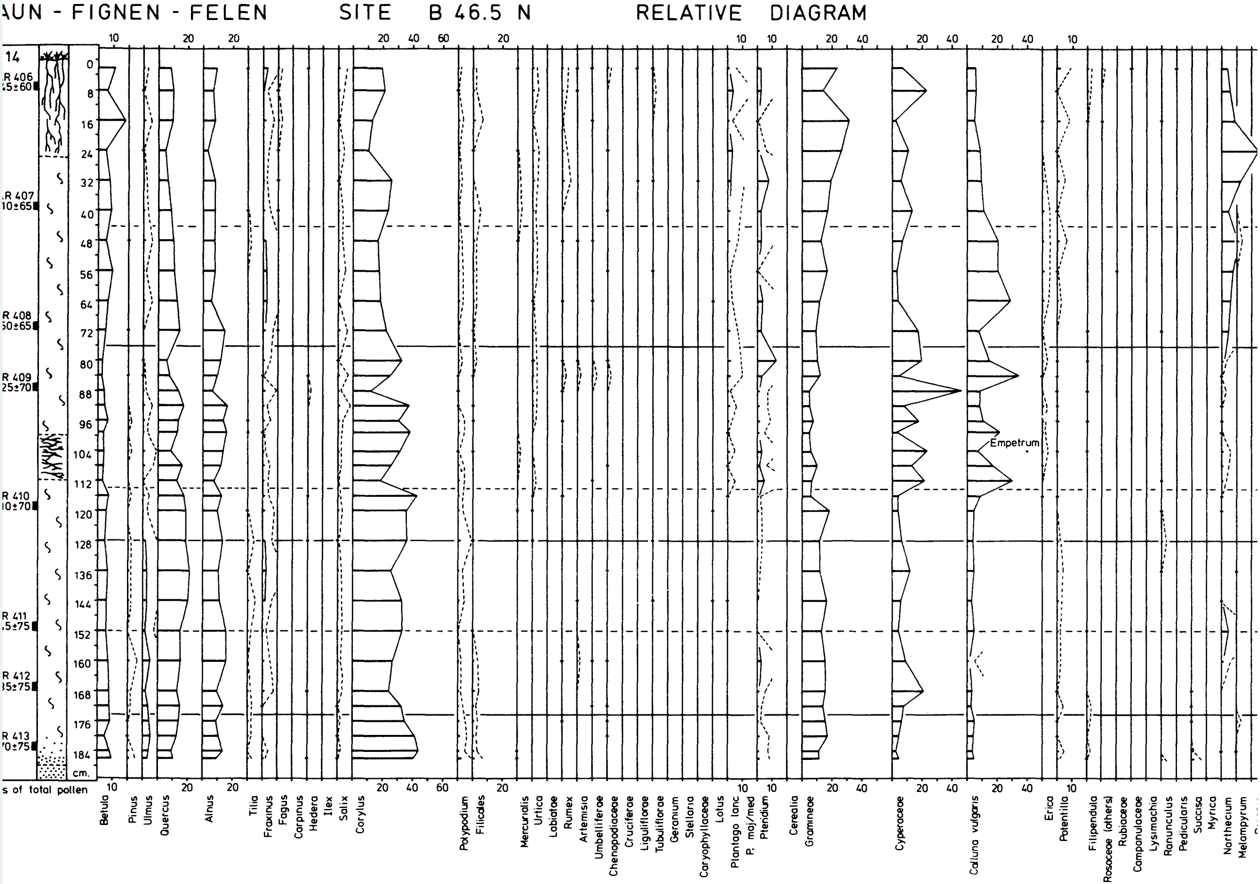
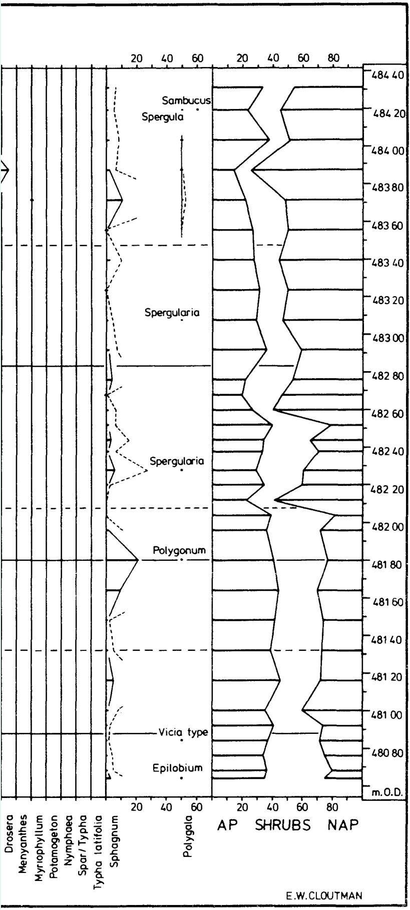
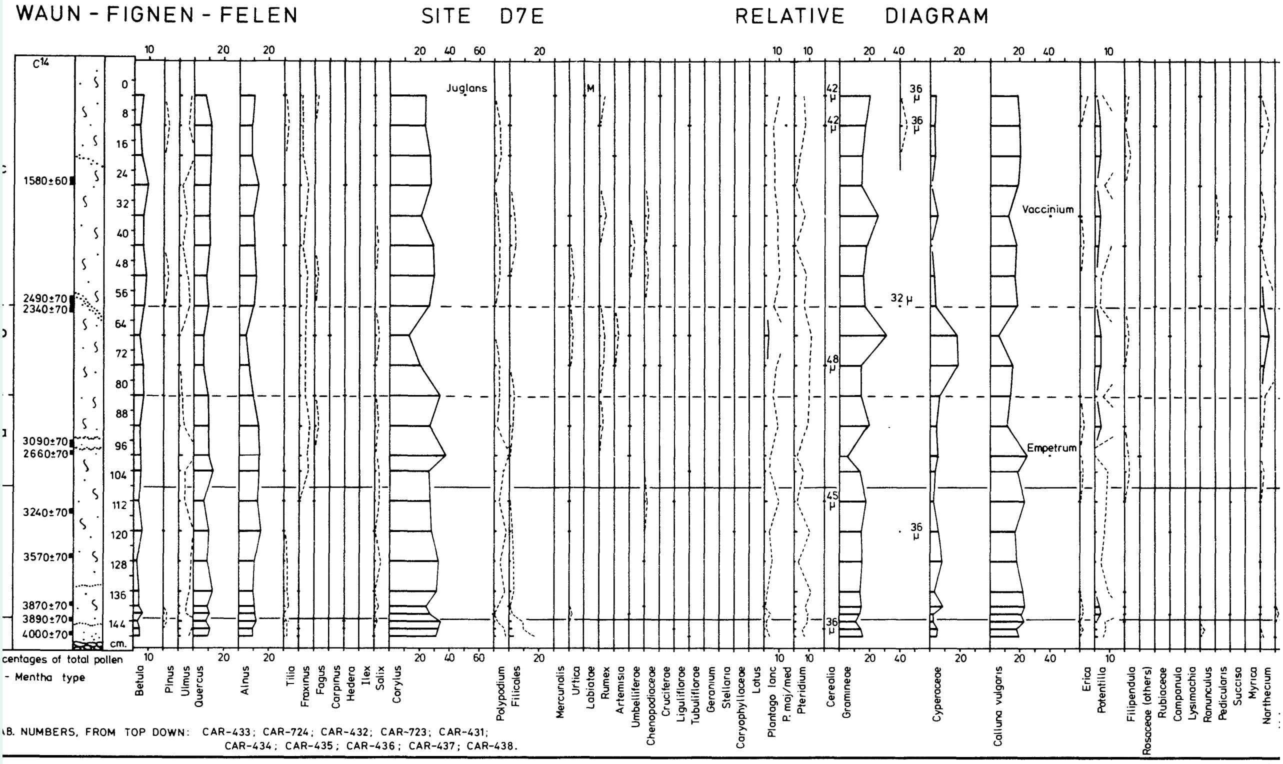


FIGURE 17. Relative total pollen diagram from site B46.5N at Waun-Fignen-Felen. Within the main eastern blanke mineral soil here remained uncovered by peat for the longest period. (Details as for figure



t peat area investigated the
5.)



IGURE 18. Relative total pollen diagram from a site (D7E) at the edge of the basin at Waun-Fignen-Felen, and at the base of th side. Peat accumulation began notably later here than at other sites in the main bog area investigated. (Details as for figu this site than at all others (see Appendix 3).)

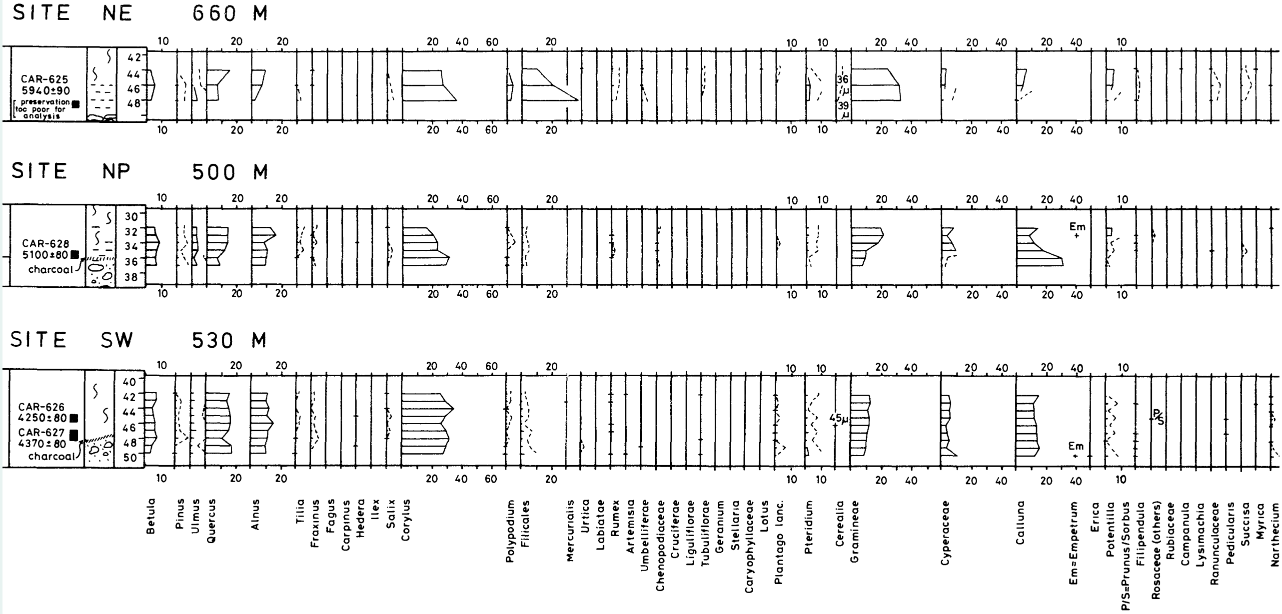
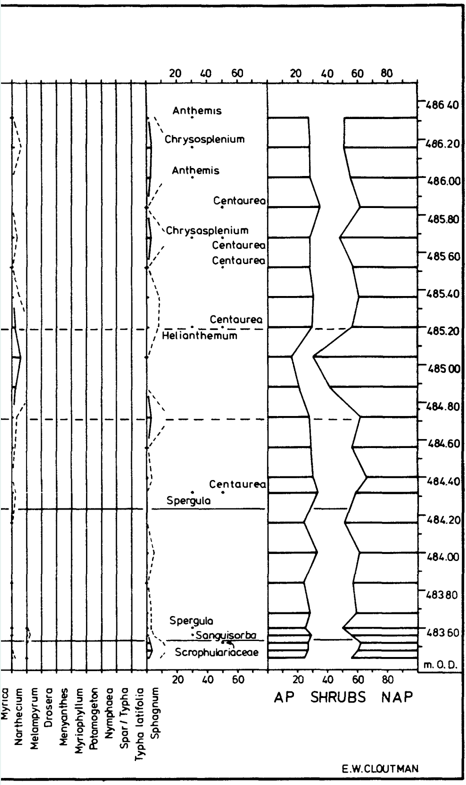
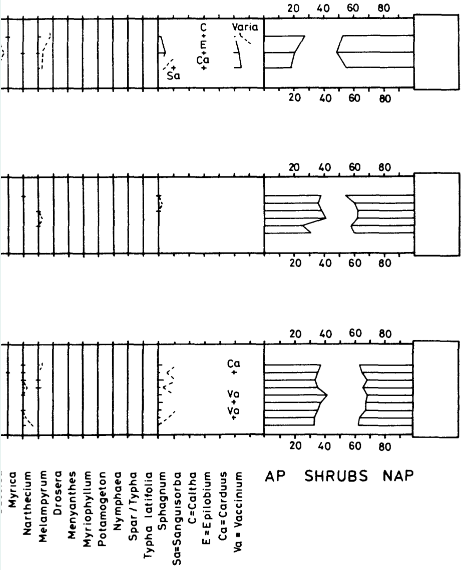


FIGURE 19. Relative total pollen diagrams from the basal deposits at three outlying sites (NE, NP and SW) Stratigraphic symbols are given in figure 4 and site locations in figure 2.



the steep slope of the limestone at the western
gure 5. The influx values are much higher at



V) at Waun-Fignen-Felen.

exceptions are EE17E, E1N, and E13N (possibly also A78E and G00), which are mainly marginal to the basin. Possibly the basin and its margins had by now become too wet even for the growth of alder.

(iv) *Gramineae* (*figure* 23)

1. Taking the preferred dating for the base of B125N (see p. 168), the high Gramineae values at *ca*. 8400–8200 years BP at the base of that profile are strongly suggestive of open conditions near the site long after the end of the Late-Devensian. These open conditions may either have persisted from the Late-Devensian or alternatively have come into existence after a period of afforestation. In either case, it appears probable that their existence is related either to grazing or to human activity or a combination of both. This point is discussed further in §5*d*.

2a. Two of the sites, E1N and B32S, which are adjacent, and possibly also B90S (again adjacent), show a distinct rise of the Gramineae curve at about 5000 years BP. This could well be due to the establishment of a grass-dominated community on the peat surface (possibly involving *Molinia*).

2b. At E13N, however, there is a distinct fall of the curve. This is related to the cessation of reedswamp conditions at the site as shown by the stratigraphic evidence (see figure 14 and Appendix 1).

(v) *Calluna* (*figure* 24)

1. At B125N the *Calluna* curve rises to *ca*. 20% at *ca*. 7900 years BP. A similar rise is seen at B90S, but this is not so well dated (see p. 163). It is notable that no such rise is seen in the centre of the basin (at G00) and thus in all probability a local event is recorded. The maximum of the *Calluna* curve in both cases is *ca*. 25% of the total pollen. Now, according to Goddard (1971), values from open *Calluna*-dominated heath away from woodland are generally greater than 25%, but she records precisely this value from the edge of a (pine) wood. In no case in her examples is the *Calluna* value above 10% where it was not a constituent of the vegetation at the sampling site. Evans & Moore (1985) do not record values of less than *ca*. 20% of total pollen in surface samples from open moorland in Northumberland where *Calluna* was present within a few metres. The relatively high values of *Calluna* at the base of the B125N and B90S profiles almost certainly, therefore, represent growth of heather at the sampling sites.

2. There is a marked difference in *Calluna* values between the sites as the accumulation of mor or peat begins. The broad difference is between values less than *ca*. 6% and greater than *ca*. 20%. According to the findings of Goddard (1971), in her studies of modern pollen rain, these values can be taken as showing local absence and local presence respectively.

The sites at which heather was initially present (2a) are EE17E, F117S, B32S, E188S and A78E. The sites at which heather was initially absent (2b) are E1N, E13N, A16W, B90S and B46.5N. These latter form a consistent group with the first two being basin margin sites. Accumulation of organic material began at the first three in the period 6700–6400 years BP. At B46.5N, however, peat accumulation began somewhat later.

3. Most of the sites listed under 2a as having high initial *Calluna* values have a substantial decline of the curve at *ca*. 6000–6200 years BP, as does the additional site B90S from the main blanket bog area. These sites appear to have been generally more heathy than others and (with the exception of EE17E; see 4) the heath dominance appears to have ended at roughly

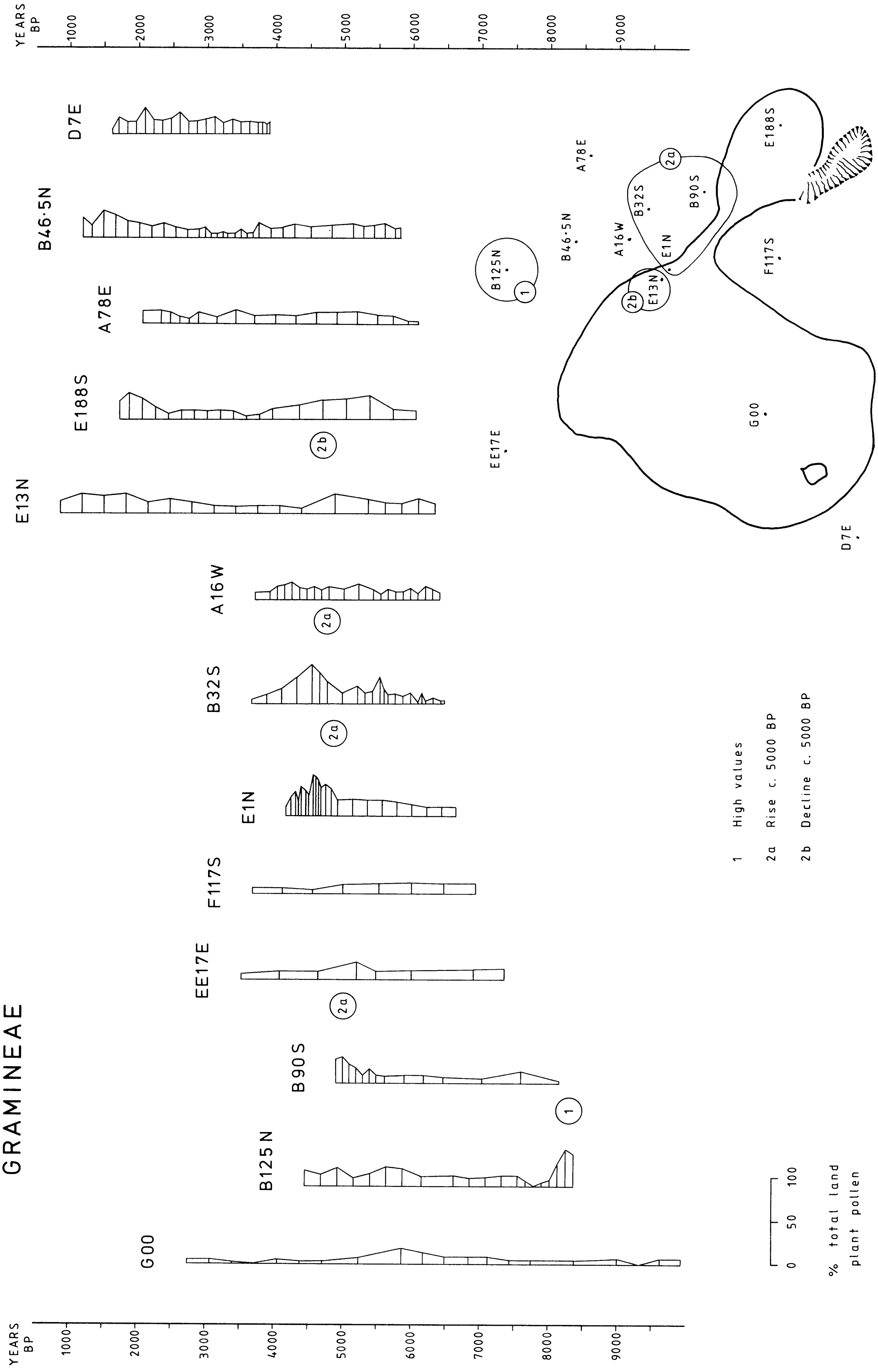


Figure 23. Pollen curves for Gramineae. The major features are numbered 1–2b. (Details as for figure 20.)

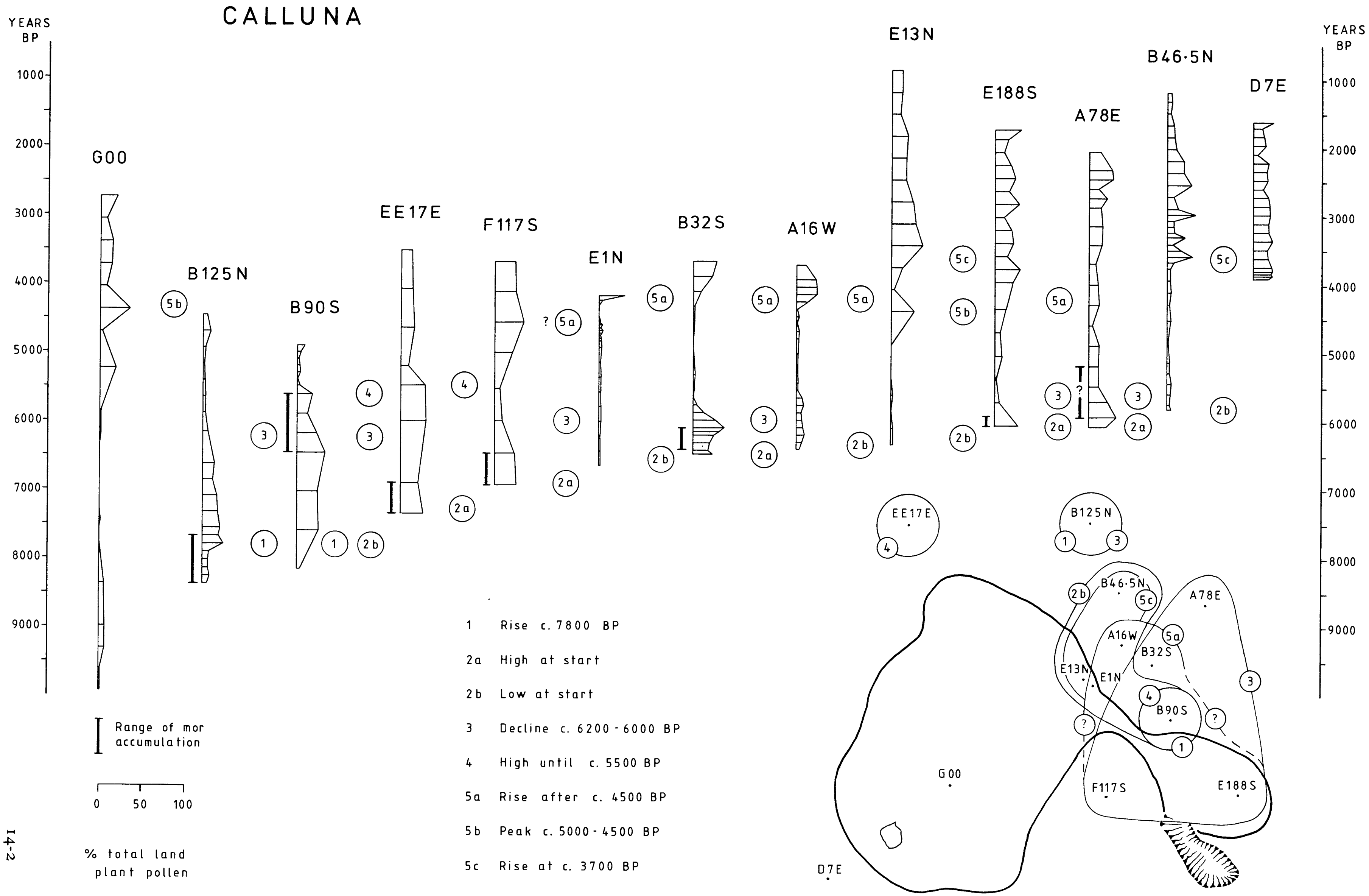


FIGURE 24. Pollen curves for *Calluna*. The major features are numbered 1–5c. (Details as for figure 20.)

the same time. The sites form a consistent group on the eastern side of the main blanket bog area (see feature 3 on map in figure 24). The decline of heather is related to the transition between mor and ombrogenous peat at F117S and B32S (and possibly also at A78E).

4. At B90S a marked decline of the *Calluna* curve associated with the mor to blanket peat transition occurs at a later date than at those sites mentioned above; that is at *ca.* 5500–5600 years BP. As an exception to the general rule it is also at this time that the *Calluna* curve declines for the first time at EE17E, although it is not there associated with the mor–peat transition. There is also a peak in the *Calluna* curve at this time at G00, presumably connected with the vegetation of the blanket peat which had by this time replaced the former reedswamp at the site.

It is noticeable that in the period from 5500–5600 to around 4000 years BP, the majority of sites have relatively low *Calluna* values. This presumably indicates that the surface of the blanket peat, which by now covered most of the area sampled, was relatively damp.

5. After this period of low values ending around 4500 years BP (though as late as 4200 years BP at B32S and A16W) there is a general rise or peak of *Calluna* values (see 5a and 5b; there is no evidence from B90S although it is tentatively included in the group in the map). This general rise of values suggests that the surface conditions of the bog became drier. At sites G00 and E13N the high *Calluna* values and apparent dryness appears to have been temporary (5b). These sites are in the former reedswamp area.

The exception to the general increase in heather cover in the main blanket bog area is B46.5N, which appears to have been relatively heather-free until *ca.* 3700 years BP when there is a prominent rise of the curve (5c). It is notable that this rise is connected with a decline of the *Corylus* curve (figure 17) which, as we have seen (*Corylus*, point 7; figure 21), may well have persisted close to that site. There is a similar late increase at E13N.

(vi) *Trees and shrubs* (AP+S) (*figure* 25)

1. Before *ca.* 5000 years BP there appear to be three different levels of the AP+S curve. Several sites have values above 70% (1a). These are B125N, B90S, F117S, E1N, B32S, A16W, A78E and B46.5N. As will be seen from the map in figure 25, these form a consistent group in the eastern blanket-peat area. Two sites, however, at opposite ends of transect E (EE17E and E188S) have values consistently below 70% (1b). These sites are marginal to the main blanket-bog area, which appears at this time to have been carrying a greater cover of woodland. Because, by *ca.* 5000 years BP all the sites concerned were actively accumulating blanket peat, the question is raised as to where such woodland could have been growing. Bearing in mind that the date of peat initiation has been shown not to be uniform, it is possible that there would still have been areas where peat growth had not yet begun within the area delimited as 1a on the map, or close to it, perhaps to the northeast. Certainly the outlying site NP to the north (see map, figure 2, and figure 19) did not begin to accumulate peat until *ca.* 5100 years BP, so mineral soils would have been available in that area long after the main bog area had become largely peat covered. An alternative explanation would be growth of woodland actually on the peat surface, although there is little evidence of this other than at site E1N at about 4900–4700 years BP.

Values for AP+S substantially below 70% (1c) are recorded at two sites (G00 and E13N). These are both in the basin area and the low values are undoubtedly related in part to the high NAP productivity of local fen and reedswamp.

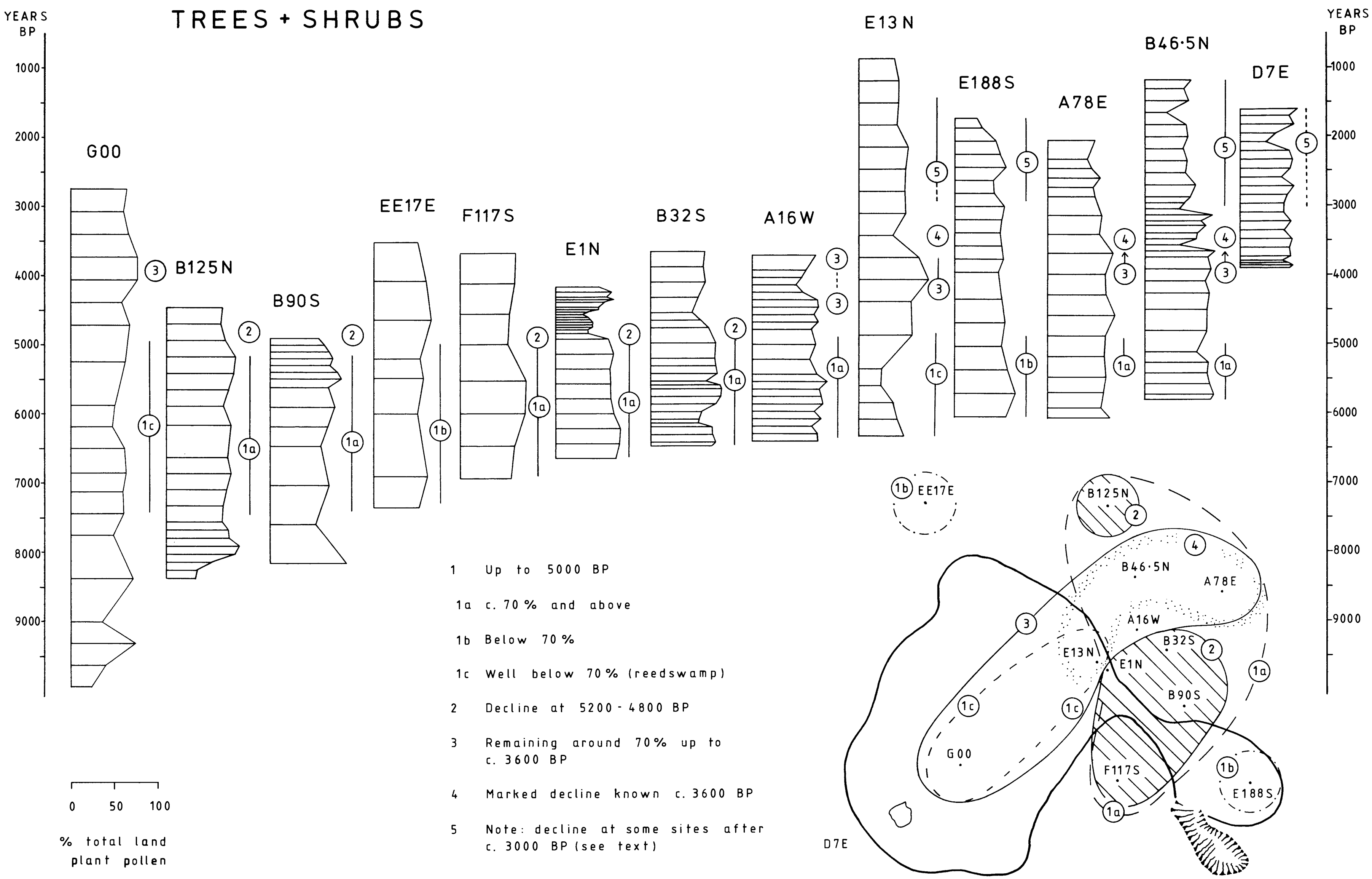


FIGURE 25. Pollen curves for trees and shrubs. The major features are numbered 1–5. (Details as for figure 20.)

2. Between *ca*. 5200 and *ca*. 4800 years BP there is a decline of the AP + S curve at some of the sites within the 1a area. There is a southern group comprising E1N, B32S, B90S and F117S, and to the north there is B125N. A real woodland decline in the area may well be represented (see 3, below).

3. In complementary fashion there is a central group of sites (G00, E13N, A16W, A78E and B46.5N) at which the AP + S values remain around 70% until *ca*. 3600 years BP. This appears to imply the persistence of woodland somewhere in the central blanket-bog area. At first sight it is curious to see the basin sites G00 and E13N in this group. The high AP + S values, particularly *Quercus*, at E13N around 4000 years BP, however, may be related to the local existence of woodland during the presumably dry phase when *Calluna* roots were present (188–196 cm).

4. Only five sites are well represented after *ca*. 3600 years BP and at three of these (grouped in the central blanket-bog area) there is a marked decline of the AP + S curve. It is notable that the two exceptions, E188S and D7E, are both close to the steep limestone slopes at the edge of the main bog area. The decline may thus again record events within the main bog area or even on the bog surface itself. Indeed, the AP + S decline at B46.5N coincides with evidence of burning (see p. 175) and the last of the very high AP + S values occurred in a black, greasy peat containing charcoal fragments (112–134 cm, see stratigraphic record in Appendix 1 and figure 17). The black peat may conceivably have been supporting woodland.

5. At all the sites represented after 3000 years BP there is a decline of the AP + S curve which may in part be due to climatic effects. At E188S, for instance, the decline is accompanied by increasing values for *Narthecium* possibly indicative of increased surface wetness. Bronze Age and later clearances may also be involved (see for instance E13N, zone 6, p. 173).

(*b*) *Reconstruction of the vegetational history in three dimensions*

A series of six annotated maps is presented in figures 26–31. These bring together the stratigraphic, pollen analytic and radiocarbon dating evidence to illustrate the vegetation spatially at Waun-Fignen-Felen in a sequence of stages between *ca*. 8000 and *ca*. 3700 years BP. The time intervals have been chosen on the basis of the changes that can be distinguished. The quality and quantity of information changes through the course of the 4000 years covered. The sites from which pollen and dating evidence is available for each stage are indicated symbolically on the maps. Because the study was designed principally to yield information about the blanket-peat area, data for the western part of the basin are sparse. For that area, the reconstruction relies mainly on the stratigraphic information and is advanced with reserve. The nature of the evidence and its interpretation is outlined below.

Map 1 (*figure* 26), *ca*. 8000 *years* BP

The 416 cm sample at site G00 has all the common trees substantially represented (save for alder, which had not yet arrived) but has a predominance of hazel pollen. The total NAP is approximately 30% but much of it is Cyperaceae, presumably derived from sedges growing close to the sampling point. Bearing this in mind, together with the fact that the sampling point is some distance from any mineral soils, we may take it that the landscape generally was reasonably well wooded. At B125N at this time, however, the basal high Gramineae values are falling, *Betula* values are high and the *Corylus* curve is rising steeply. It has been argued (p. 168) that a clearing had probably been made in the woodland near this site that was recolonized by birch and subsequently hazel. It is possible that the area around B90S was also dominated

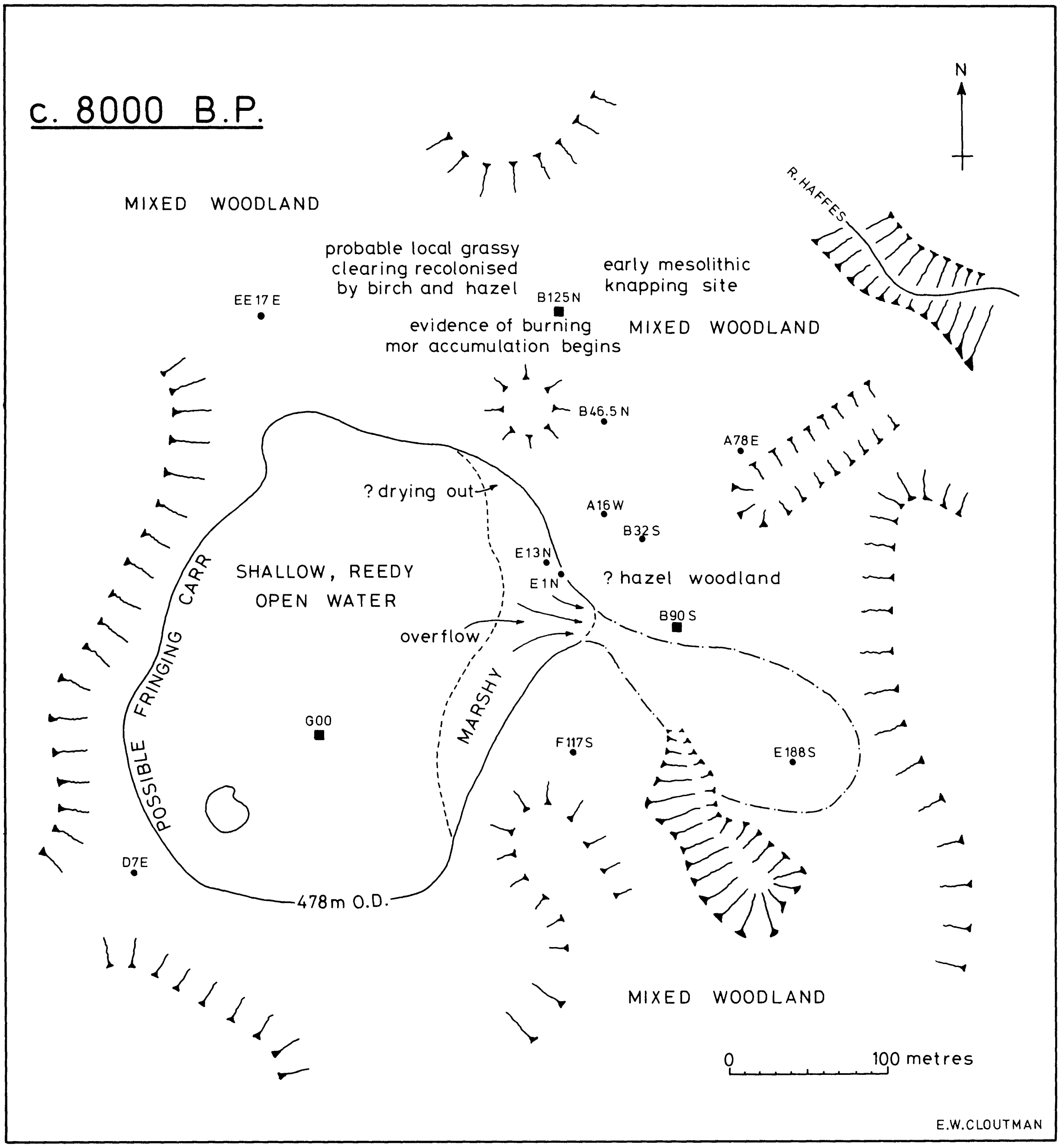


Figure 26. Reconstruction of the vegetation cover at Waun-Fignen-Felen at *ca.* 8000 years BP based on a consideration of the stratigraphic and pollen analytical evidence (see text). The sites that yield pollen analytical data for the time in question are indicated by square symbols. (The conditions indicated in the western basin area are the least dependable because the dating and pollen analytical evidence there is at a minimum.)

by hazel growing on mineral soil, although the dating evidence is weak. From the presence of wood in the basal deposits at the western side of the basin there may have been a fringe of carr along the shore, but the deposit has not been dated.

There is positive evidence of reedy conditions in the centre of the basin (G00) but the eastern edge of the basin may have been marshy, as deposition had not yet started at E1N and E13N (but see description of map 2, below). The eastern shore of the basin is tentatively indicated at a level of 477.5 m (the altitude of the 416 cm sample at G00, though if much compression has taken place it could have been higher; that is, more easterly).

Map 2 (*figure* 27), *ca.* 7500 (–7000) *years* BP

At *ca.* 7500 years BP organic deposition seems not to have begun at sites E1N and E13N. Although it is possible that this area was still dry or marshy, the lack of deposition appears anomolous.

The mineral surface at both sites (at levels of 477.7 and 477.8 m respectively) is lower than the 7500 years BP level in the centre of the basin at G00 (sample at 368 cm; altitude *ca.* 478.2 m). The mineral soil surface at E1N and E13N should, therefore, have been below the normal water level. Deposits may, of course, have been eroded, but it appears more likely that deposition of organic material was prevented by some kind of disturbance or by water movement. It is not impossible, however, that while reedy muds were being deposited in the centre of the basin, sands were being deposited at the margin owing to wave action. On the other hand, disturbance by man or animals could have been responsible.

The lowest deposits in and around the narrow outlet to the basin (south of E1N) are reedswamp peats (see transects C, 72.5–90W; F, 0–30S; A, 72–108W: figure 4). These are unfortunately undated but may well be referable to the period under discussion. Presumably it was the accumulation of these deposits that blocked the outflow of the basin into the gorge and allowed accumulation of reedy muds to continue after the early Post-glacial, during which time water had been confined behind a threshold of mineral material.

As with the 8000 years BP map, the basal woody deposits to the west of the basin suggest the probable presence of carr. There is evidence from both G00 and EE17E of the presence of alder by *ca.* 7000 years BP and it is possible that it gained its first foothold on the northern and western margins of the basin.

On the higher ground at B125N, hazel appears to have been reduced (as earlier, had birch) as mor gave way to ombrogenous peat supporting heath (see p. 169). Around EE17E mor formation continued under damp heath (see pp. 170 and 205).

By comparison with B125N the reduction of hazel and increase of heaths near the base of the B90S diagram may also have been taking place, although these events are not strictly dated. Indeed, the whole of the ridge area between B125N and B90S could well have had much hazel growing on it; we have seen (p. 181; figure 21, point 2) a concentration of high hazel values in this area before 6200–6400 years BP that may be a continuation of an earlier dominance. Unfortunately, direct evidence of its abundance before *ca.* 7500 years BP is lacking except at B125N.

Map 3 (*figure* 28), *ca.* 6500 *years* BP

By 6500 years BP accumulation of organic deposits was under way at nine of the sites and the reconstruction in general is based on much firmer evidence.

Accumulation had begun at both E13N and E1N. At the former site there are distinct reedswamp peats, but at the latter there is a sandy mud during the deposition of which there appears to have been some erosion or soil disturbance (see p. 171 and map 2 (figure 27)). It would be expected that deposits further into the basin, adjacent to these sites, would be of similar aquatic or telmatic nature. Immediately to the west and north of E1N and E13N,

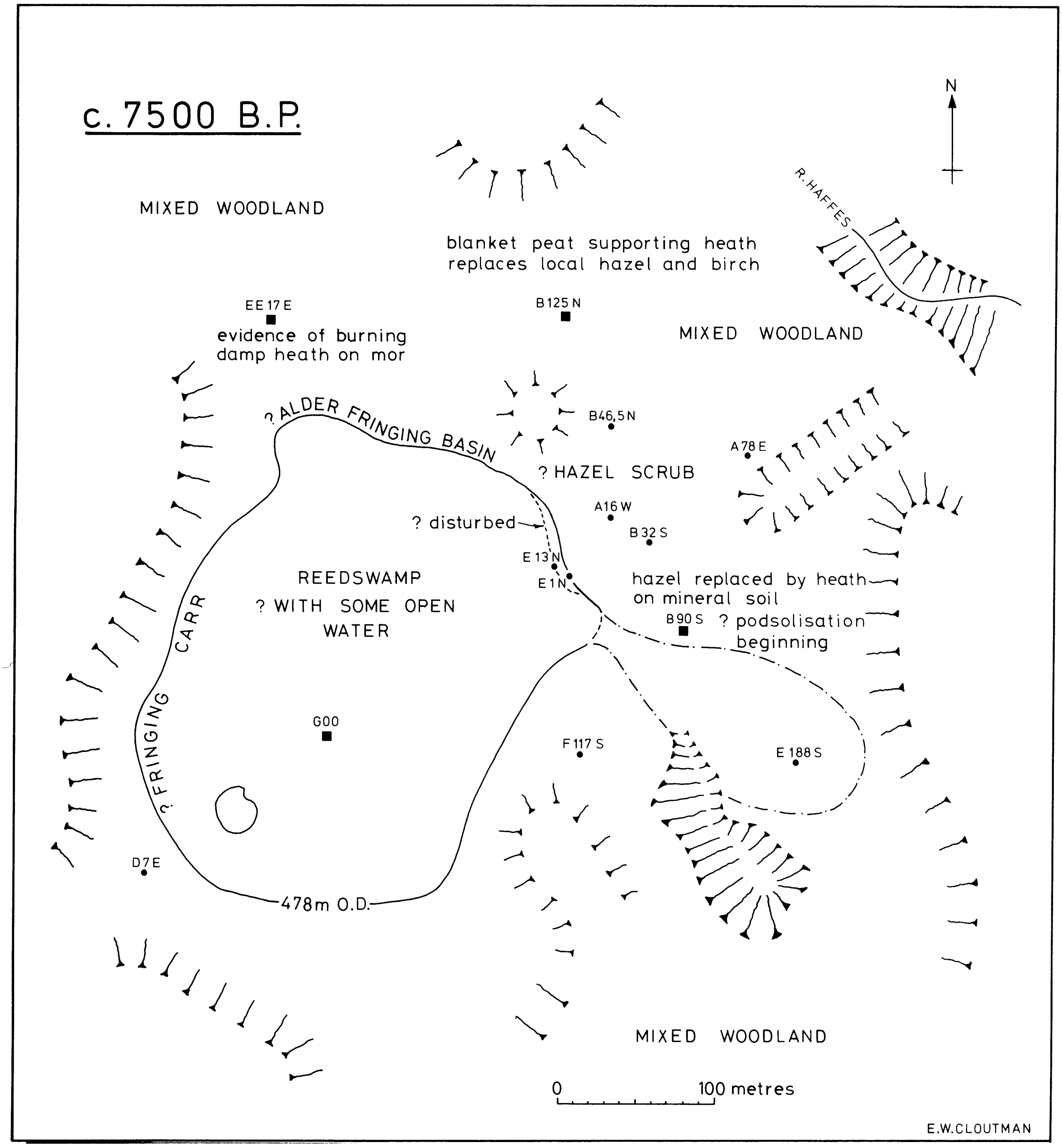


Figure 27. Reconstruction of the vegetation cover at Waun-Fignen-Felen at *ca*. 7500 years BP. (Details as in figure 26.)

however, the deposits often contain *Calluna* and *Eriophorum* and must therefore have accumulated under acid conditions. Consideration of the sections suggests that a tongue of acid peat probably grew out, or became otherwise established, to the north and west of E13N and progressively covered the basal reedswamp deposit. Yet further to the west there may have been some open water. (This reconstruction is based on the sections (figure 4), which show that acid peats lie at a lower level than the top of the main reedswamp and mud deposits of the basin

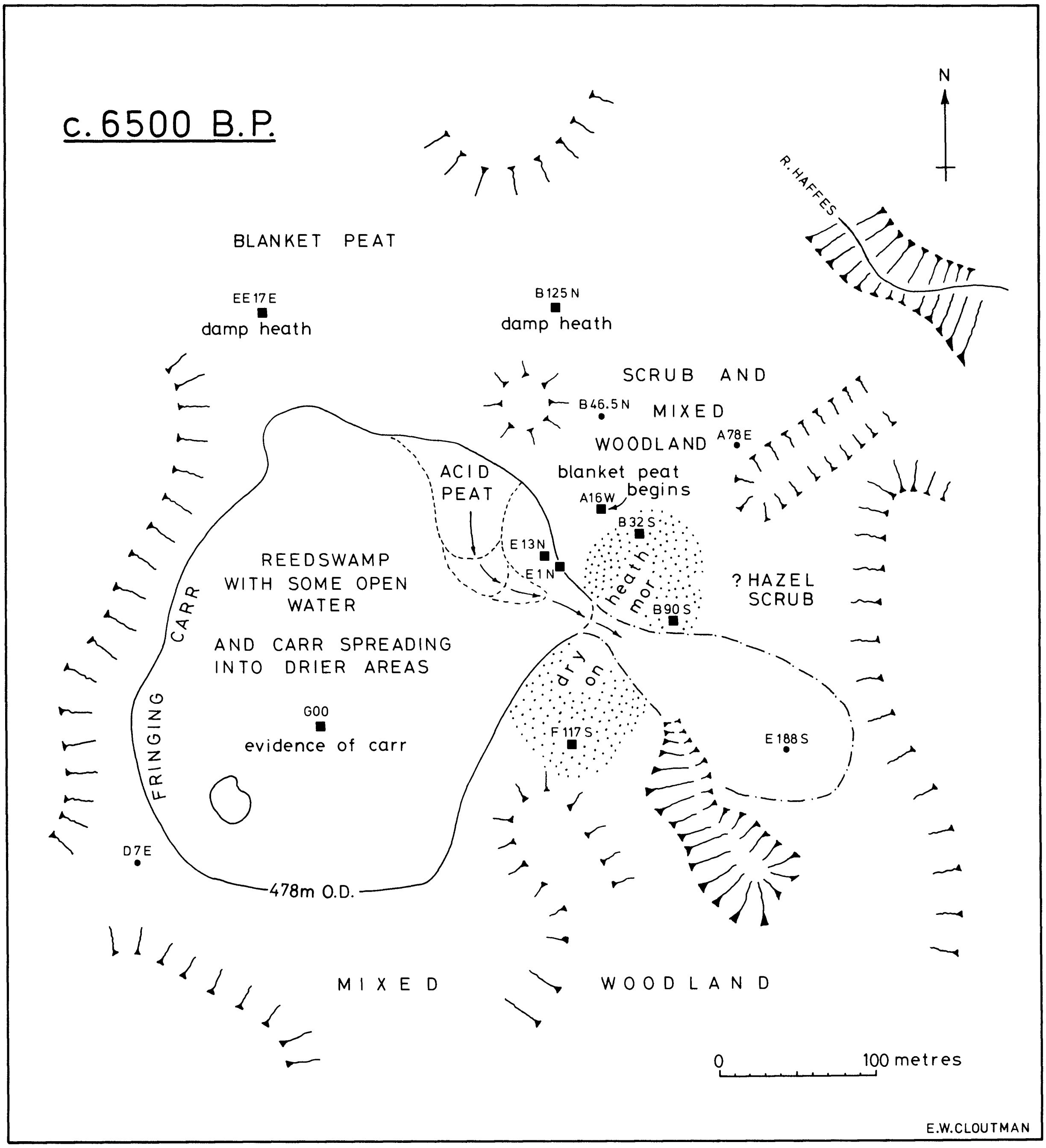


Figure 28. Reconstruction of the vegetation cover at Waun-Fignen-Felen at *ca.* 6500 years BP. (Details as in figure 26.)

further west. At E90N a humified peat with *Eriophorum* directly overlies a basal reedswamp layer contiguous with that at E1N. There is a similar sequence at A108W where granular peat with *Calluna* overlies the thin basal reedswamp peat. At C72.5–90W blanket peat overlies the basal reedswamp peat, and the same is true in transect F across the outlet of the basin.) Presumably, the growth of these acid peats (which cannot be dated precisely) was responsible – by raising the height of the outflow – for the continuation of aquatic conditions in the major part of the basin. In the basin area there would have been a maintenance of high base status by the drainage waters from the limestone slopes to the west of the site. Nevertheless, some wood appears in the section at site G00 at *ca.* 6500 years BP, and carr may have become established in some areas.

Turning to the higher ground we find that B32S, B90S and F117S all have mor deposition with relatively high *Calluna* values. We can thus envisage a south-central area of relatively dry heath. The two former sites also have high *Corylus* values at this time, suggesting the nearby presence of hazel-dominated scrub.

Another more northerly group of sites (B125N, A16W and B32S) all have relatively high AP+S values (over 70%) suggesting proximity to woodland, hazel again being an important constituent. At one of these sites (A16W) there is no basal mor deposit and high *Calluna* values are lacking. The *Corylus* values are high, but there are also substantial values for *Quercus* and *Betula*. There must, therefore, have been some mixed woodland nearby. (The basal radiocarbon date is *ca.* 5600 years BP but there are reasons for believing that blanket-peat initiation at this site began in the period under discussion, see p. 211.) Two other sites were by now under blanket peat, which had superseded the basal mor. These are B125N and EE17E, both at the northern margin of the area, which appear to have been supporting damp heath.

Map 4 (*figure* 29), *ca.* 5700 *years* BP

Deposition in the centre of the basin at G00 had by now changed from reedswamp peats to blanket peat. It seems likely that the acid peat moved westwards across the basin from an earlier point of initiation. It is noteworthy that in transects A and C (figure 4) the reedswamp peats rise westwards. Despite possible complications due to compression and compaction, this suggests that a western fringe of reedswamp may still have existed. A tentative margin to the acid peat is drawn where the reedswamp peat rises above 479 m (the altitude of the 6700 years BP level at site G00). At the eastern side of the basin we certainly find reedswamp still in existence at E13N, and continuation of deposition of the sandy mud at E1N.

Accumulation of blanket peat was under way at all sites away from the basin area except for D7E (where accumulation had not yet begun), A78E and B90S. At A78E there was a dark brown, greasy, mor-like peat with charred *Calluna* stems and leaves, whereas at B90S mor was still present and, from the high *Calluna* values, dry heath apparently persisted. Two other sites, both to the west, had high *Calluna* values. These are G00 and EE17E where the ground flora was again probably heathy.

All sites continue with relatively high values for AP+S. There must, therefore, still have been substantial woodland cover in the area. The values are generally lower (less than 70%) in the basin area (sites G00, E1N and E13N) and at the ends of transect E (EE17E and E188S). These latter areas must have been the most remote from trees. The persisting woodland was thus perhaps mainly on the ridge to the west of the gorge and on the higher ground to the northeast.

Map 5 (*figure* 30), *ca.* 4700 *years* BP

With the accumulation of blanket peat to a higher level at site G00, it is likely that the area of reedswamp was now even more restricted, having probably disappeared from the southwestern end of transect C (figure 4) (where it rises to a lower elevation than in transect A).

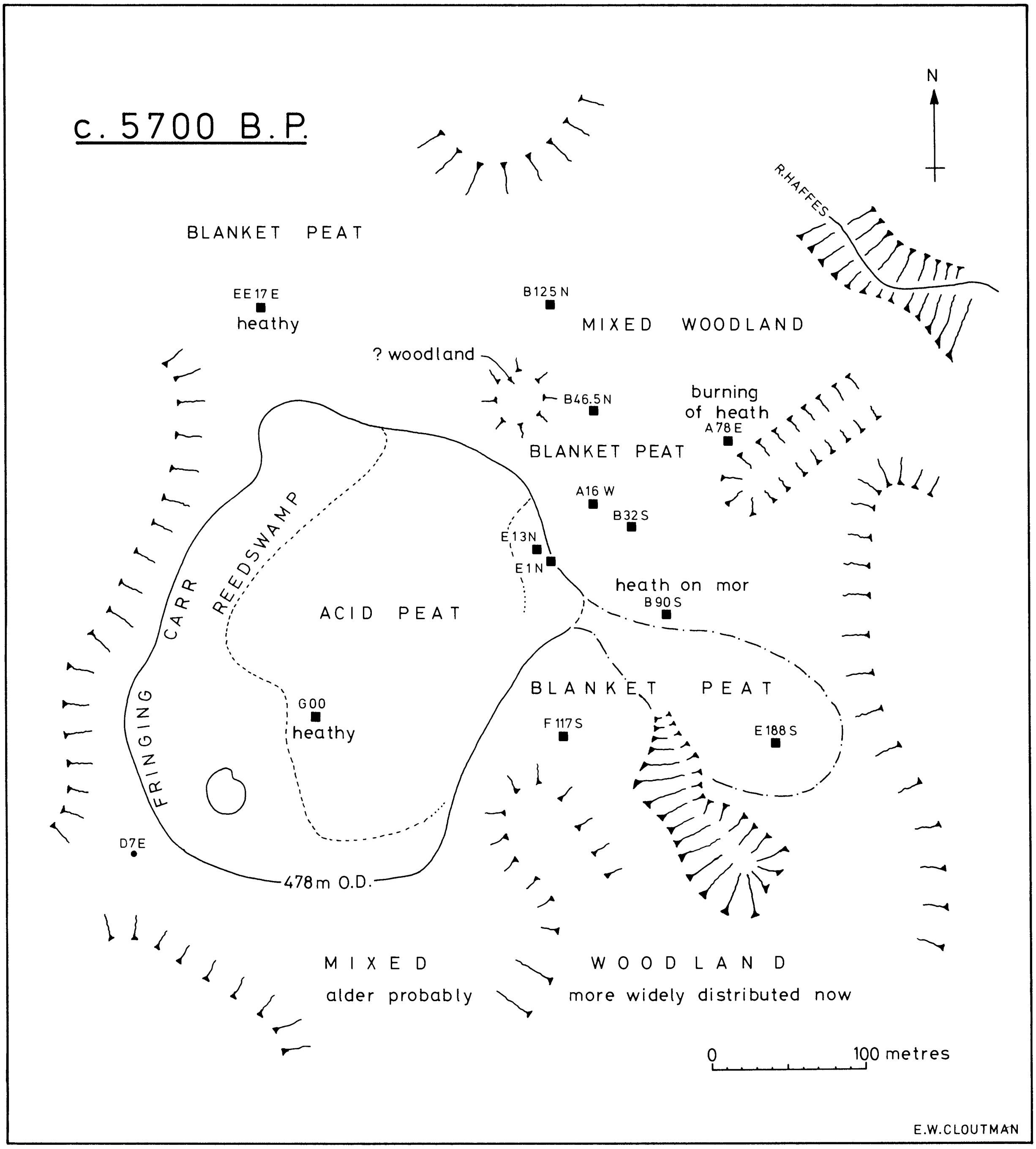


Figure 29. Reconstruction of the vegetation cover at Waun-Fignen-Felen at *ca.* 5700 years BP. (Details as in figure 26.)

Total tree and shrub values persist at over 70% at the group sites to the north of the main blanket-peat area (B125N, B46.5N, A78E and A16W), which appears thus still to have had some woodland nearby or even on the peat surface.

At E1N and the adjacent site B32S there are unusually high values for Gramineae (as also, perhaps a little earlier, at the top of the B90S diagram). These features suggest a small grassy area in the middle of the blanket peat. At E1N (and E13N) there was subsequently a layer with

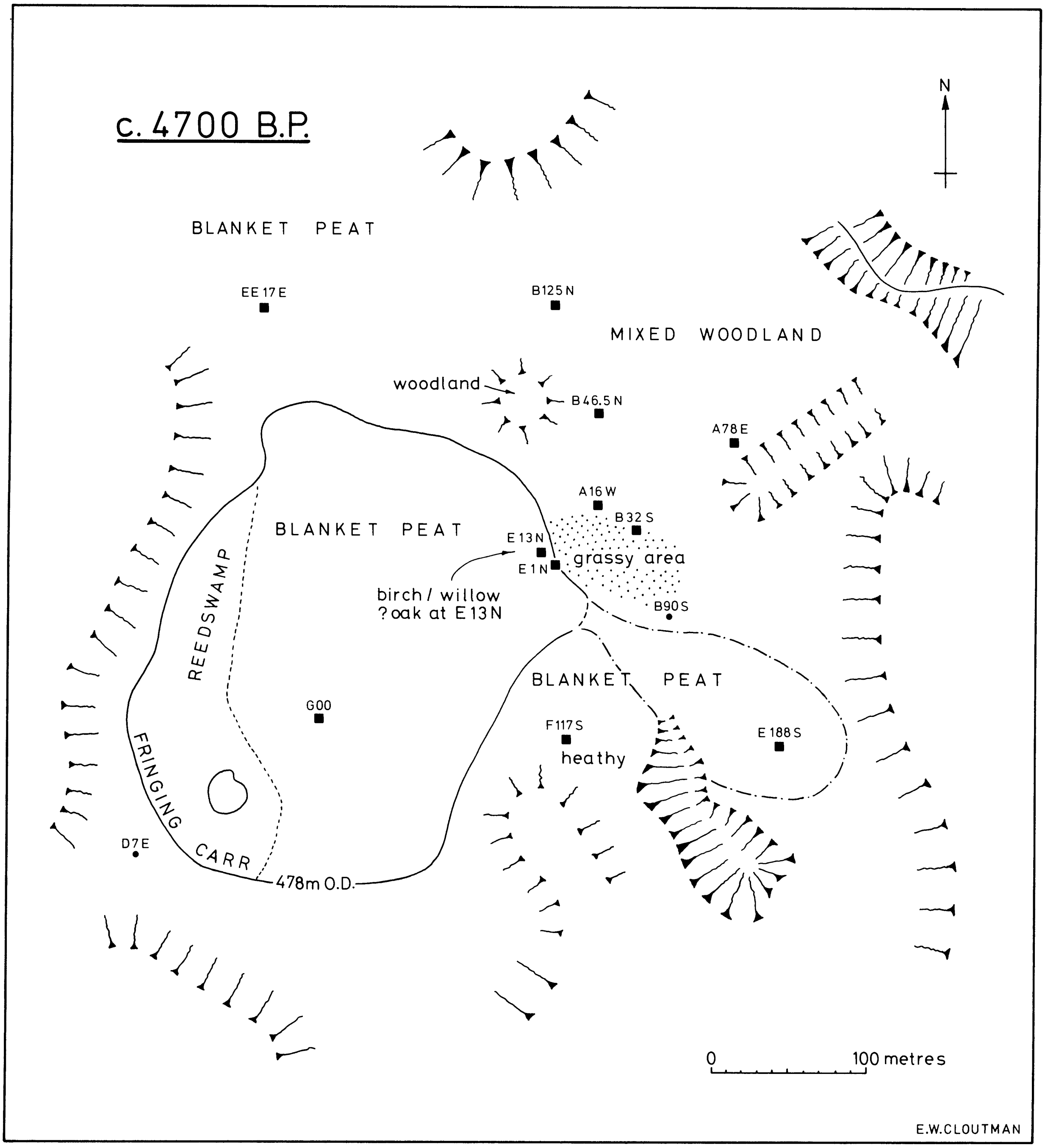


FIGURE 30. Reconstruction of the vegetation cover at Waun-Fignen-Felen at *ca.* 4700 years BP. (Details as in figure 26.)

much brushwood among which *Betula* and *Salix* was identified at E1N. A local area of carr thus existed which, from the high *Quercus* values at E13N, may have contained some oak.

Map 6 (*figure* 31), *ca.* 3700 *years* BP

At all the sites from which information is available, blanket peat was accumulating and it is likely that the whole area was now substantially peat covered. There is a general decline of tree and shrub pollen, which confirms that trees had now virtually disappeared from the area. The

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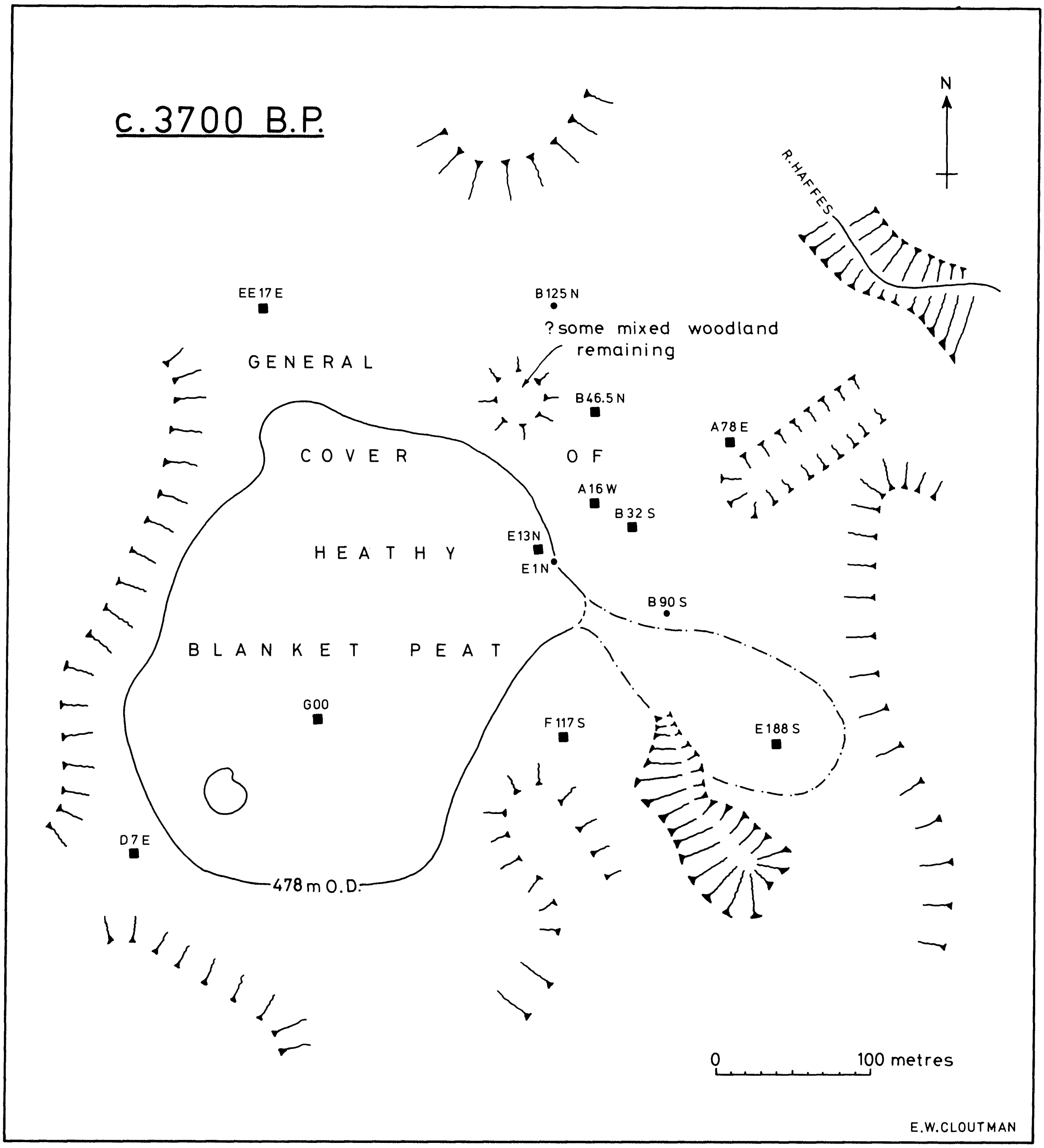

Figure 31. Reconstruction of the vegetation cover at Waun-Fignen-Felen at *ca.* 3700 years BP. (Details as in figure 26.)

exception may have been the ridge immediately to the west of site B46.5N where there are renewed high AP+S values. At all sites the *Calluna* values are relatively high, suggesting that the blanket-peat surface was rather dry.

(*c*) *Initiation of mor and ombrogenous peat: the possible role of man in the Mesolithic period*

The ^{14}C determinations for levels within basal mor, and for the base of the ombrogenous peat at the various sites, are given in table 2.

Table 2. Carbon-14 dates (BP) for mor and basal ombrogenous peat

	dates within mor (where present)		date of base of ombrogenous peat	
(a) non-basin sites				
(i) old				
B125N	7830 ± 100	(CAR-508)	7610 ± 90	(CAR-507)
	7940 ± 90	(CAR-509)		
EE17E	7020 ± 90	(CAR-621)	> 5660 ± 80	(CAR-622)
(ii) intermediate				
F117S	6770 ± 90[a]	(CAR-633)	5780 ± 80	(CAR-632)
B32S	5860 ± 80	(CAR-342)	> 5770 ± 80	(CAR-341)
	6520 ± 100[a]	(CAR-343)		
B90S	6490 ± 90[a]	(CAR-502)	5490 ± 80	(CAR-501)
E188S	6210 ± 90[a]	(CAR-445)	> 5430 ± 80	(CAR-772)
NE	5940 ± 90[a]	(CAR-625)		
A78E	5530 ± 90	(CAR-335)	? > 4310 ± 80	(CAR-334)
	5340 ± 80[a,b]	(CAR-336)		
A16W	absent		5790 ± 70	(CAR-329)
B46.5N	absent		6570 ± 70	(CAR-413)
(iii) young				
NP	5100 ± 80	(CAR-628)	—	—
SW	absent		> 4250 ± 80	(CAR-626)
			4370 ± 80	(CAR-627)
D7E	absent		4000 ± 70	(CAR-438)
(b) basin sites (ombrogenous peat above topogenous peat or mud)				
G00	—		> 5770 ± 80	(CAR-688)
			6340 ± 90	(CAR-689)
E13N	—		5230 ± 80	(CAR-639)
E1N	—		4820 ± 80	(CAR-426)

[a] Basal dates.
[b] ?Too young.

Of those sites outside the basin area, only four (A16W, B46.5N, D7E and SW) lacked a distinct basal, black, greasy, amorphous layer, which we have referred to as mor. All sites had charcoal at the base, sometimes (as at SW) in the form of a distinct band at the peat–mineral interface, even where a mor layer was absent. The basal ombrogenous peats contained either microscopic or macroscopic charcoal at all sites.

The sites outside the basin appear to fall into three groups so far as age is concerned, as follows.

A. Sites with mor dates between *ca.* 8000 and *ca.* 7000 years BP (B125N and EE17E).

B. Sites with mor dates between *ca.* 5500 and *ca.* 6500 (–6800) years BP (or basal ombrogenous peat dates between *ca.* 5500 and *ca.* 5800 years BP) (F117S, B32S, B90S, E188S, NE, A78E, A16W, B46.5N).

C. Sites with mor dates younger than *ca.* 5500 years BP (or basal ombrogenous peat dates younger than *ca.* 4500 years BP) (NP, SW, D7E).

The date of the beginning of accumulation of organic deposits outside the basin area ranges over almost 4000 years, from the oldest mor at B125N (*ca.* 7900 years BP) to the youngest ombrogenous peat on the hill slopes to the southwest of Waun-Fignen-Felen (*ca.* 4400 years BP at site SW) and within the basin area (*ca.* 4000 years BP at site D7E). As the work concentrated on the deeper peats, it would be expected that even younger peats could be found, as at the South Wales upland sites investigated by Chambers (1981) and in the Black Mountains of

South Wales (Moore *et al.* 1984) (as distinct from the Black Mountain on which the present site lies).

In view of the age range, the beginning of accumulation of organic deposits can hardly be attributed to a single climatic event. This does not rule out climatic change as a possible influence; any such effect would, however, have depended on a large number of factors such as the magnitude of the change, microtopography, aspect, soil type, drainage, vegetation cover and land use.

There is one common factor in virtually all the basal organic deposits, whether mor or ombrogenous peat, and that is the presence of charcoal. Only at site D7E was charcoal not obvious. In the mor deposits the abundance of charcoal was often such as to impart a black colour and a graphite-like texture. In the basal ombrogenous peats charcoal was less abundant, but it could occur as a distinct thin black band at the peat–mineral interface (as, for instance, at site SW). Certain instances have been quoted in which the charcoal appears to have resulted from heath burning (e.g. site A78E); in other cases it seems more likely to have resulted from the burning of woodland or scrub (e.g. site SW).

Two questions arise about these burning episodes. Firstly, were the fires natural or manmade? Secondly, is there any causal relation between the incidence of fire and the beginning of the accumulation of organic soils?

There is no direct method by which the origin of the fires can be determined. Charcoal layers are frequently found, however, in association with sites of prehistoric human activity, particularly in the Mesolithic period, and the use of fire as a deliberate form of land-use management in prehistoric times has been considered as highly probable by a number of workers (Mellars 1975, 1976; Smith 1970, 1984; Simmons *et al.* 1981; Jacobi *et al.* 1976; Tallis 1975). Mesolithic occupation sites are abundant at the peat–mineral interface at Waun-Fignen-Felen and a worked flint found at site A00 was at a level in the basal mor dated to 7700 ± 90 years BP (CAR-61). Bearing in mind the evidence of heath-burning at Waun-Fignen-Felen it is worth drawing attention to the work of Grant *et al.* (1981) showing that old heather is much less able to withstand grazing by red deer than young heather. According to other evidence mentioned by Grant *et al.*, heather is a substantial component of the diet of red deer ranging in mixed grass–heather communities. Heath-burning at Waun-Fignen-Felen, whether deliberate or accidental, could then have been indirectly beneficial to Mesolithic man. In Caithness, Robinson (1987) has concluded that fire played a major role in Mesolithic peat initiation and we discuss later the relation of burning to the initiation of organic soil accumulation at Waun-Fignen-Felen.

There is little recorded Neolithic material for upland South Wales (cf. Savory 1980, p. 212) but oblique arrowheads have been found on the eroded bog surface at Waun-Fignen-Felen. These are likely to date from late Neolithic times (S. Green, personal communication; Green 1984). It is notable that the charcoal layer and peat initiation at site SW belong to this period. There is thus some circumstantial evidence relating burning episodes to human activity.

Turning more specifically to the date of ombrogenous peat initiation, we see from table 2 that there is again a wide range. The oldest peat dates from approximately 7600 years BP (B125N) and the youngest from *ca.* 4000 years BP (D7E). Most of the dates fall within the range 5500–5800 years BP (though – by extrapolation – perhaps a little earlier). Now it is at around 6000 years BP that we see a rising trend in the *Alnus* curves at many of the sites, and the beginning of the curve at four of them (figure 22). It has been argued that alder actually became established in the basin area some considerable time before this. The expansion of alder could have a climatic explanation, in which case we might see the initiation ombrogenous peat as having a similar cause. On the other hand it has been argued by Smith (1984) that after an initial climatic change at the end of Boreal times the establishment and spread of alder is likely to have been encouraged by environmental damage by man. In the latter case we might also see the initiation of ombrogenous (blanket) peat as being connected with human activity. Deforestation and consequential rise of soil water tables that could have been part of this process have been detailed by Moore (1975) with reference to Neolithic environmental damage.

There is, however, yet another way of looking at the problem of the initiation of blanket peat. This is related to the prior accumulation of mor. We have already alluded to the fact that the mor deposits are extremely greasy and have a graphite-like texture. The question is raised, therefore, as to whether the impervious nature of the mor is connected with the initiation of blanket peat (see also Cloutman 1983). The possible importance of an impervious humus layer has been discussed in the case of late Neolithic–Bronze Age peats in northeast Ireland (Case *et al.* 1969; Proudfoot 1958) and of British blanket peats in general (Iversen 1964). It could be argued that because the mor began to accumulate at different times at Waun-Fignen-Felen, the blanket peat would be expected to be of different ages at the various sites. This is true up to a point; the oldest blanket peat above mor started to grow around 7600 years BP (site B125N) and the youngest some time after *ca.* 5100 years BP (site NP). But, as we have seen, at two of the sites a distinct mor layer was not involved (sites A16W and B46.5N). The development of blanket peat at these two sites began, however, in the period of general initiation (5500–5800 years BP) and could have resulted from lateral spreading from inception sites where mor was initially present. (Site A16W may be noted as being unusual, however, in that the lower peats may have supported some tree growth; see p. 173.)

It is striking that the high *Calluna* values associated with the mor layers generally decline once deposition has changed to ombrogenous (blanket) peat. We have seen that charcoal continues to be present, but generally as larger and more infrequent particles. A change in the frequency of burning may thus have been a contributory factor in the change from mor to blanket peat.

To draw these threads together a reconstruction must be attempted. The precise status of woodland vegetation before the accumulation of organic deposits outside the basin at Waun-Fignen-Felen is difficult to determine. The long pollen diagram from site G00 is much affected by local pollen, and only a little pollen has been obtained from the mineral soils outside the basin. There are, however, two pointers to the presence of woodland cover on the mineral soils. These are first, the AP+S value in the mineral soil at the base of the B90S diagram of approaching 90%, and secondly, the AP+S value of *ca.* 80% at the zone 1–2 transition at B125N. From the generally high *Corylus* values it appears that hazel must have had strong representation in this early woodland. We have argued that Mesolithic man probably created a clearing near site B125N around 8000 years BP and, from the evidence of burning, it seems likely that the appearance of heaths in formerly wooded areas in the period 8000–6000 years BP are also a result of human activity, even deliberate actions. Another reason for believing that this process of degradation to heath was probably induced by man's activities is the age and nature of the upland heath phase. Such a phase appears to be virtually absent elsewhere in Britain at such an early stage in upland vegetational history, although degradation to heath in the Mesolithic has been suggested by Dimbleby (Keef *et al.* 1965; Rankine *et al.* 1960). It may be noted, however, that in a more recent summary of this evidence Dimbleby (1985) appears more cautious in his conclusions in the light of new thoughts on the stratification of the Mesolithic artefacts for certain lowland sites.

Starting in the period *ca.* 8000–6000 BP, mor deposits accumulated under the heath, and there was a tendency for podsolization where the soil was sufficiently free draining. Regeneration of woodland, in particular the regrowth of birch, would have been prevented by burning or grazing. Given the impervious nature of the mor deposits, and lack of deep penetration by tree roots, there would have been a tendency for *Calluna* to be replaced by plants more tolerant of waterlogging, the whole process leading to the beginning of ombrogenous peat accumulation. Rushes appear to have had a considerable role in this process: seeds were found abundantly at site B125N, for instance (between 46 and 51 cm). The transition to ombrogenous peat took place at various times but most commonly between *ca.* 5800 and *ca.* 5500 years BP. At site B46.5N, at which ombrogenous peat began to form directly on the mineral soil in this period, there was much charcoal in the mineral–peat transition. The same is true of site SW, at which the ombrogenous peat began to form much later (*ca.* 5500 years BP). In this case burning may have played a role in ombrogenous peat initiation even though a mor layer is absent. Possibly burning removed scrub vegetation from the site, although direct evidence of this is not very strong. This itself might have been sufficient (combined with the more general waterlogging) to increase the local soil moisture content and bring about the initiation of ombrogenous peat. In the case of B46.5N we have already alluded to the possibility of lateral spread from adjacent areas, but even this appears to have required the stimulus of burning. On the other hand the D7E site, where ombrogenous peat began to form at *ca.* 4000 years BP directly over rocks, has much less clear evidence of burning and a natural lateral spread (presumably upslope) may have taken place.

(*d*) *Human influences on the vegetational history*

In the last section we discussed the possible influence of fire and other factors on the environment in Mesolithic times. We saw that heath became established at site B125N at *ca.* 7900 years BP, and that the earliest records at many of the other non-basin sites reveal similar conditions. Heath persisted for a long period, with a general reduction or disappearance occurring around 6200–6000 years BP, except for two isolated areas where it lasted until about 5500 years BP. Bearing in mind the ability of birch, in particular, and even oak, to invade heathland, it seems unlikely that heaths would have persisted for such a long period unless regeneration of woodland was in some way prevented. The obvious factors are burning and grazing. Current opinion (see, for example, Simmons, 1975*a*, *b*; Jones *et al.* 1979) is that Mesolithic populations are likely to have exploited the upland forest margin as a food resource area, at least seasonally. In particular it has been suggested that fire was used to encourage the development of pasture to attract and maintain a high population of game animals. We incline to the view that the circumstantial evidence mentioned above points to Waun-Fignen-Felen having been such an area. The lake basin would have been an added attraction for both man and wildlife. Moreover, we tentatively conclude that the establishment and maintenance of the early heath was strongly influenced by the activities of Mesolithic man. It may be noted that Walker & Lowe (1985) suggest that human activity may have been at least partly responsible for the expansion of heath in northwest Scotland, there occurring at a much later date (after *ca.* 4000 years BP), a change that was hitherto regarded as a result of natural processes such as soil deterioration.

At site B125N it will be recalled that the heath phase followed a period of relatively open conditions in which the predominant tree was birch. We have argued that the open conditions may have been a result of Mesolithic man's influence before *ca.* 8000 years BP while also considering other explanations. The decline of birch and subsequent development of heath and hazel scrub we see also as probably connected with burning and thus, by implication, probably also with the actions of Mesolithic man. Similar sequences are described by Robinson (1983, 1987) from the Scottish island of Arran, and from Caithness. From the evidence of charcoal (dated to *ca.* 8700 and 7000–7500 years BP respectively), he concludes that the major agency in bringing about the changes was fire, and that this was most probably originated by man.

Impacts of man later than the Mesolithic have usually been discerned on the basis of declines in the *Ulmus* curve and increases in possible weed and crop taxa. In recent considerations some authors prefer an explanation of the primary elm decline (i.e. that of the classical Atlantic–Sub-boreal transition of Godwin (1940, 1975) dating to approximately 5000 years BP) as largely an effect of disease (see, for example, Rackham 1980; Huntley & Birks 1982). Support for the more traditional view is given by Smith (1981), arguing from the general decline of tree pollen alongside elm that can be seen in the few absolute pollen diagrams available. So it appears still to be worthwhile to examine the behaviour of the elm- and herb-pollen curves at Waun-Fignen-Felen as indices of human impacts. In figure 32, *Ulmus* curves from the major sites are plotted as percentages of total tree pollen on a common timescale. Curves are also given for the sums of all herb taxa in which the plants would have been unlikely to have been growing on acid peat. Herb taxa definitely attributable to weed species are relatively sparse in the diagrams and the curve used is intended to represent plants of open habitat so far as is possible. In some cases (e.g. before *ca.* 5000 years BP at site G00, and after this date at E1N) the curve is clearly reflecting the presence of fen or mesotrophic peat communities. At other sites (e.g. E188S and B46.5N) a rising curve for 'open-habitat plants' is more closely associated with one or more declines of the elm curve.

The incidence of 'open-habitat plant' pollen is extremely variable at the time of the classical elm decline at *ca.* 5000 years BP. It is of interest, however, that at sites where there is no evidence of fen conditions, the curves have relatively high values before the classical elm decline. These may in part reflect the existence of dry-land open habitats in the Mesolithic period.

The main elm decline in the Welsh uplands has previously been thought possibly to have been variable in date (Taylor 1980). The variability of the expression of the elm decline in the present diagrams from a relatively small area is, therefore, of considerable interest. The following zone boundaries were defined at least in part on the basis of the behaviour of the *Ulmus* curve: zone 3–4, zone 4–5 and zone 5–6. The positions of these boundaries are indicated by horizontal lines in figure 32. The following observations may be recorded.

1. The zone 3–4 decline occurs between *ca.* 5500 and *ca.* 4950 years BP at ten of the sites.
2. The zone 4–5 decline is consistently at *ca.* 3900 years BP at three of the sites but at *ca.* 4050 and *ca.* 3750 years BP at two others.
3. The zone 5–6 minimum is consistently at *ca.* 2850 years BP at three of the sites but at *ca.* 2950 and *ca.* 2650 years BP at two others.

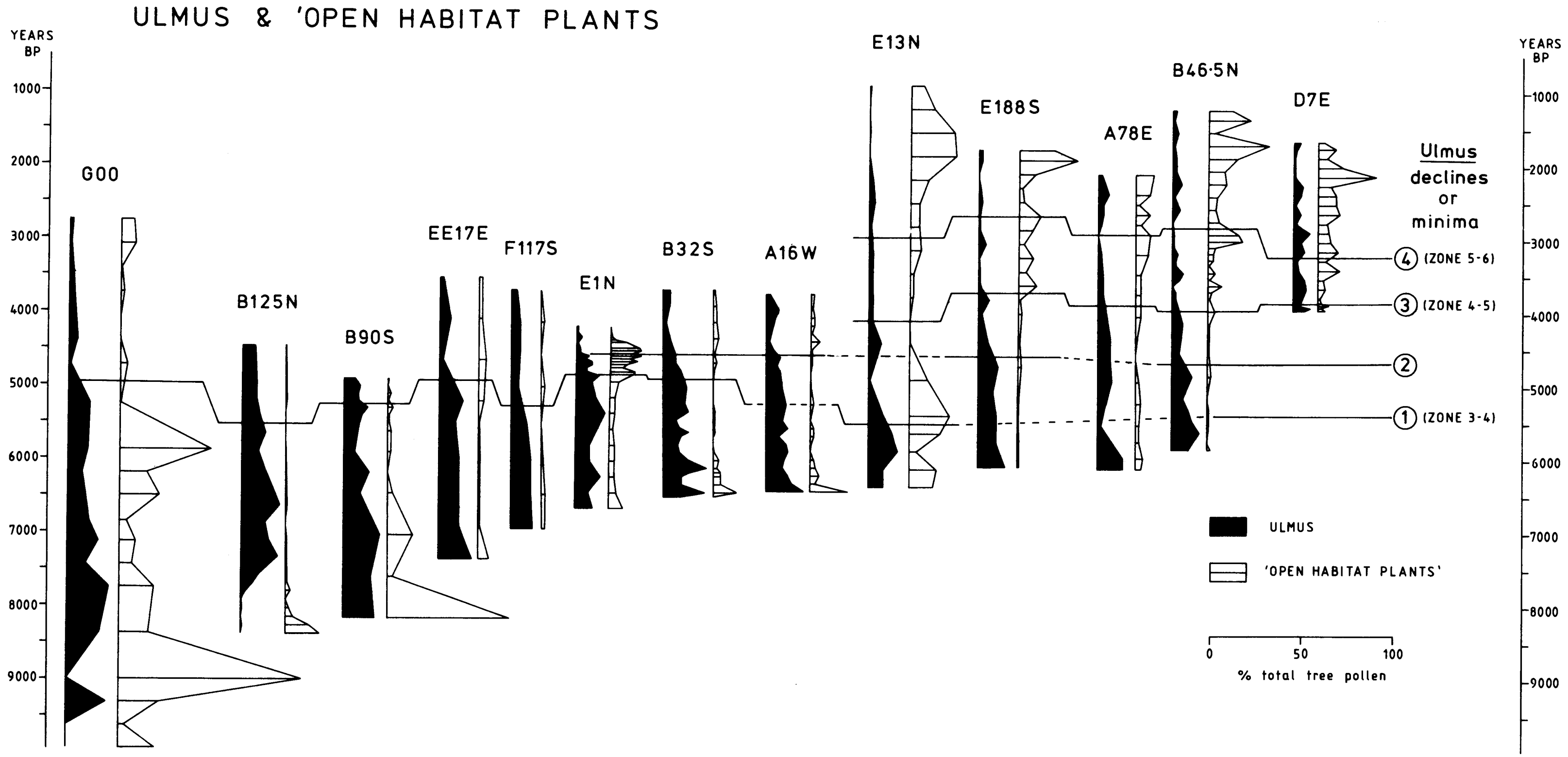

FIGURE 32. Comparative diagram showing two pollen curves for each of thirteen sites at Waun-Fignen-Felen. The values are calculated as percentages of total tree pollen (excluding *Corylus* and *Salix*). (Pollen diagrams showing all the tree pollen taxa calculated on this basis are given in the Supplement.) The vertical scale is in radiocarbon years. This timescale is derived from deposition rate curves (see Appendix 2) based on the radiocarbon dates given in the relative pollen diagrams for the individual sites (figures 4–11 and 13–19). The curves are (1) *Ulmus* (black) and (2) the sum of all pollen belonging to plants likely to have grown in open habitats (open). The latter summary curves inevitably include pollen of fen plants, but *Calluna* and other known bog plants have been excluded. The horizontal lines numbered 1–4 join declines or minima of the *Ulmus* curves of approximately the same age. Three of these (numbered 1, 3 and 4) are among the criteria adopted for delimitation of pollen assemblage zones. The first decline (probably to be regarded as the classical 'elm decline') is not well marked at all the sites. The second decline is not evident at all sites but appears consistent in age at about 4700 years BP.

If the elm declines reflect regional events then the discrepancies between the dates, where they occur, are likely to be related to the inaccuracies of the methods, both of dating and of defining the precise level of a decline or minimum. It is striking, however, that even the primary elm decline is very weakly represented at site A16W and hardly visible at E188S. This may be connected with the sampling interval but could equally signify that local, rather than regional, events are recorded. We may also note another feature of interest: five of the sites consistently exhibit an additional elm decline at *ca.* 4600 years BP. The sites are E1N, B32S, A16W, E188S and B46.5N. There appears thus to be a series of four elm declines (or minima), which are variably represented. For ease of reference these are numbered 1–4 upwards in figure 32. The fact that elm decline 2 occurs at only a few of the sites, and that these cluster in the centre of the whole group, might be taken as suggesting some local event. Because of the variability of the time interval between samples, and lack of representation at some sites, however, no firm conclusion can be drawn. It may nevertheless be noted that the lack of elm decline 2 at site A78E (where there is a regular time interval between samples) is particularly strange if a regional event is recorded. The lessons of this exercise are that exact definition of elm declines demands close sampling, that there is variability, and that local events may possibly be recorded.

Unfortunately the time period embracing elm declines 3 and 4 is represented at only a few of the sites. At all of these the curves for 'open-habitat plants' are at higher levels than hitherto, although there is no strict comparability of behaviour. This broad feature of the diagrams is perhaps best interpreted as indicating increased openness and human pressure on the local environment between *ca.* 4000 and *ca.* 2600 years BP (i.e. in the Bronze Age).

Features of the zone 5–6 transition such as the increase in *Narthecium* pollen could be interpreted as having climatic significance, but increasing runoff resulting from deforestation would have been equally likely to have affected the hydrology of the bog. Nevertheless it is worth noting that the abundance of the bog asphodel may well have persisted into historic times and given the area its name: 'the moor of the yellow bog'.

The broad picture of Bronze Age human impacts is confirmed by the detailed consideration of the individual pollen diagrams given above. It is of interest to note that middle Bronze Age artefacts of both pottery and metal have been recovered from the caves at Dan-yr-Ogof only *ca.* 2.5 km southeast of Waun-Fignen-Felen in the Tawe Valley (Mason 1968). It will be recalled that in discussing site D7E a particularly strong agricultural phase was distinguished in the late Bronze Age. It was suggested that this might represent local pressure on the hill slopes to the west of the basin. There is also quite a good evidence from at least three of the sites (E188S, A78E and B46.5N) that human pressure on the environment relaxed during the earlier Iron Age and that there was some woodland regeneration. In the later part of the Iron Age (*ca.* 2200 years BP) there appears to have been further reduction of woodland cover, which persisted through Romano-British times. At one site at least there is evidence of regeneration after this period. This is the point at which our evidence runs out but it may be noted that two of the pollen diagrams of Price & Moore (1984) from the Black Mountains, further to the east, also show a reduction of agricultural activity at the end of Romano-British times.

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Appendix 1. Stratigraphic records of pollen sampling points

The following records are based on field notes supplemented by laboratory observations.

Site G00

Four cores taken with the large-diameter hand-operated peat sampler described by Smith *et al.* (1968).

0–10 cm: modern root mat.

10–290 cm: fibrous blanket peat with frequent *Calluna*; *Eriophorum* between 56–100 and 250–270 cm. 270–290 cm less fibrous.

290–304 cm: grading into reedswamp peat with red wood. *Menyanthes* seed and ?*Betula* twig at 296 cm.

304–400 cm: *Phragmites* peat becoming compacted below 370 cm. 1.5 cm diameter ?*Betula* twigs at 332–338 cm.

400–498 cm: firm, laminated reed peat with much *Phragmites*. Small twigs and some moss below 472 cm. 496–498 cm particularly mossy and with apparent charcoal.

498–512 cm: warm-brown fine detritus mud.

> 512 cm: grey clay.

Site B125N

Monolith taken from base of peat in a very eroded area. All samples prepared for pollen analysis contained both macroscopic and microscopic charcoal.

0–44 cm: fairly humified dark-brown blanket peat containing charcoal. *Sphagnum* leaves at 8 cm and occasional mineral particles below 32 cm.

44–51 cm: black, almost amorphous peat (mor). Abundant *Juncus* seeds below 46 cm. Grading into mineral soil below 47 cm.

51 cm: sand with some organic matter, resting on a large stone.

Site B90S

Monolith taken from surface down in an extremely eroded area.

0–15 cm: dark-brown, fibrous, greasy blanket peat with charcoal; some large pieces at 12 cm.

15–18 cm: blackish, greasy, amorphous peat (mor) with charcoal fragments. Pollen at 16 cm crinkled. Increasing mineral content below 17 cm.

18–20 cm: transition to light-buff sand with charred *Calluna* at 18 cm.

20–26 cm: buff sand with some large stones. Thin indurated iron pan at 26 cm.

Site EE17E

Monolith taken from basal peat exposed in hag. Original surface intact.

0–68 cm: dark, grey-brown, compacted, fibrous blanket peat. Some *Calluna* roots at 16–18 cm. *Eriophorum* and *Calluna* at *ca.* 40 cm. Occasional (twig) charcoal below 30 cm. Darker in colour and drier below 40 cm.

68–72 cm: grey-black, greasy, amorphous peat (mor) running down between stones. Becoming increasingly sandy and very black below.

72–80 cm: grey sand between stones. (Surface of sand 172 cm below bog surface.)

80 cm: buff sand and stones with some humus content.

Site F117S

Monolith taken from basal peat exposed in hag. Original surface intact.

0–80 cm: mid-brown blanket peat. Coarsely fibrous with occasional *Eriophorum* above 48 cm but finer and darker in colour below. Some *Calluna* roots *ca.* 40 and *ca.* 52 cm.

80–85 cm: becoming more humified.

85–90 cm: black, amorphous, sandy peat (mor).

90 cm: sloping interface with buff sand with some humus. (The sand was 146 cm below the bog surface.)

Site E1N

Monolith taken from base of deposits exposed in bank of drainage channel. The uppermost deposit, perhaps originally *ca.* 1.5–2.0 m thick, was a blanket peat with much *Calluna* and *Eriophorum*. The base of this was included in the monolith.

0–15 cm: blanket peat with many *Calluna* roots and stems. Some charcoal present. Pollen generally in good condition.

15–34 cm: coarse, horizontally stratified *Eriophorum* peat, possibly also containing *Molinia*. *Juncus* seeds and mites at 22 cm. Increase of charcoal concentration below 28 cm. Pollen less well preserved than above.

34–42 cm: very dark brown muddy peat containing some mineral particles and *Phragmites* rhizomes. Several large pieces of wood identified as *Betula* and *Salix*, and some leaves of the latter. *Sphagnum* leaves at 42 cm.

42–58 cm: solid, dark-chocolate-coloured mud with an increased mineral content, separated from the deposit above by a thin layer of fine sand. Many *Juncus* seeds and occasional large pieces of charcoal.

Site B32S

Monolith taken from about 90 cm of peat with an eroded surface recolonized by *Eriophorum angustifolium* and lying on a layer of flat stones.

0–42 cm: chocolate-brown, compacted, finely fibrous blanket peat with a greasy texture. Much, largely microscopic, charcoal with a concentration at 36 cm. Pollen appearing crinkled in a characteristic manner at 38 cm. Occasional mineral particles below 32 cm.

42–48 cm: as above, but with increasing mineral content and much microscopic charcoal.

48–55 cm: black, greasy mor. Much macroscopic and microscopic charcoal. More mineral particles towards the base, and resting on a large stone.

55–70 cm: stones.

70–73 cm: pale mustard-coloured sand.

73–84 cm: humus-stained sand.

84–96 cm: grading into a pale mustard-coloured sand at 96 cm.

Site A16W

Monolith taken from eroded peat *ca.* 60 cm deep at edge of small drainage channel.

0–8 cm: dark-brown, fibrous blanket peat with *Calluna* rootlets and a little charcoal.

8–32 cm: less fibrous, dark-brown blanket peat. Much charcoal 10–16 cm and large pieces at 14 cm.

32–40 cm: as above but black and greasy; much microscopic charcoal.

40–50 cm: greasy peat; somewhat lighter in colour than above. Much charcoal at 42 and 46 cm.

50–53 cm: as above but with greater mineral content and occasional pieces of charcoal. Pollen poorly preserved at 52 cm.

53 cm: fawn-coloured sand with pebbles below 55 cm. Some charcoal present. Pollen in poor condition at 54 cm.

Site E13N

Monoliths taken from pit dug into edge of superficial drainage channel and below it. Surface possibly intact.

0–25 cm: dark-brown, highly humified peat with modern rootlets.

25–173 cm: dark-brown, fibrous blanket peat with occasional *Calluna* and *Eriophorum*. Somewhat lighter in colour and with some visible *Sphagnum* content below 77 cm. (168–173 cm, distinct layer of *Eriophorum* and ?*Molinia*; 165–171 cm, *Calluna* roots in monolith.)

173–178 cm: very humified, fibrous peat with a fine charcoal layer at 178 cm.

178–218 cm: medium-brown blanket peat with much *Eriophorum* between 178 and 182 cm. *Calluna* roots in monolith between 188 and 196 cm.

218–256 cm: highly compacted, dark-brown, fibrous reedswamp peat with occasional *Phragmites*, particularly between 238 and 242 cm.

256–260 cm: dark-brown/black muddy peat with charcoal and some mineral content (disappearing laterally in the excavation).

260 cm: light-brown, clayey sand with some gravel.

Site E188S

Monoliths taken from peat hag on southeast margin of bog.

0–10 cm: modern root mat.

10–140 cm: dark-brown, fibrous blanket peat containing some *Eriophorum* and *Calluna*. Much charcoal above 24 cm with charred leaves and stems of *Calluna* and *Erica tetralix*. *Sphagnum* leaves and *E. tetralix* seeds in sample at 40 cm. Samples between 48 and 56 cm with charred ericaceous remains. Some mineral material between 136–147 cm.

140–147 cm: black (mor-like) peat with much charcoal and some mineral particles, becoming blacker and greasier towards the base.

147 cm: thin layer of buff-coloured sand above large stones.

Site A78E

Monoliths from small peat hag on high point of eastern side of bog.

0–20 cm: humified peat with modern roots. *Calluna* leaves at 12 cm, and charcoal throughout.

20–72 cm: coarse, fibrous, dark-brown blanket peat with stems and roots of *Calluna*. Charred leaves of *Calluna* in 20 cm sample. Occasional charcoal throughout and mineral particles below 52 cm. Becoming darker in colour and with increasing content of charcoal and mineral particles below 60 cm.

72–88 cm: very dark-brown, greasy peat increasing in mineral content; numerous charred *Calluna* leaves and stems. Some stones and further increase of mineral content below 82 cm.

88 cm: buff-coloured, very compact, sandy mineral soil with pebbles.

Site B46.5N

Monoliths taken from south-facing peat hag and pit dug below it.

0–20 cm: humified peat with modern rootlets.

20–112 cm: coarse, fibrous blanket peat with *Calluna* and *Eriophorum* below 100 cm. Occasional charcoal fragments throughout and some charred ericaceous material at 112 cm.

112–134 cm: smooth, greasy blanket peat containing charcoal fragments.

134–154 cm: coarser, granular peat with *Eriophorum* and small *Calluna* twigs.

154–180 cm: dry, compacted, fine-textured blanket peat with occasional mineral particles.

180–188 cm: transition from peat to mineral soil associated with much charcoal.

188 cm: light mustard-coloured sand.

Site D7E

Monoliths taken from peat hag and excavation at western side of bog close to hill slope. The peat contains several layers of mineral particles and it was noted in the field that redeposition might have occurred, leading to problems with ^{14}C dating. Top of record begins approximately 40 cm below present surface, this uppermost peat being apparently redeposited.

0–11 cm: light-brown *Sphagnum* peat.

11–150 cm: dark-brown, fibrous blanket peat, coarse above *ca.* 70 cm and with occasional mineral particles, but finer and generally gritty below. Distinct thin layers of sandy material undulating at 20–24 and 56–64 cm, and more horizontal at 95, 98, 135 and 145 cm. Occasional charcoal fragments towards the base but no distinct layer.

150 cm: large stones and grit.

Site NE

Monolith taken from basal 50 cm of peat 75 cm deep overlying rocks *ca.* 10 m from base of scree slope forming western side of summital ridge of Fan Hir, *ca.* 1.5 km northeast of Waun-Fignen-Felen at an altitude of *ca.* 660 m O.D.

0–46 cm: fibrous, dark-brown blanket peat (rootlet penetration to 12 cm).

46–50 cm: almost black, amorphous peat in pocket between stones. Pollen samples at 46 and 48 cm contained much charcoal.

50 cm: stones.

Site NP

Monolith taken from basal 50 cm of peat *ca.* 110 cm deep from isolated peat hag on plateau approximately 0.5 km north of Waun-Fignen-Felen and some 15–20 m higher.

0–32 cm: fibrous blanket peat with occasional charcoal.

32–37 cm: very dark brown, almost black, amorphous, greasy, mor-like peat. Fine black layer at 37 cm.

> 37 cm: buff-coloured, stony sand with some humus.

Site SW

Monolith taken from basal 50 cm of peat *ca.* 130 cm deep at an altitude of *ca.* 530 m O.D. halfway up the limestone slope *ca.* 0.5 km to the southwest of Waun-Fignen-Felen.

0–48 cm: fibrous, mid-brown blanket peat with occasional *Eriophorum*. Black, charcoaly deposit at 48 cm.

> 48 cm: light-brown sand and gravel between stones.

Appendix 2. Radiocarbon dating

All radiocarbon determinations and sample pretreatments were done by Dr P. Q. Dresser in the radiocarbon-dating laboratory in the Department of Plant Science, University College, Cardiff. Most of the determinations and the counting method are described in Dresser (1985). The dates are all quoted conventionally and without calibration.

To ensure that the ^{14}C dates correlate accurately with the pollen samples, the same monoliths and cores were used for dating and pollen analyses. After sampling for pollen analysis the upper peats were sampled contiguously at 2 cm intervals for ^{14}C dating; in the highly humified and charcoal-rich basal layers, however, the sampling interval was reduced to 1 cm.

Dating was done on the fine particulate fraction. This was isolated from the peat samples by using the following technique devised by Dresser (1970). Humic acids were removed by suspending the peat in NaOH ($20\ g\ l^{-1}$). This was followed by acidification in HCl ($20\ g\ l^{-1}$) to facilitate the removal of rootlets and other large organic components by filtration, with a 250 μm sieve. A further suspension in KOH ($10\ g\ l^{-1}$) was given to remove any remaining humic acid. Finally, the fine particulate fraction was acidified in HCl ($10\ g\ l^{-1}$) (to remove carbon dioxide dissolved in the alkaline solution), washed in distilled water, and vacuum dried ready for combustion. It is considered that this fine-particulate fraction is the most reliable component for dating in that it excludes soluble humus, which may have been mobile in the profile, and large particles such as rootlets and rhizomes (cf. Dresser 1970). Nevertheless, some anomalous results were obtained; these are listed below.

Deposition-rate diagrams for each site are presented in figures A1–A3. The horizontal axes are uncalibrated radiocarbon years BP. The rectangle for each date defines the thickness of the sample and the confidence limits for one standard deviation; the ends of the horizontal lines mark the two standard deviation limits. Dates with rectangles in solid black have not been used in slope determinations owing to their suspected unreliability.

The dashed lines in the figures show the deposition rate curves used in calculation of the timescales on the pollen diagrams (figures 20–25 and 32) and in the preparation of the absolute

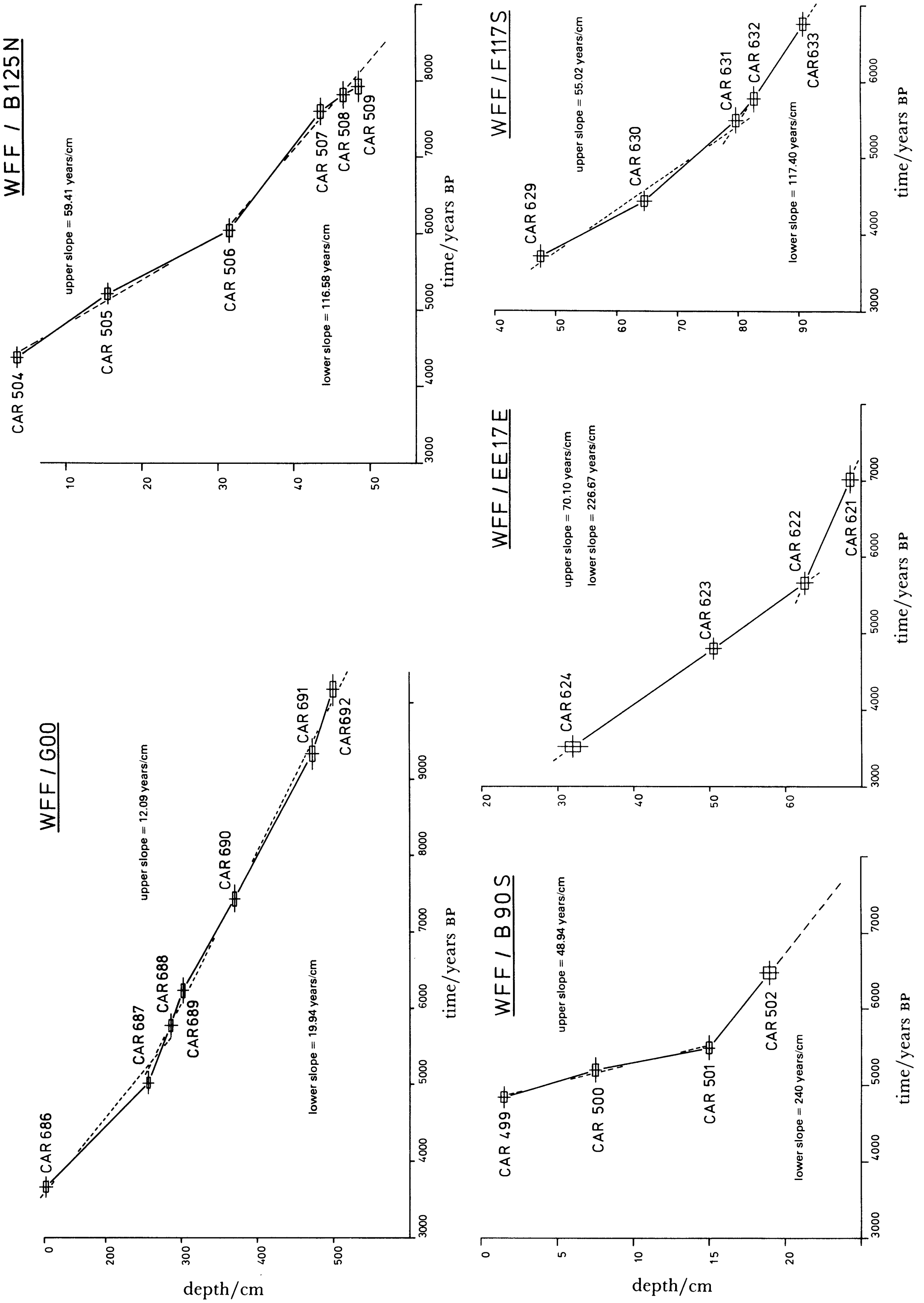

FIGURE A1. Deposition rate curves for sites G00, B125N, B90S, EE17E and F117S.

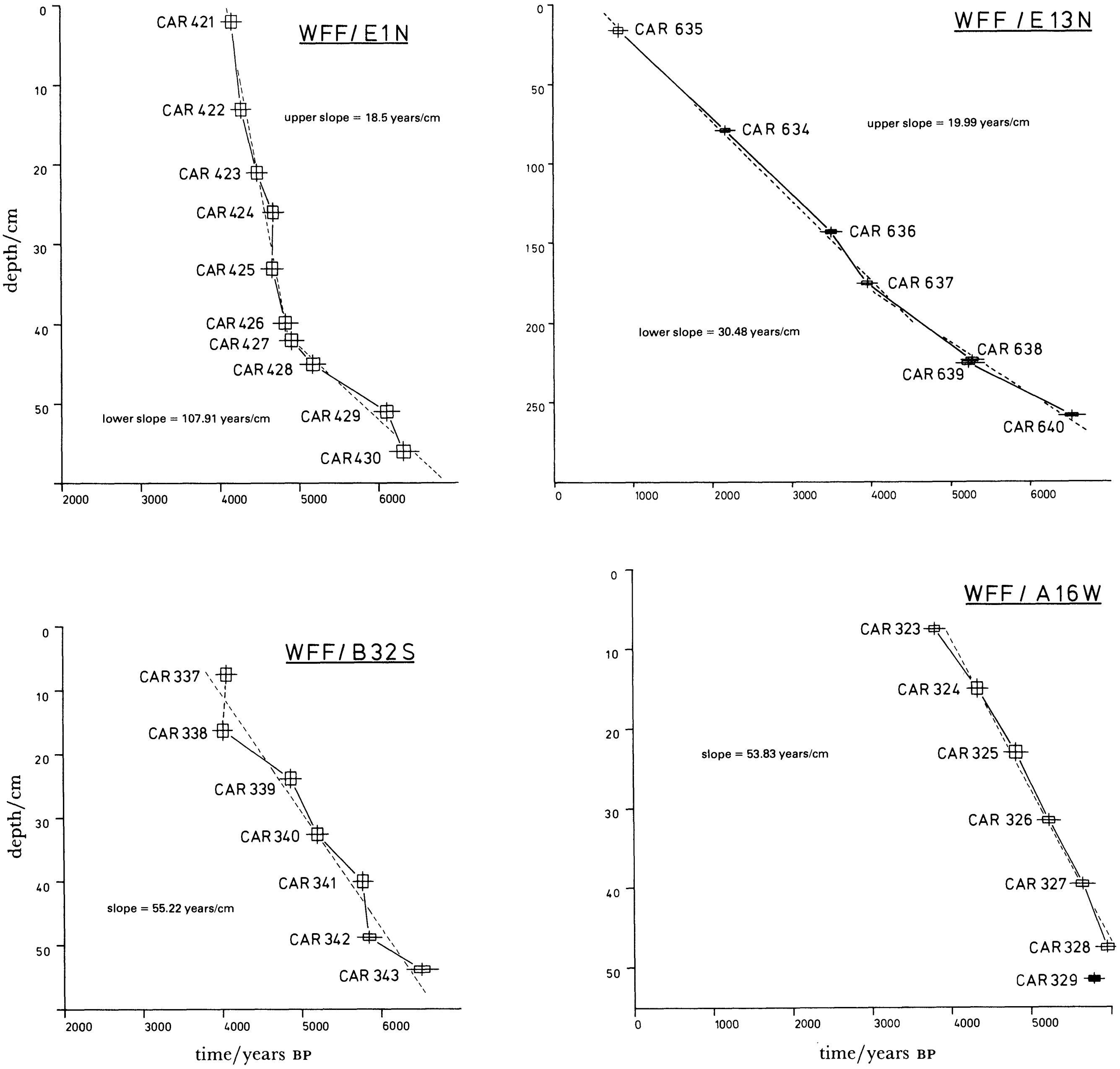

FIGURE A2. Deposition rate curves for sites E1N, E13N, B32S and A16W.

(pollen influx) diagrams (figure 12 and Supplement figures S1–S12). The lines are calculated regression lines giving the average slope. The points at which the slopes change were determined by inspection. Samples located about a change in slope were allocated dates based on both deposition rates. They were assigned to their respective slopes in a manner that maintained a chronological sequence.

The anomalies revealed by inspection of the deposition rate curves are as follows.

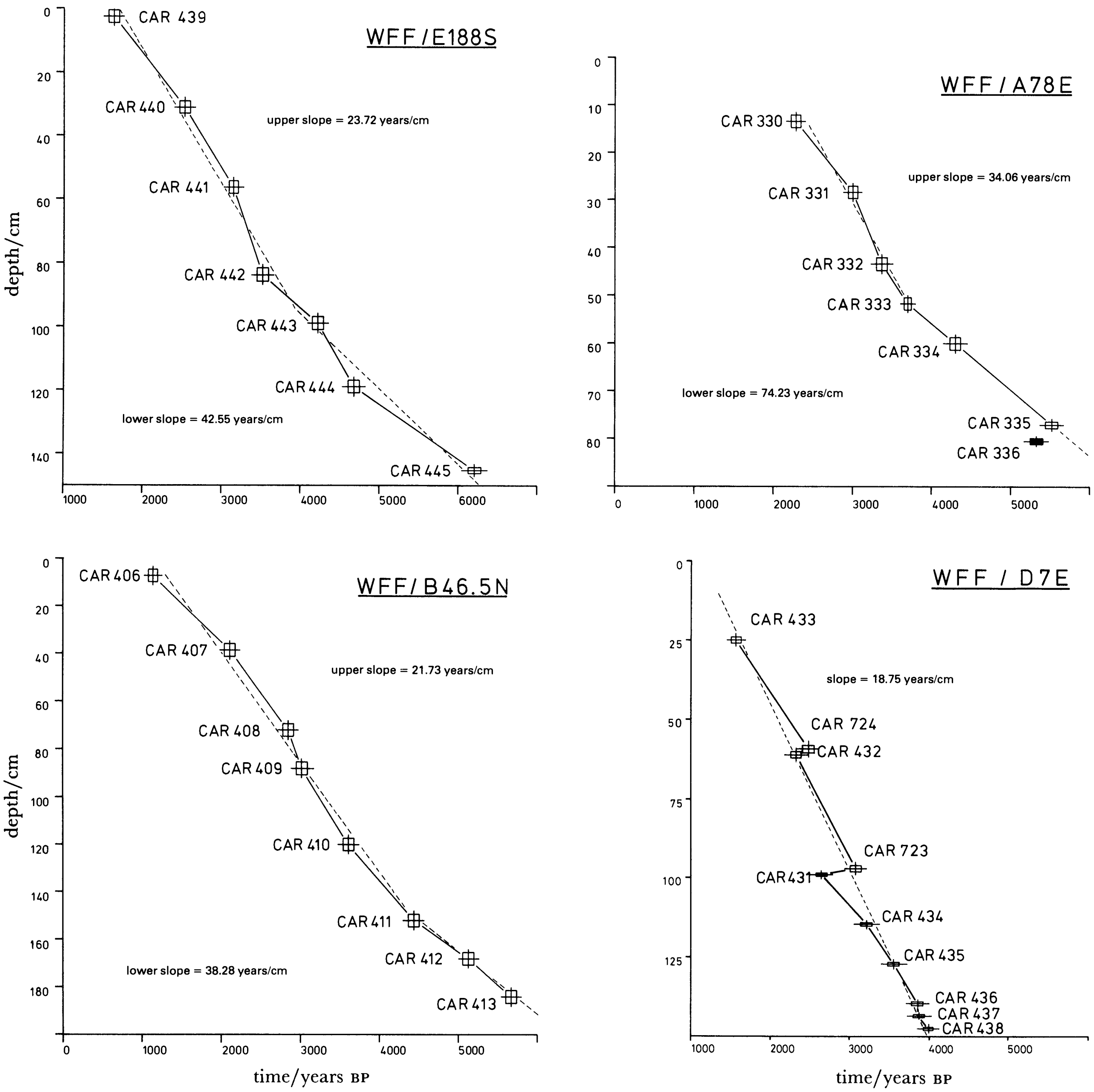

FIGURE A3. Deposition rate curves for sites E188S, A78E, B46.5N and D7E.

(*a*) *Site* A16W

Although the basal sample (CAR-329) is statistically indistinguishable in age from the sample above (CAR-328) it appears too young, from the general trend of the curve, and has been omitted from the calculations. The substrate immediately below the sample was sand with pebbles: there is thus some possibility of the concentration of penetrating rootlets adding young carbon that was not removed by the pre-treatment methods.

(*b*) *Site* A78E

A similar situation prevails at this site and again the basal sample (CAR-336) has been omitted from the calculation.

(*c*) *Site* B125N

The basal sample (CAR-509) may be too young. From the trend of the curve, however, it is unlikely to be incorrect by more than 200–300 years.

(*d*) *Site* E1N

It appears from the trend of the dates that either the basal determination (CAR-430) is young or the next above (CAR-429) is too old. Nevertheless a single regression line below CAR-427 appears to accommodate the data reasonably. If there is any error, however, it is most likely to be that the basal date (CAR-430) is too young. This is the fourth site at which this is a possibility, and the problem clearly requires further investigation.

(*e*) *Site* D7E

The 96 cm sample (CAR-431) appears too young. The peat contained lenses of mineral material resulting from downwash that suggest episodes of erratic deposition at the site. The apparently young date may be due to some such effect. The timescale must be treated with some reserve.

(*f*) *Site* B32S

The determinations appear more erratic than in other cases. Two dates (CAR-338 and CAR-342) are possibly too young. Despite the variability a single straight line appears to represent the deposition rate reasonably, but some caution must be exercised.

APPENDIX 3. ABSOLUTE POLLEN ANALYSIS

The advantage of the absolute technique is that the pollen curves for each taxon are independent of one other. There are, however, methodological problems; for instance, in establishing a standard volume of peat and in calculating accurately the deposition rate.

Although some control can be maintained in the first case, an accurate estimate of the deposition rate is more difficult, deposits being variable in their accumulation rates. Problems of uneven distributions of sediments in lakes have been discussed by Davis (1968), Davis *et al.* (1973) and Pennington (1973). Beckett (1979) considers that carefully selected raised bog sites may produce reliable pollen-influx records where ^{14}C dating is rigorous and the deposit is relatively uniform. Raised bogs have the advantage over lake deposits in that the majority of the pollen entering the sampling site is airborne. Similarly, the pollen deposited in blanket peats is mostly airborne, unless sampling is conducted in a flushed area. The disadvantages of blanket peats are their susceptibility to fluctuations in deposition rate, and the variability of pollen preservation. At the Waun-Fignen-Felen sites, however, deposition rates in the ombrogenous (not mor) deposits appear to be remarkably uniform (figures A1–A3) within the limits imposed by the number of radiocarbon determinations. Despite this, influx diagrams prove to be of limited value and they are placed on record as figures S1–S12 of the Supplement as a database for comparison with future examples. Brief discussion is given below.

Techniques

The various absolute pollen preparation techniques and their relative merits have been discussed by Peck (1974). All the methods using weights or volumes (Davis 1965, 1966; Jorgensen 1967) require many measurements of high precision to be made, and consequently are very time-consuming compared with the 'exotic' marker techniques of Benninghoff (1962), Matthews (1969) and Bonny (1972). For the sake of economy of time in the present study, a 'salting' technique was therefore employed, using a suspension of *Lycopodium* spores in glycerol. The use of tablets (Stockmarr 1971) would have been preferred, but they were unavailable.

Matthews (1969) suspended 50 mg of exotic in 25 ml of glycerol. This was considered by Bonny (1972) to be too concentrated for an accurate count to be made by using a 1.8 μl volume haemocytometer when determining the spore concentration. Her conclusion was that 25 mg of spores in 25 ml of glycerol gave the most satisfactory mixture, and this concentration has been used in the present study. To provide a stable 'pool', from which the exotic could be drawn over several years, a large volume was employed. The mixture was prepared in the following manner: 2 g of *Lycopodium* spores were dispersed in ethanol, washed in distilled water, and suspended in glacial acetic acid. Godwin's acetolysis technique was then used, and the spores were dehydrated in ethanol before finally mixing with 2 l of glycerol. After the ethanol had evaporated from the mixture, the suspension was corked and stored.

The suspension was thoroughly mixed before use by stirring overnight with a motor-driven paddle. The concentration of spores was determined by use of a haemocytometer. Data were accumulated over several years. Analysis of variance showed no significant difference over the period of investigation (Cloutman 1983). The mean for all counts has been used as the concentration of exotic in suspension.

The size of the marker spike added to each sample during pollen preparation was based on the considerations of Maher (1981). He found that the most precision for the least effort was found to be when $u = x/n = 2$, where x is the total number of fossil grains counted per sample, and n is the total number of exotic grains counted per sample. It was decided, for convenience, to keep the size of the spike constant and a suitable average for u was attained when 2 ml of stock *Lycopodium* suspension was added to each 1 cubic centimetre sample of peat. For the purposes of calculation the number of spores added to each 1 cubic centimetre sample of peat was taken to be 135560.

For preparation of the pollen samples the spore suspension was added to the peat before KOH maceration and acetylation. Bleaching was not used. The one cubic centimetre peat samples were cut with a small sampling machine (Cloutman 1987). The design is such that there is a minimum of compression or contamination of the deposits. The overall error of the machine is 4.6%.

The pollen influx, I, in grains per square centimetre per year, was calculated from the formula $I = e_p/e_c \times f_c/d_r$, where e_p is the number of exotic spores added to the 1 cubic centimetre peat sample, e_c is the number of exotics counted per sample, f_c is the number of fossil grains counted per sample, and d_r is the deposition rate in years per centimetre. The standard pollen count was 500 fossil grains of land plants per sample. For the sake of clarity the influx diagrams (figure 12 and figures S1–S25 in the Supplement) are drawn without confidence limits but an example in which 95% confidence limits are shown for selected curves may be found in Cloutman (1983).

Consideration of the influx diagrams (figure 12 *and Supplement figures* S1–S12)

Some idea of the likely range of pollen influx values that might be expected in peats can be gained from values obtained by Beckett (1979) from raised bogs in the Somerset Levels. At Meare Heath total pollen influx ranged from 100 to over 6000 grains $\mathrm{cm}^{-2}\ \mathrm{a}^{-1}$ and nearby, at Abbot's Way, values ranged between 1000 and 9000 grains $\mathrm{cm}^{-2}\ \mathrm{a}^{-1}$. In blanket peat deposits on Bodmin Moor (Brown 1977) influx values ranged between 3000 and 13000 grains $\mathrm{cm}^{-2}\ \mathrm{a}^{-1}$. At Waun-Fignen-Felen the range is much greater, values of total pollen influx in the blanket peats generally falling between 1000 and 20000 grains $\mathrm{cm}^{-2}\ \mathrm{a}^{-1}$. In the mor deposits at several of the sites and in the blanket peats at the basin site, E1N, values reached 25000 grains $\mathrm{cm}^{-2}\ \mathrm{a}^{-1}$. The highest values, up to 70000 grains $\mathrm{cm}^{-2}\ \mathrm{a}^{-1}$, are at site D7E.

Despite what appears to be good chronological control it is surprising to find that in many cases in the influx diagrams the curves tend to move in unison, i.e. they exhibit less independent behaviour than expected. Brief comments on some of the individual diagrams are given below, followed by some general remarks.

Site G00 (*figure* S1)

There is a strong parallelism between the curves. The isolated Filicales peak between *ca*. 5500 and *ca*. 6000 years BP presumably betokens local growth of ferns.

Site B125N (*figure* S2)

Departures from parallelism are shown by the Gramineae and *Calluna* curves, presumably reflecting changes in the importance of these taxa in the local ground cover. The fall of the Gramineae curve after *ca*. 8200 years BP and the subsequent rise of the *Betula* and *Corylus* curves supports the suggestion made on the basis of the relative pollen diagram of colonization of an open area.

Site B90S (*figure* S3)

The *Calluna* values rise to only *ca*. 1000 grains $\mathrm{cm}^{-2}\ \mathrm{a}^{-1}$ as compared with a figure of *ca*. 6000 at B125N. In both cases the relative pollen diagrams suggest the local growth of *Calluna* heath. It is possible, therefore, that the timescale projected for the mineral soil at B90S is incorrect.

Site EE17E (*figure* S4)

The major exceptions to general parallelism of the curves are rises of Gramineae, Cyperaceae and *Potentilla* at *ca*. 5250 years BP. Plants of this type are likely to have been growing locally.

Site F117S (*figure* S5)

The curves exhibit some independence; in particular there is a *Calluna* maximum between *ca*. 4250 and *ca*. 5250 years BP.

Site E1N (*figure* S6)

There is a dramatic general increase of pollen influx at approximately 4800 years BP when the total land-plant pollen influx rises from around 6000 grains $\mathrm{cm}^{-2}\ \mathrm{a}^{-1}$ to values of up to

20000 grains cm^{-2} a^{-1}. It is noteworthy that this increase corresponds to the lithological change from a sandy mud to ombrogenous peat, at first with remains of *Betula* and *Salix*. With the exception of a fall in Filicales influx, there is a general rise with apparently no particular reflection of the local presence of these tree species. What is clear, however, is that the increasing influx is connected with an environmental change. The sandy mud may well have been deposited in flowing water, which could conceivably have reduced pollen sedimentation. The total influx is not as low, however, as the lowest values at other sites where ombrogenous peats were accumulating.

Site A16W (*figure* S7)

At *ca*. 5500 years BP there is a slight increase of Cyperaceae influx, when the curves for all other taxa are falling.

Site B32S (*figure* 12)

Certain features of this diagram are discussed in the main text. There are high influx values for *Corylus* and *Calluna* before 6000 years BP (8000 and 6500 grains cm^{-2} a^{-1}, respectively) when both are presumed to have been growing in the vicinity of the site.

Site E188S (*figure* S9)

As at site B32S, there are very high influx values for *Corylus* and *Betula* at the base of the diagram (9500 and 6500 cm^{-2} a^{-1} respectively); local growth has again been argued. Among the herb-pollen types there is a tendency for the Cyperaceae curve to have relatively high values between *ca*. 3700 and *ca*. 2500 years BP when the curves for *Calluna* and Gramineae are relatively low. Effects of local changes of ground cover are presumably represented.

Site A78E (*figure* S10)

There is a general increase in herb-pollen influx after *ca*. 3500 years BP when the other curves remain relatively level.

Site B46.5N (*figure* S11)

There is an increase of *Calluna* and Cyperaceae influx after *ca*. 3500 years BP.

Site D7E (*figure* S12)

There is a generally high pollen influx throughout, with total influx values reaching 70000 grains cm^{-2} a^{-1}, as compared with maximum levels elsewhere in the range 10000–30000 grains cm^{-2} a^{-1}. There appear to be at least three possible explanations. (1) The site is the closest of all to the western hillslopes where peat may not have formed so extensively, particularly on screes, so that there may have been communities growing on mineral soils that produced more pollen than peat communities. (2) In the immediate lee of the hill there may have been downdraughts, or relatively still air, leading to increased pollen 'fall-out' (cf. Price & Moore 1984). (3) Most likely, from the evidence of sand layers, the site was flushed, and this might have brought about an increased influx by surface transport.

In general, such departures from parallelism of the curves as can be observed appear to be related to taxa that could have been growing on or close to the deposit accumulating at the site,

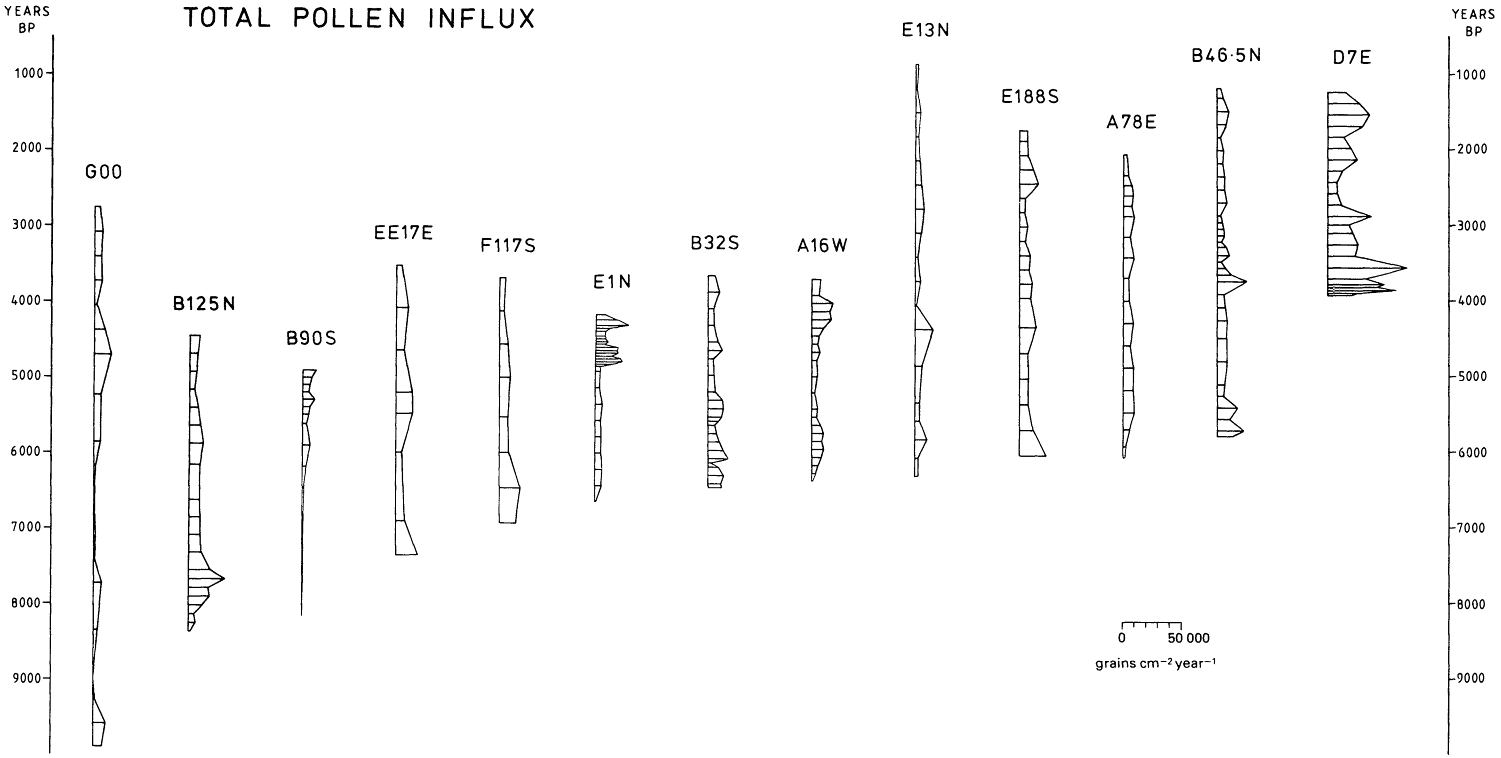

FIGURE A4. Comparative diagram showing the total pollen influx from the thirteen sites at Waun-Fignen-Felen. The complete influx diagrams may be found in figure 12 and figures S1–S12 of the Supplement (see p. 161).

in particular *Calluna*, Cyperaceae and Filicales. To some extent, therefore, the diagrams do seem to show real changes of pollen influx.

It may be noted that there are few sharp changes of influx between samples, as might have been expected if there were short-term changes of deposition rate. And yet the curves consistently drift between maxima and minima, largely in unison. The extent to which these drifts are common between sites may be judged from figure A4, in which the total pollen-influx curves for all the major sites are brought together (spores of Filicales are excluded from these curves). The period between 6500 and 4000 years BP is reasonably well represented in the diagram. Within this period there is a tendency for maxima of total influx between 6000 and 5500–5250 years BP and again after about 4750 years BP. Conversely, it might be said that there is a tendency for the total influx to fall to a minimum in the period 5500–5250 to 4750 years BP.

The sites that do not show a minimum of total influx around 5000 years BP are EE17E, F117S, A78E and G00. If the full diagrams for these sites are examined (figures S4, S5, S10 and S1) it is found that during the period in question there are particularly high influxes of pollen that appears to have local origin. The taxa involved are as follows.

EE17E: *Calluna*, Gramineae and *Potentilla* and, additionally, *Corylus* and some trees which would not have been growing on the peat but which may have persisted on nearby slopes.

F117S: *Calluna* and Cyperaceae.

A78E: Gramineae.

The diagram from site G00 is insufficiently detailed for comment.

From the considerations above, there is some reason to suggest that there is a general tendency for pollen influx to fall around 5000 years BP, but that the tendency is disguised at some sites by local floristic changes. From the data available, however, no definite conclusion can be drawn. If similar behaviour of influx curves is found elsewhere it will point to the influence of some overriding factor that adversely affected pollen productivity in general. The only factor likely to have had an effect of this magnitude is climatic change.

Appendix 4. Tree-pollen diagrams

The major pollen diagrams from Waun-Fignen-Felen are given in recalculated form, with the total arboreal pollen (excluding *Corylus* and *Salix*) as the pollen sum, in Supplement figures S13–S25. Pollen assemblage zone boundaries relying on the behaviour of the *Ulmus* curve are more readily distinguished in these diagrams than in the total pollen diagrams used in the main account.

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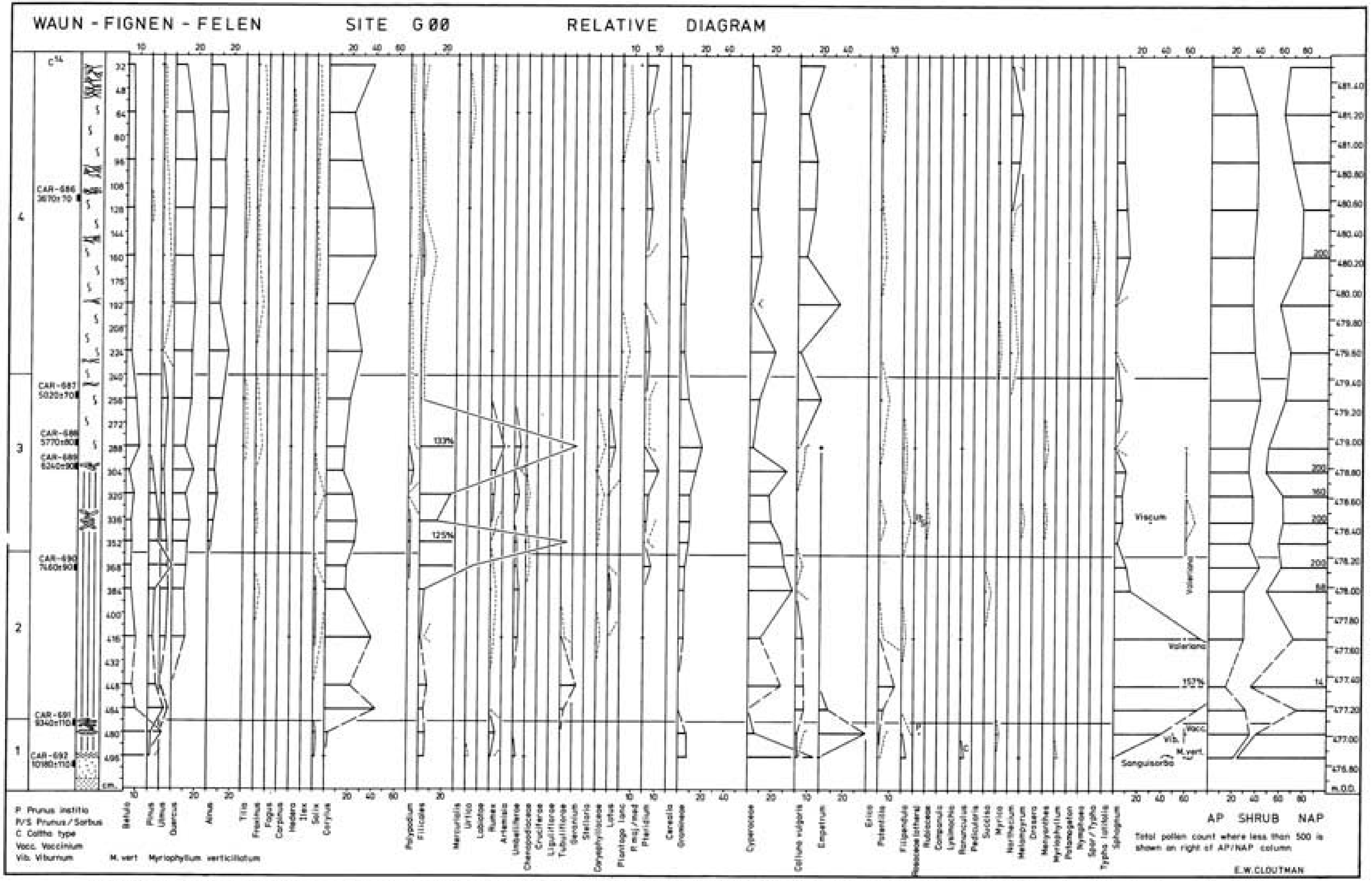


FIGURE 5. Relative total pollen diagram from the deepest part of the basin at Waun-Fignen-Felen (site G00). Stratigraphic symbols are given in figure 4 and the location of the site in figures 3 and 4. (A pollen influx diagram from the site, together with a relative pollen diagram based on tree pollen only, is given in the Supplement.)

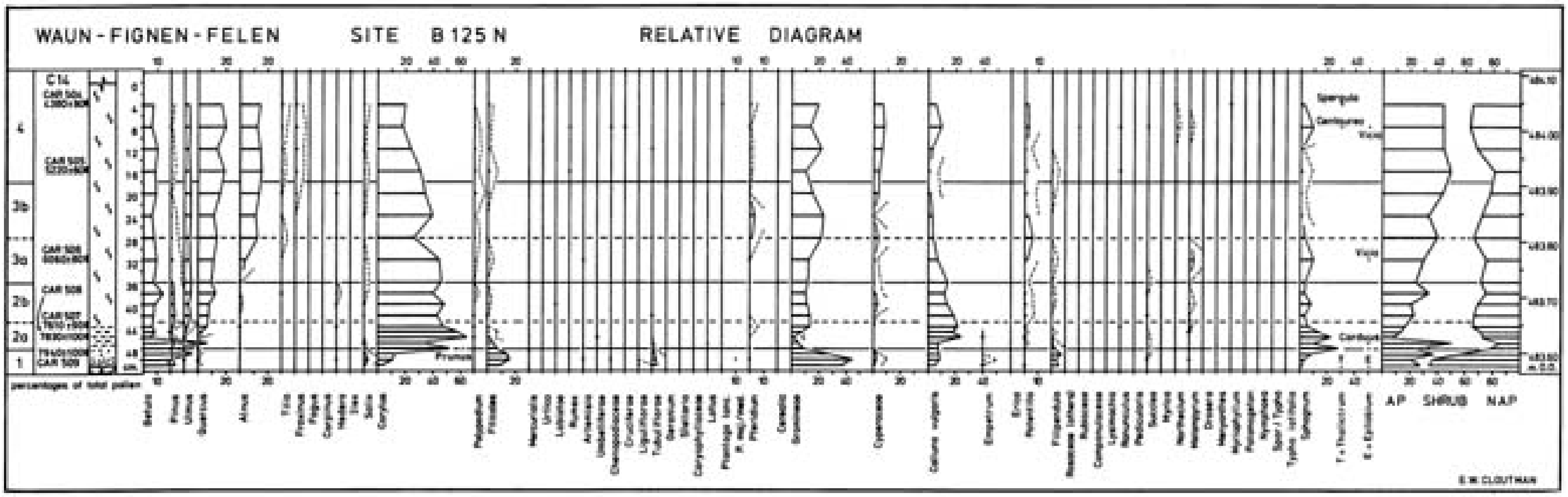


FIGURE 6. Relative total pollen diagram from the oldest mor and blanket-peat site (B125N) at Waun-Fignen-Felen. (Details as for figure 5.)

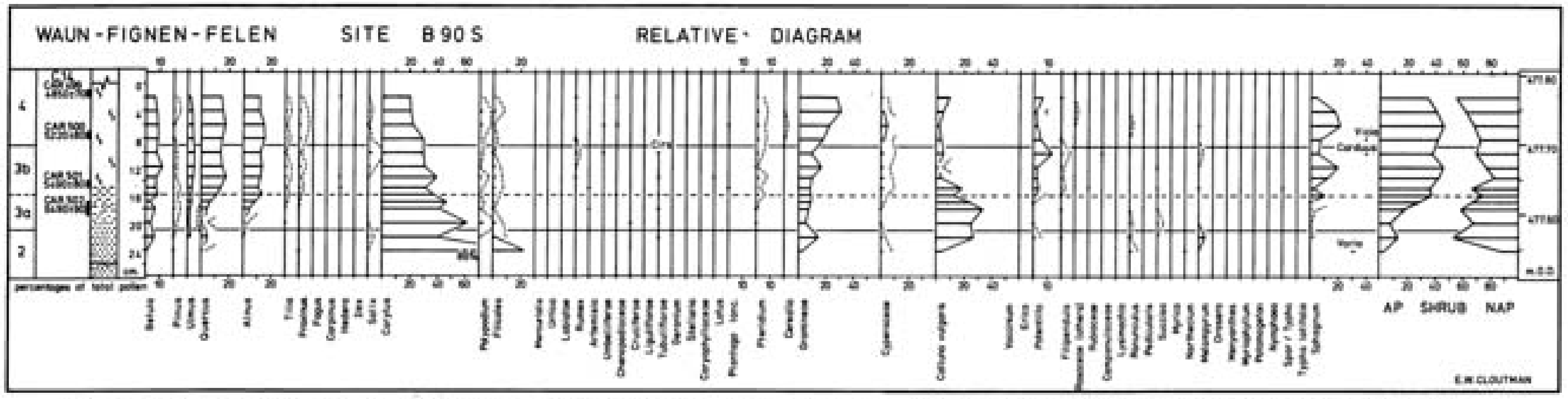


FIGURE 7. Relative total pollen diagram from a site with blanket peat above an iron pan podsol at Waun-Fignen-Felen (B90S). (Details as for figure 5.)

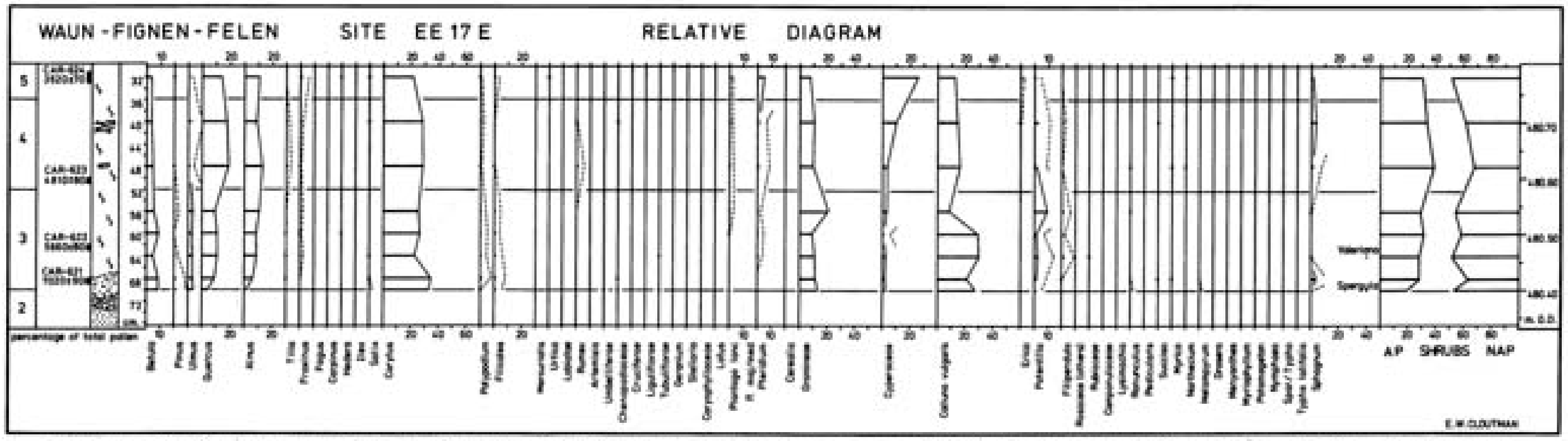


FIGURE 8. Relative total pollen diagram from one of the oldest mor and blanket peat sites (EE17E) found at Waun-Fignen-Felen. (Details as for figure 5.)

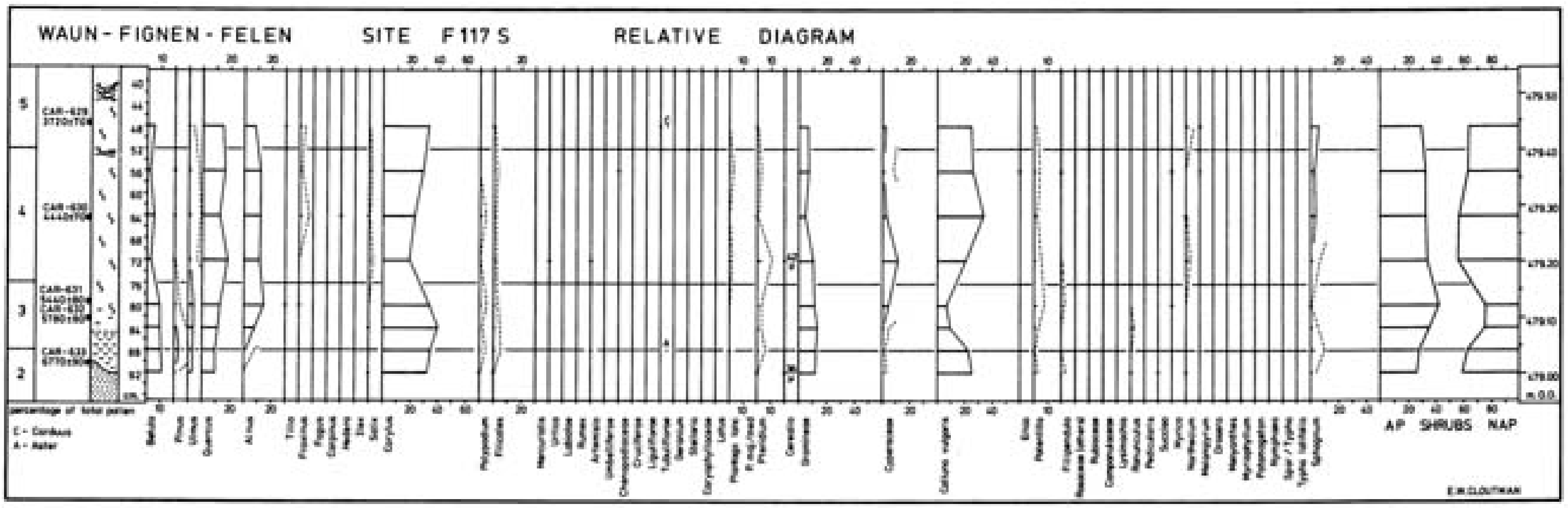


FIGURE 9. Relative total pollen diagram from a mor and blanket peat site (F117S) to the south of the basin area at Waun-Fignen-Felen. (Details as for figure 5.)

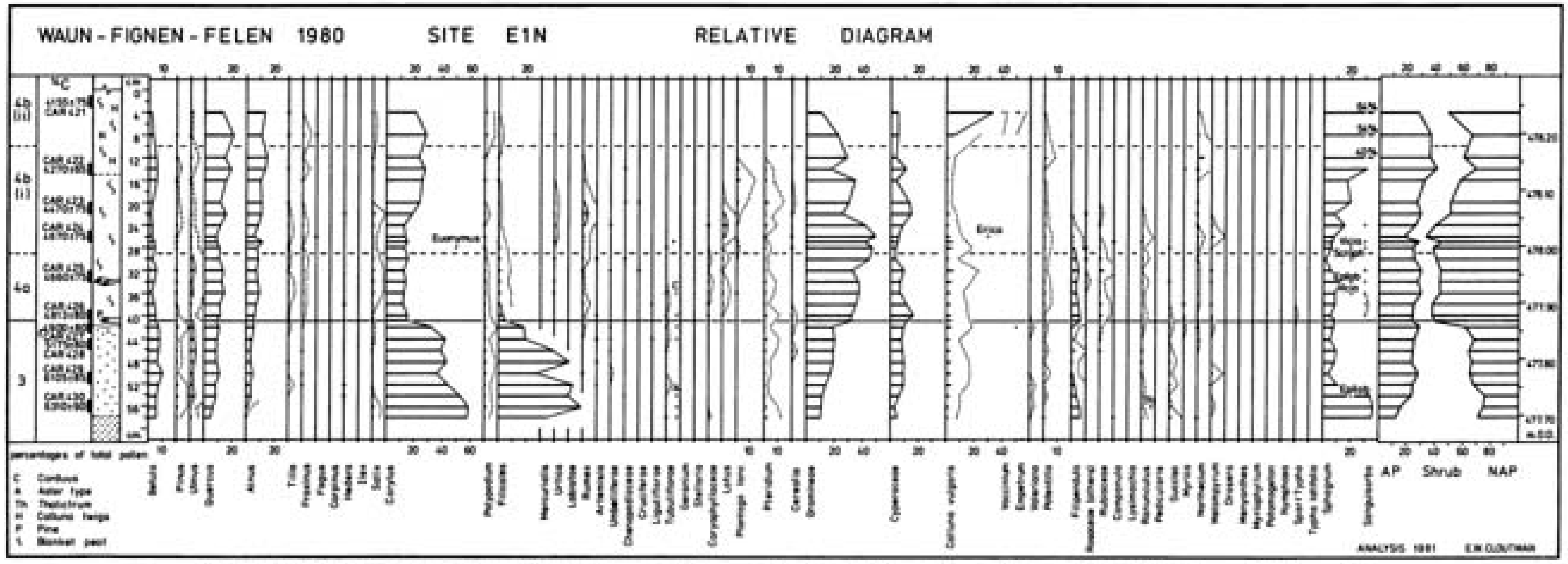


FIGURE 10. Relative total pollen diagram from a basin-margin site (E1N) at Waun-Fignen-Felen. (Details as for figure 5.)

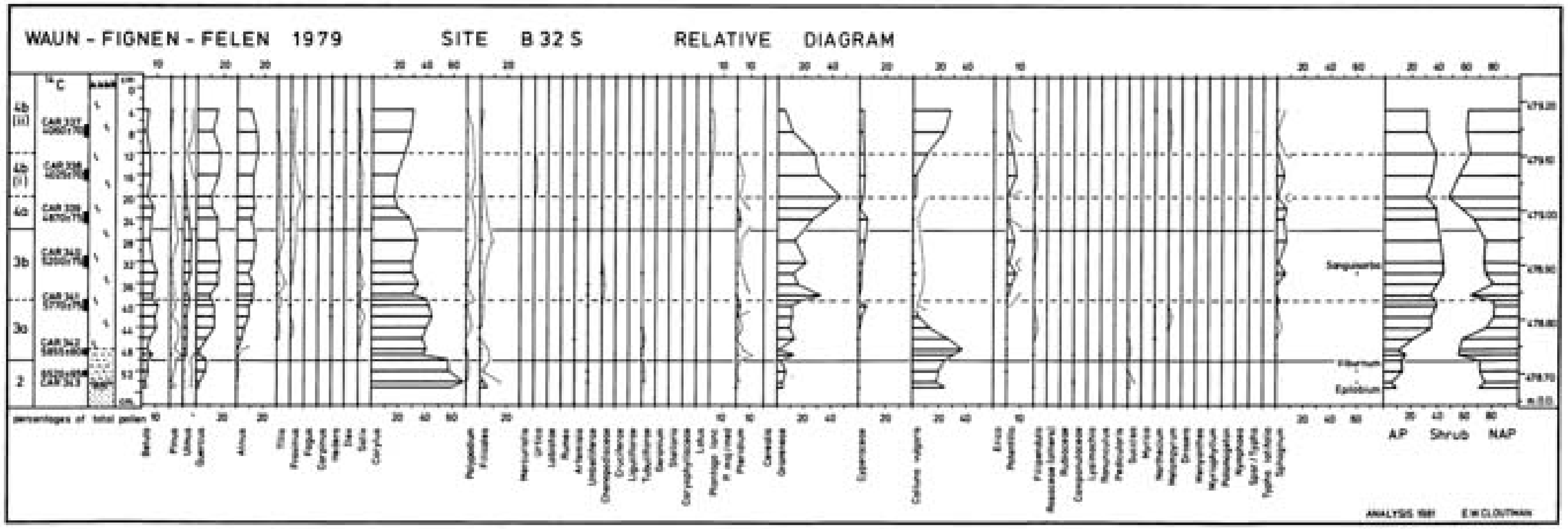


FIGURE 11. Relative total pollen diagram from a central site (B32S) in the blanket-peat area at Waun-Fignen-Felen. A pollen influx diagram from the site is given in figure 12. (Details as for figure 5.)

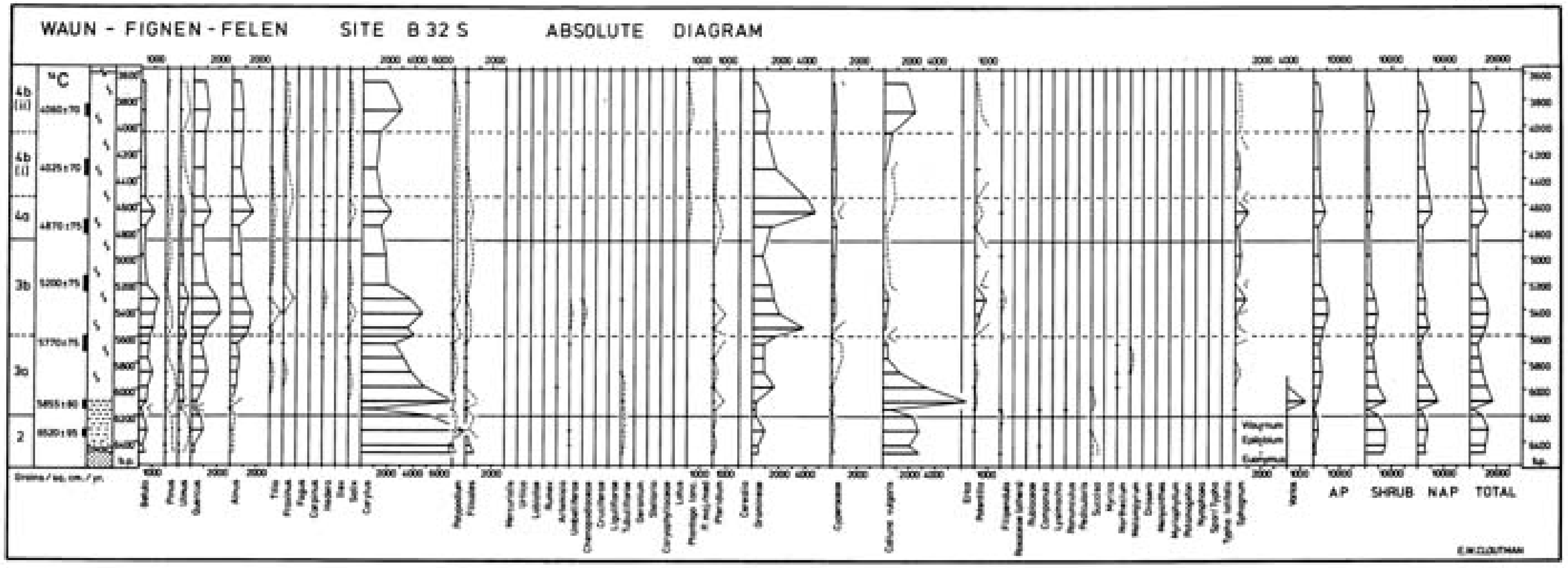


FIGURE 12. Pollen influx diagram from site B32S at Waun-Fignen-Felen. See legend to figure 11.

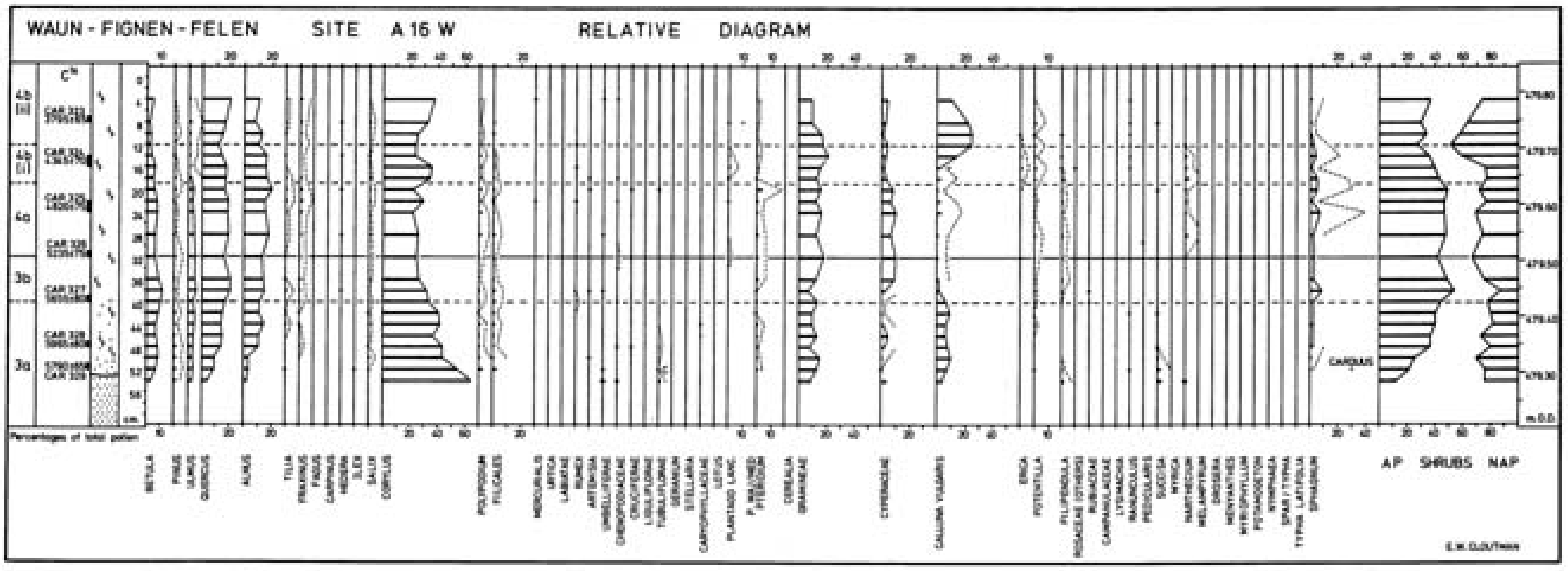


FIGURE 13. Relative total pollen diagram from the central part of the blanket peat area at Waun-Fignen-Felen (site A16W) where no distinct basal mor layer was visible. (Details as for figure 5.)

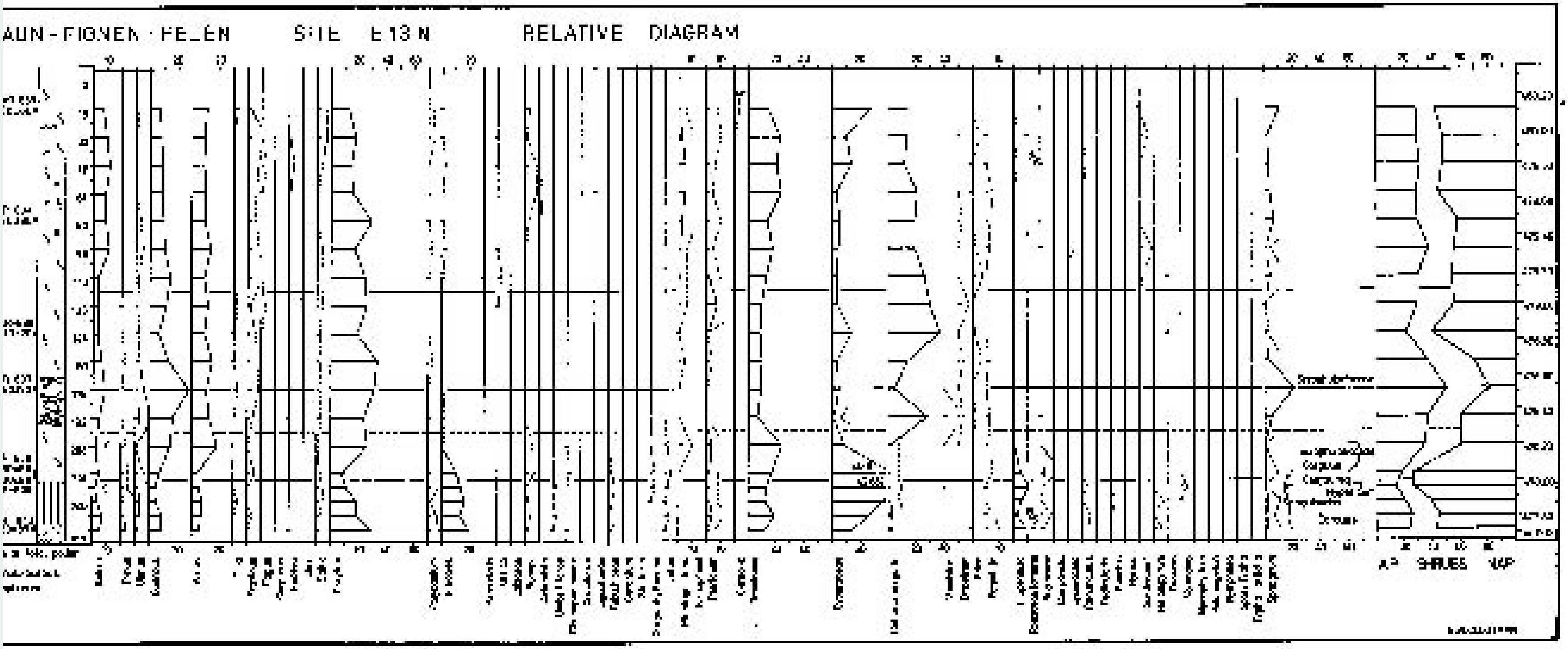


FIGURE 14. Relative total pollen diagram from a site (E13N) marginal to the basin at Waun-Fignen-Felen. Here the depositional sequence begins with reedswamp peats. (Details as for figure 5.)

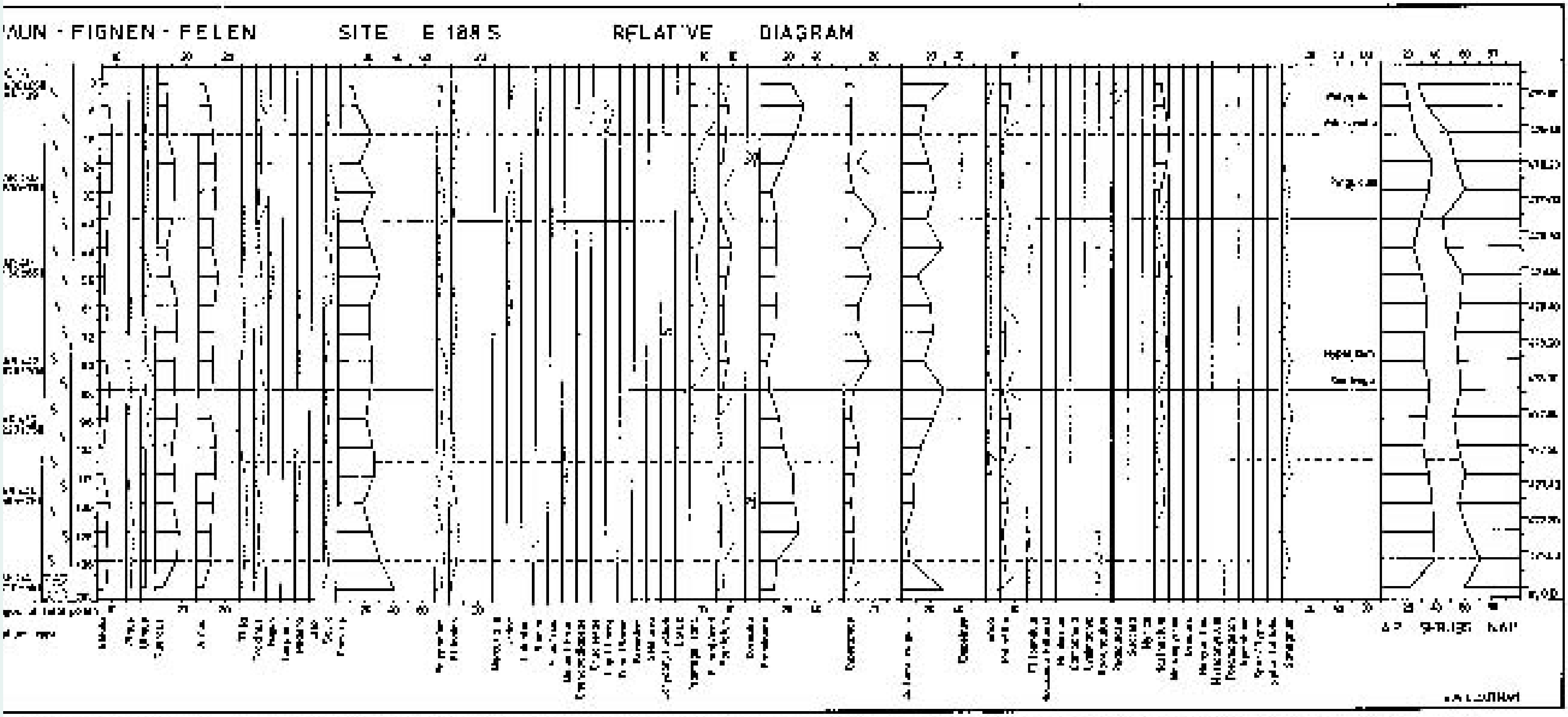


FIGURE 15. Relative total pollen diagram from the southern edge of the blanket peat area at Waun Fignen Felen (site E188S). (Details as for figure 5.)

(Facing p. 142)

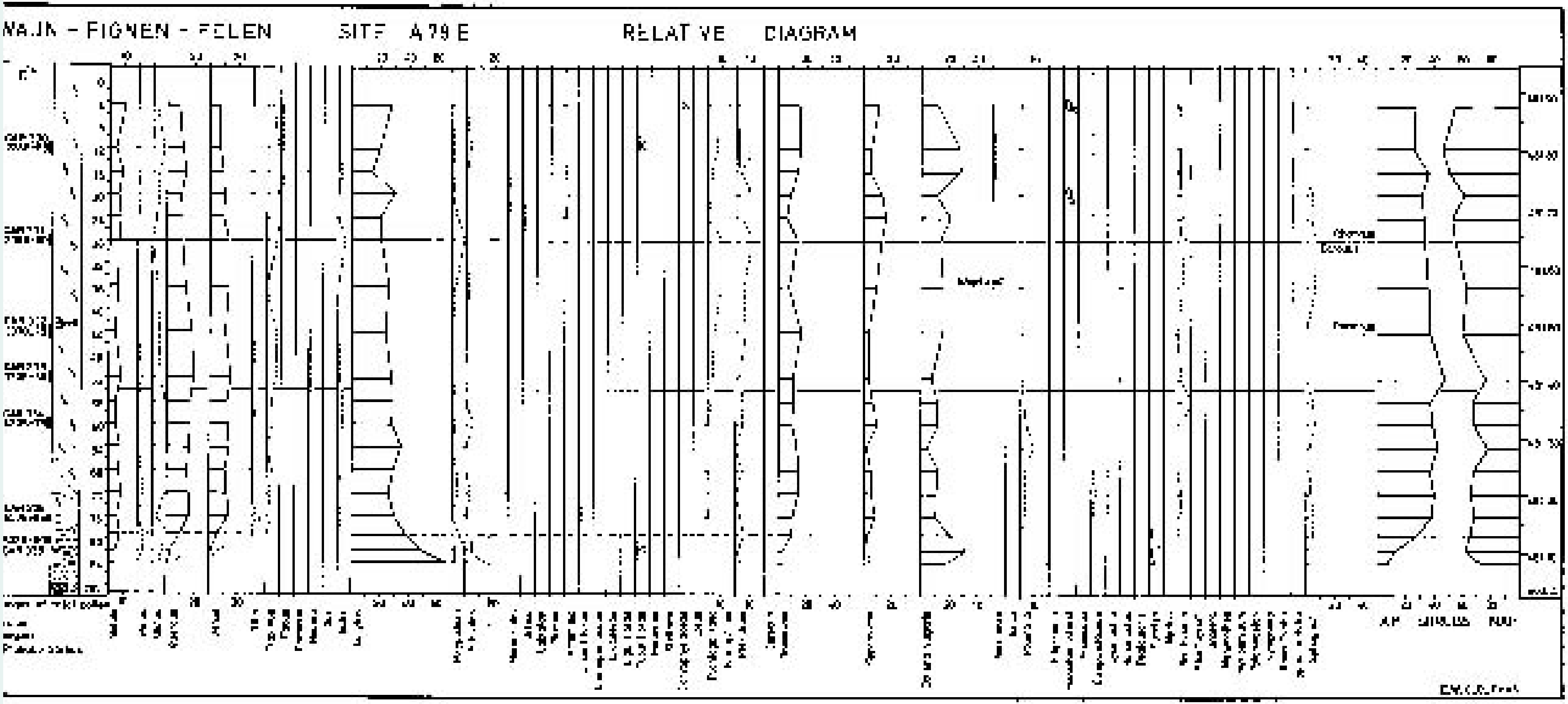


FIGURE 10. Relative total pollen diagram from the western edge of the blanket peat area at Waun Fignen Felen (site A79E). (Details as for figure 5.)

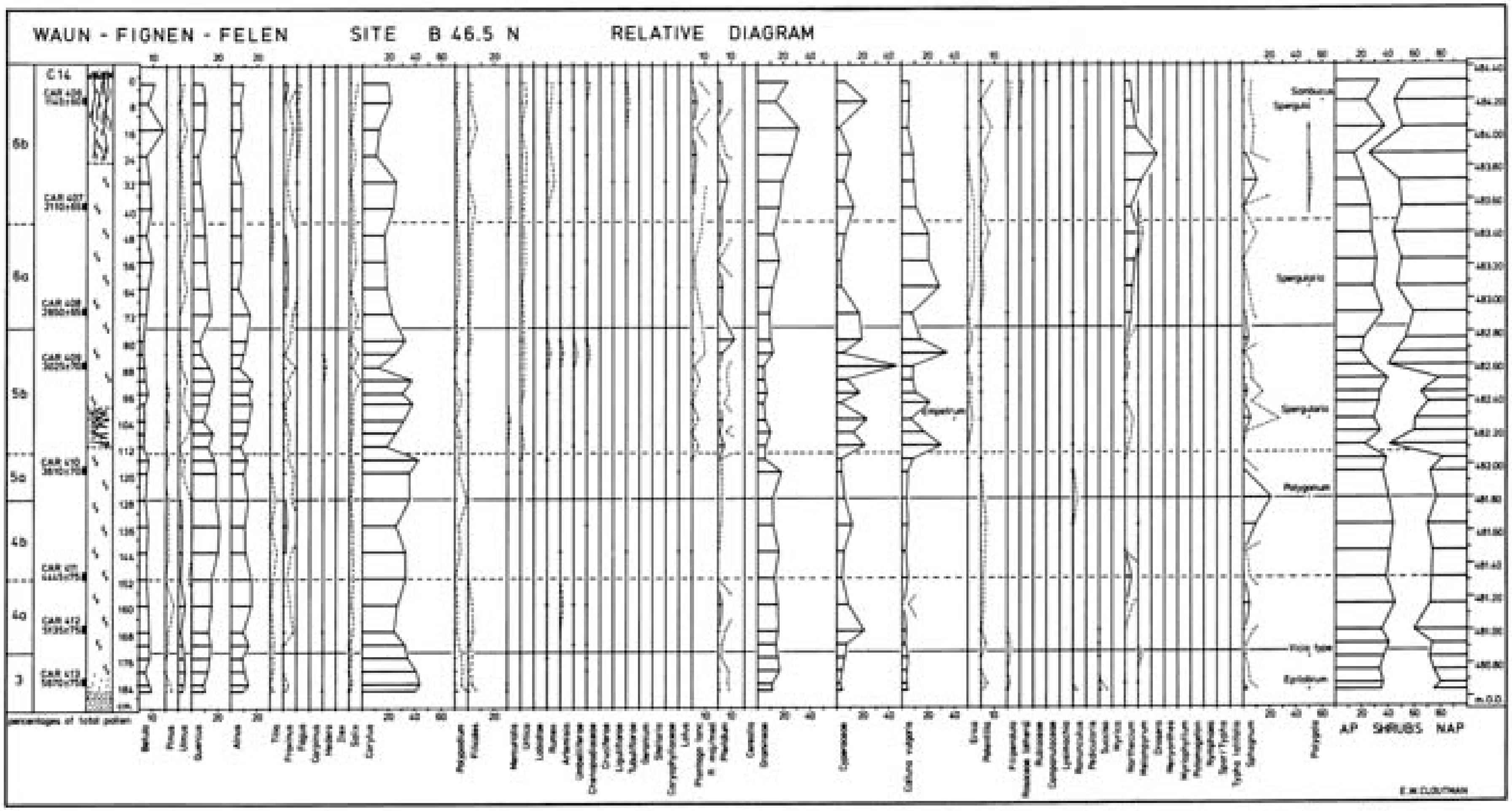
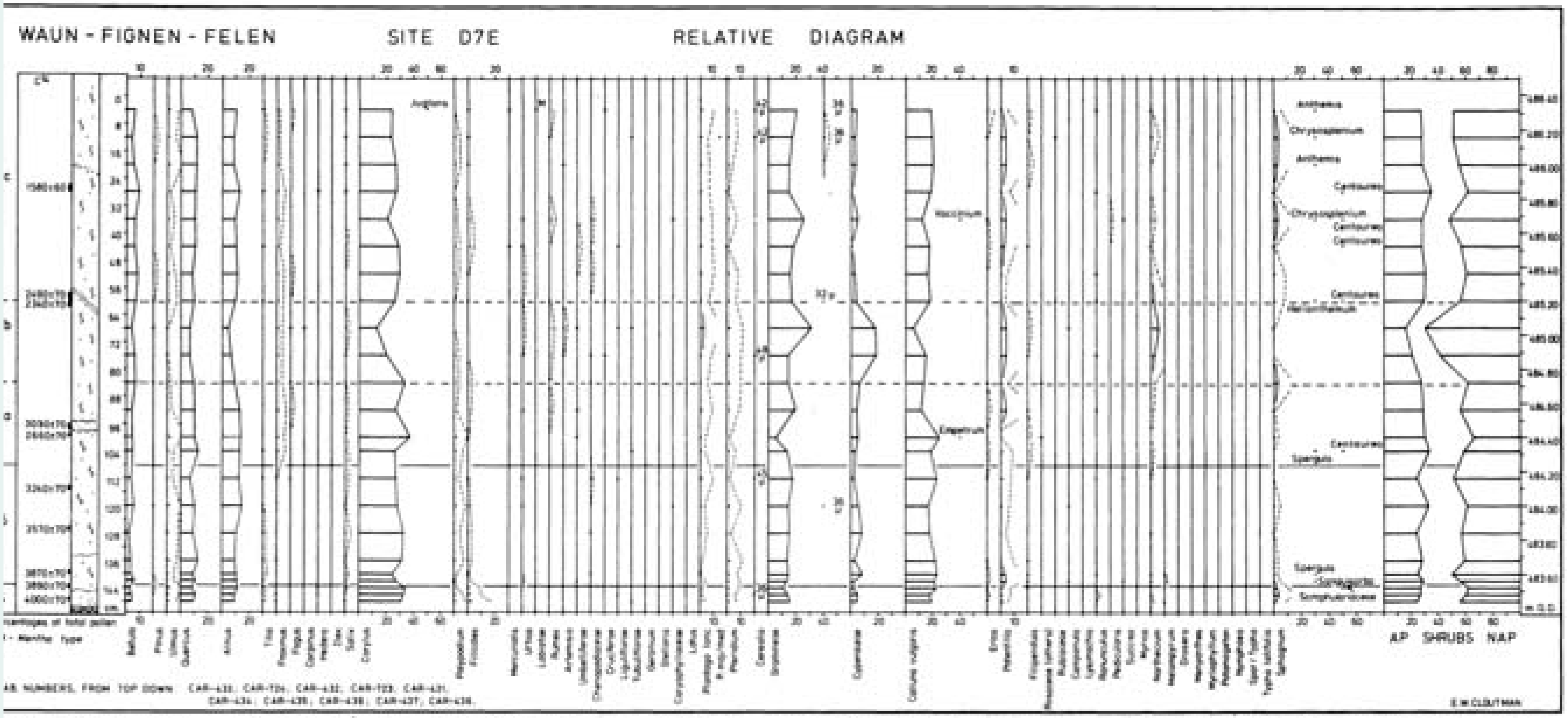


FIGURE 17. Relative total pollen diagram from site B46.5N at Waun-Fignen-Felen. Within the main eastern blanket peat area investigated the mineral soil here remained uncovered by peat for the longest period. (Details as for figure 5.)



IGURE 18. Relative total pollen diagram from a site (D7E) at the edge of the basin at Waun-Fignen-Felen, and at the base of the steep slope of the limestone at the western side. Peat accumulation began notably later here than at other sites in the main bog area investigated. (Details as for figure 5. The influx values are much higher at this site than at all others (see Appendix 3).)

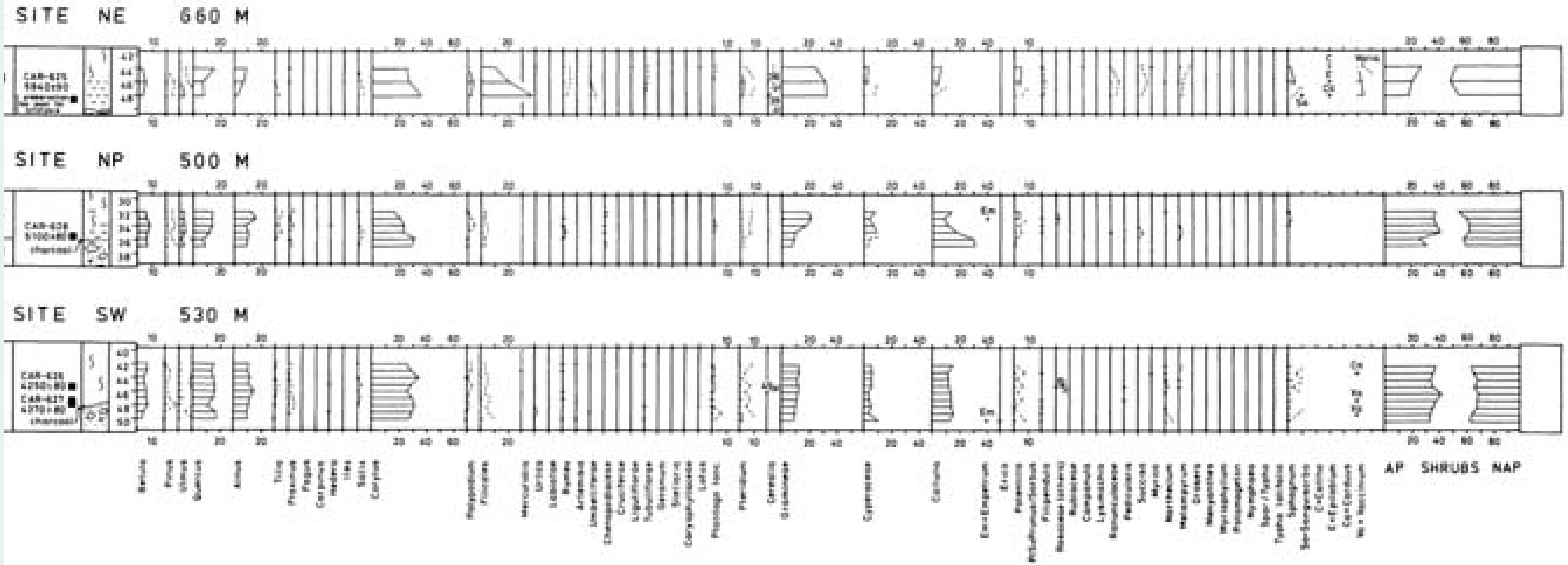


FIGURE 19. Relative total pollen diagrams from the basal deposits at three outlying sites (NE, NP and SW) at Waun-Fignen-Felen. Stratigraphic symbols are given in figure 4 and site locations in figure 2.