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PALAEOECOLOGICAL INVESTIGATIONS AT BALLYNAGILLY, A NEOLITHIC AND BRONZE AGE SETTLEMENT IN COUNTY TYRONE, NORTHERN IRELAND

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CONTENTS

The Neolithic-Bronze Age occupation site at Ballynagilly was covered by blanket peat and surrounded by a deep mire. Stratigraphic investigations, pollen analysis and ^{14}C dating were used to investigate the history of the area and to relate this to the prehistoric occupations. A series of ^{14}C measurements from the mire were used to establish a deposition rate curve from which a time scale for the vegetational history was derived. This was also used to correlate the vegetation history with ^{14}C dated prehistoric occupations.

Organic accumulation began in the deep mire about 8000 B.C. (the notation A.D./B.C. is used to denote a conventional ^{14}C age less 1950 years) and the earliest blanket peats began forming around 1000 B.C. In the early Littletonian Stage (Postglacial) a juniper phase gave way to birch and willow at *7450 B.C. (* is used to denote a date derived from the deposition rate curve). Until *6050 B.C. there was

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a period of low water level with a rich mire vegetation. Elm, oak, hazel and pine entered simultaneously at *6050 B.C. creating a dense forest cover. Alder first appeared at *4970 B.C. but did not expand until *3500 B.C.

The mid-Postglacial was examined in detail and showed evidence of Neolithic forest clearance involving burning. Charcoal of pine, oak and hazel, ^{14}C dated to *ca.* 3200 B.C. was discovered. This date coincides with those for a Neolithic house and other associated features. The Neolithic clearance phase lasted some hundreds of years with periods of minor forest regeneration. During this phase different types of agriculture may have been used. A total recovery of the forest, albeit with a different composition, was deduced to have taken place before new clearance in Beaker times at *ca.* 2000 B.C. Somewhat before this, at *2200 B.C., the final decline of pine pollen occurred but was apparently unconnected with human activity. Heath began to develop at *1800 B.C. and increased in extent following Early Bronze Age clearance of scrub woodland at *1650 B.C.

Various clearance episodes from this time through to *200 B.C. caused a further progressive deforestation. Brief regeneration after *200 B.C. was followed by indications of locally wetter conditions and renewed deforestation at A.D. *450. Despite some scrub regeneration around A.D. *800 continuing pressures on the woodland culminated in a open landscape by A.D. *1500.

1. Introduction

(*a*) *Site description*

The archaeological site of The Corby, Ballynagilly Townland is about 8 km northwest of Cookstown, County Tyrone, Northern Ireland, Irish Grid Ref: H 743837 (figure 1). The Neolithic and Beaker occupation areas are on a low hill at about 200 m above sea level in a valley surrounded by higher ground on the north and east. The hill, composed of sands and gravels, is probably of glacial origin and is surrounded by mires of various depths. To the south and east is a deep mire that was probably open water or reedswamp in prehistoric times. To the northeast there is a steep sided channel. Access to the hill in prehistoric times is likely to have been from the northwest as at present.

The archaeological site was discovered by Mr J. Brennan in 1965 when the owner was bulldozing the hill to remove blanket peat prior to excavating the sand and gravel. The quarrying continues from time to time and has now largely destroyed the site. Excavations were carried out between 1966 and 1970 by Mr A. M. ApSimon of the Department of Archaeology, University of Southampton on behalf of the Ministry of Finance for Northern Ireland (ApSimon 1976). A brief summary of the archaeological finds relevant to the palaeoecological work is given below.

(*b*) *Archaeology*

On the summit of the hill there was a western Neolithic settlement covering an area of about 200 square metres. The most important feature excavated was a rectangular house, 6.5 × 6 m (ApSimon 1969). The wall slots for the sides of the house were 0.3 m wide and up to 0.3 m deep. The walling appears to have been of split oak planking which was preserved as a vertical layer of charcoal about 10 mm thick with a vertical grain and the rays parallel to the slot. Also in this area was a pit containing Neolithic pottery, numerous hearth pits, rubbish pits and post and stake holes.

About 50 m southeast of the main Neolithic site, a Bell Beaker occupation was found. This produced large quantities of pottery and flint artifacts, but no structures. There were several pits and a few stake holes. The pottery is similar to that from other Irish Bell Beaker sites such as Dalkey Island (Liversage 1968), Lough Gur (Liversage 1958) and Rockbarton (Mitchell & O'Riordain 1942). Under the Bell Beaker occupation in one area there were traces of a Western Neolithic occupation. Over, and in places mixed with, the Beaker occupation was material from an Early Bronze Age re-utilization of the site. At the level of the underlying Neolithic occupation, a pit over 4 m long, 1 m wide and 0.8 m deep was found. The pit was filled with heat-fractured stones, charcoal and ash-stained sand. This is thought to have been a cooking place and is more likely to have been of Neolithic Age than Bell Beaker. A large, intensely burnt hearth was found about 3 m away.

An early Bronze Age occupation with 'Plainware' was found about 30 m east of the Beaker site. Another Beaker occupation occurred 100 m to the northeast. At various other points on

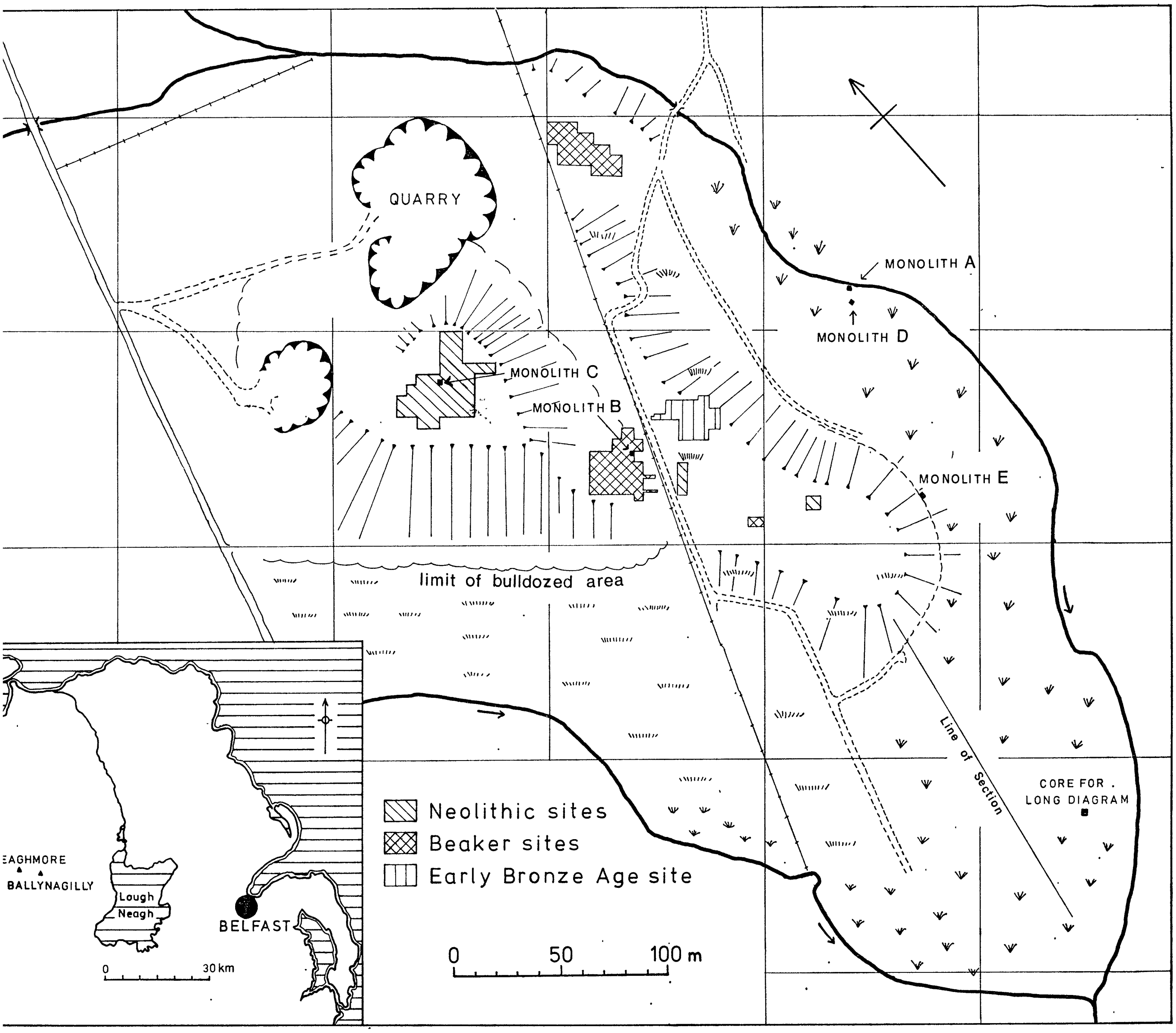

FIGURE 1. Site plan showing the relation of deep organic deposits and sample locations to the prehistoric occupation sites at Ballynagilly. (Further maps are given in ApSimon 1976.)

the hill minor Neolithic, Beaker and Bronze Age sites were encountered and northeast of the stream, surface finds indicated a substantial Neolithic occupation.

(c) *Palaeoecology*

This site provided the opportunity to associate vegetational changes with distinct prehistoric occupation phases using ^{14}C dating as the link between the two. A detailed vegetational record was provided by pollen analysis of the deep organic deposits to the south of the site. This was supplemented by analysis of blanket peat and soil samples mainly from the archaeological site.

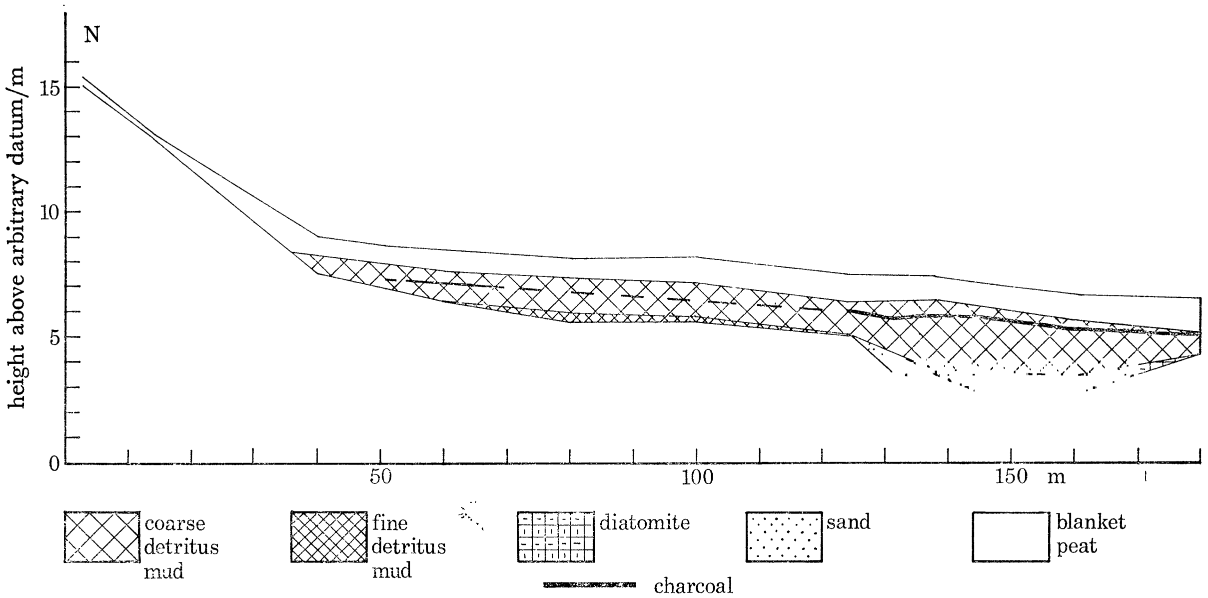

FIGURE 2. Outline section of the deep organic deposits to the south of the archaeological sites, constructed from a series of 'Hiller' borings. The line of the section is shown in figure 1.

2. STRATIGRAPHY AND METHODS

(a) *Stratigraphy and field sampling*

The stratigraphy of the organic deposits to the south of the hill on which the habitation sites were situated was investigated by borings and in stream sections. A section (figure 2) was drawn from borings on a line from the deepest point discovered in test probes, to a point on the hill near the edge of the Beaker occupation area (see figure 1). The section shows a large area of fairly shallow organic deposits with a deeper pocket of detritus muds underlain by diatomaceous mud. The shallower deposits consist of a thin layer of fine detritus mud overlain by about 1.5 m of the coarse detritus mud which also substantially fills the deeper basin. Throughout the section there is a layer of charcoal at relatively constant depth in the upper part of the coarse detritus mud.

The sequence is capped by a deposit of *ca.* 1.0 m of blanket peat. It was clear, however, from standing baulks of peat that some 0.5–1.0 m of peat had been removed by cutting along the line of the section. Attempts to obtain a large core at the deepest point failed as the deposits were too liquid. Finally a sampling point somewhat removed from the section line had to be chosen where there was a baulk, with the original surface intact, large enough for the boring equipment

(Smith, Pilcher & Singh 1968) to be erected. The stratigraphy at this point, recorded from the cores, is as follows:

0–0.23 m	Very fibrous blanket peat; probably disturbed.
0.23–1.55 m	Blanket peat with marked patches of *Calluna*, *Eriophorum* and *Sphagnum*. Charcoal present at 0.83, 0.95 and 1.35 m. (1.50–1.55 m disturbed by borer.)
1.55–1.74 m	Coarse organic deposit with occasional wood fragments. Charcoal present at 1.63–1.73 m; concentrated at 1.67 m.
1.74–2.00 m	Reedy detritus mud. Charcoal at 1.74 to 1.81 m with large pieces at 1.77–1.78 m and 1.94–1.97 m.
2.00–2.41 m	Woody reedswamp peat. Pine cone at 2.26–2.28 m.
2.41–3.15 m	Coarse detritus mud with some reeds and wood. Charcoal fragments present at 2.46 to 2.65 m, main concentration at 2.53–2.57 m.
3.15–3.31 m	Coarse detritus mud with some wood.
3.31–3.40 m	Coarse detritus mud.
3.40–3.75 m	Moss peat composed largely of *Polytrichum*.
3.75–3.96 m	Fine detritus mud.
3.96–4.00 m	Mud with fine sand and diatoms, becoming more sandy at base.

The blanket peats were sampled at five points by taking monoliths from exposures or pits. The location of these samples is shown in figure 1 and descriptions given in § 5.

(*b*) *Pollen sampling and presentation*

The 0.1 m diameter cores and the monoliths were subsampled in the laboratory. Pollen samples were taken contiguously every 5 mm from the cores and every 10 mm from the monoliths. The pollen samples were prepared by maceration in caustic soda, acetylation and, where necessary, by treatment with hydrofluoric acid. The preparations were mounted in silicone oil.

Pollen values were calculated as a percentage of the total pollen. Spores of ferns and lower plants were excluded from the pollen sum, but were calculated as a percentage of that sum. A total of approximately 500 pollen grains were counted per sample except for the lowermost eight samples from the long core where the total was approximately 200.

Two diagrams are presented from the long core. The first (figure 4) has a relatively large sampling interval (in general 80 mm) and covers a large part of the Littletonian (Postglacial) period. The second (figure 5) only covers some 1.1 m of the deposits and includes additional samples which reduce the sampling interval to 10 mm, the samples themselves being 5 mm in thickness. In both diagrams the radiocarbon dates, with their precisions, are recorded to the left of the stratigraphic column. The dates are quoted in years B.P. (years before A.D. 1950). A time scale derived from the radiocarbon dates is presented at the right of the diagrams. Local pollen assemblage zones (cf. West 1970) have been used to sub-divide the two pollen diagrams for the purposes of discussion. The assemblage zones are designated BG-1 to BG-9 and are shown on the left of the diagrams. Since these pollen assemblage zones are geochronologically dated by radiocarbon assay, they conform to the criteria for chronozones. We do not, however, at present wish to suggest designation of Ballynagilly as a type site. Certain of the assemblage zones have been subdivided, and correlations with the zonation scheme of Jessen (1949), where appropriate, are mentioned in the text.

(c) *Radiocarbon dating*

Throughout the excavations, charcoal samples were carefully and critically collected by the excavators. In the light of a preliminary study of the artifactual material from the site, a number of charcoal samples from unambiguous contexts were selected for dating. All samples including those from the peat deposits were dated in the Palaeoecology Laboratory at Queen's University,

Table 1. Radiocarbon dates from Ballynagilly archaeological contexts

(All measurements were carried out in the Palaeoecology Laboratory, Queen's University. List numbers refer to date lists published in *Radiocarbon* (see Smith, Pearson & Pilcher (1970*a*, *b*; 1971*a*, *b*; 1973*a*, *b*). Dates are conventional dates quoted both as B.P. (Before A.D. 1950) and 'B.C.' (the 'B.P.' date less 1950 years).)

list	laboratory number	description or context	date/B.P.	date/B.C.
Early Neolithic				
III	UB-305	hearth and ash pit in Neolithic area	5745 ± 90	3795
III	UB-307	pit and gully with Neolithic pottery	5640 ± 90	3690
I	UB-197	{Neolithic 'borrow' pit with Western Neolithic	5625 ± 50	3675
V	UB-559	{ pottery	5500 ± 85	3550
Neolithic				
III	UB-304	pit sealed by Neolithic artifacts	5370 ± 85	3420
V	UB-551	pre-Bell Beaker cooking place	5290 ± 50	3340
III	UB-199	post hole in Neolithic house	5230 ± 125	3280
I	UB-201	wall slot of Neolithic house	5165 ± 50	3215
III	UB-301	pit with Neolithic artifacts	4910 ± 90	2960
III	UB-306	Middle Neolithic hearth	4880 ± 110	2930
V	UB-625	pit with Western Neolithic pottery	4835 ± 55	2885
V	UB-552	pit with pottery, younger than Middle Neolithic	4205 ± 50	2255
V	UB-554	charcoal associated with Neolithic flints	4110 ± 50	2160
V	UB-553	charcoal associated with Neolithic flints	4055 ± 50	2105
Beaker				
V	UB-555	pit with Beaker pottery	4050 ± 50	2100
V	UB-558	depression with Beaker pottery	4010 ± 80	2060
III	UB-316	hearth with Beaker pottery	3960 ± 75	2010
III	UB-200	hearth pit	3905 ± 120	1955
III	UB-356	charcoal associated with Beaker pottery	3905 ± 75	1955
V	UB-556	hearth pit with Beaker pottery	3860 ± 50	1910
III	UB-309	pit with Beaker pottery	3850 ± 55	1900
V	UB-557	pit with Beaker pottery	3780 ± 70	1830
Early Bronze Age				
I	UB-198	hearth with Early Bronze Age sherd	3590 ± 60	1640
III	UB-355	charcoal with plainware	3525 ± 75	1575
III	UB-315	hearth with plainware	3480 ± 80	1530
III	UB-314	pit with plainware	3455 ± 60	1505
possibly anomalous				
VI	UB-501	pit with charcoal near Neolithic house containing one sherd of Neolithic pottery	3605 ± 55	1655
		(The charcoal at least clearly belongs to the Early Bronze Age)		
stratified charcoal layers				
I	UB-15	oak charcoal from monolith A	5195 ± 60	3245
III	UB-18	hazel charcoal from monolith E	5295 ± 90	3345
bog oak				
III	UB-293	10 annual rings, 60 years from outside, of bog oak found near site	4395 ± 80	2445

Belfast. Full details are given in *Radiocarbon* (Smith, Pearson & Pilcher 1970*a*, *b*; 1971*a*, *b*; Pearson (in preparation)). The results are summarized in tables 1 and 2. In the tables and throughout this paper, the radiocarbon dates quoted are conventional dates based on a half-life of 5570 years, denoted by the convention 'B.P.' Small capitals (A.D./B.C.) are used conventionally to express uncalibrated ^{14}C measurements on the Christian calendar.

Table 2. Radiocarbon dates for Ballynagilly peat core and monoliths

(List numbers refer to date lists published in *Radiocarbon* by the Belfast Laboratory (see Smith, Pearson & Pilcher 1970*a*, *b*; 1971*a*, *b*; 1973*a*, *b*; Pearson, in preparation). Dates are conventional dates quoted both as 'B.P.' (before A.D. 1950) and 'B.C.' (the 'B.P.' date less 1950 years.)

list	laboratory number	context	date/B.P.	date/B.C.
III	UB-242	Core, 0.40–0.44 m	695 ± 80	1255†
III	UB-244	Core, 1.20–1.24 m	2375 ± 80	425
II	UB-245	Core, 1.64–1.67 m	3135 ± 60	1185
II	UB-246	Core, 1.78–1.81 m	3340 ± 65	1390
II	UB-247	Core, 1.94–1.97 m	3620 ± 60	1670
III	UB-248	Core, 2.04–2.07 m	3955 ± 55	2005
II	UB-249	Core, 2.14–2.17 m	4025 ± 65	2075
II	UB-250	Core, 2.26–2.29 m	4340 ± 65	2390
II	UB-251	Core, 2.36–2.39 m	4540 ± 65	2590
II	UB-252	Core, 2.44–2.47 m	4850 ± 70	2900
II	UB-253	Core, 2.53–2.56 m	5145 ± 70	3195
II	UB-254	Core, 2.61–2.64 m	5575 ± 70	3625
III	UB-255	Core, 2.70–2.73 m	5920 ± 60	3970
III	UB-257	Core, 3.10–3.14 m	7275 ± 95	5325
III	UB-258	Core, 3.30–3.34 m	8095 ± 80	6145
IV	UB-322D	Core, 3.76–3.80 m	9535 ± 110	7585
IV	UB-322C	Core, 3.76–3.80 m	9180 ± 110	7230
III	UB-260	Core, 3.80–3.84 m	9595 ± 80	7645
III	UB-297	Core, 4.00–4.04 m	9595 ± 125	7645
I	UB- 15	Monolith A, 0.22–0.24 m	5195 ± 60	3245
X‡	UB-168	Monolith B, 0.22–0.24 m	1735 ± 65	215†
X	UB-171	Monolith C, 0.22–0.24 m	2525 ± 45	575
X	UB-174	Monolith D, 0.16–0.18 m	2510 ± 70	560
X	UB-175	Monolith D, 0.26–0.28 m	2940 ± 75	990
III	UB- 18	Monolith E, 0.28–0.31 m	5295 ± 90	3345

† date/A.D.
‡ List X is Pearson (in preparation).

For two pollen diagrams (figures 4 and 5) deposition rates have been derived from a graph of ^{14}C dates against depth (figure 3). The dates are plotted on this graph as bars extending either side of the mean through which the line is drawn. Where no ^{14}C determination is available for an inferred vegetational change, an interpolated date is read from this line. Dates deduced by interpolation in this way are designated by an asterisk, thus: *2150 B.C. Results given in this form are obviously subject to the statistical errors of measurement (usually one s.d. of ± 60 to ± 80), together with such errors as may have been introduced by interpolation and by the assumption of a constant deposition rate. Two interpolated dates that are closer together than the quoted error of the measurements must still, however, be considered as distinct and in the correct chronological order.

All samples shown by black bars in figure 3 were given an acid pretreatment. In this treatment the alkali-soluble humic acids are retained in the sample. Separated humic acid and particulate fractions were dated from a sample at 3.76–3.80 m (UB-322). As may be seen from figure 3, the particulate fraction date UB-322 D is conformable with the acid-treated whole peat dates UB-258 and UB-260. Since the particulate fraction is considered the most reliable (Dresser 1970) it is likely that the whole peat dates are not unduly biased by the presence of alkali-soluble materials. However, judging from the general deposition rate, the date of the basal sample (UB-297) is too young. An attempt to clarify this problem by fractionation failed, due to the low carbon content of the deposits. Because of this a date for the base of the deposits has been estimated by extrapolation of the deposition rate curve below UB-260 as shown in figure 3.

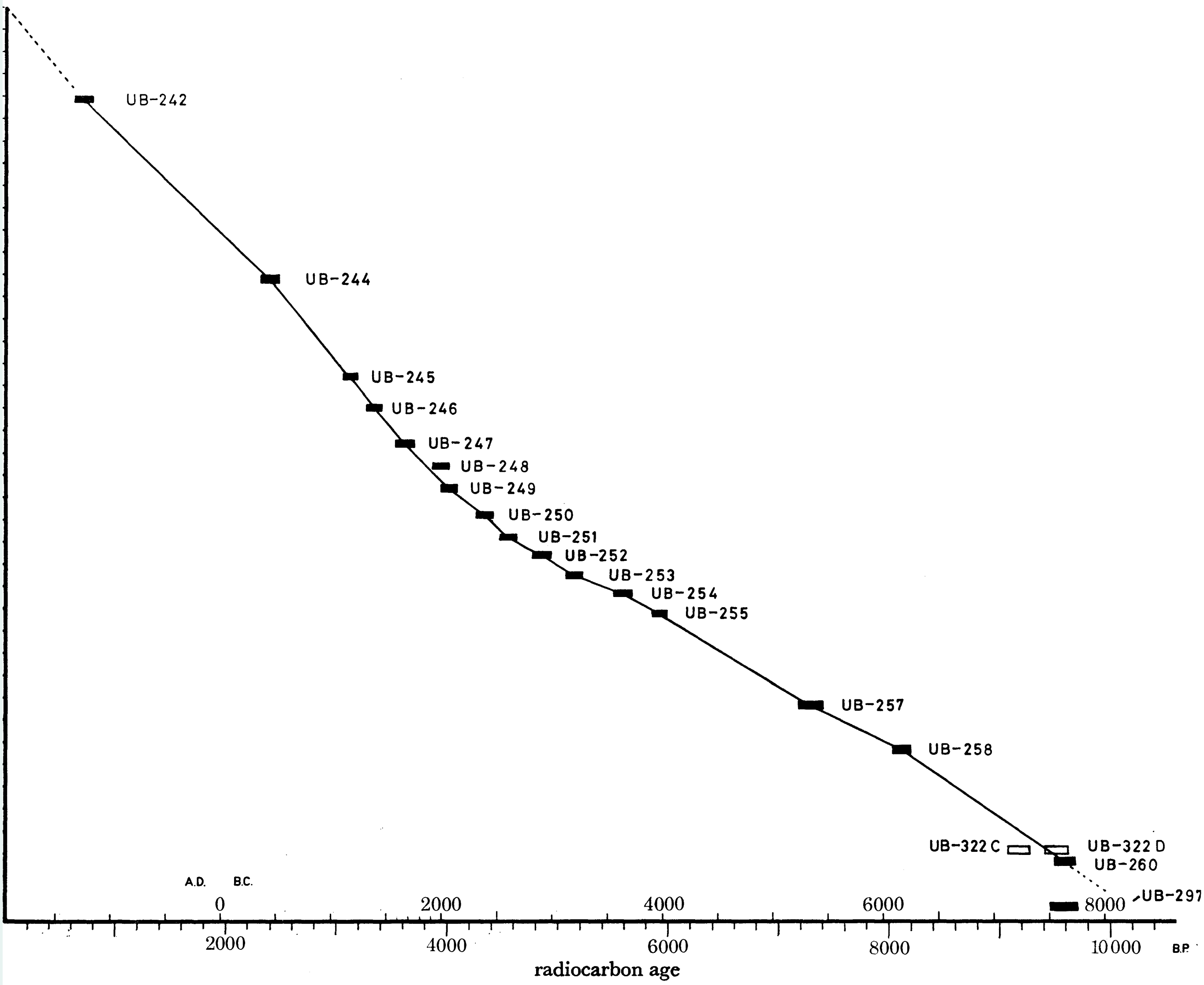

FIGURE 3. Graph of ^{14}C dates for samples 10 mm thick, against depth, for the core from which pollen diagrams given in figures 4 and 5 were constructed. The location of the core is shown in figure 1. The radiocarbon dates are listed in table 2. The length of the bars represents a 1σ error either side of the mean. Samples represented by black bars were given an acid pre-treatment. For sample UB-322 (white bar), the material was split into two fractions. UB-322C is the alkali-soluble humic acid, and UB-322D is the particulate fraction: see Smith, Pearson & Pilcher 1971 *b*.

3. General vegetational history

The early vegetational history of Ballynagilly is unfortunately confused by the possibility of contamination of the deposits. It can be seen in the diagram (figure 4) that there is an unusually early appearance of hazel pollen, an isolated peak of which falls broadly in zone BG-2. This peak is lower than the level of the ^{14}C sample UB-260 which is dated to 9595 ± 80 B.P. Hazel pollen is equally early at Red Moss, Lancashire (Hibbert *et al.* 1971) and at Scaleby Moss, Cumberland (Godwin, Walker & Willis 1957; Walker 1966). In the present case, however, the occurrence is isolated from the later major rise of the curve and is paralleled by a temporary rise of the pine curve. The low values of oak and elm speak against the idea of contamination by younger deposits. Analysis of intermediate samples revealed no deviation from the pattern in figure 4 such as might have been expected had the coring or sub-sampling procedures introduced contamination. Contamination by derived pollen appears unlikely on account of the good pollen preservation and lack of inorganic material or other evidence of redeposition. As implied above, it appears likely that the basal ^{14}C sample (UB-297) contains younger humic material while the dates above (UB-260 and UB-258) are substantially correct. There is thus a continuity in the ^{14}C series that argues against gross contamination. While several speculations could be made about the depositional conditions at this level, no single satisfactory explanation can be advanced.

*Zone BG-1, before *8000 B.C.: zone III* (sensu *Jessen*)

A pollen sample from a depth of 4.08 m contained pollen of aquatic plants, but an insufficient total was counted for inclusion in the diagram. It is clear from the high proportion of non-arboreal pollen in zone BG-1 and the presence of some characteristic pollen types, that this sandy and diatomaceous sediment accumulated at the end of the Late-Midlandian Stage. The samples up to 3.92 m may thus be assigned to zone III (*sensu* Jessen 1949). The extrapolated ^{14}C date for the end of the Late-Midlandian is similar to others from Ireland (Smith & Pilcher 1973) which fall somewhat after 10000 B.P.

*Zone BG-2, *8000–*7450 B.C. cf. zone III–IV (cf. Smith 1961): zone IV in part* (sensu *Jessen* 1949)

Zone BG-2 is distinguished by the relative abundance of juniper pollen. During this period the tree pollen rises to 60%, but this figure is enlarged by the presence of hazel pollen considered to be anomalous. In spite of this it seems that by the end of the zone there was at least partial tree cover, allowing that at least some of the grass and sedge pollen present may have been coming from the vegetation of the mire basin itself. Zone BG-2 is similar in many respects to the transition zone III/IV at Cannons Lough, Co. Londonderry (Smith 1961).

*Zone BG-3, *7450–*6050 B.C.: zone IV in part* (sensu *Jessen*)

Just before the beginning of the zone at *ca.* 7500 B.C., which is characterized by a preponderance of birch, grass and sedge pollen, there is a change in the deposits from a fine detritus mud to a *Polytrichum* peat. The long wiry stems of the moss formed a large component of the peat and the spores were very abundant in the pollen preparation. The identity of the spores was at first unknown and it was not until scanning electron micrographs were published (Pilcher 1968) that they were identified. We are indebted to Dr J. Dickson (Department of Botany, Glasgow University) for pointing out the similarity of the spores illustrated to those of *Polytrichum*. The change from aquatic deposits to a moss peat and back to aquatic deposits suggests that there may have been low water levels during the period *7500–*6300 B.C. Low water levels in the late Boreal have been recorded in many places (e.g. recorded at Hockham Mere by Godwin & Tallantire 1951), but at Ballynagilly the *Polytrichum* peat belongs to an earlier period.

In view of the virtual absence of hazel pollen, this period must be assigned to zone IV as defined by Jessen. Zone V, the period in which the hazel curve rises, is absent (cf. Watts 1961). Radiocarbon dates show no indication of a stratigraphic break at the point at which hazel, oak and elm pollen appear. The virtual absence of hazel before *6050 B.C., except for the possible contaminant hazel in zone BG-2, may therefore, be due to local conditions. Hazel pollen is present at Slieve Gallion, only 8 km away, well before *6000 B.C. and in fact first appears at *7000 B.C. (Pilcher 1973).

Zone BG-4, *6050–*4970 *B.C.*: *zone VI* (sensu *Jessen*)

The beginning of zone BG-4 is marked by the arrival of oak, elm and hazel and slightly later shows an increase of pine pollen. A change from possible semi-open birchwood to certainly closed forest conditions is indicated by the decrease of herb pollen to values less than 20% of total. The subdivision of pollen zone VI into three parts, as is usual in lowland studies following Jessen (1949), is not possible here as the elm pollen forms but a small part of the total tree pollen. A distinction could be made, however, between an early part of the zone where elm and oak are more abundant and a later part where pine is more abundant. Willow pollen forms an important component of the pollen spectra during this zone, especially at *5650 B.C. where it amounts to over 30% of the total pollen. However, the actual contribution of willow to the vegetation may have been a quite local one.

The date for the expansion of oak at *6050 B.C. is similar to the date of *ca.* 5950 B.C. at Slieve Gallion (Pilcher 1973), but the expansion of elm at Ballynagilly seems to be about 1000 years later than at Slieve Gallion. The dates for the main expansion of pine at the two sites are similar, falling at *ca.* 5600 B.C.

Zone BG-5: *4970–*3270 *B.C.*: *zone VII*a (sensu *Jessen*)

The alder pollen first consistently appears at *4970 B.C. and this marks the beginning of pollen zone VII*a*, *sensu* Jessen. According to Mitchell's criteria (Mitchell 1951), the Boreal/Atlantic transition (zone VI/VII) would come considerably later, at approximately 3500 B.C. (see Smith & Pilcher 1973). The sample at 2.88 m (just above the first sample containing alder) may have been contaminated by younger pollen seeping through a crack which was observed in the core at this depth. Apart from this single sample, the arrival of alder has little effect on the general forest composition. Grasses increase at the beginning of the zone and *Melampyrum* forms a substantial proportion of the non-tree pollen throughout the zone. There is no reason to postulate any opening of the forest cover during this phase as the grass pollen is most likely to have been derived from the mire itself, perhaps from marginal reeds, while *Melampyrum* species are capable of growing in quite dense shade and on organic deposits. The later part of this phase is covered by the more detailed diagram (figure 5) from which it can be seen that the main rise of alder pollen comes at *3500 B.C., just before the end of zone BG-5 which is drawn at the elm decline (*3270 B.C.). At the same time (*3500 B.C.) willow pollen ceases to be an important component of the pollen flora. It is possible that the alder replaced willow at this time around the lake basin.

As suggested for the nearby site of Slieve Gallion (Pilcher 1973) alder may not have substantially penetrated the uplands until about 3500 B.C.; pollen present before that time was largely wind-blown from the lowlands. The range of dates for the 'arrival' and expansion of alder is given in Smith & Pilcher (1973).

Zone BG-6: *3270–*2350 *B.C.*: *zone VII*b (sensu *Jessen*)

The whole of this zone is covered in detail by figure 5 and is discussed later. The opening of the zone is marked by the decrease of pine and elm pollen and the presence of charcoal. After *ca.* 300 years (at 2.50 m) there is a short-lived recovery of elm and pine followed by a further reduction (at 2.45 m) lasting about 300 years. During this second period plantain pollen is consistently present. As will be seen from the discussion of figure 5 these features reflect damage to the forest cover by man, but at the end of the phase there is a full recovery of the forest as evidenced by the rise of tree pollen to over 90% of the total. Holly and *Sorbus* sp. become significant constituents of the forest for a short time during this recovery.

Zone BG-7: *2350–*1800 *B.C.*

This short zone is shown in detail in figure 5. It opens with a fall of pine pollen at *2350 B.C. and covers the period of Late Neolithic and Beaker occupation of the site. The end of the zone is drawn at the major rise of heath-pollen at *1800 B.C. Further discussion is given later under § 4.

Zone BG-8: *1800 *B.C.–A.D.* *1550

Zone BG-8 is a heath dominated phase between the Beaker occupation of the site and the resurgence of tree pollen in Medieval times. The phase is subdivided for convenience of description.

Subzone BG-8a: *1800–*200 *B.C.*

From the beginning of this subzone, heath pollen rapidly rises and becomes the dominant herbaceous pollen by about *1600 B.C. During the period of time represented by this subzone, the tree pollen is reduced from about 80% at *1800 B.C. to just over 20% by *200 B.C. The pollen curves most affected are oak and alder, but hazel pollen remains relatively constant throughout.

Plantain pollen is substantially present during the whole of the subzone. This suggests increased human activity, a suggestion that is apparently confirmed by the progressive decrease of the total tree pollen curve. The decrease of the tree pollen is, however, largely brought about by the abundance of heath pollen. If this was derived from the mire surface then the fall of total tree pollen would be a misleading index of deforestation. It may be noted, however, that the rise of the heath curve takes place in a reedy deposit (with charcoal). At the sampling point at least, therefore, heaths would not have been growing on the mire surface. Taking all the evidence, including the presence of charcoal in the early part of zone BG-8, it seems likely that massive deforestation was under way. We might envisage the archaeological site, and the sandy soils around it being to some extent invaded by heaths during this period. (See discussion of monoliths B and C, § 5.)

From shortly after *1800 B.C., ash pollen becomes more frequent and hazel pollen remains relatively abundant. Ash is, of course, often seral after clearance and hazel is resistent to both fire and grazing. These features thus confirm that BG-8*a* was a period of major deforestation of the area. Although there may have been some regeneration in later times, from the continued low level of the total tree pollen curve, the forest cover appears never to have regained its original extent since this time. It appears from the radiocarbon dates that human activities in the Bronze Age and Early Iron Age were responsible for this devastation. The rather gradual nature of the decline of forest throughout the phase suggests that it may have been caused as much by grazing as by clearance. However, the initial fall of tree pollen is so clearly correlated with charcoal in the deposit that it can hardly be doubted that fire was important in the initial opening of the forest.

Subzone BG-8b: *200 *B.C.–A.D.* *500

Grass pollen is very much reduced during subzone BG-8*b* and plantain pollen completely disappears: it apparently represents a brief phase of woodland regeneration. The birch, elm, oak and hazel curves each increase to a peak at about A.D. *100 then decrease to below their former level by A.D. *500. This decline of tree pollen between A.D. *100 and *500 is largely occasioned by a steep increase of the sedge pollen curve which also accompanies a fall of the heath curve. Because of this relation, it appears likely that the increase of sedge pollen was due to local ecological changes on the mire surface, with an increase of species such as *Eriophorum* and *Trichophorum*. That the mire surface may have been becoming wetter is also suggested by the increasing *Sphagnum* values during the latter part of subzone BG-8*b* which culminate in relatively high values throughout subzone BG-8*c*. If this interpretation is valid, then the decline of the tree pollen curve in the later part of subzone BG-8*b* after A.D. *100 cannot be interpreted as being due to renewed opening of the forest. As will be seen below, however, such an explanation can be envisaged for the beginning of subzone BG-8*c*.

Subzone BG-8c: *A.D.* *500–*1550

At the beginning of the subzone the grass curve rises to a maximum and plantain pollen rises from zero to a peak and then remains consistently present. The grass maximum coincides with a sedge pollen minimum and we might thus think in terms of further local changes in the mire vegetation. However, the coincidence of the grass maximum with the plantain peak, and the presence of possible weed taxa such as *Rumex* and Cruciferae, makes it more likely that we are dealing with some renewed agricultural activity. The low tree pollen values at the beginning of subzone BG-8*c* suggest that this activity may have involved further woodland destruction. Following the grass maximum the alder and hazel curves rise slowly to peaks at A.D. *800 which presumably indicates some scrub regeneration; in contrast to subzone BG-8*b* plantain pollen continues to be present. This feature, together with the fact that from A.D. *800 to A.D. *1550 the total tree pollen curve falls from 50 to just over 10%, suggests that we are basically dealing with an agricultural phase which culminated in an open landscape. The very low total tree pollen values at the end of subzone BG-8*c* may, however, be somewhat misleading if the mire surface had become drier and was itself dominated by heaths.

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Zone BG-9: A.D. *1550 *to present*

The rapid increase in tree pollen at the beginning of this zone might be taken as suggesting reafforestation, but the real cause of this increase is probably contamination of the bog surface. The high bank from which the boring was made was almost certainly used for drying and stacking cut peat when the bog was being exploited; material from lower deposits would thus have become incorporated in the upper 20 cm of peat. In fact, some of the surface layer may be composed of crumbled peat blocks.

4. Mid-postglacial vegetational history

Figure 5 is an expansion of that part of figure 4 between *4000 B.C. (2.72 m) and *1000 B.C. (1.60 m), which allows a more detailed assessment of the vegetational changes during the Neolithic and Bronze ages. The samples for this diagram were taken from the same core as those used for figure 4 and the calculation is based on the same pollen sum. For this diagram, every other 5 mm sample from the core was analysed. The same pollen assemblage zones have been applied to the diagram as to figure 4 and sub-divided where necessary.

Zone BG-5: *4000–3270 B.C.

Only the upper part of zone BG-5, a zone whose top is drawn at the elm decline of *3270 B.C., is included in figure 5. As mentioned in the description of figure 4, the main increase in alder does not occur until about 3500 B.C. Before this, while alder pollen values are between 2 and 4 %, there are several rapid changes in the percentages of willow and sedge pollen. It is probable that willows and sedges were growing near the lake and were both reduced to very low levels when the alder increased around the lake margin. *Melampyrum* pollen is very abundant during zone BG-5 and in one sample makes up 25 % of the total pollen. The curve for *Melampyrum* follows that for willow.

Since several of the ^{14}C dates for the Neolithic occupation are spread around 3700 B.C. (see table 1), it is possible that some of the rapid vegetational changes seen in this zone were caused by man. In particular, the short-lived peak of heath pollen as alder increases may indicate some small scale opening of the forest cover. Although there is no other dated Neolithic archaeological material in Ireland from precisely this period, there is evidence of human interference with the vegetation at about 3700 B.C. at Ballyscullion in the Bann valley. At Ballyscullion (Smith, Pearson & Pilcher 1971 *a*, p. 111; Smith 1975, p. 64), small peaks of grass and plantain and other ruderal pollen were found at about 3700 B.C., well before the landnam clearance. There is nothing in the Ballynagilly pollen diagrams that *necessarily* suggests human interference with the vegetation before about 3270 B.C. but attention may be drawn to a number of features between 2.68 and 2.64/2.62 m. First, there is a temporary decline of tree pollen. This is shown only by the curves of birch, hazel and, slightly earlier, willow. Secondly, there is a peak of sedge pollen and consistent presence of Umbelliferae. During this period a single sample (2.65–2.655 m) contains pollen of Chenopodiaceae and it is at 2.65 m that charcoal was first noted during the laboratory sampling of the core (see stratigraphic record, § 2). The presence of Chenopodiaceae and Umbelliferae parallels the situation in the pre-landnam clearance phase at Ballyscullion (Smith 1975, figure 2), but we miss the more certain indicator of human activity–plantain. Chenopodiacious plants are, of course, well known weeds as are many of the Umbelliferae, though, equally members of the latter family grow in undisturbed and damp habitats. If these features of the Ballynagilly diagram were to be taken as indicators of human activity an explanation would have to be sought in terms of a form of land-use which would adversely effect hazel, birch and grasses and sequentially favour sedges and willows. Since we are unable to define precisely the spatial distribution of these species at Ballynagilly in the fourth millenium B.C., we can only give the opinion that any such interference may have involved the lake margin. It must be pointed out that no consistent ecological explanation comes to mind, and reiterated that these changes do not of necessity imply human interference. They are not of such a nature that they initially drew our attention before the early archaeological dates from the site were obtained and the Ballyscullion data had been analysed. At the same time we cannot neglect to point out that the interpolated date for the 2.65–2.655 m sample containing Chenopodiaceae is *3700 B.C., coinciding closely with the mean of the four early Neolithic ^{14}C dates from the site (see table 1). The commencement of obvious charcoal deposition at almost the same level is also likely to reflect commencement or intensification of human occupation.

Certain other minor features of zone BG-5 might also be regarded in a similar light. At a slightly lower level than the features described above (269 cm) a single pollen grain of cereal type was encountered. This level has slightly elevated hazel values and comes at the end of a temporary pine decline which coincides with a low *Betula* peak (268–271 cm). Both birch and hazel are likely to have been involved in forest regeneration and it may be that here we also have an indication of interference with the dry land forest cover in earliest Neolithic times. Such an idea might be regarded as supported by the scatter of heath pollen at the same level, at which it appears with some consistency, though the curve starts earlier in figure 4. However, because of the difficulties in identifying cereal pollen with certainty, the presence of the single grain of cereal type cannot be taken as reliably indicating that cereals were being cultivated. The beginning of the pine decline is dated by UB-255 to 3970 ± 60 B.C. and an interpolated date for this earliest cereal-type pollen recorded in the Ballynagilly diagram is *3800 B.C. While this coincides closely with the date for a hearth and ash pit in the Neolithic area (UB-305: 3795 ± 90 B.C.), it would be unwise in view of the flimsy nature of the evidence to make a firm correlation.

Zone BG-6 *3270–*2350 *B.C.*

Subzone BG-6a: *3270–*2550 *B.C.*

Zone BG-6 opens with the classical elm decline of the Atlantic–Sub-boreal transition. Subzone BG-6*b* includes evidence of the agricultural activities of Neolithic man and may be regarded as a Landnam phase (cf. Iversen 1941, 1949). The date of *3270 B.C. for the elm decline is similar to many others for the British Isles (Smith & Pilcher 1973) and is close to those from the nearby sites of Beaghmore (Pilcher 1970) and Slieve Gallion (Pilcher 1973). The actual fall of elm pollen (2.56 m) occurs between one sample and the next. The deposition rate can be estimated from figure 3 as 0.25 mm per year. Since the elm values are both consistently high below and consistently low above 2.56 m, it is probable that the actual decline occurred in the intermediate 5 mm (2.560–2.555 m) which represents a time interval of *ca.* 20 years. The clearance is thus likely to have been carried out in less than 20 years and could have taken as little as a single year. Pine pollen is reduced substantially at the same level and pine charcoal was present as a layer in the lake mud. The birch and oak curves increase slightly and that of hazel decreases. Other significant changes at the elm decline are an increase in grass pollen and bracken spores. These latter increases suggest that there was a reduction in tree cover and the creation of open ground.

It is possible at Ballynagilly to build up a picture of the forest at the time of the elm decline. Oak charcoal from Monolith A and hazel charcoal from Monolith E (figure 6) both date from the time of the elm decline. In addition some oak was utilized for the construction of the Neolithic house. From the extensive layer of pine charcoal in the deposits, pine was presumably growing locally, probably on the sandy soils of the hill itself. The elm pollen values fall so markedly that the population must have been considerably reduced, although no charcoal has been found.

In order to explain the fall of elm pollen with no apparent decrease in other trees, Mitchell (1956) suggested that the elm was growing in more or less pure stands and that these were sought out by prehistoric farmers as indicators of rich soil. On the other hand, Morrison (1959) considered that it is not possible to distinguish selective felling in a mixed forest from the felling of pure stands of elm. Smith (1964) pointed out that the presence of weeds of open ground supports the latter hypothesis and later (Smith 1970) suggested that relative diagrams may be misleading in possibly disguising real decreases of species other than elm. This suggestion is finding confirmation in recently published absolute pollen diagrams (Pennington 1975; Sims 1973). Certainly, neither of the first two hypotheses adequately explain the events recorded at Ballynagilly.

From the intensity of the occupation, the hill used for the settlement must have been at least partially cleared. It seems most unlikely that the hill supported a pure stand of elm before zone BG-6 as the elm pollen percentages recorded in the mire are consistently low. Moreover, the sand and gravel soil of the hill are certainly not the rich soils that would be required by Mitchell's hypothesis. The hypothesis that best fits the observations at Ballynagilly is that an area of mixed forest including oak, hazel and pine was burnt off to create space for the settlement. It might be postulated that elms growing on richer soils in the area were reduced by one or more of a number of mechanisms. It is known that elm leaves make excellent cattle fodder and may have been collected for this purpose. Smith (1975) has also pointed out that present day cattle will strip the bark from elms during the winter. This, or even the use of elm bark as a food source for the settlers themselves (Nordhagen 1954) would have reduced the pollen production of elms in the surrounding woodland.

An important factor in the interpretation of the Neolithic land clearance at Ballynagilly is the duration of the events shown by radiocarbon dating. This has been briefly discussed elsewhere (Pilcher, Smith, Pearson & Crowder 1971). It can be deduced from figure 3 that, following the initial clearance, open areas persisted for several hundred years. This must imply repeated clearance, grazing, or the clearance of new ground at frequent intervals. On the basis of the pollen diagram from Ballynagilly and two other sites (Beaghmore and Ballyscullion) it was suggested that the clearance phase fell into three stages: stage A, a clearance and farming stage with a possible emphasis on arable farming; stage B, a second farming stage with a possible emphasis on pastoral farming and stage C, a stage of forest regeneration. These stages were derived from a consideration of all three sites, but apply equally, of course, to Ballynagilly as an individual site. The stage letters are given within zone BG-6*a*, figure 5. The clearance and farming of stage A lasted from *3270 B.C. (2.56 m) to *2800 B.C. (2.445 m). During this time plantain pollen is scarce, grass pollen values remain high and there are two pollen grains of cereal type. Pollen of taxa containing weed species, Umbelliferae, *Rumex* and Ranunculaceae is present. The scanty evidence of cereal-type pollen at Ballynagilly is reinforced by its greater abundance at Beaghmore (Pilcher 1969, Pilcher *et al.* 1971) and prompts the idea that stage A may have had a predominance of arable farming. Within stage A there are some subsidiary features of interest. Attention may be drawn, for instance, to the presence of rosaceous pollen of *Sorbus* type before *3100 B.C. which, as elsewhere (e.g. Simmons 1969) may be taken as another indication of the opening of the forest canopy. Between *3050 and *2950 B.C. the rise of the pine and elm curves may betoken some regeneration, but pollen of cereal type is present and it must be presumed that agricultural activity continued. Thereafter (*2950–2800 B.C.) the pollen curves are relatively steady and there are no certain indicators of farming. Several of the radiocarbon dates for Middle Neolithic features (see table 1) probably fall into this period, however, and it appears unlikely that the area was deserted. There is no evidence for an increased rate of regeneration of the forest cover such as would have occurred, had the area been abandoned. Stage B begins at *2800 B.C. (2.445 m) where elm pollen is again reduced and plantain pollen becomes consistently present for a further *ca.* 150 years until *2650 B.C. (2.39 m). Consistent presence of plantain and absence of cereal pollen at Ballynagilly is again reinforced by similar features at Beaghmore and Ballyscullion. It is suggested that during this stage pastoral farming predominated. During stage B, hazel increases as it usually does during Neolithic land clearance phases in Ireland (cf. Mitchell 1956). This may be a result of its resistance to both burning and grazing.

A summary of the main features of the Neolithic clearance episode is given below:

Stage A: *3270 *B.C.* (2.56 *m*) *to* *2800 *B.C.* (2.445 m) Low elm and pine values, occasional plantain and cereal-type pollen. Farming period, possibly mainly arable.

*3270 B.C. (2.56 m)–*3050 B.C. (2.51 m)	Sudden fall of elm and pine, increase of grasses and bracken. Pine charcoal present. Slow rises in alder and oak. *Sorbus* pollen present. Plantain and cereal type pollen present. Farming period.
*3050 B.C. (2.51 m)–*2950 B.C. (2.48 m)	Rise in pine and elm curves. Some forest regeneration. Farming continues.
*2950 B.C. (2.48 m)–*2800 B.C. (2.445 m)	Minor pine decline. No direct evidence of farming, but from lack of regeneration, farming presumed to continue.

Stage B: *2800 *B.C.* (2.445 *m*) *to* *2650 *B.C.* (2.39 *m*) Elm pollen again reduced. Plantain pollen consistently present for 50 mm. Hazel maximum. Farming period; possibly pastoral.

Stage C: *2650 *B.C.* (2.39 *m*) *to* *2550 *B.C.* (2.36 *m*) Rise of tree pollen, particularly pine. Forest regeneration.

Subzone BG-6b: *2550–*2350 *B.C.*

This subzone is characterized by high pine values. It contains the highest tree pollen percentages recorded in the diagram. These features must represent, at least in part, secondary forest resulting from the regeneration that followed the Neolithic agricultural phases. Birch also increases, though somewhat later than pine, and two other significant components of this secondary forest were apparently *Sorbus* sp. and holly. The relative abundance of holly in this secondary woodland is rather puzzling. Certainly holly is likely to have been encouraged by man's activities as has been pointed out by others (e.g. Godwin 1975), but here it appears in quantity only after we presume that the pressure on the vegetation had been relaxed. The

Sorbus pollen which was identified using the scanning electron microscope, closely resembled pollen of *S. aria agg.* (the white beam) but could possibly have been *S. aucuparia* (rowan) or a mixture of both (Pilcher 1968, plate XVI). The presence of *Sorbus* in such abundance is also rather difficult to understand. Both the birch and *Sorbus* are light demanding trees so that, in spite of the very high total tree pollen values, the secondary woodland must have remained in places free of shade-casting trees. While the archaeological record suggests that the site was abandoned during this phase, the occasional occurrence of 'culture pollen' such as plantain and *Rumex* could indicate that there was still a small human population somewhere in the area if not on the same site.

Despite the interpretation that has been advanced, attention must be drawn to the decline of *Sphagnum* and grasses as the regeneration of stage C (within zone BG-6*a*) progresses. These features may imply a drying of the mire surface which may then have been colonized by pine. Had this been the case the regeneration on the dry land may have involved mainly birch, holly and *Sorbus*.

Zone BG-7: *2350–*1800 B.C.

Zone BG-7 begins where the pine and *Sorbus* curves fall and the grass curve rises at *2350 B.C. These changes occur between two consecutive samples rather as in the clearances at *3270 B.C but there is no charcoal in the peat at this higher level. It is difficult to decide if there was any real opening of the dry land forest cover at the beginning of zone BG-7 or merely an increase in water level in the basin causing replacement of pine by reedswamp. A pine cone found in the core at 2.27 m gives some support to the idea that pine may indeed have been growing on the mire. However, just before *2200 B.C. plantain pollen is present in three consecutive samples. Some further farming seems likely, therefore, in the early part of the zone and it is worth noting (ApSimon, personal communication) that there was a scatter of flint likely to be of Late Neolithic age over the hill, suggesting more activity in this phase than the dated features indicate.

Pine pollen falls below 2% of total pollen at *2150 B.C. (2.19 m) and does not recover. There is little in the Ballynagilly results to suggest that this pine decline is anthropogenic. The dates for the Beaker occupation of the site fall, in general, after the pine decline (see § 6).

From 2.22 m to the end of zone BG-7 (*2220–*1800 B.C.) the curve for oak pollen follows an unusual pattern. It rises for three to four samples, then falls between two consecutive samples. This sequence is repeated at least five times. The duration of the rise is some 40 to 60 years and the fall is of an unknown length less than 20 years. Although the whole phenomenon may be due to chance, the length of the cycle and its repetitive nature might be taken as suggesting some form of periodic felling or pollarding of the oaks. It is noteworthy that the major part of the period of the oscillating oak curve is also a time of high values for hazel. We might pose the question as to whether some form of woodland management was being used that encouraged the growth of hazel for economic reasons. The occasional occurrence of cereal type pollen in this period provides another reason for believing that the area was still occupied by at least a small human population. The high birch pollen values (2.17 to 2.12 m, *2100–*2000 B.C.) also suggests continued interference with the woodland, with some areas under regeneration.

About 175 m to the west of the main Neolithic site there was a large oak partially preserved in shallow peat. A pollen sample from under the oak showed that it belonged to zone BG-7 and a sample of ten annual rings, from 60 years from the outside, has been radiocarbon dated to 2445 ± 80 B.C. (UB-293, see table 2). Bearing in mind the precision of the radiocarbon measurement, there is some possibility that this tree belongs to the period of oscillating oak pollen values.

At *2000 B.C. (2.12 m) there is a marked decrease in total tree pollen. This is mainly due to a fall in birch pollen. Subsequently, most samples contain cereal pollen. These changes occur at the time of the Beaker occupation (see figure 7) and may be interpreted as the clearance of secondary birch scrub or woodland perhaps mainly for crop growing. From just after *2000 B.C. onwards, plantain pollen is consistently present for the rest of the period covered by figure 5. Cereal and plantain pollen in the period *2000–1800 B.C. together with nettle and *Rumex*, which indicate disturbed ground, suggest a system of mixed agriculture during Beaker times. We have seen, however, that there may have been an initial arable phase as was apparently the case in Neolithic times.

At *2000 B.C. the sedge curve rises and heath pollen begins to appear. The rise in heath pollen does not seem to be connected either with any stratigraphic change in the deposits sampled or with the initiation of blanket peat growth outside the basin as far as can be judged from the short monoliths (figure 6). It seems then that this increase in heaths could be a consequence of forest clearance and soil impoverishment. If the heaths were growing neither on the mire surface nor on surrounding blanket peat, it seems likely that they were growing in abandoned clearings (cf. Mitchell 1956; Jessen 1949, p. 264) or as a ground vegetation in open secondary woodland. The *Melampyrum* curve rises at the same time and this also may have been growing in the same habitat.

*Zone BG-8: *1800 B.C. onwards*

Only the lower part of subzone BG-8*a* is shown in figure 5. This begins with a rise in heath and *Melampyrum* pollen. Both these curves fall, however, as the birch curve rises to a maximum at 1.98 m just before *1700 B.C. At this point, birch pollen amounts to over 60% of the total pollen so that all the other pollen curves are considerably depressed. It seems unlikely that the birch peak is anything other than the result of a local regeneration of birch following Beaker forest clearance in zone BG-7.

From 1.98 m to 1.93 m charcoal is present in the deposit with quite massive lumps from 1.97 m up to 1.94 m. The dense charcoal layer thus occurs in the main across the sharp fall of total tree pollen between 1.96 m and 1.95 m. The date for the level containing charcoal is just after *1700 B.C. (UB-247, 3620 ± 60 B.P., see table 2) and is indistinguishable from the dates for the Early Bronze Age (see figure 7). This would seem to indicate that there was clearance by burning at the start of the Early Bronze Age occupation. Charcoal identified from the layer was, however, *Calluna* (heather), so that it cannot be certain that the fall of the birch curve was due to the burning of birch woodland. At *1650 B.C. (1.95 m) coinciding with the fall of the birch curve, cereal pollen becomes less common and plantain pollen increases, suggesting change to a more pastoral economy. The ash pollen which appears consistently shortly thereafter (1.93 onwards) suggests that ash was now able to take advantage of the more open conditions. The rise of heath pollen at this time still appears unconnected with the initiation of blanket peat. At the sampling point, and on the margins of the mire (monolith D, figure 6), the earliest blanket peat appears to have started to form around *1000 B.C. It is suggested that the increase of heath pollen at *1650 B.C. betokens an increase of heathland on poor soils which had been cleared, and that this heathland was maintained, perhaps by grazing, for at least 600 years before blanket peat formation began.

Between *1500 B.C. (1.86 m) and *1250 B.C. (1.77 m) there are indications of a reduction in agricultural activities; plantain pollen values are lower and the birch curve rises to high values between *1400 and *1250 B.C. However, in the later part of the birch maximum there is a resurgence of plantain pollen, and the re-appearance of charcoal. This presumably implies a renewal of agricultural activity but evidence of forest clearance does not come until *1250 B.C. (1.72 m) where the total tree pollen values fall to below 50 %. This decline of tree pollen is mainly due to a decrease in birch, oak and hazel; there is also a considerable increase in the pollen of grasses and the high plantain values are maintained. These features suggest clearance for pasture. From the presence of charcoal from this level up to 1.63 m this clearance was apparently a continuous process. It is interesting to note that the total tree pollen curve, and perhaps in particular the curve for hazel, has the same saw-tooth appearance described previously for the oak curve. In this case the cycle length is about 70 years and may again be attributable to repeated cycles of clearance. As can be seen in the longer diagram the relative abundance of grass and plantain pollen presumed to betoken the importance of pastoralism continues to the end of subzone BG-8*a* at *200 B.C. It is likely that the heaths, already important pollen contributors, were covering quite large areas of cleared ground. While it is not possible to assign a specific date to the start of blanket peat in the basin due to the gradual nature of the stratigraphic transition this change was certainly under way during the middle of subzone BG-8*a*, somewhat above the highest level included in figure 5. From blanket peat monoliths B and C (figure 6, § 5) it seems that blanket peat formation was also starting on the sandy soils at some time in subzone BG-8*a*. The overall decline in tree pollen during the subzone may be due, at least in part, to abandoned clearings going over to heath and blanket peat rather than to regenerating forest.

5. Analysis of shallow peat and soil profiles

The pollen diagrams from the five short monoliths from the blanket peat and valley deposits are presented as a single diagram (figure 6). All the monoliths were taken in 150 mm square-section monolith boxes and sub-sampled in the laboratory. The ^{14}C dates for the charcoal layers in monoliths A and E were obtained from the charcoal itself after extraction from the stratum, and not from the whole deposit. The other dates were measured on acid-treated whole peat taken from the monoliths. The dates are listed in table 2.

(*a*) *Monolith B* (*Beaker area*)

A short monolith of peat and mineral soil was taken from the Beaker occupation area (area M of ApSimon) before the blanket peat was removed by bulldozing. Contiguous 5 mm samples were taken above the peat/mineral transition and several samples were taken from the mineral soil.

The samples from the mineral part of the monolith contain very high percentages of plantain pollen similar to those found at Beaghmore (Pilcher 1969) in samples from beneath the blanket peat. As at that site there can be little doubt that the mineral soil at Ballynagilly supported pasture. This appears to have been replaced by heath at the mineral/peat transition. The apparent sharpness of the pollen changes may, however, be due to erosion rather than to any very sudden vegetational change. The sandy soils of the hill, combined with the steep slope, make erosion very rapid once the cover is removed as was apparent during the excavation of the site.

The radiocarbon date for the basal 20 mm of organic deposit is 1735 ± 65 B.P. (UB-168). Allowing for the inclusion of some later humic acids in the whole peat sample (Smith *et al* 1971 *a*), it appears that peat accumulation started some time after 0 A.D./B.C. Shortly after the blanket peat initiation, the birch pollen curve rises to a peak of over 10 % of total pollen and this value is maintained for 20 mm. This is not matched by any similar rise in the birch pollen percentages in monolith C only 50 m away or from the hillside profile 75 m in the other direction. However, in the outline mire diagram (figure 5) there is a marked peak in the birch pollen at 0.96 m or A.D. *100 which may, on the basis of the dates, be a record of the same occurrence.

(*b*) *Monolith C* (*Neolithic area*)

A short monolith through the mineral soil and peat was taken from the Neolithic area on top of the hill, before the 1967 excavations. As in monolith B, the mineral soil contains large amounts of plantain pollen, several grains of cereal type and pollen of Caryophyllaceae. This high plantain phase is preceded by high values of hazel pollen. The sequence may represent replacement of hazel scrub by farmland. The pollen was badly preserved, however, and may not be entirely representative of the vegetation. Nevertheless, plantains must still have been very abundant. As in monolith B and the Beaghmore results mentioned above, the transition from mineral to peat is very sharp. In this case the plantain pollen percentage falls from *ca.* 50 to 2 % between one 5 mm sample and the next. Simultaneously, the heath pollen rises sharply. As this monolith is from the top of the hill, it is probable that blanket peat formation was slow in the early stages and erosion may have occurred before its initiation. Further evidence of erosion before blanket peat formation is given in the consideration of monolith E. Pine pollen is absent from monolith C which by comparison with the long diagram (figure 4), indicates that the deposits have formed since *1300 B.C. The ^{14}C date for the basal 20 mm of organic deposit is 2525 ± 45 B.P. (UB-171). This is considerably earlier than the date for the peat over the Beaker site described above and shows that some form of humus accumulation began earlier on the flatter ground at the top of the hill than on the slopes where the Beaker settlement was situated. The farming activity shown by the high plantains and cereals in monolith C may be related to a level close to 1.50 m in the long diagram (figure 4), just after *1000 B.C. where a slight decline of hazel is followed by relatively high plantain values, and the presence of cereal pollen.

(*c*) *Monolith E* (*hill side*)

On the steeply sloping side of the hill between the Beaker site and the deep bog (see map, figure 1), a cutting had been made through the blanket peat which displayed an unusual profile. Under the blanket peat was the usual podsol profile beginning with greyish mineral soil containing abundant charcoal. About 0.1 m below this was the iron pan, below which was the usual bright yellow iron-stained sand. However, about 0.1 m below the iron pan, in what appeared to be natural undisturbed mineral soil, was a thick layer of charcoal, mostly of hazel. A monolith of these deposits was taken and the analysis is presented in figure 6, monolith E. Pollen was recovered from the mineral soil as far down as the lower charcoal layer.

Very high tree pollen percentages were found in the mineral soil until just below the transition to blanket peat. Substantial amounts of oak and hazel pollen and a small amount of pine pollen indicate forested conditions some time before the final disappearance of pine. The date

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obtained for the lower charcoal layer is 3345 ± 90 B.C. (UB-18, see table 2). This is close to the date for the oak charcoal in the stream bed section (UB-15, 3245 ± 60 B.C., see below and table 2) and the date for the oak planking of the Neolithic house (UB-201, 3215 ± 50 B.C., see table 1). The hazel charcoal thus appears to be further evidence of the forest clearance by the early Neolithic inhabitants.

A probable sequence of events leading to the development of the profile is as follows: burning of local hazel and general forest clearance in the Neolithic was followed by considerable erosion of the sandy soils, giving rise to the layer of sand found over the hazel charcoal. Had the redeposited sand been deposited immediately after the Neolithic clearance it would presumably have contained a high proportion of pine pollen from the pre-clearance soils. This is not the case and in any event the soil under the charcoal which may be presumed to represent the pre-Neolithic soils, is itself now devoid of pollen. Thus either the re-deposited sand was initially devoid of pollen and its present content infiltrated at a later date or it was deposited sometime after the Neolithic clearance. From the quality of preservation of the charcoal it seems likely however, that it was buried fairly rapidly. If it is taken that the pollen infiltrated into the sand then by comparison with the long diagram it is most likely to have belonged to the period *2300–1800 B.C. Later, an iron pan formed above the charcoal layer and blanket peat formation began. In this case there are not the high plantain pollen values below the blanket peat seen in monoliths B and C and this area, being on a steep slope, may have escaped the intensive land use that is suggested for the B and C sites.

(*d*) *Monolith D* (*valley excavation*)

On the valley floor, some distance below the site of monolith E, a profile was found in which there was a substantial charcoal layer stratified in the peat. It was thought that this may have been the same layer as that found under the sand higher up the hill. The analysis of the deposits is given in figure 6, monolith D. The layer was in fact composed of very finely divided charcoal and insufficient was obtained for ^{14}C dating. The vegetational changes associated with this charcoal layer are complex. Before the charcoal layer, total tree pollen percentages are high and the pollen spectra are comparable with those between *1000 and *1500 B.C. in figure 4. There follows a marked and permanent reduction in oak pollen and a temporary reduction in birch pollen. Even though alder pollen increases there is a decline in the total tree-pollen curve. The oak and birch appear to have been cleared but quickly replaced by alder which was then replaced by birch. In spite of this succession the relative abundance of grass and heath pollen suggests that the forest cover was permanently reduced. The charcoal layer is present just after the fall in oak pollen, thus the two may not necessarily be connected. The dates bracketing the birch minimum are 990 ± 75 B.C. (UB-175) and 560 ± 70 B.C. (UB-174). These results show that the changes in forest composition are relatively late and, since they find no direct parallel in figure 4 during the relevant period, may be of quite local significance. This idea is confirmed by a comparison with monolith C. At *ca.* 560/575 B.C. (UB-174, 171) the total tree pollen values suggest much more wooded conditions in the valley than on the hill. Neither the charcoal layer nor the tree pollen decline is correlated with any of the archaeologically recorded occupations of the site.

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(*e*) *Monolith A* (*stream section*)

A stream at present runs in a shallow cutting through the centre of the valley to the south east of the site. At the northern end it is bedded on gravels, but in the deeper part of the basin it runs over the organic deposits. Close to the site of monolith D, where the peat is shallow and the stream bank exposes some mineral deposits, a thick charcoal layer was found in a basal sandy silt. The charcoal appeared to have been washed into a shallow depression. A monolith was taken and sufficient charcoal recovered from the section for radiocarbon dating. All the charcoal examined was of oak. The date obtained was 5195 ± 60 B.P. (3245 B.C.) (UB-15) which is close to the date for the first clearance phase seen in figure 5 and to the dates for the Early Neolithic occupation (table 1). The charcoal clearly represents the results of Neolithic clearance, but whether or not it was derived and in a secondary stratigraphic position requires discussion.

In the samples below the charcoal, there is fairly abundant pine and abundant oak and hazel pollen. The pine and oak curves are both considerably reduced at the level of the charcoal, the oak recovering slightly afterwards. Alder increases during this time. Temporarily ignoring the date for the charcoal which could have been secondarily incorporated, the pollen evidence suggests a date before or around *2300 B.C. when the pine pollen is finally reduced to insignificant levels. The increase in birch and grasses above the charcoal layer could also fit with the changes seen at about this time in figure 4. If, on the other hand, the charcoal is in its correct stratigraphic position, then there must have been considerable variation both in the vegetation and in the pattern of clearance over a small area at *ca.* 3200 B.C. In this case we would have to envisage the damper soils of the valley as supporting oak, with pine at some distance, possibly on the lighter soils of the hill or on the peat elsewhere. The fact that pine pollen deposition is markedly reduced within 2–300 m of the edge of a pine plantation (Turner 1964) however, shows that this is a realistic possibility. Taking account of the location of the charcoal, in alluvial deposits, it is certainly possible that it was secondarily incorporated. This explanation would demand an unusual combination of erosional and depositional circumstances. The chance of obtaining a Neolithic date so close to the others by any admixture of charcoal is however so remote that we must take this as evidence that oak was indeed burnt in the course of the initial Neolithic clearance.

6. Discussion

Comparative discussion of the general Postglacial vegetational history at Ballynagilly would require reference to a large volume of unpublished material and is therefore deferred. The mid-Littletonian (Postglacial) history, however, now requires to be more closely examined in the light of the archaeological evidence from the site.

Figure 7 summarizes the radiocarbon dates for the samples from archaeological contexts and illustrates the vegetational changes on the same time scale. The units of the time scales are conventional radiocarbon years. An outline of the major features of the mid-Postglacial pollen assemblage zones is presented, together with the inferred environmental changes. The boundaries of the zones are of course accurate only within the limits of the radiocarbon measurements and the interpolations (see § 2*c*). A visual indication is given of the charcoal density in the core used for the long diagram. Superimposed on this are the two radiocarbon dates for charcoal

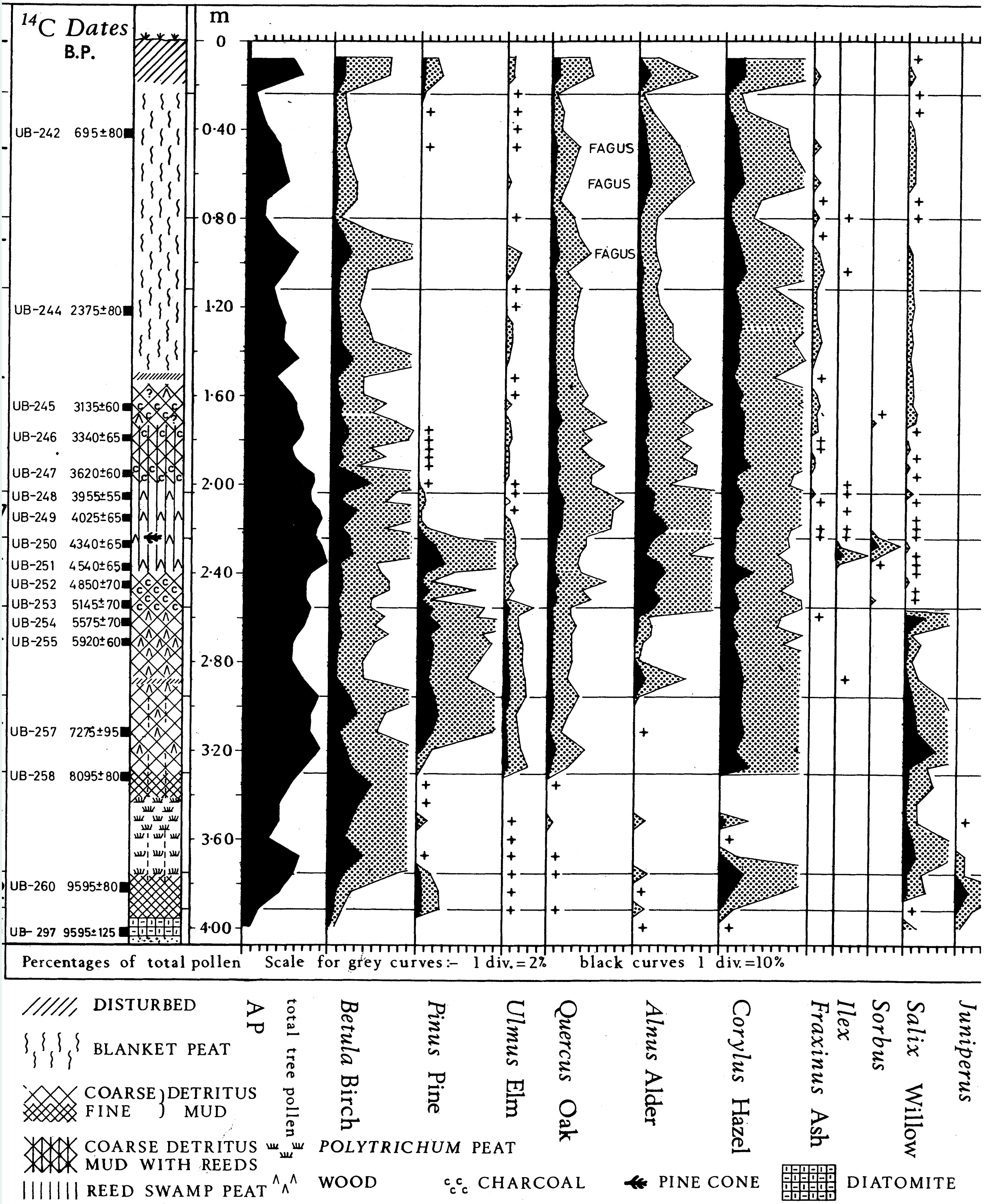
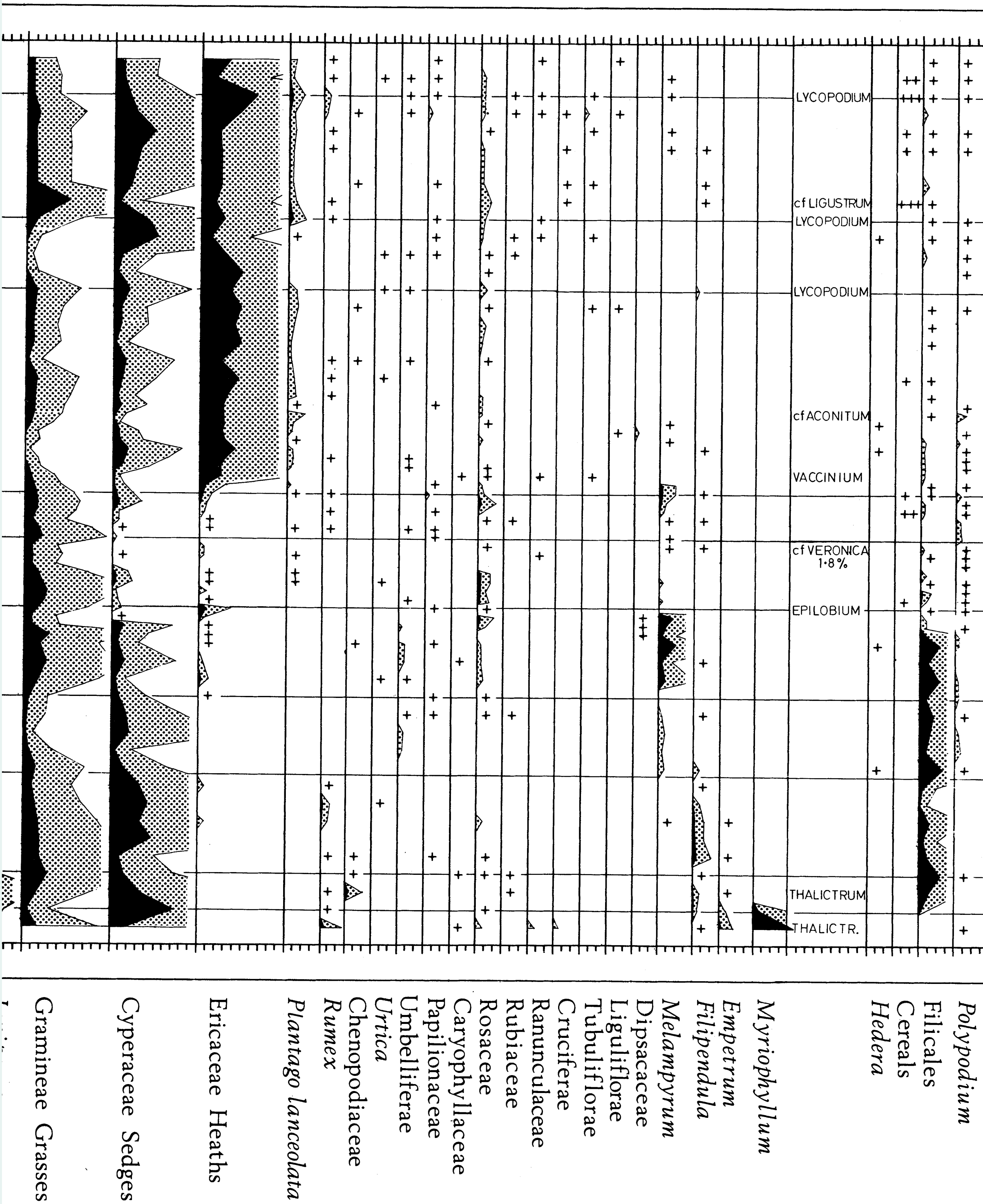
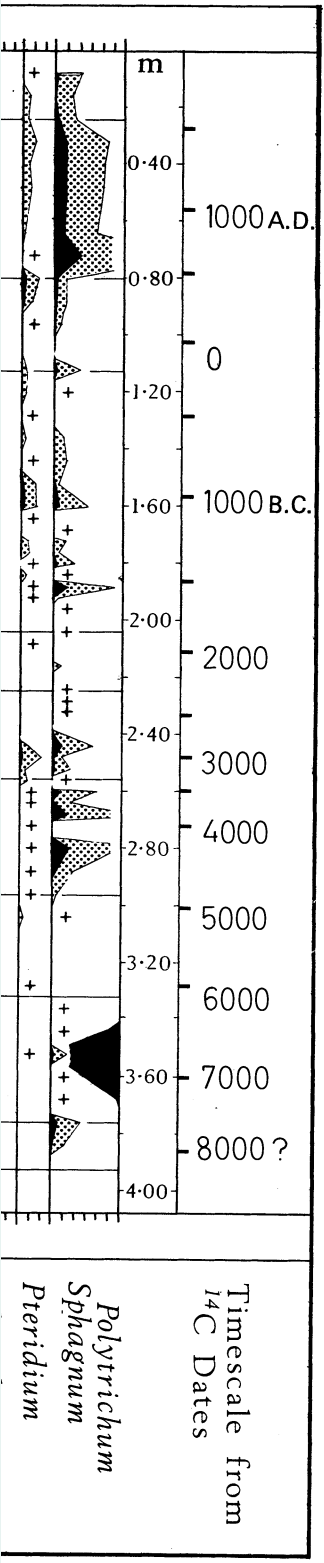


FIGURE 4. Pollen diagram from the deep organic deposits at B
figure 1 and described in the text (§ 2*a*). The radiocarbon d
of the figure is derived from figure 3: see also text (§ 2*c*).



Ballynagilly. The location of the core from which the samples were taken is shown in
dates are plotted against depth in figure 3 and listed in table 2. The time scale at the right


m
0·40
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1·20
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2·80
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3·60
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1000 A.D.
0
1000 B.C.
2000
3000
4000
5000
6000
7000
8000 ?
Pteridium
Sphagnum
Polytrichum
Timescale from ^{14}C Dates

(Facing p. 366)

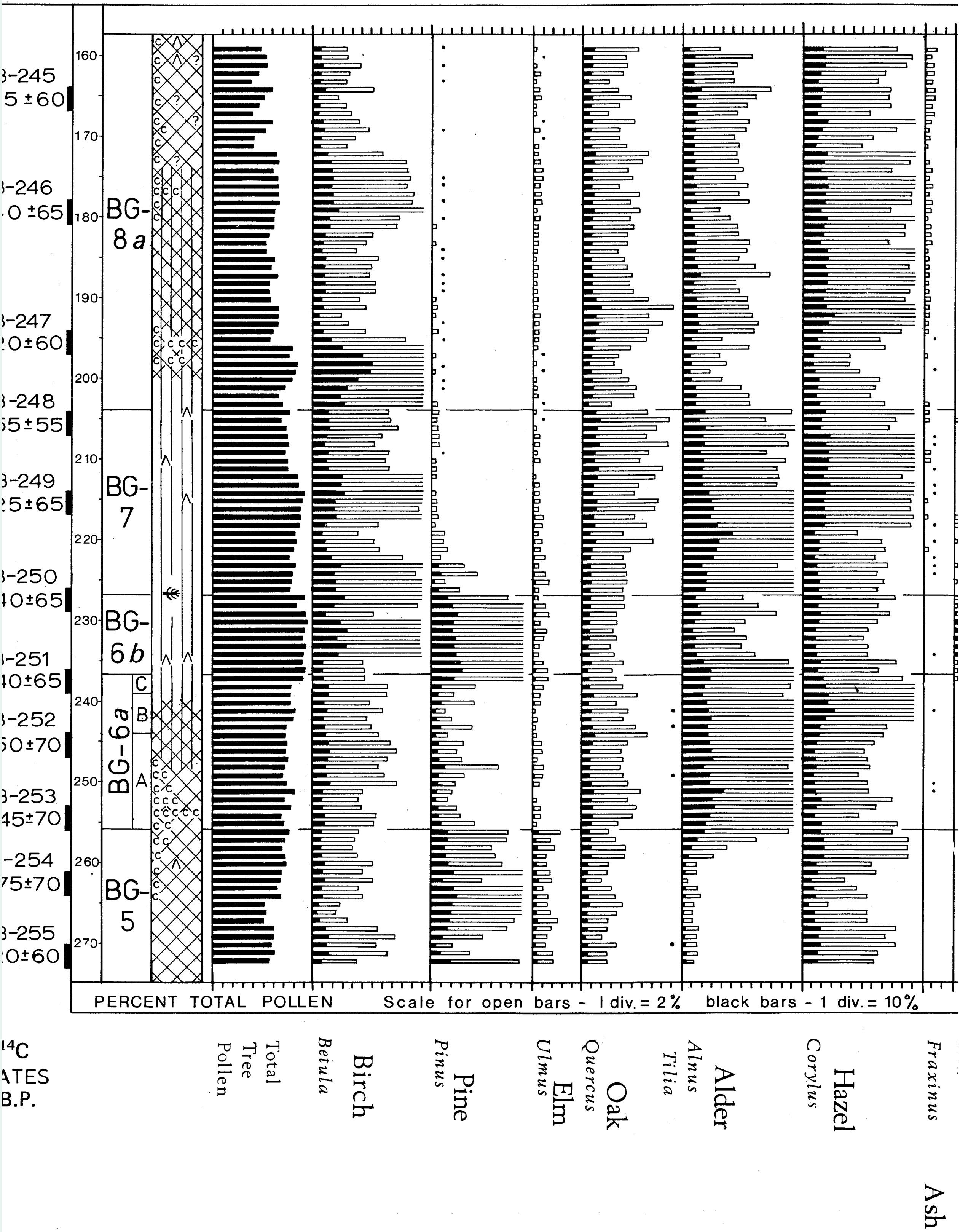
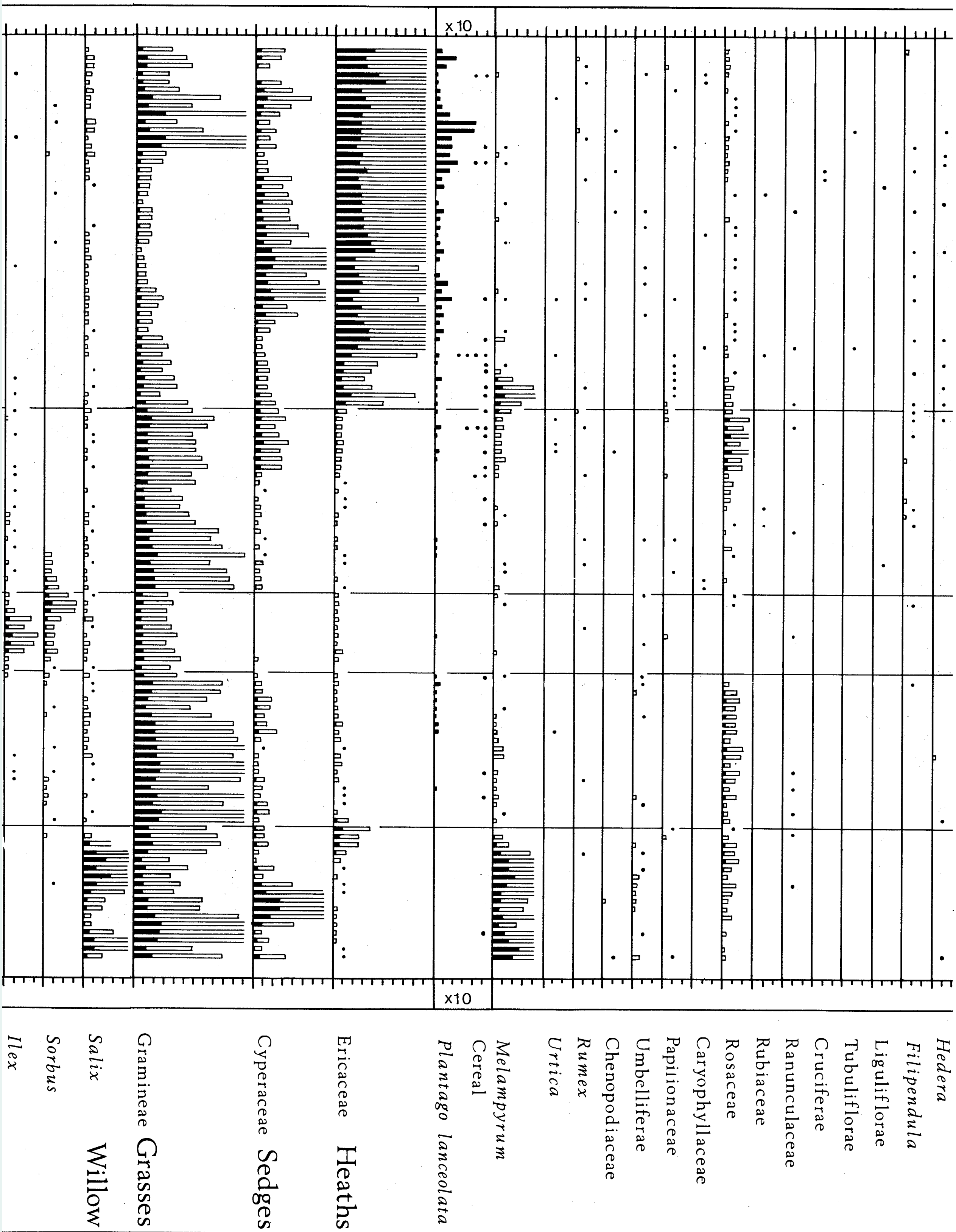


FIGURE 5. Detailed pollen diagram for the mid-Littlet
interval. The time scale at the right of the figure
in figure 4. The subdivisions A, B and C of subzo
The interpretation of this pollen diagram and its



tonian stage at Ballynagilly from the same core as for figure 4 but with a reduced sampling
: is derived from figure 3: see also the text (§2c). A key to the stratigraphic symbols is given
one BG 6a, represent the successive stages of a Neolithic 'clearance phase' of 'Landnam' type.
; relation to the prehistoric occupations of the site is summarized in figure 7.

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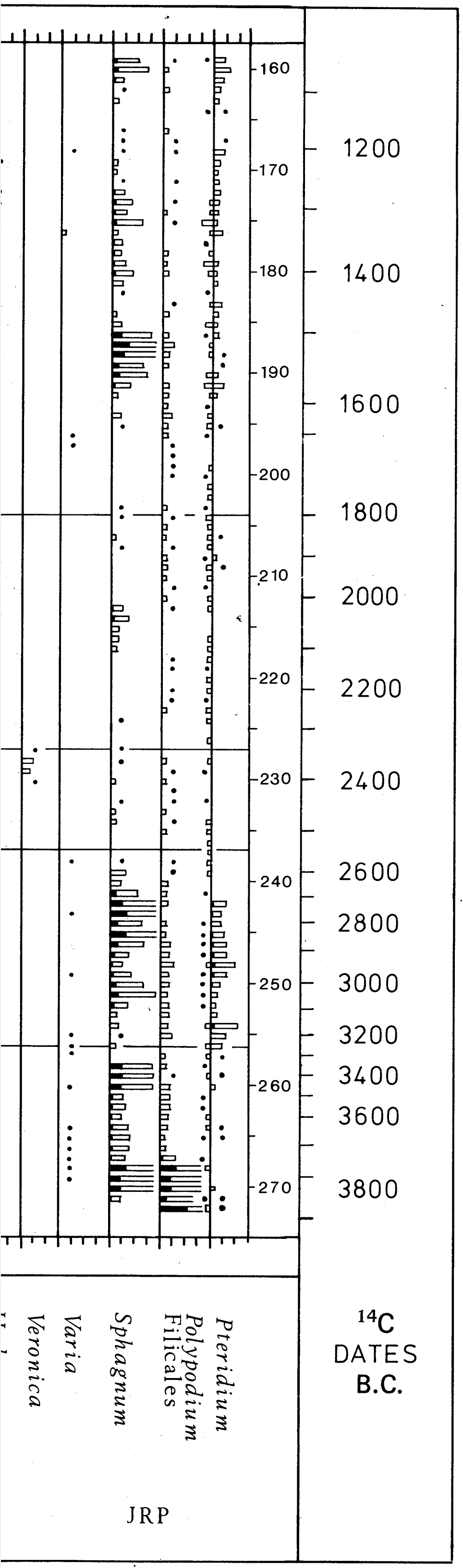

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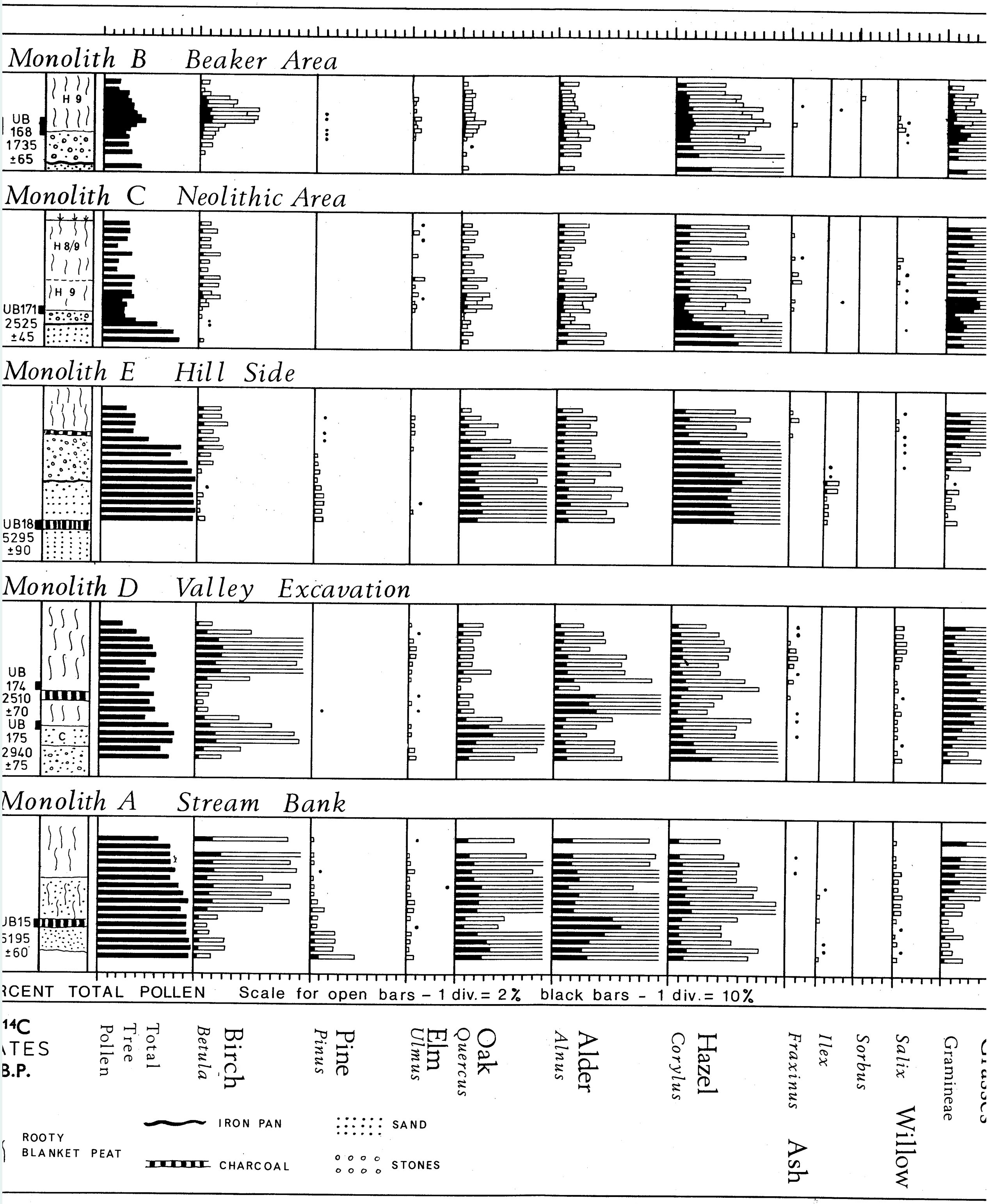
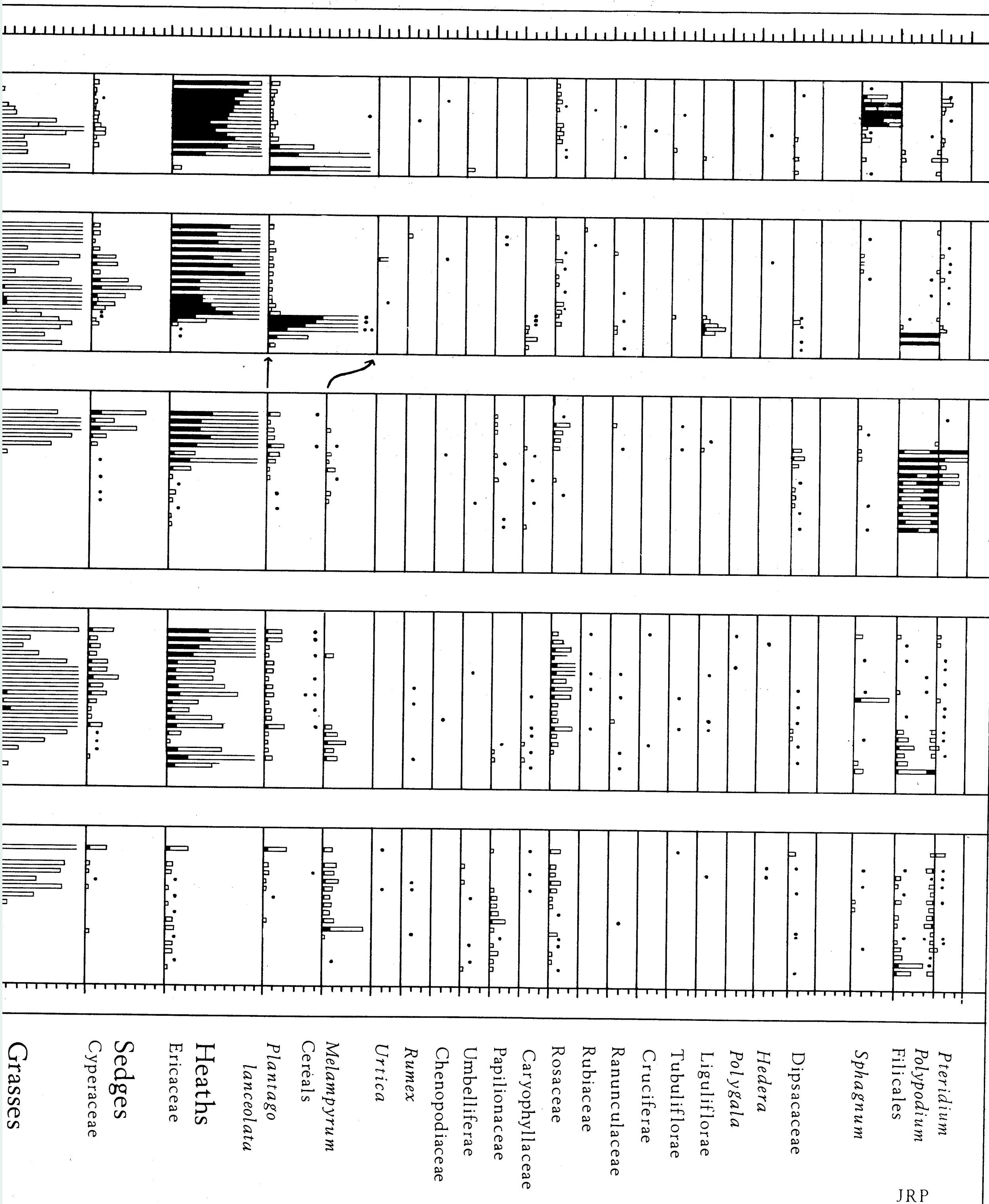


FIGURE 6. Pollen diagrams from blanket peats and underlying soils at Ballynagilly. pollen analysis are shown in figure 1. The charcoal in Monoliths A and E was are indistinguishable from those for the Neolithic house, and associated feat the long core (figures 3 and 4) containing pine charcoal. See also text and fig



y. The locations of the monoliths from which samples were taken for
is of oak and hazel respectively. The radiocarbon dates for these layers
itures. They are also indistinguishable from the date for the level in
igure 7.

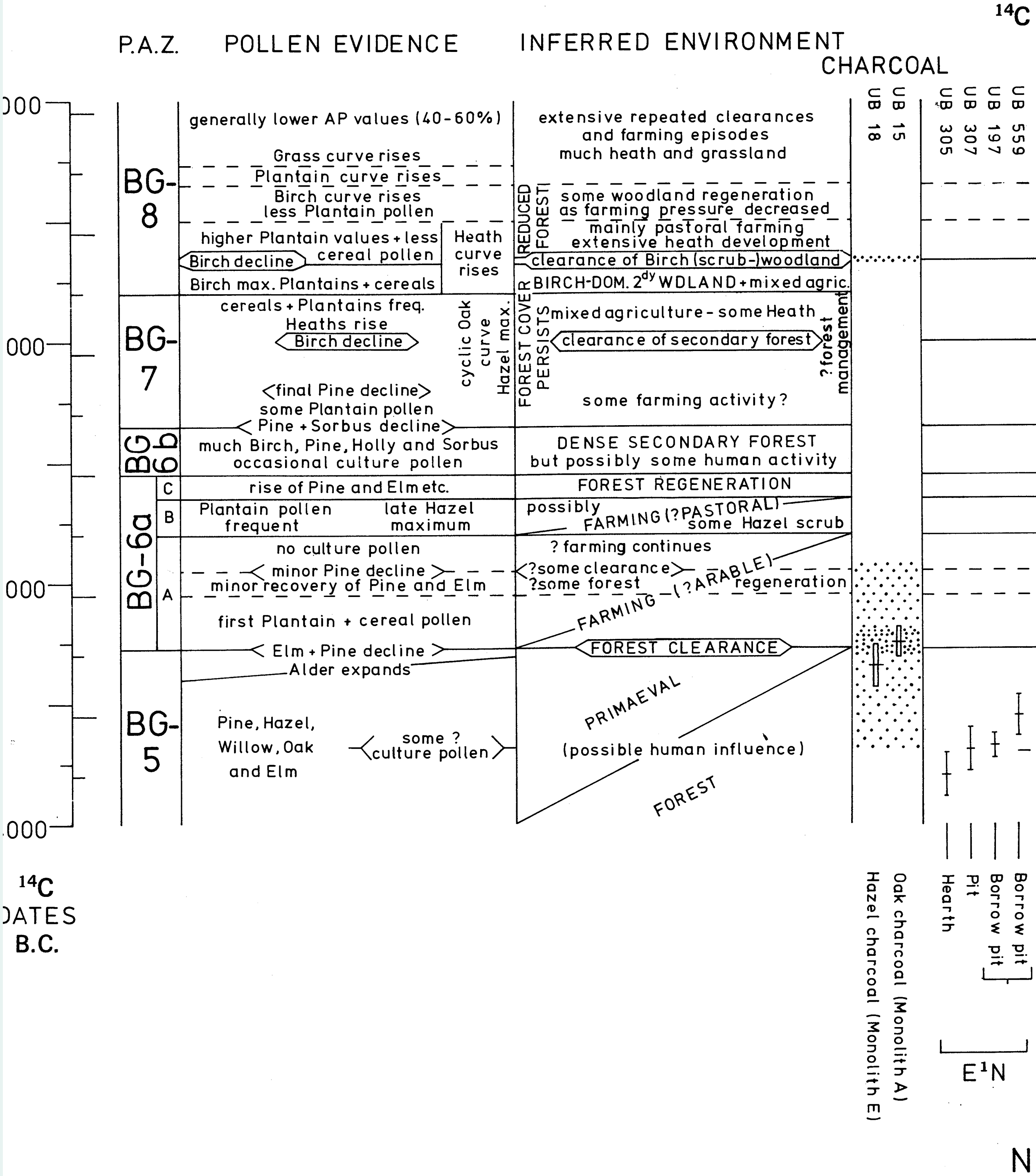
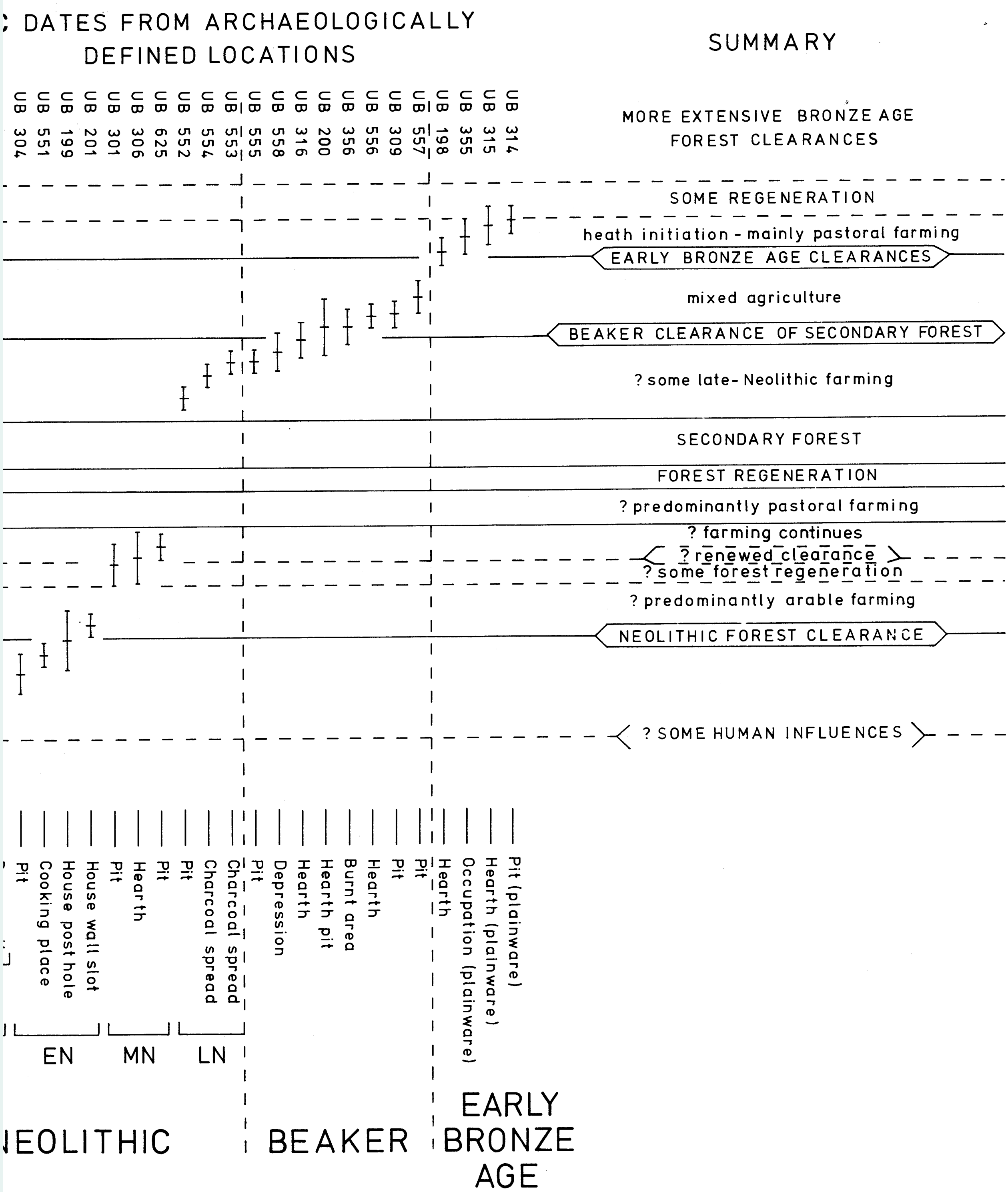
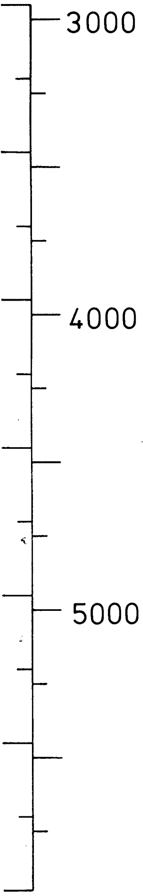


FIGURE 7. Palaeoecological-archaeological correlations for the mi
inferred environment is discussed in detail in the text (§ 4).
pollen analysis and ¹⁴C dating. At the level of the elm/pine
this representation of charcoal in the core are from charcoal
from archaeological locations, which are also listed in table
subdivisions of the Neolithic period are indicated thus: E¹
Neolithic. The time scale is in conventional ¹⁴C years; i.e. t
1950 years). The palaeoecology is related to this scale by mea
deposits (graphed in figure 3 and listed in table 2). This relat
'clearance phase' of the 'Landnam' type. At Ballynagilly
the classical Danish landnam phases (Iversen 1941, 1949);
transition of Jessen (1949) and the zone VII–VIII transitio



ıid-Littletonian Stage at Ballynagilly. The pollen evidence summarizes figure 5 and the . A visual impression is given of the concentration of charcoal in the core used for : decline, the charcoal in the core was of pine. The two ^{14}C dates superimposed on l found in mineral soil or silt underlying blanket peat (see figure 6, § 5). The ^{14}C dates : 1, were taken under the direction of Mr A. ApSimon (ApSimon 1969, 1976), whose ᴱN = earliest Neolithic; EN = early Neolithic, MN = middle Neolithic, LN = late the ^{14}C dates are 'uncalibrated' ('B.P.' = before A.D. 1950; 'B.C.' = 'B.P.' date less eans of interpolation using a closely spaced series of ^{14}C dates through the deep organic ation is subject to a number of reservations (§ 2*c*). Subzone BG 6*a* covers a Neolithic · (and elsewhere, see Pilcher *et al.* 1971) this phase is more complex, and longer, than ; see also text. The zone boundary BG-5/BG-6 is equivalent to the zone VIIa–VIIb ion of Mitchell (1956).



^{14}C
DATES
B.P.

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layers in monoliths A and E (figure 6). The dates for the archaeological samples are shown with 1 σ precisions and are arranged in chronological order.

The archaeological ^{14}C dates fall into two groups with a clear gap between them. Those in the earlier group are all from Neolithic contexts. Those in the later group are from Beaker and Early Bronze Age contexts. The four oldest samples from a hearth, and two pits with Lyles Hill ware, UB-305, UB-307, UB-197 and UB-559 fall before 3500 B.C. and are older than any other ^{14}C dated Neolithic material from Ireland and are assigned by ApSimon (1976) to his earliest Neolithic (E^1N). While it is possible that semi-fossil pine wood could have been used for burning in the Early Neolithic, this seems most unlikely as the natural forest would surely have provided all the timber required without the need for searching for waterlogged timber in the lake margins. It is likely that the timber used for construction and perhaps for burning was of substantial age, up to about 200 years. However, this argument also applies to all the other samples and in particular to the timbers from the Neolithic house. Thus the differential between four early dates and the other Neolithic dates remains. It is, on the other hand, quite possible that there were Neolithic settlers in the area before 3500 B.C. and this has been accepted by the excavator (ApSimon 1976). There is evidence for interference with the natural vegetation at this time in the Lower Bann Valley (Smith 1975) and we have noted some features of the Ballynagilly diagram that could be interpreted as anthropogenic.

The next group of samples, UB-304, UB-551, UB-199 and UB-201 which came from contexts containing Lyles Hill ware and are assigned by ApSimon to his Early Neolithic (EN), fall at the time of the elm decline (the beginning of zone BG-6, *3270 B.C.). They are indistinguishable from the dates for the two charcoal layers in monoliths A and B. The samples are from the house and associated Early Neolithic features and there is thus a firm temporal association between the elm decline and the builders of the rectangular house. While it has been generally accepted for some time that the landnam clearances in Ireland were the work of Neolithic man (Smith 1964), in this case the clearance can be associated with a specific settlement.

As has been discussed elsewhere (Pilcher *et al.* 1971 and in § 3), the Neolithic clearance phase persisted for several hundred years. Following the initial clearance pine recovered slightly and was again reduced at *2950 B.C. This date is close to those from a hearth, and two pits containing Lyles Hill ware (UB-301, 306, 625) assigned by ApSimon (1976) to his Middle Neolithic (MN). Shortly after this there are suggestions of a change to pastoral farming which ended at *2650 B.C.

The dates from archaeological contexts suggest continued occupation in the Neolithic for about 900 years. Any anthropogenic effect on the forest cover in the first half of this period seems to have been slight. Bearing in mind the uncertainties of the techniques there is good correlation between the material dated to the Early Neolithic (*sensu* ApSimon) and the first major clearance and farming period starting shortly before 3250 B.C. No dated archaeological material falls directly into the end of the farming period (BG-6*a*(B)) deduced from the pollen analyses, though there is some statistical probability that some of the Middle Neolithic material belongs here. There is however little or no possibility that any of the dated archaeological material belongs to zone BG-6*b*. This reinforces the inference from the pollen analyses that this was a period of forest regeneration and might be taken as suggesting that the site was abandoned. We have seen, however, that there is some evidence from the pollen analyses that a small population may have remained in the area. It is also interesting that no archaeological material was found to coincide directly with the pine decline at the beginning of zone BG-7 which, as we have seen, could be explained as a natural change.

The first occupation after the apparent abandonment of the site of which we have evidence seems to have been late Neolithic. This occupation is dated by the three samples (UB-552, 553, 554) from linked pits and depressions containing Sandhills type coarse stone-tempered wares. The mean date of *ca.* 2175 B.C. is hardly distinguishable from the start of the Beaker occupation for which seven dates centre around 2000 B.C. This Beaker occupation was probably responsible for the extensive clearance and farming recorded in the pollen diagrams at about 2000 B.C. The Late Neolithic population may, however, have been responsible for the suggested woodland management in zone BG-7. The remaining four dates are from Early Bronze Age contexts. Three of these relate to Plainware potsherds. All four are coincident with the period of pastoral farming and extensive heath development that followed the clearance at *1650 B.C.

This ends the dated archaeological evidence for occupation at Ballynagilly although some Middle Bronze Age pottery was found. The later clearance phases seen in the pollen diagrams from *1350 B.C. onward relate to Bronze Age and later activity perhaps largely centred on one of the nearby hills rather than the Neolithic and Beaker settlement area.

The authors wish to acknowledge the close and helpful collaboration of Mr A. ApSimon, the excavator of the archaeological site, and his colleagues. The authors are also indebted to Mr G. W. Pearson who carried out laboratory determinations of the radiocarbon dates. Financial support from the Department of Scientific and Industrial Research, latterly the Natural Environment Research Council, is gratefully acknowledged.

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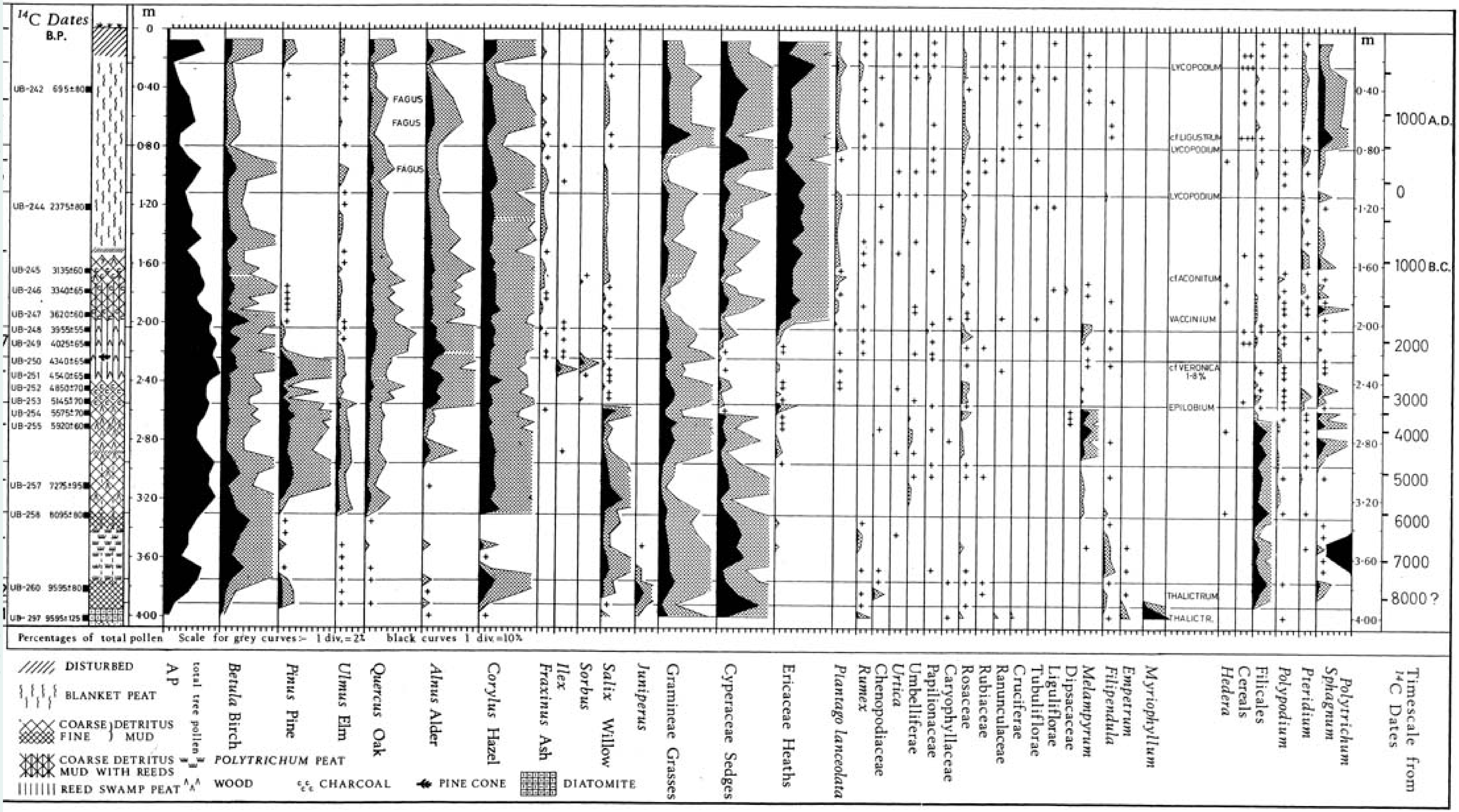

Figure 4. Pollen diagram from the deep organic deposits at Ballynagilly. The location of the core from which the samples were taken is shown in figure 1 and described in the text (§ 2*a*). The radiocarbon dates are plotted against depth in figure 3 and listed in table 2. The time scale at the right of the figure is derived from figure 3: see also text (§ 2*c*).

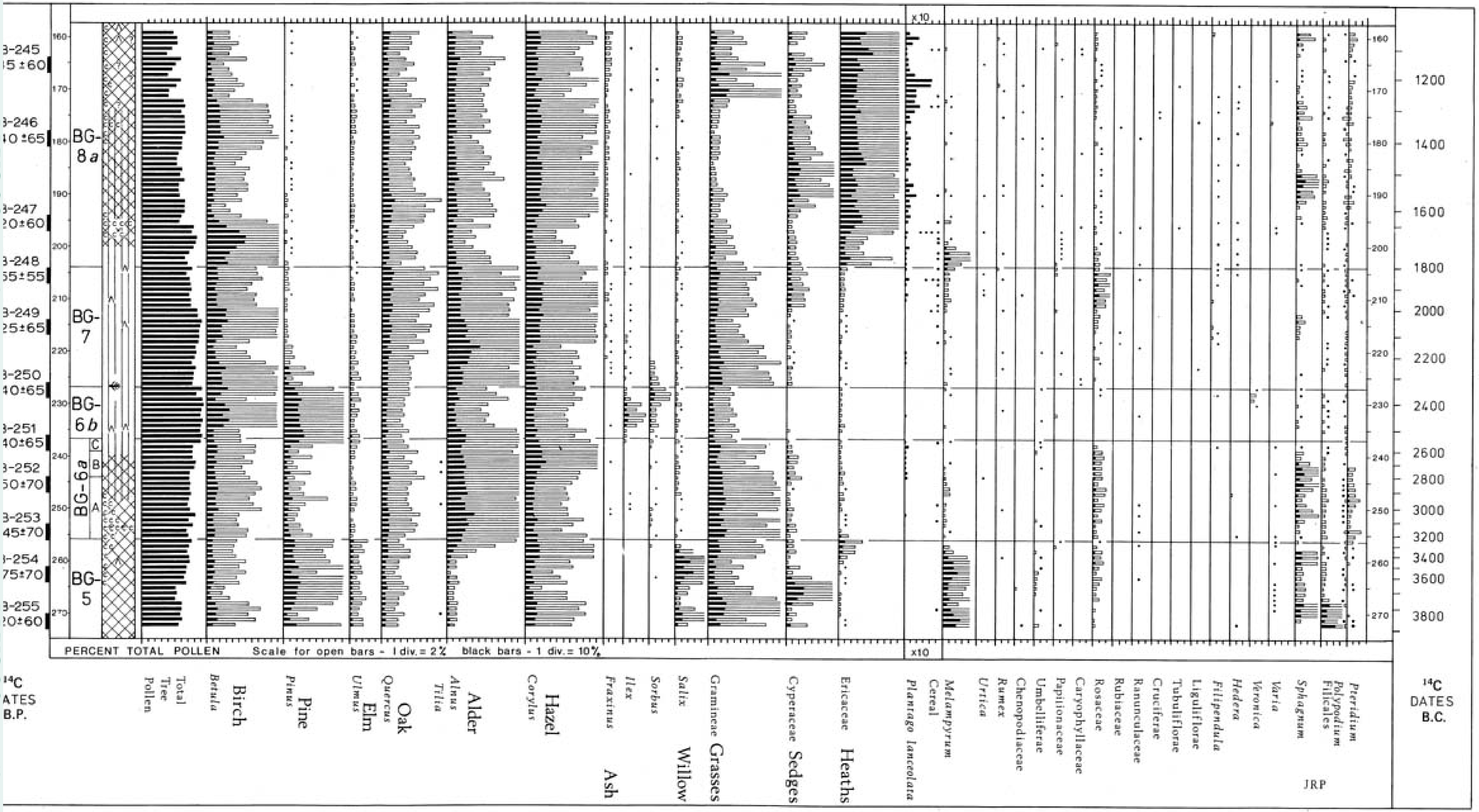

FIGURE 5. Detailed pollen diagram for the mid-Littletonian stage at Ballynagilly from the same core as for figure 4 but with a reduced sampling interval. The time scale at the right of the figure is derived from figure 3: see also the text (§2c). A key to the stratigraphic symbols is given in figure 4. The subdivisions A, B and C of subzone BG 6a, represent the successive stages of a Neolithic 'clearance phase' of 'Landnam' type. The interpretation of this pollen diagram and its relation to the prehistoric occupations of the site is summarized in figure 7.

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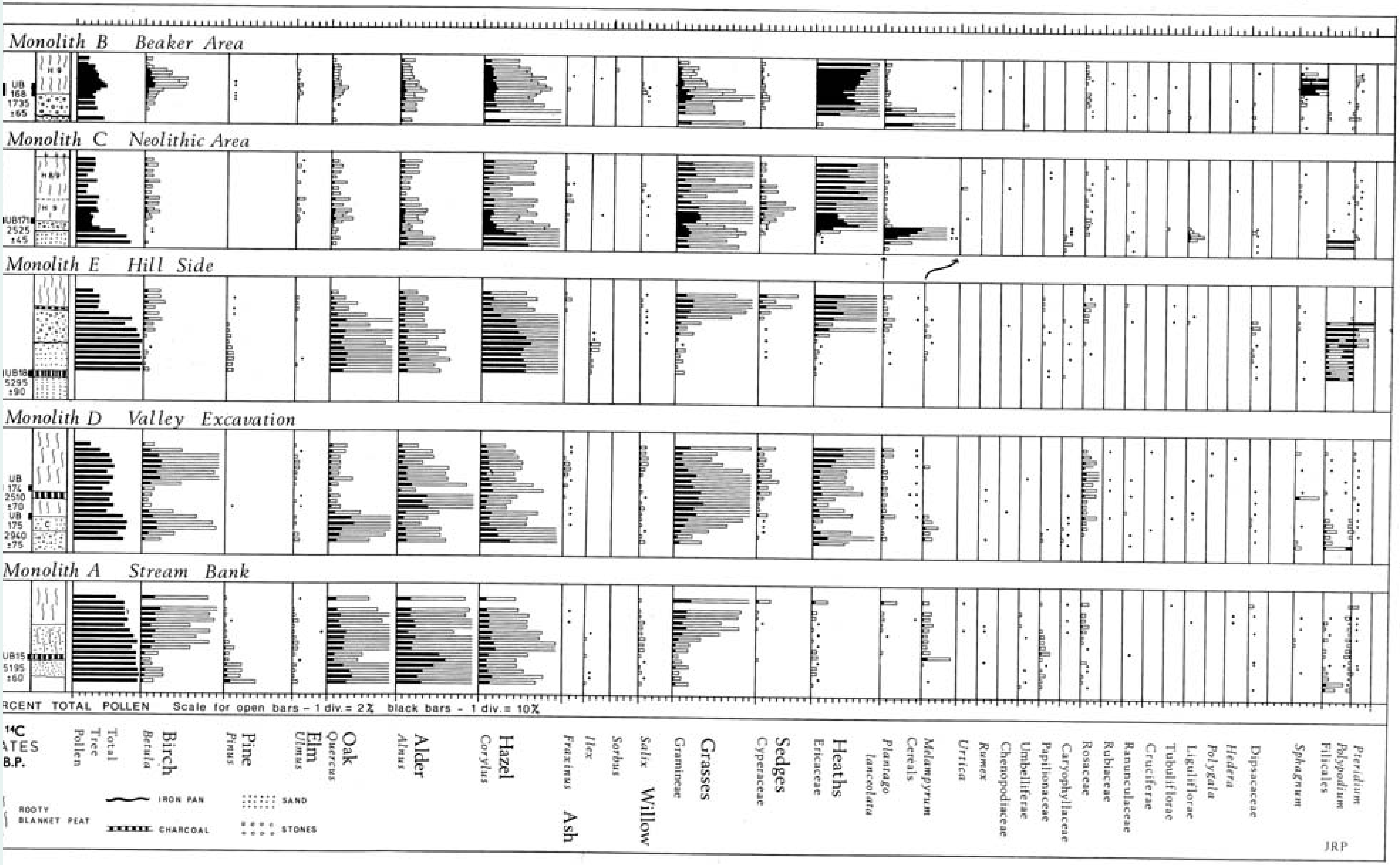

Figure 6. Pollen diagrams from blanket peats and underlying soils at Ballynagilly. The locations of the monoliths from which samples were taken for pollen analysis are shown in figure 1. The charcoal in Monoliths A and E was of oak and hazel respectively. The radiocarbon dates for these layers are indistinguishable from those for the Neolithic house, and associated features. They are also indistinguishable from the date for the level in the long core (figures 3 and 4) containing pine charcoal. See also text and figure 7.

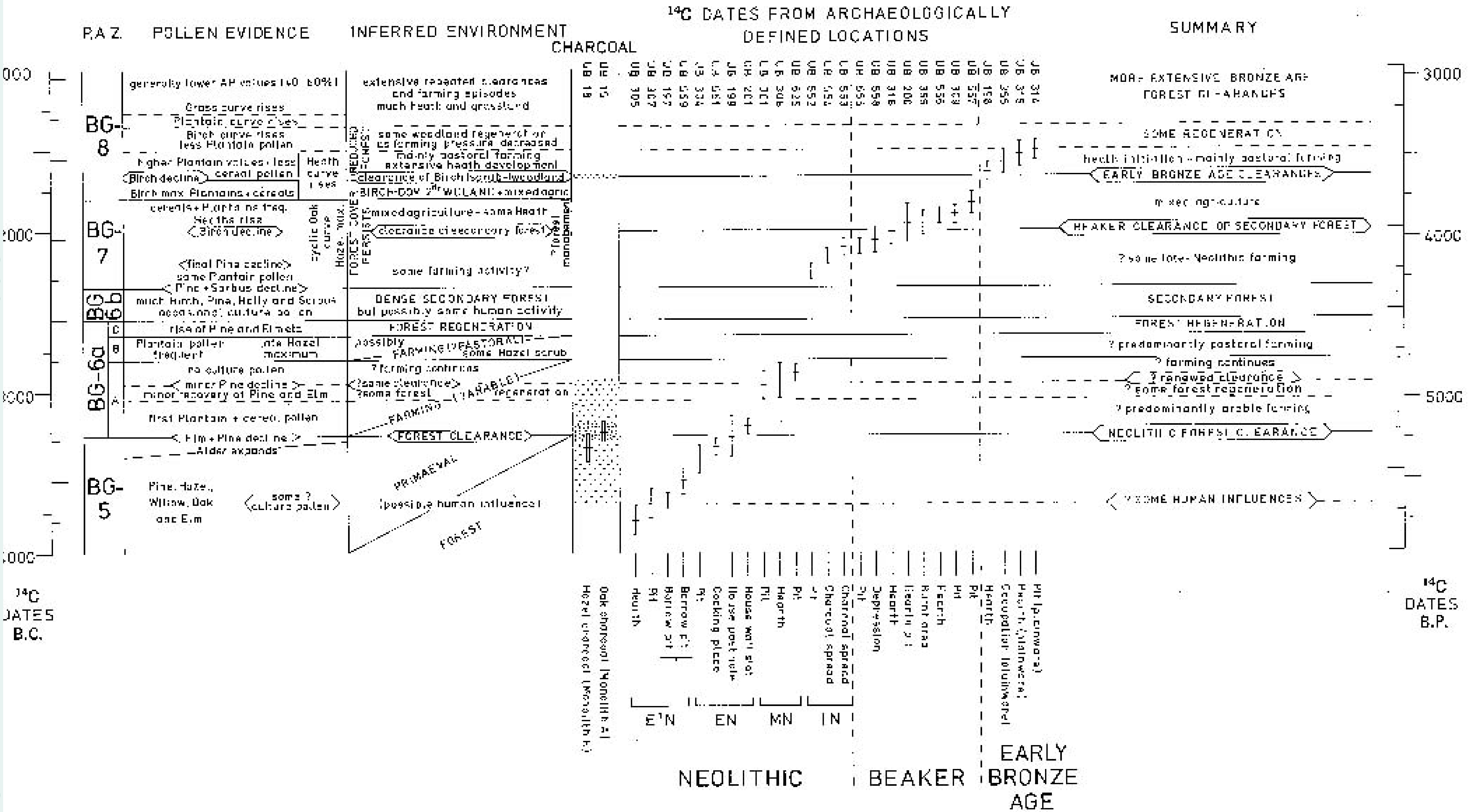

FIGURE 7. Palaeoecological-archaeological correlations for the mid-Littletonian Stage at Ballynagilly. The pollen evidence summarizes figure 5 and the inferred environment is discussed in detail in the text (§ 4). A visual impression is given of the concentration of charcoal in the core used for pollen analysis and ^{14}C dating. At the level of the elm/pine decline, the charcoal in the core was of pine. The two ^{14}C dates superimposed on this representation of charcoal in the core are from charcoal found in mineral soil or silt underlying blanket peat (see figure 6, § 3). The ^{14}C dates from archaeological locations, which are also listed in table 1, were taken under the direction of Mr A. ApSimon (ApSimon 1969, 1976), whose subdivisions of the Neolithic period are indicated thus: EAN = earliest Neolithic; EN = early Neolithic, MN = middle Neolithic, LN = late Neolithic. The time scale is in conventional ^{14}C years; i.e. the ^{14}C dates are 'uncalibrated' ('B.P.' = before A.D. 1950; 'B.C.' = 'B.P.' date less 1950 years). The palaeoecology is related to this scale by means of interpolation using a closely spaced series of ^{14}C dates through the deep organic deposits (graphed in figure 3 and listed in table 2). This relation is subject to a number of reservations (§ 2c). Subzone BG 6a covers a Neolithic 'clearance phase' of the 'Landnam' type. At Ballynagilly (and elsewhere, see Pilcher *et al.* 1971) this phase is more complex, and longer, than the classical Danish landnam phases (Iversen 1941, 1949); see also text. The zone boundary BG-5/BG-6 is equivalent to the zone VIIa–VIIb transition of Jessen (1949) and the zone VII–VIII transition of Mitchell (1956).

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