LATE-DEVENSIAN AND FLANDRIAN VEGETATIONAL HISTORY OF BODMIN MOOR, CORNWALL

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A largely palynological study of new exposures of lake and mire sediments from Bodmin Moor, Cornwall, together with radiocarbon dating of the polliniferous deposits has allowed, for the first time in southwest England, description of dated local and regional pollen assemblage zones which can be correlated with the pollen zones of Godwin and the chronozones of West.

Reconstruction of the vegetational history of the Late-Devensian, early and later Flandrian periods is attempted by using, wherever possible, values for the pollen content of sediments to illuminate real pollen taxon percentage fluctuations. Deposition of limnic sediments in the Late-Devensian started shortly before 13000 B.P. when the dominant vegetation, open grass heaths, snow-beds and flushes, reflects the cold climate. Soils at this time were subject to erosion by snow melt-water. Ensuing climatic amelioration permitted invasion by juniper scrub and about 12000 B.P. expansion of tree birches took pace. Climatic recession occurring under strongly oceanic conditions (marked by considerable amorphous solifluction of the upland soils and the development of grass/sedge mires) was initiated about 11000 B.P., but its duration here cannot be accurately estimated. Within this threefold pattern of Late-Devensian deposition 12 distinct pollen assemblages are described from four profiles. Pollen of *Artemisia norvegica*, *Astragalus alpinus* and *Saxifraga stellaris* is confined to the earlier and later colder periods. In the intervening warmer period, but *not* the colder periods, there is slight pollen and macroscopic fossil evidence of *Betula nana*.

An unexplained unconformity exists at the base of the Flandrian deposits. Early Flandrian vegetation is characterized by the spread of tree birches and *Salix* in the valleys, with *Empetrum* and juniper on the hillsides. The two latter genera are replaced before 9000 B.P. by *Corylus* followed almost immediately by the spread of *Quercus*. Throughout the Flandrian *Quercus*, *Betula* and *Corylus*, although the dominant woodland genera, probably colonized only the more sheltered sites on the upland. Archaeological and palynological records have been correlated as far as possible, the only substantial pollen record of human activity being that of *Plantago lanceolata*, which spread encouraged by Bronze Age pastoralism. There is also pollen evidence of scanty cereal cultivation.

Areas on the Atlantic fringes of Europe show a marked similarity in their early Flandrian forest history, particularly with regard to the slight rôle played by *Pinus* in relation to *Quercus* compared with stations further east. This similarity must derive from the proximity of the tempering influences of the North Atlantic Drift.

1. INTRODUCTION

(a) *Geography, vegetation and climate of southwest England*

As a geographical unit southwest England may be defined as the peninsula southwest of a line running along the east of the Brendon and Blackdown Hills in Somerset. It includes western Somerset, Devon and Cornwall (figure 1). This land mass of 10600 km^2 (4150 square miles) is bounded on the north by the Bristol Channel and on the south by the English Channel so that no place in Devon is more than 40 km from seawater and in Cornwall no more than 29 km. Most of the area lies above 122 m (400 ft) O.D., and the only extensive area of lower ground not surrounded by higher ground is at the exposed western end of Cornwall. The Armorican granite intrusions of Penwith, Carnmenellis, Hensbarrow, Bodmin Moor and Dartmoor are responsible for the western upland topography.

The maritime environment of this upland peninsula gives it a very mild but wet and windy climate. The mean January temperature at Falmouth, Cornwall (6.3 °C) is close to that of Montpellier, France, 6° further south on the Mediterranean coast. The seawater off Cornwall

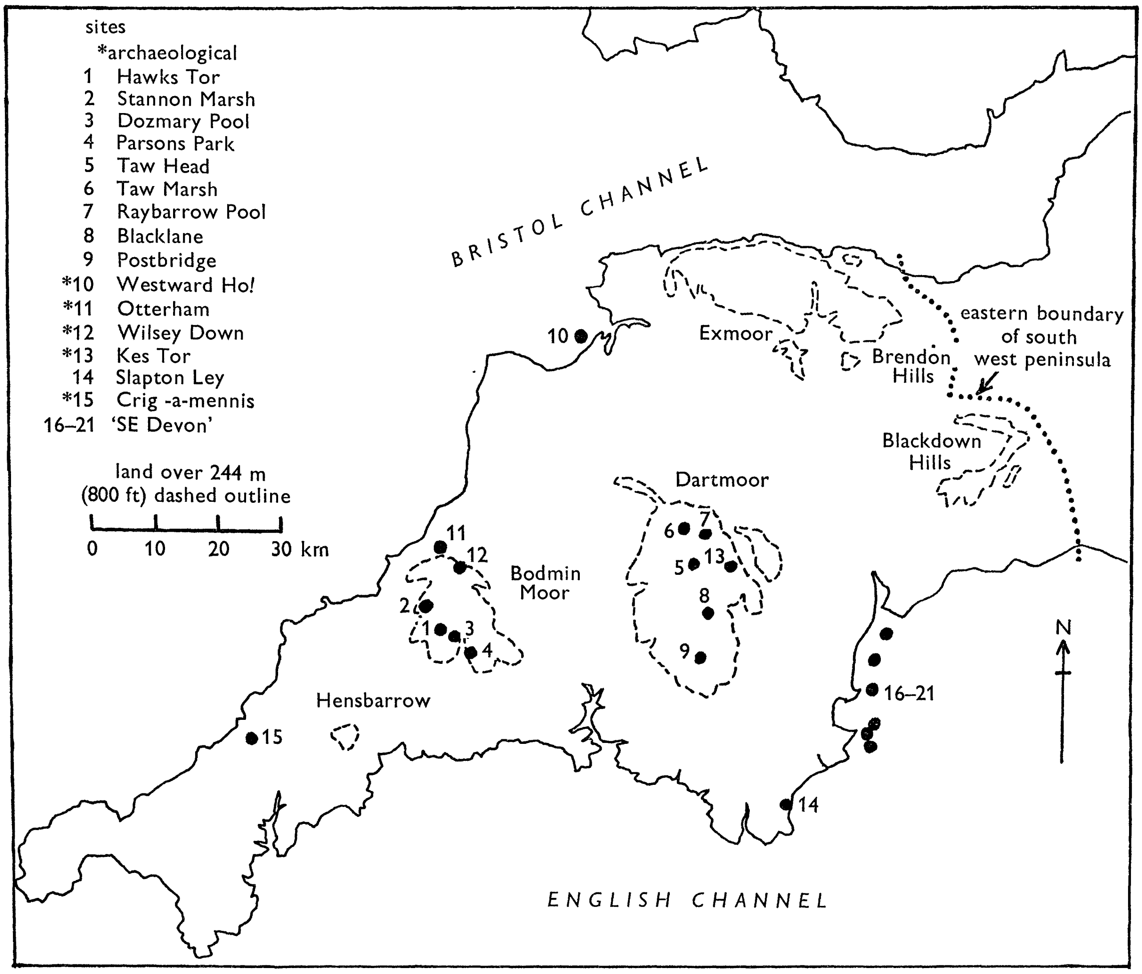

FIGURE 1. Palaeobotanical studies in Devon and Cornwall, 1950–70. References to the sites are given in the text except for Westward Ho! (Churchill 1965), Otterham and Wisley Down (Dimbleby 1965), Slapton Ley (Crabtree & Round 1967) and Crig-a-mennis (Dimbleby in Christie 1960).

has an average January temperature of 9.4 °C because it derives from the Gulf stream and North Atlantic Drift. Annual air temperature fluctuation at Falmouth (9.5 °C) is 3.2° less than at Greenwich, London and 7.8° less than at Montpellier. Annual rainfall is greater than 1140 mm (45 in) over more than a third of the area and is never less than 819 mm. The winds are predominantly westerly.

Mainly inactive blanket bog (in the wetter parts of Dartmoor), valley bogs, *Molinia*, *Nardus* and *Calluna* heaths are the typical vegetation of the southwestern moorlands now. The vegetation of Dartmoor has recently been surveyed by Ward, Jones & Manton (1972). Lowland semi-natural woodland in Cornwall is not extensive and is most abundant in the more sheltered southeast of the county. In the eleventh century the Domesday inventories indicated a similar situation. Although the ground area of woodland at that time is difficult to estimate, the majority appeared south and east of Bodmin Moor (Ravenhill, in Darby & Welldon Finn (1967)). If woodland had ever been extensive in the west, and place names suggest it was more frequent than at present (Thurston 1930), it succumbed early to the effects of human occupation surely aided by the lack of shelter from wind.

The west coast of Ireland and the western and northwestern coasts of Scotland are similarly oceanic areas with larger land area and in their 'wetness' stand apart from areas of the British Isles further east.

However in the British Isles it is only the western coasts of Ireland, Wales and southwest England that have a growing season of more than 280 days (Fairbairn 1968). This is the period of time during which the mean daily temperature is 6 °C or greater, the temperature necessary for the growth of grass crops to start. Thus the southwest segment of the British Isles has a milder climate than the northwest.

The extremities of southwest Ireland, southwest England (the Scilly Isles) and Brittany all face westward along the edge of the continental shelf north of the Bay of Biscay. This common orientation places them facing into the path of the North Atlantic Drift and its tempering influence. On the other hand, the northwestern coasts of the British Isles run parallel to the path of the North Atlantic Drift. This difference in orientation, together with the more southerly latitude of the southwestern sector of the British Isles, contributes to its milder climate as compared with the northwestern sector. These areas of western Ireland, southwest England and France possess common elements of a Lusitanian flora which finds its maximal development in the Iberian peninsula and southern France. There is also great similarity in the Atlantic affinities of their bryophyte flora (Proctor 1964). The distribution of the Lusitanian species in the British Isles falls within the areas with a growing season of 270 days or so per year as defined by Fairbairn (1968).

2. Organic deposits on Bodmin Moor

The majority of Bodmin Moor lies above 210 m o.d. and a large central area reaches over 305 m. Davidstow Moor and Wilsey Down continue the moorland northwards over slates (figure 2). The granite has been extensively kaolinized and kaolinized areas in the valleys are marshy levels.

The maximum altitude of the Moor is 419 m (Brown Willy). Dartmoor has a central area of considerable size reaching to over 490 m o.d. and its greatest altitude is 621 m o.d. at Great Willhays (figure 3). Blanket bog is well developed in two extensive tracts on Dartmoor above

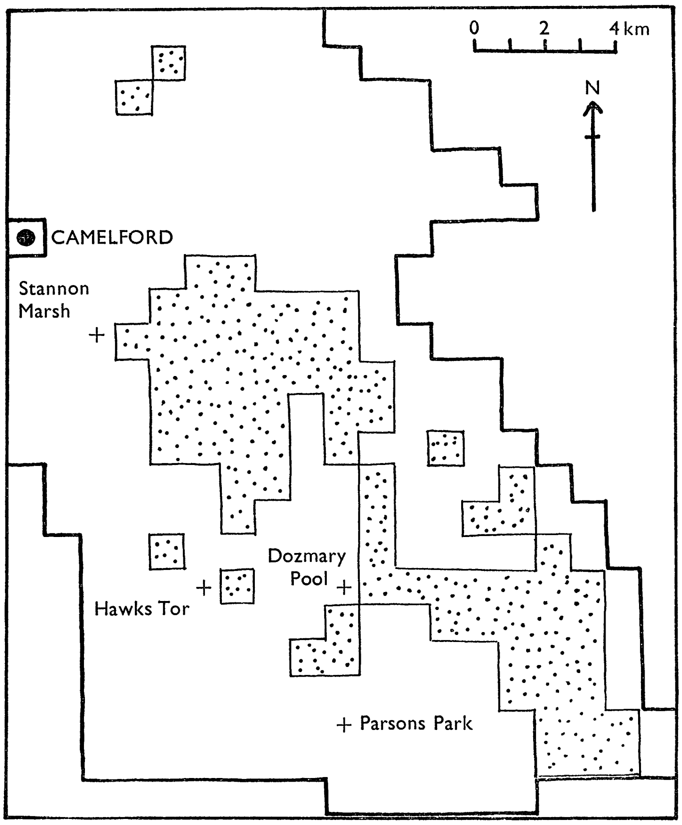

Figure 2. Bodmin Moor: sites and elevation. The kilometer squares of the national grid have been used as a basis for mapping. The heavy outline represents the boundary of land above 229 m (750 ft). The stippled area represents land above 305 m (1000 ft).

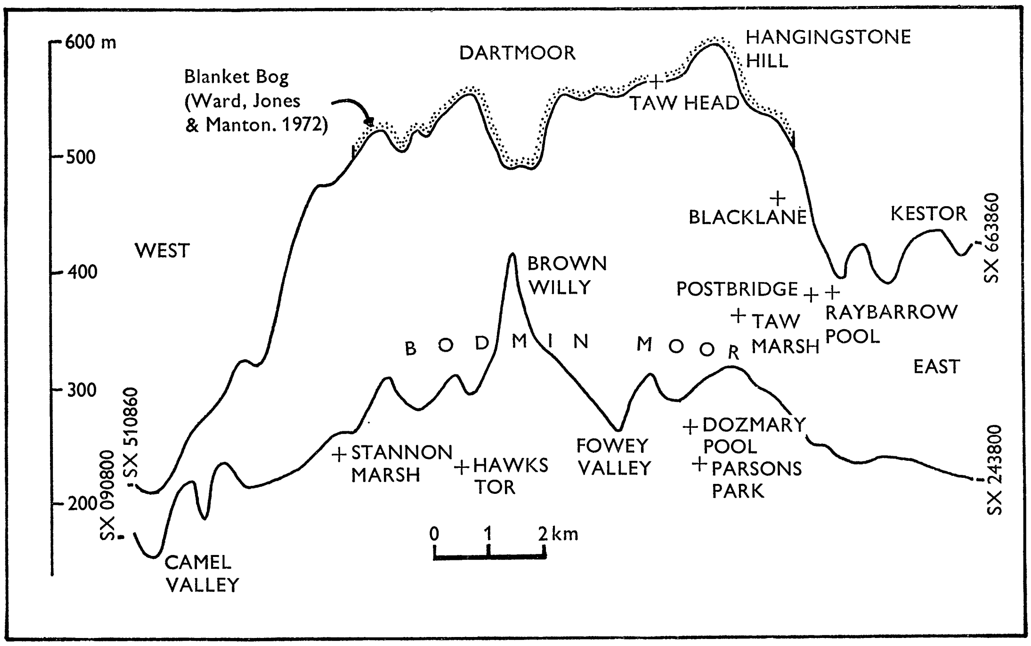

Figure 3. Topography of Bodmin Moor and Dartmoor. Two west–east transects of the higher parts of the moors superimposed. Sites mentioned in the text are projected on to the transects at their respective altitudes.

Parsons Park 1969

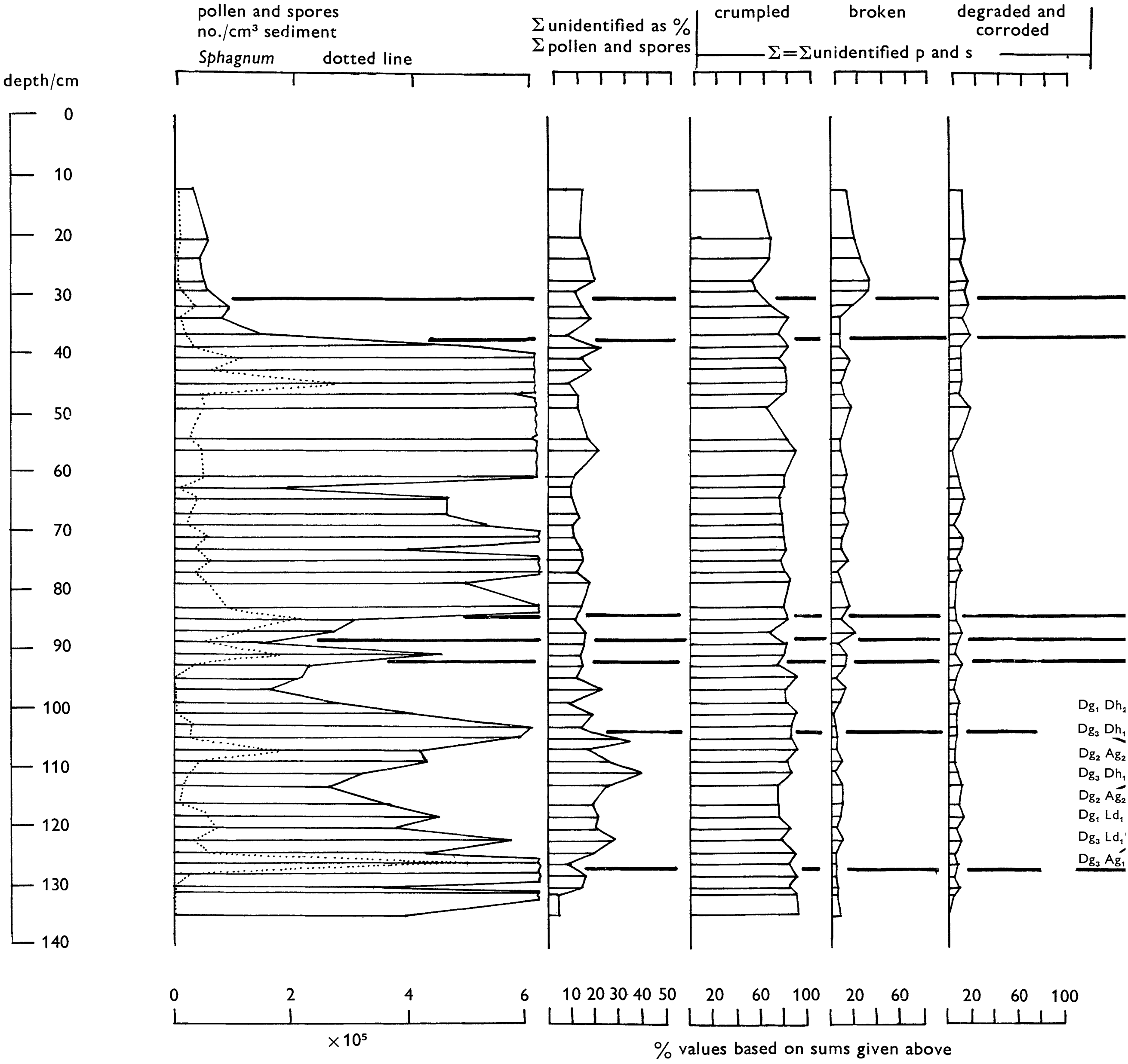

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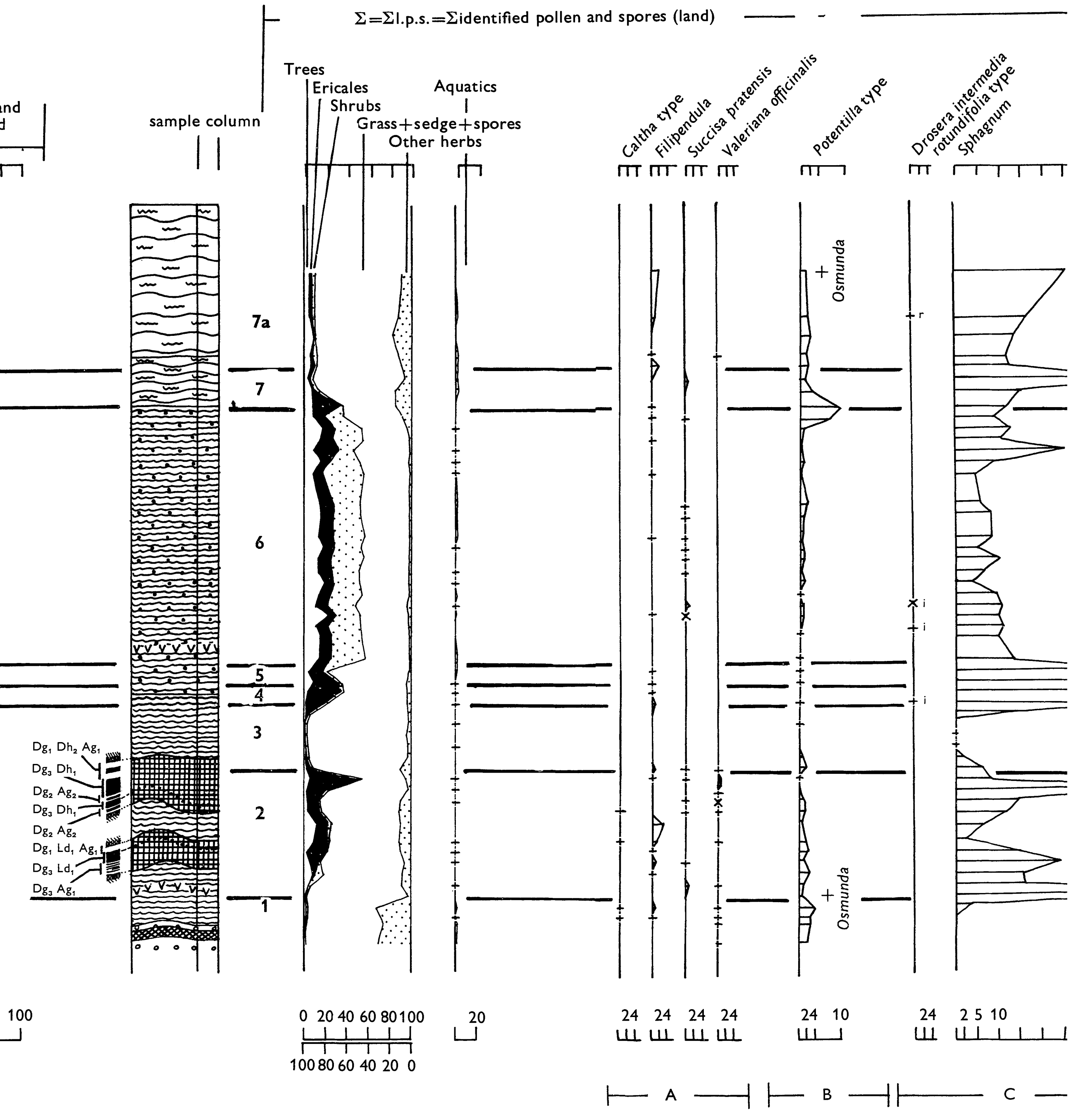
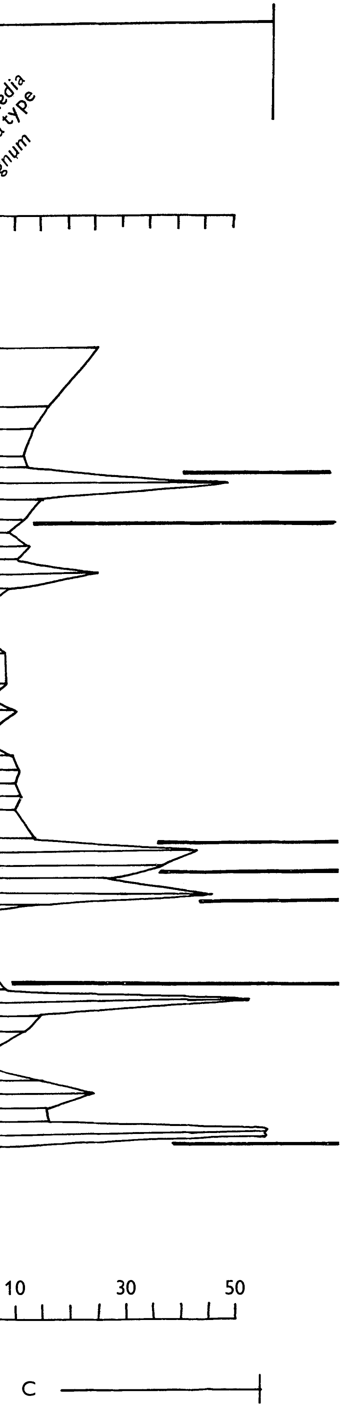
Figure 4. Pollen diagram: Parsons P



Parsons Park, 1969. General information and taxon groups A–C.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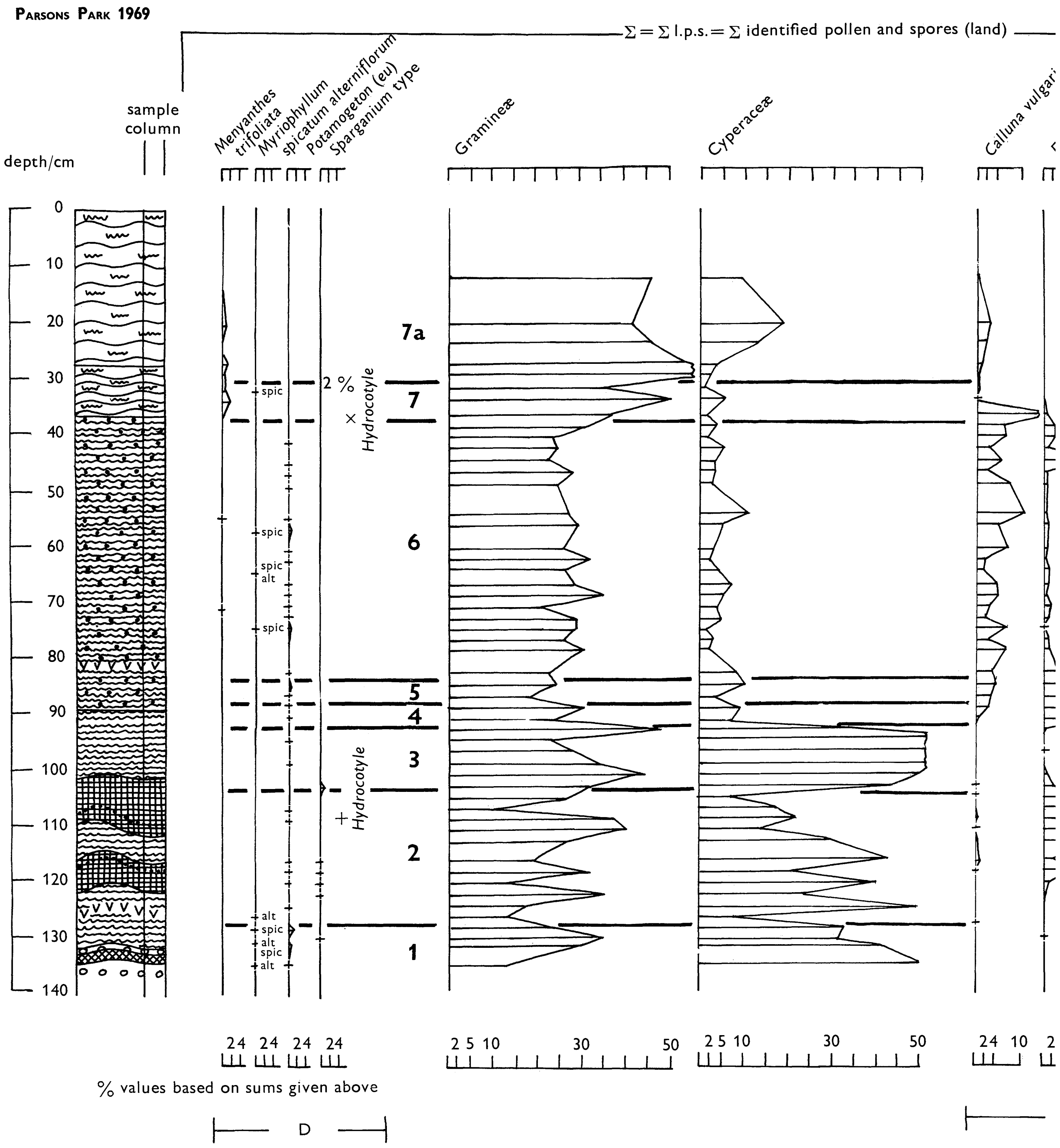
PARSONS PARK 1969
Σ = Σ l.p.s. = Σ identified pollen and spores (land)
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sample column
Menyanthes trifoliata
Myriophyllum spicatum alterniflorum
Potamogeton (eu)
Sparganium type
Gramineæ
Cyperaceæ
Calluna vulgari
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% values based on sums given above
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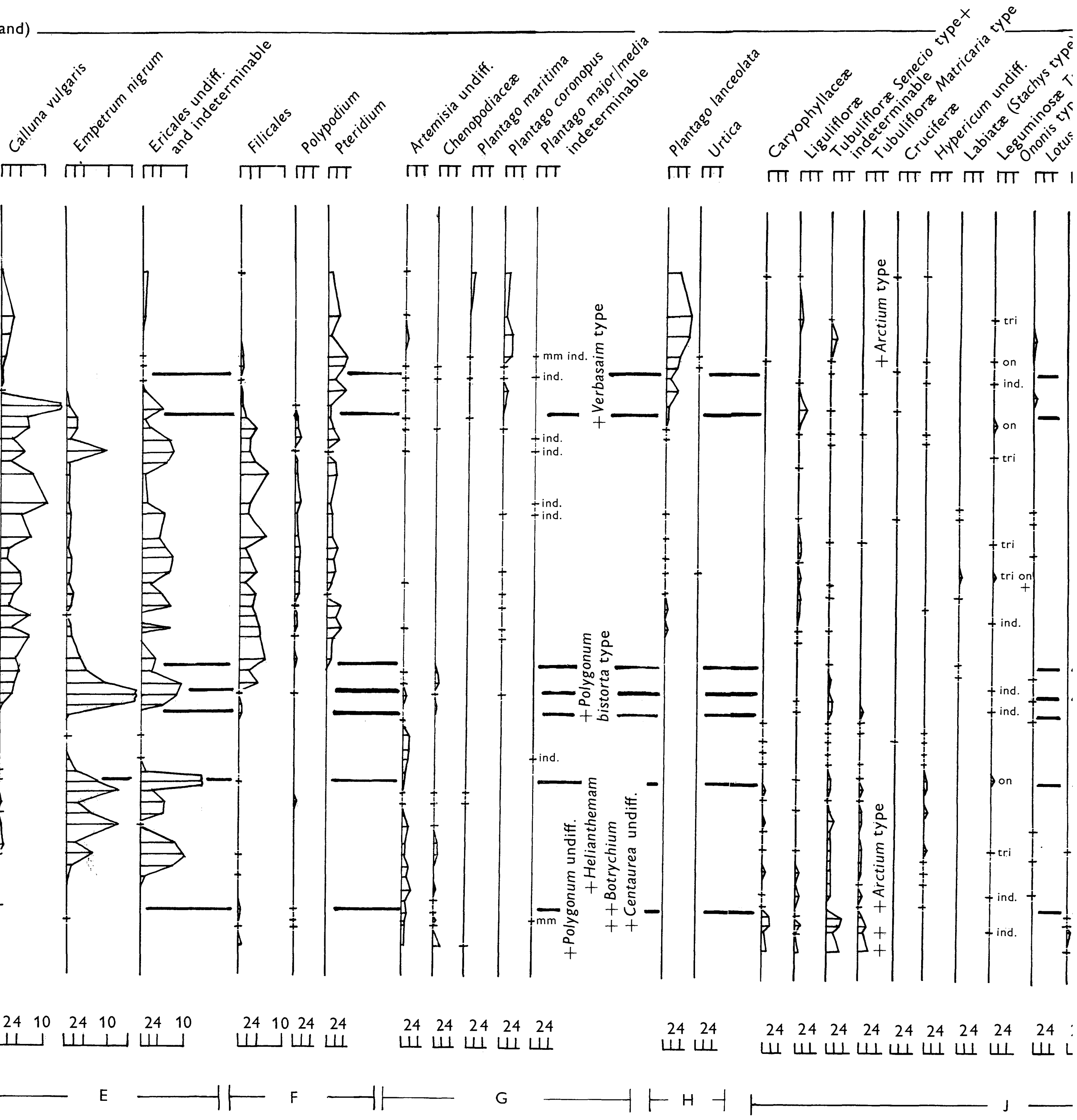
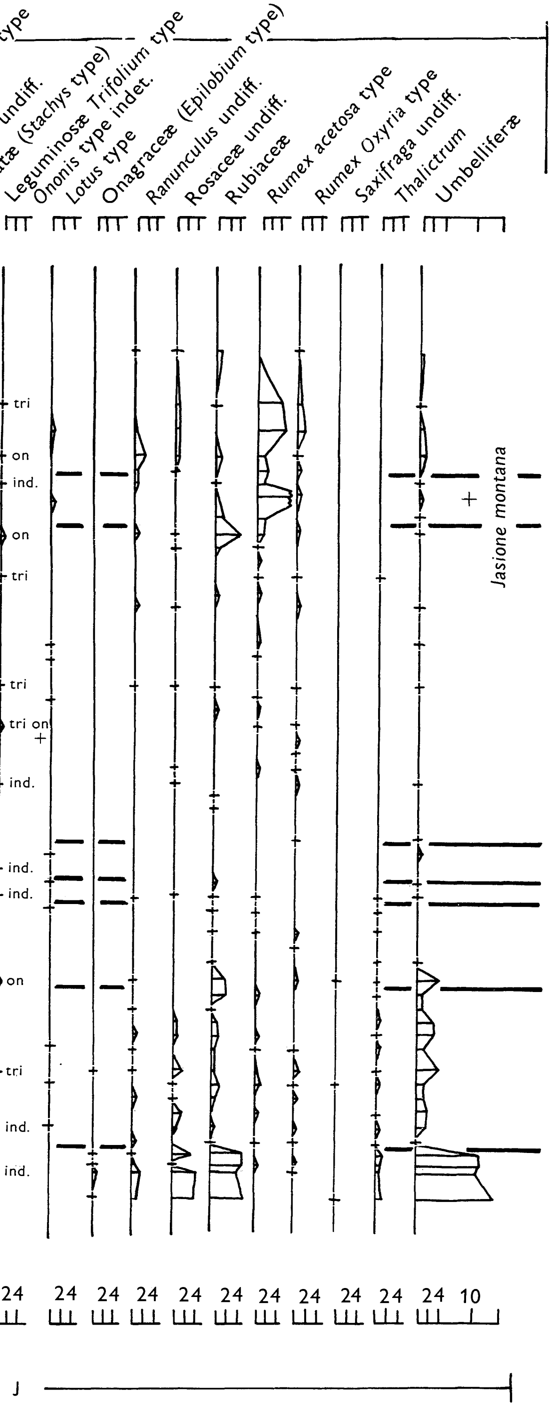
FIGURE 5. Po



URE 5. Pollen diagram: Parsons Park, 1969. Taxon groups D–J.


ype
undiff.
tæ (Stachys type)
Leguminosæ Trifolium type
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Lotus type
Onagraceæ (Epilobium type)
Ranunculus undiff.
Rosaceæ undiff.
Rubiaceæ
Rumex acetosa type
Rumex Oxyria type
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460 m o.d., where the average annual rainfall is 1778 mm (Simmons 1964*a*; Ward, Jones & Manton 1972; Shorter, Ravenhill & Gregory 1969). This blanket bog has ceased active growth and is rapidly being eroded in some areas (Simmons 1963). Peat cutting has been extensive in the past.

TABLE 1. PEAT STRATIGRAPHY ON BODMIN MOOR AND DARTMOOR

pollen zones (*sensu* Godwin 1956)	Bodmin Moor (site altitudes about 244 m o.d.)			Dartmoor (site altitudes 366–549 m o.d.) Simmons (1964*a*)
	Conolly, Godwin & Megaw (1950)	Dickson (1965)	Brown (1972)	
VIII	unhumified *Sphagnum*/ *Eriophorum* or *Molinia* peats	—	unhumified *Sphagnum*/ *Eriophorum* peat	*Sphagnum* peat
VIIb		—		*Sphagnum* peat or amorphous peat
VIIa	humified *Sphagnum*/ *Eriophorum*/*Calluna* peat with charcoal	—	humified *Sphagnum*/ *Eriophorum*/*Calluna* peat with charcoal	
VI	lake muds, sedge peats	—	*Sphagnum*/sedge peats	amorphous peat with charcoal
V	wood peats	—	↑ wood peats	↑
IV	lake muds	—	↑ *Sphagnum*/sedge peats	lake muds
III	gravels and laminated silts	gravel ? laminated silts	gravels and silts	—
II	wood peats, sedge peats	—	fen peats with wood, sedge peats	—
I	gravels and silts	? laminated silts	gravels and laminated silts	—

On Bodmin Moor with lower altitude and rainfall blanket bog is rare. Two small tracts of peat unrestricted to valley bottoms are represented in the Geological Survey drift maps (1 in, n.s. 336 and 347) on Smallacombe and Langstone Downs lying above 305 m due east of Dozmary Pool (figure 2). Extremely thin layers of inactive blanket peat or mineral soils normally cover the hillsides. Evidence presented here suggests that blanket peat spread onto the hillsides after about 500 b.c., but it is clear that it never developed as extensively or as deeply as on Dartmoor.

The upland valley floors are flat. Hiller borer transects and exposures in kaolin pits indicate that now the valley peats are usually 1–2 m thick. Deeper deposits have been recorded (Reid, Barrow & Sherlock 1911) and may still exist. It is very likely that many deeper deposits have been reduced by peat cutting.

(*a*) *Peat stratigraphy*

The uppermost peat is usually golden-brown and unhumified. It can be *Sphagnum*/*Eriophorum* or *Molinia* peat. At the much higher Dartmoor sites the uppermost peats are pure *Sphagnum* peats (Simmons 1964*a*). Below these is a chocolate brown, moderately humified peat and below this a dark, well humified peat containing abundant charcoal, either in discrete layers or throughout. Deeper organic sediments are sticky and grade into detritus muds or sedge peats and overlie either basal gravel or materials of Late-Devensian date. These observations are summarized in table 1 together with a broad pollen zone correlation.

3. METHODS OF FOSSIL ANALYSIS

(a) *Introduction*

Five monoliths and two Livingstone cores from three sites on Bodmin Moor were subject to pollen and macrofossil analysis. The stratigraphy of each monolith and core was described from a fresh-cut surface as soon after return to the laboratory as possible. Troels-Smith's (1955) system of sediment description was applied to the stratigraphy of the Parsons Park monolith, the first to be examined. The stratigraphy of the monoliths and cores is presented in §4.

Pollen samples from the sediments were normally taken at 2 cm intervals (continuous 1 cm samples at the base of monolith no. 3, Hawks Tor; wider intervals in unhumified peats) and the pollen samples were treated to yield both their pollen and macroscopic fossil content. The macrofossil contents of these routine analyses are not listed separately but are incorporated into the stratigraphical descriptions.

(b) *Late-Devensian plant macrofossil analysis*

A special analysis of the plant macrofossil content of the sediments from Late-Devensian pollen assemblage zones and subzones at Hawks Tor (all monoliths) was made and is presented in table 5, §5. Each sample was examined (after soaking in 5% NaOH solution for 1–2 days) by sieving on a 7, 25 and 100 mesh sieve series. The material held on each sieve was sorted and identified as far as possible.

(c) *Pollen analysis*

Since pollen content ('absolute pollen frequency', 'pollen concentration') information is obtained from any sediment with little more effort than is used in obtaining simple percentage frequency information, a method for estimating pollen content was chosen. At the inception of the work it was planned to make use of a suitable radiocarbon date series to calculate pollen accumulation rates (as defined by Davis (1969)). However, the frequent sediment-type changes and shallowness of the deposits of this study have precluded accurate estimation of short-lived sediment accumulation rates and hence have precluded the use of pollen accumulation rates in the type of analysis presented by Davis.

Nevertheless, pollen content information has usefully allowed distinction between percentage changes that are caused by fluctuations of one taxon and those changes that occur in one taxon as a result of fluctuation in another. Methods already published for the determination of pollen content have all been devised for use with lake sediments. In this study sediments of several types were encountered. Most difficulties were encountered in the sampling of unhumified peats, but the consistency of the pollen contents of these peats suggests that the sampling errors associated with them are low.

The methods for estimating pollen content of Davis (1966), Benninghof (1962) and Matthews (1969) were combined so that pollen content was calculated from the density of an added exotic (*Nyssa sylvatica* Marsh.). Simultaneously estimates of losses from the sample during processing were made by estimating the amount of exotic lost. Bonny (1972) gave a critical account of a similar combination of previous methods.

Pollen samples were normally taken by inserting a square-section brass tube into the sediment and extruding an accurately cut length of its contents. The sampler was provided with accurately spaced slots as cutting surfaces and the volume of the samples was slightly less than 1 cm^3.

Routine analysis of slides was carried out by using a Leitz SM microscope at a magnification of 500 diameters. Critical observations were made at a magnification of 1187 diameters with a flourite oil-immersion objective NA 1.32. Conventional and phase-contrast (1000 diameters, objective NA 1.30) optics on two Leitz Laborlux microscopes fitted with a prismatic comparator head were used for direct comparison of fossil and reference material.

The limits of each pollen taxon referred to, together with identification criteria where necessary, are available from the author.

The pollen diagram curves are drawn to the nearest 0.5 % and percentages below 0.25 % are recorded by '+'. A pollen taxon occurrence outside the area of a slide that was counted is recorded by 'X'.

On the pollen diagrams the taxa are grouped as follows:

A	fen and mire plants of base-rich habitats
B	fen and mire plants of variable base-status requirement
C	fen and mire plants of base-poor habitats
D	aquatic plants (requiring open water for optimal development)
E	ericaceous shrubs
F	pteridophytes not included elsewhere
G	open ground plants
H	cereals and weeds of cultivation
J	other herbs of variable habitats (includes Gramineae and Cyperaceae which are grouped separately because of their high percentage values).
K	trees
L	shrubs
M	contaminants (see appendix 1).

Abbreviations used in the following account are:

P.P.	Parsons Park
H.T.	Hawks Tor
D.P.	Dozmary Pool
B.M.	Bodmin Moor
S.M.	Stannon Marsh
p.a.z.	pollen assemblage zone (zonule)
l.p.s.	land pollen and spores
a.p.	arboreal pollen
n.a.p.	non-arboreal pollen

(*d*) *Errors in pollen analysis*

A full discussion of the quantitative errors involved in the methods used is provided in Brown (1972); a summary is provided in appendix 1, together with a discussion of qualitative errors involved with the use of the exotic, *Nyssa*.

4. SITES, STRATIGRAPHY AND POLLEN ASSEMBLAGE ZONES

(*a*) *Introduction*

A short description of each site is followed by an account of the stratigraphy of each exposure and a description of the pollen assemblage zones defined from the pollen spectra found in the sediments. Pollen assemblage zones were defined to be used as convenient descriptive units in

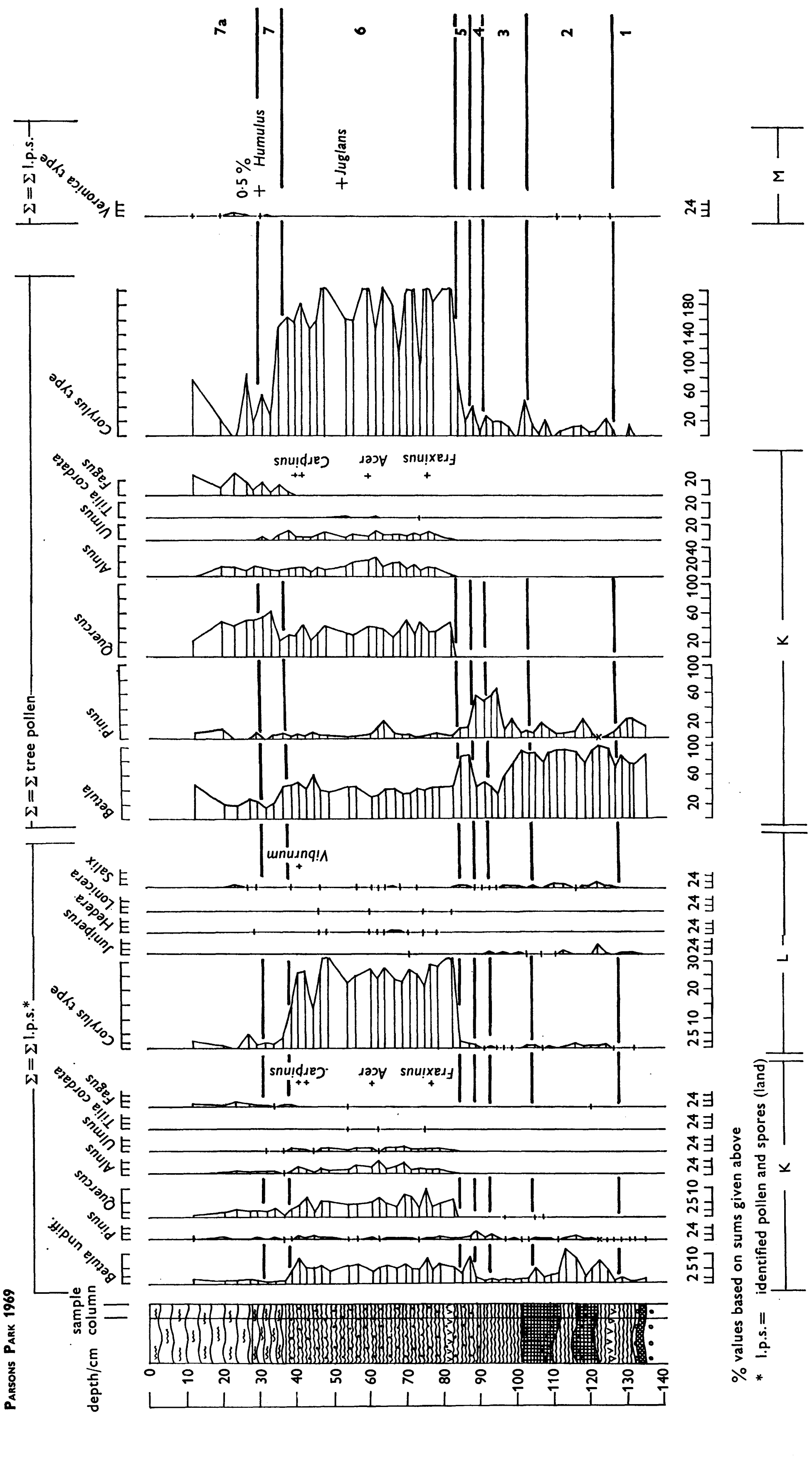

FIGURE 6. Pollen diagram: Parsons Park, 1969. Taxon groups K–M.

correlating and interpreting vegetational history. They are biostratigraphical units described as suggested by the American Commission on Stratigraphic Nomenclature (1961). The pollen assemblage zones, subzones and zonules of this study are the near-homogeneous series of pollen assemblages in contiguous samples remaining after the rigid visual application of somewhat arbitrary criteria for the definition of discontinuities in the pollen diagrams. The criteria are at five hierarchical levels. Definition of discontinuities started from the base of the deposit. Because deposition has not always been continuous only the lower boundaries of the pollen assemblage zones have been defined. Local pollen assemblage zones were defined for each site as recommended by West (1970); each zone and subzone has a verbal title which incorporates some or all of the distinctive taxa, each zone also has a number. Correlation of the local pollen assemblage zones in a regional context is made later (figure 28, §9).

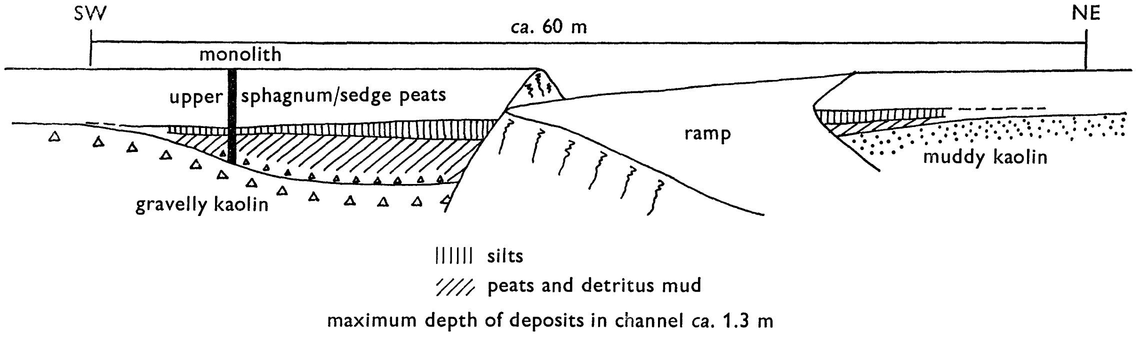

Figure 7. Sketch section: Parsons Park, northwest pit face, 1969.

Levels of discontinuity selection were as follows:

(1) Tree taxa greater or less than 5 % of Σ (l.p.s.–*Sphagnum*†).
(2) Discontinuity of next major taxon (excluding Gramineae,‡ aquatic and fen elements,§ *Sphagnum*†).
(3) Change in ratio Gramineae/Cyperaceae.|| (Zone definition completed.)
(4) Discontinuity of next major taxon (excluding aquatic and fen elements,§ *Sphagnum*†). (Subzone definition completed.)
(5) Discontinuity of next major taxon. (Zonule definition completed.)

Discontinuities may be of degree or presence–absence type.

(*b*) *Parsons Park*

(i) *Descriptions of site*

Pollen analytical results (figures 4–6) are available from a monolith from an exposure on the northwest face of Park China Clay pit of ECLP, at an altitude of 229 m o.d. (grid ref. SX195708). The face reveals a distinct channel feature (figure 7). The monolith was removed in 1969. The site name of Conolly *et al.* (1950) has been retained.

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† Discounts the depressive and local effects of high *Sphagnum* spore frequency on a.p. frequency.

‡ Gramineae is a major taxon at all sites and normally discontinuities of this taxon do not give useful subdivisions.

§ Excluded because of their normally strictly local derivation (thus zonules may be of strictly local import).

|| Both are dominant in the lower sequences at H.T. and P.P.

(ii) *Stratigraphy*

The sediments were described verbally as well as with the notation of Troels-Smith (1955). This diagnosis is given after the verbal description.

cm from surface	
0–28	very coarse, golden, unhumified *Sphagnum/Eriophorum* peat; Th4^1
28–37	moderately humified, red-brown, *Sphagnum/Eriophorum* peat; Th1^2, Dg^1 Dh2
37–90	black, highly humified peat with large monocotyledonous fragments and carbonized fragments throughout; at 84–90 cm the peat is stickier than above; occasional *Juncus* seeds 72–89 cm; Dh4
81–82	*Salix* twigs
90–102	highly humified black peat with large monocotyledonous fragments; no carbonized fragments, Dh4
102–112	contorted, tenacious dark buff silt with lighter banding and a layer of minute carbonized fragments (see figure 4 for structure and diagnosis)
112–117	highly humified black peat with large, monocotyledonous fragments and *Eriophorum vaginatum* sclerenchyma spindles; Dg2, Dh2, Ag tr
117–122	contorted tenacious dark buff silt with lighter banding and a layer of minute charcoal fragments (see figure 4 for structure and diagnosis)
122–132½	highly humified black peat; *Carex* nutlets scattered throughout; salix twigs at 126 cm; Dg1 Dh2 Ld1 Dl tr
132½–133½	gravel
133½–135	dark brown, fine detritus mud; Ld4
135–	gravel

(iii) *Pollen assemblage zones* (*figures* 4–6), *starting at the base*

PP1 PP 1969 127–135 cm Cyperaceae–Umbelliferae assemblage zone. n.a.p./a.p. high (> 19). Cyperaceae and Gramineae dominant. Umbelliferae, Rubiaceae, *Potentilla*-type and Tubuliflorae all important. *Sphagnum* absent. Lower contact unknown.

PP2 PP 1969 103–127 cm Cyperaceae–*Betula*–*Empetrum* assemblage zone. n.a.p./a.p. about 14. *Betula* and *Pinus* the only tree taxa present. Cyperaceae and Gramineae dominant. Umbelliferae, Rubiaceae, *Potentilla*-type and Tubuliflorae less important than in p.a.z. PP1. *Empetrum* appears at 8 %, there is a small *Salix* peak. *Sphagnum* values high. Lower contact with p.a.z. PP1, defined by rise in *Betula* values. (> 90 % *Betula* pollen is of tree type.)

PP3 PP 1969 92–103 cm Cyperaceae–*Artemisia* assemblage zone. n.a.p./a.p. high (> 19). Cyperaceae dominant with values > 50 %. High Gramineae values. *Artemisia vulgaris*-type the dominant herb taxon after Cyperaceae and Gramineae. No *Sphagnum*. Lower contact with p.a.z. PP2, defined by rapid Cyperaceae increase.

PP4 PP 1969 88–92 cm Cyperaceae–*Empetrum* assemblage zone. n.a.p./a.p. decreasing. Gramineae dominant. Cyperaceae values much lower than in p.a.z. PP3. *Calluna* appears, *Empetrum* present at 10–15 %. *Sphagnum* important. Lower contact with p.a.z. PP3, defined by rise of *Empetrum* and *Calluna*.

PP5 PP 1969 85–88 cm *Betula*–*Empetrum* assemblage zone. n.a.p./a.p. continues to decrease. *Betula* values similar to those of p.a.z. PP2. Gramineae dominant, Cyperaceae values low. Filicales appear at 4 %. *Calluna* and *Empetrum* present. *Sphagnum* important. Lower contact with p.a.z. PP4, defined by the rise of Filicales.

PP6 PP 1969 37–83 cm *Corylus*-type–*Betula* assemblage zone. n.a.p./a.p. about 6. Gramineae and *Corylus*-type dominant. *Quercus*, *Ulmus* and *Alnus* appear simultaneously (? lower boundary an unconformity). *Plantago lanceolata* and *P. coronopus* present throughout at low levels. *Sphagnum* values lower than in p.a.z. PP5, PP6. Lower contact with p.a.z. PP5, defined by the appearance of *Quercus*, *Ulmus* and *Alnus*.

PP7 PP 1969 12–37 cm *Plantago lanceolata*–*Rumex acetosa*-type assemblage zone. n.a.p./a.p. values rise to 9. Values of *Betula*, *Ulmus*, and *Corylus*-type decrease relative to those of *Alnus* and *Quercus*. *P. lanceolata* and *R. acetosa*-type appear up to 5 %. Other herbaceous taxa show slight increases. *Polypodium*, Filicales and *Empetrum* virtually absent. *Pteridium* values greater than those of p.a.z. PP6. Lower contact with p.a.z. PP6, defined by the appearance of *P. lancoelata* and *R. acetosa*-type in quantity.

One subzone distinguished:

Subzone PP7a 12–30 cm Cyperaceae subzone. Defined by high values of Cyperaceae (*ca.* 15 %), and maximal (*ca.* 5 %) values of *P. lanceolata.*

(*c*) *Hawks Tor*

(i) *Description of site*

Pollen analytical results are available from three monoliths (nos. 2, 3 and 4) taken from an exposure on the northeast face of Hawks Tor China Clay pit of ECLP (grid ref. SX152747) at an altitude of 229 m O.D. A section of the face is presented in figure 16. Monolith no. 2 was taken in 1970, the others in 1971. See figures 8–12.

(ii) *Monolith* 2: *stratigraphy*

Field observation of 'hummock and pool' features in the uppermost peat of monolith 2 was made but not recorded.

cm from surface	
0–22	as 22–40 cm but not collected
22–40	very coarse, golden, unhumified *Sphagnum*/*Eriophorum* peat with occasional *Sphagnum* capsules and *Rhynchospora alba* fruits
40–59	coarse, golden unhumified *Sphagnum*/*Eriophorum* peat with frequent *Menyanthes* seeds and a fine detritus not present above; *Sphagnum* capsules, *Juncus* seeds and plants of *Drepanocladus fluitans* present
59–67	moderately humified chocolate brown *Sphagnum*/*Eriophorum* peat with occasional *Juncus* seeds and *Sphagnum* capsules
67–89	Highly humified black (? *Eriophorum*) peat with large monocotyledonous fragments; *Juncus* seeds occasional throughout
89–95	chocolate brown, unhumified peat with *Eriophorum vaginatum* tussock bases frequent; occasional *Juncus*, *Erica* cf. *tetralix* and *Calluna* seeds and *Potentilla* cf. *erecta* fruits
95–140	highly humified black peat with monocotyledonous fragments; carbonized fragments throughout; small clayey lenses 124–125 cm containing abundant *Juncus* seeds and birch bark; from 129–140 cm the peat is more sticky than above
140–158	tenacious, dark brown, moderately humified sedge peat; no carbonized material; *Juncus* and *Viola palustris* seeds occasional *Carex* nutlets occasional in lower section

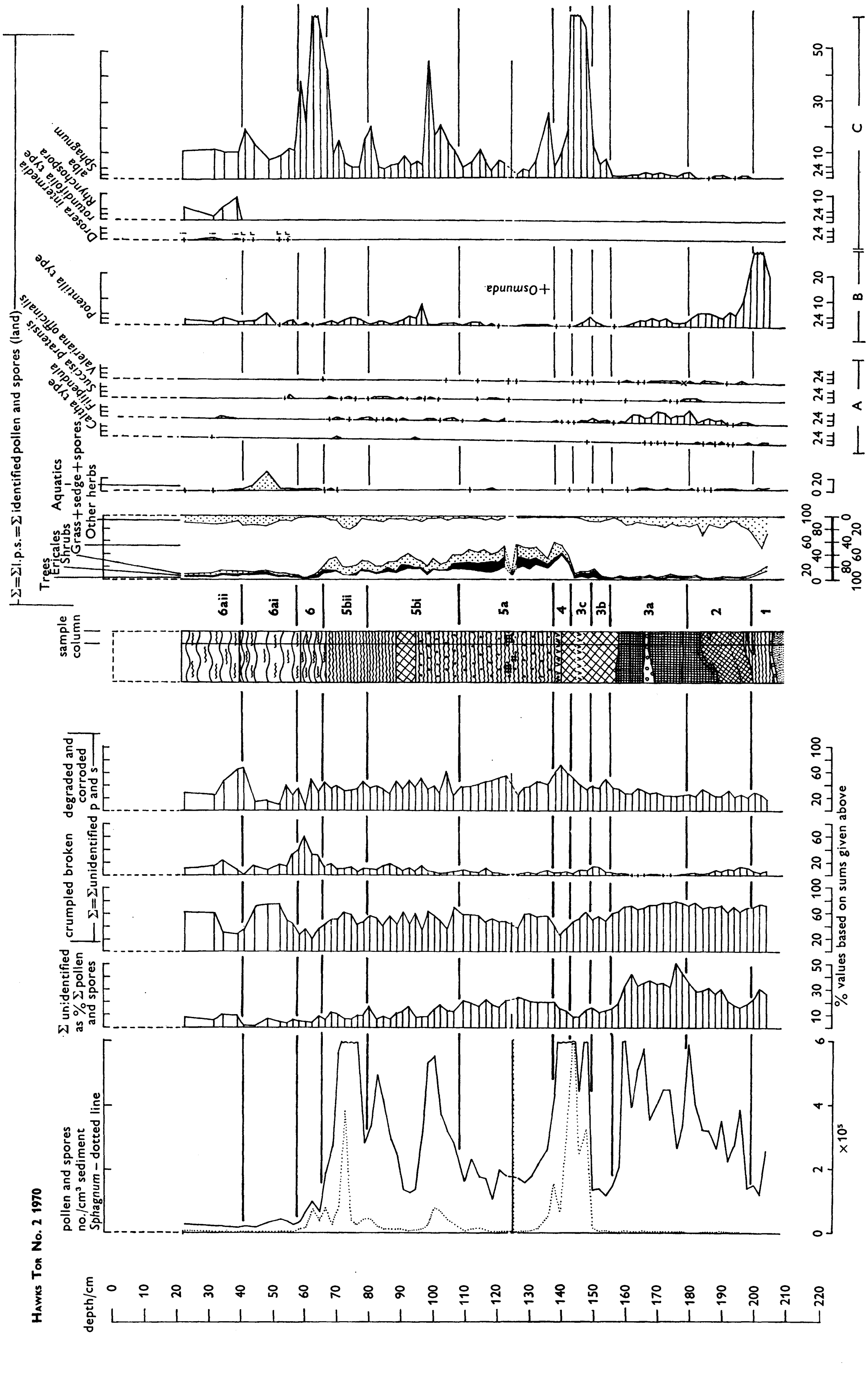
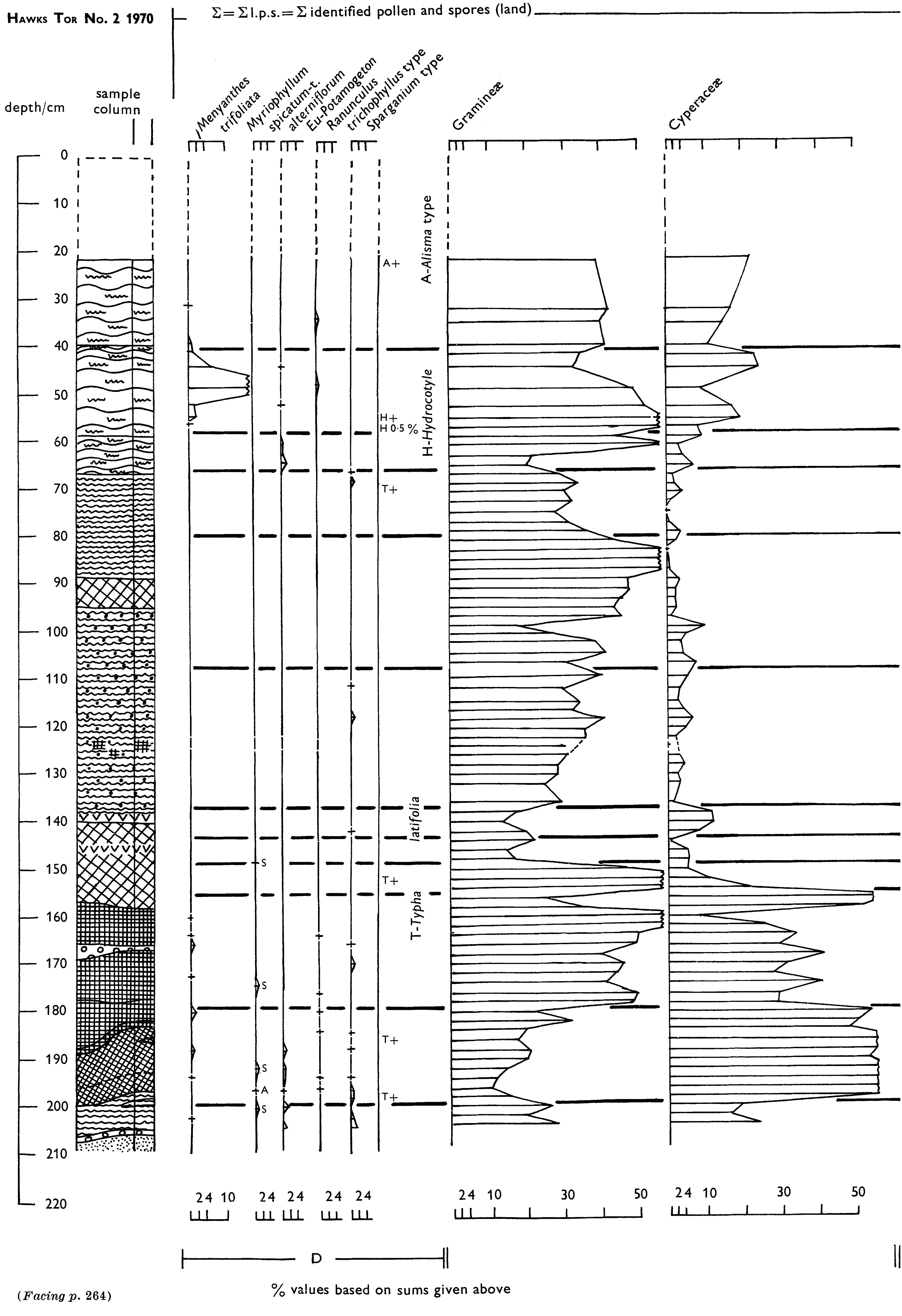


FIGURE 8. Pollen diagram: Hawks Tor monolith no. 2. General information and taxon groups A–C.


HAWKS TOR No. 2 1970
Σ = Σ l.p.s. = Σ identified pollen and spores (land)
depth/cm
sample column
Menyanthes trifoliata
Myriophyllum spicatum-t.
alterniflorum
Eu-Potamogeton
Ranunculus trichophyllus type
Sparganium type
Gramineæ
Cyperaceæ
A-Alisma type
A+
H-Hydrocotyle
H+
H 0·5 %
T-Typha latifolia
T+
S
A
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
2 4 10
2 4
2 4 10 30 50
D
% values based on sums given above

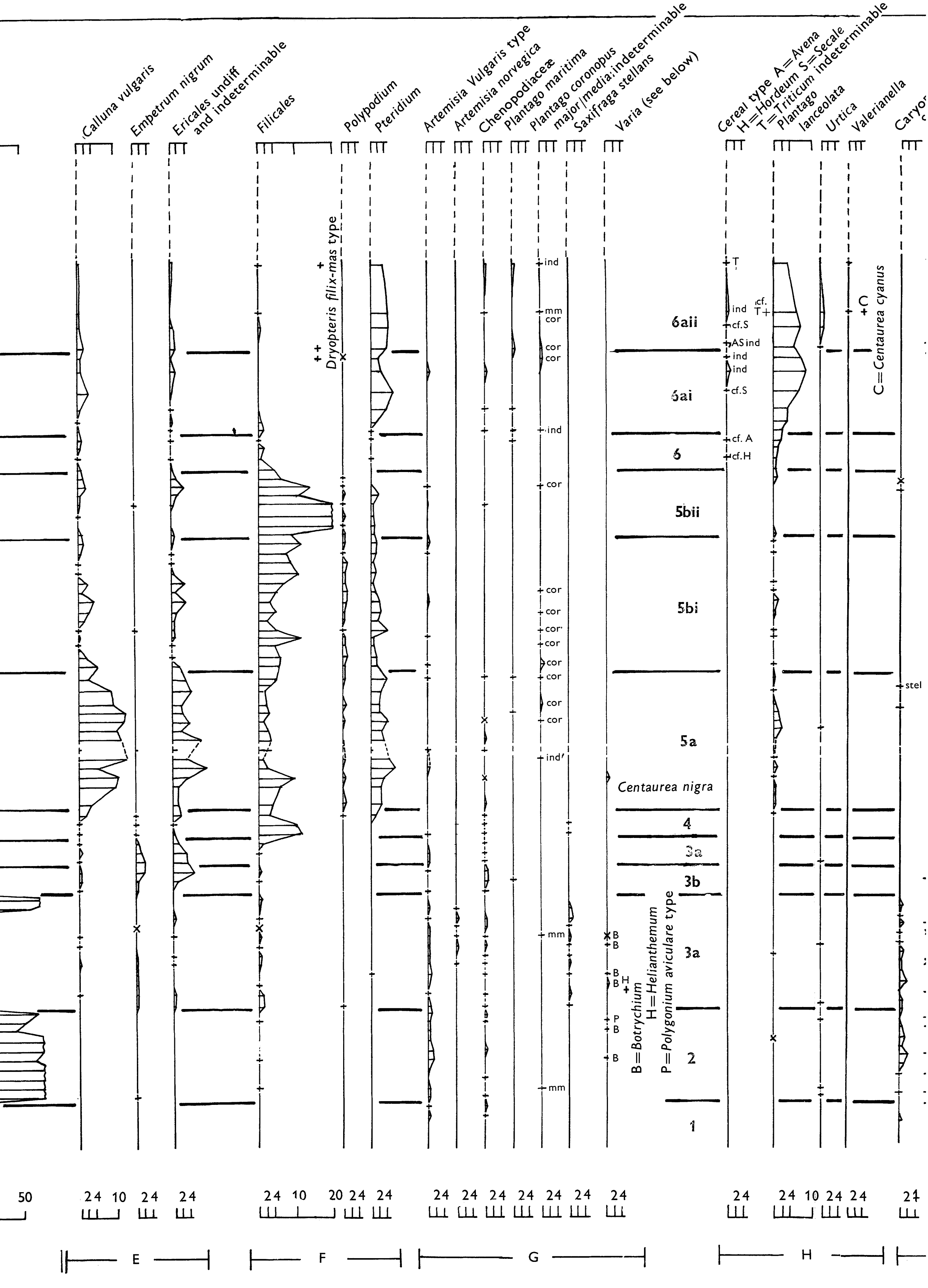
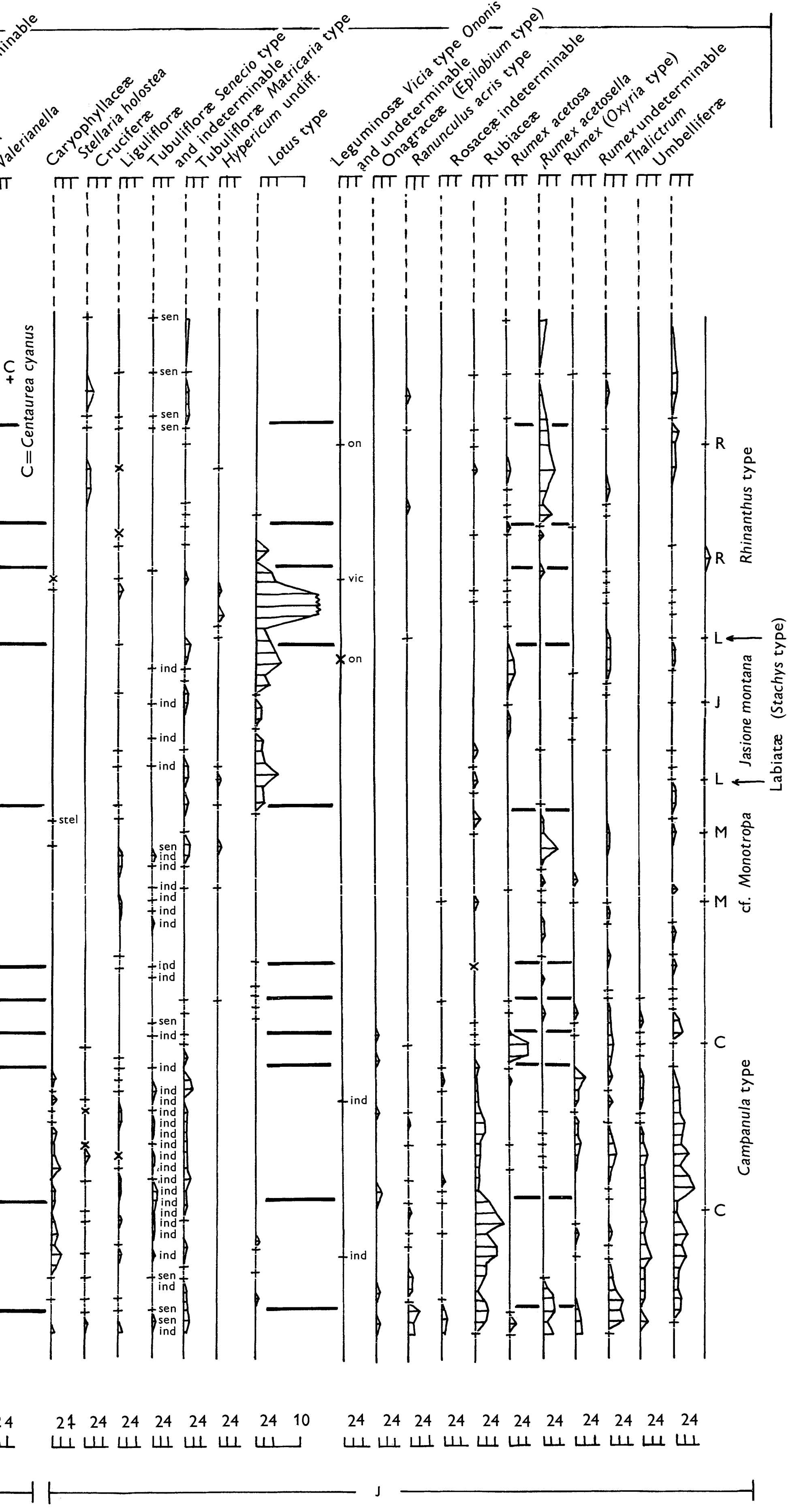
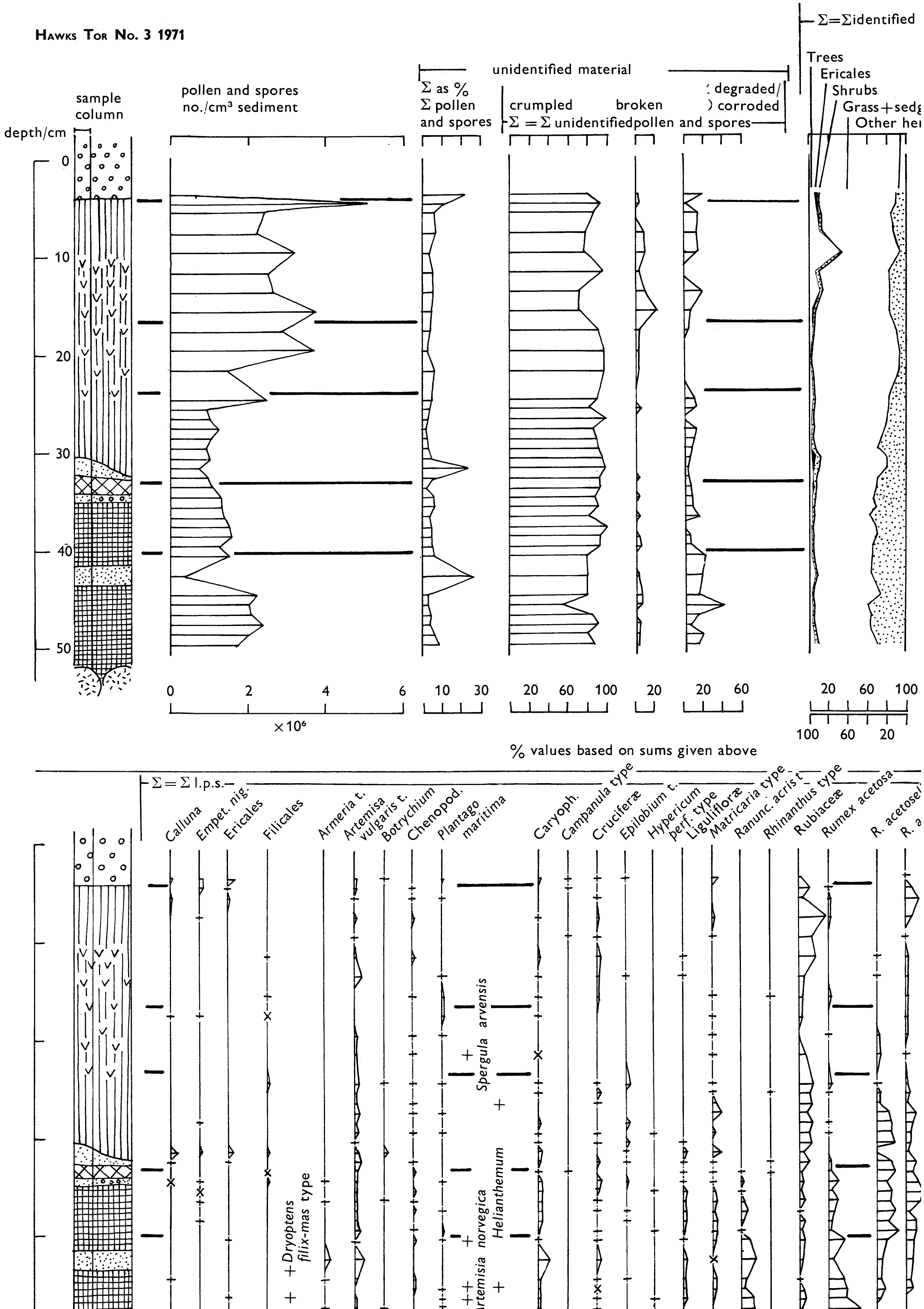
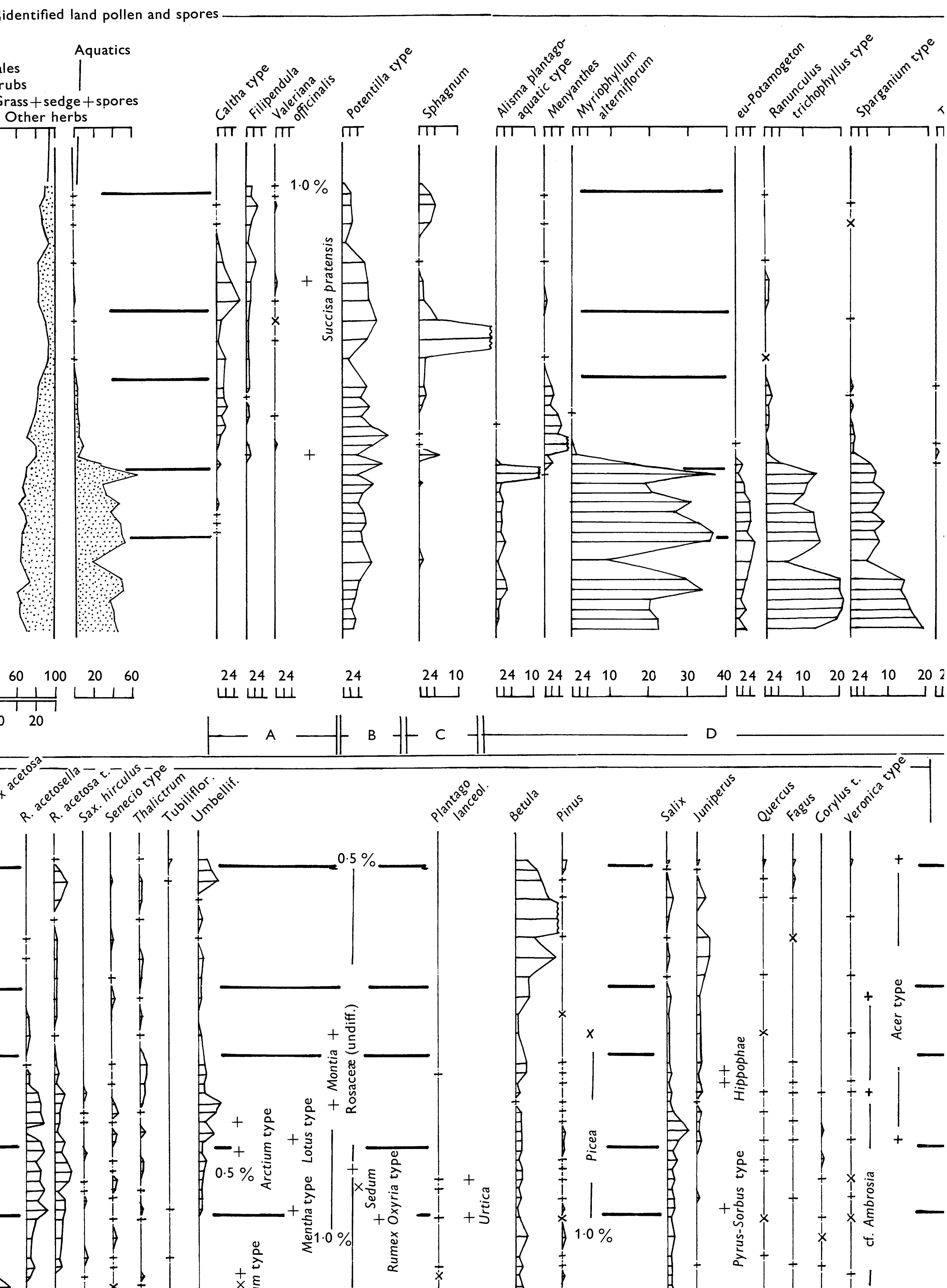


FIGURE 9. Pollen diagram: Hawks Tor monolith no. 2. Taxon groups D–J.

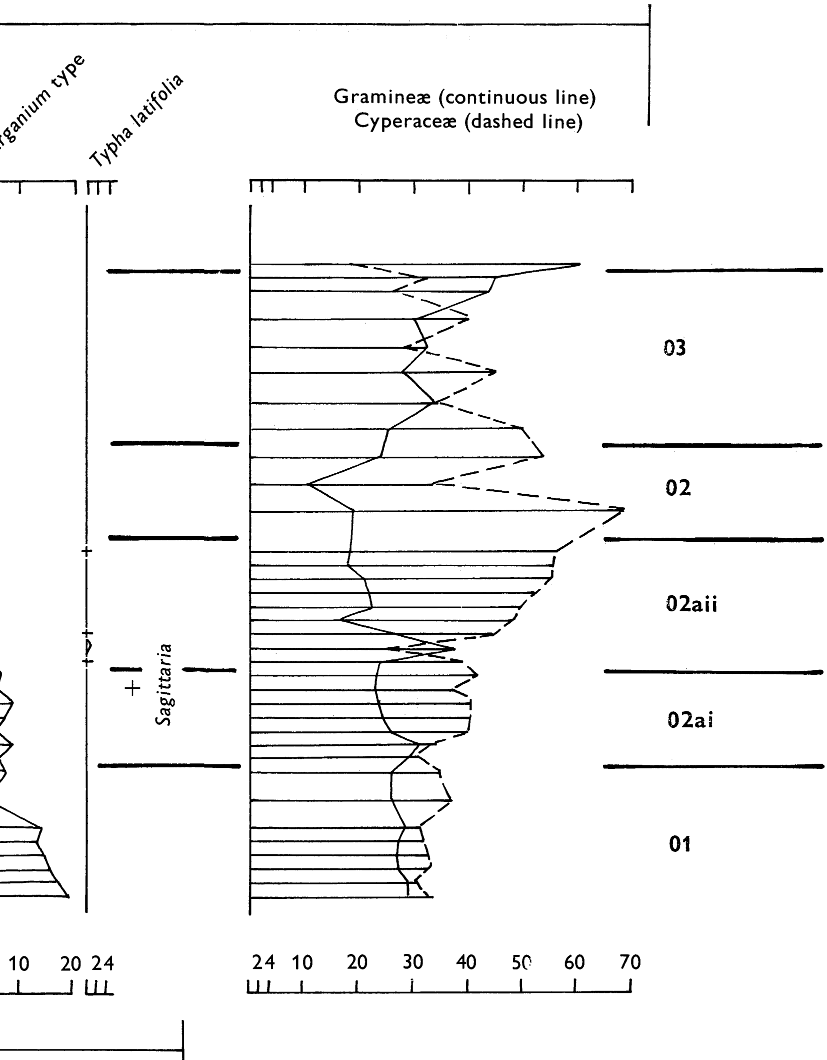

minable
Valerianella
Caryophyllaceæ
Stellaria holostea
Cruciferæ
Liguliflorae
Tubulifloræ Senecio type and indeterminable
Tubulifloræ Matricaria type
Hypericum undiff.
Lotus type
Leguminosæ Vicia type Ononis type and undeterminable
Onagraceæ (Epilobium type)
Ranunculus acris type
Rosaceæ indeterminable
Rubiaceæ
Rumex acetosa
Rumex acetosella
Rumex (Oxyria type)
Rumex undeterminable
Thalictrum
Umbelliferæ
C=Centaurea cyanus
+C
sen
ind
stel
on
vic
R
L
J
M
C
Rhinanthus type
Jasione montana
Labiatæ (Stachys type)
cf. Monotropa
Campanula type
24
10
J

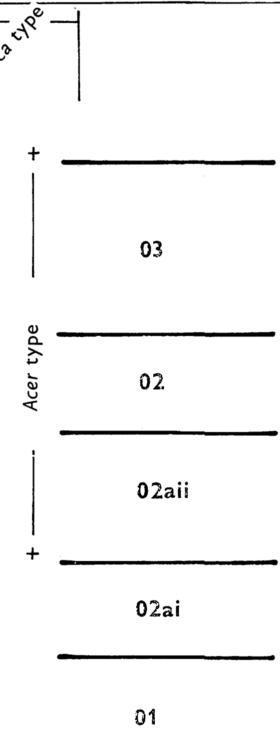
Hawks Tor No. 3 1971

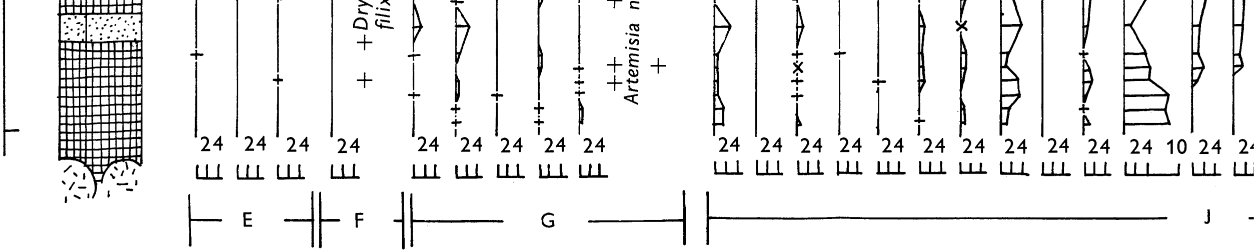




identified land pollen and spores
Aquatics
ales
rubs
Grass + sedge + spores
Other herbs
Caltha type
Filipendula
Valeriana officinalis
Potentilla type
Sphagnum
Alisma plantago-aquatica type
Menyanthes
Myriophyllum alterniflorum
eu-Potamogeton
Ranunculus trichophyllus type
Sparganium type
1·0 %
Succisa pratensis
60
100
20
60
24
10
20
30
40
0
A
B
C
D
x acetosa
R. acetosella
R. acetosa t.
Sax. hirculus
Senecio type
Thalictrum
Tubiliflor.
Umbellif.
Plantago lanceol.
Betula
Pinus
Salix
Juniperus
Quercus
Fagus
Corylus t.
Veronica type
0·5 %
Montia
Rosaceæ (undiff.)
Arctium type
Lotus type
Mentha type
Sedum
Rumex Oxyria type
Urtica
Picea
Hippophae
Pyrus-Sorbus type
cf. Ambrosia
Acer type
m type


rganium type
Typha latifolia
Gramineæ (continuous line)
Cyperaceæ (dashed line)
Sagittaria
03
02
02aii
02ai
01
10
20
24
24
10
20
30
40
50
60
70


a type
Acer type
03
02
02aii
02ai
01


Dry filix
Artemisia n
24
24
24
24
24
24
24
24
24
24
24
24
24
24
24
24
24
24
24
24
10
24
E
F
G
J

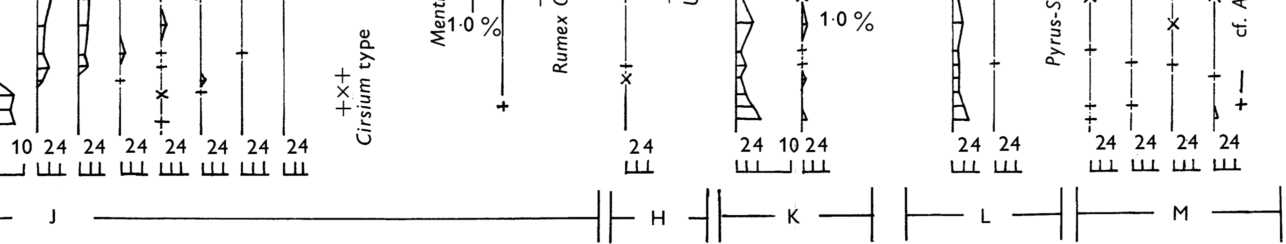


FIGURE 11. Pollen diagram: Hawks Tor monolith no. 3.

01

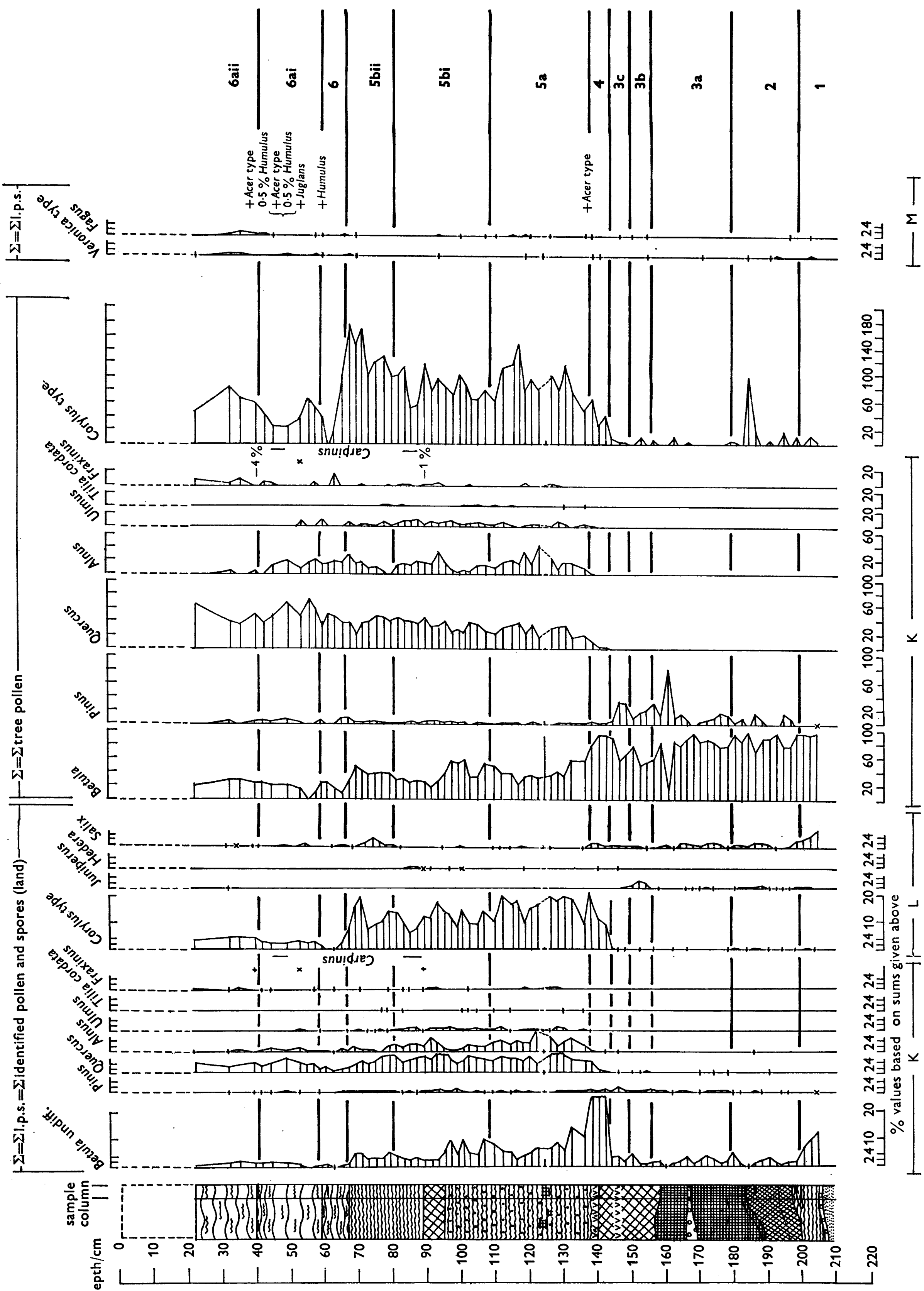


FIGURE 10. Pollen diagram: Hawks Tor monolith no. 2. Taxon groups K–M.

158–166	tenacious light buff silt with occasional *Juncus* seeds
166–167	gravel lens
167–178	tenacious light buff silt with *Juncus* seeds throughout darker organic band at 174 cm
178–184	sticky dark buff silt with light band 183–184 cm
184–197	dark brown, moderately humified sedge peat, sticky, with dark blotching; fragments coarser 193–197 cm; *Carex* nutlets throughout
197–205	moderately humified fen peat with wood, blackish-brown, with coarse bands; *Potentilla palustris* fruits and *Betula* wood throughout
205–206	gravel
206–	kaolin

(iii) *Pollen assemblage zones* (figures 8–10), *starting at the base*

HT1 HT no. 2 1970 198–205 cm Cyperaceae–*Potentilla*-type assemblage zone. n.a.p./a.p. high (*ca.* 9). *Betula* the only tree taxon present. *Potentilla*-type values > 25 %. Gramineae and Cyperaceae dominant. *Rumex* taxa, Rubiaceae and *Ranunculus acris*-type important amongst herbaceous flora. Lower contact unknown. (No *Betula nana* pollen present.)

HT2 HT no. 2 1970 178–198 cm Cyperaceae–Rubiaceae assemblage zone. n.a.p./a.p. very high (> 19). Cyperaceae values 50 %. Gramineae values similar to p.a.z. HT1. *Potentilla*-type important but Rubiaceae show values higher than in p.a.z. HT1 and 3a. *Rumex* taxa, *Thalictrum*, and Umbelliferae important amongst herbs. Lower contact with p.a.z. HT1, defined by the increase of Cyperaceae.

HT3 HT no. 2 1970 142–178 cm Gramineae–Cyperaceae assemblage zone. n.a.p./a.p. very high (> 19). Gramineae and Cyperaceae dominant, their values increasing and decreasing respectively. *Sphagnum* appears at low values. Lower contact with p.a.z. HT2, defined by the increase in Gramineae values.

Three subzones recognized

Subzone HT3a 154–178 cm *Saxifraga stellaris* subzone. *S. stellaris* is exclusive to this subzone. *Sphagnum* values low. *Filipendula* values higher than in any other p.a.z. *Artemisia norvegica* exclusive.

Subzone HT3b 148–154 cm *Rumex acetosa* subzone. Defined by peak in *Rumex acetosa* and *Juniperus* values. *Empetrum* and *Sphagnum* increase.

Subzone HT3c 142–148 cm *Empetrum* subzone. *Empetrum* values as high as in subzone HT3b. Herbaceous taxa of little importance. High Gramineae values (> 50 %).

HT4 HT no. 2 1970 136–142 cm *Betula*–*Corylus*-type assemblage zone. n.a.p./a.p. very low (*ca.* 1.5). *Betula* values 20 %, *Quercus* and *Corylus*-type appear. Filicales appear, Gramineae and *Sphagnum* have low values. Lower contact with p.a.z. HT3c, defined by the increase of *Betula* and *Corylus*-type.

HT5 HT no. 2 1970 65–136 cm *Corylus*-type assemblage zone. n.a.p./a.p. slowly increasing with an average value of 9. Gramineae and *Corylus*-type dominant. *Polypodium*, *Pteridium*, *Calluna* appear. *Ulmus*, *Alnus* and *Tilia* appear. *Plantago lanceolata* is present throughout at low levels. Lower contact with p.a.z. HT4, defined by the appearance of *Polypodium* and *Pteridium*.

Two subzones are recognized

Subzone HT5a 108–136 cm *Calluna* subzone. Defined by higher values of *Calluna, Pteridium* and *Plantago lanceolata.*

Subzone HT5b 65–108 cm *Pteridium* subzone. Defined by lower *Calluna* values than in p.a.z. HT5a, a persistance of *Pteridium* and increasing *Filipendula* values.

Two zonules are recognized

Zonule HT5bi 79–108 cm *Lotus*-type appears.

Zonule HT5bii 65–79 cm *Lotus*-type and Filicales both with values > 10 %. Peak of *Salix* values.

HT6 HT no. 2 1970 22–65 cm *Plantago lanceolata* assemblage zone. n.a.p./a.p. about 14; Gramineae dominant, Cyperaceae values increasing; *Betula, Ulmus* and *Corylus*-type values decrease to a greater extent than those of *Quercus* and *Alnus*; *P. lanceolata* and *Rumex acetosella* values are high (5–10 % and 4 % respectively). *Pteridium* values are high, cereal-type present throughout. Lower contact with zonule HT5bii, defined by the appearance of *P. lanceolata* and *R. acetosella* in quantity.

One subzone is recognized

Subzone HT6a 22–58 cm Cyperaceae subzone. Defined by *Pteridium* values > 4 %, a continuous *R. acetosella* record and Cyperaceae values of 10–20 %.

Two zonules are recognized

Zonule HT6ai 40–58 cm *Menyanthes trifoliata* values very high with *Drosera rotundifolia*-type throughout.

Zonule HT6aii 22–40 cm *Rhynchospora alba* and *Drosera intermedia* present throughout. *Menyanthes* absent.

(iv) *Monolith* 3: *stratigraphy*

cm from monolith top

0–4 fine, angular quartz gravel with infrequent, minute rootlet fragments

4–23 moderately humified dark brown sedge peat with fresh *Betula* twigs; dry, compact and not sticky; trigonous *Carex* nutlets abundant, *Potentilla palustris* fruits rare

23–30½ moderately humified lighter brown sedge peat without wood; wetter than above, compact, not sticky; trigonous and biconvex *Carex* nutlets frequent above 29 cm; *Menyanthes trifoliata* seeds 28–30½ cm

30½–32½ grey kaolin band, of variable thickness, with moss fragments

32½–35 moderately coarse detritus mud strongly banded with kaolin and gravel; *Callitriche intermedia* seeds frequent; *Ranunculus* subgen. *Batrachium* achenes, biconvex *Carex* nutlets, *Alisma plantago-aquatica* seeds, *Potentilla palustris* fruits, *Potamogeton alpinus* fruits, *Hippuris vulgaris* seeds and *Cristatella mucedo* statoblasts all occasional

35–41½ blotchy, organic, light buff silt with slight grey banding; roots from the sediments immediately above penetrate from 35–52 cm; *Callitriche intermedia* seeds abundant, *Eloecharis* sp. nutlets frequent, *Ranunculus* subgen. *Batrachium* achenes, *Myriophyllum* *alterniflorum* fruits biconvex *Carex* nutlets, *Potamogeton natans* fruits, *Alisma plantago-aquatica* seeds, *Potentilla palustris* fruits, *Chara* and *Nitella*-type oospores and *Cristatella mucedo* statoblasts all occasional

41½–43½ grey kaolin band

43½–52 blotched organic silt, light buff in colour, no grey banding; *Callitriche intermedia* seeds abundant, *Ranunculus* subgen. *Batrachium* achenes frequent, *Sparganium angustifolium* nutlets, *Subularia aquatica* seeds, biconvex *Carex* nutlets, *Myriophyllum alterniflorum* fruits, *Potamogeton* cf. *trichoides* fruits, *Alisma plantago-aquatica* seeds and *Nitella*-type oospores all frequent

52– granitic boulders

(v) *Pollen assemblage zones* (figure 11), *starting at base*

HT01 HT no. 3 1971 39–52 cm Cyperaceae–*Ranunculus acris*-type assemblage zone. n.a.p./a.p. extremely high (> 40). *Betula* and *Pinus* present at extremely low levels. Gramineae and Cyperaceae values about 30 %. A very wide range of herbaceous taxa present with *Ranunculus acris*-type at its highest frequency. *Rumex acetosa* and *R. acetosella* important, *Artemisia norvegica* exclusive to this p.a.z. Aquatics frequent. Lower contact unknown.

HT02 HT no. 3 1971 16.5–39 cm Umbelliferae–*Juniperus* assemblage zone; n.a.p./a.p. extremely high (> 40); *Betula* and *Pinus* present at extremely low levels; *Juniperus* percentages 1–2, Umbelliferae 1–5. A very wide range of herbaceous taxa present with *Rumex acetosella* and Umbelliferae of chief importance; Gramineae values begin to drop and those of Cyperaceae to rise. Lower contact with p.a.z. HT01, defined by the appearance of Umbelliferae; *Juniperus* begins its continuous curve a little above the base of the zone.

One subzone is recognized

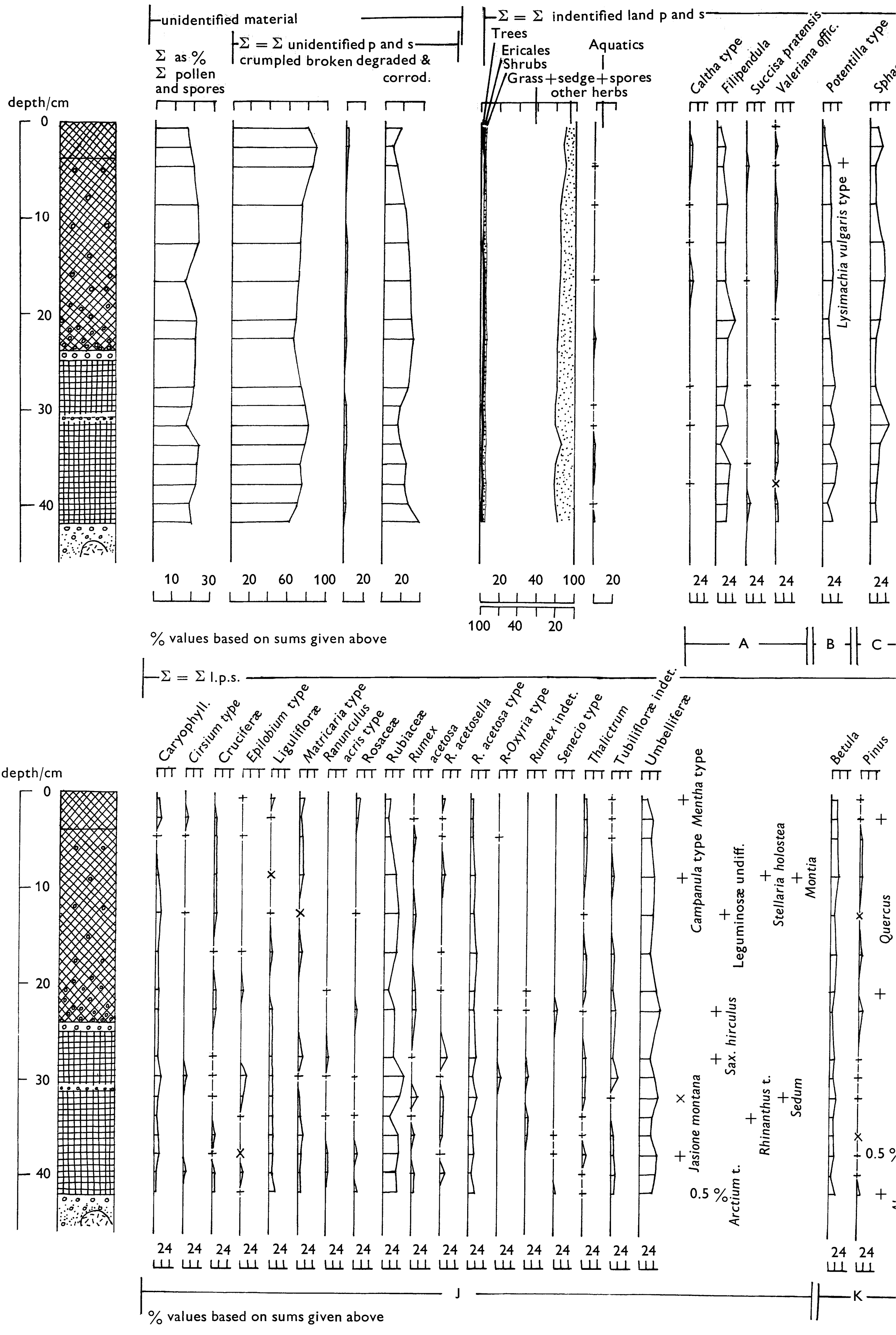
Subzone HT02a 24–39 cm *Epilobium*-type subzone. Defined by the presence of *Epilobium* type, virtually absent elsewhere. This subzone is the only section of p.a.z. HT02 to have abundant aquatic pollen.

Two zonules are recognized

Zonule HT02ai 33–39 cm *Myriophyllum alterniflorum* dominant.

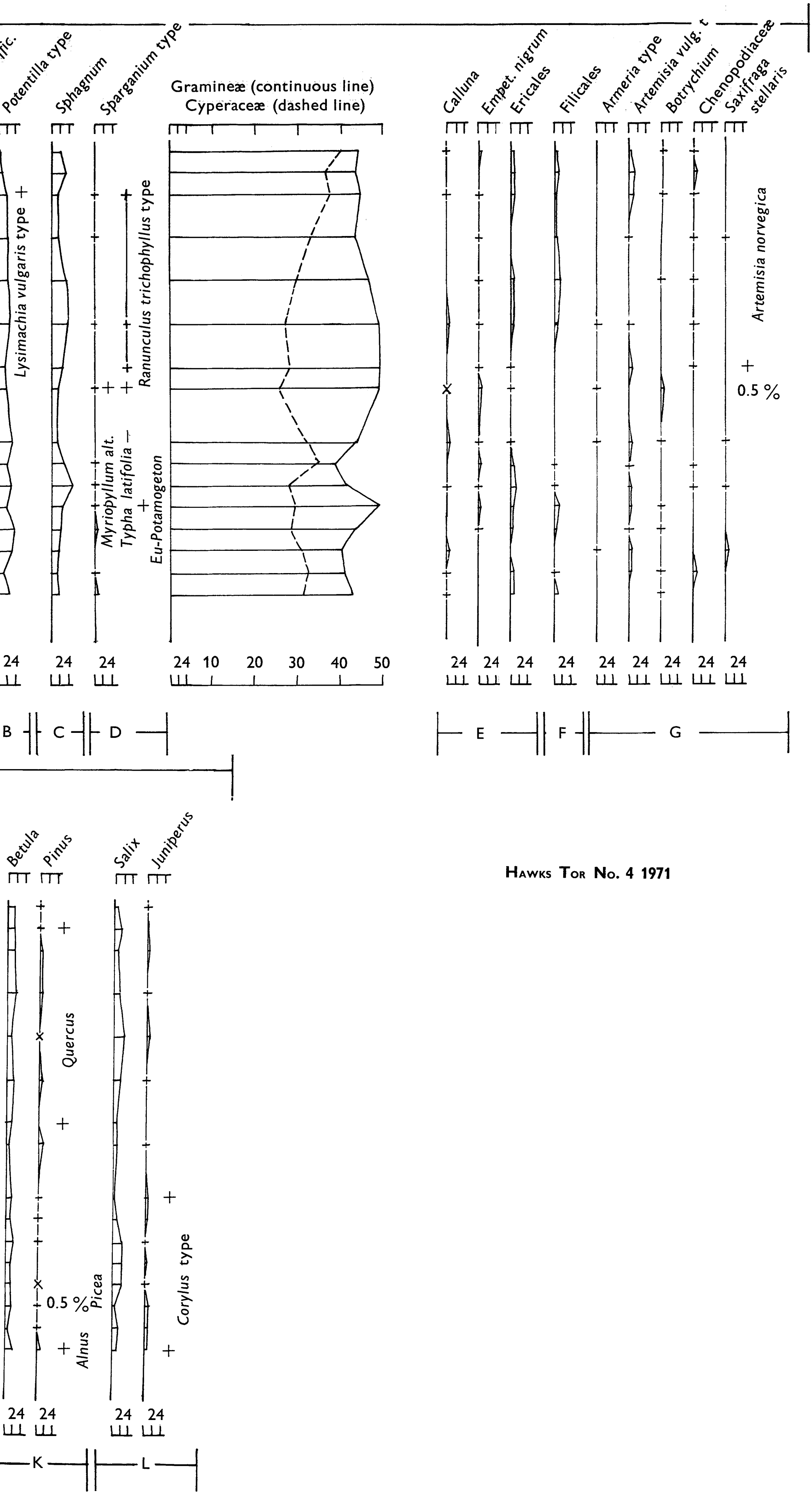
Zonule HT02aii 24–33 cm *Myriophyllum alterniflorum* absent, *Menyanthes trifoliata* reaches its highest values. *Typha latifolia* is exclusive to this zonule.

HT03 HT no. 3 1971 4–16.5 cm *Betula*–Rubiaceae–*Juniperus* assemblage zone. n.a.p./a.p. about 13. *Betula* (95 % tree type) at frequencies of 5–30 % the only tree taxon besides *Pinus*. *Juniperus* and Rubiaceae reach their highest values. Gramineae and Cyperaceae values are equal, between 30–40 %. The herbaceous flora is much reduced in comparison with p.a.z. HT01 and 02 but is still varied and besides Rubiaceae, *Rumex acetosa*-type, Cruciferae, *Thalictrum*, Umbelliferae and *Artemisia vulgaris*-type are important. Obligate aquatic taxa are absent but fen and mire taxa are important. Lower contact with p.a.z. HT02, defined by the increase of *Betula* and *Juniperus*.

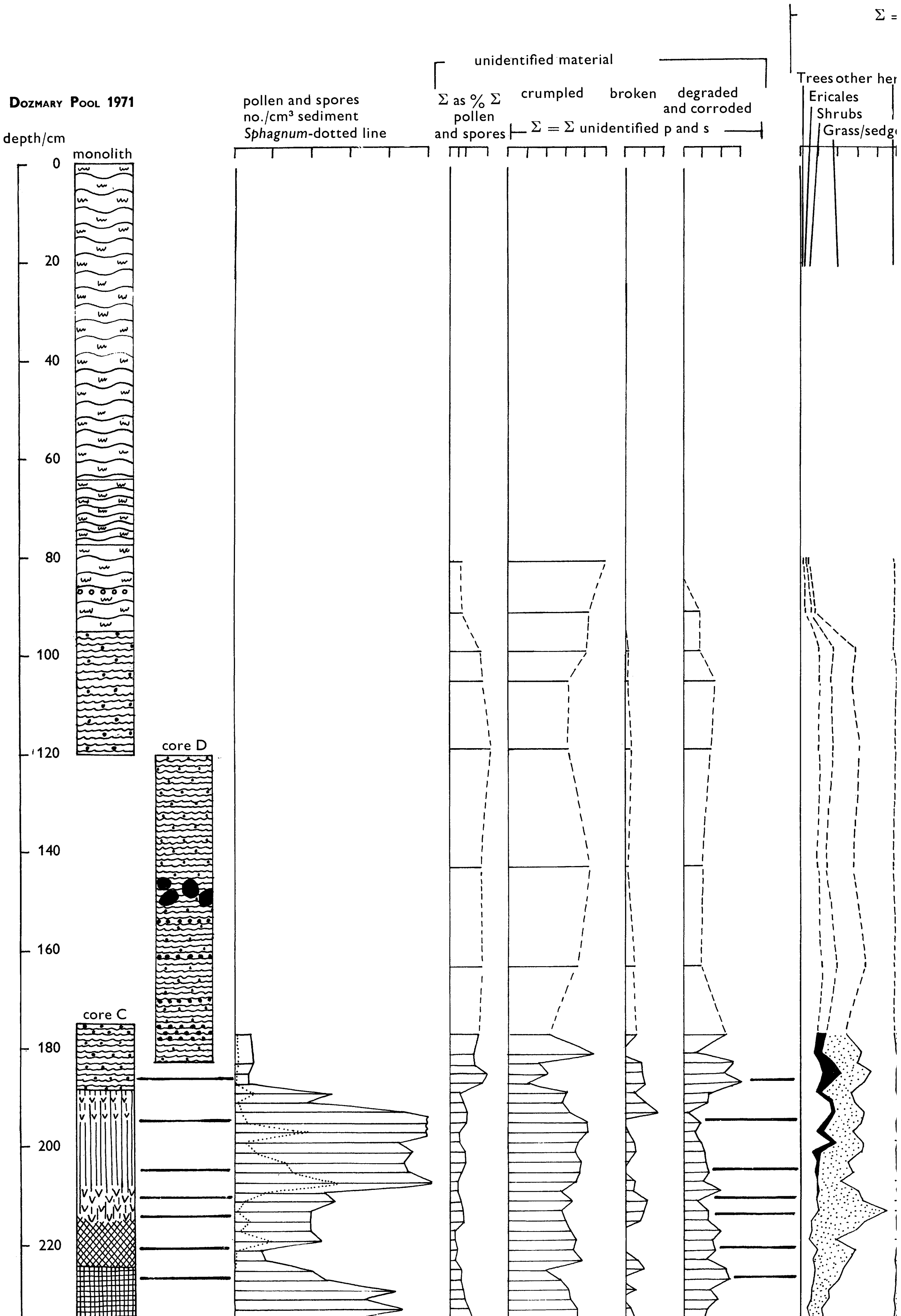


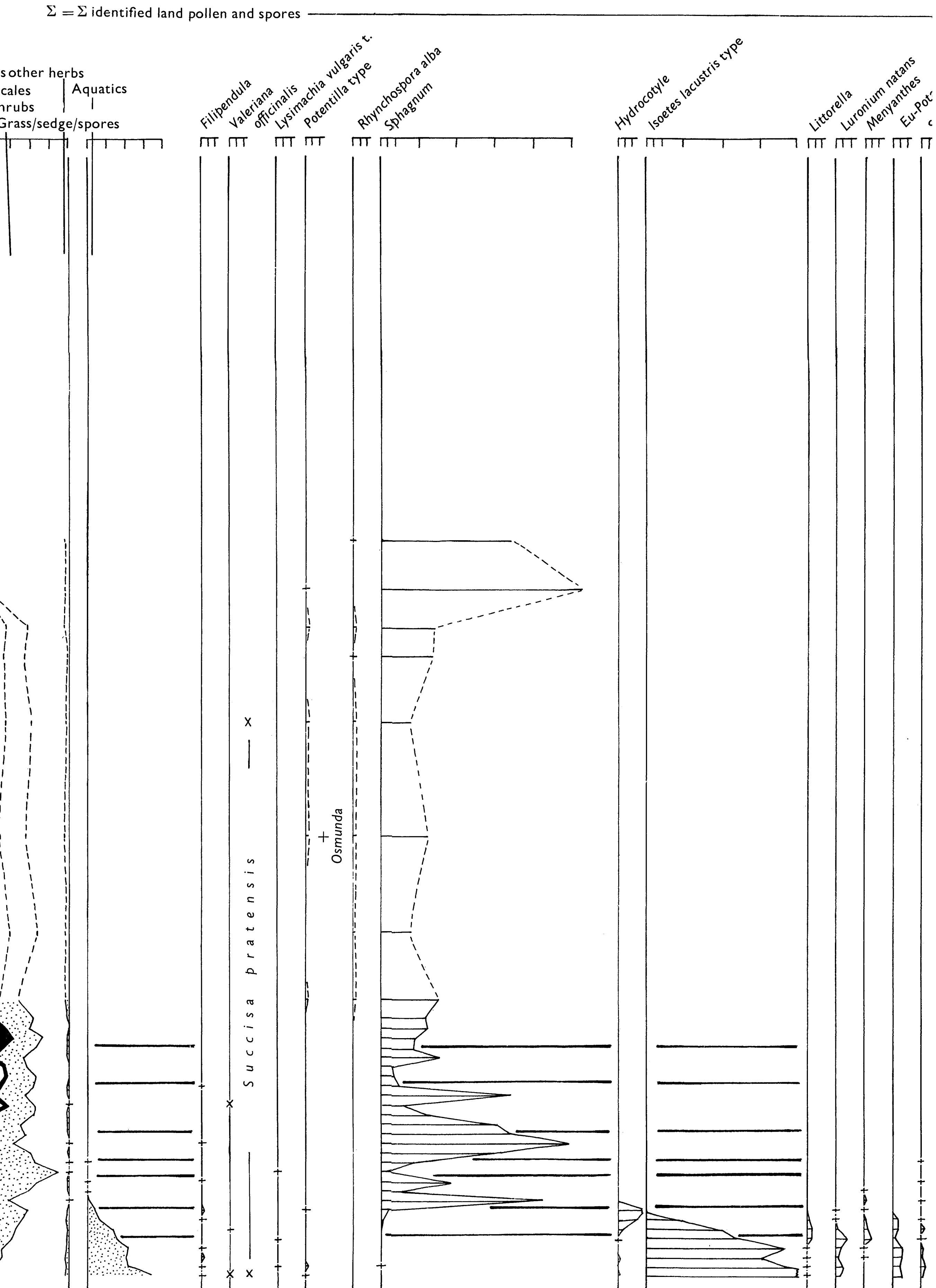
(Facing p. 268)

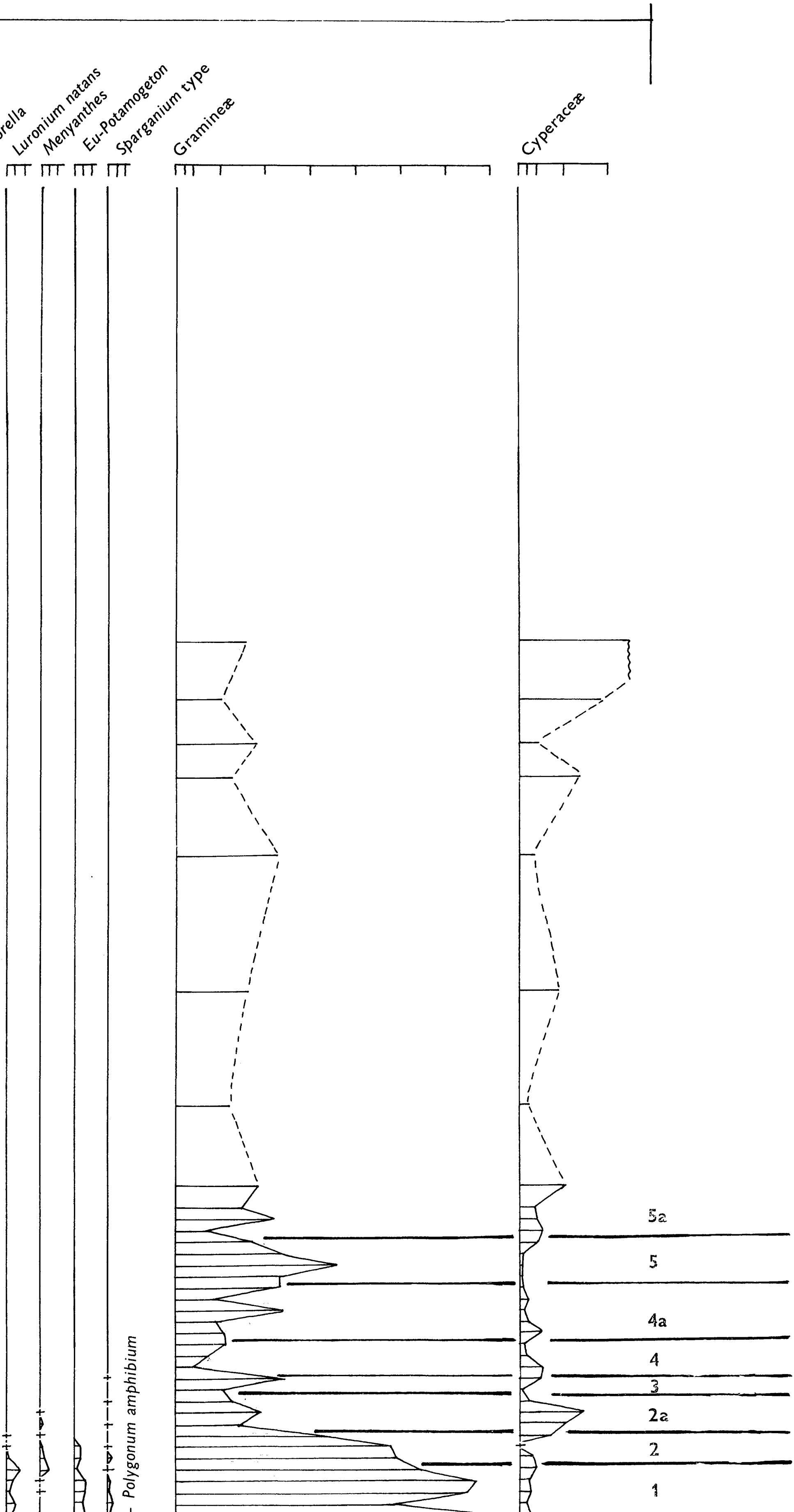
FIGURE 12. Pollen diagram: Hawks Tor mon

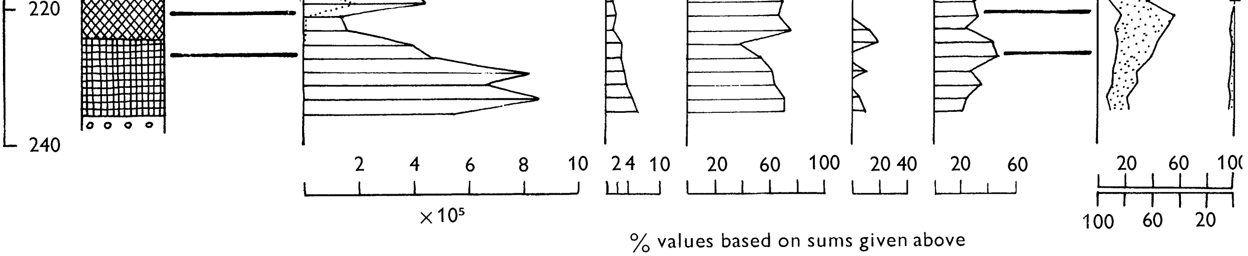


s Tor monolith no. 4.


DOZMARY POOL 1971
depth/cm
monolith
core D
core C
0
20
40
60
80
100
120
140
160
180
200
220
pollen and spores
no./cm³ sediment
Sphagnum-dotted line
unidentified material
Σ as % Σ
pollen
and spores
crumpled
broken
degraded
and corroded
Σ = Σ unidentified p and s
Σ =
Trees
other her
Ericales
Shrubs
Grass/sedg


Σ = Σ identified land pollen and spores
s other herbs
cales
hrubs
Grass/sedge/spores
Aquatics
Filipendula
Valeriana officinalis
Lysimachia vulgaris t.
Potentilla type
Rhynchospora alba
Sphagnum
Hydrocotyle
Isoetes lacustris type
Littorella
Luronium natans
Menyanthes
Eu-Pot
Succisa pratensis
Osmunda


rella
Luronium natans
Menyanthes
Eu-Potamogeton
Sparganium type
Gramineæ
Cyperaceæ
Polygonum amphibium
5a
5
4a
4
3
2a
2
1


220
240
2
4
6
8
10
× 10⁵
2 4 10
20 60 100
20 40
20 60
20 60 100
100 60 20
% values based on sums given above

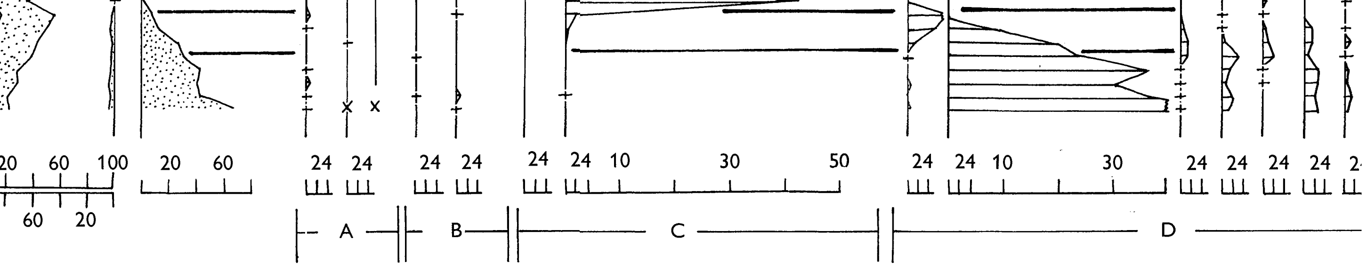
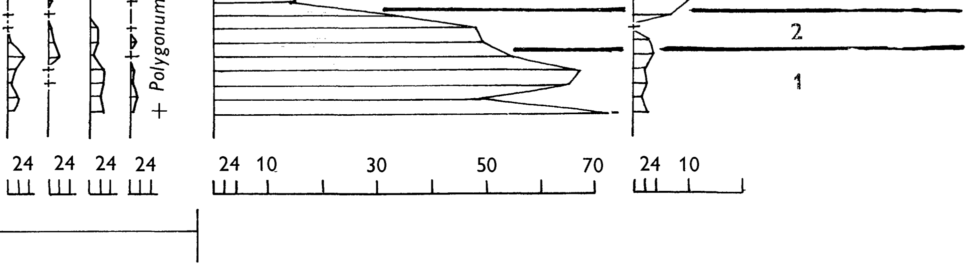


FIGURE 13. Pollen diagram: Dozmary Pool. General information and taxon groups A–D.


+ Polygonum
2
1
24
24
24
24
24
10
30
50
70
24
10

Dozmary Pool 1971

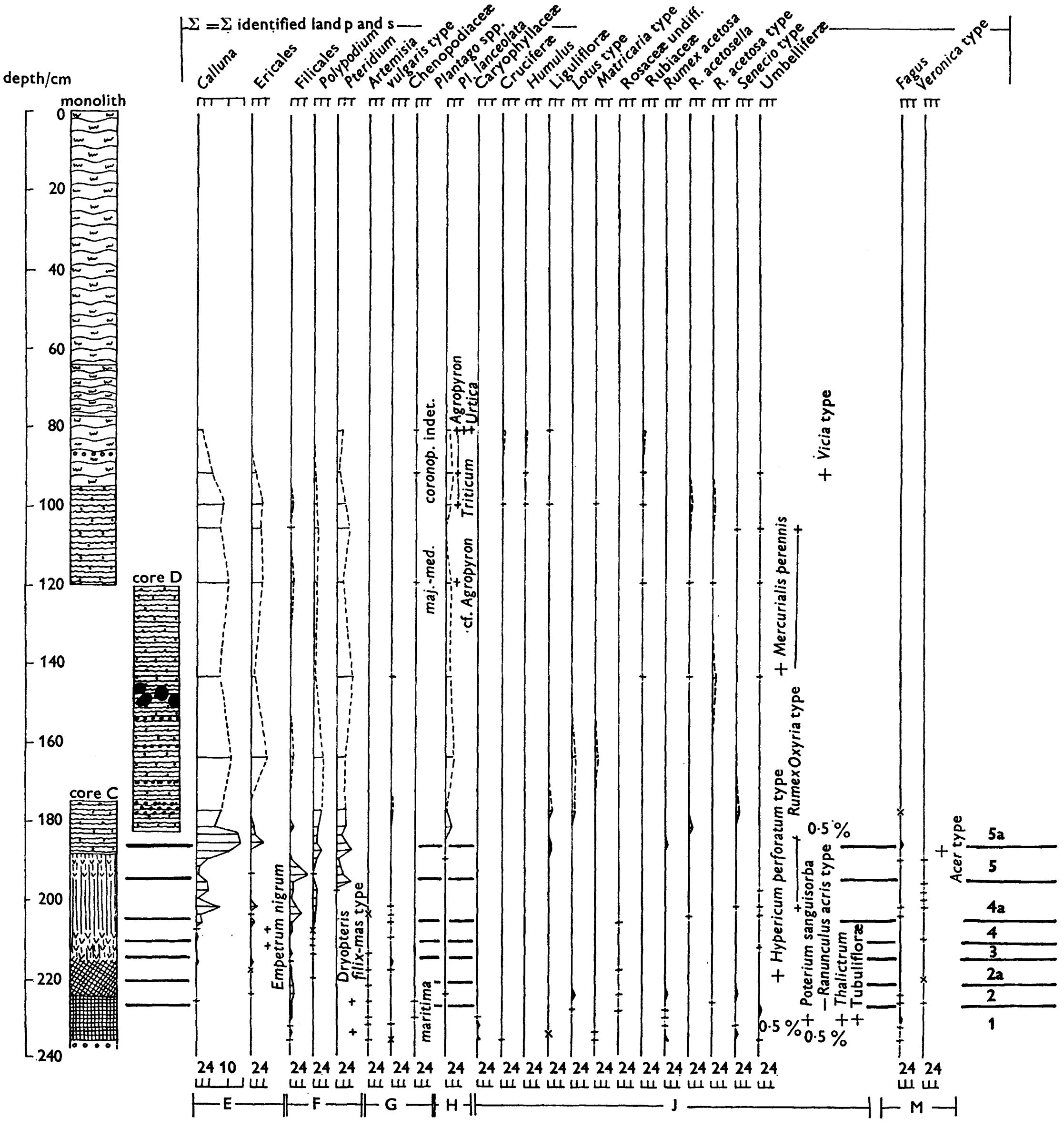


FIGURE 14. Pollen diagram: Dozmary Pool. Taxon groups E–J and M.

Sample no. 35 from the uppermost gravel of this monolith (3–4 cm) has n.a.p./a.p. higher (19), lower *Betula* values, low Cyperaceae values (20 %) and much higher (60 %) Gramineae values, good representation of Ericales, *Empetrum* and *Calluna*. Fen and mire taxa are virtually absent.

(vi) *Monolith* 4: *stratigraphy*

cm from monolith top	
0–4	silty detritus mud with little gravel, *Carex* nutlets and *Juncus* seeds abundant
4–24	silty detritus mud becoming gradually more silty and gravelly towards the bottom; of lighter colour but exactly the same texture as the sediment above; *Carex* nutlets and *Juncus* seeds frequent; *Hippuris vulgaris* fruits present
24–25	fine angular gravel
25–42	light buff banded silt with some gravel, grading into fine gravel at 42 cm and into gravelly kaolin below that; gravel band at 31 cm, distinct dark organic band at 38.5 cm (0.5 cm thick); *Carex* nutlets and *Hippuris vulgaris* fruits present; rootlets from the peats above 0 cm penetrate into these sediments

(vii) *Pollen assemblage zone* (figure 12)

HT001 HT no. 4 1971 0–42 Gramineae–Cyperaceae–Umbelliferae assemblage zone. n.a.p./a.p. > 50 throughout. Values of Gramineae are 40–50 %, Cyperaceae 30–40 % throughout. The terrestrial herbaceous flora is varied, Rubiaceae and Umbelliferae the most important taxa with values of 2–4 %. Caryophyllaceae and *Rumex acetosa*-type are the only other land taxa with continuous curves. Amongst fen and aquatic species *Filipendula*, *Potentilla*-type and *Sphagnum* all have values of 2–4 % throughout and are the most important taxa. *Sparganium*-type, *Valeriana officinalis*, and *Caltha*-type are present consistently. *Betula* values are never greater than 2 %. *Salix* and *Juniperus* present throughout at low values.

(*d*) *Dozmary Pool*

(i) *Description of site*

At the southwest end of Dozmary Pool (altitude 265 m O.D., grid ref. SX192744) is a mire at present covered with a typical raised bog community including *Eriophorum vaginatum*, *Rhynchospora alba*, *Calluna vulgaris*, *Erica tetralix*, *Narthecium ossifragrum*, *Molinia caerulea* and *Juncus effusus*. It is bounded on the north and west sides by a lagg and on the south by the drainage stream from the lake. On the east is the lake which is 5.5 m deep at most (Davey 1909). A transect across the bog from northwest to southeast shows that in fact the dome of the bog is very slight (about 70 cm above the general level) and is at the northwestern end. It is covered with *Molinia caerulea*, presumably because it is a little better drained than the rest of the bog.

Pollen analytical results (figures 13–15) are available from a 1.2 m monolith, a 7.6 cm (3 in) Livingstone core (core D) taken from the base of the monolith downwards and a 5.0 cm (2 in) Livingstone core (core C) from the base of the deposits. This series forms a continuous sequence through the raised bog at its northern end (see figure 7). Core A (used for radiocarbon assay samples) is a duplicate of core C displaced laterally by 0.6 m.

(ii) *Stratigraphy* (*composite of monolith and cores C and D*)

cm from surface	
0–64	coarse, unhumified *Sphagnum/Eriophorum vaginatum* peat
64–77	slightly humified *Sphagnum/E. vaginatum* peat
77–93	coarse, unhumified *Sphagnum/E. vaginatum* peat with angular quartz gravel (< 1 cm diameter) 80–85 cm
93–188	blackish, well humified *Sphagnum/E. vaginatum/Calluna* (raised bog) peat with carbonized material throughout and charcoal fragments in distinct bands at 146, 154, 170 and 175–180 cm; large chunks of burnt peat 145–150 cm. *Calluna* flowers, leaves and twigs frequent throughout
188–207	highly humified monocotyledonous peat with fresh wood fragments at 190, 193 and 197 cm; thin black band at 198 cm; frequent minute carbonized fragments throughout, fungal perithecia frequent in the upper half
207–215	highly humified sedge peat with abundant fresh *Salix* wood; *Carex* nutlets are frequent at the top and *Juncus* seeds at the base
215–224	medium and fine detritus mud with a fibrous layer at 220 cm and dark band at 223 cm; *Juncus* seeds frequent throughout. *Carex* nutlets, *Littorella uniflora* and *Hydrocotyle vulgaris* fruits, *Menyanthes trifoliata* seeds occasional towards the base
224–235	fine, very silty detritus mud; megaspores of *Isoëtes lacustris* and *I. echinospora* abundant oospores of *Nitella*-type, *Elatine hexandra*, *Luronium natans*, and *Juncus* seeds occasional, *Potamogeton natans* fruits rare, *Sphagnum* leaves present
235–	kaolin

(iii) *Pollen assemblage zones* (figures 13–15), *starting at the base*

DP1 DP core C 1971 227–235 cm Gramineae assemblage zone. n.a.p./a.p. about 9. Gramineae dominant with only low values of Cyperaceae, *Betula* and *Quercus*. *Corylus*-type values rising. Filicales, Caryophyllaceae, *Senecio*-type, *Matricaria*-type and *Rumex acetosa* present. *Isoëtes lacustris*-type microspores abundant, *Sparganium*-type and *Luronium natans* most frequent in this p.a.z. Other aquatics occasional. Lower contact unknown.

DP2 DP core C 1971 214–227 cm *Corylus*-type–Gramineae assemblage zone. n.a.p./a.p. decreasing. *Corylus*-type values rise rapidly, *Betula* and *Quercus* rise slowly. Gramineae initially dominant with high frequencies of *Isoëtes lacustris*-type microspores. *Hydrocotyle*, *Littorella* and *Menyanthes* reach their highest values. Lower contact with p.a.z. DP1, defined by *Corylus*-type rise.

One subzone is recognized

Subzone DP2a 214–221 cm Cyperaceae subzone. Defined by the continuous presence of *Ulmus* at low values. Gramineae values are much lower than in the main p.a.z. and are similar to Cyperaceae values. Herbaceous flora spectrum is reduced, aquatic taxa virtually absent. *Sphagnum* present in quantity.

DP3 DP core C 1971 210–214 cm Salix assemblage zone. n.a.p./a.p. about 4. *Betula* values greater than 10 %. *Salix* values are > 40 % with consequent lowered *Corylus*-type values. Lower contact with p.a.z. DP2a, defined by the increase of *Salix* values.

DP4 DP core C 1971 195–210 cm *Corylus*-type assemblage zone. n.a.p./a.p. falls throughout. *Corylus*-type and tree taxa dominant. *Quercus* values > 10 %, *Betula* values < 10 %. Herbaceous flora poor. *Polypodium* and *Calluna* appear and have continuous curves. *Sphagnum* values rise rapidly. Lower contact with p.a.z. DP3, defined by the appearance of *Calluna*.

One subzone is recognized

Subzone DP4a 195–205 cm *Calluna* subzone. *Calluna*, Filicales and *Ulmus* all show increased values. *Corylus*-type values reach their highest.

DP5 DP core C 1971 173–195 cm *Corylus*-type–*Pteridium* assemblage zone. n.a.p./a.p. values similar to those of p.a.z. DP4, rising. *Corylus*-type values slowly fall. *Pteridium* appears, herbaceous flora generally poor. *Betula* values initially > 20 % but later fall. Lower contact with p.a.z. DP4a, defined by the appearance of *Pteridium*.

One subzone is recognized

Subzone DP5a 173–187 cm *Calluna*-*Alnus* subzone. Defined by the appearance of *Alnus*, *Tilia cordata*, and *Fraxinus*. Values of *Calluna* and Cyperaceae show a sharp rise.

Pollen analysis at close intervals was not continued into the 3 inch core (core D) and monolith. By comparison with the analyses from HT no. 2 and PP the upper limit of p.a.z. DP5 is probably at about 95 cm below the surface.

(*e*) *Radiocarbon dating of pollen assemblage zones*

Sixteen samples from these sediments were forwarded to Dr V. R. Switsur of the Radiocarbon Dating Laboratory, Cambridge University, for radiocarbon assay. Samples from the monoliths were 2 cm slices of the complete monolith, samples from the 5.0 cm (2 in) Livingstone cores were 4–5 cm segments. All exposed and contaminated surfaces were cut from the samples before removal to the dating laboratory and an attempt to remove all larger roots deposited sub-contemporaneously with the silty sediments was made by the author.

Dating was restricted to pollen assemblage zones ante-dating the *Alnus* pollen rise since sediments above the level at which this falls were often contaminated by the penetration of living roots from the surface. Since roots that must have penetrated the sediments soon after their deposition have been found in the samples dated, the date estimates (listed in table 2) must be considered as minimum ages for the particular sediments. This is because, wherever possible, although visible rootlets were removed this is unlikely to have been achieved completely. The date numbered Q975 from the lower part of Hawks Tor monolith 3 is inconsistent with the two dates immediately above it and with the pollen assemblage and stratigraphical contexts in which it is placed. It may be that inefficient removal of more recent rootlets which penetrated the sediment is responsible for this young date, but similar reversals (again in limnic sediments) have been observed at Scaleby Moss (Godwin, Walker & Willis 1957) and Red Moss (Hibbert, Switsur & West 1971), both at the base of deposition. As indicated in both those papers the alternative explanations for such a date reversal are numerous.

In view of this reversal the date from the base of monolith 3 (Q979, 13088 ± 300 B.P.) must be treated with special caution. It may be quite reliable or it may be falsely young, although it *is* quite acceptable within the context of the upper three dates from the monolith. These radiocarbon date estimates are used in correlation of pollen assemblage zones in figures 18, 20 and 28 (a correlation of local and regional pollen assemblage zones on Bodmin Moor). Date Q975 is *not* incorporated into these diagrams.

(*f*) *Pollen influx rates on Bodmin Moor*

Although the very compact and frequently changing nature of the deposits does not allow accurate determination of short-lived sediment accumulation rates (since the radiocarbon date series is spaced widely) approximate estimates of sediment accumulation rates have been made.

TABLE 2. RADIOCARBON DATES: BODMIN MOOR SERIES

site	lab. no.	depth and sediment	p.a.z.	age and uncertainty (years B.P.)
DP core A†	Q1025	183–189 cm raised bog peat	DP5/5a	6451 ± 65
DP core C	Q1024	187–191 cm humified monocot peat	DP5	6793 ± 70
DP core C	Q1023	205–209 cm humified sedge peat/ *Salix wood*	DP4	7925 ± 100
DP core C	Q1022	219–223 cm medium fine detritus mud	DP2/2a	8829 ± 100
DP core A†	Q1021	230–235 cm silty detritus mud	DP1 (base)	9053 ± 120
HT no. 2	Q1020	141–143 cm humified sedge peat/ wood	HT3c/4	9061 ± 160
HT no. 2	Q1019	143–145 cm humified sedge peat	HT3c	9295 ± 180
HT no. 2	Q1018	150–152 cm humified sedge peat	HT3b	9544 ± 180
HT no. 2	Q1017	153–155 cm unhumified sedge peat	HT3a/3b	9654 ± 190
HT no. 2	Q1016	179–181 cm dark buff silt	HT2 top	10884 ± 210
HT no. 2	Q1015	199–201 cm birch fen peat	HT1 top	11069 ± 220
HT no. 3	Q977	15–17 cm sedge peat with Betula wood	HT02 top	11553 ± 280
HT no. 3	Q978	28–30 cm sedge peat	HT02ai/aii	12354 ± 300
HT no. 3	Q976	32–34 cm banded coarse detritus mud	HT02ai/aii	12635 ± 300
HT no. 3	Q975	38–40 cm banded organic silt	HT02ai base	11758 ± 300
HT no. 3	Q979	49–51 cm organic silt	HT01 base	13088 ± 300

† Core A was taken at the same time as core C; it is laterally displaced 0.6 m from core C. The uppermost and lowermost radiocarbon date samples were taken from core A (which was stratigraphically identical to core C) because these particular sediments were irretrievably disturbed during pollen sampling.

The values for pollen influx rates derived from the approximated sediment accumulation rates and accurately determined pollen contents are presented in table 3. Pollen influx rates have only been estimated where radiocarbon date sequences fall onto a straight line in the date/depth plots. It is clear that even these very approximate figures for pollen influx are in accord with values derived from closely-dated sediment series both in Britain and the U.S.A.

The low 'early post-glacial' (early Flandrian) values for pollen influx at Blelham Bog and on Bodmin Moor reflect the open vegetation at these sites (§ 6). Higher values for pollen influx in the North American sites and at some levels on Bodmin Moor indicate the proximity of widespread tree cover at the site. In general the 'late-glacial' (Late-Devensian) pollen influx values at all sites are one degree of magnitude smaller than those of the Flandrian.

Later (§ 5) the evidence of climatic amelioration 13000 radiocarbon years ago at Hawks Tor and Blelham Bog is compared. Although the palynological evidence is unequivocally in agreement at both sites it is interesting to note that at Hawks Tor a shallow lake began to dry out at this time whereas limnic deposition at Blelham Bog was continuous. As a result the pollen influx rate at Hawks Tor rapidly falls at the opening of the pre-Allerød (*sensu stricto*) amelioration whereas the tenfold *increase* of pollen influx at this time at Blelham Bog is very distinct and is used by Pennington & Bonny (1970) as evidence for climatic amelioration.

Table 3. Pollen influx rates (grains per cm^2 per year) at selected sites

	site			
age	Bodmin Moor	Blelham Bog, Westmorland (Pennington & Bonny 1970)	Lake of Clouds, Minn. U.S.A. (Craig 1972)	Rogers Lake Conn. U.S.A. (Davis 1969)
Flandrian	3–13 (16–24†)			oak phase 20–30
8000 B.P.			pine phase 20–40	50
9000 B.P.			spruce phase 14	15
10 300 B.P.		1.5		
Late-Devenisan	1.7–6.7	*ca.* 0.1–2.5	1.6–5.0	1.0

† Under birch/willow carr.

5. Late-Devensian history

Sediments deposited before *ca.* 10300 B.P., the Late-Devensian/Flandrian boundary, and those correlated with them, are discussed. A summary of the vegetation recorded in them and a correlation of the pollen assemblage zones is made in figure 18.

(*a*) *Hawks Tor vegetation history*

(i) *Monolith no.* 2

Assemblage zone HT1, Cyperaceae–*Potentilla*-type zone

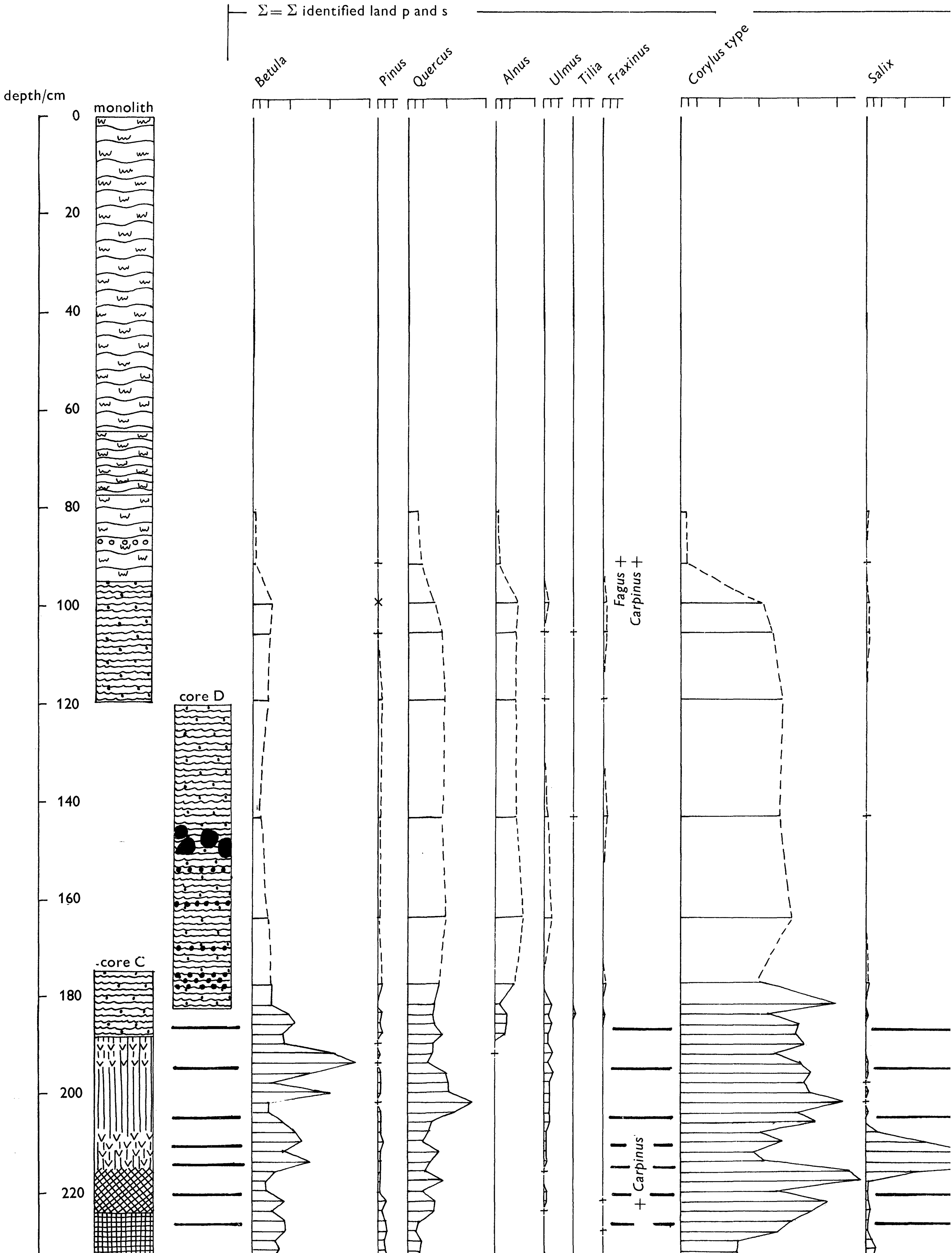
The sediment spanned by this assemblage zone and deposited up to 11069 ± 220 B.P. is a humified fen peat with coarser bands, containing many *Potentilla palustris* fruits and *Betula* wood. The high values of *Potentilla*-type pollen are ascribed to *P. palustris*. The scattered aquatics and frequency of *Salix* and tree *Betula* pollen indicate deposition in birch/willow carr on a moderately base rich soil. The varied herbaceous record suggests the richness of the fen flora, and the virtual absence of strictly open-ground species indicates that the carr area was large and prevented much infiltration of pollen from some distance, if indeed there were open-ground communities on the hillsides.

Assemblage zone HT2, Cyperaceae–Rubiaceae zone

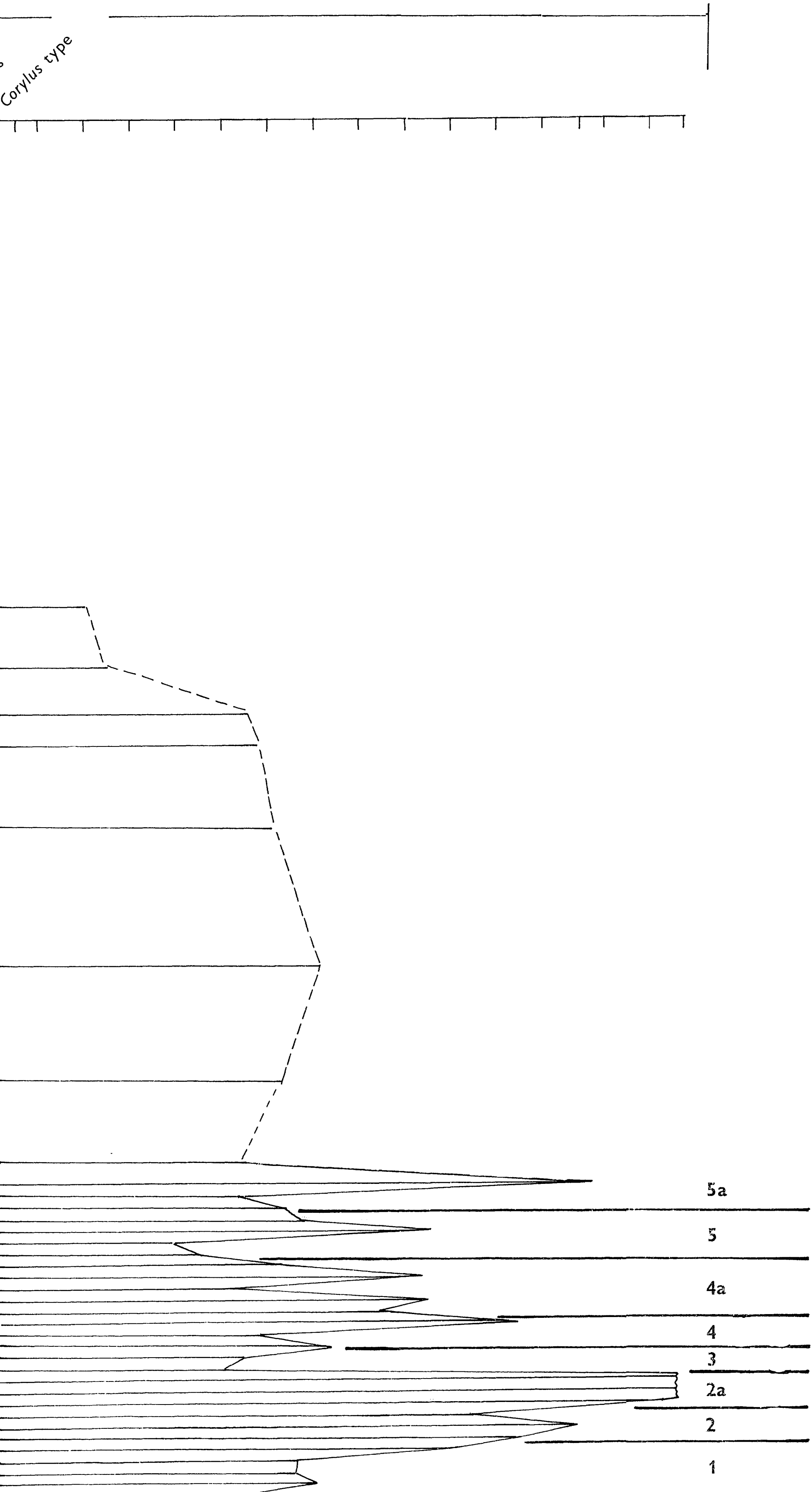
The sediments spanned by this p.a.z. are a sticky, humified sedge peat and dark buff silt. The macroscopic fossil content is listed in table 4. Percentage values of Cyperaceae pollen are generally greater than 50, mostly attributable to local *Carex* growth. *Potentilla*-type, *Betula* and *Salix* pollen show diminished values compared with p.a.z. HT1, while *Filipendula*, *Valeriana officinalis* and *Menyanthes* appear. The two latter species are also present macroscopically. Percentages of Caryophyllaceae (*Lychnis flos-cuculi* seeds are present), *Artemisia vulgaris*-type and Rubiaceae pollen are greater than in p.a.z. HT1.

These changes indicate transition from moderately base rich fen carr to mesotrophic sedge mire dominated by *Carex*. Open ground vegetation on the hillsides is apparent.

DOZMARY POOL 1971




alix
Hedera
Pyrus-Sorbus type
Viburnum opulus
Genista type
Σ = Σ Tree pollen
Betula
Pinus
Quercus
Alnus
Ulmus
Tilia
Fraxinus
Corylus type
Ilex +
+ Lonicera +
+ Prunus type
+ Cratægus


Corylus type
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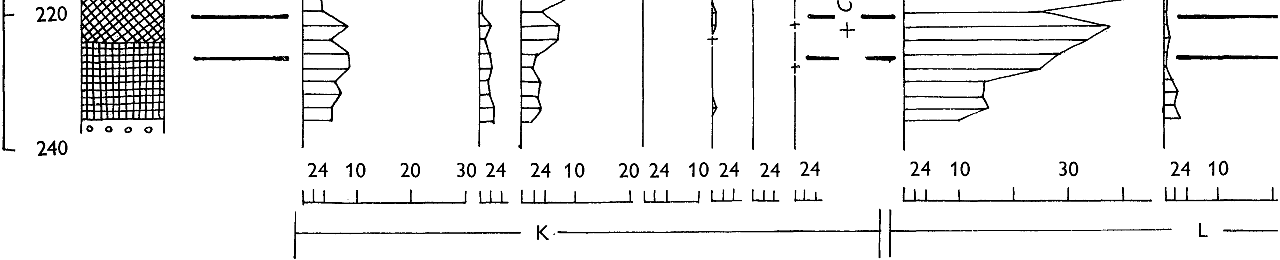
5
4a
4
3
2a
2
1


220
240
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24 10 30 24 10
K
L
C
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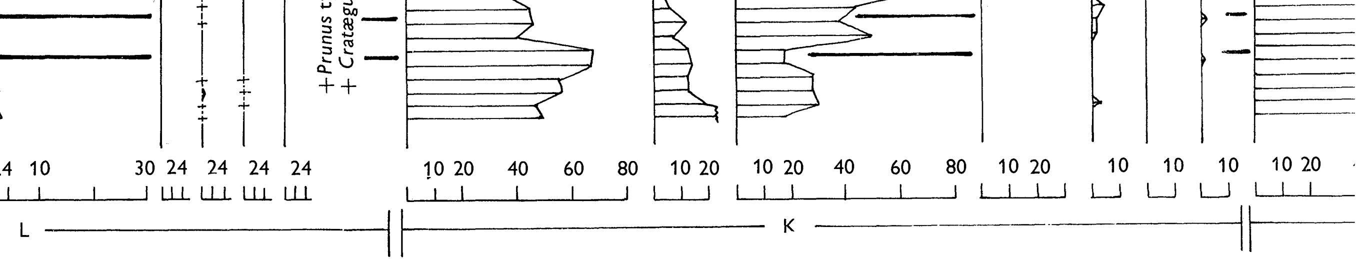
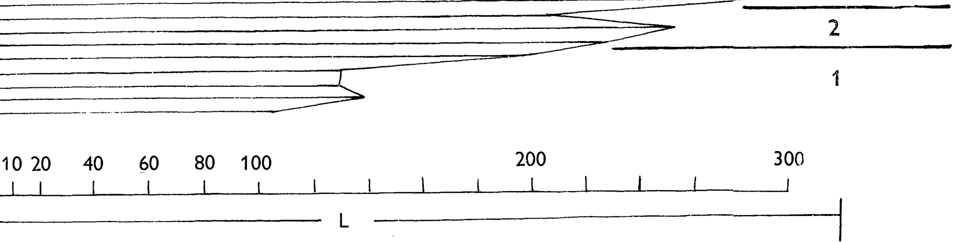


FIGURE 15. Pollen diagram: Dozmary Pool. Taxon groups K and L.


2
1
10
20
40
60
80
100
200
300
L

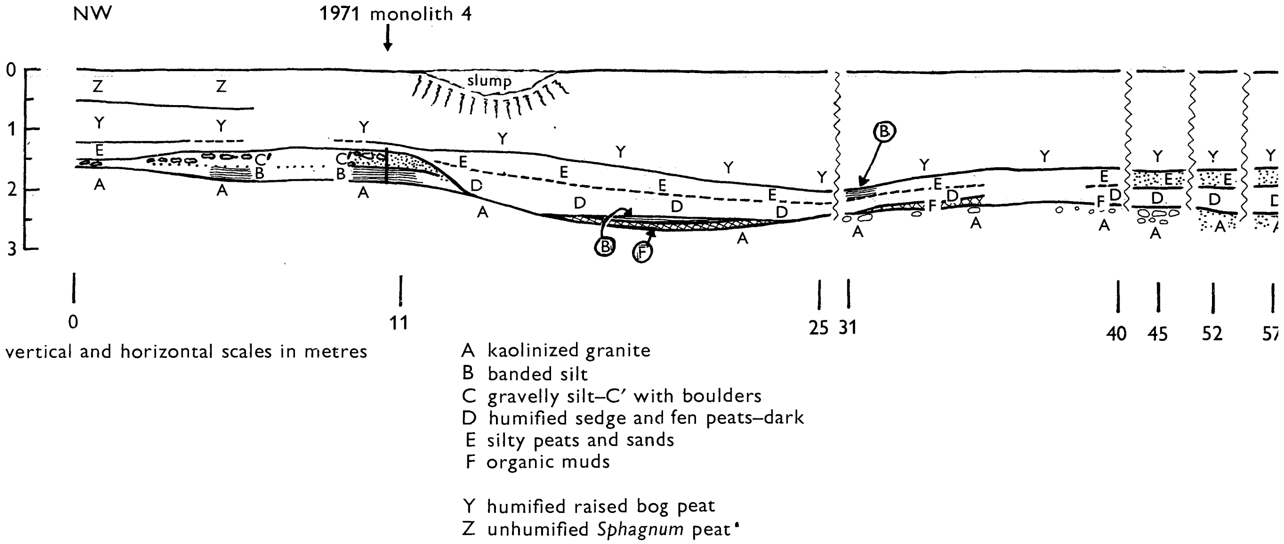


FIGURE 16. Hawks Tor, 1970–
showing the k

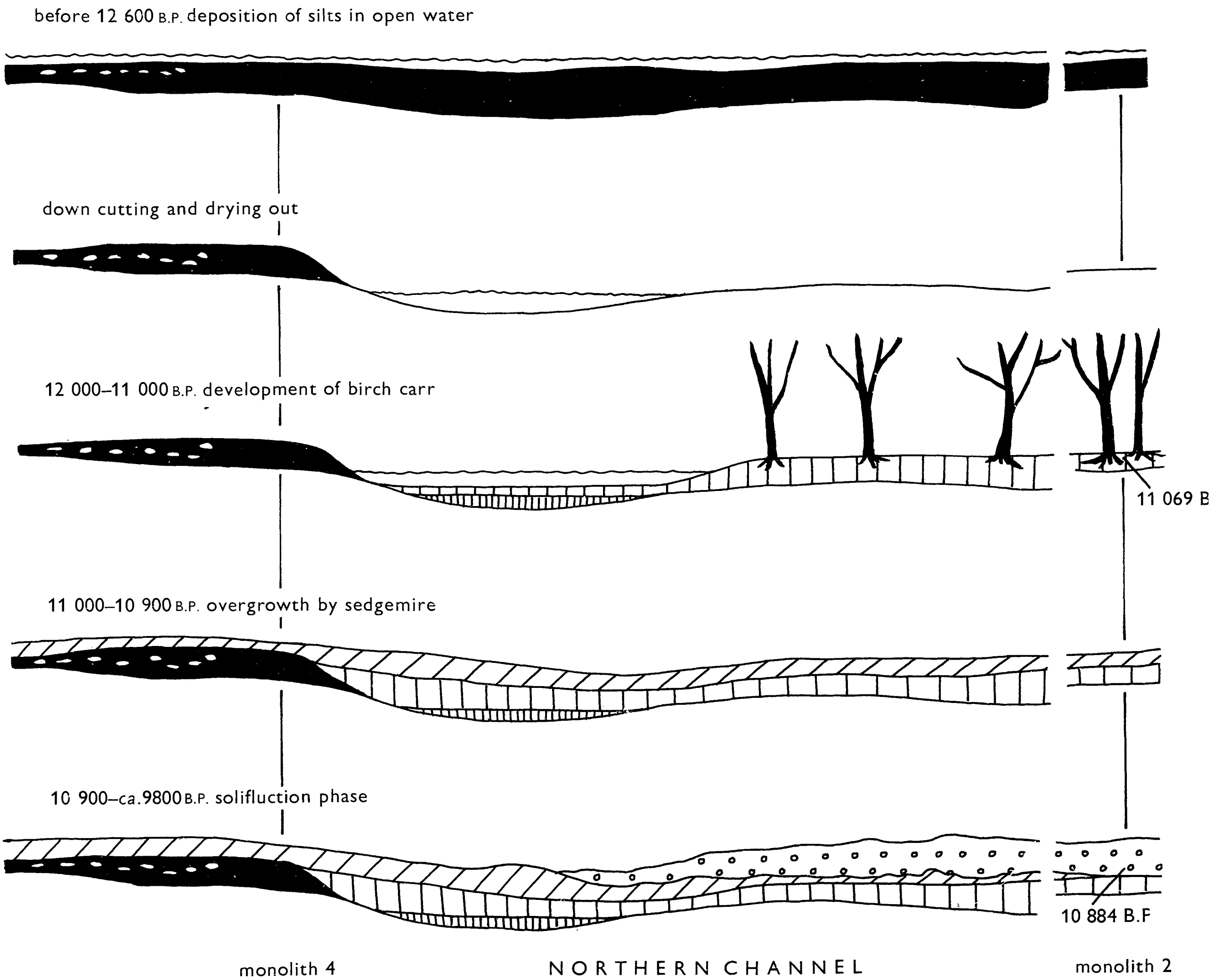
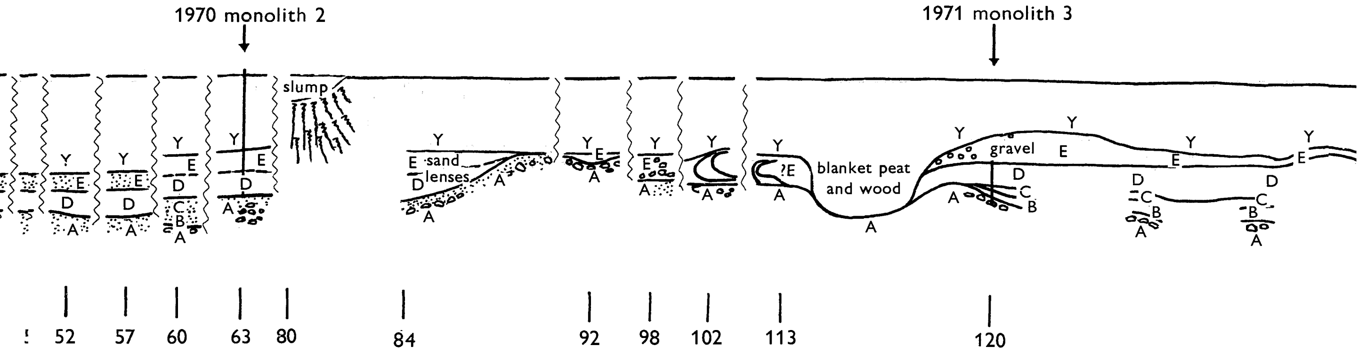
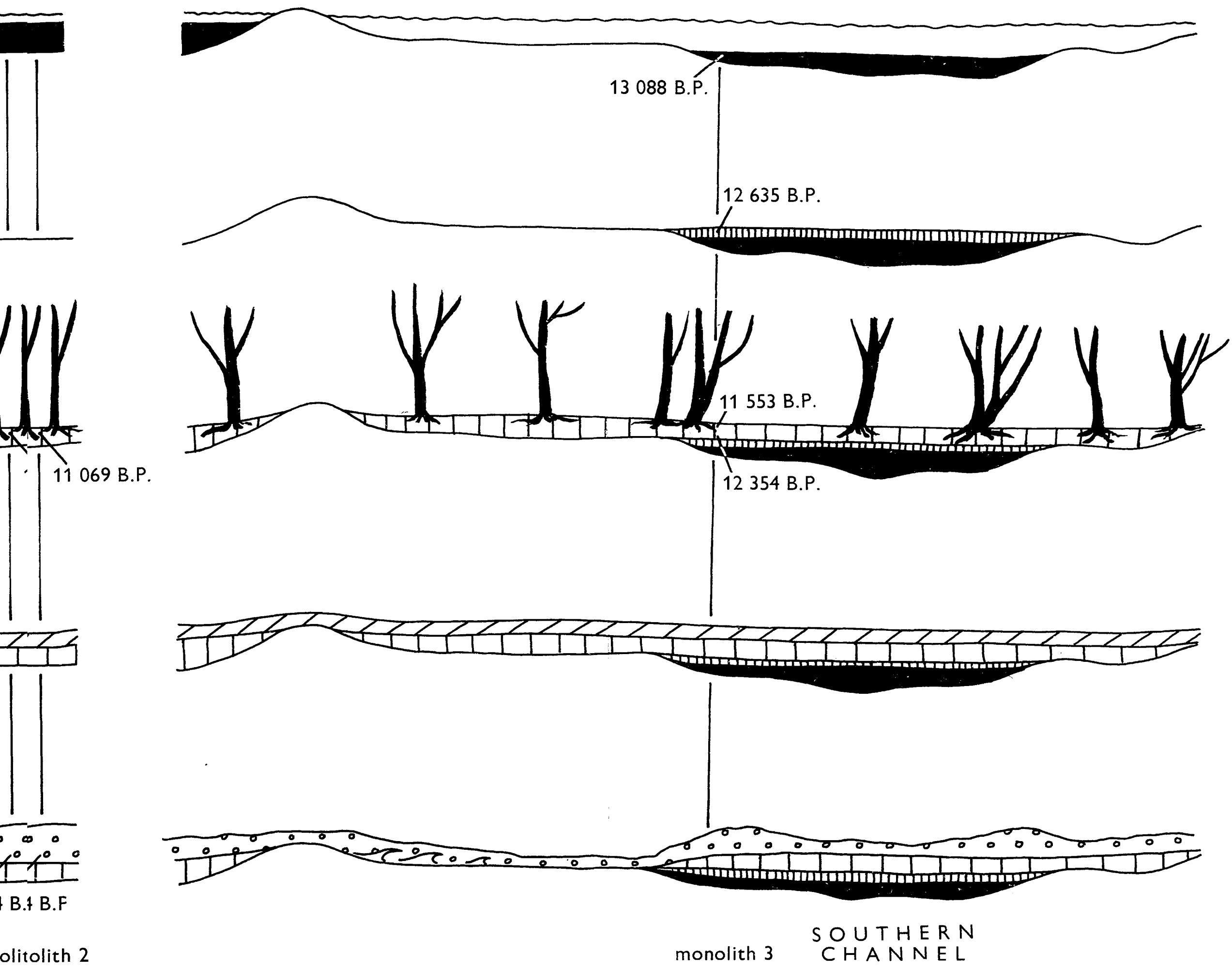


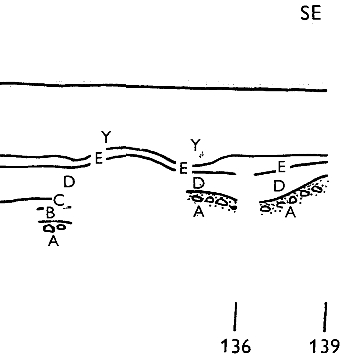
FIGURE 17. Sketch summary of depositional
Late-Devensian giving rise to the stra



'or.'or, 1970–1. Sketch section of the northeast face of the pit
vinving the location of monoliths 2, 3 and 4.



oospositional events at Hawks Tor in the
o to the stratigraphy of figure 16.


SE
Y
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D
C
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A
Y
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D
A
E
D
A
136
139

TABLE 4. PLANT MACROFOSSILS FROM LATE-DEVENSIAN LAYERS AT HAWKS TOR

	monolith (depth/cm and p.a.z.)																	
	no. 3						no. 4					no. 2						
taxon	40–54 HT01	34–38 HT02ai	24–32 HT02aii	18–24 HT02	4 16 HT03	0–4	34–42 HT001	26–34 HT001	14–24 HT001	4–14 HT001	0–4 HT001	197–201 HT1	189–197 HT2	181–189 HT2	177–179 HT3a	166–177 HT3a	158–166 HT3a	155–158 HT3a
fruits and seeds																		
Alisma plantago-aquatica	o	o	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex aquatilis/bigelowii	—	r	o	o	—	—	r	r	r	o	o	—	o	—	—	r	o	f
trigonous *Carex*	—	—	—	—	—	—	f	f	a	f	o	—	o	f	r	—	—	—
Carex fragments	r	—	o	f	—	—	a	a	a	a	o	—	—	f	r	—	—	—
Carex cf. *nigra*	r	o	r	o	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex rostrata	—	—	a	a	a	—	—	—	—	—	—	—	—	—	—	—	—	—
Campanula rotundifolia	—	—	—	—	—	—	—	—	—	—	—	—	r	—	—	—	—	—
Callitriche intermedia	a	a	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eleocharis palustris	a	a	—	—	—	—	—	—	—	—	—	—	r	—	—	—	—	—
Epilobium alsinifolium	r	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hippuris vulgaris	r	r	—	—	—	—	r	—	—	r	—	—	—	—	—	—	—	—
Juncus effusus/ conglomeratus	—	—	—	—	—	r	o	o	f	f	f	—	—	—	—	f	—	—
Luzula arcuata	—	—	—	—	—	r	o	r	o	—	o	—	o	—	—	—	—	—
Lychnis flos-cuculi	—	—	r	r	—	—	—	—	—	—	—	—	r	f	o	—	—	—
Menyanthes trifoliata	—	—	r	r	r	—	—	—	—	—	—	—	o	—	—	—	—	—
Montia fontana ssp. *fontana*	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Myriophyllum alt.	f	o	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Phragmites communis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—
Potamogeton natans	o	o	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potamogeton pusillus	r	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potamogeton sp.	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potentilla palustris	r	r	r	r	o	—	—	—	—	—	—	+	a	—	—	—	—	—
Ranunculus (*Batrachium*)	f	o	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rumex acetosella agg.	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sparganium angustifolium	a	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Valeriana officinalis	—	—	—	—	—	—	—	—	—	—	r	—	r	—	—	—	—	—
Viola cf. *palustris*	—	—	—	—	r	—	r	r	r	—	—	—	r	—	—	—	—	—
Subularia aquatica	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nitella-type oospores	o	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cristatella† statoblasts	r	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
mosses																		
Acrocladium stramineum	—	—	—	—	—	—	—	—	o	r	—	—	—	—	r	r	o	f
Drepanocladus fluitans	o	r	—	—	o	—	o	f	r	o	o	—	—	—	—	—	r	—
Polytrichum sp.	—	—	—	—	—	r	o	r	—	—	—	—	r	—	—	—	—	—
Polytrichum alpinum	—	r	—	—	—	—	r	—	—	—	—	—	—	—	—	—	—	—
Ceratodon purpureus	—	—	—	—	—	—	—	r	r	—	—	—	—	—	—	—	—	—
Sphagnum sp.	—	—	—	—	—	—	—	r	r	r	r	—	—	—	—	—	—	—
Sphagnum papillosum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	r	—
Pleurozium schreberi	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—
Drepanocladus uncinatus	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—
twig fragments	—	—	r	o	f	—	—	r	—	—	—	+	o	—	—	—	—	—
gravel	o	r	—	—	—	a	o	a	a	a	r	—	—	—	—	—	—	—
charcoal fragments	r	r	—	r	r	o	o	r	—	—	—	—	—	—	—	—	—	—

—	absent	in relation to the volume of sediment examined
r	rare	
o	occasional	
f	frequent	
a	abundant	

\+ observed in pollen samples
† a bryozoan.

Subzone HT3a, *Saxifraga stellaris* subzone

The sediments spanned by this assemblage zone are light and dark organic silts containing gravel lenses. Macroscopic remains are listed in table 4. The basal silt is dated 10884 ± 210 B.P. (in fact, the upper part of p.a.z. HT2). Meagre traces of pollen of aquatics are further diminished and percentage values of *Potentilla*-type decrease again. Pollen of *Filipendula* shows increased values. Deposition of these silts by solifluction is strongly suggested, firstly by the observed involutions of this and lower layers, secondly by the presence in the silts of remains of upland plants requiring and indicating open habitats (*Calluna*, *Empetrum nigrum*, *Artemisia norvegica*, *Saxifraga stellaris*, *Helianthemum* etc.), thirdly by the high percentages of unidentified damaged pollen in the silts (Birks 1969). Much of the Gramineae pollen may be derived from upland grassland.

If older material was admixed with the silts during the postulated solifluction episode then the date of 10884 ± 210 B.P. may be greater than the sediment age.

Persistence of continuing mire conditions locally, presumably with some soil enrichment resulting from enriched drainage water, is indicated by the increased *Filipendula* and Umbelliferae values. A radiocarbn date of 9654 ± 190 B.P. spans the boundary of subzone HT3a and 3b in sedge peat (see §6).

Deposition of p.a.z. HT1, 2 and 3a

Lithological, pollen and radiocarbon assay evidence points to deposition during the Late-Devensian. Definite solifluction features in the silts and lowest peat are indicated in the extensive mixing of these layers along the exposure. The silts of pollen assemblage zone HT3a are considered as a classical solifluction mud/gravel mix deposited by slumping onto the mire surf face, possibly in a single event.

(ii) *Monolith no.* 3

Assemblage zone HT01, Cyperaceae–*Ranunculus acris*-type zone

This p.a.z. spans the lower buff silts including a 2 cm kaolin band, deposition of which started at least 13000 radiocarbon years ago. Fruits and seeds of aquatic species are abundant in the silt, they are listed in table 4. They, and the *Nitella*-type oospores, indicate deposition of the silt in clear, still, perhaps mesotrophic, but peaty, water. The channel feature from which the monolith was taken (figure 17, §4) is less than 1 m deep and the remaining macroscopic flora indicates shallow water and littoral habitats, muddy in places, with *Callitriche intermedia*, *Ranunculus* subgen. *Batrachium*, *Sparganium* cf. *angustifolium*, and *Alisma plantago-aquatica.*

Pollen of Cruciferae was referable to *Subularia aquatica* (found as a macrofossil). Besides the frequent pollen of taxa already encountered as macrofossils, that of Gramineae and Cyperaceae is most abundant together with a rich herbaceous flora indicative of open grassland, presumably very wet in the valley bottom. Pollen of *Ranunculus acris*-type and *Rumex acetosa* is important. The presence of *Armeria*-type, *Helianthemum*, *Botrychium*, Chenopodiaceae, *Artemisia vulgaris*-type and *Artemisia norvegica*, Liguliflorae, Caryophyllaceae and *Matricaria*-type pollen together indicates the absence of tall-herb communities and points to essentially disturbed soils and short-turf grassland away from the open water. Pollen of *Ononis*-type referable to *Astragalus alpinus* is restricted to this p.a.z. and to p.a. zonule HT02ai.

Assemblage zone HT02, Umbelliferae–*Juniperus* zone

This assemblage zone spans the upper banded buff silt, kaolin bands of varying thickness with gravel, and a moderately humified sedge peat containing fresh wood in its upper parts.

Subzone HT02a, zonule i

This zonule spans the upper banded silt. Abundant fruits and seeds of aquatics are present, much as in p.a.z. HT01, but biconvex *Carex* nutlets, *Hippuris vulgaris* and *Potentilla palustris* fruits are found in the upper samples. Remaining taxa are listed in table 4. Together with the coarse silt banding these macrofossils suggest a shallowing of the water at about 12600 B.P.

The pollen taxa present are much as in p.a.z. HT01, although amongst the aquatics *Sparganium*-type is less important, *Caltha*-type makes its first appearance and Cyperaceae values begin to increase. This evidence is in accord with the postulated shallowing of the water leading to the growth of a sedge mire.

Subzone HT02a, zonule ii

This zonule spans the moderately humified sedge peat without wood, the base of which was deposited about 12300 years B.P. *Menyanthes trifoliata* seeds and biconvex *Carex* nutlets are present in the lower samples whilst they are absent in the uppermost where trigonous *Carex* nutlets are abundant; remaining macrofossil taxa are listed in table 4. Pollen of all aquatic species except *Menyanthes* and *Typha latifolia* is of little importance. *Sphagnum* spores (with low values), *Caltha*-type, *Valeriana officinalis* and *Succisa pratensis* pollen appear, while *Potentilla*-type persists. Percentage values of Cyperaceae decrease throughout.

Deposition under a tall-herb-rich fen associated with a falling water table accounts for these assemblages of pollen and macrofossils. The herbaceous pollen flora of p.a.z. HT01 persists in its essentials and pollen values of Umbelliferae and *Epilobium*-type reach their highest at these levels. Pollen of *Juniperus*, first appearing in zonule HT02ai, begins a continuous curve in the zonule, indicating persistent local growth, presumably on the better dranied slopes around the valley.

The upper part of p.a.z. HT02 spans part of the moderately humified sedge peat containing *Betula* wood. Trigonous *Carex* nutlets and *Potentilla palustris* fruits are the only macrofossils of note, others are listed in table 4. Pollen of aquatics, except for a few grains of *Menyanthes*, is absent. Pollen of mire and fen species is much as in zonule HT02aii except for the massive *Sphagnum* spore peak. Cyperaceae values reach their highest here, but at the level that wood becomes abundant (the boundary of p.a.z. HT02/03) frequencies of *Betula* (tree type) pollen increase. The low birch pollen percentages of p.a.z. HT02 (upper part) are a function of small numbers and *not* the high *Sphagnum* percentages. Pollen of any but those herbaceous species likely to occur within the developing birch carr that is indicated is absent. This suggests that the carr canopy was closed and probably quite extensive. Its development may be seen as a response to the drying of the tall-herb fen surface resulting from a falling water table.

Assemblage zone HT03, *Betula*–Rubiaceae–*Juniperus* zone

This p.a.z. spans the upper, moderately humified sedge peat containing fresh wood. Sediment immediately below the pollen assemblage zone boundary is dated 11553 ± 280 B.P. Trigonous *Carex* nutlets and *Potentilla palustris* fruits are the only macrofossils of note, others are listed in table 4. Except for a few grains of *Menyanthes*, pollen of aquatics is absent. Pollen of *Caltha*-type and *Potentilla*-type have decreased percentage values whilst those of *Filipendula* increase. This indicates a further lowering of local water table level. Rapidly rising percentages of Gramineae pollen also suggest this and the undoubted local abundance of birch carr (tree *Betula* anthers were found in the pollen preparations) would aid drying of the substratum. *Artemisia vulgaris*-type and Chenopodiaceae are the only remaining taxa exclusive to open ground habitats and the other herbaceous pollen flora is poor in both types and representation, Rubiaceae being the dominant. This clearly indicates the closed and extensive tree canopy at the site which would reduce the incorporation of all but the most locally derived pollen.

Deposition of p.a.z. HT01, 02 and 03

The lithology, macrofossil and pollen content of this section indicate the transition from clear, shallow, base poor, open water through tall-herb fen to birch carr. The open water was probably a small lake fed from the surrounding slopes.

(iii) *Monolith no.* 4

Assemblage zone HT001, Gramineae–Cyperaceae–Umbelliferae zone

This assemblage spans all the sediments of monolith no. 4 in spite of the unconformable junction between the uppermost detritus muds (figure 16). Biconvex and trigonous *Carex* nutlets and seeds of *Juncus effusus* or *conglomeratus* are the most frequent macrofossils; others are listed in table 4. The pollen curves are almost constant throughout, with only a slight change associated with the uppermost detritus mud. The sediment types and their general coarseness indicate deposition in shallow water, although pollen of obligate aquatics is rare. Change from almost wholly inorganic to partially organic sedimentation at 24 cm may indicate the stabilization of some surrounding soils (with consequently reduced inwash of silt) since evidence of hydroseral change in the pollen spectrum is lacking. However, the gravel and boulder content of the detritus mud shows that soil movement was still active. The neat banding of the lower silts indicates deposition in still or relatively slow-flowing water.

The very high total value of Gramineae and Cyperaceae pollen percentages indicates deposition in an open, treeless environment; valley fen of medium base-status with perhaps some *Salix* bushes surrounding the open water. *Empetrum* heath, *Juniperus* scrub and open ground communities probably occupied the drier hillsides.

Deposition of p.a.z. HT001

The stratigraphy indicated in figures 16 and 17 suggests that the unconformity at the top of monolith 4 covers a considerable period. Pollen assemblage zone HT01 is directly comparable with p.a.z. HT2 and 3a and the uppermost sample (in gravel) from monolith 3 (above p.a.z. HT03). However, the part of p.a.z. HT001 *above* the unconformity was deposited after 11069 ± 220 B.P., sometime during the post-Allerød recession, whereas sediments below the unconformity, directly comparable in assemblage with p.a.z. HT01 and 02 in all except their lack of aquatic pollen, must have been deposited *before* the Allerød, as summarized in figure 17.

(*b*) *Summary of Hawks Tor sediment deposition history*

In summary, pollen analysis and radiocarbon dating at Hawks Tor indicate sediments of type D (figures 16 and 17) to be of Allerød age as defined by radiocarbon dates (Godwin & Willis 1959). Sediments underlying type D are either immediately pre-Allerød in age (as in monolith 3) or bedrock (as in monolith 2). The immediately pre-Allerød sediments are banded silts or clayey gravel laid down in open water. A pre-Allerød downcutting event, associated with a change in drainage, has cut a channel cleanly into the pre-Allerød sediments of the northwest end of the northern channel (at 11 m).

Allerød deposition has taken place in the two large channels indicated in figure 16, the more northerly of which was cut in the pre-Allerød. Birch carr spread in the wet hollows of an underlying surface moulded both by periglacial activity in the Devensian and probably by drainage activity in the Late–Devensian.

Post-Allerød deposits overlie those of the Allerød conformably at the northern end of the northern channel in this section. At its southern edge (monolith 2) and in the shallow southern channel (monolith 3) the post-Allerød solifluction deposits have cut into the Allerød or early post-Allerød sediments. The transported deposits of the southern channel are sands or gravels compared with the organic or banded silts deposited *in situ* at the upper part of the northern channel infill.

(*c*) *Parsons Park vegetation history*

Assemblage zone PP1, Cyperaceae–Umbelliferae zone

This assemblage zone spans a fine, siltless, detritus mud separated from a highly humified peat with abundant *Carex* nutlets by a shallow gravel layer. Pollen of *Myriophyllum spicatum*-type, *Valeriana officinalis* and Umbelliferae suggests a moderately base-rich tall-herb fen community by open, shallow water. *Eu-Potamogeton*, *Potentilla*-type and *Thalictrum* are also present. The absence of tree pollen and presence of *Juniperus*, *Artemisia*, Chenopodiaceae, Caryophyllaceae and *Matricaria*-type indicates open regional vegetation.

Assemblage zone PP2, Cyperaceae–*Betula–Empetrum* zone

This assemblage zone spans a humified (fen wood) peat and two series of banded organic silts separated by a humified peat containing abundant sclerenchyma spindles from the leaf bases of *Eripophorum vaginatum* and other coarse sedge fragments.

The record of *E. vaginatum* suggests a reduction of local soil base status. Persistence of *eu-Potamogeton* and *Valeriana officinalis* together with *Sparganium*-type and *Hydrocotyle* confirms a locally high water table.

The banded organic silts are interpreted as surface flooding phases related to stream drainage as is observable at present in the upper courses of the Plym, Dartmoor and the Fowey rivers. Individual bands are of variable thickness and structure and are not traceable for long distances laterally. Peaks in the percentage values of badly damaged pollen are associated with the thickest silt layers supporting this view of their origin in transportation (Birks 1969). Higher values of *Salix* and *Betula* pollen in this assemblage zone (at least 91 % of *Betula* pollen is of tree type), especially associated with the *in situ* organic deposits indicate the local development of areas of carr separated by stands of *Eriophorum vaginatum* and *Sphagnum* spp. The shallow peak of *Corylus*-type pollen may indicate local stands of *Myrica*. Persistence of Umbelliferae, Rubiaceae, *Potentilla*-type, *Matricaria*-type, Caryophyllaceae and *Rumex acetosa*-type indicates that a tall herb fen community was also present in the valley bottom. The presence of *Helianthemum* suggests that open vegetation persisted on the hillsides.

Pollen of *Empetrum nigrum* reaches high values in this p.a.z., its most likely habitat being well-drained hillside soils. Two peaks of poorly preserved Ericaceous pollen are associated with the deepest bands of the flooding phase silts. Much of this pollen is likely to be that of *E. nigrum* damaged in transit with the silt. An intervening peak of well-preserved *E. nigrum* pollen is interpreted as being deposited on the mire surface by outwash from the air. The summed curve of *E. nigrum* + Ericales is much smoother than either individual curve and suggests that the pollen of hillside *Empetrum* has been deposited in two distinct ways.

Assemblage zone PP3, Cyperaceae–*Artemisia* zone

This assemblage zone spans only one sediment type, a highly humified sedge peat. *Artemisia* is the only open-ground genus present and is the taxon with greatest frequency after Cyperaceae (values of greater than 50 %) and Gramineae. No other herbaceous taxa show more than scattered frequencies in this assemblage and *Betula* percentages are extremely low.

This evidence suggests that a sedge mire occupying the valley floor, perhaps with scattered *Salix* clumps, replaced the birch carr of p.a.z. PP2. Grass-covered hillsides with a good scattering of herbaceous species and *Artemisia* surrounded the mire.

Deposition of p.a.z. PP1, 2 and 3

Lithological and pollen evidence suggests a Late-Devensian date spanning the Allerød oscillation for these sediments. The assemblages are very similar to those of Hawks Tor HT1, 2 and 3a.

(*d*) *Plant communities*

46 defined taxa of Late-Devensian pollen or plant macrofossils were recovered additional to those listed by Conolly *et al.* (1950) and Dickson (1965). Some of the additional taxa are of more limited extent than those of previous authors and may include species from their looser taxa. Definitions of all the pollen taxa of this study are available from the author. Notes on the identification of some critical Late-Devensian plant macrofossils are provided at the end of this section. Appendix 2 is a list of Late-Devensian fossil taxa. Floristic information from the studies of Conolly *et al.* (1950) and Dickson (1965) has been freely used in the discussion below and is acknowledged in the appropriate places.

(i) *Pre- and post-Allerød sediments*

For the *purposes of this immediate discussion only* sediments occurring outside the limits of the *Betula* curve at the arbitrary 5 % level are termed 'pre-Allerød' before the birch rise and 'post-Allerød' if they come after the birch fall as illustrated in the pollen diagrams presented here. Analogous sediments from the earlier studies are categorized in the same way, regardless of the *Betula* pollen frequencies within them. (See § (*d*) (v) for a fuller discussion of this usage.)

Close identification of the fossil species provides sufficient information to suggest some of the plant communities responsible for the fossil assemblages.

Specially considered are:

		Armeria maritima	pm
Artemisia norvegica†	pm	*Epilobium alsinifolium*†	m
Astragalus alpinus†		*Juncus effusus* or *conglomeratus*†	m
Betula nana‡	(p)m	*Luzula arcuata*†	m
Bidens cernua	pm	*Montia fontana* ssp. *fontana*	pm
Botrychium	spores	*Salix herbacea*‡	m
Carex aquatilis or *bigelowii*	m	*Saxifraga stellaris*	pm

(pm, Pollen and macrofossil; m, macrofossil only; †, observed only in this study, ‡, data of Conolly *et al.*)

Typical assemblages of macrofossils are

- p.a.z. HT001 (lower)
  - *Carex aquatilis* or *bigelowii*
  - trigonous *Carex* sp.
  - *Juncus effusus* or *conglomeratus*
  - *Luzula arcuata*
  - *Viola* cf. *palustris* 1.3
- p.a.z. HT3a
  - *Carex aquatilis* or *bigelowii*
  - *Juncus effusus* or *conglomeratus* 1.6
- sample above p.a.z. HT03
  - *Carex* sp. (much worn)
  - *Luzula arcuata*
  - *Juncus effusus* or *conglomeratus* 3.0

Figures given after the assemblages are the grass/sedge pollen ratios: they are always greater than unity.

(ii) *Comparison with present-day Scottish montane communities*

In searching for modern parallels to the Late-Devensian plant communities of an extremely oceanic west-European environment such as Bodmin Moor, examination of present-day montane communities from a similar environment is more advisable than examination of Arctic or sub-Arctic communities. McVean & Ratcliffe (1962) provided a rich corpus of information on the plant communities of the Scottish Highlands. A brief summary of the species composition of distinctive montane communities listed by McVean & Ratcliffe, in which the fossil taxa from Bodmin Moor occur, is given below.

Luzula arcuata is exclusive to the *Gymnomitrion-Salix herbacea* snow-bed vegetation occurring on gentle slopes from 914–1219 m (3000–4000 ft) indifferent to aspect. The plant cover is often incomplete and the surface typically shows a high water content (associated with amorphous solifluction) whereas the association occupies open, exposed ground or areas of deep snow accumulation. Of Late-Devensian taxa from Bodmin Moor listed above *Carex bigelowii* and *Salix herbacea* occur in this assocation.

Montia fontana ssp. *fontana* is highly selective for the oligotrophic bryophyte spring association of McVean & Ratcliffe. Of the species occurring in this association *Caltha palustris*, *Epilobium alsinifolium*, *Ranunculus acris*, *Rumex acetosa*, *Saxifraga stellaris*, *Thalictrum alpinum* and *Viola palustris* have been found in the Late-Devensian sediments of Bodmin Moor.

Artemisia norvegica in its Scottish stations is found in the *Juncus trifidus-Festuca ovina* nodum of lichen-rich *J. trifidus* heath. Of the species occurring in this associational nodum *Salix herbacea*, *Armeria maritima* and *Carex bigelowii* have been found in the Late-Devensian sediments of Bodmin Moor. The community is one of wideswept erosion surfaces from 610–1128 m (2000–3700 ft) often associated with structured solifluction.

Armeria maritima is also a constant species of species-rich *Rhacomitrium* heath, *Carex bigelowii* is again an associate. *A. maritima* may be very frequent in the cushion-herb facies of *Rhacomitrium* heath. These associations are best developed on gentle slopes from 610–1219 m (2000–4000 ft).

In the Scottish Highlands *Astragalus alpinus* is restricted to the *Dryas-Salix reticulata* provisional nodum of the *Dryas* heath association. *Betula nana* is highly selective for the shrub rich facies of

Calluneto-Eriophoretum. Its associates are *Calluna vulgaris*, *Empetrum hermaphroditum*, *E. nigrum*, *Erica tetralix*, *Eriophorum angustifolium*, *E. vaginatum*, *Juncus squarrosus*, *Rubus chamaemorus* and *Vaccinium* spp.

Bidens cernua flourishes on soils subject to a fluctuating water table, especially those flooded in the winter. *Botrychium lunaria* is a species of well-drained short-turf grassland and rock ledges. *Juncus effusus* and *conglomeratus* are almost ubiquitous in the British Isles, *J. effusus* being the physiognomic dominant of extensive *J. effusus-Sphagnum* mires.

The three assemblages of macrofossils listed at the opening of this section occur in silts, sometimes banded or intermixed with gravel, and pure gravel. The main elements of these assemblages occur also in the laminated silt examined by Dickson (1965) together with an aquatic flora. In addition, the moss flora of Dickson's laminated silt contained five species of *Polytrichum* including *P. alpinum* and *P. norvegicum*, the latter virtually an obligate chionophile. This latter species together with *Bidens cernua*, *Salix herbacea* and *Betula nana* led him to conclude that the silt had its origin in transport by snow-bed melt waters. Only well-preserved leaves of *Polytrichum alpinum* have been observed in this study (table 4). Badly worn leaf fragments may belong to other species. *Acrocladium stramineum*, *Drepanocladus fluitans*, *D. uncinatus*, *Pleurozium schreberi*, *Sphagnum papillosum* and *Ceratodon purpureus* are the other Late-Devensian mosses of this study, all having been previously observed by Dickson (1965). *Ceratodon* and *Pleurozium* favour acid soils and *Drepanocladus uncinatus*, wet gravelly soils. The remaining species are frequent in upland mires.

The origin of the fossil assemblages of the pre- and post-Allerød silts from Bodmin Moor must lie within communities similar to those listed from the Scottish Highlands, a collection of snow-bed, flush and lichen/moss heath vegetation. The silts have been deposited either by amorphous solifluction (monolith nos. 2 and 3 at Hawks Tor (above the Allerød peat)) or have been unloaded into shallow water by drainage water from flushes and springs, the variable activity of which has caused the banding.

That the pre- and post-Allerød communities of Bodmin Moor are not exact equivalents of the present-day montane communities of Scotland is shown by the absence of the following species in the macrofossil record:

Lycopodium annotinum
L. alpinum
L. selago
Cryptogramma crispa
Dryas octopetala
Juncus trifidus

Each of these is distinct in macro- or microfossil form and some have been observed in Late-Devensian deposits from the British Isles (see, for example, Moore 1970; Pennington 1970). *Dryas* is listed because, although an exacting calcicole, its calcicolous associate *Astragalus alpinus* has been found in the Bodmin sediments. Absence of these species from the Cornish fossil record does not prove their absence from Cornish Late-Devensian vegetation but exact equivalence of the present-day and Late-Devensian vegetation of these two separated areas is not expected.

The macrofossil assemblage of p.a.z. HT01 and 02ai (monolith no. 3) is of a distinct aquatic facies (discussed in the general survey above) but, like the laminated silts of Dickson (1965), three elements of the montane communities discussed in this section are present:

Carex aquatilis or *bigelowii*
Epilobium alsinifolium
Montia (pollen referable to *M. fontana* agg.)

The ratio of grass/sedge pollen is a little under unity. The admixture of the upland and aquatic element macrofossils together with this pollen ratio indicates that transported and *in situ* fossil assemblages have been integrated in the banded silts. (The grass/sedge ratio of a typical sedge mire assemblage, p.a.z. HT2, is 0.3, that of the upland snow-bed, flush and heath communities discussed above, 1.3–3.0. Integration of these two pollen assemblages in the same sediment gives a ratio of about 1.0 or a little less.)

Without radiocarbon cross-correlation it is not possible to demonstrate the broad contemporaneity of assemblages HT001 (lower) and HT01/02ai which their stratigraphical relationship and general similarity allow (figure 16). In the observable exposure the basal silts of monolith 3 are much nearer a shore line than those of monolith 4. This may be the reason for the richer aquatic assemblage in the silts of monolith 3 (p.a.z. HT01/02a) since Birks (1973) has demonstrated the extremely local representation of littoral and shallow-water vegetation by its propagules in North American lakes. A suggested scheme of events at Hawks Tor giving rise to the observed stratigraphy is sketched in figure 17 (§4).

(iii) *The effects of solifluction of soils*

The soil mixing attendant upon Late-Devensian cryoturbation in this area, which lacks basic rocks, can only have led to mild soil enrichment. Absence of the *exacting* montane calcicoles of the Scottish Highlands (listed by McVean & Ratcliffe 1962) in the fossil record reflects the absence of calcareous or strongly basic rocks. Fossil presence of the calcicole *Astragalus alpinus* in the absence of *Dryas octopetala*, a species with which it occurs in Scotland, seems strange. *Botrychium lunaria*, *Carex pulicaris*, *Filipendula ulmaria*, *Plantago lanceolata*, *Valeriana officinalis* and *Thalictrum alpinum*, all listed as montane calcicoles by McVean & Ratcliffe (requiring soil pH greater than 4.8, Ca^{2+} concentration greater than 30 mg/100 g soil), are present in Late-Devensian sediments from Bodmin Moor. Likewise the calcifuges (requiring soil pH less than 4.5, Ca^{2+} concentration less than 30 mg/100 g soil) *Eriophorum vaginatum*, *Sphagnum papillosum*, *Betula nana*, and *Rhynchospora alba*. These categories are by no means exclusive, and, furthermore, McVean & Ratcliffe have indicated that the supposedly normal calcifuge habit of some taxa, especially in the Ericaceae, may not be universal. That is, they may flourish in slightly calcareous soils or they might grow on thin acid soils immediately overlying limestones. The pollen record of these two situations would not be distinguishable. Overall, the Late-Devensian fossil flora of Bodmin Moor indicates no more than the range of soil base-status expected of an area of upland acid rock.

(iv) *Indications of pre- and post-Allerød climate*

The first radiocarbon dated continuous *Juniperus* pollen record occurs in p.a.z. HT02aii at least 1000 radiocarbon years before the maximal development of Allerød birch carr (discussed in the general survey, above). The appearance of *Juniperus* pollen might be the record of immigration of open juniper scrub onto better drained hillsides. The fruitstone recorded by Conolly *et al.* (1950) from zone II sediments indicates that juniper was locally present.

In Scotland the altitudinal range of dwarf juniper heath (*J. communis* ssp. *nana*) is characteristically in the 305 m (1000 ft) immediately below the low–mid alpine communities discussed above, although there can be considerable overlap (McVean & Ratcliffe 1962). Bearing in mind that similarity, not exact equivalence, of the present-day montane communities of Scotland and the Late-Devensian communities of Bodmin Moor has been suggested, then if the well-used parallel between altitudinal zonation of vegetation at a point in time and temporal succession of similar types of vegetation with climatic fluctuation is applied, it must be argued that the immigration of juniper scrub suggested in the pollen assemblages records a climatic amelioration. If the record is of tall juniper scrub (*J. communis* ssp. *communis*) rather than dwarf juniper heath (distinction on palynological grounds is not possible) then very distinct climatic improvement took place.

It is conceivable that *Juniperus* was present at a very early stage in the pre-Allerød and responded to climatic amelioration by increased flowering (rather than immigration from outside the area) although the apparent instability of soils in the early Late-Devensian that precluded organic deposition is unlikely to have permitted the persistence of *Juniperus* for any length of time.

The pollen grain of *Sagittaria* (p.a.z. HT02ai) just below the beginning of the continuous juniper curve argues again for climatic amelioration since the two European species of *Sagittaria* at present have a distinctly continental distribution. *S. sagittifolia* is only frequent in Britain from S. Lancashire and Yorkshire southwards.

The hydrosere recorded in p.a.z. HT02aii might well be the response to increased summer temperature or overall increases in evapo-transpiration in the period immediately before 12600 B.P. which would cause reduction in surface water volumes. A similar argument is used to explain the Boreal hydrosere at Dozmary Pool (§6). Change from primarily inorganic to organic deposition in p.a.z. HT001 (monolith 3), too, may be the expression, in deeper water deposits, of this postulated climatic amelioration. Stabilization of some soils would result in less coarse inorganic material being available for water transport.

It was the cautious opinion of Conolly & Dahl (1970) that Late-Devensian depression of the present mean summer maximum temperature was less in southwest England than other parts of the British Isles. A new estimate of this depression is calculated in table 5, based on more abundant floristic information than was available to Conolly & Dahl. Their data for the limiting isotherms of mean maximum summer temperature have been used for all the species for which they presented information which also occur in the pre- and post-Allerød sediments of Bodmin Moor.

A limiting isotherm of mean summer maximum temperature is calculated for each species occurring on Bodmin Moor by using Conolly & Dahl's method, and their cautions (in estimation of the effect of oceanicity on the limiting isotherms) apply. Since the average value of the calculated limiting isotherms is 22.5 °C and the present mean summer maximum temperature of Bodmin Moor is 25 °C a depression of the mean maximum of about 2.5 °C in the pre- and post-Allerød is implied.

The diatom analysis by Ross (in Conolly *et al.* 1950) of basal muds resting on gravel at Hawks Tor revealed a predominantly temperate flora. Arctic-alpine and temperate-Arctic elements were few. Since this assemblage was associated with *Potamogeton* and *Myriophyllum alterniflorum* macrofossils and pollen it is correlated by the present author with p.a.z. HT01, for it occurred in a corresponding stratigraphic position. The diatom flora might be the earliest reflection of the improved climate detected in the pollen record immediately above. Iversen (1954) argued that aquatic plants and, presumably, planktonic forms in particular, would react quickly to climatic amelioration during the Late-Devensian by migration because aquatic habitats were frequent and always provided a tempering milieu for plant growth.

What part in causing the depression of temperature the eustatically lowered sea-levels

Table 5. Limiting isotherms for Late-Devensian plants occurring on Bodmin Moor

	Northern England	Wales, Central and South England	Highland Scotland	Iceland	Scandinavia	S.W. England (calculated according to Conolly & Dahl)
Betula nana†	X		22+			22+
Carex aquatilis	25/26	25/26		23		24/25
C. bigelowii	25	23	23	X	27	22
Epilobium alsinifolium‡	25	X	23			23
Luzula arcuata‡			21	23		25+
Salix herbacea	25	25	23	24	26	24
Saxifraga stellaris	25	25	24	24+	25	24
Subularia aquatica	25+	25	24	22		24
Thalictrum alpinum	25−	X	23		27	22
Artemisia norvegica‡			X		22	?

All isotherms are of the mean summer maximum temperature (°C).
X, species distribution sparse, cannot be correlated with an isotherm.
+, greater than the temperature indicated.
−, less than the temperature indicated.
† Data of Conolly *et al.* (1950).
‡ Found in this study only.

around the south-west peninsula played is open to speculation. Conolly & Dahl used a lapse rate of 0.6 °C per 100 m in calculation of limiting isotherms. Thus at the Devensian maximum, if sea-levels were lowered 100 m below o.d. (Fairbridge 1960), a depression of 0.6 °C might be expected by virtue of the effectively increased altitude of the land masses. This approach is obviousy much simplified but suggests that the effect of eustatically lowered sealevels during the latter part of the Late-Devensian probably played little part in depressing the mean summer maximum temperature. The present author has indicated (unpublished) that the mean sea-level in the Bristol Channel was 36.6 m below o.d. in the early Flandrian and it must have been substantially lower in the latter part of the Late-Devensian.

(v) *Allerød sediments*

Since the *Betula* pollen percentage curve distinctly increases to more than 5 % Σ l.p.s. and then decreases below 5 % Σ l.p.s. in the Late-Devensian, it was decided to equate this birch pollen maximum with Godwin's (1956) pollen zone II (see figure 28, § 9). The two radiocarbon dates that bracket this percentage curve change are 11 553 ± 280 and 11 069 ± 220 b.p.

It is clear from these dates that the birch pollen maximum is developed only in the latter part of the Allerød period *sensu stricto* (*ca.* 12 000–*ca.* 10 800 b.p., Godwin & Willis 1959). Nevertheless, *for the convenience of this discussion*, sediments in which the birch pollen maximum occurs are referred to as 'Allerød'. These are the sediments of p.a.z. HT1, HT03 and PP2; they all contain fresh wood, some of which is birch.

No fruits or catkin scales of tree birches have been found in this or previous studies, but the abundance of tree birch pollen, the birch wood and tree birch anthers in the sediments and the floristic assemblages of the p.a.z. all point to the maximal development of birch or birch/willow carr. The list of taxa present in these sediments and the corresponding wood peats of Conolly *et al.* (1950) is much shorter than that of the pre-Allerød sediments. This reduction is attributed to the representation of one terrestrial facies in the Allerød as against aquatic, telmatic and terrestrial facies of the pre-Allerød.

Conolly *et al.* (1950) ascribed both the *Carex*-wood peats and the underlying muds and detritus that occurred 'below the zone III solifluction gravels' to zone II. Zone II had been defined mainly on a stratigraphic basis and equated with the Allerød because sediments in it were more organic than those above or below. It is clear from the stratigraphy of Hawks Tor monolith 3 that the muds underlying the fen wood peat are ascribable to a pre-Allerød (older than 12000 B.P.) period with open 'montane' vegetation. If the sediment depth is plotted against the radiocarbon dates for monolith 3 then the boundary of p.a.z. HT02aii and HT02 falls at about 12000 B.P. on the time scale (the opening of the Allerød *sensu stricto*), and birch wood first appears at this level. Thus only the upper part of p.a.z. HT02 and p.a.z. HT03 are truly Allerød in age, the underlying sediments are pre-Allerød *sensu stricto*.

The floral lists from the pollen 'zone II' of Conolly *et al.* are not in accord with their Allerød interpretation of all the organic sediments below the 'zone III solifluction gravel', but rather with the interpretation suggested here, exemplified in the sediments of monolith 3.

Conolly *et al.* did present a puzzling single record of *Betula nana* from the wood peats (Allerød, *sensu stricto*). The absence of other cold-climate indicators, however, cannot be used alone as an argument for an Allerød climatic amelioration since the enclosed nature of the birch carr that developed would prevent extensve incorporation of pollen from the surrounding communities. The carr development, the associated maximum of juniper pollen percentages and the presence of a juniper fruitstone point, themselves, to climatic amelioration as discussed earlier. The nutlet of *Lycopus europaeus* recovered from the wood peats by Conolly *et al.* (1950) also indicates the persistence of milder conditions. *Lycopus* does not generally occur north of 62° in Scandinavia and has a south-easterly distribution in the British Isles, a little more widespread than *Sagittaria sagittifolia*, although in the British Isles both are only ubiquitous within the 26 °C mean summer maximum isotherm.

(*e*) *Late-Devensian climate on Bodmin Moor*

(i) *The amplitude of temperature fluctuations*

The relatively meagre evidence from the fossil assemblages and the complex control of interacting climatic variables on the determination of species distribution do not allow accurate numerical estimates of the individual elements of past climate. However, compared with an average mean summer maximum temperature of 22.5 °C *at most* represented in the available pre- and post Allerød deposits (derived above) a corresponding temperature of 25 °C at least is indicated for the Allerød (not unlike that of the present) by *Sagittaria* and *Lycopus europaeus*. Fluctuation of this temperature parameter must have been at least 2.5 °C during the Late-Devensian.

ii) *The form of the climatic amelioration*

In monolith 3 from Hawks Tor (this study) the appearance of the continuous *Juniperus* curve was interpreted as a response to climatic amelioration. This response is evident at least 1000 radiocarbon years *before* the maximal development of birch carr which is referable to the latter part of the Allerød *sensu stricto*. The low juniper percentages at his time, in contrast to those of western Ireland (Watts 1963), Mid-Wales (Moore 1970) and N.W. England (Pennington

1970; Pennington & Bonny 1970) are a peculiarity of the southwest peninsula (as is the Flandrian absence of *Pinus* (see § 8)). They cannot alone be used to argue only slight climatic improvement. There is no palynological indication of climatic recession in the 1000 or more radiocarbon years between the appearance of *Juniperus* and the *Betula* pollen maximum, and hence no evidence of a Bølling oscillation, *sensu lato*. However, as discussed by Pennington (1970), a climatic recession at this time might not be expressed in the pollen record if it was short-lived or if it was of slight amplitude. On the evidence of the plant remains no distinction between a single or double oscillation in the latter part of the Late-Devensian can be made for Bodmin Moor.

Pennington & Bonny (1970) showed a tenfold increase of pollen influx into the sediments of Blelham Bog, Westmorland, at about 13000 B.P. A peak of juniper pollen percentages and influx followed. The peak of birch pollen used to define the Allerød occurred between *ca.* 12250 and 11950 B.P. and was followed by another (smaller) juniper peak. This evidence is interpreted by the authors as a result of climatic amelioration before the opening of the Allerød *sensu stricto* (judged both from the birch pollen curve and the radiocarbon dates). The situation on Bodmin Moor is directly comparable with that at Blelham Bog in that climatic amelioration is abundantly evident at about 13000 years B.P. However at Hawks Tor there is no well-marked herb pollen zone to equate with zone Ba (*Rumex acetosa*-type/Gramineae zone) at Blelham: polliniferous deposits antedating 13000 B.P. are apparently absent at Hawks Tor.

The post-Allerød climatic recession at Blelham Bog begins at about 11350 B.P. which, as the authors suggest, is about 500 radiocarbon years too early if the period is equated with the Younger Dryas.

(iii) *The nature of the climatic fluctuation*

The pre- and post-Allerød assemblages were derived from communities frequently associated with solifluction phenomena. Amorphous solifluction (slumping of soils) is associated particularly with the water-saturation of soils by snow melt-water whereas structured solifluction (stone stripes, polygons etc., occasionally leading to soil-slumping) results from ice penetration of the upper soil layers and the sorting of frost-susceptible matrices (Dahl 1956). Amorphous solifluction is associated with climates in which the annual average soil temperature is greater than 0 °C, and when the soil temperature fluctuation is reduced. These are features of an oceanic rather than a continental climate in northwest Europe.

Even though, at Parsons Park, *Artemisia*, commonly regarded as a 'steppe plant', is the most frequent pollen taxon after Gramineae and Cyperaceae, its low values indicate oceanicity of climate in the post-Allerød period. It is postulated that in the post-Allerød, under the influence of a humid airstream, continually decreasing average annual temperatures increased the frequency and amount of snowfall, at least on the higher altitude moorland. The size of snow-beds, the area of solifluction and its duration increased to such an extent that all but the most ephemeral stands of hillside vegetation were destroyed. The cumulative effect of either polar maritime or continental anticyclonic air (the latter suggested in Brown 1971) travelling over the seas southwest of the British Isles might have achieved this lowering of temperature.

The virtual absence of *Empetrum nigrum* in these supposedly oceanic pre- and post-Allerød climates is ascribed here to the physical instability of the soils. It is unlikely that the slight soil enrichment attendant upon solifluction (discussed above) would have any suppressive effect on the distribution of *Empetrum* in this area.

In summary, climatic fluctuation on Bodmin Moor in the latter part of the Late-Devensian took place in a strongly oceanic context and must be seen largely as the product of changing evapotranspiration rates and temperatures acting within that context. A curve representing an integration of these parameters may be drawn against a time scale as in figure 18. Although the detail of the curve is uncertain, least of all around the 'optimum', it provides the best type of summary to the postulated causes of vegetational change in this period.

(*f*) *Notes on Late-Devensian records of interest*

Attention is drawn to some records of particular interest from the phytogeographical or ecological aspects. The characters of certain macrofossils are recorded if not widely available in previous publications. Distributional data are taken from Hultén (1950) and Perring & Walters (1962).

Artemisia norvegica
(pollen – Hawks Tor p.a.z. HT001, 01, and above 03)

This eurasiatic arctic-montane species (Hultén 1950) is at present found in the northwest Highlands of Scotland and north of Dovrefjellet in Norway. The next nearest stations are in the Ural mountains and around the Lena river. The few pollen grains from the pre- and post-Allerød sediments in this study are important for their implication of low annual average temperatures at these times. Characters of the pollen of *A. norvegica* have recently been discussed by Praglowski (1971).

Astragalus alpinus
(pollen – Hawks Tor p.a.z. HT01, 02)

Classified by Hultén (1950) as a circumpolar arctic-montane species. At present in the British Isles it is restricted to base-rich rocks of the eastern Scottish Highlands and in Scandinavia the species (*sensu lato*) is found on the east side of the peninsular mountain chain, in east Sweden and east Finland. It is generally distributed throughout Scandinavia north of 65°.

Bidens cernua
(pollen (cf. *Bidens*) – Hawks Tor p.a.z. HT2 and (Dickson 1965) Stannon, Late-Devensian laminated silt)
(fruits – Stannon, Late-Devensian laminated silt (Dickson 1965)).

The fruits are a certain specific identification, the pollen is a generic identification based on the length of the echinae (6–8 μm), which are curved. The fossil assemblages and sediment types associated with these records point to *Bidens cernua* occupying exactly the type of habitat it prefers today; wet places where standing water accumulates in winter. The species has a southern and eastern distribution in the British Isles at present but there are older records from the Bodmin Moor area.

Campanula rotundifolia
(seed – Hawks Tor p.a.z. HT2)

Seed 0.95 mm long. Cells 90–100 μm long. Both parameters are greater than in *C. persicifolia*, the only seeds which might be confused with those of *C. rotundifolia*.

This record is important for its implied indication of well drained open soils (particularly sands and gravels) being present in the earlier part of the post-Allerød.

Epilobium alsinifolium

(seeds – Hawks Tor p.a.z. HT01, 02)

Three seeds varying in length within the ranges of *E. alsinifolium* and *E. palustre*. The polygonal surface cells lack tubercles which are characteristic in *E. palustre* (see also Dickson, Dickson & Mitchell 1970).

This European arctic-montane species (Hultén 1950) is at present found mainly in northern England and Scotland in the British Isles. In Scandinavia it is most frequent north of 60° but is rare in southern Finland.

Hippophaë

(pollen – Hawks Tor p.a.z. HT02)

Classified by Hultén (1950) as a southeast European-south Siberian species. In Britain its suggested 'native' distribution is along the east coast from the Forth to Kent; in Scandinavia a little along the Norwegian coast from 64° to 60°, in Denmark and around the Gulf of Bothnia.

A germination requirement for cold may be the reason for the coincidence of its southern limit in Eurasia with the 10 °C mean January isotherm. Inland growth is generally on gravel and sand banks, especialy if calcareous, and growth is best if sheltered from wind. Low temperatures in general leave the plant unaffected (Pearson & Rogers 1962).

The fossil record of *Hippophaë* in continental Europe has, in the light of its autecology, been taken to indicate its rôle as a pioneer woodland plant (summarized by Godwin 1956). This slight record at Hawks Tor is probably of wind-borne pollen, but there seems no reason why the plants should not have grown on Bodmin Moor during the pre- and post-Allerød since suitable situations must have been abundant. If it ever was established, though, it might well have suffered from the effects of the exposure of the Moor.

Hippuris vulgaris

(fruits – Hawks Tor p.a.z. HT001, 01, 02. Also reported by Conolly *et al.* (1950) from pre-Allerød muds at Hawks Tor and by Dickson (1965) from Late-Devensian silts at Stannon)

This is a plant at present favouring base-rich waters, and its distribution in the British Isles is principally in the areas of calcareous rock or in areas through which drainage of calcareous water takes place. Its abundance in the pre-Allerød lake sediments may be an indication of soil-enrichment attendant upon solifluction, but the record of *Myriophyllum alterniflorum*, a plant favouring base-poor waters, is richest at the same time as that of *Hippuris vulgaris*, a seeming contradiction.

Juniperus

(pollen – throughout the latter part of the Late-Devensian and early Flandrian)

(fruit – Allerød wood peat, Conolly *et al.* 1950)

It was pointed out earlier in this section that the record of juniper in the latter part of the Late-Devensian on Bodmin Moor is not as abundant as in the west of Ireland. The same is true of the early Flandrian records of the species. It is difficult to suggest a reason for this vegetational difference in areas otherwise very similar. At present *J. communis* ssp. *communis* is recorded from one locality in the extreme west of Cornwall and more frequently in western and north-western Ireland and elsewhere in the British Isles. A prostrate form is recorded from the Lizard peninsula but is intermediate in character between ssp. *communis* and ssp. *nana* (Perring 1968).

Luzula arcuata

(seeds – Hawks Tor p.a.z. HT001, 2, 3 and above 03)

Fossil seeds were 1.1–1.3 mm long and the epidermal cells were 50–55 μm long, a high proportion being isodiametric. *L. multiflora* and *L. luzuloides* are similar but the epidermis in these has a high proportion of elongate cells.

A circumpolar arctic-montane plant (Hultén 1950). In the British Isles this species is at present only found in the Cairngorms and the western fringes of Scotland; in Scandinavia in the peninsular mountain chain.

Osmunda

(spores – Parsons Park p.a.z. PP2 and throughout the Flandrian)

The Allerød record (a single spore) of this essentially southern plant (in Europe it does not occur north of southern Norway) suggests its presence around the sheltered valley floor mires and indicates the mild oceanicity of this period in southwest England. It has certainly persisted from the Late-Devensian through to the present in southwest England.

Picea

(pollen – Hawks Tor, p.a.z. HT001, 01, 02)

This is almost certainly the record of wind transported pollen, most probably derived from continental European populations, borne on anticyclonic easterly winds.

Plantago lanceolata

(pollen – Hawks Tor, p.a.z. HT01, 02, 2, 3a and in the Flandrian)

The pre- and post-Allerød records confirm local presence of the species and indicate the instability of the open plant communities of exposed and soliflucted soils.

Pyrus-Sorbus-type

(pollen – Hawks Tor, p.a.z. HT02 and in the Boreal)

Almost certainly the record of the light-demanding *Sorbus aucuparia*, present on Bodmin Moor and Dartmoor today.

Sagittaria

(pollen – Hawks Tor, p.a.z. HT02)

Sagittaria sagittifolia, classed by Hultén (1950) as a west European-south Siberian species, is generally established in Scandinavia east of the peninsular mountain chain and south of 65°. It is very common south of the Baltic. In the British Isles it is only really common south of southern Lancashire and Yorkshire. It is rare in Wales and southwest England. *Sagittaria natans* Pall. shows a more continental distribution. The Hawks Tor record is likely to be that of *S. sagittifolia* and, as suggested, probably records the initiation of climatic amelioration before the Allerød birch pollen rise.

Subularia aquatica

(seeds – Hawks Tor, p.a.z. HT01, also recorded by Conolly *et al.* 1950)

A boreal, circumpolar plant (Hultén 1950). It has a European distribution principally in Fennoscandia, Iceland, N.W. Britain and the west of Ireland.

Woodhead (1951) indicated that it only flourished when permanently submerged in static water. Its normal associates at the present day are *Littorella uniflora*, *Lobelia dortmanna*, *Isoëtes lacustris* and, in Belgium, *Elatine hexandra*. These species have not been observed in the Late-Devensian of Bodmin Moor but only in the Boreal of Dozmary Pool, where *Subularia* seemed to be absent. At present the nearest station for *Subularia* is in Dyfed, Wales.

6. Flandrian history: the period up to the Atlantic

Conclusions about the extent and nature of upland woodland communities are made only briefly in the general survey below. A fuller discussion is found in § 6 (*f*).

(*a*) *Dozmary Pool*

Assemblage zone DP1, Gramineae zone

The assemblage zone is restricted to the basal very silty detritus mud which started to accumulate 9053 ± 120 radiocarbon years ago. Megaspores of *Isoëtes lacustris* and *I. echinospora* are present and microspores, the majority referable to *I. echinospora* on the basis of size, abundant. Oospores of *Nitella*-type, seeds of *Elatine hexandra*, *Luronium natans*, fruits of *Potamogeton natans* and *Sphagnum* leaves indicate deposition in a shallow, clear water, base poor, gravelly lake. Pollen of *Luronium*, *Hydrocotyle*, *Littorella uniflora*, eu-*Potamogeton* and *Polygonum amphibium* all confirm this.

High percentage values of Gramineae and low values of tree pollen (*Betula* and *Quercus*) together with the rich herbaceous flora which includes *Poterium sanguisorba* indicate an open regional vegetation of short-turf grassland with trees limited to small areas or more continuously distributed at some distance.

Assemblage zone DP2, *Corylus*-type–Gramineae zone.

The very silty mud of p.a.z. DP1 gives way to a fine detritus mud. Initially pollen and macroscopic fossils of *Hydrocotyle vulgaris*, *Littorella uniflora* and *Menyanthes trifoliata* indicate telmatic conditions. Pollen of *Luronium natans* and *Sparganium*-type persists at lower percentage levels, while microspores of *Isoëtes lacustris*-type rapidly decrease in frequency and number. Megaspores of *Isoëtes* are absent.

Subazone DP2, Cyperaceae subzone

Increasing Cyperaceae values, biconvex *Carex* (cf. *nigra*) nutlets in the mud, appearance of abundant *Sphagnum* spores and the disappearance of most aquatic pollen suggests that a *Carex*/*Sphagnum* mire formed above the local water table; the first terrestrial stage of an active hydroseral succession. *Ulmus* pollen appears for the first time amongst the tree pollen at a level dated 8829 ± 100 B.P. and *Corylus*-type values continue to rise. The persistence of the herbaceous flora and Gramineae pollen confirms the restricted area of woodland, probably limited to sheltered valleys.

Assemblage zone DP3, *Salix* zone

Whilst this pollen assemblage is broadly similar to that of p.a.z. DP2a, *Salix* pollen reaches percentages much higher than 40 (total pollen and spores) in the lower part of the wood peat, indicating local development of fen carr. Higher values of *Betula* point to a mixed tree layer in the carr.

Assemblage zone DP4, *Corylus*-type zone and subzone DP4a, *Calluna* subzone.

This assemblage zone spans the upper part of wood peat laid down in fen carr and the lower part of a highly humified sedge peat containing some wood and abundant carbonized fragments. High *Betula* and *Salix* frequencies point to the initial persistence of fen carr in sediments dated 7925 ± 100 B.P.

The fen carr was swamped by active mire growth as evidenced by the re-establishment of high *Sphagnum* frequencies, and the appearance of *Calluna* pollen. A sparse, but varied herbaceous pollen flora, fern spores and increasing Gramineae values occur.

Percentage values of *Quercus* and *Ulmus* pollen are higher. Bearing in mind the higher percentages of *Sphagnum* spores in subzone 4a, increased percentages of these two tree species are interpreted as the record of continued spread of open woodland in the area. *Quercus* and *Ulmus* probably restricted themselves to better drained hillsides rather than valley floors.

Assemblage zone DP5, *Corylus*-type–*Pteridium* zone

This zone spans the upper part of humified sedge peat (which in this zone contains abundant fungal perithecia) and the base of the *Sphagnum/Eriophorum vaginatum/Calluna* peat. Sediment below this boundary was deposited 6793 ± 70 radiocarbon years ago.

Gramineae and *Betula* pollen percentages peak in the lower part of the zone and *Pteridium* spores appear. *Pteridium* prefers well-drained soils and has been considered as a relict of vanished woodland when found in open areas (Tansley 1939). It may be that the pattern of pollen curve fluctuations in this p.a.z. records the restriction of woodland found on better drained soils (*Quercus* and *Ulmus*) by fire, with an associated rapid spread of *Betula*, Gramineae and *Pteridium*.

Subzone DP5a, *Calluna–Alnus* subzone

The lower boundary of this subzone, dated 6451 ± 65 B.P., corresponds with the base of the raised bog peat. *Calluna* pollen is present at higher percentages than in p.a.z. DP4a and macroscopic remains confirm its growth on the bog surface. Increased Cyperaceae values are attributed to lush growth of *Eriophorum vaginatum*, tussock bases of which are abundant in the peat. *Alnus* appears amongst the tree pollen for the first time, recording the development of alder carr around the mire, together with *Fraxinus* and *Tilia cordata*. These tree taxa indicate the onset of a mild, but wetter, climate, as does the development of raised bog peat itself. Maintained values of *Quercus*, lower than in assemblage zone DP4a, but with lower values of *Betula* and tree pollen in general, indicate a recession of woodland as waterlogging of sites began.

Deposition of p.a.z. DP1, 2, 3, 4 and 5

It is clear from stratigraphic evidence, macro- and micro-fossils that these assemblages record the hydroseral succession

base poor, clear lake ⟶ *Spagnum*–sedge mire ⟶ birch-willow carr

followed by renewed paludification and the development of a raised bog. Renewed paludification may have resulted from a rise in lake water level caused by blocking of the lake drainage exit at the s.w. corner (figure 9) by fen carr. Thurston (1930) recollected the report that ‘in the dry summer of 1826, in opening a deep level through the moor at Dozmary Pool to supply a Grist Mill and the machinery of a mine with water, the roots of large oaks and alders were found at about four feet below the surface, which had evidently been cut off with the saw.'

This channel must have been made in the southwest corner of the basin near the present stream exit (which is in very silty peat) and suggests that carr had certainly developed in this better drained corner of the mire.

At present, active peat growth is taking place on the raised bog surface, but the lakeside edge of the bog is indented by a series of small erosion bays. These indicate the existence of an equilibrium between the lateral expansion of the bog and its destruction by wave action generated by prevailing winds. The zone in which equilibrium is achieved is probably related to the boundary of an area sheltered from prevailing winds provided by the ridge at the southwest end of the lake.

Winds, predominantly from the western sector, are likely to have limited bog expansion in the same way throughout the Flandrian, and so the lake has probably been continuously open water since the Late-Devensian.

(i) *The tree pollen spectra at Dozmary Pool*

Three assemblages of tree pollen are displayed and, except for that at the base of the deposit, they are introduced by a gradual increase in one of their constituent curves. That is, there seem to be no unconformities present. The series is:

Alnus + *Ulmus* + *Quercus* + *Betula*
――――――――――――― 6451 ± 65 B.P.
Ulmus + *Quercus* + *Betula*
――――――――――――― 8829 ± 100 B.P.
(base) *Quercus* + *Betula*
…………………………………… 9053 ± 120 B.P.

Even the basal values of *Quercus* rise slowly and argue for its expansion shortly before the start of deposition at this site. In the Flandrian deposits of Parsons Park only the uppermost assemblage appears, immediately above what are interpreted as early Flandrian peats with *Betula* as their important tree taxon.

At Hawks Tor (monolith 2) the uppermost assemblage of Dozmary Pool-type appears immediately above an assemblage of the lowest type. The rise of the *Quercus* curve at Hawks Tor is dated 9061 ± 160 B.P. Thus an unconformity of at least 2600 radiocarbon years at Hawks Tor, and certainly longer at Parsons Park, is indicated.

(*b*) *Hawks Tor* (*monolith no.* 2)

Subzone HT3b, *Rumex acetosa* subzone

This assemblage, the base of which is dated 9654 ± 190 B.P., occurs in a moderately humified sedge peat. *Potentilla*-type and *Filipendula* pollen are present at low levels together with *Salix*. *Sphagnum* values increase rapidly and Gramineae values are exceptionally high. Cyperaceae values rapidly drop to low levels. Development of a *Sphagnum*/sedge mire in wet grassland is inferred. The rise of *Empetrum* and *Calluna* percentages, together with the peak of *Juniperus* values and only a slight rise of *Betula* values suggests open hillside vegetation of juniper scrub and dwarf-shrub heath on well drained soils. The juniper peak is dated 9544 ± 180 B.P.

Subzone HT3c, *Empetrum* subzone

The moderately humified sedge peat of this assemblage is dated 9295 ± 180 B.P. and contains birch wood. *Sphagnum* and *Empetrum* percentages (and numbers) reach their highest while *Potentilla*-type shows a low peak and *Juniperus* pollen disappears.

Continued mire development with local birch growth in the valley bottoms and on some hillsides is suggested (the *Betula* percentages are suppressed by high *Sphagnum* spore values, but the number of *Betula* grains increases rapidly). The *Empetrum* curve records well-colonized open hillsides and a prevailing oceanic climate (Brown 1971).

Assemblage zone HT4, *Betula-Corylus*-type zone

This assemblage zone spans the boundary of sedge peat and humified black (raised bog) peat containing much carbonized material. Fresh *Betula* wood is abundant at the boundary. *Sphagnum* spore percentages drop while *Salix* values show a slight peak. *Betula* numbers and percentages are extremely high. The development of birch/willow carr, with a dense understory of ferns, on the mire surface is indicated.

Corylus-type values gradually rise in this p.a.z. starting between 9295 ± 180 and 9061 ± 160 B.P. and *Quercus* appears with low values at the latter date. *Empetrum* pollen persists suggesting that the hillside colonization by *Corylus* and *Quercus* was by no means complete.

Deposition of assemblage zones HT3b, 3c and 4

This series indicates initial development of a wet-surfaced (abundant *Sphagnum*) mire on Late-Devensian sediments and subsequent development of fen carr on the mire surface. The date of the base of this series, 9654 ± 190 B.P., is a little young for the accepted opening of the Flandrian (*ca.* 10300 years B.P., Godwin & Willis 1959), and may indicate a break in deposition between the Late-Devensian and Flandrian. This possibility is discussed below (§6(*e*)). The boundary of p.a.z. HT4 and 5 marks an unconformity of at least 2600 radiocarbon years.

(*c*) *Parsons Park*

Assemblage zone PP4, Cyperaceae-*Empetrum* zone

This assemblage zone spans the boundary between highly humified monocotyledon peats without and with carbonized material. Herbaceous taxa apart from Gramineae and Cyperaceae are present at only very low levels. *Sphagnum* spore numbers and frequencies are high with those of Gramineae and Cyperaceae respectively lower.

Development of a *Sphagnum*/sedge mire on the valley floor and spreading of *Empetrum*/*Calluna* heath on the better drained hillsides are suggested.

Assemblage zone PP5, *Betula-Empetrum* zone

This assemblage occurs wholly within highly humified peat with carbonized material and just below fresh *Salix* twigs. In all respects the herbaceous pollen assemblage is smilar to that of p.a.z. PP4 and the high *Sphagnum* percentages of that p.a.z. persist. *Empetrum* values decrease but *Betula* appears in quantity together with fern spores. Overgrowth of the *Sphagnum*/sedge mire by areas of birch/willow carr is suggested. The demise of *Empetrum* values may result from diminished incorporation of upland pollen caused by the carr canopy.

Deposition of assemblage zones PP4 and 5

These assemblage zones indicate initiation of *Sphagnum*/sedge mire growth in the early Flandrian with later overgrowth by birch/willow carr as at Hawks Tor. Assemblages at the two sites are very similar, but the paucity of the *Juniperus* record and shortness of the sequences at Parsons Park indicate a possibly unconformable record. The boundary of p.a.z. PP5 and 6 records an unconformity.

(*d*) *Indications of early Flandrian climatic change*

Iversen (1954) interpreted the fossil record of juniper scrub as a transition between park tundra and temperate forest vegetation. The same interpretation is applied to the record of juniper scrub in p.a.z. HT3b. It is likely that the *Juniperus* stands recorded in the Late-Devensian, which flourished during the Allerød, withstood the post-Allerød climatic recession protected in areas of late snow lie and relatively stable soils. The *Juniperus* peak of 9544 ± 180 B.P. is the first detectable response, in these sediments, to early Flandrian climatic amelioration.

Continued amelioration is indicated both by the development of birch/willow carr on the *Sphagnum*/sedge mires and by disappearance of juniper pollen, ascribed to the demise of juniper scrub in the face of hillside invasion by *Betula*. It is likely, in view of the continuing *Empetrum* record, that this hillside birchwood was limited in area and it was probably quite open.

Hedera appears at Hawks Tor about 9200 radiocarbon years ago, before the spread of *Corylus*. Iversen (1944) presented evidence that in Denmark *Hedera* only flourishes when average winter temperatures are greater than -1.5 °C and average summer temperatures are at least 13 °C. In the more oceanic situation of southwest England with its cool summers higher winter limiting temperatures might be expected, and this early record of *Hedera* must indicate sustained climatic improvement. The appearance of *Corylus* is a further response to amelioration but its steady, rather than explosive, rise (in an area apparently ideally open for colonization) may indicate the exposed upland situation rather than a steady, not sudden, improvement of climate.

The shallowing and mire overgrowth of part of Dozmary Pool at this time indicates either that overall precipitation decreased or that under the prevailing temperature régime evapotranspiration increased. Since this upland area is at present strongly influenced by incoming humid air from the Atlantic it may be that decreased precipitation was more important in achieving lowered water levels than increased evapotranspiration. The arresting of mire growth at Parsons Park and Hawks Tor during this period and a delay in resumption until after 6451 ± 65 B.P. supports the notion of this period having a 'dry' climate.

At the end of this 'dry' period (p.a.z. DP5, about 6800 radiocarbon years ago) the pollen curves were interpreted as indicating that upland fires altered the woodland composition. Although carbonized material is found in younger, even Late-Devensian sediments, in small quantity, there is no certainty that it was produced as a result of fire. The fluctuation of pollen curves discussed above is the first palynological evidence explicable as a result of fire. The abundance of *Hedera* and *Lonicera* pollen at Dozmary Pool coincides with this period and it is clearly indicated as the driest period in a climatic régime that had improved continuously since the opening of the Flandrian 3000 radiocarbon years before.

(*e*) *Early Flandrian unconformities*

Godwin & Willis (1959) in a discussion of radiocarbon dates from the British Isles demonstrated an unconformity at the base of the Flandrian at Hawks Tor. They suggested that paludification attendant upon the early Flandrian climatic amelioration was not immediate. The samples for dating were taken from the exposure many years after those for the pollen analysis of Conolly *et al.* (1950), but the dates are consistent with the pollen assemblages with which they are associated. The dating of sediments from p.a.z. HT3b and 3c indicates that the stratigraphically lowest sediments that show signs of climatic amelioration in the Flandrian were deposited about 9600 radiocarbon years ago. Although the ages are greater than those presented for Hawks Tor by Godwin & Willis and, indeed, belong to stratigraphically older assemblages, they are much younger than might be expected if a date of *ca.* 10300 years B.P. (Godwin & Willis 1959) is taken as the opening of the Flandrian in Britain. The newly dated sediments of this study also represent a phase of paludification on apparently post-Allerød solifluction material as did the lowest sediments of Conolly *et al.* (1950). There is no certain explanation of this apparent unconformity, but the *caveat* regarding the interpretation of these new radiocarbon ages as minimum estimates (see §4) must be borne in mind.

Later unconformities, which occur here during the period of expansion of thermophilous tree species, were not observed by Conolly *et al.* (1950). Because of active kaolin extraction at Parsons Park and Hawks Tor the sections discussed here are nearer the margins of organic deposits than those studied by Conolly *et al.* Comparison of the new Hawks Tor and Parsons Park sections with those of the previous study, with the new Dozmary Pool diagram presented here, and with the diagram of Simmons (1964*a*) for Blacklane on Dartmoor shows that these unconformities occur in the periods of pollen zones V and VI. Godwin & Tallantire (1951) stressed the warm and dry nature of the climate in the Late Boreal (pollen zone VIc) that caused the drying of Hockham Mere, Norfolk, and reduction of its size to one-fifth its initial area. Marginal borings at Hockham show reworked deposits and the intrusion of wind-blown silt at this level. The marginal unconformities at Hawks Tor and Parsons Park are ascribed to a similar reduction in the area of active bog growth.

It seems likely that these unconformities were caused by cessation of bog growth for a period considerably longer than that of p.a.z. DP5 (which lasted perhaps 200 radiocarbon years – the driest period, corresponding with pollen zone VIc (figure 28)) since Dozmary Pool itself was reduced in area soon after 9000 years B.P. in response to an effectively drier climate. An unlikely alternative is that mire growth ceased only in the driest period and that previously-laid deposits were then eroded.

The Boreal summer climate of Bodmin Moor seems to have been much warmer and drier than might be expected from its western upland position, but it is this author's opinion that the area was under increased influence of warmer and drier continental air masses at the time (Brown 1971).

Retention of water sufficient to form a lake and support the growth of the mire at Dozmary Pool during the driest Boreal period is a property of the restricted drainage outlet of the Dozmary catchment which is, as a basin rather than a valley, of different form from those of Hawks Tor and Parsons Park. In addition the greater altitude (about 38 m) of Dozmary Pool than of Hawks Tor and Parsons Park might result in a greater average annual rainfall. Shorter *et al.* (1969) summarized figures suggesting that such an altitudinal increase on the western moors can add at least 25–75 mm to the annual average precipitation at present.

It is convenient at this point to discuss in more detail the precise extent, nature and composition of the upland tree communities. Pollen spectra from the early Atlantic period (§7) are discussed solely because they are representative of a fairly stable set of tree communities.

Table 6. Early Atlantic tree pollen on Bodmin Moor

Betula	*Quercus*	*Ulmus*	*Alnus*	*Tilia*	*Fraxinus*	*Corylus*-type
538	450	63	175	4	6	1778
which are in the approximate ratio:						
8.5 :	7 :	1 :	3 :	— :	— :	28

(*f*) *Nature and composition of the upland tree and shrub communities*

Throughout this study distinction between the wet valley floors and the better drained soils of the hillsides is made. It is assumed that of the trees represented by abundant pollen in the fossil record *Betula* and *Alnus* (and *Salix*) would be more frequent on the valley floor whilst *Quercus* and *Ulmus* (and *Corylus*) would be more frequent on the hillsides although this distinction would not be absolute. It is interesting to observe that the oaks of Wistman's Wood on Dartmoor are in an exposed position which is well drained, rather than in the sheltered valley bottom. The pollen sums of seven taxa from 15 samples of early Atlantic age from Bodmin Moor (five samples each from p.a.z. HT5a DP5a and DP6) are listed in table 6.

Corylus-type (referable to *Corylus avellana*) pollen is four times as frequent as *Betula* or *Quercus*. Against the background of low tree pollen percentages this must indicate that the *Corylus* was in the form of extensive scrub, probably on the hillsides. An example of widespread *Corylus* scrub on the Burren, Co. Clare, in a very exposed situation (comparable with that of Bodmin Moor) is given by Tansley (1939). The prevalence of scrub on Bodin Moor in the Atlantic when all the thermophilous trees had undergone their maximal expansion indicates the suppressive effect of exposure on the development of extensive tall woodland. It was remarked earlier in this section that the gradual rise of *Corylus*-type percentage values in this ideally colonizable area might well be the result of upland exposure. It seems that despite ideal climatic conditions for the expansion of these thermophilous plants the exposed nature of the upland placed a brake on the initial expansion of *Corylus* and the later expansion of tree species.

Betula, *Quercus*, and in the Atlantic, *Alnus*, were the dominants of the true woodland. Some *Alnus* may have reached onto the hillsides among, presumably, both *Quercus robur* and *Q. petraea*. Low proportions of *Ulmus*, *Tilia* and *Fraxinus* indicate the local lack of calcareous soils on the high Moor. Although there were quite possibly scattered individuals of these genera among the oaks of the Moor they were undoubtedly more frequent in the woodland of the basic dolerite and greenstone outcrops at lower altitude around the Moor.

In well-attested Flandrian deposits from southern England (Seagrief 1959, 1960; Seagrief & Godwin 1960) the a.p. component is almost always 90–95 % of all pollen. The only taxa with any frequency in the remaining 5–10 % are aquatic, mire and fen species. Together with the occasional extremely abrupt tree taxon percentage changes (for instance, of *Alnus*, in association with wood peat) these percentages have been interpreted as indicating the prevalence of dense woodland around the site of deposition. Low a.p. percentages in these southern sites are associated with only Late-Devensian deposits and are held to indicate open regional vegetation.

The upland Flandrian peats in southwest England (and, e.g., Mid-Wales, Moore & Chater 1969) rarely show a.p. frequencies of more than 20–30 % total pollen. When higher values are found (e.g. Hawks Tor p.a.z. HT4, a *Betula* peak; Llyn Gynon (Moore & Chater 1969), pollen zone VIIa, an *Alnus* peak) they are associated both with evidence indicating local presence (e.g. wood) and with violent fluctuations of the pollen curves.

It would appear then that the upland Flandrian tree pollen percentages of the southwest must normally be regarded as indicating, at most, scattered woodland. This is confirmed by comparison with modern pollen spectra from *Sphagnum* polsters taken from the Fowey Valley (table 7). They clearly indicate firstly the depressive effect of high *Sphagnum* spore frequencies on a.p. percentages and secondly, when due account for the *Sphagnum* frequencies is made, that a very small area of woodland around the depositional site on the valley floor is responsible for an a.p. percentage of nearly 30.

Since in the fossil spectra presented in this and the following section the *Sphagnum* percentages are about 10 % Σ (land pollen and spores) and a.p. percentages are about 20 % Σ (land pollen and spores) they cannot be interpreted as the record of continuous forest cover over Bodmin Moor.

The evidence of tin-stream sections (summarized by Ussher 1879) is that trees did grow, at some period, at least up to 244 m (800 ft) on Bodmin Moor and they were sometimes large. Pattison (1847) (recollected by Ussher 1879) recorded the finding of a 8.5 m tree trunk (species unstated) of 51 cm diameter, resting in black, compressed peat 10 m below the surface.

Table 7. Pollen spectra from surface samples

	sample number							
	1		3		4		6	
	A	B	A	B	A	B	A	B
Betula	1.5	2.0	1.5	3.5	—	—	1.5	4.5
Pinus	3.0	4.0	1.0	2.0	1.0	1.5	1.0	2.5
Ulmus	0.5	1.0	+	+	0.5	0.5	+	0.5
Quercus	5.0	7.0	3.0	6.5	3.0	3.5	7.0	20.0
Alnus	0.5	0.5	0.5	0.5	0.5	0.5	+	0.5
Fraxinus	0.5	0.5	+	+	+	+	+	0.5
Fagus	—	—	0.5	1.0	—	—	+	0.5
Corylus-type	1.0	1.0	0.5	1.0	0.5	1.0	0.5	1.5
Salix	—	—	0.5	1.0	+	+	+	0.5
Gramineae	53.0	70.0	27.5	59.0	48.5	60.5	14.0	41.0
Cyperaceae	2.5	3.5	4.0	9.0	1.0	1.5	2.0	5.5
Sphagnum	24.0	32.0	52.0	111.5	18.5	23.0	66.0	194.5
Filicales	+	+	1.0	1.5	1.5	1.5	0.5	1.0
pastoral weeds	3.0	3.5	2.0	4.0	1.5	2.0	2.0	6.0 †
arable weeds	0.5	0.5	1.0	2.0	2.0	2.5	+	1.0

Figures in columns 'A' are % Σ (land pollen and spores).
Figures in columns 'B' are % Σ (land pollen).
Pastoral weeds: *Plantago lanceolata, P. major/media, Rumex acetosella, R. acetosa.*
Arable weeds: Liguliflorae, Tubuliflorae, Cruciferae, Caryophyllaceae, Chenopodiaceae, *Rumex-Oxyria*-type.

samples

1 *Sphagnum papillosum* polster from raised bog, Dozmary Pool.
3 *S. cuspidatum* polster, valley fen in Fowey Valley, 6 m from 0.2 ha clump of *Salix atrocinerea.*
4 *S. palustre* polster, valley fen in Fowey Valley, 46 m south of a large area of *Salix* scrub.
6 *S. cuspidatum* polster, valley fen between, and bordered on one side by *Quercus robus/Salix* stands.

† Average value of $\left(\frac{\Sigma \text{ pastoral weeds}}{\Sigma\,(\text{arable weeds}+\text{pastoral weeds})}\right) = 72\,\%$.

'Bog timber' has not been reported away from valley floors; together with the pollen evidence of the restricted area of tree growth, this suggests that the sheltered valley bottoms and some sheltered hillsides (the area of which is severely limited by the rounded contours of Bodmin Moor) were the only places for trees to flourish in the Flandrian.

In summary the 'forest cover' of Bodmin Moor, after the Boreal climatic optimum, its postulated fires and community instability, was at most an extensive cover of hazel scrub on the more, but not totally exposed, valley sides, with oak woodland restricted to the sheltered hillsides and birch/alder woods best developed on the wet valley floors around the mires.

Although an element of the lowland 'pollen rain' must be present in the upland fossil spectra it will be a very insignificant proportion of the total pollen. It is inadvisable to speculate on the extent and composition of lowland woodland, although an examination of the records of submerged forests around the coasts (summarized by Ussher 1879) showed that while oak and alder were most frequently found, elm, ash, holly, hazel, willow, fir (pine?) and beech were also present.

The early Flandrian vegetation of Bodmin Moor is summarized in figure 20.

7. FLANDRIAN HISTORY: THE ATLANTIC AND LATER PERIODS

The events recorded in the upper peats of the Hawks Tor and Parsons Park monoliths and the Dozmary Pool monolith and core are substantially similar. A full pollen analysis was made only at the first two sites.

(*a*) *Hawks Tor* (*monolith no.* 2)

Assemblage zone HT5, *Corylus*-type zone

This zone spans three sediment types and its base occurs above a long unconformity (see §6 (*b*)). The lowest sediment is humified black (raised bog) peat with abundant carbonized material which may include true charcoal fragments. At 125 cm there are thin silt lenses containing fragments of birch bark, *Juncus* seeds and a distinctive pollen assemblage. The large bark and *Juncus* seed content suggests an origin in water transport rather than wind, maybe a brief stream overspill event. Above the raised bog peat is unhumified *Sphagnum*/*Eriophorum vaginatum* peat and above this, highly humified monocotyledonous (? *Eriophorum*) peat, both without carbonized material.

The raised bog of this p.a.z. was surrounded by open woodland of limited extent (see §6 (*b*)) and certainly by lagg carr at its edge. Sizeable birch branches were observed in this peat at the valley margin in 1972 (when the peat had been cut back 6–9 m for a roadway), a record of the carr vegetation.

Percentage values of Gramineae rise continuously in this p.a.z., whilst those of trees and shrubs continue to decrease until Gramineae pollen achieves a value of 50 %. At this level the percentage curves and numbers of *Lotus*-type pollen and fern spores increase abruptly. *Plantago lanceolata* is present at low levels throughout.

Subzone HT5a, *Calluna* subzone

In general the *Sphagnum*, Cyperaceae, aquatic and mire taxon values are low, while grass values begin to rise. High *Calluna* and Ericales values suggest local growth on the mire surface (since lower Ericales values of p.a.z. HT5bi are associated with *Erica* cf. *tetralix* seeds), indicating that the surface was fairly dry.

Polypodium spores, *Alnus*, *Ulmus*, *Tilia*, *Fraxinus* and *Hedera* pollen indicate a mild, moist climate. It seems likely that *Polypodium* was growing epiphytically on trees.

Zonule HT5bi, *Lotus*-type zonule

Lower values of *Calluna* and Ericales and the appearance of *Filipendula*, *Lotus*-type, *Succisa pratensis* and *Potentilla*-type pollen, together with macrofossils of *Potentilla* cf. *erecta* and *Erica* cf. *tetralix* in the unhumified peat band suggest a wetter mire surface.

Zonule HT5bii, *Salix–Lotus*-type–Filicales zonule

This zonule spans the upper part of the humified (? *Eriophorum*) peat without carbonized material. *Lotus*-type values show a massive peak, together with *Filipendula*, *Potentilla*-type and *Succisa pratensis* values similar to those in zonule HT5bi. *Salix* and Filicales show distinct peaks which are associated with the demise of Gramineae values. Aquatic species, *Sparganium*-type and *Typha latifolia* begin to appear. Fern sporangia appear as macrofossils.

This assemblage indicates that the mire surface became much wetter and there was more free water in the vicinity in which the aquatics were established.

Within the overall trend to wetness illustrated by p.a.z. HT5 are fluctuations of percentage curves that are interpreted as reflecting extremely local vegetational change. In that they record vegetational response to changes in surface water régime of this valley they may be regionally significant. However, the fluctuations are not present in the corresponding p.a.z. at Parsons Park.

The percentage fluctuations are summarized in figure 21 and are interpreted in vegetational, drainage and climatic terms. The *rationale* for these particular interpetations is as follows

(*a*) High *Sphagnum* spore percentages record a high local water table on the mire surface because *Sphagnum* plants *in situ* will respond rapidly, by increased growth, to abundant surface water.

(*b*) High *Alnus*/*Betula* ratios reflect ideal conditions for the flourishing of *Alnus* in and around the lagg, that is, abundant soil water is present. Whether the *Alnus* populations increased at the expense of *Betula* in response to the increase of soil water, or whether *Alnus* flowered more profusely makes little difference to the pollen record. Low *Alnus*/*Betula* ratios probably record a decreased soil water content favouring the flourishing of birch. In the context of p.a.z. HT5 the pollen record is interpreted as if populations changed size.

(*c*) High frequencies of *Salix* and *Calluna*, neither of which has very well dispersed pollen, are associated with wet and dry mire surfaces respectively.

The frequent *Lotus*-type pollen of p.a.z. HT5 corresponds closely with that of *L. pedunculatus*, which is frequent in the wetter parts of the raised bog at Dozmary Pool today, but in view of the variability of the reference material this identification is only tentative. The percentage values certainly indicate local growth of a *Lotus* species.

Assemblage zone HT6, *Plantago lanceolata* zone and subzone HT6a, Cyperaceae subzone.

This zone spans *Sphagnum*/*Eriophorum* peat which is steadily less humified towards the surface. There is one band of greater humification at about 40 cm. Leaves of *Sphagnum papillosum* and *Drepanocladus fluitans* are frequent. Initially *Sphagnum* spore frequencies are high and then drop. Gramineae pollen initially reaches high values (masked by those of *Sphagnum*) which then slowly decrease whilst those of Cyperaceae increase steadily.

Development of a very wet *Sphagnum*/sedge vegetation on the surface of the previous raised bog is indicated. Presence of *eu-Potamogeton* pollen may be the record of bog pool species.

Sustained decreases of tree pollen frequencies in the presence of more or less stable *Sphagnum* spore frequencies of p.a.z. HT6a together with increased Gramineae and decreased *Corylus*-type values suggest a demise of woodland on the upland. The mire facies in the valley suggests a climate 'wet' enough to support the growth of blanket bog, at least on gentle slopes. Blanket bog extension may well have reduced the area of upland woodland. *Polypodium*, which at Dozmary Pool appeared with the expansion of thermophilous tree taxa, and which was probably epiphytically associated with them, disappears in this p.a.z., perhaps further evidence for the disappearance of upland woodland.

Plantago lanceolata, *Rumex acetosa* and *Pteridium* reach their highest values in p.a.z. HT6. Pollen of various cereal taxa, *Urtica*, *Valerianella* and *Centaurea cyanus* indicates cultivation of soils. Pollen of Chenopodiaceae and Cruciferae is most abundant in subzone HT6a. The scattered pollen *Genista*-type (referable to *Ulex*) supports the idea of a more open, base-poor upland vegetation developed in response to increased precipitation. *Tilia* pollen is absent.

The palynological indications of human activity in the area and its implications are considered later in this section.

Zonules i and ii of subzone HT6a are defined solely on the behaviour of *Menyanthes trifoliata* and *Drosera rotundifolia*-type (which show a peak and presence respectively in zonule i) and of *Rhynochospora alba* and *Drosera intermedia* (which show a peak and presence respectively in zonule ii). This sequence records a pool-hummock transition (Godwin 1956), typical of a wet raised bog surface, several of which were observed in the field exposure. *Hydrocotyle* and *eu-Potamogeton* pollen are associated with the postulated pool feature rather than the hummock.

Deposition of p.a.z. HT5 and 6

As indicated in figure 21 the lower of these assemblage zones seems the product of raised bog growth in a climate with a high precipitation/evaporation ratio. The mire surface became wetter, perhaps the result of locally impeded drainage. Since there is no overall barrier to drainage in the Hawks Tor valley this increased wetness of the mire is attributed to an increasing precipitation/evaporation ratio leading to the accumulation of surface water in excess of the drainage capacity of the valley at that time. The upper assemblage records the vegetational response to this increased precipitation/evaporation ratio when it reached a particular threshold level (Conway 1948) allowing the growth of blanket peat. Since the area of woodland was reduced and the warmth-demanding *Tilia* and *Hedera* disappear in p.a.z. HT6a it is probable that the increased precipitation/evaporation ratio was caused partly by a temperature decrease, at least during the summer period, if not the whole year.

Simmons (1964*a*) on Dartmoor, and Moore & Chater (1969) for Mid-Wales have indicated that blanket bog growth started on sloping mineral soils during pollen zone VII, and in particular around the VIIa/VIIb transition. Blanket bog growth on level soils started earlier in pollen zone VII. The initiation of blanket bog growth is ascribed by them to an increased precipitation/evaporation ratio. The initiation of blanket bog growth can be dated to pollen zone VII times in a large number of sites in upland Britain, although it is clear that the cause is similar at most sites, the variable time of initiation results from variability of altitude and local topography which control the threshold values of the precipitation/evaporation ratio necessary for blanket bog growth. Pollen assemblage zone HT5 of this study is correlated with pollen zone VII (see figure 28, §9). At Hawks Tor, although climatic change is evident in pollen assemblage zone HT5, the locally determined threshold for blanket bog formation is not achieved until the end of the zone (about 1100 B.C., see figure 26). This late initiation on Bodmin Moor as compared with Dartmoor is probably a function of the low altitude of the moorland and sites studied (see figure 3, §1).

(*b*) *Parsons Park*

Assemblage zone PP6, *Corylus*-type–*Betula* zone

This zone spans the greater part of humified monocotyledon peat with carbonized material and its base occurs above an unconformity (see §6). Throughout the assemblage there is a scattering of *Potentilla*-type, *eu-Potamogeton* and *Myriophyllum* pollen together with *Drosera intermedia* in the lower part. *Sphagnum* spore numbers and percentages are almost all lower than below the unconformity. This assemblage is very similar to that produced by raised bog (e.g. Dozmary Pool, p.a.z. DP5a). The sampling site is quite near the valley margin and presumably the site of the lagg. Stability of the pollen assemblage may indicate (in contrast to Hawks Tor p.a.z. HT5) a valley drainage system well able to cope with increased volumes of surface water. *Eu-Potamogeton* pollen may be derived from bog pool species or from plants in the lagg, where *Myriophyllum* spp. would occur.

Corylus-type values which are persistently high, generally low tree pollen percentages and the persistence of *Empetrum* all suggest an open regional vegetation, although the records of *Hedera*, *Lonicera* and *Polypodium* all indicate the proximity of some trees.

Assemblage zone PP7, *Plantago lanceolata*–*Rumex acetosa*-type zone

This p.a.z. occurs in increasingly less humified *Sphagnum*/*Eriophorum* peat in which *Sphagnum papillosum*, *S. palustre* and *Aulacomnium palustre* plants are well preserved.

The increase in values of *Potentilla*-type, *Menyanthes* and *Filipendula* pollen together with the presence of *Hydrocotyle* suggest a wetter mire surface than previously. The relative rise of Gramineae pollen percentages and fall of tree percentages against the steady *Sphagnum* percentages indicates a recession of woodland and opening of upland vegetation. *Corylus*-type virtually disappears. *Quercus* values increase, *Betula* values decrease and *Ulmus* pollen disappears. *Polypodium* spores also disappear and *Tilia* is absent. Pollen of *Plantago lanceolata* and *Rumex acetosa*-type becomes frequent. Although pollen of cereal type was observed it has not been recorded.

Human activity, demise of woodland and opening of moorland vegetation are indicated.

Subzone PP7a, Cyperaceae subzone

Similar in all respects to the zonal assemblage except that Cyperaceae values reach levels only exceeded in Late-Devensian sediments. This real increase in numbers is attributed to increased cover of *Eriophorum vaginatum* on the mire surface.

Deposition of p.a.z. PP6 and 7

In all respects the record of these assemblages is similar to that at Hawks Tor in indicating the continuous growth of raised bog in the valleys, at first more slowly and then rapidly. The increase in growth rate is associated with climatic recession and is simultaneous with the demise of upland woodland. Closer comparison of events at the two sites is difficult because the Parsons Park section is so compact, but the apparent steady submission of the mire at Hawks Tor to

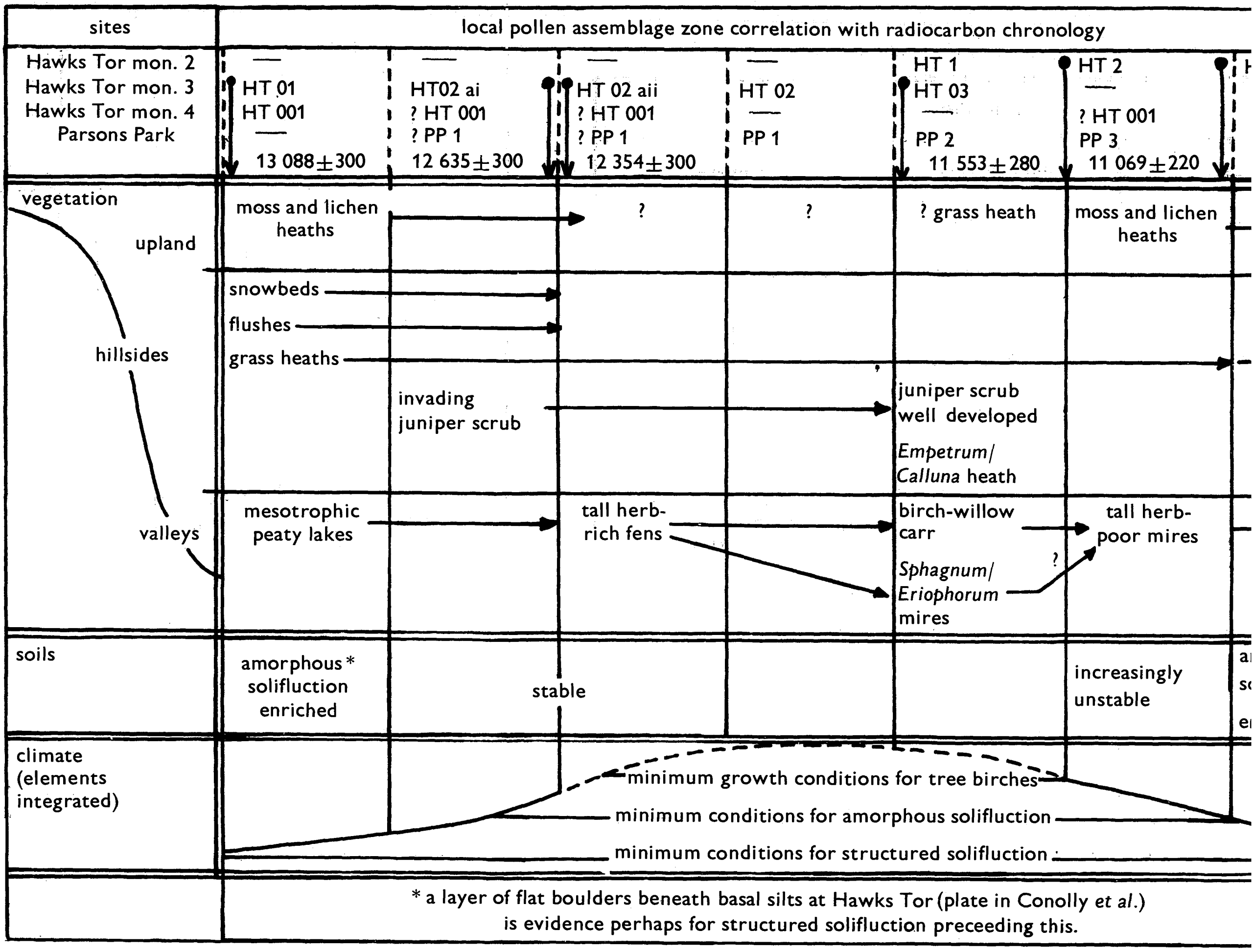


FIGURE 18. Late-Devensian soils and vegetation on Bodmin Moor.

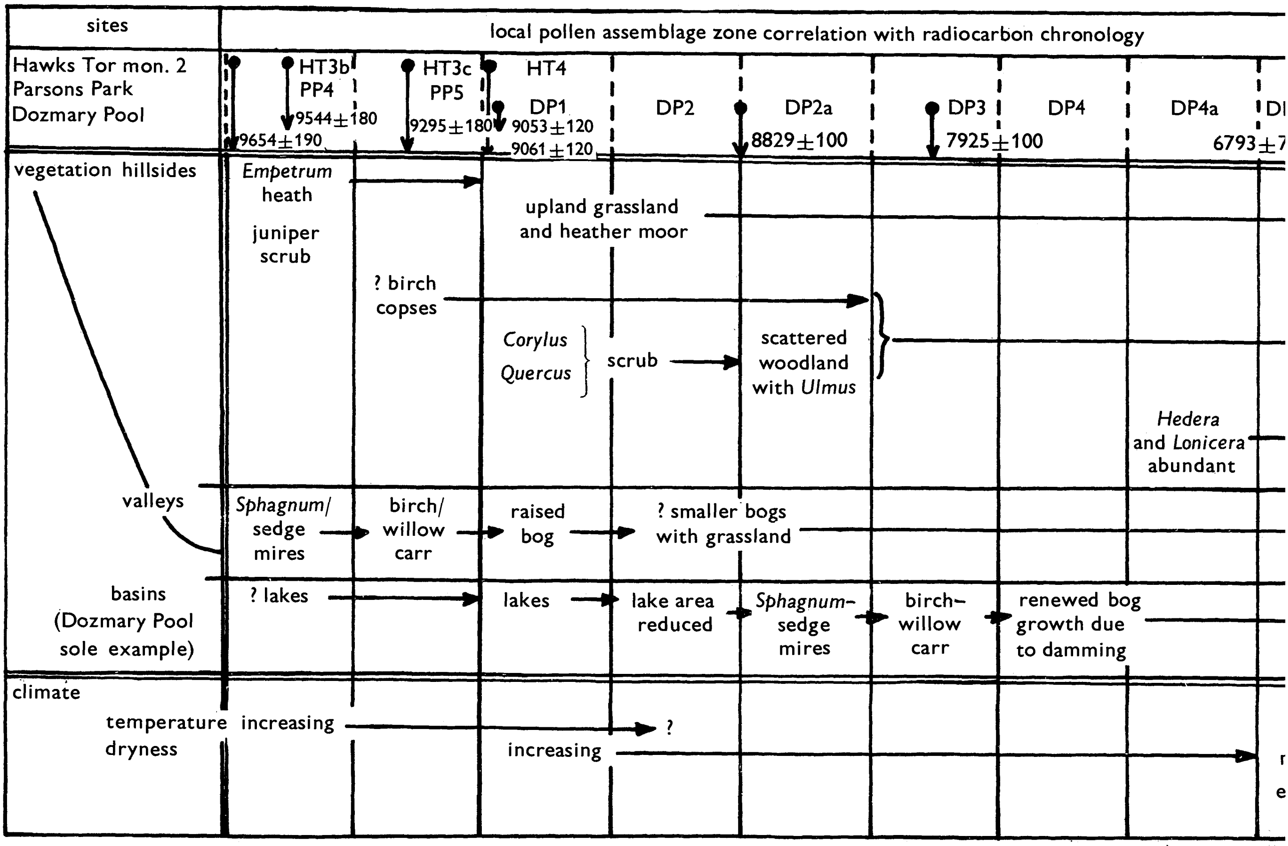


FIGURE 20. Early Flandrian vegetation on Bodmin Moor.

±220	HT 3a — — — 10 884±210
lichen hs	→
→	widespread snowbeds ?
erb- nires	→
gly	amorphous solifluction enriched

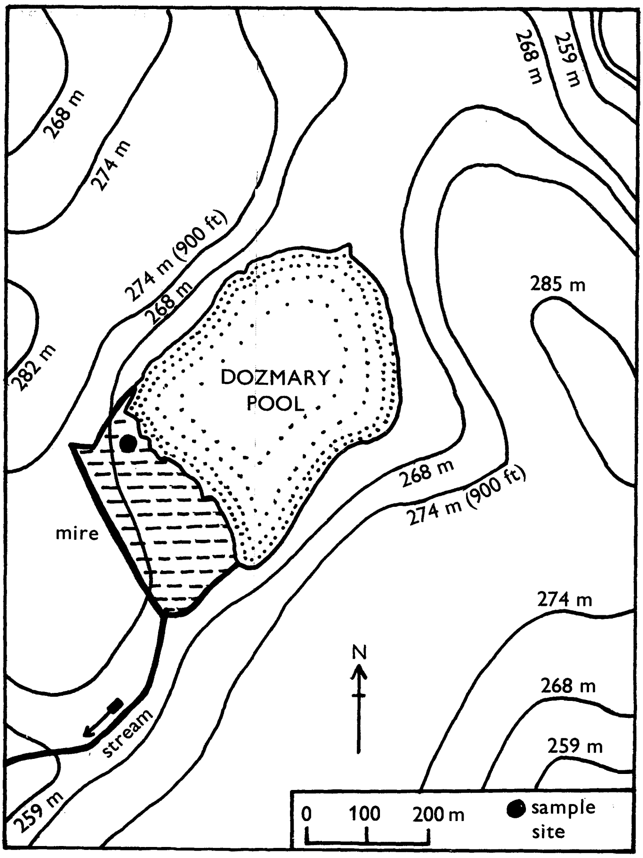


FIGURE 19. The topography of the Dozmary Pool catchment.

P4a	DP5 6793±70	DP5a 6451±65
→	→	
→		slight recession ? penetration of *Alnus*
dera *nicera* ndant →		
→		raised bogs redevelop alder carr
→		raised bog develops alder carr
→	maximal extensive fires	much reduced

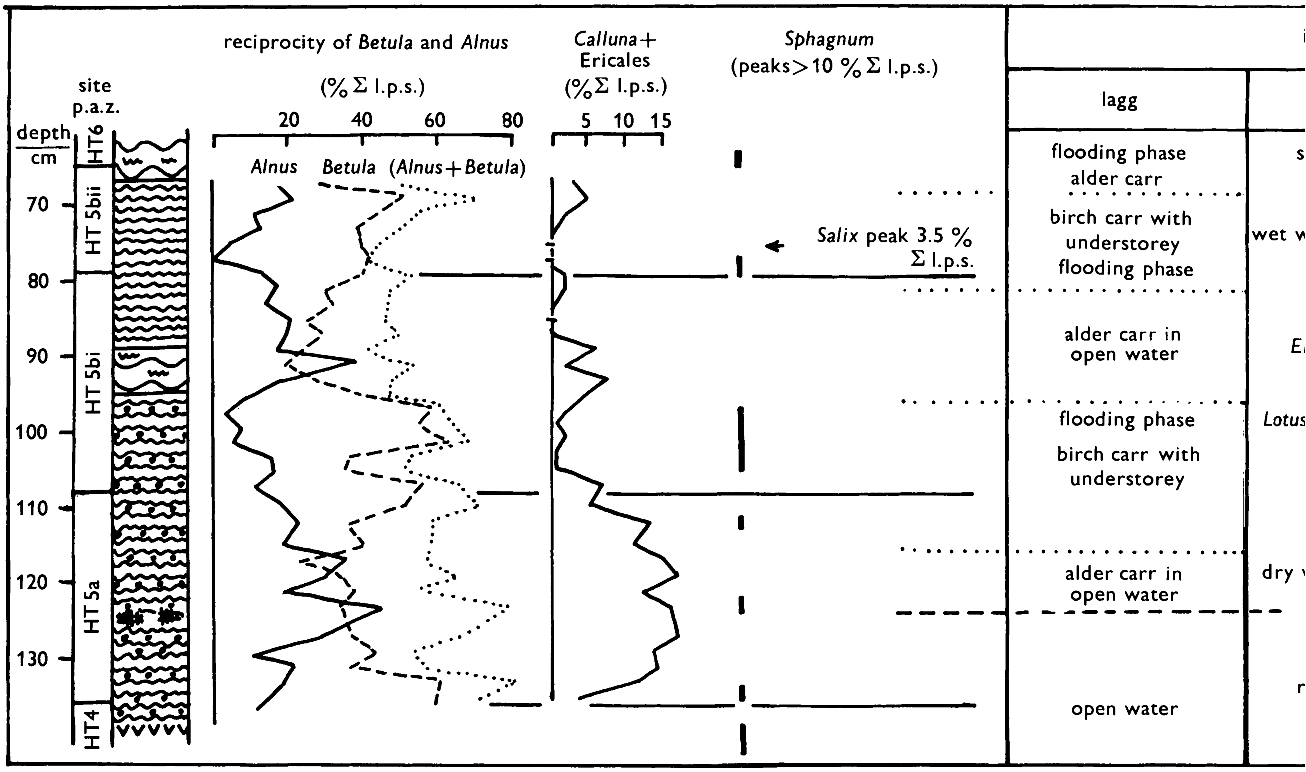
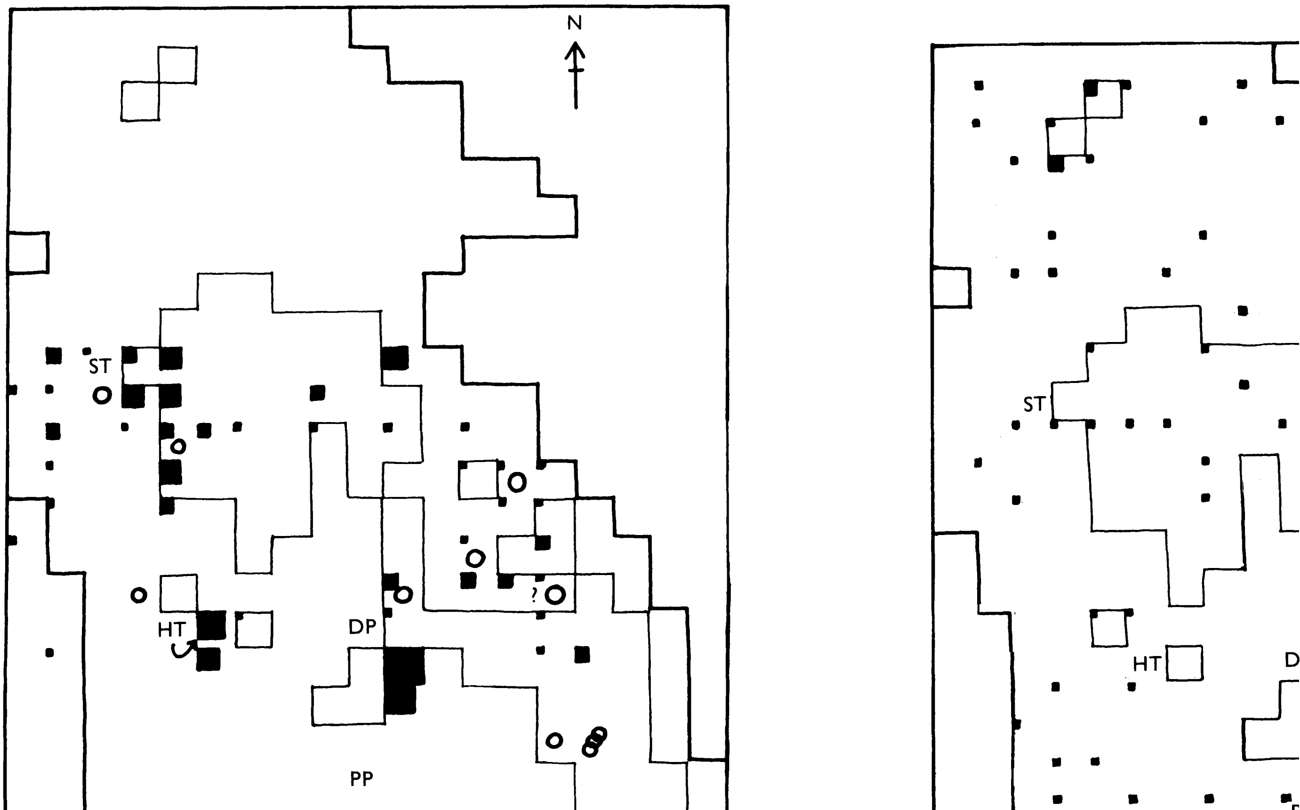


FIGURE 21. Interpretation of pollen assemblage zone HT5 – mire growth and clima



interpretation	
mire surface	climate
sphagna dominant	
wet with *Lotus pedunc* *Potentilla erecta* *Erica tetralix.* *Erioph. vag.*	persistently wet with a low and decreasing precipitation/evaporation ratio
Eriophorum vaginatum established	leads to more frequent flooding of lagg and saturation of mire surface valley-floor trees overgrown by mire
Lotus and Potentilla appear	Trees on slopes less disturbed
dry with *Calluna* abundant	
brief flooding	open vegetation of upland soils cannot stabilize hill run-off
rising above valley water table	

nd climate.

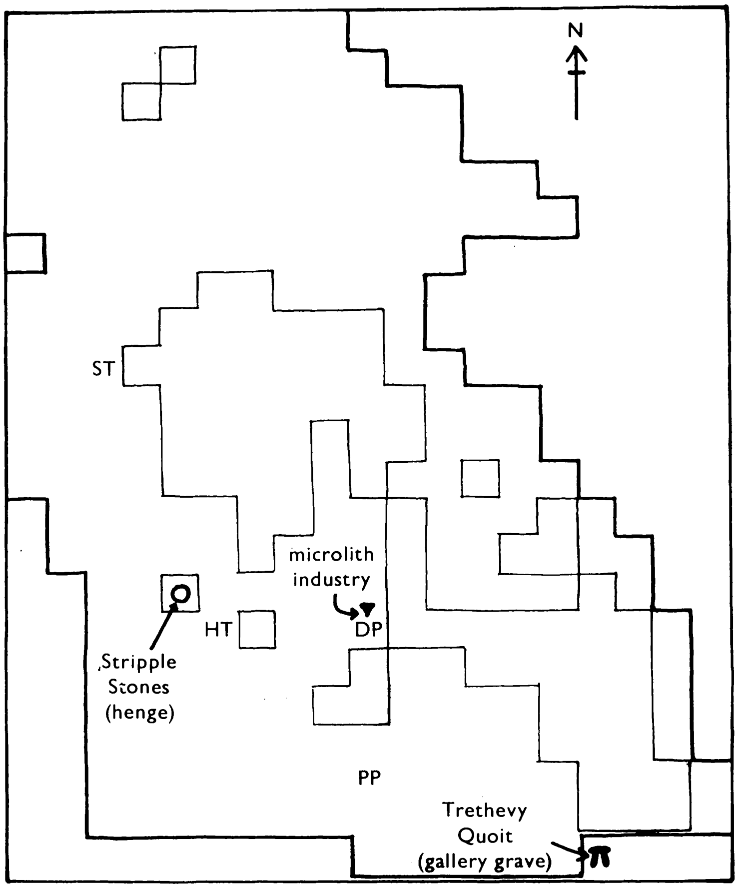
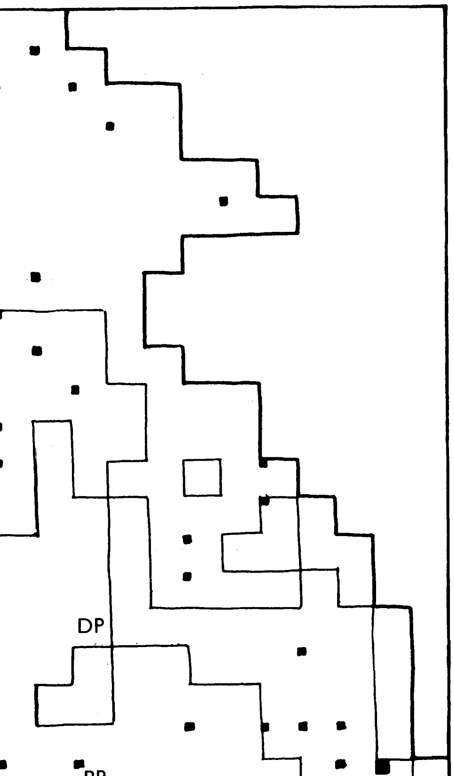
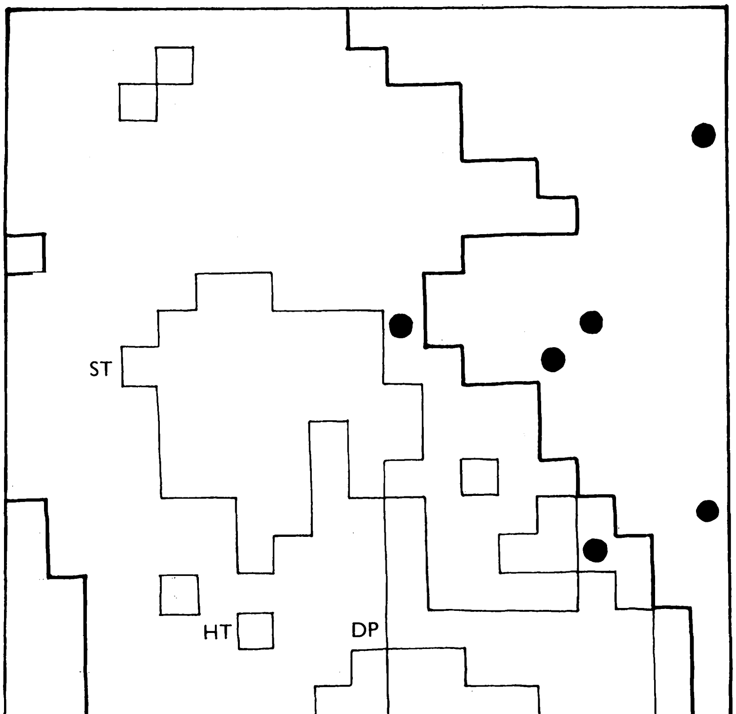


FIGURE 22. Bodmin Moor – Mesolithic and Neolithic structures. Map base as in figure 2 (p. 256).





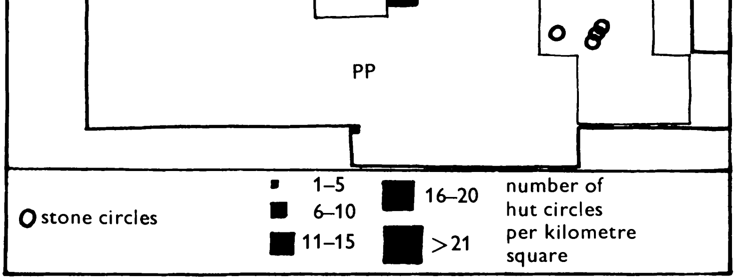
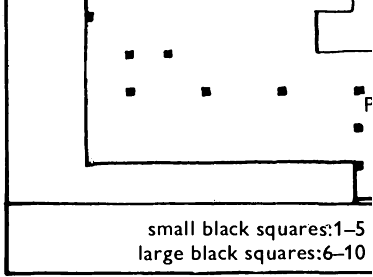
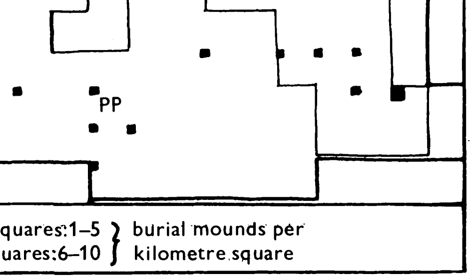


FIGURE 23. Bodmin Moore – Bronze Age hut circles and stone circles.



FIGURES 24. Bodmin Moor



min Moor – Bronze Age burial mounds.

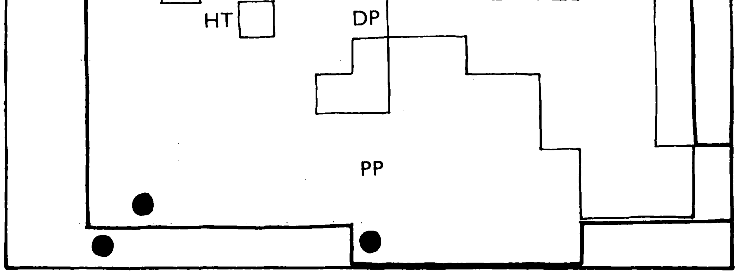


FIGURE 25. Bodmin Moor – Iron Age camps.
Each black circle represents one camp.

a continuously deteriorating climate compared with apparent stability at Parsons Park is attributed to local differences in the efficiency of valley drainage systems. Similar events in the pollen record at the level of increased rate of growth indicate the event to be regionally contemporaneous.

(*c*) *Dating of the upper Flandrian deposits*

Radiocarbon dating of these p.a.z. was not attempted because modern roots contaminate the upper peats (see § 4). Thus dating of these sediments must be by comparison and analogy with other evidence which is presented below.

(i) *Evidence from the sediments and manifestation of the 'elm decline'*

Initiation of rapid mire growth in the upper sediments is broadly contemporaneous at all three sites since it is related to the same set of pollen curve fluctuations, some of which will have regional significance. It may be that the distinct change from humified to unhumified peat can be correlated with the RY III recurrence surface of Granlund (1932), that most strongly developed and frequently observed in N.W. Europe (Godwin 1956). This would lend the transition a date of *ca.* 500 B.C.

A decline of *Ulmus* pollen percentages dated between 5400 and 5000 B.P. (Godwin 1960*a*) is a frequent feature of northwest European pollen diagrams. At neither Hawks Tor nor Parsons Park is there a distinct decline of elm pollen below the postulated RY III level. It may well be that in this upland area of exposed, non-calcareous rocks, the elm was never established in sufficient numbers to react distinctly to the cause of the elm decline. If it did react distinctly its pollen record in these deposits is so poor to start with that changes in pollen productivity or population size at some distance would be virtually undetectable. At Dozmary Pool, however, there *is* a decline of *Ulmus* values between 160 and 120 cm. If the sidereal date estimate for the level of increased peat growth rate is correct, and peat growth at constant rate is assumed from the dated rise of *Alnus* percentages to this level then peat deposited 5000 radiocarbon years ago (the 'elm decline' date) should occur at 148 cm.† This level *is* on the downward slope of elm percentage values. It is assumed, then, that the 'elm decline' is manifest somewhere between 120 and 160 cm at Dozmary Pool.

(ii) *Evidence from archaeology*

The archaeological record of the southwest peninsula is rich, but recent investigation and interpretation have considerably modified older ideas based upon it. The number of definitive statements about prehistoric population size and distribution that can be made is inevitably small, and new field recordng of monuments reveals many more than have been mapped previously (Thomas 1969). Summaries of southwestern archaeology in general (Fox 1964), and of the Palaeolithic, Mesolithic, Bronze and Iron Ages in Cornwall in particular (Thomas 1958, 1969; Dudley 1958) are available and the following summary is based on these. All dates are given in sidereal years B.C. or A.D.

Mesolithic (figure 22)

Microlith floors, 30–40 in number, are concentrated on the north and extreme west coasts of Cornwall. Dozmary Pool is the only known microlith site on Bodmin Moor, but the

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† This calculation is only an approximation since the sideral and radiocarbon chronologies are not in phase in this period (Stuiver 1970).

Maglemosian microliths have only been found in an unstratified context (Wainwright 1960; Thomas personal communication).

Neolithic (figure 22)

In many sites Neolithic flints are stratified immediately above Mesolithic and in the Land's End peninsula the areas of the two are mutually exclusive, suggesting temporal overlap of the two cultures about 3000 B.C. Spatial concentration of known sites is in the Land's End peninsula, although one of the five southwestern henges is on Bodmin Moor (Stripple Stones near Hawks Tor). Evidence from Carn Brea, Cornwall (Mercer 1970*a*) and Hembury, Devon (summarized by Fox 1964) shows that the Neolithic economy was based on partly pastoral and partly arable farming. *Triticum dicoccum* and *Hordeum* were certainly cultivated.

Of the Megalithic peoples who arrived from France and Iberia the evidence of tombs points to their distribution around the coasts and particularly on the Land's End peninsula. This distribution reflects maritime immigration. On Bodmin Moor Trethevy Quoit (a gallery grave) is the only known Megalithic monument.

Bronze Age (figures 23 and 24)

Between about 2000 and 1700 B.C. the first Beaker People arrived in Britain, principally from the east. Evidence indicates abundant cultural ties between the southwest and southern England, and some with France, late in this period. Known settlements are, again, coastal, but concentrations of beakers are found on Dartmoor besides the Land's End peninsula and Bristol Channel coast. Association of Beaker and Food Vessel Peoples is indicated by the contents of the cremation burials associated with stone rows on Dartmoor. Stone circles were built independently, but excavation of the cairn at St Neot, Bodmin Moor (Wainwright 1965) indicates that the same people were responsible for stone rows and circles. Nine circles occur on Bodmin Moor and may broadly be dated between 1700 and 1500 B.C.

Bronze Age artefacts have been found in association with tin-streaming works and it is clear that the immigrants of this period were concerned with extraction of metals. That cultural independence of the southwest, although not isolation, prevailed at this time is clear from the available artefacts. It may be ascribed to the persisting influence of the Neolithic and Megalithic cultures, which were not, though, entirely isolated from peoples further east (Peacock 1969). The period 1300–500 B.C. was a long stable period in the Bronze Age when consolidation of settlements, expansion of population, and development of new tools took place. Many of the hut circles in the open moorland (which occur in distinct concentrations as compared with contemporaneous burial mounds) are ascribable to this period. Excavation of the hut circles at Stannon Down (Mercer 1970*b*) showed that cultivation was a minor part of the agricultural economy of a settlement dated (principally by pottery) to the period 1500–1100 B.C. The Garrow Tor (Bodmin Moor) mixed farming settlement was occupied in the period 200–100 B.C. at the opening of the La Tène Iron Age (Dudley 1958). The archaeological evidence indicates that the abundant fields associated with the Bronze Age settlements are related to a primarily pastoral economy.

Iron Age (figure 25)

The predominant Iron Age culture of the southwest peninsula was La Tène I, the peoples arriving between 200 and 100 B.C. from France. The preceding Late Hallstatt peoples, whose first settlements in the southwest were concerned with tin-trading, are little represented in the area, and the Belgic groups of 100–1 B.C. seem, at the most, to have been refugees from the east. Persistent Bronze Age-type culture on the moorlands (indicated by the Garrow Tor excavation) was contemporaneous and had direct contact with the La Tène peoples who built numerous multivallate hill forts mainly outside the upland area. There is plentiful indication that principally pastoral agriculture was their economic mainstay, but the centralization of metal-working was an important advance in economic development.

In summary it appears that Bodmin Moor only became *colonized* during the Bronze Age, and then probably at a steady rate, by people whose agricultural economy was pastoral rather than arable. This occupation persisted into the Iron Age when a similar economy was increasingly practised outside the upland areas by tribal, rather than village or family groups.

Cereal pollen percentages at all three sites are very low. At Hawks Tor the site is within 500 m of at least 16 hut circles and so the cereal pollen record of any cultivation associated with this settlement should be distinct (Heim 1962). The sparse cereal pollen can only indicate a very small cultivated area, if indeed there was one, associated with the settlement.

Mercer (1970*b*), in the excavation at Stannon, estimated the cultivated area associated with 18 hut circles to be 0.7 ha. He calculated that at least 41 ha were necessary to support the population of the settlement on an arable basis alone. The scarcity of querns indicates the small part that grain played in the economy.

TABLE 8. WEED POLLEN SPECTRA OF UPPERMOST PEATS AT HAWKS TOR AND PARSONS PARK

(The percentage index in column four is an adaptation of the 'arable/pastoral index' of Turner (1964).)

pollen assemblage zone	Σ pastoral† weed pollen	Σ arable† weed pollen	pastoral weeds as % of agricultural (pastoral + arable) weed pollen
HT6ai	10	2	83
	15	3	83
	18	1	95
	22	3	88
	30	3	91
	40	3	93
HT6aii	37	4	90
	28	5	85
	18	2	90
	28	6	82
	20	6	77
PP7	9	12	43
	69	6	92
	24	4	86
PP7a	37	8	82
	19	3	86
	21	4	84
	73	12	86
	15	5	75
Present day (Fowey Valley)	—	—	72

† Pastoral and arable weeds are listed in table 7, §6.

During the period in which cereal pollen is present in the peats percentages of *Plantago lanceolata*, *Rumex acetosella* and *Urtica* pollen and *Pteridium* spores increase. These are all perennials associated with grazed, rather than regularly cultivated, ground. In summary, the ratio of pastoral weed to total weed (pastoral + arable) pollen is high (table 8), completely in accord with the notion of predominantly pastoral agriculture developed from palynological and archaeological evidence.

The simplest interpretation to place on the pollen curves is that primarily pastoral agriculture was well developed only after the sub-Boreal–sub-Atlantic recession (RY III level, *ca.* 500 B.C.), but that a little cereal growing, at least, was taking place right at the beginning of this recession. Later tailing off of *Plantago lanceolata* percentages, both at Hawks Tor and Parsons Park may indicate a decline of upland agriculture. Whether the curve of *Plantago lanceolata* below the level at which cereals appear records human activity is discussed in § 6 (*d*) (i).

(iii) *Correlation of the archaeological and pollen records*

Placing the broad interpretation of the pollen record beside the archaeological record the respective chronologies are not in agreement – the pollen evidence of maximal agricultural activity comes well after both the Bronze Age upland and La Tène lowland occupation periods.

The stratigraphic evidence at all three sites in this study shows that increased rates of peat growth developed in at least two stages. A moderately humified peat appears between the highly humified and very fresh peats. If the upper peat junction is equated with the opening of the sub-Atlantic (and RY III) and the lower equated with RY IV (dated to 1200 B.C. (Granlund 1932)) then the simplest interpretations of the pollen and archaeological records correspond well (figure 26).

(*d*) *Anthropogenic interference with vegetation*

(i) *Before the Bronze Age*

If the revised chronology of peat accumulation presented in figure 26 is taken as correct the Dozmary Pool 'elm decline' level, with all the assumptions that its calculation involves, should be at about 145 cm. Levels here, and below, must correspond with the Mesolithic period. The microlith industry at Dozmary Pool might be associated with any of these levels although the large burnt peat fragments at 145–150 cm may relate to the microlith occupation. The fragments are large pieces of raised bog peat, mainly *Eriophorum vaginatum* tussock bases, which have burned until a charcoal layer, developed outside, prevented combustion of the inner peat. These fragments are recorded as 'charcoal' from the same levels by Conolly *et al.* (1950), but the tree pollen curve fluctuations associated with this level in their diagram were not discussed in any detail by them because they were considered insufficiently detailed. It is clear that exact determination of the nature of this burning layer, which is so distinct, and its relation to the Mesolithic occupation levels awaits a full survey of the basin in an archaeological context.

After considering the possibility that woodland on Dartmoor was never extensive (Simmons 1963) Simmons (1964*a*) argued that the forested area of Dartmoor, at least in the drier Boreal, was quite large. However, his diagrams are interpreted here as indicating essentially open moorland, as on Bodmin Moor, with perhaps slightly greater open woodland cover (see § 6). On his interpretation of the Dartmoor pollen curves (as indicating initially widespread forests) rest Simmons' later postulations of the nature of human interference with the vegetation.

At Blacklane, Dartmoor (Simmons 1964*a*), curves of Gramineae pollen and *Pteridium* spores rise about the level of the *Alnus* rise, and *Artemisia* and Chenopodiaceae appear above. This is interpreted by him in the same way as a similar record at Dozmary Pool (p.a.z. DP5a) here – as a record of Boreal fires opening the forest and altering its composition. However, Simmons attributes the fire to human influence (directly or indirectly) rather than to a feature of the dry climate alone, as here. That *Plantago lanceolata* curves above these levels are continuous at low values, and that carbonized material and charcoal fragments are present at least until the postulated RY IV (1100 B.C.) have been attributed by Simmons (1964*a*, 1969) and Smith (1970) to human interference.

The emphasis of interpretation has largely been on deliberate burning policies (e.g. for driving game). It is indeed clear that Neolithic peoples used Bodmin Moor for hunting (finds of arrow heads are frequent) and deliberate burning policies may have been important although the evidence is insufficient to make a final decision.

At Hawks Tor during the post-Boreal period the total tree pollen percentages decline steadily, a corollary of increasing grass pollen percentages, since the numbers of tree pollen grains are constant. However, the birch and alder values and numbers decrease, while those of oak rise. This was interpreted (see figure 21) as the effect of an increasingly 'wet' climate allowing expansion of valley bog at the expense of valley woodland leaving upland woodland, on better drained soils, unaffected. Increase of Gramineae pollen percentages is also attributable to this mire expansion. There is thus no post-Boreal evidence of fire reducing the small area of upland woodland that seems to have existed and *deliberate clearance* of woodland by later Mesolithic or Neolithic peoples cannot have been of any measurable extent and, indeed, would seem to have been unnecessary in view of the open landscape.

(ii) *The Bronze Age and after: upland occupation*

Palynological indication after the postulated RY IV level is, initially, of steadily increasing pastoral agriculture with a little arable, as discussed above. At Kes Tor, Dartmoor, Blackburn (in Fox 1954) showed that Iron Age tillage took place after the growth of blanket peat had started. Macroscopic records of grain by Jessen & Helbaek (summarized by Godwin 1956) in southwest England are predominantly of naked and hulled barley, *Hordeum polystichum*, with some *Triticum dicoccum*. *Avena* had only been observed in a Viking context at Hellesvean, Cornwall, and *Secale* not at all. In the pollen record, however, the two latter genera and similar pollen types have been observed at Hawks Tor. The record of *Secale cereale* and *Centaurea cyanus* pollen (two species often closely associated (Salisbury 1964)) in the same assemblage zone strongly suggest that rye was cultivated.

Spores of *Pteridium* are abundant in the Bronze Age and later peats: this is consistent with the postulate that bracken invaded the undisturbed field boundaries and perhaps the grazed fields. Pearsall (1951) pointed out that upland *Pteridium* stands are destroyed in cattle grazings because the animals eat the young fronds and trample the young growth. In other grazing areas *Pteridium* maintans its hold. The abundance of *Pteridium* spores in the upper peats may indicate that the area was lightly grazed by cattle (and sheep) or that sheep were the principal livestock or that the areas around the mires were left ungrazed. The frequencies of *Pteridium* spores indicate that *Pteridium* was abundant around the mires, since no *Pteridium* spores were observed in the modern spectra from the Fowey Valley (summarized in table 7, §6), although *Pteridium* stands are extensive on the grazed hillsides of the valley at present. (However, the weed pollen flora of these modern spectra is fully consistent with the pastoral economy; 72 % of all weed pollen is of pastoral type.)

It may be that in the Bronze Age period of pastoral agriculture *Pteridium* spread onto the drier marginal slopes of the mires as well as into the fields from the woodland habitats it had formerly occupied, which were severely reduced in area by bog enlargement. Simmons (1963) suggested that the demise of *Alnus* in pollen zone VIII times on Dartmoor was also an indication of destruction by tin-streamers as much as by blanket bog extension. An abrupt demise of *Alnus* similar to that described by Simmons is present in p.a.z. HT6ai/6aii in this study.

Concomitant with the spread of *Pteridium*, favoured by pastoralism, was an expansion of *Ulex* which would be easily dispersed by ants (Tansley 1939) and spread in this open situation. It was possibly derived from populations in the hazel scrub.

Two grains of *Castanea* pollen recorded from p.a.z. HT6 and HT6aii may indicate the establishment of the tree locally in, or before, the Bronze Age, possibly the result of Beaker, or earlier, imports of the nuts as a tradeable commodity.

(iii) *The Iron Age: lowland occupation*

The record of *Fagus* pollen in this study is complicated by its presence as a contaminant in the *Nyssa* suspension used to calculate pollen content. When appropriate (see appendix 1) examination of the *Fagus* percentages is made, it is clear that the true *Fagus* record is limited to the less humified peats above the postulated RY IV. In the diagrams of Conolly *et al.* (1950) where such contamination was not a problem, *Fagus* appeared in a similar stratigraphic position (only at Hawks Tor) and was used to define, partly, pollen zone VIII. Only the percentages of *Quercus* pollen rise relative to other tree species in these upper peats and indicate the increased importance of *Quercus* in the woodland of this wetter period. The spread of *Fagus* in this cooler and wetter period is best explained (Godwin 1956) in terms of its easier establishment in woodland that has been disturbed by human activity. It may be that in Cornwall it was the intrusion of Iron Age peoples into the forested lowlands that allowed *Fagus* to spread.

In summary, the record of p.a.z. HT5 and 6 and PP6 and 7 extends almost from the beginning of the Atlantic period (shortly after 6500 B.P.) well into the sub-Atlantic period and the uppermost peats probably date from within the Christian period. Vegetational changes observed within this period are summarized in figure 27.

(*e*) *Notes on Flandrian records of interest*

Elatine hexandra

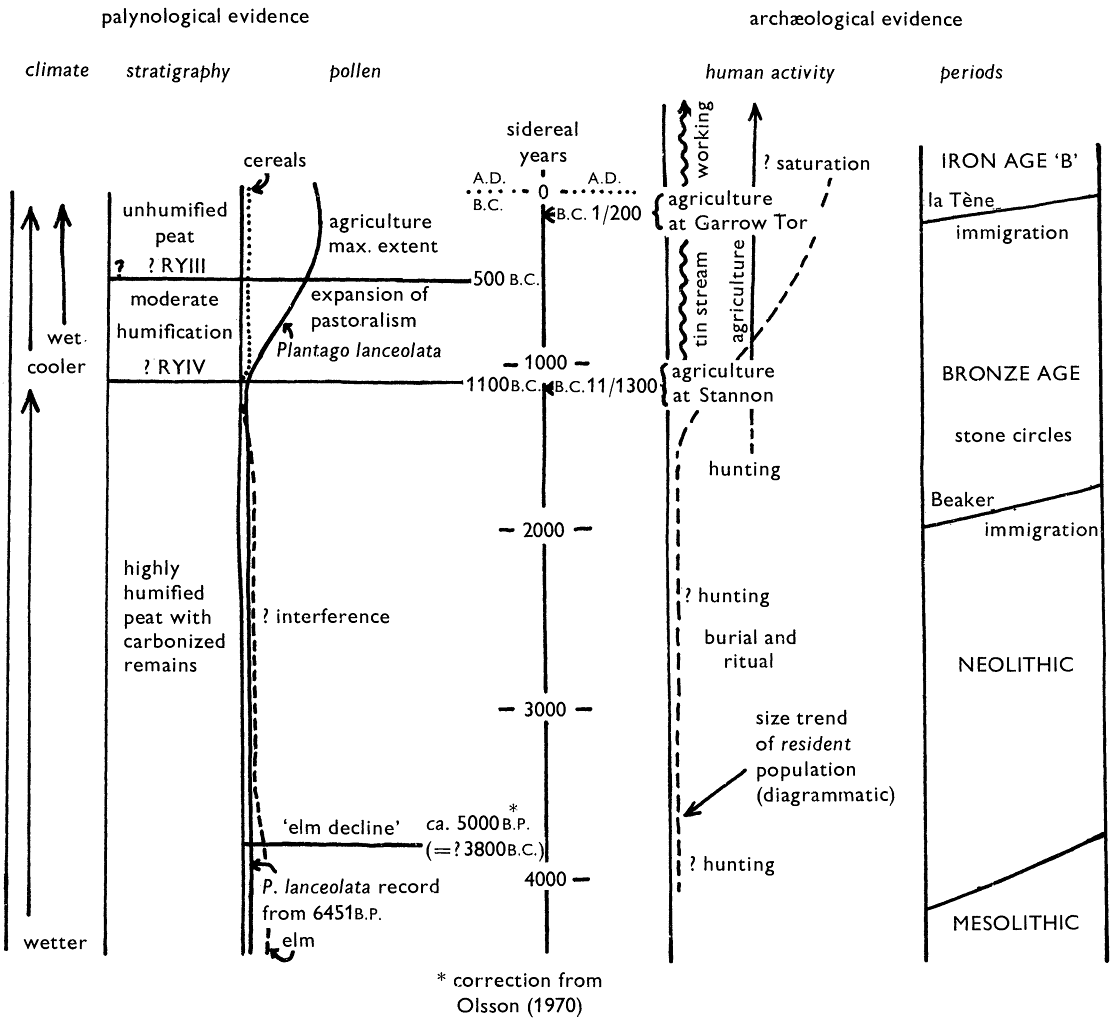
(seeds – Dozmary Pool, p.a.z. DP1)

A European–Atlantic plant (Hultén 1950), it is found only south of 60° in peninsular Scandinavia, not at all in Finland. It has a scattered distribution in the British Isles. This species was present with *Luronium natans* (see below) 9000 radiocarbon years ago in Cornwall but it alone is now found there.

Ilex

(pollen – Dozmary Pool, above p.a.z. DP5a (near ?RY IV), also recorded by Conolly *et al.* (1950) from Dozmary Pool, early pollen zone VII)

This European–Atlantic plant (Hultén 1950) at present occurs in Scandinavia only in the extreme west of Norway and in Denmark. It is generally distributed throughout the British



* correction from Olsson (1970)

Figure 26. Pollen stratigraphical and archaeological correlation on Bodmin Moor.

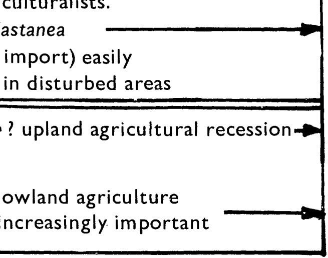
sites	local pollen assemblage zones with chronology of figure 26				
Hawks Tor mon. 2 Parsons Park Dozmary Pool	HT5a PP6 DP5a 6451 ± 65 B.P.* 5500 B.C.	HT5bi PP6	HT5bii PP6 ca. 1100 B.C.	HT6 PP7 ca. 500 B.C.	HT6ai PP7a
vegetation					
summits	? grass/ericaceous heath →			area extended by pastoral economy	
hillsides exposed	scrubby oaks extensive hazel scrub →	spreading slightly →		severely cut back by spread of mires and failing climate →	some oakwood and hazel scrub p
sheltered	tall oak woods →			rapid spread of *Pteridium* and *Ulex* in place of trees	
valleys	birch/alder woods →	area reduced slightly →		severely cut back by spread of mires	very small area
	raised bogs →	spreading slowly →		blanket bog develops	
surrounding lowlands	? dense oak woodland especially on sheltered se side. elm, lime and ash more frequent than in upland woodland →				woodland opened by la Tène agriculturalists *Fagus* and *Castanea* (? a Beaker import) ea established in disturbe

6ai 7a	HT6aii PP7a
my →	→
akwood zel scrub persists →	→
x →	→
small areas persist →	→
→	→
pened by culturalists. *astanea* → import) easily in disturbed areas	→

lowlands	especially on sheltered se side. elm, lime and ash more frequent than in upland woodland →	→	→	→	la Tene agriculturalists *Fagus* and *Castanea* (? a Beaker import) ea established in disturbe
human activity	hunting →	→	primarily pastoral agriculture established on upland →	→	? upland a lowland agr increasingly

*Approximation from Olsson (1970).

FIGURE 27. Later Flandrian vegetation on Bodmin Moor.


culturalists.
astanea
import) easily
in disturbed areas
? upland agricultural recession
owland agriculture
ncreasingly important

(*Facing p.* 308)

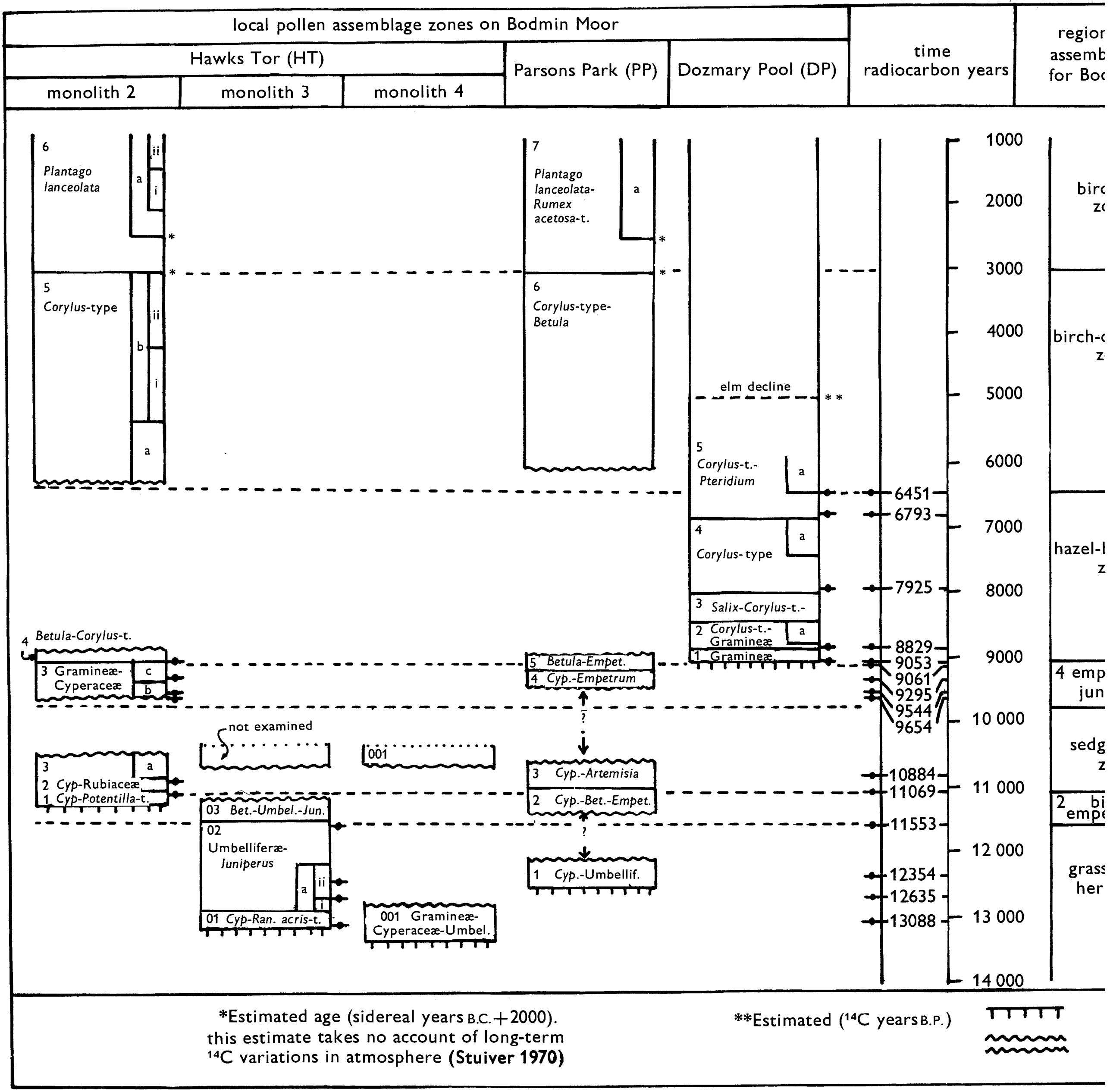
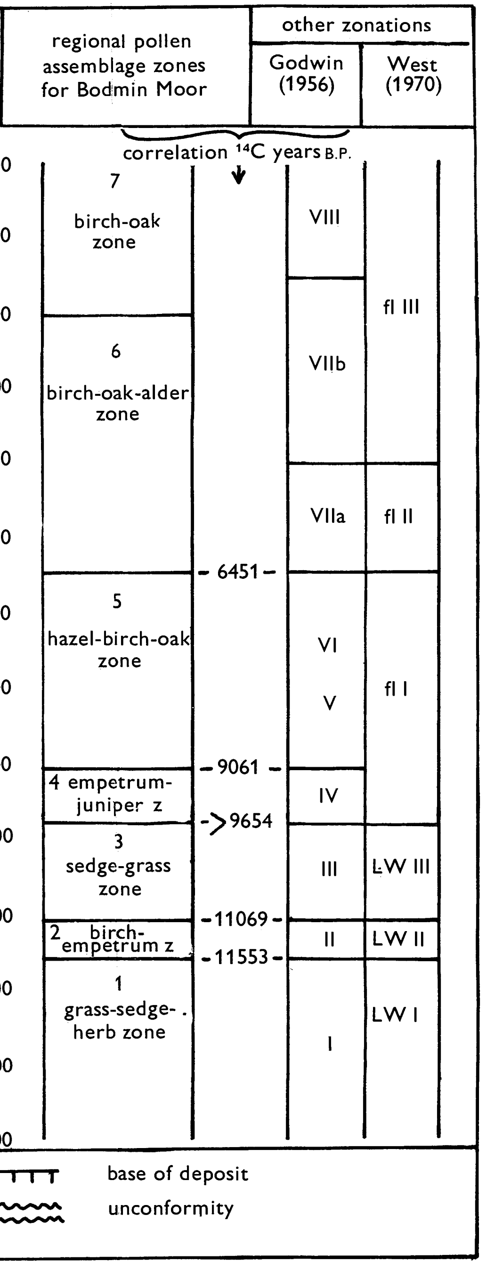


FIGURE 28. Local and regional pollen assemblage zones on Bodmin Moor.


regional pollen assemblage zones for Bodmin Moor
other zonations
Godwin (1956)
West (1970)
correlation ¹⁴C years B.P.
7 birch-oak zone
6 birch-oak-alder zone
5 hazel-birch-oak zone
4 empetrum-juniper z
3 sedge-grass zone
2 birch-empetrum z
1 grass-sedge-herb zone
6451
9061
>9654
11069
11553
VIII
VIIb
VIIa
VI
V
IV
III
II
I
fl III
fl II
fl I
LW III
LW II
LW I
base of deposit
unconformity

oor.

Isles. Its Norwegian distribution coincides with the most oceanic (Poore & McVean 1957) area of that country and Godwin's (1956) summary presented the overwhelming evidence for the restriction of *Ilex* to areas with a temperate, oceanic climate. In particular, it cannot grow when the mean temperature of the coldest month drops below −1 °C (Iversen 1944).

The single record from this study may be added to the two of Conolly *et al.* from the same site. In view of the low pollen productivity and entomophilous habit of the plant they may be taken to indicate that the mildest oceanic periods in southwest England were the Atlantic and sub-Boreal. This again emphasizes the climatic affinity of southwest England and Ireland, since the Pennine records indicate that the sub-Atlantic was the most oceanic period in Central England (summarized by Godwin, 1956).

Luronium natans
(pollen and seeds – Dozmary Pool, p.a.z. DP1, 2)

A European–Atlantic species (Hultén 1950) with a distribution in Scandinavia along the west coast of Denmark. In the British Isles it is found in northern Wales, Salop and the Lake District. The reasons for its restriction to these areas of Britain today are not clear, but its present range is consistent with the climatic interpretation of the pollen assemblage zones in which the seeds and pollen occur at Dozmary Pool, that is, a climate both warmer and drier than the extremes of oceanic, but still oceanic in essence.

Littorella uniflora
(pollen – Dozmary Pool, p.a.z. DP1, 2)

A sub-Atlantic species (Hultén 1950). In Scandinavia at present it has a scattered distribution between 65° and 60° and is most frequent in southern Sweden from 60° southwards. In the British Isles it is most frequent in northwest Scotland, north- and southwest Ireland, northwest Wales and southwest England. It is however absent from Bodmin Moor at present.

Poterium sanguisorba
(pollen – Dozmary Pool, p.a.z. DP1)

This species is most commonly associated, though not exclusively, with calcareous grassland. It is scattered throughout Cornwall at present. This single pollen record may indicate the existence of fairly dry, short-turf, neutral grassland on Bodmin Moor in the Boreal which must have been reduced in area under the effects of later climatic recession and increased precipitation.

8. Discussion: the Atlantic affinity of southwest England

As judged by its vegetational history southwest England has been dominated for at least the past 13000 radiocarbon years by climates tempered by, and mostly generated over, the neighbouring Atlantic Ocean. The two broad conclusions made from the study of the Late-Devensian deposits of Bodmin Moor were that climates in that period were strongly oceanic and that vegetation was subject to extreme exposure. It is, however, in the development of the Flandrian forests that southwest England convincingly shows its similarities with other areas on the Atlantic seaboard of Europe.

(a) *Early Flandrian forest development in western Europe*

(i) *The British Isles*

A tree pollen percentage curve that begins at low levels and maintains them before rising to higher values can be interpreted in two ways. The first is that the low values represent long-distance transport of pollen from approaching populations before the expansion of populations at the depositional site; the second is that the low values represent pioneer populations at the depositional site and the higher percentages record the later expanded population. Both interpretations imply a gradual expansion of the species in any one area.

There is evidence for the early (pollen zone IV) establishment of *Quercus* at Gosport, Hampshire (Godwin 1945) in open pine–birch woodland. The diagrams of Seagrief (1959, 1960) and Seagrief & Godwin (1960), however, showed dense pinewoods elsewhere in the early Flandrian of southern England. Percentage curves of *Quercus* and *Ulmus* pollen reflected this either by having low introductory values or by remaining extremely low throughout. At Thatcham, Berkshire, 69 km north of Gosport, oak expanded about 9800 B.P. (Godwin & Willis 1964) and at 9500 B.P. formed 20–30 % of the tree pollen (Churchill 1962; Godwin & Willis 1964).

Thus the evidence for very early Flandrian establishment of *Quercus* in the pine–birch woodland of southern England is very strong. Oak must have spread rapidly north- and westwards from there because it is recorded at Roddans Port, Northern Ireland by 9100 B.P. (Godwin & Willis, in Morrison & Stephens 1965) and Scaleby Moss, Cumberland by 9000 B.P. (Godwin *et al.* 1957).

On neither Bodmin Moor nor Dartmoor do the *Quercus* pollen curves have prolonged low-percentage introductory phases. The curves are interpreted by the present author as indicating immediate expansion of oak populations. They never covered the whole of the uplands, being restricted by the lack of shelter, but they rapidly achieved their maximum possible extent and became the dominant upland tree species (see §6). Oak began to expand about 9060 B.P. at Hawks Tor and Dozmary Pool shortly after the expansion of *Corylus* (between about 9250 and 9060 B.P.). The immediate expansion of *Quercus* is ascribed to the extensive areas of grassland, open birch woods and immature *Corylus* scrub that covered the uplands, which would have provided little competition for advancing oak populations. Pine was absent, at least on the moorlands, in southwest England. The high *Pinus* pollen percentages found by Clarke (1970) in marine deposits off S.E. Devon and the record of 'fir' (? pine) wood in the submerged peat of Falmouth (Ussher 1879) are slight indications that pine might have grown at lower altitudes on the sheltered south coast of southwest England.

The much stronger birch record throughout the Flandrian on Bodmin Moor, as compared with Dartmoor and, even more so, southern England, may be ascribed to its survival in a very open landscape which was preserved by exposure to the elements rather than by human activity. In Ireland the expansion of *Corylus* seemed initially (pollen zone V times) favoured in the areas where *Pinus* was absent, that is, the southwest and north. Pine spread rapidly and early through the central plains and by pollen zone VIc times had reached all areas of the island (Jessen 1949).

(ii) *Western France*

In western France, from the English Channel southwards, *Quercus* and *Corylus*, after appearing simultaneously, replaced *Pinus* early in the Flandrian (Elhaï 1959; Nilsson 1960; Planchais

1967), about 9040 B.P. in the Dordogne (Donner 1969). At Biarritz, in the far southwest, *Quercus* appeared long before 9960 B.P., at which date *Corylus* expanded (Oldfield 1964*a*, *b*). Paquereau (1964) suggested that expansion of *Quercus* in this very early Flandrian period may have been from populations taking refuge in the sheltered, sunny valleys of the Massif Central during the latter part of the Late-Devensian. In Brittany, as in southwest England, *Pinus* values in the Flandrian were always low and *Betula* values were highest in the early Flandrian (van Zeist 1963).

In central and eastern France expansion of *Quercus* and, later, of *Alnus* seem delayed relative to the west coast (summarized by Donner 1969). Only in upland central France did *Betula* appear in strength in early Flandrian tree communities.

In summary, *Pinus* spread rapidly northwestward in the British Isles in response to early Flandrian climatic amelioration. Where *Pinus* was not established *Corylus* and, later, *Quercus* expanded rapidly, as in southwest England, southwest Ireland and northern Ireland. Where *Pinus* was established, *Corylus* and *Quercus* expansion generally occurred after a lag phase of establishment.

In France, early rapid expansion of *Quercus* took place in the western plains, usually in the presence of *Pinus* (but in its absence in the peninsula of Brittany).

It is clear that the oceanicity of the Atlantic seaboard of this part of Europe put *Pinus* at a disadvantage when *in direct competition* with *Quercus* when climatic amelioration started. To be precise about the nature of the disadvantage is impossible as the meagre knowledge of the requirements of the two genera (summarized by Jones (1959, *Quercus*) and Carlisle & Brown (1968, *Pinus*)) indicates. It may be that in the northwestern *extremities* of Europe light-requiring pine seedlings were shaded out by birches which arrived early (Iversen (1954), pointed out that birch has a greater migration rate than pine) and were suppressed by the later growth of oaks. On the other hand, in the western areas where pine was established early young seedlings were probably shaded out by oaks which had established themselves under the open canopy of pine.

Independence of thermophilous trees and *Corylus* from the influence of *Pinus* during the Flandrian is thus a characteristic of these western fringes of Europe. In fact, *Pinus* did respond, by expansion, to the dryness of the Boreal in some of these areas (e.g. Ireland, Jessen, 1949), but not in southwest England. *Quercus ilex* responded in France by northward expansion from the Aquitane basin into the Paris basin (Planchais 1967).)

(*b*) *Early Flandrian oak and elm records*

Mitchell (1951) stressed that the relative times of *Quercus* and *Ulmus* expansion in Ireland in the early Flandrian depended very much upon the calcium status of the soils involved. *Ulmus* tended to expand first in calcareous areas.

In southwest England then, the expansion of *Quercus* before *Ulmus* is not unexpected since the bedrock, especially on the Dartmoor and Bodmin Moor uplands, is acidic. Further east on the calcareous soils of southern England expansion of *Ulmus* before *Quercus* or simultaneous expansion is observed (Seagrief 1959, 1960; Seagrief & Godwin 1960).

In western France *Ulmus* percentages were generally low, but elm appeared, with *Quercus*, soon after the expansion of *Corylus* (Donner 1969; Planchais 1967). The pollen records indicate that elm did not take part in the Flandrian woodland of France to such an extent as it did in the British Isles.

In view of this and Mitchell's *caveat* on the influence of the soil base-status on the relative expansion of oak and elm it is unwise to lay stress on the relative expansion of these two trees in the comparison of widely differing areas. This Oldfield (1964*a*) did in comparing Simmons' (1964*a*) Blacklane (Dartmoor) diagram with events at Biarritz.

9. CORRELATION OF POLLEN ASSEMBLAGE ZONES

Figure 28 presents a correlation of the local pollen assemblage zones defined in §4 and discussed in §5, 6 and 7. Regional pollen assemblage zones for Bodmin Moor (BM 1–7) are suggested and correlated with the pollen zones of Godwin (1956) and the chronozones of West (1970). Radiocarbon dates are given for the pollen zone or chronozone boundaries wherever possible, but it must be borne in mind that these are minimum estimates. Because *Pinus* is absent from Bodmin Moor and Dartmoor and *Quercus* expanded only slightly after *Corylus* and before *Ulmus* the direct application of the Godwin zonation of V and VI and the West zonation of Fl 1a, 1b and 1c is not possible.

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APPENDIX 1. ERRORS INVOLVED IN POLLEN ANALYSIS

(*a*) *Quantitative errors*

Errors in the estimation of the numbers of pollen grains reaching the slide from the sediment arise from the following (and also the probable adherence to apparatus surfaces of unknown quantities of pollen):

(1) variation in sediment sample size using the square-section sampler:
volume sediment $0.87\ \mathrm{cm}^3 \pm 1.15\,\%$;

(2) variation of volume of pollen suspension in tertiary butyl alcohol:
volume suspension $20\ \mathrm{cm}^3 \pm 2.50\,\%$
or $40\ \mathrm{cm}^3 \pm 1.25\,\%$;

(3) variation of aliquot volumes pipetted from the tertiary butyl alcohol suspension:
volume of aliquot $0.1\ \mathrm{cm}^3 \pm 0.1\,\%$;

(4) maximum loss resulting from adhesion to surface of aliquot pipette:
$-0.5\,\%$.

The maximum errors arising from the use of a 20 cm^3 suspension and two aliquots placed on a slide are:

$+3.9\,\% \quad -4.4\,\%$.

Validity of pollen content estimates

Hartman's (1968) formula was used to calculate these values. The value of the interval within which, with 95 % confidence, the true value of the pollen content falls is

$$(2\sqrt{[(\text{covariance indigenous pollen content})^2 + (\text{covar. } \textit{Nyssa} \text{ count})^2 + (\text{covar. volume of sample})^2)]}.$$

Values calculated for representative samples vary from 9.4 to 16.0 %, high pollen counts and high percentages of *Nyssa* giving the lower values. In view of this a doubling of the pollen content from one sample to the next can be regarded as highly significant and an increase of at least $1\frac{1}{2}$ times is indicative of a real increase of pollen content.

(*b*) *Qualitative errors*

The exotic pollen supply was not pure. A sample of the *Nyssa sylvatica* pollen (Greer Drug and Chemical Co., U.S.A.) was acetolysed for 15 min in 10:1 glacial acetic:conc. sulphuric acids, washed and suspended in warm safranin-stained glycerin jelly. Five series of counts from five separate preparations were made and are presented in table 9.

This record of inherent contamination in the original *Nyssa* suspension modifies some of the pollen records. Occurrence of the contaminant pollen taxa at low frequency in the counted pollen samples probably results from contamination alone if the frequency of the contaminant is similar (2σ range) or less than that expected from the number of *Nyssa* grains counted in the sample. If the contaminant frequency is much greater than that expected from the number of *Nyssa* grains counted then the suspected 'contaminant' is almost certainly indigenous.

Table 10 shows that *Fagus* and *Quercus* occurrences in the Late-Devensian are ascribable to contamination as is occurrence of *Veronica*-type, both here and in the upper, unhumified Flandrian peats. *Betula* and *Pinus* values, on the other hand, are always significantly higher than expected from the number of *Nyssa* grains counted. *Juglans* and *Carya*, although not observed in this survey of contaminantts, have each been observed once in this study. They almost certainly derive from the *Nyssa* supply.

There is thus a possible source of mixture of recent and fossil pollen grains which must be borne in mind when discussing the significance of taxa of ecological importance which occur only in low pollen frequencies.

TABLE 9. *NYSSA* CONTAMINANTS: FREQUENCY IN FRESH SUSPENSION

	number counted	frequency (%)	frequency per 1000 *Nyssa* ± 1 s.d. (assuming random suspension)
Nyssa	6112	98.8	
Betula	31	0.50	5.01 ± 2.23
Gramineae	9	0.15	1.50 ± 1.23
Veronica-type	6	0.10	1.00 ± 1.00
Humulus	4	0.05	0.65 ± 0.81
Quercus, *Pinus*	3	0.05	0.50 ± 0.71
Fagus, cf. *Plantago coronopus*	2	0.05	0.33 ± 0.57
Corylus-type, *Tsuga canadensis*, cf. *Ambrosia*, *Acer*-type	1	0.03	0.10 ± 0.32

TABLE 10. *NYSSA* CONTAMINANTS: FREQUENCY IN COUNTED SAMPLES

(Numbers expected are printed above those observed.)

site	p.a.z.	*Betula*	*Veronica*-type	*Pinus*	*Fagus*	*Quercus*
			Late-Devensian			
HT	1, 2, 3a	—	11 ± 11 7	—	4 ± 7 3	2 ± 2 4
HT	2, 3a	39 ± 17 263	—	5 ± 7 41	—	—
PP	1, 2, 3	—	10 ± 10 5	5 ± 5 69	3 ± 5 2	2 ± 3 4
PP	3	7 ± 3 38	—	—	—	—
PP	2	8 ± 4 24	—	—	—	—
			Flandrian			
PP	7, 7a	—	16 ± 16 9	—	5 ± 9 29	—

APPENDIX 2. LATE-DEVENSIAN PLANT TAXA FROM BODMIN MOOR

This is a complete list compiled from Conolly *et al.* (1950), Dickson (1965) and this study. All are pollen records unless otherwise stated e.g.

mp	macrofossil and pollen record;
m	macrofossil record only.

An asterisk indicates that the taxon was found in this study only. Indication is made of which Late-Devensian divisions (pre-Allerød, Allerød, or post-Allerød) have produced the taxon. When the sole record is that of Dickson X indicates that period of deposition is unknown. +, present, −, not observed.

			pre-Allerød	Allerød	post-Allerød
	mp	*Alisma plantago-aquatica*	+	+	−
	*	*Alnus*	+	−	+
	*	*Arctium*-type	+	+	−
		Armeria-type	+	−	+
	m	*Armeria maritima*	X		
		Artemisia	+	+	+
	*	*Artemisia norvegica*	+	−	+
	*	*Artemisia vulgaris*-type	+	+	+
	*	*Astragalus alpinus*	+	−	−
10		*Betula*	+	+	+
	m	*Betula nana*	−	+	−
	mp	*Bidens cernua*	−	−	+
	m	*Callitriche autumnalis*	+	−	−
	m	*Callitriche intermedia*	+	−	−
	*	*Calluna vulgaris*	+	+	+
	mp	*Caltha palustris*	+	+	+
		Campanula-type	+	+	+
	*m	*Campanula rotundifolia*	−	−	+
	m	*Carduus* or *Cirsium*	+	+	+
20	m	*Carex*	+	+	+
	m	*Carex aquatilis* or *bigelowii*	+	−	+
	m	*Carex echinata*	+	−	−
	m	*Carex* cf. *nigra*	+	−	−
	m	*Carex pulicaris*	+	−	−
	m	*Carex rostrata*	+	+	−
	mp	Caryophyllaceae	+	+	+
	*	*Centaurea*	−	−	+
		Chenopodiaceae	+	+	+
		Cirsium-type	+	+	+
30		Compositae	+	+	+
		Corylus-type	+	+	+
		Cruciferae	+	+	+
		Cyperaceae	+	+	+
	m	*Eleocharis*	+	−	−
	m	*Eleocharis palustris*	+	−	+
	mp	*Empetrum nigrum*	+	+	+
		Epilobium-type	+	+	+
	*m	*Epilobium alsinifolium*	+	−	−
		Ericales	+	+	+
40	m	*Erica tetralix*	+	−	−
	m	*Eriophorum*	−	+	−
	*m	*Eriophorum vaginatum*	−	+	−
		Filipendula	+	+	+
		Gramineae	+	+	+
	m	*Groenlandia densa*	+	−	−
		Helianthemum	+	+	+
	*	*Hippophaë*	+	−	−
	m	*Hippuris vulgaris*	+	−	−
	*	*Hydrocotyle*	−	+	−
50	*	*Hypericum perforatum*-type	+	+	+
	*	*Jasione montana*	+	−	−
	m	*Juncus*	+	−	−
	*m	*Juncus effusus* or *conglomeratus*	+	−	+
	mp	*Juniperus*	+	+	+

				pre-Allerød	Allerød	post-Allerød
	*	Leguminosae		+	+	+
	m	*Leontodon autumnalis*		+	–	–
		Liguliflorae		+	+	+
		cf. *Ligustrum*		–	+	–
	*	*Lotus*-type		+	+	+
60	m	*Luzula*	X			
	*m	*Luzula arcuata*		+	–	+
	*m	*Lychnis flos-cuculi*		+	–	+
	m	*Lycopus europaeus*		–	+	–
	*	*Lysimachia vulgaris*-type		–	–	+
		Matricaria-type		+	+	+
	*	*Mentha*-type		+	+	+
		Mentha-Prunella-type		–	+	–
	mp	*Menyanthes trifoliata*		+	+	+
		Montia		+	–	–
70	m	*Montia fontana* ssp. *fontana*		+	–	–
	mp	*Myriophyllum alterniflorum*		+	+	+
	*	*Myriophyllum spicatum*-type		+	+	+
		Nymphaea		+	–	–
		Ononis-type		–	–	+
	*m	*Phragmites communis*		–	–	+
	*	*Picea*		+	–	–
		Pinus		+	+	+
		Plantago		–	+	–
	*	*Plantago lanceolata*		+	–	+
80		*Plantago maritima*		+	+	+
		Polemonium		+	–	–
	*	*Polygonum*		+	–	–
	*	*Polygonum aviculare*-type		–	–	+
		Polygonum cf. *bistorta*		–	–	+
	*	*eu-Potamogeton*		+	+	+
	mp	*Potamogeton*		+	+	+
	m	*Potamogeton alpinus*		+	–	–
	m	*Potamogeton berchtoldii*	X			
	m	*Potamogeton crispus*		+	–	–
90	m	*Potamogeton* cf. *gramineus*	X			
	m	*Potamogeton natans*		+	–	–
	m	*Potamogeton obtusifolius*	X			
	m	*Potamogeton perfoliatus*	X			
	m	*Potamogeton* cf. *pusillus*		+	–	–
	*m	*Potamogeton* cf. *trichoides*		+	–	–
		Potentilla-type		+	+	+
	m	*Potentilla palustris*		+	+	+
	*	*Pyrus-Sorbus*-type		+	–	–
		Quercus		+	+	+
100	mp	*Ranunculus*		+	+	+
	m	*Ranunculus* subgen. *Batrachium*		+	+	+
	*	*Ranunculus acris*-type		+	+	+
	m	*Ranunculus flammula*		+	–	–
	*	*Ranunculus trichophyllus*-type		+	+	+
	*	*Rhinanthus*-type		+	+	–
	m	*Rhynchospora alba*		+	–	–
	m	cf. *Rorippa*		+	–	–
	*	Rosaceae		+	+	+
		Rubiaceae		+	+	+
110		*Rumex*		+	+	+
	mp	*Rumex acetosa*		+	+	+
	*	*Rumex acetosa*-type		+	+	+
	mp	*Rumex acetosella* agg.		+	+	+

				pre-Allerød	Allerød	post Allerød
	m	*Rumex aquaticus*		+	–	–
	*	*Rumex-Oxyria*-type		+	+	+
	m	*Sagina subulata* or *saginoides*		+	–	–
	*	*Sagittaria*		+	–	–
	mp	*Salix*		+	+	+
	m	*Salix herbacea*		+	–	–
120	mp	*Saxifraga* sp. incl. *granulata*		+	+	+
	*	*Saxifraga hirculus*		+	–	–
	m	*Saxifraga* cf. *hypnoides*		+	–	–
	mp	*Saxifraga stellaris*		+	–	+
	m	*Schoenoplectus* cf. *tabernae-montani*	X			
	m	cf. *Scirpus*		+	–	–
	*	*Sedum*		+	–	–
		Senecio-type		+	+	+
	m	cf. *Sorbus aucuparia*		–	+	–
		Sparganium-type		+	+	+
130	m	*Sparganium angustifolium*		+	–	–
	m	*Sparganium minimum*		+	–	–
	m	*Sparganium ?neglectum*		+	–	–
	*	*Spergula arvensis*		+	–	–
	*	*Stellaria holostea*		+	–	–
	m	*Subularia aquatica*		+	–	–
		Succisa pratensis		+	+	+
		Thalictrum		+	+	+
	m	*Thalictrum alpinum*		+	–	–
	*	*Trifolium*-type		–	+	–
140	*	Tubuliflorae		+	+	+
	m	*Typha*		+	–	–
	*	*Typha latifolia*		+	+	+
		Ulmus		–	+	+
		Umbelliferae		+	+	+
	*	*Urtica*		+	–	+
		Valeriana		+	+	+
	mp	*Valeriana officinalis*		+	+	+
	m	*Veronica anagallis-aquatica*		+	–	–
	m	*Veronica* cf. *scutellata*		+	–	–
150	m	*Viola* cf. *palustris*		+	+	+

REFERENCES

American Commission on Stratigraphic Nomenclature 1961 Code of Stratigraphic Nomenclature. *Bull. Am. Ass. Petrol. Geol.* **45**, 645–665.

Andersen, S. Th. 1970 The relative pollen productivity and pollen representation of North European trees, and correction factors for tree pollen spectra: *Danm. geol. Unders.* Series **II**, **96**, 1–99.

Andrew, R. 1971 Exine pattern in the pollen of British species of *Tilia*. *New Phytol.* **70**, 683–686.

Benninghof, W. S. 1962 Calculations of pollen and spore density in sediments by addition of exotic pollen in known quantities. *Pollen Spores* **4**, 332–333.

Beug, H-J. 1961 *Leitfaden der Pollenbestimmung*, **1**. Jena: Springer Verlag.

Birks, H. H. 1973 Modern macrofossil assemblages in lake sediments in Minnesota. In *Quaternary plant ecology* (B. E. S. Spring 1972 Symposium) (eds H. J. B. Birks & R. G. West), pp. 173–189. Oxford: Blackwell.

Birks, H. J. B. 1968 The identification of *Betula nana* pollen. *New Phytol.* **67**, 309–314.

Birks, H. J. B. 1970 Inwashed Pollen Spectra at Loch Fada, Isle of Skye. *New Phytol.* **69**, 807–820.

Bonny, A. P. 1972 A method for determining absolute pollen frequencies in lake sediments. *New Phytol.* **71**, 393–405.

Brown, A. P. 1971 The *Empetrum* pollen record as a climatic indicator in the Late-Weichselian and early Flandrian of the British Isles. *New Phytol.* **70**, 841–849.

Brown, A. P. 1972 Late-Weichselian and Flandrian vegetation of Bodmin Moor, Cornwall. Ph.D. dissertation, Cambridge University.

Carlisle, A. & Brown, A. H. F. 1968 Biological Flora of the British Isles: *Pinus sylvestris* L. *J. Ecol.* **56**, 269–307.

Cerceau, M-T. 1959 Clé de détermination d'Ombellifères de France et d'Afrique du Nord d'après leurs grains de pollen. *Pollen Spores* **1**, 145–190.

Chanda, S. 1963 On the pollen morphology of some Scandinavian Caryophyllaceae. *Grana palynol.* **3**, 67–89.

Christie, P. M. 1960 Crig-a-mennis: a Bronze Age barrow at Liskey, Perranzabuloe, Cornwall. *Proc. Prehist. Soc.* **26**, 76–97.

Churchill, D. M. 1962 The stratigraphy of the mesolithic sites III and IV at Thatcham, Berkshire, England. *Proc. Prehist. Soc.* **28**, 362–370.

Churchill, D. M. 1965 The kitchen midden site at Westward Ho!, Devon, England: ecology, age and relation to changes in land and sea level. *Proc. Prehist. Soc.* **31**, 74–84.

Clapham, A. R., Tutin, T. G. & Warburg, E. F. 1962 *Flora of the British Isles*, 2nd ed. Cambridge University Press.

Clarke, R. H. 1970 Quaternary sediments off south-east Devon: *Q. Jl Geol. Soc. Lond.* **125**, 277–318.

Coombe, D. E. & Frost, L. C. 1956 The nature and origin of the soils over the Cornish serpentine. *J. Ecol.* **44**, 605–615.

Conolly, A. P. & Dahl, E. 1970 Maximum summer temperature in relation to the modern and Quaternary distributions of certain arctic-montane species in the British Isles. In *Studies in the vegetational history of the British Isles* (eds D. Walker & R. G. West), pp. 159–223. Cambridge University Press.

Conolly, A. P., Godwin, H. & Megaw, E. M. 1950 Studies in the post-glacial history of British vegetation. 11. Late-glacial deposits in Cornwall. *Phil. Trans. R. Soc. Lond.* B **234**, 397–469.

Conway, V. 1948 Von Post's work on climatic rhythms. *New Phytol.* **47**, 220–237.

Crabtree, K. & Round, F. E. 1967 Analysis of a core from Slapton Ley. *New Phytol.* **66**, 255–270.

Craig, A. J. 1972 Pollen influx to laminated sediments. A pollen diagram from north eastern Minnesota. *Ecology* **53**, 46–57.

Dahl, E. 1956 Rondane: mountain vegetation in south Norway and its relation to the environment. *Norske Vidensk.-Acad. Oslo*, pp. 1–374.

Darby, H. C. & Welldon Finn, R. (eds) 1967 *The Domesday geography of southwest England.* Cambridge University Press.

Davis, M. B. 1966 Determination of absolute pollen frequency. *Ecology* **47**, 310–311.

Davis, M. B. 1969 Climatic change in southern Connecticut recorded by pollen deposition at Rogers Lake. *Ecology* **50**, 409–422.

Dickson, J. H. 1965 Historical biogeography of the British moss flora. Ph.D. dissertation, University of Cambridge.

Dickson, C. A., Dickson, J. H. & Mitchell, G. F. 1970 The Late-Weichselian flora of the Isle of Man. *Phil. Trans. R. Soc. Lond.* B **258**, 31–79.

Dimbleby, G. W. 1963 Pollen analysis from two Cornish barrows. *Jl R. Instn. Cornwall* N.S. **4**, 364–375.

Donner, J. J. 1969 Holocene pollen diagrams from the Beaune Valley, Dordogne. *Pollen Spores* **11**, 97–116.

Dudley, D. 1958 The early Iron Age in Cornwall. *Proc. W. Cornwall Fld Club* **2** no. 2, 47–54.

Edmonds, E. A., McKeown, M. C. & Williams, M. 1969 *Southwest England*, British regional geology. London: H.M.S.O.

Elhaï, H. 1959 Analyse pollinique de deux tourbières normandes. *Pollen Spores* **1**, 59–76.

Fairbairn, W. A. 1968 Climatic zonation in the British Isles. *Forestry* **41**, 117–130.

Fairbridge, R. W. 1960 The changing level of the sea. *Sci. Am.* **202**, 70–79.

Ferguson, I. K. & Webb, D. A. 1970 Pollen morphology in the genus *Saxifraga* and its taxonomic significance. *Bot. J. Linn. Soc.* **63**, 295–311.

Fox, A. 1954 Excavations at Kes Tor, an early Iron Age site near Chagford, Devon. *Rep. Trans. Devon Ass. Advnmt. Sci.* **86**, 21–62.

Fox, A. 1964 *Southwest England.* London: Thames & Hudson.

Godwin, H. 1945 A submerged peat in Portsmouth Harbour. *New Phytol.* **44**, 152–155.

Godwin, H. 1956 *The history of the British Flora.* Cambridge University Press.

Godwin, H. 1960*a* Radiocarbon dating and Quaternary history in Britian. *Proc. R. Soc. Lond.* B **153**, 287–320.

Godwin, H. 1960*b* Studies in the post-glacial history of the British vegetation. 14. Late-glacial deposits at Moss Lake, Liverpool. *Phil. Trans. R. Soc. Lond.* B **242**, 127–149.

Godwin, H. & Tallantire, P. A. 1951 Studies in the post-glacial history of British vegetation. 12. Hockham Mere, Norfolk. *J. Ecol.* **39**, 285–307.

Godwin, H., Walker, D. & Willis, E. H. 1957 Radiocarbon dating and post-glacial vegetational history: Scaleby Moss. *Proc. R. Soc. Lond.* B **147**, 352–366.

Godwin, H. & Willis, E. H. 1959 Radiocarbon dating of the Late-glacial period in Britian. *Proc. R. Soc. Lond.* B **150**, 199–215.

Granlund, E. 1932 De svenska högmossernas geologi. *Sver. geol. Unders. Afh. Årsb* **26**, 1, C, 1–193.

Hartman, A. A. 1968 A study on pollen dispersal and sedimentation in the western part of the Netherlands. *Acta Bot. Neerl.* **17**, 506–549.

Heim, J. 1962 Recherches sur les relations entre la végétation actuelle et le spectre pollinique récent dans les Ardennes Belges. *Bull. Soc. r. Bot. Belg.* **96**, 5–92.

Hibbert, F. A., Switsur, V. R. & West, R. G. 1971 Radiocarbon dating of Flandrian pollen zones at Red Moss, Lancashire. *Proc. R. Soc. Lond.* B **177**, 161–176.

Hultén, E. 1950 *Atlas of the distribution of vascular plants in northwest Europe.* Stockholm: Generalstabens Litografiska Anstalts Förlag.

Iversen, J. 1944 *Viscum, Hedera* and *Ilex* as climatic indicators. *Geol. För. Stockh. Förh.* **66**, 463–483.

Iversen, J. 1947 Diskussionsindlaeg i: Nordiskt kvartärgeologiskt möte den 5–9 november 1945. *Geol. För. Stockh. Förh.* **69**, 205–252.

Iversen, J. 1954 The late-glacial flora of Denmark and its relation to climate and soil. *Danm. geol. Unders.* Series II **80**, 87–119.

Jessen, K. 1949 Studies on late-Quaternary deposits and flora history of Ireland. *Proc. R. Ir. Acad.* B **52**, 85–290.

Jones, E. W. 1959 Biological flora of the British Isles. *Quercus* L. *J. Ecol.* **47**, 169–222.

McVean, D. N. & Ratcliffe, D. A. 1962 *The plant communities of the Scottish Highlands.* Monographs of the Nature Conservancy No. 1. London: H.M.S.O.

Matthews, J. 1969 The assessment of a method for the determination of absolute pollen frequencies. *New Phytol.* **68**, 161–166.

Mercer, R. J. 1970*a* The neolithic settlement at Carn Brea: Preliminary Report, 1970. *Cornish Archaeology* **9**, 53–62.

Mercer, R. J. 1970*b* The excavation of a Bronze Age hut-circle settlement, Stannon Down. *Cornish Archaeology* **9**, 17–46.

Mitchell, G. F. 1951 Studies in Irish Quaternary deposits, 7. *Proc. R. Ir. Acad.* B **53**, 111–206.

Moore, P. D. 1970 Studies in the vegetational history of mid-Wales. II. The late-glacial period in Cardiganshire. *New Phytol.* **69**, 363–375.

Moore, P. D. & Chater, E. H. 1969 Studies in the vegetational history of mid-Wales. I. The post glacial period in Cardiganshire. *New Phytol.* **68**, 183–196.

Morrison, M. E. S. & Stephens, N. 1965 A submerged late-Quaternary deposit at Roddon's Port on the north-east coast of Ireland. *Phil. Trans. R. Soc.* B **249**, 221–255.

Nilsson, T. 1960 Recherches palynologiques dans la vallée de la Somme. *Pollen Spores* **2**, 235–262.

Oldfield, F. 1959 The pollen morphology of some of the west-European Ericales. *Pollen Spores* **1**, 19–48.

Oldfield, F. 1964*a* Late-Quaternary vegetational history in southwest France. *Pollen Spores* **6**, 157–168.

Oldfield, F. 1964*b* Late-Quaternary deposits at Le Mourra, Biarritz, southwest France. *New Phytol.* **63**, 374–409.

Olsson, I. U. 1970 Explanation of plate IV [of the Proceedings of the XIIth Nobel Symposium, *Radiocarbon Variations and Absolute Chronology* pp. 625–626. Almqvist and Wiksell, Stockholm]. (Title of plate: 'Conventional Radiocarbon Ages as a function of Dendrochronological Ages for wood from the Northern Hemisphere as determined by four Laboratories'.)

Paquereau, M-M. 1964 Flores et climates post-glaciaires en Gironde. *Act. Soc. Linn. Bordeaux* **101**, 1–156.

Peacock, D. P. S. 1969 Neolithic pottery production in Cornwall. *Antiquity* **43**, 145–149.

Pearsall, W. H. 1951 *Mountains and moorlands*, 1st ed. London: Collins.

Pearson, M. C. & Rogers, J. A. 1962 Biological flora of the British Isles. *Hippophaë rhamnoides* L. *J. Ecol.* **50**, 501–513.

Pennington, W. 1970 Vegetational history in northwest England. In *Studies in the vegetational history of the British Isles* (eds D. Walker & R. G. West), pp. 41–79. Cambridge University Press.

Pennington, W. & Bonny, A. P. 1970 Absolute pollen diagram from the British Late-glacial: *Nature, Lond.* **226**, 871–873.

Perring, F. H. & Walters, S. M. 1962 *Atlas of the British flora.* London: Nelson.

Perring, F. H. 1968 *Critical supplement to the Atlas of the British flora.* London: Nelson.

Planchais, N. 1967 Analyse pollinique de la tourbière de Gizeux (Indre-et-Loire) et étude du chêne vert a l'optimum climatique. *Pollen Spores* **9**, 505–520.

Poore, M. D. & McVean, D. N. 1957 A new approach to Scottish mountain vegetation. *J. Ecol.* **45**, 401–439.

Praglowski, J. 1971 The pollen morphology of the Scandinavian species of *Artemisia* L. *Pollen Spores* **13**, 381–404.

Proctor, M. C. F. 1964 The phytogeography of the Dartmoor bryophytes. In *Dartmoor essays* (ed. I. G. Simmons), pp. 141–172. *Devon Ass. Advmnt. Sci.*

Ravenhill, W. 1967 In *The Domesday geography of Cornwall* (eds H. C. Darby & R. Welldon Finn). Cambridge University Press.

Reid, C., Barrow, G., Sherlock, R. L., MacAlister D. A. & Dewey, H. 1911 *Geology of the country around Tavistock and Launceston.* Mem. Geol. Surv. Gt. Britain.

Rouse, G. D. & Edlin, H. L. 1957 The forests of southwest England. *Forestry* **31**, 27–51.

Salisbury, E. J. 1964 *Weeds and aliens.* London: Collins.

Seagrief, S. C. 1959 Pollen diagrams from southern England: Wareham, Dorset and Nursling, Hampshire. *New Phytol.* **58**, 316–325.

Seagrief, S. C. 1960 Pollen diagrams from southern England: Cranes Moore, Hampshire. *New Phytol.* **59**, 73–83.

Seagrief, S. C. & Godwin, H. 1960 Pollen diagrams from southern England: Elstead, Surrey, *New Phytol.* **59**, 84–91.

Shorter, A. H., Ravenhill, W. L. D. & Gregory, K. J. 1969 *Southwest England.* London: Nelson.

Simmons, I. G. 1963 The blanket bog of Dartmoor. *Rep. Trans. Devon Ass. Advnmt. Sci.* **95**, 180–196.

Simmons, I. G. 1964*a* Pollen diagrams from Dartmoor. *New Phytol.* **63**, 165–180.

Simmons, I. G. 1964*b* An ecological history of Dartmoor. *Dartmoor essays* (ed. I. G. Simmons), pp. 191–215. Devon Ass. Advnmt. Sci.

Simmons, I. G. 1969 Environment and early Man on Dartmoor, Devon, England. *Proc. Prehist. Soc.* **35**, 203–219.

Smith, A. G. 1970 The influence of mesolithic and neolithic man on vegetation: a discussion. In *Studies in the vegetational history of the British Isles* (eds D. Walker & R. G. West). Cambridge University Press.

Sorsa, P. 1964 Studies on the spore morphology of Fennoscandian fern species. *Acta Bot. Fenn.* **1**, 179–201.

Stuiver, M. 1970 Long term ^{14}C variations: in Proceedings of the XIIth Nobel Symposium. Stockholm: Almqvist & Wiksell.

Tansley, A. G. 1939 *The British Islands and their vegetation,* 1st ed. Cambridge University Press.

Tauber, H. 1967 Investigations of the mode of pollen transfer in forested areas. *Rev. Palaeobotan. Palynol.* **3**, 277–286.

Thomas, C. 1958 The palaeolithic and mesolithic periods in Cornwall. *Proc. W. Cornwall Fld Club* **2**, no. 2, 5–12.

Thomas, C. 1969 The Bronze Age in the southwest. *Archaeological Rev.* **4**, 3–13.

Thurston, E. 1930 *British and foreign trees and shrubs in Cornwall.* Cambridge University Press.

Troels-Smith, J. 1955 Karakterisering af løse jordarter. *Danm. geol. Unders.* ser. 4 **10**, 1–73.

Turner, J. 1964 The anthropogenic factor in vegetational history. 1. Tregaron and Whixall mosses. *New Phytol.* **63**, 73–90.

Ussher, W. E. A. 1879 Pleistocene geology of Cornwall. IV. Submerged forests and stream tin gravels. *Geol. Mag.* N.S. Decade II, **6**, 251–263.

Van der Spoel-Walvius, M. R. 1963 Les charactéristiques de l'exine chez quelques espèces de *Quercus. Acta Bot. Neerl.* **12**, 525–532.

Van Zeist, W. 1963 Recherches palynologiques en Bretagne occidentale. *Norois* **10**, 5–19.

Wainwright, G. J. 1960 Three microlithic industries from southwest England and their affinities: *Proc. Prehist. Soc.* **26**, 193–201.

Wainwright, G. J. 1965 Excavation of a cairn at St Neot, Bodmin Moor. *Cornish Archaeology* **4**, 4–9.

Ward, S. D., Jones, A. D. & Manton, M. 1972 The Vegetation of Dartmoor. *Field Studies* **3**, 505–533.

Watts, W. A. 1963 Late-glacial pollen zones in western Ireland. *Ir. Geog.* **4**, 367–376.

West, R. G. 1970 Pollen zones in the Pleistocene of Great Britian and their correlation. *New Phytol.* **69**, 1179–1183.

Woodhead, N. 1951 Biological Flora of the British Isles: *Subularia* L. *J. Ecol.* **39**, 465–469.

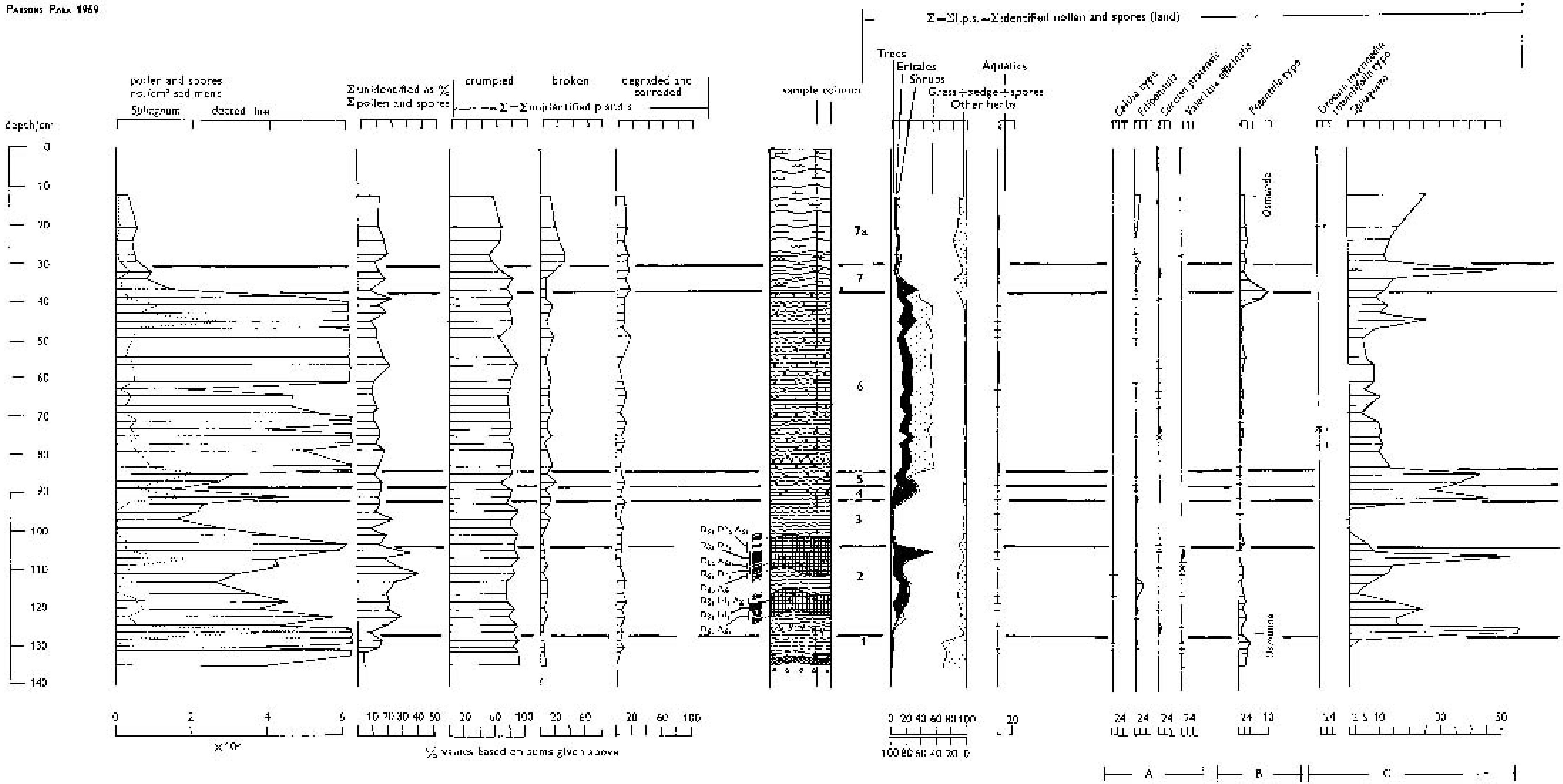

FIGURE 4. Pollen diagram: Parsons Park, 1964. General information and taxon groups A–C.

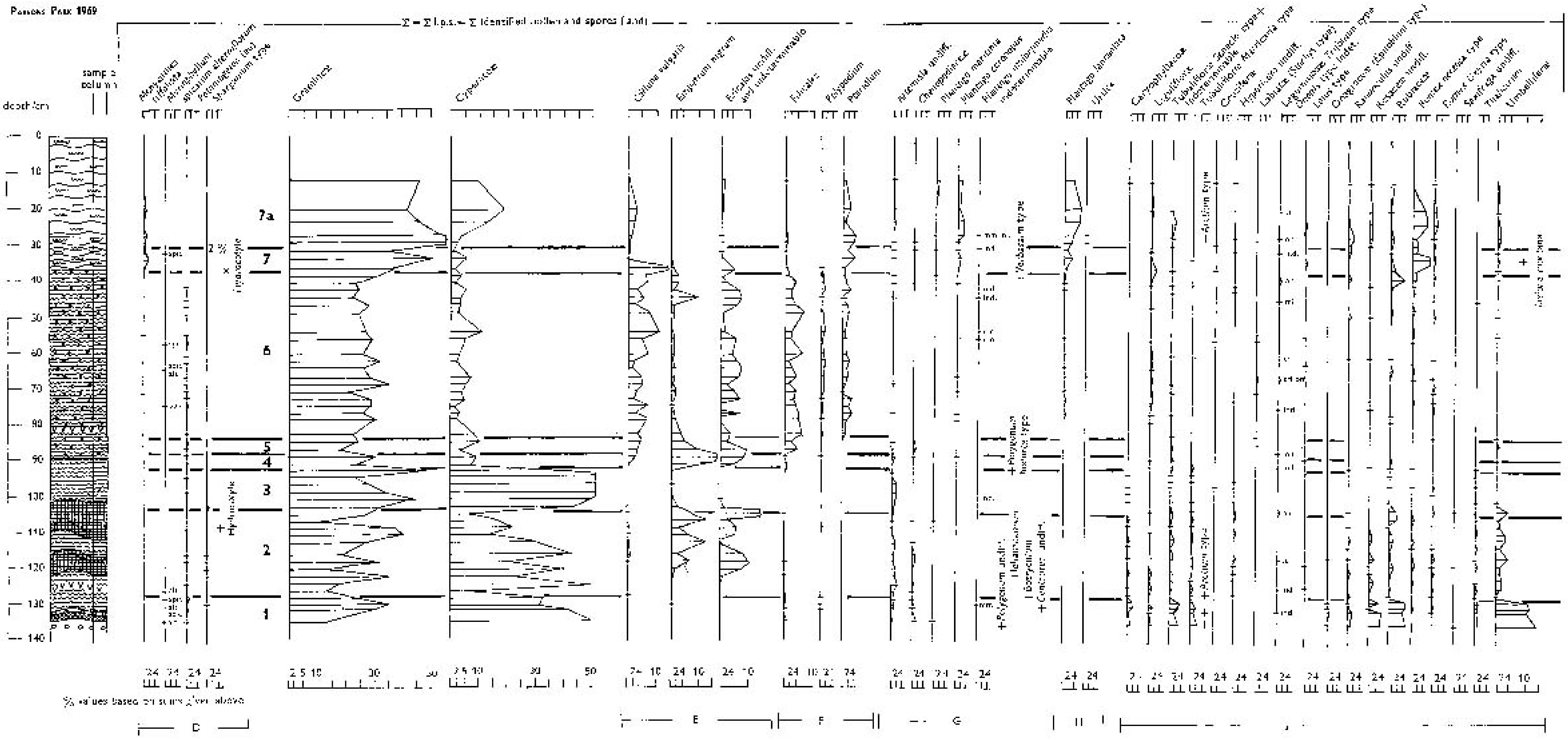

Figure 5. Pollen diagram: Parsons Park, 1969. Taxon groups D–J.

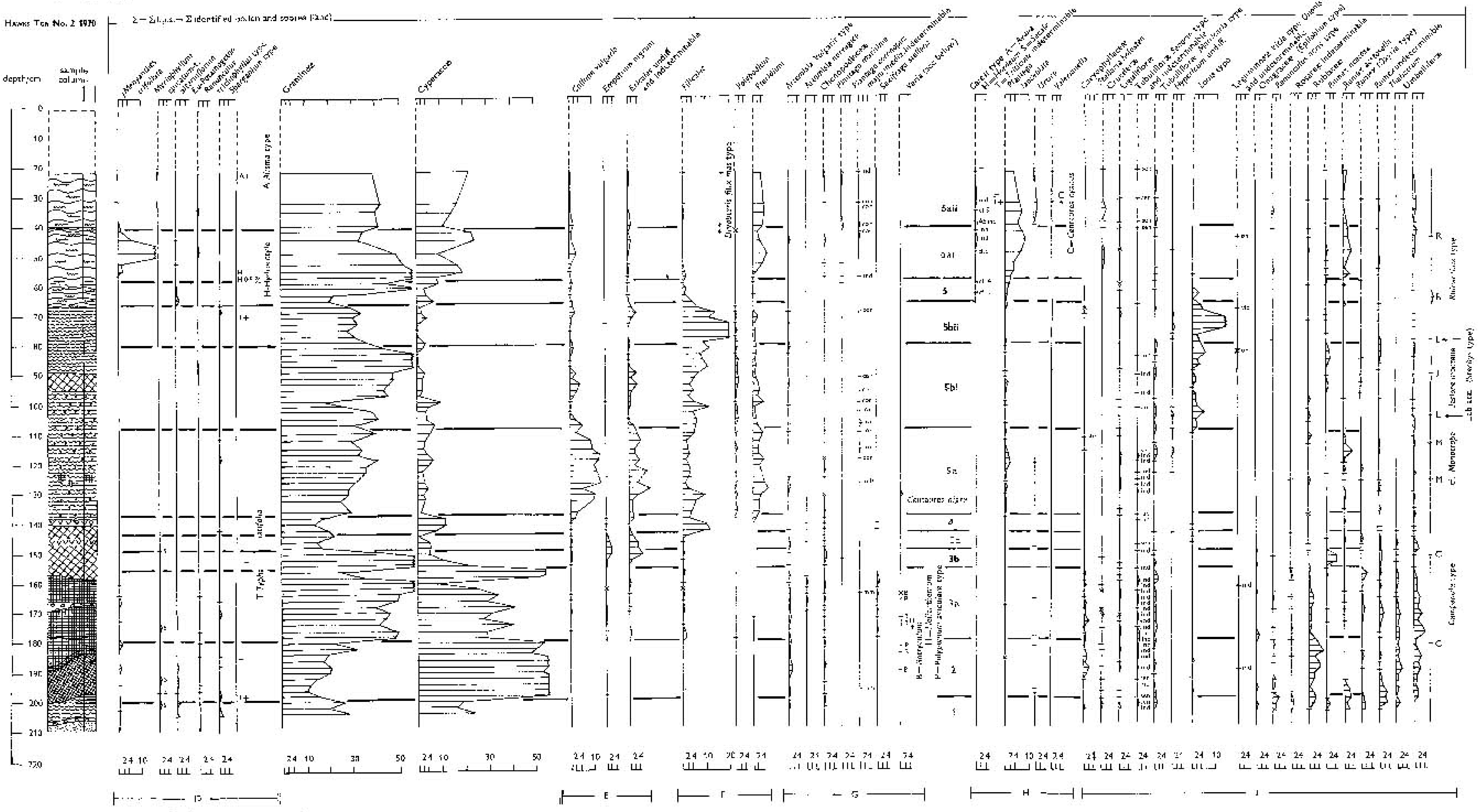

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Figure 9. Pollen diagram: Hawks Tor monolith no. 2. Taxon groups D–J.

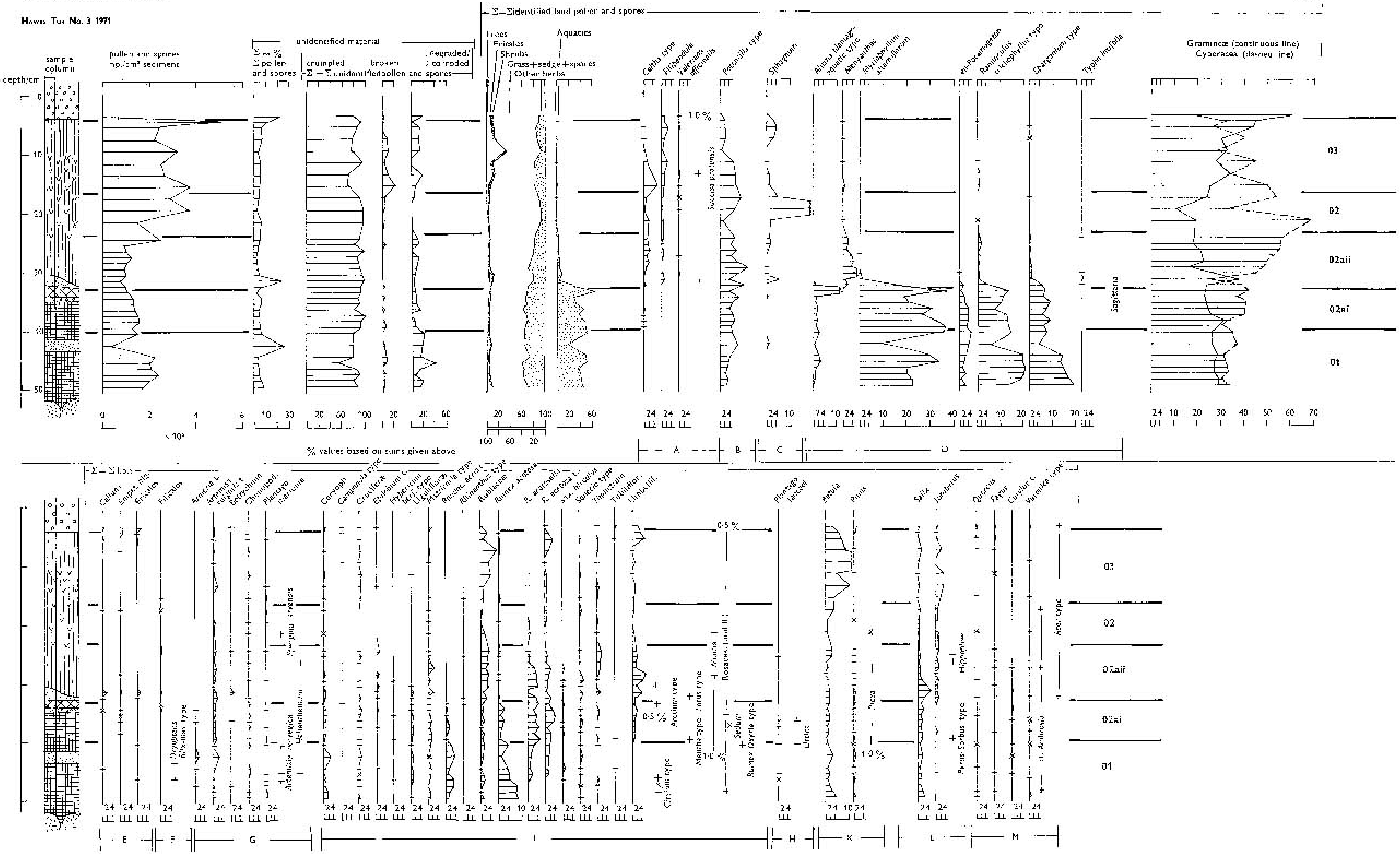


Figure 11. Pollen diagram: Hawks Tor monolith no. 3.

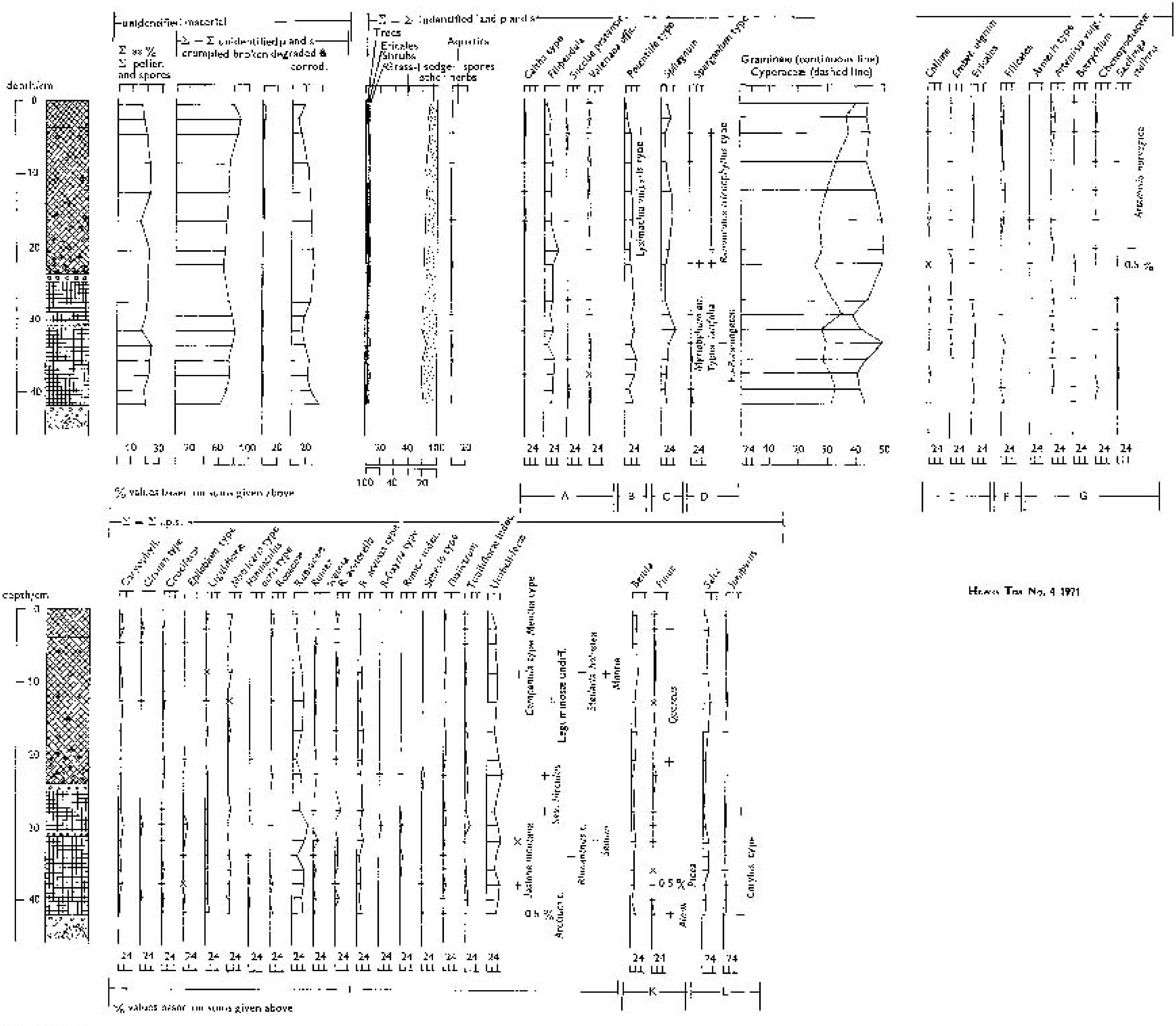


FIGURE 12. Pollen diagram: Hawks Tor monolith no. 4.

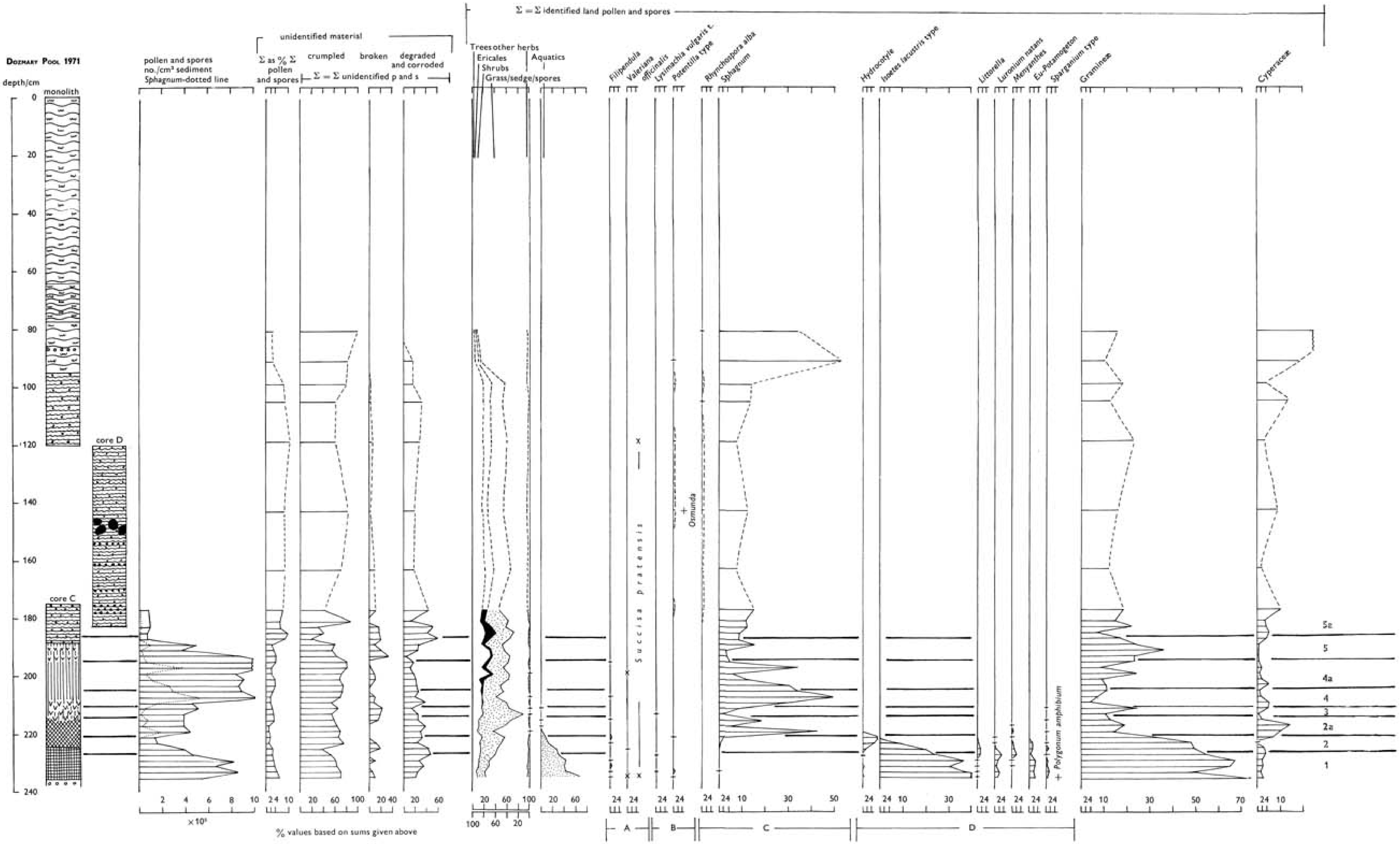


FIGURE 13. Pollen diagram: Dozmary Pool. General information and taxon groups A–D.

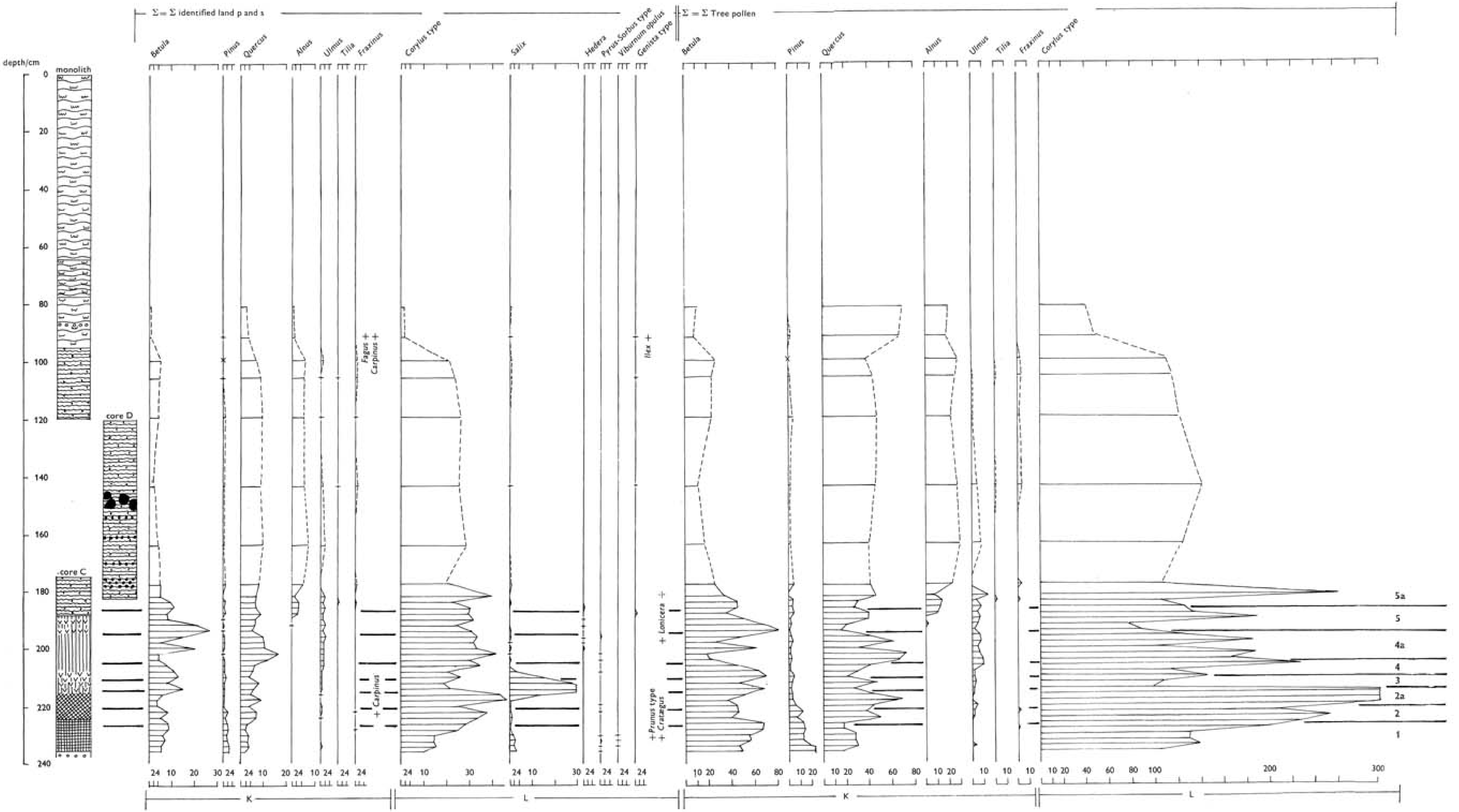


FIGURE 15. Pollen diagram: Dozmary Pool. Taxon groups K and L.

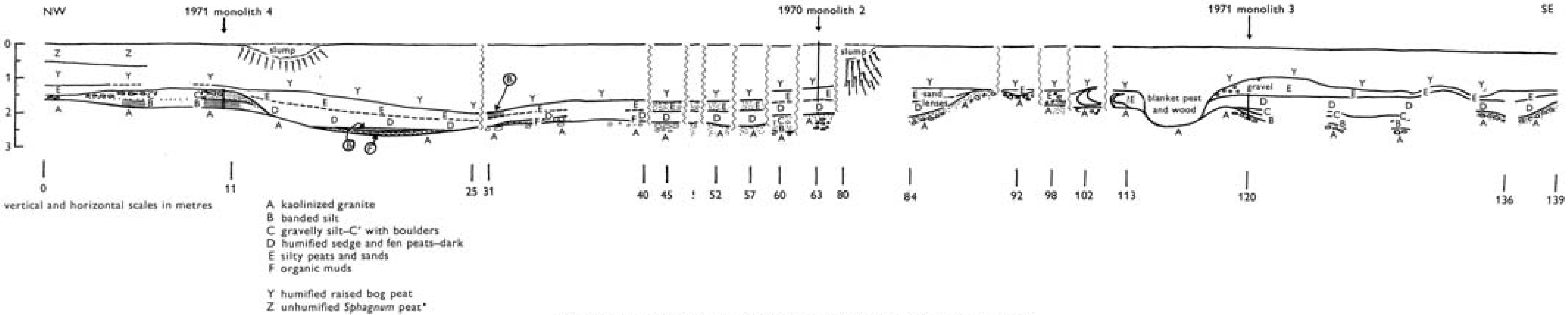


FIGURE 16. Hawks Tor˙or, 1970–1. Sketch section of the northeast face of the pit showinving the location of monoliths 2, 3 and 4.

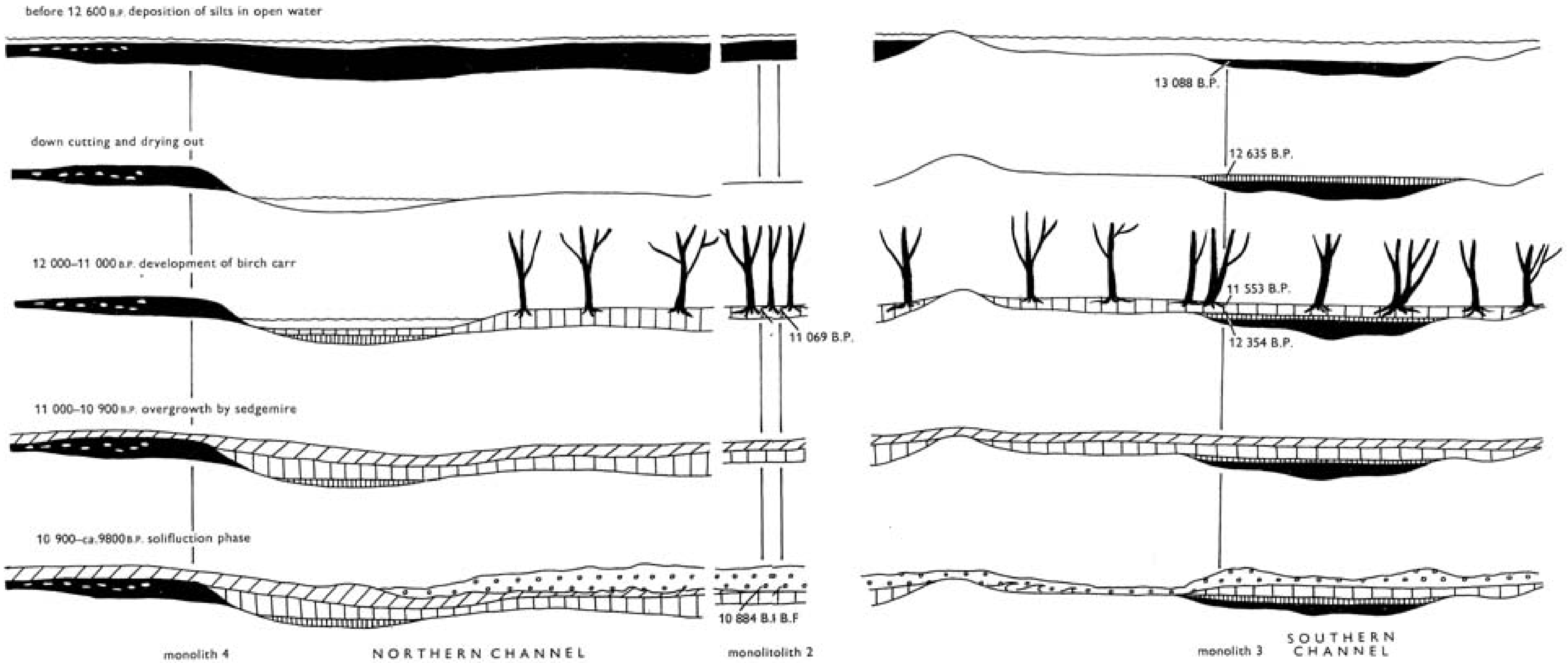


FIGURE 17. Sketch summary of depospositional events at Hawks Tor in the Late-Devensian giving rise to to the stratigraphy of figure 16.

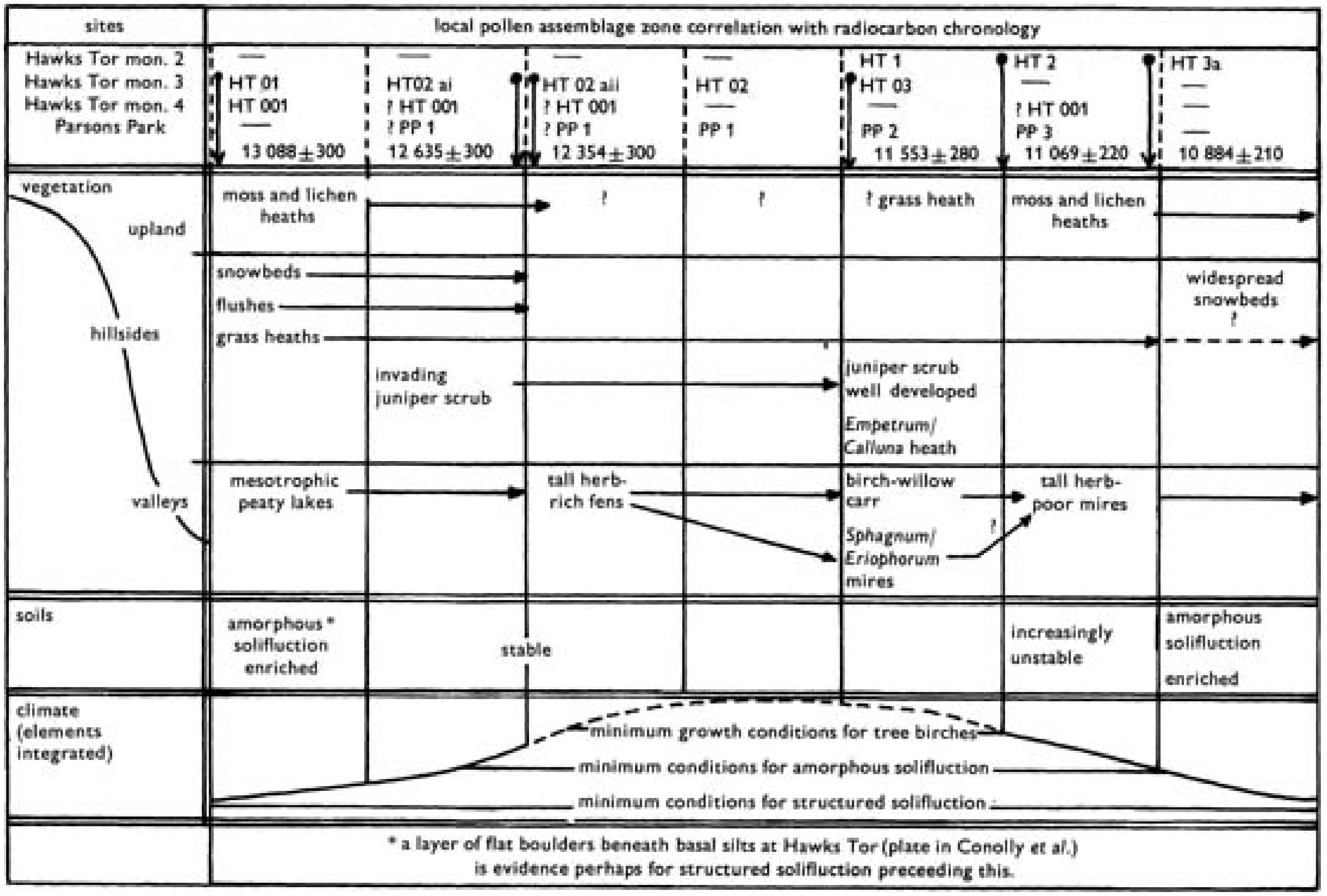


Figure 18. Late-Devensian soils and vegetation on Bodmin Moor.

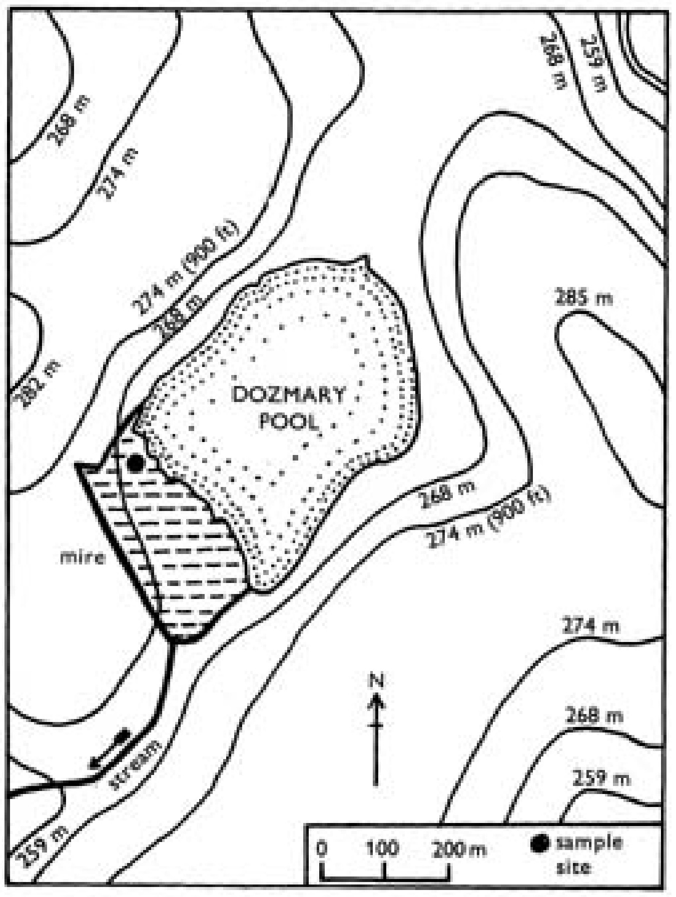


Figure 19. The topography of the Dozmary Pool catchment.

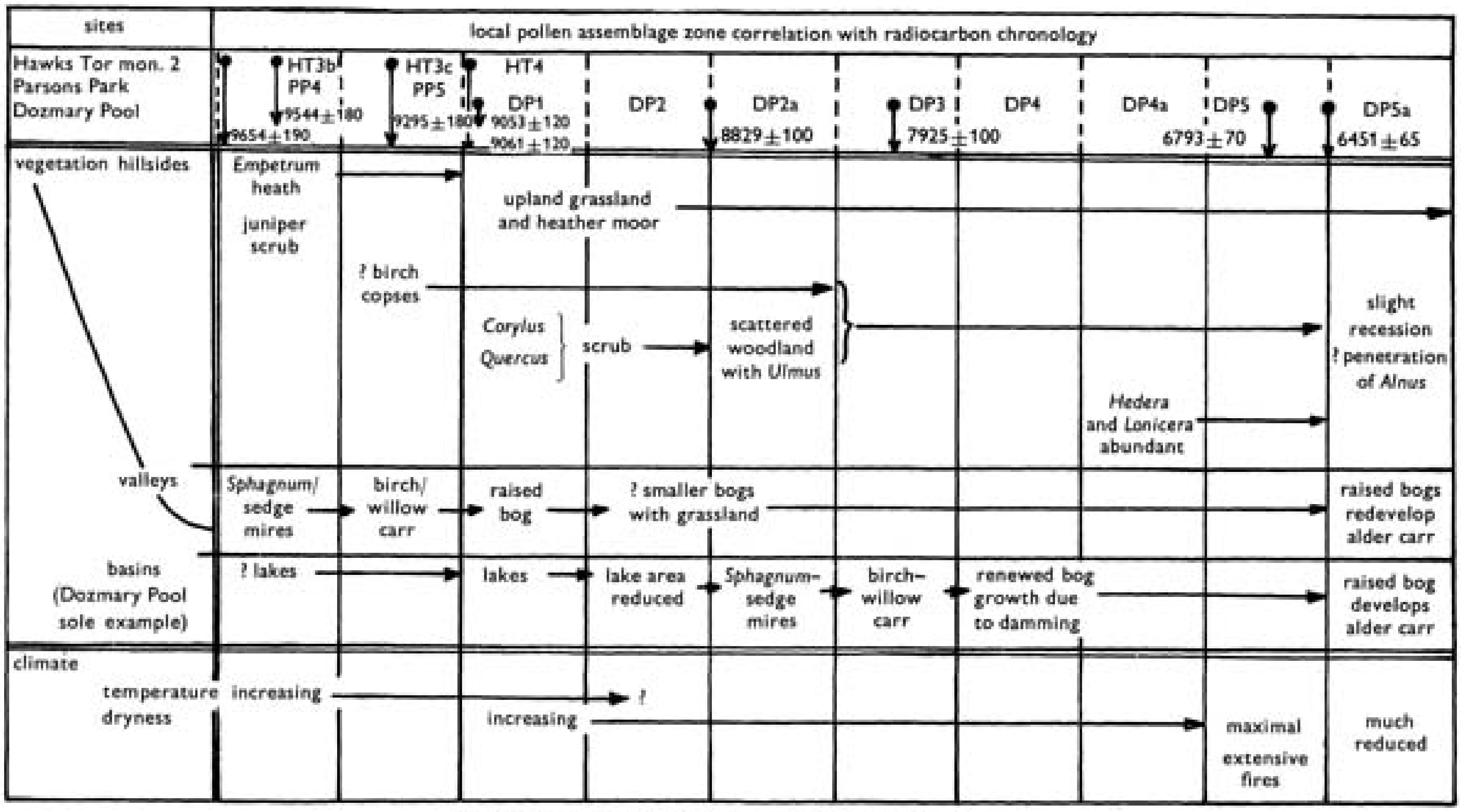


Figure 20. Early Flandrian vegetation on Bodmin Moor.

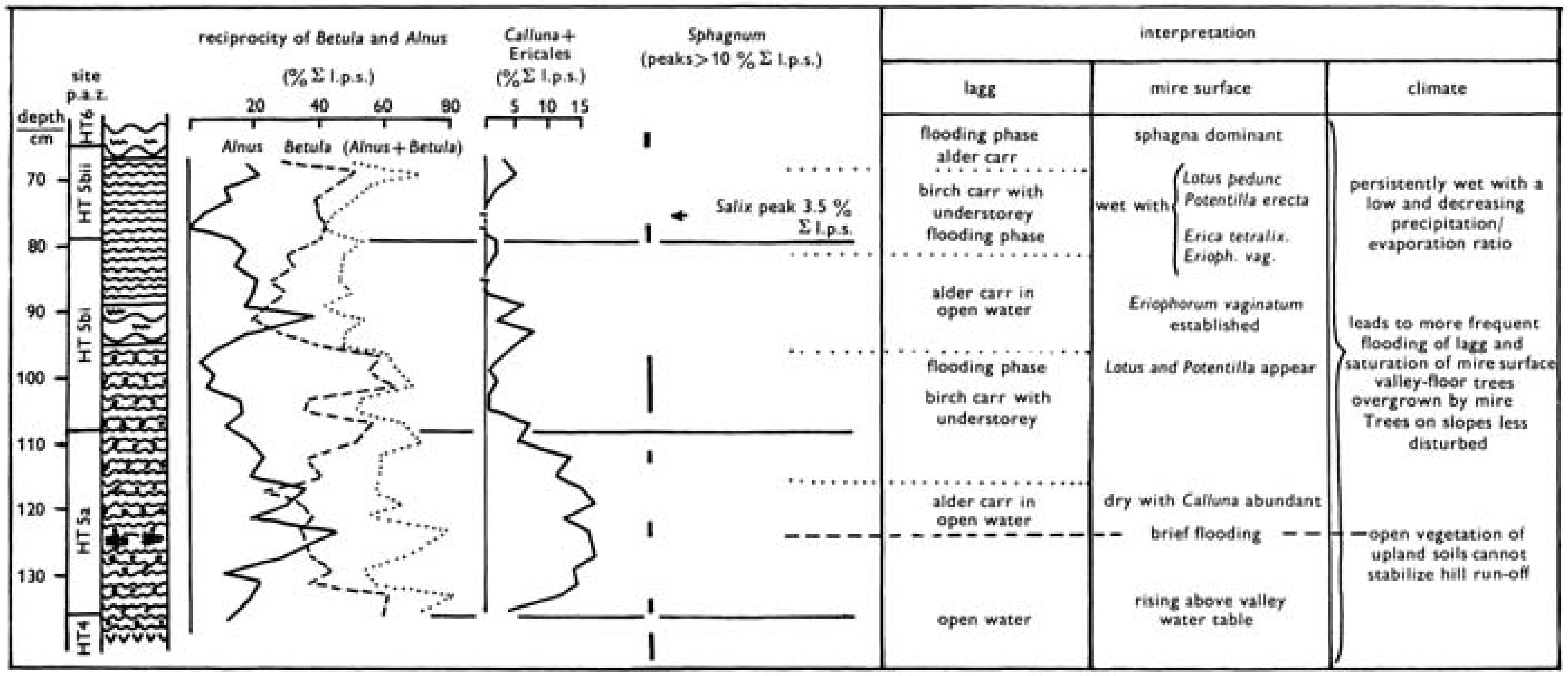


FIGURE 21. Interpretation of pollen assemblage zone HT5 – mire growth and climate.

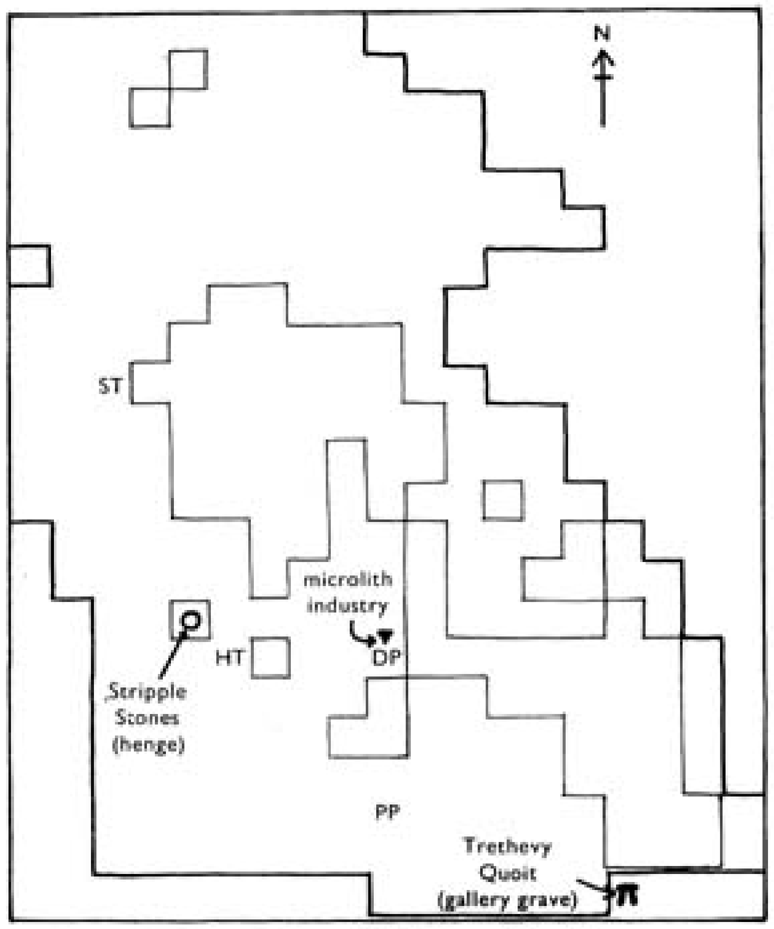


FIGURE 22. Bodmin Moor – Mesolithic and Neolithic structures. Map base as in figure 2 (p. 256).

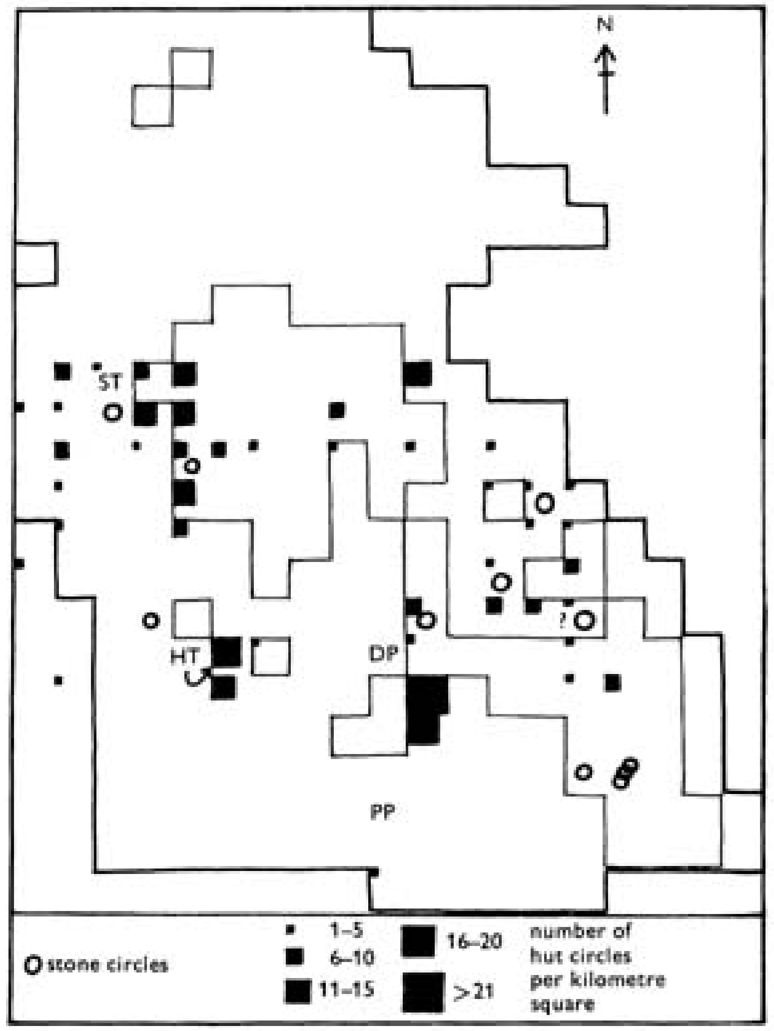
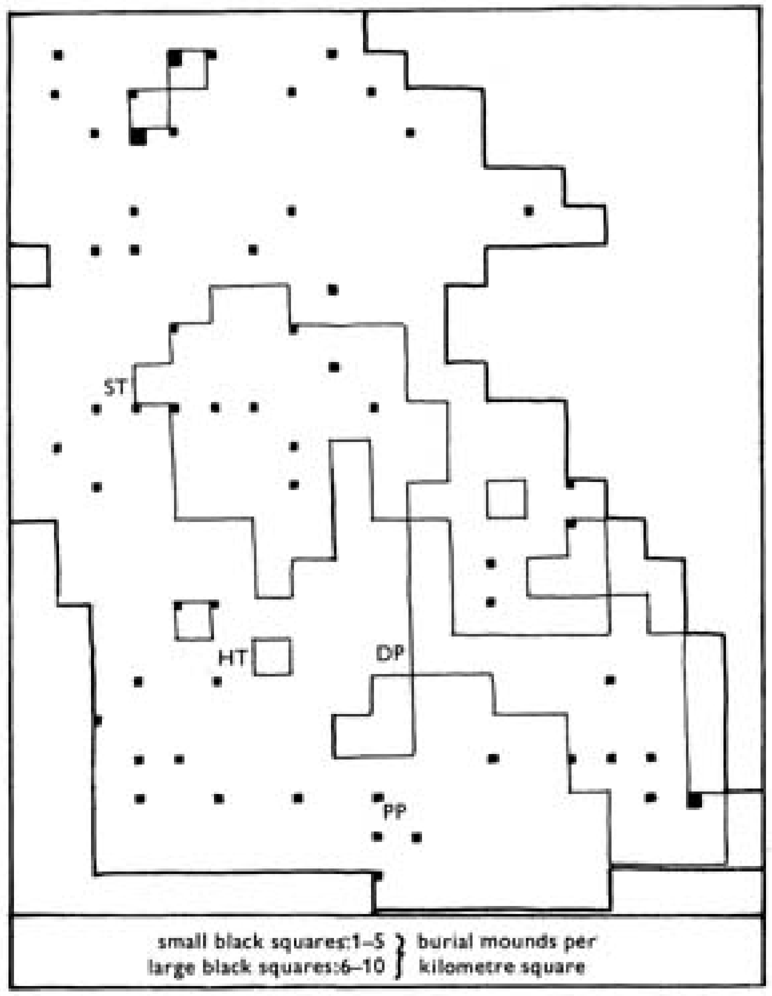


FIGURE 23. Bodmin Moore – Bronze Age hut circles and stone circles.



FIGURES 24. Bodmin Moor – Bronze Age burial mounds.

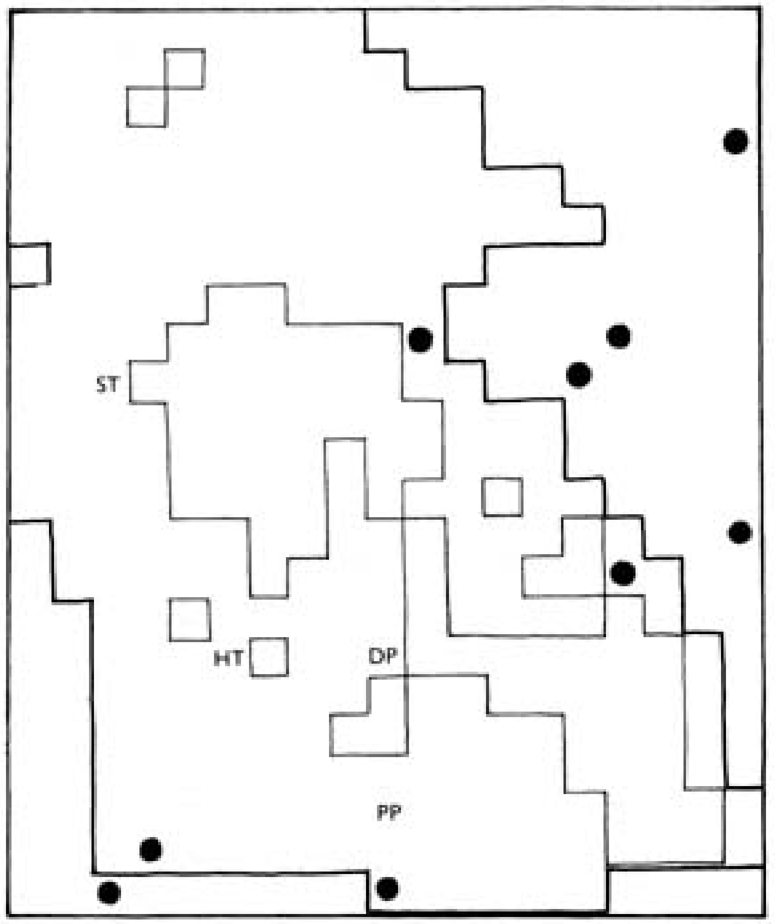


FIGURE 25. Bodmin Moor – Iron Age camps. Each black circle represents one camp.

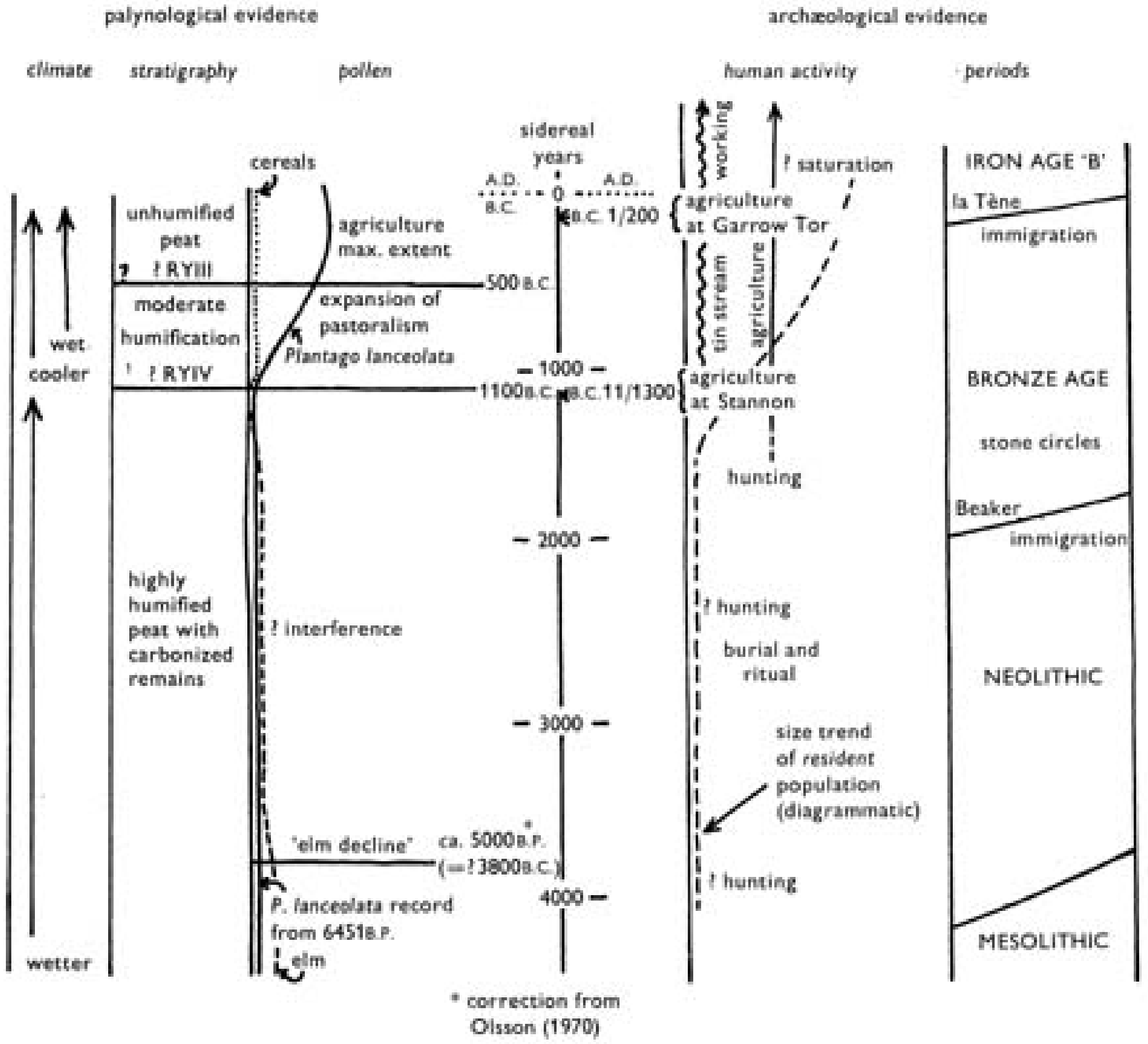
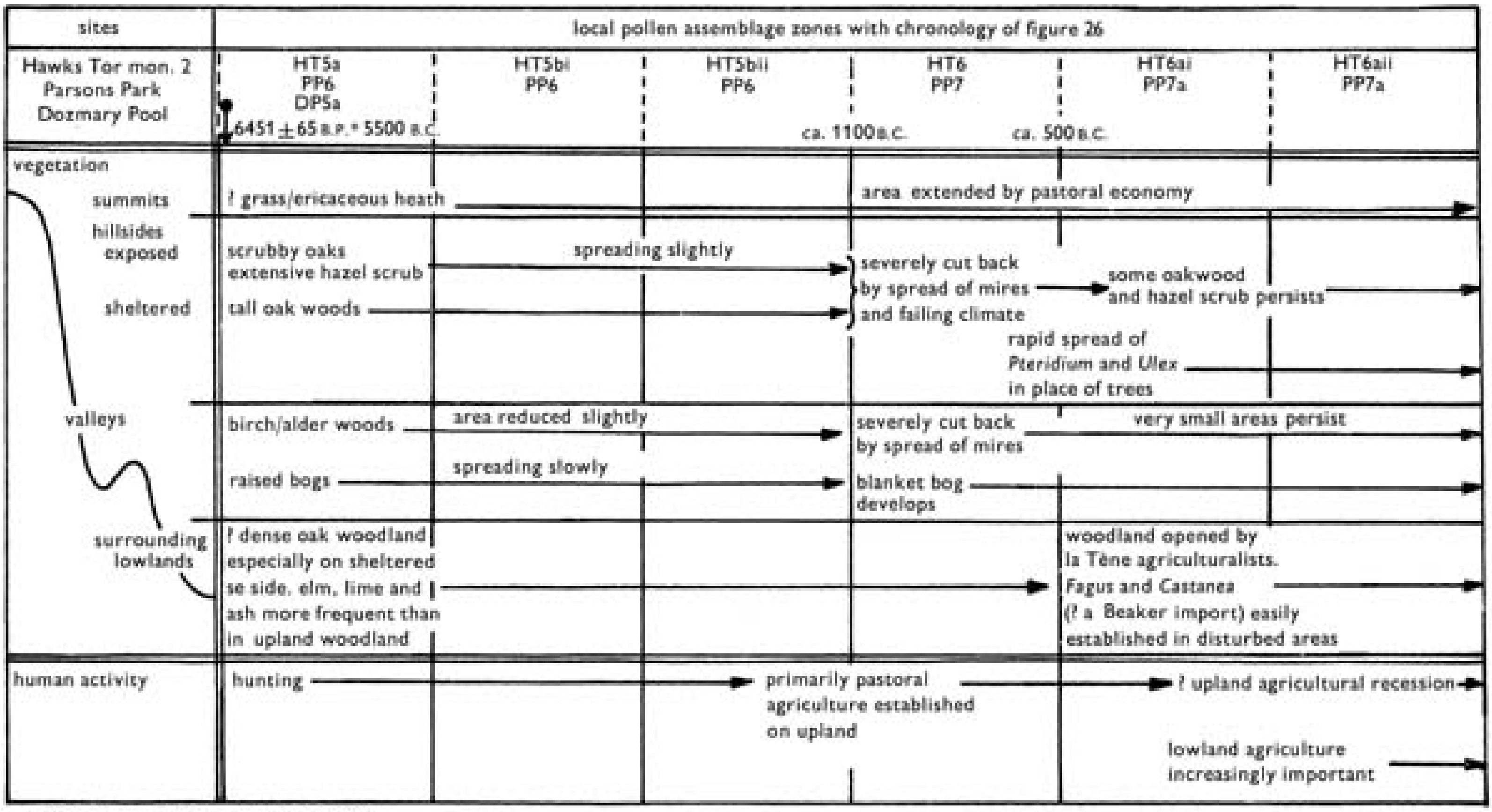


FIGURE 26. Pollen stratigraphical and archaeological correlation on Bodmin Moor.



sites	local pollen assemblage zones with chronology of figure 26					
Hawks Tor mon. 2 Parsons Park Dozmary Pool	HT5a PP6 DP5a 6451 ± 65 B.P.* 5500 B.C.	HT5bi PP6	HT5bii PP6 ca. 1100 B.C.	HT6 PP7 ca. 500 B.C.	HT6ai PP7a	HT6aii PP7a
vegetation						
summits	? grass/ericaceous heath →			area extended by pastoral economy →		
hillsides exposed	scrubby oaks extensive hazel scrub →	spreading slightly →		severely cut back by spread of mires and failing climate →	some oakwood and hazel scrub persists →	
sheltered	tall oak woods →					
				rapid spread of *Pteridium* and *Ulex* in place of trees →		
valleys	birch/alder woods →	area reduced slightly →		severely cut back by spread of mires	very small areas persist →	
	raised bogs →	spreading slowly →		blanket bog develops →		
surrounding lowlands	? dense oak woodland especially on sheltered se side, elm, lime and ash more frequent than in upland woodland →				woodland opened by la Tène agriculturalists. *Fagus* and *Castanea* (? a Beaker import) easily established in disturbed areas →	
human activity	hunting →		primarily pastoral agriculture established on upland →		? upland agricultural recession →	
					lowland agriculture increasingly important →	

*Approximation from Olsson (1970).

FIGURE 27. Later Flandrian vegetation on Bodmin Moor.

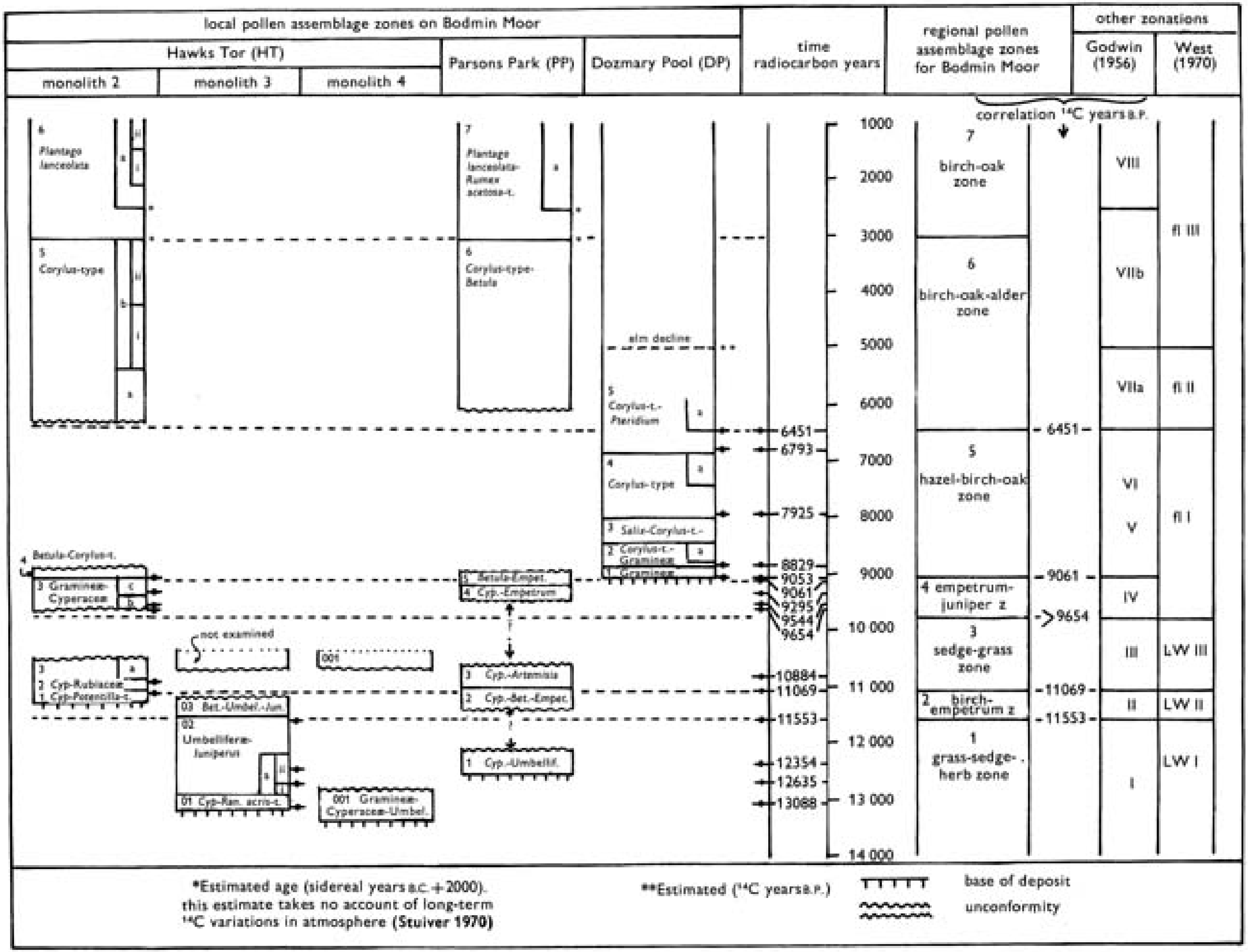


FIGURE 28. Local and regional pollen assemblage zones on Bodmin Moor.