PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

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# STUDIES OF THE POST-GLACIAL HISTORY OF BRITISH VEGETATION

# XVI. FLANDRIAN DEPOSITS OF THE FENLAND MARGIN AT HOLME FEN AND WHITTLESEY MERE, HUNTS.

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Stratigraphic survey, pollen analysis, micro- and macrofossil plant identification and radiocarbon dating have been employed to elucidate the origin and character of the deposits of the western margin of the East Anglian Fenland within the area of Holme Fen and the former Whittlesey and Trundle Meres, Huntingdonshire. As a consequence of waterlogging, alder fen-woods became established upon the Jurassic Clay fen floor some 6000 years ago; they were succeeded in turn by eutrophic *Cladium*-dominated fen which gave place to floating 'scraw bog' and ultimately to acidic raised bog, that persisted in Holme Fen and round Whittlesey Mere until after A.D. 1850. A considerable number of acidicolous flowering plants and mosses are now recorded sub-fossil from these deposits. Pollen analyses disclose the characteristic 'elm-decline' attributable to early Neolithic activity and much more extensive woodland clearance and agriculture in the middle Bronze Age when thin clay layers intrusive into the raised bogs and radiocarbon dated to 1400 B.C.,† are interpreted as the consequences of soil erosion and flooding from the adjacent uplands. Failure of these clay bands to enter Whittlesey Mere basin is attributed to the presence of the high dome of the surrounding raised bog. Still more extensive agricultural activity is indicated by the pollen analyses in the later periods. The growth of raised bog was interrupted in the Whittlesey Mere basin by the sudden incursion of clays and silts deposited in salt or brackish water, the landwards facies of the 'Fen Clay' of all the South Level area of the Fens. Again presumably because of the barrier of high raised bog round Whittlesey Mere these minerogenic deposits did not extend either into Holme Fen or into the basin of Trundle Mere. After an interval of marine retrogression, referable to a period embracing the Bronze Age–Iron Age transition and during which fresh-water peat formed over the clays and silts in Whittlesey Mere basin, renewed flooding caused the deposition of the fresh-water shell marl whose outline represents the extent of the former Trundle and Whittlesey Meres. It seems clear that this was the consequence of backing up of fresh calcareous water from the uplands against the banks of the natural channel of the River Nene raised by tidal action in the renewed marine transgression of the Iron Age and Romano-British period. Historical and physiographic evidence indicates that the river formed the northern bank of Whittlesey Mere, and that the mere was related to the natural river in the same way as Red Mere in the South Level and Ugg, Brick, Ramsey and Benwick Meres in the Middle Level. The effects of artificial drainage (especially that of Whittlesey Mere since *ca.* 1850) are followed: the great and well documented loss in surface height is attributed to initial compaction and subsequent wastage, and the northern half of the bed of Whittlesey Mere is shown to be at a higher level than the southern half on account of the clays and silts that underlie only the northern part. Development in the Whittlesey–Holme area is tentatively correlated with that already established for the Woodwalton Fen area of the Fenland margin contiguous to the south and with the South Level as a whole.

## 1. Introduction

In the 1930s members of the newly formed Fenland Research Committee concentrated a good deal of attention on establishing the main features of stratigraphy in the East Anglian Fenland basin surrounding the Wash. Activities centred in the southern part of the basin, mostly the South Level drainage area, where there were widespread and often deep peat deposits suitable for pollen analysis. By the use of this method, then recently developed in combination with correlated geological and archaeological evidence, a consistent pattern was discovered reflecting the alternation of fresh-water and salt-water conditions in the region. On the landward side the fen deposits are largely or wholly peat, but further sea-ward the peat is split into an 'Upper Peat' and a 'Lower Peat' by an increasing thickness of soft buttery clay, the 'Fen Clay' that formed in brackish water during an extensive marine transgression. In a wide belt round the Wash the Upper Peat is overlaid by many feet of silt, the 'Upper Silt' deposited in a further phase of marine transgression. This last phase was represented inland by the raised silt banks of tidal rivers (roddons) traversing the peat lands, and beyond the limit of tidal action, by the fresh-water shell marl of large fresh-water lakes such as Soham, Streatham and Red

† B.P. and B.C., after dates, signifies that the ages are in radiocarbon years.



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Meres. In the broadest terms it seemed that the Lower Peat was of Neolithic age, the Upper Peat referable to the Bronze Age and the Upper silts to the Iron Age and Romano-British time. By peat stratigraphic and pollen-analytic studies the fen-margin deposits with their continuous deep peats, buried forests and shell marls, were related to the one basic stratigraphic pattern, though the evidence of marine transgression and retrogression was then only indirect. Such marginal deposits were very well represented in the neighbourhood of Woodwalton Fen,

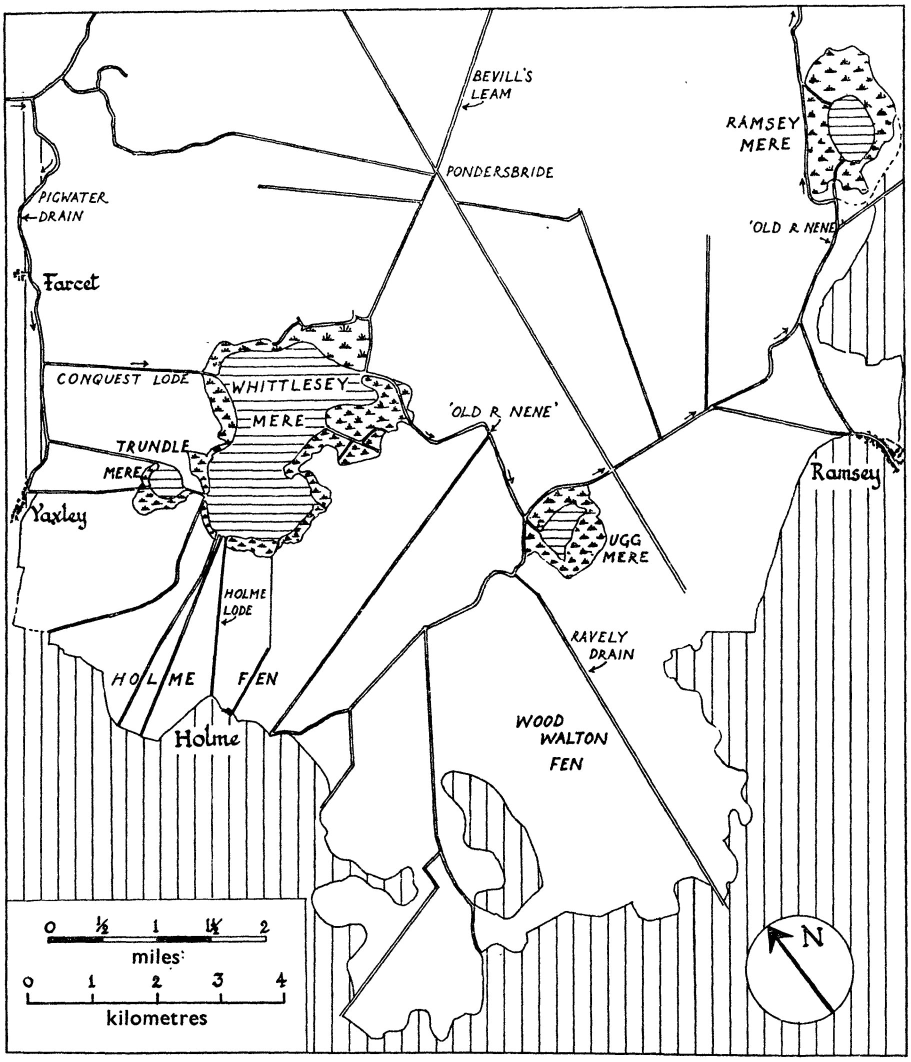


FIGURE 1. Map showing the eastern margin of the Middle Level fenland about 140 years ago. The fen meres had not yet been drained but the natural river system had almost entirely been replaced by a network of straight artificial drains. The map shows the relative positions of Woodwalton Fen and Ugg Mere, where the last detailed stratigraphy had been reported (Godwin & Clifford 1938) and the area of the present investigation, Holme Fen and Whittlesey Mere. Trundle Mere has been briefly reported on in both papers.

Huntingdonshire where they were rather fully examined (Godwin & Clifford 1938). The Fen Clay, again splitting the peat into 'Upper' and 'Lower', was shown to taper out landwards into peat deposits much more acidic than those of the South Level, and it was soon confirmed that raised bog must have been prevalent in the region up to recent historic time. At Ugg Mere shell marl was demonstrated to overlie the Upper Peat (which itself overlaid Fen Clay), but at

Trundle Mere, nearer the fen margin, the shell marl overlaid continuous acidic *Sphagnum* peat above open water fen deposits.

This sequence corresponded with that demonstrated in the South Level, but intrinsic evidence was lacking for dating the consecutive stages except that of pollen analysis, which certainly suggested that both areas were reflecting the same sequence of events. The correspondence was emphasized also by an extensive series of borings that carried the stratigraphy of the Middle Level seawards to Guyhirne and Wisbech, and that demonstrated continuity of the Upper Peat and the surface of the Fen Clay round the north of the gravel islands of Chatteris and March, thus out of the Middle Level and down into the South Level drainage district. Comparison was made of pollen diagrams throughout both the Middle and South Levels, and the coordinated results for the whole Fenland basin were considered as evidence for the progressive change of relative land- and sea-level in the Fenland throughout the Post-glacial Flandrian period (Godwin 1940).

No similarly extensive surveys of Fenland stratigraphy were subsequently undertaken but J. N. Jennings was able to make the important demonstration that the shell marls of the drained 'Red Mere' or 'Reed Mere' were contemporaneous in origin with the (at least partly) Romano-British silts of the roddon of the River Little Ouse that abutted its flank when it was a tidal river within levées (Jennings 1950).

There remained however considerable promise in further investigation of the Fenland margin west of Woodwalton Fen and north of the village of Holme in Huntingdonshire (Nat. Grid Ref. 53/205893). Holme Fen, with deep and relatively undisturbed peat deposits was by the early 1950s, a Nature Reserve accessible to investigation, as were now the deposits contiguous with it, of the bed and borders of the extinct Whittlesey Mere, which before its drainage in 1852 had been the second largest fresh-water lake in England (figure 1). Accordingly it was here that Vishnu-Mittre occupied himself in working for a Cambridge Ph.D. degree during 1957–9. Shortly thereafter samples taken at the site of the long Holme Fen pollen series were subjected to radiocarbon assay (Godwin & Willis 1960). Yearly day visits to the Holme Fen site have also been subsequently made by the Tripos classes of the Cambridge Botany School, yielding general confirmation of the stratigraphic sequence and some extension of the list of species identified in the peat deposits. Dr R. G. West allows us to make use of these additional results.

## 2. The undrained condition of the region

In any attempted reconstruction of Fenland history it is important, so far as possible, to begin by visualizing the natural condition of any given region as it was before roads, railways, drainage works and agricultural settlement affected it and before peat cutting, wastage and contraction had modified it. In particular it is desirable to establish the natural river system and natural open waters of the Fenland before they were so largely destroyed by artificial drainage that continued intermittently from Roman times onwards.

The late Mr Gordon Fowler actively pursued into the 1940s his reconstruction of the extinct natural waterways of the Fenland, relying both upon aerial photographic survey and extensive personal field investigations. We have the results published in the *J. R. geog. Soc.* (1933), in the map he supplied to the Wicken Fen Guide (1946) and in notes he transferred to the 1 inch O.S. maps of the senior author. It is evident from these that, as indicated already (Godwin & Clifford 1938, Fig. 31), a major natural river channel in the form of a roddon extended from Outwell on the Old Croft River, upstream round the island of March and as far as Flood's Ferry. He traced the same stream with diminished roddon features but meanders of the same amplitude, westwards from Benwick village along the so-called 'River Nene (Old Course)' to the south-eastern corner of Whittlesey Mere. Although cultivation and drainage have made it now difficult to trace roddon silts at ground surface into this part of its course there seems no reason to doubt that this is another instance of a large mere formed by backing up of fresh water at the limit of tidal range of a major stream active in the pre-Roman Iron Age and Romano-British period. It is significant that Fowler shows a branch of the same channel passing by Ramsey St Mary's on the north flank of Ugg Mere and as far as the smaller Brick Mere to the west of it. All three of these meres, together with Trundle Mere, adjacent to Whittlesey Mere on the west, conform to the common pattern of disposition and causation shown also in Benwick and Ramsey Meres as well as those of the South Level (see figure 2).

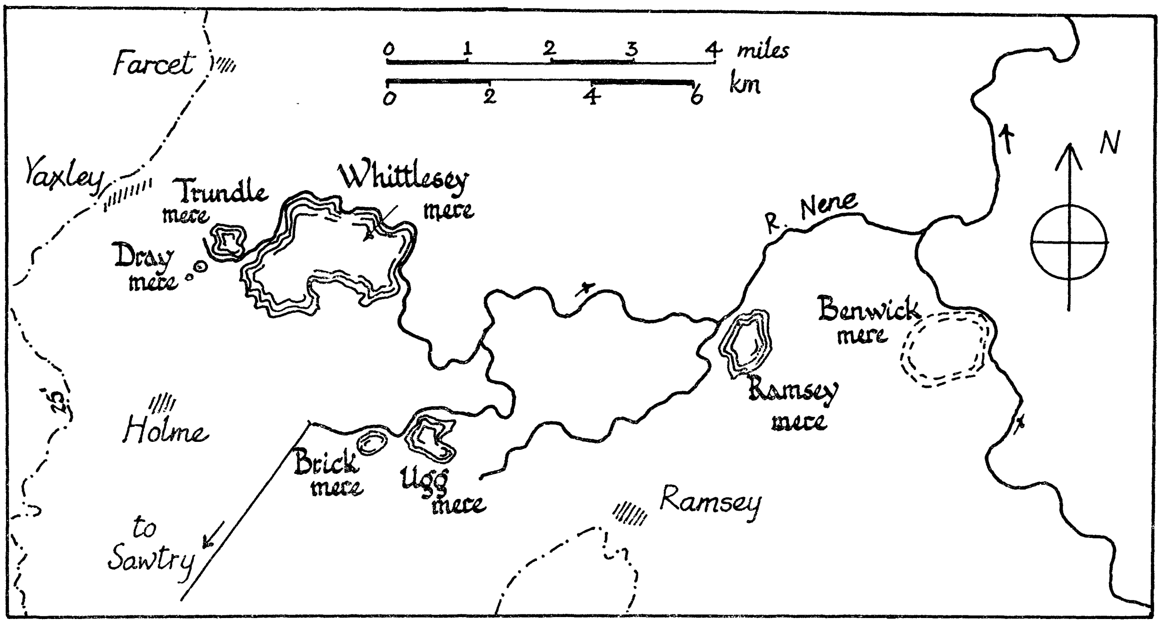


FIGURE 2. Attempted reconstruction of the pre-drainage topography of the Fenland margin in the Whittlesey–Ramsey region. The mere outlines are largely derived from the 1824 Ordnance Survey, the river courses primarily from field evidence and substantially the late G. Fowler's assessment of it. The upland margin is indicated by the 25 ft contour and the location of fen-margin villages. The mediaeval Monk's Lode to Sawtry has been added (see text).

A good deal of historical evidence indicates that the River Nene, as we shall call the natural river contiguous to Whittlesey Mere, was an open stream from Anglo-Saxon times. Part of the sinuous course of the modern river along the south boundary of Trundle Mere, and downstream of Whittlesey Mere to the east and south, carries the parish boundaries, and in the *Chronicon Petroburgense*, written A.D. *ca.* 1020 (Darby 1940) there is the passage rendered 'In the north part of the pool (Witelesmere) is a water by the name Merelade going out of the river Nen, where is the northern boundary of the pool itself'. This indicates that the river did not flow through the mere and that it had banks defining its course and separating it from the mere. It seems likely that such banks were in fact levées of tidal silt built up in Iron Age or Romano-British time, though subsequent embanking and repair has made it impossible to prove this.

The natural meaders of the embanked channel do of course strongly suggest its natural origin (figure 23, plate 23).

The course downstream is referred to in an agreement between the abbeys of Ramsey and Sawtry in 1192 (Darby 1940) by which closure of the channels made in the marshes between Whittlesey and Ugg Meres specifically excepted 'the great channel which runs from Whittlesea Mere to Sawtry, which shall remain open, for by it the monks of Sawtry bring stones and such necessaries for the building of their monastery and of their offices'. This can scarcely be other than the natural channel of the Nene between Whittlesey Mere and Ugg Mere, and thence as the straight artificial cut, Monk's Lode, south to the fen margin at Sawtry.

Yaxley Lode that bounds (the shell marl of) Trundle Mere on the south has a sinuous course and Drainage Board borings *in this region* show at two points that its banks are made of deep clays and silts to a height of +2.4 or 3.3 m (8 or 10 ft) O.D., though such deposits are absent away from the channel. It is this winding part of the lode that carries the ancient boundary and it seems to have cut off Dray Mere on the flank opposite to Trundle Mere.

This evidence makes it reasonable to reconstruct the pre-drainage situation as indicated in the map of figure 2. The relation of the Nene to Whittlesey, Trundle and Dray meres is reflected in a similar situation in a southern branch of the natural R. Nene mapped by Fowler. From its confluence with the channel from Whittlesey Mere (now about 1.61 km (1 mile) north of Ramsey St Mary's church), it leads upstream to the west with its southern bank adjoining first Ugg Mere and then Brick Mere. It is into this branch of the R. Nene that leads the mediaeval Monk's Lode to Sawtry mentioned earlier.

Ramsey Mere appears to have had a similar flanking situation to the larger natural R. Nene a few miles downstream with Benwick Mere also lateral to a major tributary close by, according to Fowler the natural course of the River Great Ouse.

In the vicinity of Whittlesey and Trundle meres at the time we are now considering, acidic raised bogs extended to the fen-margin, and the presence of substantial shell marl in the meres seems at first sight anomalous: it presumably is due to the calcareous water from the uplands brought in by drainage streams, and increasingly constricted by growth of the large raised bogs just as one still finds in the central Irish plain. Such minor streams have disappeared with subsequent drainage improvement.

It is to a natural topography and hydrology of the kind we have here reconstructed that any evolutionary development of the Whittlesey area must eventually lead.

## 3. The raised bog area: Holme Fen

### (*a*) *Gross stratigraphy*

In 1952 during field classes from the Cambridge Botany School it was established that three borings spaced northeastwards along the Caldecote Dyke, between the railway culvert and the former margin of Whittlesey Mere (figure 3), all yielded a similar stratigraphic sequence above the basal hard clay of well-humified *Sphagnum-Calluna-Eriophorum vaginatum* peat (about 150 cm thick), separated by a transitional brush-wood peat containing *Betula* (about 10 cm) from a coarse-detritus reed-swamp peat or mud peat with abundant *Phragmites* and *Cladium* (about 50–120 cm), overlying a basal wood peat of variable depth (depending no doubt on the chance encounters of the borer). The following field-notes from the middle one of the three borings illustrate the more detailed stratigraphy.

(i) *Holme Fen: site* 1 (6 April 1956)

| cm | |
|---|---|
| 0–75 | chocolate-brown, much mouldered *Sphagnum-Calluna* peat |
| 75–100 | somewhat less humified *Sphagnum-Calluna* peat |
| 100–130 | dark chocolate-brown *Sphagnum-Calluna* peat with abundant ericoid twigs, ? *Scirpus* at 105, remains of *Eriophorum vaginatum* at 100 and 115, birch twig at 120, *Scirpus caespitosus* at 130 |
| 130–140 | amorphous grey-brown peat with ericoid rootlets and traces of monocotyledon leaves; *Alnus* fruit at about 135 |
| 140–150 | aquatic laminated peat with occasional ericoid twigs |
| 150–168 | yellow-brown peat with *Sphagnum* and ericoid twigs – ? quickly-formed aquatic peat |
| 168–183 | yellow-brown reed-swamp peat with rhizomes and fruits of *Cladium* and occasional fruits of *Menyanthes* and cf. *Hypnum* at 180 |
| 183–200 | many *Cladium* fruits: abundant yellow-brown *Hypnum* peat |
| 200–210 | coarse detritus mud-peat or reed-swamp peat with fruits of *Cladium* |
| 210–220 | laminated yellow-brown *Hypnum* peat with fruits of *Cladium* and *Hypnum* remains at 215 |
| 220–225 | abundant rhizomes and rootlets of *Phragmites* |
| 225–240 | dark reddish-brown peat with frequent small wood fragments; *Potamogeton* fruit at 226 and *Alnus* fruit at 230 |
| 240–250 | more substantial and abundant wood |
| 250–275 | dark brown, rather strongly humified peat with few remains |
| 275–300 | wood peat, abundant large remains of yellow wood some monocotyledon stems: large yellow wood at 298 |
| 300–320 | as above, but very wet |
| 325 | blue-grey clay |

Similar stratigraphy was exhibited at the site chosen for more detailed investigation (bore E, figure 3) on Short Drove, 770 m southeast of Holme Lode. The site was especially favourable because the drain beside the drove had been recently deepened, peat had not been cut from the drove banks and low water levels allowed us to dig a deep inspection and sampling pit to a depth of 200 cm; below this the Hiller borer was employed. The site was several times revisited. Pollen analysis samples were secured at close intervals, layer samples were used for laboratory identification of macroscopic plant remains, and when the major horizons had been determined in the pollen sequence, carefully cleaned sections were taken for radiocarbon dating (*vide infra*). The stratigraphic sequence is given below.

(ii) *Holme Fen: bore E*

| cm | |
|---|---|
| 0–32.5 | extremely dark very highly humified old *Sphagnum-Calluna* peat with *Eriophorum vaginatum*; peat more or less structureless, *Calluna* twigs and rootlets becoming recognizable between 18 and 32.5; *Cenococcum* abundant; numerous charcoal fragments between 18 and 30 |

| | |
|---|---|
| 32.5–35 | pale brown less humified strongly laminated aquatic *Sphagnum* peat with *S. acutifolia* and *S. cymbifolia*; abundant *Calluna* and *Eriophorum vaginatum*; *Cenococcum* frequent |
| 35–50 | highly humified *Sphagnum-Calluna* peat with locally abundant *Eriophorum vaginatum* and *E. angustifolium*, at 49 a small twig cf. birch; charcoal fragments frequent between 40 and 45 |
| 50–57.5 | a pale brown moss peat with abundant *Sphagnum cymbifolium* and *S. acutifolia*; charcoal fragments at 50–52.5 |
| 57.5–85 | very much compressed and highly humified dark brown *Spagnum-Calluna* peat with abundant *Calluna*; at 65 and 72.5 a very extensive thin blue-grey clay layer. Each accompanied by flat *Phragmites* stems (probably flood layers), at 80 a substantial twig of cf. *Myrica*. Charcoal fragments between 67.5 and 75 |
| 85–92.5 | very strongly laminated yellow-brown *Sphagnum* peat with abundant leaves of *Andromeda*, twigs and shoots of *Calluna* and *Cladonia*; rhizomes of *Eriophorum* |
| 92.5–100 | old highly humified *Sphagnum-Calluna* peat with frequent *Eriophorum* and *Calluna*; abundant *Sphagnum acutifolia* |
| 100–117.5 | blackish *Polytrichum-Sphagnum* peat with frequent seeds of *Menyanthes; Cladonia* common; woody fragments of alder and fruits of Cyperaceae; charcoal fragments at 115 |
| 117.5–130 | yellow-grey very strongly laminated peat with abundant seeds of *Menyanthes*; *Sphagnum* poorly present |
| 130–140 | yellow layer very much laminated with frequent *Andromeda* and occasional *Phragmites* |
| 140–150 | quickly grown peat with *Phragmites* and rhizomes of *Cladium mariscus* and abundant large *Betula* stems; at 145 a big woody fragment of alder; few fruits of Cyperaceae, fern sporangia, *Sphagnum* and *Polytrichum* present |
| 150–195 | yellow-brown *Phragmites-Cladium* peat cf. coarse detritus with fragments of birch stems in the upper 5 cm; fern sporangia, cyperaceous fruits and fruits of *Cladium* and woody fragments present; a few colonies of *Pediastrum* present |
| 195–250 | blackish-brown *Cladium* peat with rootlets of sedges, *Hypnum* moss present |
| 250–275 | blackish-brown *Cladium* brush-wood peat with fern sporangia |
| 275–310 | blackish-brown very crumbly brush-wood peat with abundant fern sporangia and woody fragments |
| 310–317 | mud |

The thin clay layers at 65 and 72.5 cm are an intrusive element (considered later, §3 (*f*) (iii)) in the sequence that is otherwise highly typical of raised bog development in areas becoming subject to general paludification. A similar development has been established throughout Holme Fen at least to the margins of the former meres of Whittlesey and Trundle, by the lines of borings shown in figure 3 and by individual boreholes. It has been fully confirmed by the excavation in the last few years by the Nature Conservancy of a large pool, on the flanks of which good sections have been exposed and on the floor of which are the stumps and trunks of the woods entombed when general water-logging began. The ombrogenous peat itself shows the characteristic banded structure resulting from the complex pool and hummock structure of the vegetation that gave rise to it, though not evidently on the small classic pattern described by Osvald (1923, 1949). Its character is borne out by identifications made by ourselves and by other Botany School students subsequently of remains of such plants as the following

*Calluna vulgaris* (abundant twigs, flowers, seeds, anthers and pollen)
*Andromeda polifolia* (leaves and leafy twigs)
*Oxycoccus palustris* (leafy stems, anthers and seeds)
*Vaccinium vitis-idaea*
*Empetrum nigrum* (pollen – rarely)
*Eriophorum vaginatum* (stem bases and roots)
*E. angustifolium* (stem bases, rhizomes, cuticle and roots)
*Scheuchzeria palustris*
*Rhyncospora* cf *alba* (pollen)
*Epipactis palustris*
*Drosera* spp. (pollen)
*Scirpus caespitosus* (stem bases – tentatively)
*Bryophyta* (see Dickson 1973)
*Calliergon giganteum*
*Dicranum undulatum*
*D. varia*
*Drepanocladus revolvens*
*Meesia longiseta*
*Pleurozium schreberi*
*Polytrichum alpestre*
*Pohlia nutans*
*Sphagnum papillosum*
*Sphagnum* spp.
lichens
*Cladonia* spp. (shoots)

This list, to which the records at Trundle Mere contribute additions, strongly underlines the reality of the former presence of active raised bog hereabouts. As Dickson notes, some of these plants are no longer found in East Anglia and *Meesia longiseta* no longer grows in Britain.

(iii) *Trundle Mere*

It had already been established (Godwin & Clifford 1938) that in the neighbourhood of the former Trundle Mere, west of Whittlesey Mere, there were deep deposits of *Sphagnum-Calluna-Eriophorum* peat and that indeed the calcareous shell marl of the former lake rested upon deposits of this kind. In subsequent years deep sections exposed in widening Yaxley Lode at the eastern end of the mere showed deep ombrogenous peat also extending towards the former Whittlesey Mere, and now a series of borings confirms that raised bog must formerly have extended right through from Holme Fen over the whole of the Trundle Mere region.

The gross stratigraphy at the mere in 1938 was reported as follows:

| cm | |
|---|---|
| 0–45 | calcareous marl |
| 45–60 | dark brown to black acidic peat, the uppermost a *Sphagnum-Calluna* horizon |
| 60–120 | *Eriophorum-Betula* brushwood peat |

| | |
|---|---|
| 120–220 | *Sphagnum-Eriophorum-Calluna* peat |
| 220–257 | transition peat with Characeae, *Cladium* and abundant Cyperaceae, along with abundant *Sphagnum* material |
| 257–330 | brushwood peat with birch wood and bark |

The tree and non-tree pollen, spores and other remains confirmed this sequence, particularly the presence of two brush-wood layers, the aquatic origin of the peat directly overlying the lower one, and the abundant presence of species typical of oligotrophic mires.

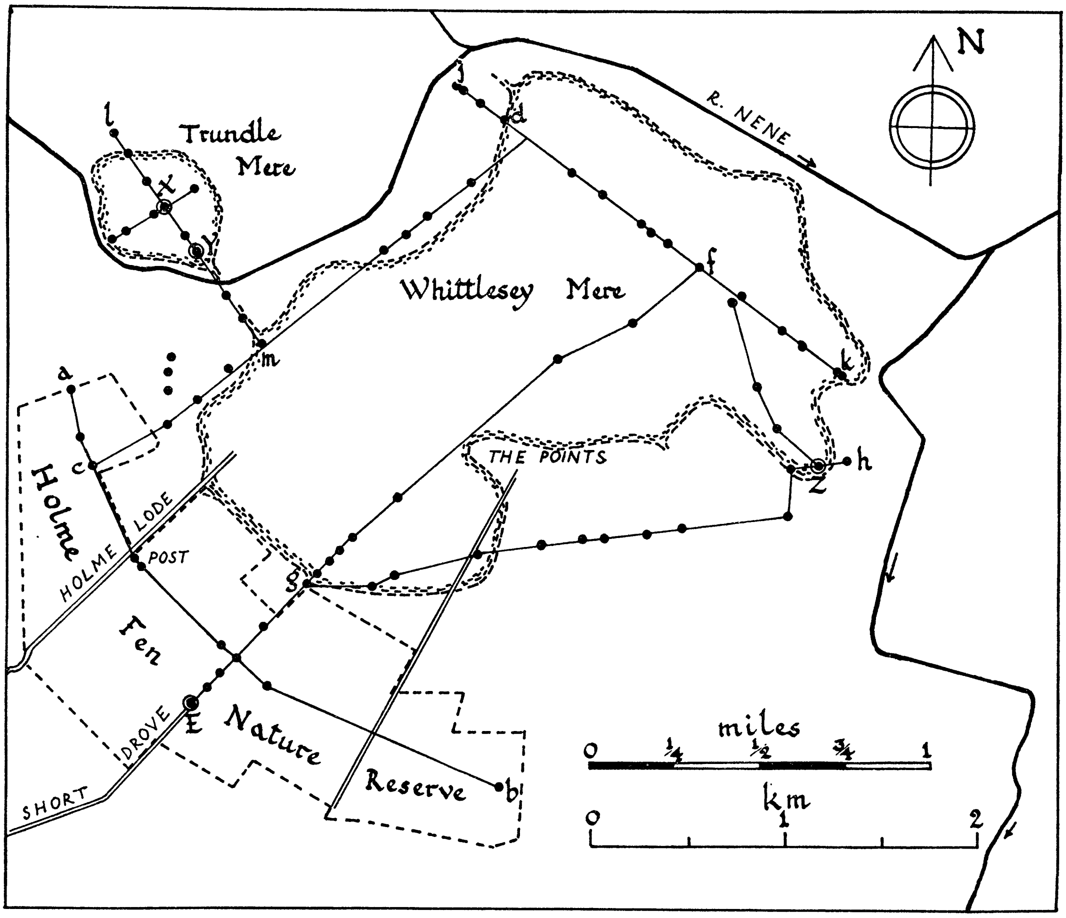


FIGURE 3. Map showing the location of boreholes and excavations. The Holme Fen Nature Reserve is almost entirely dried-out raised bog, colonized since 1852 by tree-birches. The outlines of Whittlesey Mere and Trundle Mere are taken from Lenny's map of 1833: they were surrounded by a wide belt of reed-swamp, and the area of open water varied greatly from year to year. The river course is that in recent O.S. maps. The lines of section shown in figures 13, 15 and 16 are lettered. Sites of pollen analytic series are indicated by the ringed spots, Y, Z, E and X. E was the site of radiocarbon dating and X that of the series described by Godwin & Clifford (1938).

More detailed stratigraphy provided by the recent observations is indicated by the following description, based on laboratory determinations supplemented by field-notes, at the site Y (figure 3) near the SE margin of the former Mere, and from which the pollen and spore analyses were subsequently made: it lies just outside the limits of the calcareous marl.

| cm | |
|---|---|
| 0–35 | *Hypnum* peat with *Hypnum cupressiforme*, *Scorpidium scorpioides*, *Drepanocladus* sp. cf. *lycopodioides* and stems of *Myrica gale*; charcoal fragments, *Pediastrum* and *Botryococcus* present |
| 35–42.5 | *Eriophorum-Hypnum* peat with abundant *Eriophorum vaginatum*, *Hypnum cupressiforme* and *Scorpidium scorpioides* |
| 42.5–55 | *Eriophorum-Calluna-Sphagnum* peat with occasional *Hypnum* and *Scorpidium;* charcoal fragments frequent between 45 and 55 |
| 55–102.5 | narrow-leaved *Sphagnum* peat with a birch stem at 60 followed by *Sphagnum acutifolia* peat with abundant *Caluna*; alternating layers of *Sphagnum-Eriophorum* peat at 60, 65, 75 and between 80 and 87.5; charcoal fragments frequent between 55 and 85 and between 95 and 100; algal colonies rare |
| 102.5–110 | *Sphagnum acutifolia-Calluna-Dicranum* peat with *Dicranum bergeri*, *Drepanocladus* sp. and occasional *Hypnum* moss and *Eriophorum vaginatum*; at 100 rhizomes of *E. vaginatum* and *Cladium mariscus* |
| 110–117.5 | *Hypnum-Dicranum* peat with *Dicranum bergeri*, *Dicranum* sp., *Dicranella varia* with less frequent *Sphagnum* twigs and flowers of *Calluna* and anthers and seeds of *Erica tetralix*. Few fruits of *Cladium mariscus*; *Pediastrum* and *Botryococcus* also present |
| 117.5–125 | *Dicranum-Sphagnum* peat with *Dicranum* sp. cf. *Scoparium*, *Aulacomnium palustre*, *Sphagnum cymbifolia*, *Drepanocladus* sp. and *Thuidium* sp.; seeds, flowers and anthers of *Calluna* and seeds and anthers of *Erica*. Charcoal fragments frequent between 115 and 125 |
| 125–147.5 | *Sphagnum-Calluna* peat with *Sphagnum acutifolia* and *cymbifolia*, *Calluna*, *Erica tetralix* and *cinerea* and numerous seeds of *Menyanthes*; other mosses include *Hypnum cupressiforme*, *Thuidium tamariscinum*, *Dicranum bergeri*, *Dicranella varia* and *Aulacomnium palustre*; a carbonized caryopsis |
| at 137.5 | charcoal fragments frequent; a fruit of *Cladium mariscus* at 145 |
| 147.5–157.5 | *Sphagnum-Calluna* peat with *S. acutifolia* and *S. cuspidata*, *Calluna*, *Erica tetralix* and *cinerea*; cyperaceous rootlets frequent; a fruit of *Cladium mariscus* at 147.5; charcoal fragments frequent between 147.5 and 155; a few algal colonies; a carbonized caryopsis at 150 |
| 157.5–160 | *Sphagnum-Calluna-Eriophorum vaginatum* peat with abundant *Sphagnum acutifolia* |
| 160–167.5 | *Eriophorum-Sphagnum-Calluna* peat with *Cladonia*; charcoal at 167.5 |
| 167.5–172.5 | *Sphagnum acutifolia-Dicranum* peat with *Eriophorum vaginatum* and very frequent seeds and flowers of *Calluna vulgaris*, anthers of *Andromeda*, *Oxycoccus* and *Erica tetralix*; charcoal very frequent |
| 172.5–182.5 | *Dicranum bergeri-Sphagnum-Calluna* peat with *Eriophorum vaginatum* and *Erica tetralix*; charcoal present |
| 182.5–185 | *Calluna-Eriophorum-Cladonia* peat; charcoal present |
| 185–187.5 | *Sphagnum-Hypnum* peat with *S. acutifolia*, *Hypnum*, *Scorpidium* and *Dicranum bergeri*; *Eriophorum vaginatum* and charcoal present |
| 187.5–190 | *Sphagnum-Calluna* peat with *Erica tetralix* and *Cladonia* |
| 190–192.5 | *Eriophorum vaginatum-Calluna* peat with *Erica tetralix*, *Oxycoccus* and abundant *Cladonia*; *Sphagna* poorly present |




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192.5–202.5 *Sphagnum-Calluna-Eriophorum* peat with narrow- and broad-leaved *Sphagna* (*S. cymbifolia* and *acutifolia*). *Cladonia* and cyperaceous rootlets frequent; charcoal at 202.5

202.5–210 *Sphagnum* moss peat with *S. acitifolia* and *cymbifolia*, *Dicranum bergeri*, *Dicranella varia*, *Aulacomnium palustre*, *Thuidium tamariscinum*; frequent seeds and flowers of *Calluna*, anthers of *Oxycoccus* and *Andromeda*; few fruits of *Cladium mariscus*; charcoal from 202.5 to 207.5

210–220 *Sphagnum* moss peat with abundant *S. acutifolia* and *Dicranella varia* (a), *Dicranum bergeri* (f), *Pohlia delicatula* (r) and *Hypnum cupressiforme* (r); *Calluna*, *Erica* and *Cladonia* present; charcoal between 215 and 220

220–222.5 *Sphagnum* peat with abundant *S. cuspidata* and *cymbifolia*

222.5–230 *Sphagnum-Calluna* peat with *S. acutifolia* and *cymbifolia*, *Dicranum bergeri*, *Dicranella varia*, *Pohlia delicatula*; seeds and flowers of *Calluna* and anthers of *Andromeda* frequent; *Eriophorum vaginatum* abundant between 220 and 225; algal colonies frequent

230–252 *Hypnum-Drepanocladus* peat with *Hypnum cupressiforme*, *Scorpidium scorpioides* and fruits of *Cladium mariscus*; charcoal at 252; abundant colonies of *Pediastrum*, *Coelastrum* and *Botryococcus*

252–260 *Sphagnum-Eriophorum* peat with equally abundant *S. acutifolia*, *cymbifolia* and *cuspidata*; *Dicranella varia* and *Hypnum* moss frequent; fruits of *Cladium mariscus*, cyperaceous rootlets and fern sporangia very frequent; fruits of *Carex* rare; charcoal at 260; algal colonies abundant

260–270 moss peat with abundant *Eriophorum vaginatum*, *Dicranella varia*, *Hypnum* sp., *Thuidium* sp., *Aulacomnium palustre* more abundant than *Sphagna*; fruits of *Potamogeton*, cyperaceous rootlets and fern sporangia frequent

270–277.5 *Sphagnum* moss peat with *S. cymbifolia*, *S. cuspidata*, *Hypnum*, *Dicranella varia* and rare *Drepanocladus*; cyperaceous and moss stems and rootlets very frequent

277.5–280 *Dicranella-Eriophorum* peat with poor *Sphagnum*; fruits of *Cladium mariscus* and woody fragments

280–295 highly humified organic detritus with very poor *Sphagna* and abundant woody fragments; fruits of *Cladium mariscus* frequent; charcoal fragments at 290 and 295

295–297.5 moss peat with poor *Sphagna*, *Dicranella*, *Dicranum*, *Hypnum* and *Calluna* and sporangia of ferns

297.5–305 *Sphagnum* moss peat with abundant narrow and broad-leaved *Sphagna*, *Dicranum bergeri*, *Dicranella varia*, *Drepanocladus* and *Hypnum* with flowers and seeds of *Calluna* and fruits of *Carex*; anthers of *Andromeda polifolia*; charcoal at 300

305–375 very fine organic detritus with few moss cuticles, woody fragments, fruits of *Carex*, rootlets of Cyperaceae and fern sporangia, fruits of *Cladium mariscus* in the upper layers; charcoal between 305 and 325 and between 350 and 375

This sequence broadly corresponds with that published in 1938. The lower eutrophic brushwood layer is confirmed and the succeeding aquatic deposits with high algal frequencies, and *Cladium* remains along with *Sphagna*. Likewise the long succeeding stage of oligotrophic bog peat, to be displaced in the upper 50 cm or so by the final wet and increasingly eutrophic stage with high frequencies of aquatic plants and some revival of algal representation. The interruption of the acid mire deposits by a birch brush-wood stage followed by flooding is not represented in the later profile, but it is notable that the deposits of this stage differ throughout from those of typical raised bog in often containing rhizomes of *Cladium mariscus*, seeds of *Nuphar*, *Nymphaea* and *Menyanthes* and mosses such as *Scorpidium scorpioides* and *Drepanocladus* sp., that indicate diminished oligotrophy.

This rather suggests that because of the tendency for drainage to accumulate in this basin the oligotrophic mire type may have been what is called in Ireland 'scraw bog', in which large floating mats of *Sphagnum-Calluna-Eriophorum* vegetation exist in a matrix of half-solidified submerged aquatic but mostly oligotrophic plants, the whole slowly sinking and consolidating under its own weight as it grows. It was a deposit somewhat of this kind that filled the Meare Poole, Somerset (Godwin 1955) and it was well represented at Aamose, the great Zealand mire where Troels-Smith's meticulous stratigraphic studies showed the former role of the floating islands that rose and fell as the water levels altered (Troels-Smith 1953), and that sometimes bore local human occupation sites on their surface and traces thereof in the muds alongside and even below. See also the account of Whybunbury Moss (Poore & Walker 1958–9) and the discussion of the role of floating islands in post-glacial hydroseres by Walker (1970).

Among the species indicative of oligotrophic conditions and not recorded in the Holme Fen list we have

*Erica tetralix*
*E. cinerea*
*Aulacomnium palustre*

## (*b*) *Pollen analyses*

### (i) *Method and sites*

Pollen analyses have been used in these investigations first to complement the evidence of macroscopic plant remains in the reconstruction of the former mire communities, secondly to provide a rough chronology for the history of development of the deposits and stratigraphy of the area and thirdly, to reflect changes in the vegetation of the surrounding upland induced by woodland clearance and the introduction of agriculture.

The methods employed are those generally used in the Cambridge Sub-department of Quaternary Research involving disintegration with dilute alkali, followed by chlorination, acetolysis and mounting, unstained in glycerine. Two hundred to five hundred tree pollen grains per sample were counted and *Corylus* was not reckoned in the total tree pollen diagram. These preparations provided not only material for the provision of diagrams of arboreal and non-arboreal pollen, of aquatic and mire plants and agricultural indicators but yielded information on the relative abundance of important genera of algae (illustrated in figure 10) and upon the varying frequency of fungal remains (the subject of separate publication).

Pollen analyses were concentrated upon two major sequences, one in Holme Fen and one at Trundle Mere, at sites for which the stratigraphy has already been described: both are in the raised bog area and the latter close to the site of less intensive analyses by Godwin & Clifford (1938). A shorter pollen-series made at a site in the area of the former Whittlesey Mere has only subsidiary importance (site Z).

(ii) *Pollen zonation and forest history*

The pollen diagrams from the Woodwalton area and from Trundle Mere, published in 1938, were zoned according to a local Fenland system which in part followed the emerging zonation system for the British Isles as a whole, but which, in its sub-division of zone VII was frankly based upon the strong local development of two periods (sub-zones b and d) during which extensive fen-woods developed during phases of dryness, alternating with two periods (sub-zones a and c) of greater wetness when fen-woods were almost absent save at fen-margins. This sub-division has here been abandoned in favour of the two sub-zones a and b of the general scheme for England and Wales introduced in 1940 (Godwin 1940*a*). We have however retained the early transition zone VII–VIII to facilitate comparison with the earlier Fenland studies primarily correlated through archaeological and geological history (see Godwin 1940*b*). Roughly speaking, zone VII–VIII was pre-Roman Iron Age, as sub-zone VIId was Bronze Age and VIIc and b were Neolithic: in the present zoning VIIb is Neolithic and Bronze Age together. The relation of the two schemata is shown below.

| 1938–40 papers | | present usage | forest composition | climatic periods |
|---|---|---|---|---|
| VIII | | | alder–oak–elm–birch (beech) (transition) | Sub-atlantic |
| VII–VIII | | | | |
| | d | | | Sub-boreal |
| | | b | | |
| VII | c | | | |
| | – – – – – | – – – – – | alder–oak–elm–lime | – – – – – – – |
| | b | | | |
| | | a | | Atlantic |
| | a | | | |

It has become increasingly accepted that the development of any pollen-zonation to serve as a chronological reference system has become exceedingly problematic for the last four or five thousand years during which man has so much affected the natural forest cover. All the same by relying upon the broad shifts in composition of the upland forest the zonation we have used seems to give results consistent with other stratigraphic, archaeological and radiocarbon evidence available.

Instead of the normal setting out of a pollen diagram including all arboreal pollen, we felt it more instructive to incorporate the tree pollen curves in three separate diagrams showing respectively (*a*) fen-wood and raised bog elements, (*b*) upland mixed-oak forest elements – *Quercus*, *Ulmus*, *Tilia* and (*c*) indicators of agricultural activity. This has the great advantage of facilitating the separate recognition of the local and regional vegetational history while not preventing recognition of the zonation criteria.

The zonation criteria are those previously applied to this Fenland region. The lower part of both Holme Fen and Trundle Mere are referable to zone VIIa since the high *Alnus* excludes zone VI and the high *Ulmus* and *Tilia* frequencies indicate a date in the hypsithermal, as do the high values for *Hedera* (0.65 % of arboreal pollen). Recognition of the zone VIIa/VIIb boundary, as also later zone boundaries, is facilitated by repeating the method used in the earlier fenland papers, of separately expressing the values for *Ulmus*, *Quercus* and *Tilia*, each as a percentage of the sum of the three, thus revealing changes in the upland mixed oak woodland substantially unaffected by local growth of fen woods. It will be seen from figure 7 that, as in the earlier diagrams, in zone VIIa *Tilia* is more abundant than *Ulmus* and in VIIb, though both have declined, *Ulmus* has done so substantially more (and suddenly at the zone opening) so that they are now sub-equal. The end of zone VIIb is indicated by a drastic reduction in *Tilia* values which are henceforward below those of *Ulmus*. *Quercus* values show a steady relative increase from base to top of both diagrams, and these indeed show remarkable correspondence. The following figures (Vishnu-Mittre 1971) show the results for the Trundle Mere analyses.

| pollen-zone | VIIa | VIIb | VII–VIII | VIII |
|---|---|---|---|---|
| grains counted *Tilia cordata* | 368 | 646 | 47 | 7 |
| *T. platyphyllos* | 19 | 66 | 5 | 3 |
| *Tilia* as approximate % total *Ulmus* + *Quercus* + *Tilia* | 20 | 15 | 2 | 1 |

The results from Holme Fen were similar. It proved possible to recognize separately the pollen of the winter and summer limes, but that of the former (*T. cordata*) was much the more abundant. The low frequencies of *T. platyphyllos* precluded separate use of its pollen curve as a zone index but it seemed to have shared the changes exhibited by the more abundant species: both are characteristic of the hypsithermal, and both were no doubt selectively exploited.

It has become apparent that a dramatically sudden and permanent decrease in elm pollen frequencies characterized the zone VIIa/b boundary throughout this country and indeed radiocarbon dating has confirmed a rather close synchroneity of the 'elm decline' everywhere.

Zone VIII is particularly characterized by very great expansion of clearance and agricultural activity, and it may possibly be on this account that in the arboreal pollen count it shows increased values and a continuous curve for beech (*Fagus*), lower and sporadic, but increased hornbeam (*Carpinus*) and much increased substantial values for birches (*Betula*), not attributable to locally developed fen-woods.

Although it is conceded that the zone boundaries are hard to define precisely there is no reason to doubt the broad validity of the zoning we have proposed: it gives excellent concordance between the sites and is not contradicted by other types of evidence including that of radiocarbon dating.

### (*c*) *Radiocarbon dating at Holme Fen: site E*

After the pollen analyses at Holme Fen had been largely completed the site from which they had been taken was revisited during 1959, the excavation faces were cut back and cleaned, and, by using the upper clay bands of the profile as depth markers, samples of wood were secured at three critical horizons, all directly related to the pollen zonation. They yielded results as follows (Godwin & Willis 1960):

Q-403 65 cm — 3400 ± 120 B.P.
*Calluna* twigs from upper of two thin clay layers at zone boundary VIIb/VII–VIII.

Q-404 70 cm — 3415 ± 120 B.P.
*Calluna* twigs and *Eriophorum vaginatum* shoots from the lower of two thin clay layers at zone boundary VIIb/VII–VIII, with pronounced but temporary phase of agricultural activity.

Q-405 135 cm — 4190 ± 130 B.P.
*Betula* wood *in situ* in fenwood peat at base of ombrogenous *Sphagnum* peat: middle of zone VIIb.

Q-406 205 cm — 4958 ± 130 B.P.
Wood (? *Alnus*) grown *in situ* in *Cladium* fen: the zone VIIa/VIIb boundary with *Ulmus* decline, relative decrease of *Tilia* and earliest indications of agricultural activity.

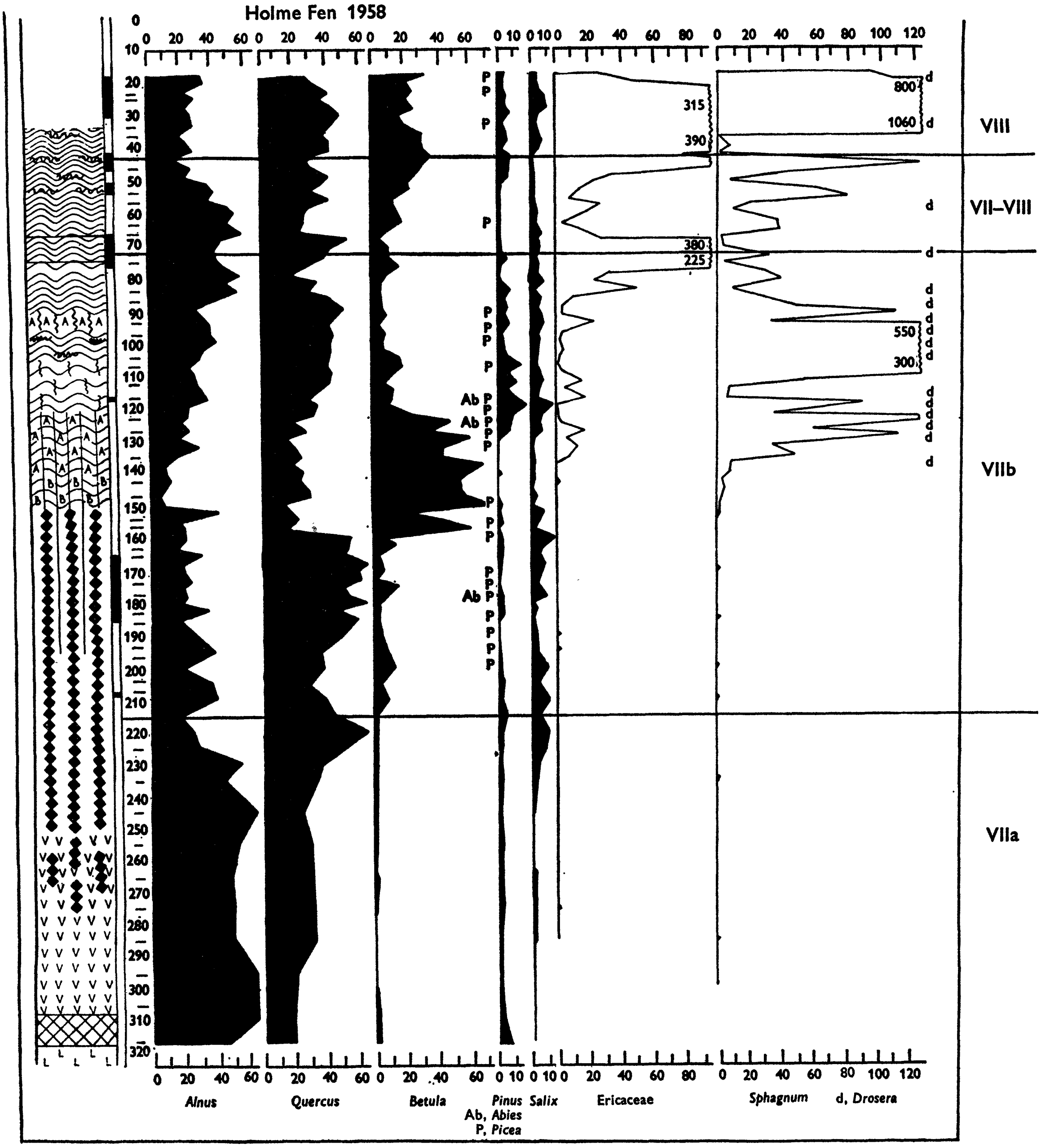


FIGURE 4. Pollen diagram from Holme Fen, E, showing mostly components of local fen woods and of raised bog. Stratigraphic symbols as shown below figure 18.

Taken in conjunction with the zoned pollen diagrams we now have the framework of a chronological system against which we can evaluate the ecological-stratigraphic evolution of the area, and, by extrapolation, that of Whittlesey Mere also.

### (*d*) *Vegetational sequence at Holme Fen*

Reference to the stratigraphic descriptions already given and the pollen diagrams showing respectively components of fen-woods plus raised bog (figure 4) and aquatics (figure 8) allows us to make the following summary for site E.

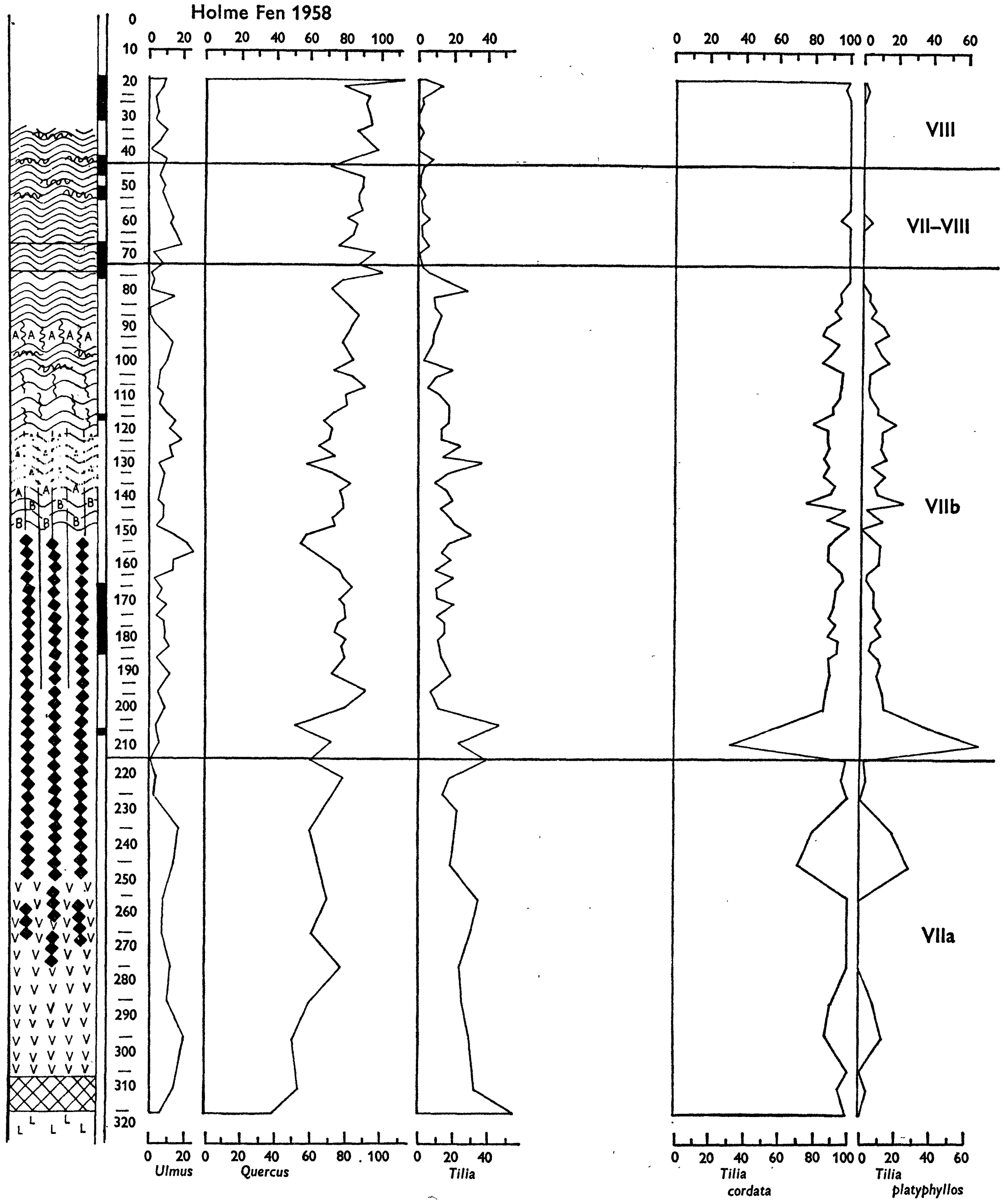


FIGURE 5. Pollen diagram from Holme Fen, E, showing trees of the mixed oak woodland of the upland: oak, elm and lime shown as percentages of the sum of the three. Right, *Tilia cordata* and *T. platyphyllos* pollen as proportions of total *Tilia* pollen.

(1) From 310 to 255 cm: wet alder fen-woods, indicated by macroscopic alder wood throughout, persistent high values for alder pollen with moderately frequent fern sporangia and spores but virtually no pollen of sedges. *Cladium* rhizomes towards the top intrusive from the succeeding phase.

(2) From 255 to 150 cm: wet *Cladium-Phragmites* fen with strong suggestion of *Magnocaricetum* in the high curve for Cyperaceous pollen: some colonies of *Pediastrum* and a

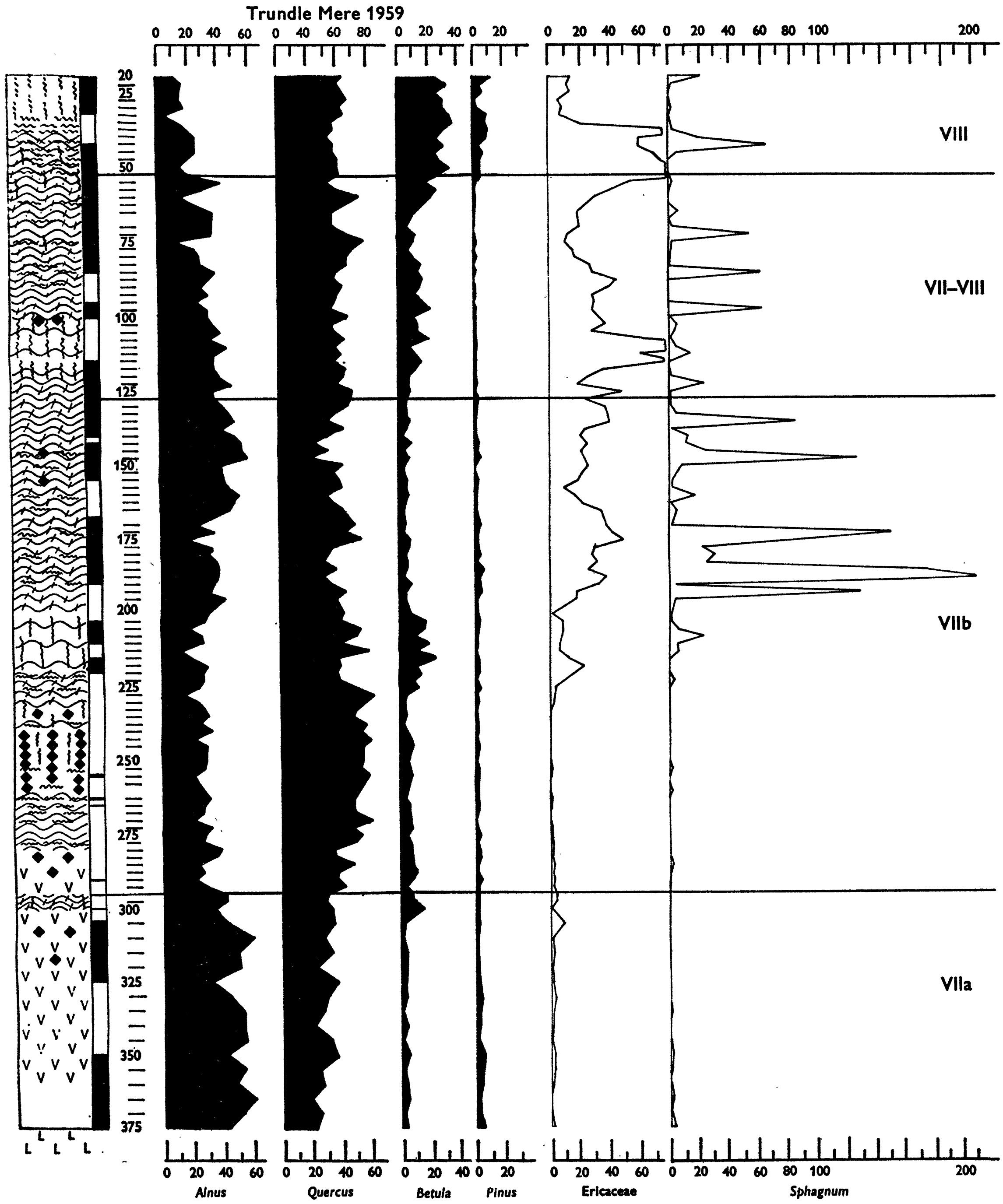


FIGURE 6. Pollen diagram from Trundle Mere, Y, showing major components of local fen woods and, right, of raised bog. Stratigraphic symbols as shown below figure 18.

particularly wet phase with high values for pollen of *Typha*, '*Sparganium*' and some *Nymphaea* and *Menyanthes* between 185 and 215 cm (just above the horizon of the $^{14}$C date of 4958 ± 130 B.P.). Some willow and occasional alder growing in the wet fen. Immediately before the phase of greatest wetness very high values for spores of *Osmunda* and of other ferns possibly indicate consequences of flooding not so much at the site as in neighbouring fen-woods on slighly higher ground.



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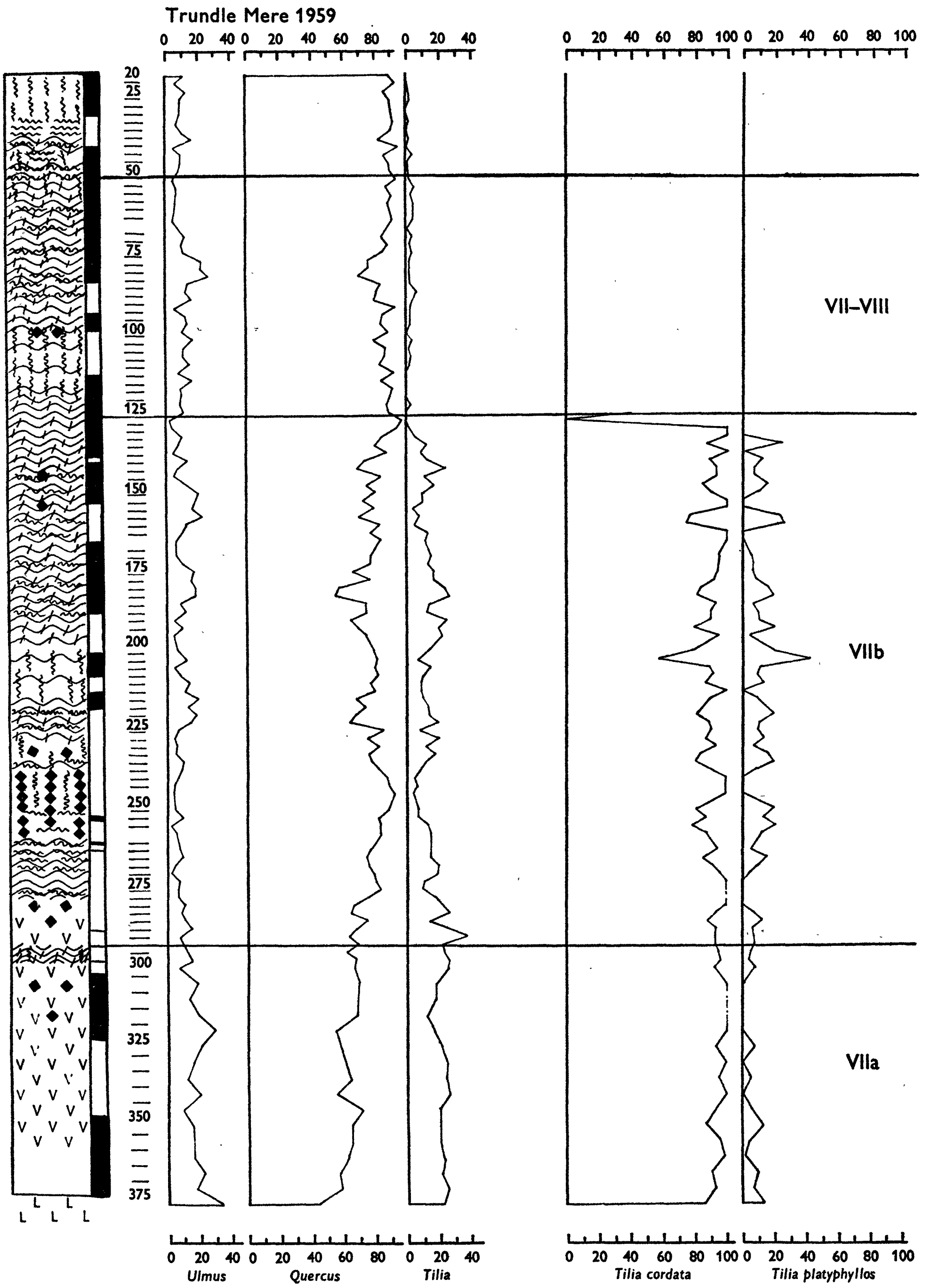


FIGURE 7. Pollen diagram from Trundle Mere, Y, showing trees of the mixed oak woodland of the upland: oak, elm and lime shown as percentages of the sum of the three. Right, *Tilia cordata* and *T. platyphyllos* pollen as proportions of total *Tilia* pollen.

(3) From 150 to 120 cm: from 150 cm there is a pronounced change in the trophic state of the site, the peat type now suggests a mesotrophic mire with abundant *Sphagnum* and some *Phragmites*. High pollen frequencies of *Betula* pollen show local growth of birches and both alder and birch stems (the latter abundant) occur from 150 to 140 cm along with some *Cladium* persistent from the previous fen-stage, a few algal colonies of *Pediastrum*





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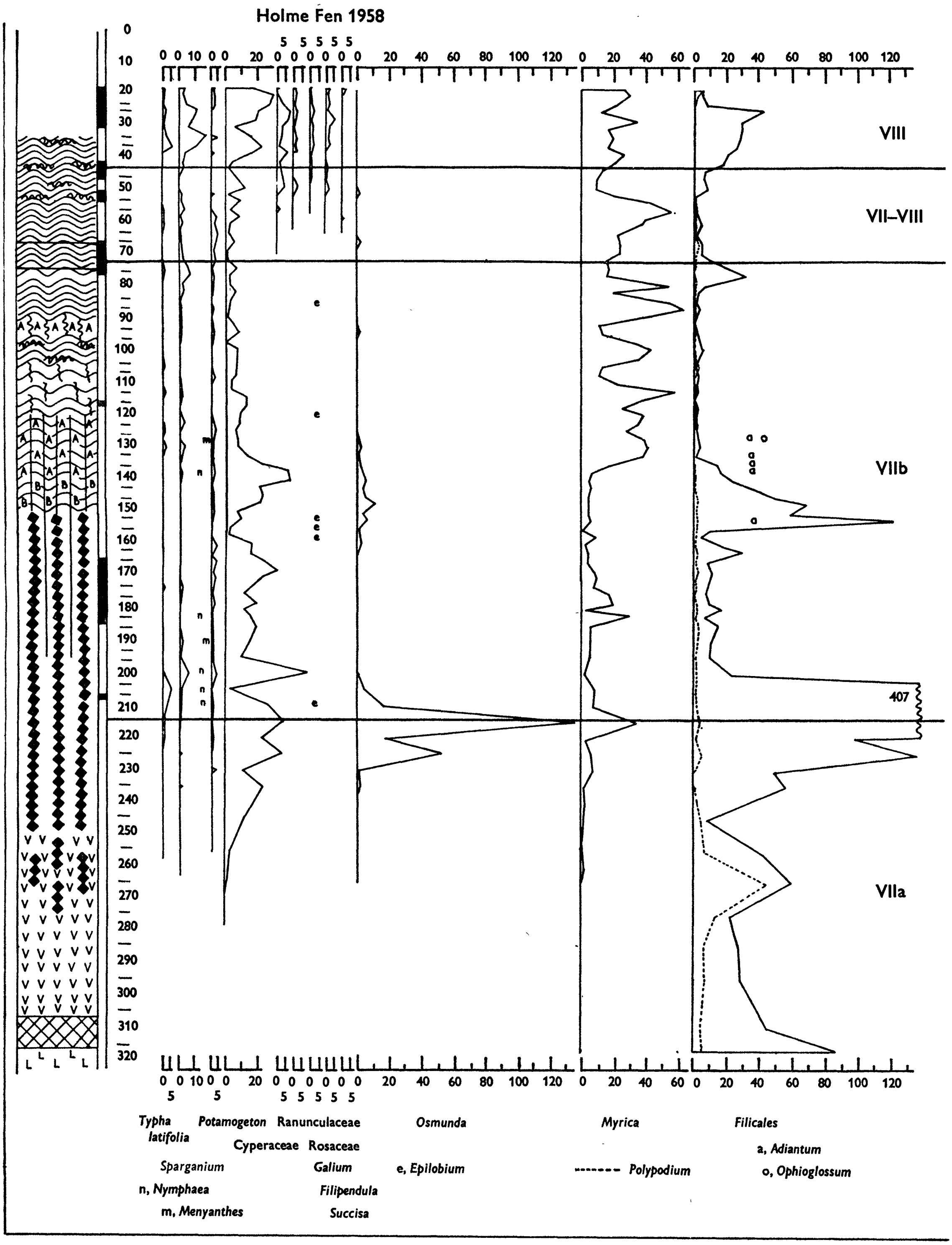


FIGURE 8. Pollen diagram from Holme Fen, E, showing percentage changes in pollen of aquatic plants, of *Myrica gale* and of spores of various ferns.



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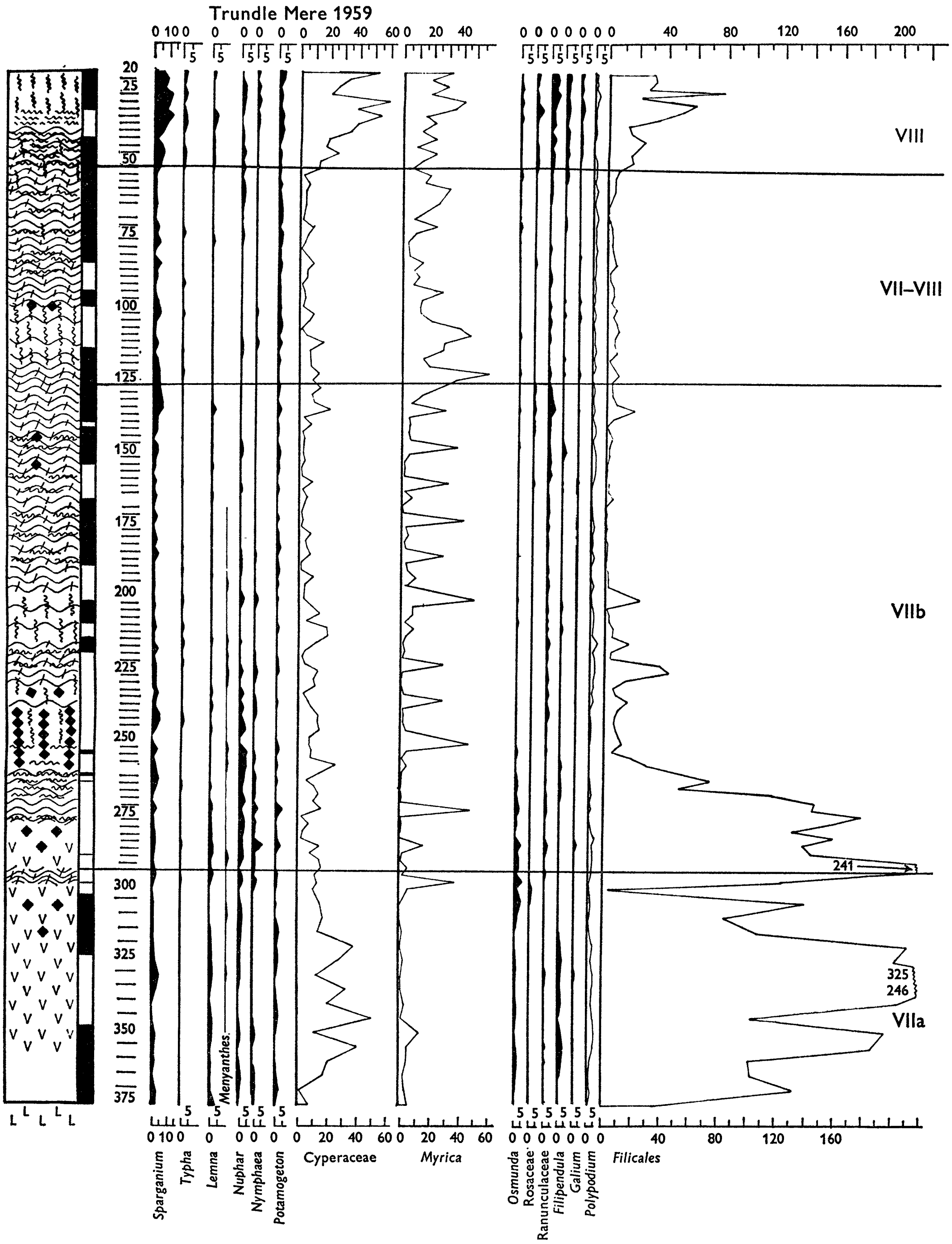


Figure 9. Pollen diagram from Trundle Mere, Y, showing percentage changes in pollen of aquatic plants, some categories of marsh plants and fern spores.

and *Coelastrum*, but also the moss *Polytrichum* sp. It clearly represents a brief 'Zwischenmoorwald' phase such as very commonly occurs at the initiation of oligotrophic mire formation. From 140 to 130 cm the strongly laminated peat contains frequent *Andromeda polifolia* and from 130 to 120 cm the strong laminations are strewn abundantly with seeds of *Menyanthes* showing the characteristic progressive water-logging of the acidic fen woods.


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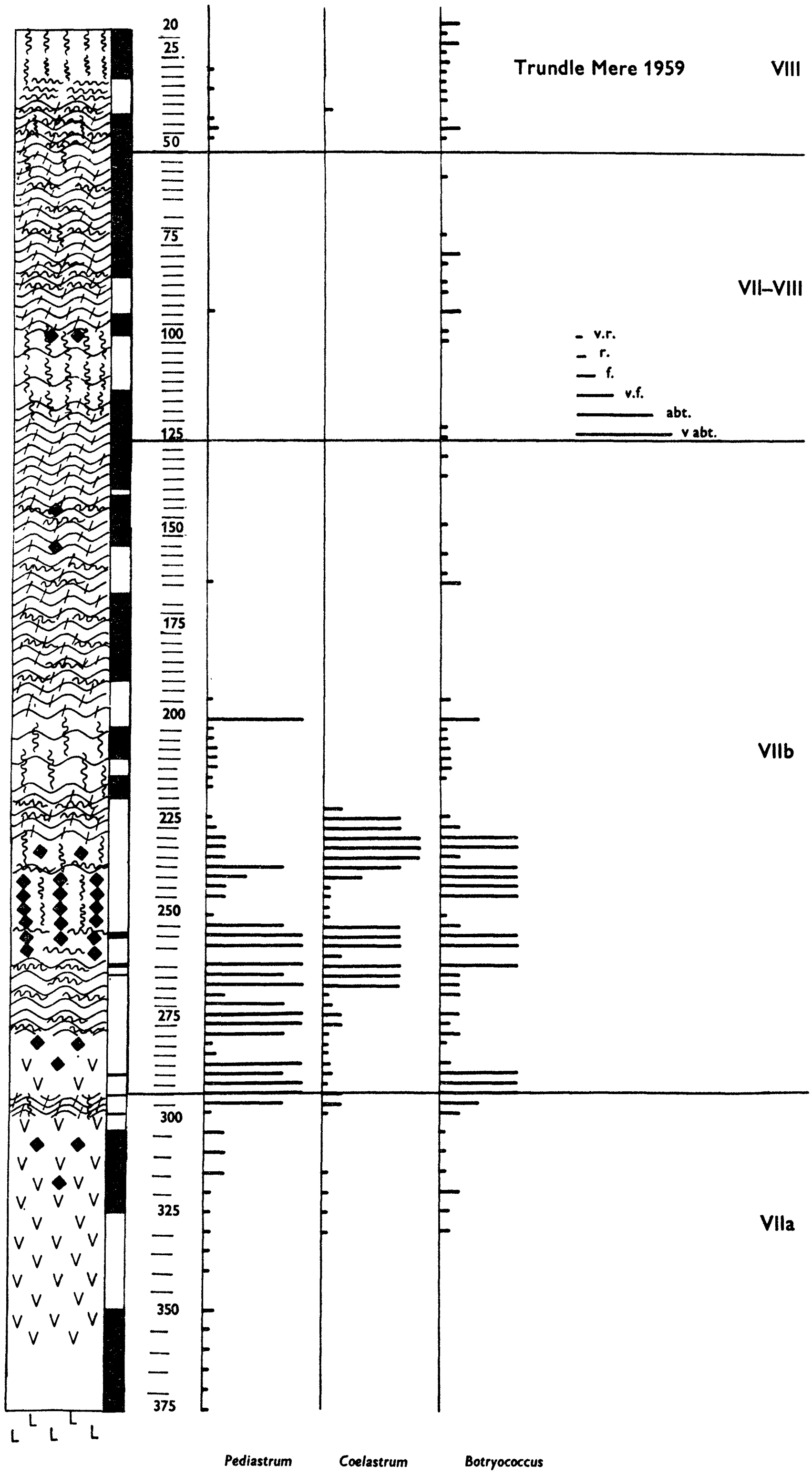


FIGURE 10. Diagram from Trundle Mere, Y, showing frequency changes in three major genera of colonial algae.



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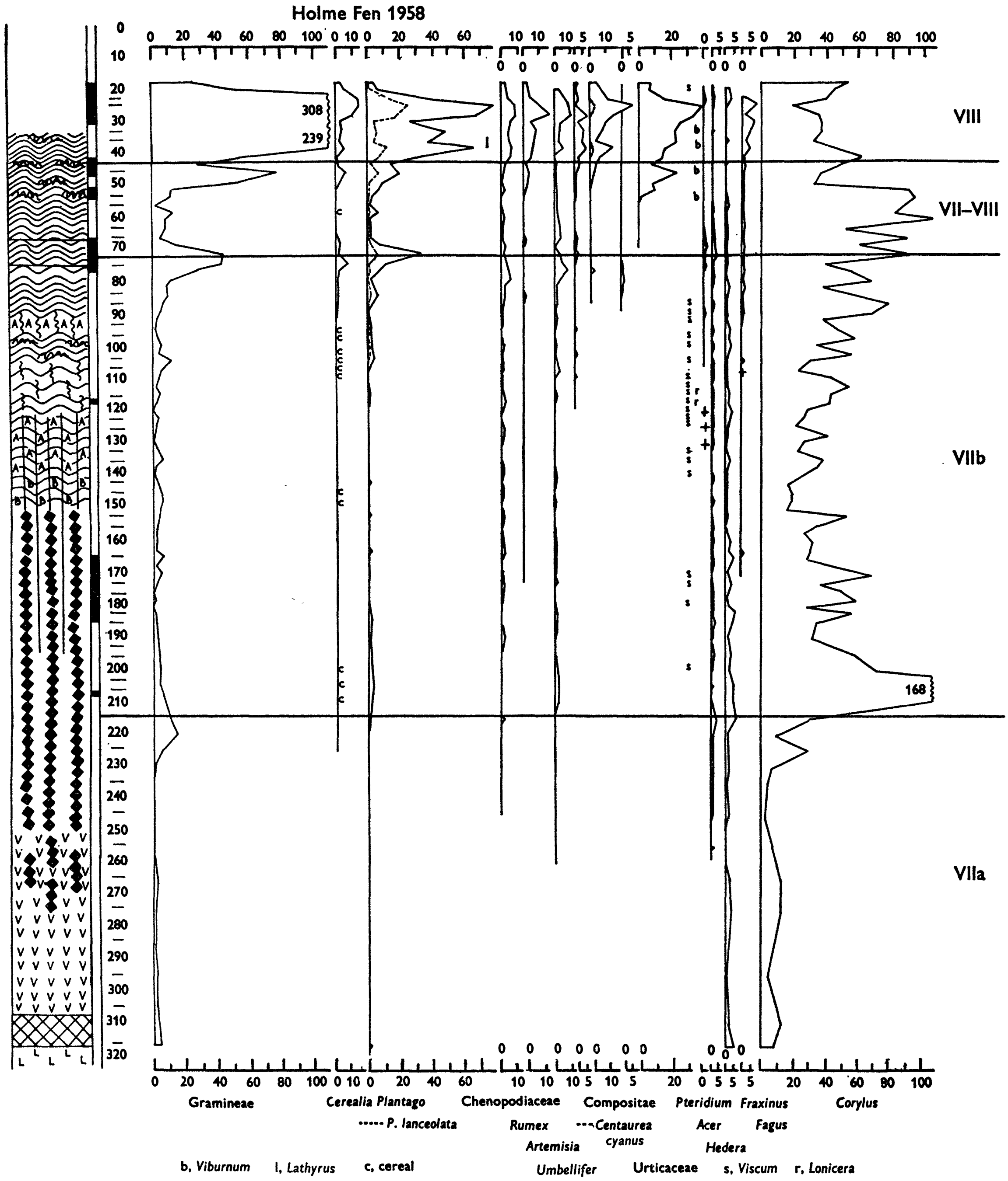


FIGURE 11. Pollen diagram from Holme Fen, E, showing agricultural indicators. Earliest clearance activity about the zone VIIa/b boundary (Early Neolithic), the next, corresponding with the clay bands in the peat, about 1400 B.C. (Middle Bronze Age), and the largest subsequently and presumably in part at least Iron Age. *Corylus* is included as particularly responsive to woodland clearance.



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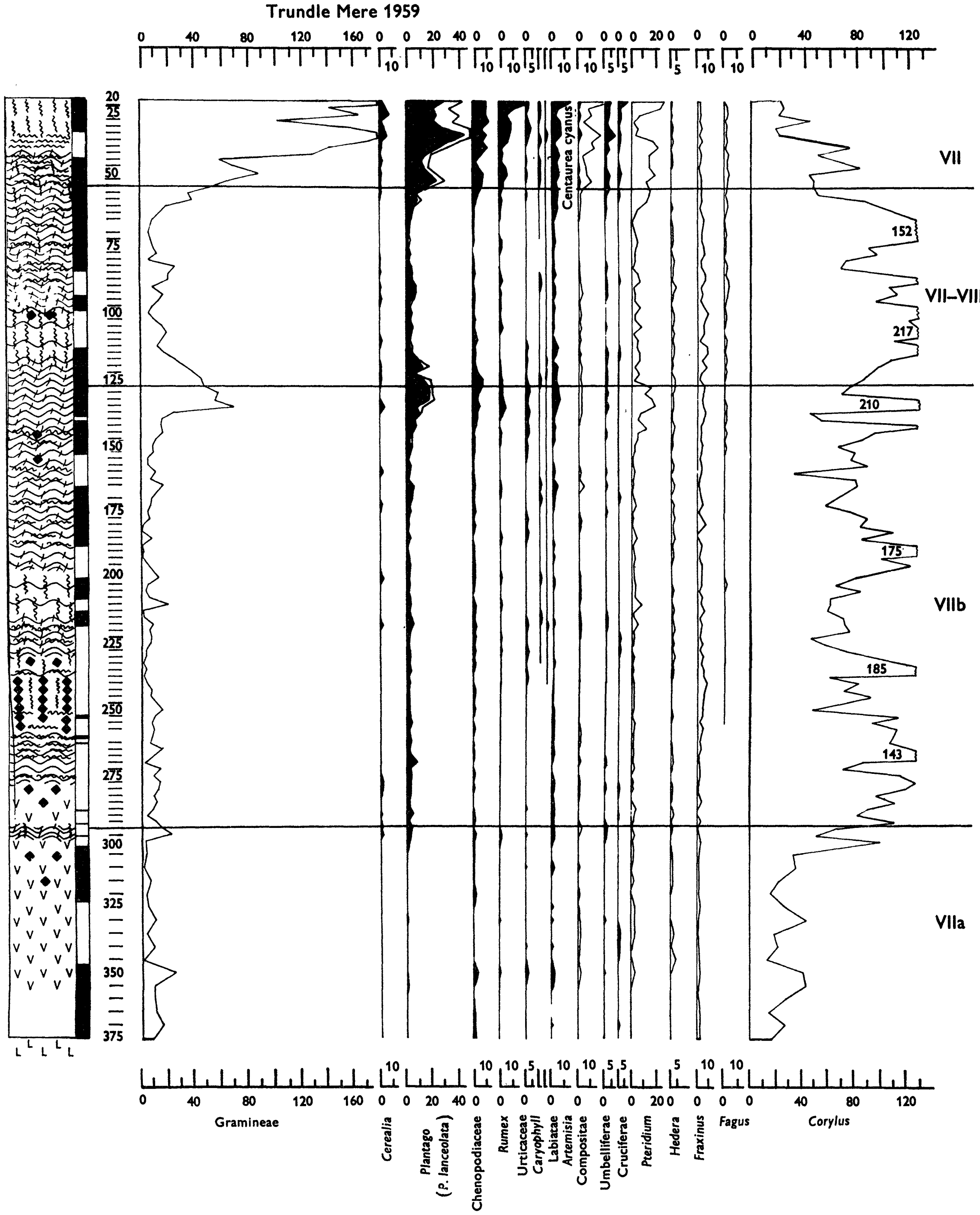


FIGURE 12. Pollen diagram from Trundle Mere, Y, showing agricultural indicators. The major alterations in agricultural activity may readily be matched with those in the Holme Fen diagram (figure 11).

(4) From 120 cm to surface: from 140 cm upwards high values for ericoid pollen and for *Sphagnum* spores accompany all the stratigraphic and macroscopic evidence for oligotrophy and the growth of raised bog. The whole depth to 120 cm is a strongly banded *Sphagnum-Calluna-Eriophorum* peat with local representation of *Eriophorum angustifolium* as well as *E. vaginatum*, *Andromeda*, *Myrica* and *Betula*, and indicates that active raised bog


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persisted on Holme Fen from about 4000 B.P. to the time of historic drainage of the area. Peaks in the ericoid pollen values suggest the possibility of temporary dry stages with the bog surfaces covered with *Calluna* at 65–75 cm and 25–45 cm. The earlier of these corresponds with the occurrence of thin clay bands in the peat quite alien to the normal bog sequences: they are discussed later. Fairly substantial pine pollen frequencies through most of the raised bog deposit, but particularly just after the local acidic fen-wood phase indicate the local growth of pine on the raised bog surfaces, a suggestion borne out by abundant evidence in the region, much already reported (Godwin & Clifford 1938).

There is no difficulty in applying this scheme of stratigraphic-vegetational evolution to all parts of Holme Fen so far reconnoitred. The excavations made by the Nature Conservancy make evident that the basal fen-wood stage followed water-logging of the woodlands that previously grew on the boulder-clay soils: stumps and fallen trunks of oak were entombed in the lowest layers and are still *in situ*, a situation especially familiar throughout the fenlands of the South Level.

### (*e*) *Vegetational sequence at Trundle Mere*

The point was made in 1938 by Godwin and Clifford that, of sites then considered, Trundle Mere was that in which the pollen record was least affected by local fen vegetation. Because of its position in the deeper part of the drainage basin and its distance from the upland, fen-woods were less strongly represented in the stratigraphic record and the pollen diagrams than in more marginal situations. None the less in the Trundle Mere, B site (X in map, figure 3) a lower eutrophic fen-wood stage above the basal clay and an upper birch wood stage in the acid bog just below the shell marl of the former Mere were recognized. The summarized vegetational sequence for the site now investigated, Trundle Mere, site Y, appears to have been as follows:

(1) From 375 to 300 cm: wet alder fen woods indicated by macroscopic wood with sustained high *Alnus* pollen frequencies, fern sporangia and very high percentages of fern spores, with a terminal short phase of higher frequencies of *Osmunda* spores about the time of the zone VIIa/VIIb boundary, i.e. 5000 years B.P.

(2) From 300 to 265 cm: flooded fen-woods with a good deal of open water indicated by the continuing high values for fern spores, by fern sporangia and woody fragments alongside very high values for the colonial algae (*Pediastrum*, *Coelastrum* and *Botryococcus*, see figure 10) and increased, substantial curves for pollen of such open water aquatic flowering plants as *Nuphar*, *Nymphaea* and *Lemna*. At some levels there are fruits of *Cladium*, along with various *Sphagna* and other mosses, suggesting the beginning stages of the scraw bog.

(3) From 265 to 220 cm: wet scraw bog is indicated by strong representation in the macro-remains of the species typical of raised bog communities along with *Cladium mariscus* and continued high frequencies of algal colonies.

(4) From 220 to 50 cm: from 220 cm algal frequencies are low and curves both for ericoid pollen and *Sphagnum* spores have become high and continuous. Normally consolidated raised bog has succeeded the scraw bog for all the normal components are consistently represented and only here and there are *Cladium* or *Menyanthes* present.

(5) From 50 to 20 cm: reed-swamp with open water was now present at about the opening of pollen-zone VIII. This community is indicated by considerably increased values in the pollen diagrams for such genera as *Typha*, '*Sparganium*' (a type that embraces *Typha*

*angustifolia*), *Filipendula* and for the family Cyperaceae, together with increased frequencies for *Nuphar*, *Nymphaea* and *Lemna* and increased but still low frequencies of the colonial algae. The abundance of *Scorpidium scorpioides* in the mosses is also notable and it seems probable that we have here the reed swamp marginal to the deeper parts of the basin, such as Trundle Mere B, where shell marl was now forming in more open water, and clearly the conditions were becoming eutrophic again.

It seems apparent that a vegetational sequence of this kind is typical of the whole Trundle Mere region and indeed represents a wetter facies of the developmental series in Holme Fen. Field observations fully confirm continuity between the two areas and show that from about the middle of zone VII raised bog communities in a broad sense prevailed until historic time save in individual localities where the influx of calcareous water from outside made its influence felt. It remains to be considered (§4) how far the oligotrophic vegetation extended into the area of the former Whittlesey Mere.

### (*f*) *Forest clearance and husbandry*

#### (i) *Neolithic: pollen evidence*

At Holme Fen, 1958 (site E) (figure 11), between approximately 230 and 200 cm there is strong evidence of anthropogenic influence: this includes the level at 215 cm where the zone VIIa/b boundary has been drawn. Although the individual pollen samples are neither large enough nor closely enough spaced to constitute a basis for safe deduction of successive vegetation stages in the clearance episode, they are ample to demonstrate the reality and general character of the episode as a 'temporary clearance' of the kind by now so often reported from the Neolithic. The indicators are (as everywhere) a substantial *Ulmus* pollen decline, a considerable decline in *Quercus* at 220–210 cm, the first appearance, initial peak and continuing low values for *Plantago lanceolata*, first appearance of *Chenopodiaceae* and of *cerealia*, first appearance and continuing low values of *Artemisia*, a large peak in the grasses followed by one of *Corylus*. The whole is readily interpretable in terms of the temporary forest clearances described by J. Turner (1962, 1964) and the time span at Holme (of the order of 300 years for the whole episode) agrees with that which she reported from Whixall Moss, and that demonstrated at Fallahogy by Smith & Willis (1961–2).

At Trundle Mere, 1959 (site Y), likewise at the zone VIIa/b boundary, similar indications are present (figure 12). A smooth decline in pollen of *Ulmus* extends over a long span, and the effects noted at Holme Fen upon Gramineae, *Plantago*, *Artemisia*, cerealia and *Corylus* are evident but far less decisively than at that site. It suggests the registration, in a site distant from the upland forests, of numerous temporary forest clearances begun about 5000 years B.P., but going on through zone VIIb, rather than the effect of one or two nearby clearances as at Holme Fen.

It is of course already accepted not only that the *Ulmus* decline is a consistent component of the earliest Neolithic agricultural activity in western Europe, but that radiocarbon dates in this and other countries show it to be synchronous about 5000 years B.P. over wide regions.

It should be noted in passing that within zone VIIb there are some effects on the woodland composition not readily linked with an anthropogenic cause. These are best seen in the Holme Fen diagram (figure 5) and include (*a*) a peak of *Tilia* pollen values during the occupation phase, (*b*) continued scattered high values for *Viscum*, (*c*) *Acer* and *Fagus* first appearing in the middle of the zone, and (*d*) *Hedera*, after appearing late in VIIa, continuing through zone VIIb. Some degree of climatic response may well be involved.

(ii) *Middle Bronze Age: pollen evidence*

In the Holme Fen, 1958 pollen diagrams the boundary between zone VIIb and the VII/VIII transition zone has been placed where there is a decisive and irreversible fall in the values of *Tilia* pollen relative to those of *Quercus* and *Ulmus*. Bracketing this horizon, are the two thin clay bands whose respective radiocarbon ages are 3400 ± 120 and 3415 ± 120 years B.P., and at this level, approximately between 80 and 65 cm, there is evidence for a short forest clearance episode definitely more pronounced than that in the early Neolithic. It seems quite probable that *Tilia* suffered selective felling: other tree pollen genera are not differentially affected, though *Pinus* values may be significantly lowered. Grass pollen at its peak reaches over 40 % of the total tree pollen count, and *Plantago* over 30 %: there are peaks also of pollen of cerealia, *Centaurea*, *Chenopodiaceae*, *Compositae* and *Urticaceae*, those of the three last categories and the isolated grain of *Centaurea cyanus* occurring earlier than the grass-plantain maxima. We may see in this perhaps evidence that pasture tended to succeed arable during the episode, which, to judge from the time scale of peat accumulation cannot greatly have exceeded 150 years duration.

At Trundle Mere, 1959 between 140 and 115 cm the pollen diagrams (figure 12) show a clearance episode of similar dimensions and character again at the horizon of the sudden and permanent decrease in *Tilia* pollen frequency that marks the end of zone VIIb (figure 7). Although the herbaceous pollen curves show similar features to those at Holme Fen, their expression is more diffuse, grass pollen reaches higher maxima, and although *Plantago* pollen is less frequent, the component of it attributable to *P. lanceolata* is considerably higher. Cerealia pollen though present is less frequent and both *Rumex* and *Pteridium* are more strongly represented than in the Holme Fen diagram. One might conjecture that, as in the Neolithic episodes, we here have registered collection from more distant sources and that these contained a larger element of pasture.

We need not hesitate to accept for this passing clearance stage the Middle Bronze Age attribution suggested by the two radiocarbon determinations, for at this period there is plentiful evidence of man throughout the peat fenland, and locally at Pondersbridge was found a Middle Bronze Age rapier and as near as Woodwalton Fen two Middle Bronze Age palstaves, one of them (at Castle Hill farm) placed tentatively by pollen-analysis at the horizon of the sharp decrease in *Tilia* frequency we have recognized already. It is noteworthy that Fox (1923), in his *Archaeology of the Cambridge Region* cites the discovery of a bronze sickle with flanged palstave and rapier from Downham Fen, indicating cereal cultivation in the Middle Bronze Age fenlands.

(iii) *Middle Bronze Age: soil erosion*

The lines of section a–b, c–d, E–f: figures 3, 13, 15*a*, and the map (figure 14) show the result of careful field search to define the extent of the thin clay bands of which those at 65 and 70 cm in the Holme Fen pollen series are typical. These were carefully radiocarbon dated, care having been taken to select for sampling only horizontal ericoid twigs that were certainly contemporaneous with the peat deposition and included none of the intrusive living birch roots that infested the upper peat. We have already indicated that the results closely correspond at about 1400 B.C. They not only traverse Holme Fen east to west (figure 13*a*) but field survey clearly shows that the clay bands extend to that southern part of Whittlesey Mere into which Fen Clay had never penetrated, prevented by the existence already of a sufficiently high peat mire. No contact could be shown there or elsewhere with the marginal extension of the Fen Clay. The comment prematurely made (Godwin & Willis 1960) in the note on samples Q-403 and Q-404 that they represented an extension of the Fen Clay was therefore incorrect. It is altogether more likely that they represent the deposits of freshwater flooding bearing from the upland near Holme village, clays from woodland soils exposed to erosion by the Middle Bronze Age clearances: parallel instances are not uncommon in the pollen-analytic literature. With passing of the clearance phase and healing of the forest cover that are clearly apparent in the pollen analyses, clay deposition evidently ceased. It is not surprising that the more distant and possibly higher raised bog at the Trundle Mere site should not exhibit similar clay layers.

(iv) *Late Bronze Age: pollen evidence*

The uppermost 30 cm of the pollen diagrams from Holme Fen, 1958 shows all the evidence for woodland clearance and agriculture on a scale greatly exceeding anything previously recognizable. It begins with a dramatic and sustained fall in *Corylus* pollen together with substantial increases in the spores of bracken, a clearance indicator, and of indices of husbandry, most of which attain their maxima between 30 and 20 cm. These maxima are very high: in relation to total tree pollen Gramineae show values of 200–300 %, cereals over 10 %, *Plantago* over 60 %, Compositae over 20 %, together with lesser but substantial frequencies of Chenopodiaceae, *Rumex* and Umbelliferae. The presence of cereal cultivation is emphasized by the presence of small frequencies of the pollen of cornflower (*Centaurea cyanus*) and by the fact that *Plantago lanceolata* accounts for no more than a third of the totals for *Plantago*

In comparison with the preceding Middle Bronze Age clearance episode it is apparent that there has been a great extension of cleared woodland and that even the hazel has now largely been suppressed. As *Fraxinus*, that persisted through the earlier episode is now scarcely represented, it seems likely that secondary growth was prevented, except apparently for *Fagus*. The very high frequencies of grass pollen make it probable that substantial pasturage of some kind was maintained alongside the arable cultivation.

At Trundle Mere at an equivalent stage in the pollen zonation, the uppermost 40 cm show evidence of extensive forest clearance and agriculture similar to that at Holme Fen. The *Corylus* decrease is just as sudden, steep and progressive and most of the indicator curves again show their maxima in the upper half of the recorded episodes. Again the cereal pollen curve is accompanied by that of cornflower, and here also by Cruciferae, Caryophyllaceae and Labiatae alongside the more abundant Chenopodiaceae, *Rumex*, *Artemisia* and *Umbelliferae*. The grass pollen reaches over 160 % of the total tree pollen and in the abundant plantain total, *Plantago lanceolata* is much the largest constituent, so that again grassland co-existed with arable cultivation. *Pteridium* responding by increase at the onset of the episode, is much diminished in the later phase of presumably more intensive exploitation. As with the Holme Fen evidence, it is again apparent that this terminal episode produced much more substantial effects than that in the Middle Bronze Age. At both sites however there seems one consistent exception from the general expansion of the curves of agricultural indicators: those for *Urticaceae* (nettles) and *Artemisia* (primarily no doubt the common mugwort) show either decrease or smaller proportionate rise. If *Urtica dioica* and *Artemisia vulgaris* are primarily concerned this might reflect greater efficiency of deep cultivation, a consequence that would follow improved ploughing techniques such as were introduced in the Late Bronze Age.

A convergence of evidence makes it highly probable that this episode must indeed be referred


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to this cultural phase. If we use the well attested sequence of radiocarbon dates at Holme Fen, to give a rate of peat accumulation after the Middle Bronze Age episode at 1400 B.C., the later clearance episode appears to have begun about 1000 B.C. Similarly by transfer of the Holme Fen dates for the elm-decline (beginning of VIIb) and the Middle Bronze Age clearance (end of VIIb) to Trundle Mere, 1959 the later clearance appears to have begun about 800 B.C. This strong indication of a Late Bronze Age context accords fully with the known heavy settlement throughout the peat Fenlands (Fox 1923) and by the local abundance of artefacts of this period in the immediate area of Whittlesey Mere.

The break after the Middle Bronze Age episode was evident in both sites, but it is to be noted that archaeological opinion is consistent with this. Fox (1923) wrote that 'Half-way through the Late Bronze Age, in the eighth and seventh centuries, the southeast and east received fresh agricultural settlers from the Late Bronze Age peoples of the Continent – westerly groups in the complex of culture distinguished by urnfields or cremation cemeteries – and this movement had some effect even on the more distant parts of Britain and Ireland': he indicated that they practised a 'less pastoral' type of agriculture. More recently A. L. F. Rivet, in his *Introduction to the Ordnance Survey map of Southern Britain in the Iron Age* (1962) wrote that these urnfield people were associated with the ox-drawn scratch plough that accompanied the initiation of the small square 'Celtic field system'. Apart from the suggestion already made of more efficient arable cultivation our data allow no more direct inference of such a system.

We have finally to recall that despite a heavy concentration of pre-Roman Iron Age occupation throughout southern and western Britain, traces of this period throughout the Fenland are exceedingly sparse, a consequence convincingly attributed to bad edaphic circumstances, primarily widespread water-logging due either to increased rainfall, to renewed marine transgression or to both coinciding. It is impossible to conceive such an event as having occurred between the two upper clearance episodes of Holme Fen and Trundle Mere for there is no stratigraphic evidence for massive flooding at that time, but immediately following the latest (presumably Late Bronze Age) agricultural episode at Trundle Mere we can see, especially by reference to the earlier diagram of Trundle Mere, 1936, that there now was established an open lake depositing shell-marl directly over what was hitherto ombrogenous acidic bog. We shall see that the evidence of stratigraphy, more especially from Whittlesey Mere itself, strongly supports the archaeological correlation we here propose. It seems improbable that activities of either the pre-Roman or Romano-British period could be represented in either of our two long pollen diagrams: in the one shell-marl deposition had already intervened, and from the other all peat of that age has disappeared.

## 4. The former Whittlesey Mere

### (*a*) *Topographic relations*

As the levellings show, the fen floor deepens gradually from Holme Fen and Trundle Mere towards the east: the former Whittlesey Mere seems to have been bounded on the north by low gravel islands in Farcet Fen, on the south by the raised bog development in Holme Fen and to the west we may assume a ridge in the fen floor behind which was the raised bog again of the Trundle Mere area. As we shall see, the Mere itself was the product of two marine transgressions introducing minerogenic sediments from the open Fenland to the east, associated in the case of the later one, with backing up of freshwater in the deeper areas next to the fen margin.

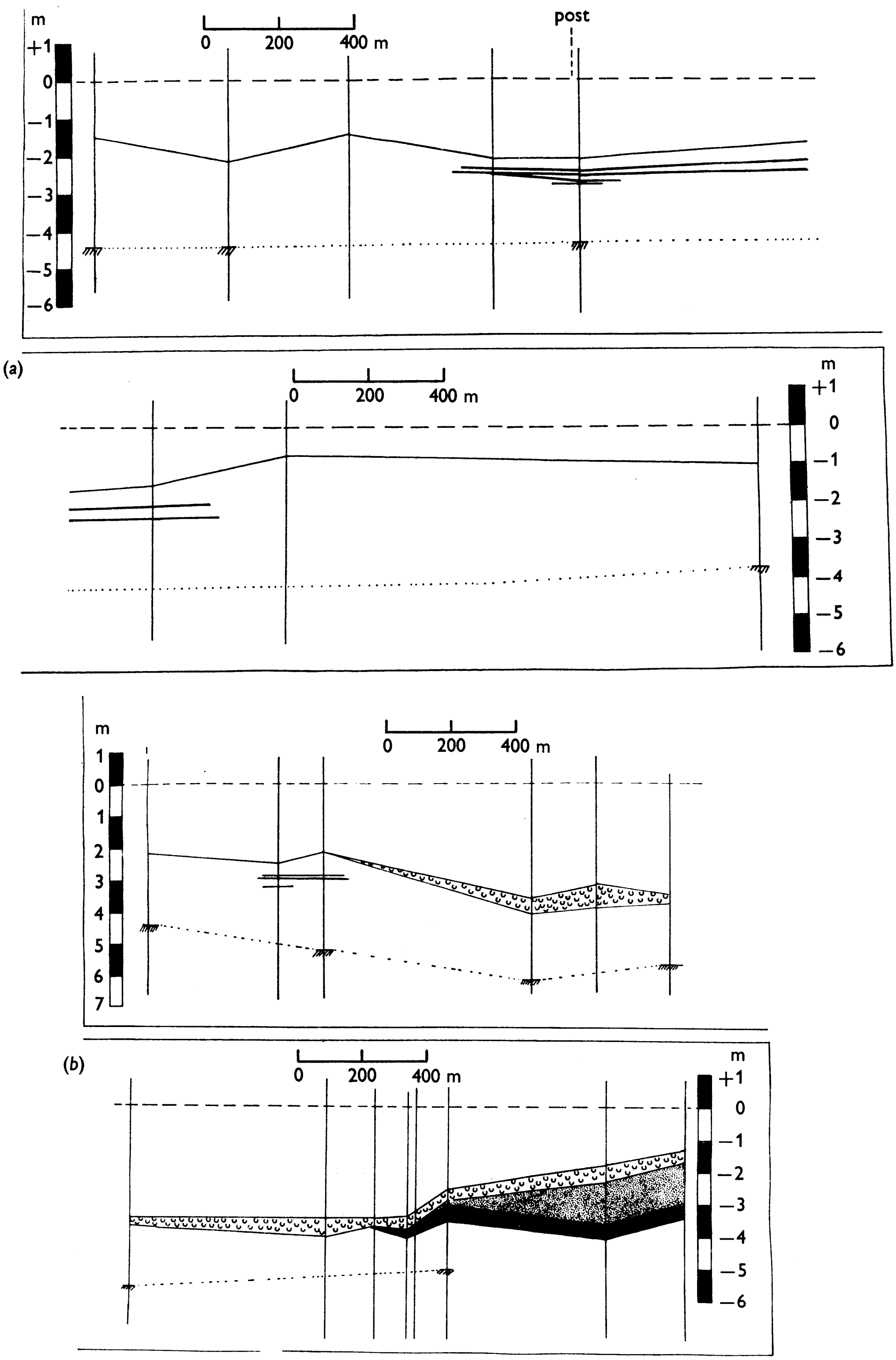


FIGURE 13. (*a*) Section across Holme Fen from east to west along the line a–b in figure 3. (*b*) Section from Holme Fen along the western margin of Whittlesey Mere along the line, c–d in figure 3. Symbols: fen-floor, shaded; peat, white; clays, black; silts, dotted: shell marl, shell sign.

The investigations very largely took the form of levelled borings and ditch side excavations, supplemented by records of the Drainage Authorities: only at one site was a pollen analytic series undertaken. Unfortunately, samples secured for radiocarbon assay proved unacceptable because of a high content of secondarily intruded rootlets. None the less lateral continuity with the established sequences already described for Holme Fen and Trundle Mere on the one hand and the general Fenland sequence already worked out to the east and downstream along the R. Nene allowed us to set the Mere deposits into a comprehensive developmental history of the region. Sufficient laboratory examination of fruits, seeds, mosses, etc., confirmed field recognition of the main types of deposit but detailed recording of individual borings was made only occasionally.

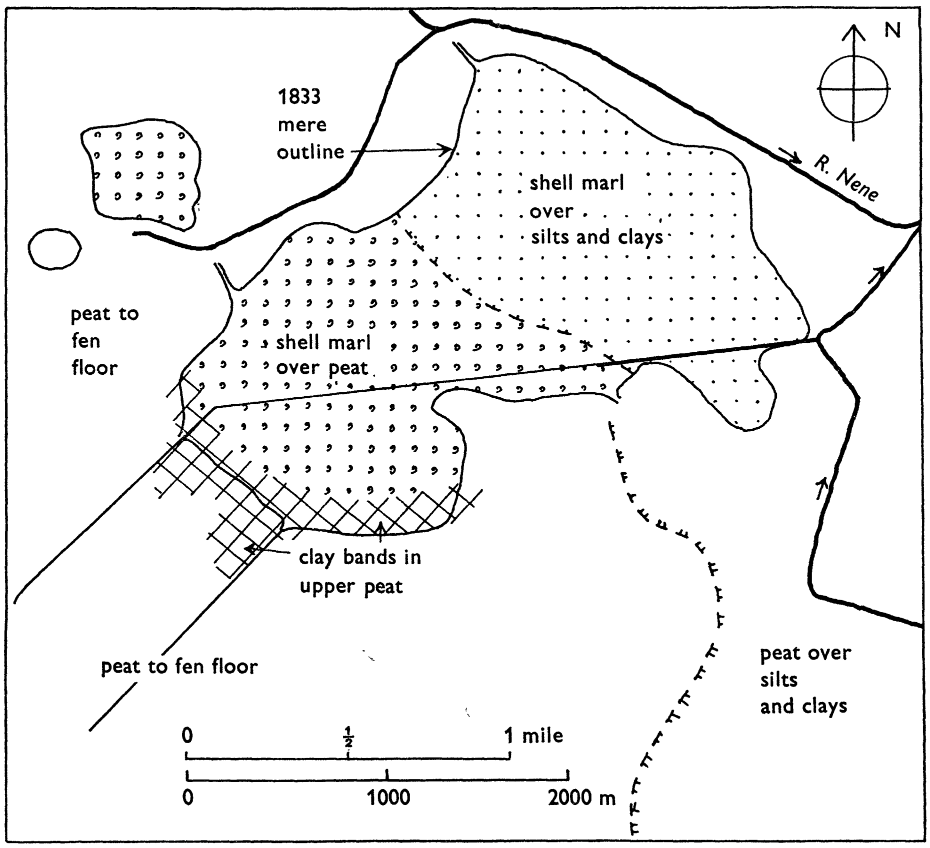


FIGURE 14. The vertical sequences of fen deposits shown by boring in the bed of Whittlesey Mere and its vicinity. The mere outline and that of Trundle and Dray Mere are taken from Lenny's pre-drainage map of 1833. The northern half of the mere has shell marl over the silts and clays of the main 'Fen Clay' marine transgression (upper peat sometimes intervening): over the rest of the mere bed shell marl rests upon deep peat continuous to the fen floor. This difference has caused the fen surface after drainage to be several feet higher in the northern half of the mere (with a perceptible rise at the boundary) the silts and clays having contracted relatively little. The Bronze Age clay layers, presumed flood deposits, are shown extending to what later became the southern mere-margin: they were arrested at time of deposition by existing peat bog. (See also reconstruction, figure 22.)

The stratigraphic examination we have already considered and the sections of figures 13 and 15 demonstrate that throughout Holme Fen and in the region of Trundle Mere, organogenic deposits extend from the fen floor to the present surface, consisting of wood peats, fen peats and various forms of ombrotrophic peat, terminated in Trundle Mere itself by a final layer of

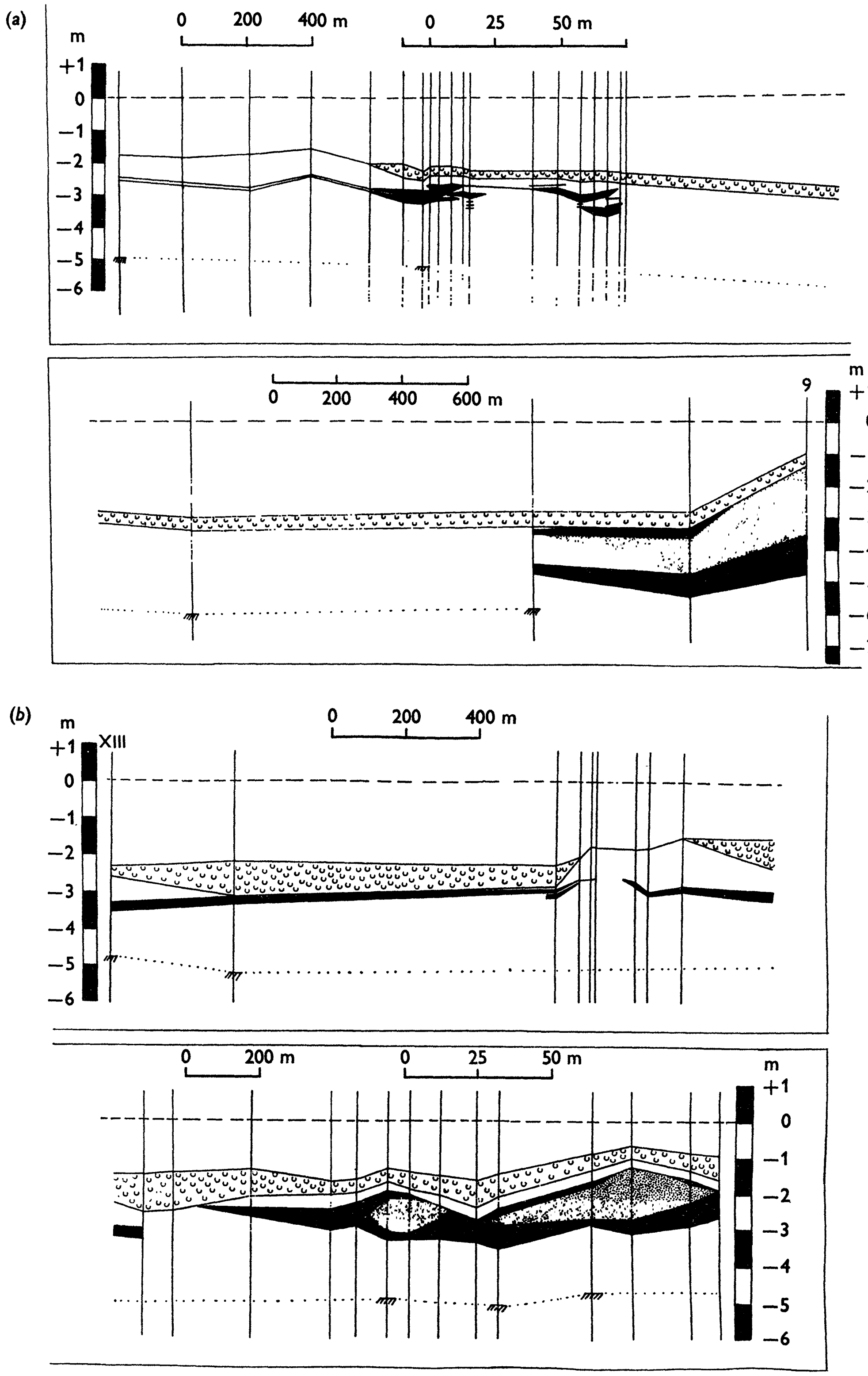


FIGURE 15. (*a*) Section from the eastern side of Holme Fen across Whittlesey Mere along the line E–f in figure 3. (*b*) Section along the south (eastern) margin of Whittlesey Mere along the line g–h in figure 3. Symbols as in figure 13.



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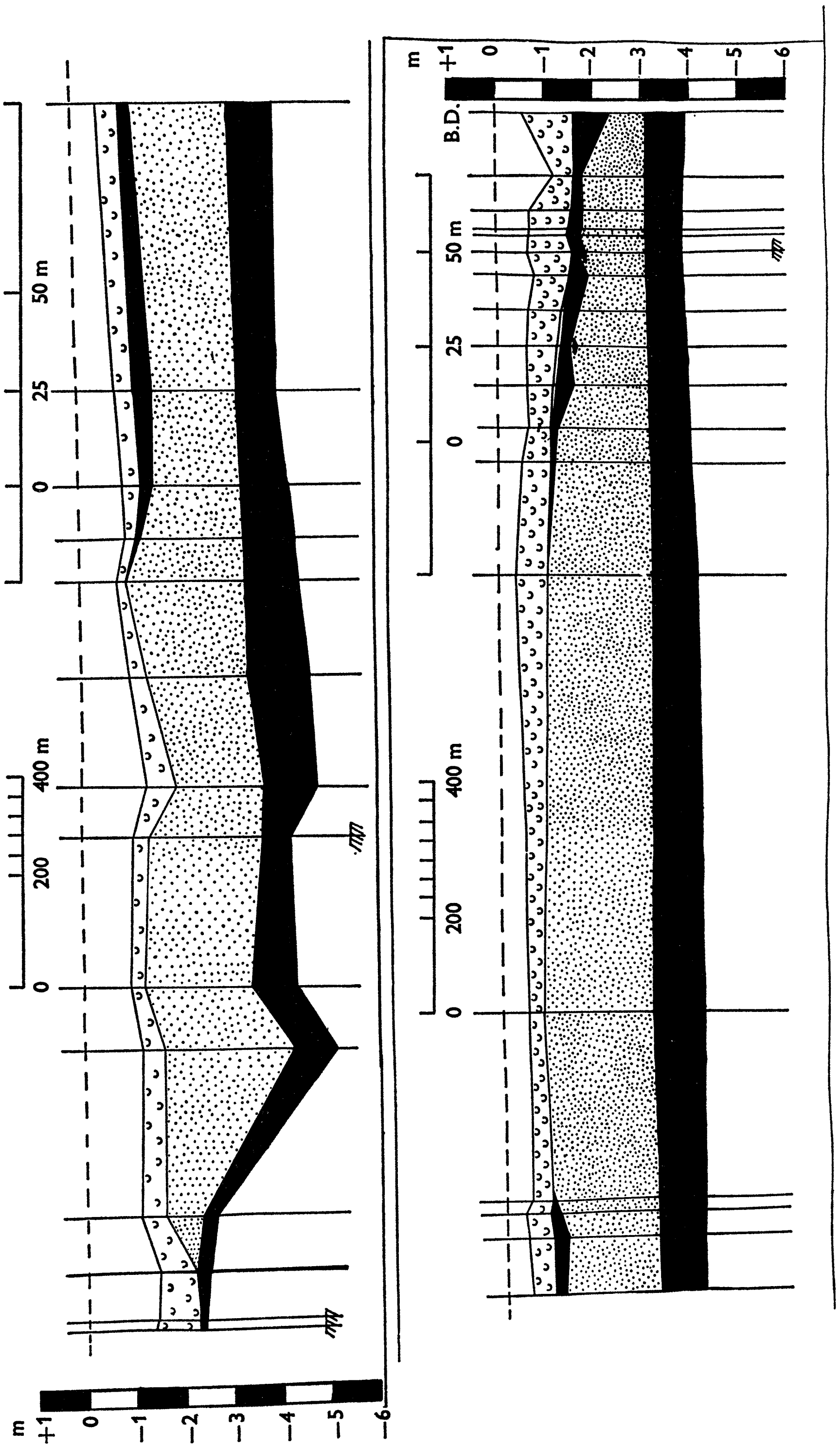


Figure 16. Section passing from northwest to southeast across the northern bed of Whittlesey Mere along the line j–k. Symbols as in figure 13.

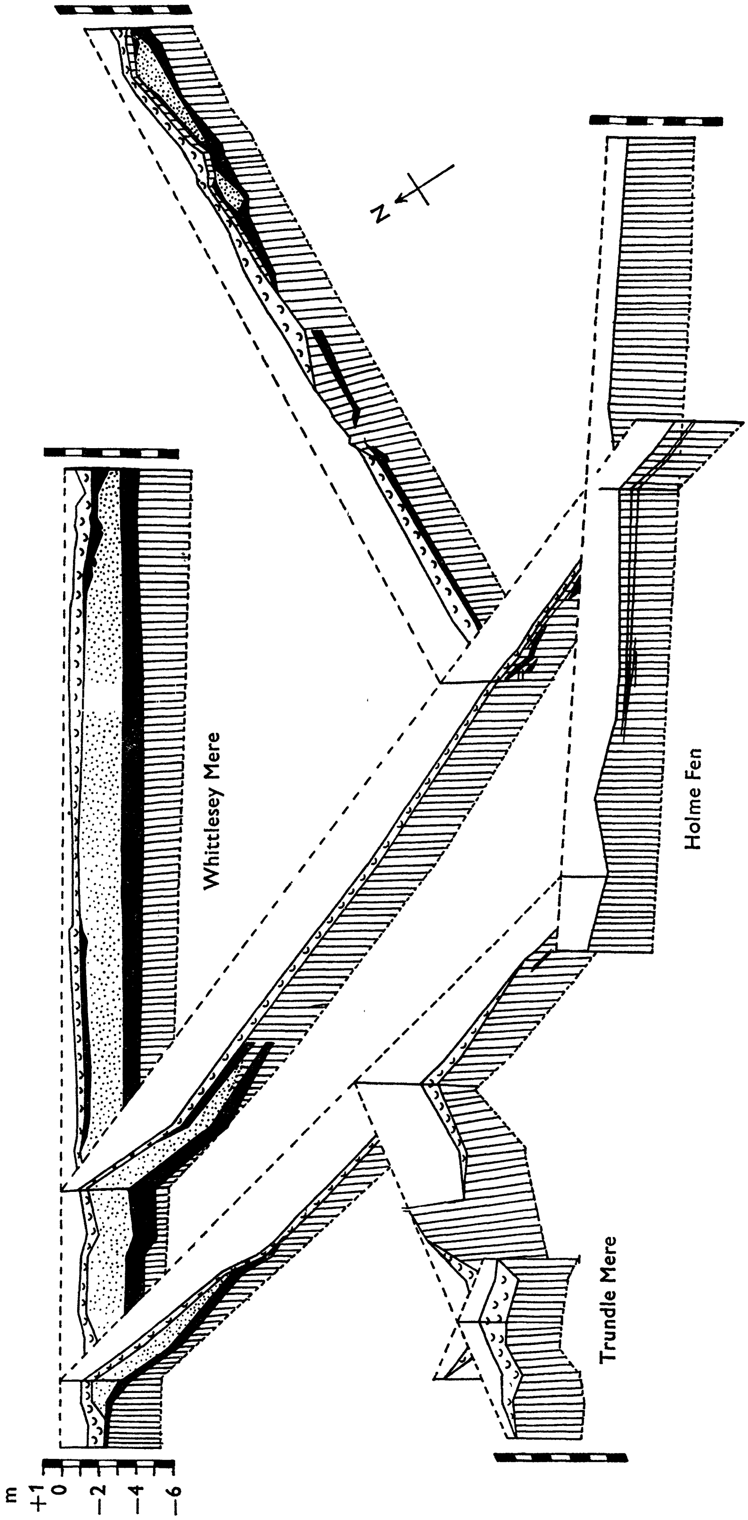


Figure 17. Solid diagram indicating broad stratigraphic relation of the fen deposits of the Whittlesey Mere–Trundle Mere–Holme Fen region. All categories of peat are shown by the parallel hatchings: other symbols as in figures 13, 15, 16.



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shell marl. We now consider those sections that extend northeastwards along the northwest margin of (the former) Whittlesey Mere (c–d: figure 13*b*), that extend from Holme Fen northeastwards across the mere (E–f: figure 15*a*) and from its southern margin cut across the eastern section of the mere (g–h: figure 15*b*). These are supplemented by a long section crossing the northern half of the mere from NW to SE (despite its location on the so-called 'boundary dyke') (j–k: figure 16). The locations are given in figure 3 and the information given by them and various shorter linking sections is jointly presented in the perspective solid reconstruction of figure 17. One main conclusion is clear; over the southwestern half of the former mere there is shell marl overlying continuous deep peat or muds whereas the northeastern half is characterized by the presence of a deposit of clays and silts up to as much as 3.0 m in thickness that overlies deep peat and muds to the fen-floor, and is itself overlaid everywhere by the shell marl, often however with the intervention of an upper layer of peat, as at the northern end of the northeasterly marginal section. The map (figure 14) makes this relation clear and shows also that these clays and silts are only a westerly extension of the vast area of occurrence of the 'Fen Clay' throughout the landward part of the Fenland basin. This continuity was easily confirmed by scattered borings, records and ditch sections examined locally: it was of course no more than the conclusion reached by Skertchly (1877).

### (*b*) *Vegetational development*

It is apparent that the peat sequence is very similar on both sides of the ridge separating Trundle Mere from the western part of Whittlesey Mere. The lower peats have the same admixture of plant remains indicative on the one hand of open and somewhat eutrophic water (abundant fruits of *Chara* and frequent fruits or seeds of *Cladium mariscus* and aquatic flowering plants) and oligotrophic species such as *Erica cinerea*, *Calluna vulgaris* and *Empetrum nigrum* with abundant *Sphagna*. Thus the evidence is again suggestive of a rather prolonged phase of scraw bog that developed after the initial phase of alder fen woods certified by the abundance of woody fragments, alder pollen and *Dryopteris thelypteris* together with *Rubus fruticosus* and woodland mosses. As at Trundle Mere, the floating scraw bog gave place in time to more solid raised bog, peat typical of which extends up to the overlying shell marl (figure 18).

The sections in Holme Fen have shown that towards Whittlesey Mere the content of both *Cladium* and *Phragmites* tends to diminish and the peat becomes a mixture of humified *Sphagna* and woody fragments with *Menyanthes* seeds, a type of deposit changing upwards into *Sphagnum*-*Calluna* peat with an increasing content of *Eriophorum vaginatum* at the top. One has the impression that oligotrophic plant communities tended to occur in the Mere basin earlier than in Holme Fen, and it is apparent that the whole southern half of the Mere area was occupied by scraw bog or raised bog right up to the time when the open lake came into being.

In sections extending northwards into the Mere basin the peat is seen to be divided by an increasing thickness of silts and clay into a thin upper peat and a deep lower peat. In the central and northern half of the Mere the transition from the lower raised bog peat is shown by a varying thickness of *Phragmites* peat with fruits or seeds of *Potamogeton*, *Nuphar*, *Nymphaea*, *Menyanthes* and *Cladium mariscus*, all indicative of shallow, open and somewhat eutrophic water. Rhizomes of *Phragmites* are often seen abundantly penetrating the basal Fen Clay: it is a plant tolerant of brackish water and in some places a 1–2 cm layer of cockle shells (*Cardium edule*) testifies to a further increased salinity (figure 19).

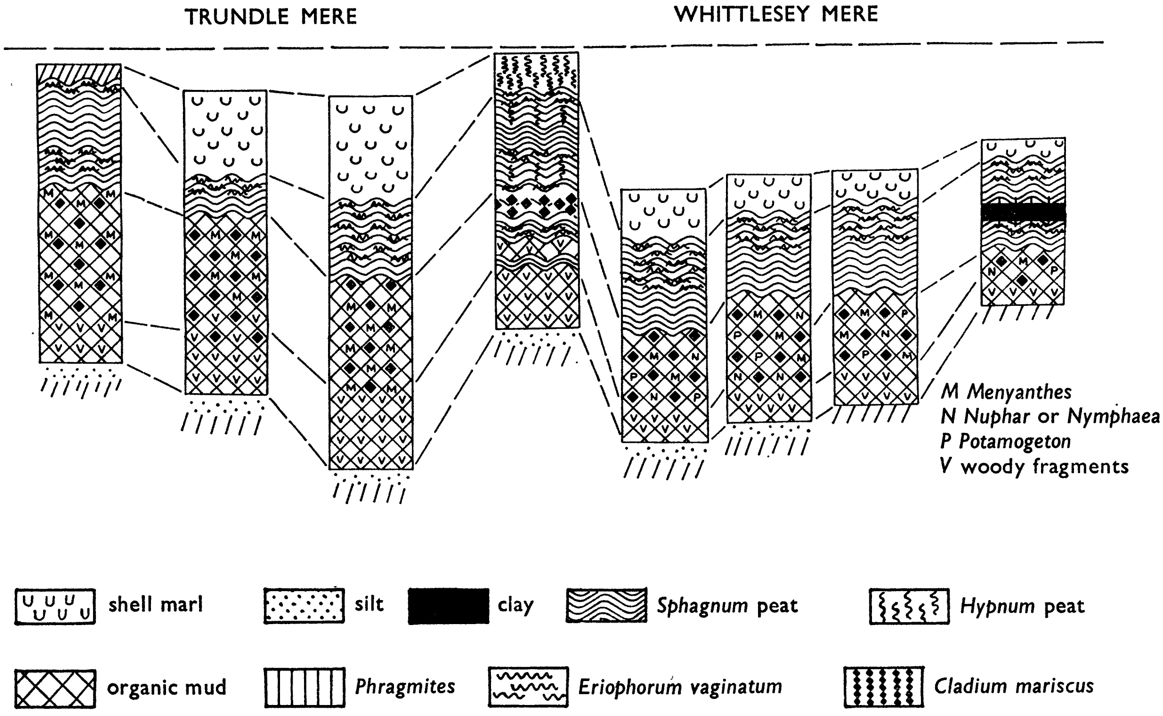


FIGURE 18. Stratigraphic sequence at sites along the line of section Trundle Mere–Whittlesey Mere, with key to the stratigraphic symbols employed here and elsewhere throughout the paper.

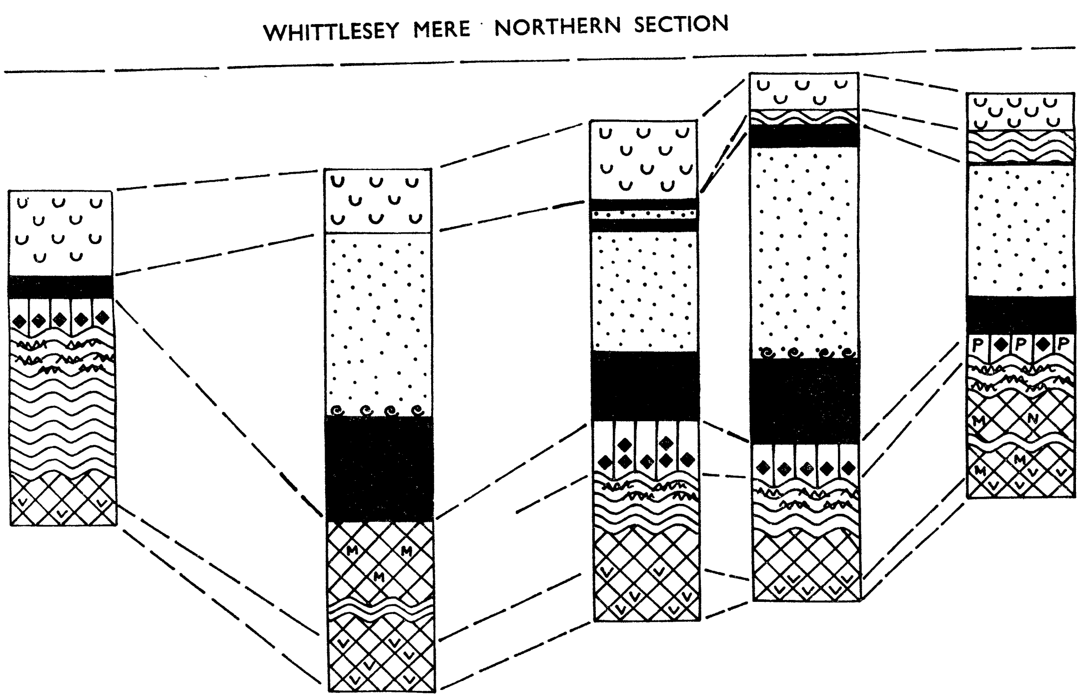


FIGURE 19. Stratigraphic sequence at sites along the line of section across the northern half of Whittlesey Mere (line j–k). Stratigraphic symbols as shown below figure 18.

### (*c*) *Fen Clay and silt*

The sections (E–f, g–h and j–k: figures 15 and 16) show that wherever there is a substantial thickness of these mineral sediments the Fen Clay has a thick core of silt, indicative no doubt of greater velocity in deposition and easier access of tidal water. In places these silts form ridges and banks that now protrude from the drained fenland to the north of the Mere as had been previously observed also in the Green Dyke area near Ugg Mere (Godwin & Clifford 1938). Recent air photographs of the region between Whittlesey and Ramsey afford an excellent basis for research into what appears as a dense dendritic pattern of creeks possibly attributable to this phase. It seems evident that during the transgression responsible for these deposits, the clay margin did not taper out gradually as into the wet eutrophic fen communities at Woodwalton and Wood Fen (Ely) but, after submerging the lower margins of the raised bogs in the Mere basin, it was arrested by the higher bog to the west and south, against which the mineral deposits were relatively steeply banked. This topographic circumstance must be the explanation also of how little the transgression is reflected by flooding in the hinterland of Holme Fen and Trundle Mere.

### (*d*) *Upper peat*

The character of the upper peat that overlies the clay and silts in the northern half of the mere is indicated by the macroscopic analysis of one column through it:

| cm | |
|---|---|
| 2.5–15.0 | *Sphagnum* leaves abundant (narrow-leaved *Sphagnum*) with numerous fern sporangia, and with charcoal fragments; fern sporangia rare, fruits of Charales at 13 |
| 18.0 | fern sporangia abundant, *Sphagnum* leaves and charcoal fragments |
| 20.0 | *Sphagnum* and fern sporangia, fruits of Charales, no charcoal fragments |
| 23.0–25.5 | fern sporangia and cyperaceous rootlets, *Sphagnum* leaves rare; fruits of *Chara* |
| 28.0–30.5 | *Sphagnum* absent, fern sporangia abundant; fruits of *Chara*, leaves of *Hypnum* moss, fruit stones of *Potamogeton*, moss capsules other than those of *Sphagnum*, charcoal fragments; a fruit of *Polygonum* sp. at 30.5; a few colonies of *Pediastrum* |
| 33.0–35.5 | fern sporangia, no mosses, *Chara* fruits, charcoal fragments rare; woody tissues; colonies of *Pediastrum* frequent |
| 38.0 | charcoal fragments rare, one fruit stone of *Potamogeton*, woody tissues, colonies of *Pediastrum* very frequent |

This points to an accumulation in shallow open water containing much detritus derived from surrounding *Sphagnum* bog and fen wood, possibly with floating mats of bryophyta, chiefly of acute-leaved *Sphagna*. The pollen analyses from site Z (figure 20) supplement this evidence. The pollen of reed-swamp plants and of floating or rooted aquatics is frequent throughout the organic section of the column, while ericoid pollen, present in low frequency throughout is more abundant at the top, as also are spores of *Sphagna*. Fern spores are extremely abundant throughout. The overall picture is very similar to that derived for the comparable upper peat layer at Ugg Mere (Godwin & Clifford 1938, figure 9) where, above the Fen Clay, an upper acidic peat had high frequencies of aquatic pollen below, with increasing ericoid frequencies to the top, and exceedingly high frequencies of fern spores especially in the lower half of the peat deposit. Higher frequencies of pollen of Chenopodiaceae type at the base were taken to reflect

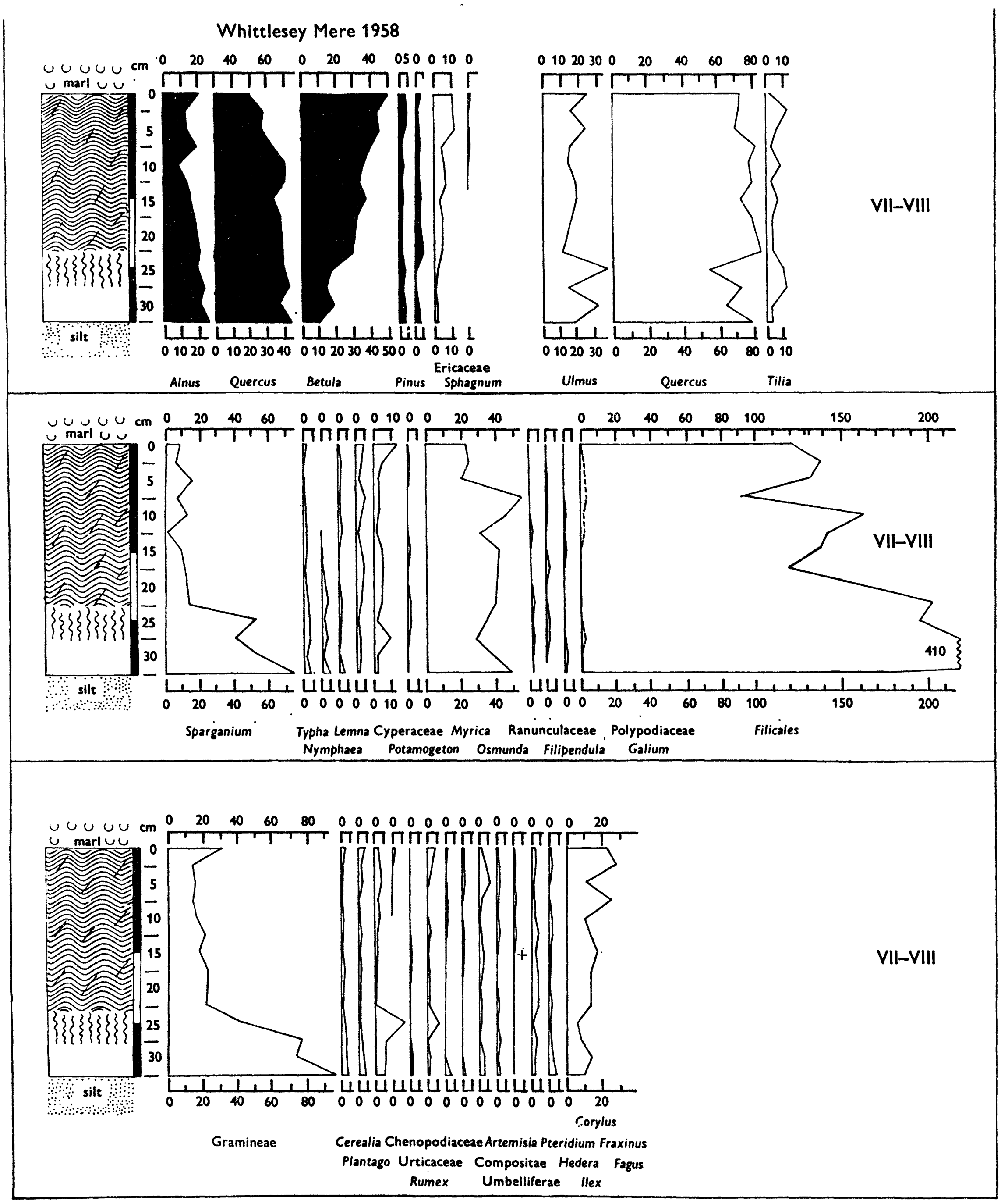


FIGURE 20. Pollen diagrams of the upper peat at site Z in the northern half of Whittlesey. Upper, tree pollen and raised bog components; middle, aquatic plants and ferns; lower, indicators of clearance and agriculture.

the local presence of brackish water communities, and similar increased pollen frequency of this kind is recognizable also in the Whittlesey Mere data. It was here that droppings of *Alces alces* were recovered that were subsequently dated 3260 ± 110 B.P. (Q-546). This date corresponds with the attribution of the Whittlesey upper peat to pollen zone VII–VIII based essentially upon the tree-pollen curves, but supported less directly also by the pollen curves


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indicative of agricultural activity. At both Holme Fen and Trundle Mere there was an initial Middle Bronze Age phase of clearance activity at the end of zone VIIb, followed after relative quiescence, by a more substantial activity near the opening of zone VIII. The same indicators are present throughout the upper peat in Whittlesey Mere in frequencies indicative of the period between the two Bronze Age phases of special activity and there is indication both at top and base of proximity to these two phases. It may be significant that here, as we have remarked at the two other sites, pollen of Compositae is much more conspicuous as the latter phase approaches, whereas that of *Urtica* is more frequent in the earlier phase.

We have made no investigation of the shell marl either in Whittlesey or in Trundle Mere, but there is no reason to doubt the general conclusions regarding it that were reached by Skertchley (1877).

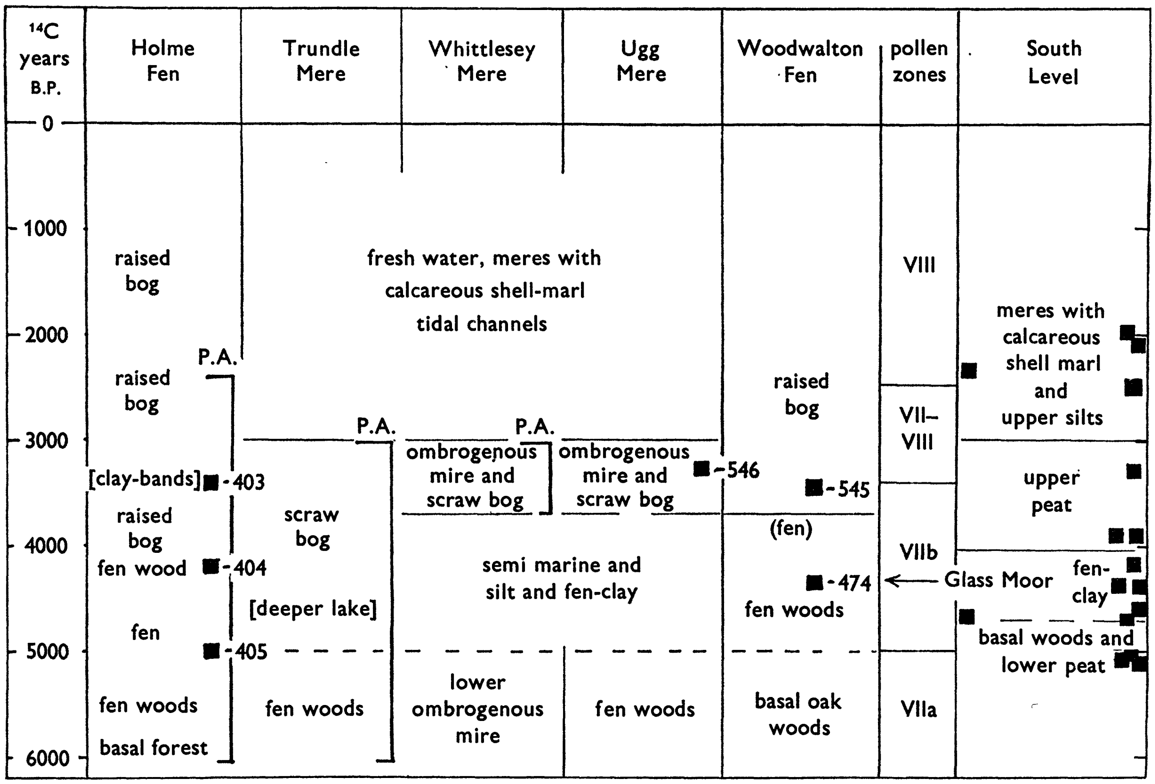


Figure 21. Correlation scheme for vegetational history of the Holme Fen–Whittlesey Mere region with those of the neighbouring Ugg Mere–Woodwalton Fen area and, in more general terms, with most of the more remote South Level region. The sites are keyed together by the radiocarbon dates, indicated by black squares (those of the Holme and Woodwalton areas accompanied by the Cambridge Laboratory, Q, numbers) and by pollen analyses whose extent is indicated by lines labelled P.A.

## 5. History of development

### (*a*) *Correlations, local and general*

The evidence we have set out in the foregoing sections allows correlation of developmental sequences on the one hand within the Whittlesey–Holme area itself and on the other, within the larger region of adjoining Fenland that earlier studies have dealt with. The latter purpose is served by figure 21, which is a modification of the schema employed to describe the Flandrian deposits in the Woodwalton Fen area (Godwin & Clifford 1938). The application of radiocarbon dating has given some precision to the sequence and has confirmed broadly the correlations suggested by other evidence. Many more samples from carefully chosen sites would be needed however to resolve the problems of precise timing that remain.

In the South Level, deposits of Late Weichselian and Early Flandrian age occur only in the wide channels of rivers excavated when the North Sea stood far below its present level and there is no clear evidence of such in the Whittlesey Mere area except in the suggestion from Drainage Authority records that a deep channel may exist beneath the meandering course of the 'Old Nene', and in the record of arctic birch (*Betula nana*) from the base of the Engine Drain in Whittlesey Mere itself, possibly associated with the same channel.

If we extrapolate the Holme Fen radiocarbon date sequence to the base of the peat it seems likely that peat formation began there about 6000 years B.P., a conclusion in correspondence with the pollen-analytic reference to the middle of (EW) zone VIIa. As deep excavations made by the Nature Conservancy show, at this stage large forest trees growing on the basal clay were embedded in accumulating peat.† It is evident that this date substantially precedes the general age of the basal buried forests in the South Level and indicates the likelihood of local water-logging in the Holme–Yaxley basin having begun well before the effects of marine transgression reached the area. The early and sustained acidity of the peat deposits of the basin accords with this view and we have to accept that by the time brackish water reached the region, possibly 4500–4000 years B.P., the basin already contained extensive mires of ombrogenous peat that remained over large areas relatively unaffected by the transgression. The sharp boundary of the silts and clays on the side towards Holme Fen indeed seems only explicable if they were abutting against the margin of an active raised bog already growing there, and we have seen that the silts and clays indeed overlie ombrogenous peats.

Probably behind the highest bank of raised bog the drainage from the Holme–Connington uplands continued to sustain more or less eutrophic fen deposits but in time these too were converted to ombrogenous bog, so that raised bog became extensive throughout the area, persisting indeed right through until the period of artificial drainage and exploitation.

We specifically did not attempt to resolve the nature of the 'Fen Clay' transgression, but it has become increasingly apparent that it may well differ here from its timing and character in the South Level. The evidence of the growth of *Cardium edule*, of much coarser and irregularly deposited mineral sediments, as well as the pollen analytic indications of halophytic communities all suggest the likelihood of more direct access of tidal water: there is indeed some possibility that marine influences may have persisted here later than in the South Level. It is an issue of much intrinsic interest since it could be bound up with differential tilting of the Fenland and later marine incursion from northern rather than southern estuaries: only specific field studies with appropriate radiocarbon dating are likely to resolve the matter, but meanwhile caution is advisable in extending northwards datings derived essentially from the South Level. We have one clear indication of the local onset of the Fen Clay deposition in the radiocarbon date of 4345 ± 110 B.P. from Glass Moor (Q-474) for the growth of cockles on pine stumps beneath the clay.

† Dr. R. A. Switsur has now completed radiocarbon assays of samples secured at this excavation by himself and the senior author. The results are dates for the outer rings of a large prostrate oak, Q-1296: 6600 ± 120 B.P., and for the detritus mud lying beneath it, Q-1297: 6794 ± 120 B.P. These dates amply confirm the conclusions drawn in the text.

There is every reason to equate the shell-marl deposits of the Whittlesey area with those of the South Level, but it has to be noted that since the 1938–40 papers were published, evidence has increasingly suggested that the marine transgression that caused them to form was not entirely of Romano-British age but had begun in the pre-Roman Iron Age, possibly as early as 3000 B.P. Nothing in the Whittlesey area opposes such a concept, nor unfortunately does the area appear to afford opportunity for a critical dating of the event. Although quite decisive in its oligotrophic character, the scraw bog that formed between the two marine transgressions, at Whittlesey as at Ugg Mere seems to have represented no very long span of time on either side of the date $3260 \pm 110$ B.P. for elk droppings in peat of this character at Ugg Mere (Q-546), and the date of $3415 \pm 110$ B.P. for acid peat above the maximal extension of Fen Clay at Woodwalton (Q-545).

(*b*) *Effects of drainage*

It is not necessary to reiterate here the story of the drainage of Whittlesey Mere since it is so well documented by its prime originator and advocate, Mr W. Wells, M.P. for Huntingdon (Skertchley 1877), and has already been outlined in the previous paper on the Woodwalton Fen deposits (Godwin & Clifford 1938). Suffice it to say that the application of new steam-powered drainage machinery in a very short time after its installation in 1851 laid dry the bed of what had been the largest freshwater lake in Britain south of Windermere. The lake bed itself was brought under arable cultivation and compaction and wastage, hastened by some paring, extraction and burning of the peat, affected the surrounding peat land, so that surface ground levels fell by many feet. Mr Wells had the foresight and energy to provide the means of registering this process by inserting in Holme Fen in 1851 a long cast-iron column the head of which was level with the contemporary peat surface of 1848. Its base, thought to have been set in the basal hard clay beneath the peat proved, upon later investigation, to have rested upon a cast iron frame bolted to four stout oak piles driven into the basal clay. It provided therefore a relatively stable base for the column, which, during subsequent years has been increasingly exposed by contraction and wastage of the surrounding peat. This process was described by Fowler (1933) and the record was continued after the area had been taken over by the Nature Conservancy and particularly by the chief engineer, Mr L. F. Fillenham, of the Middle Level Commissioners who, in 1957, excavated the existing post, then in some danger of collapse and replaced it by a new cast-iron column exactly set so that its head was at the same level as the original. It was at this time that the foundation of the first post was revealed. This post was removed and adjacent to it was set up the present post based upon a reinforced concrete pile driven 2.5 m (8.0 ft) into the basal clay and secured firmly to a new cast iron column, which is now inset with brass plates giving Ordnance Datum level (Newlyn) and the heights of the peat surface at various dates transposed from the dates and photography in Fowler's 1933 paper (Fillenham 1963).

In the neighbourhood of the Holme Post, the peat surface in 1848 stood at about $+1.8$ m ($+6.0$ ft) O.D., and borings show the fen floor 7.3 m ($-24$ ft) below this, i.e. about $-5.5$ m ($-18.0$ ft) O.D. The recent (1957) height of the peat surface is about $-2.5$ m ($-8$ ft) O.D. The peat thickness has diminished from 7.3 to 3.3 m (24 to 10 ft). As the thin clay layers dated 3400 B.P. are only 0.9 m (3 ft) from the present surface, 2.1 m (7 ft) above the base whose age is estimated at about 6000 B.P. the diminution in height must have been greatest in the uppermost peat, as indeed would be expected. It seems most probable that the earliest phase of lowering was chiefly due to compaction of the raised-bog peat, and that subsequently some paring or even trench cutting of peat took place with surface burning associated with attempts at arable culture. In this later period wastage of the uppermost peat by biological oxidation must have played an increasing role. Fowler records that cultivation of the peat surface in this area ceased about 1877 and since this time birch woodland has occupied much of it, although a few raised bog species persist locally and respond to favourable modification of the habitat.

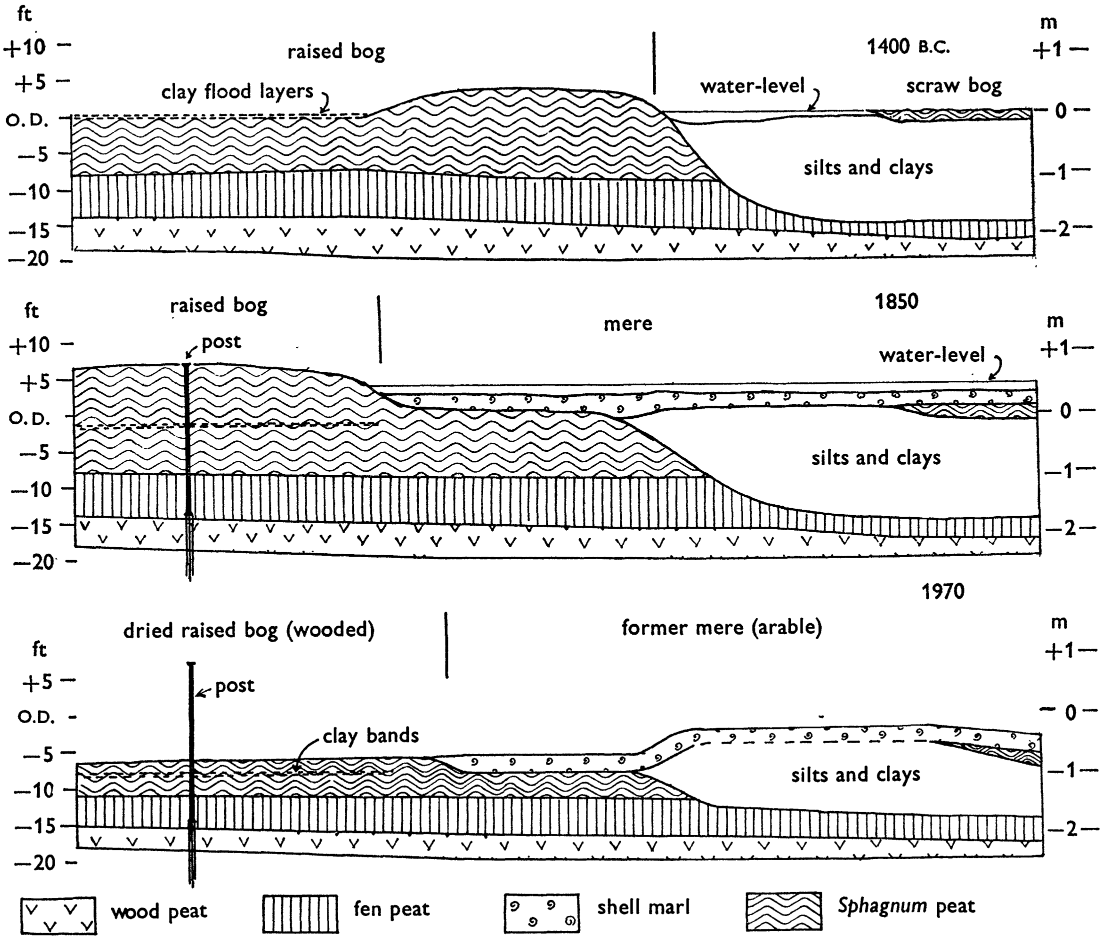


Figure 22. Schematic transect from Holme Fen into Whittlesey Mere showing for three periods, 1400 b.c., a.d. 1850 and a.d. 1970 the broad categories of Flandrian deposits above the fen floor in their measured or calculated height relation to one another. It is intended to illustrate how active raised bog had limited the Fen Clay transgression and subsequently the clay flood layers of *circa* 1400 b.c. and had afterwards confined the freshwater Whittlesey Mere. Finally it illustrates how a combination of peat exploitation and drainage since 1850 has exposed the Holme Post, and how differential shrinkage over peat and 'Fen Clay' respectively has led to one half of the present cultivated mere bed lying some feet lower in level than the other.

The effect of drainage upon the height of the exposed bed of the Mere itself is of particular interest. Not only is the original margin revealed still by a decline in level from the surrounding peat but the Mere now is seen as composed of a southern half, where the shell marl overlies only peat and where surface levels are generally − *ca.* 2 m ( − 6 or 7 ft ) o.d., and the northern half where the shell marl overlies a substantial thickness of silt and clay, and the surface is about − 0.6 m ( − 2 ft) o.d. This difference in height is very perceptible on the flat fen roads and is evident as a clear ridge across the extent of the former lake (cf. figure 14). It has


FIGURE 23. Vertical air photograph in which the northeastern part of the bed of Whittlesey Mere is shown by the white shell marl contrasting with the darker peat land round it and especially on its southern boundary with Holme Fen (b). The straightened drainage channels of the 'Old River Nene' cut directly across the meandering course (a) of the natural river (see figure 2) whose silt levées limited the northern side of the mere. At (c) there are pronounced relict creek systems apparently draining eastwards from the banks of the natural river, but their age and relationships still await investigation (cf. however Green Dyke area, Godwin & Clifford 1938). (Photograph by the Department of Aerial Photography, University of Cambridge.)





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FIGURE 24. Vertical air photograph of the nature reserve at Holme Fen. Holme Fen Lode (road) crosses the picture diagonally and (a) marks the clearing beside the Holme post. The margin of Whittlesey Mere abuts on the peat of Holme Fen at (c) where pale shell marl forms the surface deposits. Since the drainage of the mere in 1850 dense birch woods have colonized the dried surface of the former raised bog. At (b) is a deep excavation made for the Nature Conservancy and extending to the tree layer on the fen floor. On Short's Drove at (d) is the site of the Holme Fen pollen series and radiocarbon dates. (Photograph by the Department of Aerial Photography, University of Cambridge.)


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followed of course from the relatively small effect of compaction and wastage after drainage upon the minerogenic deposits. It should be noted however that even before 1851 the southern half of the Mere had been somewhat the deeper part. Water level in the Mere before the drainage apparently stood about +1.2 m (+4.0 ft) O.D. with the top of the shell-marl about −0.6 m (−2.0 ft) and the top of the silts and clays half a metre or so lower, i.e. not very different from the height 100 years after the drainage.

These results of levelling in relation to recent drainage indicate that the water-levels during the Fen Clay transgression cannot well have been lower than about −1.5 m (−5 ft) O.D., and must accordingly have been contained by neighbouring raised bog that prevented access of tidal water to Holme Fen, which at that time, as we have shown, was lower-lying wet fen. This barrier of raised bog, persisting until 1400 B.C., was presumably the obstacle which prevented the freshwater clay bands, caused by Bronze Age clearance, from extending into contact with the clays and silts of the earlier transgression. This we have sought to convey in the purely schematic transect from Holme Fen to Whittlesey Mere reconstructed in figure 22. It is then followed by a transect representing conditions just before the 1851 Mere drainage, by which time the clay bands had been buried by a further growth of raised bog peat, while the silts and clays, in places overgrown by scraw bog and incipient raised bog, had all been covered by calcareous shell marl that had also overspread the raised bog when the Mere attained its full pre-drainage extent in the early Sub-atlantic (Iron Age–Romano-British) period. The third transect represents the present condition after the drainage had exposed the upper half of the Holme Post, and produced the differential lowering of the surface of the bed of the two halves of the Mere.

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