STUDIES OF THE POST-GLACIAL HISTORY OF BRITISH VEGETATION

I. ORIGIN AND STRATIGRAPHY OF FENLAND DEPOSITS NEAR WOODWALTON, HUNTS.

II. ORIGIN AND STRATIGRAPHY OF DEPOSITS IN SOUTHERN FENLAND

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PART I. ORIGIN AND STRATIGRAPHY OF FENLAND DEPOSITS NEAR WOODWALTON, HUNTS.

INTRODUCTION

The fenland basin of East Anglia is a shallow depression centred round the Wash and filled with extensive post-glacial deposits of peat or of estuarine silt and clay. The alternation of these deposits, and changes in their character, are the record of a complex history of climatic alteration, marine transgression and regression, and of vegetational evolution. The Fenland Research Committee, founded in 1932, has for its object the elucidation of this history, which is of importance not only intrinsically, but in relation also to the post-glacial history of the adjoining margin of western Europe, to the history of human settlement in Britain, and to the theory of peat stratigraphy and vegetational history in this country.

Results of intensive investigations at fenland sites of particular archaeological interest have already been published: they represent the correlated research of specialists in several sciences. The first paper dealing principally with peat stratigraphy and vegetational history was that of the present authors on the deposits at Wood Fen, near Ely (H. and M. E. Godwin and M. H. Clifford 1935). They now report the results of more extensive observations of similar character in another portion of the fenland basin where the deposits have a wider range of character and of age.

1. TOPOGRAPHY, HISTORY AND METHOD

The area dealt with is a bay on the western margin of the fen between Peterborough and Farcet on the north, and the village of Woodwalton, 6 miles north of Huntingdon, on the south (fig. 1). This basin is about 6 miles (10 km.) across from north to south, and lies open to the main fen region on the north-east side. The surrounding country consists of low gentle hills of Oxford clay, largely covered with boulder clay, and so disposed that they form a low ridge, close round the basin. They enclose a very small river-catchment area, from which no streams of any size drain into the basin. This is a feature of importance in interpretation of the vegetational history of the area, as is also the low lime content of the boulder clay and the fact that the more calcareous Jurassic strata (oolites, etc.) outcrop only west of the watershed.

The region has been notable for the occurrence in it, until recent times, of several large fenland "meres" of which the best known were Whittlesey, Ugg and Trundle Meres, with Ramsey and Benwick Meres not far to the east. These were all very shallow lakes, of which fair historical records persist. The largest, Whittlesey Mere, was the second largest fresh-water lake in England, and was famous for sailing and skating. It was drained in 1851, and the landowner, Mr Wells, has left a valuable account of conditions before draining and observations on the effects of this draining. The other meres appear to have been drained in the years just before.

At the time of the first ordnance survey (1824), and before the mere drainings, the so-called "Old River Nene" entered the area from the north by an artificial channel (the Pigwater), crossing a neck of marine gravel between Horsey Hills and the upland.

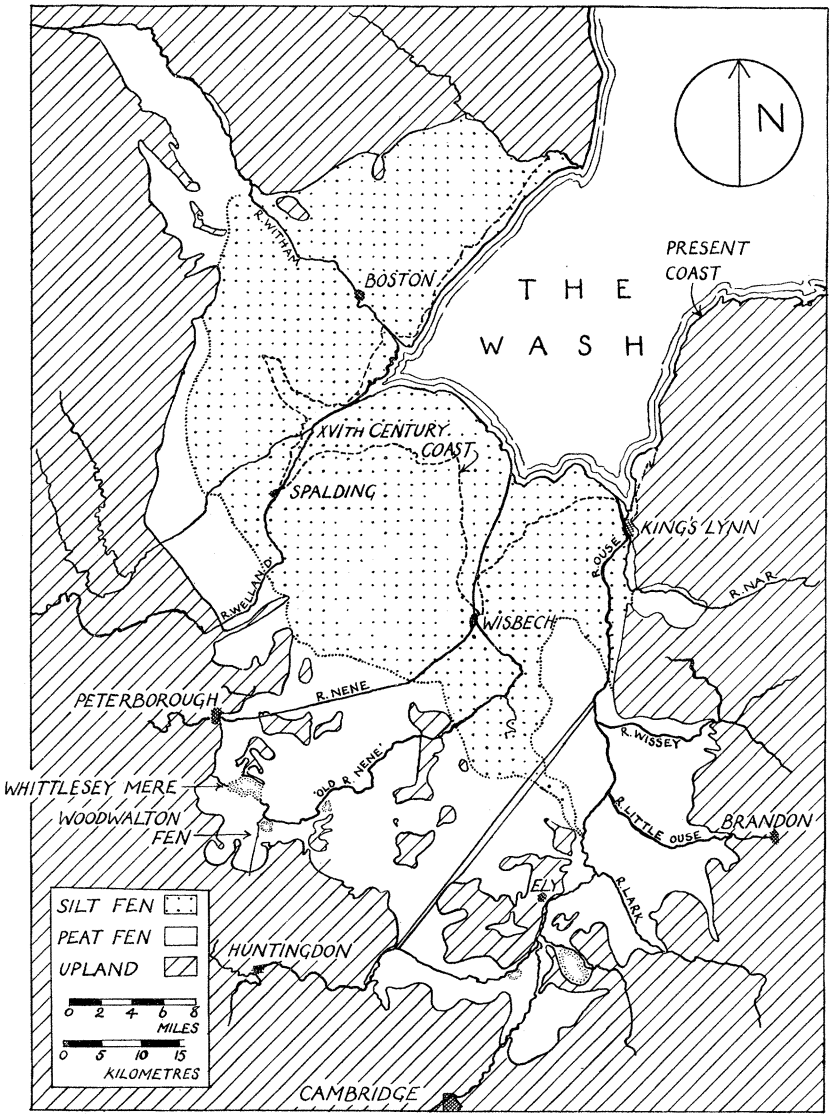


Fig. 1. Map of the fenland basin to show the disposition of silt fen, peat fen and upland, with the situation of the Woodwalton Fen area dealt with in this paper. The existing, much modified, courses of the chief rivers are shown and the former lakes or "meres" (dotted). It will be noted that large islands, usually of jurassic clay, protrude through the fen deposits: when the rivers cross these, their channels are artificial.

It is shown as entering Whittlesey Mere by Conquest Lode. There are two outlets, the one quite straight, a drain leading to Guyhirne, and the other, more irregular, leading into the edge of Ugg Mere (fig. 2).

From Ugg it is shown as a partly straightened channel leading to Ramsey Mere—to which it has only a lateral connexion—and thence towards Benwick and March. Though the lower part of this river system appears to be natural, the upper portion leading into Whittlesey, and from Whittlesey by Ugg to Ramsey, has been so much altered by man that it is impossible to say what was the original relation of the river to the meres. It certainly seems likely that the waters of the "Old River Nene" were artificially carried through Conquest Lode into Whittlesey, and that normally this stream had its exit farther north.

Trundle Mere was apparently linked to Whittlesey Mere only by a narrow lateral channel. Their relationships are evident in the sketch map taken from a survey of 1833 (fig. 2).

The comparatively late draining of the area has allowed the peat deposits to suffer much less destruction than in other parts of the fens. A particularly favourable locality was offered by Woodwalton Fen, now kept uncultivated by the National Council for the Preservation of Nature Reserves.

The absence of the upper peat layers over a large part of the section is attributable to peat cutting and to some cultivation, neither of which, however, greatly affected the present investigation. The local fen people say that at one time corn could be grown on Woodwalton Fen in summer, although it was completely flooded in winter. The cultivation is said to have ceased when the upper black peat had been destroyed and the plough had reached the red "moory" layer, which can safely be presumed to have been acidic *Sphagnum* peat. At this stage the fen was parcelled out for turf-digging, in the course of which as much as 3 ft. of peat have often been removed. It is said that in this digging remains of pine trees were found associated with *Sphagnum* peat, though not necessarily with the purest layers.

The structure of the marginal deposits of this area was investigated by a combination of field work and laboratory analysis. By excavation and boring, beds of peat, silt and clay were traced laterally along predetermined lines of section, and the data were co-ordinated by a levelling survey accurate to 1–2 cm. Detailed stratigraphy of peat layers was established by microscopic identification of plant remains in suitable samples, and specialist advice was obtained upon silt samples containing Foraminifera and diatoms. Vertical series of samples at small intervals were collected and investigated by the pollen-analysis technique. Details of the preparation and analysis of the plant material will be found in the papers by Godwin (1934) and Clifford (1937).

2. General stratigraphy

A. *The Long Section. Woodwalton Fen* (*Z* to *Z′*) (see map, fig. 2 and section, fig. 3)

Several reasons determined the choice of this section as the base-line for the whole survey. It runs for the greater part of its length of 3 miles through derelict ground which for many years has been under trees or bushes; it lies along one of the smaller arms of the bay, and includes the transition from shallow marginal profiles to deeper profiles of the fen basin itself. Corresponding with this, there is a fall in level of the ground surface from south to north along the line of section.

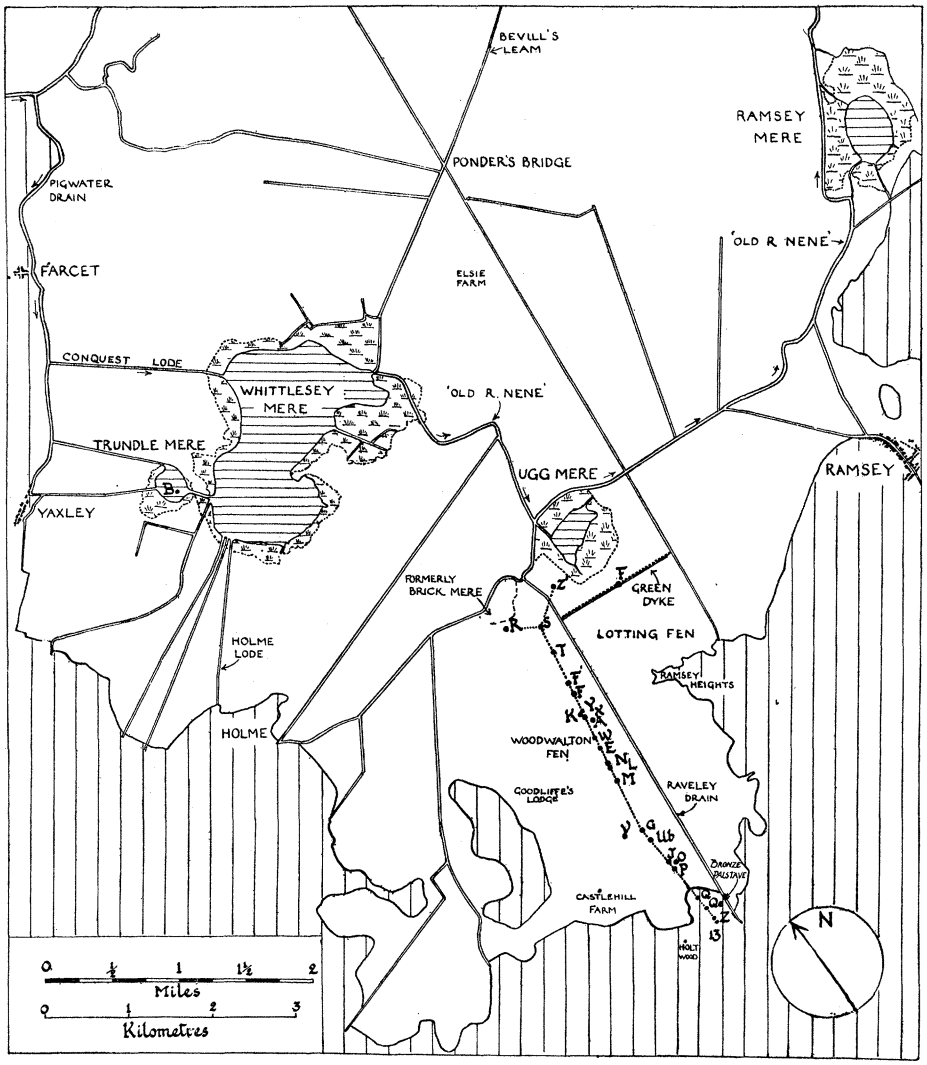


FIG. 2. Map to show the fenland of the Woodwalton Whittlesey area, as shown in the Eau Brink Drainage maps of Lenny in 1833. It shows the outlines of Trundle, Whittlesey, Ugg and Ramsey Meres before they were drained, but Ugg Mere, it should be noted, once extended across Green Dyke to the south, so that it has already undergone shrinkage. Marsh or bog is shown round all the meres. Roads have not been shown on the map; the double lines show the chief waterways. The (artificial) course of the "Old River Nene" is shown by arrows. The lines of section described in this paper are shown by dotted lines, and the sites of borings, excavations etc., by names or lettered spots.

The upland areas are vertically hatched: the blank part of the map is fenland deposits of peat or silt and clay, save for a small gravel area in the north-west, not specially indicated.

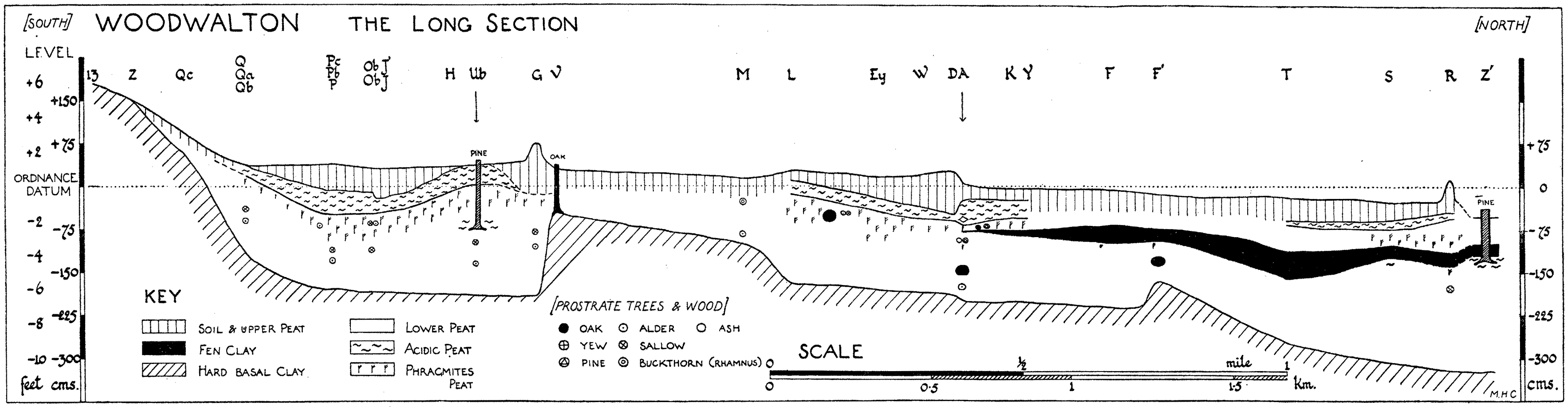


FIG. 3. The long section ZZ', through Woodwalton Fen from south to north, showing especially the landwards termination of the fen clay, and the extensive development of *Sphagnum* peat in the upper layers. Each letter along the section represents a bore or an excavation. The top soil extends deep enough, over much of the section, to suggest loss of the *Sphagnum* layer by weathering.

(1) *Excavation A.*

In describing the section it will be convenient first to consider the excavation made at site *A*, for, lying at the transition point between marginal and non-marginal profiles, it serves best as a key to the whole. At this point the ground level is +6 cm. (+0·2 ft.) O.D. Newlyn, the hard clay of the bottom coming on at −200 cm. (−6·6 ft.) O.D. The bottom 105 cm. consists in general of a porridgy peat, very yellowish when first cut but rapidly blackening on exposure to air. This peat is, from its abundance of

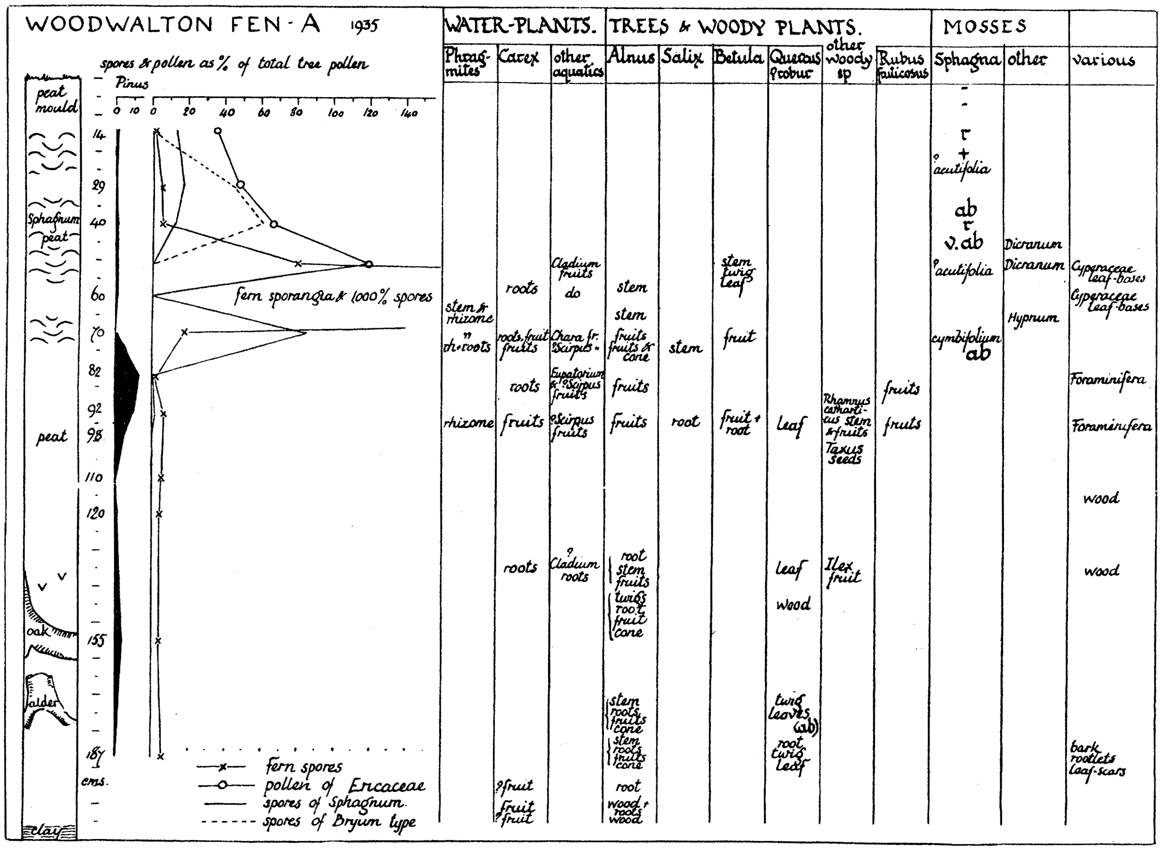


FIG. 4. Diagram showing correlation of results of field stratigraphy, counts of non-tree pollen and spores, and abbreviated micro-analysis of plant remains at Woodwalton *A*. The pine pollen curve has been given to facilitate relation also to the tree-pollen diagram.

twigs, roots and bud-scales, to be regarded as a wood peat (see fig. 4). Stools of alder and oak occur at various levels here and at site *B*, some 15 m. to the east. Most of the oaks seen in the basal peats of Woodwalton Fen are prostrate trunks, often up to 2 ft. 6 in. or more in diameter and lying south-west to north-east, normally with the root crown still intact. Towards the top of this basal wood peat (i.e. at 90–120 cm.) there is a marked increase in the diversity of woodland species represented—*Rhamnus catharticus* and *Frangula alnus*, *Betula pubescens*, *Fraxinus excelsior* and *Taxus baccata* with the woodland mosses *Thuidium tamariscinum*, *Hylocomium triquetrum* and *Eurhynchium Stokesii*.

Scirpus lacustris is, however, already present at 100 cm., and the layers immediately above (73–90 cm.) contain no wood, but many aquatic and fen species, including *Typha*, *Scirpus lacustris*, *Phragmites*, *Eupatorium cannabinum* and *Juncus* (? *glaucus*). From its structure this is apparently a *Caricetum* peat. More important is the presence, between 82 and 100 cm., of brackish water Foraminifera (*Rotalia beccari*, *Cristellaria*?) and fruits of *Atriplex* sp.

Lower Sphagnum *band*. Between 70 and 73 cm. is a very distinct band which appeared whitish and scaly as the section face dried, composed almost entirely of *Sphagnum cymbifolium*. Traceable as a continuous band for some 20 m. in the excavation, it was subsequently proved less continuous over a very wide area in the fen as a whole, always occurring at the bottom of the acidic peat.

Cladium *zone*. Peculiar to section *A* is the overlying 15 cm. of black, cheesy peat without *Sphagnum*, and containing fruits of *Cladium mariscus* and dark crimson-purple rhizomes, apparently of the same plant. From 55 to 30 cm., at which level soil-forming influences become felt, there occurs a well-marked but internally complex bed composed of alternating layers of fresh, small-leaved Sphagna (chiefly of the group *cuspidata*) and of dark chocolate-coloured *Calluna* peat. A greater or less amount of *Eriophorum vaginatum* peat may occur at the base of the *Calluna* layers. The bedding lines are inclined at various angles, thus cutting up the peat, when viewed over a wider zone than section *A* itself, into lenticular masses. These groupings are repeated three times in the present instance as the following scheme indicates:

	Peat content	Approx. depth below surface (cm.)
3	*Eriophorum* and *Calluna*	30
	Sphagnum	37
2	*Calluna*	43
	Eriophorum	
	Sphagnum	
1	*Calluna*	50
	Eriophorum	
	Sphagnum	

The fern and moss spores and the non-tree pollen counted in the pollen analyses at this site accord closely with the stratigraphy as already outlined. It will be seen from fig. 4 that *Sphagnum* spores first become abundant in the *S. cymbifolium* layer at the top of the wood peat, and that they are abundant with pollen of the Ericaceae and moss spores, in the upper layers of *Sphagnum* peat. The maximum of fern spores at 60 cm. suggests a phase such as that in a rather similar stratigraphical position at *E* (fig. 5).

(2) *Adjacent sites.*

From site *A* to *L* (fig. 3), a distance of one-third of a mile (*c.* 535 m.) to the south this upper acidic peat is clearly traceable as a continuous undulating bed present in the sides of the drainage dykes, with internal lenticular bedding developed to a greater or lesser degree locally. Immediately adjacent to *A* it was found to contain large stems of *Calluna*, so well preserved as to be identifiable with certainty by section cutting, also twigs with leaves of the same species, together with the characteristic leaves of *Andromeda polifolia*. The peat bed is seen in its simplest form near *W* (fig. 3), where it is made up as follows:

Surface soil

Calluna, *Eriophorum vaginatum*
Sphagna (*cuspidata*)
Polytrichum

Sphagnum cymbifolium

Black mat of fern rootlets

Aquatic *Phragmites* peat locally changing into a clean fibrous layer of fine rootlets and occasional rhizomes of Cyperaceous (?) type (Magnocaricetum).

At this site a small trunk of *Juniperus communis* was obtained from a newly cut ditch, but it was not possible to confirm the exact level. It seemed likely that it corresponded with the top of the *Phragmites* peat or with the *Dryopteris thelypteris* horizon.

The greatest development and complexity of acid peat is to be found close to site *E* (see fig. 3). It lies above a *Phragmites* peat which locally passes laterally into a wood peat, and is separated from the *Phragmites* peat by a layer of the black shiny rootlets of *Dryopteris thelypteris*, with some birch twigs. Overlying this there is a local development of almost pure *Sphagnum cymbifolium* peat giving place above to the banded zones of acute-leaved Sphagna and *Calluna-Eriophorum* peat. No attempt has been made in the diagram to represent the lenticular bedding. Associated species of considerable interest are *Andromeda polifolia*, *Vaccinium oxycoccus*, *Aulacomnium palustre* and *Polytrichum strictum*, all in the *Sphagnum* layers. *S. cymbifolium* does not seem to occur outside the lowest layers, many of the layers being very homogeneous, and composed almost entirely of a single species. Unfortunately the stem leaves are much more rarely preserved than the branch leaves, so that the frequency of specific determinations of Sphagna is reduced. The species so far identified belong to the *acutifolia* and *cuspidata* groups. These include *S. Russowii* (42–47 cm., det. W. R. Sherrin) which is normally a moss of wooded regions. A peat block dug from the same dyke, but of which the exact provenance is not known, gave what is possibly *S. fuscum* (W.R.S.), a tussock-forming moss of raised bogs. A similar block yielded *S. recurvum* P. Beauv. agg. (? subsp. *S. fallax* von Klinggr.), a member of the *cuspidata* group and a species found in pools.

The assemblage of species recognized from the banded *Sphagnum-Calluna-Eriophorum* peat instantly suggests the flora of a raised bog (Hochmoor), and the banding is relatable to the cycles of the "regeneration-complex" described by Osvald (1923) for such bogs. This is confirmed by Professor Osvald himself, who saw the material and who also added that the sequence from *Phragmites* peat, through layers of *Dryopteris* rootlets, and *Sphagnum cymbifolium* peat to the regeneration-complex peat, was highly characteristic of the basal layers of many of the Swedish raised bogs. These circumstances have left us in no doubt that raised bog did actually begin at this time to develop in the Woodwalton area. Evidence is given later that elsewhere in the neighbourhood the development was greater and the bogs persisted until very recently.

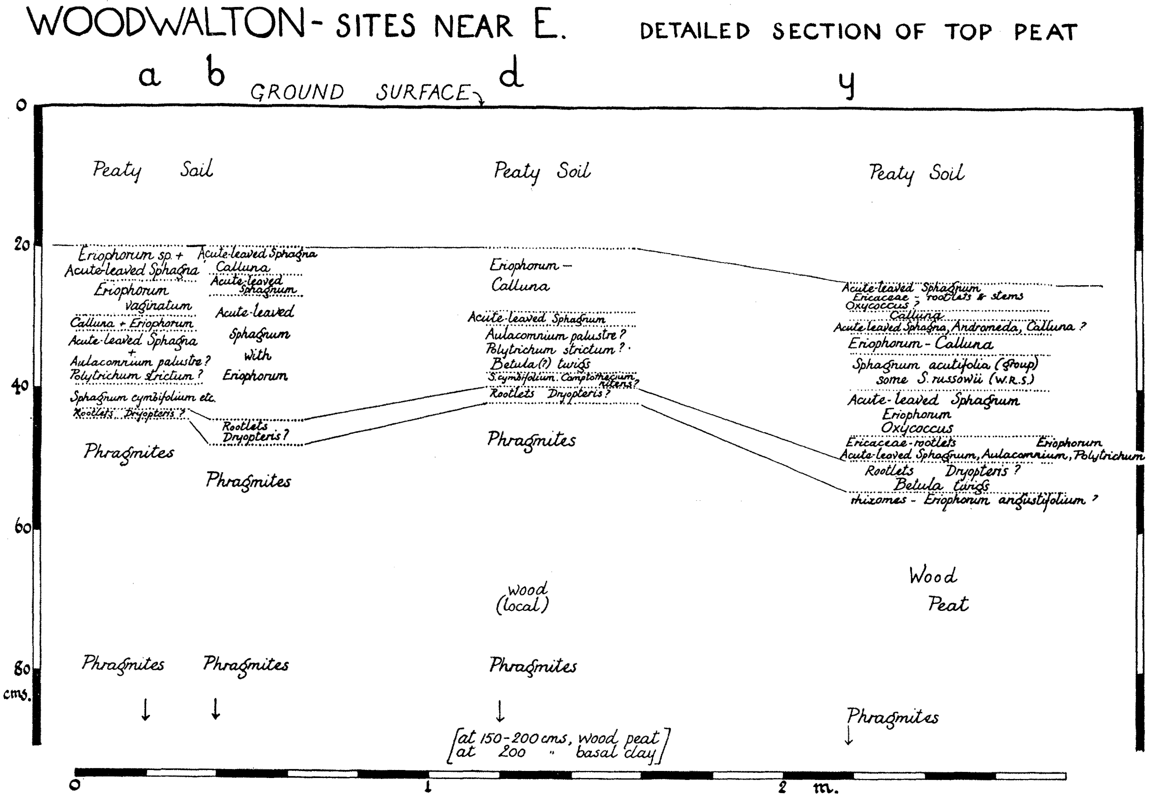


Fig. 5. Detailed section through upper fen deposits at four contiguous sites near Woodwalton *E*, showing results of micro-analysis of columns of the upper peat. Throughout *Phragmites* peat or wood peat is succeeded by a layer of fern rootlets and then a substantial thickness of *Sphagnum* peat with typical raised-bog species. *Sphagnum cymbifolium* is sometimes present above the fern layer. Different layers of the peat are separated by dotted lines, and equivalent horizons at the four sites are linked by continuous lines.

In the northerly direction from *A* the acidic layer rapidly becomes simpler in structure as the marginal regions are left behind, and a soft clay layer is interposed beneath it to divide the section into an upper and lower peat. Between *A* and *K* (fig. 3) there was found in a dyke wall, apparently lying between the soft clay and the acidic layer, root crowns and wood of *Taxus baccata*, *Quercus* sp. and *Pinus silvestris*. The oak was found to be rooted in the fen clay, which cannot therefore have been waterlogged when the oak was growing. Beyond *K* the upper part of the profile at *Y* was as shown below:

Soil (weathered peat)
Finely laminated (but *not* lenticular) peat, of fine-leaved Sphagna
Aquatic peat + *Salix* leaves (?) + *Sphagnum cymbifolium*
Phragmites peat
Soft grey clay
Phragmites peat

The *Sphagnum* peat shows no trace of complex bedding. Beyond *Y* it is missing, no doubt because the upper layers have been removed by peat-cutting and, beyond *F*, by cultivation.

(3) *Bore R and excavation S.*

For proper appreciation of the changes in passing from the margin, reference should be made to the northern end of the section. Here bore *R* shows the bottom to have shelved rapidly to its greatest depth of −320 cm. (−10·5 ft.) O.D., whilst the band of soft blue-grey clay has become thicker and in general slightly lower in level. The nature of this clay will be considered in the description of the Green Dyke section. Above it lie 30 cm. of peat containing *Phragmites* and some wood fragments; this is in turn overlain by 30 cm. of brown-black cheesy peat with traces of wood. Just below soil level, from 50 to 70 cm., is a black, fibrous layer with *Eriophorum* peat, the only indication here of the presence of an acidicolous community. A short distance north of *R* is the historic site of Brick Mere, which appears to have been one of the earliest meres to be drained, since it is shown as under cultivation in the 1824 map. In general, however, cultivation seems to have been very destructive in this region, and surface examination reveals no trace of shell marl or other evidence of the former lake-bed. About 15 m. south of *R* a certain amount of *Sphagnum* peat does occur at a depth of 35–40 cm. below the surface, with acute-leaved Sphagna above and *S. cymbifolium* with *Polytrichum* (?) below, the whole overlying *Phragmites* peat.

At *S*, which lies just south of *R*, a peat digging exposed 15 cm. of acidic peat containing acute-leaved Sphagna, *Aulacomnium* (?), *Calluna*, *Eriophorum* and *Menyanthes* (seeds), with abundant *Sphagnum cymbifolium*, *Polytrichum* and some alder (or birch?) twigs at the base. This is separated from the soft clay by 30 cm. of *Phragmites* peat. *Phragmites* also occurs within the clay itself, which is here only 20 cm. thick, whilst below there were shewn some 20 cm. of *Phragmites*-Cyperaceous peat. At 20 cm. below the bottom of the soft clay there were abundant red seeds of *Menyanthes* accompanied by *Sphagnum* leaves and one fern sporangium. Over the whole of the area between *F* and *R* (fig. 3) bog oaks are frequently excavated, and the farmer states that they invariably underlie the soft clay and are prostrate. One of these was encountered in bore *F′*, and it would seem certain that they are part of the same basal oakwood horizon as in profile *A*. But the oaks do not constitute the only forest horizon to be found in this part of the section. Fir trees (i.e. *Pinus*) are reported as having once been numerous about *R* and to the west of it, many excavated stools still lying about on the surface, but it was not possible to recover their proper horizon in the immediate locality. The farmer records that they were usually very small (some 6 in. diam.) and were often lying just on top of the soft clay. At a site *Z′* a little less than ½ mile to the east, several were, however, found *in situ* together at a level of −135 cm. (−4·4 ft.) O.D. The clay was here so thin and the pine stools so interbedded with it that it was exceedingly difficult to disentangle their relative levels, but it was found that the root crowns grew upon a greasy, highly decayed peat known locally as "bear's muck",* and containing *Menyanthes*, *Salix*, Cyperaceae and *Phragmites* with some *Eriophorum* and *Calluna*, *Sphagnum* and *Aulacomnium* doubtfully present. At a distance of only 1–2 m. careful excavation proved the presence *in situ* of red disk-like scales of pine bark in this "bear's muck" under 2 ft. of soft grey tenacious clay, showing that some at least of the pines antedate the clay. Their relative level is indicated on the Long Section.

(4) *The landward margin.*

To complete the examination of the present section, sites to the south of *L* remain to be described. It will be noticed that between *L* and *V* the level of the fen rises considerably, reaching as high as −45 cm. (−1·65 ft.) O.D. This is the consequence of a subterranean ridge of hard clay crossing the local peat-filled bay from Ramsey Heights in the east to Castlehill Farm, Higney Grange, in the west. So far as could be determined, there is no deep channel crossing this bar, which may therefore at some former period have made the area to the south a centre of independent drainage. At one point the clay actually outcrops as an island some 50 ft. (15·25 m.) in diameter. From this island when peat-cutting was formerly in progress, pottery dishes, bones and clay smoking pipes used to be recovered. Fragments can still be found. Within memory the island has not been covered with peat, and from the character of the remains it appears to have been an encampment of the early drainers. The effect of the ridge on existing vegetation is also very noticeable, a result of the improved drainage of the overlying peat, particularly during dry periods. The peat in many places is crumbly and deeply weathered, a circumstance which with peat cutting may account for our failure to trace acidic peat between *L* and *Ub* (fig. 3). Part of the area about *V* is notable as the locality of some of the botanical records for which Woodwalton is well known among taxonomists, e.g. *Calluna vulgaris*, *Erica tetralix*, *Chlora perfoliata*, *Dianthus prolifer*, etc. There is also a very dense rabbit population, since the area is high and winter flooding rare. Stumps of several oak trees protrude from the peat hereabouts. Excavation shows them to be rooted *in situ* on the basal clay and not on peat. They are not, therefore, stratigraphically relatable to the other oaks previously described, and may be much later in age. Their wood, however, where not exposed, is in the condition of bog oak.

(5) *Pine tree pit, Ub.*

Beyond *V* the fen bottom again descends steeply, and a wood-peat containing abundant remains of alder and sallow fills the lower levels. At *Ub* a pine stool was excavated, and found to be *in situ* on peat and rooted with an exceedingly flat crown at about −75 cm. (−2·5 ft.) O.D. The detailed floristic composition of the profile appears in the accompanying table (fig. 6), whence it can be seen that the pine grew at

* Foetid *Phragmites* peat is generally known in the fens as "bear's muck" or "devil's dung": it often has a high clay content and would then correspond with the German "Darg".

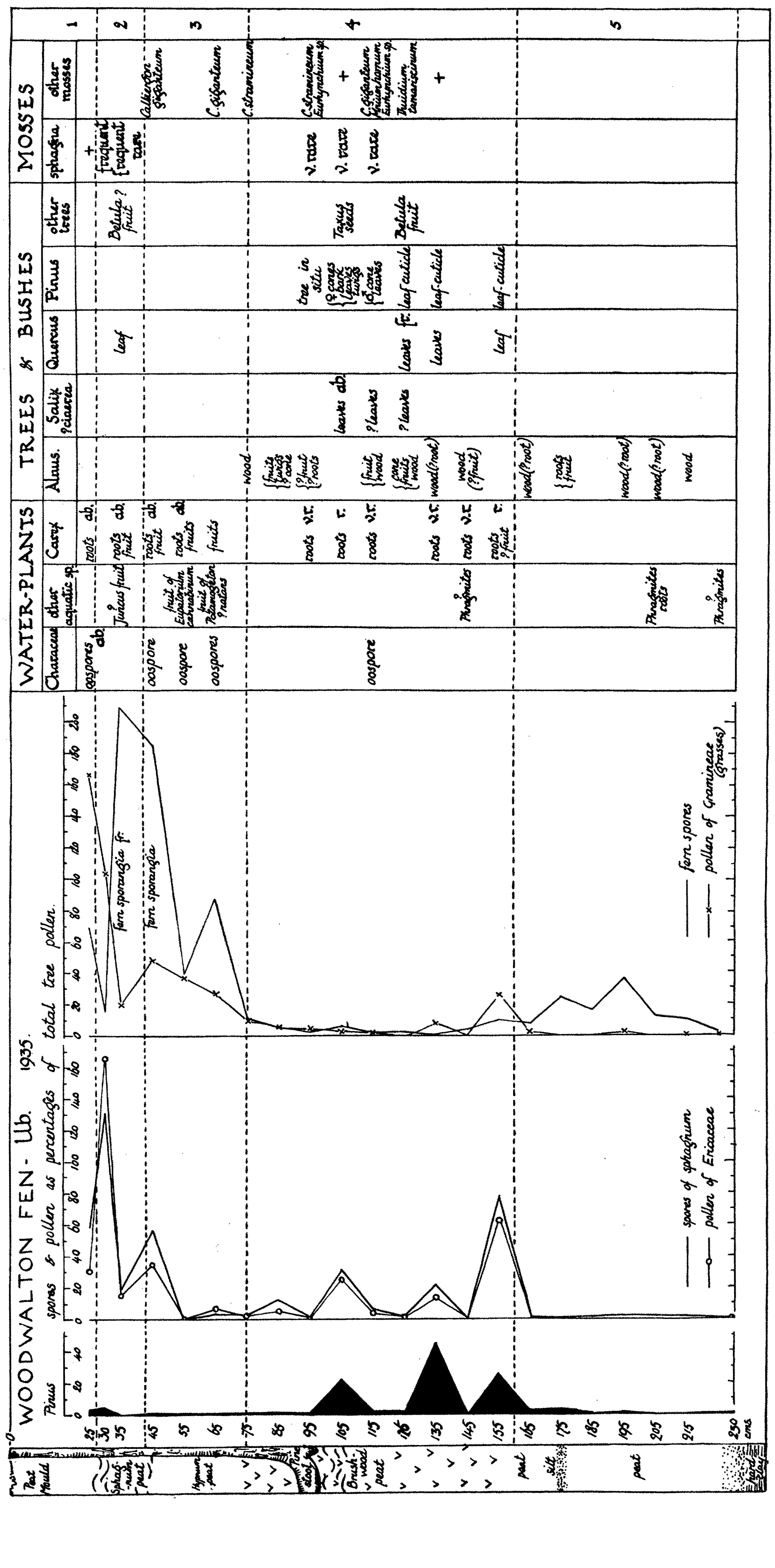


FIG. 6. Diagram showing correlation of results of field-stratigraphy, counts of non-tree pollen and spores, and micro-analysis of plant remains at the marginal site, Woodwalton *Ub*. The pine pollen curve has been given to facilitate relation to the tree-pollen diagram.

the top of an alder-sallow peat. Numerous cones and leaves were found at its base, which suggests either that the root system in life was very superficial or that this individual tree commenced growth in an existing pinewood.

The pine was also associated with *Taxus* nuts and numerous woodland mosses, Sphagna being very rare. Overlying it was a fen peat with *Chara*, *Carices*, *Eupatorium* and *Calliergon stramineum*, Sphagna being absent. Next above this came 15 cm. of peat rich in Sphagna and fern sporangia. The uppermost identifiable horizon just over it suggests the return of wetter, less acidic conditions. It will be seen from fig. 6 how the non-tree pollen and fern spores correspond with the other stratigraphical indices. *Sphagnum* spores and pollen of Ericaceae are present in small amount in the upper brushwood peat which bore pine: they are absent below this, and reach their greatest development in the upper *Sphagnum* layer. As in Woodwalton *A*, the base of this main *Sphagnum* layer is marked by high percentages of fern spores (see also notes on site *E*).

The horizon of acid peat is traceable right to the fen margin, at least in the droves, where it again comes within reach of weathering. It was also traced as far to the south-west as Holt Wood, where beneath the flat root crowns of recent fallen oaks, which had been growing on the wet peat, there was a thin compactly laminated layer of *S. intermedium* agg., overlying an alderwood peat. The trees (2 ft. 6 in. (*c*. 75 cm.) diam. in the bole) had been growing there for many years, protecting the peat beneath them. Broadly speaking, the acid peat centres about *E* as the region of maximum development, and sites in the plane at right angles to the Long Section demonstrate its continuity. Thus at Goodliff's Lodge, which lies 1·5 miles (some 2400 m.) north of Holt Wood and two-thirds of a mile (1070 m.) to the south-west of *A*, much *Sphagnum* peat (or "clunch", as it is called locally) was dug during the Great War for conversion into animal food at the Molassine (Speechly's) Farm on the Burbeach Stream (Brick Mere district). Some of this peat, which is a *Sphagnum fuscum-rubellum* type, remains and is still cut for fuel. An oak tree was seen at a level of 1 ft. below this *Sphagnum* horizon, whilst *Dryopteris* remains (?burned) and *Sphagnum cymbifolium* were seen in a block of unknown provenance from this district. On the opposite side of the section, some third of a mile (535 m.) to the south-east of *A* and near the fen margin, a pine tree was excavated in Heights Drove, the root crown being found *in situ* at a level of −27 cm. (0·9 ft.) O.D., which is the level equivalent to the top of the acidic peat at *A*. It was rooted over a layer containing *S. cymbifolium* (freq.), *S. cuspidata* grp. (rare), *Menyanthes* seeds and sallow leaves with alder or birch twigs at the base, this layer being in turn underlain by aquatic peat. (The root system as at *Ub* was well developed on the north-east side, but the south-west side was not fully excavated.) A yew trunk was also seen ploughed up from an approximately equivalent depth in the neighbourhood. The level of the oak horizon, on the contrary, is approx. −127 cm. (−4·2 ft.) O.D. hereabouts, and several were seen excavated which had flat, peat-filled root crowns indicative of growth *in situ* upon peat.

An opportunity of studying the relation of the bog-oak horizon to the substratum was afforded at Castlehill Farm, Higney Grange, a site right on the fen margin. Here many trees had been excavated during farming operations, several showing unmistakable signs of having grown before the onset of peat-forming conditions, their crowns being filled with crumbly, silty clay containing broken flints and other stones. Such stools had steeply descending root systems. Others, on the contrary, had, like those in Heights Drove, greatly flattened stools with the roots radiating at right angles to the trunk axis, the whole crown being filled with black peat without any trace of clay or alluvium. It would seem, then, that the basal wood-peat of the fen is to be interpreted as formed by a damp oakwood on clay passing into a fen oakwood as a result of worsening drainage. A similar transition was reported at Wood Fen by the present authors (1935).

In summarizing the Long Section *ZZ′* the following are the chief stratigraphical features:

(1) At the fen margin on the south there is a single peat bed, but to the north this is split into two by the intrusion of a wedge of soft grey clay which thins out before reaching *A*, where it is only represented by foraminiferal tests.

(2) This clay overlies a basal wood-peat with oak and alder below, and *Pinus*, *Betula*, *Taxus*, *Salix*, *Rhamnus*, etc., above. In more marginal regions the clay is represented by a *Phragmites* aquatic peat, but this horizon is not traceable stratigraphically beyond *L*.

(3) Above the clay *Phragmites* peat continues for a time, giving rise to a wood-peat with *Betula*, *Pinus* and possibly *Juniperus* and *Taxus*.

(4) This gives place regionally to an acidic community dominated by *Sphagnum* spp. and *Calluna*, but this phase is more strongly developed on the landward side of the fen. It is generally initiated by communities with abundant remains of ferns, either rootlets, or sporangia and spores, or all.

(5) There is some indication in the topmost layers, of a return of wet fen conditions.

B. *The Green Dyke Section* (see fig. 7)

Since it had proved impossible to discover the lake-bed deposits of Brick Mere, for correlation with other parts of the main section, *ZZ′* (fig. 3), the authors turned to an examination of the site of Ugg Mere. This examination was much facilitated by the recently completed widening of Green Dyke, which runs for over a mile due east and west, just crossing the southern part of the former mere. If extended a quarter of a mile (400 m.) to the west the line of Green Dyke cuts base-line *ZZ′* (fig. 2) at right angles between sites *S* and *T*. The widening provided throughout the dyke length a clean section to the dyke bottom, a vertical distance of about 1·5 m. (5 ft.). The dyke bank was measured and roughly staked, and careful measurements were made of the profile at intervals varying from 1 to 50 m. according to the abruptness of local change in the beds. The basal layers not exposed in the dyke were proved at intervals by boreholes. Records were co-ordinated for relative level by the water surface in the dyke, and also were related to O.D. through the Engine House gauge at the western end.

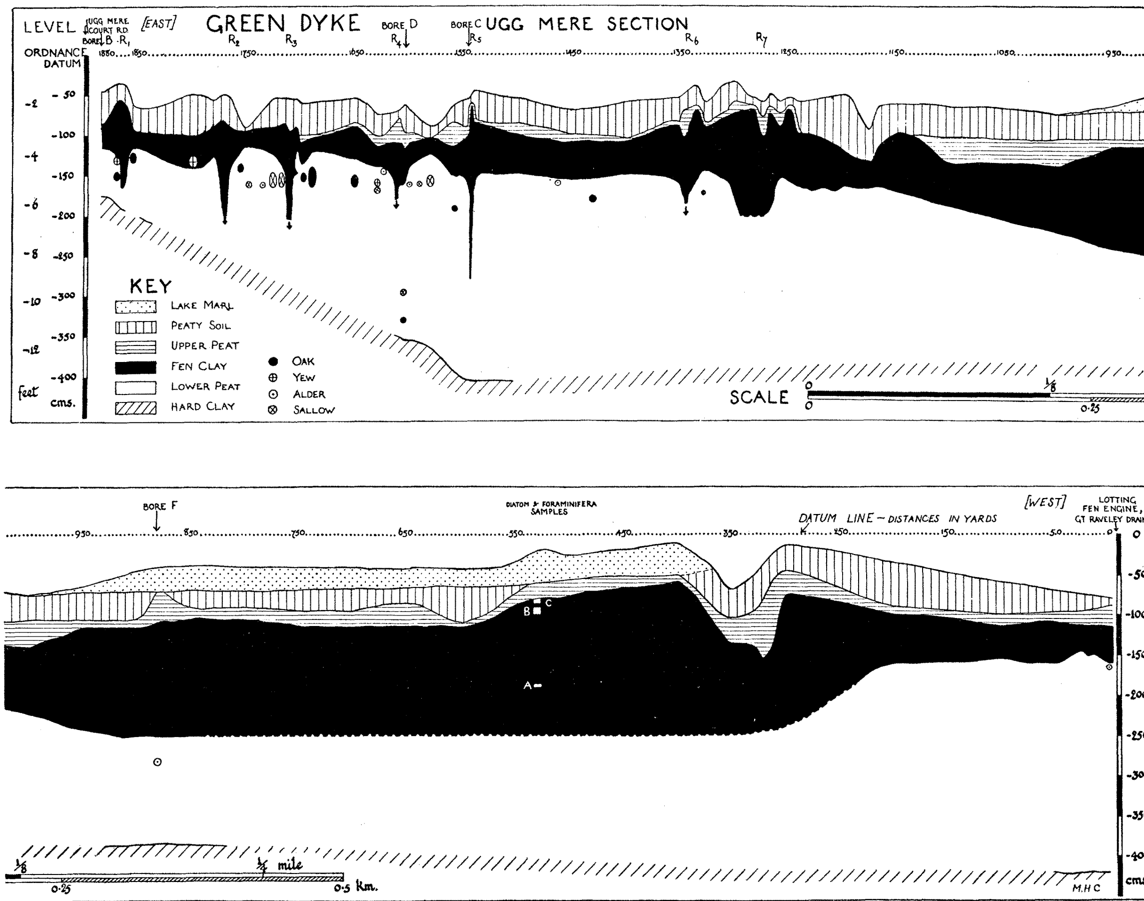


FIG. 7. Section along the full length of Green Dyke, from east to west. It shows the sequence of lake marl, upper peat, fen clay and lower brushwood peat across the basin which formerly held Ugg Mere. The fen clay deposit is saucer-shaped, thinning at the edges and the brushwood peat below it contains many more trees marginally than centrally. Sharp boundary lines are not given when the exact transition level is unproved. Between 1150 and 550 on the datum line, weathered peat is shown below lake marl and above undisturbed upper peat. The lake marl is still recognizable at the top of the weathered peat and at bore *F*, lake marl lies on the undisturbed upper peat.

In considering fig. 7, drawn from the above data, there should be noted the change of scale from section *ZZ′*, necessitated by the greater detail. It will be more convenient to analyse this section by considering at once the major stratigraphical horizons from below upwards, particular importance attaching to the relations of the mere bed and the buttery clay.

(1) *The lower peat.*

The surface of the basal hard clay which is blue or slightly yellow, in contrast to the fen clay almost mica-free and containing small stony fragments, falls from −175 cm. (−5·75 ft.) O.D. at the eastern (Ugg Mere Court Road) end to −400 cm. (−13·1 ft.) at bore *C*. Associated with this transition from a semi-marginal to a non-marginal site there is a gradual diminution in the abundance of stools of oak, yew, sallow and alder, which are present at the top of the lower peat until the last stool, an oak, is left at 1327 yd. on the datum. The majority have every appearance of growth *in situ*, though one of the yews, at 1800 yd. on the datum, lies within the soft clay. Other yews have very oblique root crowns, which may be due either to growth on a nearly vertical surface or to a semi-prostrate habit on a more level substratum.

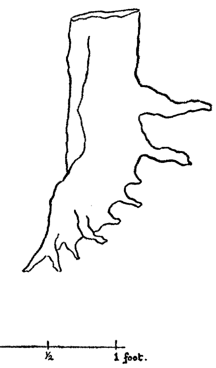


FIG. 8. Diagram showing root system of a yew (*Taxus*) found on the Green Dyke section, at 1800 yards on the datum. The tilted root crown is very common in yew stools found in the fenland peats.

(2) *The fen clay and silt.*

A little beyond the last oak the overlying soft clay thickens, its base falling rapidly to −250 cm. (−8·2 ft.) O.D. but rising again at the western end, where it once more thins out. Associated with this rise is the reappearance of the tree horizon at the top of the lower peat. In brief, the section reveals the soft clay as a saucer-shaped mass, which is higher and thinner at the extreme limits, just as in the Long Section. The detailed structure is, however, much more complex, particularly in the marginal region to the east. Here steep-sided channels descend to a depth of at least 130 cm. (4·25 ft.) into the lower peat, as at sites *R* 1–7. Bore *C* was made through the channel *R* 5 and shows its base to reach to −280 cm. (−9·2 ft.) O.D., a lower level than the general run of soft clay in the locality, so far as this is known from borings. The channels give strong indication of having been eroded into the lower peat at a period subsequent to its accumulation, their walls ordinarily being nearly vertical and in at least one instance (*R* 3) being undercut into the peat. The clay filling the lower portions of these channels is a dark grey-blue clay, slightly silty but soft and buttery to the touch. It is also exceedingly micaceous, as is the soft clay throughout the section. Above, it grades into a light clayey silt, brown or yellow in colour, and very micaceous. Such a gradation is present in the soft clay profile throughout the section. Maximum siltiness is only developed, however, in those ridges which coincide with the deep channels. Several of these ridges appear at the present time as conspicuous surface features in consequence of their elevation above the surrounding ground level. At first, because they could be traced longitudinally for some distance, and were not to be regarded as shoals, they were thought to be former watercourses, now in the state of roddons (Fowler 1933). They cannot, however, be recent (post-clay) in origin because there is no evidence whatever of their courses having been cut subsequent to the deposition of the clay. Moreover, in all instances the upper peat bed, or its weathered remains, is continuous over the summit of these ridges; in places ploughing has not yet disturbed the base of it. In the centre of the ridges *R*6 and *R*7 there is some suggestion of a stream bed, also filled with material continuous with the upper peat horizon.

(3) *The upper peat.*

This was traced almost continuously through the length of the section, being noticeable where it was still out of reach of weathering and ploughing, as a very hard, black layer often nearly structureless, but laminated, and with vertical jointing, which farmers record as having developed in consequence of intensified drainage coinciding with several dry summers. Only occasionally, as near bore *F*, was its structure well enough preserved to permit specific identifications, and then Sphagna (including *S. cymbifolium* (?), *S. acutifolium* (agg.)), *Camptothecium* (? *nitens*) and *Menyanthes trifoliata* were observed, corresponding with the less strongly developed acidic layers of the non-marginal part of section *ZZ′*. In this connexion the previous history of Green Dyke itself is of some interest. It is recorded by local inhabitants that until about 40 years ago it was a bank, puddled on the south side to prevent the waters of Lotting Fen, which stood at a higher level, from draining into the Ugg Mere district. This bank stood some 3 ft. higher than the present ground level. With the replacement of the original windmills by more powerful steam pumping plant the bank was dug down for fuel, being composed of "clunch" (i.e. presumably *Sphagnum* peat). The farmers also record the former occurrence here of pine stools, but no trunks, in the peat above the soft clay.

(4) *The mere silt.*

The portion of the mere that is cut across lies at the centre of the section. Rarely more than 40 cm. (1·3 ft.) thick, the grey heavy silt or marl of the lake-bed contains some fresh-water shells, including the genera *Limnaea*, *Planorbis* and *Dreissenia*. It is here greatly disturbed by ploughing, but from the evidence of this section and from a careful survey of the whole mere-bed at other places where the marl was much thicker, it can definitely be stated that at no known point are the recent mere deposits in continuity with those of the soft clay, a hard upper peat-bed always being interposed between them. The boundaries of the former mere as traced by the marl-bed were found to coincide very well with the limits given on the old maps, but no associated river channels, either infall or outfall, could be found.

(5) *Diatoms and Foraminifera in fen silt and clay.*

At 530 m. on the Green Dyke section line a set of three samples was collected in the vertical positions shown below:

C	85–90 cm. above water-level	Transition to upper peat
B	70–80 cm. above water-level	Coarse silt
A	20 cm. below water-level	Fine grey silt

A few metres away from the site a fourth sample, D, was collected from the top part of the soft clay, immediately below the upper peat, and containing visible remains of *Phragmites*.

Each of the samples was divided into two parts, and the two sets so obtained were analysed by Chr. Brockmann of Wesermünde for diatoms and by Dr Macfadyen of Baghdad for Foraminifera. The reports kindly made by these experts are given as appendices to this paper, but it will be convenient to summarize their conclusions briefly.

Dr Macfadyen found thirty-five species of recent Foraminifera in sample A, and thirty-four of these are regarded as indicating brackish water conditions with "some ingress of tidal water"; one species, commonly held to be marine, is also present. Sample B contained only nine species of recent Foraminifera, which suggest that "sample B was laid down in fresher water than sample A". Sample C contained extremely few Foraminifera, belonging to seven species, and indicating deposition "in almost fresh water".

It is quite clear that the maximum marine influence is at A and the minimum at C, though even at the latter Dr Macfadyen thinks there were "rare incursions of a little more marine and silty water". Sample D contained no Foraminifera.

From the diatom content Chr. Brockmann concludes that in samples A, B and C marine influence is unmistakable, but he comments on the smallness of the diatom content and suggests that these deposits contain marine sediment laid down by storm tides.

In sample D the only diatom is the brackish water species *Campylodiscus echeneis* which suggests the colonization of a brackish water marsh.

It will be seen that there is a remarkable agreement between the conclusions of Dr Macfadyen and Chr. Brockmann, and that there is little doubt that the fen silt and clay were deposited in a brackish water area penetrated by high tides.

The upper part of the bed represents progressive freshening of the water, and transition through a Phragmitetum from brackish water to fresh-water marsh.

In view of these conclusions it is extremely interesting to note the high pollen content of Chenopodiaceae type through the silt-clay samples of Ugg Mere *F*, and the maxima of *Nymphaea*, *Potamogeton* and *Sparganium* pollens, which follow at the transition to the upper peat (see fig. 9).

It will be noted that this diagram strongly indicates not only the transition from brackish to shallow fresh water, mentioned above, but the enormous maxima of fern spores, succeeded by low but definite amounts of *Sphagnum* spores and ericoid pollen. This corresponds with the nature of the transition to the upper *Sphagnum* peat already described on the Long Section. *Sphagnum* spores and ericoid pollen disappear from the upper samples with the approach of the conditions of mere formation (fig. 9).

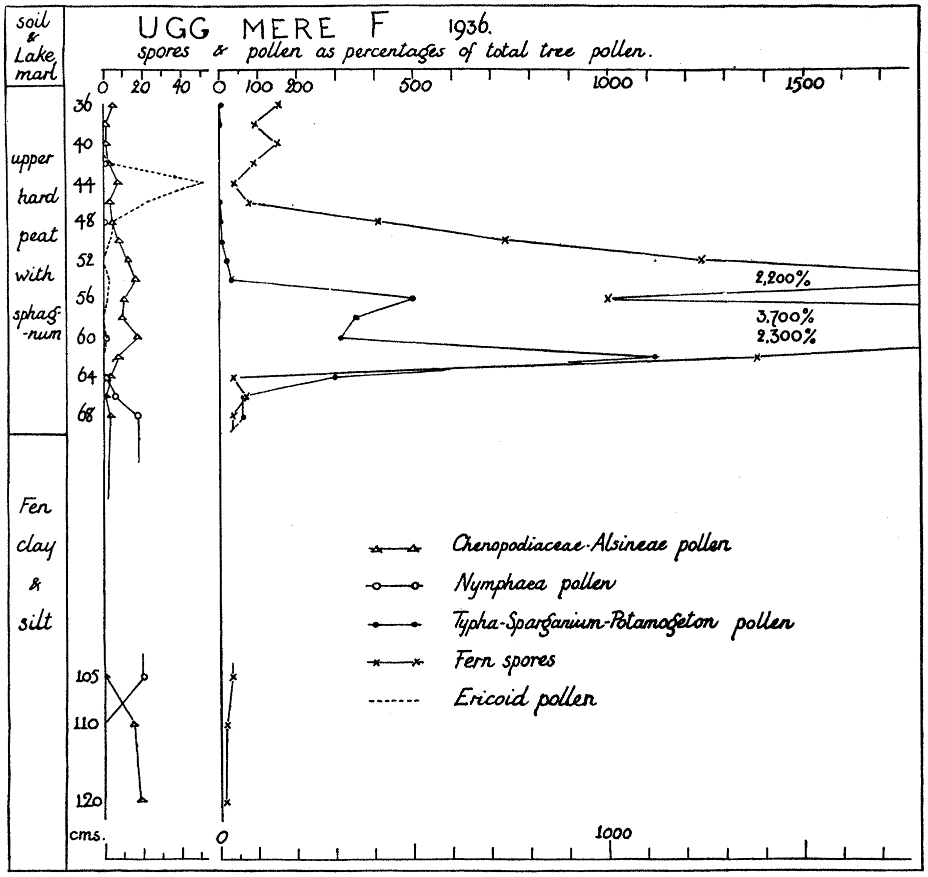


FIG. 9. Diagram showing counts of non-tree pollen and spores in the upper layers of fen deposits at Ugg Mere *F*. Note the successive maxima in Chenopodiaceae-type pollen, water-lily pollen, pollen of shallow water and reed-swamp, fern-spores, and ericoid pollen. This sequence corresponds with change from brackish water through a fresh-water lake to a fern community and then an oligotrophic *Sphagnum* community.

C. *Trundle Mere*

(1) *Stratigraphy.*

The persistence at Ugg of the bed of the historic mere made the preservation in this neighbourhood of relatively recent peats, such as have been destroyed over the fens as a whole, seem a possibility. But because of the considerable disturbance of the mere marl and the thinness of the intermediate peat bed it was decided to extend investigation to Trundle Mere, some 3½ miles (5·6 km.) to the NW. This brought our observations into a region for which there are considerable data of changes in topography after drainage, which make possible reconstruction of the former relationships between the levels of the meres and their bog margins and those of the river systems. Moreover, it was known from previous borings that the fen beds in this district continued to a considerable depth (−20 ft. O.D.), with the consequent possibility of the lower levels being an older peat than any at Ugg.

The general stratigraphy in the immediate neighbourhood of bore *B* (Trundle Mere), which was the one ultimately employed for pollen analysis, is shown in fig. 10. The former mere bed persists as a brown shelly marl, but its mean surface level is at −120 cm. O.D. (−4 ft.) approx., compared with −60 cm. (−2 ft.) for the general surface level at Ugg. The marl here is at the present time richer in shells than that at Ugg. The molluscan fauna has a fresh-water facies, as was shown by Skertchly (1877), who gave the species list. It included the following species:

Pisidium amnicum	*Succinea putris*
Sphaerium (Cyclas) corneum	*Limnea peregra*
Bithinia tentaculata	

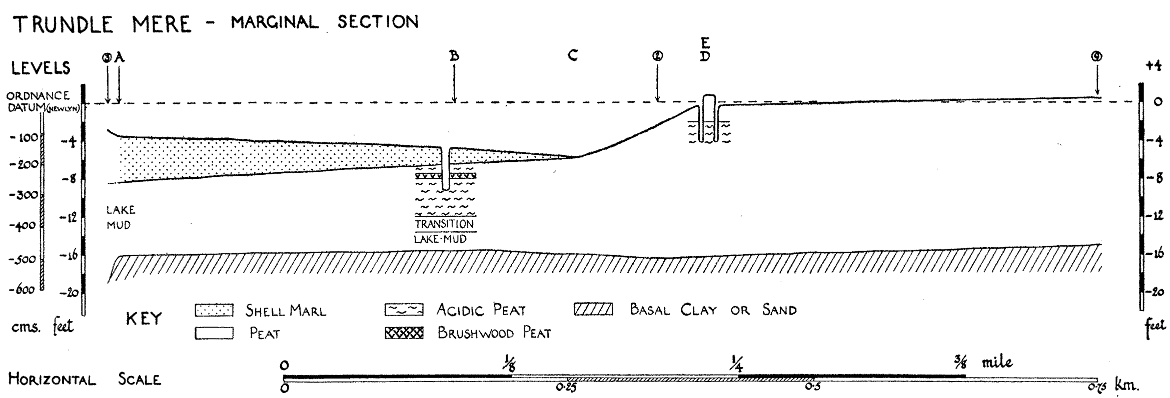


FIG. 10. Section through part of Trundle Mere, showing calcareous lake marl above oligotrophic peat. The slope of the bank of the former mere is evident. The lettered sites represent observations by the authors: the numbered ones, surface levels and total depths from the records of the Ouse Drainage Board. The relation of the beds at *A* and *B* to one another are not known, save for the lake marl.

Skertchly records *Dreissenia* as occurring only at Ugg, and not at Whittlesey, but this is erroneous.

The peat areas surrounding the mere deposits, at least to the north-east and north, stand out as sloping black banks rising to O.D. level, and they appear to represent, to some extent, the former mere margin. Such banks were quite absent at Ugg Mere.

At *B*, where the ground-level is −145 cm. (−4·8 ft.) O.D., some 45 cm. of calcareous marl overlie a dark brown or black acid peat, the topmost layers of which constitute a *Sphagnum-Calluna* horizon. Beneath this a layer of *Eriophorum-Betula* brushwood peat with abundant remains of a woodland moss, *Thuidium tamariscinum*, occurs at about −230 cm. (−7·5 ft.) O.D. (see fig. 11). Thence to about −365 cm. (−12·0 ft.) the peat is made up of layers of *Sphagnum* leaves, *Eriophorum* leaf-bases and ericaceous rootlets. A moss, identified, so far as its preservation allows, as *Dicranum Bergeri*, is very abundant at certain levels. The distribution in Britain of this rare moss shows it confined at the present time to the Eastern Lowlands of Scotland and the Highlands. From −365 cm. to −412 cm. (−13·5 ft.) O.D. is a transition region where the peat contains *Cladium mariscus*, Cyperaceae rootlets, and Characeae oospores in addition to abundant *Sphagnum* material. Lower, at −412 cm., there begins a second wood horizon, in which Sphagna are absent, the general species composition, so far as it was determinable, suggesting a fen scrub, though the lowest layers of all again include some Sphagna. Lying on the ground surface adjacent to bore *B* was a small stool of *Pinus sylvestris* with numerous poorly grown annual rings, and a total diameter of about 9 cm. (3·5 in.). Its exact provenance could not be determined.

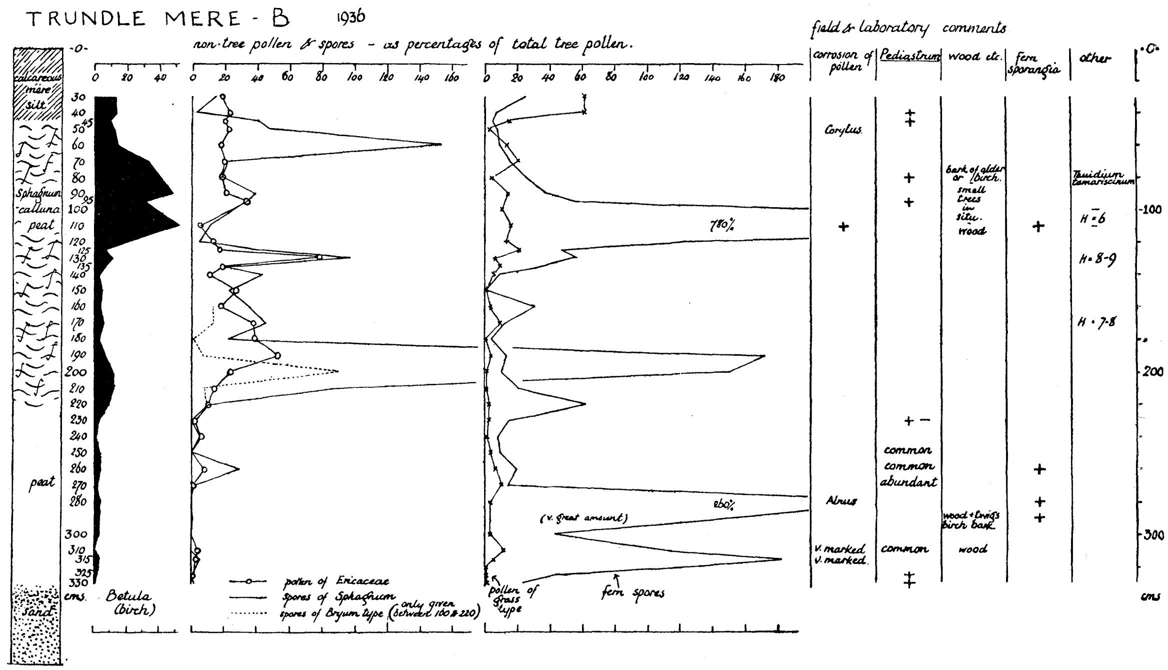


FIG. 11. Diagram showing correlation of results of field stratigraphy, counts of non-tree pollen and spores, and micro-analysis of plant remains at Trundle *B*. The birch pollen curve is given to facilitate relation to the tree-pollen diagram.

In the direction of bore *A* the shell marl thickens, whilst at *A* no trace of the underlying acid peat was found, a chocolate brown, organic lake deposit with occasional pieces of wood continuing to the bottom at −488 cm. (−16 ft.) O.D. In the opposite direction from *B*, at site *E*, which is situated slightly north of the line of section, and of which the exact level is not known, acid peat was traced in a ditch section from a presumed level of approximately −75 cm. (−2·5 ft.) O.D. downwards. Towards the top of this peat there was a mat of well-preserved *Hypnum scorpioides*, both over and underlain by *Sphagnum cymbifolium*. There also occurred beds of narrow-leaved Sphagna with interbedded

Cladium mariscus	rhiz.
Andromeda polifolia	lvs.
Vaccinium oxycoccus	st.
Calluna vulgaris	st.
Myrica gale	st.

Menyanthes trifoliata was seen near the base of the section. In places *Sphagnum cymbifolium* formed pure beds of considerable thickness and was well preserved. This type of peat continued at least as deep as −122 cm. (−4 ft.) O.D. Beyond *E* the ground-level lies fairly uniformly at about O.D. level.

(2) *Historical evidence for an oligotrophic (acid bog) flora near Trundle Mere.*

Reference has already been made to reports of former extensive beds of "red turf" and "clunch" in the Woodwalton area and of numerous pine trees encountered when the beds were cut for fuel. Records of the character of the reclaimed land about Whittlesey and Trundle Meres occur in the writings of Mr W. Wells, who was M.P. for Holme in this district and was personally responsible for the development of the area. "Whittlesey Mere in its ancient state comprised 1600 acres, but already at the time when the works for its drainage were commenced, the ordinary water acreage had diminished to little more than 1000 acres. Around the shores a margin of silty deposit had been formed, which though often dry was liable to submersion upon the slightest rise of the water in the Mere. Beyond this margin of silt which varied in breadth from 50 to 500 yards, and was valuable from the excellent reeds it grew, there extended, especially towards the south and west, where the level of the surrounding land was lowest, a large tract of peat moss which, though generally free from water during the summer was constantly flooded in winter. On the north and east sides the level of the surrounding land was higher—sufficiently high indeed to be cultivated by the aid of windmills, and approaching more nearly to the borders of the Mere, left less room for either the inner circle of silty reed shoal, or for the outer circle of peat moss" (Wells 1860).

"At a distance of 2 miles from the Mere, and near the village of Holme, a corner of the peaty tract runs up to the higher land and about 230 acres of this has been taken into a home farm, nearly 200 acres having been first covered with clay to an average depth of $3\frac{1}{2}$ inches....The operation was finished in the spring of 1866....Of the 230 acres taken into the farm, although a small proportion had been more or less under cultivation, some for two or three years, by far the larger part consisted of the roughest kind of bog....The surface of the rough bog, though levelled and prepared for its coating of soil as well as was possible, consisted mainly of lumps of fibrous and nearly wholly vegetable peat having no sand in it, and looking much like masses of dark coloured tow or oakum. Beneath this upper covering of a loose dry growth of vegetable matter there exists, at a depth of a foot or so, a stratum of a hard, dry red 'moor', or peat in another form. This seam is from 10–18 inches in thickness, and is of such a nature that the roots of no plants appear able to penetrate it. Immediately below this obdurate band the character of the peat changes. It becomes soft, dark and greasy, and, when reached in process of cultivation, is found to be very fairly fertile.... It is sought to get rid of this sterile seam of red 'moory' peat by very deep subsoil ploughing. This process repeated at intervals brings more and more of the objectionable substance to the surface, where it is raked into heaps and burned" (Wells 1870). The description "tow-like" is still applied in the district to the *Eriophorum* peats previously described, whilst the dry, red "moory" peat would suggest a *Sphagnum* horizon.

In a former paper (1935) the present writers discussed the reliability of a statement by Mr Wells in his "History of the Bedford Level" (1830) to the effect that "the turf moors are covered with such plants as the Heath, Ling and Fern, the Myrica gale, plants and natural productions, and a grass with a beautiful white tuft, called the Cotton Grass, are found in abundance". Doubt was cast upon this statement by Mr W. Marshall of Ely, writing in 1878, in Miller and Skertchly ("The Fenland"). When the above paper was written our state of knowledge did not warrant more than a tentative advocacy for the acceptance of the original record, but it now appears certain that Mr Wells was, indeed, in this account describing accurately some part of the vegetation of that region of the fenland which was best known to him, i.e. about Whittlesey Mere, Mr Marshall's experiences in the Ely district being the reason for his denial of Wells's account. Support for this belief is afforded by reference to herbarium records. The following is a list of rare or extinct species characteristic of acidic bog, drawn largely from the county flora list for Huntingdonshire with the localities, and their dates where known (Druce 1926). It is interesting to observe how these records centre about Whittlesey Mere and Holme. Whether this is a primary limitation, or whether it is attributable rather to the influence of changed drainage relationships not being felt there until very late in historic time, is difficult to determine. Many of the records date to within a few years of the drainage of Whittlesey Mere in 1850.

Pinguicula vulgaris Holme Fen		Paley
Drosera anglica Holme Fen, Whittlesey Mere	Very rare, perhaps extinct (G.C.D.) 1848	Newbould
D. longifolia Bog, near Whittlesey Mere	Extinct, if ever found? (G.C.D.) 1860	
D. rotundifolia Holme Fen, Whittlesey Mere	Rare (G.C.D.) 1848	Newbould Huntly
Andromeda polifolia Hunts. (no definite locality)		Hooker, from Watson per M. J. Berkeley MS.
Vaccinium oxycoccus Holme Fen, Whittlesey	Rare, probably extinct (G.C.D.)	
Calluna vulgaris Holme Fen, Yaxley Woodwalton Fen	Still present 1936	
Erica tetralix Holme Fen, Yaxley Whittlesey Woodwalton	Rare (G.C.D.) 1925 1912	Druce
Eriophorum angustifolium Holme Fen	Rare (G.C.D.)	Druce
Narthecium ossifragum Holme Fen, Whittlesey Mere	Rare and decreasing (G.C.D.) 1860	

Blechnum spicant (*boreale*)	Very rare (G.C.D.)	
Whittlesey Mere	1860	
Holme Fen	1883	Paley
Dryopteris Oreopteris (*montana*)	Rare or extinct (G.C.D.)	
Whittlesey Mere	1860	Paley
Splachnum ampullaceum		
Whittlesey Mere	1834	E. Broome

Comments accompanied by the initials G. C. D. are those of G. C. Druce. Original sources of the above records include the Marchioness of Huntly's herbarium at Orton, Hunts.; Newbould's "Catalogue of Huntingdonshire plants", ed. Alfred Fryer; F. A. Paley, "A List of 400 wild flowering plants, being a contribution to the Flora of Peterborough"; and E. Broome in the Henslow Herbarium, C.U. Botany School. It is to be noticed that several of the above have already been mentioned as occurring in a subfossil condition at various depths in the peat of Woodwalton Fen and Trundle Mere. It is probable that the recent flora has developed continuously from the fossil flora.

3. Pollen analysis

(1) *Method*

Samples for pollen analysis were collected by a Hiller auger, and were prepared either by the hot-alkali method or by a modified form of the chlorination-hydrolysis method of Erdtman, according to the density of their pollen content. Four sites were investigated:

(1) Woodwalton *Ub*, which is a marginal site with a subfossil pine tree horizon.

(2) Woodwalton *A*, which lies just beyond the landward margin of the fen clay.

(3) Ugg *F*, in the bed of the former mere.

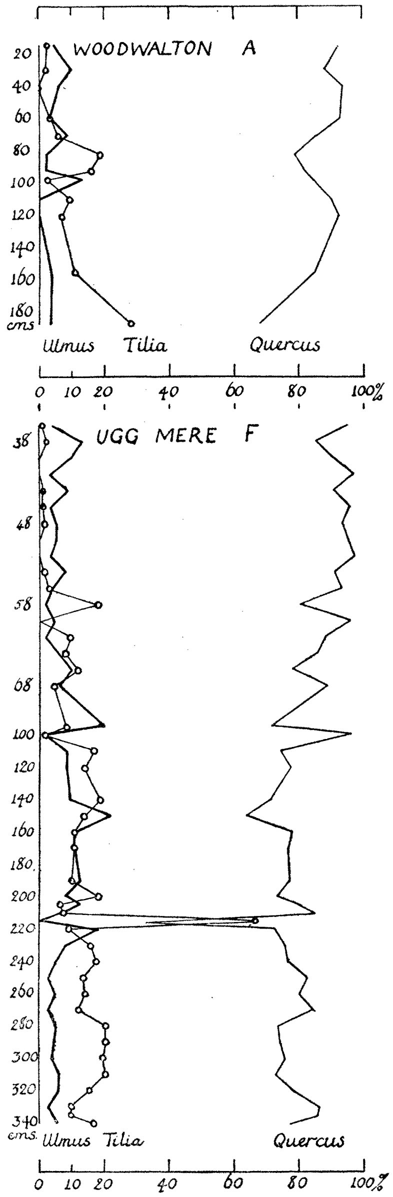
(4) Trundle *B*, in the bed of the mere, not on any direct line of section linking with the Woodwalton area.

For each site the results have been expressed in the form of three diagrams. Figs. 14–17 show at the four sites the percentages throughout the profile of all the separate tree pollens, and of hazel pollen, expressed as a percentage of the total tree pollen. (Figs. 4, 6, 9, 11 shows similarly the values of non-tree pollen fern and moss-spores expressed in terms of the total tree pollen, set alongside a table of the most striking plant remains other than pollen. Figs. 12 and 13 express values for a special group of trees, separated from the rest to facilitate analysis (see p. 349).

(2) *Separation of the Local and Regional Factors*

The four sites of the Woodwalton area of which pollen sequences have been obtained, prove, on examination, to need careful analysis before they can be correlated with one another. This analysis is one which reveals principles of considerable general interest in the interpretation of pollen analysis results, more particularly, however, those of the English fenland.

The sites, Woodwalton *Ub*, Woodwalton *A*, Ugg Mere *F*, Trundle Mere *B*, form a series of increasing distance from the fen margin,* and it is this factor which largely



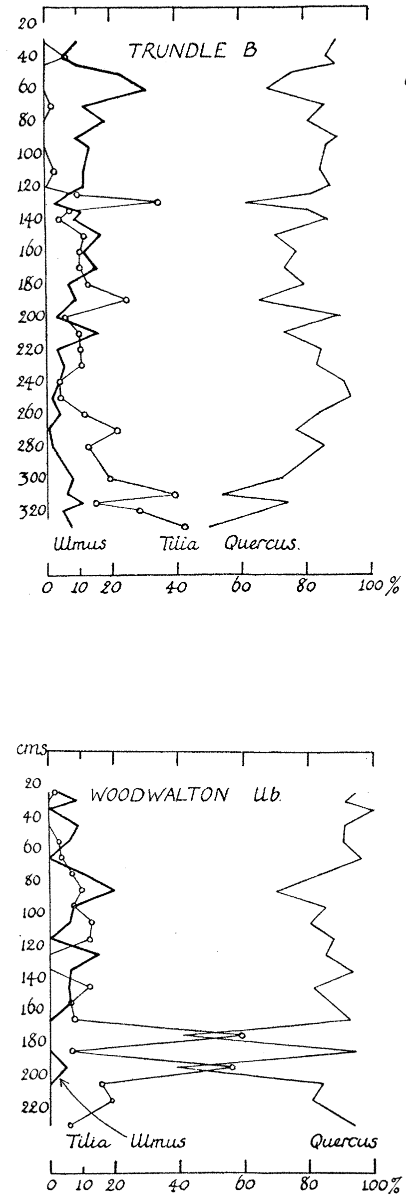


FIG. 12. Woodwalton *A*, and Ugg Mere *F*. FIG. 13. Woodwalton *Ub*, and Trundle Mere *B*.

Oak, elm, and lime pollen treated independently of other tree pollen. Pollen of each genus is expressed as a percentage of the sum of the three.

accounts for differences between their respective pollen diagrams. It is probable from the stratigraphy that the deposits at all four sites were formed approximately over the

* Trundle *B* represents a non-marginal site better than its actual distance from the fen margin suggests, for it is in a steep-sided basin occupied by lake or raised-bog deposits to the exclusion of marginal fen woods.

same period of time, they lie within a short distance of one another, and yet a brief examination of the four diagrams shows marked and regular differences between them.

It will be seen at once that through the series there is a progressive increase in the relative amounts of *Ulmus*, *Quercus*, *Tilia*, *Corylus* and *Fagus*, all of which are essentially forest trees or shrubs, and not, save *Quercus* sometimes, inhabitants of fen woods. The pollen of these trees occurs most abundantly in the sites farthest from the fen margin.

By contrast, it will be noted that pine and alder show a complementary decrease through the series, and that *Betula* behaves very irregularly. These three trees are characteristic components of the woods of the fen margin, or in some instances of the bog surface, very frequently associated with sallow, pollen of which is, however, infrequent.

The broad interpretation of these results would appear to be that the fen edge formerly supported "fen margin woods", and that peats formed in them are dominated by the local pollen of their characteristic trees. With increasing distance from the fen margin the influence of the pollen from these woods rapidly diminishes, and it becomes submerged in the general pollen rain derived from the woodland of the whole countryside surrounding the fenlands. Thus it will be from those areas which lie deepest in the fens that will come the diagrams most representative of the general forest composition of the countryside as a whole. Only where local fen woods have grown on the peat surface will the diagrams suffer from a specific local factor.

This conclusion suggests that the pine woods which formerly grew on the fen margin at Woodwalton *Ub* probably exercised so little influence on the general pollen rain of the fens, that it cannot be recognized in the Trundle *B* diagram only a mile or so away.

A similar explanation probably holds for the failure, formerly reported, to recognize a pine phase in the Black Bank diagram (near Ely), although this site was within a very short distance of the extensive fen margin pinewoods of Wood Fen (Godwin and Clifford 1935). Similar conclusions have been reached by Swedish investigators.

It becomes clear that the local growth of fen woods makes interpretation of the pollen diagram very difficult, and it is clear from the frequent occurrences of brushwood peat in the sections, that at certain times these must have been extensive in the Woodwalton area.

As a means of avoiding these difficulties we have recalculated our results for the trees *Ulmus*, *Quercus* and *Tilia*, and each has been expressed as a percentage of the sum of the three. These are trees relatively uninfluenced by the local factor, for *Ulmus* and *Tilia* do not grow in the fen woods and *Quercus*, although it grows in mature fen woods, is at the same time overwhelmingly characteristic also of the general forest cover. The amounts of these three trees in relation to one another should be independent of local effects, and this is indicated by the striking uniformity of the recalculated results.

As is shown by figs. 12 and 13 all four diagrams show the same relative magnitude of the three components, and the same sequence of three major phases (1) with *Tilia* exceeding *Ulmus*, (2) with *Tilia* and *Ulmus* equal, and (3) with *Ulmus* exceeding *Tilia*.

It is most unlikely that the *Tilia* maxima and minima, or the relation of *Tilia* to *Ulmus*, is affected by local fen woods containing *Tilia*, since the *Tilia* percentage is high in sites distant from the fen margins, and since these maxima occur in different types of deposit, for example, brushwood peat and raised-bog peat.

Had it been possible to have used larger counts of *Tilia* and *Ulmus* pollen, doubtless greater correspondence in detail would have emerged. As it is, a purely tentative basis for correlation of the four sites is given by the serial letters on the right of each figure, which represent equivalent horizons.

With this common basis of similarity in all four sites, it is clear that the fen beds at all of them were developing more or less together, a fact already apparent from the stratigraphy.

It is also possible to advance from this recognition of the regional component of all the diagrams to a detailed consideration of how local factors have differently influenced each of them.

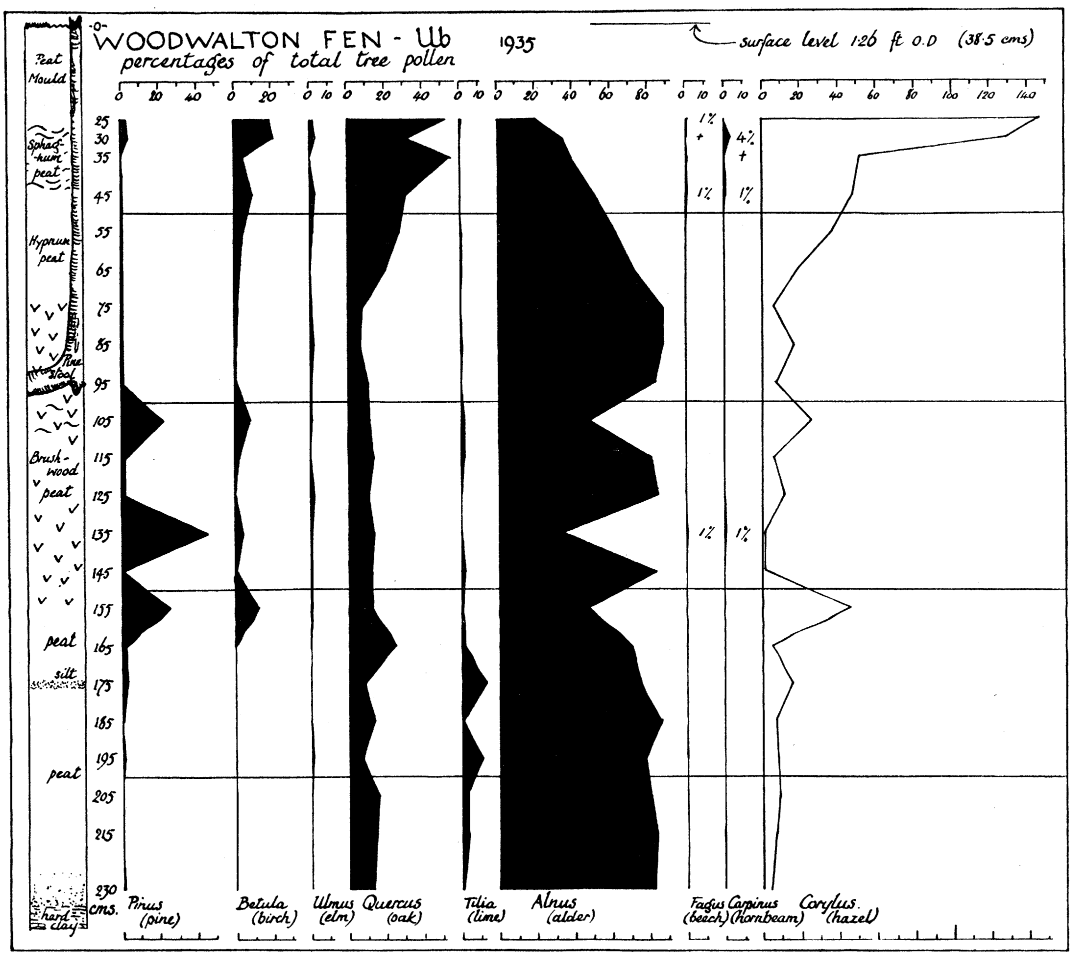


FIG. 14. Field stratigraphy and tree-pollen percentages at Woodwalton *Ub*. Beech and hornbeam values are shown by figures.

Woodwalton Ub (fig. 14).

Through almost the whole of this diagram alder pollen predominates, a result of the extensive development of brushwood on the site or very close to it. From 165 to 95 cm. pines were growing *in situ*, and were responsible for the three pronounced maxima of pine pollen. The presence of these woods is strikingly clear from the microscopic analysis of peats shown in fig. 6, and already discussed. The local factor, it will be noticed, causes very low values for the pollen of hazel and of the mixed-oak forest trees.

The sudden very sharp rise of hazel at the top of the diagram, together with mixed-oak forest components, goes with a decrease of alder pollen and is indicative of the destruction of the local fen woods, first by extensive development of *Sphagnum* peat, and perhaps later by widespread rise of the water-level.

Woodwalton A (fig. 15).

The lower part of the diagram, from 187 to 110 cm., is marked by a dominance of alder clearly associated with brushwood peat, and low values for the pollen of hazel and *Quercetum mixtum*. At 98 cm. there is a birch maximum followed at 82 cm. by

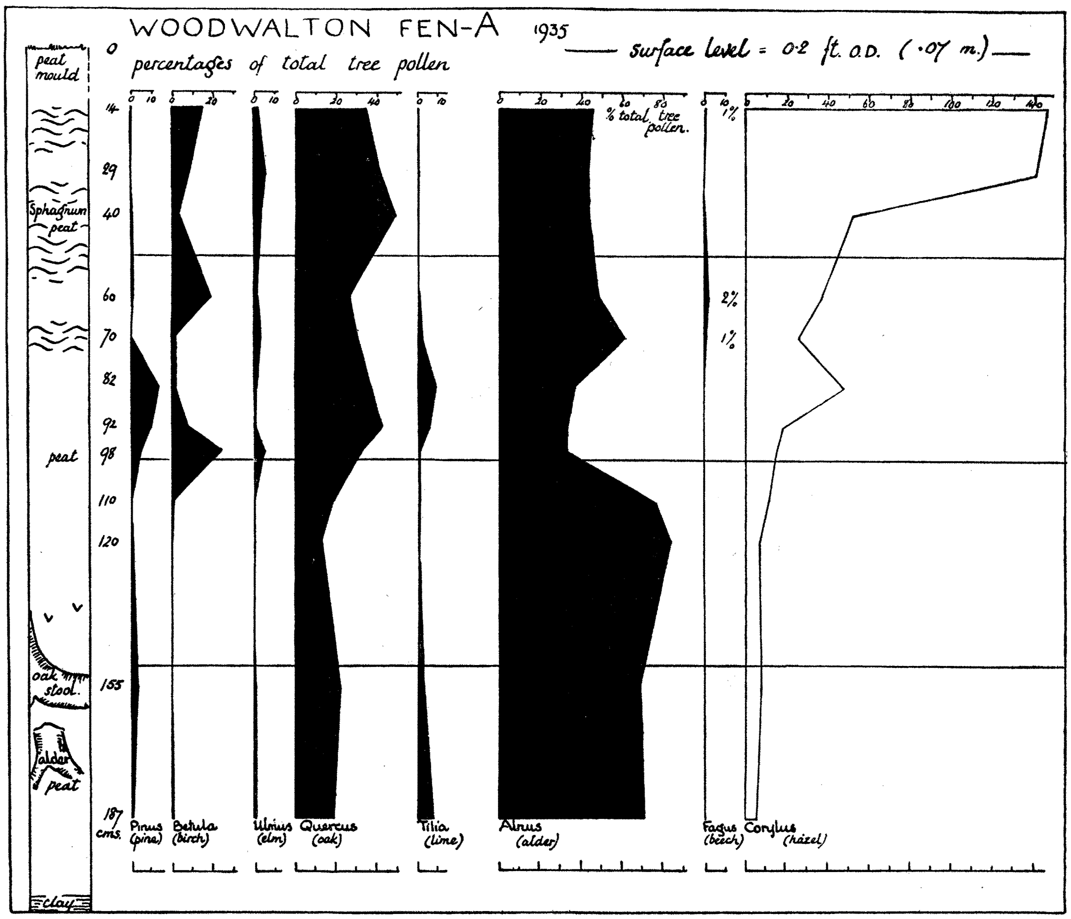


FIG. 15. Field stratigraphy and tree-pollen percentages at Woodwalton *A*. Beech values are shown by figures.

a pine maximum. This pine maximum occurs exactly at the horizon in which the tests of Foraminifera, together with seeds of *Scirpus*, occur in the middle of brushwood peat. These remains indicate wet conditions, and must imply a temporary setback in the extension of marginal fen woods. This no doubt accounts for the sudden increase of pine pollen from the neighbouring fen woods, as well as the rises in pollen of oak, lime and hazel from the general pollen rain. The birch maximum is presumably also associated with the marginal fen woods, since remains of birch are to be found in the peat at *A*, and corresponding but smaller maxima of birch occur in the *Ub* diagram.

As in Woodwalton *Ub* the upper part of the diagram shows very sudden increase in the amount of hazel pollen, and here again this seems to be associated with the

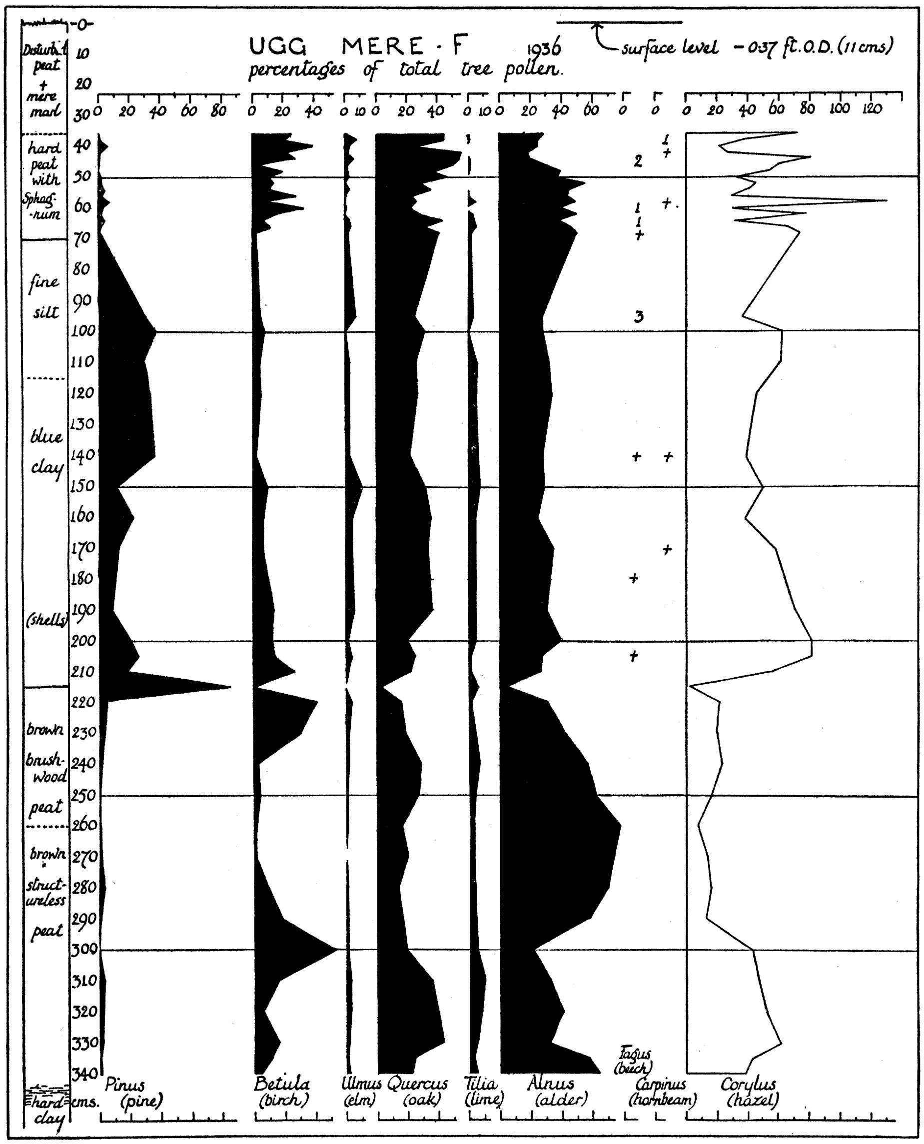


FIG. 16. Field stratigraphy and tree-pollen percentages at Ugg Mere *F*. Beech and hornbeam values are shown by figures. More detailed notes on stratigraphy are given in figs. 7 and 9.

destruction of the local fen woods following formation of *Sphagnum* peat, of the raised-bog type.

Ugg Mere F (fig. 16).

From 310 to 220 cm. the Ugg Mere diagram shows the unmistakable influence o local fen woods, the brown brushwood peat, or amorphous peat formed from it, correspond with that part of the diagram showing two maxima of birch separated by a region of high values for the alder pollen, and corresponding low values for the hazel and mixed-oak wood trees. Immediately before this phase, before the local fen woods had developed in this basin, local influences were less felt and the general pollen rain is more faithfully indicated. (The microscopic analysis of the peat from 330 to 310 cm. confirms this, showing fruits of *Typha*, *Cladium* and *Menyanthes*, plus *Carex* roots, in a peat composed largely of *Sphagnum subsecunda* (group) and fern remains. Wood was conspicuously absent. The *subsecunda* are characteristically Sphagna of pools, so that the general indication is of a wet *Sphagnum*-covered depression with abundant pools, possibly only local.)

Above 220 cm. the pollen diagram is marked by very striking increases in the pine and hazel pollen, and as this corresponds stratigraphically with the deposition of the fen clay and silt under estuarine conditions, there can be little doubt that these rises again indicate no more than the destruction of the local fen woods and increased emphasis on the pollen derived from the countryside as a whole, and from the still surviving pinewoods of the fen margin (e.g. at *Ub*). At 70 cm. the estuarine deposits give place to fresh-water deposits and then to *Sphagnum* peat: pollen of hazel and of mixed-oak forest trees remain high, but pine pollen diminishes, since, as we have already seen, by this time the marginal pinewoods were being covered by *Sphagnum* peat.

The rise of birch pollen in this part of the diagram may well be a local effect produced by birchwoods growing on the raised-bog surface, as in the site next discussed.

Trundle Mere B (fig. 17).

This site is certainly that of the four most removed from the influence of the fen margin, and of the fen margin woods, and, as we have already indicated, it is this fact which appears to be responsible for the high pollen values of hazel and mixed-oak forest trees.

There is at the base of the diagram some indication of the formation of brushwood peat, and this corresponds with high values for alder pollen and low values for oak and hazel. From 120 to 60 cm. again, there is a layer of brushwood in the peat corresponding with a maximum of birch pollen, and this certainly appears to be a purely local effect.

With these two exceptions the diagram seems to be a far more trustworthy index to the drift in forest composition of the countryside as a whole than the three other sites.

The nature of the deposits, indeed, mainly lake mud oligotrophic *Sphagnum* peat and calcareous mere silt, would suggest in themselves the greatest freedom from the influence of local sources of tree pollen.

If these interpretations are correct we are faced with the fact that a very large part of the variations of the curves of pollen diagrams from fens may be due to the influence of local woods growing on the peat surface or near by, and to changes in the relative importance of such local factors upon the regional pollen rain.

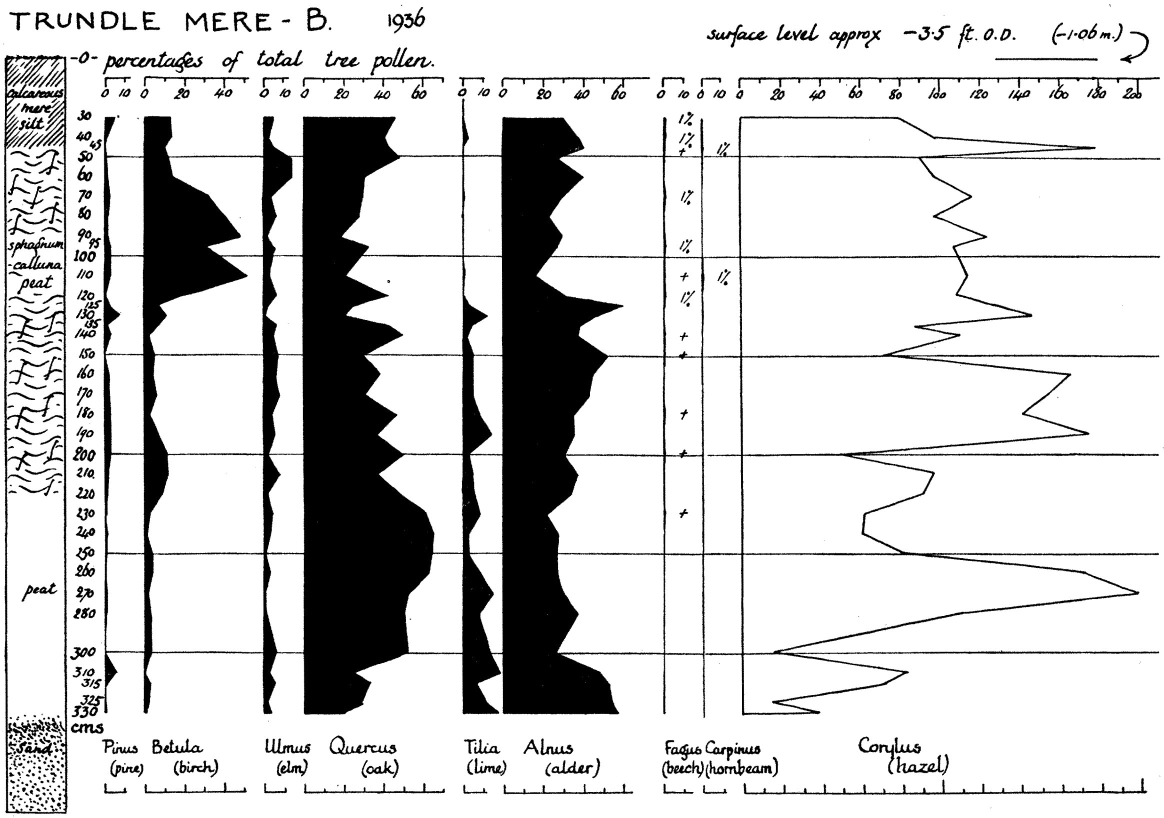


FIG. 17. Field stratigraphy and tree-pollen percentages at Trundle Mere *B*. Beech and hornbeam values are shown by figures.

Such an analysis as that given above would appear to be a necessary preliminary to the compilation of a regional pollen diagram, or to correlation between different groups of sites, such as will be attempted in Part II of this paper, between the four sites of this area, and those of other parts of the fens.

Without anticipating such correlation now, we may draw attention to a few points of general interst in the diagrams:

(1) Since they all contain abundant alder pollen throughout, they are clearly post-Boreal in age.

(2) They show good correspondence with one another in the appearance of beech and hornbeam, both of which are present in small amounts through the upper part of

each diagram. Beech pollen is, as usually in East Anglia, the more abundant. Both occur sparsely in the fen clay and silt, but they are more abundant above this bed.

4. Archaeological correlation

Available archaeological data in the region of the fenland with which this paper deals is so inadequately recorded that it would appear to have little value for purposes of correlation. Records dealing with the immediate neighbourhood of the Long Section are summarized below.

Woodwalton

(1) Neolithic stone implements are frequent on the uplands about Castlehill Farm and are also recovered from fields with peaty soil, but they seem to have no stratigraphical value (Garrood 1935).

(2) An Early Middle Bronze Age palstave with infolded flanges was found by Mr J. Robins in Great Raveley Fen on the east side of the Raveley Drain (O.S. 6 in. sheet XIV, N.W. Hunts., opposite L of Raveley Drain). He was digging out a "bog oak" and it was found at a depth of 3 ft. 6 in. to 4 ft. "among the roots" (Garrood 1930). Local enquiry at first suggested that this bog oak might have been one disturbed by a dredger when cleaning the dyke, this being of frequent occurrence, as the oak horizon is generally at dyke bottom in the Raveley Drain. The palstave might thus have been incorporated in the root system of the tree secondarily. But reference to the map shows that the site of the discovery is extremely marginal and, from what has previously been stated in connexion with the oaks at site *V* and at Castlehill Farm, it will be realized that even if the axe was genuinely *in situ* all the bog oaks of this district are not necessarily contemporaneous with those of the lower peat. Nevertheless, the significant fact remains that oak trees were growing at or after Middle Bronze Age times, on sites which afterwards became wet enough to preserve the trees in growing peat.

(3) A Bronze Age socketed adze was found lying on a "bog oak" at Castlehill Farm (Garrood 1929). Further enquiry suggested that this was ploughed up in a peat field from a depth of about 15 in. and cannot, therefore, be regarded as undisturbed.

(4) *Ramsey St Mary*. A Middle Bronze Age spearhead was ploughed up some twenty years ago on New Fen Farm between Ramsey and Ramsey St Mary. This site lies approximately on the landward boundary of the buttery clay, and the record suggests that the find was relatively superficial (Garrood 1930).

(5) There is a beaker, apparently of Abercromby's *C* type, in the Peterborough Museum, recorded as being found with skeletons on a gravel hillock, probably a tumulus, in the fen close to the course of the Nene, Ramsey St Mary (Fox 1923).

(6) At Elsie Farm, some miles north of Ugg Mere, the underlying gravel outcrops as a small island thinly capped in places with boulder clay. Dr J. G. D. Clarke visited the site at the request of the authors and found numerous primary flakes and cores,

not precisely datable but possibly from a Mesolithic industry. Careful investigation failed to reveal the possibility of tracing any scatter into the surrounding peat.

There follows a list of archaeological records which, whilst suggestive of considerable human activity in the district during the middle period of the Bronze Age, are too inadequately recorded to afford more specific information.

Ramsey Fen. A palstave-like bronze chisel in the Wisbech Museum (Fox 1923).

Warboys Fen. A bronze socketed spearhead in the Cambridge Museum of Archaeology (Fox 1923).

Conington Fen. A bronze socketed spearhead found on Bruce's Castle Farm (Garrood 1923).

Whittlesey Mere. (*a*) A bronze socketed spearhead "found in the draining of Whittlesey Mere", and now in the Peterborough Museum (Fox 1923).

(*b*) A slightly flanged flat axe now in the Peterborough Museum.

(*c*) A socketed bronze axe, labelled Peterborough, but found in the mere according to the curator of the Peterborough Museum, Mr J. W. Brodger (Fox 1923).

(*d*) A bronze socketed adze now in the Wisbech Museum (Garrood 1929).

(*e*) A monoxylous canoe of oak (Heathcote 1876).

Yaxley Fen. A flat bronze axe in the British Museum (Fox 1923).

Pondersbridge (*Pond's Bridge*). A middle Bronze Age spade-hilted rapier was found here with the point sticking in the underlying clay, and is now in the Peterborough Museum.

The fact that so much of this material is referable to the Bronze Age is strikingly in agreement with the circumstance long recognized by fen archaeologists, and particularly emphasized by Fox (1923), that throughout the south-western fenland remains of the Bronze Age are extremely abundant, in greatest contrast with those of the preceding and following periods.

It is a feature strongly suggestive of increased habitability, i.e. dryness, of the fenland during the Bronze Age. The stratigraphical position of deposits of this period is discussed in the second part of this paper, but it is indicated by the Pondersbridge find that they were formed after the deposition of the fen clay. Their formation was evidently followed by a period of increased wetness and already indicated by the conditions of the palstave discovery in the Raveley Drain.

5. Local correlation and history of development (see figs. 18 and 19)

Fig. 18 summarizes the presumed correlation of the four sites which have been described. In fig. 19 an attempt has been made to show in diagrammatic form the interrelationship of the several components of the fen deposits.

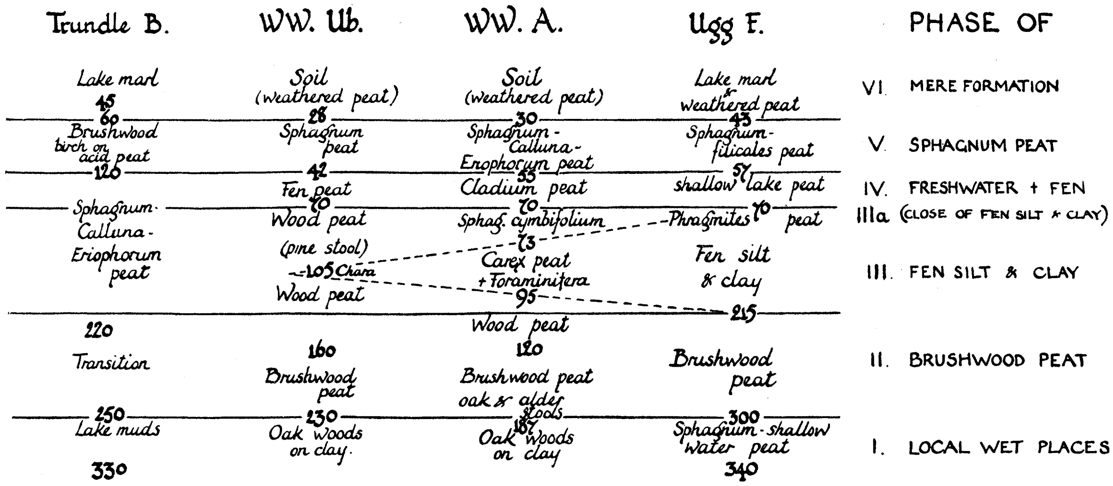


FIG. 18. Correlation table between the four sites of the Woodwalton area, from which pollen sequences have been taken. They represent a sequence of three sites (Woodwalton *Ub*–Woodwalton *A*–Ugg *F*) at increasing distance from the fen margin, and the fourth site (Trundle *B*) is in a basin somewhat isolated from the others. At each site the succeeding layers of different fen deposits are given, separated from one another by a figure representing the depth in centimetres. The horizontal lines show the sequence of phases of fenland history recognized by the authors, and the vertical scales of the four profiles have been distorted to fit this. The wedge enclosed by dotted lines merely links together the communities indicative of wetness during the phase of fen silt and clay. The thickness given to the different phases has no relation to time.

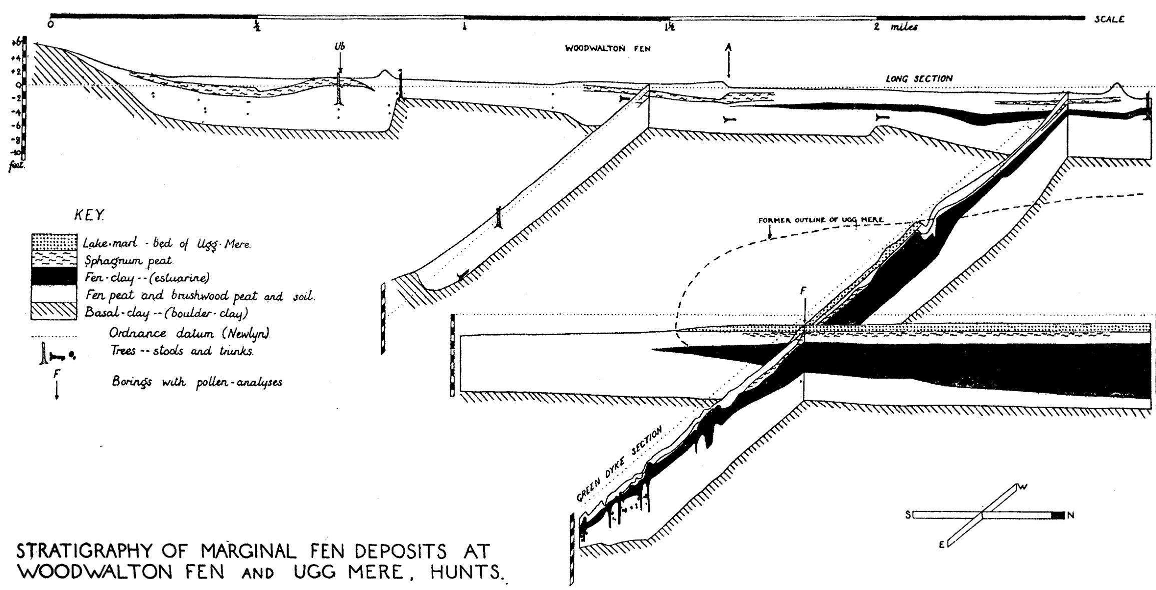


FIG. 19. Solid diagram showing disposition of post-glacial fen deposits at the fen margin near Woodwalton.

(1) *The beginning of peat formation*

Nowhere in the area have Boreal peat deposits been found, but presumably not long after the close of the Boreal period there was a shallow lake in the Trundle Mere basin, and the Ugg Mere basin was a wet depression with abundant Sphagna and small pools. The higher parts of the basin carried oakwoods on clay, and the lime tree (*Tilia*) was probably an important constituent of them.

(2) *Lower peat phase*

Wetter climate or worsened drainage soon caused peat formation to extend from the two lake basins, and the oaks upon clay were killed and preserved in a rapidly growing brushwood peat.

At Trundle Mere there was open water, but over most parts of the region, including the Ugg Mere basin, fen woods of alder and sallow gave rise to considerable thicknesses of brushwood peat; locally these woods contained birch, oak and yew. As time went on the fen woods became progressively drier, and a richer woody flora characterizes the peat they formed. Especially towards the fen margin, birchwoods, and more especially pinewoods, were formed, and here and there the wood floor was free enough from basic flooding to allow some Sphagna to grow. At about this time the overgrown lake at Trundle began to develop into a raised bog by the rapid formation of oligtrophic peat-forming communities of *Sphagnum* and the Ericaceae, etc.

(3) *Fen clay and silt phase*

These wooded fens now became subject to the incursion of brackish flood water, and were no doubt converted into shallow lagoons marginally, and into a shallow sea away from the edge. Apparently only the highest tides brought salt water into our area, the conditions, mostly salty at first, gradually gave place to those of fresh water. During the most marine phase the extremely fine and uniform fen clay, so often known as "buttery clay", was laid down, and later as the water became fresher, so also the deposit became more silty. The four sites were very differently affected. The Ugg Mere basin was filled with several feet of silt and clay, but this quickly tapered away to the fen margin. At Woodwalton *A*, brackish water caused development of *Caricetum* in the woodland and brought in tests of Foraminifera, but at Woodwalton *Ub* there is little sign of any interruption of the growth of the pinewoods. At Trundle *B* also, growth of the *Sphagnum* peat was apparently unaffected by the marine transgression, though Whittlesey Mere, which it adjoins, was filled with clay and silt.

(3*a*) *Close of the fen clay and silt stage*

As the deposition of silt in the area slackened and ceased, the surface became locally drier and the marginal areas, made temporarily wetter, showed development of their vegetation to drier stages. Sometimes trees grew on the fen clay surface. Pine-woods continued to grow at *Ub*, and at *WW. A*, *Sphagnum cymbifolium* developed abundantly. This phase was, however, short and not evident in any but sites on the edge of the fen clay.

(4) *Fresh-water phase of upper peat*

The clay- and silt-filled basins, as well as the marginal fen woods, now became subject to a general increase in wetness apparently unconnected with marine transgression, for no trace of brackishness or clay deposition is found. Over the silt in Ugg, there was fresh water with *Nymphaea*, *Sparganium*, *Potamogeton*, etc., at *WW. A*, and *WW. Ub*, fens with abundant *Phragmites*, *Carices*, Characeae, and species of similar requirement. Trundle Mere was apparently no more affected by this phase than by the two preceding.

(5) Sphagnum *peat phase of upper peat*

So far as can be seen there now followed over the entire region a general development of oligotrophic communities and a layer of *Sphagnum* peat, of *Sphagnum-Eriophorum-Calluna* peat, or some variant of this type, formed everywhere, usually over remains of eutrophic communities. In the neighbourhood of *WW. A* the characteristic beginnings of raised bog (Hochmoor) were made, and several cycles of regeneration formed their lens-like banded peat. This development may have been very much more extensive than now appears, for peat cutting and cultivation have removed this layer over wide areas. It can, however, be traced across the Ugg Mere basin in characteristic form, though greatly compacted and much weathered.

During this phase dwarf pine, juniper and birch grew in the Woodwalton fen area, and this is probably the period in which the surface of the large raised bog at Trundle *B* was colonized by birchwood with occasional pine.

(6) *Formation of the Meres*

It is only here and there that evidence remains of the period succeeding the *Sphagnum* peat phase. At Ugg *F* there is a greasy grey marl mixed with the upper peat, containing shells, and which is clearly the remains of the lake bed, but at Trundle *B* there is some thickness of undisturbed calcareous lake-marl, directly over the oligotrophic peat.

This reflects an extremely severe change in conditions and one which doubtless affected the whole of the fenland: the establishment of a calcareous lake *above* a mature raised bog is a much less familiar process than the converse.

That the lake did not cover by any means all the existing bog surface is shown by the persistence until recent times of many characteristic raised bog species.

Appendix I

Foraminifera from Fenland Deposits at Ugg Mere, Whittlesey[1]
(collected by Dr H. Godwin) by Dr W. A. Macfadyen, Baghdad

The washed residues of samples A and B both consisted of brown micaceous silt, all of which passed a sieve of 150 meshes to the inch; there was much vegetable matter. Sample B contained in addition many tiny fragments of red-burnt clay.

From sample A are recorded thirty-five species of sub-Recent Foraminifera, of which only nine species are more frequent than very rare. Five kinds of other indigenous microfossils are recorded, including some five species of Ostracods which occur in considerable numbers. Four minute foraminiferal species derived from the Cretaceous are also recorded, three of them being more frequent than very rare. The common indigenous Foraminifera are all but one usual in deposits believed to have been laid down in brackish water of salinity considerably below that of sea water. The other indigenous microfossils agree with this origin. The abundant micaceous silt with some very small Cretaceous Foraminifera, and a few rare indigenous Foraminifera of more marine aspect than the commonly occurring forms seem to indicate some ingress of tidal water coming up from the sea.

The frequent *Elphidium oceanense* is an unusual feature; it is not a common fossil in the fenland deposits so far studied, though I have had it in small numbers from nine samples. I have it abundantly in recent shore sands from Dunkerque and Sandwich, and in Holocene clays presumed to be of purely marine origin from Island Magee, Antrim, Northern Ireland, and Loch Alsh, west Scotland.

From sample B are recorded only ten species of indigenous Foraminifera of which only two, *Rotalia beccarii* and *Trochammina inflata*, are other than very rare. The relative frequency of the other indigenous microfossils, all of which are typically associated with fresh or nearly fresh water, supports the view that sample B was laid down in fresher water than sample A. The frequency of derived Cretaceous Foraminifera of very small size, and the abundant silt, would, however, point to some ingress of the sea, were there not the scarcity of sub-Recent Foraminifera of more purely marine aspect. A similar condition of micaceous silt with baked clay fragments and other indigenous microfossils but no Foraminifera, either indigenous or derived, was found in a specimen from Well Fen Farm, 2½ miles north-east of March.

One unusual circumstance in sample B is the absence of Ostracods, which are almost always found in these deposits. Their absence is not readily explainable. The chalk spheres are abundant and so preserved or weathered that a number of them possess holes which look like apertures; these can hardly be due to accidental piercing.

Sample C, 85–90 cm. (above water), labelled "grey transition clay, vertically above A and B" gave a fair-sized residue of blackish earthy-looking vegetable fragments with many rootlets and a little grey silt. Foraminifera very few.

It is concluded from the fauna shown in the list concluding this note, that the

[1] For position of sites and stratigraphy, see p. 340.

deposit C was laid down in almost fresh water. The presence of more than single specimens of only the species of *Trochammina*, and of *Nonion depressulus*, suggests traces of an indigenous foraminiferal fauna. The small silt content, plus single specimens of Foraminifera of rather more marine aspect, in addition to traces of Cretaceous fossils, suggest rare incursions of a little more-marine and silty water.

Fen foraminifera	Ugg Mere A	B	C
? *Centropyxis* sp.	*I*	.	.
Quinqueloculina fusca Brady	*I*	.	.
Q. schlumbergeri (H.-A. and E.)	*I*	.	.
Cornuspira involvens (Reuss)	*I*	.	.
Trochammina inflata (Montagu)	*V*	*X*	*V*
T. macrescens Brady	*I*	*I*	*I*
T. ochracea (Williamson)	*I*	*I*	.
T. squamata Jones and Parker	*I*	.	.
Buliminella elegantissima (d'Orbigny	*I*	*I*	*I*
Virgulina fusiformis (Williamson)	*V*	*I*	.
Bolivina striatula Cushman	*I*	.	.
B. pseudoplicata H.-A. and E.	*I*	.	.
B. spathulata (Williamson)	*I*	.	.
B. variabilis (Williamson)	*I*	.	*I*
B. aff. dilatata Reuss	*I*	.	.
Lagena clavata (d'Orbigny)	*I*	.	.
L. laevis (Montagu)	*I*	.	.
L. lineata (Williamson)	*I*	.	.
L. biancae (Seguenza)	*X*	*I*	.
L. marginata (Walker and Boys)	*V*	*I*	.
L. perlucida (Montagu)	*I*	.	.
Cristellaria sp.	*I*	.	.
Guttulina lactea (Walker and Jacob)	*I*	.	.
Globigerina bulloides d'Orbigny	*I*	.	.
G. pachyderma (Ehrenberg)	.	*I*	.
Patellina corrugata Williamson	*I*	.	.
Discorbis williamsoni Chapman and Parr	*I*	.	.
D. obtusus (d'Orbigny)	*X*	.	.
D. praegeri (H.-A. and E.)	*I*	.	.
Lamarckina haliotidea (H.-A. and E.)	*I*	.	.
Cibicides lobatulus (Walker and Jacob)	*I*	.	.
Rotalia beccarii (Linné)	*L*	*X*	*I*
Nonion depressulus (Walker and Jacob)	*L*	*I*	*V*
N. pompilioides (Fichtel and Moll)	*I*	.	.
Elphidium excavatum (Terquem)	*X*	.	.
E. oceanense (d'Orbigny)	*X*	.	.
E. incertum (Williamson)	.	.	*I*
Total	35	10	7

Derived from the Cretaceous	A	B	C
Bulimina murchisoniana d'Orbigny	*I*	.	.
Neobulimina canadensis Cushman and Wickenden	.	*X*	.
Pseudotextularia globulosa (Ehrenberg)	*X*	.	.
Eouvigerina serrata (Chapman)	.	*I*	.
Lagena apiculata (Reuss)	.	*I*	.
Dentalina communis d'Orbigny	.	*I*	.
Globigerina aspera (Ehrenberg)	*V*	*I*	.
G. cretacea d'Orbigny	.	.	*I*
Chalk spheres	*X*	*C*	*V*
Total	4	6	2

Other indigenous microfossils

	Ugg Mere A	Ugg Mere B	C
Ostracods (about 5 spp.)	*L*		*I*
Diatoms:*			
Eupodiscus argus Ehrenberg	*X*	*X*	*V*
Campylodiscus costatus Wm. Smith	*V*	*V*	*I*
Triceratium favus Ehrenberg	*I*	*I*	.
Melosira arenaria Moore	*I*	*I*	.
Tailed brown globes (unidentified)	.	*X*	.
Total	5	5	3

I = very rare; *V* = rare; *X* = frequent; *L* = common; *C* = abundant.

* Kindly identified by Mr N. Ingram Hendey, F.L.S.

Sample D, labelled "Soft clay at *S* 1 Upper Zone, Ugg Mere", a slight distance away from A, B and C gave a rather large residue, practically entirely of brown peaty fragments, not rootlets. No Foraminifera nor other microfauna were found in this sample.

Appendix II. Diatom content of samples from fen clay and silt at Ugg Mere

By Chr. Brockmann, Wesermünde—L.

Ihrer Beurteilung der Im Moor eingelagerten Kleischichten glaube ich beipflichten zu können. Ich fand in den 4 Proben folgende Arten.

	A	B	C	D
Melosira sulcata	+	+	+	.
M. westi	+	.	.	.
Podosira stelliger	+	+	+	.
Coscinodiscus radiatus	+	+	.	.
C. obscurus	.	+	.	.
C. normani	.	+	.	.
C. excentricus	+	+	+	.
Actinoptychus undulatus	+	+	+	.
Auliscus sculptus	+	.	.	.
Triceratium favus	+	+	+	.
Biddulphia rhombus	+	+	.	.
Grammatophora oceanica	.	+	+	.
Raphoneis amphiceros	+	+	.	.
R. surirella	+	+	+	.
Diploneis bombus	+	+	+	.
D. didyma	+	+	+	.
D. ovalis	+	+	.	.
D. smithi	.	+	.	.
Navicula lyra	+	.	+	.
Scoliopleura tumida	.	+	.	.
Nitzschia navicularis	+	+	+	.
N. punctata	+	+	.	.
Surirella striatula	+	.	.	.
Campylodiscus echeneis	+	+	+	+

In A, B, C sind die marinen Einflüsse unverkennbar. Die wichtigste Charakterform der drei Proben ist *Diploneis bombus*, die hier in einer Kümmerform auftritt. Auffallend ist der *geringe* Diatomeengehalt Ihrer Proben. Echter "Klei", das heist, der Boden, der aus dem von mir als Schlick (vgl. Diatomeen und Schlick im Jadegebiet) bezeichneten Bildung entstanden ist, hat an der Nordseeküste meistens einen viel höheren Diatomeengehalt; es sei denn, das der ursprüngliche Bestand an Schalen durch Verwitterung verschwunden ist. Nach meiner Ansicht handelt es sich bei Ihren Proben um Ablagerungen, die durch Sturmfluten mit dem marinen Sediment beschickt worden sind.

Probe D enthält die Brackwasserform *Campylodiscus echeneis* in ziemlicher Häufigkeit. Die Art bevorzugt seichte, stehende Brackwasserbecken. Hier handelt es sich anscheinend um einen in Verlandung begriffenen Brackwassersumpf.

PART II. ORIGIN AND STRATIGRAPHY OF DEPOSITS IN SOUTHERN FENLAND

Introduction

Part I concluded by describing the vegetational history in the Woodwalton area of the fenland margin throughout a series of phases each now represented by characteristic fen deposits. These phases were briefly as follows: (1) *The beginning of peat formation* and destruction of oakwoods on clay. (2) *The lower peat stage*, at first open water or alder brushwood, passing gradually into drier fen woods with oak, birch and yew, or marginally with pine. (3) *The fen clay and silt stage*, in which as a result of marine transgression, shallow open water covered the peat surface, and silt and clay were deposited in brackish water. (3*a*) *The end of the fen-clay stage*, with a short phase, perhaps evident on the margins only, of tree growth on peat over the fen clay. (4) *The fresh-water phase of the upper peat*, with formation of open water or fens. (5) *The* Sphagnum-*peat phase of the upper peat*, in which oligotrophic peat developed widely, sometimes with birch and pine upon it. (6) *The phase of formation of the meres*, in which calcareous lake-marl was deposited over the acidic *Sphagnum* peat. We may summarize these conclusions by saying that a sequence of wet and dry phases succeeded one another, the deposits of each wet phase occupying in turn less and less of the area of the basin as it became progressively filled up. The wet phase which initiated peat growth in the area affected all the basin, the phase of the fen clay produced less extensive deposits, and the lake marls of the last wet stage occupy relatively small central areas.

We did not express our views on the causes of this pronounced sequence of stages, preferring to relate it first to the developmental history of the southern part of the fens as a whole. Part II is devoted to a consideration of this correlation, and follows three main lines of enquiry: (*a*) the establishment of lateral continuity of the fen beds by boring and the drawing up of sections; (*b*) by the recognition, from the nature of the fen beds, of equivalent phases of development in different parts of the fens; and (*c*) by dating the fen beds, especially the peats, by pollen analysis.

1. Sections between Wisbech and the fen margin

In shallow coastal bays or wide estuaries, such as the fenland basin, it is clear that the relative movement of land and sea may have had very great influence on the course of peat formation. In such an area the seaward deposits will tend to be silts and clays and the landward deposits peat: during submergences the silts and clays will transgress previously formed peats, and during emergence peat will extend seawards over the silts and clays. Thus an alternate wedging out of silts and clays on the one side and of peats on the other is to be expected, and this is, in fact, realized. We can cite in confirmation the figure by Wildfang (fig. 20) of a schematic section through the east Friesian marshes between Dollart and the Ley Bucht. Landwards there is only one peat bed, seawards there are two, separated and overlaid by marine deposits, and at places between, there may be four or five peat beds. It will be realized that the peat-clay junction is nowhere really a synchronous horizon—it marks, at each point where it occurs, the time at which fresh-water conditions gave place to semi-marine, or vice versa. At the same time it is perfectly clear that the section represents two phases of extensive peat formation, and two alternating phases of marine transgression, and to this extent the main beds of the marsh deposits do occur with sufficient constancy to have a separate and recognizable identity.

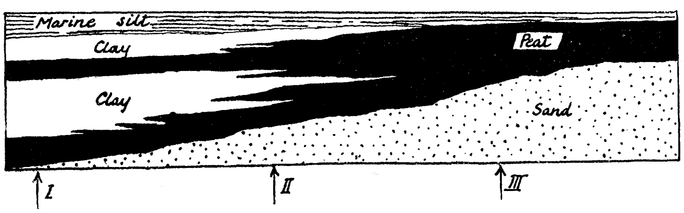


Fig. 20. Diagrammatic section through the coastal marshes of the north-west German coast, showing the alternate wedging-out of fresh-water and marine deposits (after Wildfang).

The recognition of these circumstances and the publication of detailed sections to confirm their accuracy should resolve the conflicting views of Skertchly (1877), on the one hand, who held that the fen clay was not of stratigraphic value, and of geologists such as Sedgwick and Bonney, who on the other hand attributed too much constancy to the sequence of the main fen beds.

A structure similar to that shown in Wildfang's figure can be deduced with great probability for the fenland peats of East Anglia, but to establish it, it is desirable to construct sections from the fen margin towards the sea. In the marginal regions near Woodwalton hand-borings were not unduly difficult, but with the increasing thicknesses of silts and clays on the seaward side they became increasingly laborious. By great good fortune we were able, however, to make use of the results of an extensive system of borings made by the River Great Ouse Catchment Board in the neighbourhood of Whittlesey, Benwick and March, and by the River Nene Catchment Board at Dog-in-a-Doublet sluice and at Wisbech. These borings, which are shown in the sections by numerical indices, are often unsatisfactory in that they do not reach the hard fen floor, and show only the coarse stratigraphy. Nevertheless, they are very frequent, and have been supplemented at critical points by our own observations on the ground, and by our own borings.

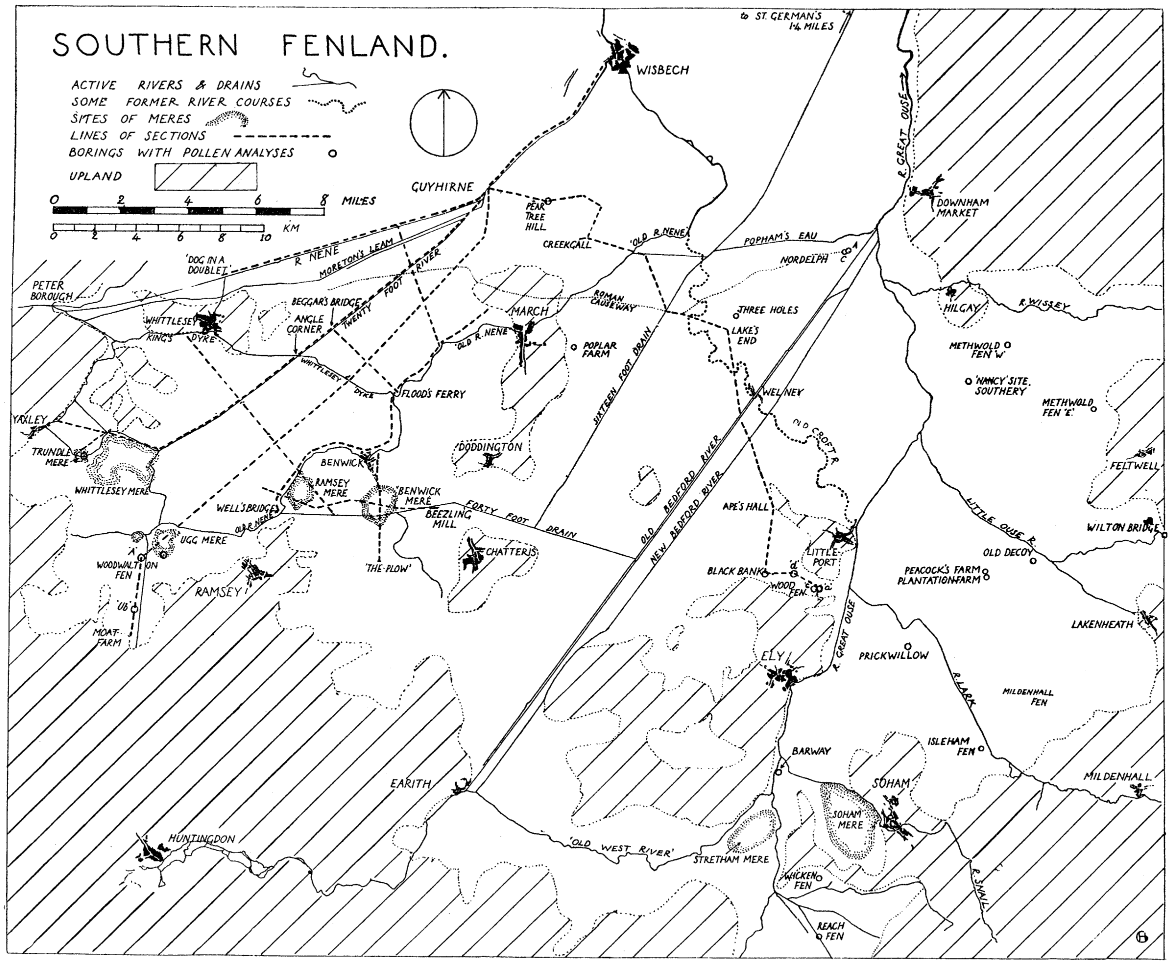


Fig. 21. Sketch-map through the southern part of Fenland showing the outline of the fen basin, the chief islands, sites of former meres, and chief towns. The chief drains are shown, the present and former courses of important rivers, the lines of sections and sites of pollen analytical investigations.

The data are presented in the form of a series of long sections from scattered marginal sites all converging upon the Guyhirne and Wisbech district. Their position has been drawn on the accompanying map of the district (fig. 21). They include sections:

(1) from Moat Farm (on the Woodwalton Long Section) to Hobbs Bridge and Guyhirne; (2) from Ramsey Mereside to March, as far as possible by way of the Old Nene Channel; (3) a subsidiary section connecting Benwick Mere with the old river channel; (4) from Yaxley (Trundle Mere district) to Wisbech; (5) from Dog-in-a-Doublet (between Whittlesey and March) to Pear Tree Hill (Coldham Station). In addition four transverse sections have been prepared including: (1) from Crease Bank (King's Dike, Whittlesey) to Betty's Nose, Benwick, transecting Ramsey Mere; (2) from Ramsey Mereside to Beezling Fen (Doddington), transecting the sites of the former Ramsey and Benwick Meres; (3) from Beggar's Bridge (Twenty-Foot River) to Flood's Ferry; (4) from Bank House Farm (River Nene near Guyhirne), to Turves Fen Engine (Old Nene, near March).

In this way a detailed picture is presented of the stratigraphy of the fen deposits of the whole area.

It will be profitable to consider first the section Moat Farm to Guyhirne (fig. 22), as this includes the marginal Woodwalton section already described in Part I. Sufficient borings exist to indicate that there is, over the whole area, a lower peat bed below the fen clay, and the few borings which penetrate this lower peat suggest that it is a single bed, lying directly on the fen floor, though beyond the seawards end of the section, at Guyhirne Bridge, the lower peat seems to have split into two. The upper surface of the peat is not flat, but follows to some extent the contour of the fen floor, partly, no doubt, because of compression after its formation. The basal beds rise at the seaward end of the section to outcrop as the March island. The rather surprising topography of the surface of the fen clay is at once apparent. Falling from a high shore-line level of minus 2 ft. 6 in. O.D. at Woodwalton *A*, to a general level of minus 4 ft. O.D. in the Ugg Mere district, its surface reaches a maximum depth of minus 6 ft. 6 in. O.D. at Ramsey St Mary *K*, which *may* indicate that the present course of the Old Nene at this locality in some measure at least coincides with the ancient channel. Between *K* and borehole 41 the fen clay rises to O.D. level, thereafter undulating at about the same value as far as bore 10, a distance of some 7 miles. Beyond Ugg Mere the upper peat, as a recognizable bed, is present in the section only in the region between bores 10 and 11. Evidence of its former existence is traceable, however, over a much wider area than this, as peaty soil in depressions between silt ridges on the cultivated surface of the fen clay. With the exception of the silt in the Old Nene roddon cut through near March, and the isolated boring at Guyhirne, there is no deposit which might reasonably be regarded as equivalent to the mere bed at Ugg, and no trace whatever of the existence of any extensive sheet of superficial silt.

The section Ramsey Mereside to March, following as closely as possible the meandering channel of the Old Nene, is shown in fig. 23. It contrasts strongly with the previous section in two respects: (1) The fen clay only rarely rises to O.D., and then chiefly because the section temporarily leaves the river channel (e.g. between bores 31 and 32). (2) Possibly because the surface of the fen clay is so low, the upper

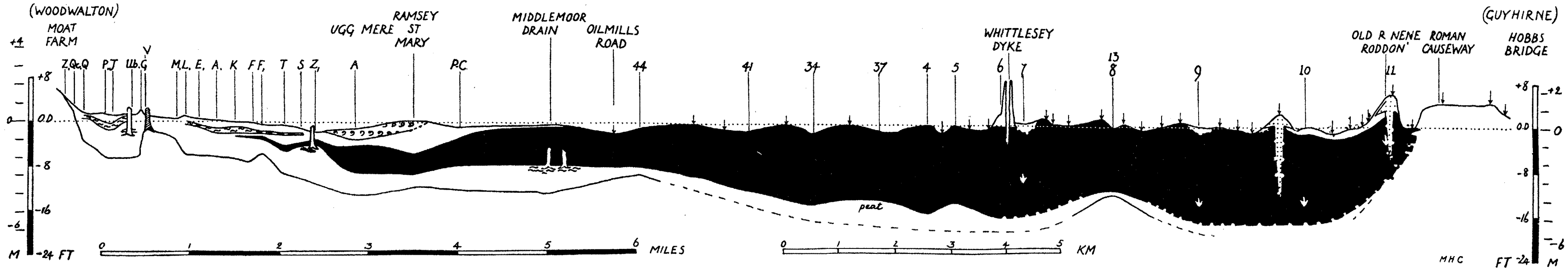


FIG. 22. Section from the fen margin at Moat Farm, Woodwalton to Guyhirne. The fen clay separates an upper and lower peat bed: the upper peat bed has been mostly removed by cultivation in the eastern (right) part of the section. Peat is shown white, and the fen clay or silt, black. Letters represent borings by the authors, figures borings by the River Great Ouse Drainage Board, and arrows spot-levels on the ground. Broken lines represent uncertain (unproved) boundaries, and arrows in the fen beds the bottom of borings. Nothing is shown below the surface of the hard rocks of the fen floor. The same conventions are used for the other sections unless the contrary is stated.

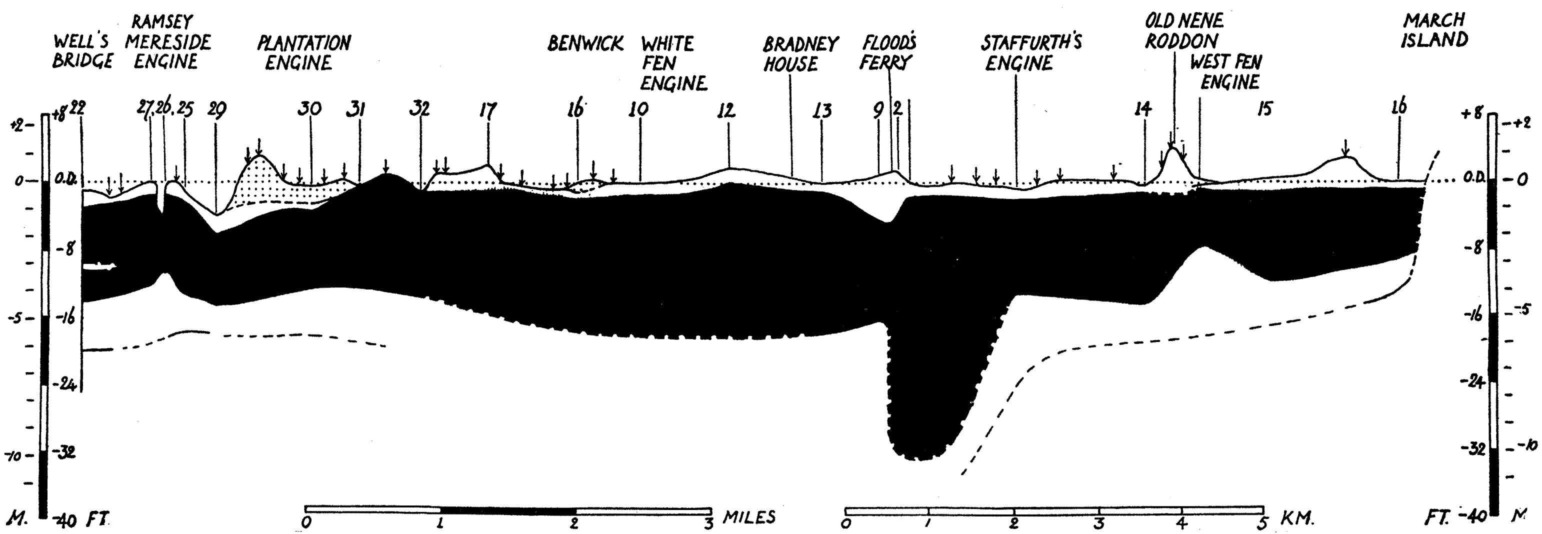


FIG. 23. Section from Ramsey Mereside to the island of March by way of the natural channel called the "Old River Nene". The borings at Flood's Ferry show the centre of this channel to have been deep. (Symbols as in legend to Fig. 22.)

peat is easily recognizable throughout the section, as a band of undisturbed peat. In such places as bore 29, and Flood's Ferry, the depth of the upper peat would seem to suggest that the centre of the river channel had been found. At Flood's Ferry this possibility is further strengthened by the failure of the bore to reach a lower peat even at $-29\frac{1}{2}$ ft. O.D., the lower part of the fen clay here grading into very sandy silt with shells. Between Benwick and Flood's Ferry patches of pinkish silt have been traced above the hard upper peat bed, but the embanking of the river has made these superficial beds very difficult to determine.

A patch of such silt is shown on the section at borehole Benwick 16, but it is difficult to say to what late stage of the history of the channel it ought to be referred.

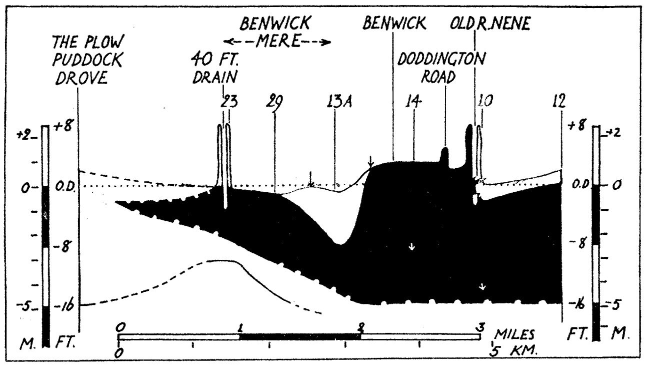


FIG. 24. Section from "the Plow", Puddock Drove when there is continuous peat, across Benwick Mere to the Old River Nene. (Symbols as in legend to fig. 22.)

At this point it is convenient to consider the subsidiary and the transverse sections which relate the sites of Benwick and Ramsey Meres to the river system. The section running from Puddock Drove to Benwick village (fig. 24) cuts across the old outfall of the former Ouse where it left Benwick Mere (13*A*), but shows no deposits from the bed of the former mere, because the high level of the surface of the fen clay has maintained these deposits within reach of extensive drainage, cultivation, and weathering. The profile of the Plow, Puddock Drove, is derived from Skertchly, spot levels on the present drove surface serving to relate the older data approximately to the newer. The section shows that the fen clay must go out abruptly within the region between bore 23 and the Plow, a distance of about 1 mile. The transverse section from the Old Nene to Beezling Mill (fig. 25) again fails to allow recognition of the deposits of Benwick Mere, but it illustrates strikingly how this mere formed over high fen clay, whilst Ramsey Mere formed on the low fen-clay surface associated with the Old Nene system. At Ramsey Mere once again, cultivation would seem to have destroyed all clear evidence of the mere deposits, although the upper peat bed remains clear enough.

The third main section (fig. 26) runs from the margin of Yaxley Fen, in the neighbourhood of Trundle Mere, follows the length of Bevill's Leam and the Twenty-Foot River as far as Rings End; additional data for Guyhirne and Wisbech are inscribed in the diagram on the same scale. It is very unfortunate that this line of section does not traverse the bed of Whittlesey Mere, so that the relationship of both Trundle Mere and Whittlesey Mere to the fen clay and the subterranean topography might have been determined. It proved, however, impossible to secure permission to investigate this important area, and it was necessary to make the line of section, after leaving Bevill's Leam, pass north of the mere along the North-western Cut, under the edge of the Arlmynde's Hills outcrop, and thence direct to the Pig Water Drain. The local stratigraphy of Trundle Mere was briefly presented in Part I, and summarized as a section approximately transverse to the present line. Noteworthy features of the present section include: (1) Undulation of the fen floor, which is so strongly marked in the neighbourhood of Arlmynde's Hills and Pondersbridge, that the lower peat and the fen clay are localized in channels or basins. The upper peat still covers many of the

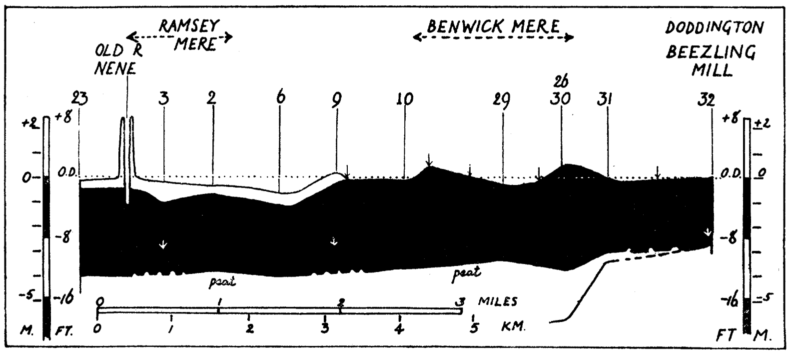


Fig. 25. Section from the Old River Nene to Beezling Mill, Doddington. The section crosses the sites of Ramsey and Benwick meres, but no mere deposits are recognizable. Ramsey mere overlaid peat, but the site of Benwick mere now shows only the surface of the fen clay. (Symbols as in legend to fig. 22.)

ridges in the fen floor, but small islands such as that at Elsie's Farm (already mentioned as an archaeological site) are also special instances of the same phenomenon, and may themselves have been peat-covered at an earlier period. (2) The fen clay can be traced lapping out against these submerged islands, just as against the fen margins. A review of all the available data shows that no fen clay reached the area of Yaxley Fen, enclosed by Yaxley Lode to the south and by the Arlmynde's Hills to the north-east. It has further been observed by the writers that no fen clay occurs under the western end of Whittlesey Mere, and that the normal feathering out of the soft clay can be traced there. (3) Throughout the section the general level of the fen clay surface is low, so that it resembles the section from Ramsey Mereside by the old river channel to March more closely than that from Moat Farm to Hobb's Bridge. Of the three long sections so far described, the middle one shows the highest surface of the fen clay. The channel of the Old Nene might be expected to show a low level for the fen clay in the most southerly section, but it is perhaps remarkable to find the same low level in the

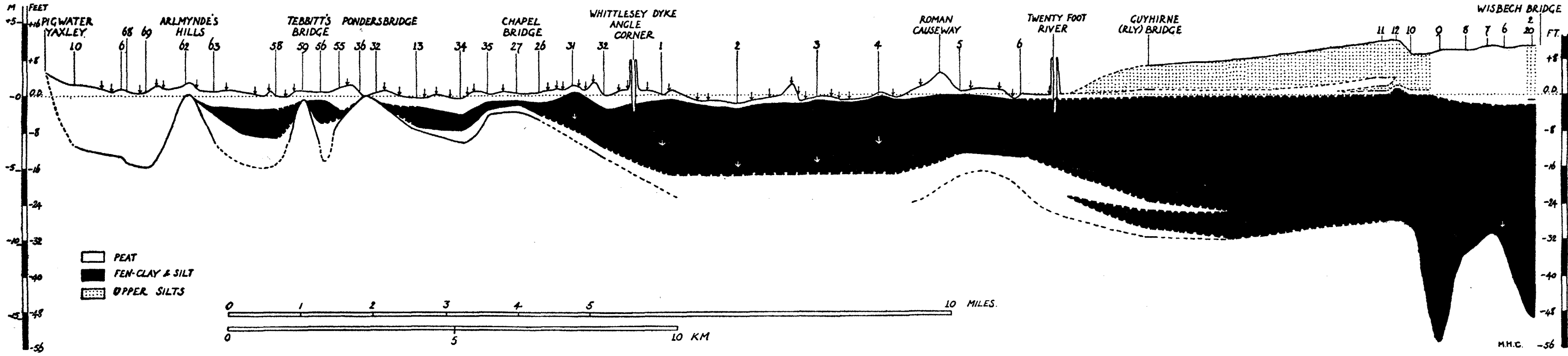


FIG. 26. Section from the fen margin at Yaxley, to the main former estuary of fenland at Wisbech. The upper silts (shown dotted) taper out south-west of Guyhirne: they overlie a peat bed which is a continuation of the upper peat above the fen clay in the peat fens. Note the high level of the silt-land. (Symbols as in legend to fig. 22.)

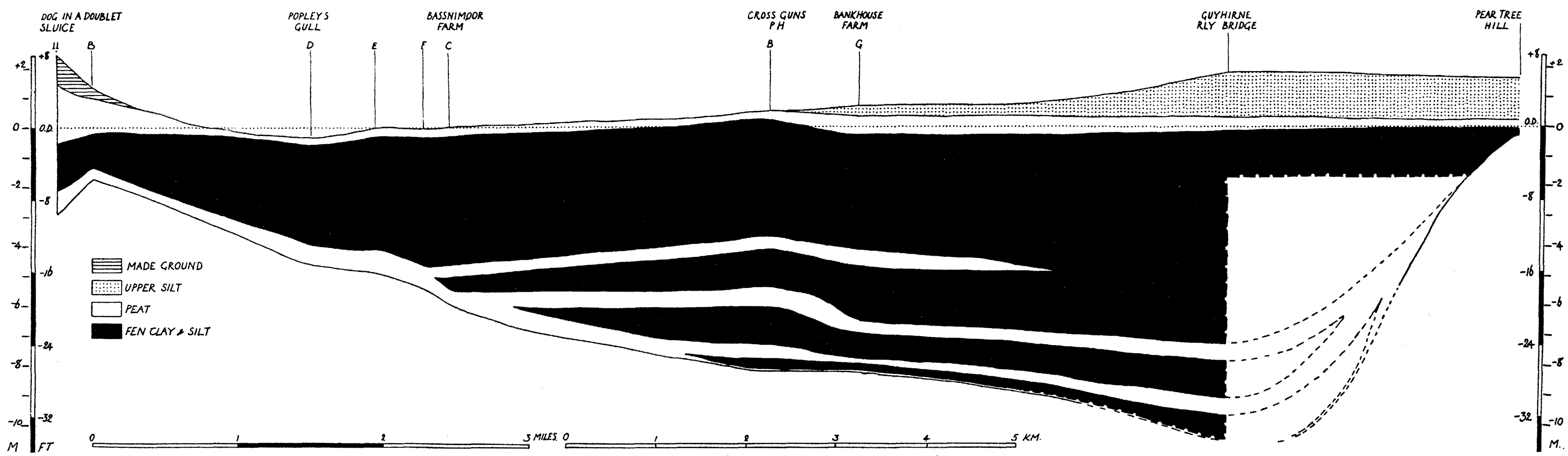


FIG. 27. Section from "Dog-in-a-Doublet", near Whittlesey, to Pear Tree Hill; another section towards the seaward side of the fens. The upper silts are dotted and the upper peat continues below them at about O.D. The lower peat bed tapers into three towards Guyhirne. (Symbols as in legend to fig. 22.)

northerly section, where the two chief waterways, Bevill's Leam and the Twenty-Foot River, are both artificial waterways. (4) Doubtless as a result of the low surface level of the fen clay, the upper peat is present as a continuous bed, traceable as far as the point where the Twenty-Foot River turns eastward to Hobb's Bridge. It would appear continuous with the upper peat bed beneath silt at Guyhirne, and it will later be shown to be continuous with the upper peat of the whole Dog-in-a-Doublet—Guyhirne region. Before Guyhirne is reached the lower peat would seem to divide into two beds, a phenomenon more carefully considered in describing the next section. (5) The borings at Wisbech indicate that the original land surface is now at a great depth, coming on between −32 ft. and −56 ft. O.D. The profile is composed almost exclusively of silts, no doubt because the sites all lie within the old estuary of the Ouse. At levels between O.D. and 4 ft. O.D., there occur thin, discontinuous seams of peat and peaty mud which may represent the upper peat of Guyhirne now reduced to an infilling of small channels.

The last longitudinal section to be considered is the most northern of all (fig. 27). Commencing on the landward side in the district lying to the north of the Whittlesey and Eastrea islands, it may be regarded as proving the deposits of a topographically distinct drainage area, the outfall of which, in pre-drainage times, was not by way of the Old Nene system to March and Upwell. Little in fact is yet known concerning the ancient waterways of this part of the fens, except that both the present course of the River Nene, which enters the Fenland at Peterborough, and Moreton's Leam, are artificial cuts. It is the opinion of Major Gordon Fowler that the meandering Cat-water, which passes northward to St Vincent's Cross, at one time formed part of the natural course of the River Nene. The conclusion would appear valid that the area now being examined was open to flooding by water from the Nene system, from which water the Woodwalton district was previously shown to have been isolated in pre-drainage times.

At Dog-in-a-Doublet sluice the base of the upper peat is at −2 ft. O.D. The peat is also excellently preserved, being up to 6 ft. thick, though this may be due to preservation beneath clays of the made bank of the River Nene, since the adjacent fields show lower surface levels of approximately +2 ft. O.D. Beyond bore *E*, the fen clay rises to about O.D. and the upper peat is only represented by a peaty soil over the ploughed surface of the fen clay. The peaty soil is much more evident in the various small hollows present in the fen surface, and this produces mosaic patterns in the growing cereal crops. The high surface level of the fen clay would suggest that this district was not part of a river channel in post-fen-clay times, although other features of the section may be the result of the existence here of such a channel in the time of the lower peat. The existence of an older channel is suggested by the rapidity with which the basal deposits reach depths of the order of −26 ft. O.D., as the margin is left. At the same time the relation of the lower peat to the fen clay has become more complex. It is possible to trace the lower peat near bores *F*, *C* and *B* dividing twice to form three lower peat beds which interdigitate with the fen clay. This area must therefore have been a centre of equilibrium about which the conditions of fresh and brackish water fluctuated repeatedly during the period of land sea-level change that culminated in the phase of the most widespread sheet of fen clay. It was doubtless a knowledge of the existence of such sites of multiple peat beds that led Skertchly to declare the fen clay to have no reality as a definite horizon. This and the previous sections, however, show that it is laterally continuous over a very wide area, and that its maximum extension is a recognizable and important phase in the fenland development.

Before Guyhirne is reached the uppermost bed of the lower peat has feathered out. The great depth of the hard beds in this district made borings with a hand drill exceedingly difficult, and the fact that the fen floor rises to form the March Island instead of maintaining its original seaward gradient, practically limited our attention to the upper peat bed. Between Bankhouse Farm *G* and Guyhirne, the upper peat, as originally described by Skertchly, passes beneath a natural deposit of silt which varies locally from blue to pinkish in colour.* Superficially the silt terminates on the landward side in irregular processes, and as an infilling of former river channels, whilst on the seaward side it is continuous with the pink silts of the Old Ouse estuary about Upwell and Wisbech. At Pear Tree Hill a peat bed of equivalent level to the upper peat at Guyhirne was found below some 5 ft. of such silt, from which Romano-British objects are said to have been recovered, and above a bed of soft fen clay. There was no lower peat bed because of the high level of the gravel substratum.

We may summarize the information derived from this group of fen sections in the conclusion that the main fen beds are traceable with certainty from the fen margin to Wisbech. The lower peat and the fen clay are continuous and thick deposits. Naturally the lower peat merges into upper peat at the fen margin and divides into minor peat beds on the seaward side. The fen clay does not extend quite to the fen margin, and appears to have a more irregular and higher surface in some places, and to be more silty there: these places of high level form a broad ridge running north-east through Glass-moor towards Ring's End. This ridge is clearly shown in three shorter sections, figs. 28–30, which are taken transversely across the main line of the Woodwalton-Wisbech line. They are King's Dyke, Whittlesey to Benwick, Beggar's Bridge to Flood's Ferry, and New River Nene to Old River Nene.

It seems possible that this ridge represents the main axis of deposition of the fen clay and silt and the channel by which it entered this part of the fens. If this were so it might explain why the fen clay to the east and south of the March-Chatteris island chain is so uniform and "buttery", whilst that to the north and west of the ridge, where our present sections lie, is more variable, higher, and often so much more silty. This

* It is of considerable interest that at bore *F* there was encountered a band of *Sphagnum cymbifolium* peat in the solitary lower peat bed just below the buttery clay. This would seem to indicate tendencies in the vegetational development of this district, just before the fen clay formed, similar to those noted in the neighbourhood of Ugg Mere.

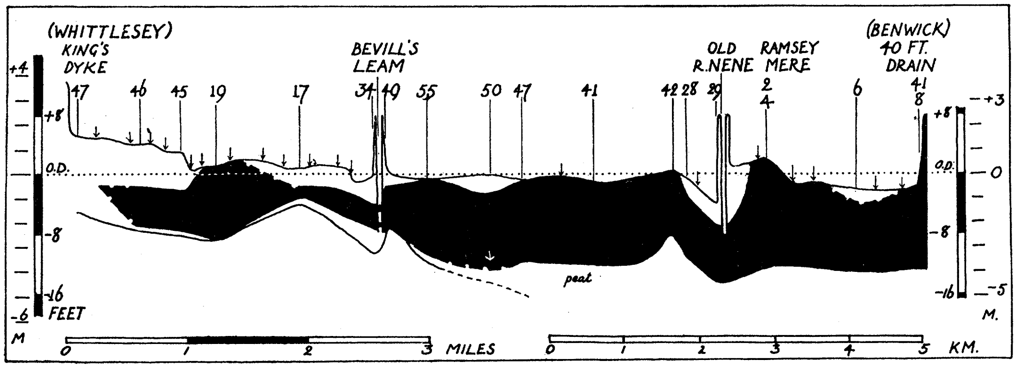


FIG. 28. Section from King's Dyke, Whittlesey, south-east to Ramsey Mere. Where the surface of the fen clay is highest, near the Old River Nene, the upper peat has wasted away. (Symbols as in legend of fig. 22.)

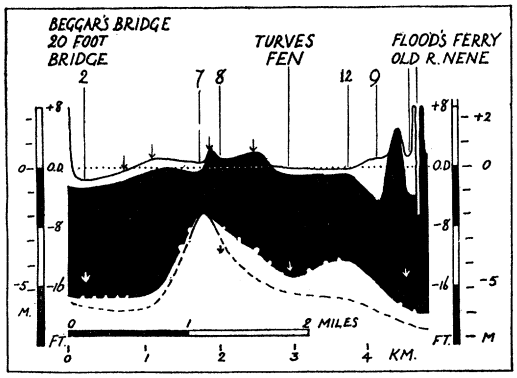


FIG. 29. Section from Beggar's Bridge, south-east to Flood's Ferry. (Symbols as in legends of fig. 22.)

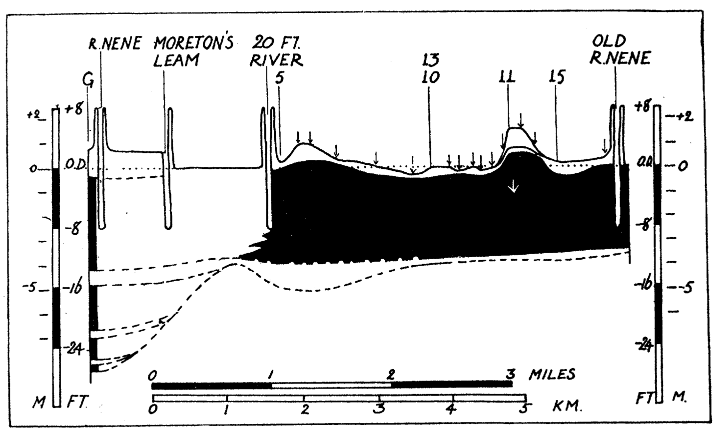


FIG. 30. Section from Bankhouse Farm *G*, across Moreton's Leam, and the Twenty-Foot River, to the Old River Nene 2 miles west of Guyhirne. Figs. 28–30 are transverse sections progressively nearer the fen estuary: the lower peat in the last is split into three. (Symbols as in legends to fig. 22.)

possibility is one which might be tested by systematic foraminiferal and diatom analysis over the area.

There is sufficient evidence to show that the upper peat, though much destroyed by cultivation, was formerly continuous over the whole area, but evidence of its precise character is scanty.

At the seaward margin the upper peat is overlaid by the thinned out margin of the fen silts, which form the great area of silt land round the Wash.

These silts have Romano-British sites on them, and extend into the peat fens as raised banks or "roddons". They have been shown (Godwin 1938) to be formed as the levees of estuaries or tidal channels, though at the present day few or none of them are active waterways. Their formation in many instances was completed during the Romano-British period, for archaeological remains of this age occur freely both in and upon the silts of which they are made. Analyses by Dr Macfadyen show that these roddon silts were deposited in estuarine conditions approximating to marine (Macfadyen in Clark (1933) and in Godwin (1938)), in rather clear contrast with the deposition of the fen clay which seems over wide areas to have taken place in brackish to fresh water.

River systems

Since the upper silts represent a specific and dateable phase of marine transgression after formation of the upper peat, the question at once arises of their possible equivalence to the wet, but fresh-water phase represented in the fen margin sites, by the calcareous lake marls of Trundle or Ugg Mere, which also overlie the upper peat. With this in mind preliminary field observations and some borings were made, to see how far the roddon silts of the ancient river system are continuous with the upper silts of the seaward fens, and the extent to which they can be used to link the seaward silts with the mere deposits.

The ancient river system between Benwick and the Old Croft River, the main estuary of the old fenland, has been traced by Major G. Fowler, who kindly gave us material for the sketch-map (fig. 31). The main river there shown is, according to him, the ancient course of the Great Ouse entering the fens at St Ives and flowing north by Earith and to the west of Chatteris. It circles to the north of the March Island as a huge roddon and thence east to its confluence with the Old Croft River near Upwell. There is no evidence that the natural river channel cut through the March gravels as Skertchley supposed. From March upstream the roddon diminishes fairly rapidly in size. Its form is beautifully preserved in a large abandoned ox-bow at Stafforth's Bridge, where it has the shape of a wide double silt bank and a peat-filled central channel. At Flood's Ferry, a mile further upstream, it has the structure shown by the section in fig. 32. The present river Nene there flows in a channel which we interpret as one natural bank (A) and one artificial (B). The second natural bank (C) still exists outside (B), and borings indicate that it is built of silts in the form, and to the height

(6 ft. O.D.) of a natural river bank. A deep deposit of silty peat within this bank is held to represent the former river channel: from it were recovered remains of *Cladium* and *Potamogeton*. Outside this western bank the soil level gradually falls to about O.D., and borings show a typical profile with a thin layer of peaty soil above the fen clay. The eastern silt bank was levelled but not bored. Outside the eastern bank a very careful attempt was made to establish the relation of the roddon silt to the upper peat and the fen clay. Cultivation of the surface layers made it impossible to give an exactly measured profile: nevertheless, the authors are convinced that the dotted lines in the

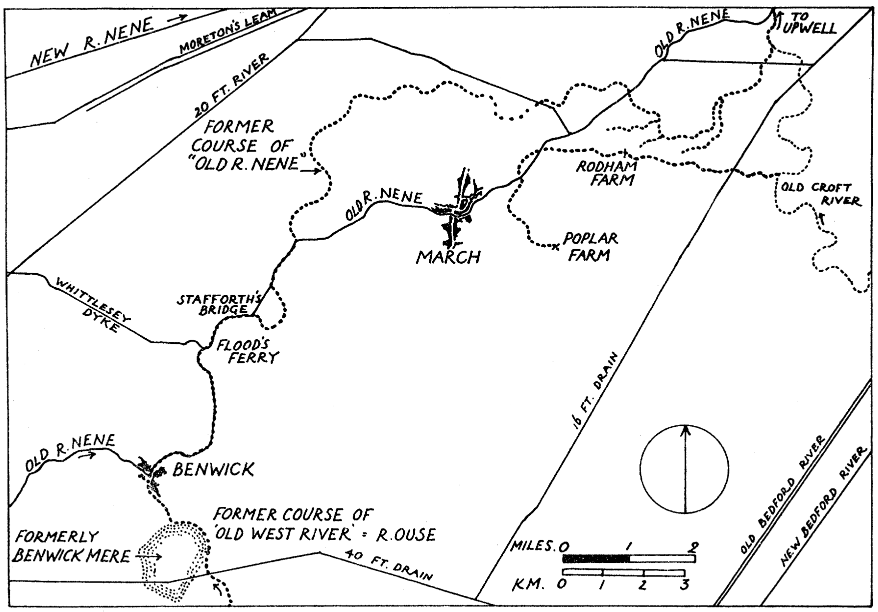


FIG. 31. Sketch map showing ancient river courses near March (after G. Fowler). The Old River Nene from Benwick part way to March is the natural channel of the River Ouse, it is traceable as a big "roddon" to the north of March and joins the main estuary at Upwell. Another roddon from Poplar Farm runs by Rodham Farm also into the Old Croft River and carries the Roman causeway.

section substantially indicate the true relations of the layers. It was quite evident that the roddon silts tapered out over some 2–3 ft. of upper peat, which itself rested on the surface of the fen clay at about -2 ft. O.D. It is clear that the roddon silts overlie the upper peat here just as the big sheet of upper silt overlies it at Guyhirne and Pear Tree Hill. This relationship has been much more clearly shown in a section of the Poplar Farm roddon, near March, which is a tributary of this river system (Godwin 1938).

It was the intention of the authors to trace the silts of the roddons towards the fen meres, and to find how the roddon and the mere deposits were related to one another. The roddon silts of the Ouse, were, however found to disappear between Flood's Ferry and the place where the old river channel reached the former outfall of Benwick Mere, the most seaward of the meres of this district. As we have already said, it is improbable

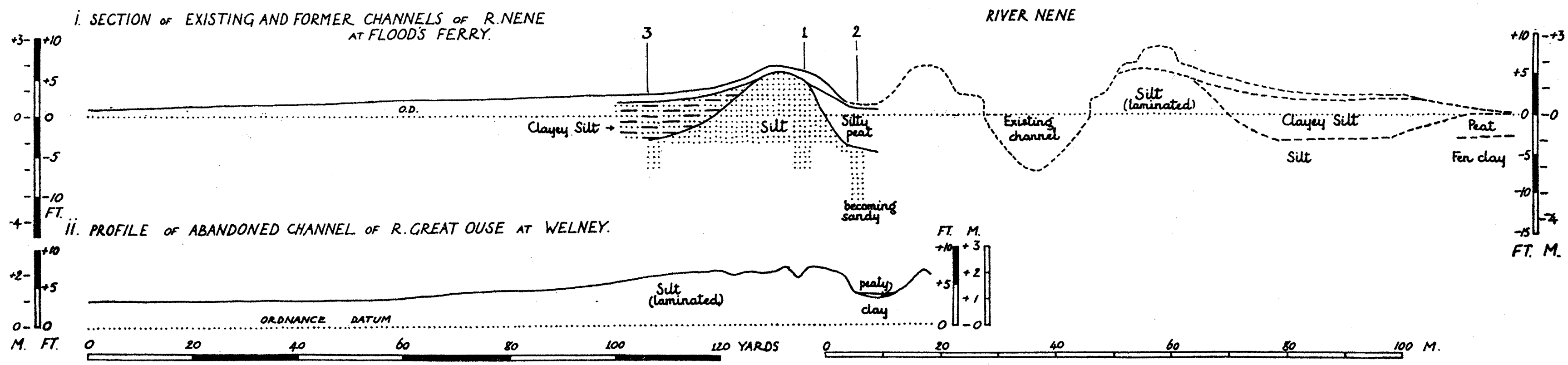


FIG. 32. Diagrammatic section of the river channels (i) at Flood's Ferry. The natural silt banks are shown, and the marginal bank silts taper over the upper peat, which itself overlies fen clay. An artificial bank has been built between the natural banks, (ii) shows the surface levels across the former channel of the River Great Ouse at Welney, with the gently sloping natural banks of silt.

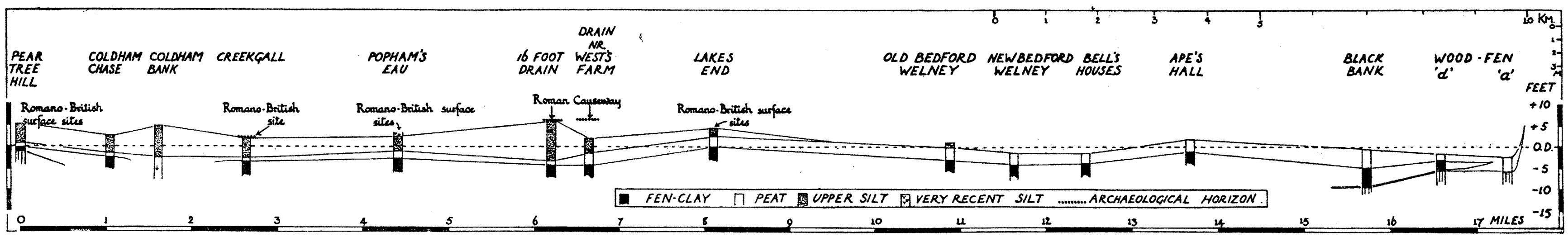


FIG. 33. Section from Pear Tree Hill to Wood Fen, Ely. In this section nothing below the surface of the fen clay is included. It shows the continuity of the fen-clay surface, of the upper peat above it and the tapering sheet of silt above this peat on the seaward side. The silt surface was occupied in the Romano-British period. Note the vastly exaggerated vertical scale.

that the natural course of the river Nene was ever by way of Woodwalton and Ugg Meres; it is much more likely that it flowed seawards much to the north of the Woodwalton district. It seems certain, therefore, that the former Ouse was the only large river system connected with the area, and gave rise to the only large roddons in it. There is therefore small chance of demonstrating lateral continuity between the lake marls and the upper silts *via* the roddon silts, though both overlie some thickness of the upper peat.

It might be thought that in these circumstances a comparison of the relative levels of the lake marl and roddon silts would be of value. Since the lake deposits were forming the fen drainage has, of course, caused some subsidence. It is very fortunate that the careful records of Wells at the drainage of Whittlesey Mere enable us to get a clear idea of the pre-drainage level of the mere, and, from this, a somewhat less exact idea of the level of the lake marls. The marls formerly lay between $-0{\cdot}5$ and $-4{\cdot}5$ ft. O.D. (Newlyn), with the lake level at $+2{\cdot}5$ ft. The surface of the upper silts at the seaward side of the fens is 10 ft. or more above O.D., as are the roddon silts at the seaward end. Further inland one would expect the silt banks to become lower (as tidal influence diminishes upwards along the rivers), and at Flood's Ferry we have seen they are at only $+6$ ft. O.D. The former level of $+2{\cdot}5$ ft. in the meres would agree well with the idea that they might have been in existence when the roddon silts were forming. Exact evidence of such contemporaneity is, however, lacking.

2. Correlation with the South Level

From the fen margin at Somersham, and going north through Chatteris, Doddington and March, there is a substantial ridge in the fen floor, forming islands carrying the towns above named, and extending between them as a barrier across which only the most superficial fen deposits are continuous.

The area so far considered in this paper lies to the west of this ridge, and the fens of the "South Level" drainage area, where most previous work of the Fenland Research Committee has been done, lie to the east of it.

In attempting to correlate the fen deposits of the two areas the ridge prevents the employment of any direct line of section between the two. It is, however, possible to work round the northern end of the ridge at March, and to bring a line of section from Pear Tree Hill (see section, fig. 33) to the east of March, and southwards by Welney towards Littleport and Ely, where it is possible to link up with the published observations at Wood Fen. Just north of the island of Littleport is the landwards termination of the great roddon of the historic channel of the "Old Croft River", or Ouse, and it is quite a simple matter to carry the fen stratigraphy across this roddon into the still more easterly part of the South Level (see map, fig. 21).

This section is not concerned with any deposits lower than the surface of the fen clay, but it is nevertheless of very great interest. It shows in the clearest possible manner the tapering out on the landward side of the thick upper silts and the continuity below these silts of the upper peat. Moreover, at almost every site on the silt land we were able to show a relation to a surface occupation of Romano-British age. At Creekgall Farm the profile passed through the Romano-British layer itself, and at the Sixteen-Foot Drain the profile passed through the gravel of the Roman causeway which the section also touched at West's Farm, and which has also been investigated farther east at Nordelph (see p. 391), and farther west at Rodham's Farm, near March (see Fowler 1933).

Since this long section from Pear Tree Hill to Wood Fen establishes the lateral continuity of the fen clay and of the upper peat, it is reasonable to assume that these beds are identical in the Woodwalton area and in the South Level. The roddon silts are of similar age in both, and we may therefore assume the same general stratigraphy throughout the southern part of fenland.

With this as a basis it will be instructive to review the evidence of conditions of formation of the fen deposits in the South Level. Of the South Level sites, the most important are those at Wood Fen, Ely (Godwin, H. and M. E. and Clifford 1935), and those on the Little Ouse roddon at Shippea Hill, investigated by the Fenland Research Committee at the two neighbouring sites of Peacock's Farm (Clark, Godwin and Clifford 1935) and Plantation Farm (Clark 1933).

The Wood Fen area is on the fen margin and shows the classic buried fen forest described by Skertchley: the Shippea Hill sites have revealed their distinct archaeological horizons stratified in the fen deposits, and here the roddon lies above a deep river channel cut in the fen floor, a channel containing older peats than any so far found in the fen area. The positions of other sites referred to are marked on the map (fig. 21): they include Wilton Bridge (Godwin 1935), Methwold Fen (Godwin, Clark and Clifford 1934), Mildenhall Fen (Clark 1936), Southery Fen (Fowler, Lethbridge and Sayce 1931; Clark 1933), Nordelph (Kenny 1933), and St German's (Godwin and Edmunds 1933; Macfadyen 1933). It will be convenient to consider in succession the stages of formation of the fen beds as they affect these different sites, and as they compare with the Woodwalton sites.

Formation of the lower peat

Near Shippea Hill, at the sites known as Plantation Farm and Peacock's Farm, the Fenland Research Committee have made intensive investigations into the deposits of the channel of the Little Ouse River, and have correlated there the phases of fen formation with archaeological, botanical and geological events (Clark 1933; Clark, Godwin and Clifford 1935). The structure of the channel is shown in the section reproduced in fig. 34, from which it will be seen that the wide ancient river channel cut in the basal sands is filled with successive layers of lower peat, fen clay and upper peat. Towards or after the end of formation of the lower peat a channel was cut through it, which afterwards was filled with fen clay and silt. Similarly, after some thickness of upper peat had formed, a channel was cut into it, and into the fen clay and silt below: this channel was lined with peat, and then filled with silt. In this way was formed the raised bank, or "roddon". Although the Little Ouse hereabouts now runs in a straight artificial channel, the parish boundary closely follows the line of the roddon, so that it seems very likely that the river persisted as an open waterway at least until the ninth century, when the parish boundaries were established. The most remarkable feature of these sites was the established stratification into the fen deposits of no fewer than three archaeological horizons, of which the upper—Early Bronze Age—was represented at both sites. These horizons have been indicated in the diagram. At the Peacock Farm investigations large peat samples were recovered from the lower peat, and these were analysed for plant remains: unfortunately, in the lowest part of the peat conditions made it impossible to secure anything but small auger samples.

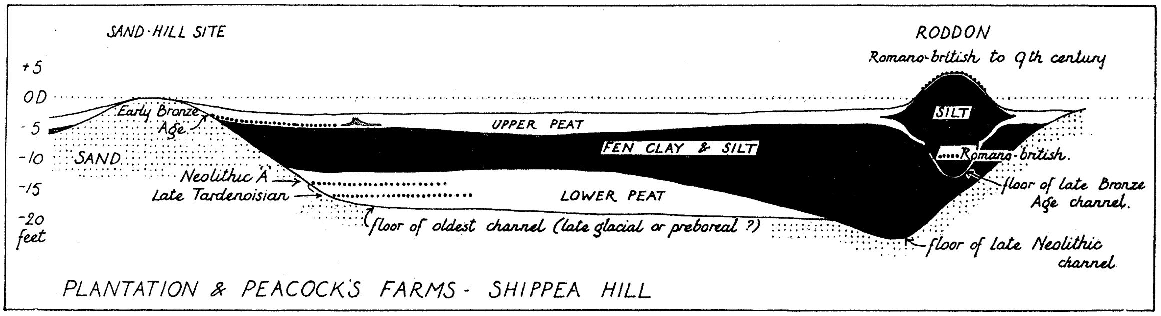


FIG. 34. Diagrammatic section of deposits in the old channel of the River Little Ouse at Shippea Hill. The sand hillock on the left was occupied by prehistoric man, who, at those periods, left the artefacts now stratified into the channel deposits. Successive phases of erosion and deposition mark the history of the river, which is now a "roddon".

The results of analysis of the lower peat are given in the diagram (fig. 35). It will be seen that a Mesolithic (late Tardenoisian) horizon was found in a sandy black layer 20 in. (50 cm.) above the base of the lower peat. This was shown by pollen analysis to correspond to the Boreal-Atlantic transition, and there was evidence from boring and pollen analysis that the correlation held also at the earlier Plantation Farm site. A Neolithic "A" horizon was also established in the layer of sandy peat 20 in. from the top of the lower peat. Above and below the Neolithic horizon there was abundant microscopic wood in the peat: this corresponds closely with the results of the peat analysis. Below 30 in., plant remains were few—fruits of *Eupatorium cannabinum* and *root* wood of *Alnus*. Above 30 in., however, there was stem wood of alder, of *Fraxinus*, *Corylus*, *Ulmus* and *Rhamnus catharticus*. With them were fruits of *R. catharticus*, *Cornus sanguineus*, *Corylus* and *Rubus idaeus* and leaves of *Quercus*. This, with roots and fruits of carices throughout, strongly suggests progressive change, during formation of the lower peat, from open water or fen conditions, to alder brushwood and then to fen woods of markedly drier aspect and richer floristic character. This sequence was reflected in the pollen diagram (fig. 36), where, in the alder brushwood phase the overwhelming effect of local alder pollen is evident, and where, in the drier fen-wood stage which followed, tree pollen was too badly preserved and too sparse to count.

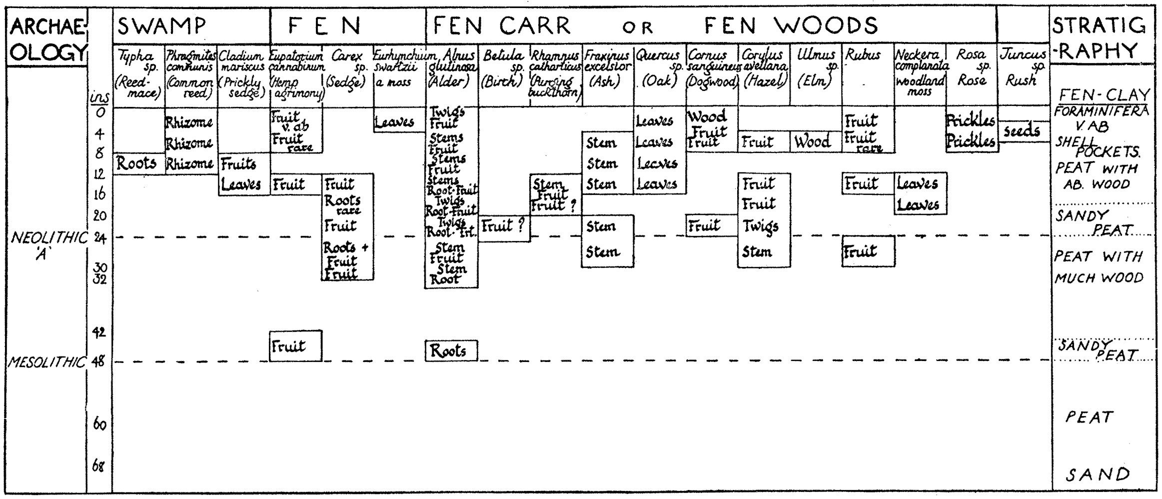


FIG. 35. Plant remains, other than pollen, identified from the lower peat of the channel at Peacock's Farm, Shippea Hill. They strongly indicate formation of fen carr or fen woods in the upper part of this peat bed.

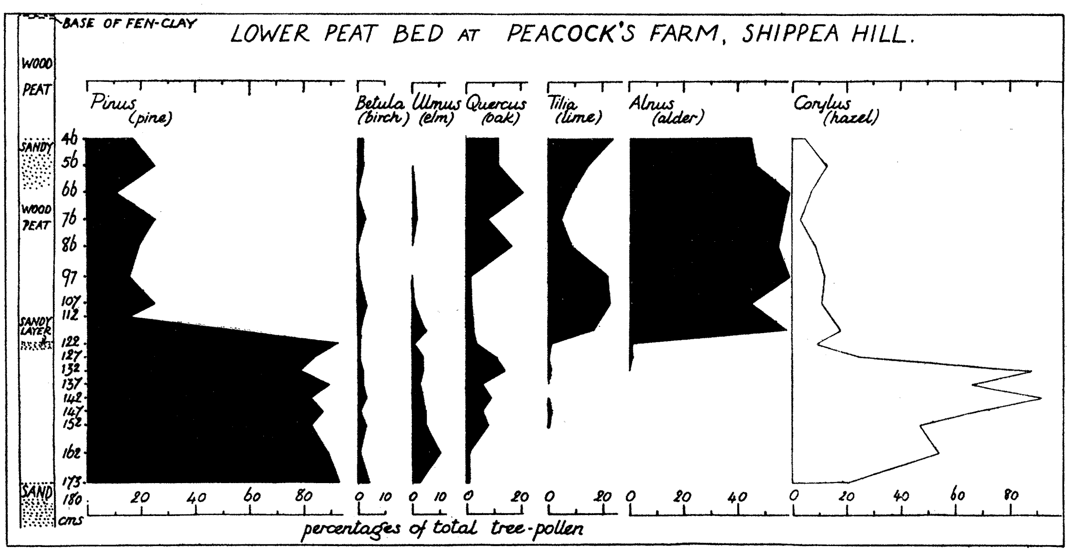


FIG. 36. Pollen diagram through the lower peat of the channel at Peacock's Farm, Shippea Hill. The lower sandy layer is the late Tardenoisian horizon, corresponding with the sudden displacement of pine by alder in the tree-pollen.

This development of the lower peat is exactly comparable with that at Woodwalton and Ugg Mere (Part I), where also alder brushwood gave place to a drier and richer fen wood with *Quercus* and *Taxus*, just before the deposition of the fen clay.

The plant remains in the top of the lower peat at Peacock's Farm clearly indicate the return of wetter conditions with the onset of the fen-clay phase. Remains of *Phragmites*, *Typha*, *Cladium mariscus*, *Aulacomnium androgynum* and *Eurhynchium swartzii* are confirmed by the presence of local pockets of shell-marl, from the molluscan fauna of which Mr Kennard deduced "a shallow swamp, not subject to desiccation" with a climate probably warmer than to-day.

It will be recalled that the Woodwalton sites were sufficiently marginal to show the tapering out of the fen clay in the middle of a phase of fen-wood development. It is exceedingly interesting to find an exact parallel in a marginal site of the South Level, that is, the saddle of Wood Fen between the clay islands of Brick Hill, Ely, and Littleport (Godwin and Clifford 1935). This is the classic site from which Skertchly described the buried forests of fenland. He distinguished five separate horizons: (1) (lowest), oak, (2) oak-yew, (3) pine, (4) pine, (5) alder-willow-sallow. Of these the lowest was a layer of oaks rooted in boulder clay, but the rest were trees which had grown *in situ* on peat. It appeared from examination of the local stratigraphy that

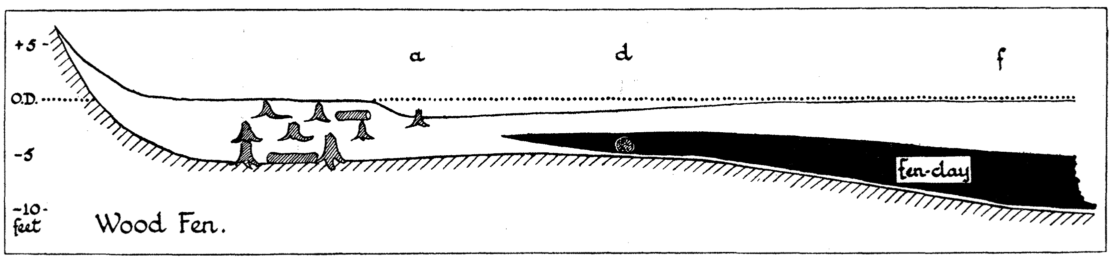


FIG. 37. Diagram showing disposition of peat (white), fen clay (black), and buried forest at Wood Fen, near Ely.

these wood layers were still traceable in the continuous single peat bed of the higher parts of Wood Fen (e.g. sites *a* and *c*), but that in marginal sites (e.g. site *d*) the peat was split into two by the margin of the fen clay (see fig. 37). Pollen analysis and examination of other micro-fossils at site *a* showed that the fen-clay phase probably fitted between the oak-yew horizon and the succeeding pine horizons, although very likely some pines were already present in the oak-yew phase. At site *c*, along with much *Phragmites*, at the base of the peat were abundant remains of carices, with some indications of the presence of alder and oak, and at one level, oospores of Characeae. Rather higher, but still below the main pine horizon, were remains of alder, birch, sallow, and yew, and for the first time the moss *Sphagnum cymbifolium* became abundant in local pockets (fig. 38).

The conclusion then drawn was that there had been a progressive development from (1) a phase of accumulation of alkaline fen peat with local alder brushwood, to (2), an acid "*Zwischenmoorwald*"* of drier aspect, followed by a halt reflecting the local influence of the deposition of the fen clay.

* *Zwischenmoorwald*. This term is used for the vegetation found as transition between mixed fen woods and the early stages of acidic raised bog. It is marked by increase of pine at the expense of deciduous trees and by the establishment of oligotrophic species, especially Sphagna.

This sequence agrees with the development of the lower peat both at Woodwalton and at Shippea Hill, and it will be recalled that in marginal sites at Woodwalton there was a pronounced tendency for local development of "Zwischenmoorwald" Sphagna, at the corresponding phase of fen-wood development. It is interesting to note how at site *d* the occurrence of a large prostrate oak in the thin fen clay corresponds with the notion that the fen clay invaded a peat country covered with fen woods. Similarly at Green Dyke, Woodwalton, there was a prostrate yew in the fen clay, and at Pondersbridge another small yew.

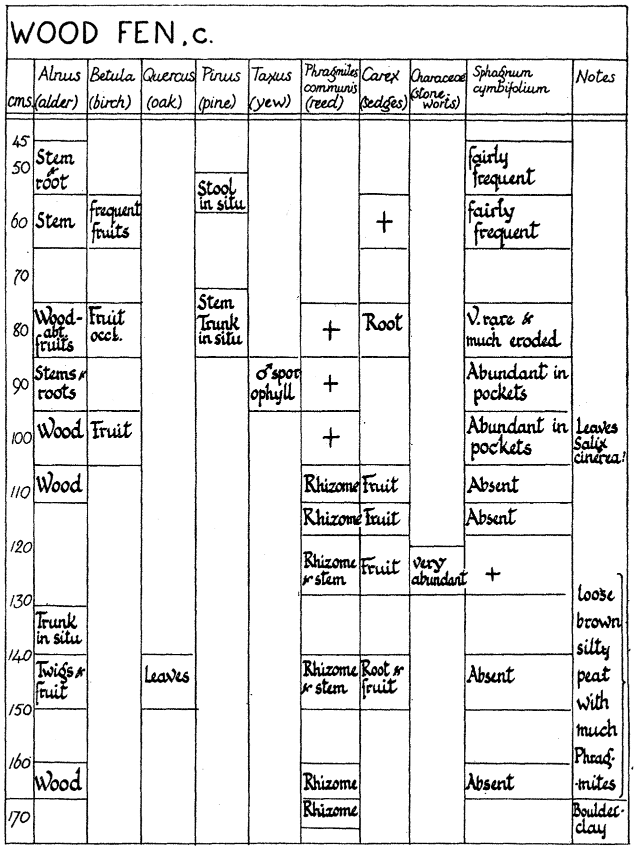


FIG. 38. Plant remains at site *c*, Wood Fen near Ely. This site shows tree stumps *in situ* with strong indications that in its upper layers it was a semi-acidic fen woodland.

There is little doubt that the course of the pollen curves in the diagram for site *a* (fig. 39) reflects almost completely the local sequence of fen woods, by its successive maxima of different tree pollens.

Two other sites in the South Level, Queen's Ground—Methwold (Godwin, Clark and Clifford 1934), and Wilton Bridge (Godwin 1935), show late Boreal peat at the base of the profile, and may therefore be expected to yield evidence of the character of the lower peat. Both, however, lack a direct indication of the fen-clay horizon. At the former site, although roots of carices and remains of *Cladium* were present in the lower part of the peat, alder and other identified wood was present, and the pollen diagram in its lower half gives such unmistakable evidence of the importance of alder, that alder fen woods must have grown extensively on the peat surface in Atlantic times (fig. 40). Precisely similar effects are shown in the diagram from Wilton Bridge, a profile in the ancient valley of the Little Ouse, a few miles above the Shippea Hill sites and beyond the limits of the fen-clay deposition (fig. 41). Here, too, after the onset of the Atlantic period alder woods must have been very abundant.

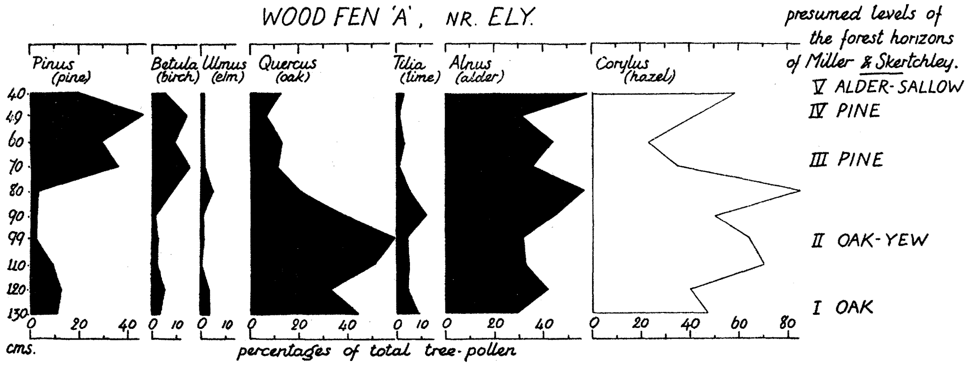


FIG. 39. Pollen analyses at site *A*, Wood Fen, showing probable correlation with the five forest horizons described by Miller and Skertchly.

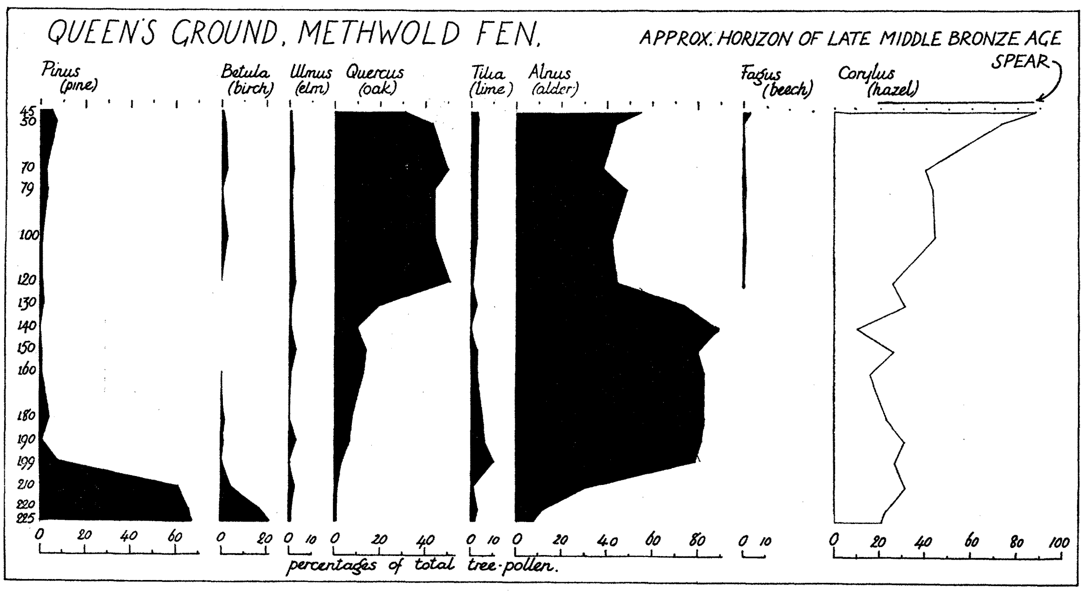


FIG. 40. Pollen analyses at Queen's Ground, Methwold showing the approximate horizon of a late Middle-Bronze-Age spear. The alder dominance in the lower part of the section is due to local fen woods. The basal samples are Boreal.

At neither of these two sites is there further evidence for progressive drying of the peat in the "lower peat" phase.

A further site which may be considered is that at St German's, near King's Lynn (Godwin and Edmunds 1933; Macfadyen 1933). It is so much more seaward than the other South Level sites mentioned, that the greater part of the profile is composed of marine or semi-marine clay and silt. The alternation of these with the four peat beds is shown in fig. 42, which also incorporates deductions from the peat, and from the foraminiferal analyses made by Dr Macfadyen. In the judgment of the authors the two lowest of the four peat beds probably relate to the phase of the "lower peat" formation. The lowest, or "1 inch" peat bed (A), is hardly more than the peaty

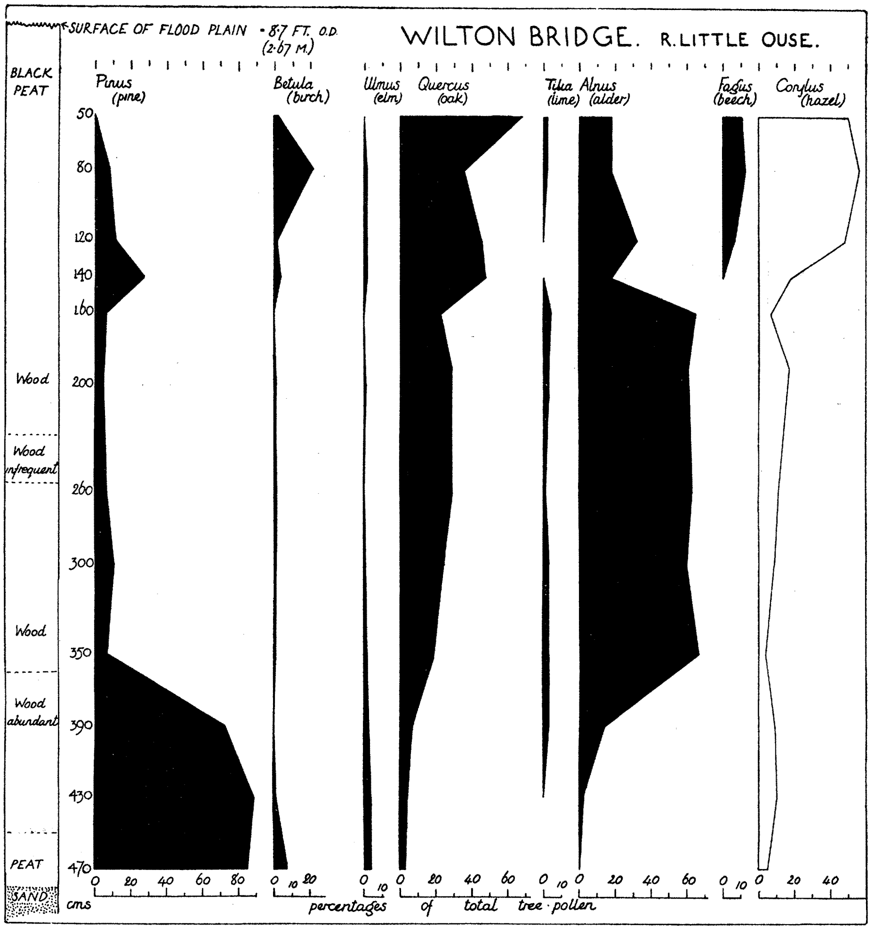


FIG. 41. Pollen analyses in the channel of the River Little Ouse at Wilton Bridge. The bottom samples are Boreal. From 350 to 160 cm. local alder woods dominate the diagram, but above this wetter conditions allow the general pollen-rain of the countryside to be reflected.

surface of the Kimmeridge Clay. Separated from this by 6 ft. of clay shown by the Foraminifera to be a brackish water deposit, was the "six-inch" peat bed (C). This bed contained abundant stools of small oak trees grown *in situ* and their prostrate trunks. The pollen diagram of the bed is shown in fig. 43. A2, A3 and A4 are a vertical series of samples taken at one site and approximately 1 in. (2·5 cm.) apart. At a nearby place, sample D2 was taken immediately below the fallen trunk of an oak, and D1 immediately above it. In the figures the analyses of A2, A3 and A4 have been set on a fixed vertical scale, and D1 and D2 have been subsequently inserted in

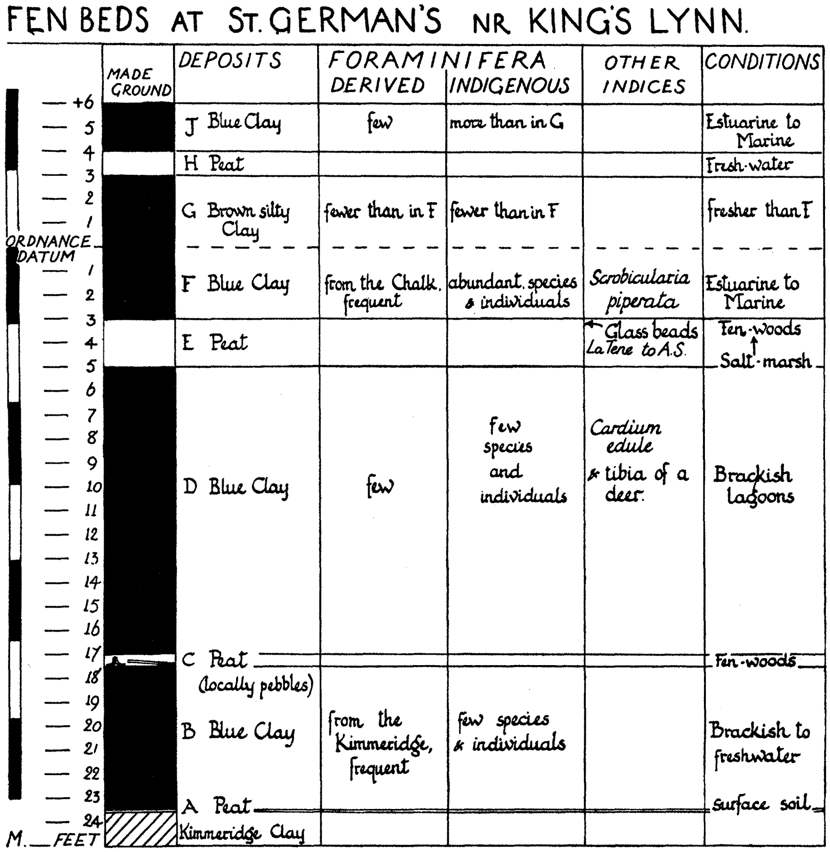


FIG. 42. Stratigraphy of fen beds at St German's, near King's Lynn, showing results of foraminiferal analyses by W. A. Macfadyen and the inferences as to conditions which they support.

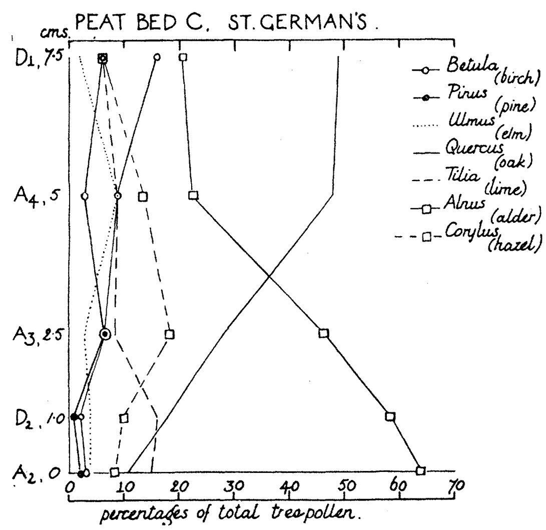


FIG. 43. Pollen analysis of peat bed *C*, St German's. This is a thin bed with small oak trees *in situ* in it. The pollen drifts from dominance of alder to dominance of oak, reflecting replacement of alder scrub by fen oak woods.

positions indicated by their pollen content. There can be little doubt that this bed represents a transition from lacustrine marsh to alder brushwood and then to fen oakwood. It seems reasonable to regard this as the seawards representation of the dry fen oakwood phase found in the inland peats already described. This correlation is supported by consideration of the pollen diagrams, by the relation to O.D. level, and by the brackish water character of the overlying 12 ft. of soft clay, which, it is suggested, represents the phase of formation of the fen clay. The top of this soft clay, the base of the "two-foot" peat-bed (E), is −6·25 ft. O.D. (Newlyn).

A last site which may conveniently be introduced during consideration of the lower peat phase is that at Ingoldmells on the south Lincolnshire coast. Though this site is distant from those so far considered, there is no doubt that it represents the former northerly coastal extension of fenland. After visiting the site with Professor Swinnerton, pollen series were collected and analysed from the two peat beds exposed, and results of these analyses have already been published (Godwin, in Steers 1934). Such correlation as we can make with it will serve as a step towards understanding the history and age of other submerged peats and forest layers of our coasts.

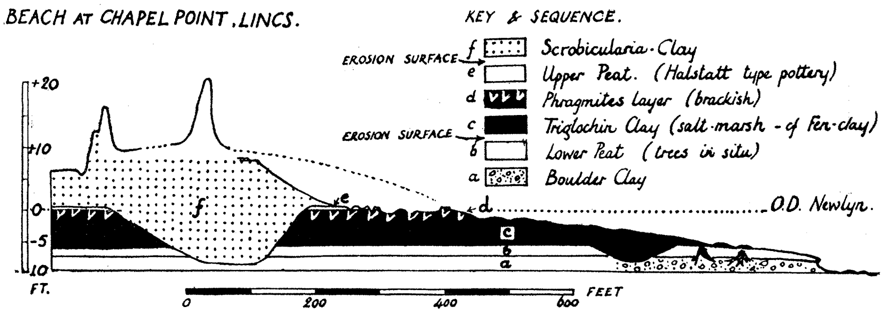


FIG. 44. Diagrammatic profile of shore deposits at Chapel Point, Lincolnshire. The key shows the sequence in which they lie. The lower peat bed is a forest layer with large trees *in situ*; the upper peat corresponds with a Halstatt occupation.

After careful observation and measurement over several years Professor Swinnerton made out the sequence of foreshore deposits shown in the section of fig. 44 (Swinnerton 1931). There is a basal peat bed with oak stools *in situ* rooted, some in the boulder clay and some in peat. This is separated by an erosion surface from salt-marsh clays, which pass gradually into clays with *Phragmites*, and these give place to a thin upper peat bed in which are remains of *Salix* and *Taxus*. This upper peat is of the greatest interest, since it coincides with a salt-making industry of the Halstatt type (close of the Bronze Age—early Iron Age).

A strong erosion surface has cut channels through this peat, and has been succeeded by so-called "Scrobicularia clays". It is suggested that these clays post-date the occupation of an adjacent Roman site.

The lower shore peat at Ingoldmells is correlated by us with the later (Neolithic) fen-wood phase of the lower peat formation in the fens. It is interesting to note that the flora includes oak, alder, birch, *Prunus* and yew, and it should be noted that erosion channels cut through this layer as they did through the lower peat at Peacock's Farm. Possibly the elevation responsible for such erosion was related to the drying of the peat surface which made tree growth very abundant towards the end of the lower peat phase. Pollen analyses of the lower shore peat only indicate by their very high alder pollen values the likelihood of great local abundance of this tree, as in alder brushwood.

It may be recalled that Mr S. H. Warren had described the discovery of Neolithic implements on the surface on which the lower peat formed (Warren 1907), but they did not permit of any accurate dating.

Formation of the fen clay

At Woodwalton and Ugg Mere, we have indicated that the fen clay penetrated a country in the stage of fen woods, but that marginally it barely interrupted their growth, so that some tree remains are found in and just above the clay, as well as continuously beyond its edge. That a similar condition applied in the South Level seems to be shown by the discovery of fallen oaks in the fen clay at Peacock's Farm, and at Wood Fen. At Wood Fen also the oak-yew (?pine) woods were hardly affected by the spread of the fen clay into their immediate neighbourhood.

Foraminiferal analyses of the fen clay have been made in many parts of the fens by Dr Macfadyen, and those from Ugg Mere and St German's have already been cited. His analyses of the fen clay at Shippea Hill (Peacock's Farm), agree with those elsewhere: he concludes "in the whole bed therefore, there seems to be indicated a transition from semi-marine silty clay to nearly fresh-water siltless clay, immediately before the deposition of the overlying upper peat". Samples from the fen clay on the Littleport-Mildenhall Drain, $1\frac{3}{4}$ miles south-east of the Shippea Hill railway crossing, and from the top of Blackwing Drove, Prickwillow, near Ely, give similar results (Fowler 1933).

At the Poplar Farm Roddon, near March (Godwin 1938), a site midway between the Woodwalton and South Level areas, Dr Macfadyen's conclusions from analysis of the top of the fen clay are that it "shows the usual type of fauna of clays deposited in relatively fresh water, with few species".

This stress is laid on the character of the fen clay because the work of the same investigator clearly shows that the next phase of marine transgression in the fens produced deposits which consistently indicate much more nearly marine conditions of deposition. The faunistic content therefore is an index of fen development valuable as a means of correlation.

It is interesting to consider again the deposits at Ingoldmells already referred to. The lower shore peat has been taken to correspond with the late Neolithic fen-wood phase at the close of the lower peat stage. It may be supposed that the clays, therefore, which cover it, correspond with the fen clay. Their contents show with great clarity the circumstances of their formation. The blue-grey clays at the base of the deposit are full of the remains of such typical salt-marsh plants as *Triglochin maritimum*, *Juncus maritimus*, *Phragmites communis*, *Statice* and *Armeria*. The central mass of purple clay contains markings suggestive of *Salicornia*. Above them are blue-grey clays like those at the base, with abundant *Triglochin*, *Juncus*, *Statice* and *Armeria*. They are succeeded by clays full of *Phragmites*, which pass conformably into the upper peat.

This sequence shows a slow subsidence, which first formed high salt marshes and then covered them with low salt-marsh. We know, however, from ecological measurements on the Norfolk coast (Chapman in Steers 1934), that *Salicornia* does not grow below mean sea-level, and the absence of *Scrobicularia* and *Cardium* confirms the view that the surface did not sink below this level. Afterwards the story is one of progressive emergence and the gradual transformation of high salt marsh into *Phragmitetum*, such as may be seen on Norfolk salt marshes to-day, and then to fen. The slow rate of subsidence and the moderate extent of it correspond closely with conditions postulated already for deposition of the fen clay, and strengthen our belief that these beds are equivalent. It will later appear that the correlation suggested by Professor Swinnerton, between these deposits and the fen deposits, is maintained in our own scheme.

The upper peat

It will be recalled that the upper peat in the Woodwalton area extended consistently, and far seaward, over the fen clay, and that near the fen margin it was marked by the development of raised bog peat locally supporting trees. In the fens of the South Level, a corresponding development of oligotrophic peat is rarely represented at all. It is best shown, in sites so far examined, in Wood Fen, Ely, where abundant Sphagna are associated with the pine-forest horizon at a period post-dating the fen clay, but the Sphagna are not raised bog species. Here and there similar marginal sites on the South Level show a slight development of *Sphagnum* peat (e.g. Westmoor Common near Little Downham), but it generally represents only a transitional fen wood, and true development of raised bog seems to have been entirely absent from the region.

We may suggest an explanation for the striking contrast between the Woodwalton and South Level districts by consideration of the conditions under which raised bogs can develop.

The requisites for the development of true raised bog, with its characteristic convex shape and oligotrophic communities of *Sphagna*, *Calluna*, *Eriophorum* and their associates, appear to be: (1) A suitable climatic range—in this country probably a rainfall between 40 and 20 in., without active evaporation conditions. (2) A situation free from danger of flooding by water of high base content, which would prevent growth of Sphagna. The frequent association, here and in Europe and North America, of raised bogs with lakes in morainic or glaciated valleys, suggests that possibly the Sphagna which begin the formation of oligotrophic peat do so on a *floating* vegetation mat, which rides the lake water until it has grown high enough to escape effective flooding. It may be that wherever flooding is severer, and when the drainage water is harder, development of raised bogs is prevented by flooding, even when climatic conditions are themselves suitable.

In the fenland basin heavy flooding might be due to either marine transgression, causing backing up of fresh water, or to high rainfall. The former cause might be expected to operate more or less equally over all parts of the fenland, but high rainfall would most affect those parts, the eastern fens, where abundant rivers (Cam, Lark, Little Ouse, Nar) flow from the Chalk outcrop, into the Great Ouse. Their waters are very hard.

Least affected by flooding will be such an area as the Woodwalton basin, with a tiny catchment area and no large rivers entering it, and a countryside covered with clay of relatively low lime content. This is probably the explanation of the extensive development of the raised-bog communities in this locality, and the limitation of oligotrophic species in other parts of the fens to marginal localities and phases of fen history which were specially favourable to them. The greatest observed thickness of pure raised-bog peat, that in Trundle Mere, occurred above lake deposits, so that here it is possible that the special condition of a floating vegetation mat existed.

If these views on the development of acidic raised-bog peat in the fenland are correct, then it follows that periods of the highest rainfall, such as the Atlantic period, were by no means necessarily most favourable, but rather that diminished rainfall (though probably not below the present) led to the general formation and extension of such peats. Moreover, in those parts liable to the influence of changed sea-level, such peats could develop only in a phase of stability or of marine regression.

Thus the great phase of *Sphagnum* peat formation which followed the deposition of the "old" fen clay was probably one of climatic dryness and of marine regression. At this time the fen margins developed acidic peat, bearing pine and birch woods, and far into the fens a cover of *Sphagnum-Calluna* moor developed.

Only at locally favoured sites, such as Trundle Mere and, to a lesser extent, the rest of the Woodwalton basin, could acidic peat form during other phases than this. In all probability parts of the raised bogs began there in the Atlantic period and continued into the last century. Elsewhere, as we have said, the general formation of acidic peat was limited to a much shorter period, probably corresponding with part or all of the Sub-Boreal time.

Perhaps the most satisfactory method of dealing with the formation of the upper peat would be to trace it laterally from the explored sites of the Woodwalton area seawards along the section towards Wisbech and thence back to the South Level. Unfortunately, however, the upper peat is so badly preserved there that only at a few locally favoured sites can it profitably be examined.

One of these was Dog-in-a-Doublet sluice, where fruits of *Iris*, *Nuphar luteum*, *Menyanthes*, leaves of sallow and wood of alder were recovered from a *Phragmites* peat which was separated by some four feet of structureless peat from the fen clay below (fig. 27). Although about Woodwalton the upper peat contains oligotrophic species, these become less abundant with distance from the fen margin, and Dog-in-a-Doublet shows no trace of them.

At Pear Tree Hill, further seawards, the only recognizable plants in the upper peat were abundant remains of *Typha* sp., some *Juncus* and *Eupatorium cannabinum*. The pollen analyses at this site, by the very strong influence of alder suggest the presence of alder-brushwood. It will be recalled that this peat is sealed below by fen clay, and above by the silts which have Romano-British sites upon them. Although *Sphagnum* peat is very abundant in the Woodwalton area, in the South Level the upper peat does not usually include remains of oligotrophic communities, and former conditions of increasing dryness seem to have been represented by development of the vegetation from fen, through brushwood to fen woods. At Woodwalton, after deposition of the fen clay, raised bog formation did not begin at once, but after the clay formation there was at marginal sites a brief phase of dryness (which might be considered to represent the end of the woodland phase of the lower peat), and then a short phase of fresh-water fen. In the South Level there is little that is parallel to this, though the evidence for a general phase of dryness in the upper peat is strong. It will be convenient to consider the sites of the South Level one by one, and it will be noted that they afford many very valuable instances of archaeological correlation with horizons in the upper peat.

At both Peacock's Farm and Plantation Farm, Shippea Hill, it was demonstrated that there had been Early Bronze Age occupation on the sandhills of the river margin, and that the debris of these occupation sites was stratified in a layer a few inches above the base of the upper peat (see fig. 34). At Peacock's Farm, willow stumps were found *in situ* about 12 in. (30 cm.) above the surface of the fen clay, a possible parallel to the dry phase above the clay at Woodwalton. Above this, the condition of the upper peat made analyses very difficult, but it appeared to have been a *Phragmites* peat, with fruits of *Cladium*, fruits and roots of sedges, and leaves of *Salix cinerea*. In the pollen diagrams from both sites (fig. 45), the pollen of aquatic species is seen to increase very rapidly above the Early Bronze Age level. It is unlikely that this represents the wet phase just over the clay at sites such as Ugg *F* or Woodwalton *A*; it is more likely to represent the onset of the wet conditions of the Iron Age. Later peat is missing from the section.

A similar stratigraphy was recorded from a site in the fens near the island of Southery. Here an Early Bronze Age female skeleton was found, with jet necklace and bronze pin, in the upper peat at a level only 3 in. above the top of the fen clay (Fowler, Lethbridge and Sayce 1931).

At Wood Fen there is evidence of the development of marginal sites during the phase of formation of the upper peat. At site *a*, where the buried forests are best developed, the horizon shown to post-date the fen clay is that in which the pine woods were so extensive. As will be evident from the table in fig. 38 comparative dryness of the period is guaranteed not only by the tree growth, but by the relatively rich development with them of the low-moor *Sphagnum cymbifolium*, which would not tolerate much flooding with alkaline water. A Middle Bronze Age spear head was found close by, on the fen edge of Wood Fen, on sand below thin peat, and its level might be held to suggest that it was covered at about the period of the pine forest formation.

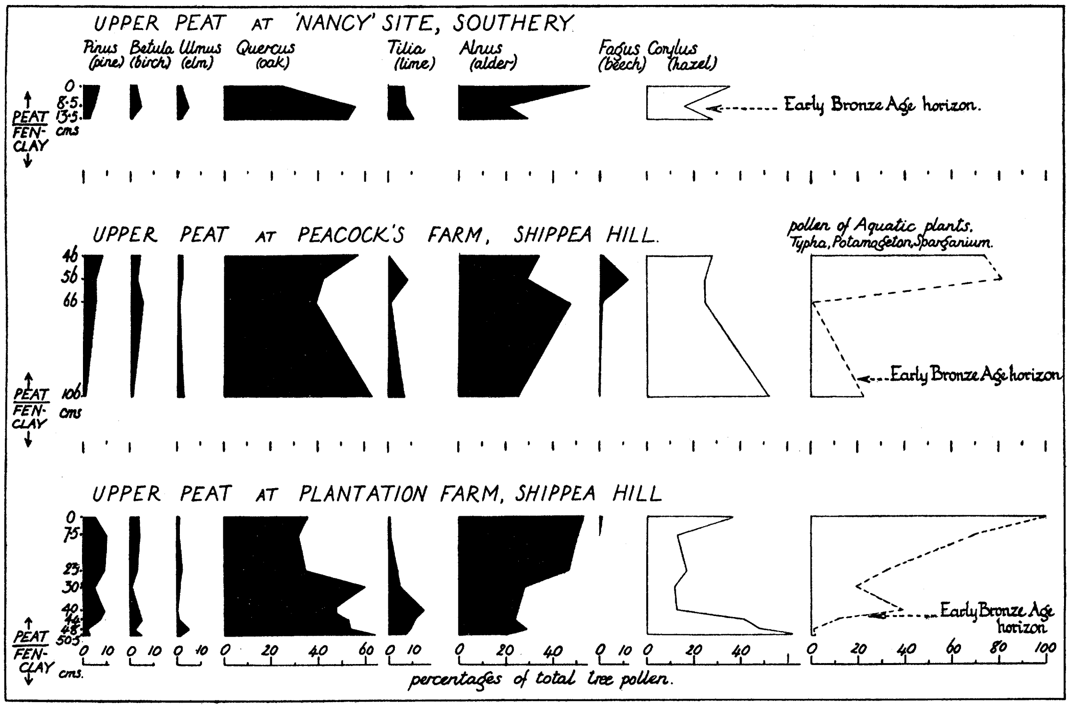


FIG. 45. Pollen diagrams through the upper peat overlying fen clay at three sites, in each of which an Early Bronze Age horizon has been recognized. The rising pollen curve of aquatic plants indicates increasing wetness, probably at the close of the Bronze Age.

Moving towards the seaward side of the fens we may consider in turn the three sites —Nordelph Roman Causeway, St German's and Ingoldmells, at each of which the upper peat is seen above a semi-marine deposit which formed in the fen-clay phase.

The Nordelph site is of particular interest because of the archaeological investigation made there by Dr Kenny (1933). He was concerned to demonstrate the occurrence of a Roman bridge where a gravel causeway on the bank of a roddon crossed the confluence of a tributary stream, represented by another roddon. He showed conclusively that the Roman causeway was laid on the roddon silts, and Roman ware was also found deep in these silts. It was established by boring in the floor of the excavation that the roddon silts overlaid a peat bed 115 cm. thick, below which a soft buttery clay (fen clay) extended to a depth of 4 m. farther. That this peat and fen clay were not local effects of the roddon channel was shown by a boring 100 m. away in the next field, site *C*. There, below 40 cm. of silt, there was peat to 130 cm., and the fen clay to about 5·0 m. Lower peat was absent, the fen-clay getting coarser and full of chalk fragments at the base. The general relation of the deposits at site *A* is given in fig. 46

which shows in profile the beds below the eastern bridge abutment of the causeway. It appears from the levels given by Kenny that the surface of the fen clay is about −1·4 ft. O.D., which agrees with its level at sites already considered. It would seem, therefore, that the profiles we give in the two pollen diagrams represent a phase of peat formation between the Early Bronze Age and the Romano-British period. Unfortunately the peat was lacking in other identifiable remains, but the pollen diagrams nevertheless indicate interesting features in the local conditions.

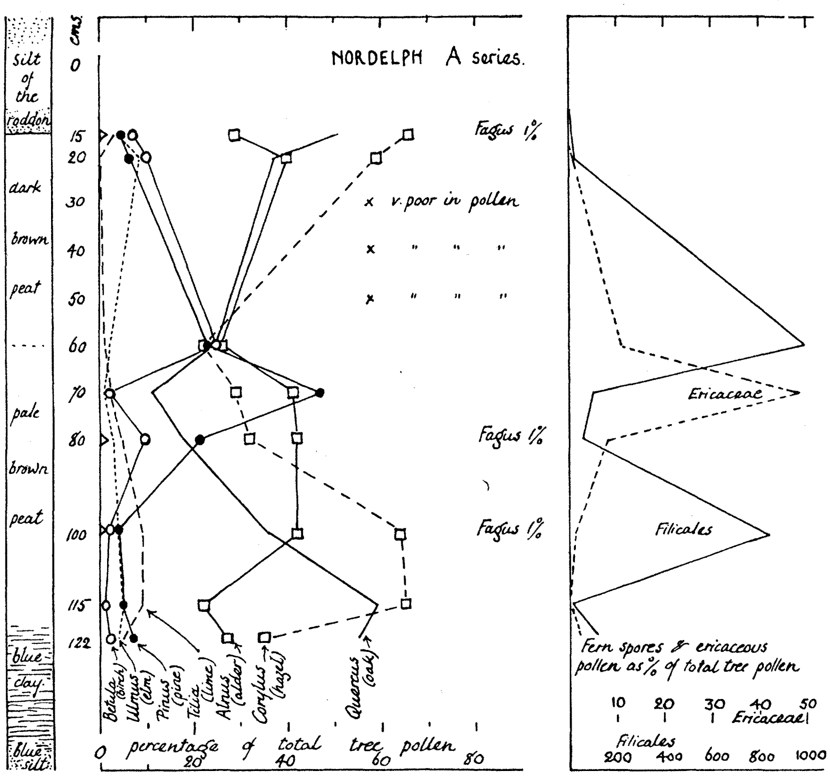


FIG. 46. Pollen analyses at Nordelph *A*, of the peat bed lying between fen clay and the silt of a roddon which was a river in Roman times. The pollen curves show a pine maximum probably due to local pine woods on the peat surface, corresponding with a maximum of ericoid pollen.

At *A* the middle of the peat layer shows pronounced maxima of pine pollen and of pollen of ericoid type. The corresponding depression in the *Corylus* curve suggests the local growth of these pines, which may well have grown on a peat surface becoming mildly acidic. The poor preservation of pollen in the upper layers agrees with this. At site *C* (fig. 47) the maxima of pine and ericoid pollen are repeated, and the high tree pollen frequency at the same level strengthens the view that there were local developments of fen woods with pine. This recalls at once the Wood Fen pine forests of similar age.

At St German's, from what we have already written, it will be clear that we regard the "two-foot" peat layer (*E*), as having formed in the upper peat phase (fig. 42). It has already been shown (Godwin 1934) how the pollen diagram can be interpreted as showing a sequence of development from salt marsh, through alder-willow brushwood, to an oak-woodland in the early stages of which the total tree pollen content was high, but in the later and drier stages of which the pollen was too corroded and sparse to count. The tree pollen curves show progressive replacement of alder by oak, so that the woodland doubtless was a fen oakwood. It is interesting also to note the double

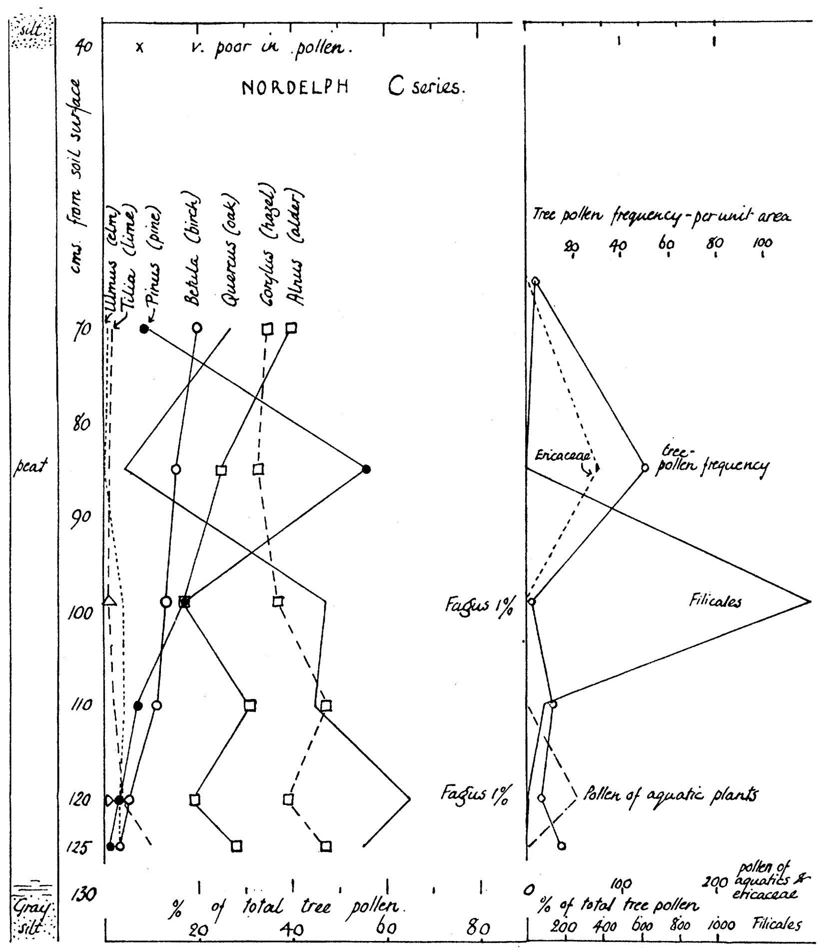


FIG. 47. Pollen analyses at Nordelph *C*, of the peat-bed above the fen clay. This site is close to Nordelph *A*, and also shows maxima of pine and ericoid pollen.

maxima of fern spores on either side of the maximum of tree pollen, as at the two Nordelph sites, and one must conclude that a very similar development was involved in both. A feature of very great interest in this St German's peat was the discovery in the top few inches of the deposit of a number of glass beads. These were examined by Mr Beck (Beck in Godwin and Edmunds 1933). Although he was unable to say more than that they might be either la Tène or Saxon, the former possibility strengthens the views we now advance of the correlation of this bed.

At Chapel Point on the Lincolnshire coast (fig. 44) we have already indicated that it is the upper shore peat which we consider to correspond (in part at least) with the upper peat in the fens. This peat is clearly a wood peat in its upper layers, and contains recognizable branches of *Salix* and *Taxus*. It was not possible to obtain pollen samples through the bed, but a single analysis gave the following results, expressed as percentages of total tree pollen: *Tilia* 0, *Betula* 41, *Pinus* 41, *Alnus* 10, *Quercus* 7, *Ulmus* 1, *Corylus* 15. A second analysis showed, *Tilia* 0, *Betula* 33, *Pinus* 44, *Alnus* 14, *Quercus* 8, *Ulmus* 1, *Corylus* 25. The analyses also showed large numbers of *Sphagnum* and fern spores and some pollen of ericoid type: it is not unreasonable to suppose local development of pine and birch '*Zwischenmoorwald*' on the peat surface here. At excavations on the coastal plain at Mablethorpe, 10 miles to the north, abundant pines were found growing in peat at levels which would agree well with this. The pollen analysis of peat from the base of the forest layer at Mablethorpe gave: *Tilia* 0, *Betula* 8, *Pinus* 68, *Alnus* 19, *Quercus* 4, *Ulmus* 1, *Corylus* 28.

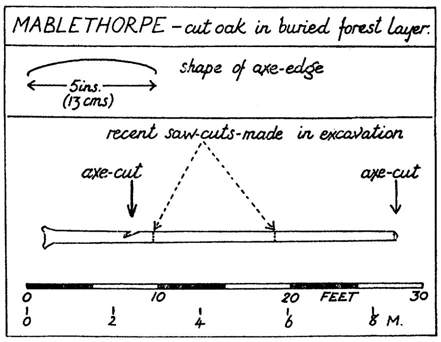


FIG. 48. A worked oak tree, cut by a metal axe from the buried tree layer at Mablethorpe, Lincs.

The great interest of the Chapel Point site is that the upper peat has been shown to have been forming during the occupation of a Halstatt (Late Bronze Age or Early Iron Age) salt-making industry. It was therefore particularly impressive to find that one or two of the pines from the Mablethorpe excavation had been cut, *before* deposition in the peat, by a tool which Professor Swinnerton and one of the present authors (H. G.) agreed must have been a metal axe. A sketch of the cut tree is shown (fig. 48).

If we now return to those sites on the South Level which are so marginal that they lie outside the limits of the fen clay, it is still possible, in some instances to indicate the probable horizon of the formation of the upper peat. At Queen's Ground, Methwold Fen, a late Middle Bronze Age spearhead was found during peat digging (Godwin, Clark and Clifford 1934), and it seems clear that it may be referred to an horizon in the peat at which was found the stool of a substantial yew tree. At a late Bronze Age site on Mildenhall Fen (Clark 1936), charcoal and pollen analyses alike suggest the prevalence of alder-sallow brushwood, with some slight indication of the presence of *Sphagnum*. Unpublished analyses from Wicken Fen agree with those from Wilton Bridge (fig. 41) in showing maxima of pine and birch pollen in the upper parts of the diagrams, but it is still not clear if they represent local development of these trees on the fen surface.

Broadly speaking there can be no doubt that the phase of formation of the upper peat was one of dryness, and that it corresponded with part or all of the Bronze Age. This no doubt is the explanation of the extraordinary abundance of Bronze Age remains in the peat fens of the eastern fen margin, so convincingly demonstrated by Fox (1923). At no other period is there indication of so intensive an occupation of the peat fens.

There is little means of telling exactly how long this phase of peat formation really lasted, but the Late Iron Age beads at St German's suggest that it may have gone on until the time of the Roman invasion of Britain. In the fens thick deposits of roddon silt (above the upper peat) had been colonized by about the end of the twelfth century A.D.

It would be misleading to close this description of the upper peat phase without calling attention to one of its most striking characteristics—the fact that between it and overlying deposits there is very frequently a most marked erosion surface. At Chapel Point, Swinnerton shows that channels cut many feet through the upper peat into the lower clays, and he recalls that Skertchly figured similar erosion through the thickest peat bed exposed along Popham's Eau, a bed which is almost certainly the same as the "two foot" peat bed at St German's. At the Poplar Farm roddon, the same erosion is well marked (Godwin 1938), the Peacock's Farm roddon (fig. 34) flowed in a similar channel cut through the upper peat, and Fowler also records that the upper surface of the fen clay is everywhere abundantly cut into by "old runs", such as that at Southery. These in all likelihood belong to the same phase of relative land elevation which must have persisted during the later stages of formation of the "upper peat", probably in the Late Bronze Age or Iron Age. As with the erosion in the Late Neolithic, so here the improved drainage may have enhanced the dryness of the fen peats.

Lake marl formation and the upper silt

In the immediate neighbourhood of Woodwalton it was shown that at all sites where sufficient upper peat remained, the pollen analyses and peat constitution suggested near the top a return of wet conditions, whilst at Ugg Mere and Trundle Mere considerable layers of calcareous lake marl were deposited over the top peat, and in the form of roddons these silts extended during Romano-British times along river channels into the peat fens.

The lake marls

In the South Level the meres, upper silts and the roddons are also represented. The meres, such as Soham and Streatham meres, persisted until recent historic time, and correspond in character with those near Woodwalton.

They were very shallow lakes, containing calcareous marl, and like those near

Woodwalton, they occupied the *landward* side of the fens, at or beyond the margin of the fen clay and the roddon silts. In this position they correspond with most of the Norfolk Broads: they are to be distinguished from the meres which formerly existed in East Fen, near Boston, upon the silt country. Not only, however, were these meres to be found in the South Level, but it is there that were found the wide superficial sheets of shell marl described by Skertchly: these also were fresh-water lacustrine deposits. At their maximum development, north of Shippea Hill, they reach a thickness of 2–3 ft. (60–100 cm.), and Skertchly specifically commented on the absence of similar deposits from other parts of the fens. It seems very likely to us that the reason for this is the topographic character already described for the South Level, as an area fed by numerous large streams from the chalk hills, liable, much beyond other parts of the fens, to flooding with alkaline water. It is a great pity that no archaeological discoveries have been recorded from these shell marls, nor has their stratigraphical position been exactly determined. At Wicken Fen, however, which is quite close to the former site of Soham Mere, and where the upper peat has been less wasted than elsewhere, there is, over large parts of the fen, just below the peat surface, a layer of pure shell-marl about 30 cm. thick. This is so extensive and uniform that in all probability it represents the phase of lake-marl formation in the South Level as a whole, and the pollen diagrams which have been made at Wicken afford perhaps the only means of dating this phase. Peat growth above the marl shows that open water here gave place to fen, whilst meres remained in other places. The pronounced increase in wetness of the fens which must have accompanied the mere formation is, however, recognizable, we believe, in almost every pollen diagram from the fens that includes young enough upper peat. As will be seen especially in the Wilton Bridge diagram (where also the upper few cm. are a shell marl), above 120 cm., there is a great recession of alder pollen, and a corresponding increase in the trees more typical of dry land (see fig. 41). The behaviour of *Corylus* is especially striking. It seems obvious that the increasing wetness has destroyed the local alder scrub on the fen surface and the regional pollen rain of the countryside is at last strongly represented. In the Wicken Fen diagram the same sequence is clear; as at Wilton Bridge the wet phase is here preceded by a short period in which there is a marked increase in pine pollen, an indication, no doubt, of the end of the dry Sub-Boreal period in which the pines grew on peat at Wood Fen.

At Wood Fen itself it will be recalled that Skertchly described a fifth forest horizon of alder-willow-sallow above the pine layer, a transition certainly indicative of wetter conditions, and one reflected at the top of the pollen diagram (site *A*, fig. 37), by the falling pine and rising alder and hazel curves. The onset of increasing wetness may also explain the hitherto obscure drift of the pollen curves at Black Bank, site *f*, about 1 mile west of Wood Fen (fig. 49). It will be seen that above the fen clay was a phase of high alder pollen with low oak and hazel: this probably represented local alder scrub developing during the phase of the pine woods at Wood Fen, and would explain why pine pollen is so weakly represented in the figure. Above this there is marked recession of alder and pronounced increase in oak and hazel, with, incidentally, some beech: this is presumably the wet phase in which the alder scrub was destroyed and in which the regional pollen component predominates. Pine is not high because by this time the pine woods on peat have themselves succumbed.

It will be recalled that the pollen diagrams from the Woodwalton area (Part I) all showed the same signs of increasing wetness at the very top of the profile.

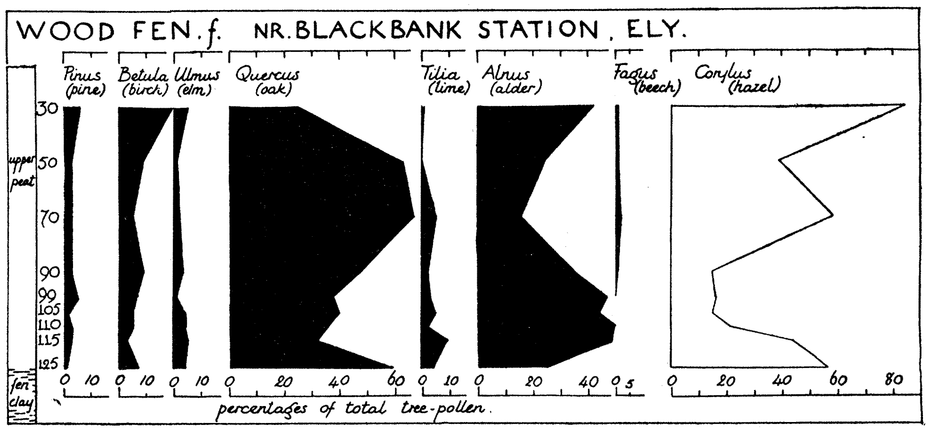


FIG. 49. Pollen analysis at Wood Fen *f*. (Blackbank), of the upper peat over the fen clay. The lowest phase of dominant alder reflects fen woods in a first dry phase; it is followed by a phase of increasing wetness, in which oak and hazel reach much greater importance.

At the Peacock's Farm site, considerably above the Early Bronze Age horizon there are pockets of shell marl in the upper peat, but it is not clear, if they are related in date to the large deposits of shell marl in the area or to the roddon silts. Too much of the upper peat has been destroyed. This is also true of the Methwold Fen diagram and many others from the drained fens of the South Level.

The silts.

The surface of the silt land which occupies all the seaward part of the fens, has been shown to have been densely settled in Romano-British times, and it has already been shown that these silts taper out over the upper peat, as at Pear Tree Hill. The roddons, which were the extensions of this silt into the peat fens, are similarly of Roman date. Not only are Romano-British sites on the surface (cf. Rodham Farm, Fowler 1933; Roman Causeway at March, Kenny 1933) but artefacts of the same period have been recovered from deep in the roddon channels themselves, in many feet of silt (cf. Peacock's Farm, Clark *et al.* 1935; Roman Causeway at Nordelph, Kenny 1933). The thesis that not only were the immature roddon banks settled in Romano-British times, but that the roddons formed *during* this period has been most strongly supported by the recent unpublished excavations of Mr C. W. Phillips, F.S.A., at Welney. He found there several superimposed occupation sites separated by silts formed as the banks of the roddon were progressively raised.

Analyses of roddon silts from several sites have been made by Dr Macfadyen. These include Peacock's Farm, Rodham Farm and Poplar Farm near March. They all agree in the marked abundance of Foraminifera in species and in individuals, especially of species indicative of fairly marine conditions. He says for instance of the Little Ouse roddon at Peacock's Farm, that the silts "appear to have been deposited from tidal estuarine water flowing up the ancient waterway" and adds "they are thus of more nearly marine nature than the Buttery Clay" (i.e. fen clay).

In view of this it is interesting to recall conditions at this time at St German's and Ingoldmells. At St German's clays containing *Scrobicularia* were formed over the two foot peat bed (fig. 42); they were shown by Dr Macfadyen's analyses to have a richer content of both derived and indigenous foraminifera than any of the lower clays. He held that they represented appreciably more marine conditions than these earlier clays.

At Ingoldmells the erosion of the upper peat was followed by deposition of the upper clays, characterized by *Scrobicularia* as well as *Cardium*.

The subsidence must have been greater than that responsible for the lower clays, because these molluscs flourish only below mid-tide level. This still agrees with our views on the correlation of these beds with the rest of the fens, and though Swinnerton suggests that "the subsidence which was followed by the deposition of *Scrobicularia* clays took place after the Roman occupation", the evidence does not exclude the possibility that the subsidence could have occurred *during* part of the Roman occupation. In view of evidence from the rest of fenland this is presumably what happened.

In only one instance has it been possible to deduce from plant remains the marine influences during the Roman period. A black organic deposit containing Romano-British pot rubbish excavated by Mr C. W. Phillips in a former course of the Old Croft river at Welney was found to contain *Scirpus maritimus*, *S. lacustris*, *Oenanthe lachenalii*, *Apium graveolens*, *Suaeda maritima*? and some partially charred fragments of oak.

Between the phase of erosion of the upper peat surface and the estuarine conditions of Romano-British times, there must have been a period of comparative stagnation and this is presumably represented by the peat lining of the old roddon channel at Peacock's Farm, and by the greasy (silt-containing) peat filling the channels of the old runs. This peat often contains masses of leaves and twigs of sallow (*Salix cinerea*), and in the two instances where the mollusca have been examined, Dr Kennard has said that they indicate a deep, sluggish, fresh-water stream. The primary fact of marine transgression during Romano-British times seems beyond question, and as we should expect, it is clear that it affected both the Woodwalton-Wisbech area and other parts of the fens. What remains uncertain is the possible relation between deposition of the upper silts and formation of the lake marls. Historical evidence collected by Dr Darby indicates that the meres were in existence about 1020 (Darby 1936). Only six centuries therefore separate this period from the close of the Roman occupation, and there is thus a distinct possibility that they already existed in Roman times, or that they might even represent the landward results of the conditions which brought about roddon formation. Further investigations are very desirable.

In conclusion we may comment on the few fenland deposits which seem to be later than the Roman silt. At St German's (fig. 42), it will be recalled, there is an upper peat (*H*) overlying the clay and silt (*F*) which we have taken to be the Roman deposits. It is itself overlaid by more silt (*J*), also of rather marine or estuarine character. There is little indication of the age of these deposits, though pollen analysis of the peat bed may be of use at some later date. It seems clear, however, that this top peat is represented at other sites not far from St German's, especially in the series of sections along Popham's Eau described by Skertchly. These sections extend in a series about 2 miles long, eastwards from the silt-filled estuary of the Ouse near Outwell. They were not, unfortunately, levelled by Skertchly, and he uses them to illustrate the rapid alternation of marine and fresh-water deposits, with which he discredits the validity of the fen clay as a determinable bed. It is instructive to rearrange the sections so as to present them, as far as possible, in their true relative heights. This has been done in fig. 50,

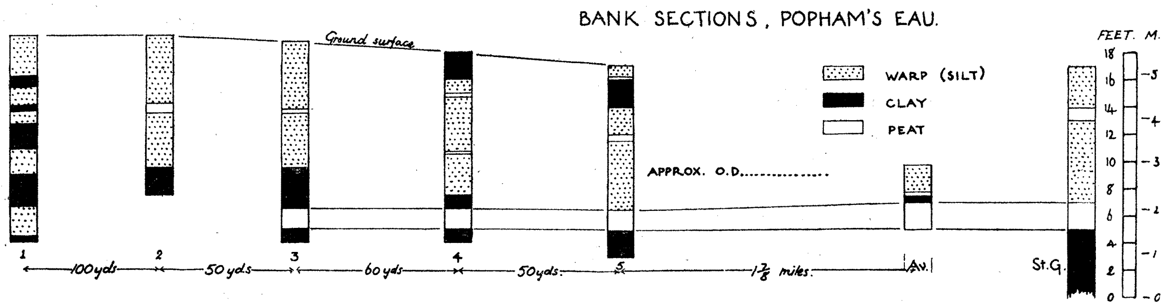


FIG. 50. Bank sections at Popham's Eau. Data from Skertchly rearranged to give the probable relations of the beds. The main fen estuary is on the extreme left. Note the constancy of the largest peat bed which overlies clay and is covered by clay and silt with minor peat beds.

which shows the criteria and modifications employed. It now appears that the silt surface slopes progressively down from the west, as would be expected on the flanks of the great main estuary of the fens. The lower peat (the Bronze Age "upper peat") is continuous throughout save for the erosion channels noted by Skertchley, though it is naturally missing towards the centre of the estuary. It is still traceable in the bank of the drain, at the present day. If this bed is, as we suggest, the "upper peat" of the fens, then the peat bed or beds above will probably correspond with the highest peat at St German's. In the absence of more data it is hardly profitable to consider of what age such peat beds might be, but they may some day be related to the mediaeval history of the fens.

Conclusion and discussion

The evidence here given strongly supports the view that those correlations of fen deposits between the Woodwalton area and the South Level, which were suggested by the lines of borings and establishment of levels, are fully borne out by a comparison of the evidence as to development conditions in the two areas.

The history of formation of post-glacial deposits in the southern fenlands can evidently be related to a series of well marked phases which are recognizable throughout the area, and which offer considerable opportunity for correlation with geological and archaeological events and with change of climate.

CHRONOLOGY (APPROX)	PHASES OF FEN HISTORY	ARCHAEOLOGICAL HORIZONS	MAJOR FEATURES OF THE PERIODS.	CONDITIONS AT SITES: MARGINAL	MIDDLE	SEAWARD	PREVALENT STATE	LAND LEVEL RELATIVE TO SEA	CLIMATIC EVIDENCE IN FENS.	CLIMATIC PERIODS	RECURRENCE HORIZONS (DRYNESS IN S. SWEDEN) GRANLUND.
1900 1,500 1,000	DRAINAGE & MARSHLAND RECLAMATION	HISTORIC		PEAT GROWTH		SILT LOCAL PEAT	WET (locally dry)	? LOW ? HIGH	WET	RECENT SUB-ATLANTIC (cold & wet)	X RY I
500 A.D.	UPPER SILT & MERES	ROMANO-BRITISH	MARINE TRANSGRESSION	?MERES	RODDON SILTS	UPPER SILTS	WET	LOW	WET (LAKE MARL)		X RY II
0 B.C. 500 ?1,500	UPPER PEAT	IRON AGE (LA TÈNE, HALSTATT) BRONZE AGE EARLY BRONZE AGE Beaker 'A'	stagnation-phase Brush wood on raised-bogs – Marginal pine woods & tendency to form acidic (sphagnum) peat [Wet phase [Dry-phase - local woods]	OLD RUNS CUT PINE & YEW IN FEN-WOODS - SOME ACIDIC PEAT	RODDON-CHANNELS CUT FEN-WOOD ↑ BRUSH-WOOD ↑ FEN	FEN PEAT REED PEAT	(DRY) DRY	HIGH	WET (IRON AGE IN FENS) DRY (RAISED BOGS)	SUB-BOREAL (warm, dry continental)	WETTER ↑ X RY III ? RY IV
?2,000	FEN CLAY		shallow brackish lagoons EXTENSIVE BUT SHALLOW MARINE TRANSGRESSION	FEN-WOODS	FEN-CLAY	SILT	WET	LOW	WARM (TILIA)		DRIER ↑
3,500	LOWER PEAT	(ESSEX) Beaker 'B' NEOLITHIC NEOLITHIC 'A'	Dry Fen woods alder brush-wood peat-formation becoming general in Fens	EROSION CHANNELS CUT DRY OAK FEN-WOODS			DRY WET	HIGH ? LOW	WARM (MOLLUSCA) ? DRY (BLOWN SAND) INCREASING WETNESS (ALDER)	? ATLANTIC (warm & wet)	? RY V ↓ WETTER
5,500		LATE TARDENOISIAN MESOLITHIC	peat forming only in river channels etc.						? DRY (BLOWN SAND) DRY (NO ALDER)	BOREAL (warm, dry)	
7,500			peat at JUDY HARD. & on DOGGER & LEMAN & OWER BANKS.- N. SEA.					V. HIGH, SAY 200' (61 M.) HIGHER THAN NOW		PRE-BOREAL (cold)	

Fig. 51. General correlation table for the fenland deposits. (For details see text.)

This correlation can be best expressed as the correlation table and the correlation diagram shown in fig. 51.

We shall demonstrate in a later paper that pollen analyses of sites throughout the southern fenlands accord fully with the general scheme of correlation now set out.

The major features of the table speak for themselves, but there are certain questions of interpretation of evidence which require brief discussion. These are dealt with below.

Erosion channels

At the end of the phase of both the "lower" and the "upper" peat formation, there was a period in which erosion channels were cut through the peat beds and often through the beds below them.

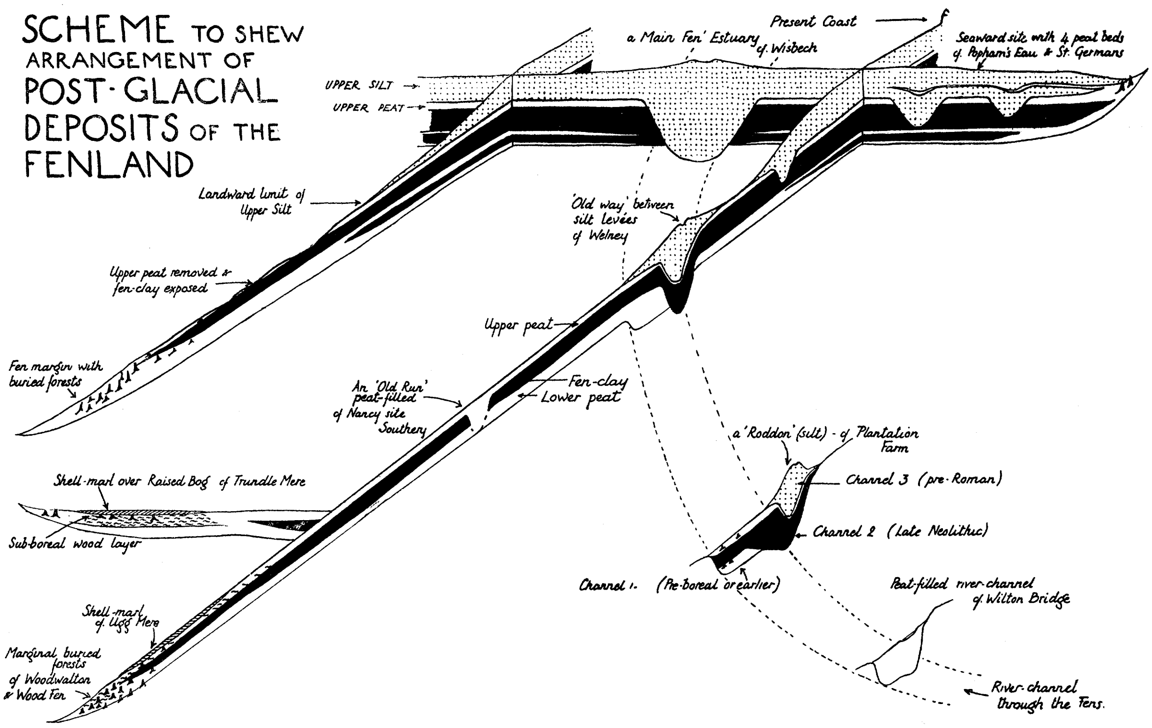


FIG. 52. A purely schematic figure to show the type of variation in fen deposits found at different levels and at different distances from the sea. It only shows the *principles* of arrangement of the fen beds.

In a previous paper members of the Fenland Research Committee have accounted for each of these by supposing a phase of land elevation *following* formation of the peat. It now appears to the present authors that in some instances (e.g. between the lower peat and deposition of the fen clay) the time available has been too short for this, and they have assumed that land elevation responsible for the erosion was in progress during the later stages of peat formation and did, in fact contribute to the marked dryness of such stages. Direct evidence of the truth of this is hard to come by, and Professor Swinnerton has assumed that the erosion through the two corresponding coastal peats at Chapel Point was caused by the fact that the subsidence, in its early stages, brought within reach of the tidal oscillation ground previously out of reach of it. We find it difficult, however, to accept this hypothesis for the very wide area of the fens in which these erosion phenomena are found.

Wetness and dryness

We have already noted that interpretation of Fenland history is complicated by the fact that dryness and wetness of the surface is affected by the operation of at least three major factors—climate, relative movement of land and sea, and the natural successional tendencies of vegetation. The last factor can usually be estimated, but the relative importance to be attached to each of the two former is both important and difficult to decide. We have therefore given one column of the table to a statement of the wetness or dryness of the fen surface at any period, and in the following columns have added information as to the extent to which climate, on the one hand, or land and sea movement, on the other, are likely to have been involved.

On the extreme right are given the classical climatic periods of Blytt and Sernander and the conditions they were held to show in Scandinavia, also the later conclusions of Granlund—especially with regard to the main "recurrence surfaces" in raised bogs. These are well-marked phases of arrested growth and can be taken to correspond with periods of climatic dryness. The most marked of these is *RY* III, at the end of the Bronze Age. *RY* V, corresponds in Sweden with the "Passage Grave" part of the Neolithic and therefore must be set below the fen clay.

Climatic inferences

Abundance of *Pinus* in the upper peat phase is of very dubious climatic significance. It has been held to indicate increasing continentality, but it may equally well represent development of fen woods to a stage of dryness and mild acidification. This reflects dryness, which may have had both a tectonic and climatic origin—i.e. in marine regression as well as climatic dryness. There is reason to think that the raised bog development at this time must have needed both.

Relative abundance of *Tilia* in pollen diagrams from early Atlantic to middle or late Sub-Boreal, suggests the maximum warmth period lay between these times—this is generally agreed. This coincides with Kennard's conclusions about molluscs from the top of the lower peat.

The time allotted to formation of the fen clays is admittedly short, and the period is a mere guess, but shortness is imperative if the fenland story here put together is not to conflict with the evidence from the Essex coast (Warren 1936). From this coast, at sites now between tide levels, there is good evidence for continuous human occupation on the same surface from Mesolithic times to the end of the Neolithic and the onset of the "B" Beaker culture. After this, occupation abruptly ceased, and this may be related to the deposition of clays following subsidence. Since the transgression which caused formation of the fen clays *must* have been represented by some deposition, or some interruption of occupation at these levels on the Essex coast, it can hardly correspond with anything but these overlying blue clays. In the fens, however, there is clear evidence that the major extension of the fen clay is overlaid by Early Bronze Age cultures containing "A" Beaker material. Though it may be granted by archaeologists that the "B" beaker culture was (locally?) earlier than the "A" culture, yet the time gap between the two cannot have been considerable, and the time left for formation of the fen clay can therefore hardly exceed 500 years if it was indeed so much.

Fen clay

We do not now propose to discuss the origin of the fen clay, but it is probable that it was produced as sea-borne silt, and did not come into the fens by the rivers draining the upland (see Macfadyen 1933). Had the material been river-borne there should be some deposits of coarser silts and gravels on the landward side of the fen clay and round the immediate former channels of the rivers where they entered the fens. Such deposits are absent. It can be shown, for instance, that on the old channel of the Little Ouse the fen clay tapers out a few miles above Peacock's Farm, and that at Wilton Bridge the same channel is full of peats which completely embrace the period in which the fen clay was formed.

We understand also that the opinion of the Great Ouse Catchment Board research officers is not contrary to the idea that such great masses of material could have entered the fens from the Wash, in the course of a period of the order of 500 years.

It cannot fail to strike any observer of Fenland geology that there is an extremely marked contrast between the character and extent of the fen clay, and those of the upper silts. It is very striking that the later deposit, which is the more marine, should be so much more restricted in extent than the earlier, almost brackish, deposit. There is some probability that the fen clay was deposited in a large land-locked lagoon area, perhaps resembling the undrained Zuyder Zee, but the present-day equivalent of the formation of the upper silts is not apparent to the present authors.

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SUMMARY

The plant remains of the fen deposits have been analysed, and stratigraphy has been determined from profiles and from extensive borings: the methods of pollen analysis have been employed to indicate the drift of local vegetation phases on the fens themselves.

Part I deals with the Woodwalton Fen area, a part of the fenland margin south of Peterborough, where the fen peats have been little damaged by drainage and peat-cutting. It is shown that on the landward side there is a single peat bed, which is separated into two not far from the fen margin, by the tapering edge of a bed of fen clay shown by foraminiferal and diatom analysis to have been laid down in brackish water. This clay, which must have represented a marine transgression, interrupted a phase of extensive development of fen woods, at first mainly alder-oak, and later pine-birch. Tree remains are very abundant. The peat above the fen clay showed clear evidence of the development of acidic *Sphagnum* peat of the kind found only in raised bogs ("Hochmoore"). This type of peat was previously unrecognized in the fens, and it reflects conditions of freedom from flooding by alkaline water. It is probable that this phase corresponds with the Bronze Age, and that in the succeeding Iron Age conditions changed sharply. The acid *Sphagnum* peat is overlaid by the calcareous lake marl of Ugg Mere and Trundle Mere, lakes which were only recently drained. They are thus shown to have had a very recent origin.

Part II of the paper extends the observations in the Woodwalton area towards the sea and towards the southern half of the fens. A series of long sections has been constructed which converge towards Wisbech (upon the main estuary of the last phase of fen history). These sections show that the upper and lower peats, separated by the fen clay, occur regularly and continuously over the entire area. On the seaward side they are overlaid by an upper layer of semi-marine silt deposited in the Romano-British period. By a long series of shallow bores the above series of sections was linked to the known profiles at Wood Fen, Ely. Thence it was clear that the phases of lower peat, fen clay, upper peat and upper silt could be accepted as broad major divisions across the whole of the southern part of the Fenland.

Peat formation in the Boreal period was restricted to places of local wetness, such as deep river valleys. A dry phase at the Boreal-Atlantic transition corresponded with a late Tardenoisian culture horizon. Peat formation became general in the fens in the Atlantic period, and the fens became wooded in the Neolithic period, during the end of which time, or just after which, there was an extensive but shallow marine transgression which caused the fen clay to be formed. The succeeding period in the fens began with "A" Beaker culture and during the Bronze Age they were dry: the fens were either wooded or formed raised bogs, and were fairly habitable. The ensuing Iron Age must have been wet. The Roman period was marked by the deposition of considerable thicknesses of semi-marine silt in a wide belt on the seaward side of the fens, and in tongues along the courses of the estuaries. There were human settlements upon the silt whilst it was forming, and its present surface shows the remains of dense occupation. The great meres of the Fenland probably formed either in the Iron Age or the Romano-British period.

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