PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Studies in the Post-Glacial History of British Vegetation. III. Fenland Pollen Diagrams. IV. Post-Glacial Changes in Relative Land- and Sea-Level in the English Fenland

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STUDIES OF THE POST-GLACIAL HISTORY OF BRITISH VEGETATION

III. FENLAND POLLEN DIAGRAMS

IV. POST-GLACIAL CHANGES OF RELATIVE LAND- AND SEA-LEVEL IN THE ENGLISH FENLAND

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[Plate 21]

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PART III. FENLAND POLLEN DIAGRAMS

Introduction

Since 1932 the Cambridge Fenland Research Committee has been engaged in solving the problem of the history of the deposits of the Fenland basin, by the many methods appropriate to the archaeologists, geologists, geographers and botanists who make up that body. Since so large a part of the Fenland basin is filled with peat or with alternating beds of peat or silt, a study of vegetational development in the area has inevitably meant co-ordination of botanical work with that of specialists in other subjects, and has led, in itself, to a study of Fenland stratigraphy. In the two preceding papers of this series an account has been given of the stratigraphy of the southern part of the Fenlands, so far as this has been determinable by study of the lateral continuity of peat and other beds, by observations on the remains of organisms in them, and by correlation with archaeological indices (Godwin and Clifford 1938). In these papers comparatively little reference has been made to the results of pollen analysis, and it is with the application of this method to studies of Fenland deposits that the present paper is concerned. It purposes to add another type of evidence for the correlation of fen beds, and to show that this evidence both confirms and extends the results previously described.

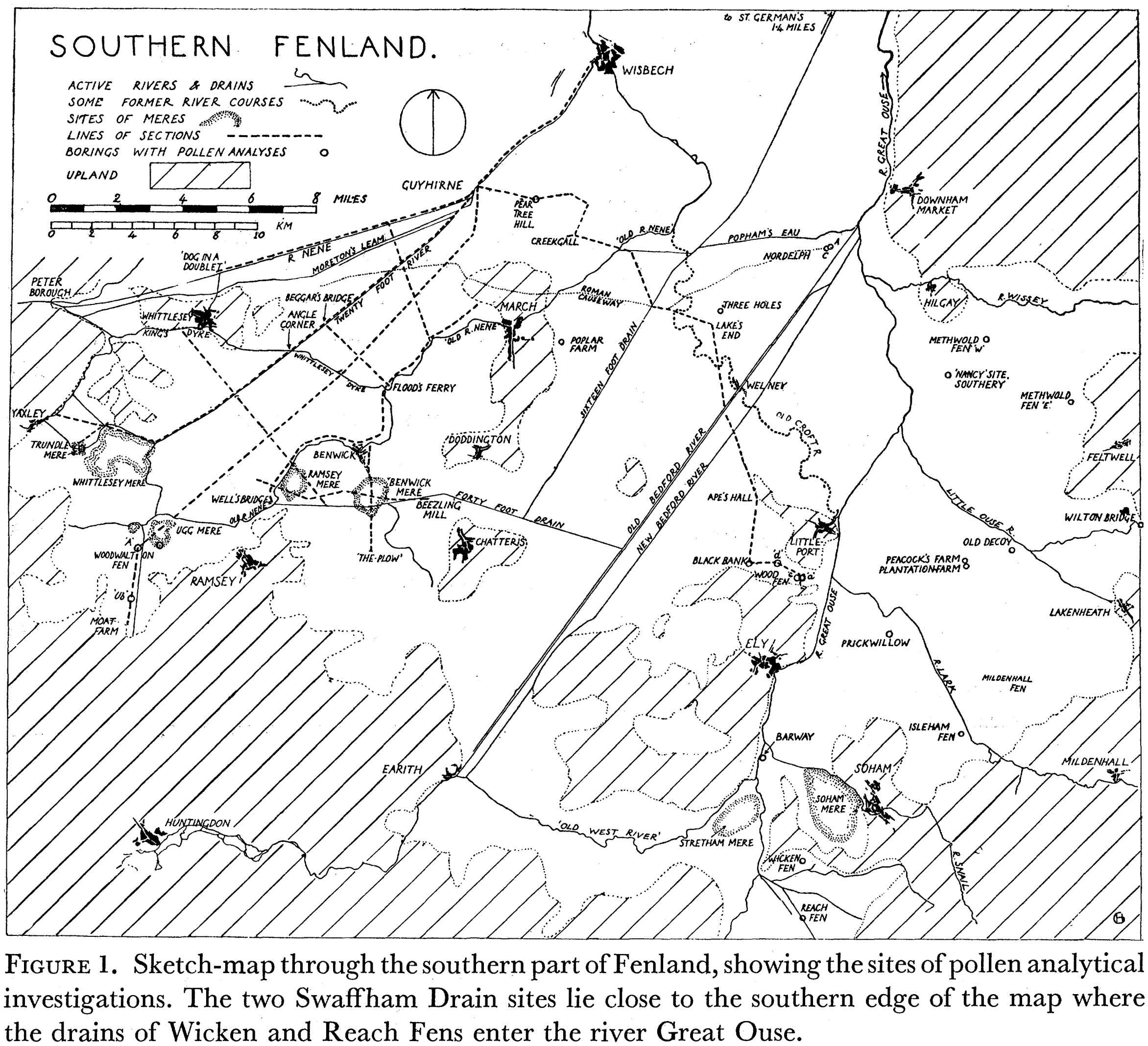

FIGURE 1. Sketch-map through the southern part of Fenland, showing the sites of pollen analytical investigations. The two Swaffham Drain sites lie close to the southern edge of the map where the drains of Wicken and Reach Fens enter the river Great Ouse.

The position from which this paper begins can be readily taken from figures 2 and 30, which are from the last paper of this series, and give respectively a solid diagram to show the general *principles* of the relations of the fen beds to one another, and a correlation table designed to include the major features of post-glacial fenland history. The latter has been slightly altered to accommodate present findings, and to it have been added the numbered forest zones described in this paper.

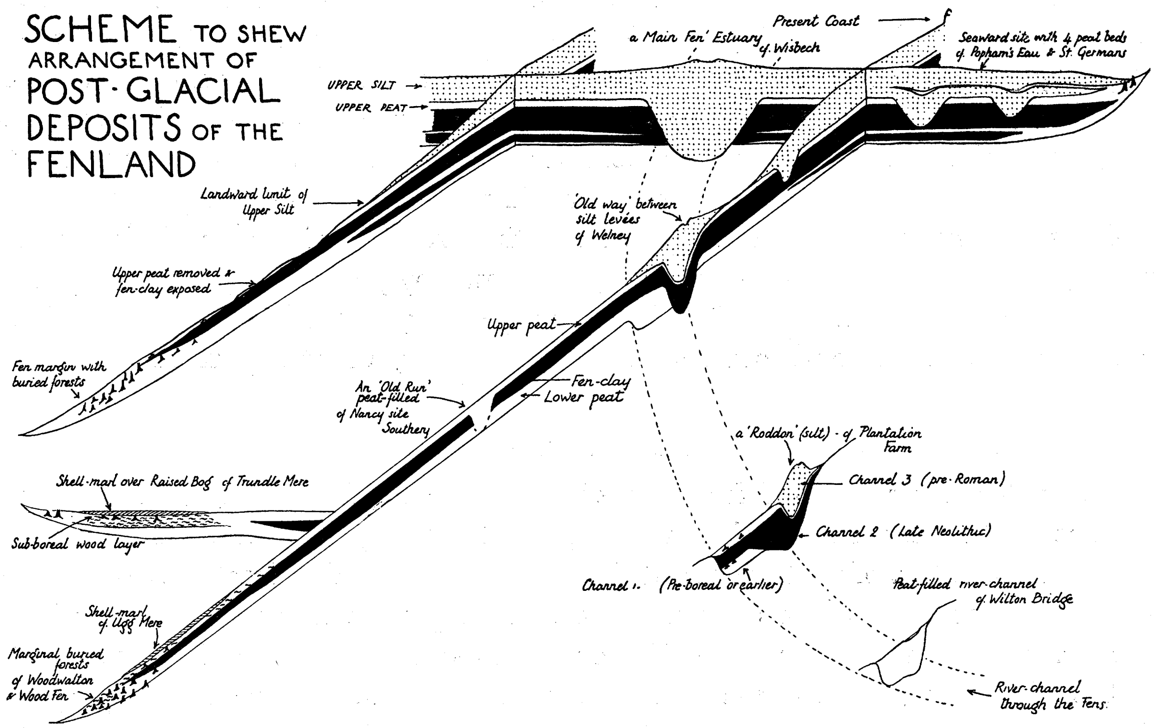

FIGURE 2. A purely schematic figure to show the type of variation in fen deposits found at different levels and at different distances from the sea. It only shows the principles of arrangement of the fen beds.

POLLEN ANALYSIS METHOD

It is not any longer necessary to explain in detail the principles of pollen analysis: they have been set out elsewhere (Godwin 1934). It will, however, be recalled that the method is based on the identification of the membranes of pollen grains of forest trees. These grains, widespread by the wind, have been incorporated in growing deposits of all kinds, and, given suitably anaerobic conditions, they are sufficiently preserved to be identifiable when extracted at the present day. Thus the examination of the pollen content of successive layers in a deposit will reflect the changes in forest composition which have taken place in the countryside throughout the whole period of its formation. By studies all over Europe it has become possible to establish a co-ordinated scheme of history for the complex development which the forests have followed in response to widespread climatic changes during and after retreat of the ice of the last glacial period. In this way pollen analysis reflects not only forest history but also the underlying climatic changes, and it may therefore be employed as a chronological scale against which other post-glacial events can be measured. It has, in fact, been accurately correlated on the continent with phases of human culture and with detailed geological history, such as the stages of the Baltic Sea and the deposition of de Geer's varved clays.

Several difficulties stand in the way of a direct correlation of continental results with those of the Fenland. In the first place some of the valuable index trees of the continent are absent from Britain, e.g. *Picea* and *Abies*, whilst others, such as *Fagus* and *Carpinus*, are here at their north-western limit, and form relatively limited areas of woodland, and those limited to specific soil types. In the second place it is to be expected that the more temperate and more oceanic climate of this country will tend to smooth out climatic changes so that changes in forest composition may be less rapid and less extensive than on the continent. For these reasons it is preferable to attempt to establish a correlation of forest history, as shown by pollen analysis, directly with our own post-glacial indices of archaeology, geology, and climate, before making comparison with the continent. This paper is, in effect, an attempt to do this.

Preparation

The material was prepared for analysis in varying ways, depending upon the nature of its contents. Peat samples, rich in pollen, were treated by a modification of the alkali method: about 2 g. of peat were heated in 25 ml. of 10% KOH until, by solution of the humic material, the mass had disintegrated completely. This was usually finished in 2 hr. Digestion was carried out in a boiling-tube with condenser, in a water-bath at 100° C. The digest was then strained through coarse muslin to remove larger plant fragments, and the filtrate was centrifuged and washed with water three times. After the final washing, the fine residue was mixed with about twice its bulk of hot safranin-glycerine jelly. After thorough stirring, five comparable slides were made from this jelly suspension.

Where the pollen was sparser the initial digestion with alkali and washing was followed by oxidation by the sodium chlorate method of Erdtman, and hydrolysis of the polysaccharides, such as cellulose, by hot acid. After washing, the mounting was done as before described.

For samples rich in silica or silicates the foregoing procedure was extended by boiling the sample for 2 or 3 min. in concentrated hydrofluoric acid, subsequently washing in 7% hydrochloric acid and then in water.

The results are presented as percentages of the total tree pollen, and the hazel is expressed as a percentage of this, although not itself reckoned in the tree pollen.

The local pollen component

In the great raised (*Sphagnum*) bogs, from which so many of the published pollen series come, the pollen catch is derived almost solely from the surrounding dry land, and its composition reflects a forest history directly controlled by climate.

It is one of the great disadvantages of pollen analysis work in Fenland that much of the peat was formed under brushwood, in which alder, and, to a less extent, pine, birch, and oak were present. The local influence of such woods is often clearly recognizable in the pollen diagrams, and it has been already shown in Paper I (Godwin and Clifford 1938) how the diagrams serve as useful indicators of local or general conditions of wetness or dryness of the fens themselves.

Any interpretation, therefore, of Fenland pollen diagrams has to take cognizance of the double source of the pollen rain, the one general and climatically controlled, the other reflecting local rather than general climate and influenced by successional development of fen vegetation and by such factors as movement of land- and sea-level, which alter drainage relations in estuarine regions.

From our summary of the correlations of fen beds reproduced in figure 30 (see p. 284), it will be clear that in the post-Boreal period the fens have suffered, broadly speaking, three phases of dryness, each terminated abruptly by a sudden increase of wetness with a gradual restoration of dryness. In the dry phases fen woods developed, and in the wet ones they were destroyed. The dry periods show marked local rise of alder pollen. In the wet periods a fall in the alder pollen indicates destruction of the fen woods, and then oak pollen from the upland rises in complementary fashion.

This alternation in succeeding periods of the pollen from local and from regional sources is, of course, better developed in some regions than in others. Those a mile or two from the fen margin, such as Old Decoy, show it best, but it remains a valuable index to Fenland history, and a recognizable component in all the pollen diagrams of the fens. It forms, as it were, a shifting background against which the regional climatic effects have always to be viewed. Where it is particularly desirable to exclude the local factors from a pollen series, some advantage can be gained by recalculating the values for oak, elm, and lime separately, since these are trees which are mostly characteristic of sites other than fen woods. The gain from doing this has already been shown (Paper I of this series).

Zoning of pollen diagrams

A study of the pollen diagrams of the Fenland and adjacent parts of East Anglia allows the recognition of the following zones. We must begin with the "post-glacial" period, since deposits of the "late-glacial" period corresponding with the Dryas clays and cold-temperate Allerød deposits of continental workers (e.g. Jessen, Gross, Nilsson and Schütrumpf) have not yet been recovered from this region. We have now proposed a series of numbered zones, based directly on the pollen analyses, into which the Fenland diagrams seem consistently divisible. These zones are here used for local correlations but they are based upon a consideration of those from a much wider area of Britain. We mention their possible relation to the Blytt-Sernander periods, but they are independent of that scheme.

Post-glacial period

Birch-pine zone IV. For this period evidence in the fens is remarkably scanty, and it can only be recognized with certainty at the base of the Brancaster (Judy Hard), and Old Decoy diagrams. It appears there to be characterized by the dominance of birch and pine, with smaller amounts of willow; but quantities of the warmth-loving trees such as *Ulmus*, *Alnus* and *Quercus* are already present discontinuously, together with small amounts of *Corylus*. The presence of alder and lime pollen in some diagrams is probably due to long-distance air transport of these grains. At the end of zone IV the dominance of birch gives place to that of pine. The end of this period is also marked by a sharp fall of the non-tree/tree pollen ratio, from which it may be inferred that former openly wooded land was becoming more densely forest-clad. We tentatively suggest that zone IV falls in the pre-Boreal of continental authors and corresponds with zone IV of Jessen for Denmark.

Pine zone V. The dominance of birch is replaced by that of pine (i.e. in East Anglia), and hazel is now present continuously at low values which rise rapidly at the end of the period. Very low but fairly continuous values of elm and oak are present. Alder and lime are practically absent, and a *Salix* maximum often occurs in the middle of the zone. We regard this zone as the first part of the Boreal period, and as corresponding with zone V in Jessen's zones for Denmark. It is to be noted that outside East Anglia the character of this zone may alter appreciably, notably in the west.

Pine-hazel zone VI. Zone VI is readily divisible into three minor zones, *a*, *b* and *c*. At the commencement of zone *a*, the oldest, pine is the dominant tree, and the mixed-oak forest trees and the hazel are present only in small amounts. Immediately, however, the hazel values rise rapidly to extremely high levels, beginning a series of peaks in the hazel curve which, in many diagrams, are not equalled at any time subsequently. As this is happening the values for pollen of oak and elm form continuous steady curves with a sharp initial rise. It is highly characteristic that the elm rises sooner than the oak, and at the level of the first maximum, elm pollen much exceeds that of oak. This phase is probably recognizable in other parts of Britain, and it can be found equally well in the diagrams from southern Sweden, Denmark and western Europe generally, although, hitherto, special attention has not been called to it.

Phase *b* is marked by the oak pollen values exceeding those of the elm, and by the continued absence of lime except in single samples. The alder, if present, is limited to low values. The pine values are lower than in phase *a*, but the hazel values, after falling from the peak in phase *a*, show other maxima.

Phase *c* continues to show oak and elm in the proportions of phase *b*, but here lime appears as a continuous curve which steadily rises into the following period: at the end of phase *c* lime pollen may exceed that of oak or elm. The alder values begin to rise during phase *c*, and rise rapidly at the end. Pine, however, shows a strong tendency to a secondary maximum in this phase, a fact probably attributable to a local dryness of the bog surfaces which allowed pines to grow upon them. If this is so we may expect the horizon sometimes to show other maxima, e.g. birch or even alder, or to have pollen spectra obscured by pollen destruction. It seems reasonable to recognize this phase as the "Boreal Wasserstandminimum" of continental writers. During phase *c* the hazel generally shows diminishing values.

Throughout all three parts of zone VI birch is present only in small amounts in this area, but where it occurs it is most abundant in the older phases, and diminishes upwards. *Salix* is practically absent. Zone VI is regarded as corresponding with the greater part of the Boreal period, which is made up by zones V and VI as in Jessen's zones for Denmark.

The extent to which these subdivisions of zone VI are recognizable can be gathered from a comparison of four East Anglian sites, namely, Broxbourne, Old Decoy, Peacock's Farm, and Judy Hard, Brancaster. Although it will be seen that the results from these four places agree substantially with the description given above for the course of pollen diagrams zones V and VI, there are several marked differences. For instance, in only one diagram (Judy Hard) is the hazel maximum of phase VI *a* clearly shown, and phase VI *c*, at Old Decoy, shows much more alder than the other sites. Such differences we regard as probably due either to the wide spacing of the samples or to local effects disturbing the general run of the diagram. It seems quite clear, for instance, that Old Decoy and Peacock's Farm both owe their very high pine values in phases VI *a* and *b* to the close proximity of the sandy "Breck" country, and the pine woods which doubtless covered this area were probably not very favourable to hazel undergrowth.

However, the validity of the three phases, we suggest, will be tested more satisfactorily when it is possible to compare diagrams from a much wider area.

Alder mixed-oak forest zone (*VII–VIII*). Properly speaking, the alder mixed-oak forest zone can be said to extend, in East Anglia, from the end of zone VI to the present day. We shall see, however, that the behaviour of the lime, beech, hornbeam and birch allow its clear separation into two zones VII and VIII, which are widely recognizable elsewhere in Britain.

Alder, oak, elm, lime forest zone (*VII*). The beginning of this period is marked by sudden replacement of pine by alder as the most abundant tree pollen. In some parts of the country it is birch which is thus displaced, but always the rise of alder takes place with startling suddenness. This is not likely to be connected with immigration of the tree, since in East Anglia, for instance, it has been present in small amount since zone IV. Its sudden explosive development over such enormously wide areas can only be due to widespread climatic change, and a change which would so affect the alder without substantially affecting the other warmth-loving trees in the diagrams can hardly be anything other than a great increase in wetness.

Another feature marking the beginning of zone VII is the rise of *Tilia* pollen to values exceeding those of the elm and sometimes those of the oak. These relatively high values for *Tilia* persist almost to the end of zone VII: in zone VIII *Tilia* is unimportant or absent. That the maximum development of the lime should be confined to this period confirms the idea that it represents the warmest part of the post-glacial period. Throughout zone VII so much of the Fenland peat was formed in alder fen wood that the local influence of alder greatly modifies the pollen diagrams, obscuring the effects of climatic variations on the pollen rain from the upland. It is only by utilizing the profound *local* changes that it is possible to subdivide the long zone. It is clear, however, that within zone VII were two major phases of relative dryness, and extension of woodland on the surface of the fens. During these phases the woods of the fen margin tended to develop alder, oak, yew, birch or pine woods, and pollen series which pass through such sites show the local influence of these trees in the diagram. At sites, however, removed from the fen margin, although peat continued to form, it showed little indication of a climatic effect on the general forest composition of the countryside round the fens. This, it seems to the author, is true also of most parts of Britain. The dry conditions of the latter part of the Bronze Age in much of Britain allowed pine and birch to colonize the dried surfaces of bogs, and to extend to unoccupied ground on the mountain side, but it did not allow pine and birch to displace the alder, mixed-oak forest in the general cover of the country as a whole. Thus, some bog diagrams show during this time pronounced birch and pine maxima, whereas others show no trace of them at all.

In the Fenland the formation of the fen clay very greatly affected the pollen diagrams by destruction of all but the most marginal fen woods, thus effectively setting a phase of wetness between two periods of dryness and extension of fen woods. It will thus prove possible over much of the Fenland to recognize within zone VII, four subzones: VII *a*, in which open sedge fens prevailed; VII *b*, in which the diagrams show very strong local influences of alder and sometimes also of pine and birch as well; VII *c*, in which the transgression of the fen clay stage has caused local effects to be very small; and VII *d*, a phase of partial recovery from the wetness of the previous stage, marked by the development of fen woods of alder in all but the wettest places.

It will be noted that fluctuations in the pollen from trees of the upland confirm the reality of these subzones, at least in the landward half of the fens. Subzone VII *b* has high *Tilia* values and quite low *Ulmus*, but within zone VII *c*, both are high, although *Ulmus* shows a well-marked minimum at the transition and also about two-thirds of the way up the zone. Another minimum in the *Ulmus* curve marks the transition to zone VII *d*, and very near the same level a *Tilia* maximum. At the end of VII *d* the *Tilia* curve is virtually extinguished, although that of *Ulmus* goes on. It will thus be recognized that the relative importance of *Ulmus* and *Tilia*, both trees of the upland, can be made to support an extension of the Fenland zonation, far beyond the Woodwalton area for which its importance has already been shown (Godwin and Clifford 1938).

It is naturally recognized that the clay-peat interfaces are not likely to be synchronous horizons over the Fenland as a whole.

Transition zone VII–VIII

The end of zone VII *d* is characterized in the Fenland by several marked changes in the pollen curves, which make it the most clearly defined horizon between the Boreal-Atlantic contact (VI–VII) and the present day. The characteristic features are these: (i) a well-marked but short *Pinus* maximum, (ii) the commencement of a substantial rise in *Betula* which is maintained in the following period, (iii) the extinction of the *Tilia* curve, or its sudden fall to low values, (iv) a temporary minimum in the *Ulmus* curve, and (v) the beginning of a steady rise in the curve of *Fagus*, which has been present irregularly before this.

It does not follow that all these criteria will be evident at all sites. The *Pinus* maximum, at fen-margin sites, may be merged in a longer period of dominance by local pine woods, or other fen woods. The same may be true of *Betula*. *Fagus* is also not of much diagnostic value save in sites on the eastern fen margin close enough to the chalk, on which the beech grew: this we know from the substantial amounts of pollen. The behaviour of the *Ulmus* and *Tilia* curves is more consistent, as both were widespread upland trees, but local pollen from fen woods may reduce their relative proportions so much as to give the curves a dubious validity. In this zone also the *Corylus* begins to rise, although this is more marked in the following zone. The *Corylus* curve also is much more irregular in behaviour than the rest, changing greatly from site to site.

Although these qualifications are necessary, it is, nevertheless, a striking fact that similar changes to these can be readily seen in other parts of Britain, as far afield, at least, as Somerset, Shropshire, and Cardiganshire. It represents, therefore, a well-marked and general climatic change, and it seems reasonable to regard it as the onset of the climatic "deterioration" which indicates the change from sub-Boreal to sub-Atlantic all over north-western Europe. At the same time it is evident that this "deterioration" was not necessarily sudden, and we propose to use the transition zone VII–VIII to cover this period of change. The cold and wet conditions of zone VIII, which we regard as equivalent to the sub-Atlantic, were by no means always recognizable in the local vegetation of the transition zone. Thus the *Pinus* pollen maximum is often related to local layers of pine wood, and the rising *Betula* to local birch woods. Zone VII–VIII must have still been conspicuously dry in many parts of the Fenland.

The upper part of the zone is marked by a distinct *Ulmus* maximum.

Alder-oak-elm-birch (beech) forest, zone VIII

In zone VIII the characteristic proportions attained by the pollen curves at the top of the transition zone are maintained. *Betula* and *Fagus* keep the high values reached there, and at sites near the eastern fen border *Carpinus* may appear as a continuous curve. *Pinus* has almost disappeared and *Tilia*, at least in the lower part of zone VIII, is practically absent. *Ulmus* continues present in fair amount, and a marked minimum, following the maximum at the top of zone VII–VIII, shows the beginning of zone VIII.

In some parts of the fens, especially the landward parts, the stratigraphy shows zone VIII to have been characterized by a great increase in wetness, so that the pollen diagrams show the pronounced effect of destruction of fen woods. The *Alnus* pollen diminishes and the diagrams more faithfully represent the forest composition of the countryside as a whole. *Quercus* tends to replace *Alnus* as the dominant pollen, but high values of *Betula* also persist. The rise of *Corylus* is particularly noteworthy.

It is unfortunate that for East Anglia few diagrams can be given which continue the curves with certainty up to a living bog surface of the present day, and it is probable that some, or all, of the deposits of zone VIII are missing from all the diagrams. Deposition of shell marl or of estuarine silt closes the record in some sites, and where these are not present cutting or wastage following drainage have removed the upper peat layers.

As we have indicated above, we regard zone VIII as corresponding with the sub-Atlantic period, or Jessen's zone IX for Denmark. It is not proposed to discuss at this stage how our zonation VII, VII–VIII, VIII corresponds with the near-continental sub-Boreal: sub-Atlantic contact, with its well-marked "Grenz-horizont". For the moment we need only say that our proposed transition zone is probably recognizable in Britain outside Fenland.

Zone VII probably represents the whole of the Atlantic and most, or all, of the sub-Boreal periods of the Blytt-Sernander scheme. At the present time there seems no means of distinguishing in the pollen diagrams of this country evidence for a clear separation of these two periods, and some alternative subdivision of the whole of this long period may well be found.

The broad correlations we have proposed are as follows:

	Fenland zones	Blytt and Sernander	Jessen's zones for Denmark
VIII	Alder-oak-elm-birch (beech) zone	Sub-Atlantic	IX
VII–VIII	Transition		
VII *d*		Sub-Boreal	VIII
VII *c*	Alder-oak-elm-lime zone		
VII *b*			
VII *a*		Atlantic	VII
VI *c*	Pine-hazel zone		VI
VI *b*		Boreal	
VI *a*			
V	Pine zone		V
IV	Birch-pine zone	Pre-Boreal	IV

Grouped diagrams from the Fenland basin

A. *The natural bed of the river Little Ouse*

The natural course of the river Little Ouse is extremely well shown by air photography, which picks out at once the meandering course of a silt roddon* running from

* A roddon is the bank formed by the natural levées of an estuarine river, now revealed meandering through the peat fens, although no stream remains. See Parts I and II.

near the Fenland margin at Wilton Bridge, crossing and recrossing the Mildenhall-Littleport road, and finally merging with the roddon of the Old Croft River near to Littleport (see figure 3). Only near Wilton Bridge does the river still occupy its natural channel.

Wherever investigated it has been found that the course of the roddon follows that of a wider channel cut deep into the fen floor and filled with post-glacial alluvial deposits. Within this old river is to be found the longest series of deposition yet encountered in the Fenland, and for this reason it may be chosen as the introduction to our co-ordination of Fenland pollen diagrams. It is the more satisfactory since, as we have already shown (Godwin and Clifford 1938, II), prehistoric men of many periods established themselves on the river side and left their traces stratified in its deposits.

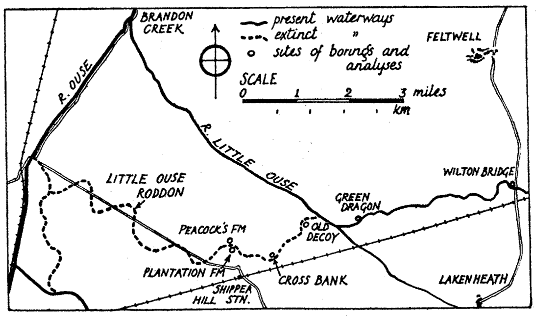

FIGURE 3. Sketch-map to show how the present channel of the river Little Ouse has been altered artificially, and to show the disposition of sites along the natural channel.

The sites we shall consider are Plantation Farm and Peacock's Farm which lie farthest downstream near to Shippea Hill, Wilton Bridge farther upstream and about 5·4 miles (8·7 km.) away, and Old Decoy which lies about midway between Shippea Hill and Wilton Bridge. It will be convenient to begin with the Old Decoy diagram, since it contains older deposits than the others.

Old Decoy (figure 4). This site lies within a meander of the Little Ouse roddon about 550 yd. (500 m.) south of its junction with the straight new artificial river: it is very close to the point where the upper roddon silts terminate upstream, and must also be close to the landward edge of the underlying fen clay. It will be seen that the stratigraphy shows an upper and a lower peat bed separated by soft fen clay. The latter is penetrated throughout by *Phragmites*, a clear indication of its deposition in brackish or nearly fresh water.

The base of the diagram, from 590 to 625 cm., falls within zone IV. *Betula* and *Pinus* are much the most important trees, but *Betula* clearly predominates. All the other warmth-loving trees are present, though not necessarily forming continuous curves, and it seems probable that the pollen of *Alnus* and *Tilia* at least has been blown from a long distance into a country sparsely populated with trees. This suggestion is strongly supported by the fact that the curve for the ratio of non-tree pollen to tree pollen has high values in zone IV, and falls sharply at the transition to zone V. Within zone IV there is also a continuous *Salix* pollen curve, a feature consistent with open conditions.

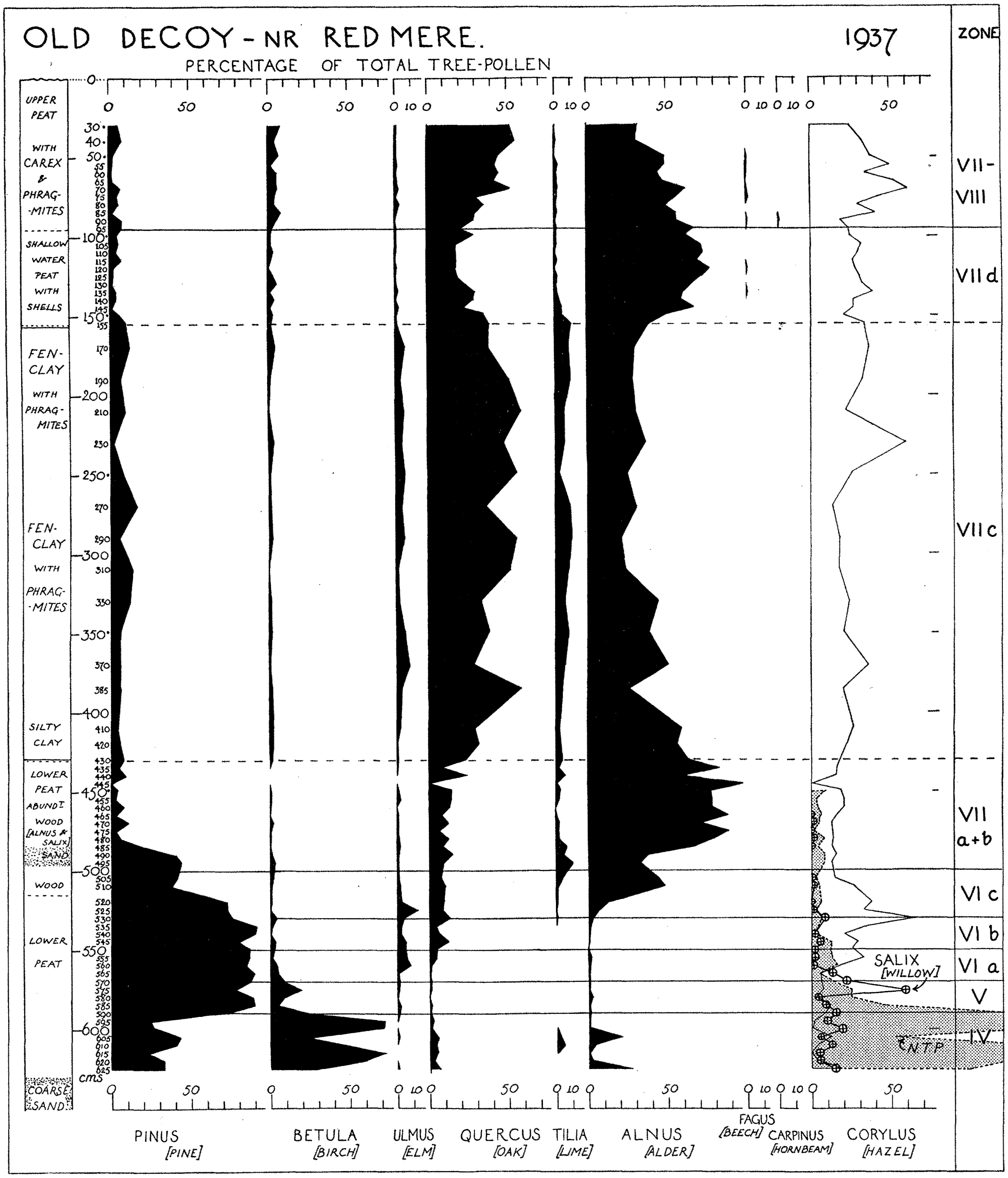

FIGURE 4. Pollen diagram for Old Decoy in the natural channel of the river Little Ouse, near the landward termination of the fen clay. The curve marked N.T.P. shows the ratio of non-tree pollen to tree pollen below 450 cm.

Following zone IV is a comparatively short zone from 590 to 570 cm. This is zone V, in which a sudden replacement of *Betula* dominance by *Pinus* dominance indicates marked climatic change. *Ulmus*, *Quercus*, *Alnus*, and *Corylus* continue in small amounts through the zone, but at the beginning of the next zone three of them show sharply rising values.

Zone VI, which begins at 570 cm., can be spoken of as the pine-hazel zone and is readily divisible into three subzones, *a*, *b*, and *c*. In the earliest (570–550 cm.), *Ulmus* preponderates over *Quercus* although both have risen sharply, and *Corylus* also rises abruptly to a maximum: *Tilia* is absent. Subzone *b* shows *Quercus* exceeding *Ulmus*, with high *Corylus* values and still no *Tilia*. The third subzone extends from 530 to 500 cm., and shows the establishment and increase of *Tilia*, the beginnings of replacement of *Pinus* by *Alnus*, and a depression of the *Corylus* curve. The *Ulmus* curve has also fallen. The transition to zone VII is extremely well marked. It shows the swift replacement of *Pinus* by *Alnus* as the dominant tree: in other parts of the country it may be *Betula* which is replaced in this way. Immediately above the transition there is a decided *Tilia* maximum, and at about this level there is a considerable amount of sand blown into the peat of the river channel. It presumably reflects some local effect of dryness and exposure of the ground surface.

Almost the whole of the rest of the diagram falls within zone VII, which is characterized throughout by the preponderance of *Alnus* and *Quercus* and the presence of fair amounts of *Tilia*.

We have already indicated that the subdivision of zone VII is determined by the incursion of the fen clay, so that the boundary between VII *d* and VII *c* lies at 155 cm., and that between VII *c* and VII *b* at 430 cm., VII *a* and VII *b* are not separable. It will be noted that the fen clay produces extremely large effects on the course of the diagrams. Zones VII *a*, *b*, and VII *d* are dominated by *Alnus* which was doubtless growing in local fen woods, but in zone VII *c* the *Alnus* falls, and all the pollen curves of trees from the upland show corresponding high values. This rise affects *Quercus*, *Ulmus*, *Tilia*, *Pinus*, and perhaps *Corylus*.

It is difficult in this diagram to say where the boundary should be set between zones VII and VII–VIII, but at 75 cm. it will be seen that *Betula* begins to rise, *Ulmus* exceeds *Tilia*, *Fagus* increases in amount, and there is some suggestion of a *Pinus* maximum. The probability that this is the onset of zone VII–VIII is supported by the fact that the peat there shows a change to a drier character.

A clear view of the stratigraphy of the peat beds at this site emerges from an examination by Dr M. H. Clifford of plant remains in the coarse residue of our peat digests. He reports as follows: "The Upper Peat appears throughout to be aquatic in character, with fresh-water shells from 155 to 80 cm. and *Cladium mariscus* from 130 to 60 cm., both constantly represented, together with smaller amounts of *Scirpus* and oospores of the Characeae. At the 40 cm. level fern sporangia become abundant, together with cyperaceous rootlets and woody material: these may well indicate the beginning of a drier stage of growth of fen woods or carr.

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"The Lower Peat has a well-developed wood layer from 520 to 440 cm. with occasional sand grains. Wood of *Alnus* and *Salix* is present, and at 470 cm. *Quercus* is represented by leaf tissue. The most interesting identification is, however, that of the woodland moss, *Neckera complanata* at 430 cm., just beneath the fen clay."

It will be recalled that the formation of fen woods at the top of the lower peat has already been widely recognized, and it will be shown later in this paper that a similar development occurs in the upper peat some distance above its junction with the fen clay.

Shippea Hill. At Shippea Hill two investigations have been made by the Fenland Research Committee, and their results for the relationship of stratigraphy and archaeology have been recalled in Paper II (Godwin and Clifford 1938).

The pollen diagram through the lower peat bed at Peacock's Farm (figure 5) shows that the bottom 50 cm., or thereabouts, is referable to zone VI, and it is quite easy to recognize the subzones *a*, *b*, and *c* on the criteria already given. It is clear that the bottom sample is very near the end of zone V. About 120 cm., the diagram is referable to zone VII *a* and, above 46 cm., to zone VII *b*, for there the wood peat reflects very dry conditions and the pollen has been too badly preserved for analysis.

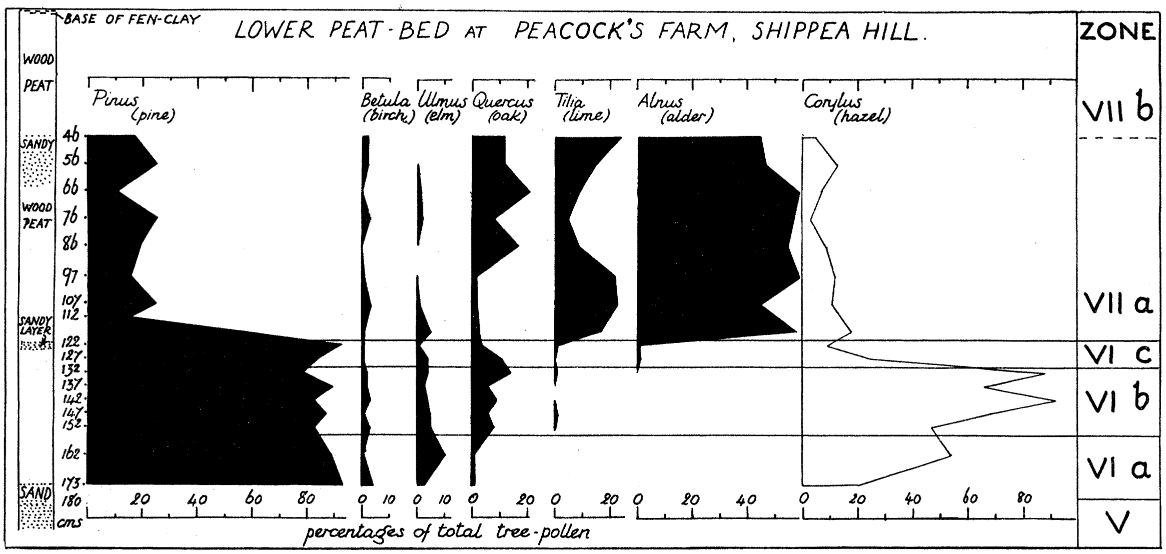

FIGURE 5. Pollen diagram through the lower peat bed at Peacock's Farm, near Shippea Hill. It lies in the natural channel of the river Little Ouse below the fen clay.

It is very interesting to note that at the very end of zone VI *c* is the sandy layer which contained Mesolithic (late Tardenoisian) artefacts. A similar sandy layer at Old Decoy was perhaps slightly above this level.

Another sandy layer occurs between about 46 and 66 cm., in the Peacock's Farm site, that is, at about the transition from zone VII *a* to VII *b*, and this contained Neolithic *A* artefacts.

It is interesting to recall that pollen analyses through the lower peat made previously at the Plantation Farm site (Clark *et al.* 1933) showed an equally clear indication that the base was referable to zone VI and the upper part to zone VII. Moreover, from very close to the bottom of the lower peat one of the borings brought to the surface a small flint flake evidently struck by a microlithic technique, and embedded in a peat sample probably belonging to zone VI*b* or VI*c*.

There is very strong evidence that in north-western Europe the period II of the Mesolithic (Clark 1936) corresponds broadly with zone V and VI.

At the Shippea Hill sites the fen clay was not subjected to pollen analysis, but analysis, from such of the upper peat as remains, has been carried out both at Plantation Farm and at Peacock's Farm. These results are given in figure 22 (see p. 273). The two series are very similar and can be almost entirely referred to zone VII*d*. The increasing dryness after the cessation of the fen clay formation is shown by the displacement of oak by the alder and a corresponding fall in the *Corylus*. This probably marks the establishment of local alder fen woods. The recognition of zone VII*d* is strengthened by the high values of *Tilia* at the base, rapidly diminishing towards the top. It seems probable that at Peacock's Farm, the transition to zone VII–VIII occurs about 60 cm., for there the beech values rise suddenly. On the other hand, the rise of aquatic pollen shows increasing wetness. Probably at Plantation Farm zone VII–VIII begins at the very top of the series. Both at Plantation Farm and Peacock's Farm it has been clearly shown that immediately over the fen clay there occurs an early Bronze Age horizon, which is thus in the beginning of zone VII*d*.

All the more recent peat has been removed from the top of these sites, as is shown not only by the pollen sequence, but by the low level of the present surface, and the virtual absence of the shell marl characteristic of the last stages of Fenland history in this region.

Wilton bridge. A boring put down beside the present river at Wilton Bridge evidently fell within the original channel of the Little Ouse for it showed a depth of 480 cm. of peat, in which, however, the stratigraphy was rather ill-marked. The pollen diagram (figure 6) clearly shows that the peat below 385 cm. probably formed in zones VI*b* and VI*c*, the very severe preponderance of pine being no doubt due to the position of this site within the Breckland margin.

The peat from 385 to 147 cm. lies within zone VII, but the site is sufficiently far outside the area of the fen clay for the diagram to have been beyond reach of the effects of this period, although the field notes show a zone of peat (about 230–260 cm.) in which wood is infrequent. At 147 cm. the sharp transition to zone VII-VIII is clearly marked. There is a *Pinus* maximum, *Betula* thereafter maintaining high values. *Tilia* shows a great diminution, *Fagus* forms a continuous curve, *Alnus* is displaced by *Quercus*, and *Corylus* rises suddenly. The 100 cm. level may be regarded as the beginning of zone VIII, in which the same changes are maintained. These changes show a fuller representation of the general cover of the Breckland than in zone VII, where the drier conditions allowed alder fen woods to dominate the local pollen rain.

It should be noted for comparison with the other sites in this series that from 360 to 450 cm. the peat contains very abundant wood, and that about the transition of zone VI to zone VII the pollen is small and decayed, whilst at 350 cm. there is silt in the peat.

Green Dragon. The surface of the peat at Wilton Bridge was +8·7 ft. O.D. Thus the base was about −7 ft. O.D. at this point. Nevertheless, the fen clay evidently did not

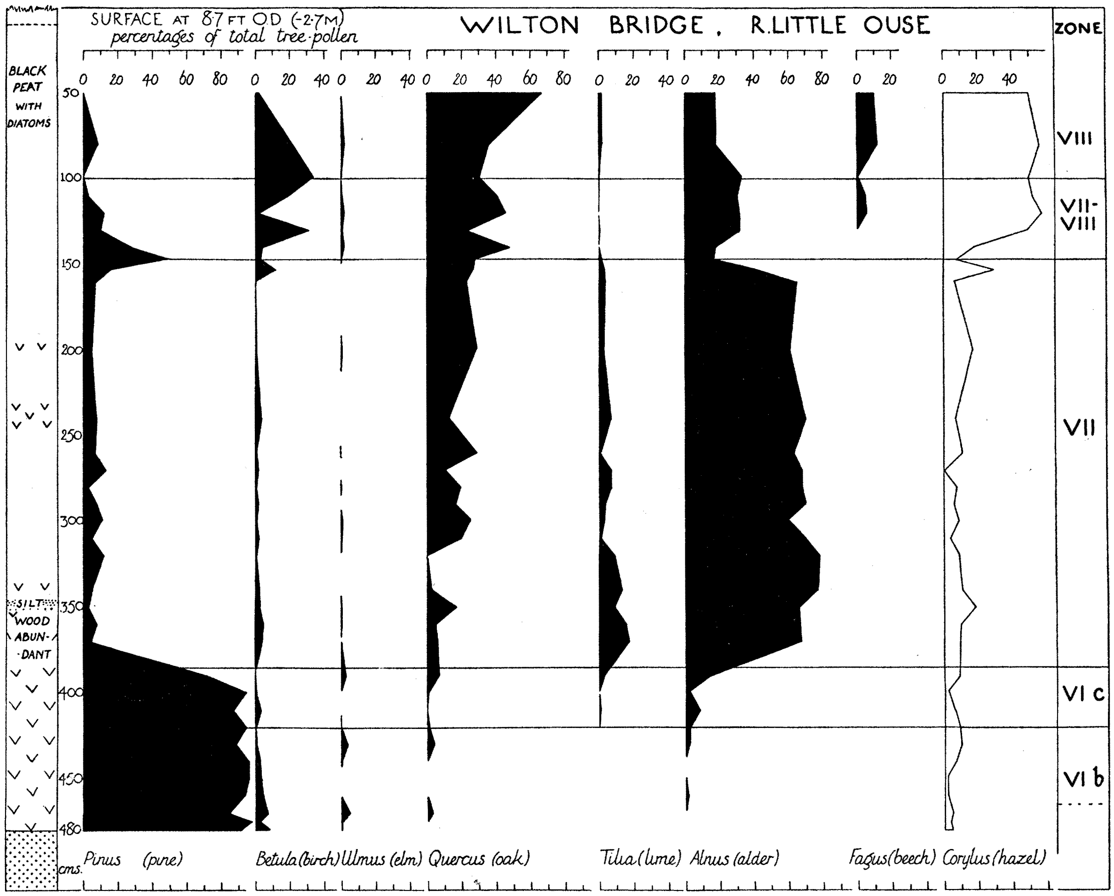

FIGURE 6. Pollen diagram from the natural channel of the river Little Ouse at Wilton Bridge. For symbols see figure 7.

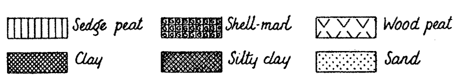

FIGURE 7. Key to symbols for stratigraphy employed in figures 6–11.

extend into it. A boring was therefore made about midway between Old Decoy and Wilton Bridge, still within the channel of the Little Ouse opposite the "Green Dragon" and the old bridge at the northern end of Botany Bay. The boring here also showed no sign of fen clay, but *Carex* peat with occasional wood and fresh-water shells extended down to sand at 420 cm.

Although it has not been possible to trace with certainty the former channel between Old Decoy and this site, there can be little doubt that they do in fact lie in the same channel. This is of importance because it shows absolutely no trace *on the landward side* of any deposit related to the fen clay, and thus makes it extremely improbable that this deposit was brought down by rivers from the uplands round the fen basin. It must therefore have been sea-borne.

Cross Bank. About midway between Old Decoy and the Shippea Hill sites the Little Ouse roddon crosses the artificial structure known as Cross Bank; close to this point a boring put down in the middle of one of the meanders of the roddon showed the following section:

cm.	
0– 75	Black *Carex-Phragmites* peat.
75–120	*Carex* peat with sallow wood at bottom.
120–160	Wood peat with some sallow.
160–170	Transition.
170–390	Soft grey clay with abundant *Phragmites*.
390–420	Transition to wood peat.
	Boring discontinued—base of the channel not reached.

It will be seen that this sequence confirms the general character already attributed to the other sites, notably the dryness indicated in the wood peat just above and just below the fen clay, and the decidedly fresh-water tendency shown by the abundant *Phragmites* in the fen clay.

It seems very probable that other Fen rivers had channels like that of the Little Ouse cut deep into the floor of the Fens. In particular, borings done by the river Great Ouse Catchment Board have shown such a channel for the river Lark and the erection of railway and road bridges in the Fenland often calls attention to them. The pollen zonation at the base of Old Decoy shows that the erosion of such channels must have taken place at least as early as the pre-Boreal period, but it is to be noted that erosion to a present depth of -20 ft. O.D. would have been quite possible at that time, since pollen analyses of peat from the bed of the North Sea have also been shown to be of pre-Boreal age (Godwin 1934). At this time the sea-level was some 200 ft. (61 m.) lower than it is now in relation to the land.

Deposits of as great an age as this are very rare outside the ancient river channels of the Fenland, and peat formation did not become general over most of the Fenland until some time in zone VII *a* or *b*. Thus, although at Plantation Farm an upper and a lower peat bed separated by fen clay are present continuously outside the river channel, the lower peat bed is only a few inches thick and clearly post-dates zone VI: the same phenomenon will be evident in diagrams considered later.

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B. *The Wicken-Upware and Methwold districts*

The sites in these two areas merit consideration together because they show fairly long and continuous peat profiles which are uninterrupted by the fen clay or fen silts, since they lie outside the range of extension of these deposits. Within the Wicken-Upware district pollen diagrams have been made for the sites Wicken Fen B, Reach Fen B, Swaffham Drain A and Swaffham Drain B. There are also a few less important sites from which subsidiary evidence is available.

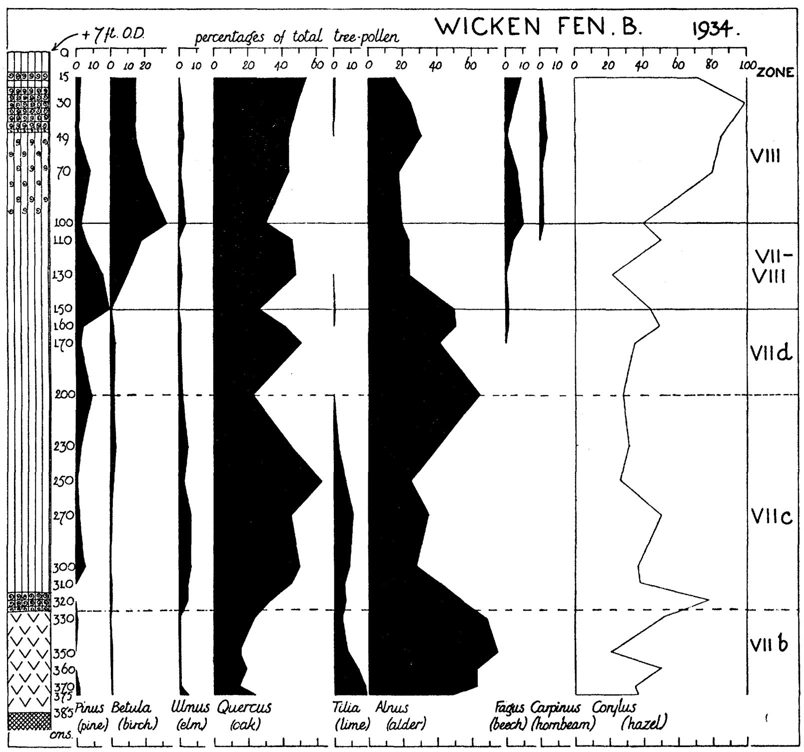

FIGURE 8. Pollen diagram from the main drove at Wicken Fen, Cambs. The site is outside the range of the fen clay. The top of the figure passes through a layer of shell marl which is well-developed over most of the fen. For symbols see figure 7.

Wicken Fen B. Wicken Sedge Fen is a large area of undrained fenland carrying semi-natural fen vegetation and, though its surface lies at +7 ft. O.D., some feet above the surrounding drained fen, it is kept wet by its enclosing banks of Gault clay. It is unlikely that peat has been cut from the old droves, or that drainage has much affected them save, perhaps, in the last two or three centuries. The pollen series from borings in the drove therefore probably extend almost to the present day. The first boring in the Main Drove was 300 yards (275 m.) from the landward edge of the fen, and showed peat 2·7 m. in depth over Gault clay. The lower part of the peat was very woody. The second boring was 10 yards (9 m.) from Drainers' Dyke and showed the stratigraphy set out beside the pollen diagram in figure 8.

On the Gault clay rests a wood peat which corresponds with a pronounced local preponderance of alder pollen. At 326 cm. the wood peat is replaced by a sedge peat, the base of which is shelly, and with the onset of this wetter phase comes the partial displacement of *Alnus* by *Quercus* pollen. By 200 cm. the *Alnus* has recovered its dominance, and, although fen-wood peat is not present here, we can only interpret the diagram as reflecting local increase in the development of such woods in a period of comparative dryness. The interpretation now advanced of this alternation of two dry periods in which fen woods developed, separated by a middle wetter period, is that they represent zones VII *b*, *c*, and *d*, respectively, of our main sequence, the wetness of zone VII *c* being the effect produced by ponding up of fresh water during the fen clay transgression, in those marginal regions beyond reach of deposition of clay itself. This interpretation receives strong confirmation from two sources other than the local stratigraphy, namely, the levels and the regional components of the pollen diagrams.

Thus the transition from zones VII *b* to VII *c* at 326 cm. is at −3·5 ft. O.D. At Shippea Hill the fen clay extends to a height of about −2·0 ft. and elsewhere to somewhat over O.D. When we consider that the clay was deposited in water somewhat above this level, it is clear that at any rate the late stages of the fen clay transgression must have been felt at Wicken at the level just mentioned, and might well have caused replacement of fen woods by sedge fen.

The subzone VII *b*, moreover, shows *Tilia* values greatly exceeding *Ulmus*, whilst in zone VII *d* *Tilia* has almost disappeared. This behaviour of the upland trees has already been made a basis for correlating the fen diagrams in the Woodwalton area (Godwin and Clifford 1938, I), and appears to characterize these zones widely in the Fens.

It is clear that the 150 cm. level represents well-defined changes in the pollen series. There is (i) a pronounced *Pinus* maximum, (ii) the beginning of a high *Betula* curve, (iii) absence of *Tilia*, (iv) the establishment of a substantial *Fagus* curve, (v) the *Carpinus* curve in smaller amount following the *Fagus* curve, and (vi) a pronounced rise in the *Corylus* curve. There can be little doubt that this indicates the transition zone VII–VIII already noted at Wilton Bridge. It ends at the 100 cm. level which is here accompanied by a clear stratigraphy emphasizing the marked increase of wetness during zone VIII. From 100 to 49 cm. the sedge peat contains abundant fresh-water shells, but from 49 to 12 cm. there is a stiff white shell marl which could only have formed under open-water conditions. This shell marl is, at least in a broad sense, part of the same formation of shell marl which Skertchly described as so widespread in the south-eastern Fenland. From its superficial position we can be sure that it belongs to the most recent stage of fen development and is probably to be equated with the shell marl exposed by the drainage of Fenland meres within historic times. The surface of the shell marl at Wicken is thinly covered with sedge peat, but one cannot say how far this replacement of shell marl reflects dryness due to drainage, dryness due to climatic change, or dryness following natural hydroseral development.

Reach Lode (figure 9). Close to the bank of Reach Lode two borings were put down in May 1937, but the stratigraphy is so similar in both that only one will be described, namely, that from which pollen samples were taken. This site, Reach B, lies about 1430 yards (1300 m.) east from the junction of Reach Lode with Wicken Lode.

The gross stratigraphy shows the same threefold character as Wicken B, a lower wood peat, a middle sedge peat and an upper shell marl, and the pollen diagram also follows closely the character of that at Wicken B. The top of zone VII *d* is probably near the top of the diagram, and the junction of zones VII *d* and VII *c* about 115 cm. The junction of zones VII *b* and VII *c* lies about 235 cm. It seems likely that the base

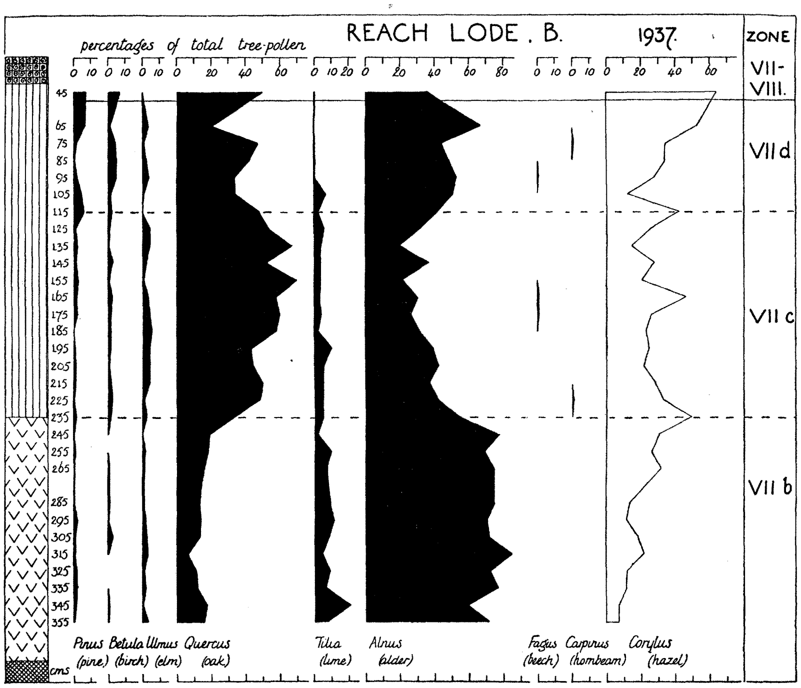

FIGURE 9. Pollen diagram from beside the bank of Reach Lode. The upper layers have been destroyed by cultivation. For symbols see figure 7.

of the series is somewhat older than the base of the Wicken diagram, for the wood peat of zone VII *b* is rather deeper. Once again the levels do not contradict the view that subzone VII *c* corresponds with the fen clay, for the top of the wood peat, estimated by reference to the lode water-level, lies at $-5{\cdot}2$ ft. O.D. and the top of zone VII *c* at $-1{\cdot}3$ ft. O.D.

It should be mentioned that at 275 cm. in this series (and at an equivalent level in the other Reach boring) there was, for a few centimetres, a slight admixture of soft grey clay with the wood peat. We are not inclined to regard this as more than a quite local effect in view of the general absence of fen clay from this district.

Swaffham Drain. A fortunate chance allows us to bring an archaeological find into correlation with the stratigraphy and pollen zonation of this district.

In March 1938, deepening was being undertaken in the portion of Swaffham Engine

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Drain close to the pumping station at Upware, through which the waters of Swaffham Fen are pumped into the river Cam. In this process Mr Hall of Wicken, who was trimming the bank scooped by the mechanical excavator, dislodged with his shovel from the intact peat wall a polished stone axe (see plate 21, A and B). Although he did not mark the site at the time, the peculiar relation of the path on which he stood when he touched the axe enabled him to identify the vertical position very closely (about plus or minus 3 in. (10 cm.)), and the lateral position somewhat less certainly. It was thus possible to say with fair certainty from which level the axe came in relation to the stratigraphy and pollen samples afterwards taken. The site was 300 yards (275 m.) westwards along the drain from the pumping station.

At the axe site the section was as follows:

cm.	
0	Surface.
0– 80	Dark brown crumbly peat, the upper part much disturbed.
80–112	Dark brown fibrous peat.
105	Stone axe.
112–125	Wood peat, consisting mostly of alder. Lowest trees with roots penetrating layer next below.
125–155	Clayey silt.
155–165	Fine sand and gravel.
165–225	Coarse sand.

A series (A) of samples for pollen analysis was taken at this site.

Only a few yards away the bank showed a much clearer and fuller stratigraphy.

cm.	
0	Grass-grown surface.
0– 10	Surface soil.
10– 30	White shell marl.
30–100	Black very decomposed fen peat—probably a sedge peat with a basal transition layer of reed peat (*Phragmites*).
100–130	Alder wood peat with few sallow, (?) ash, and occasional large prostrate oaks, representing many generations of tree growth, the earliest rooting in the layer below.
130–230	Silty sand and fine gravel.

This sequence was found still better developed in the bank, some 48 yards (44 m.), towards the pumping station from the axe site. From the cleaned face, samples (series B) were taken for pollen analysis. The stratigraphy was:

cm.	
0– 40	Made soil.
40– 95	Shell marl.
95–205	Black sedge peat.
205–240	Alder-wood peat.
240–250	Silty clay.
250–	Sand.

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The sands and gravels shown below the peats in these profiles form a bank on which the pumping station is built: westwards along the drain they thin out and disappear, the peat then resting on the surface of Gault clay, which also underlies the sands and gravels.

Examination of the bank confirmed the threefold division of the peat beds evident in these three profiles. Material digested with alkali in the laboratory yielded clear confirmation of the field diagnoses of the peat types. Throughout the fibrous sedge peat the samples were rich in rootlets of sedge, and most of them contained the fruits of the sword sedge (*Cladium mariscus*) which still grows abundantly in Wicken Fen, a bare mile away, and which very probably formed most of this peat. This same layer yielded some oospores of the Characeae (stoneworts), decayed moss stems, and the middle of the layer in series B was interrupted by a thin layer of small twigs and abundant wood.

From the basal wood peat the trees mentioned were identified microscopically, also one fruit of alder, together with two fruits of *Carex* sp. and one fruit of *Ranunculus*.

It will be recognized that the gross stratigraphy is the same as that at Wicken B and Reach Lode B. As at those sites, the pollen diagrams yield strong confirmatory evidence of the local stratigraphy, as well as clues to climate and chronology by their reflexion of the general forest cover of the uplands.

The diagram from Swaffham Drain B (figure 11) shows two very striking maxima in the *Alnus* pollen curve, one near the beginning and one near the end of the profile. Of these the former develops within the layer of wood peat. If we maintain the interpretation already advanced for Wicken B and Reach Lode B, it will be clear that the two *Alnus* maxima fall into zones VII *b* and VII *d*, with the depression corresponding to the fen-clay stage of zone VII *c*.

Indications of the nearness of zone VII–VIII at the top of the diagram may perhaps be seen in the rising *Pinus* and *Betula*. As at Wicken and Reach Lode, this horizon would still be beneath the shell marl.

The pollen diagram of Swaffham Drain A (figure 10), taken at the axe site itself, evidently covers a shorter sequence than the B series, and represents only the basal portion of that series. It shows the same *Alnus* pollen peak giving way to high values for *Quercus* pollen where the wood peat layer is replaced by sedge peat. The axe horizon was just above this transition, therefore lying just over the boundary between zones VII *b* and VII *c*, the only two zones here covered by the pollen series.

I am very much indebted to Dr Grahame Clark for an opinion on the typology of the axe. He informs me that axes of this type are commonly associated with both Neolithic A and Neolithic B cultures, but that their use probably persisted during the Bronze Age in places where conditions delayed the widespread adoption of metal. A rock-slice from the axe was cut and examined by Dr F. Cole Phillips and Dr Nockolds of the University Department of Mineralogy and Petrology, Cambridge. They reported that the axe is made of a "rather decomposed andesitic rock". Mr F. S.

Wallis of the Bristol Museum and Art Gallery reported that the axe was made of the Graig Lwyd rock of Penmaenmawr, north Wales. In 1919 Hazzledine Warren described at this site a "neolithic Sheffield", a tremendous prehistoric manufactory of stone axes (Warren 1919, 1922), and since that time the products of this site have been

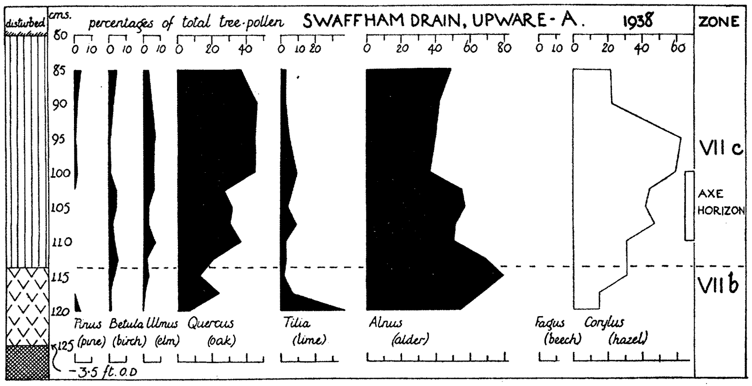

FIGURE 10. Pollen diagram from the site of discovery of the Neolithic stone axe on the Swaffham Engine Drain near Upware. For symbols see figure 7.

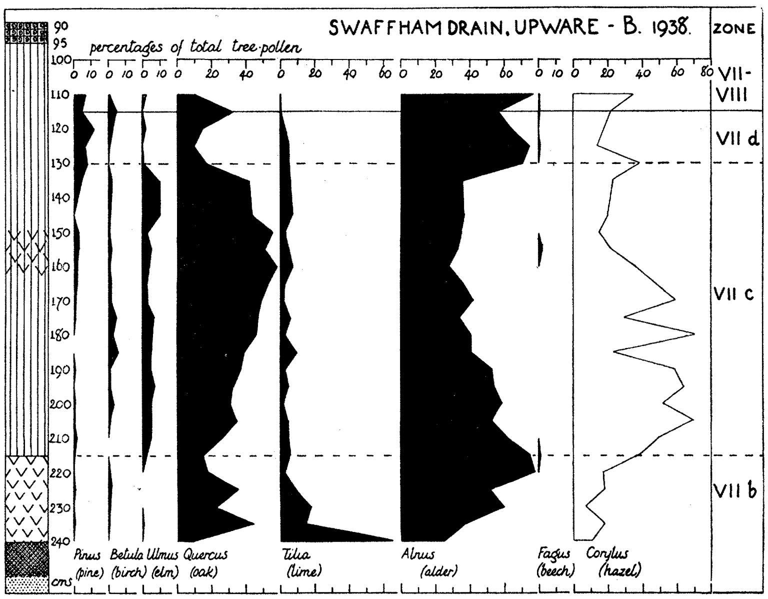

FIGURE 11. Pollen diagram from site on Swaffham Engine Drain near Upware. This site is adjacent to the Neolithic axe site (figure 10), but covers a longer sequence of undisturbed deposits. For symbols see figure 7.

found very widely in this country. After seeing rock slices, kindly sent to us by Mr Hazzledine Warren, from flakes taken at the flaking sites on Graig Lwyd itself, Dr Cole Phillips and Dr Nockolds agree that the marginal part of the Penmaenmawr intrusion very probably did supply the axe material. Professor O. T. Jones, F.R.S., agrees with this view, and the absence of other known sites of the manufacture of such andesitic axes makes this derivation almost certain. In this case, Dr Grahame Clark informs me that it cannot well be earlier than Neolithic "B" in age, nor is it likely to be much later, a dating of great interest in view of the stratigraphy of the finding-place.

It accords satisfactorily with the archaeological correlations so far mentioned, that a late Neolithic horizon should fall into the end of zone VII*b* or the beginning of zone VII*c*, for at Shippea Hill the Neolithic "A" horizon was in the early part of zone VII*b*. Moreover, in the investigations made by the Fenland Research Committee on the Essex coast (Warren *et al.* 1934), it was shown that continuous occupation of a living surface (now revealed on the shore) had lasted until the "B" beaker period, and then had apparently been ended by the deposition of a blue clay which was regarded as the equivalent of the fen clay farther north. It is very striking that here at Upware we again have an artifact of late Neolithic age just below the presumed horizon of the base of the fen clay. The likelihood that the transition from zone VII*b* to VII*c* at this axe site really corresponds with the phase of increasing wetness produced by the fen clay transgression is not contradicted by the levels, for this boundary at the Swaffham Drain sites lies at −3 ft. O.D.

Brett Fen. In the agricultural operations on the drained parts of Burwell and neighbouring fens, large trees are constantly encountered. As the drained peat wastes away they come within reach of the plough and must then be dug out by the farmer. They are usually prostrate oaks, often of great size, for example 70–90 ft. of straight bole below the first branch, the form of a typical high forest tree. Several such trees were encountered in the east boundary dyke of Brett Fen, quite close to Wicken Poor's Fen. It was of interest to determine the growth conditions of these trees, and in August 1933, with Dr T. M. Harris, the author excavated a large stump visible in this dyke at about 40 yards south of Monks' Lode. The tree had a radius of about 0·4 m., and showed about thirty-five annual rings per decimetre. A section dug about 1·5 m. from the centre of the tree showed 0·8 m. of peat overlying stiff grey clay with typical Gault clay fossils. Stout roots of the oak penetrated directly into this clay to a depth of at least 1·0 m., thus showing beyond doubt that the tree antedated the phase of water-logging and peat formation. This is doubtless true of most of the big trees excavated at this level. Nevertheless, the lower peat is densely crowded with wood, mostly alder, and clearly represents the fen-wood phase (zone VII*b*) already described.

The comparative dryness of this part of the Fenland in the oak-forest and alder-wood stage corresponds with the frequency with which polished stone axes have been found there.

It will be recalled that Fox (1923) has also laid stress on the abundance of Bronze Age remains from this portion of the Fenland. The sites we have so far examined all show the indications of alder fen woods in zone VII*d*, but very little indication of dryness in the gross stratigraphy. It seems probable that such effects of dryness were still more marginal than the sites we have here described, or were more developed in zone VII–VIII which lies at the top of our diagrams. By now peat digging, coprolite digging and peat wastage have removed most of the peat from which much evidence could be sought.

Methwold Fen—W. Methwold Fen is a large area lying between the "island" of Southery and the Chalk upland of Methwold to the east. It is convenient to consider it here, for, although rather far distant from Upware and Wicken, it also contains long pollen series which lie at, or outside, the margin of the fen clay. The first of these sites, Methwold Fen—W, is on the property of Mr Steward, 1·9 miles (3·1 km.) north-east of Southery, about 500 yards (457 m.) north of the north-west corner or Decoy Wood, and about 500 yards west of the road between Sam's Cut Drain and Five Mile House on the Wissey. This position is rather close to the upland on which stands the village of

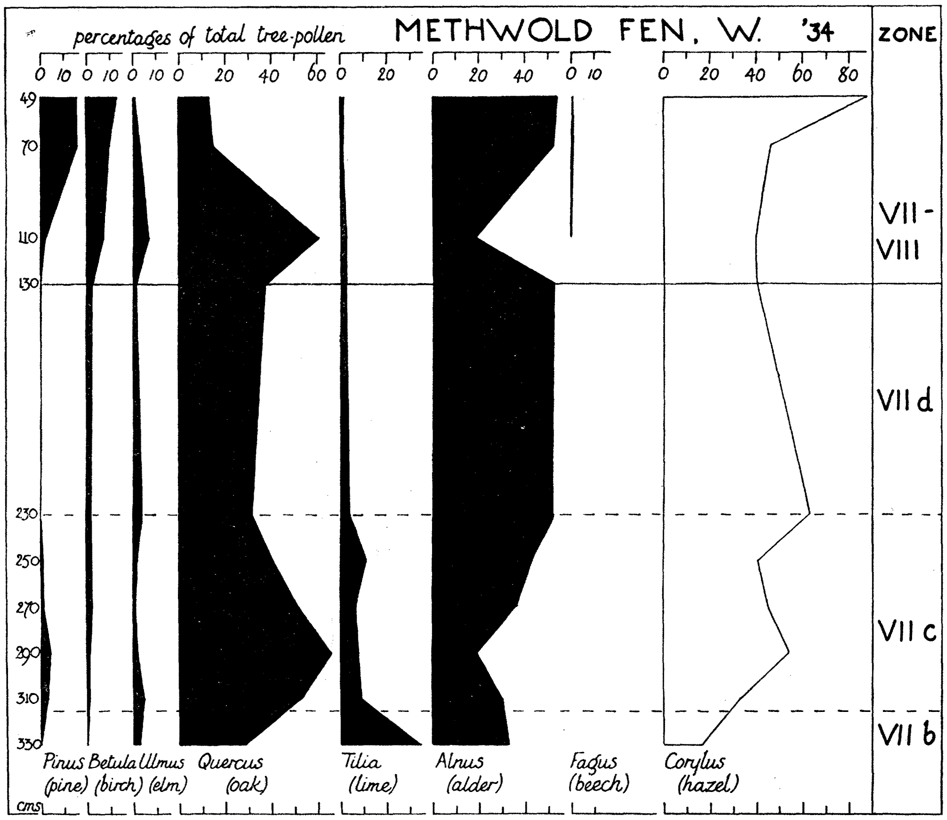

FIGURE 12. Pollen diagram, Methwold Fen, W. Sparseness of pollen is responsible for the long gaps between counted samples.

Hilgay. The pollen diagram (figure 12) suffers from a large gap (180–230 cm.) in which pollen was too sparse to count, but is understandable by reference to the Wicken B diagram (figure 8). The *Tilia* curve at the base is very similar. It is clear that the diagram above 130 cm. should go into zone VII–VIII: the *Pinus*, *Betula*, *Ulmus* and *Fagus* curves indicate this clearly and the rest do not disagree. Below 130 cm., the diagram falls entirely into zone VII, and, judging especially from the behaviour of the *Alnus*-*Quercus* relationship and the *Tilia* curve, we have zoned the diagram 130–230 cm. zone VII*d*, 230–315 cm. zone VII*c*, 315–330 cm. zone VII*b*. Unfortunately, the gross stratigraphy was difficult to make out, but the field record shows at 270 cm. downwards a transition to a grey silty peat full of *Phragmites*. This falls in the zone VII*c* and may well represent the marginal fen clay itself, for the underlying fen floor at 330 cm. is coarse sand and gravel. The field notes also record wood as more abundant in the peat between 150 and 250 cm., which would fall within zone VII *d*.

Queen's Ground, Methwold Fen. This site lies close to the fen margin, 1·8 miles (2·9 km.) south-west of the village of Methwold Hithe. It is of particular interest as the site of the discovery of a late middle Bronze Age spear in conditions which allowed its provenance to be established with fair certainty (see references in Parts I and II). Its horizon is given in the pollen diagram (figure 13), and it is interesting to note that at the same horizon in the peat cuttings close by was found a prostrate yew tree with a double trunk 12 ft. (3·6 m.) long, and a root crown indicating growth *in situ*. This reflects the

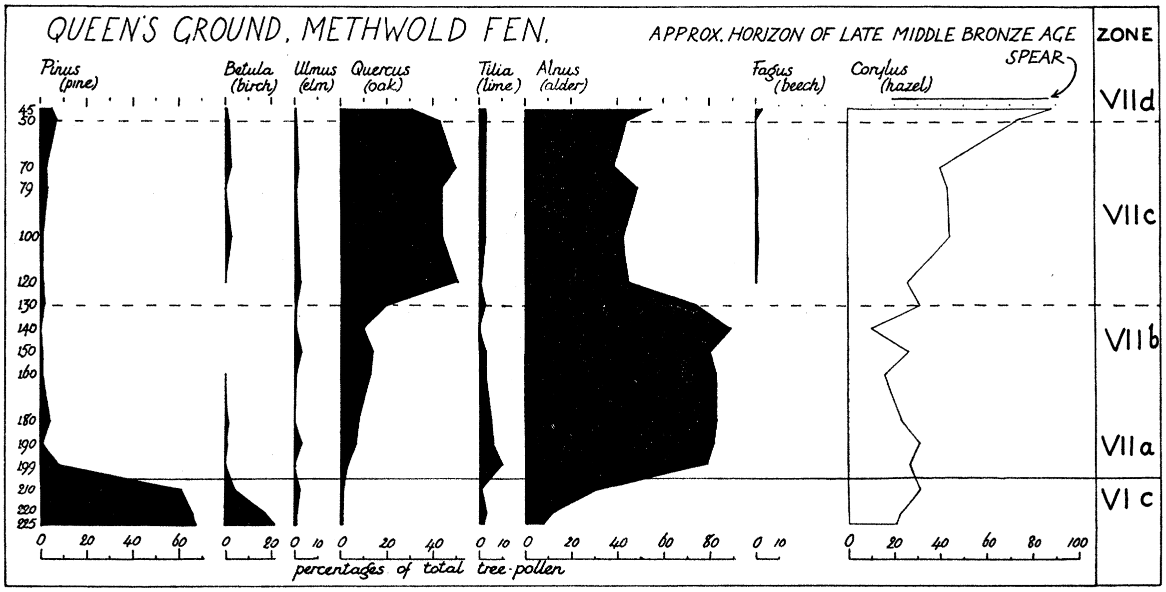

FIGURE 13. Pollen diagram at Queen's Ground, Methwold (referred to in map of figure 1 as Methwold Fen, "E"). The probable horizon of discovery of a late Middle Bronze Age spear is shown just above the top of the diagram.

dry conditions of the period and confirms the suggestion that the diagram above 50 cm. falls in zone VII *d*. The rising *Pinus* curve agrees with this and makes it not improbable that the spear and yew-tree horizon was at the base of zone VII–VIII. From 50 to 130 cm. falls into zone VII *c*, and from 130 to 205 cm. into zones VII *a* and *b*, in which the *Alnus* curve is very high. From 205 cm. to the base, which lies upon boulder clay, the diagram falls within zone VI *c*. The transition VI–VII is very clearly marked by the replacement of *Pinus* and *Betula* by *Alnus*, and the high *Tilia* values at the base of zone VII *a* are very typical. It is unusual to find peat of zone VI in Fenland sites other than the old river channels: its occurrence here is probably related to the springs which emerge from the chalk at the fen margin close by.

The gross stratigraphy, although carefully investigated, yielded an extremely diffuse picture of the conditions of peat formation and can hardly be said either to support or refute the interpretation we now put upon the pollen diagram. The exception to this is the *Taxus* rooted at the spear horizon.

C. *The Woodwalton district*

The stratigraphy of sites within this area has already been considered in detail in Part I of this series (Godwin and Clifford 1938), and it will only be necessary to superpose on the pollen diagrams the general zonation now proposed.

Ugg Mere F. It is clear from the pollen diagram (figure 14) that no deposits of zone VI

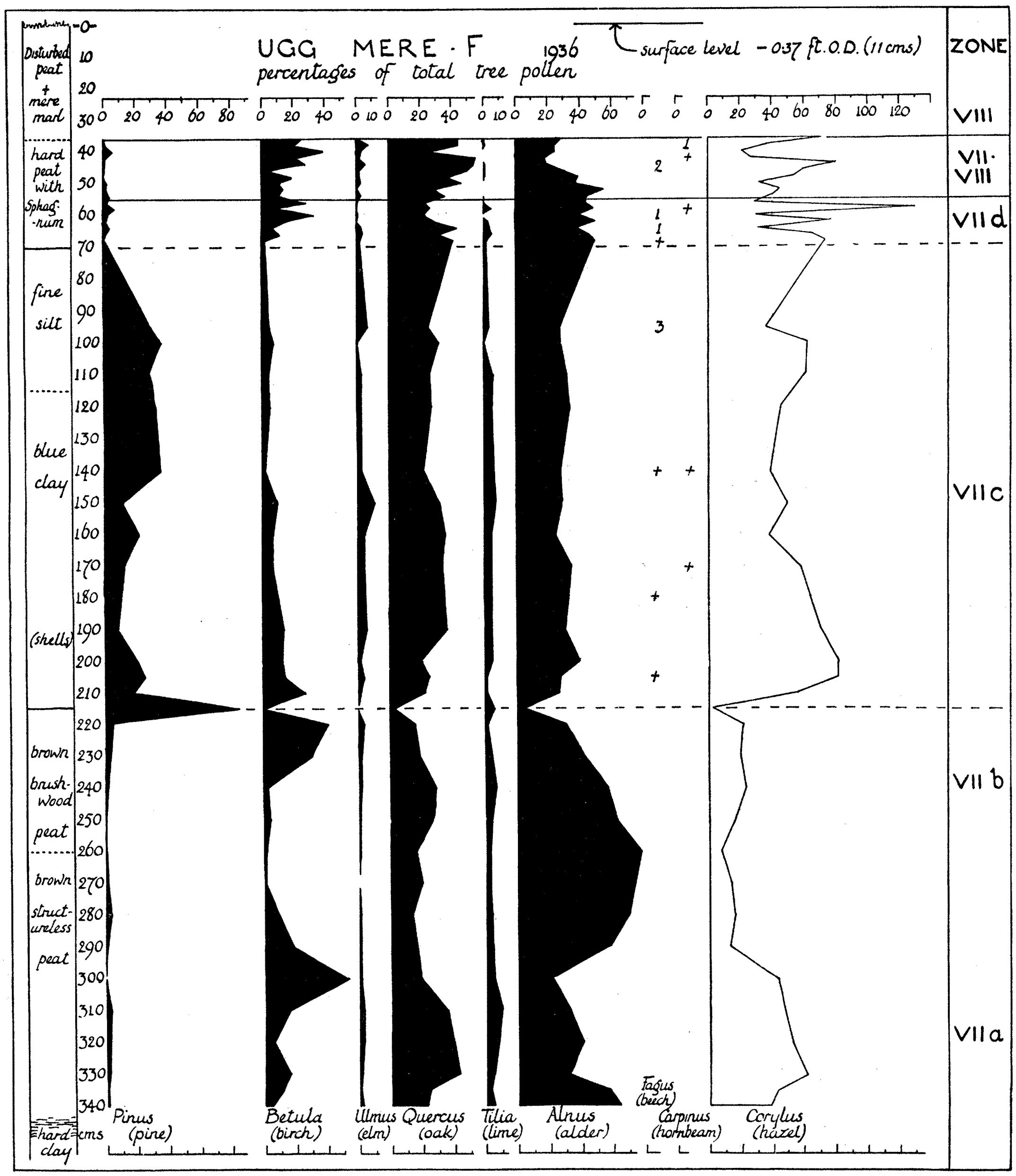

FIGURE 14. Pollen diagram at Ugg Mere, F, near Woodwalton, Hunts. The diagram passes through fen clay but stops at the base of the shelly deposits of the former mere.

are present, practically the whole of the samples fall within zone VII, and the presence of a typical development of the fen clay itself allows us at once to distinguish the sub-zones *b*, *c* and *d* as shown. The relationship of *Ulmus* to *Tilia* pollen has already been discussed in the earlier paper, and it will be noted that if the base of zone VII *d* is drawn at about 70 cm. the behaviour of *Ulmus* and *Tilia* corresponds with that in the fen districts already described. The upper peat at this site is extremely compressed and probably extends over both zone VII *d* and zone VII–VIII. In the latter *Sphagnum* peat developed, and this was followed, at the top of the diagram, in zone VIII, by the formation of the calcareous mere deposits. The gross stratigraphy and the high *Alnus* pollen curve below the fen clay show that during this time brushwood developed. Probably below 300 cm. the diagram represents zone VII *a*.

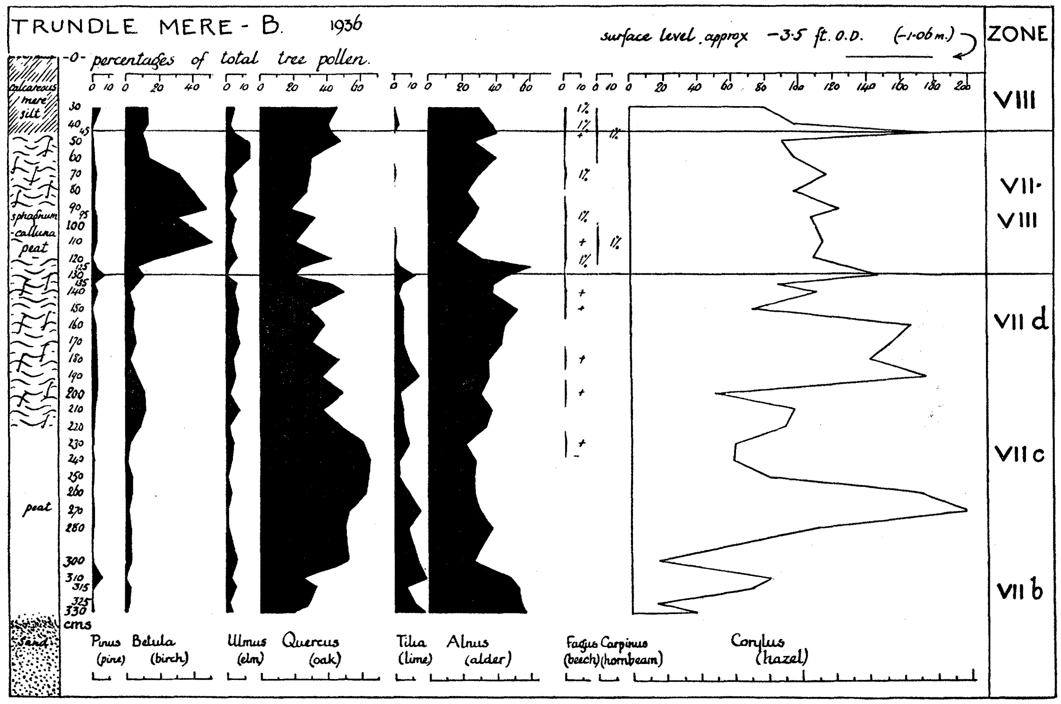

FIGURE 15. Pollen diagram at Trundle Mere, B, near Yaxley, Hunts. The site is in the bed of the former mere.

It is instructive to compare this diagram with that for Old Decoy (figure 4) where, in a rather distant part of the fens, the pollen series crosses the fen clay in a similar manner.

Trundle Mere B (figure 15). As with Ugg Mere F, most of the series here lies in zone VII. Zone VIII probably begins right at the top of the diagram and corresponds with the calcarious mere deposits. Zone VII–VIII begins at 130 cm. and includes a marked *Betula* maximum caused by the local development of birch woods on the surface of the raised bog following increasing dryness. The *Ulmus* maximum and disappearance of *Tilia* at the base of the zone are characteristic, and there is also a small *Pinus* maximum. The fen clay is not represented here, and it is not altogether clear where the boundaries of zone VII*c* should be placed. We have already given reasons for putting the contact with VII*b* at about 210 cm., but on analogy with the Wicken-Upware district it may well lie at about 300 cm., below which level *Alnus* preponderates. If this view is held, the high *Alnus* values between about 190 and 130 cm. fall into zone VII*d* and between 300 and 190 cm. is zone VII*c*.

Woodwalton Fen A and Ub. Both these sites are so marginal that the local conditions have a tremendous effect on the pollen diagrams. Their interpretation and correlation have already been discussed, and the zonations shown in figures 16 and 17 are based on this analysis. Above the fen-clay zone, VII*c*, is the marked alder maximum of zone VII*d*, and, following this, the zone VII–VIII in which the raised-bog peat layers developed. Unfortunately, the conflict of local and regional influences make interpretation of the diagrams particularly difficult.

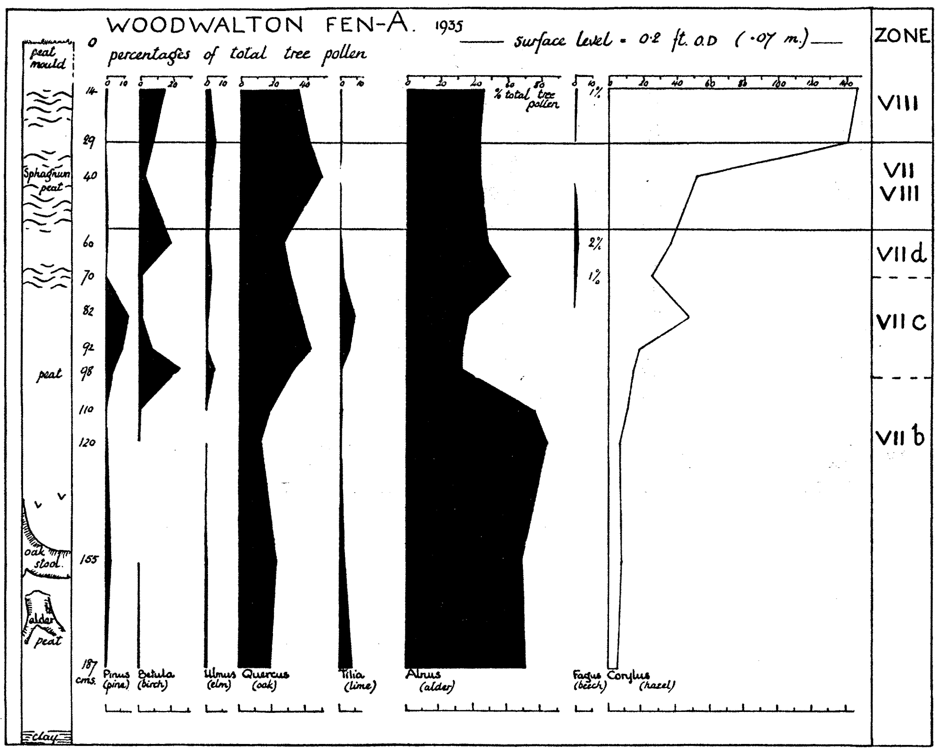

FIGURE 16. Pollen diagram at Woodwalton, A, Hunts. The diagram is profoundly affected by local influences.

D. *Sites with peat over fen clay and covered by fen silt* (figure 19)

The five sites discussed here can be considered to correspond in a stratigraphical sense with one another. In each the pollen series has been taken through the upper peat bed where it lies above the fen clay, and where at the same time, it is sealed in by a deposit of the upper silt. At Pear Tree Hill the upper silt is part of the general silt cover of the Fenland; at the other sites the top silt is that of one or other of the roddons which represent the landward extension of the upper silts. Three Holes is the site of a Romano-British settlement, pointed out to me by Major Gordon Fowler, about 0·7 miles (1·1 km.) north-east of Lakes End near Upware. The peat bed was

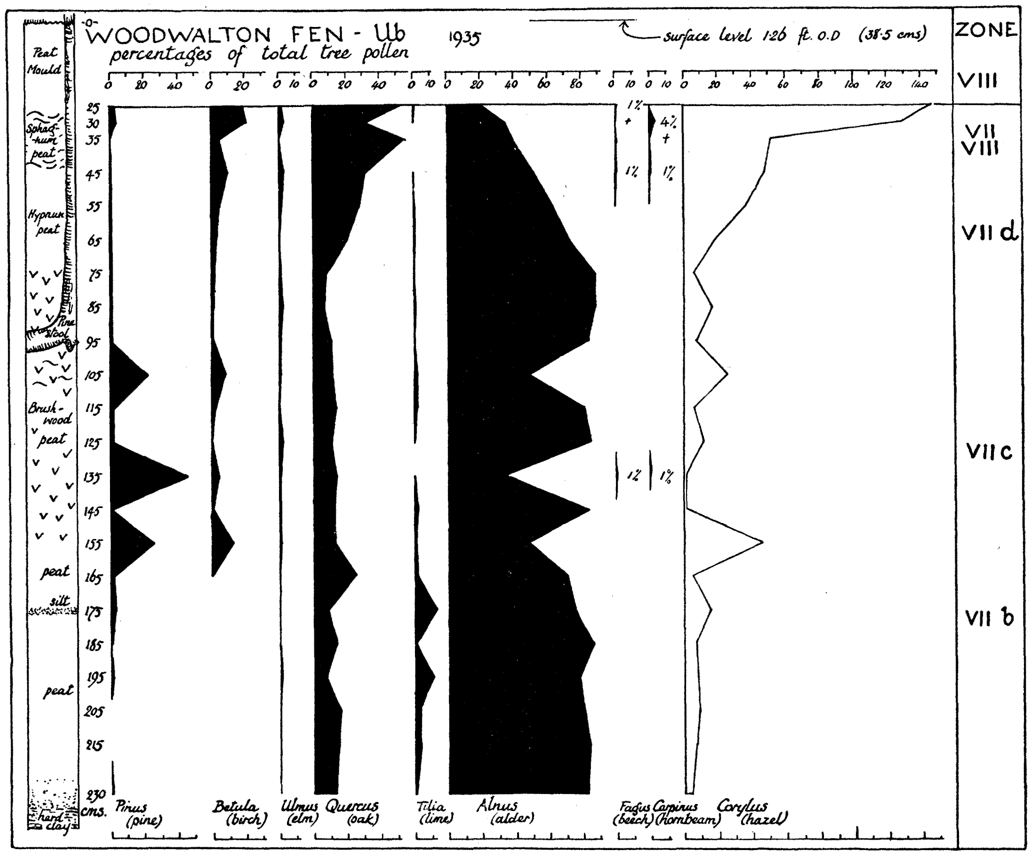

FIGURE 17. Pollen diagram at Woodwalton, Ub, where pine stumps are now visible at the ground surface.

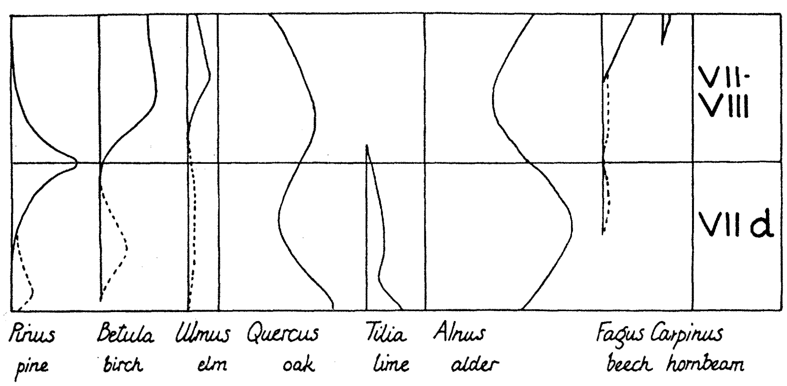

FIGURE 18. Diagram to show the usual drift of the pollen curves through zones VII*d* and VII–VIII. There has been no attempt to indicate true percentages, and it must be realized that there are considerable variations from this scheme in some sites.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

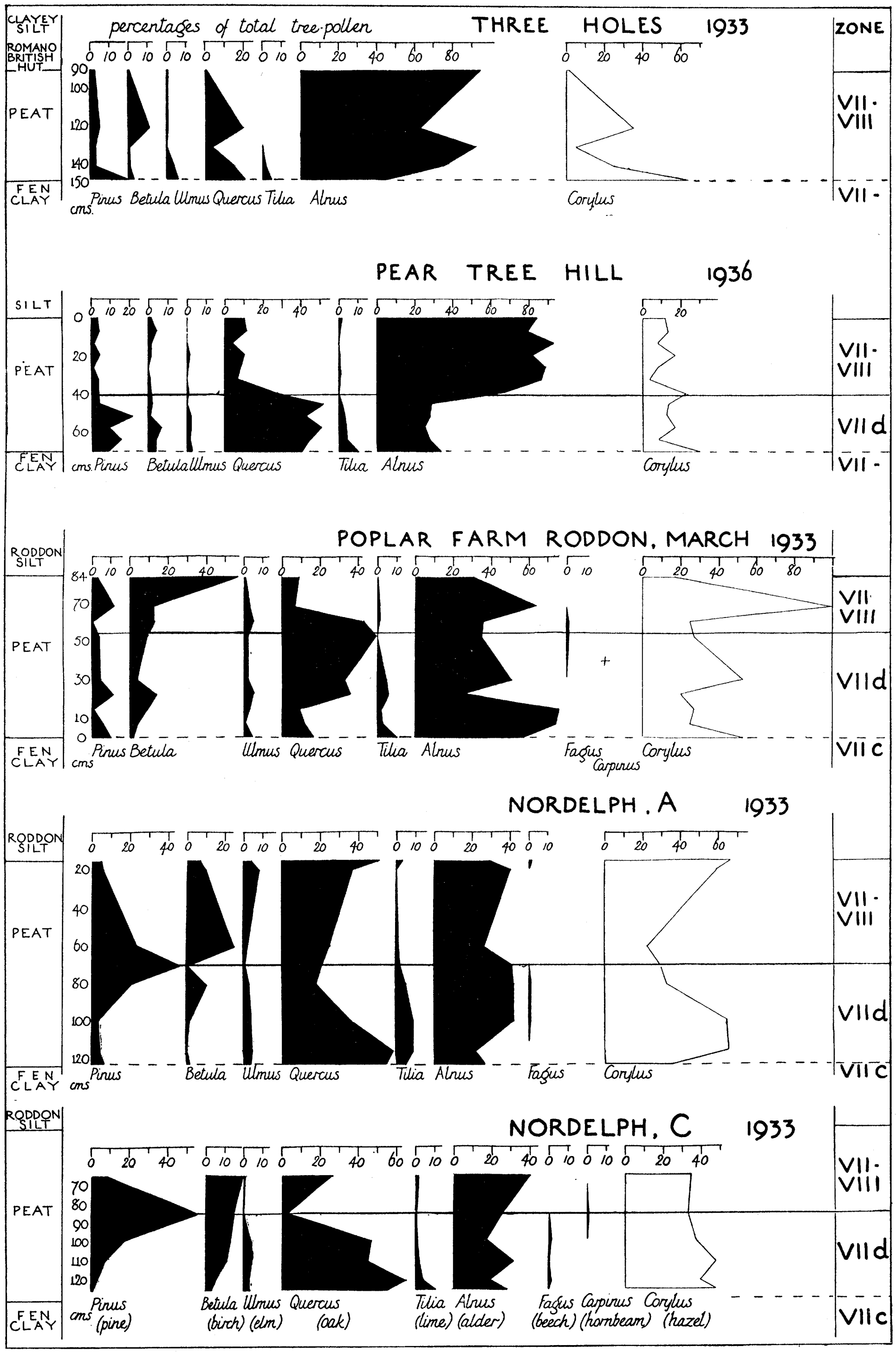

FIGURE 19. Pollen diagrams from five sites in which the upper peat lies over fen clay and is covered by the upper silt. The upper silt at Three Holes, Pear Tree Hill, Nordelph A and C, and probably at Poplar Farm also, contains Romano-British remains.

covered by 90 cm. of silt, in which there were abundant Romano-British remains. This silt is part of the huge roddon of the Old Croft River, the former main estuary of the Fenland, the centre of which follows a meandering course to the north about one mile eastwards of this site.

Below the peat bed a blue silt extended to a further 5·5 m., and no lower peat was encountered. This must have represented the estuary deposit of the fen clay period, a suggestion borne out by the foraminiferal analysis of Dr Macfadyen (1933).

The March Roddon site has been described in detail in an account of the origin of roddons (Godwin 1938); it lies 1·6 miles east-south-east of the centre of March, on a roddon which is a tributary of the very large roddon which carries the Roman Causeway from Denver by March to Peterborough. Clay "squeezes" of a type common in the Romano-British period were found in the roddon silt here and the fen-clay surface was clearly exposed.

The site at Pear Tree Hill lies just to the east of Pear Tree Hill farm and 0·29 miles (0·45 km.) east of Coldham station on the railway between March and Wisbech. It is of interest in that the surface of the overlying silt in the nearby fields showed abundant traces of Romano-British occupation. The site is shown in one of the fen sections in Paper II of this series (p. 376, figure 33, Godwin and Clifford 1938).

The two sites at Nordelph have been referred to in the same paper; the roddon silt at this point was demonstrated by Kenny to be of Romano-British age, and we have already indicated that the pollen diagrams, especially the non-tree pollen, afford evidence of local dryness during the peat formation.

It will probably be a convenience to consult, for this and the following series of diagrams, the diagram of figure 18, which has been drawn up to demonstrate the appearance of the pollen curves when they appear in their most recognizable shape, through the zones VII *d* and VII–VIII, which lie above the fen clay but below the lake marl or roddon silts.

Nordelph A. The lower part of the diagram (122–70 cm.) shows high *Alnus* values and diminishing *Tilia*: this is VII *d*. At 70 cm. is a *Pinus* maximum marking the onset of zone VII–VIII, in which the *Betula* is high and *Tilia* absent. The non-tree pollen described in Paper II indicate that all the peat here was formed under dry conditions which probably were most marked in the zone VII–VIII.

Nordelph C. The series at this locality corresponds closely with that for Nordelph A, but, although including all zone VII *d*, stops short, possibly through wastage, just above the transition to zone VII–VIII.

March Roddon. This series appears to be roughly comparable with that from Nordelph A. It has the lower half in zone VII *d*, with high *Alnus* and high *Tilia* at the base, and an upper half (zone VII–VIII) with high *Betula* and no *Tilia*. The boundary between the two zones is not here marked by a local *Pinus* maximum: possibly it is represented by local *Quercus*.

Three Holes. This site differs from the preceding three in that already at the base

Tilia is disappearing, there is high *Pinus*, whilst very soon high *Betula* values occur. There can be little doubt that only zone VII–VIII is represented.

Pear Tree Hill. The conditions at Three Holes are repeated closely here: little of anything besides zone VII–VIII is present. At these sites, which lie nearer the sea than any hitherto considered, it appears that fen clay formation continued to the end of zone VII *d*.

E. *Sites with peat above and below fen clay*

Under this heading we include three diagrams from the Wood Fen area, between Littleport and Ely. These have been already considered in relation to the local stratigraphy (H. and M. E. Godwin and Clifford 1935; and Paper II of this series). A fourth site lies quite near, in Black Wing Drove, Prickwillow, about 1000 yards (914 m.) south of Prickwillow bridge, and 420 yards (385 m.) south-west along the deep drain from Padney Hill Farm. In all these sites the ground surface is peat, which has wasted to greater or less extent.

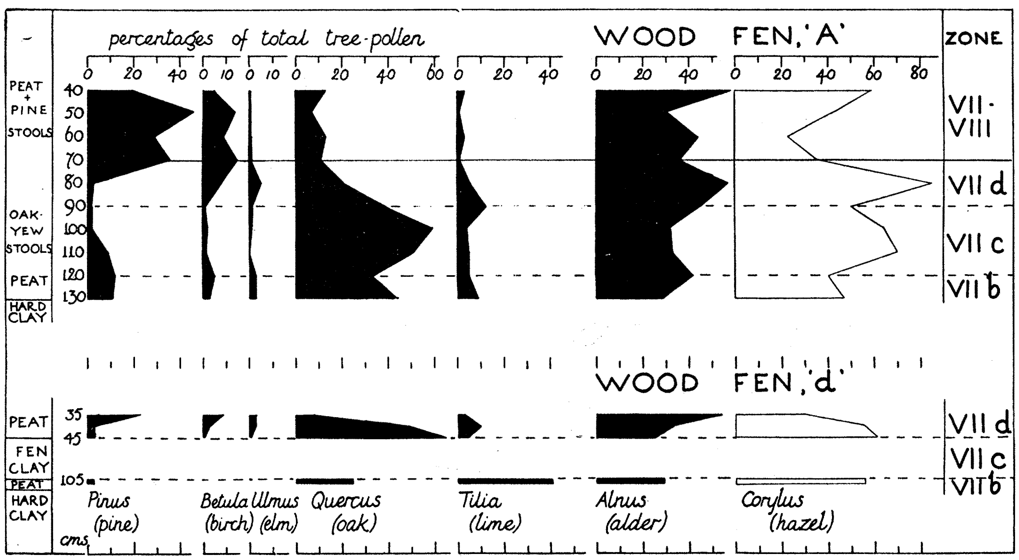

FIGURE 20. Pollen diagrams from two sites at Wood Fen, between Ely and Littleport. Wood Fen "A" is just beyond reach of the fen clay and passes through well-marked "forest horizons", Wood Fen "*d*" is at the margin of the fen clay.

Wood Fen "A" (figure 20). The non-tree pollen and the local stratigraphy indicate that at this site, which immediately adjoins the edge of the fen clay, zone VII *c* lies between about 90 and 120 cm. In zone VII *b*, which preceded it, there was development locally of *Quercus-Taxus* woods on peat, and their growth was only interrupted at the end of zone VII *c*. From 90 to 70 cm. is zone VII *d* with *Alnus* predominant, and above 70 cm. is zone VII–VIII, in which subacidic *Pinus* woods developed. The behaviour of *Betula*, *Ulmus* and *Tilia* is consistent with this view.

Wood Fen "*d*" (figure 20). This site lies close to "A" and shows thin fen clay separating two narrow peat beds. The upper peat is clearly referable to zone VII *d*, and the single sample from the lower peat is consistent with zone VII *b*, although the *Tilia* is abnormal.

Black Bank (*Wood Fen, f*) (figure 21). This site, although so close to the other Wood Fen sites, is remarkable in showing no effect of local pine woods. Its zonation is quite clear, however, if compared with that of the March Roddon site already considered. The upper peat shows from 125 to 70 cm. a dominance of *Alnus* with high basal values for *Tilia*: this is zone VII *d*. At about 70 cm. is the onset of zone VII–VIII with rising *Betula*, extinction of the *Tilia* curve, some *Fagus* and probably local *Quercus*.

The single sample from below the fen clay (here 145 cm. thick) is consistent with samples from zone VII *b*.

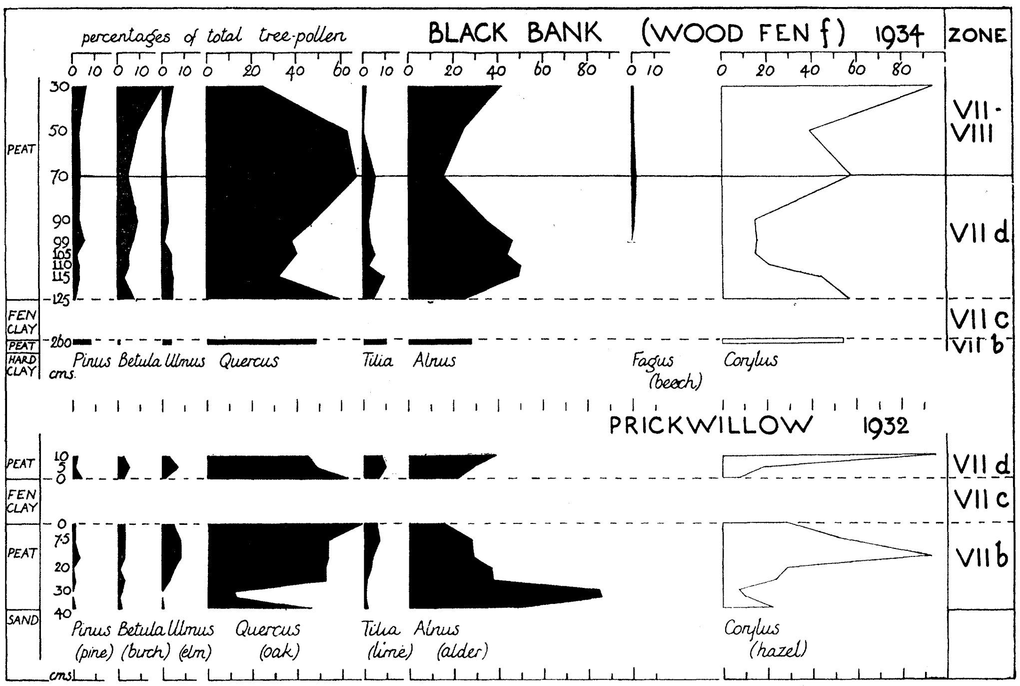

FIGURE 21. Pollen diagrams from two sites near Ely, which have peat above and below the fen clay. Although close to the pine forests growing at Wood Fen the Black Bank diagram shows no trace of a pine maximum.

Prickwillow (figure 21). The three samples in series above the fen clay agree with the base of zone VII *d*. (Note high *Tilia* and rising *Alnus*.) The samples below the fen clay must be put into zone VII *b*; the interchange they show between dominance of *Alnus* and dominance of *Quercus* probably reflects destruction of local fen woods at the approach of the wet period.

F. *Short series with peat over fen clay or the fen floor*

Under this head are mentioned three short series which have archaeological or other associations.

Southery Fen ("*Nancy*" *site*) (figure 22). In Southery Fen, about ½ mile east-south-east of Southery Church, during widening of a drainage ditch, a female skeleton was found, lying on about 3 in. (7·5 cm.) of peat over fen clay, and covered by another 21 in. (53 cm.) of peat. The discovery has been described by Lethbridge, Fowler and Sayce (1931). From the necklace of barrel-shaped jet beads and the bronze pin found with her, it was assumed that the skeleton was of the Early Bronze Age. There was no indication of burial, so that the horizon of discovery was probably contemporaneous with the skeleton. Pollen samples were collected from within 3 ft. (92 cm.) of the feet of the skeleton and in undisturbed peat. Although only three samples were analysed, they are quite clearly referable to zone VII *d*, showing the same displacement of *Quercus* by *Alnus* as the dominant pollen, which has been so often remarked just above the fen clay. Equally characteristic are the high *Tilia* values.

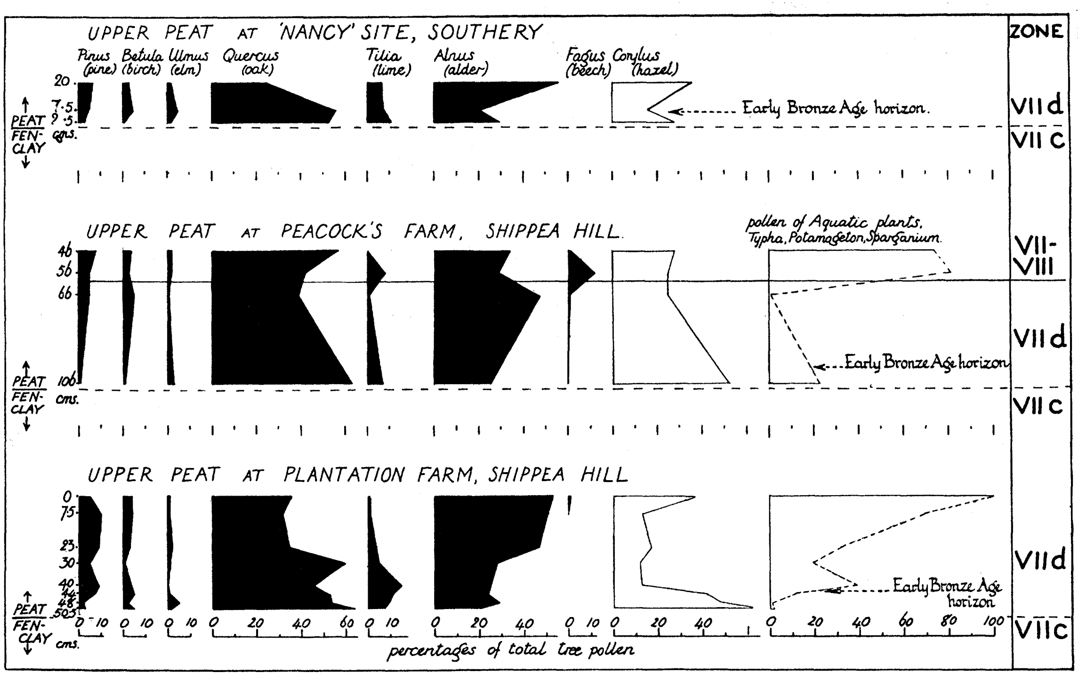

FIGURE 22. Pollen diagrams from three sites with thin peat overlying fen clay. In each an Early Bronze Age horizon is found in the base of the peat.

Barway Causeway (figure 23). In 1934 Mr T. Lethbridge and Mr Gordon Fowler discovered a brushwood causeway apparently crossing the fen between the western edge of Soham Upland and Barway, and the extreme southern end of the Isle of Ely at Little Thetford. A section showed the causeway to be made of stakes driven into the surface of the basal clay. About 10–15 in. (25–28 cm.) of wood peat overlay the hard clay surface. The top of this wood peat was probably the surface of the causeway, for it showed abundant sand pockets, quite out of place in any natural fen sequence hereabouts. This surface was covered with "made-ground" of peaty clay with fresh-water shells. A sequence of samples through the peat overlying the hard clay gave the results shown in figure 23. They evidently fall into zone VII *d*. The replacement of *Quercus* by *Alnus* as the dominant pollen is shown, and high values for *Tilia* at the base. The peat is doubtless unduly compressed, and the general indications seem to show the beginnings of zone VII–VIII at the top of the series. It is interesting to note that Late Bronze Age artifacts have been recovered from the site, most probably in relation to the causeway, which was presumably being used in zone VII–VIII, and, perhaps, later also.

It is interesting to find that the pollen series is instructive, since it is likely that the wood peat may well have been added to artificially in consolidating the causeway.

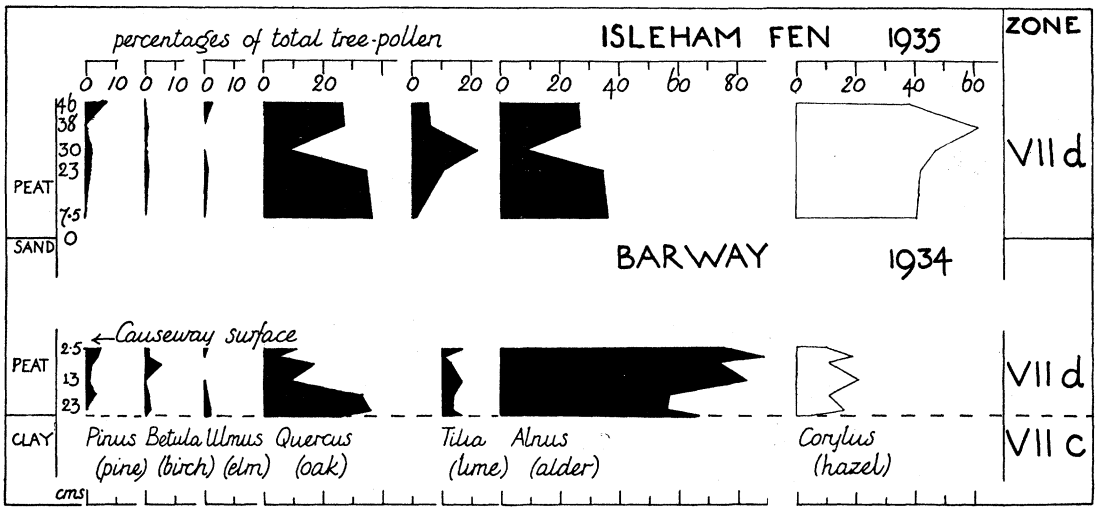

FIGURE 23. Two short pollen series from zone VII. That at Isleham Fen carries large trees below the peat and is pre-Roman. That at Barway is related to a causeway which is probably Bronze Age in date.

Isleham Fen (figure 23). This site lies about 1·5 miles (2·4 km.) north-north-east of Isleham Church, and about 400 yards south-west from the bank of the river Lark. Fen clay is absent, a shallow peat here overlying sand in which were growing, before peat formation killed and preserved them, enormous trees of *Quercus* and *Taxus*. A fallen oak excavated here had a trunk 75 ft. (23 m.) long and a basal girth of 8 ft. 6 in. (2·6 m.): a stool of yew had a girth of 14 ft. 6 in. (4·5 m.). (The flank of Isleham Fen, about 1 mile west of the village, also showed abundant stumps of yew in the shallow peat, but these had one-sided root systems like those reported from Green Dyke, Woodwalton, and were small: they had probably grown on the peat surface itself.) In the field near to the site of the large trees Major Fowler reported that Roman remains had been recovered from a "slade", i.e. a bank of shell marl representing a Roman water-course. It is therefore clear that the trees, and probably their covering of peat, predate the Roman period. The slade must have been active when the surrounding land was peat covered, for it now stands up as a bank above the wasting peat. The pollen series is short, but it can hardly be placed elsewhere than in zone VII*d*. The high *Tilia* values preclude a later date, unless, as seems unlikely, we are dealing with a deposit predating the fen clay.

Mildenhall Fen. In 1936 members of the Fenland Research Committee (Clark 1936 *b*) published the results of investigating a Late Bronze Age settlement in Mildenhall Fen. It was possible to establish a scatter of artifacts from the sand-hill surface into the shallow peat close by, and pollen samples through the occupation horizon were secured. The pollen diagram (figure 24) shows at the occupation horizon moderately good evidence for the transition from zones VII*d* to VII–VIII. *Tilia* ends at this level, *Pinus* is highest there; some *Fagus* occurs above it. Throughout *Alnus* is decidedly the dominant influence.

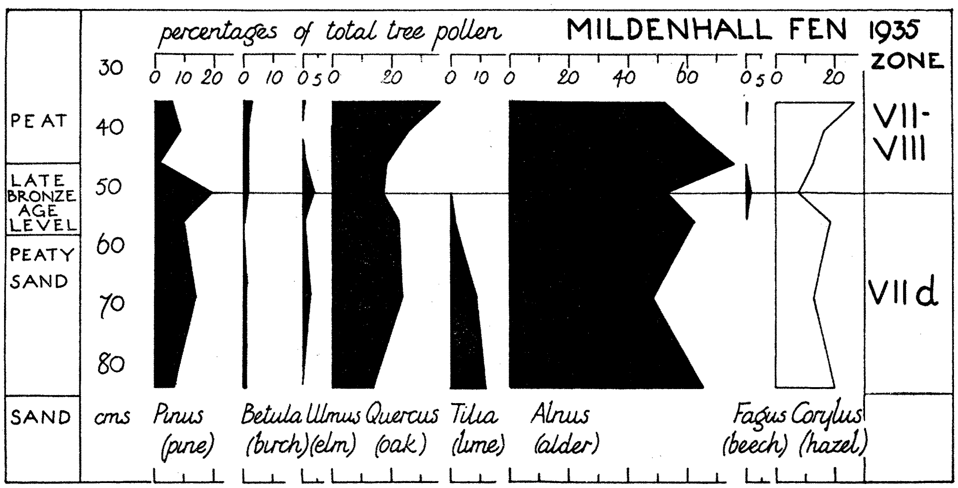

FIGURE 24. Pollen diagram from Mildenhall Fen showing correlation with the occupation of a Late Bronze Age hut site.

G. *Seaward or coastal sites*

In this group are included the sites of Wiggenhall St German's and of Ingoldmells on the Lincolnshire coast. Both were referred to in Paper II, where their stratigraphy was considered.

St German's (figure 25). At this site four peat beds alternate with estuarine clays. The character and levels of the beds led us to suggest that the peat bed E, second from the top, corresponded with the upper peat in the landward part of the Fens. The pollen curves confirm this view, for, although not interpretable when first described (Godwin, H. and M. E. 1933), it now seems very probable that this bed falls into zone VII–VIII. *Tilia* is absent, the base of the bed is marked by high *Pinus*, *Betula* is high throughout, and there is a marked *Ulmus* maximum in the upper part of the zone. The dry character of the deposit has already been shown by the non-tree pollen which shows the local development of oak fen woods towards the top of the bed. Within an inch or two of the top of the bed (some 30 cm. *above* the top of the tree-pollen diagram) were found glass beads, the nearest typological equivalents to which are La Tène to Anglo-Saxon in age. The lateness of this rather unsatisfactory correlation agrees with the late zonation we give to the lower part of this bed. It will be recalled that at two other seaward sites, Three Holes, and Pear Tree Hill, the zone VII *d* was not represented as peat bed, and zone VII–VIII alone occurred between the fen clay and the upper fen silt. It seems clear that the fen clay formation continued later at the seaward than at the landward side of the fens.

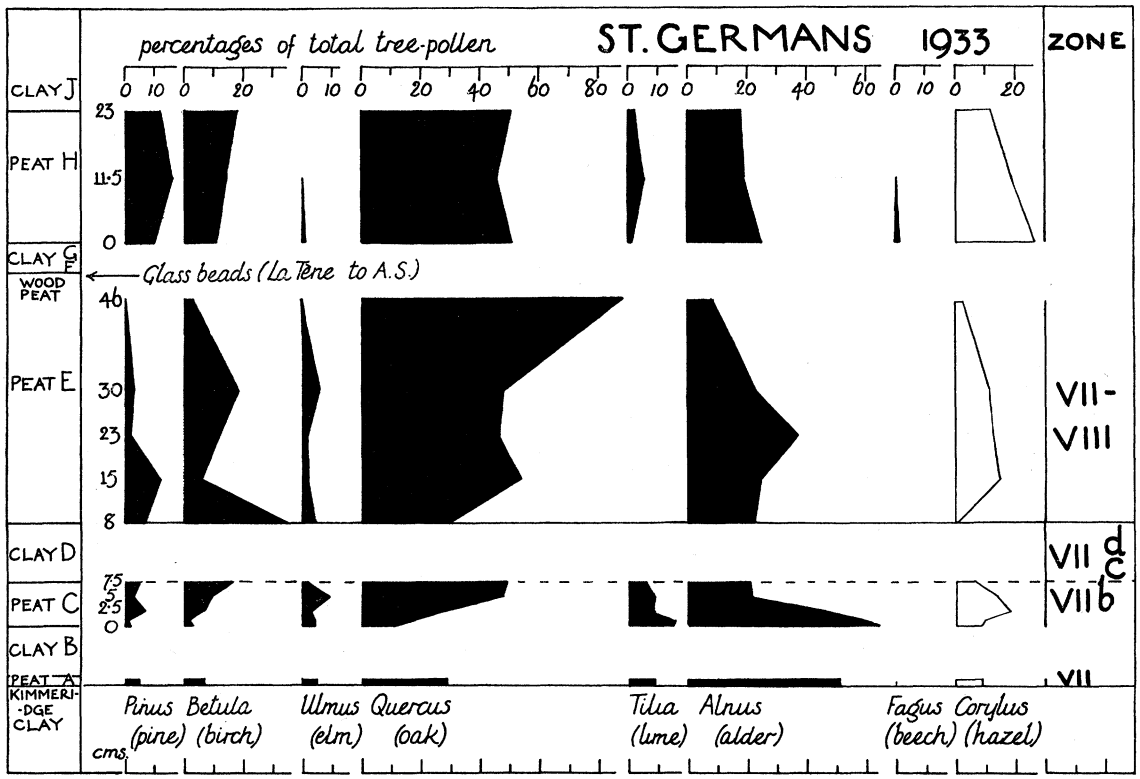

FIGURE 25. Pollen diagrams through the four successive peat beds at Wiggenhall St German's, near King's Lynn. No pollen samples could be counted from the upper part of bed E, at the top of which the glass beads were found.

The peat bed, third from the top (*c*), contained small stools of oak *in situ*, and it was suggested that it corresponded to the wood peat beneath the fen clay in landward sites. Such a reference to zone VII *b* fits the pollen composition satisfactorily.

The single sample from the basal peat bed (A) cannot be placed accurately, but must relate to either zones VII *a* or VII *b*.

The uppermost peat bed (H) is of particular interest, since it appears to belong to a stage of peat growth later than any so far recovered from the rest of the fens. It will be noted that once more *Tilia* is present in some amount, and *Ulmus* is absent, whilst both

Pinus and *Betula* are fairly well represented. Only further investigations will determine its age or the zonation into which it fits.

Ingoldmells (figure 26). In our former consideration of the two shore peats at Ingoldmells the view was put forward that the so-called "Triglochin Clay" separating them was equivalent to the fen clay. They therefore corresponded, one to the upper peat, and the other to the top of the lower peat in the landward part of the fens. The pollen diagram supports this view. The upper peat, however, lacking *Tilia* and containing very much, doubtless, local *Pinus* and *Betula*, must be referred to zone VII–VIII, like bed E at St German's. It will be recalled that it contained a Halstatt salt-making industry, a correlation not out of accord with the others already mentioned for this zone.

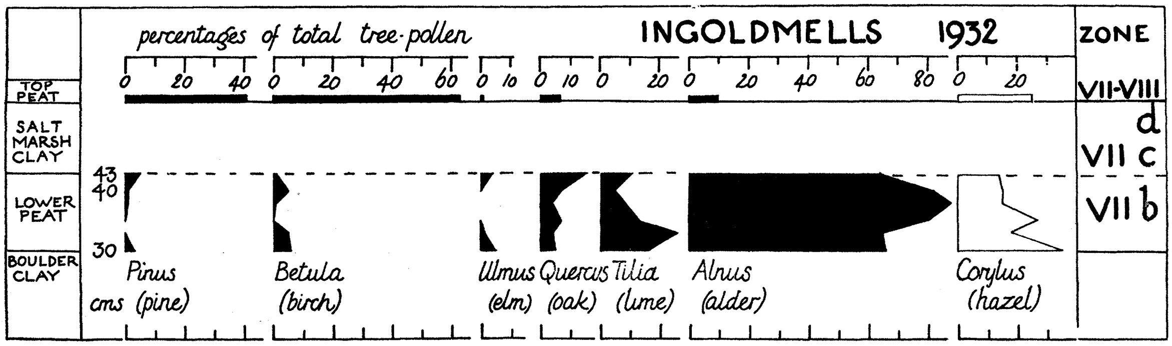

FIGURE 26. Pollen diagrams of the two peat beds exposed on the Lincolnshire coast at Ingoldmells Pt. The upper peat contained a Halstatt salt-making industry.

The lower peat, with its very pronounced *Tilia* maximum and marked *Ulmus* minimum a little higher, might well lie in zone VII*b* (cf. base of Wicken B diagram). It should, however, be noted that possibly the top of the lower peat was eroded and removed before the clay was laid down upon it. The only archaeological correlations which have been suggested for this bed are rather vaguely determinable "Neolithic" which agrees, for what it is worth, with other correlations with zone VII*b*.

Hunstanton. Patches of what is very probably the equivalent of the lower peat at Ingoldmells are sometimes exposed on the foreshore between Hunstanton and Holme-next-the-sea. A single sample taken from this bed gave the following percentage composition: *Pinus* 3, *Betula* 2, *Ulmus* 0, *Quercus* 12, *Tilia* 10, *Alnus* 73, *Corylus* 7. This agrees surprisingly well with the character of the lower bed at Ingoldmells. It is of interest, since from this peat bed a flint celt was recovered, said by R. A. Smith (1919) to be of the "Dolmen period".

STATUS OF FOREST TREES INDICATED BY POLLEN DIAGRAMS

Pinus. Perhaps the most striking feature of the pine curves in our diagrams is the continuity of pollen of this tree from zone IV (pre-Boreal) to zone VIII. Many diagrams show this, including those so close to the Breckland that they must have reflected pine growing on those sandy soils themselves. Although the diagrams perhaps hardly reach the present day, that of Wicken B must come close to it: they jointly offer the strongest evidence for the natural status of pine in this part of Britain.

The optimum pine forest period was clearly in zones V and VII, and at sites near the Breckland other trees are poorly represented then. The pine never again reached this frequency on the upland, although recovering some importance in zones VII–VIII and VIII. Rises in pine pollen after zone VI are mostly due to the development of marginal pine or pine-birch woods where conditions allowed the peat surface to become suitably dry. This happened in many places at the transition in zone VII–VIII and also at the end of zone VII *b* and in zone VII *c* at sites not reached by the fen clay, such as Woodwalton. The best defined of these local developments was that which gave the maximum employed to mark the end of zone VII *d*, which probably coincided with middle or late Bronze Age.

Betula. The birch has not been dominant in the Fenland diagrams since zone IV, the pre-Boreal. Its inferior status throughout the rest of the post-glacial period contrasts markedly with its importance in the north and west of this country. After low values throughout zone VII it rises in zones VII–VIII and VIII. In some places, e.g. Trundle Mere, this reflects local birch woods on peat, but it occurs also at sites such as Wicken Fen and Wilton Bridge, where the conditions are locally very wet. It seems probable that at this time birch also spread on the sandy soils near the eastern border of the Fenland.

Ulmus. Like the pine, this tree is not likely to have entered into the composition of fen woods. Its fluctuations in the pollen diagrams (so far as they are not concealed by local fluctuations in other tree pollen) probably have a direct climatic explanation. In this connexion it is most interesting to note the sudden expansion of elm pollen in the Boreal period. In zone VI *a* it regularly exceeds oak pollen, and in zone VI *b* equals it. In zone VI *c* it diminishes, and low values persist thereafter up to the present day. It is a clear indication that some elm is indigenous in East Anglia, but whether the *Ulmus nitens*, now so common, or another species is not determinable.

Quercus. Even in zone IV there is a scatter of oak pollen, but this tree clearly began to spread effectively in zone VI *b*, the middle of the Boreal period. After this time it was evidently the most important tree of the surrounding upland, and from time to time it played some part also in the drier fen woods (e.g. Wood Fen in zone VII *b*, Woodwalton in zone VII *b* and possibly Poplar Farm in zone VII *d*). The complication of local factors does not allow the later general drift of oak in the upland forest to be closely followed.

Tilia. Lime probably first grew as a common forest tree here in zone VI *c*, where its sudden expansion is a marked characteristic, reflecting most probably rising temperature. Throughout zone VII the lime remains important and must have been conspicuous in the oak forest of the upland: in diagrams reflecting the regional pollen rain it maintains 5–15 % of the total tree pollen. It is of interest that the pollen of

Tilia cordata and *T. platyphyllos* is distinguishable morphologically, and all the thousands of grains seen in the Fenland have been of *T. cordata*. Natural lime in the neighbourhood of Fenland is scarce to-day, though Elwes reported extensive woods in Bedfordshire.

During zone VII *d* *Tilia* pollen suffered a marked diminution. At the base of the upper peat, often corresponding with the Early Bronze Age horizon, there are high lime values, but it rapidly disappears after this, the opening of zone VII–VIII generally showing further reduction to insignificant amounts. This probably marks the climatic degeneration (lowered temperatures) of the opening of the sub-Atlantic. Some slight recovery of *Tilia* may have followed (cf. Wilton Bridge, and St German's H).

A very interesting feature shown by the *Tilia* pollen is the regularity with which very high values occur in the bottom layer of the peat, especially where this overlies fen clay. The values are so big that one must suppose either differential preservation favouring *Tilia*, or a local temporary increase of *Tilia* under the transitional conditions. The effect is perhaps comparable with the very high pine pollen values sometimes found in estuarine clay (e.g. Ugg Mere F).

Alnus. More than any other tree the alder characterizes the pollen diagrams of Fenland, often in such abundance that it obscures the pollen curves for other trees. Its wood is exceedingly prevalent, and alder fen woods played a tremendous role in Fenland history. Not until zone VI *a*, however, did the tree begin to extend appreciably. The sudden rise which marks the onset of zone VII must have meant a very rapid betterment of some factor previously limiting the spread of this tree. Inasmuch as the change is sudden and very widespread in western Europe, and as elm and oak have already expanded, we may probably explain this as due to increased wetness.

The course of the alder after this expansion reflects the building and destruction of fen woods, but when the diagrams reflect the regional pollen rain, alder is still important (*c.* 30–40 %), and there can be no doubt that it was a natural and abundant constituent of the upland mixed-oak forest.

Fagus. Here and there scattered pollen of the beech occurs in zone VII *c*. In small but more constant amount it occurs in zone VII *d*. In a few sites near the eastern fen margin the beech expands in zone VII–VIII, and in zone VIII is present in such substantial amount that it must have formed fair stands on the upland, most probably on the chalk. Although present in small amounts in the earlier zones, it occurs in so many diagrams that the native status of the tree cannot be in doubt. It will be recognized that the many archaeological correlations of the zones clearly establish that the beech was here in pre-Roman, and indeed in Bronze Age time. The gradual extension in the Bronze Age and more rapid extension in the sub-Atlantic corresponds closely with the behaviour of beech on the nearby continent and clearly indicates that its movements were climatically controlled.

Carpinus. The pollen of hornbeam in much reduced amount follows that of the beech, and is, in consequence, very sporadic indeed. Only in the Wicken B diagram is enough of its pollen present (in zone VIII) to indicate that stands of the tree were growing close by. This region would probably now be regarded as outside the natural limit of native hornbeam woods, as would indeed be true for the beech.

Corylus. Of all the pollen shown in the diagrams none is so difficult to interpret as the hazel: it differs very greatly between neighbouring series (cf. Woodwalton area), and the more closely samples are analysed the more intricate do its fluctuations become. The key to its complex form is still to seek, but it may eventually prove of great value.

The early history of the species is indicated in a typical manner in the Old Decoy and Peacock's Farm diagrams. It was present only sporadically in zones IV and V, but responded to the increased warmth of zone VI by sudden expansion to the well-known *Corylus* maxima of the Boreal period. In zone VI *c* the values diminished. Thereafter no effective analysis has been possible.

It is clear that the bush contributed greatly to the regional pollen rain and must have formed part of the upland mixed-oak forest. It is uncertain if it occurred in the fen woods, and it seems not now to grow in the fen woods of the Norfolk Broads, perhaps our nearest living equivalent to the former wood vegetation of the Fenland.

Discussion and conclusion

At the end of Paper II of this series we drew up a scheme to express primary relationships of Fenland stratigraphy and the outline of the developmental history of the post-glacial Fenland deposits (figure 30, p. 284). This scheme was based upon the stratigraphy, levels, and archaeological correlations. Such pollen diagrams as were considered were employed for the light they threw on the local conditions of deposition of the beds.

For the first time we have now added to this a study of the pollen diagrams themselves. They are from all the sites mentioned in Parts I and II of this series, and from many others. They represent the fairly continuous observations of the last seven or eight years, but effective co-ordination has only now become possible. The zoning we have described for them is essentially derived from the Fenland diagrams themselves, and stands independently. Nevertheless, it is quite clear that the major zones can be easily matched in other parts of Britain and of the near part of the continent. Such zones probably reflect widespread climatic changes and justify the use of pollen analysis as a means of applying or extending chronological scales of some fineness. It will be evident that our delimitation of zone VII *c* (corresponding with the fen-clay phase in the landward fens) is not primarily of this kind, though it possesses certain characteristics of more than local applicability.

Most of our series have been deliberately limited to the peat deposits: the clays and silts have been left unanalysed, partly because of the greater labour their analysis entails, and partly because it seems possible that they may contain substantial amounts of pollen from the erosion of the peat beds they cover, or from other pollen-bearing deposits. Iversen drew attention to this error in deposits produced from eroded boulder clay (Iversen 1936).

Our zoned diagrams in this paper number thirty-four, of varying length and many passing through more than one peat bed. They relate to most of the important post-glacial fen deposits and include nineteen or twenty archaeological correlations of varying value. The approximate time range of each of the diagrams has been set out in figure 27, together with the stratigraphical and archaeological correlations. The results are broadly as follows:

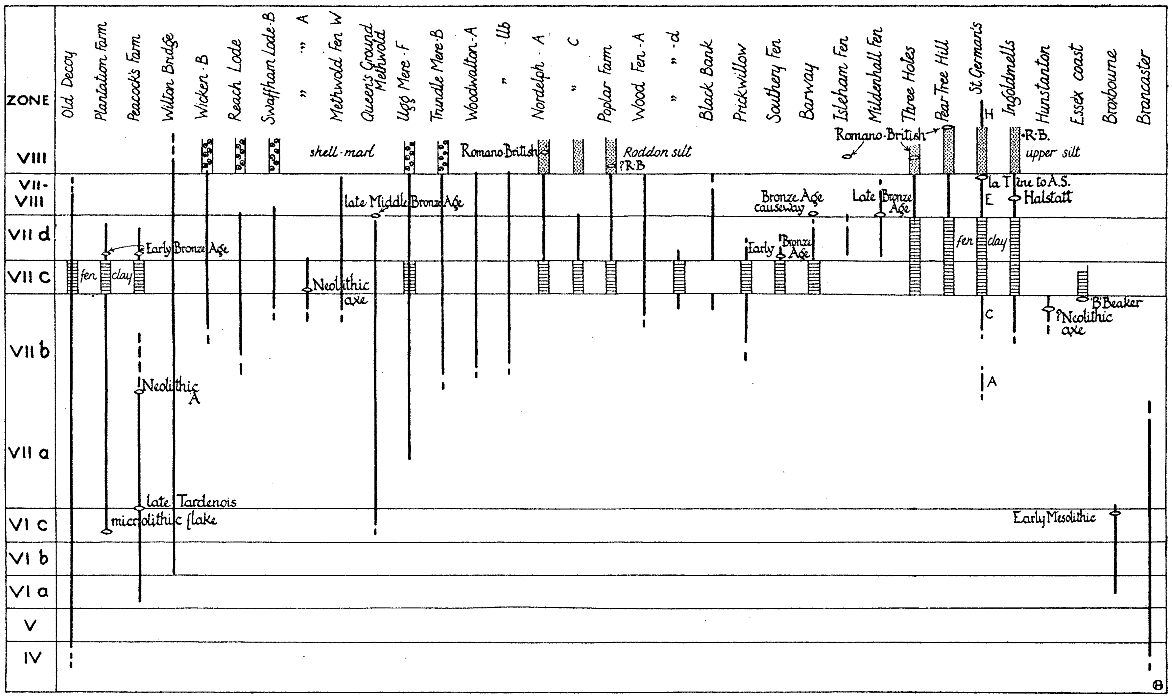

FIGURE 27. Table expressing the archaeological correlations of all the pollen sequences here described. Each pollen series is shown by a heavy vertical line. Although the shell marl and the upper silt have both been placed in zone VIII it is not clear that they are precisely the same age. There is also no clue as to the age of the upper peat bed at St German's. The fen clay, upper silt and shell marl are shown respectively by shading, dots, and the snail symbol.

There was almost no peat formation in the Fen basin before zone VII *b* (say middle Atlantic times). The sample analysed by Erdtman from the river Lark was resting on the fen clay in the early part of zone VII *d*, and his attribution of Early Atlantic age to it was erroneous. In zone IV we have only samples from Old Decoy, the bed of the natural Little Ouse. This was the pre-Boreal period in which analyses of Dogger Bank moorlog show the North Sea to have carried fresh-water fen on surfaces now submerged 200 ft. (Godwin 1934 for references). Other sites in the same channel show diagrams beginning in zones VI *a*, VI *b*, and VI *c*. These all fall into the Boreal period, at the end of which is the late Tardenois horizon of Peacock's Farm. The microlithic flint found in the borer at Plantation Farm was somewhat older. Dr G. Clark in his *Mesolithic Settlement of Northern Europe* gives evidence that elsewhere in Europe the Middle and

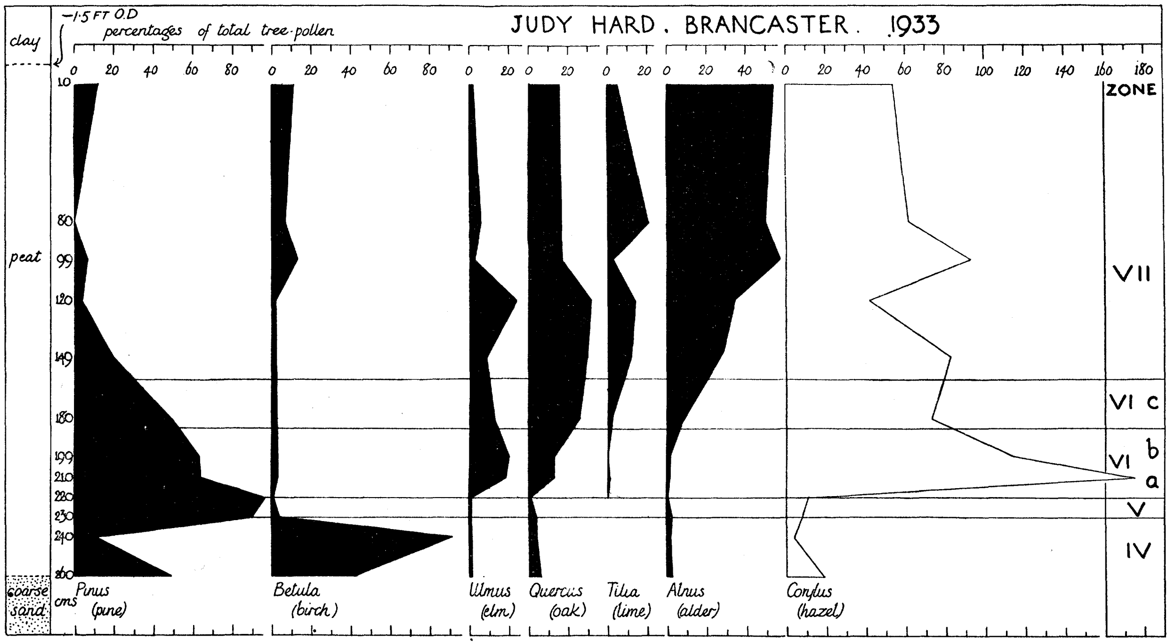

FIGURE 28. Pollen diagram from Judy Hard, Brancaster. Here a submerged peat bed is visible in the estuary with its surface just below mean sea-level. The oldest part of the series is in zone IV, but it is difficult to say when the top was formed, although probably in some part of zone VII. The series shows close parallelism of the early zones with those of the Fenland.

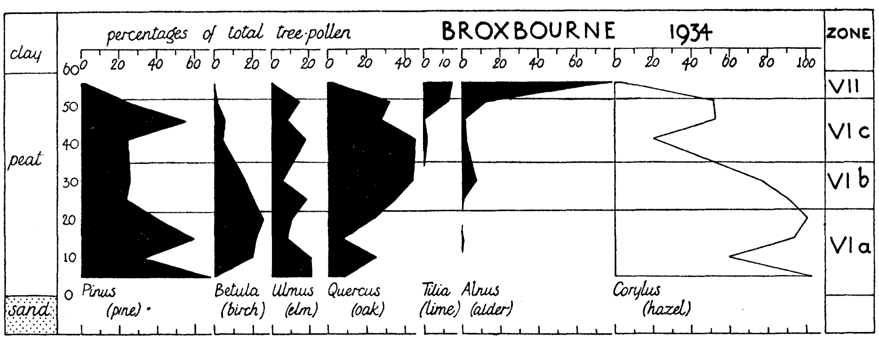

FIGURE 29. Pollen diagram from Rickoff's pit, Broxbourne. An early Mesolithic horizon found close to this series probably fitted very close to the end of zone VI*c*. The diagram shows a division of zone VII quite clearly comparable with that in the Fens (see Warren, S. H. *et al.* 1934).

late Tardenoisian also fell at the same time, i.e. the end of the Boreal period. The only other site so far yielding Boreal peat in the Fenland has been that of Queen's Ground, Methwold, where the presence of local springs may have influenced it. It seems that really old peat deposits will seldom be encountered in the Fenland outside the deep natural river channels.

The lower part of zone VII is crossed by only five of our diagrams, and a division into zones VII *a* and VII *b* is not of great value. Although at several sites the top of the lower peat has developed quite a dry fen wood below the fen clay, in several sites zone VII is alder wood peat to the bottom. The early Neolithic horizon at Peacock's Farm falls at the base of zone VII *b* and the Neolithic axe from Swaffham Drain probably at the top of zone VII *b*. It seems likely that the Hunstanton stone axe was also from this zone. The Fenland Research Committee in their work on the Essex coast found a long period of occupation terminated with a "B" Beaker culture and overlaid by a blue semi-marine clay, which it is quite reasonable to refer to the fen-clay transgression.

Outside the river channels the peat development of the Fenland seems to have begun and to have become general in zone VII *b*.

The opening of zone VII *d* in the south-eastern Fenland clearly coincided with the Early Bronze Age, for the Shippea Hill and Southery sites show this culture just over the fen clay. In most parts the peat bore alder fen woods, and on the seaward side the deposition of fen clay continued through this zone.

The end of zone VII *d*, and the beginning of zone VII–VIII showed marked changes in the pollen curves. Late or late Middle Bronze Age horizons fall within this zone, and, as we should expect from the abundance of archaeological evidence, this was probably a very dry period. This dryness was shown in the local fen woods as far seawards as St German's, by pine and birch woods on peat at Wood Fen, Nordelph, yews at Methwold Fen, raised-bog peat at Woodwalton and birch scrub on raised-bog at Trundle Mere. The pine woods at Mablethorpe, referred to in Paper II of this series, probably also fell into this zone, together with the upper shore peat at Ingoldmells, in which a Halstatt industry was found. The Barway causeway also fits here.

Almost no pollen series in Fenland extend into zone VIII, for at landward sites the peat gives place to shell marl devoid of pollen, and at seaward sites to the semi-marine upper silt. There is clear evidence that the upper silts in some places at least were forming in the Romano-British period, and their present surface is often also densely covered with settlements of this period. The commencement of the shell marl has never been dated archaeologically, but it is clear that since it overlies zone VII–VIII, as does the roddon silt, it may be of the same age, and is, in any case, post-Bronze Age. It remains possible, though unproved, that the shell marl was formed in fresh-water meres caused in landward regions of the fens, by the marine transgression in seaward regions.

The outstanding gap in the sequence so far outlined is that for the Iron Age. This, on the continental analogy, would fall into zone VII–VIII or the early part of zone VIII. It has generally been assumed that the Fenlands were too wet to carry a population of the Iron Age, and the commencement of mere formation may relate to this archaeological period.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

At seaward sites, however, there seems little opportunity for any equivalent *wet* period following zone VII–VIII, and preceding the roddon silts with Romano-British remains in them. This is very clear at the Nordelph causeway excavation and at Three Holes. At St German's the beads show rather late Iron Age above a wood peat, and at Ingoldmells the Halstatt horizon is in pine-birch wood peat. The possibility that the Bronze Age cultures persisted in the Fenland and so excluded the Iron Age cultures, is not countenanced by archaeologists, who point out that the Fenland waterways were main routes for entry of Iron Age folk to this country from the continent, and if any folk at all lived in the peat fens their remains must have shown indications of the Iron Age cultures.

Chronology (approx)	Phases of fen history	Archaeological horizons	Major features of the periods	Conditions at sites: Marginal	Conditions at sites: Middle	Conditions at sites: Seaward	Prevalent state	Land level relative to sea	Climatic evidence in fens	Climatic periods	Recurrence horizons (dryness in S. Sweden) Granlund	Forest zones	
1900 1,500 1,000 500	Drainage & marshland reclamation	Historic		Peat growth	Peat growth	Silt Local peat	Wet (locally dry)	? low ? high	Wet	Recent Sub-Atlantic (cold & wet)	X RY I	VIII	alder ·oak ·elm ·birch (beech)
A.D. 0	Upper silt & meres	Romano-British	Marine transgression	? Meres	Roddon silts	Upper silts	Wet	Low	Wet (lake marl)		X RY II		
B.C. 500	Upper peat	Iron Age (La Tène, Halstatt) Bronze Age Early Bronze Age Beaker 'A'	stagnation phase Brushwood 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-wood Silt	(Dry) Dry	High	Wet (Iron Age in fens) Dry (raised bogs)	Sub-Boreal (warm, dry continental)	Wetter ↑ X RY III ? RY IV	VII–VIII VII d	Transition
?1,500	Fen clay		shallow brackish lagoons extensive but shallow marine transgression	Fen-woods	Fen-clay	Silt	Wet	Low	Warm (Tilia)		Drier ↑	VII c	alder ·oak
?2,000 3,500	Lower peat	(Essex) Beaker 'B' Neolithic Neolithic 'A'	Dry fen woods alder brush wood peat-formation becoming general in Fens peat forming only in river channels etc.	Erosion channels cut Dry oak fen-woods	Erosion channels cut Dry oak fen-woods	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	VII b VII a	elm ·lime
5,500		Late Tardenoisian Mesolithic							? Dry (blown sand) Dry (no alder)	Boreal (warm dry)		VI c VI b VI a	pine ·hazel
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)		V IV	pine birch ·pine

FIGURE 30. The correlation table for Fenland deposits published in Part II of this series, slightly amended, and completed by the addition of the forest zones derived from the pollen analyses.

The only possibility remaining, therefore, is to recognize that there was no Iron Age settlement on the landward side of the fens, but that conditions permitted it on more seaward areas. This remarkable position could possibly be explained by the hypothesis that the worsening of climate with which the sub-Atlantic began caused the landward sides of the Fens to be extensively flooded: the shell marl began to form very widely, more especially in the basins near the upland. On the seaward side, however, this climatic effect was offset by marine retrogression, the evidence for which lies in the erosion channels cut through the upper peat, and often through the underlying fen clay.

Investigation of suitable coastal Iron Age sites such as the Red Hills of the Essex coast may perhaps serve to establish or refute these suggestions.

In attempting to produce a co-ordinated scheme for Fenland development the evidence of stratigraphy, levels, archaeology and pollen analysis has been taken together. No one line of evidence has been considered to have essentially more validity than another, for our knowledge along each line is very imperfect. It has been our aim to construct a scheme which should, however, in the end be contradicted severely by none of these lines of evidence. The truth of such a scheme rests on its *general* applicability.

PART IV. POST-GLACIAL CHANGES OF RELATIVE LAND- AND SEA-LEVEL IN THE ENGLISH FENLAND

The materials we have organized in the preceding three papers of this series put us into a position from which some preliminary formulation can be made of changes in the relative levels of land and sea in the Fenland during the post-glacial period.

The graph conventions

We propose to develop this formulation by the mechanical device of constructing a type of graph which will incorporate our chief evidence and allow the final expression of a curve of changing land-level in relation to sea-level. The base line of the graph carries the time scale, which is directly derived from the co-ordination table with which Paper III of this series ended. It will be realized that the dating in years is subject to considerable error since it has been deduced indirectly from Swedish varve clay through the media of pollen analysis and archaeology. Each site yielding relevant information is marked by a horizontal or sloping line, the length of which extends over the period to which it can be safely attributed. The line is set above or below the base-line at the distance in feet which the evidence shows for the land height in relation to sea-level at that time. If the land must have been at *least* this altitude in relation to this sea-level an arrow projects upwards from the horizontal line. When the evidence is such that it gives a fair presumption of the limits between which the former sea-level must have lain, then a single-hatched area indicates what these limits are. In every instance an index on the graph bears a figure by which it is referred to in the text. This text will briefly explain the evidence on which the index has been made. It has sometimes been convenient to employ not a horizontal, but a slightly sloping line to represent a period of formation of a peat bed. The beginning of this line represents the evidence of date and level of the base of the bed, and the end of the line the evidence of its top layers.

Having filled in these symbols for all the data available, the curve of land-level in relation to sea-level must be drawn as follows. It will pass at some point above each line with an upwards-pointing arrow, and must pass at some place through each shaded area.

The nature of the evidence

Before giving the detailed evidence for all the separate indices, it will be desirable to outline some of the simple theoretical assumptions on which the conclusions rest. These specially concern two points, viz. (1) the nature and relative levels of fresh water and marine or semi-marine deposits at the seaward end of natural river systems, (2) the conditions under which some of our major Fenland deposits were formed, notably the fen clay.

It seems clear to the author that on the East Anglian coast the river systems end in a coastal area built up by tidal deposits to about the height of high-water spring tides. A similar deposition goes on behind shingle spits and bars to form the typical salt-marshes of the Blakeney-Scolt region. If a river enters the sea at a place where conditions permit of deposition of tide-borne material, then salt-marsh deposits will form in a coastal belt to the height of spring tides, and banks of this material will tend to be built up round the rivers. Further upstream, as the tidal wave dies out, and the range of tidal movement lessens, the marsh deposits (now finer in grade) are not built up so high above mean sea-level. The silt or mud levées of the rivers thus diminish in height from the coast inland. The marsh land behind these banks similarly slopes down from a maximum height of about +10 ft. O.D., at the seaward side, to values not much above mean sea-level on the landward side. Under these conditions, with streams of low gradient and small volume like the Bure and Thurne, just at or above the influence of tidal movement, the river may merge into an open lake or "broad" of fresh water, surrounded by fresh-water fen communities forming topogenous peat at only one or two feet above mean sea-level. This is perfectly true of Barton and Sutton Broads, for instance, at the present day. Moreover, it is this structure of the coastal deposits which explains the nature of the disastrous flooding of Horsey Mere in February 1938. Only a narrow bank and sea wall separates Horsey Mere from the North Sea, although it was in unbroken but distant communication by open rivers to the sea, at Yarmouth many miles to the south. When the sea wall broke, the Mere was disastrously flooded by many feet of salt water, a clear enough indication of the height of the Mere and its surrounding peat-land in relation to mean sea-level.

A consideration of three of the best developed coastal Fenland areas in Britain, the East Anglian Fenlands, the Norfolk "Broads", and the Somerset "Levels" will show that in each there is, on the seaward side, a belt of silt formed up to high-tide level, now enclosed, drained and cultivated, and behind it a region of topogenous peat formation, with a surface level not much above mean sea-level. The difference in altitude between the surface of the silt land and of the peat land is not essentially due to shrinkage and wastage of the peat following drainage, although it was emphasized

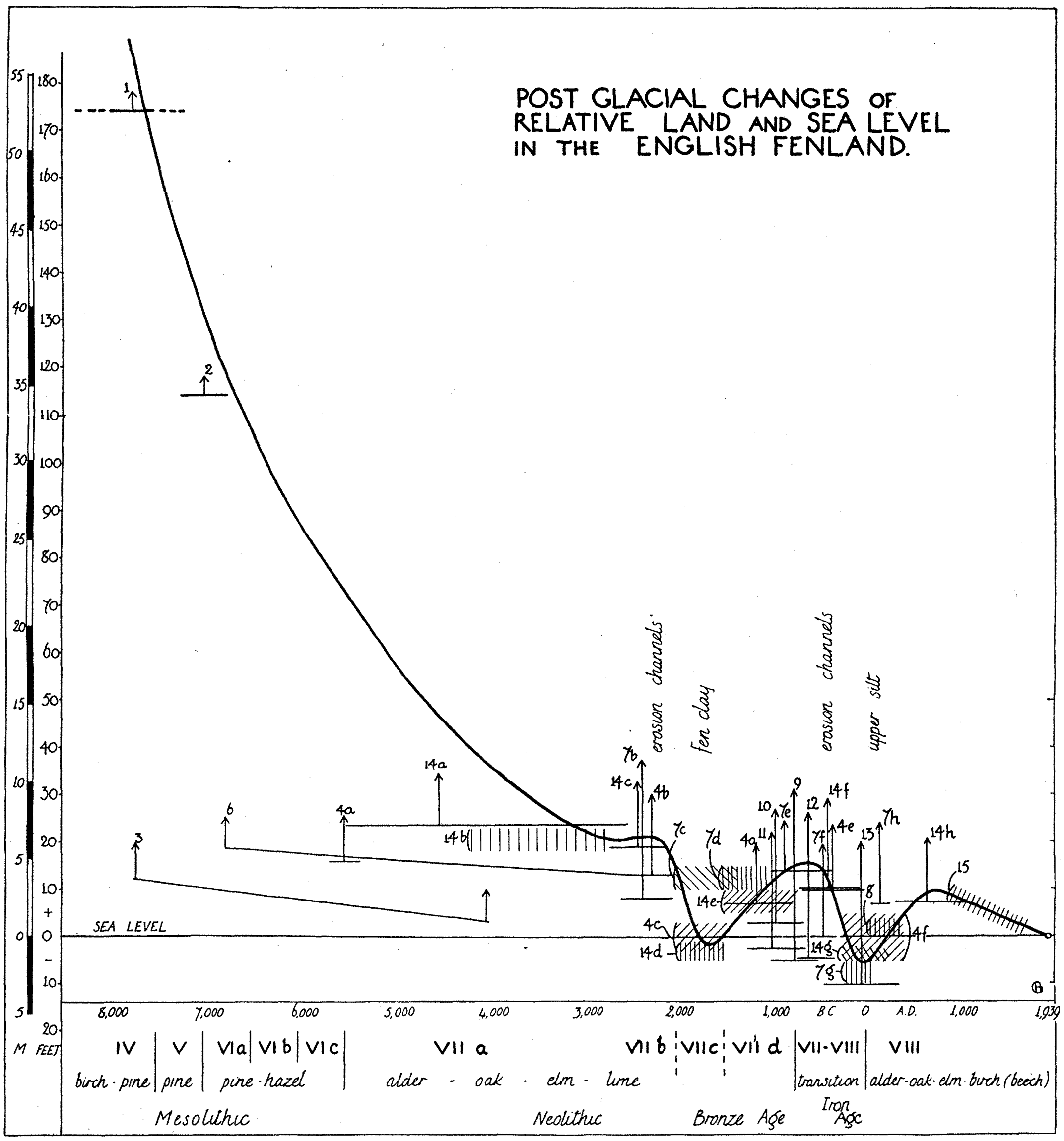

FIGURE 31. The thick curve represents the relation of land-level to sea-level in the Fenland throughout the period indicated on the base-line. Each lettered area or line is an index of relative level to which reference is made in the text. The diagram is meant to imply nothing of the absolute movement of land- and sea-level: sea-level has been regarded as constant only as a convention. The shading indicates the probable range within which, at a given time, land-level stood in relation to sea-level.

by these effects. We consider the distinction between the two types of terrain to be due to the conditions of formation indicated above. This appears to be the accepted explanation of the structure of the north-west German coastal marshes, where the "Hochland" and "Sietland" respectively correspond in character, level, and disposition with our coastal silt lands and the peat lands lying behind them (Godwin 1938).

These circumstances have led the author to take the view put forward by Clement Reid (1913), that peat can form at the landward end of a tidal river at an altitude as low as mean sea-level. It is clear that ordinary fresh-water peat of any kind does not form below sea-level. At the seaward end of the river system fresh-water peat cannot, of course, form lower than high-tide mark of the ordinary (and perhaps of exceptional) spring tides. We might consider +10 ft. O.D. as the lower limit on this coast.

From these considerations it follows that in using the presence of a peat bed as evidence of the relative position of land- and sea-level during the time of its formation it will add to our accuracy if we can specify how far away, by river, the sea was during this time. Though desirable, this is naturally sometimes difficult.

Sometimes deposits of the highest lying salt marsh (e.g. *Juncetum maritimae* or *Phragmitetum*) are recognizable, and where this is so they indicate former sea-level closely, for the work of Chapman at Scolt Head (1934) has shown that there the highest salt marshes lie at about +10 ft. O.D., and no salt marsh at all forms below mean sea-level. It may be recalled that the author's view, supported strongly by Chapman, is that the normal succession of these salt marshes passes through a *Phragmitetum* into a fresh-water fen and thence to fen woods. This sequence, as shown for instance in coastal deposits at St German's, or Ingoldmells, gives direct information of former sea-level.

The brackish water fen clay which occurs over such a large area of the Fenland clearly furnishes evidence of extensive marine transgression, and we shall use its present disposition as evidence for past alterations in the relation of land- and sea-level. In doing so, however, it becomes necessary to consider the conditions under which this clay was deposited. The material was brought in from the sea, for along the natural river channels the deposit tapers away into fresh-water peat. The material, nevertheless, over the very extensive areas where it is developed as the typical "blue buttery clay", contains a large proportion of very small particle size, so that it must have been deposited in very quiet water. The evidence of the diatoms and Foraminifera suggest brackish-water lagoon areas reached by salt water at high tides, but also maintained by natural precipitation and river drainage into the Fenland basin. Marine influences were most marked at the base, and the bed became progressively fresher to the transition to peat at the upper surface. The clay is deeper in the river channels, but its upper surface tends to be flat, suggesting the progressive filling of the lagoon. Over large distances in the South Level it seems likely that the clay deposition was extremely rapid, since Early Bronze Age horizons lie in the peat above it, and the peat below it can hardly be other than late Neolithic.

It is difficult perhaps to point to a natural area, where, at the present day, deposition is going on under similar conditions, but the author takes the view that an event like the breaking of the Horsey sea wall would have produced just such conditions had the breach been left open. Possibly the formation of the Zuyder Zee was also a comparable phenomenon, but in both instances it should be noted that the episode began by the sea establishing a short cut to the low-lying hinterland by a breach through a coastal barrier, and we have yet to identify any such barrier in relation to the fen clay formation.

It is naturally of importance to estimate the depth of water in which the fen clay was formed: the faunal evidence only indicates a depth of a few feet, and the tapering out of the fen clay into the marginal wood peats (as at Woodwalton) at the general level of the fen clay surface, with no widespread marginal forest destruction beyond this point, suggests the same thing. When the fen clay was forming, this water-level must have corresponded closely with mean sea-level, for the actual sea-coast was far distant and the tidal influence restricted. It seems unnecessary to postulate a change in relative land- and sea-level during formation of the main body of the fen clay, since progressive filling of the lagoon would account for all its essential characters. In the preceding paper we have made zone VII*c* to correspond with the fen clay deposition within the area where it forms as typical "blue buttery clay", for in this area the age of the bottom and surface can be fairly well established. Further seawards, however, we have shown that the upper surface of the fen clay is of later date, and this is naturally reckoned with in our estimations of land- and sea-level relationships.

Since publication of Parts I and II of this series, discussion with Major G. Fowler has brought out strongly the complexity of the evidence for the dating of the upper sites in relation to the Romano-British period. It appears on the one hand that Romano-British occupation sites *from the first to the third century* thickly cover the silt surface, overlaid by only a very thin layer of later silt, so that deposition must have been largely ended by the early Roman period. On the other hand, although the sites were admittedly water-courses, Roman pots were found 6 ft. deep in the roddon silt both at Nordelph and at Shippea Hill; they were respectively second or third century, and late Castor (third or fourth century) in type. Similarly, Mr C. W. Phillips, in his excavations at Welney (unpublished), has shown some 6 ft. of tidal silt separating two occupation levels on the bank of the roddon, the lowest first to third century and the uppermost third or fourth century. Moreover, Major Fowler has pointed out that one of the largest roddons in the Fenland is so straight that it must have been an artificial waterway (and as such it could only be Roman), yet it has huge natural levées of silt, the surfaces of which show a dense Romano-British occupation. It seems clear that silt both formed and was colonized in the Romano-British period, although possibly deposition began before this time. It is quite possible that the Romans occupied the Fenland behind extensive protective works against a rising sea-level. It is apparent, however, that we need much closer study of the abundant evidence of Fenland conditions throughout this time. It has been already shown from the faunal content that the roddon silt was deposited under more marine conditions than the fen clay, and on the view already outlined we must regard the roddons as natural banks of tidal streams.

These banks were at high-tide level near the sea, and sank gradually towards mean sea-level in an upstream direction. It follows that in judging the former relative height of land- and sea-level from the present height of a roddon, we must take into account, so far as possible, the distance of the site from the sea when the banks were being formed.

It seems possible that the building of coastal silt banks and river levées is a normal process on certain types of coast during submergence, and that formation of a deposit like the fen clay follows when the coastal bank is broached and by a short cut the low hinterland is flooded.

A factor that is hard to allow for satisfactorily in the calculation of indices is the consolidation and compression of the deposits during and after formation. Except in special instances this has not been very seriously considered, on the grounds that most compression takes place during deposition, and that lowering of the fen surface, except for the first swift effect of primary drainage, is a wastage affecting removal of top layers rather than continued contraction of the peat as a whole.

There must necessarily be points of doubtful interpretation in the evidence, and the most important of such is certainly that concerning the "erosion channels" which cut through both the upper and lower peat beds of the Fenland. It has been the view of the Fenland Research Committee, supported by Professor O. T. Jones, that these represented phases of marine retrogression, but it must be mentioned that similar channels on the Lincolnshire coast at Ingoldmells were interpreted by Professor Swinnerton as caused during the onset of a marine transgression. For the time being the former view is preferred, and this does not conflict with our other evidence.

It should be understood that this paper attempts to establish only *relative* position of land- and sea-levels. It is not concerned at this time to distinguish either land movement or sea-level movement in absolute terms. It is our view that the progressive development of curves of the type now shown, from all parts of north-western Europe, but especially from Britain, is the direct route by which a resolution of land- and sea-level movement into isostatic and eustatic components can be made. Although some such suitable evidence for comparison exists, it has not been here brought into consideration.

List of index points

(1) From time to time submerged peat or "moorlog" has been recovered by trawlers from known depths in the North Sea. These samples have been subjected to pollen analysis by Erdtman, Vermeer-Louman, and H. and M. E. Godwin. The results (Godwin 1934) show that at depths from 18 to 29 fathoms, fresh-water peat was accumulating during zone IV, i.e. the birch-pine or pre-Boreal period. This interpretation has been accepted by eminent pollen-analysis specialists such as Jessen (1935). Since this time, therefore, we can reckon a net subsidence of at least 174 ft. (53 m.).

Although many of these sites are rather far from the Fenland basin as it appears to-day, the magnitude of the change certainly makes it necessary to take account of them here.

(2) On the Leman and Ower banks, off the Norfolk coast, the discovery of a Mesolithic fish-spear by the trawler *Colinda*, led to the recovery and analysis of peat submerged at 19–20 fathoms. The results of Erdtman and ourselves (H. and M. E. Godwin 1933) showed this peat to be clearly referable to the transition from zone V to zone VI. The peat was clearly in place on the sea-floor and it is, therefore, certain that since this time there has been a net subsidence of at least 114 ft. (35 m.).

(3) *Judy Hard, Brancaster* (H. and M. E. Godwin 1934). At this coastal site a peat bed rests on sand at −10 ft. O.D., and its upper surface is covered at −1·5 ft. O.D. with clay. Pollen analysis shows that the peat extends from zone IV well into zone VII. Over this period the sea-level must have been at least 12 ft. (base) to 3·5 ft. (top) above its present level. Taking account of the compression of the peat by the clay above it might reduce the latter figure to 0. The matter is not of importance for other data cover the period.

(4*a*) *Plantation Farm, Shippea Hill*. The lower peat bed here shows the transition zone VI to zone VII at −16·2 ft. O.D. (4·9 m.). When the peat of this age was forming, therefore, the land must have stood at least 16·2 ft. higher in relation to the sea than it now does.

(4*b*) Before the deposition of fen clay, the lower channel was eroded through the lower peat, presumably during zone VII*b*. The channel reaches a depth of −23 ft. (7·0 m.) O.D., and since erosion cannot have gone on below low-tide mark (say 10 ft. below mean sea-level) land-level must have been at least +13 ft. above present O.D., and might well have been higher.

(4*c*) The fen clay which formed in zone VII*c* was, on the evidence of Foraminifera, deposited in shallow lagoon-like regions reached by only small amounts of sea water. This agrees with the brackish to sweet character of the fen clay at Old Decoy, just upstream. The fen clay here must have formed in a lagoon with the water surface just about mean sea-level, and deposition probably continued almost up to this level. This is especially clear at the top of the bed where the evidence points to fresher conditions. The top of the fen clay lies at about −3·0 ft. O.D., so that during deposition of the clay the land was probably very close to its present altitude in relation to sea-level.

(4*d*) The upper peat, in zone VII*d*, here must have formed above mean sea-level. Its base in places is as low as −7·0 ft., and the land must, therefore, then have stood at least 7 ft. higher than now.

(4*e*) At a period which we suppose to have been in zone VII–VIII, the upper channel was cut through the upper peat and fen clay to about 13·3 ft. below O.D. For this to happen the land-level must have been at least 3 ft. higher than now, and as we know the upper peat stretched far seawards it seems reasonable to suppose it was as much as 10 ft. higher.

(4*f*) In the Romano-British period the roddon silts filled the channel cut in the previous period, and built up levées to Ordnance Datum at this site. For these deposits to have formed the land-level cannot well have been either much higher or much lower than it now is: it seems reasonable to allow a margin of about 5 ft. either way for the former land-level in relation to sea-level.

(5) *Peacock's Farm, Shippea Hill.* The lower peat bed at this site has its base (in zone VI*a*) at −18·4 ft. O.D. (5·6 m.), the transition zone VI–VII is at −16·8 ft. (5·1 m.), and the top (end of zone VII*b*) at −12·8 ft. (3·9 m.). Since this peat cannot have formed below sea-level these figures give us minimal distances by which the height of land-level above sea-level must have exceeded its present value. These values agree closely with those from the Plantation Farm site just quoted, and it will evidently not be profitable to repeat a category of indices for all the beds at this second site. Unfortunately, the long series at Old Decoy has not been levelled, but it is so close to those at Shippea Hill that the levels of the beds are probably very closely similar.

(6) *Wood Fen.* The fen clay margin here lies at −5·0 ft. O.D. and the water-level during this stage must have been little above this. We may, therefore, assume the land to have been close to its present level (say 2 ft. below its present level). The level of the margin of this deposit at other places is similar and need not be quoted again.

(7*a*) *Ingoldmells, Lincs.* (Swinnerton 1931). The lower forest exposed on this shore, now lies at −8·0 ft. O.D. and is referable to zone VII*b*, during which time, therefore, the land must have stood at least 8 ft. higher than now. (If peat formation was going on very close to the sea, it must have been still higher than this, say 18 ft., but sufficient evidence is lacking for this to be assumed.)

(7*b*) Shallow erosion channels afterwards cut through the lower peat and into the boulder clay: it is perhaps possible that these could have been cut with the land no higher above sea-level than now, but some few feet of elevation seems more probable, since erosion must now go on through a bed already formed in the same place.

(7*c*) The Triglochin clay which overlies the lower peat is a clear index to sea-level, for it represents the upper salt marsh such as forms now at +8 to +10 ft. O.D. (see Chapman in *Scolt Head Island*, ed. Steers 1934). It now lies at −1 to −6 ft. O.D. The deposit could have formed with the land at about 10–15 ft. above its present level. It formed in the period VII*c*, VII*d*.

(7*d*) The *Phragmites* layer above the Triglochin clay must have formed at high-tide mark (say +11 ft. O.D.). It is now about −1 ft. O.D., so that the land was evidently then about 12 ft. higher above sea-level than now. This deposit, to judge from the pollen analysis of the peat above it, formed in zone VII*d*.

(7*e*) Above the *Phragmites* clay at 0 to +1 ft. O.D. is the upper wood peat containing the Halstatt horizon. As it overlies salt-marsh deposits conformably it was presumably still close to the sea, but out of reach of high tides, say at least 12–15 ft. higher than now. The salt making at this site also suggests that the sea must have been close by.

(7*f*) Through the upper peat channels have been cut which trench into the boulder clay to −9 ft. O.D. In this phase the land cannot have been lower than its present level, though it was probably higher.

(7*g*) The Scrobicularia clay above the upper peat is now at about 0 to +7·0 ft. O.D. To judge from their content of *Scrobicularia* and *Cardium* its lowest layers formed just below low-water neap tide levels, i.e. with the land probably 5–10 ft. lower than now. Swinnerton suggests that this clay post-dates the Roman occupation referred to below, but it may equally coincide with the early part of the Romano-British period.

(7*h*) A Roman occupation level (first to third centuries), now only about +5 ft. O.D., indicates a period when the land-level must have been some 7 ft. or so higher than to-day. This should be considered with the evidence from the roddons and silt land in the Fenland, which were extensively colonized in this part of Romano-British times. The surface of the roddon silt is about Ordnance Datum at Shippea Hill, grading down to this along the former river channel from the seaward side. It is hard to see how, if the land had been 7 ft. higher than now, the roddon silts could have built up so high. It may still be possible that the Ingoldmells Roman site lay behind protective sea walls, although Swinnerton found no trace of them. Alternatively, we may put forward the view that the bulk of the upper silt in the Fenland had been deposited before the Romano-British colonization of the first century, that during the first to third centuries there was temporary marine regression, and that at the end of this time marine transgression, though not extensive, again became apparent.

(8) *Nordelph Roman Bridge* (Kenny 1933). A large roddon at Nordelph bears on one flank a substantial causeway of gravel, the well-known Roman road from Denver to Peterborough. On this flank the presence of a lateral silt roddon showed a tributary stream. That these streams were active waterways when the causeway was in use was shown by excavation at the place where the causeway meets the tributary roddon. At this place the abutments of a bridge were found on either side the tributary, and lateral extensions of the causeway leading down to a ford. The bridge abutments are at a level of +4·7 ft. O.D. (the earlier published reference of +15·8 ft. is erroneous), and the bed of the tributary channel beneath the bridge, where it has cut into the underlying peat and has later filled with silt, lies at about −3·7 ft. O.D. The site was some miles distant from the coast of that time as is shown by the maximum rise and fall of the tributary stream, a bare 8 ft. This evidence seems to show that at the time of the causeway and bridge (possibly second to fourth centuries) the land stood very close to its present altitude in relation to the sea. It was possibly some 2 ft. higher than now.

(9) *Late Bronze Age site—Mildenhall Fen.* This site was at +7·0 ft. O.D. Since settlement can hardly have been on land lower than 2 ft. above mean sea-level, the land at this time cannot have been more than 5 ft. lower than at present.

(10) *Wood Fen Farm.* A middle Bronze Age spear was found here at −1·0 ft. O.D., on the hard ground surface. If this reflects an occupation, then the land surface must have been at least 3 ft. higher above sea-level than now.

(11) *Isleham Fen.* A middle Bronze Age site here was at +5·0 ft. O.D. and shows that the land-level cannot have been more than 2 or 3 ft. below its present level.

(12) *Wilton Bridge.* At Wilton Bridge, the base of zone VII–VIII is at +5·0 ft. O.D. and indicates that the land-level cannot have been more than 5 ft. below its present level. This diagram extends back to zone VI *b* where the base is at −6·5 ft. The evidence already outlined here shows, of course, that the land-level was then much more above its present height than the 6–7 ft. indicated.

(13) *Runcton Holme—Norfolk* (Clark and Hawkes 1933). On the eastern edge of the Fenland—from 450 B.C. to A.D. 350—a gravel mound with its surface at about 20 ft. O.D., was continuously occupied. At this time, therefore, the land can never have sunk so much as 20 ft. below its present level, and probably not more than a limit of 10 ft., for the site must have been close to salt water since the pottery shows that some salt making was carried on. It is not perhaps likely that the inhabitants chose a site for salt manufacture much above high-tide mark, and for what this evidence is worth, it suggests that the land-level was not then much above the present level. This has not been set in the graph.

Wiggenhall St German's (Godwin, H. and M. E., and Edmunds, F. H. 1933). This is the site where deep excavations for the new Middle Level sluice gave excellent opportunities for studying a long series of fen beds. Although rather close to the present coast, the blue clays which make up most of the lower half of the exposure (beds B and D) are shown by their Foraminifera to have formed in brackish lagoons. It seems certain that during their deposition only high tides entered, and that the area was one of restricted tidal range some distance, by open water, from the sea.

(14 *a*) Peat bed A at the base of the St German's series, is now at −23·5 ft. O.D.; peat could only have formed, therefore, with the land at least 23·5 ft. higher than now. The age is very uncertain, but certainly in zones VII *a* or *b*.

(14 *b*) The deposition of brackish water clay B above peat bed A apparently took place in lagoon conditions. If the water surface was about 3 ft. above the present surface of the bed and this corresponded roughly with mean sea-level when the clay was forming, the land-level at that time must have been about 20·5 ft. higher than now.

(14 *c*) The peat bed C at −17·0 ft. O.D. contains oak stools *in situ*, and lies between clay beds B and D deposited in water of very restricted tidal range. It must have been at least 2·0 ft. above mean sea-level to have grown unaffected by the tide, i.e. the land was at least 19 ft. higher above sea-level than at present. The zone of the bed is presumed to be zone VII *b*.

(14 *d*) The blue clay of bed D, which lies between −5·0 and −17·0 ft. O.D., is held to correspond with zones VII *c* and VII *d*. It was deposited in only moderately brackish water, but contains *Cardium edule* so that perhaps access of spring tides or neap-tide high-water can be assumed. This is the bed which corresponds with the fen clay of the South Level and it will be noted that its upper surface is at the same level. If the water

surface was about 3 ft. above the final level of the clay surface, then the land-level must have been about 2 ft. below its present height. This holds at least for the formation of the top of the bed, but since the clay is so deep (12 ft.) it may be questioned whether its uniformity of character may not mean that, with a slowly sinking coast, deposition was keeping pace with a rising water-level in the lagoon. This has not, however, been taken account of in the graph index.

(14*e*) The base of peat bed E at −5 ft. O.D. has been shown to represent the transition from salt-marsh to fresh-water fen. We do not, however, know at what altitude above mean sea-level this transition took place. It was, in all probability, between +5·0 ft. and mean sea-level, for nothing in the clay suggests conditions of large tidal range. These figures suggest that land was from 5 to 10 ft. higher in relation to the sea than it now is.

(14*f*) Peat bed E, at the top of which were found glass beads, we have referred to zone VII–VIII. It now lies at about −3·0 to −5·0 ft. O.D. When the base of the bed was formed the tidal range was probably small, but when the top was formed, just before deposition of the Scrobicularia clay, the range was probably much greater. A tidal range of 12 ft. at the time of the end of the peat bed would suggest that the land must have been at least 11 ft. above its present level in relation to the sea.

(14*g*) The Scrobicularia clay F, over this peat bed, is now at 0 to −3·0 ft. O.D. It is likely that Scrobicularia would be growing below low water of neap tide (say 5 ft. below mean sea-level) and so the bed during formation was probably rather more than 2–5 ft. lower than now.

(14*h*) Although it has been indicated that the upper peat bed H, at St German's, is of uncertain age, it must fall in zone VIII and it is now at about +3 to +4 ft. O.D. If the sea was close at this time the land must have been at least 7 or 8 ft. higher than now.

(15) *Sea walls*. Major G. Fowler has produced evidence, as yet unpublished, by levelling the parallel sea walls behind the shores of the Wash, that as they have been successively built the land has sunk. The successively younger banks have been higher and higher. This gives a downwards movement of perhaps 8 ft. in the last nine hundred years or so. Major Fowler has kindly sent me the following note which expresses his present views of this evidence.

The innermost seabank in the coastal area of the fens between the present outfall of the Nene at Sutton Bridge and of the Ouse at King's Lynn, is called "the Roman bank" in most publications since the time of Dugdale's mid-seventeenth-century *History of Embanking and Drainage*. It is also so named on Ordnance Survey maps. However, there is no evidence to show that it is of Roman origin, but a good deal of a circumstantial nature to indicate that it is early monastic. Before the seventeenth century it was always called *Fossatum Maris* or the Sea Bank. Dugdale had no sound reasons for starting the Roman bank theory.

The original bank, which was not more than 3 ft. high, appears to have been built in a piecemeal and irregular way, as if by different local interests. This view is supported by the fact that late medieval documents show that the upkeep and repeatedly ordered heightening of this

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bank was the obligation of those whose land abutted on it. Evidently the bank existed before the Norman Conquest, because villages just within it have associated names, such as Walsoken, West Walton and Walpole recorded in Domesday Book. Seaward from this oldest bank are several other banks, evidently built for the reclamation of salt marshes. They vary in number up to at most four on any straight lines drawn outwards to the sea. Some seem to have enclosed quite limited areas. All except the most recent bank completed in about 1919, have been levelled down in most places so that if the general difference of level of ground is to be obtained, work must start from some distance each side. Where as much as about fifty years or more separates the time of the construction of these banks, the general level of the ground on the seaward side is, in each case, higher than that of the landward one. Thus the land steps upwards towards the sea till one reaches the present salt marshes. Their level (which cannot be greater than the highest spring tide) is considerably above that of the land behind the "Fossatum Maris" or so-called "Roman Bank".

I think that if the differences of levels and dates of banks are ascertained, their collation will produce some interesting conclusions regarding changes in sea-level from, say, the tenth to the sixteenth century, and then at intervals up to the present time. The present salt marshes appear to be growing seaward at about one-third of a mile per ten years. I suggest that all this indicates that sea-level has been rising for part, if not all, of the last thousand years, and more so recently.

The author would like to thank Major Fowler for having so kindly provided this note, and at the same time to express his indebtedness to Dr S. E. Hollingworth who has beneficially criticized the manuscript of this paper.

Conclusions

Perhaps the most striking feature of the graph is the fact that it should be possible to construct at all a single curve which violates none of the evidence except two indices at Ingoldmells: one is the Roman level already referred to, and the other is the Triglochin clay (7*c*) which is too high by 10 or 15 ft. Possibly local tidal conditions suffice to explain this. The consistency of the data is a strong support for the general validity of the curve, and it will be of very great interest to see how far future discoveries in the Fenland are capable of fitting it.

The chief value of the curve is that it clearly demonstrates the great extent of marine transgression since the early post-Glacial, and also gives some measure of the rate at which it progressed. It may be said that the early indices give only minimum values, but these are in themselves striking enough, and it must be remembered that peat of Atlantic age (zone VII) is never encountered save in the shallower parts of the North Sea.

The early and late parts of the curve are based on fewer indices than the rest. Especially in zone VII stratigraphic evidence of a possible phase of marine retrogression or stability is scanty and the depression at 3000 B.C., is based on one site only. Only deep excavations or detailed deep borings in the most seaward parts of Fenland will provide the necessary evidence for this period. The evidence is beyond reach of hand-borings, and much of it may be under the waters of the Wash and the North Sea.

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The later part of the curve is difficult to establish since the most recent changes have been small and the most recent deposits very liable to disturbance. There is probably some material historical evidence, as, for instance, in reports of periods of particularly severe flooding, but this has never been critically surveyed.

In the period between the Neolithic and Romano-British times, for which our evidence is best, there is clear indication of the continued progress of the general transgression. There is some evidence, which we have accepted, that the transgression was broken by two periods of retrogression, one in the Bronze Age and the other after the Iron Age. In each of these erosion channels appear to have cut through peat beds and underlying deposits. Possibly a third retrogression was in progress about 2500 B.C. The evidence presented seems to require periods of emergence breaking a long trend of submergence. Schütte has demonstrated that "elevation" at least once broke the general trend of "sinking" on the north-west German coast in the same period. It is, moreover, clear, in the author's view, that the combination of factors determining eustatic and isostatic control of relative land- and sea-movement is so complex that a simple resultant such as unbroken "sinking", or sinking broken by periods of halt, is less likely than some combination of "sinking" and "elevation". To be sure, the "sinking" has much the upper hand in this part of the North Sea.

Although the scheme presented is incomplete and will clearly need some amendment, it is trusted that it may be of service as a first approach to a quantitative statement of movements of great scientific and economic importance. We have not attempted any comparison with phenomena of the same kind on other British coasts or just across the North Sea, though it will be apparent that such comparisons will become increasingly desirable as our evidence increases.

The changing face of the Fenland

Now that we have surveyed the evidence thus far available for the linking together of the events that have made up the last ten thousand years of Fenland history, it may be advantageous to abandon close-range enquiry for the moment, and put forward instead a simple survey, in the most general terms, of what has happened to our area throughout this long period of time. We may perhaps take the role of long-lived geographical observers able to watch, from some aerial viewpoint, the progress of change in Fenland through succeeding millennia.

We first look back upon that part of Fenland history which we have spoken of as pre-Boreal, and which perhaps ended 7500 years before Christ. At this time the area we now call the Fenland could have had no claim to such a title. The floor of the Fenland basin revealed the wide parallel outcrops of Jurassic clays, Greensand, and Gault clay, heavily plastered in some parts with boulder clays or glacial gravels. That portion between Littleport, Mildenhall and Brandon was covered with a boulder clay influenced largely by the local Greensand, and it was no doubt already heavily leached, and loose and acidic in character. Over all this countryside there probably extended open woodland of pine and birch, resembling in general character that of northern Europe or northern Canada to-day. Only locally favoured spots carried the trees of warmer climates. Through this sparsely wooded region ran the wide river valleys, cut when the volume of their waters was much greater, and now mostly filled with flat sedge fen bordering a shrunken stream. Some two or three hundred miles downstream these rivers merged into the Fenland of that date, and over the bed of the present North Sea, Mesolithic hunters and fisherfolk could reach the rest of the Continent. The sea lay then north of the Dogger Bank.

As the climate now began decisively to improve with the onset of the Boreal period, warmth-loving trees replaced the birch and pine, more rapidly on the clay soils than on the sands. Gradually through the course of a few centuries, the landscape saw the replacement of birch by pine, and the establishment of elm and oak woods with undergrowth of hazel. No doubt a generous cover of deciduous forest soon clothed all our present Fenland save the wet watercourses and infrequent lakes. The prevalence of hazel suggests that it may also have formed open scrub or dense undergrowth below trees of light canopy such as the ash. The increasing geniality of climate towards the end of the Boreal period allowed the alder and linden to appear in locally favoured places.

The linden was the small-leaved species, *Tilia cordata*, but we cannot say what was the species of elm then so abundant: it may have been the Wych elm (*Ulmus glabra*) which still regenerates naturally in Britain, or possibly it was one of the East Anglian elms of less definite status, such as *Ulmus nitens*, *U. minor*, or *U. procera*.

The late Tardenoisian (Mesolithic) people of the Shippea Hill site, encamped on the sandy hillocks by the Little Ouse River: the sand surface and the valley fen were strewn with remains of bones from animals killed in the forest, and with microlithic flints from weapons and tools.

At about 5500 B.C., the Fenland forest area became affected by the increasing wetness of the climate, and the alder assumed a role of great importance in the woodland composition, which indeed it never relinquished until the historic clearance and drainage of English forest land. The woodlands of this Atlantic period were warmer than those of to-day, and oak, alder and lime predominated in them. This was the golden age of the post-Glacial forest, and tall, well-grown timber covered a countryside through which at first the late Mesolithic people, and later the Neolithic folk, made their settlements. The green forest cover was still broken only by the winding river valleys, full of sedge fen and clumps of alder and sallow, but the aerial view would have disclosed a shore line probably not far distant from that of to-day: the ocean had by this time closed over the wide North Sea fenland. Within the Neolithic period far-reaching changes took place. Whether because of the encroaching sea or of the wet climate, the Fenland area now became generally waterlogged. With the growth of reeds and sedges, black fen peat began to cover the woodland floor, and to embed the huge trunks and stools of the forest trees killed by the exclusion of air from their roots. Only rapidly growing soft peat could have sealed up these great timber trees before decay could remove them. The forest trees, with crowns already shaped by the prevalent south-west wind, all fell to the north-east. These fallen forests were mostly oak, but locally the destruction also overtook woodland containing abundant yews of vast proportions. Sealed in by the growing peat along with the forest trees were the stone celts of the Neolithic people, tools not destined to come to light until disturbed by peat diggers' beckets,* or the spades of the coprolite workers on the eastern fen margin.

Through the Neolithic period we can picture the Fenland as a vast tract of sedge fen, much the same in extent as now: open water was rather infrequent and the sedge fen tended to be freely invaded by alder, sallow and birch, particularly at the margin of the upland. This tendency to invasion of the peat land by woody species became much more marked towards the end of the Neolithic period, and for some miles these marginal woods extended into the fen basin. They must have been extremely inhospitable, with alder, birch and sallow forming a light canopy above an undergrowth of abundant sedge and reed. It is unlikely that prehistoric man ventured much on the quaky black surface, where the only places of moderate firmness were the tree stools themselves. Modern man equally avoids the fen carr of the Norfolk Broads to-day. The wetness of the conditions is shown by the way in which generations of these trees were successively imbedded.

Towards the end of the Neolithic period increasing dryness had made itself apparent, and not only did fen woods stretch over the peat surface far towards the sea, but near the fen margin they were dry enough to be invaded by a large proportion of oaks, and in some places, by pines and yews.

An extensive and typical woodland undergrowth developed, with shrubs such as hazel, dogwood and buckthorn, with brambles and woodland mosses, which in some places included the low-moor species of *Sphagnum*. The rivers, no longer level with the peat surface, increased the dryness by cutting their beds more deeply through the soft peat.

The face of this wooded fenland was now suddenly changed by an extensive invasion by the sea, very possibly begun by the breaking of a coastal bar like that recently broached between the sea and the Norfolk Broads.

Within a short time almost the whole of the fenland area had become a brackish lagoon a few feet in depth, where fresh water from the uplands was held up by the high mean sea-level, and mixed with the salty incursions of the spring tides. It is likely that coastal banks of sand and silt were formed, and behind them in this large shallow lake, was deposited all the silt and clay brought up from the sea by the invading

* A "becket" was the tool, usually of wood shod with iron, by which the "cesses" or turves of peat were cut (see Skertchly 1877). Public-houses called "The Spade and Becket" are still to be found in the peat fens.

high tides. These were the conditions in which the "fen clay" (the so-called "buttery clay") was deposited.

The waters supported little life, although dwarf cockles sometimes established themselves, and there are fairly frequent remains of brackish water Foraminifera. On the landward margins of this brackish sea, which extended in the south-west well beyond Littleport and Ely, the water was fresh enough to allow a dense growth of the common reed (*Phragmites communis*), much as it now grows on the shores of the Baltic. Up the river channels these reed beds gave place to fresh-water sedge fen, and elsewhere round the fen margin the brackish water must have extended right up to the existing fen woods. In a remarkably short period of time many feet of soft fen clay had been laid down over the earlier fen peat. We do not know the whereabouts of the main estuary of the Fenland at this time, but it may well have been north of the historic estuary at Wisbech.

The early Bronze Age which had now begun, saw the gradual re-establishment of fresh-water fen over a large part of the Fenland basin. At first sedge fen, perhaps with local open water, and then fen woods of alder and sallow re-established themselves, clothing the surface of the fen clay with a new mantle of peat. This process began at the margins and extended progressively seawards, and in the more marginal parts the fen woods which had been hardly affected by the marine invasion, continued to form woods of pine, yew and oak. Climatic conditions were dry or at least continental, and the isolated basin between Holme and Yaxley, south of Peterborough, developed extensive raised bogs in the absence of flooding by alkaline water. Once more, towards the end of the Bronze Age, dry fen woods growing on the peat had extended across the full width of the fens and far seaward. At this time prehistoric man must have passed freely over the fen surface, for his bronze tools and weapons are found very abundantly in the peat.

The climate now became (from the human standpoint) much worse. With the change to the Iron Age at about 500 B.C., the climate became both colder and wetter; the lime tree practically vanished from the forest cover of the upland, and birch became more abundant. The Fenlands must have become quite uninhabitable, for no traces of Iron Age man have been found in them, and it may be that, at this time, there were formed the large shallow meres which were such a striking feature of the undrained Fenland. It seems probable that the fen woods were replaced by wet sedge fens or shallow open water, in which the calcareous waters from the upland supported a vast population of stoneworts and mollusca. Only at a few sites, on the seaward side of the fens, is there any evidence of peat surfaces habitable by man.

The effect of climatic deterioration was heightened during the Roman period by a further phase of marine invasion, which differed, however, from the preceding one in that it did not produce a large inland lake to be filled with brackish mud, but gave rise to extensive coastal salt-marshes of silt, and raised river banks or levées which penetrated far into the peat country. It is difficult to say exactly when this marine invasion began, but it was certainly continuing in the early part of the Roman period. On the salt-marsh landscape, heavily marked with the wriggling courses of tidal creeks, the Roman period agriculturalists established themselves in great numbers, so that for the first time the fens took on an orderly and artificial appearance like that of to-day. This effect was, however, restricted to the seaward "marshes". Further inland Romano-British agriculture spread its fields along the silt banks of the river channels, but behind these banks lay the waterlogged sedge fens, cut off from drainage to the rivers, and quite unused by man. We have yet to learn the extent of the drainage works undertaken in this period: there are many indications that they were extensive, and there is some evidence that they were carried out during the last stages of the marine invasion itself. It is a striking fact that the silts of this marine invasion reflect marine conditions more strongly marked than those of the fen clay invasion, and it is clear that strong tides must have flowed far up the fen rivers during their deposition.

From this time onwards the fen strata yield less and less evidence of former conditions, and we pass progressively into the territory of the geographical historian. We need only recall that throughout the *dark ages* the fenlands remained virtually untenanted. Not only do the wet peatlands yield no trace of human occupation, but even the fertile silt lands exploited in the Roman period were abandoned. The cause of this change is unknown. Peat was formed over the silt banks of the Roman river system, and reached a height of about 12 ft. O.D. round the fen margin. At the time of Domesday the chief wealth of the fenland lay in wild fowl and fish, which were abundant in the rivers and the great meres of Whittlesea, Ramsey, Benwick, Streatham, Soham and Redmere, together with those of different type on the silt land near Boston.

When the drainage of the fenland took effective hold in the seventeenth century and accelerated its pace through the eighteenth and nineteenth centuries, those changes appeared which have given the characteristic present-day aspect to the area. Long straight channels have been cut, controlled by sluices and fed by pumping stations; the large meres have all been drained; the peat surface has been cut up into fields and the land is a mosaic of crops through which, in the winter, black peat, white shell marl, or the buff silts indicate something of the former natural topography. The progressive lowering of the water table has caused first a contraction, and then a progressive wastage of the peat, so that the ground level, falling at a rate often as much as 1 in. a year, is now in many places below sea-level. The rivers remain perched between high banks above the surrounding drained land, and the wastage of peat from the flanks of the old Romano-British river levées reveals them as wide gentle banks wandering across the peat fens, and carrying on their crests a high proportion of the Fenland farm houses. The silt land towards the Wash becomes once more the scene of intensive agriculture and the building of sea banks from time to time adds fresh strips of high-level salt-marsh to the cultivable land.

One may wonder how apparent to the aerial observer is the slow forward creep of the sea towards the next marine invasion, and whether he would find more cause for alarm or safer means of defence than the fen-dwellers of to-day, who see in the growing difficulties of fen drainage to the sea and in raising tide-levels no indication that the old interplay of land and sea movement may be threatening a new submergence, and the old destruction.

The author in conclusion wishes again to state his gratefulness to the many friends who have helped with this work, especially the members of the Fenland Research Committee, his wife who carried out much of the critical and laborious laboratory analysis, and assisted the field work, and Sir Albert Seward, F.R.S., who has encouraged and helped forward these investigations from the outset. The borer used for sampling was purchased by a grant of the Royal Society of London, which we gratefully acknowledge. Among those who kindly helped in the labour of field borings were Professor J. S. Turner, Professor T. M. Harris, and Dr M. H. Clifford.

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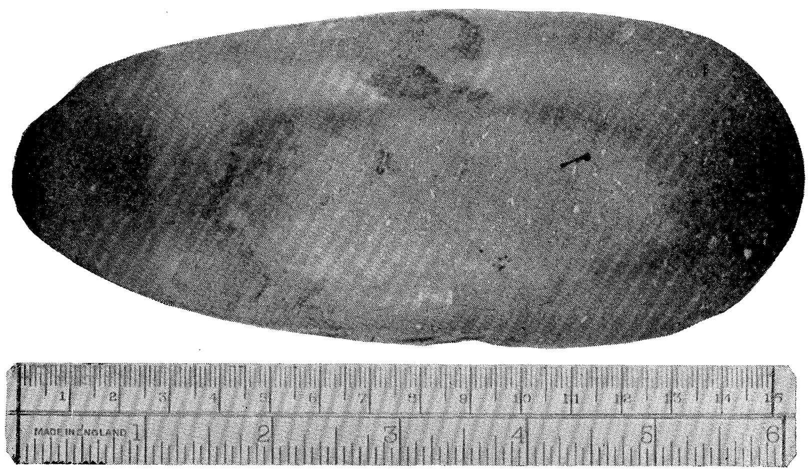
Description of Plate 21

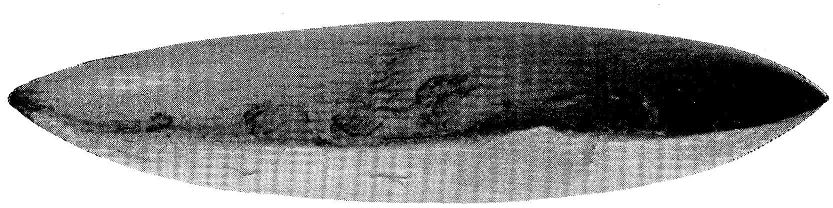
A, B. Late Neolithic stone axe, made of Graig Lwyd rock, north Wales, found in the bank of the Swaffham Engine Drain near Upware, Cambs. Its position in relation to the fen deposits and pollen zones is shown in figures 10 and 11.

C. Middle Bronze Age spear found on the surface at Wood Fen Farm, near Ely. Peat has recently wasted from this surface, which lies at about $-1{\cdot}0$ ft. O.D.

A



B



C

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

A

B

C

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

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