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THE MIDDLE PLEISTOCENE DEPOSITS AT MARKS TEY, ESSEX

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CONTENTS

At Marks Tey, Essex, Pleistocene lacustrine sediments rest on chalky boulder clay and occupy a deep, narrow trough cut into the subglacial surface. The central deposits of the former lake basin consist of laminated clay muds, partly brecciated, overlain by laminated grey clay, which is at present exploited for brickmaking. Together these strata have a maximum proved thickness of at least 35 m. The marginal sediments of the basin are thinner and more organic, and indicate some fluctuation of water level during deposition.

Palaeobotanical evidence suggests that the basin was formed during the Lowestoft glaciation, possibly by subglacial erosion, and was gradually infilled during the course of the entire Hoxnian interglacial and the earliest part of the ensuing Gipping glacial period.

Pollen analysis of the lacustrine deposits yielded the first complete vegetational record throughout the Hoxnian interglacial from the Lowestoft Late-glacial to the Gipping Early-glacial periods. The vegetational and climatic development of the interglacial can be reconstructed from the palaeobotanical evidence. The grey clay of Gipping age contained a macroflora of 'full-glacial' aspect.

Of particular note are (1) the closing zones of the interglacial (Ho III and Ho IV), which have not been fully recorded before; (2) the occurrence during this period of such exotic plant types as *Vitis*, *Pterocarya* and *Erica* cf. *terminalis*; and (3) a high non-tree pollen phase during subzone Ho IIc similar to that recorded by West (1956) from the same subzone at Hoxne.

A preliminary investigation has been made of diatomaceous lamination structures in the interglacial clay mud. This lamination, which appears to be annual, suggests that the timespan of the interglacial period was of the order of 30000 to 50000 years.

The interglacial deposits rest on chalky boulder clay, corresponding to the Springfield Till of Clayton (1957, 1960). There is no sign of till overlying the lacustrine deposits. Nearby, other Hoxnian deposits at Copford and Rivenhall End, Kelvedon, rest in a similar stratigraphic position. This fact implies that all the till deposits of south-east Essex belong to the Lowestoft glaciation, and that the Gipping ice advance did not extend as far south as commonly assumed.

1. Introduction

For over a century it has been known that patches of Pleistocene lacustrine deposits occur in association with chalky boulder clay at Copford, Essex, and nearby at Marks Tey. In 1953 Pike & Godwin suggested that the latter were of Hoxnian age. Until now it has been impossible to make firm stratigraphical correlations between the drift complex of south-east Essex and the standard East Anglian Pleistocene sequence (West 1963; West & Wilson 1966). Consequently an investigation of the Marks Tey deposits, in particular of their vegetational history, seemed long overdue.

W. H. Dalton surveyed the Colchester district for the Geological Survey between 1873 and 1875 (Dalton 1880). He noted 'the Post-glacial beds near Marks Tey' and described sections from two small pits, probably now ponds to the south of the present workings. Mrs A. M. Gifford of the University of Southampton produced a short, unpublished report on the brickpit and deposits in 1948, and Dr S. L. Duigan made some trial borings and pollen analyses in 1953. In 1963 R. W. Andrews submitted a M.Sc. thesis to the University of London, containing a discussion of lamination features from the grey clay of the brickpit.

The Pleistocene lacustrine deposits at Marks Tey occupy an area immediately surrounding the Marks Tey Brick and Tile Works (National Grid Reference TL 912242) about 400 m north of Marks Tey church. The land surface here lies at about 30 to 34 m O.D. The extent and boundaries of the deposits are discussed below. Marks Tey is situated 8 km west of Colchester at the junction of the main A12 and A120 roads. In relation to other sites of Hoxnian age, this site lies 60 km south-south-west of Hoxne and 27 km west-north-west of Clacton-on-Sea (see figure 1). The brickpit at Marks Tey, which has been worked by Messrs W. H. Collier Ltd. since about 1863, provides the only accessible exposures of the deposits.

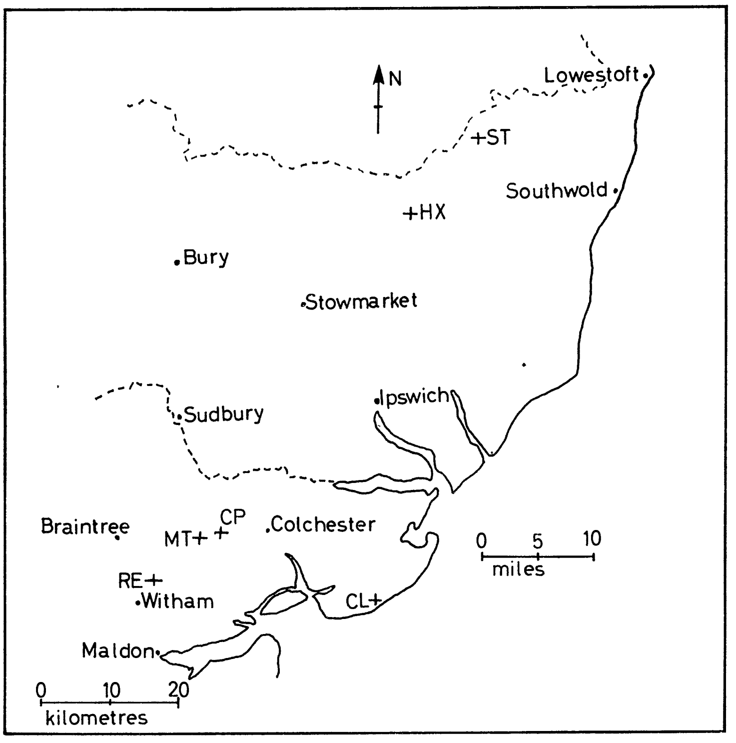

Figure 1. Hoxnian interglacial sites in southern East Anglia. CL, Clacton; CP, Copford; HX, Hoxne; MT, Marks Tey; RE, Rivenhall End; ST, Saint Cross, South Elmham.

2. The stratigraphy of the Pleistocene deposits

(a) *Sources of evidence*

The sections of grey clay now being worked in the brickpit offer the only good exposures. The main pit is about 18 m deep and approximately 300 × 120 m in area. Around it are a number of smaller, shallower pits, now overgrown, partly filled in or flooded. Only a few abandoned faces, where the clay contained too many sand seams for brickmaking, and the recently worked sections can be readily examined without a great deal of hard digging.

These open sections everywhere reveal grey clay, generally laminated. So-called peaty bands have been recorded, but none are visible at present, though fine gravel seams occur, sometimes stained darkly with manganese oxide.

The large number of borings put down for Messrs W. H. Collier Ltd within and around the margins of their expanding brickpit, together with the records of old pit sections, are a rich source of information. These are often difficult to interpret, as they emphasize the variation of clays and 'loams' suitable for brick-making. Because such boreholes were sunk to detect brick-earth they rarely penetrated far into the lower strata of the deposits. Many, in fact, were put down outside the actual area of the lacustrine deposits.

British Railways put down three borings in 1962 along the railway line beside the pit. Two of these penetrated lacustrine deposits. A full list of all such records and of one of Dr S. L. Duigan's trial auger holes, whose records have also been available to me, are given in Turner (1966) and their position indicated in figure 2.

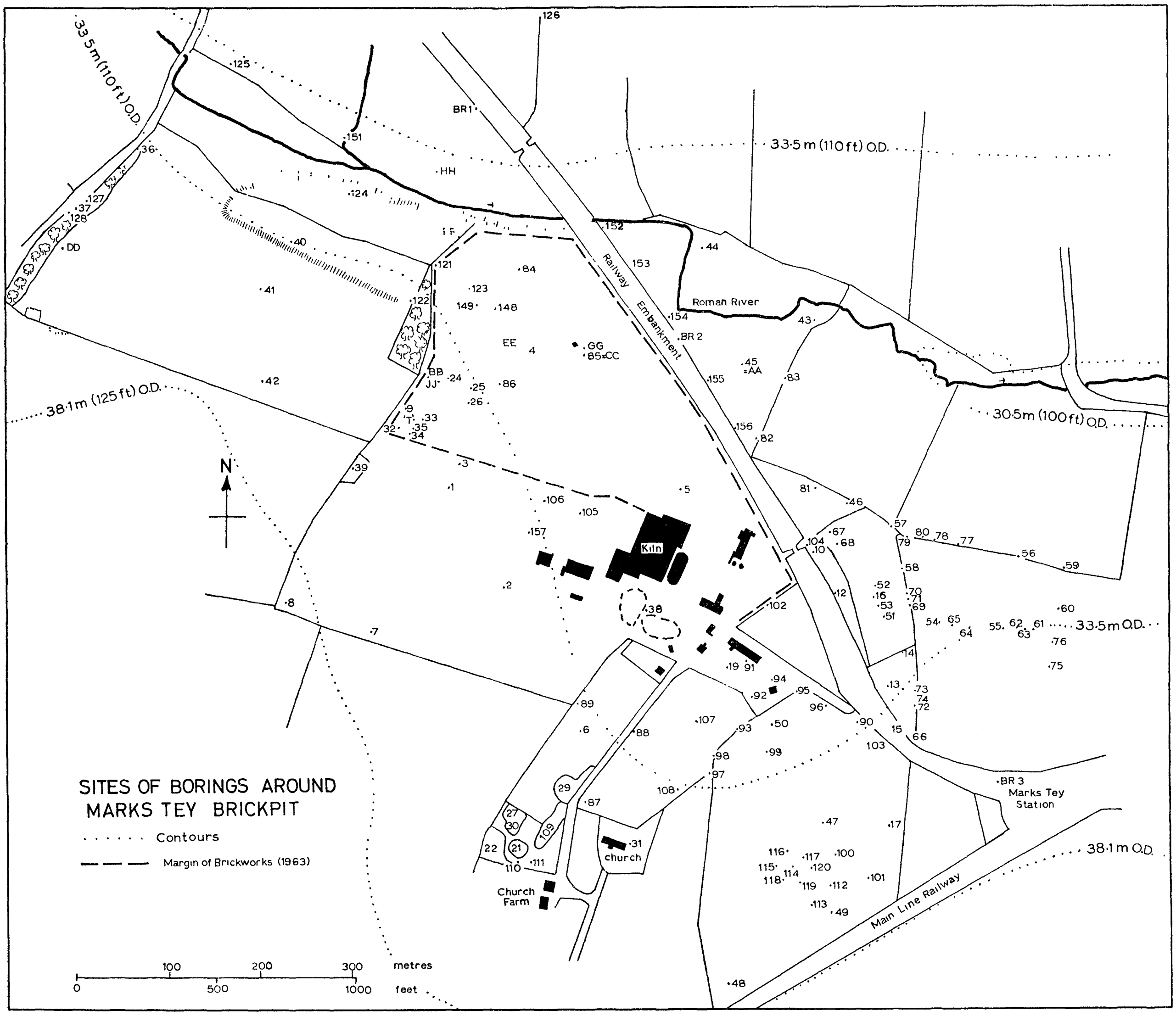

FIGURE 2. Location of borings around the Marks Tey brickpit.

Collier's records indicated that strata of a more organic nature underlay the grey clay of the brickpit. Consequently a fresh series of borings was undertaken to clarify the stratigraphy of the lacustrine deposits and to obtain samples for pollen analysis.

As at Hoxne (West 1956) a $1\frac{1}{2}$ in (40 mm) diameter shipwright's auger was used for borings AA, BB, CC and a few minor borings. Although this auger distorts the microstratigraphy of the strata, major sediment types can easily be distinguished and, with care, uncontaminated samples for pollen analysis can be extracted at close intervals.

The deepest borehole, GG, was put down by Messrs Rand of Stowmarket and financed by a grant from the Royal Society. Continuous cores were taken to a depth of 21.4 m with a standard 4 in (10 cm) internal diameter percussion corer, giving cores 30 to 45 cm in length. A similar corer was used for boring JJ, whilst boring HH was carried out with a 12 cm diameter auger.

(*b*) *The succession of glacial deposits around Marks Tey*

The clearest stratigraphical evidence for the local sequence of glacial and interglacial deposits comes from a series of trial borings made by Messrs Legrand Adsco for the Essex County Council along the line of the proposed Marks Tey–Stanway by-pass. This series extends eastwards from the neighbourhood of the Marks Tey brickyard, past the disused brickworks at Copford, to the outskirts of Colchester.

From these sources it is possible to draw up a geological section for the Marks Tey–Copford–Stanway area giving a consistent picture of the stratigraphical relationships between boulder clay, glacial gravels and lacustrine deposits (figure 3).

Geological sequence in the Marks Tey area:

(*a*) Recent alluvium of the Roman River
(*b*) Solifluction deposits. Hillwash, sand and gravel
(*c*) Lacustrine beds (glacial and interglacial) at Marks Tey and Copford
(*d*) Boulder clay
(*e*) Glacial sand and gravels
(*f*) London Clay

Stratigraphically the key horizons are the lacustrine interglacial deposits. Pollen analyses from Marks Tey, described below, confirm that these deposits are largely of Hoxnian age. At Marks Tey the lacustrine deposits are capped by a thin layer of angular gravel.

The boulder clay of the district is generally chalky, except where weathered, and contains abundant flints and also quartz, quartzite and other erratics. Thin seams of gravel are in some places intercalated within it. Up to 6 m of boulder clay have been recorded in borings near Marks Tey, but to the north-west, on the extensive till-covered plateau of High Essex, this deposit is often much thicker. Nowhere is there any sign of boulder clay overlying the lacustrine deposits.

The underlying glacial sands and gravels are 7.5 m thick in borings to the south and east of the brickpit, but similar glacial gravels up to 30 m thick are extensively exploited at Stanway and Birch.

At Marks Tey and Copford the lacustrine deposits occupy deep depressions in the boulder clay. These depressions must be reflexions of underlying troughs or valleys in the subglacial surface, since they extend down well below the general surface level of the London Clay in the neighbourhood. At Marks Tey lacustrine sediments extend down to a level of at least -6.1 m O.D.; at Copford, by-pass borings MS 105 and 109 (see figure 3) failed to reach the base of the boulder clay at 0.9 and 2.4 m O.D. respectively, whereas nearby borings had penetrated London Clay below glacial gravel at 28.4 m (boring MS 219) and 31.4 m O.D. (boring MS 110).

Similar subglacial valleys and channels, generally cut deeply and rather narrowly into chalk or London Clay, are recorded from a number of sites in southern and eastern East Anglia. During the present investigations another trough containing boulder clay and interglacial deposits of Hoxnian age was detected at Rivenhall End, Kelvedon, 11 km south-west of Marks Tey (National Grid Reference TL 839165). This trough is cut down at least to -2.1 m O.D. The present valley of the River Blackwater overlies a similar but more extensive subglacial valley infilled with glacial deposits, the base of which is well below O.D. Woodland (1946) gives borehole evidence for a number of buried channels; others have been described from the Yare

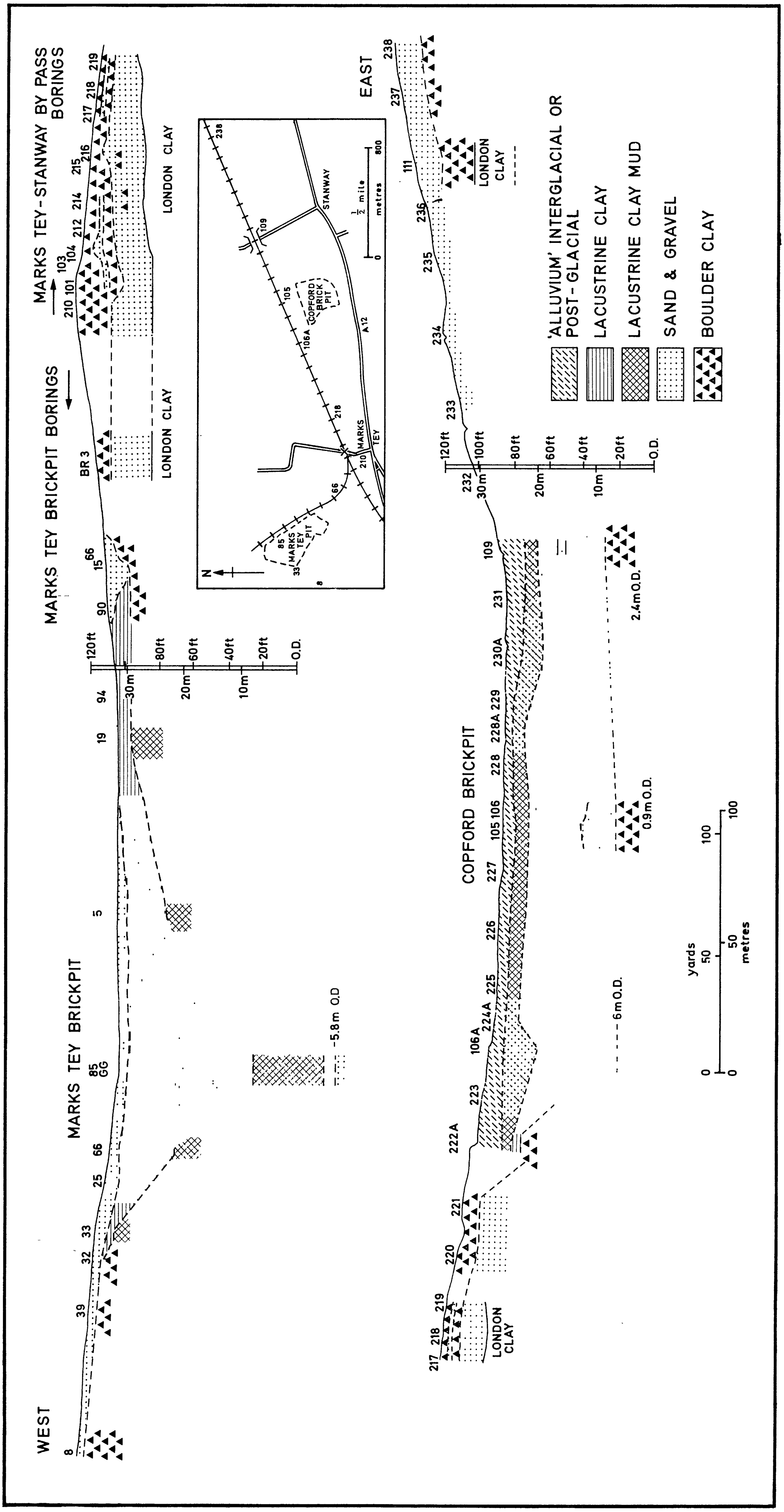

FIGURE 3. Stratigraphic section of the Pleistocene deposits between Marks Tey and Stanway.

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Valley (Funnell 1958) and the Gipping Valley (Boswell 1913; Spencer 1967). There is agreement that most of these channels, which have highly uneven floors, discontinuous courses and no clear gradient towards sea-level, have little to do with preglacial river channels but must have been incised by subglacial meltwater under pressure. They frequently seem to be associated with deposits of the Lowestoft glaciation. Certainly this explanation is the most acceptable for the features at Marks Tey and Copford. A connexion between the troughs at the latter sites has not yet been traced, although they are only about 1.5 km apart and appear to have a similar orientation.

(*c*) *The situation of the lacustrine deposits*

The lacustrine deposits at Marks Tey occupy a trench about 450 m wide, over 900 m long and in places at least 36 m deep along its central axis (figure 4). The site of these deposits is a gently sloping valley, running west–east and traversed by the Roman River, a meandering stream. The surface topography gives little indication of the presence and extent of the underlying lacustrine deposits. The present valley is in fact a subsequent feature and the trench of lacustrine sediments appears to run north-west–south-east across it.

Human interference has much altered the landscape during the past 120 years. Disturbance includes extensive changes of level around the brickpit because of excavation of clay and dumping of overburden, construction of a railway embankment across the valley, diversion of the Roman River and the building of a floodbank to the north-west of the brickpit.

No single borehole at Marks Tey has proved lacustrine deposits, glacial deposits and London Clay. However, boring GG showed at least 35 m of lacustrine sediments to have existed in the centre of the basin, which extended down to below −5.8 m O.D. The London Clay surface, on the other hand, has been demonstrated to the north of the brickpit at Aldham Hall at a height of 36 m O.D., to the south at 32 to 34 m O.D. (Collier's borings 114, 115, 116 and pit section 21) and to the east of the pit at 25.9 m O.D. (boring BR 3). Below the Marks Tey brickpit there is thus a depression in the London Clay surface of well over 30 m.

Chalky boulder clay outcrops on the surface in many places around the margins of the trench of lacustrine deposits. Boring records show that the boulder clay surface dips beneath the lacustrine deposits (figures 4 and 5), and boulder clay and gravels probably floor the trench as shown at Copford (figure 3). There is certainly an aquifer below the lacustrine deposits since boring GG was terminated by artesian water flowing at a rate of 14000 to 18000 litres per hour.

From the stratigraphic records of boreholes around the brickpit, it is possible to trace the extent of the former lake basin. The O.D. heights of the boulder clay surface and of the base of the lacustrine deposits, where reached, give some indication of the morphology of the basin vacated by the melting ice (figure 4).

The basin is roughly rectangular in shape, its long axis trending north-north-west to south-south-east. The north-western limits of the basin cannot yet be defined, but the boreholes farthest in that direction (BR 1, HH, 124, 36) still show a fair thickness of lacustrine sediments. In the south-east corner there is a narrow channel leading into a second basin which is probably smaller and shallower. Its margins and extent are not yet defined either.

Figure 4 also gives the thicknesses of lake sediments measured in boreholes and sections. Along the western and north-eastern shores of the basin, the floor of the deposits plunges steeply towards the centre, with a gradient of about 1 in 4 between borings AA and BR 2. This fact is well illustrated by stratigraphical sections A and B (figures 5 and 6). The original trough vacated by the ice must have had very steep sides indeed. This feature, slightly modified, appears to have

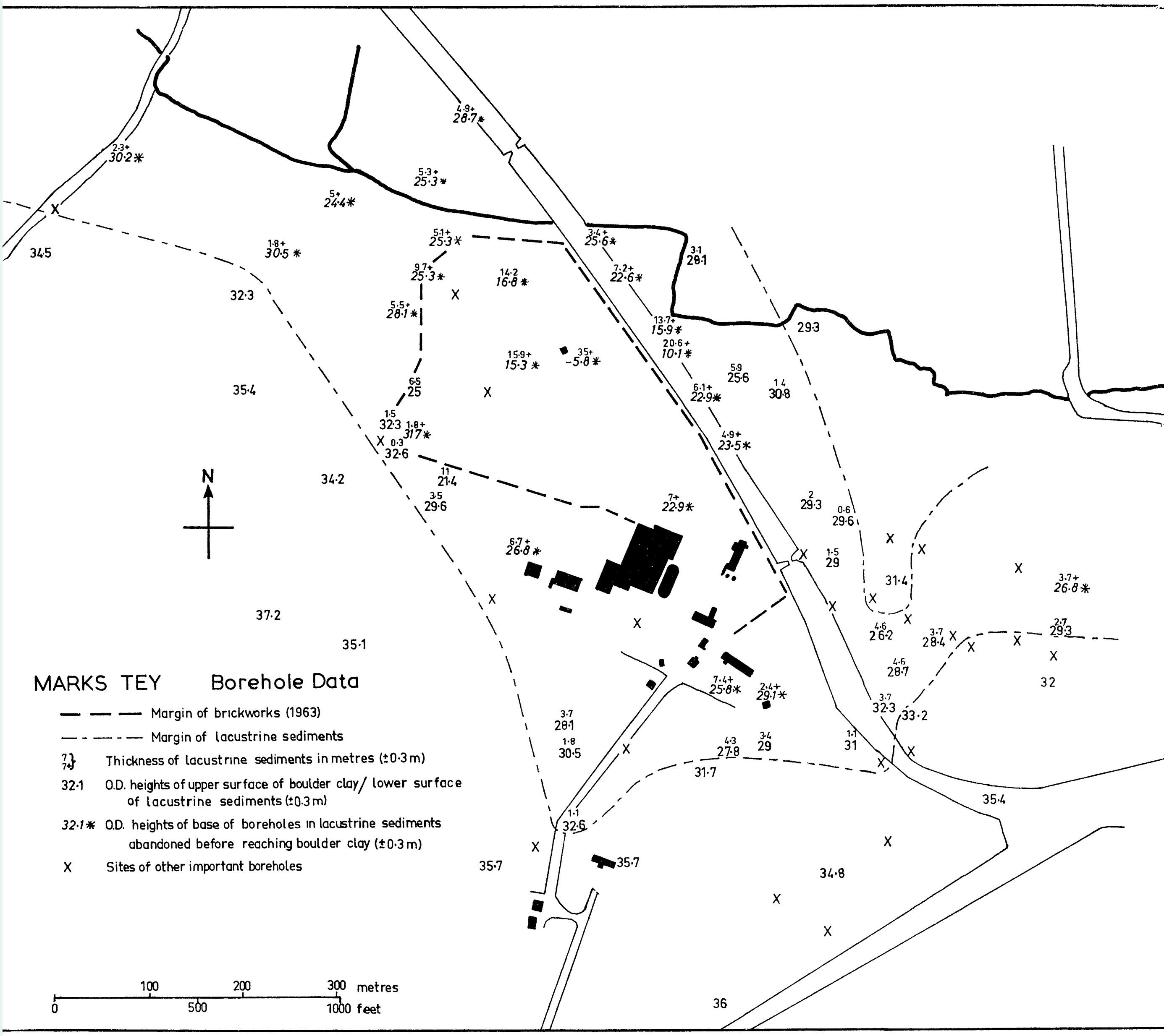


FIGURE 4. Borehole data from Marks Tey.

persisted throughout the Hoxnian interglacial until a great deal of sedimentation had taken place and infilled the lake basin during early Gipping times. Under such conditions it is easy to explain the slumped and brecciated sediments detected in the deeper parts of the lake deposits.

The upper surface of the lacustrine deposits lies at *ca.* 33 m O.D. along their margins and at 30 to 31.5 m O.D. in the centre of the basin, where it has probably been lowered by settling and compaction. Near the Roman River the margin of the deposits lies at *ca.* 30 m O.D., but here the surface has probably been cut down by subsequent erosion. The presence of Mollusca such as *Bithynia tentaculata* and *Valvata piscinalis* indicate a gentle flow of water through the lake, presumably to the east towards Copford. However erosion has removed any topographical

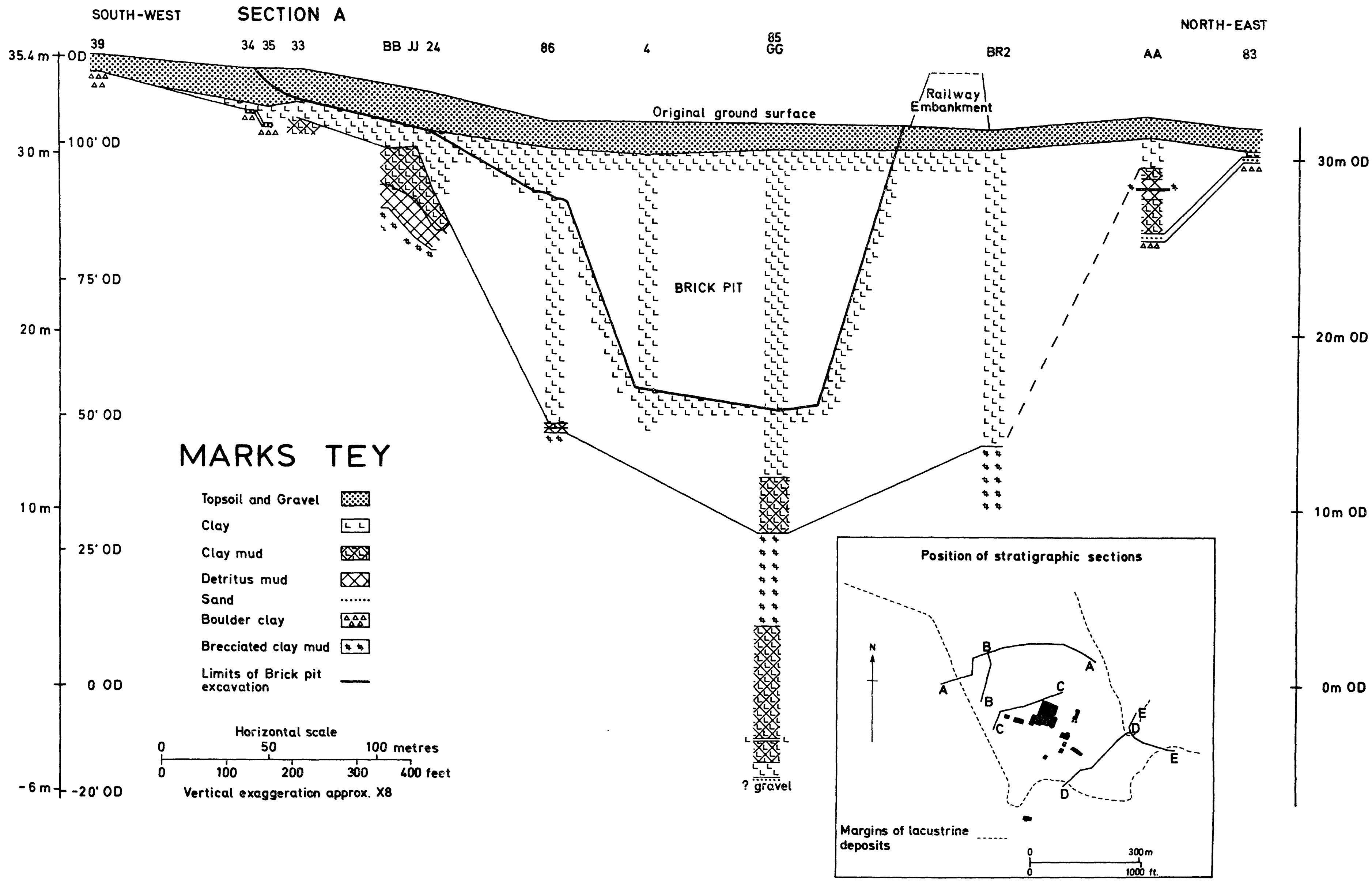


Figure 5. Stratigraphic section A across the lacustrine deposits at Marks Tey.

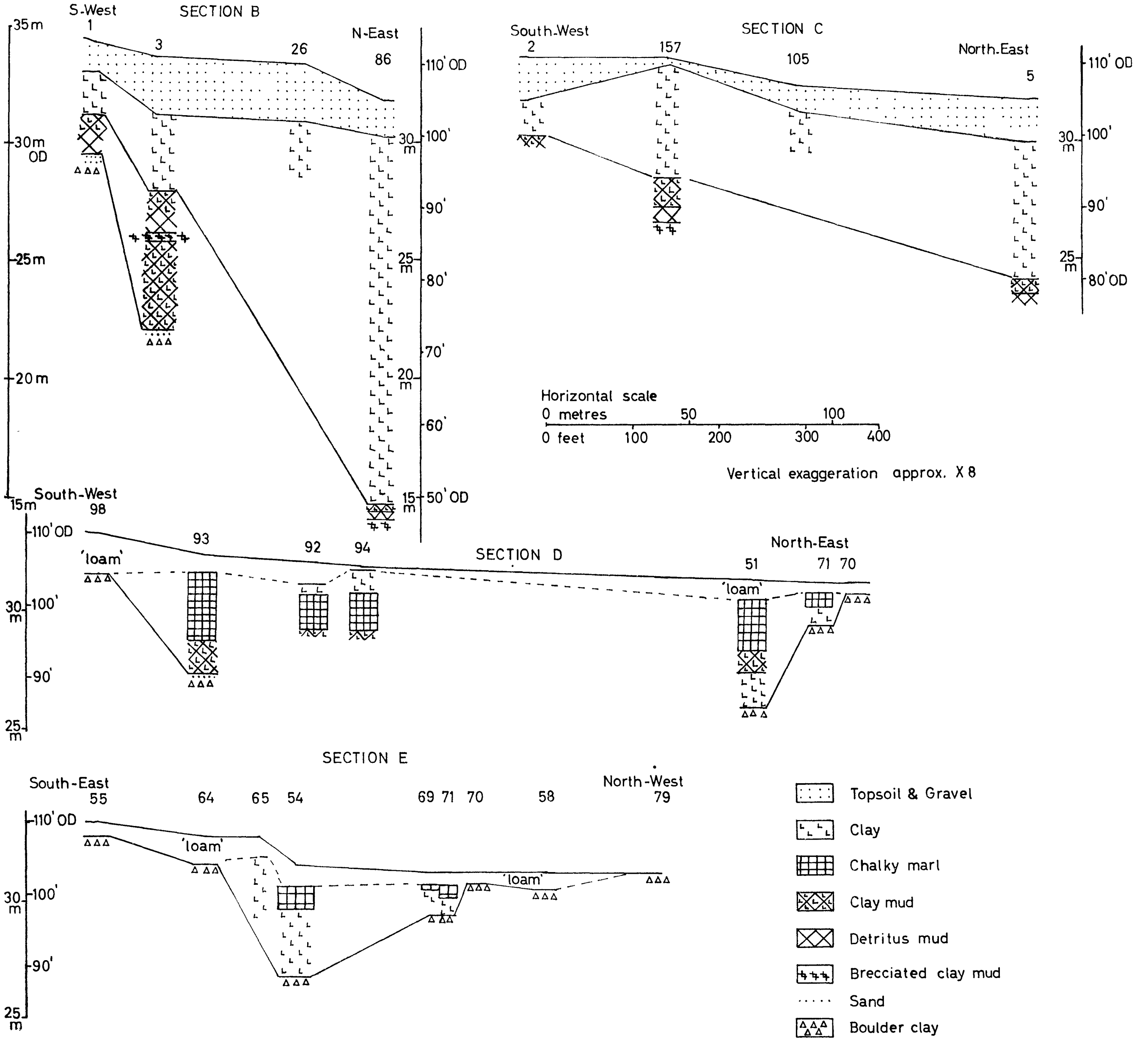


FIGURE 6. Stratigraphic sections B, C, D and E across the lacustrine deposits at Marks Tey.

feature that could have retained the lake waters at a level of 33 to 34 m O.D. during Middle Pleistocene times.

(*d*) *The sediments and their stratigraphy*

The only good evidence for the actual sediments comes from the borings and sections examined during the present investigation. With these data it is possible to interpret reliably the earlier borehole data and to form a good picture of the general stratigraphy. The boring records make it plain that the deposits cannot be divided and described as a series of clearly defined strata extending over most of the basin, as at Hoxne (West 1956). It is more convenient to discuss the stratigraphy under the headings of central and marginal deposits.

(i) *The central deposits of the lake basin*

The sediments and stratigraphy of the central deposits are known largely from borehole GG (Collier's borehole 85 in part) and from recent borings through the laminated grey clay (HH and JJ) and exposed sections of clay in the brickpit. The general succession consists of (*a*) the stratigraphy of the brickpit, and (*b*) the stratigraphy (simplified) of borehole GG, which entered deposits underlying the brickpit. All the sediments are highly calcareous.

(*a*) *The stratigraphy of the brickpit*

Topsoil.	
Orange-grey clay with seams of chalk gravel and 'race' (calcium carbonate concretions). This stratum in places disturbed by cryoturbation.	0.6–0.9 m
Coarse, angular flint gravel with some rounded erratic pebbles and boulders.	0.45 m
1.5–3 m massive unlaminated grey clay, bluish in colour immediately below the gravel. It contains occasional large flints and sand seams, and one persistent shelly seam and passes down evenly into grey, finely laminated silty clay, generally showing rhythmic banding of clay and silt layers, which contrast prominently on weathered surfaces, and with occasional seams of sand and race.	*ca.* 14–16 m

(*b*) *The stratigraphy of the deposits underlying the brickpit*

Grey laminated clay, as above.	4.04 m
Grey-brown, more organic, banded clay with allochthonous fragments of clay mud.	3.13 m
Brecciated, finely laminated, khaki-brown clay mud, resting on a thin contorted layer of grey clay.	5.37 m
Finely laminated, khaki to grey-brown clay mud, becoming greyer and banded towards the base.	6.26 m
Silty grey clay with a thin sand seam.	0.12 m
Banded, indistinctly laminated, grey and grey-brown clay mud.	1.18 m
Grey clay, becoming sandier towards the base.	1.10 m
Grey chalky sand.	0.21 m
Grey clay.	0.03 m

Borehole GG was the deepest exploratory borehole put down, and from its core the pollen diagrams Marks Tey IA and IB (figures 7 to 10) were prepared. Its record is given in full.

Boring GG

Site: lowest part of the main brickpit, just to the east of the crushing plant. Surface height: 15.9 m O.D. National Grid Reference: TL 91082443.

GG 0–177 cm

Mottled orange-grey clay.

177–314 cm

Laminated, medium to dark grey clay, with distinctive light grey clay layers at 186–194 cm and 254 cm. Passing into

314–404 cm

Unevenly banded clay, showing layers, 5–10 cm thick, of grey, orange-grey and grey-brown clay in irregular order which merge indistinctly into one another. This clay sometimes contains fine brecciated flakes and nodules of orange-grey clay and clay mud. Passing into

404–717 cm

Distinctly and finely laminated grey clay and grey-brown clay mud. Lighter coloured layers of grey silty clay, varying in thickness from 0.3–2 cm, alternate with grey-brown, brown or blackish layers of silt, 0.3–1 cm thick. Towards the base of the bed the darker bands become more pronounced and the lighter ones thinner. When broken across, the material of the darker layers reveals many platy reworked fragments of brown, silty, sometimes shelly clay mud and of grey clay. The lighter layers also contain some reworked material.

717–771 cm

Khaki-brown clay mud (drying to grey), thoroughly brecciated into angular fragments 1–10 cm across, lying in a matrix of finer fragments of the same material. Most of these fragments show well defined lamination of the order of 1–2 mm with alternating dark and yellow-buff laminae.

771–842 cm

Faintly laminated khaki-brown clay mud. Dip of the laminations about 50°; probably a single large inclined block of clay mud within the breccia.

842–1251 cm

As 717–771 cm, with lenses of dark grey silt between the brecciated blocks at 869–879 cm and irregular fine clay lenses and a 1 cm dark organic silt layer at 1116–1118 cm.

1251–1254 cm

Contorted seam of grey clay containing brecciated fragments of brown clay mud.

1254–1845 cm

Finely laminated, rather fissile, dark, khaki or grey-brown clay mud, becoming greyish in colour and very light on drying out. Fine, silty, organic, brown laminae alternate with grey, buff-yellow or white laminae; each lamination pair is generally less than 1 mm thick. A slight irregularity of the lamination occurs between 1282 and 1285 cm and a thin brecciated horizon occurs at 1455–1460 cm. Below 1707 cm the lamination becomes finer and sometimes indistinct. Passing into

1845–1880 cm

Laminated dark to khaki-brown and grey clay mud showing irregular alternating grey and brown bands, 0.5–3 cm thick. Lamination often poorly developed.

1880–1892 cm

Silty grey clay with a seam of dark grey sand and a 5 cm angular flint at 1891 cm.

1892–2010 cm

Banded and laminated silty clay mud, as 1845–1880 cm, becoming a more even-coloured brownish grey laminated clay below 1981 cm. Passing smoothly into

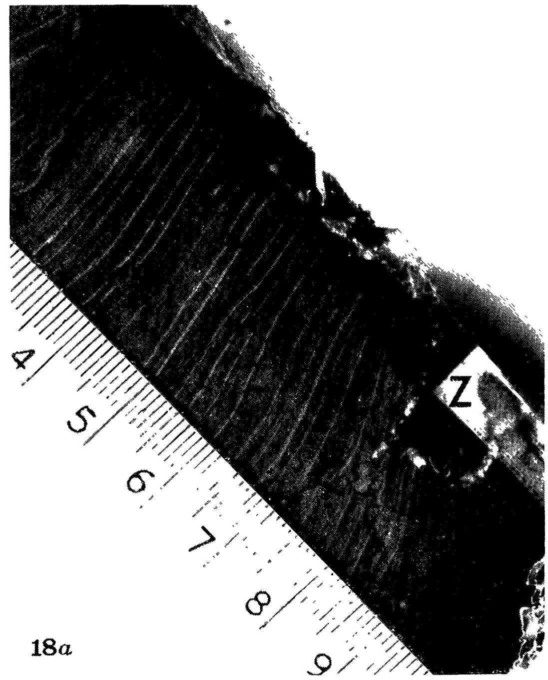
2010–2087 cm

Firm grey clay, faintly laminated, with occasional shell fragments between 2012 and 2022 cm, thin lamellae of redeposited $CaCO_3$ from 2040 to 2070 cm and fine inorganic black speckling.

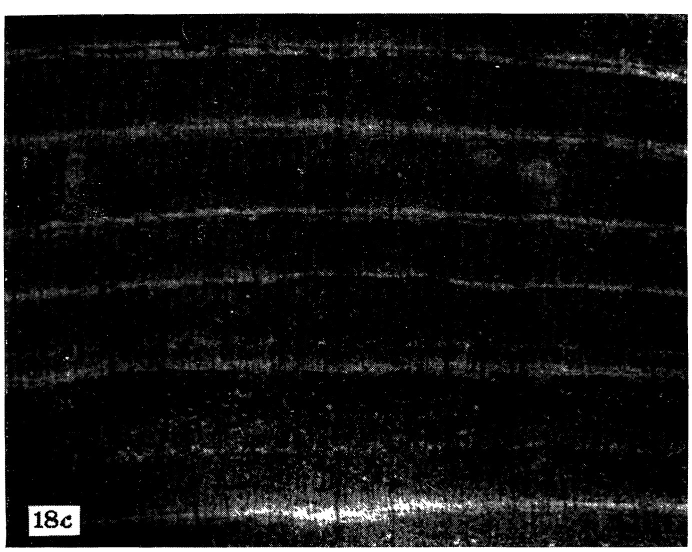
2087–2120 cm

Sandy to silty grey clay with two thin seams of sand and fine chalk gravel at 2095 and 2116 cm.

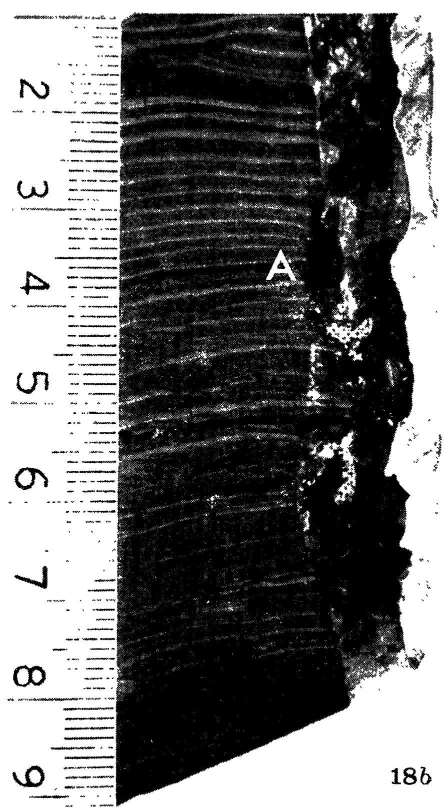
17



18*a*



18*c*



18*b*

Figure 17. Laminated grey clay from the brickpit sections, about 5 m below the top of the clay. × 0.5.

Figure 18*a*. Laminated interglacial clay mud; core section GG 1554–1564 cm. The broader lamination above horizon Z coincides with the onset of the high non-tree pollen phase of subzone Ho II c. Scale of centimetres.

Figure 18*b*. Laminated interglacial clay mud; core section GG 1528–1537 cm. Scale of centimetres.

Figure 18*c*. Lamination detail from the same core section at horizon A. × 7.

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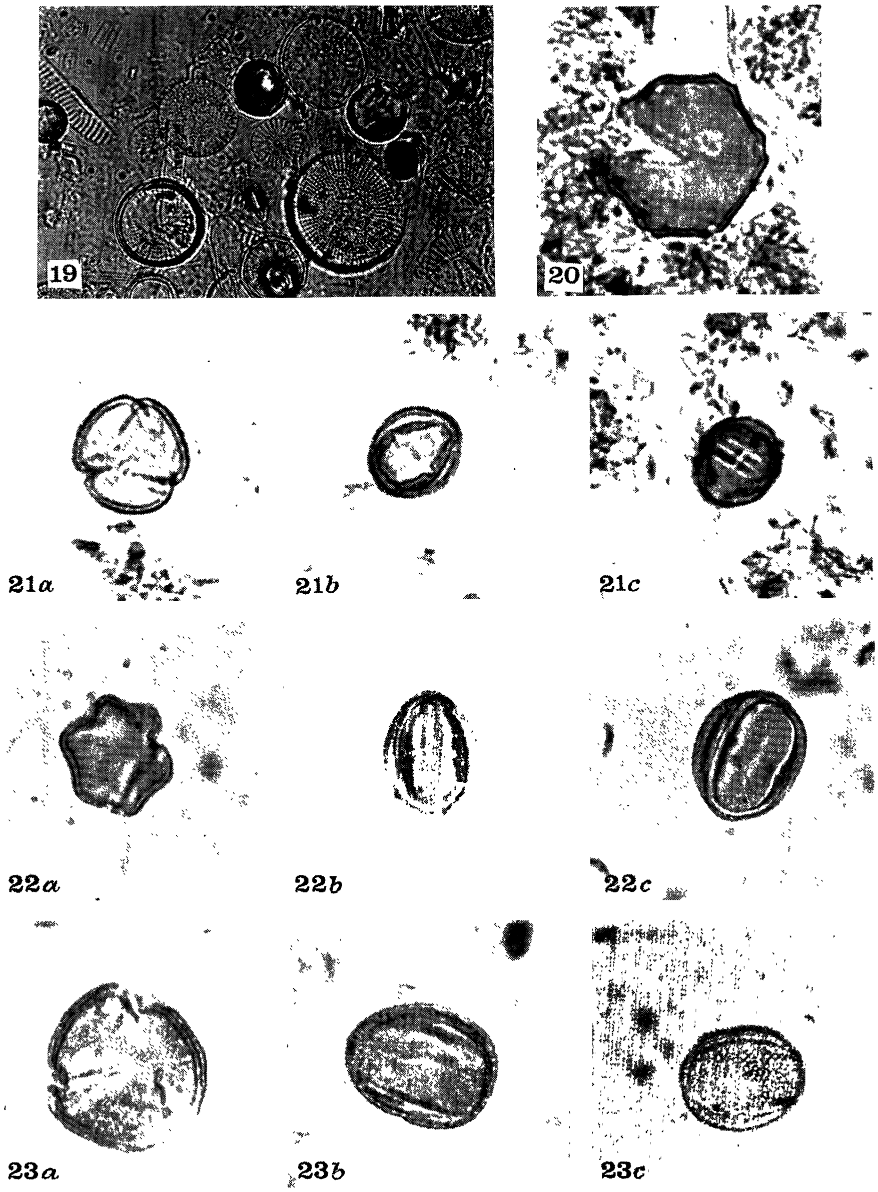

FIGURE 19. Diatom preparation from GG 1417 cm with abundant *Stephanodiscus astraea* var. *minutula*.

FIGURE 20. *Pterocarya* sp.

FIGURE 21 *a–c*. *Erica* cf. *terminalis*.

FIGURE 22 *a–c*. *Vitis* cf. *vinifera*.

FIGURE 23 *a–c*. The unidentified pollen Type X.

Magnification of all figures on this plate, × 750.

2120–2141 cm

Medium-coarse grey sand with fine chalk gravel, derived Cretaceous foraminifera and sponge spicules.

2141–2144 cm

Finely bedded, silty, grey clay. Artesian water was struck at this level. It rose to the surface and continued to flow at a rate of 14000–18000 litres per hour for a month before the borehole was sealed off. End of boring.

The interpretation of the microstratigraphy of this borehole is strongly influenced by the pollen analyses which were made from it (figures 7 to 10).

The grey clay below GG 2020 cm contained no autochthonous pollen, but some quantity of Mesozoic spores (*Classopollis*, *Crassosphaera*, hystrichospheres) which could have been derived immediately from the boulder clay. The virtual absence of pollen suggests either that sedimentation was very rapid or that the basin was still largely ice-covered at this period. Above GG 2020 cm the clay contains pollen, occasional freshwater shells and seeds, sufficient to assign the deposit to the Lowestoftian Late-glacial period.

Both the microstratigraphy of the cores and the results of the pollen analyses suggested there had been slumping of sediments between GG 1790 and 1892 cm. The silty grey clay from GG 1880 to 1892 cm contained almost no pollen and appears to have formed the sole of this section of slumped deposits. The sediments from GG 1790 to 1880 cm give a pollen diagram similar to that from GG 1900 to 2000 cm, below the slip plane. Likewise the colour banding of the clay mud from these two sections of cores can also be matched when compared. It is, therefore, accepted that this section of sediment is repeated in borehole GG. This slumping causes repetition but no major hiatus in the pollen diagram.

The banding of the clay mud at this level appears to be due to irregular variations in the deposition of organic and inorganic material. Both types of sediment, brown organic silty clay mud and grey silty clay mud, show definite but often indistinct microlamination similar to that described from higher sections of the borehole. Pollen analyses from adjacent grey and brown bands show no consistent differences, and the significance of this cyclic sedimentary feature is unclear.

The clay mud between GG 1254 and 1845 cm and also most of the brecciated clay mud from GG 717 to 1254 cm shows fine but distinct microlamination. This lamination consists of pairs of alternating, pale, white or buff and darker brown laminae (figure 18, plate 73). Each lamination pair is usually less than 1 mm in thickness. The pale laminae are fairly sharply defined at the base but grade finely upwards into the darker laminae. Below GG 1700 cm the laminae are very thin, closely spaced and the sedimentation somewhat irregular, but above this level and particularly between GG 1520 and 1570 cm the lamination is generally distinct, well defined and regularly developed. The nature and implications of this rhythmic sedimentation are discussed in more detail below. The formation and preservation of such structures strongly suggests deposition in relatively deep water under sheltered conditions.

Two minor irregularities of the laminated clay mud at GG 1282–1285 cm and GG 1455–1460 cm indicate a slight slumping of the deposits. A more considerable disturbance of the sediments is present between GG 717 and 1254 cm. Here the deposits consist of an irregular jumble of angular brecciated blocks of highly fissile laminated clay mud, ranging in size from very fine fragments, forming a matrix, to larger lumps, including a single inclined block of clay mud *ca.* 70 cm thick (GG 771–842 cm). This brecciated deposit rests on a contorted 3 cm layer of grey clay separating it from similar but undisturbed clay mud beneath. The grey clay evidently forms the sole and slip plane of this considerable slump of deposits. Occasional thin intruded lenses of grey clay and silt are found higher up in the breccia.

Other deep boreholes seem to register this brecciation. The evidence suggests a major and probably single episode of slumping of deposits down the steep slopes of the lake floor, which were being increasingly overloaded by sedimentation towards the end of the interglacial period, as forest cover declined and erosion increased. The brecciated deposits consist of deep-water interglacial sediments, but the actual slumping seems to have taken place during the Gipping Early-glacial period, since the well-stratified sediments immediately overlying the breccia contain pollen of this age as well as reworked interglacial clay mud.

At the deepest part of the brickpit early-glacial sediments must have totalled a thickness of at least 22 m. These consisted largely of a remarkably uniform, light to medium grey, highly calcareous silty clay, generally laminated and containing occasional thin seams of grey sand, fine gravel and race. In the centre of the pit about 15 m of this clay have already been removed for brickmaking and a further 7 m of early-glacial sediments, rather more organic at depth, were recorded in borehole GG. Towards the margins of the basin of deposition, however, the clay stratum of this age thins out considerably (see sections A and B, figures 5 and 6).

Some indication of the extent of this clay is given by the past and present brickpit excavations. At present the workings are extending to the north-west, where there are still considerable thicknesses of clay. To the north-east the brickpit is limited by the railway embankment, but borings suggest that the clay does not extend very far beyond it. On the south-west the brickpit is limited by a thickening of sandy lenses in the upper part of the clay, the removal of which is uneconomic.

Apart from the top 1.5–3 m, the grey clay shows fairly uniform lamination *ca.* 2–3 mm thick, owing to clay/silt graded bedding. This lamination, in appearance and scale akin to classic glacial varves, is discussed later. The clay also shows a much coarser rhythmic banding of alternate silty and clayey layers within the clay; they average 2–3 cm and are most prominent on exposed, slightly weathered faces in the brickpit, where different oxidation colours are produced; the clay rich bands remain grey, whereas the siltier ones turn orange-brown. These bands vary in thickness; either clay or silt ones may predominate but lamination is clearer in the clay ones (figure 17, plate 73). A counted total of about 300 bands from two contiguous vertical sections was recorded from 7 m of clay (Dr J. McManus, personal communication).

From this banding the strata are seen to have a definite dip. This is erratic, can vary considerably along the exposed sections but is generally towards the centre of the basin. The recent excavations in the north-western end of the pit have moved into a zone that shows a sharp and rather unexpected westerly dip. The clay is often finely faulted. Movement probably took place during settlement soon after the original deposition of the sediment, but some of the larger faults are undoubtedly recent, caused by excavation of the brickpit.

The grey clay, like the deposits underlying it, is certainly lacustrine in origin. It contains much reworked interglacial pollen and Mesozoic spores and a great deal of angular, unabraded, silt size quartz grains. Its main constituent is undoubtedly the local Lowestoft boulder clay, washed directly and in large quantities into the lake basin or perhaps partly windblown, as climate deteriorated and erosion increased at the onset of the Gipping glaciation. The seams of sand and fine gravel within the clay, when seen in section in the pit, tend to form shallow channel features. However these channels do not cut down into the laminated clay but lie conformably within it, which suggests increasingly shallow deltaic conditions as the basin silted up.

Pollen spectra from the clay are so contaminated with interglacial pollen that they give no clear evidence of the local conditions of deposition and environment. Some of the sandier seams in the clay contain plant macrofossils which again suggest disturbed soil conditions and a discontinuous vegetational cover on the slopes around the lake. Other fossils from the clay include occasional fish remains, one of which has been identified as *Salmo* sp. (salmon or trout) (Andrews 1963), land and freshwater shells, possibly reworked and concentrated in a band about 3 m from the top of the clay (see appendix). A Middle Acheulean handaxe, in fresh condition, is reported to have been found in the clay at a depth of about 9 m 'in the middle of the pit', and is now in Colchester Museum.

The upper 1.5–3 m of grey clay, exposed in current working faces at the north-west end of the brickpit and seen in borings FF and HH, is neither laminated nor banded, but it too contains seams of grey sand and the shelly band already mentioned. Also present in it are isolated large unabraded flints, often 15 cm in size. These flints can hardly have been carried into the deposit by any means but floating ice.

The uppermost part of the clay, where unweathered, is a bright almost turquoise blue. It is overlain by a bed of very coarse angular flint gravel, 0.5 m thick, containing rounded boulders and pebbles of quartzite, vein-quartz and other erratics, including Carboniferous, Triassic, Mesozoic and igneous material, and also another Middle Acheulean handaxe.

Above the gravel lies a thin layer of stony clay containing seams of race. Along the western boundary of the pit, at present a bank beside a copse, this clay shows signs of cryoturbation. In origin it is probably a solifluxion deposit derived from the slightly higher marginal outcrops of the grey clay. There is no sign of boulder clay overlying the lacustrine strata.

(ii) *The marginal deposits of the lake basin*

The marginal deposits naturally show a greater variety of sediment types than the central deposits. However, there are almost no open exposures, because the strata have no economic value. Nevertheless, their extent and the margins of the basin are known from the borings put down by Messrs Collier (figure 4). These borings were initially difficult to interpret in sedimentary terms. During the present investigations two auger holes (AA, BB) and a 4 in percussion borehole (JJ) were put down. These not only gave pollen diagrams (figures 11 to 14) and a detailed stratigraphy but also clarified the nature of the sediments described in other boreholes. Dr Duigan's borehole 'T' was also useful in this respect.

Borehole AA was put down to the east of the brickpit in a meadow between the railway line and the Roman River, near the north-eastern margin of the lake deposits. Boreholes BB, JJ and 'T' were all sited in the south-west corner of the brickpit, close to the western margin of the basin. These borings suggested that the same succession of sediments, though varying in thickness in individual boreholes, occurred on both sides of the basin. Pollen analyses showed that the main sedimentary changes were synchronous in borings AA and BB. The general succession of marginal sediments is set out below, with their pollen zone chronology as described in §4. This same sequence of deposits can be recognized in many of Messrs Collier's boring records, for example, from the western and south-western marginal deposits, boreholes 121, 122, 3, 24 and 89, and from the north-eastern margin, boreholes 44 and 45.

The stratigraphy of the marginal deposits

sediment types	pollen zones
Topsoil	
Cryoturbated sandy clay, fine gravel and race	
Grey clay	e Gi 1
Grey to grey-brown clay mud	Ho IV b, e Gi 1
Brown organic clay mud and detritus mud; this stratum often contains a layer of brecciated older clay mud	Ho IV a
Grey-brown to grey clay mud	Ho III a, Ho III b
Grey sand	
Bluish-grey chalky boulder clay	

All these sediments are highly calcareous, except for the brown organic clay mud and detritus mud, which are only weakly so.

Pollen analyses indicate that all the marginal deposits examined belong to the latter half of the Hoxnian interglacial (zones Ho III, IV) or to the Gipping Early-glacial (zone e Gi 1). Either the lake did not fill up until comparatively late in the interglacial, or marginal deposits from earlier zones were removed by erosion during a temporary fall in lake level.

The primary sources of information on the nature and stratigraphy of the marginal deposits are the records of boreholes AA, BB, JJ and 'T'.

Boring AA

Type: 1½ in auger hole. Pollen diagram: Marks Tey II. Site: in the meadow between the Roman River and the railway embankment, east-north-east of the brickpit, approximately on the site of Collier's borehole 45. Surface height: 32.6 m O.D. National Grid Reference: TL 91262441.

0– 40 cm	Topsoil.
40–230 cm	Yellow-brown silty sand, greyer and more clayey below.
230–290 cm	Stiff grey, finely silty clay.
290–365 cm	Grey-brown silty clay mud.
365–405 cm	Blackish-brown, medium-fine detritus mud.
405–435 cm	Brecciated, light brown shelly clay mud.
435–475 cm	Dark brown shelly detritus mud with a few layers of brecciated clay mud.
475–675 cm	Grey-brown to grey silty clay mud, sometimes shelly and with occasional small stones.
675–715 cm	Grey chalk sand, coarser at the base.
715 cm	Bluish-grey chalky boulder clay.

Borings BB, JJ and 'T' come from the south-west corner of the brickpit. All show the same general stratigraphy and only the record for boring BB is given here.

Boring BB

Type: 1½ in auger hole. Pollen diagram: Marks Tey III. Site: near the western boundary hedge of the brickworks enclosure, opposite the south-west edge of the adjoining copse. Surface height: *ca.* 32.3 m O.D. National Grid Reference: TL 90912438.

0– 30 cm	Topsoil.
30–175 cm	Mottled brown and grey clay with calcium carbonate concretions.
175–400 cm	Silty grey-brown clay mud.

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400–525 cm Dark brown, medium-fine detritus mud with some bands of clay mud, becoming shelly below 500 cm.

525–675 cm Brecciated grey-brown clay mud, occasionally with thin layers of detritus mud.

675–685 cm Grey clayey sand and silt; boring ended in coarse sand at 685 cm.

Two distinct factors appear to have influenced the marginal sedimentation of the lake during the latter part of the interglacial period. The first was a fluctuation of the water level and thus of the depth of water in which deposition took place; the second was the relative proportions of inorganic and of organic material, both autochthonous and allochthonous, which were being laid down.

From zone Ho III to IV a, the marginal areas of the lake grew progressively shallower, presumably as sediment accumulated. The sediment type changed accordingly from grey clay mud, to brown clay mud, then to highly organic clay mud and detritus muds (the 'peaty' layers of Collier's records).

During subzone Ho IV a, a sudden marked fall in the water level of the lake occurred, which led to the exposure of areas of clay mud deposited during the previous zone, and to the subaerial erosion and brecciated redeposition of this material. In boreholes BB, JJ and 'T' this event is recorded by a thick stratum of brecciated clay mud (BB 525–675 cm, JJ 641–661 cm+, 'T' 200–? 300 cm) underlying the highly organic deposits of subzone Ho IV a. In borehole AA, on the other side of the basin, it occurs as a thinner layer of brecciated clay mud (AA 405–435 cm) actually contained within the detritus mud of subzone Ho IV a, which fact allows the age of the brecciation to be fixed precisely. This brecciated horizon is referred to in many of Collier's borehole records as the 'hard layer', a practical description fully confirmed during the sinking of borehole JJ. The height of this brecciated layer is rather variable (AA 28.3–28.6 m O.D., BB 25.5–27 m O.D., 'T' *ca.* 30.5–31.5 m O.D.), but presumably much brecciated material was being washed into the lake and redeposited at some depth below the water level.

The lake level appears to have recovered rapidly and, indeed, to have risen even higher than before. Detritus mud was again deposited; it passes upwards into clay mud and then into grey clay. The latter is, in part, the lateral equivalent of the laminated grey clay of the brickpit.

The upper part of this succession shows a distinct although gradual change from organic to inorganic sediments, a reflexion of the deterioration of climatic conditions. During the interglacial period a large amount of organic material, both autochthonous and allochthonous, was deposited in the lake, especially in shallow water. The vegetational and edaphic conditions of subzone Ho IV a particularly favoured such organic sedimentation. In the final subzone of the interglacial, Ho IV b, and more especially during the Gipping Early-glacial, the conditions already described with reference to the grey clay of the brickpit led to increasingly inorganic sedimentation.

It is not easy to explain the sudden and temporary drop in lake level that occurred during subzone Ho IV a. It seems to have occurred during the most oceanic period of the Hoxnian interglacial, when a climatic explanation such as drought seems least acceptable on the basis of the vegetational evidence available. An alteration in the outfall of the lake would not have produced a merely temporary fall of water level, though diversion of a stream feeding the lake might.

At any rate the brecciation of the marginal deposits is quite distinct from the collapse brecciation already described from the central deposits. Both stratigraphical and pollen analytical evidence show that these took place at different periods in the history of the lake.

Different sediment facies occur in other marginal areas of the lake basin. Most of Collier's boring records from the shallow eastern end of the main lake basin (e.g. 51, 81, 93 and 104) describe a 'chalky' deposit above 'peat', presumably the detritus mud of subzone Ho IV a (see sections D and E, figure 6). This chalky deposit may be a true marl but is more likely a highly calcareous but well oxidized clay mud, a sediment type that occurs in the upper part of the Hoxnian interglacial deposit at Rivenhall End, Kelvedon. No recent boreholes have probed this chalky area of the deposits, so their nature, stratigraphy and age are in doubt.

(iii) *Correlation of the central and marginal facies*

The sediment types and major events shown by the marginal and central deposits of the basin are compared and summarized in table 1.

TABLE 1

vegetational zones	central deposits: sediment type	central deposits: events	marginal deposits: sediment type	marginal deposits: events
e Gi	glacial gravel	final infilling of lake basin		
	grey clay			
			grey clay	
	laminated grey clay	slumping and brecciation of earlier deposits	— — —	
			clay mud	
Ho IV b	hiatus: deposits dispersed by later slumping			
Ho IV a			organic clay mud and detritus mud	temporary fall in lake level: brecciation
Ho III a,b	laminated organic clay mud		clay mud	
				rise in lake level
Ho II a–c				
Ho I	banded, often laminated clay mud	minor slumping	no deposition or deposits eroded	
l Lo	grey clay sand and fine gravel			
		final retreat of Lowestoft ice sheet		
			boulder clay	

3. Lamination structures in the lacustrine deposits

The central deposits of the Marks Tey basin show some form of lamination or banding almost from top to bottom. These features, which are well displayed in the cores of borehole GG and in the grey clay sections of the brickpit, result from a variety of physical and biogenic processes. However, different types of lamination are found in the glacial and in the interglacial strata.

Glacial sediments: the late-glacial clay below GG 2010 cm is only very faintly laminated and shows no distinct rhythmic structures, whereas the bulk of the early-glacial grey clay of the brickpit shows broad alternate rhythmic banding of silty and more clayey layers, 2 to 3 cm thick. Within these bands occurs finer regular lamination of the order of 2 to 3 mm caused by graded bedding of the sediment. In borehole GG this banded, laminated grey clay passes downward into an irregularly colour banded clay which contains an increasing amount of redeposited interglacial clay mud.

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Interglacial sediments: these show the following lamination structures.

(1) GG 717–1251 cm. Brecciated lumps of organic clay mud showing fine light and dark lamination as described for the clay mud below.

(2) GG 1254–1845 cm. Finely developed, extremely regular light and dark lamination, 0.5 to 1 mm in thickness. Below GG 1707 cm the laminae become finer and somewhat less regular.

(3) Between GG 1845 and 1880 cm and similarly between GG 1892 and 2010 cm, the clay mud shows rhythmic colour-banding, whereas the finer lamination becomes much less distinct and somewhat interrupted.

Andrews (1963) carried out a study of the lamination of the grey clay at Marks Tey but felt unable to reach any definite conclusions about its nature and origin, perhaps because he did not consider the clay a deposit of glacial age. The rhythmic banding of the early-glacial clay and also of the lower part of the interglacial clay mud are interesting phenomena which still require investigation.

Lamination structures occur frequently in glacial sediments, but are comparatively rare in temperate interglacial or Post-glacial sediments. The regularity and definition of lamination in both the Gipping Early-glacial grey clay of the brickpit and the underlying Hoxnian interglacial clay mud make the site especially favourable for an investigation of the sedimentary processes involved. Because the strikingly regular lamination of the clay mud is associated with a lengthy pollen diagram it seemed particularly desirable to learn whether or not the sedimentary porcesses could be linked with annual phenomena or used in any other way to give a time scale for the Hoxnian interglacial period. The preliminary results of this study may be presented at this point.

(*a*) *The lamination of the interglacial clay mud*

The general appearance of the lamination (see photographs, figure 22, plate 74) was described above in the section on the central deposits of the basin. The laminated clay mud is extremely calcareous. Dry-weight analyses of this sediment at a number of horizons showed it consisted fairly uniformly of 60 to 65 % calcium carbonate, *ca.* 30 % silt and clay (including diatom frustules) and 6 to 8 % organic matter. A range of samples were taken from cores of borehole GG, impregnated with Araldite resin CY 212, according to the method described by Catt & Robinson (1961), and thin sectioned. These samples, though few, cover the major variations in lamination within the clay mud. The cores at GG 1417 and GG 1556 cm show the well-developed lamination typical of the clay mud between GG 1254 and 1700 cm. At GG 1705 cm the lamination is finer and less distinct, at GG 1790 cm it is irregular with thick pale calcareous bands, and at GG 1821 cm it is fine and indistinct.

At GG 1417 and 1556 cm thin sections show that the light buff or white laminae consist almost entirely of diatom frustules closely packed in a calcareous matrix. The vast majority of these frustules are circular, 10 to 25 μm in diameter, and identified as *Stephanodiscus astraea* var. *minutula* Grun. (figure 19, plate 74). The pale diatomaceous layers usually grade upwards into a rather pure layer of fine grained calcite and then into increasingly organic material. The darker laminae consist of organic debris and diatoms, including abundant *Stephanodiscus*, in a matrix of fine calcite crystals. Between the top of each dark organic lamina and the base of the light diatomaceous one overlying it a more abrupt transition takes place.

At GG 1705 cm fine laminae containing *Stephanodiscus* also occur. These laminae are separated by a number of other fine laminae, alternately organic and calcareous. The cycle of deposition, being either less regular or more complex, is more difficult to make out here. At

GG 1821 cm, the fine lamination consists entirely of thin, sometimes discontinuous laminae of organic material alternating with thin laminae of calcite. Though *Stephanodiscus* is absent the lamination resembles that at GG 1705 cm.

Rhythmic lamination is best developed between GG 1259 and 1700 cm, and it is possible to make fairly accurate counts of the number of laminations (i.e. pairs of laminae) from the cores of this section of the borehole. Some allowance must be made for faintly or incompletely developed laminae, for slight irregularities in the sedimentation and for material lost between cores. In fact the length of the cores suggests that the latter is surprisingly little. The total counting error should be well below 10 %

core no.	depth (cm)	no. of lamination pairs	no. of lamination pairs not counted but estimated
XXXIX	GG 1254–1259	44	—
XL	GG 1259–1290	203	11
XLI	GG 1290–1320	200	—
XLII	GG 1320–1351	160	—
XLIII	GG 1351–1381	267	12
XLIV	GG 1381–1412	252	—
XLV	GG 1412–1442	283	16
XLVI	GG 1442–1473	215	13
Here the core is brecciated for 4.5 cm; no estimation was made for this portion.			
XLVII	GG 1473–1503	330	—
XLVIII	GG 1503–1534	357	—
XLIX	GG 1534–1564	174	13
L	GG 1564–1595	341	20
LI	GG 1595–1625	354	39
LII	GG 1625–1656	311	23
LIII	GG 1656–1686	493	128
LIV	GG 1686–1705	546	—

Portions of the last two cores were very finely laminated, and the structure may not be strictly comparable with those of the overlying cores. The total of 4530 lamination pairs counted from 451 cm of clay mud represent subzone Ho II c and, in part, subzone Ho III a of the Hoxnian interglacial. This count includes 275 lamination pairs, which were reckoned as present but poorly developed. As suggested previously a counting error of up to 10 % should also be considered as additional.

A strongly rhythmic cycle of deposition is clearly represented by these sections of the borehole, a fact emphasized by two features in particular: (1) the regular deposition of almost pure layers of the frustules of *Stephanodiscus astraea* var. *minutula*; and (2) a gradual increase in the proportion of organic material being deposited following each episode of mass diatom deposition. Further, although it is not possible to prove fluctuations in the precipitation of calcium carbonate, because the matrix of the entire sediment consists of this material, it nevertheless appears that a period of high calcium carbonate deposition took place immediately after the formation of the diatomaceous layers, because these latter are generally overlain by a thin, almost pure layer of calcite crystals.

Below GG 1700 cm the lamination structures have not yet been studied critically enough. Here the diatomaceous layers are much less pronounced, but a definite and, in general, fairly regular alternation of pale calcareous and darker organic laminae appear to exist in the cores of sediment formed during the early part of the interglacial period. The laminations are more finely spaced than in the higher parts of the boring and cannot be counted accurately. A reasonable estimate is that 5000 to 10 000 lamination pairs are present in the 190 cm of sediment which represent the timespan of zone Ho I and subzones Ho II a and Ho II b.

Laminated Post-glacial lacustrine sediments have been described from the Faulenseemoos near Spiez, Switzerland (Welten 1944) and from Little Round Lake and McKay Lake, Ontario (Tippett 1964). The lamination of all three deposits is due to alternating laminae of calcareous marl and organic detritus. The order of thickness of the laminae is similar to those from Marks Tey. This lamination is claimed to be annual and the mechanism by which seasonal deposition of calcium carbonate takes place is succinctly described by Deevey (in Shapley 1953). 'Deposition of marl is a biochemical process. Photosynthesis by algae and rooted plants removes carbon dioxide, and some of these plants can also remove bicarbonate ions as such. If this removal is continued, the acidity of the water may decrease to such a point that the solubility product of calcium carbonate is exceeded, and the lime precipitates. The precipitation is favored by high temperature, owing to increased solubility of gaseous carbon dioxide.'

Precipitation of calcium carbonate, which forms a fine lamina of calcareous marl, is at maximum in spring and early summer, when high concentrations of calcium carbonate in solution in lake waters coincide with a period of rapid plant growth and rising water temperature. At all these sites pollen and diatom analyses have provided further evidence that the lamination is likely to be annual.

Obviously this type of lamination can form only where the local conditions are highly calcareous. However, diatom flushes can also cause visible lamination of less calcareous sediments. Dewall (1928) and Giesenhagen (1925) described diatom lamination from non-calcareous diatomite (Kieselgur) deposits of Holstein interglacial age from Munster–Breloh on the Lüneburger Heide. According to Dewall this lamination consists of light layers composed almost entirely of the diatom *Melosira italica* alternating with darker more organic layers containing abundant *Synedra ulna*. *S. ulna* is a spring flushing species and *M. italica* an autumn one. Dewall therefore regarded each lamination pair, which were on average *ca.* 1.7 mm thick, as the annual sediment of the interglacial lake. He brought no other lines of evidence forward to support this conclusion.

The interglacial deposits at Bilshausen, Germany, also show lamination structures (Müller 1965). Pollen studies suggest that these are also cyclic annual features and that the interglacial period represented, probably the Cromerian, had a duration of 28 000 to 36 000 years.

The conditions under which such lamination structures, once formed, are preserved intact are even more restricting. Such laminations are essentially deep-water features and survive only where the normal scavenging and burrowing fauna of a lake bottom is excluded and prevented from reworking the surface sediment, and where currents do not disturb the even deposition of organic and inorganic particles. Such conditions occur only in relatively deep lakes in which a thermocline forms during the summer months and isolates the deeper water of the lake. The water below the thermocline rapidly becomes deoxygenated, stagnant and unable to support any bottom fauna. The recent sediments of Lake Zürich show annual lamination (Nipkow 1920, 1928). The deeper waters of the lake suffer from a similar but permanent deoxygenation and stagnation, which is attributed to human pollution.

At Marks Tey the lake was over 30 m deep when the lamination was forming. Its steep sides and narrow shape probably caused a sharp temperature gradient in the water, so encouraging formation of a thermocline. Whereas it cannot yet be stated that the lamination structures at

Marks Tey are certainly annual, a plausible interpretation of the phenomena involved can be advanced to suggest that they are.

According to Hustedt (1930), *Stephanodiscus astraea* var, *minutula*, a diatom present in the plankton of some North German lakes throughout the year, tends to develop during winter and early spring as a 'mass form' and to produce flushes of great abundance. Following Hustedt the diatomaceous laminae at Marks Tey represent the sediment produced each year after the winter or early spring flush of *Stephanodiscus astraea*. Rising temperature and plant growth during the spring led to the further precipitation of a thin but rather pure layer of calcium carbonate, such as exists in Post-glacial laminated sediments already described. During summer and particularly in autumn, the continued growth and decay of both plants and animals in and around the lake caused the sedimentation to become increasingly organic until the process was interrupted by the sudden diatom flush of the next year and the commencement of a new cycle.

The fact that these cycles continued with great regularity over a long period of time must favour a seasonal interpretation of some kind. The ecology of *S. astraea* is not well known; its flushes are not directly controlled by temperature factors but by nutrient conditions. However, preliminary unpublished pollen studies of the lamination structures on a finer scale also show indications of cyclic pollen deposition which can be interpreted as annual, though further study is desirable.

If the laminations were annual, then subzone Ho II c lasted about 2700 years and the earlier part of subzone Ho III a lasted another 2000 years. Such an estimate is comparable to the known temporal scale of Flandrian Post-glacial vegetational change. An extension of this reasoning (Shackleton & Turner 1967), based partly on rate of sedimentation, gives an estimate of 30 000 to 50 000 years for the total length of the Hoxnian interglacial. This estimate supports the opinion of Srodon (1957) and of Van der Vlerk & Florschütz (1953) that the duration of the so-called 'Great' interglacial was of an order similar to that of the Eemian interglacial rather than a period up to 240 000 years as envisaged by Penck & Brückner (1909), Brooks (1949) and Zeuner (1950). Moreover, an interglacial period of this shorter length fits well with the temperature curves deduced from deep sea cores by Emiliani (1966). The only other direct assessment of the duration of an interglacial period, that from Bilshausen, Germany (Müller 1965), is of a similar order.

(*b*) *The lamination of the early-glacial clay*

Two samples of laminated clay were thin sectioned after impregnation with Araldite CY 212. These were collected from (*a*) a horizon 6 m below the clay surface in a working face on the north-western side of the pit, and (*b*) from a lower horizon at a depth of *ca.* 10 m from the top of the clay bank behind the crusher-feeder plant in the centre of the pit. Both samples showed similar lamination structures.

The clay consists of fine angular quartz grains set in a matrix of fine-grained clay minerals and calcite. A little organic material is also present. The laminae, each 2 to 3 mm thick, are defined by marked graded bedding. The lowest part of each lamina contains many angular quartz grains up to 35 μm in diameter; their size diminished upwards, and the upper part of each lamina consisted largely of fine-grained clay minerals and calcite, abruptly overlain by the coarser material of the succeeding lamina.

Unlike classical Scandinavian Late-glacial varved clays, the Marks Tey clay contains relatively high percentages of fine organic matter, much of which is clearly derived directly from reworked interglacial sediments, a fact amply confirmed by the abundant presence in the clay of redeposited interglacial pollen. Moreover, the Marks Tey clay contains plant macrofossils indicative of arctic vegetation, fish remains and a fresh Acheulean handaxe, whereas most other varved clays are virtually unfossiliferous.

The lamination occurs regularly through nearly 18 m of grey clay, with an estimated total of 5000 to 8000 laminae. They differ consistently from classical varves, perhaps because they were formed under early-glacial rather than late-glacial conditions. At present there is no evidence at all that these lamination structures were annual, only that conditions in the lake favoured rhythmic graded bedding of its sediments over a long period of time.

4. The palaeobotany of the deposits

The vegetational history of the deposits has been studied by means of pollen analysis. The vegetational record covers the entire Hoxnian interglacial, as well as small portions of the preceding and succeeding glacial periods. A sequence through the earlier part of the interglacial was obtained from the deep central basin of the lake deposits, but the sequences from the latter part came from borings through the marginal deposits. These sequences overlap to cover the complete temperate phase of the interglacial.

Plant macrofossils were recovered sparsely from the lower sequence, more abundantly from the marginal deposits and also from the overlying early-glacial laminated grey clay. These macrofossils provide valuable evidence of the local marshland and and aquatic flora, whereas the pollen spectra give a broader regional picture of the vegetation.

(*a*) *Pollen analysis*

All the pollen analyses are expressed as percentages of a pollen sum based on total land pollen (i.e. total pollen less aquatics and spores). Counts are also given for derived spores, which include Hystrichospheres, *Classopollis*, *Crassosphaera*, triradiate spores and *Pinus haploxylon* type pollen, and for *Pediastrum* colonies. The alga *Botryococcus* also occurred in almost every polleniferous sample, but was not counted. *Potamogeton* pollen was only counted for pollen diagrams Marks Tey IA and IB. Pollen Type X is a tricolpate, reticulate pollen grain of unknown identity, characteristic of Hoxnian deposits in East Anglia and of contemporary Gortian deposits in Ireland. Its occurrence is discussed later. Counts for *Corylus* may include *Myrica*.

(i) *The pollen diagrams*

The results of the pollen analyses are presented in the following diagrams:

Marks Tey IA	From the lower part of borehole GG (figures 7 and 8)
Marks Tey IB	From the upper part of borehole GG (figures 9 and 10)
Marks Tey II	From boring AA (figures 11 and 12)
Marks Tey III	From boring BB (figures 13 and 14)

Figure 15 is a composite pollen diagram, based on the above results, which covers the vegetational development of the complete Hoxnian interglacial period.

Marks Tey IA and IB

As described in the record of borehole GG, a small slump caused a duplication of sediments in the lower part of the deposits (GG 1790–1880 cm, GG 1900–2000 cm), which is reflected by the pollen analyses. Pollen samples from the brecciated strata (GG 717–1251 cm) were taken from discrete lumps of clay mud. However, the thin grey clay at the base of the breccia (GG

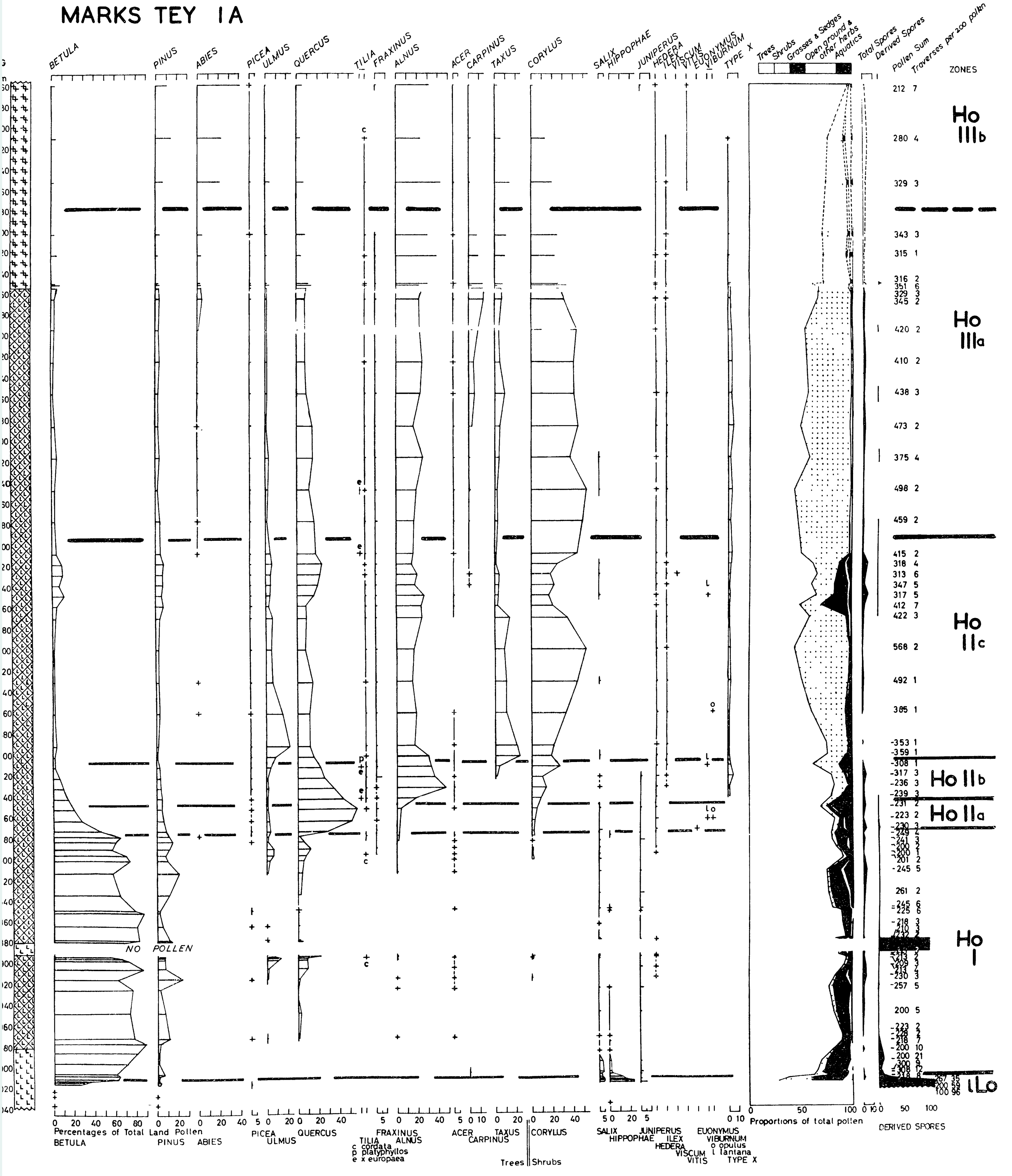

FIGURE 7. Tree pollen diagram, Marks Tey IA.

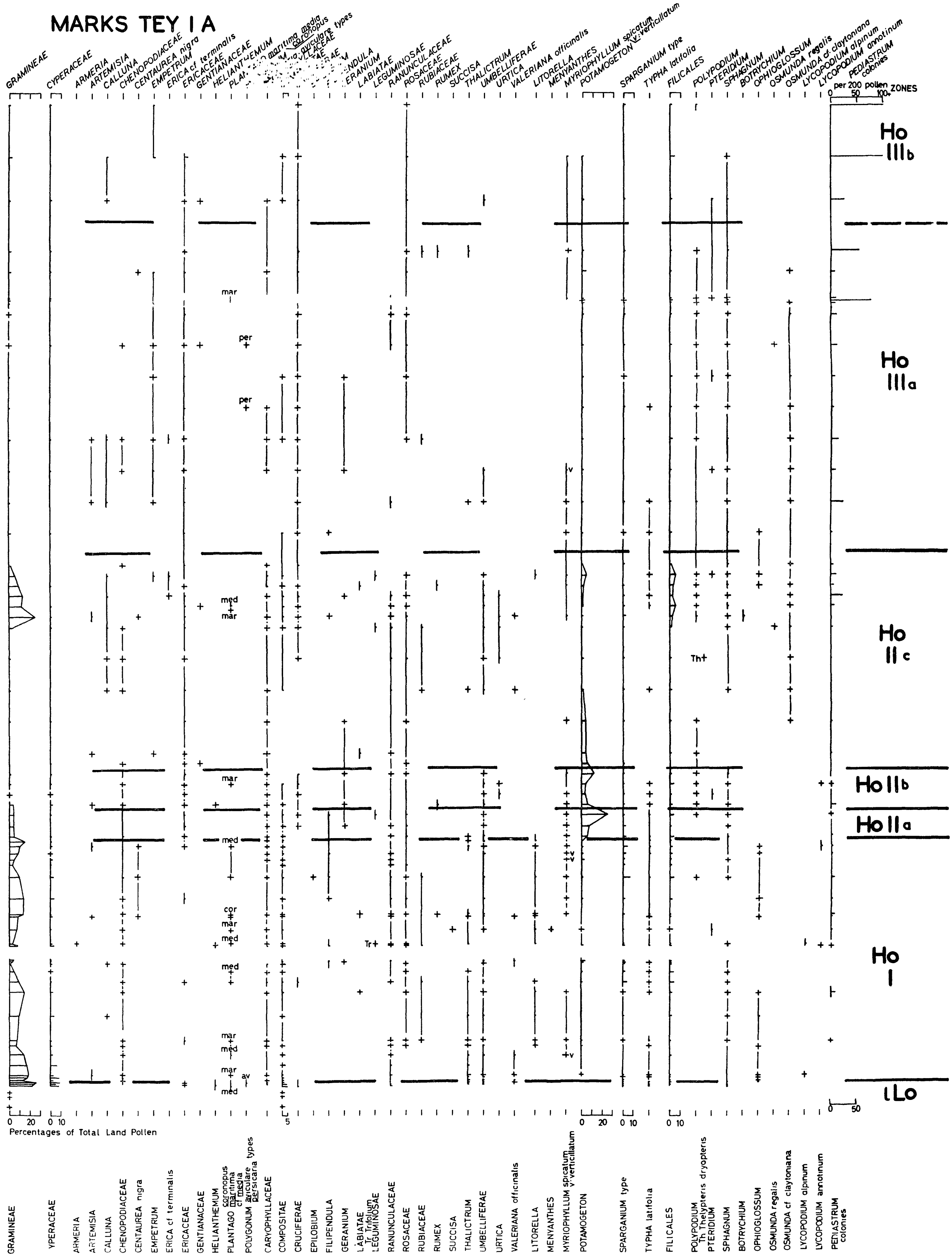

FIGURE 8. Non-tree pollen diagram, Marks Tey, I A.

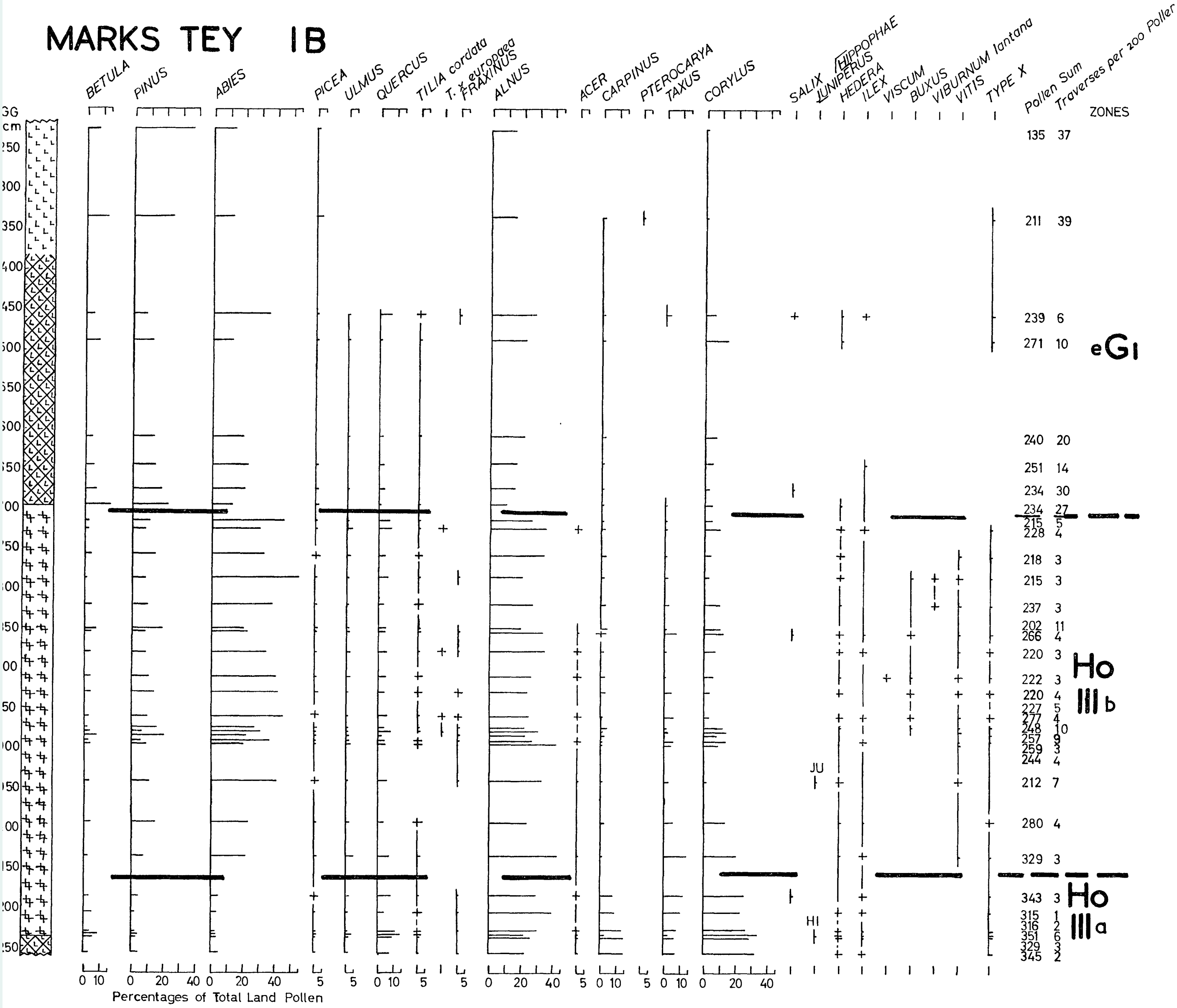

FIGURE 9. Tree pollen diagram, Marks Tey I B.

1252 cm) and a thin grey silt layer within it (GG 870 cm) show significantly different pollen spectra. Above GG 717 cm the sediments visibly contain redeposited clay mud, and pollen spectra here are greatly affected by this contamination.

Marks Tey II

Boring AA penetrated a brecciated horizon between AA 405 and 435 cm. Pollen analyses from AA 420 cm and particularly from a lump of brecciated clay mud at this horizon (AA 420 Q) indicate that the reworked material came from sediments of the previous zone of the interglacial:

	Betula	*Pinus*	*Abies*	*Alnus*	*Carpinus*	Gramineae	Ericaceae
AA 395 cm	8%	39%	16%	10%	½%	8½%	6%
AA 420 cm	6	13	48	20	3	2	1
AA 420 Q	2	12	47	22	6	1½	½
AA 450 cm	14	30	12	10	½	6	13

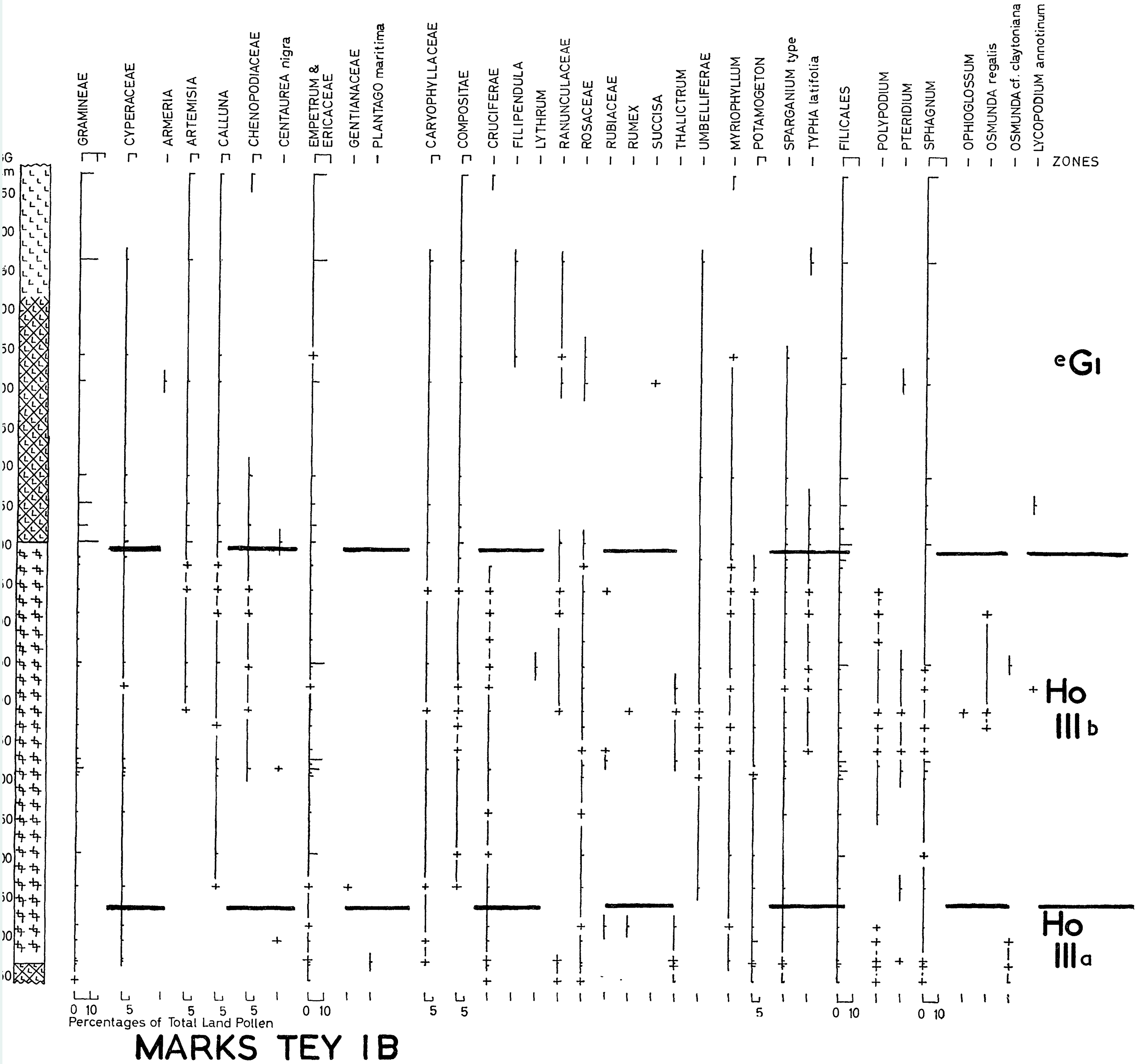

FIGURE 10. Non-tree pollen diagram, Marks Tey I B.

The spectra from AA 395 cm and AA 450 cm are characteristic of pollen subzone Ho IV a, that from AA 420 Q of pollen subzone Ho III b. The lowest pollen spectrum, AA 705 cm, from sand immediately overlying boulder clay, is probably contaminated by pollen downwash, and the uppermost, AA 280 cm, may have been affected by weathering and cryoturbation.

Marks Tey III

The lower strata of this boring (BB 525–675 cm) were also brecciated, but the pollen samples did not consist of individual lumps of sediment. The uppermost spectra (e.g. from BB 100 cm) almost certainly contain a proportion of reworked pollen.

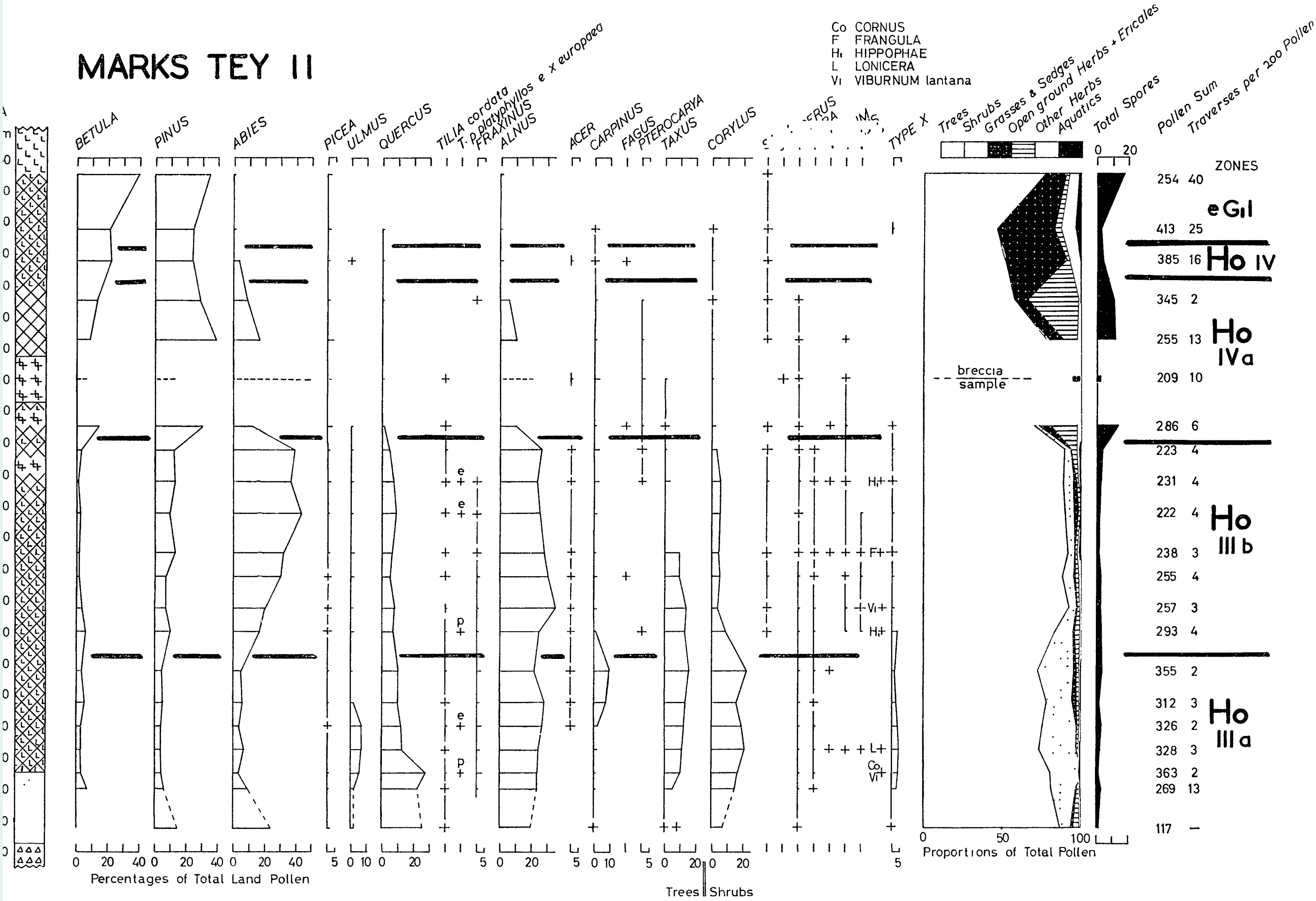

FIGURE 11. Tree pollen diagram, Marks Tey II.

(ii) *Zonation of the pollen diagrams*

The pollen diagrams have been described according to a general system of interglacial zonation, more fully discussed elsewhere (Turner & West 1968), based on four major subperiods of vegetational development. These subperiods may be regarded as natural biostratigraphic zones and can be recognized in pollen diagrams from the Cromerian, Hoxnian-Holstein and Eemian interglacials from the British Isles across North-West Europe to Poland.

On this basis, the following sequence of zones has been distinguished at Marks Tey:

Zone l Lo *The Lowestoftian Late-glacial zone*—characterized by a low ratio of tree to non-tree pollen. *Hippophaë* shows very high pollen values, *Betula* is also present.

Zone Ho I *The Hoxnian Pre-temperate zone*—showing a closed boreal forest vegetation dominated by *Betula*, with *Pinus* the only other important tree.

Zone Ho II *The Hoxnian Early-temperate zone*—characterized by the establishment and dominance of the mixed-oak forest vegetation.

Zone Ho III *The Hoxnian Late-temperate zone*—showing the progressive decline of mixed-oak forest trees, accompanied by the spread of initially *Carpinus* then *Abies*.

Zone Ho IV *The Hoxnian Post-temperate zone*—with the return of *Pinus* and *Betula* to dominance. Heath communities, first with *Empetrum*, then with grassland, begin to replace the forest.

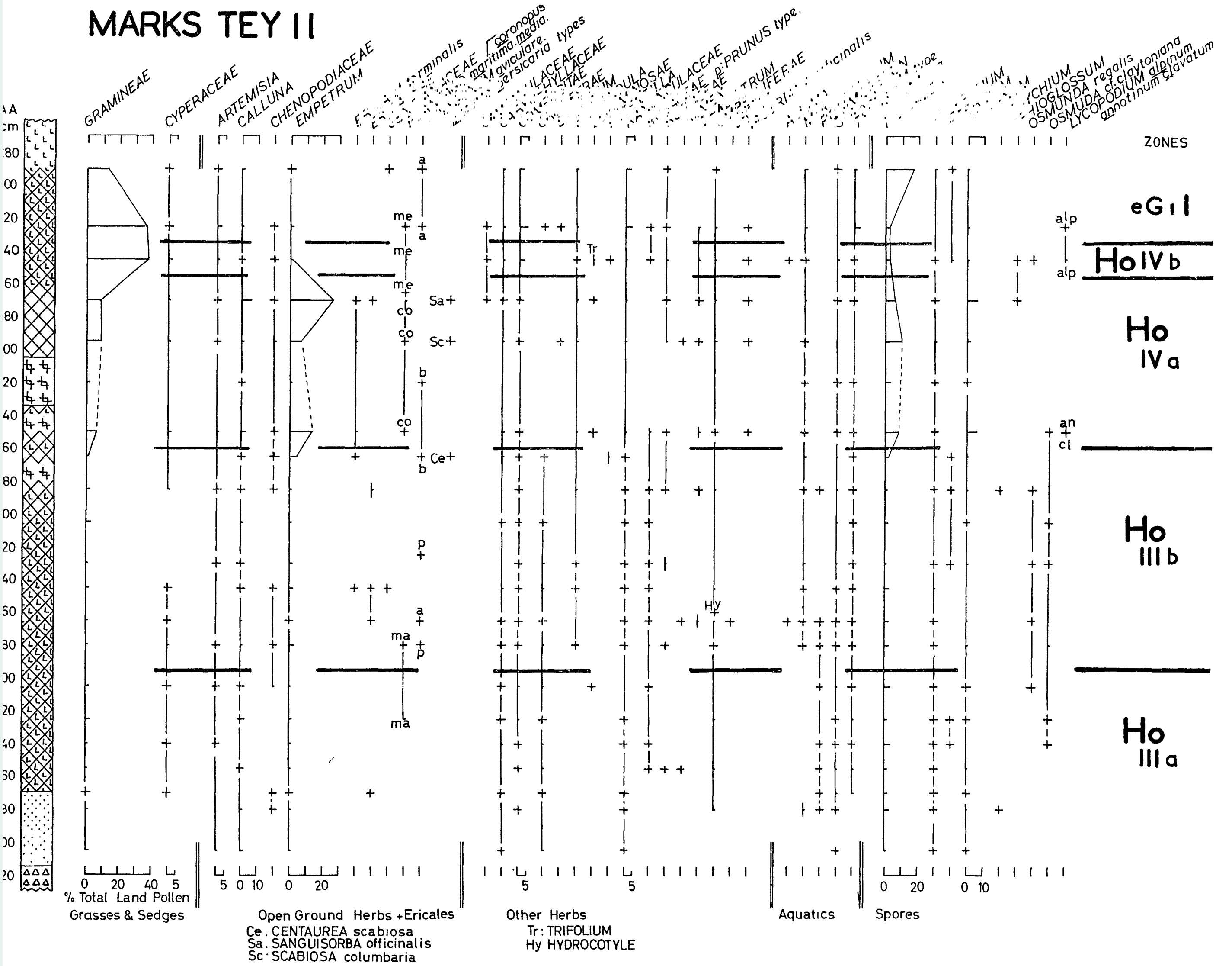

FIGURE 12. Non-tree pollen diagram, Marks Tey II.

Zone e Gi *The Gipping Early-glacial zone*—Heath communities dominate as the forest declines considerably. Non-tree pollen exceeds tree pollen. Eventually open vegetational communities with a true periglacial flora take over.

Vegetational changes within these major zones are recognized and defined as subzones, but these may have only a local or possibly regional significance within East Anglia. The pollen stratigraphy of zone l Lo is better represented at Hoxne (West 1956). Pollen evidence for zone e Gi is generally obscured by the presence of much reworked interglacial pollen, but there is good macrofossil evidence for the flora, particularly from Marks Tey and also from Hoxne.

The numbering of West's (1956) zonation of the incomplete sequence of deposits at the type site at Hoxne differs slightly from that of the more general zonation scheme proposed here and elsewhere (Turner & West 1968; see also West 1968):

Marks Tey (after Turner & West 1968)	Hoxne (after West 1956)
e Gi, Ho IVb, a, Ho IIIb	IV
a	III
Ho IIc	IId
b	IIc
a	IIb
Ho I	IIa
l Lo	Ib to e

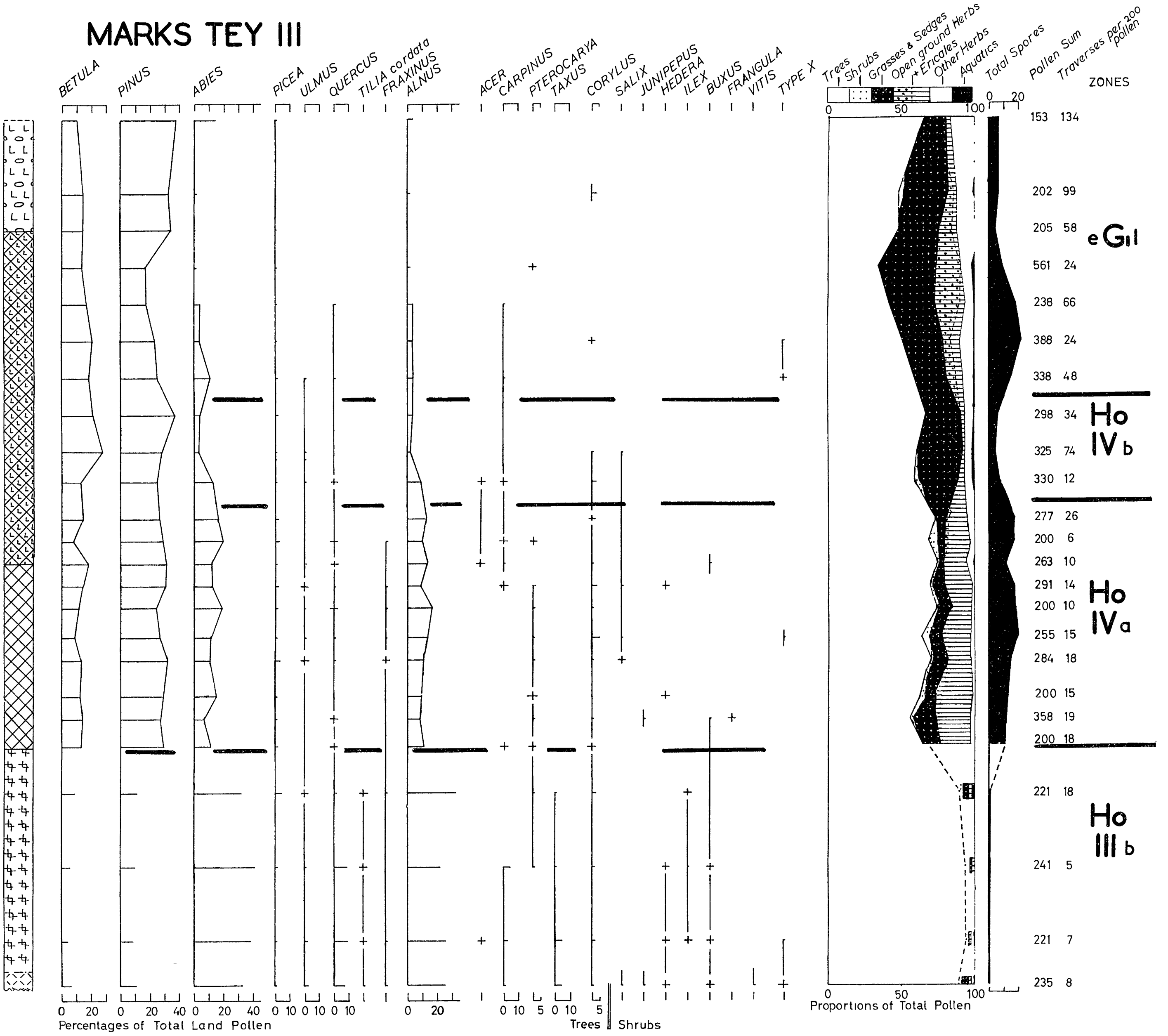

FIGURE 13. Tree pollen diagram, Marks Tey III.

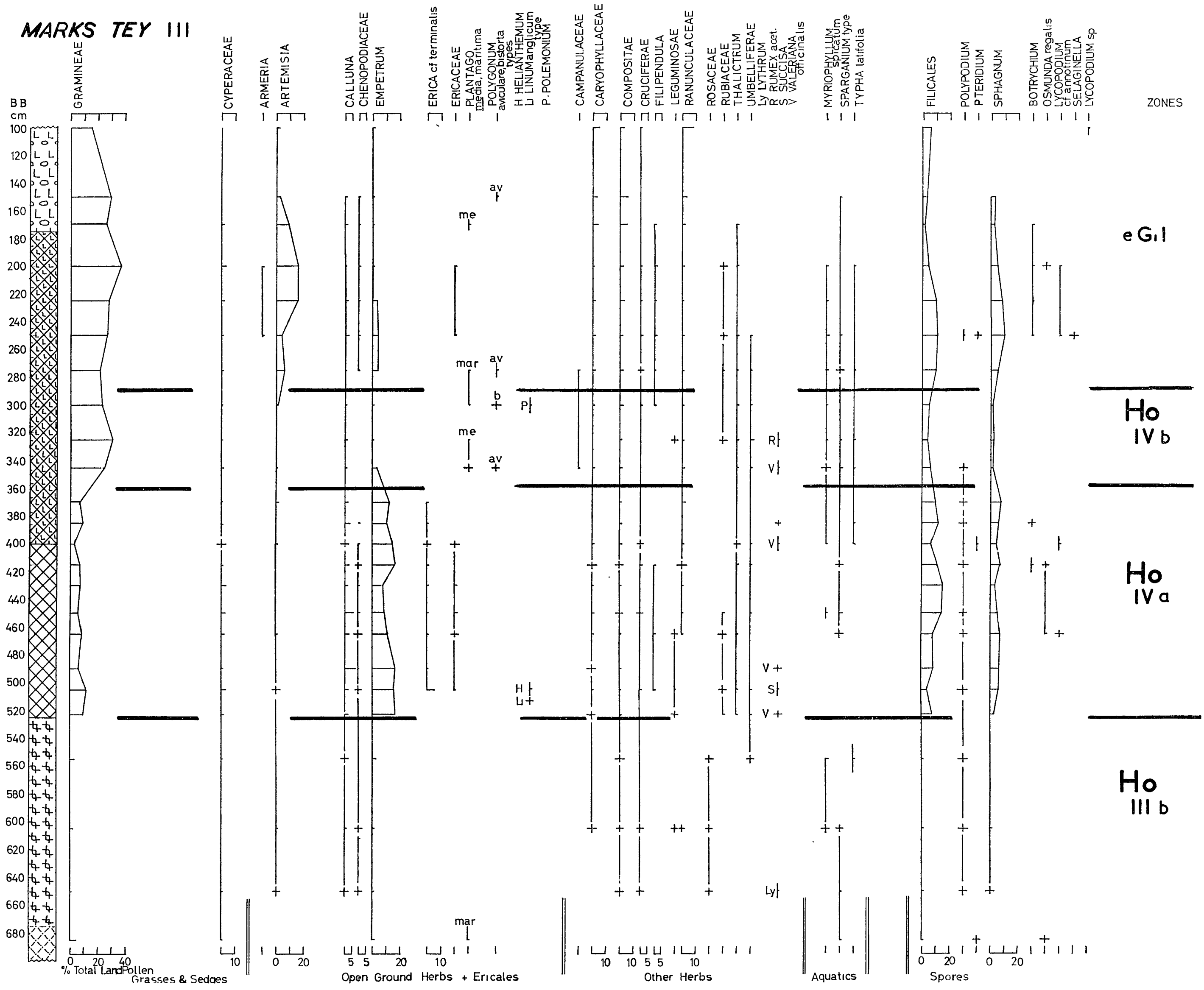

FIGURE 14. Non-tree pollen diagram, Marks Tey III.

The following detailed description of the characteristics of these pollen zones and subzones at Marks Tey is based on pollen diagrams Marks Tey IA, II and III.

Zone l Lo (Marks Tey IA, 2013–2142 cm)

This zone, characterized by a high ratio of non-tree pollen to tree pollen, is not well developed at Marks Tey. Whereas at Hoxne West distinguished a number of subzones (b to e), all the Marks Tey pollen spectra from this zone are probably referable to the final subzone e. The dominant pollen types are *Betula* (26 to 37 %), Gramineae (22 to 26 %) and typically *Hippophaë* (15 to 24 %).

Zone Ho I (Marks Tey IA, 1778–1880 cm, also 1892–2013 cm)

The base of this zone is drawn where tree pollen totals first exceed non-tree pollen. Throughout the zone the dominant tree pollen is *Betula:* it always exceeds 50 % of the total pollen, with

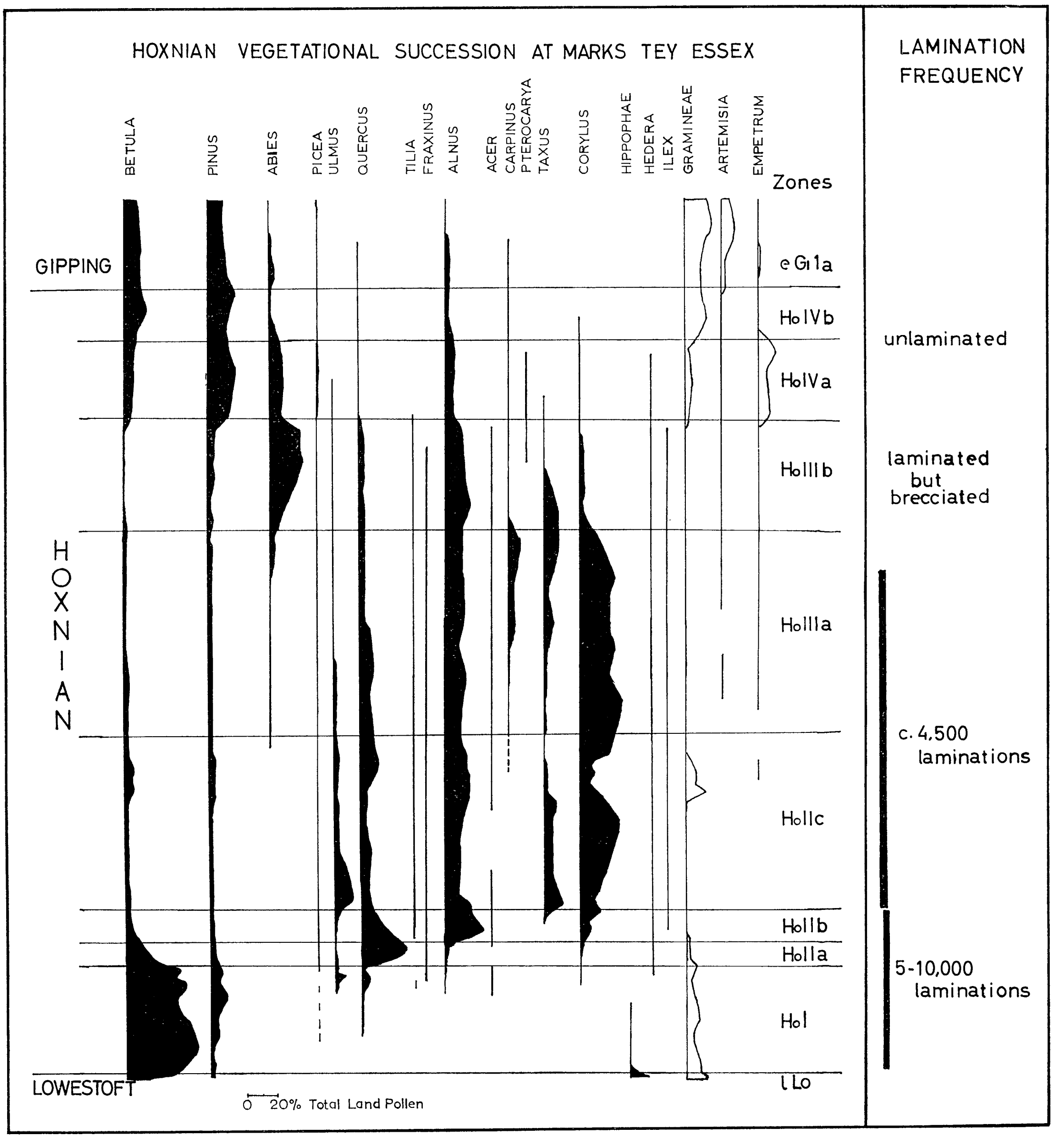

FIGURE 15. Hoxnian vegetational succession at Marks Tey (composite pollen diagram).

a maximum value of 89 %. In diagram Marks Tey I A, most of this zone is repeated by slumping of the strata. No formal subdivision of the zone is presented here, but three successive vegetational phases seem to be distinguishable. In the early part of the zone *Betula* rises rapidly to high values (60 to 80 %), whilst *Pinus* shows low values (2 to 6 %). Later there is a distinct increase in *Pinus* values (10 to 23 %). Finally in a short but well-marked phase *Ulmus* and *Quercus*, previously present only as traces, reach sudden temporary maxima of 13 % and 21 % respectively prior to the decline of *Betula* and the major expansion of *Quercus* heralding zone Ho II. Herbaceous pollen types (10 to 20 %) are varied and still present in significant amounts.

Zone Ho II (Marks Tey IA, 1509–1778 cm)

The pollen spectra from this zone are dominated strongly by mixed-oak forest tree species. Non-tree pollen values are extremely low, except during an interesting phase towards the end of the zone (Marks Tey IA, 1519–1559 cm). The zone divides into three subzones, based on the immigration and expansion of particular thermophilous trees, and corresponding in definition almost exactly to the subzones described by West from Hoxne.

Subzone Ho IIa (Marks Tey IA, 1752–1778 cm). *Quercus–Betula–Pinus* subzone

The subzone begins with the rapid rise of *Quercus*, which increases to a maximum of 56 %. *Betula* and *Pinus* decline correspondingly.

Subzone Ho IIb (Marks Tey I A, 1712–1752 cm). *Alnus–Quercus–Corylus* subzone

This subzone shows a rapid initial rise of *Alnus* to 47 %, and a more gradual rise of *Corylus* to 27 %. *Tilia* occurs consistently for the first time in this interglacial, and *Quercus* values decline slowly throughout the subzone.

Subzone Ho IIc (Marks Tey IA, 1509–1712 dm). *Alnus–Corylus–Ulmus–Taxus–Quercus* subzone

This subzone begins with a distinct initial rise in both the *Ulmus* and *Taxus* curves. These decline later but *Corylus* expands steadily and markedly to outnumber all other pollen totals with a value of 53 %.

Herbaceous pollen values are generally extremely low (< 3 %), but during the middle of this subzone the vegetational succession is suddenly interrupted by a temporary phase with high non-tree pollen, similar to that recorded from the same subzone at Hoxne.

Zone Ho III (Marks Tey IA, 1254–1509 cm; Marks Tey II, 465–680 cm)

At Marks Tey, as at Hoxne, the base of this stage is taken as the point where *Carpinus* first forms a continuous curve. The zone is characterized by the development of *Carpinus* and then of *Abies* pollen values and the simultaneous decline of mixed-oak forest elements.

Subzone Ho IIIa (Marks Tey IA, 1254–1509 cm; Marks Tey II, 605–680 cm) *Alnus–Corylus–Quercus–Carpinus* subzone

This subzone is characterized by the rise of *Carpinus* to a maximum of 14 % and by low values of *Abies*. *Quercus*, *Ulmus* and later *Corylus* values decline slowly but steadily. *Alnus* remains important.

Subzone Ho IIIb (Marks Tey II, 465–605 cm). *Abies–Alnus* subzone

The subzone opens with a strongly pronounced rise in *Abies* values which reach 45 to 50 %. Pollen curves of the mixed-oak forest trees continue to fall, though *Alnus* does not decline. *Pterocarya*, *Vitis* and *Buxus* pollen occur sparsely.

Zone Ho IV (Marks Tey II, 345–465 cm; Marks Tey III, 300–525 cm)

This zone is marked by the re-appearance in quantity of non-tree pollen types, particularly *Empetrum* and Gramineae. Tree pollen totals fall to 70 to 80 % or less. At the same time *Pinus* and *Betula* increase at the expense of all other trees. Mixed-oak forest trees occur only in traces, and

Abies and *Alnus* decline steadily. The zone can be divided into two subzones on the basis of the dominant types of non-tree pollen.

Subzone Ho IVa (Marks Tey II, 370–465 cm; Marks Tey III, 370–525 cm) *Pinus–Betula–Abies–Empetrum* subzone

The subzone opens with a considerable expansion of *Empetrum* to values of 15 to 20 %, *Pinus* and *Betula* rise simultaneously. *Pterocarya* is present in low quantity.

Subzone Ho IVb (Marks Tey II, 345–370 cm; Marks Tey III, 300–370 cm) *Pinus–Betula–Gramineae* subzone

In this zone Gramineae pollen expands in place of *Empetrum*. The only trees to show high values are *Pinus* (25 to 36 %) and *Betula* (21 to 27 %), but tree pollen still exceeds non-tree pollen in abundance.

Zone e Gi (Marks Tey II, 290–345 cm; Marks Tey III, 100–300 cm)

The onset of this zone and of the glacial period is ideally considered to begin where non-tree pollen totals exceed those of tree pollen. This definition appears to be valid at Marks Tey, where the base of the zone is also characterized by an increase in *Artemisia* pollen. Pollen spectra from the later part of the zone at Marks Tey are highly contaminated with reworked interglacial pollen, but the initial part of the zone may be defined as a distinct vegetational subzone.

Subzone e Gi 1a (Marks Tey II, 290–345 cm; Marks Tey III, 100–300 cm). Gramineae–*Artemisia–Pinus–Betula* subzone

Non-tree pollen is dominant, particularly Gramineae (20 to 37 %) and *Artemisia* (rising to 16 %). *Pinus* and *Betula* are still important but declining.

(iii) *Miscellaneous pollen spectra*

Pollen analyses from the early-glacial grey clay.

Two minor series of pollen samples were examined from the grey clay of the brickpit. They came from boring CC, a trial auger hole close to the site of borehole GG, and from an open section EE on the western side of the brickpit (see figure 2) at a higher level (*ca*. 92 m O.D.). These pollen spectra are presented in table 2.

The four spectra from boring CC contain significant amounts of thermophilous pollen such as *Abies*, *Quercus*, *Corylus* and *Carpinus*. However, they resemble no normal spectra from the interglacial deposits because they also contain quite high percentages of Gramineae pollen as well as such pollen types as *Armeria*, *Artemisia*, *Helianthemum*, *Plantago*, *Polygonum* and also *Lycopodium* spores. The latter are typical constituents of the Gipping Early-glacial flora, and it is clear that the thermophilous pollen, though abundant, is a reworked contaminant. The spectra from section EE also show high percentages of *Abies* and *Pinus* pollen, which are presumably derived from reworked marginal sediments of zones Ho III and Ho IV. Indeed pollen samples EE Za and b were taken from small lumps of detritus mud washed from the gravel seam between EE 245–281 cm, and these are clearly derived directly from sediment of subzone Ho IVa. The plant macrofossils from section EE suggest an arctic and almost certainly treeless vegetation at this time, a condition it would be impossible to envisage from the contaminated pollen spectra.

Table 2. Miscellaneous pollen spectra from the Early-glacial laminated grey clay

percentages of total land pollen	CC 75 cm	CC 235 cm	CC 325 cm	CC 550 cm	EE 80 cm	EE 212 cm	EE 244 cm	EE 250 cm	EE 314 cm	EE Za	EE Zb
Betula	6	7½	6½	9	7½	15½	13½	8½	15½	14	11
Pinus	19	18½	18½	15½	35	45	43½	36½	32½	33	27
Abies	15	17	16½	17	24	5	4½	20½	19	8	10
Picea	½	1	2	1	5	1½	1	.	4½	2	1½
Ulmus	½	2	1	1	.	.	.	.	.	.	.
Quercus	5½	4	1½	5	.	.	½	½	.	.	.
Tilia	½	½	+	+	1	.	.	.	.	.	.
Fraxinus	½	.	½	1	.	.	.	.	.	.	.
Alnus	19	19	19	21½	9	3	9½	5	6	6	3
Acer	.	.	.	+	.	.	.	.	.	.	.
Carpinus	½	1½	1½	3	.	.	½	.	.	.	.
Pterocarya	.	.	.	.	.	.	.	.	.	½	.
Taxus	not counted but sparsely present				.	.	.	.	.	.	.
Corylus	12	12½	15	11	.	½	½	½	.	½	½
Salix	.	.	.	.	.	.	.	½	.	.	.
Hedera	½	+	½	½	.	.	.	.	.	.	.
Ilex	.	½	½	+	.	.	.	.	.	.	.
Type X	½	½	1	1	.	.	.	.	.	.	.
Gramineae	8½	5½	7	7	6½	14½	1½	7	12½	11	10½
Cyperaceae	.	½	½	½	1	.	.	.	.	1	1
Armeria	+	.	.	+	.	.	.	½	.	.	.
Artemisia	1½	2	1½	+	1	2	3½	1½	.	½	.
Calluna	1½	2	½	1	1½	.	½	1½	.	3	6
Chenopodiaceae	.	+	½	+	.	.	.	.	1½	.	.
Empetrum + Ericaceae	3	3	2	1½	5½	3½	7½	2	.	17½	27½
Erica cf. *terminalis*	.	.	.	.	1	.	.	.	.	1½	1½
Helianthemum	.	½	½	.	.	.	.	.	.	.	.
Plantago cf. *media*	.	.	.	+	1	½	.	.	.	.	.
Polygonum cf. *persicaria*	.	½	.	.	.	.	.	.	.	.	.
Caryophyllaceae	2	½	½	1	.	.	2	8½	3	.	.
Compositae	1	1	1	1½	.	5½	3½	5½	3	1	.
Cruciferae	½	½	½	1	.	½	5	.	1½	½	.
Filipendula	½	.	+	½	.	.	.	.	.	.	.
Leguminosae	.	½	.	.	.	.	.	.	.	.	.
Ranunculaceae	½	.	.	1	1	½	½	.	.	½	.
Rosaceae	½	.	.	.	.	.	.	.	.	.	.
Rubiaceae	.	.	.	.	.	½	.	.	.	.	.
Rumex	½	.	.	+	.	.	.	.	.	.	.
Succisa	.	.	.	+	.	.	.	.	.	.	.
Thalictrum	½	.	½	.	.	.	.	.	.	.	.
Umbelliferae	.	.	.	.	.	½	.	.	.	.	
Myriophyllum	½	.	+	½	1	½	1½	.	.	.	.
Potamogeton	.	.	.	.	1	.	.	.	.	.	.
Sparganium type	+	+	+	+	.	.	.	.	.	.	.
Typha latifolia	.	.	+	.	.	½	.	.	.	.	.
Filicales	4½	4	3	2	2½	.	9	5	1½	4½	2½
Polypodium	+	1	½	+	.	.	.	½	.	.	.
Pteridium	½	.	.	.	.	.	.	.	.	.	.
Sphagnum	2½	4	5	1	5	7	24	1½	9½	6½	7
Botrychium	.	.	+	.	.	.	.	.	.	.	.
Ophioglossum	.	+	.	.	.	.	.	.	.	.	.
Lycopodium annotinum	.	+	.	.	.	.	.	.	.	.	.
L. alpinum	.	½	.	.	.	.	.	.	.	.	.
pollen-sum	300	284	297	273	122	144	136	140	65	235	189
traverse index/200 pollen	19	19	16	15	49	44	63	97	72	28	16

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Pollen analyses from boring 'T'

Dr S. L. Duigan has kindly provided details of two pollen spectra from her trial boring 'T', from organic clay mud at T 95 cm and at T 200 cm. These spectra confirm that this stratum was laid down during subzone Ho IV a, as in the neighbouring boring BB.

(*b*) *Plant macrofossils*

(i) *From interglacial and late-glacial strata*

Borings AA and BB: regularly spaced samples from these borings were specially washed for macrofossils. Fruits and seeds recovered during the preparation of pollen samples have also been added to the totals.

Abbreviations used in the floral lists: a, achene; an, fern annulus; b-s, bud scale; cal, calyx; car, caryopsis; fr, fruit; fst, fruitstone; l, leaf; l-s, leaf scale; msp, microspores; Msp, megasporangia; n, nutlet; o, oospore; p, pollen; s, seed; sc, sclerenchyma spindles; sk, spikelet; sp, spores; v, capsule valve; w, wood. A, terrestrial plants; B, helophytes; C, hydrophytes.

Boring AA

		zones...	e Gi I a	Ho IV a		Ho III b			Ho III a			
		depth (cm)...	325	365–375	375–400	500–525	525–550	550–575	600–625	625–650	650–675	675–685
A	*Abies* sp.	w	.	.	X	.	.	.	.	.	.	.
	Alnus sp.	fr	.	.	.	.	.	.	.	.	2	.
	Plantago major	s	.	.	.	.	.	.	.	1	.	.
B	*Alisma* sp.	fr	.	.	.	.	.	1	.	.	.	.
	Ranunculus sceleratus	a	.	.	3	.	.	.	.	.	.	.
C	*Naias marina*	fr	.	.	.	3	1	4	1	4	8	.
	Potamogeton pectinatus	fst	1	.	2	.	.	.	.	.	.	.
	Zannichellia palustris	a	.	.	2	1	.	1	1	.	.	.
	Chara sp.	o	.	+	.	.	.	.	.	.	.	.

Boring BB

		zones...	Ho IV b		Ho IV a						Ho III b
		depth (cm)...	300–325	325–350	350–375	375–400	400–425	425–450	450–475	475–500	500–525
A	*Abies* sp.	w	.	.	.	X	.	.	.	.	.
	Betula pubescens	fr	.	.	.	.	.	.	.	1	.
	Betula sp.	fr	.	.	.	.	.	.	.	.	1
	Erica sp.	l	.	.	.	.	.	.	.	2	.
	Sorbus aucuparia	fr	.	.	.	.	.	1	.	.	.
	Taxus baccata	s	.	.	2	.	.	.	.	.	.
	Tripleurospermum maritimum	a	.	.	.	.	.	.	.	.	1
	Urtica dioica	fr	.	1	.	.	1	3	.	2	2
B	*Alisma* sp.	fr	.	2	.	.	.	.	.	.	.
	Carex sp.	n	.	.	.	.	.	1	.	.	.
	Eleocharis palustris	n	1	.	.	.	.	.	.	.	.
	Eriophorum vaginatum	sc	.	.	.	.	.	.	.	9	.
	Juncus inflexus	s	.	.	1	.	.	.	.	.	.
	Lycopus europaeus	n	1	.	.	.	.	.	.	.	.
	Narthecium ossifragum	s	.	.	.	.	.	1	.	.	.
	Ranunculus sceleratus	a	.	.	.	.	.	1	1	5	14

Boring BB (*cont.*)

zones...		Ho IVb		Ho IVa						Ho IIIb
depth (cm)...		300–325	325–350	350–375	375–400	400–425	425–450	450–475	475–500	500–525
C *Lemna* sp.	s	.	.	.	.	.	.	.	1	.
Myriophyllum spicatum	n	1	7	.	.	.	1	.	.	3
Potamogeton crispus	fst	.	2	.	.	.	1	.	.	5
Potamogeton natans	fst	.	.	.	.	.	.	.	.	2
Potamogeton pectinatus	fst	.	1	.	.	.	.	.	.	.
Potamogeton polygonifolius	fst	.	.	.	1	.	.	.	.	.
Potamogeton praelongus	fst	.	.	.	.	.	.	.	.	1
Potamogeton sp.	fst	.	1	1	.	.	1	.	.	1
Ranunculus subg. *Batrachium*	a	.	1	1	.	.	.	.	1	.
Zannichellia palustris	a	7	27	1	.	.	1	.	.	1

Subzone e Gi 1a		BB 200–225 cm	BB 225–250 cm	BB 325–350 cm
Chara	o	1	.	10
Nitella	o	4	4	.

Borehole GG: Plant macrofossils were much less abundant in these deep-water sediments than in the marginal deposits. Although samples were not washed for macrofossils, the following were recovered during pollen sampling. Numbers in parentheses indicate more than one specimen.

A	*Betula pendula*	fr	Zone Ho I: GG 1849 cm, 1864 cm (2), 1925 cm (2), 1986 cm
	Betula pubescens	fr	Zone Ho I: GG 1849 cm, 1864 cm, 1897 cm, 2011 cm
	Betula sp.	fr	Zone Ho I: GG 1790 cm (2), 1796 cm, 1851 cm, 1864 cm (6), 1894 cm, 1897 cm (2), 1898 cm (2), 1915 cm (2), 1925 cm (2) Subzone Ho IIa: GG 1763 cm
	Cruciferae	s	Zone e Gi: GG 500 cm (2), 620 cm
	Gramineae	sk & car	Zone Ho I: GG 1778 cm, 1851 cm
	Hippophaë rhamnoides	l-s	Zone l Lo: GG 2014 (2)
	cf. *Ulmus*	l	Subzone Ho IIIb: GG 1027 cm
B	*Carex* sp.	n	Zone Ho I: GG 1925 cm
	Typha angustifolia L.	s	Zone l Lo: GG 2014 cm, 2016 cm, 2018–2020 cm Subzone Ho IIc: GG 1559 cm
C	*Ceratophyllum demersum*	l	Zone Ho I: GG 1950
	Naias marina	fr	Subzone Ho IIc: GG 1628 cm (8)
	Zannichellia palustris	a	Zone e Gi: GG 437 cm
— — —	— — —	— —	— — — — — — — — — —
	Filicales	an	Zone e Gi: GG 620 cm, 704 cm
	Chara	o	Zone l Lo: GG 2013 cm Zone Ho I: abundant in most samples Subzone Ho IIa: GG 1773 cm Subzone Ho IIc: GG 1559 cm Zone e Gi: GG 380 cm, 437 cm, 500 cm, 620 cm
	Nitella	o	Zone l Lo: GG 2014 cm, 2023 cm Zone Ho I: GG 1778 cm, 1880 cm Zone e Gi: GG 405 cm

The cores of borehole JJ contain abundant macrofossils, which have not yet been fully examined. Megaspores of the water fern *Azolla filiculoides* occur in sediments of subzone Ho IV a (JJ 480–492 cm).

(ii) *From the early-glacial grey clay*

Samples of grey clay and of fine gravel seams within the clay were collected from section EE on the western side of the brickpit. Sample MTX came from the gravel seam EE 245–281 cm and MTZ from the same seam a few feet farther along the face, where the gravel contained small peat lumps. Pollen analysis shows that these peat fragments derive from strata of subzone Ho IVa. Some of the fruits and seeds washed from this gravel seam may be similarly derived, but in general the macrofloral remains listed below are very different from those found in the interglacial sediments and belong to the Gipping Early-glacial period.

			EE 212 cm	MT X (= EE 245–281 cm)	MT Z (= EE 245–281 cm)	EE 300–320 cm
A	*Arabis* sp.	s	.	.	1	.
	Armeria maritima	cal	.	11	5	2
	Betula sp.	fr	.	.	.	1
	Campanula rotundifolia	s	.	.	1	.
	Caryophyllaceae	s	.	2	2	.
	Cerastium sp.	s	.	.	1	.
	Cruciferae	s	2	26	65	12
	Cruciferae	v	.	13	14	14
	Graminae	sk & car	.	28	17	18
	Linum perenne	s	.	1	1	.
	Oxyria digyna	fr	1	2	2	6
	Potentilla tabernaemontani or *crantzii*	a	.	1	.	.
	Potentilla sp.	a	.	.	3	3
	Salix sp.	b-s	.	.	1	.
	Silene maritima or *vulgaris*	s	.	.	2	.
	Silene cf. *wahlbergella*	s	1	.	.	.
B	*Carex* sp.	n	.	1	2	.
	Ranunculus sceleratus	a	.	1	1	.
	Scirpus sp.	n	.	.	.	1
	Typha latifolia	s	.	.	1	.
C	*Callitriche* sp.	fr	.	.	.	1
	Zannichellia palustris	a	.	1	1	1
	Chara	o	2	1	9	.
	Nitella	o	.	1	.	.

The delicate Cruciferae capsule valves were certainly not reworked. A variety of types were present, including *Alyssum*, *Draba*, cf. *Erophila* and probably *Arabis*, of which a seed was also found.

Further plant macrofossils were washed from the grey clay from a blackish organic band at a depth of 490 cm in borehole HH. Species found were:

Anthemis cotula	a	1
Aphanes microcarpa	a	1
Chenopodium cf. *album*	s	3
Rumex sp.	n	1
Ranunculus flammula	a	14
Potamogeton filiformis	fst	2
Ranunculus subg. *Batrachium*	a	18
Chara	o	26

Miss J. Allison had identified a number of plant macrofossils from samples of the grey clay collected at Marks Tey by Mrs Gifford in 1948. They included *Armeria*, *Linum* and *Oxyria* and also *Atriplex*, *Carduus* and *Myriophyllum spicatum* (Godwin 1956). With further collecting it would doubtless be possible to obtain a much richer flora from these strata.

(iii) *Moss remains*

Dr J. H. Dickson has kindly identified a number of moss remains from the deposits.

Zone e Gi

Acrocladium giganteum (Schp.) Richards & Wallace	HH 490 cm
Drepanocladus sp.	HH 490 cm
Neckera cf. *complanata* (Hedw.) Hüben	GG 629 cm
Sphagnum sg. *Inophloea*	GG 629 cm

Subzone Ho IVa

Sphagnum sg. *Inophloea*	BB 400–425 cm
Sphagnum sg. *Litophloea*	BB 400–425 cm

Subzone Ho IIIb

Sphagnum sg. *Inophloea*	BB 500–525 cm
Neckera cf. *complanata* (Hedw.) Hüben	GG 1013 cm
cf. *Brachythecium velutinum* (Hedw.) B., S. & G.	AA 485 cm

Subzone Ho IIb

Neckera complanata (Hedw.) Hüben	GG 1712 cm

(*c*) *The plant list and notes on plant records of particular interest*

Table 3 provides a full list of the plant remains from Marks Tey, exclusive of the moss remains which have already been listed. Records in parentheses refer to single pollen grains which can probably be regarded as reworked.

TABLE 3

species		l Lo	Ho I	Ho IIa	Ho IIb	Ho IIc	Ho IIIa	Ho IIIb	Ho IVa	Ho IVb	e Gi Ia	e Gi
Abies cf. *alba* Mill.	p,w	.	(X)	.	.	X	X	X	X	X	X	.
Acer sp.	p	.	X	X	X	X	X	X	X	X	.	.
Alisma sp.	p,fr	.	.	.	.	.	.	X	.	X	.	.
Alnus cf. *glutinosa* (L.) Gaertn.	p,fr	.	X	X	X	X	X	X	X	X	X	.
Anthemis cotula L.	a	.	.	.	.	.	.	.	.	.	.	X
Aphanes microcarpa (Boiss. Reut.) Rothm.	a	.	.	.	.	.	.	.	.	.	.	X
Arabis sp.	s	.	.	.	.	.	.	.	.	.	.	X
Armeria maritima (Mill.) Willd.	p,cal	.	X	.	.	.	.	.	.	.	X	X
Artemisia spp.	p	.	X	.	X	X	X	X	X	X	X	.
Atriplex sp.	s	.	.	.	.	.	.	.	.	.	.	X
Betula cf. *nana* L.	p	X	X	.	.	.	.	.	.	.	.	.
B. pendula Roth	fr	.	X	.	.	.	.	.	.	.	.	.
B. pubescens Ehrh.	fr	.	X	.	.	.	.	.	.	.	.	.
Betula spp.	p,fr	X	X	X	X	X	X	X	X	X	X	X
Buxus cf. *sempervirens* L.	p	.	.	.	.	.	X	X	X	.	.	.
Callitriche sp.	fr	.	.	.	.	.	.	.	.	.	.	X
Calluna vulgaris (L.) Hull.	p	.	X	.	.	X	X	X	X	X	X	.
Campanula rotundifolia L.	s	.	.	.	.	.	.	.	.	.	.	X
Campanulaceae	p	.	.	.	.	.	.	.	X	X	X	.
Carduus sp.	a	.	.	.	.	.	.	.	.	.	.	X
Carex spp.	n	.	X	.	.	.	.	.	X	.	.	X
Carpinus betulus L.	p	.	(X)	.	.	X	X	X	X	X	X	.
Caryophyllaceae	p,s	X	X	X	X	X	X	X	X	X	X	X

TABLE 3 (*cont.*)

species		l Lo	Ho I	Ho IIa	Ho IIb	Ho IIc	Ho IIIa	Ho IIIb	Ho IVa	Ho IVb	e Gi 1a	e Gi
Centaurea nigra L.	p	.	X	.	.	X	X	.	.	.	.	.
C. scabiosa L.	p	.	.	.	.	.	.	X	.	.	.	.
Cerastium sp.	s	.	.	.	.	.	.	.	.	.	.	X
cf. *Ceratophyllum demersum* L.	l	.	X	.	.	.	.	.	.	.	.	.
Chenopodiaceae	p	.	X	X	X	X	X	X	X	X	X	.
Chenopodium cf. *album* L.	s	.	.	.	.	.	.	.	.	.	.	X
Compositae sect. Liguliflorae	p	X	X	X	X	X	X	X	X	X	X	.
Compositae sect. Tubiflorae	p	X	X	X	X	X	X	X	X	X	X	.
Corylus avellana L.	p	.	X	X	X	X	X	X	X	X	X	.
Cruciferae	p,s,v	X	X	X	X	X	X	X	X	X	X	X
Cyperaceae	p	X	X	X	X	X	X	X	X	X	X	.
Eleocharis palustris (L.) Roem. & Schult.	n	.	.	.	.	.	.	.	.	X	.	.
Empetrum nigrum L.	p	.	.	.	.	X	X	X	X	X	X	.
Epilobium sp.	p	.	X	.	.	.	.	.	.	.	.	.
Erica cf. *terminalis* Salisb.	p	.	.	.	.	X	X	X	X	.	.	.
Ericaceae	p,l	X	X	X	X	X	X	X	X	X	X	.
Euonymus europaeus L.	p	.	.	X	.	.	.	.	.	.	.	.
Fagus cf. *sylvatica* L.	p	.	.	.	.	.	.	X	X	X	.	.
Filipendula sp.	p	.	X	X	.	X	X	X	X	X	.	.
Frangula alnus Mill.	p	.	.	.	.	.	.	.	X	.	.	.
Fraxinus excelsior L.	p	.	X	X	X	X	X	X	X	.	.	.
Gentianaceae	p	.	.	.	.	X	X	X	.	.	X	.
Geranium sp.	p	.	X	X	X	X	X	.	.	.	.	.
Gramineae	p,sk car	X	X	X	X	X	X	X	X	X	X	X
Hedera helix L.	p	.	X	X	X	X	X	X	X	.	.	.
Helianthemum sp.	p	X	X	.	X	.	.	.	X	.	.	.
Hippophaë rhamnoides L.	p,l,s	X	X	.	.	.	.	X	.	.	.	.
Hydrocotyle vulgaris L.	p	.	.	.	.	.	.	X	.	.	.	.
Ilex aquifolium L.	p	.	.	.	X	X	X	X	.	.	.	.
Juncus inflexus L.	s	.	.	.	.	.	.	.	X	.	.	.
Juniperus communis L.	p	X	X	X	X	.	.	X	X	.	.	.
Labiatae	p	.	X	.	.	X	.	.	.	.	.	.
Leguminosae	p	.	.	X	.	X	X	X	X	X	.	.
Lemna sp.	s	.	.	.	.	.	.	.	X	.	.	.
Linum perenne L.	s	.	.	.	.	.	.	.	.	.	.	X
Linum sp.	p	.	.	.	.	.	.	.	X	.	.	.
Litorella uniflora (L.) Aschers.	p	.	X	.	.	X	.	.	.	.	.	.
Lonicera sp.	p	.	.	.	.	.	X	.	.	.	.	.
Lycopus europaeus L.	n	.	.	.	.	.	.	.	.	X	.	.
Lythrum sp.	p	.	.	.	.	.	X	.	.	.	.	.
Menyanthes trifoliata L.	p	.	X	.	.	.	.	.	.	.	.	.
Myriophyllum spicatum L.	p,n	.	X	X	X	X	X	X	X	X	X	X
M. verticillatum L.	p	.	X	.	.	.	X	.	.	.	.	.
Naias marina L.	fr	.	.	.	.	X	X	X	.	.	.	.
Narthecium ossifragum (L.) Hudson	s	.	.	.	.	.	.	.	X	.	.	.
Oxyria digyna (L.) Hill	fr	.	.	.	.	.	.	.	.	.	.	X
Picea cf. *abies* (L.) Karst	p	X	X	X	X	X	X	X	X	X	X	.
Pinus sylvestris L.	p	X	X	X	X	X	X	X	X	X	X	.
Plantago coronopus L.	p	.	X	.	.	.	.	.	X	.	.	.
P. major L.	s	.	.	.	.	.	X	.	.	.	.	.
P. maritima L.	p	.	X	.	X	X	X	X	.	X	X	.
Plantago cf. *media* L. (media-major type)	p	X	X	.	.	X	.	.	X	X	X	.
Polemonium sp.	p	.	.	.	.	.	.	.	.	X	.	.
Polygonum cf. *aviculare* L.	p	X	.	.	.	.	.	X	.	X	X	.

TABLE 3 (*cont.*)

species		l Lo	Ho I	Ho IIa	Ho IIb	Ho IIc	Ho IIIa	Ho IIIb	Ho IVa	Ho IVb	e Gi 1a	e Gi
P. bistorta L.	p	.	.	.	.	.	.	X	X	X	.	.
P. cf. *persicaria* L.	p	.	.	.	.	.	X	X	.	.	.	.
Potamogeton crispus L.	fst	.	.	.	.	.	.	X	X	X	.	.
P. filiformis Pers.	fst	.	.	.	.	.	.	.	.	.	.	X
P. natans L.	fst	.	.	.	.	.	.	X	.	.	.	.
P. pectinatus L.	fst	.	.	.	.	.	.	.	X	X	X	.
P. polygonifolius Pourr.	fst	.	.	.	.	.	.	.	X	.	.	.
P. praelongus Wulf.	fst	.	.	.	.	.	.	X	.	.	.	.
Potamogeton spp.	p,fst	.	X	X	X	X	X	X	X	X	.	.
Potentilla crantzii (Crantz) G. Beck ex Fritsch or *tabernaemontani* Aschers.	a	.	.	.	.	.	.	.	.	.	.	X
Potentilla spp.	p,a	.	.	.	.	.	.	X	.	X	.	X
Prunus type	p	.	X	.	.	.	X	X	.	.	.	.
Pterocarya sp.	p	.	.	.	.	.	.	X	X	.	.	.
Quercus spp.	p	.	X	X	X	X	X	X	X	X	X	.
Ranunculus flammula L.	a	.	.	.	.	.	.	.	.	.	.	X
R. sceleratus L.	a	.	.	.	.	.	.	X	X	.	.	X
Ranunculus subg. *Batrachium*	a	.	.	.	.	.	.	.	X	X	.	X
Ranunculaceae	p	X	X	X	X	X	X	X	X	X	X	.
Rosaceae	p	.	X	X	X	X	X	X	X	X	X	.
Rubiaceae	p	.	X	.	.	X	X	X	X	X	X	.
Rumex acetosa L.	p	.	.	.	.	.	.	.	X	X	.	.
Rumex spp.	p,n	.	X	.	X	X	X	X	.	.	.	X
Salix spp.	p,b-s	X	X	X	X	X	X	X	X	X	X	X
Sanguisorba officinalis L.	p	.	.	.	.	.	.	.	X	.	.	.
Scabiosa columbaria L.	p	.	.	.	.	.	.	.	X	.	.	.
Scirpus sp.	n	.	.	.	.	.	.	.	.	.	.	X
Silene maritima With. or *vulgaris* (Moench) Garcke	s	.	.	.	.	.	.	.	.	.	.	X
Silene cf. *wahlbergella* Chowdhuri	s	.	.	.	.	.	.	.	.	.	.	X
Sorbus aucuparia L.	fr	.	.	.	.	.	.	.	X	.	.	.
Sparganium type	p	X	X	X	X	X	X	X	X	X	X	.
Succisa pratensis Moench	p	.	X	.	.	.	.	.	X	.	.	.
Taxus baccata L.	p,s	.	.	.	X	X	X	X	X	.	.	.
Thalictrum sp.	p	X	X	X	.	X	X	X	X	X	X	.
Thelycrania sanguinea (L.) Fourr.	p	.	.	.	.	.	X	.	.	.	.	.
Tilia cordata Mill.	p	.	X	X	X	X	X	X	X	.	.	.
T. platyphyllos Scop.	p	.	.	.	.	X	X	X	.	.	.	.
T. x *europaea* L.	p	.	.	.	X	X	X	X	.	.	.	.
Trifolium spp.	p	.	X	.	.	.	.	.	.	X	.	.
Tripleurospermum maritimum (L.) Koch	a	.	.	.	.	.	.	.	.	X	.	.
Typha latifolia L.	p,s	X	X	X	X	X	X	X	X	X	X	X
T. angustifolia L.	s	X	.	.	.	X	.	.	.	.	.	.
Ulmus spp.	p,l	.	X	X	X	X	X	X	X	X	X	.
Umbelliferae	p	X	X	X	X	X	X	X	X	X	X	.
Urtica dioica L.	p,fr	.	.	.	X	X	.	X	X	X	.	.
Valeriana officinalis L.	p	X	X	.	.	X	.	.	X	X	X	.
Viburnum lantana L.	p	.	.	X	X	X	X	X	.	.	.	.
V. opulus L.	p	.	.	X	.	X	.	.	.	.	.	.
Viscum album L.	p	.	.	.	.	X	X	X	X	.	.	.
Vitis cf. *vinifera* L.	p	.	.	.	.	.	X	X	.	.	.	.
Zannichellia palustris L.	a	.	.	.	.	.	X	X	X	.	X	X
Type X	p	.	.	.	X	X	X	X	X	X	X	.
Azolla filiculoides Lam.	Msp	.	.	.	.	.	.	.	X	.	.	.
Botrychium lunaria (L.) Sw.	sp.	.	.	.	.	X	X	X	X	.	X	.
Lycopodium alpinum L.	sp	.	X	.	.	.	.	.	.	X	X	.
L. annotinum L.	sp	.	X	.	X	.	.	.	X	.	X	.

TABLE 3 (*cont.*)

species		l Lo	Ho I	Ho IIa	Ho IIb	Ho IIc	Ho IIIa	Ho IIIb	Ho IVa	Ho IVb	e Gi 1a	e Gi
L. clavatum L.	sp	.	.	.	.	.	.	.	X	.	.	.
Ophioglossum vulgatum L.	sp	.	X	.	.	X	X	.	X	X	.	.
Osmunda cf. *claytoniana* L.	sp	.	.	.	.	X	X	X	X	.	.	.
O. regalis L.	sp	.	.	.	.	X	X	X	X	X	X	.
Polypodium vulgare L.	sp	.	X	X	X	X	X	X	X	X	X	.
Pteridium aquilinum (L.) Kuhn	sp	.	X	.	X	X	X	X	X	X	X	.
Selaginella selaginoides (L.) Link	msp	.	.	.	.	.	.	.	.	.	X	.
Thelypteris dryopteris (L.) Slosson	sp	.	.	.	.	X	.	.	.	.	.	.
Filicales	sp	X	X	X	X	X	X	X	X	X	X	.
Sphagnum spp.	sp	X	X	X	X	X	X	X	X	X	X	.
Chara spp.	o	X	X	X	.	X	.	.	X	X	X	X
Nitella spp.	o	X	X	.	.	.	.	.	.	.	X	X

The bryophyte remains have already been fully listed.

Particular plant records from Marks Tey, considered to be of biogeographical or taxonomic interest, are now discussed further.

Abies cf. *alba*

Both wood and pollen of *Abies* were found at Marks Tey. The tree is known to have occurred in Britain during both the Cromerian and Hoxnian interglacial periods, but not more recently as a native. Jessen, Andersen & Farrington (1959) have demonstrated that the living European species *Abies alba* was present in Ireland during interglacial times. Today *A. alba* is virtually absent from the lowlands of north-west Europe and in particular from the Atlantic seaboard, except for a very isolated and doubtfully native colony in Normandy (Maire 1904). Possibly the progressive glaciation of western Europe led to the extinction of any biotypes of *Abies alba* that had been able to colonize these more oceanic lowland areas.

Acer spp.

Pollen of *Acer* was found from every zone of the interglacial. That from the temperate and later zones can probably be referred to *A. campestre*, although the pollen of that species is not morphologically distinctive. However, the *Acer* pollen from the Pre-temperate zone Ho I appears to possess a coarser, more curly striate surface pattern. On ecological as well as morphological grounds it should be attributed to a different species, perhaps *A. platanoides*.

Betula cf. *nana*

Pollen resembling that of *B. nana* was found frequently in pollen spectra from zone l Lo but sparingly from the lower part of zone Ho I. However, in the pollen analyses separate counts were not made for dwarf and tree birches.

Buxus cf. *sempervirens*

Small amounts of *Buxus* pollen occurred regularly in spectra of subzones Ho III b and Ho IV a. *Buxus* probably grew as a shrub within the *Abies* forest, as it does in south-eastern Europe today. *Buxus* pollen has been found in the Hoxnian deposits at Birmingham (Kelly 1964) and in Ireland (Jessen *et al.* 1959; Watts 1964) and in the Continental Holsteinian deposits from Denmark (Andersen 1965), Hanover (von Rochow 1953) and Berlin (Erd 1962). It can therefore be regarded as a species characteristic of the Late- and Post-temperate zones of the Holstein interglacial.

Erica cf. *terminalis*

A distinctive tricolporate pollen type, 25 to 30 μm in size, occurred in some frequency in pollen spectra from subzone Ho IVa and sporadically from other subzones. Its most noticeable feature, strongly thickened margins of the furrows, is normally characteristic of Ericaceae pollen tetrads. The only European species of *Erica* whose pollen occurs in monads and not tetrads is *Erica terminalis* (= *E. stricta*), a western Mediterranean species occurring in Corsica, Sardinia, southern Italy, south-west Spain and north-west Morocco. Nevertheless, the fossil pollen matches very well with that of this species (photographs, figure 21, plate 74).

The habitat of *E. terminalis* is shady places by streams and it is slightly more tolerant of mildly calcareous soils than most other species of *Erica*. It would be important to confirm this specific identification by the discovery of seeds or leaves definitely attributable to *E. terminalis*, since the occurrence of such a restricted Mediterranean species in Britain during the Hoxnian interglacial must be an unusual and significant feature.

Eriophorum vaginatum

Sclerenchyma spindles from the leaf bases of *E. vaginatum* were recovered from the detritus mud of subzone Ho IVa. These spindles, 1.5 to 2 mm long, which do not occur in the other common species of *Eriophorum*, possess a characteristic surface pattern.

Fagus cf. *sylvatica*

Three pollen grains of *Fagus* were found in widely separated spectra referable to subzones Ho IIIb, Ho IVa and Ho IVb in pollen diagram Marks Tey II. The occurrence of *Fagus* during interglacial periods in Britain and, indeed, in northern Europe as a whole, has long been regarded as extremely tentative (Averdieck 1964). However, five cupule fragments were found at Gort (Jessen *et al.* 1959), and Reid (1882) recorded leaves of *Fagus* from the Cromer Forest Bed series. There has been scant record of *Fagus* pollen, but the tree is known to be an extremely low pollen producer. It is conceivable that the beech pollen at Marks Tey was secondarily derived from an unknown source, but on the whole its presence adds weight to the idea that the tree existed at a very low frequency in the forest during at least the Hoxnian and probably other interglacial periods.

Picea cf. *abies*

Small quantities of *Picea* pollen were found throughout the interglacial deposits at Marks Tey. It was evidently present during the early zones of the Hoxnian interglacial, a feature characteristic of Continental Holsteinian pollen diagrams too. *Picea* occurred in Britain during all the major interglacial and some interstadial periods but has been absent as a native plant during the Flandrian Post-glacial.

Pterocarya sp.

One of the most significant botanical discoveries at Marks Tey is the persistent appearance of *Pterocarya* in pollen spectra from subzones Ho IIIb and Ho IVa. Previously it had been assumed that *Pterocarya* became permanently extinct in the British Isles after the Antian interglacial (West 1961 *b*). The *Pterocarya* pollen at Marks Tey is certainly contemporary with the deposits and not derived. Firstly it occurs in a highly organic sediment containing a very low proportion of secondary pollen and spores; secondly *Pterocarya* pollen was detected at the same stratigraphic horizon from borings on both sides of the lake basin as well as from a reworked pebble of sediment of the same age (pollen sample EE Za) (photograph, figure 20, plate 74).

Several other recent pollen analytical investigations provide further evidence confirming the immigration of this tree into north-west Europe during the latter part of the Holsteinian interglacial. Andersen (1965) has pollen of this tree from Vejlby, Denmark; Erd (1962) from the Paludina beds of Berlin; and Wolf & Lorenz (1963) from another site in East Germany near Görlitz. There are records of *Pterocarya* pollen from a number of sites in Poland belonging to the same interglacial period (Środoń 1955; Jurkiewiczowa & Mamakowa 1960; Janczyk-Kopikowa 1963). Macrofossils of *Pterocarya* have been found at a site, said to be Holsteinian, at Frimmersdorf near Köln (von der Brelie, Kilpper & Teichmüller 1959) and there are older unconfirmed records from Bad Cannstadt (Bertsch 1927) and Essen (Kräusel 1937). Today *P. fraxinifolia*, the species most closely resembling the fossil material, is restricted to the Caucasus and the environs of the Caspian Sea, whilst other species occur in Eastern Asia.

Silene cf. *wahlbergella*

A winged seed clearly belonging to the Caryophyllaceae was found in the laminated grey clay (EE 212 cm). This seed was examined by Mrs J. H. Dickson, who identified it as *Silene* cf. *wahlbergella*, which she has also recently found (unpublished) in glacial deposits from Broome, Norfolk. The seeds of *S. wahlbergella* (= *Melandrium apetalum*) have prominent swollen wings and cells with strongly sinuous margins. Those of the closely related *S. furcata* have narrow wings and similar but slightly smaller cells. The fossil, though crumpled and torn, has the swollen wings of *S. wahlbergella* but the cell pattern is partly obscured and difficult to measure. Both *S. wahlbergella* and *S. furcata* are circumpolar plants that occur in northern Scandinavia, the U.S.S.R. and arctic America.

Vitis cf. *vinifera*

Pollen of *Vitis* was found regularly in deposits of subzone Ho IIIb (photographs, figure 22, plate 74). It compared closely with pollen of *V. vinifera*, an identification made more probable by the discovery of a seed of *V. vinifera* ssp. *sylvestris* from the interglacial deposits at Hoxne (Turner 1968 *b*). On the Continent *Vitis* seeds have been found from Holsteinian deposits at Neede in the Netherlands (Florschütz & Jonker 1942), Wunstorf near Hanover (von Rochow 1953) and at the Polish sites, Syrniki (Sobolewska 1956), Ciechanki Krzesimovskie (Brem 1953) and Suszno (Środoń 1965). Pollen of *Vitis* has been overlooked in interglacial deposits until recently when Andersen (1963) found traces of it at Tornskov, and Erd (1962) recorded it from Eemian sites near Berlin. At these sites *Vitis* is almost always associated with *Abies* and *Buxus* and can be regarded as a characteristic species of the Holstein Late-temperate zone.

Type X

An unknown tricolpate, reticulate pollen type occurred frequently in the interglacial deposits at Hoxne and at Kilbeg and Gort in Ireland (Watts 1959). This pollen type, referred to as Type X, was found regularly at Marks Tey from subzone Ho IIb to subzone Ho IIIb. It attained maximum values of *ca.* 5 % during subzone Ho IIIa. It has also been detected in pollen samples from Clacton and appears to be a characteristic feature of Hoxnian temperate pollen spectra. At Hoxne, from West's unpublished data, it appeared during the same subzone as at Marks Tey and sometimes reached values of 7 to 9 % of the tree pollen towards the end of zone Ho II.

Pollen grains of Type X are illustrated by photographs (figure 23, plate 74) and are generally 27 to 30 μm long. Despite all attempts it has not yet been possible to identify this pollen type. Its closest resemblance is to *Phillyrea* which, however, possesses long narrow pores. Its distribution in time during the interglacial parallels that of *Ilex*. Its occurrence during the temperate zones of the interglacial and its negligible response to the high non-tree pollen phase of subzone Ho II c both suggest that it was produced by a forest shrub, perhaps a member of the Oleaceae, rather than by a herbaceous plant.

Azolla filiculoides

Megasporangia of the water fern *Azolla* occur in sediments of subzone Ho IV a from borehole JJ. *Azolla* has been found at most Hoxnian interglacial sites in Britain and is very characteristic of them, although it also occurs in Cromerian sediments. It has a similar stratigraphic distribution on the Continent, where it ranges from the Tiglian to the Holsteinian. It is never found in Eemian deposits, except where redeposited from older sediments, and is therefore presumed to have become extinct in Europe during the Saale (Gipping) glaciation. Its native distribution today is North and South America, but it has been extensively spread by human agency and has thus been reintroduced into western Europe.

Osmunda cf. *claytoniana*

Spores resembling those of *O. claytoniana* occurred sparsely in sediments of subzones Ho II c to Ho IV a. Similar spores have been found by West (1956) at Hoxne, by Szafer (1953, 1954), Dyakowska (1956) and Sobolewska (1956) from Masovian I (Holsteinian) deposits in Poland, by Zagwijn (1960) from the Tiglian interglacial in the Netherlands and by other workers elsewhere.

The identification of fossil *Osmunda* spores has been a matter of debate. Ananova & Kulmina (1965) consider both *O. claytoniana* and *O. cinnamomea* to be present in Russian interglacial deposits. Both these species today have disjunct distributions in America and east Asia but are absent from Europe. Andersen (1961) believes that 'the fossil *Osmunda* spores vary continually, and it cannot be considered to be certain that two distinct species were present. The extremes correspond to *O. regalis* and *O. cinnamomea* respectively'. He prefers to discount all records of *O. claytoniana* from Europe. Andersen's view can be criticized on two grounds. First, the fossil material under consideration from this and other European sites falls well outside the range of variation of modern European *Osmunda regalis* spores. Actually typical *O. regalis* spores are present in interglacial deposits, as at Marks Tey, where they have a slightly different time range to those referred to as *O.* cf. *claytoniana*. Secondly, Andersen's key to *Osmunda* spores fails to represent the full variation of *O. claytoniana* spores. This latter species has by far the most variable spore morphology of the three species, particularly between Asian (var. *vestita*) and American material. In the opinion of the present author the critical European fossil material falls easily within the potential variation of this species. The possibility of *O. cinnamomea* being present cannot of course be excluded. Further study of these spore types is obviously necessary, a task that the present author has undertaken.

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5. The vegetational and climatic history of the deposits

The vegetational and climatic history of the interglacial period and adjacent glacial zones can be reconstructed from the results of the botanical investigations. West (1956) has already given a detailed account of the vegetational history of the earlier part of the interglacial period at Hoxne, and the results from Marks Tey complement his to a very large extent. However, the vegetation of the latter part of the interglacial is here described in detail for the first time.

The setting. The final retreat of the Lowestoft ice sheet from East Anglia left behind a bare undulating terrain covered by chalky boulder clay and other glacial debris. At Marks Tey a discontinuous narrow valley in the form of a steep-sided trough running north-west to south-east cut across such terrain. Within this trough ice, sheltered from ablation, apparently persisted for some time into the Late-glacial period, when the surrounding countryside had already become clothed in open vegetation and *Hippophaë* scrub. Once this ice had thawed a lake formed at Marks Tey, perhaps 1500 m long, some 500 m wide and extremely steep sided. Shallow at first, the lake rose rapidly to a level of 32 to 34 m O.D. giving a depth of over 30 m during much of the interglacial period.

The Lowestoftian Late-glacial

Zone l Lo

At Hoxne the vegetation of the main part of this zone was characterized by wide expanses of *Hippophaë* scrub. The earliest Marks Tey pollen spectra suggest a later period, when *Hippophaë* scrubland was declining, though still important, and giving way to open grassland and an increasing amount of birch copse. The vegetational pattern was probably a mosaic of relatively dry slopes and hummocks and damp, poorly drained hollows. The drier parts would support *Betula* copses with tree birches and *B. nana* present, *Hippophaë* and *Juniperus* scrub and grassland with a diverse flora of open ground herbs (*Helianthemum*, *Plantago* cf. *media*, *Polygonum aviculare*, Compositae, Caryophyllaceae, Cruciferae). On damper sites and round the lake margins grew willows (*Salix*), sedges, ferns and a variety of marshland herbs (*Valeriana officinalis*, Ranunculaceae, *Thalictrum*, *Ophioglossum vulgatum* as well as *Typha latifolia. T. angustifolia* and *Sparganium*). The occurrence of Ericaceae pollen and *Sphagnum* spores suggest patches of vegetation growing under more acidic soil conditions. The low amounts of *Pinus* pollen were probably wind transported from a distance, although West considered pine was locally present at Hoxne during the final substage of this zone.

Recent evidence from Hoxne (Turner 1968*a*) suggests that the earlier part of the Lowestoftian Late-glacial was milder climatically than had previously been thought. Towards the end of the zone at Marks Tey the climate was certainly warmer than sub-arctic. Mild summers permitted the spread of tree birches and the growth of *Typha* spp., which Iversen (1954) regards as requiring a mean July temperature of at least 14 °C, that is a summer temperature as warm if not warmer than most of lowland Scotland today. It is not possible however to gauge the severity of winter conditions at this time.

The Hoxnian Pre-temperate zone

Zone Ho I

This zone and the opening of the interglacial period are marked by the expansion of the birch copses to form continuous, though not closed, birch forest. *Hippophaë*, which cannot withstand much competition from other trees and shrubs, was shaded out and eventually eliminated.

Grassland was also reduced but herbaceous communities still existed both in the open and on the lightly shaded forest floor. A wide variety of herbaceous types from such habitats has been found. *Armeria*, *Artemisia*, *Plantago maritima*, P. cf. *media*, *P. coronopus* certainly grew in open habitats and *Stellaria holostea* in the forest, but other herbs present included *Centaurea nigra*, *Succisa pratensis*, *Galium*, *Rumex*, *Trifolium*, *Lycopodium alpinum*, *L. annotinum* as well as members of the Compositae, Caryophyllaceae, Umbelliferae, Rosaceae and Labiatae. *Juniperus* occurred locally.

The composition of the forest itself changed slowly during this zone. The dominant trees throughout were the tree birches, *Betula pubescens* and *B. pendula*. *Pinus*, which certainly immigrated at the beginning of the zone, if not earlier, had to compete with established birch forest but steadily became an important element in the vegetation. *Quercus* and *Picea* also appeared in small quantity. The regular occurrence of *Acer* is interesting. Birch forest seems an unlikely habitat for the native *A. campestre*, so a boreal species like *A. platanoides* may have been present. Towards the end of the zone there was a sudden but temporary expansion of *Quercus* and *Ulmus* at the expense of the birch-pine forest. *Corylus*, *Alnus*, *Tilia cordata* and *Hedera* also appeared in small quantity. Open habitats were severely reduced. But this spread of temperate trees was soon checked; pine and birch recovered for a short while, whilst *Quercus*, very temporarily, and *Ulmus*, for a longer period, were reduced to lesser importance in the forest. This first expansion of temperate trees is important. Because these trees are present so early in the interglacial, their subsequent behaviour in zone Ho II must be related to ecological or climatic factors and not to differential immigration rates from glacial refugia.

There is also evidence for the development of various vegetational communities which from now on persist throughout the interglacial. The marshland flora is represented by the same plant types as in the previous zone, as well as by *Epilobium* and *Filipendula*. The presence of *Calluna*, *Menyanthes*, *Lycopodium* spp., *Pteridium* and *Sphagnum* suggest that a few small areas in the neighbourhood were already developing neutral to acid soil conditions with bog communities. In the lake itself grew a flora typical of eutrophic waters, with *Myriophyllum spicatum*, *M. verticillatum*, *Potamogeton* spp. and Characeae. Also *Litorella* was present in this pre-temperate zone, a plant today more common in neutral to oligotrophic lakes.

Clearly there was a general climatic amelioration during this zone. Nevertheless, this progression received a sudden but temporary check soon after the initial expansion of mixed-oak forest trees. A drop in winter temperatures would give a plausible explanation of the vegetational changes.

The Hoxnian Early-temperate zone

Zone Ho II

During this zone a temperate mixed-oak forest developed over the countryside around Marks Tey. The woodland became denser and, though at first the presence of *Juniperus* and such herbs as *Artemisia*, Chenopodiaceae and Compositae suggest a limited persistence of grassland and scrub, these communities were rapidly eliminated. Other persistent pollen types must represent the ground flora of the mixed-oak forest; they include *Geranium*, *Urtica*, Rosaceae (probably rosaceous shrubs), Caryophyllaceae, Cruciferae and Umbelliferae. Ferns were also frequent, including *Dryopteris*, *Polypodium vulgare*, *Thelypteris dryopteris* and later *Osmunda* spp.

During the final subzone Ho IIc, there was a dramatic break in the vegetational succession. A sudden, although temporary, return of grassland indicates a catastrophe in the natural development of the mixed-oak forest vegetation. This phase is closely paralleled by the high non-tree pollen phase described by West from the same subzone at Hoxne.

Throughout this zone the forest was undergoing a series of dynamic changes as different species expanded or declined in ecological importance. These changes correspond almost exactly to those described by West from Hoxne and from the neighbouring Norfolk site of Saint Cross South Elmham (West 1961*a*), and the subdivision of the zone is based on these changes.

Subzone Ho IIa

During this subzone, oak expanded considerably at the expense of the birch–pine forest. *Ulmus* occurred in small quantity, but much less abundantly than during its brief expansion in zone Ho I. *Fraxinus*, *Corylus* and, more sparsely, *Alnus* were also present. The shrub layer of the forest contained such plants as *Euonymus europaeus*, *Viburnum opulus*, *V. lantana* and *Hedera helix*. *Picea* occurred in small quantity throughout zone Ho II.

Subzone Ho IIb

Alnus, rare during the previous subzone, now spread to become the dominant tree pollen producer of this subzone. Such high percentages of alder pollen are found, not only here but in nearly every other Hoxnian pollen diagram, that it is clear that the tree grew not only in marginal woods beside the lake but also as an integral component of the mosaic of mixed-oak forest vegetation.

With the expansion of *Alnus*, further changes took place in the composition of the forest. The trees which seem to have given way to alder were *Quercus* and *Betula*. Now lime appeared, both *Tilia cordata* and more rarely *T. platyphyllos*, although *Tilia* was never as abundant at Marks Tey as at Hoxne and at Saint Cross South Elmham. The hybrid *Tilia* × *europaea* is also recorded. *Pinus*, *Ulmus*, *Picea*, *Fraxinus* and *Acer* were all present in the forest but not very important.

The shrub layer of the forest also changed in composition. Once *Alnus* had made its maximum impact on the forest, *Corylus* began to increase. *Ilex* immigrated at this time and with it very likely an unidentified shrub, the pollen of which, Type X, consistently appears with that of *Ilex* throughout the rest of the temperate period of the interglacial.

During this subzone, expansion of the forest almost eliminated the remaining open habitats. As *Alnus* colonized marshland and the damper parts of the woodland, and *Corylus* scrub formed a much denser canopy below the main tree layer, so the ground flora was much reduced.

Subzone Ho IIc

The forest continued to change in composition during the early part of this subzone. *Ulmus* and *Taxus* spread and the hazel, *Corylus*, attained an abundance where its pollen totals exceeded the sum pollen of all other types. It is unfortunately very difficult to assess the precise ecological changes which were taking place. We do not know which species of elm was present, nor can we be certain which habitats were being colonized by *Taxus* after considering the diversity of its Post-glacial occurrences (Godwin 1956). The abundance of *Corylus* at a time of forest maturity is remarkable, though paralleled in certain Irish Post-glacial pollen diagrams (Mitchell 1956). Normally *Corylus* is associated with the shrub layer of mature forest and subordinate in pollen production to the canopy-forming trees. In this subzone at Marks Tey such trees lost ground noticeably as *Corylus* expanded, whereas alder growing in the damper parts of the forest remained constant in frequency. Clearly a very real change in the status of *Corylus* was taking place. West (1961*c*) has noted the changing behaviour of this shrub during successive interglacial periods, and there may be real grounds for considering it as a species whose ecological preferences have been altering rapidly and fundamentally during the Middle and Late Pleistocene.

These developments in the forest were abruptly interrupted by a calamity, perhaps a forest fire, which appears to have affected the vegetation over a wide area of southern East Anglia. The results of this catastrophe, the disruption of the forest and its gradual recovery, are such unusual events that they are described and discussed separately in §6 below.

West (1956) believed that this subzone, apart from the changes induced by the high non-tree pollen phase, suggested 'a definite impression of revertance' at Hoxne. As particular evidence for this trend he cited a spread of *Betula*, *Pinus* and *Alnus*, contrasting with a decline of *Corylus*, *Fraxinus*, *Hedera* and *Ilex*. At Marks Tey the pollen curves for these plants emphatically show no signs of revertance at this period. At the end of this subzone and during the ensuing subzone Ho III a, the pollen frequencies of *Betula* and *Pinus* are very low and almost at a minimum; *Corylus* regained its dominance in the forest, whereas *Hedera* and *Ilex* persisted undiminished. Likewise, *Viscum*, mistletoe, a noted thermophile, appeared for the first time in this subzone. In fact the evidence for revertance at Hoxne itself is much weaker if the pollen curves are calculated on the basis of total land pollen instead of tree pollen.

In general terms, the climate of zone Ho II was temperate, with mild winters and moist but warm summers. Subzone Ho II a was ushered in by a distinct amelioration of temperature. The appearance of *Hedera* is reckoned to imply that the average temperature of the coldest month was above -1.5 °C (Iversen 1944). There seem to have been no sharp oscillations of temperature during this period. West regarded subzone Ho II b as the termal optimum of the interglacial, followed by a decline of temperature in subzone Ho II c. He based this opinion largely on the period of maximum abundance of *Tilia cordata*, but for the very same reasons Kelly (1964) recognized subzone Ho II c to be the warmest period of the interglacial at Nechells, Birmingham. *Tilia* is probably affected by edaphic as well as climatic changes and so not an unequivocal climatic indicator in the present author's opinion. At Marks Tey at least subzone Ho III a may have been just as warm as the two previous subzones, and there is no evidence at all that any one was markedly warmer than the others.

There can be little doubt that the climate became wetter during the course of zone Ho II. The striking expansion of *Alnus* during subzone Ho II b invites a direct comparison with the Atlantic period of the Post-glacial and suggests a definite increase in rainfall.

The Hoxnian Late-temperate zone

Zone Ho III

The expansion of late-immigrating temperate trees, especially *Carpinus* and *Abies*, and a concomittant decline of the mixed-oak forest characterize the vegetation of this zone. This particular transition is recorded not only from the Hoxnian interglacial period, but also from the Ipswichian and Cromerian and their Continental equivalents. In short the succession seems to be a well defined feature of interglacial vegetation. It is, moreover, a development that appears to be largely independent of climatic change but associated with the general degeneration and acidification of forest soils, that occurs during the temperate period of an interglacial as leaching progresses (Turner & West 1968; Iversen 1958; Andersen 1966).

Subzone Ho III a

The vegetation of this subzone was initially similar to that of subzone Ho II c prior to the disturbances associated with the high non-tree pollen phase. *Corylus*, whatever its ecological role, was still the largest pollen producer, and *Alnus* was also abundant. *Taxus* was recovering slowly but steadily from its set-back during the non-tree pollen phase. *Pinus*, *Betula* and *Picea* occurred only sparsely. The behaviour of *Carpinus* is the critical feature of this subzone. When *Carpinus* and *Abies* immigrated, the latter made little impact on the vegetation, but *Carpinus*, having established itself, spread vigorously at the expense of *Quercus* and *Ulmus*. Within the forest *Thelycrania* (*Cornus*), *Prunus* and *Lonicera* were present, and ferns such as *Osmunda* spp. flourished. From this period onward the mixed-oak forest dwindled in ecological importance.

The plant record suggests a persistence of open habitats of limited extent, with such herbs as *Artemisia*, *Centaurea nigra*, *Plantago maritima*, *P. major*, *Polygonum* cf. *persicaria*, Compositae, Chenopodiaceae and Gentianaceae. The lake itself still contained an eutrophic aquatic flora with *Naias marina*, *Zannichellia palustris* as well as *Potamogeton* spp. and *Myriophyllum* spp.

Both West (1956) and Kelly (1964) considered this subzone might have had a more continental climate than the previous subzones, with a reduced rainfall and colder winters. They pointed to the presence of *Carpinus* at Hoxne and the contemporary expansion of *Picea* at Birmingham, where *Carpinus* was virtually absent, to support this view. In fact the evidence of *Carpinus* does nothing more than reflect the present native distribution of the tree in the British Isles today, and conditions need not have been colder or drier than at present. Conversely the regular occurrence of *Taxus*, *Ilex*, *Hedera* and *Empetrum* all suggest that the climate was still a moist one with mild winters.

Subzone Ho III b

The vegetation of this subzone is perhaps the most interesting and distinctive of the Hoxnian interglacial. *Corylus* and *Carpinus*, the dominant trees of the drier parts of the forest in the previous subzone, were restricted and replaced by *Abies*, which spread quite suddenly, and with *Alnus* dominated the forest. Trees of the mixed-oak forest persisted but only sparsely, although they included the thermophilous *Tilia platyphyllos*. During the first part of the subzone *Taxus* was fairly prominent, then declined sharply. *Pinus* grew more common as the *Abies* forest developed, but other boreal trees, such as *Betula* and *Picea*, remained unimportant until the end of the subzone. For the first time during the interglacial period traces of *Fagus* and *Pterocarya* are recorded.

Characteristic plants of the shrub layer at this time were *Buxus*, which today is often associated with *Abies* forest in Central Europe, and *Vitis*, the natural habitat of which is generally damp valley woodland. *Hedera* and *Ilex* were still present together with *Viscum*.

At this time *Abies* forest must have spread over the boulder clay slopes around Marks Tey, whilst the damper areas supported alder carr. *Abies* is noted as a low pollen producer in comparison with other conifers. The abundance of its pollen can only mean that it was present in large quantities in the immediate vicinity of the lake. Both the dominant trees possess strong deep tap roots which must have favoured their growth on the heavy boulder clay soils.

Again there is pollen evidence of open habitats, supported by macrofloral records from the marginal deposits of the lake. There was little grass pollen but *Artemisia*, *Centaurea scabiosa*, *Plantago maritima*, *Polygonum aviculare*, *P.* cf. *persicaria*, *P. bistorta*, *Tripleurospermum maritimum* and other forbs were present, and there is continuing evidence of heathland vegetation with *Empetrum* and Ericaceae.

Fossil fruits and seeds give a better picture of the aquatic and marsh flora than previously. *Alisma*, *Ranunculus sceleratus*, *Lythrum*, *Typha* and *Sparganium* grew along the lake shore, whilst the lake itself contained *Naias marina*, *Myriophyllum spicatum*, *Potamogeton crispus*, *P. natans*, *P. praelongus* and *Zannichellia palustris*.

Despite the development of coniferous forest, winter temperatures were still mild in the early part of this subzone, as suggested by the presence of such plants as *Hedera*, *Ilex*, *Taxus*, *Buxus* and *Viscum*. Later their decline suggests the onset of cooler winters. *Vitis*, by contrast, is tolerant of cold winters but demands high summer temperatures. It may be observed that the expansion of *Abies* is also characteristic of zone III of this interglacial in Poland, and there, on the evidence of water plants, the zone is regarded as the thermal maximum of the period (Szafer 1953). It cannot, however, be assumed that the dramatic rise of *Abies*, which is so characteristic of Holsteinian–Hoxnian pollen diagrams, was even approximately synchronous across Europe.

There seems little doubt that this subzone was a period of increasing rainfall. Jessen *et al.* (1959) have very effectively compared the vegetation of this subzone at Gort in Western Ireland with the present vegetation of the Caucasus and the Colchic areas of the Black Sea coast, areas which are characterized by a high rainfall spread evenly over the year, warm moist summers and mild winters without prolonged periods of frost. The vegetation at Marks Tey was not so oceanic in aspect as that at Gort, but the presence of *Pterocarya* and of *Vitis* are again reminiscent of the Caucasus.

The Hoxnian Post-temperate zone

Zone Ho IV

Domination of the forest by boreal trees, *Pinus* and *Betula*, and development within the forest of extensive heath and grassland communities are the principal features of this zone.

Subzone Ho IVa

With the onset of this subzone several important changes in the vegetation took place. The forest lost its basically temperate aspect, and also began to open out and give place to grassland and, in particular, to *Empetrum* heath. At the same time the plant record suggests that soil conditions in the area had changed from alkaline to become dominantly neutral or acid. *Pinus* became the dominant forest tree, although *Abies* was still plentiful. *Betula* increased substantially and very likely formed open woodlands associated with acid heath. Fruits of *Betula pubescens* occur in the lake sediments of this subzone. *Picea*, never an important forest tree at any stage of this interglacial at Marks Tey, was most frequent at this time. Probably the heavy soils of the boulder clay did not suit its shallow rooting system. Few traces of mixed-oak forest were present. Shrubs were not abundant. *Buxus* persisted, presumably as an associate of *Abies*. *Hedera* and *Viscum* occurred less frequently, and *Ilex* had disappeared. Other shrubs, such as *Frangula*, *Sorbus aucuparia* and perhaps *Juniperus*, reflect more acid soil conditions than previously.

A small but important feature is the low but regular appearance of *Pterocarya* during this subzone. In its contemporary habitats in the Caucasus, *P. fraxinifolia* is reported to occur 'always in the moist or very wet places, to which it is better adapted even than the alder' (Elwes & Henry 1906). *Alnus*, in fact, showed a striking decline and, despite the high rainfall, other plant communities, notably acid bog (McVean 1956), were replacing alder carr.

Evidence of bog communities is abundant in the highly organic marginal deposits of the lake. These contain not only wood fragments (*Abies*) but also *Sphagnum* leaves (referable to both subgenus *Litophloea* and the peat-forming subgenus *Inophloea*), sclerenchyma spindles of *Eriophorum vaginatum*, *Carex* nutlets, leaves of *Erica tetralix*, a fruitstone of *Potamogeton polygonifolius* and a seed of *Narthecium ossifragum*, all characteristic bog plants. Pollen analyses show large amounts of *Empetrum nigrum*, which can only mean fairly extensive *Empetrum* heathland in the immediate neighbourhood of the lake. This bog and heathland carried *Calluna*, other Ericaceae including what appears to be the western Mediterranean species *Erica terminalis*, *Lycopodium annotinum*, *L. clavatum*, many ferns, *Osmunda*, *Polypodium*, *Botrychium lunaria*, *Ophioglossum vulgatum* and, of course, much *Sphagnum*.

Grassland communities also spread, which contained *Artemisia*, *Helianthemum*, *Linum*, *Plantago coronopus*, *Scabiosa columbaria* and *Succisa pratensis*. There is a general increase in herbaceous pollen of many types, derived either from grassland or from an increasingly open forest floor.

Despite the development of bog and heath nearby, plant macrofossil remains suggest that the flora of the lake and its margins changed little, and that the waters of the lake remained eutrophic.

The climate of subzone Ho IV a was probably more oceanic and wetter than the preceding one. There was extensive development of acid bog and *Empetrum* heathland in what is today one of the driest parts of England, a region in many ways more continental in its climate and vegetation than the neighbouring coastal lowlands of Germany and Denmark. For example, *Empetrum*, abundant today in the bogs of Jutland, is virtually absent from suitable habitats in south-east England. Winters must have been still fairly mild, because *Hedera* persisted, and both *Abies* and *Pterocarya*, although susceptible to spring frosts, seem to have grown well. At the beginning of the subzone temperatures seem even to have been warm enough for *Lemna* to flower and fruit. Nevertheless, as the subzone progressed, a general temperature decline seems to have taken place.

Subzone Ho IV b

The vegetation of this subzone reflects the transition between the last subzone and the colder and more open conditions of the Gipping Early-glacial period. *Pinus* continued to dominate the forest. The increasing frequency of *Betula* suggests the more open nature of woodland cover. *Picea* was the only other tree to occur regularly. Both *Abies* and *Alnus* declined considerably and became relatively unimportant.

Open habitats increased in area. There was a big expansion of grassland, particularly at the expense of *Empetrum* heath. In contrast to the last subzone, calcicolous plants dominated these communities. Not only do pollen values of *Empetrum* fall but also those of *Calluna* and

Cyperaceae as well as spore totals of Filicales and *Sphagnum*. *Pterocarya* and *Erica* cf. *terminalis* vanished. The opening of the forest and the colder climate probably accelerated soil erosion and re-exposed the more calcareous subsoil on the boulder clay. Amongst the wide variety of herbaceous plants present were Compositae, Caryophyllaceae, Ranunculaceae, Umbelliferae, *Thalictrum*, *Plantago* cf. *media*, *P. maritima*, *Polygonum* cf. *aviculare*, *P. bistorta*, *Trifolium*, *Polemonium*, *Potentilla*, *Artemisia*, *Rumex acetosa*, Campanulaceae, Rubiaceae, *Polypodium*, *Pteridium*, *Lycopodium alpinum*, *Oophioglossum vulgatum* and *Osmunda regalis*.

The aspect of the aquatic flora was similar throughout zone Ho IV. Further records of marsh plants at this time include *Alisma*, *Lycopus europaeus*, *Eleocharis palustris* and *Juncus inflexus*.

The climate appears to have grown rapidly colder and drier during this subzone. The boreal forest dominated, *Hedera* became extinct, *Abies* and *Alnus* were laregely suppressed, and oceanic heathland could no longer be maintained.

The Gipping Early-glacial

Zone e Gi

The onset of an Early-glacial period is defined in theory as the moment at which open habitats had replaced forest to the extent that non-tree pollen totals exceed tree pollen totals. At Marks Tey this point is also marked by definite vegetational changes.

Subzone e Gi 1 a

At this time the boreal woodland itself began to decline and give place to grassland. Previously, despite the general opening of the forest, *Pinus* and *Betula* had increased in abundance. A little *Picea* persisted, but the *Abies* and *Alnus* pollen present, together with that of *Empetrum* and other acid heathland plants, was probably derived largely from the erosion and redeposition of peat deposits and podsols formed during subzone Ho IV a.

The most important vegetational development of the subzone was the spread of grassland heaths rich in *Artemisia*, which gave what is sometimes described as sub-arctic park landscape. The most abundant herbaceous plants suggested by the pollen diagrams are Gramineae and *Artemisia*, followed by Caryophyllaceae, Compositae and Ranunculaceae. Amongst the herbs present were *Armeria*, *Plantago* cf. *media*, *P. maritima*, *Polygonum* cf. *aviculare*, *Botrychium*, *Lycopodium annotinum*, *L. alpinum*, *Selaginella selaginoides*, Campanulaceae, Chenopodiaceae and Cruciferae.

The climate of this zone was increasingly severe, and the rich and varied flora suggests not only open conditions but also the progressive breakdown of a continuous vegetation cover and soil surface, presumably due to the onset of periglacial cryoturbation and solifluction processes.

The lake still contained *Myriophyllum spicatum*, *Potamogeton pectinatus*, *Chara* and *Nitella*. Particularly abundant too was the alga *Pediastrum*, though it had been fairly plentiful during most of the latter half of the interglacial.

A comparison may be drawn between this Early Gipping zone and the Early Weichselian vegetation described by Andersen (1961) from Denmark (zones W 1 and W 2), by Zagwijn (1961) from the Netherlands (zone EW 1) and West's unpublished results from the Early Weichselian deposits at Wretton, Norfolk. Grassland–*Artemisia* heaths seem to be a characteristic and widespread feature of early-glacial vegetation and are typically accompanied by such herbs as *Armeria*, *Plantago* spp., Caryophyllaceae, Compositae and *Helianthemum*, though the latter is barely represented at Marks Tey. Andersen (1961) suggested that *Artemisia* was intolerant of prolonged snow cover, which accounted for its relative abundance in the Weichselian Early- and Late-glacial periods, but its relative absence from the intervening Pleniglacial.

The vegetation of a later stage of the Gipping Early-glacial period is represented by the macroflora from the laminated grey clay of the brickpit, though nothing is known of the general regional vegetational spectrum since pollen evidence is obscured by the presence of abundant reworked pollen.

This macroflora suggests bare ground conditions with low-growing open vegetation. The soil and vegetation were probably undergoing continuous disturbance by solifluction and cryoturbation processes. Many of the species present are characteristic of so-called 'full-glacial' floras already known from deposits of Weichselian, Gipping and Lowestoftian age (e.g. Lambert, Pearson & Sparks 1963; Turner 1968*a*). The most abundant remains are those of grasses, crucifers and *Armeria maritima*. The crucifer remains can be referred to *Alyssum*, *Arabis*, *Draba* and *Erophila; Oxyria digyna* was also frequent. Other plants present included *Linum perenne*, *Potentilla* spp., *Cerastium*, *Campanula rotundifolia*, *Silene maritima* or *vulgaris*, *Silene* cf. *wahlbergella*, *Anthemis cotula*, *Chenopodium album*, *Aphanes microcarpa*, *Atriplex* and *Carduus*. *Silene wahlbergella* is a purely arctic species; *Oxyria* and *Draba* spp. are arctic alpine; *Armeria maritima* and *Silene maritima* form distinct communities on both mountains and sea cliffs; *Potentilla* spp. and *Linum perenne* both prefer ground conditions that are subject to some measure of disturbance. *Anthemis*, *Aphanes*, *Chenopodium*, *Atriplex* and *Carduus* spp. today tend to be weeds of waste ground.

6. The high non-tree pollen phase during subzone Ho II c

During the latter part of subzone Ho II c, a calamity disrupted the natural development of the vegetation. Pollen diagrams Marks Tey I A show the effects of this calamity, and the relevant portion of these diagrams has been figured separately to give a clearer picture of the phenomenon (figure 16). A similar high non-tree pollen phase occurred during the same subzone at Hoxne (West 1956), and a revised diagram from this site is figured beside the one from Marks Tey.

As already described, the earlier part of subzone Ho II c gave, as recorded from borehole GG 1570–1712 cm, very high pollen values for *Corylus* (30 to 50 %), considerable ones for *Alnus* (15 to 25 %) and quite significant amounts of *Quercus* (8 to 14 %), *Taxus* (9 to 14 %) and *Ulmus* (6 %), but low *Betula*, *Pinus* (2 to 3 %) and herbaceous pollen (1 to 4 %).

During the subsequent high non-tree pollen phase the following sequence of changes is recorded in the pollen diagrams:

(i) By GG 1559 cm, grass pollen had risen to 25 %; *Corylus* and *Taxus* fell sharply to 20 and 2 % respectively; *Ulmus* declined from 6 % to 2 %, but *Quercus* declined very little. Both *Pinus* (7 %) and *Betula* (4 %) increased.

(ii) Between GG 1559 and 1519 cm, grass pollen gradually declined from its peak at 25 % down to 6 %; *Corylus* and *Taxus* remained low: *Quercus* rose steadily from 8 to 24 %; *Alnus* showed a slight decrease. *Betula* rose to a maximum of 11 %, and *Pinus* remained relatively steady at 6 to 7 %. During this period, non-tree pollen types (e.g. Compositae, Cruciferae, Ericaceae) showed increased values or appeared regularly for the first time since the final closing in of the forest earlier in zone Ho II.

(iii) By GG 1509, *Corylus* had fully recovered, rising to 44 %; grasses were reduced to less than 2 %, and the aspect of the vegetation was much as it was in the earlier part of subzone Ho II c, except that *Taxus* had not recovered but had fallen from 13 % to under 1 %, *Alnus* was

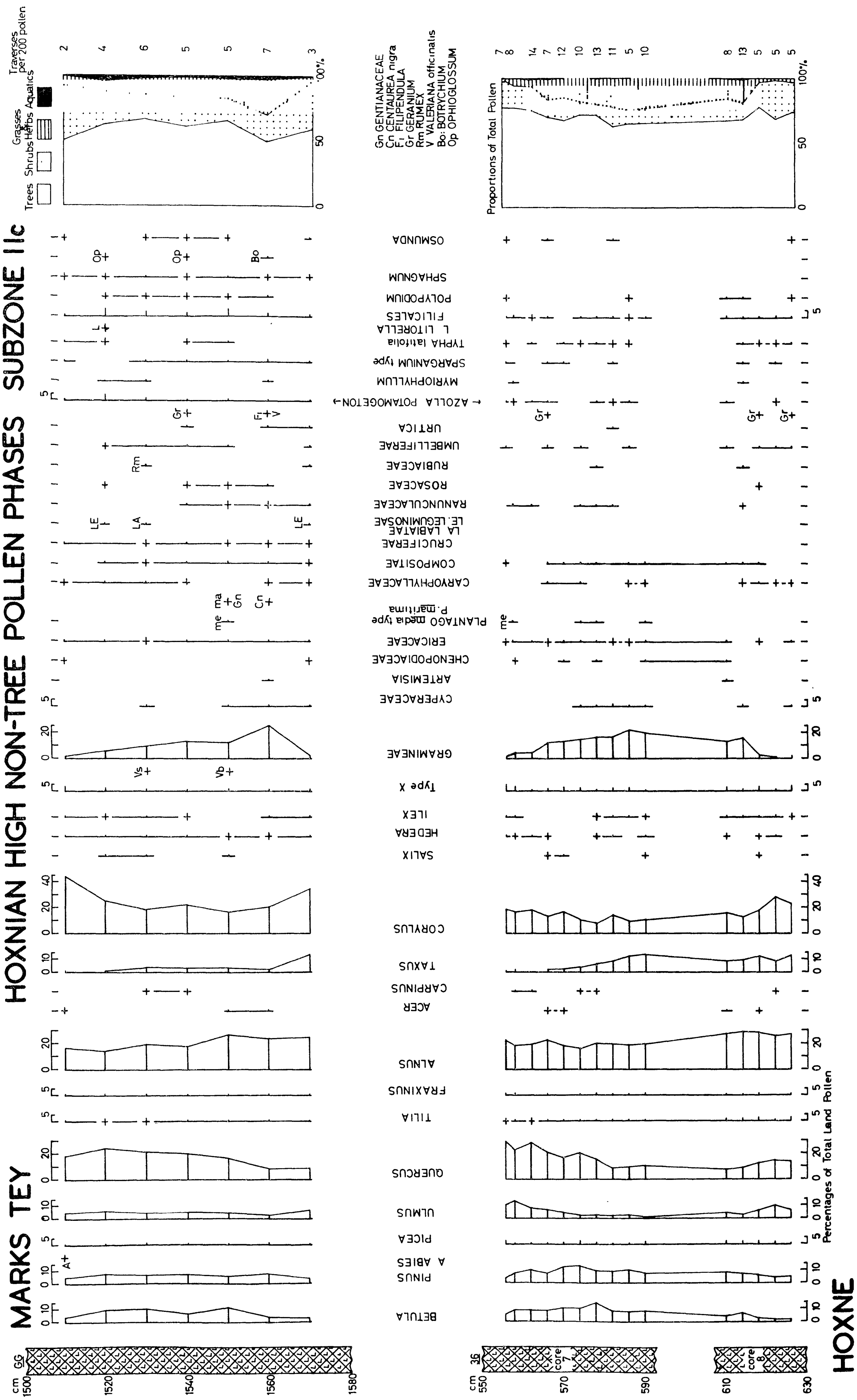


FIGURE 16. Hoxnian high non-tree pollen phases from subzone Ho IIc.

slightly reduced, and *Quercus* values had risen from 8 to 18 %. *Taxus* did not recover until sub-zone Ho III a.

Even without knowing the cause of these changes, it is possible to reconstruct their sequence. Woodland containing *Corylus*, *Taxus* and some *Ulmus* was abruptly destroyed, but the wetter parts of the forest, which contained *Alnus*, were not affected. The resultant clearings were invaded by grassland and, to a lesser extent, by *Betula* and *Pinus*, trees which have a shorter regeneration time than the mixed-oak forest species and are frequent pioneer colonizers of such open habitats. The establishment of birch and other scrub enabled *Quercus* to regenerate and expand; the grassland areas diminished. Finally, *Corylus* recovered and spread rapidly once again. Amongst the herbaceous types which appeared or increased with this phase of deforestation were: Compositae, Caryophyllaceae, Cruciferae, Gentianaceae, *Artemisia*, *Centaurea nigra*, *Plantago maritima*, *P.* cf. *media*, *Erica* cf. *terminalis*, *Empetrum*, *Rumex*, *Botrychium lunaria*, *Ophioglossum vulgatum*, Filicales and *Sphagnum*.

The sediments from this level of borehole GG also show an interesting feature: the lamination in parts of the two cores GG 1503–1534 cm and GG 1534–1564 cm, which span this high non-tree pollen phase, is significantly thicker and better developed than in the cores immediately above and below. It is the grey-brown darker laminae that show this increased thickness rather than the light laminae, which are composed largely of diatom frustules. Evidently the disturbances that affected the vegetation also caused increased deposition in the lake.

The lamination pairs can easily be counted and measured. Because the cores of the borehole GG tended to expand in length on being extracted, the lamination frequency is expressed as a function of both the original estimated and the actual lengths of the cores.

core no. ...	XLVII	XLVIII		XLIX	L
depth (cm) ...	GG 1473–1503	1503–1518	1518–1534	1534–1564	1564–1595
original length (cm)	30	15	16	30	31
actual length (cm)	37	17	18	36	36
number of laminations	330	211	146	174	341
average thickness of laminations (actual) (mm)	1.1	0.8	1.2	2.1	1.1
average number of laminations per cm (actual)	8.9	12.4	8.1	4.8	9.5
average number of laminations per cm (original)	11	14.1	9.1	5.8	11

The portion of these cores that shows a perceptible thickening of the lamination is between approximately GG 1521 and GG 1562 cm. The onset of thicker lamination is quite sharp at 1562 cm (see figure 18, plate 73). If the lamination pairs are annual features, the high non-tree pollen phase, from the destruction of the forest to its recovery, must have lasted approximately 350 years.

The Hoxne non-tree pollen phase

Dr R. G. West has kindly made available the original pollen slides covering the similar phase at Hoxne. Further counts have been made for *Taxus* pollen, which was not originally recorded (West 1962), and the pollen diagram has been recalculated on the basis of total land pollen.

West has described in detail the vegetational development of this phase at Hoxne, and it has many important features in common with Marks Tey.

(1) A marked expansion of grassland and herbaceous vegetation.

(2) A depression of *Corylus* throughout the phase.

(3) A drastic decline of *Taxus*, which did not recover until later in the interglacial.

(4) An expansion of *Pinus* and *Betula* during the high non-tree pollen phase.

(5) An expansion of *Quercus* following the *Taxus* decline.

However, there are also significant differences.

(*a*) The maximum for non-tree pollen (very largely Gramineae) appears to have occurred later in the phase at Hoxne than at Marks Tey.

(*b*) At Hoxne two different stages of forest disturbance took place. The initial deforestation involved a reduction of *Corylus*, *Ulmus* and, unlike Marks Tey, also of *Quercus*. Later there was a drastic decline of *Taxus*. These stages cannot be separated at Marks Tey.

In the absence of other evidence, West regarded this phase at Hoxne as probably a purely local effect. Now the occurrence at Marks Tey of a similar phase from virtually the same stratigraphical horizon and with largely identical vegetational changes makes it increasingly probable that these phases are widespread results of the same cause. Further evidence on this matter must be sought from other Hoxnian sites awaiting investigation, such as those at Rivenhall End, Essex, and Sicklesmere (Little Welnetham), Suffolk.

The causes of this phase are difficult to assess. There is no doubt that real vegetational changes were involved. The fluctuations in the pollen curves cannot be attributed to contamination from reworked sediments. From an ecological point of view two features require explanation: (*a*) what caused the initial deforestation, and (*b*) what hindered the regeneration of *Corylus* throughout almost the whole length of the phase, say for 300 years.

A climatic explanation for this episode must be ruled out. The climate was clearly not severe enough to suppress forest growth in favour of grassland, even were exceptional conditions, such as a succession of summer droughts, to affect particular tree species adversely. Nor can changes in lake level give a satisfactory explanation. Alder communities, which must, at least in part, have grown beside the lake, were barely affected, and, although a fall in lake level would have provided temporary habitats for herbaceous communities, it would not have caused the destruction of the better drained forest. The grass pollen was scrutinized carefully in case the high values were due to the development of local reed-swamp. A variety of different types of grass pollen was present, but only a few grains resembled *Phragmites*.

There is definite evidence that Palaeolithic man was present at Hoxne during this phase (West & McBurney 1954), but West rejected this as an important factor in the origin of the phase, although his opinion has been misinterpreted by Oakley (in Ovey 1964). At first sight the phase is reminiscent of 'landnam' clearances as shown by Post-glacial pollen diagrams. However, such Post-glacial clearances generally exhibit an increase rather than a decrease of *Corylus* pollen values and, taken as units, they were generally of a much shorter duration than the phenomena at Marks Tey and Hoxne. It seems unreasonable to attribute deliberate deforestation on a large scale to Palaeolithic man, but it is not surprising that he should make use of deforested terrain in the vicinity of water and presumably of game.

The remains of large mammals are very rare in lake deposits, but such animals were certainly present at Hoxne at this period. In 1964 two teeth of *Palaeoloxodon* (*Elephas*) *antiquus* Falconer & Cautley were recovered from stratum E of the Hoxne deposits. These teeth, probably parts of the same animal, are now in the Ipswich Museum (specimen nos. 964 and 965). Pollen analyses of the clay mud adhering to the teeth proved that both had come from a horizon within the high non-tree pollen phase. The results of these analyses are given in table 4.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Table 4. Pollen analyses from two elephant teeth from stratum E at Hoxne

Betula 10%, 5½%	*Taxus* 3%, 1½%	Ranunculaceae 1%, —
Pinus 16%, 6½%	*Corylus* 10%, 13%	Umbelliferae ½%, ½%
Picea 1½%, 1½%	*Hedera* —, ½%	*Potamogeton* —, 1%
Ulmus 2%, 4%	Gramineae 15½%, 27½%	*Sparganium* type 1%, —
Quercus 8½%, 9½%	*Plantago* cf. *media* —, ½%	Filicales —, ½%
Tilia 1%, ½%	Caryophyllaceae 1%, —	*Polypodium* 1%, —
Fraxinus 2%, 2½%	*Rumex* —, ½%	*Sphagnum* —, ½%
Alnus 22½%, 20½%	Compositae 2%, 1½%	

If large mammals were present in any numbers the grazing and browsing pressure around water holes such as the lakes at Hoxne and Marks Tey would have been intense. Such pressures cannot be invoked as a cause of the initial deforestation, but once clearings were established their effects would have hindered the regeneration of succulent woodland vegetation, particularly low-growing trees and shrubs like *Corylus*. In particular the late decline of *Taxus* could be interpreted in this way. *Taxus* regenerates satisfactorily in shade, but not under conditions of trampling and grazing (Watt 1926). Contrary to popular belief, the foliage of this tree is sometimes avidly browsed by wild and more rarely by domesticated animals (see figure 23 in Pettersson 1958), and it is particularly susceptible to browsing pressure in winter, when it is one of the few trees in the forest to retain its foliage.

The initial deforestation could best be explained at present by a major forest fire. This would account for the simultaneous destruction of the forest at both Marks Tey and at Hoxne and also for the spectrum of forest trees affected by these changes, since damp alder woodland would probably have been immune from such destruction. Some tangible evidence for fire at this time does exist. Macro-charcoal occurs in strata of this age at Hoxne, but it may be associated with the Palaeolithic occupation. More strikingly, the pollen samples from the onset of this phase at Marks Tey contain abundant microscopic charcoal fragments (50 to 100 μm in size), which are found but very rarely at other levels. Because these samples are from fine-textured, deep-water sediments formed in the centre of the lake basin, they suggest that a good deal of charcoal, perhaps wind-blown, must have suddenly been dispersed into the lake. Against this interpretation must be set the argument that mixed-oak forest is not generally very susceptible to fire under the present climatic conditions, though small fires do occasionally occur in hot summers. It is hard to envisage a fire on a scale necessary to affect both Hoxne and Marks Tey, but, once again, investigation of other Hoxnian deposits in the region may give further information.

7. Comparisons with other sites

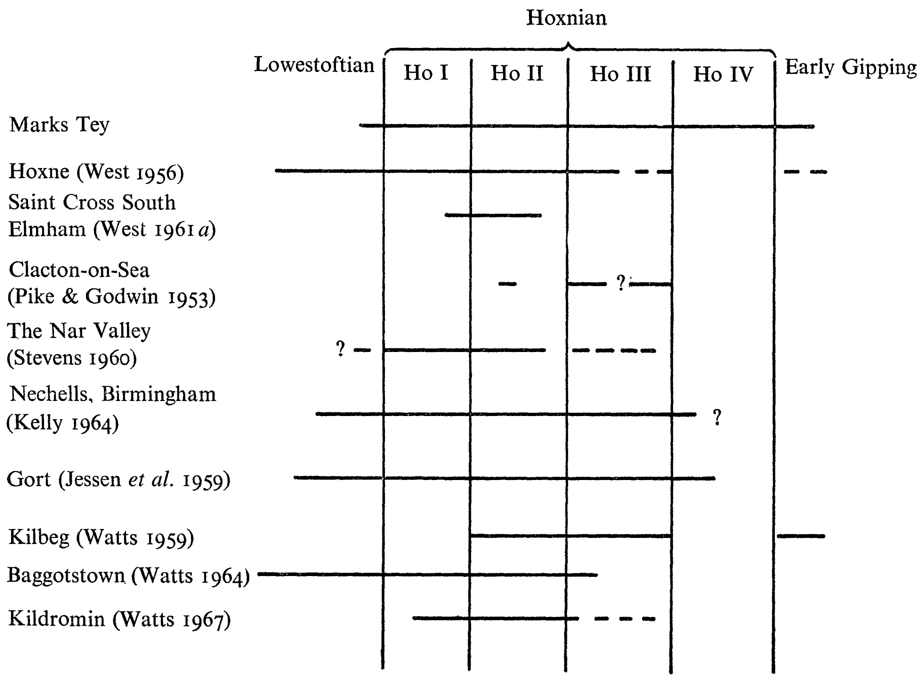
(*a*) *Comparisons with other Hoxnian interglacial deposits in Britain*

The similarity of the vegetational succession shown by the Marks Tey and Hoxne pollen diagrams leaves no doubt that the former must be ascribed to the Hoxnian interglacial. The three most prominent features that these and other Hoxnian pollen diagrams have in common are: (1) the abundance of *Hippophaë* during the preceding Lowestoftian Late-glacial period, (2) the late expansion of *Corylus* during the Early-temperate zone of the interglacial in contrast with its behaviour during the Ipswichian and Flandrian periods, (3) the abundance of *Abies* during the Late-temperate zone. *Abies* was present, though less abundant, during this zone of the Cromerian, but was absent from Britain during the Ipswichian interglacial.

In East Anglia other pollen analytical studies of Hoxnian deposits have been made at Clacton-on-Sea (Pike & Godwin 1953), Saint Cross South Elmham (West 1961 *a*) and the Nar Valley (Stevens 1960). The vegetational succession at all these sites compares very closely with Marks Tey and can be subzoned in the same way. The only other extensive Hoxnian pollen diagram from England is from Nechells, Birmingham (Kelly 1964; Duigan 1956). Here again the vegetational development was very similar to that at Marks Tey. The main difference is that at Birmingham *Carpinus* was barely represented in subzone Ho III a. Instead a great expansion of *Picea* took place at that time. The zonal correlation of the timespan of these pollen diagrams is given in table 5.

In Ireland three well-developed interglacial deposits at Gort, Co. Galway (Jessen *et al.* 1959), Kilbeg, Co. Waterford (Watts 1959) and Baggotstown, Co. Limerick (Watts 1964) appear to be of Hoxnian age and are locally termed Gortian. A more fragmentary deposit of the same age occurs at Kildromin, Co. Limerick (Watts 1967).

Table 5. A comparison of the timespan of the pollen diagrams from Marks Tey with those from other Hoxnian deposits in the British Isles



The Irish sites show a sequence of vegetational development generally comparable with the English sites, but with a striking difference in the relative proportion of *Pinus*, which is frequent, to mixed-oak forest trees. There is, nevertheless, general agreement that the sites are contemporary. The Irish deposits contain pollen of Type X, which is otherwise known only from Marks Tey, Hoxne and Clacton. The Irish sites, particularly Gort and Kilbeg, give evidence of a highly oceanic climate during the Late- and Post-temperate zones of the interglacial, when exotics such as *Rhododendron ponticum* and *Erica scoparia* flourished, and members of the existing Lusitanian element of the Irish flora (such as *Daboecia cantabrica*, *Erica mackaiana* and *E. ciliaris*) occurred well beyond the limits of their present distribution. These records can be set beside the occurrence of *Pterocarya* and *Erica* cf. *terminalis* at Marks Tey as evidence that the climatic conditions over the British Isles in general did indeed become very oceanic towards the end of the Hoxnian interglacial.

(*b*) *Comparisons with Continental Holsteinian interglacial pollen diagrams*

Until recently the vegetational succession of the Holsteinian, the penultimate interglacial period on the Continent, has been less clearly defined and less well understood than that of the Eemian interglacial, except perhaps in Poland. This was because most Holsteinian pollen diagrams were either fragmentary or of uncertain stratigraphic position. Recent investigations, particularly those of Andersen (1963, 1965), have given a better picture of the interglacial vegetation and also made earlier work easier to interpret. The fullest vegetational sequences from the period are recorded from Vejlby, Denmark (Andersen 1965), from Bantega in the Netherlands (Brouwer 1949) and from various Polish sites such as Ciechanki Krzesimovski (Brem 1953), Mokre Barkowickie (Sobolewska 1952) and Nowiny Żukowskie (Dyakowska 1952). Other important pollen diagrams are from Tornskov, Denmark (Andersen 1963) and from Hamburg-Hummelsbüttel (Hallik 1960).

The most prominent features of these Holsteinian pollen diagrams are:

(1) The dominance of *Pinus*, or of *Pinus* and *Alnus*, almost throughout the temperate period of the interglacial.

(2) The relatively low pollen values of *Quercus* and *Corylus*, even during the Early-temperate zone.

(3) The early appearance of *Picea* in the interglacial vegetational succession. It is particularly abundant in Poland during the Early-temperate zone, though less so in western Europe.

(4) The abundance of *Abies* during the Late-temperate zone, which spread northwards and westwards into areas of the lowland north European plain never colonized by this tree during the Eemian or Flandrian periods. The *Abies* forest was accompanied by a distinctive combination of plants including *Vitis*, *Buxus* and *Pterocarya*, a combination not recorded from any other interglacial period.

These features give the Holsteinian interglacial vegetation a very different aspect from the Eemian, the temperate zones of which are dominated by high pollen values for deciduous trees such as *Corylus*, *Quercus* and *Carpinus*, with *Picea* largely confined to the latter part of the interglacial. However, with respect to the dominance of *Piuus* and the low values for mixed-oak forest trees this Holsteinian vegetation differs just as much from the established picture of Hoxnian temperate vegetation in England as from that of the Eemian. Many Continental workers have had misgivings about the validity of correlating the Hoxnian interglacial of East Anglia with the Holsteinian, particularly because in Ireland there are Gortian sites that show high pine and low oak and hazel values. Unfortunately there are not yet any good pollen diagrams from critical intervening areas such as the west of England and northern France, although a fragmentary diagram probably of Holsteinian age, showing low pine values is available from Brittany (Kerfourn 1965).

The unifying feature of Gortian, Hoxnian and Holsteinian pollen diagrams is the strong development of *Abies* during the Late-temperate zone. The presence of *Abies* at Marks Tey, together with *Vitis*, *Buxus*, and *Pterocarya*, links the vegetational succession there firmly with that of Vejlby (Andersen 1965) and of the Polish sites (Środoń 1965). In the light of this evidence there can be no further doubt that the Hoxnian interglacial of East Anglia is the true equivalent of the Holstein interglacial of Continental Europe.

8. The stratigraphical implications of the Pleistocene deposits at Marks Tey

The standard Pleistocene sequence for East Anglia is based almost entirely on evidence from the northern and central parts of the region, where it is possible to relate interglacial deposits to the glacial stratigraphy. In contrast, the extremely complex drift deposits of southern East Anglia, which were mostly laid down by fluctuating ice sheets almost at the limits of their maximum extension, have received much less critical attention. Unfortunately the only published accounts of well-dated interglacial deposits from the region concern Clacton-on-Sea (Pike & Godwin 1953) and Ilford (West, Lambert & Sparks 1964), which sites both lie beyond the limit of glaciation and cannot be linked stratigraphically with the glacial deposits of the area.

In Essex, Clayton (1957, 1960) attempted to distinguish and differentiate a series of tills and gravels, but his efforts to correlate these deposits with the accepted East Anglian Pleistocene sequence have been hampered by lack of firmly dated horizons. Clayton's sequence (1960) consists of:

Springfield Till	Third glaciation
Chelmsford Gravels	Second interglacial
Maldon Till	Second glaciation
— — — — — — — — — — — — —	
Hanningfield Till	First glaciation

In some parts of south-east Essex, the Springfield Till, Chelmsford Gravels and Maldon Till are certainly found as a superimposed till–gravel–till sequence. The underlying Maldon Till is often poorly represented or absent (Turner 1937), the upper Springfield Till forms the main chalky boulder clay plateau of High Essex, and the intervening Chelmsford Gravels are widely exposed in the river valleys dissecting the plateau and along its south-eastern margin.

In the Ingrebourne valley at Hornchurch and Romford, well to the west of the area under consideration, gravels associated with the Boyn Hill (Hoxnian) terrace of the River Thames overlie a lobe of boulder clay (Holmes 1892, 1894). Because Clayton regarded this lobe as Maldon Till, he correlated the Springfield Till with the Gipping Till and the Maldon Till with the pre-Hoxnian Lowestoft Till of East Anglia.

The present investigations have shown that, in south-east Essex, Hoxnian interglacial deposits at Marks Tey, Copford and Rivenhall End, Kelvedon overlie chalky boulder clay. These sites all lie on the margins of the High Essex boulder clay plateau and there is no doubt that the chalky boulder clay concerned is Clayton's Springfield Till. At least in south-east Essex, this till must therefore be the equivalent to the Lowestoft Till and both Maldon and Springfield Tills must be ascribed to the Lowestoft glaciation. The Chelmsford Gravels represent the outwash of this glaciation, but of a minor retreat phase between two ice advances, and contain no evidence for any warmer conditions. It is very unlikely though that this tripartite division of the Lowestoftian strata in Essex can be equated with the classic Lowestoftian tripartite stratigraphy of the Norfolk and Suffolk coastal sections (West 1961 *a*). The Gipping ice advance does not appear to have reached this area of Essex. There is no trace of boulder clay overlying any of the Essex Hoxnian deposits. Indeed there is little firm evidence for the occurrence of Gipping Till anywhere south of Ipswich and Cambridgeshire.

The Hanningfield Till, according to Clayton, generally occurs as a dissected till sheet beyond the southern margin of the High Essex plateau. There is no good evidence for its presence in the Marks Tey area. Although Clayton believed this till was deposited by a much earlier ice sheet than those responsible for the Maldon and Springfield ice advances, other workers often prefer to regard it as the southerly extension of the Springfield Till or even partly as head deposits and not true till. In any case all till in south-east Essex is almost certainly Lowestoftian in age.

9. Conclusions

Pollen diagrams that give a complete vegetational sequence through the Hoxnian interglacial period are presented in this paper. Such a sequence is not available for any other interglacial deposit in Britain. The later zones of the interglacial (Ho III, Ho IV), with their interesting and important plant records of *Vitis*, *Pterocarya* and *Erica* cf. *terminalis*, have not been described before, nor has the transition from the Hoxnian interglacial to the Gipping glacial period. The presence of these exotic plants has at last provided convincing evidence that the Hoxnian interglacial period is the equivalent of the Continental Holsteinian stage. In the regional sphere, the Marks Tey deposits, together with other Hoxnian sites in the area, now offer a well-dated stratigraphic horizon within the Pleistocene succession of south-east Essex. They also show that the main spread of chalky boulder clay in that district is the equivalent of the Lowestoft Till of East Anglia. The lamination structures within the interglacial deposits are of intrinsic interest and may, on further investigation, yield reliable information about the absolute timespan of the Hoxnian interglacial period and perhaps reveal more about the nature of the exceptional non-tree pollen phase that occurred during subzone Ho IIc.

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British Railways (Eastern Region), the Highways Department of Essex County Council and the Colchester and District Water Board have all kindly placed boring records at my disposal.

Appendix

Non-marine Mollusca from the Marks Tey deposits

Mr B. W. Sparks kindly identified a number of Mollusca from the deposits. Mollusca are seldom abundant in the strata investigated, and the fauna is very restricted. The late-glacial sediments, GG 2012–2022, contain *Bithynia tentaculata* (L.), *Valvata piscinalis* (Müller) and *Pisidium* sp. Shells of *Valvata piscinalis* and opercula of *Bithynia tentaculata* occur more frequently in the marginal sediments of subzones Ho IIIa, Ho IIIb and Ho IVa. These species indicate conditions of gently flowing water.

A shelly horizon occurred in a working face in the north-west corner of the brickpit (1962–4), about 2.5 m from the top of the unlaminated early-glacial grey clay. From a sample of this shelly clay Mr Sparks extracted: *Succinea* sp. (1 specimen), *Vertigo* sp. (2), *Pupilla muscorum* L. (1) ? *Agrolimax* sp. (1), *Sphaerium corneum* L. (13), *Pisidium subtruncatum* Malm. (2) and *P. nitidum* Jenyns (33). He commented that this assemblage was derived from a variety of habitats and gave no real indication of age or climate.

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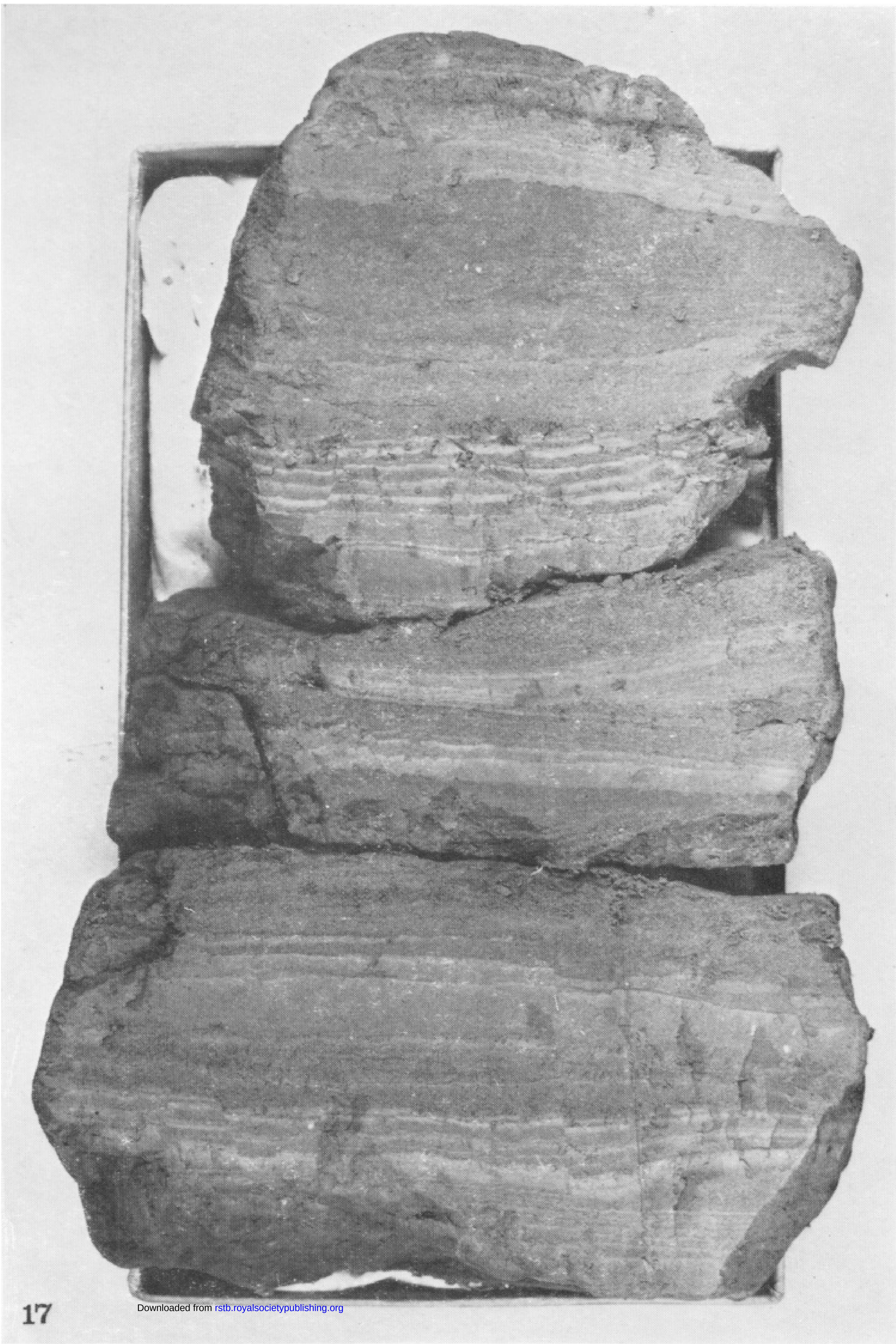
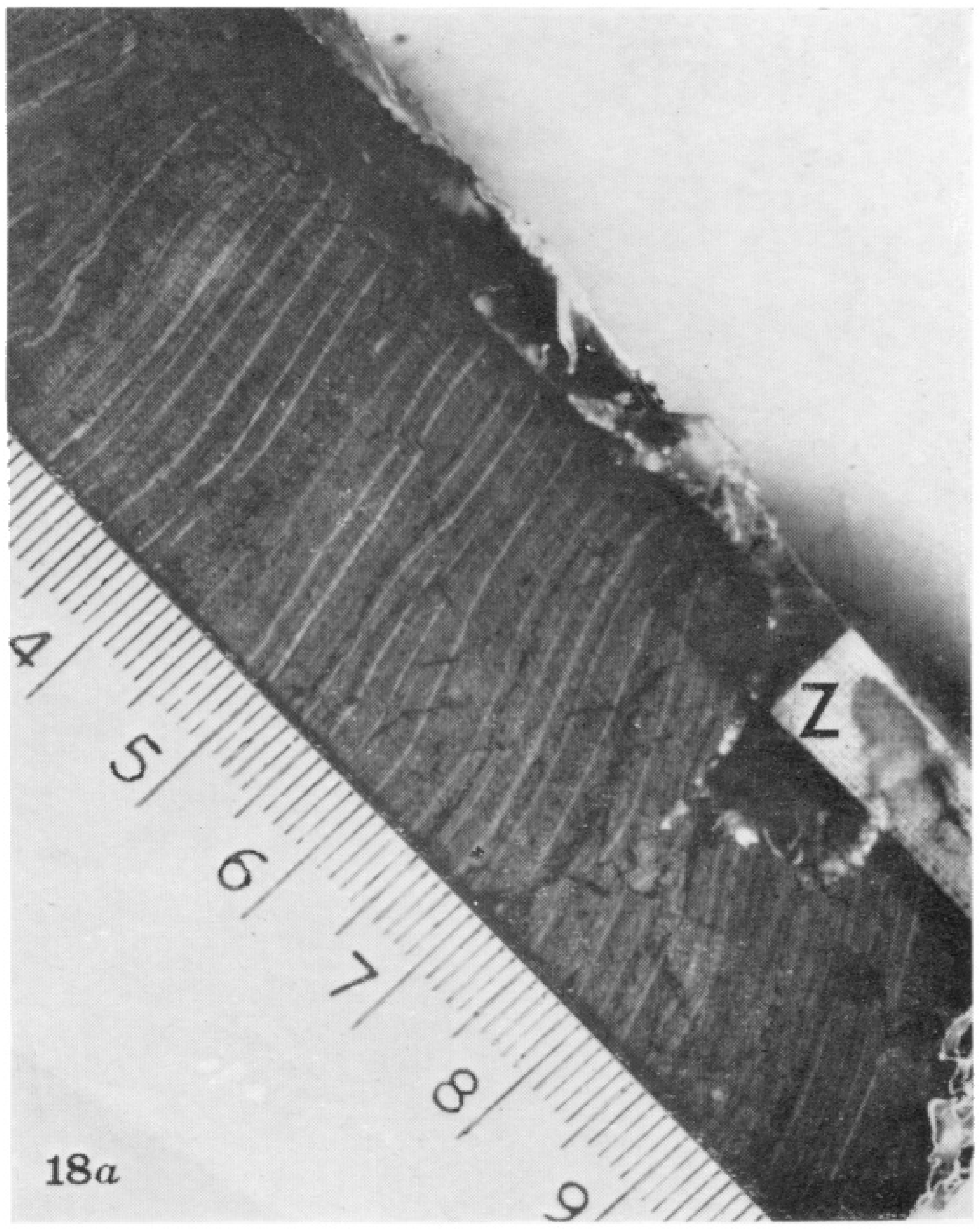
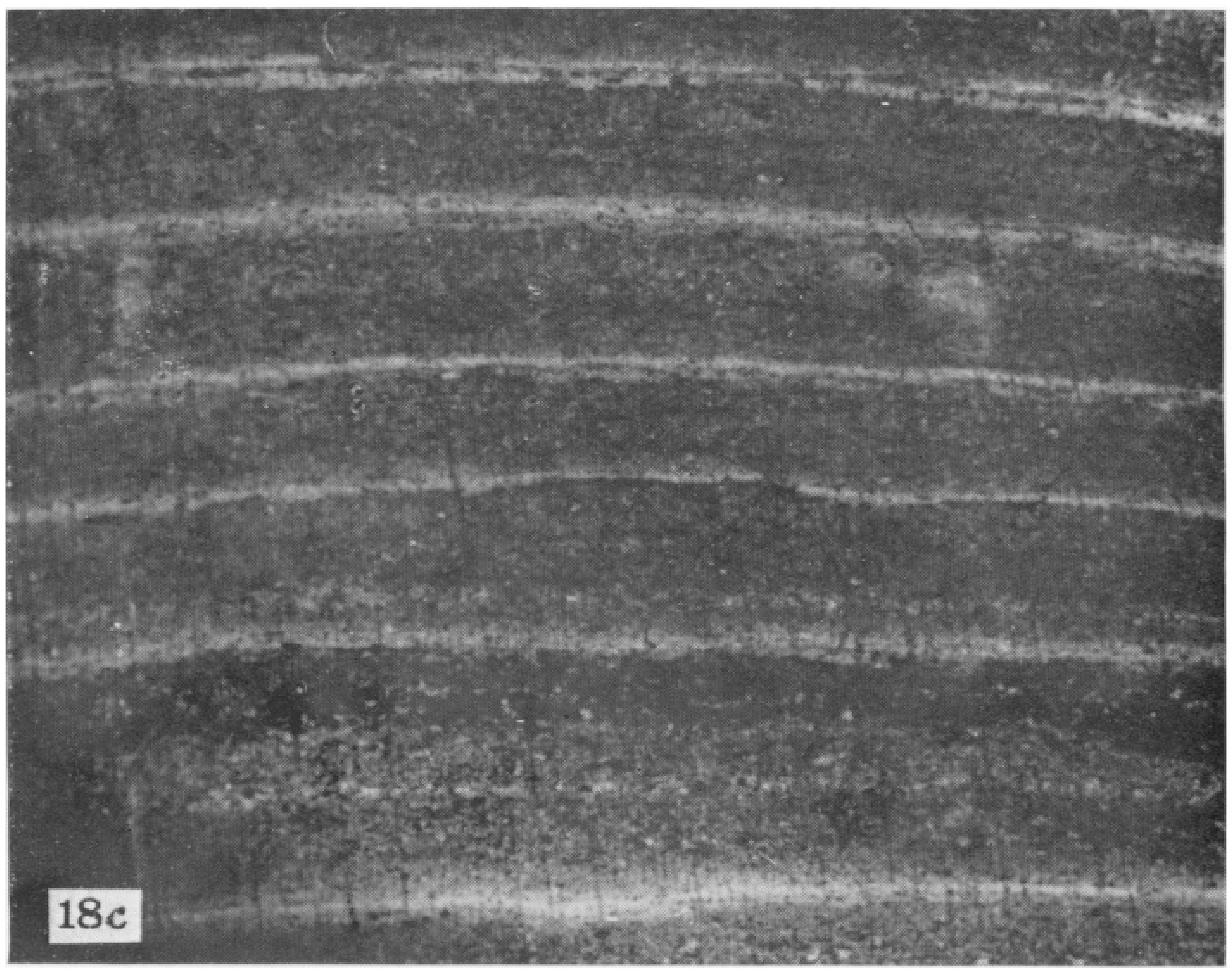


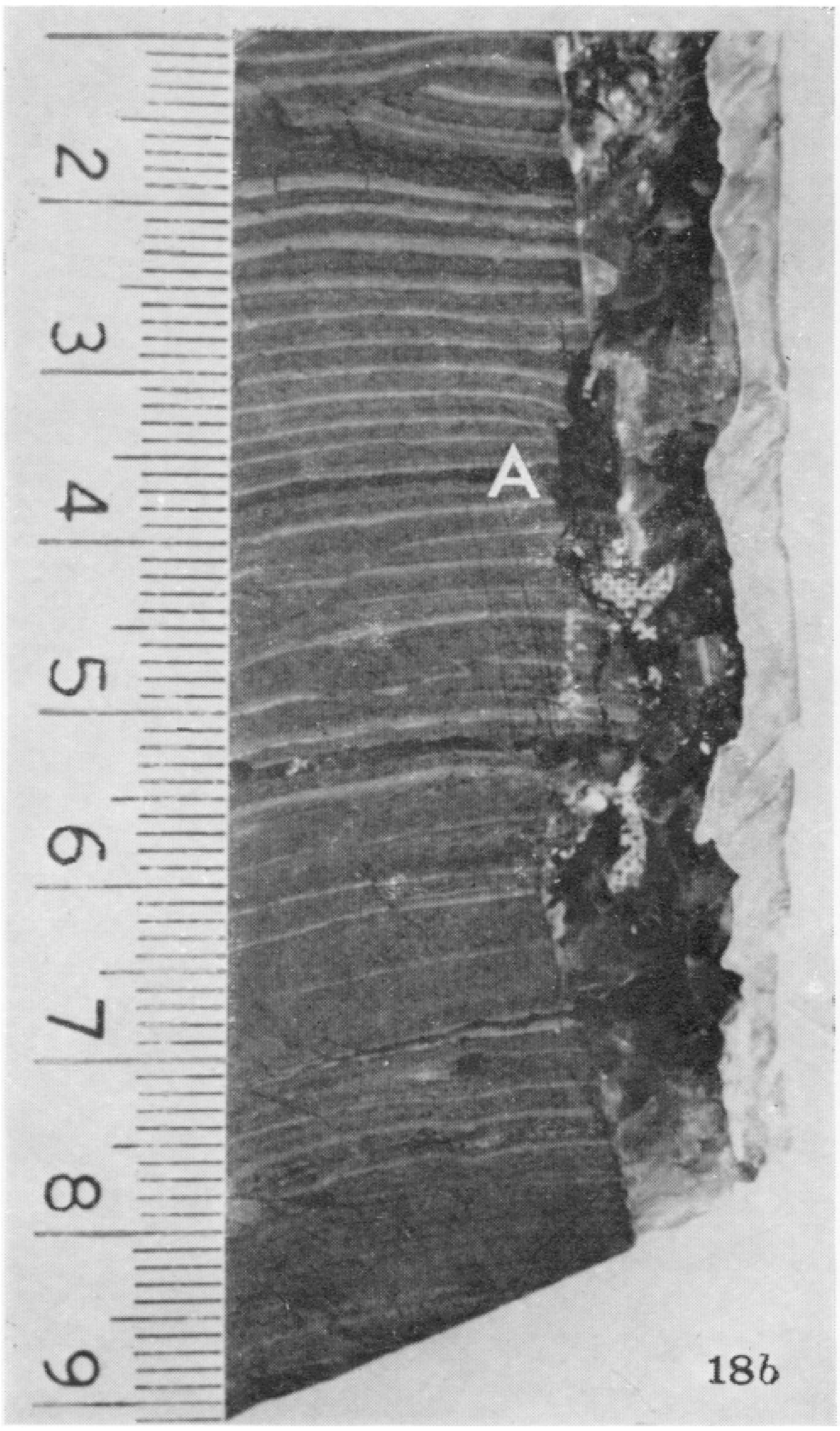
17



18*a*



18*c*



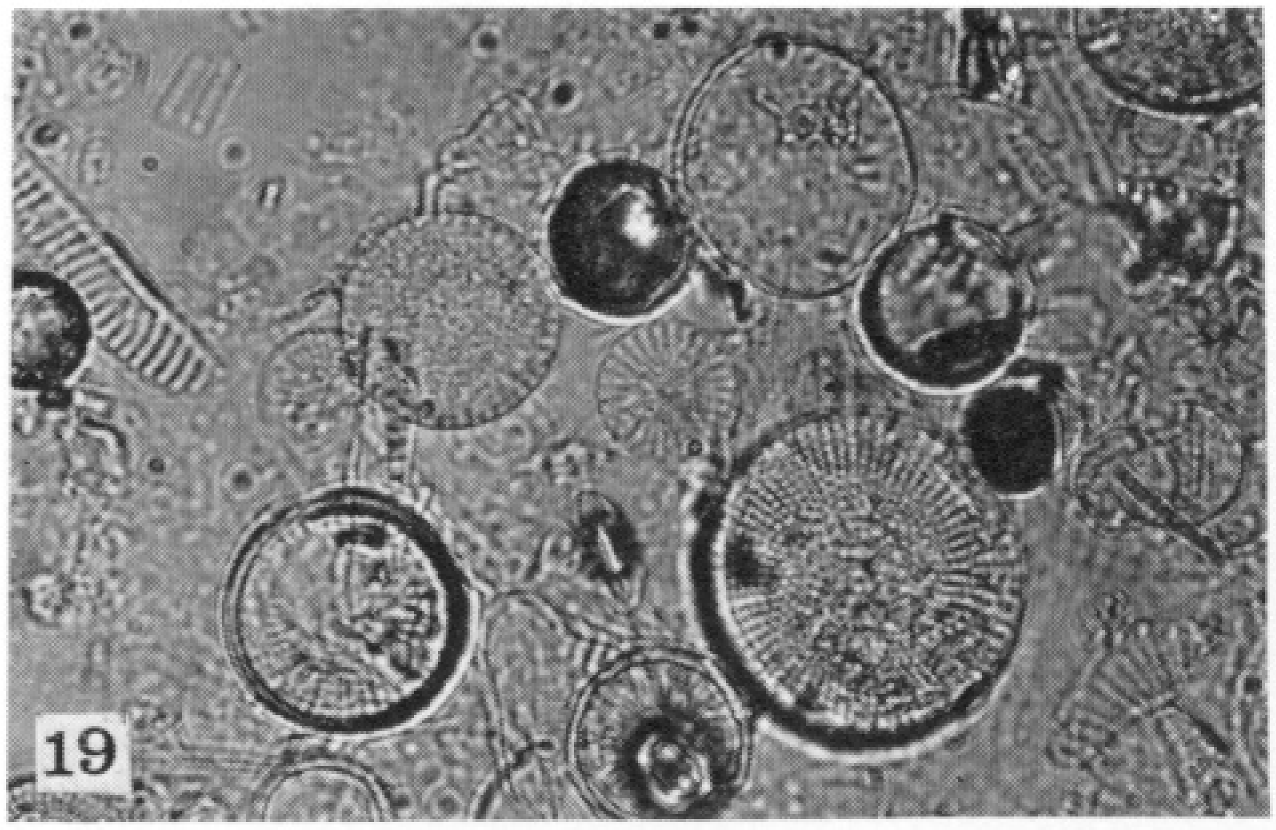
18*b*

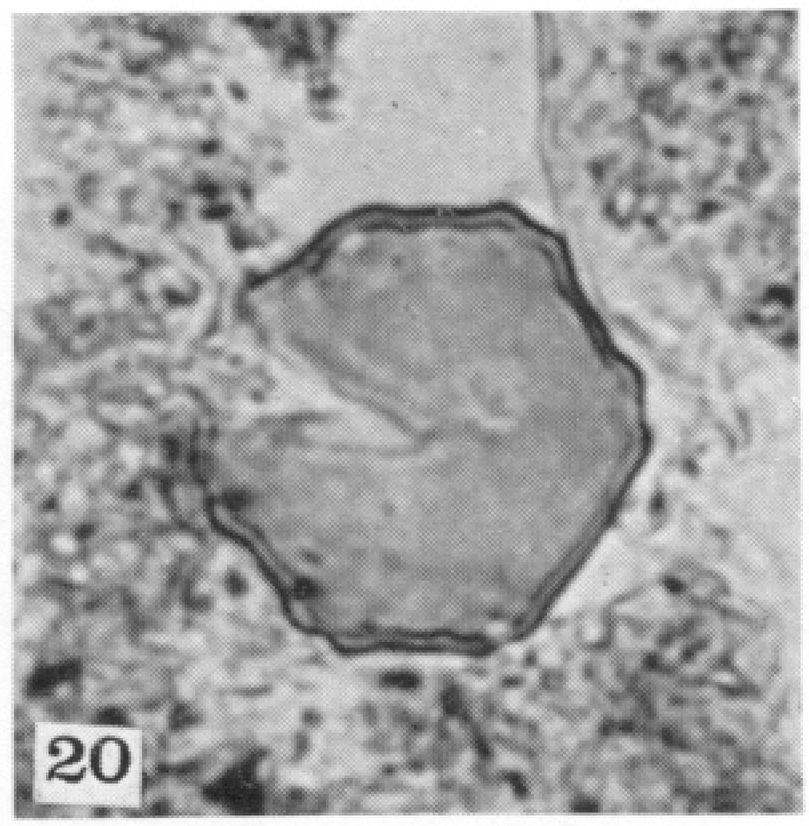
FIGURE 17. Laminated grey clay from the brickpit sections, about 5 m below the top of the clay. × 0.5.

FIGURE 18*a*. Laminated interglacial clay mud; core section GG 1554–1564 cm. The broader lamination above horizon Z coincides with the onset of the high non-tree pollen phase of subzone Ho II c. Scale of centimetres.

FIGURE 18*b*. Laminated interglacial clay mud; core section GG 1528–1537 cm. Scale of centimetres.

FIGURE 18*c*. Lamination detail from the same core section at horizon A. × 7.





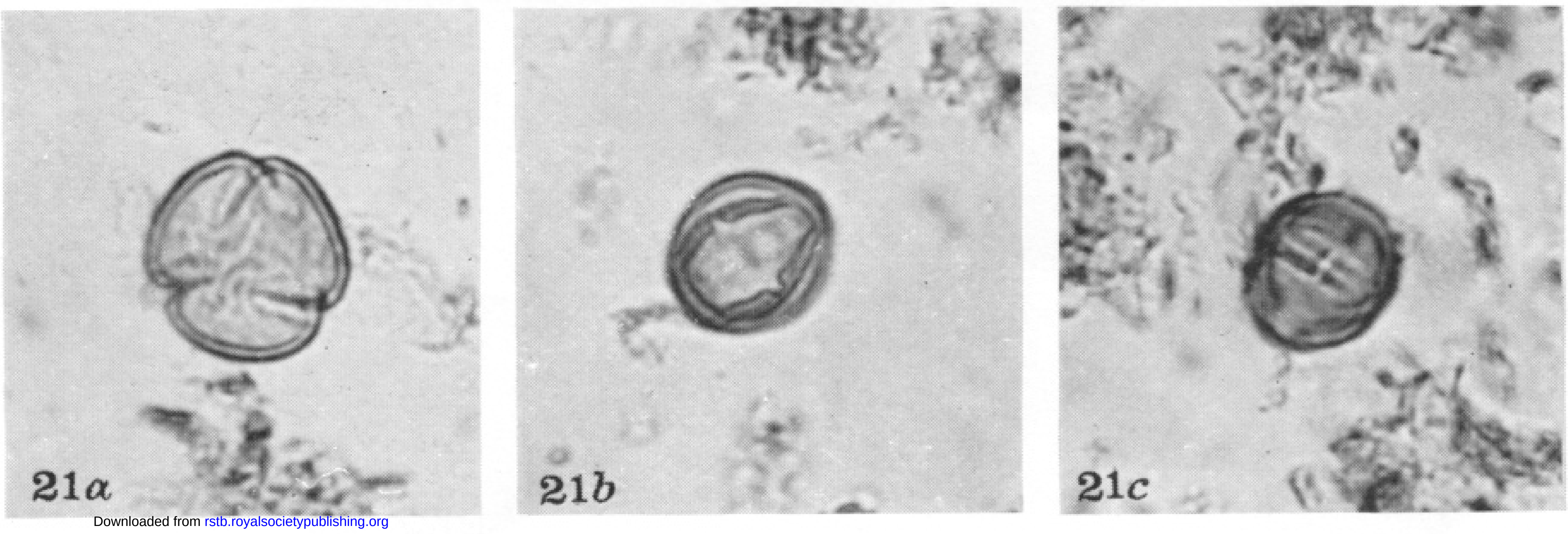


Figure 19. Diatom preparation from GG 1417 cm with abundant *Stephanodiscus astraea* var. *minutula*.

Figure 20. *Pterocarya* sp.

Figure 21 *a–c*. *Erica* cf. *terminalis*.

Figure 22 *a–c*. *Vitis* cf. *vinifera*.

Figure 23 *a–c*. The unidentified pollen Type X.