THE QUATERNARY DEPOSITS AT HOXNE, SUFFOLK

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CONTENTS

The geology and palaeobotany of Quaternary deposits at Hoxne, Suffolk, have been investigated. It is shown that immediately after the ice which laid down the Lowestoft Till had retreated a lake basin was formed in the till. In the basin a series of interglacial lacustrine sediments was deposited, first clay-mud and later detritus mud. Reworking of these sediments under a periglacial climate with a fluctuating lake water level resulted in the deposition of alternating layers of silt, drift mud and brecciated clay-mud. After this, clay, sand and gravel were deposited in the lake by solifluxion under periglacial conditions. The lake basin as a topographical feature was then entirely obliterated, and clay, sand and till were deposited unconformably on the lake sediments. This till was formed during the Gipping Glaciation. After the retreat of the ice of this glaciation, the present valleys were excavated, and later to a small extent filled by fluvial deposits. Finally, aeolian sand, which now forms the surface deposit in the area, was deposited under periglacial conditions and, probably at the same time, a cryoturbation phase occurred.

Macroscopic plant remains and pollen diagrams from the lacustrine interglacial sediments are described. They give evidence of the vegetational and climatic history of the interglacial period between the Lowestoft and Gipping Glaciations. Four major vegetational stages are distinguished; they are named the Late-Glacial, Early-Temperate, Late-Temperate and Early-Glacial stages. The Late-Glacial stage was characterized by *Hippophaë* scrub, the Early-Temperate stage by the development and persistence of mixed-oak forest, the Late-Temperate stage by the beginning of the replacement of the mixed-oak forest species by *Carpinus* and conifers, including *Picea* and *Abies*, and the Early-Glacial stage by the presence of park-tundra with scattered forest. There was a rapid climatic amelioration at the very beginning of the interglacial period, which led to a climatic optimum in the middle of the Early-Temperate stage. After that time there was a progressive deterioration of the climate, which resulted in the periglacial conditions under which the uppermost sediments of the lake were laid down.

A phase of deforestation in the Early-Temperate stage and its relation to the Lower Palaeolithic (Acheulian) artifacts found during the investigations are described; they may be associated. The stratigraphical positions of those artifacts found recently and of those found by previous investigators at Hoxne are also described.

The molluscan and mammalian faunas of the deposits and the glacial erratics from the covering till are described in Appendices.

The stratigraphy demonstrated here differs from that previously found at Hoxne in showing that there is one interglacial temperate horizon, undivided by a cold phase, whereas previously two temperate horizons separated by a cold phase had been described. The origin of this difference is explained.

A comparison of these Quaternary deposits is made with those elsewhere in Britain, in Ireland and on the continent. It is concluded that the Hoxne Interglacial is of Great (Elster/Saale, Mindel/Riss) Interglacial age.

1. Introduction

(*a*) *Location of the deposits*

The Quaternary deposits to be described occupy a small area (National Grid Reference TM175767, O.S. 1 in. Sheet No. 137), ½ mile south-west of Hoxne Low Street, a village 4½ miles east-south-east of Diss, Norfolk. They lie on the eastern flank of the River Dove, which joins the River Waveney a mile to the north. The boundaries of the area described are shown in the map of the surrounding country (figure 1). The deposits form part of a ridge of a north-east-pointing spur of the boulder-clay plateau of north Suffolk, with the valley of the River Dove to the west and that of the Gold Brook to the east. The large-scale map (figure 2) shows the topography of the area investigated. In the centre on either side of the Eye–Hoxne road are the pits of the Hoxne Brick Works. The old pit is on the east of the road and now houses the kilns; west of the road is the newer Oakley Park pit, worked at the present time.

(*b*) *History of previous research*

When scientific interest in the questions of man's antiquity first arose during the middle of the nineteenth century, Joseph Prestwich was one of the first to conduct practical investigations into the geological aspects of the problems involved. He examined the French sites where Boucher de Perthes had discovered Palaeolithic implements, and

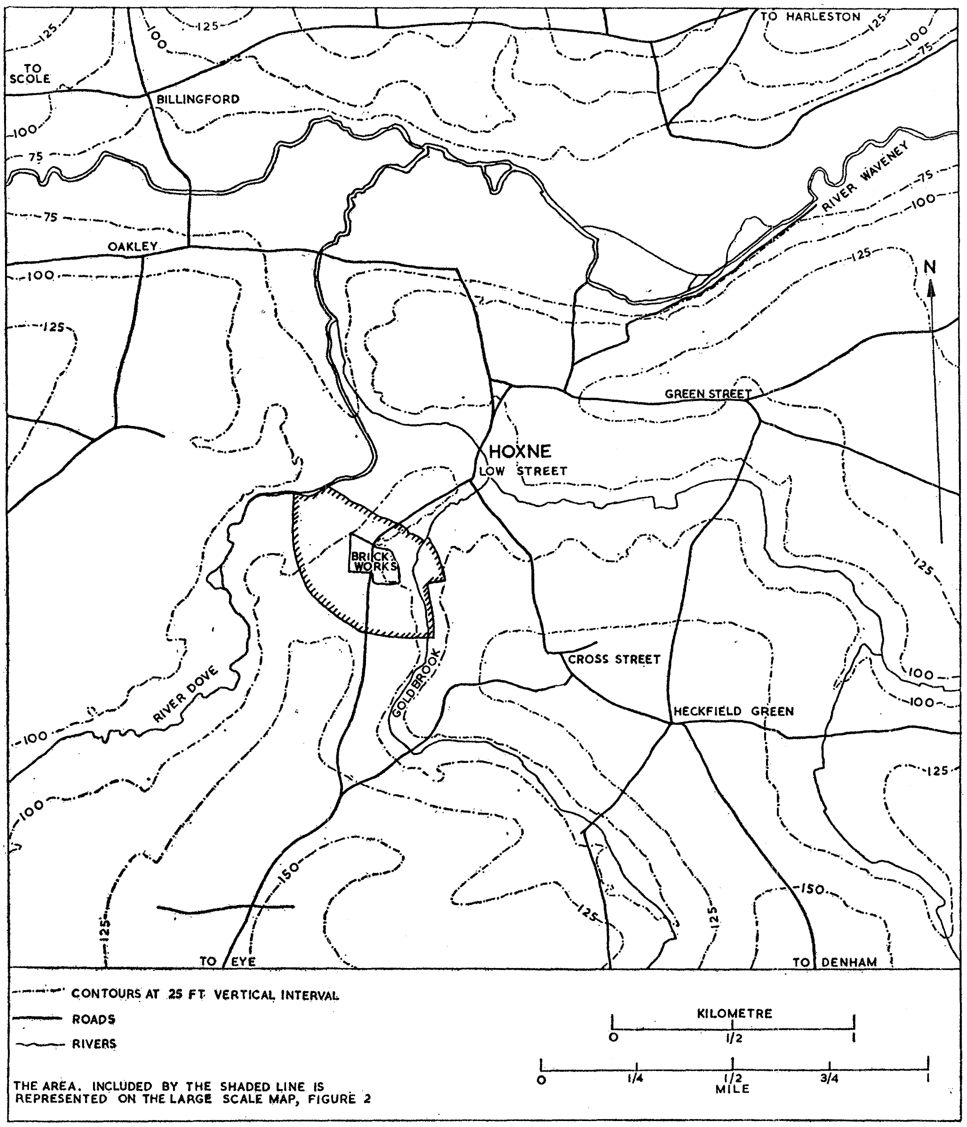

FIGURE 1. Map of the country around Hoxne.

on his return to England he visited the Brick Works at Hoxne, at the suggestion of Evans, who had told him of an early paper by John Frere on implements from this place.

Frere had found flint implements at the Brick Works in the late eighteenth century, and he described his finds in a short paper addressed to the Society of Antiquaries in 1797 (Frere 1800). This paper is remarkable for concise description and interpretation of the facts. Frere recognized the implements as 'being fabricated and used by a people who had not the use of metals'. He was thus the first to recognize the significance of these flints, but his discovery was ignored until Prestwich and Evans started their own investigations about fifty years later.

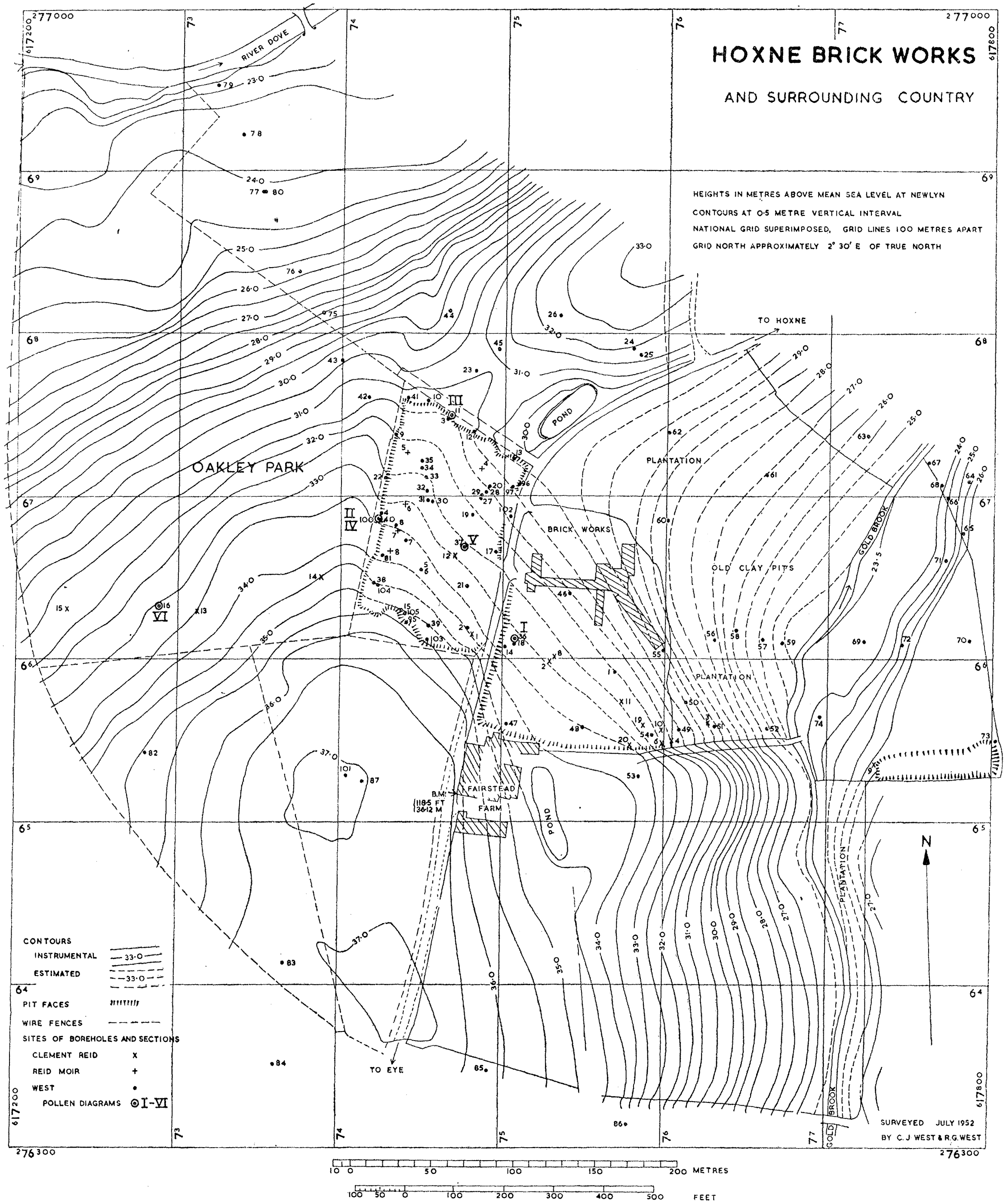

FIGURE 2

Hoxne then became a centre of investigation, for here the relation of the beds with the flint implements to the boulder clay could be seen, and so it was hoped to find evidence of the age of man in relation to the Glacial Period. Prestwich (1860) made a study of the deposits in 1859 and 1860; he concluded that the beds with the flint implements were newer than the boulder clay, but probably older than some portion of the superficial sands and gravels.

In 1876 Thomas Belt made some observations at Hoxne and suggested that the implement bearing beds might be interglacial or preglacial (Belt 1876). Later, Reid & Ridley (1888) visited the Brick Works and found a deposit with the remains of arctic plants.

A Committee of the British Association for the Advancement of Science investigated the stratigraphy and the plant and animal remains of the deposits in 1895 and 1896 (Reid 1896). The conclusions reached regarding the post-glacial (s.l.) age of man supported those of Prestwich. A second Committee of the British Association was formed in 1924 to make a further investigation into the deposits, as by this time other discoveries of flint implements had thrown doubts on the previous views of the relation of man to the Glacial Period. The conclusions of this Committee suggested the interglacial age of the beds with flint implements (Moir 1926). Further archaeological investigations were later carried out by Moir (1935).

Thus most of these investigations have been stimulated by the quest for archaeological knowledge, and that is hardly surprising when it is remembered how few are the Lower Palaeolithic stations associated with glacial deposits.

The investigations described here, however, are concerned primarily with the stratigraphy and the palaeobotany of the deposits rather than the archaeology.

2. Stratigraphy

(a) *Introduction*

The accepted scheme of the stratigraphy of the deposits was devised by Moir (1926); it is reproduced in figure 16. The evidence from a number of preliminary borings did not agree with the stratigraphical succession described by Moir, and it was therefore necessary to carry out an extensive program of boring to clarify the stratigraphy. The results from these borings confirmed the suggestion that Moir's stratigraphical scheme is incorrect. To simplify the presentation of the stratigraphical data, the results obtained in the recent investigations are described and analyzed first, and then the previous work is interpreted in terms of these results. In this way the work of previous investigators is more easily explained and the presentation of the results is not too much encumbered by references to the previous work.

The stratigraphical interpretation given here is based on data obtained from 105 boreholes and sections, sited to yield the greatest amount of information. Of the boreholes and sections, only twenty are described here, in Appendix 1. The remaining descriptions have been deposited with the Nature Conservancy, London, where they may be consulted.

The stratigraphical data obtained by Prestwich (1860), Reid (1896) and Moir (1926, 1935) are taken into account in the interpretation of the recent investigations. For clarity in referring to this previous work the following system of abbreviation is used; the author's name is represented by his initials: CR for Clement Reid and RM for Reid Moir, and the number of the borehole or section referred to is given after the author's initials. For example, CR 19 refers to Reid's borehole no. 19. The relation of the numbers of the boreholes and sections used here to those of the original papers is given in Appendix 1. The boreholes and sections of the author are not prefixed by initials but are referred to by their number only.

The area of the Brick Works and the surrounding country was surveyed in detail to form a basis for the stratigraphical work, and the map (figure 2) was constructed from this survey. The positions of the boreholes and sections made in the area in the course of the investigations, and the boreholes and sections of known position described by previous authors, are marked on this map.

The trial boring, no. 36, was made with a large boring rig, hired with the aid of a grant given by the Royal Society of London; this rig took 4 in. cores, each about 15 in. in length. The other borings were made with a shipwright's single spiral auger of $1\frac{1}{2}$in. diameter and 50 cm length. The auger to some extent distorted the microstratigraphy of the deposits, but the major sediment types could be distinguished easily. Two auger borings (nos. 5 and 6) were made close together to see whether there were any discrepancies which could be ascribed to this method of boring, but the records of the two borings were similar enough to show that there was not much distortion.

As 'earth' has been raised at Hoxne for over five centuries the amount of artificial disturbance of the ground is considerable, and it was sometimes difficult to recognize the full extent of made ground from the auger samples. Thus the surface layers of most of the boreholes in the brick pits are suspect.

(*b*) *The general succession of the Quaternary deposits in the Hoxne district*

The only general account of the geology of the Hoxne district is the *Geological Survey Memoir* explaining the Old Series Sheet 50 N.E. (Whitaker & Dalton 1887). In the memoir are described a series of drift deposits, including loam, sand, gravel and boulder clay, which mantle and conceal the older rocks of the area—Crags, Tertiary clays and Chalk. The succession of the local Quaternary deposits has more recently been described by Baden-Powell (1950, 1951 *a*). This succession is similar in most respects to the one given by Whitaker & Dalton, and it may be summarized briefly as follows, in descending order of age:

(1) Alluvium.
(2) Gipping Glaciation outwash.
(3) Hoxne Interglacial Series.
(4) Lowestoft Till.
(5) Corton Beds.

The succession below the Corton Beds is only known from two deep borings, the records of which are given by Whitaker & Dalton; they show Chalk and possibly Crag and Eocene to lie beneath the Corton Beds. On the Corton Beds rests the Lowestoft Till, which forms the surface of the major part of the north Suffolk plateau, at about 150 ft. O.D. The interglacial deposits lie in a hollow in the Lowestoft Till, and they are covered with sand and gravel, related by Baden-Powell to the outwash of the Gipping Glaciation. The present valleys are cut into the boulder-clay plateau and are considered to post-date the interglacial deposits. Figure 3 summarizes this stratigraphical sequence described by Baden-Powell, and shows his view of its relation to the topography.

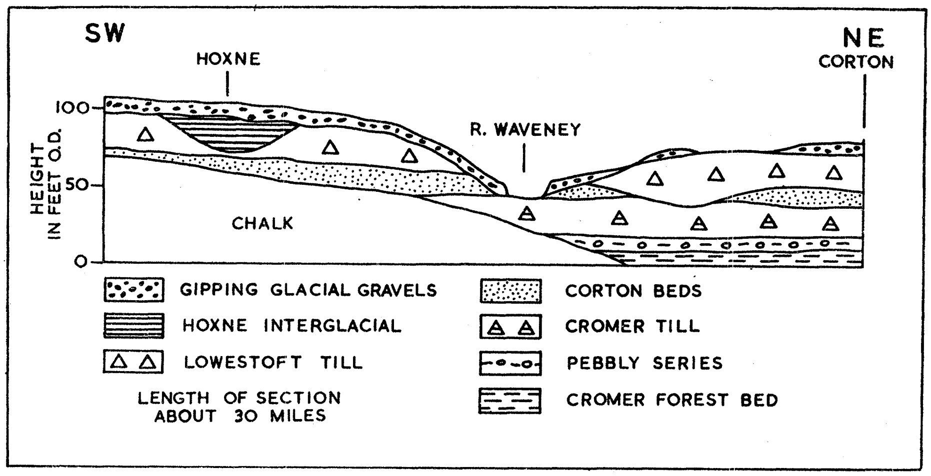

FIGURE 3. Geological sketch-map across East Anglia showing the succession of Quaternary deposits (after Baden-Powell).

(c) *Description of the strata*

The succession of deposits found in the investigations is, in descending order of age:

	deposit	designation of strata	approximate maximum thickness found
1	(River alluvium)		
	Fine sand with flints	A1	1 m
	Valley fill and hill-wash of clay, sand and gravel	H	$2\frac{1}{2}$ m
2	Unstratified clay and sand, and till of Gipping Glaciation	A2	$2\frac{1}{2}$ m
3	Stratified clay, sand and gravel	B	2 m
	Brecciated clay-mud with interbedded silt and drift mud	C	$3\frac{1}{2}$ m
	Detritus mud	D	40 cm
	Brown-green clay-mud	E	$6\frac{1}{2}$ m
	Grey clay-mud and marl	F	50 cm
4	Chalky boulder clay of Lowestoft Glaciation	G	$7\frac{1}{2}$ m

The numbers on the left refer to the numbered horizons of Baden-Powell's succession given above, and show the relation between the two sequences.

Strata F to B were deposited in a lake basin in the chalky boulder clay and are therefore local in distribution. The other strata are generally distributed in the area.

The stratigraphical results are embodied in the profiles through the deposits, figures 6 to 13, and the positions of these profiles are given in figure 5. Figure 4 explains the symbols used in the profiles. The outline drawing above each profile gives the true proportion between length and height. General views of the deposits are shown in plate 4.

(i) *Stratum G*

The chalky boulder clay forming this stratum lies immediately beneath the interglacial deposits and is exposed in several places in and near the Brick Works. It can be seen well in the north-west corner of the Oakley Park pit where it rises to within $1\frac{1}{2}$ m of the surface, and in the two old boulder-clay pits on the east side of the valley of the Gold Brook (figure 2, Grid Reference 778654 and a pit 300 m to the south of this). These sections show the boulder clay a stiff blue-grey sandy clay with many chalk pebbles, often markedly striated, with flints and other rocks, including many of Jurassic origin. The boulder clay is weathered to a mottled grey-brown colour and is much less stiff where it rises to near the surface. In such places it sometimes appears to be disturbed by cryoturbation, e.g. no. 24.

The thickness of the boulder clay varies considerably in the area. One borehole made in the 1896 investigations (CR 9) showed 24 ft. (7·3 m) of boulder clay resting on sand; two other borings made at the same time (CR 8, CR 11) met with sand below the inter-

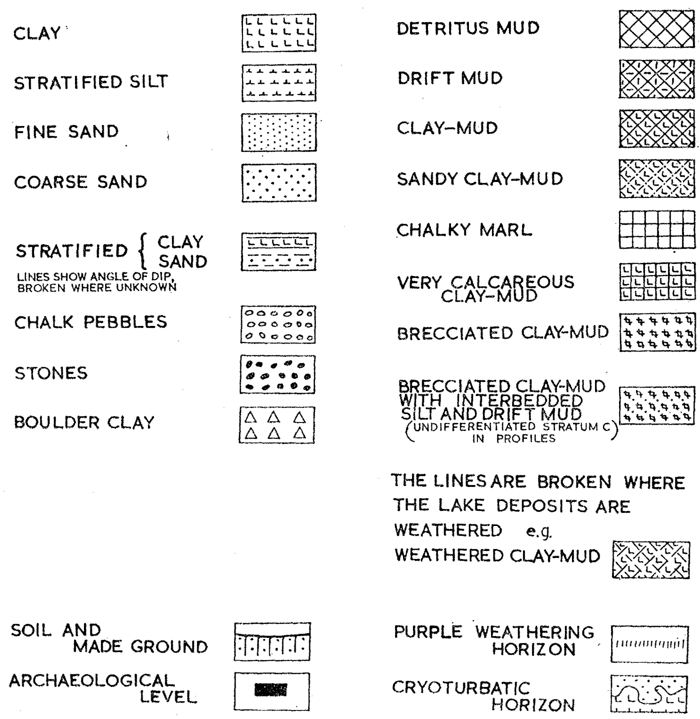

FIGURE 4. Symbols used in profiles and pollen diagrams.

glacial deposits, which led Reid (1896) to suggest that the boulder clay was absent here and the interglacial deposits lay directly on the sub-boulder clay sand (Corton Beds). The boulder clay was not pierced in any of the recent borings.

The sections exposed during the field work showed clearly the relation between the boulder clay and the overlying deposits (seen in figure 35, plate 4). There appeared to be no important erosional unconformity at the junction. The boulder clay was seen to merge into a grey sandy clay with small chalk pebbles which passed upwards into the interglacial sediments of stratum F, except in one borehole (no. 50) where grey stony sand was found between the interglacial sediment and the boulder clay. The grey sandy clay with small chalk pebbles probably represents a phase of solifluxion which took place immediately after the disappearance of the ice which laid down the boulder clay, but before the deposition of the interglacial sediments. It is included in stratum G.

The number of boreholes and sections which proved the chalky boulder clay made it possible to map approximately the contours of its surface, as shown in figure 14. The surface of the boulder clay within the area of the interglacial deposits forms a basin of very irregular pattern with partially enclosed hollows. The map suggests a kettle topography

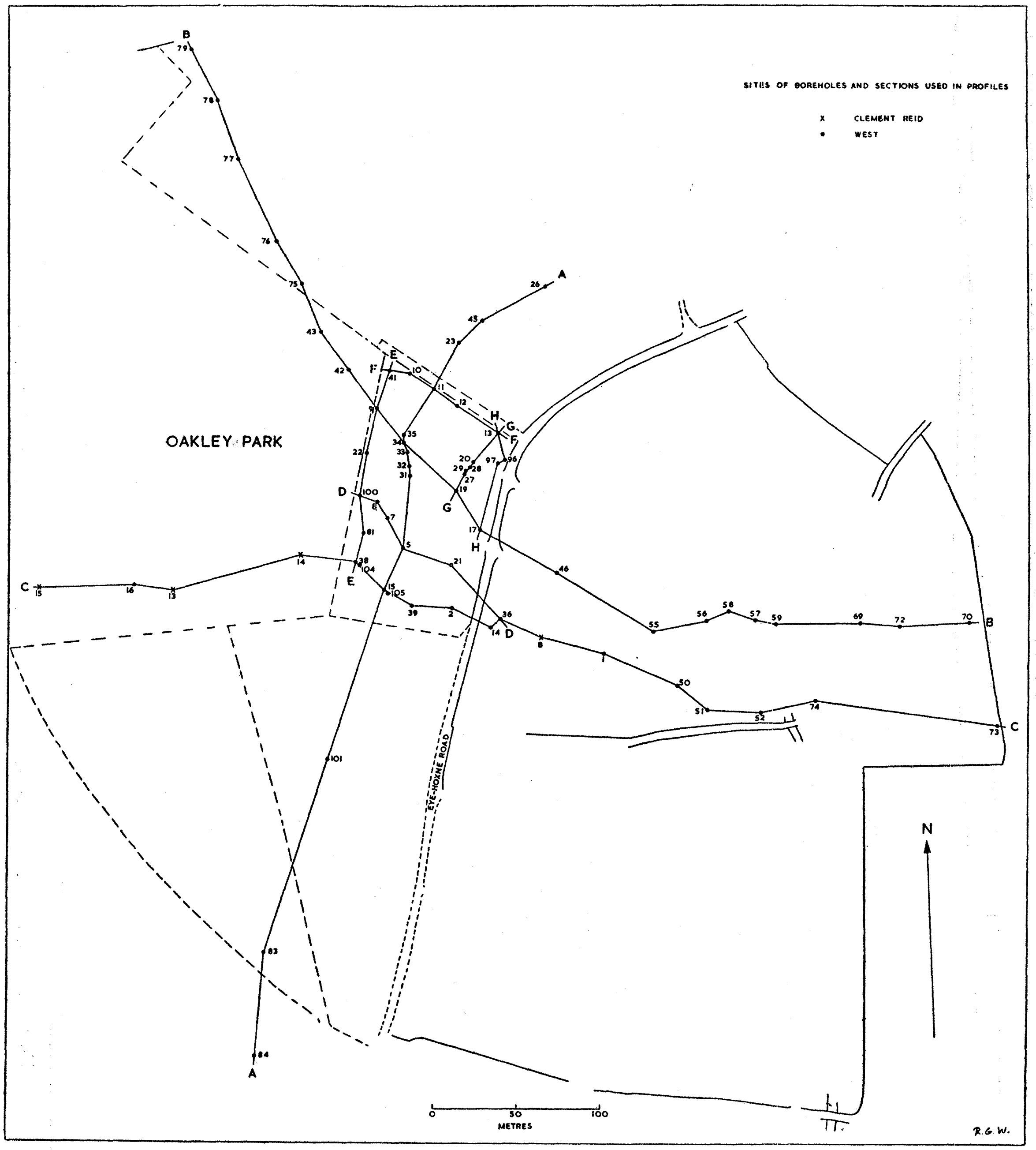

FIGURE 5. Map of the positions of the profiles A to H.

of dead ice origin. According to Flint (1947), kettle holes in unstratified drift are uncommon, and depressions in such a drift may be due to other reasons than dead-ice origin. Kettles in till moraine have been described by Fuller (1914).

The stones in the boulder clay immediately beneath the interglacial deposits show a preferred orientation (West & Donner 1956, measurement *d* of site no. 20), and there is

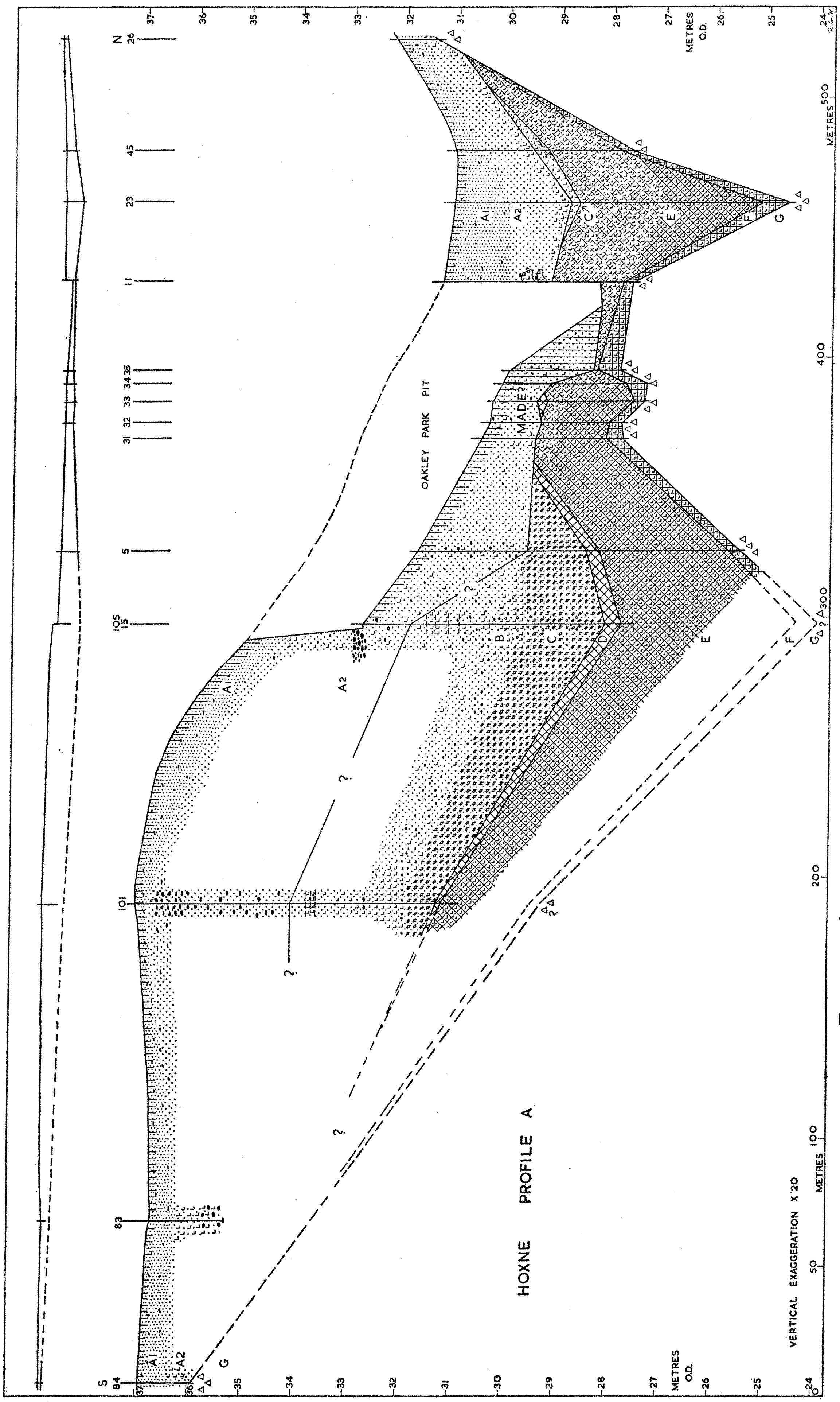

FIGURE 6. General north-south profile through the Quaternary deposits.

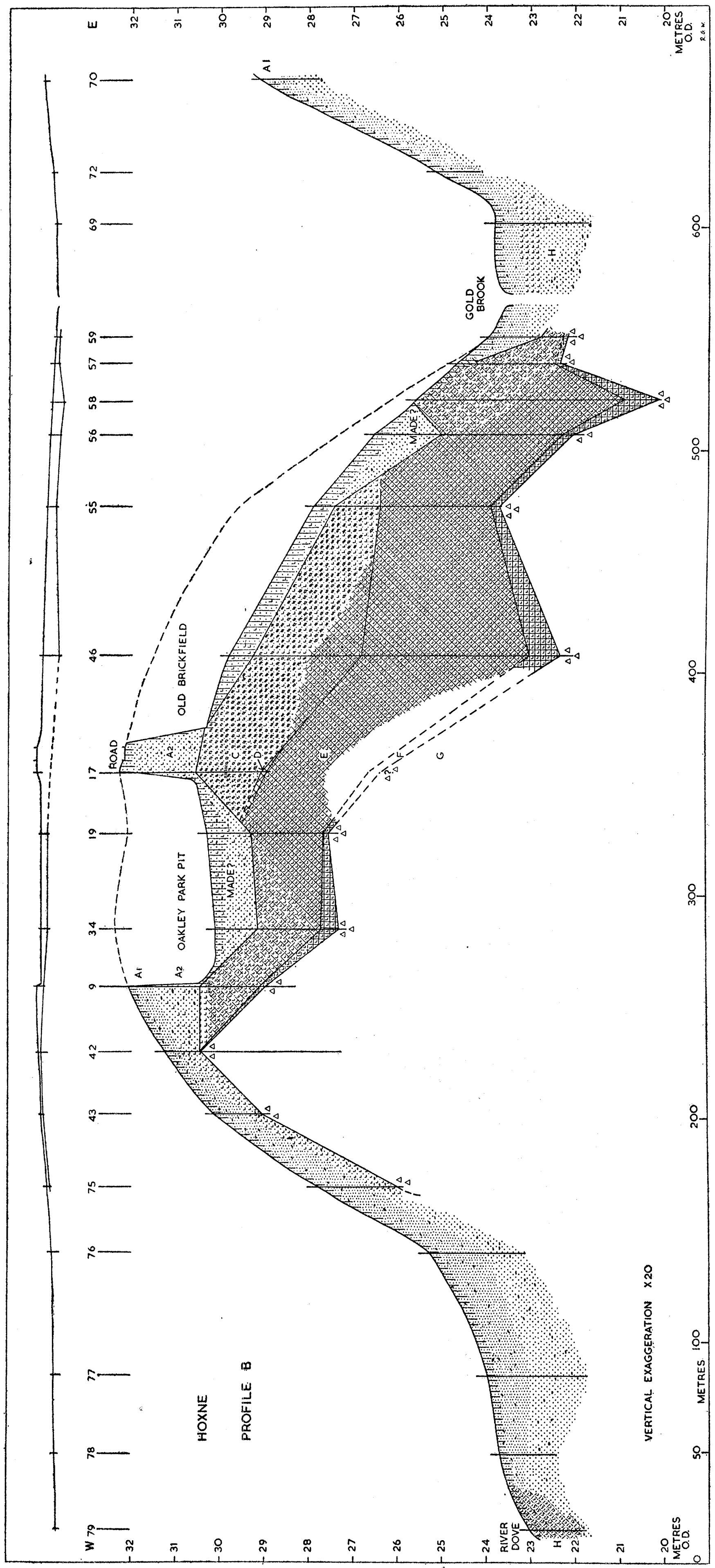

FIGURE 7. General east-west profile through the Quaternary deposits.

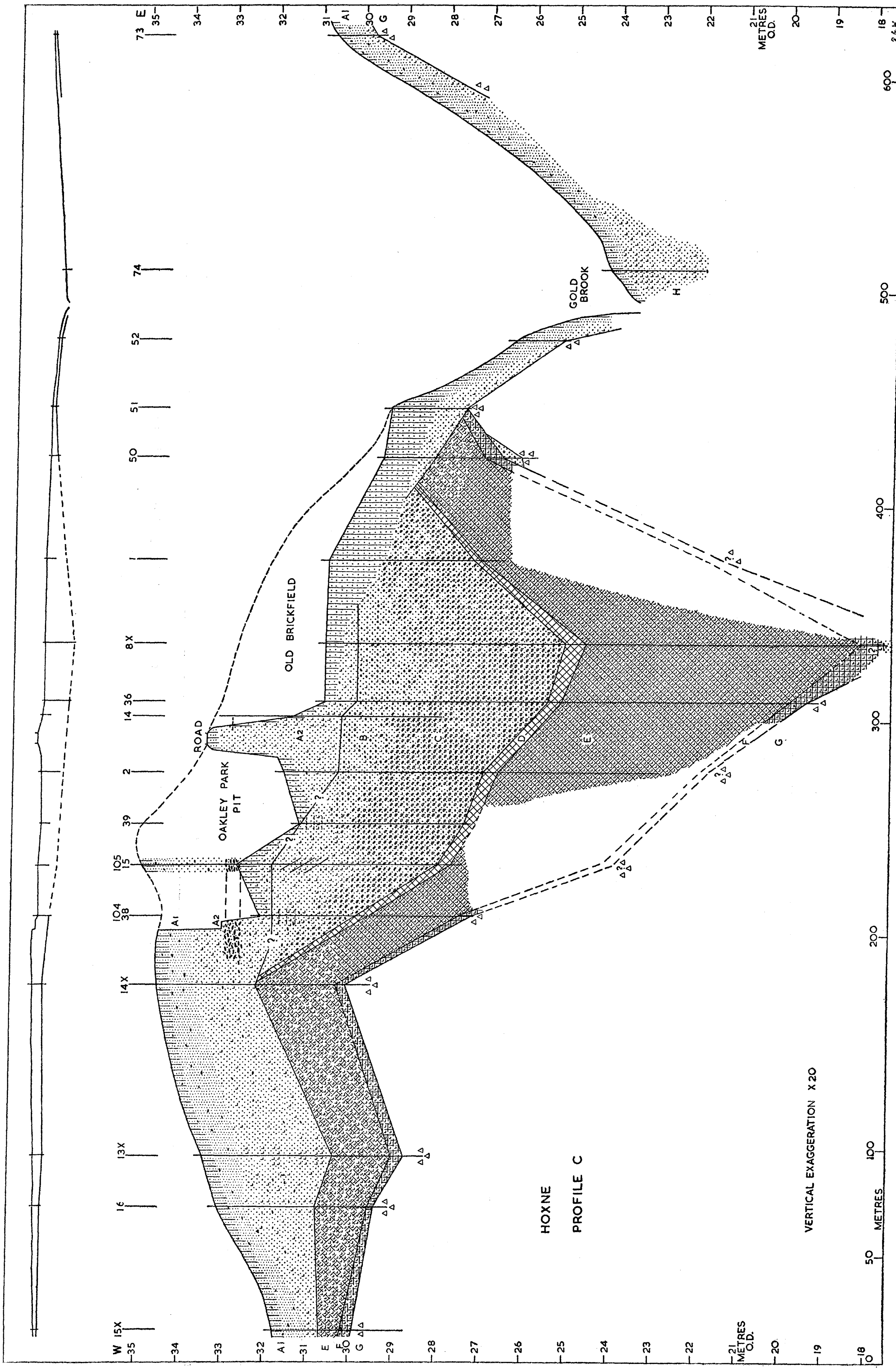

FIGURE 8. General east-west profile through the Quaternary deposits.

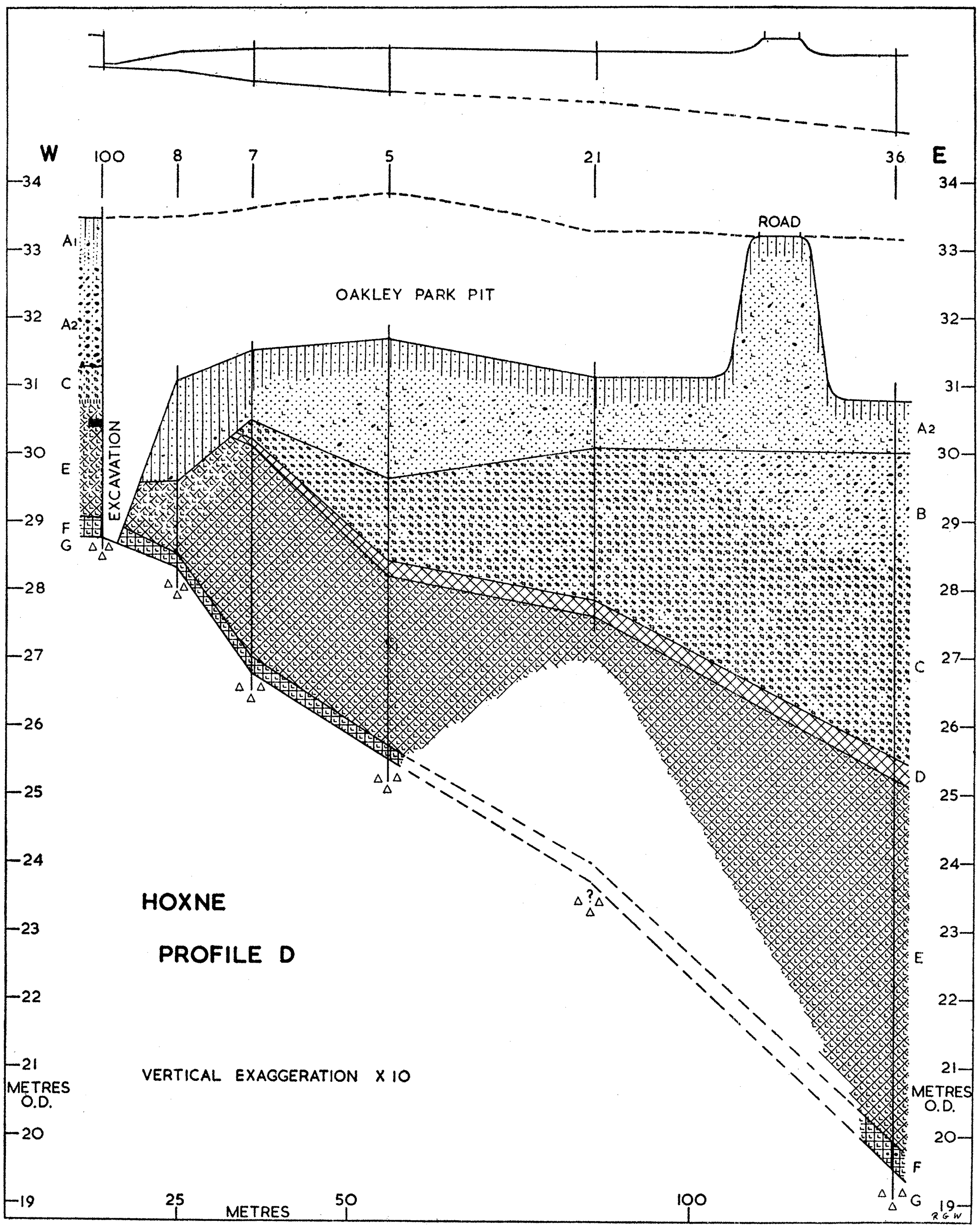

FIGURE 9. Profile demonstrating the position of the archaeological horizon in the lake deposits.

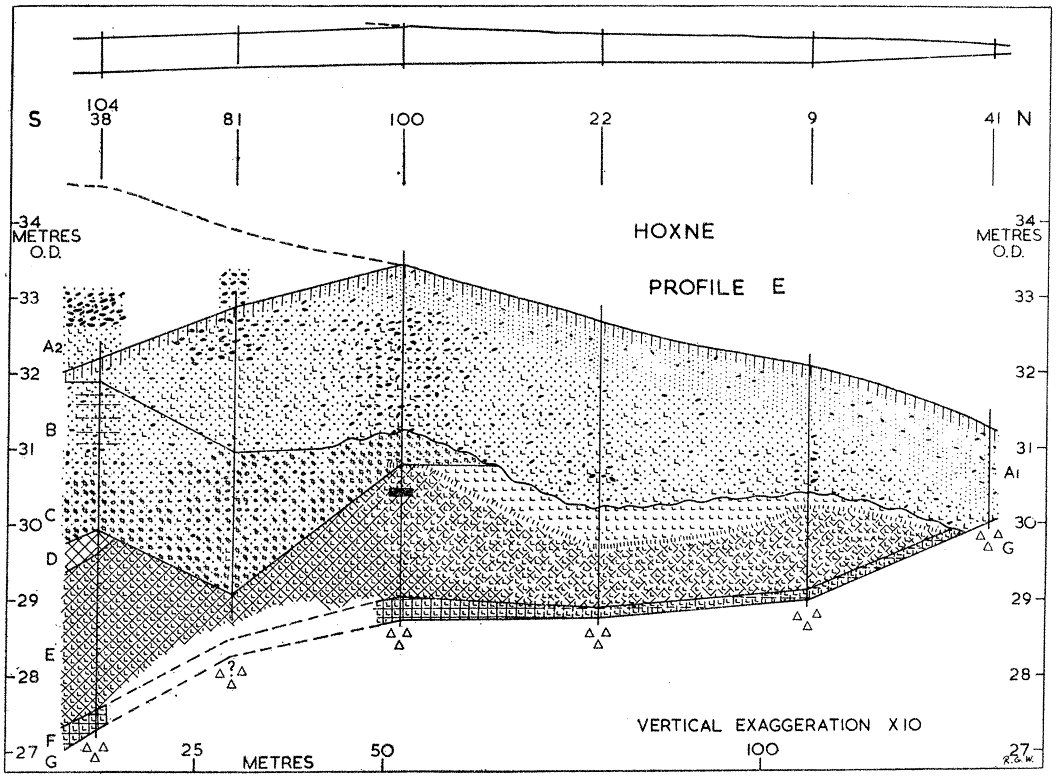

FIGURE 10. Profile demonstrating the position of the archaeological horizon in the lake deposits.

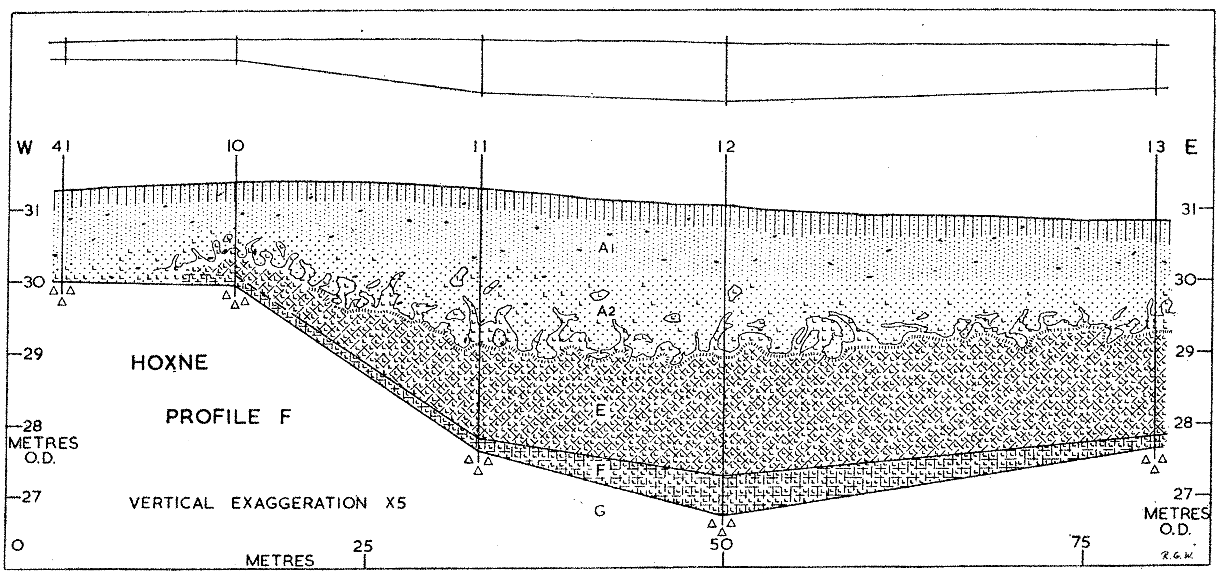

FIGURE 11. Profile along the north face of the Oakley Park pit.

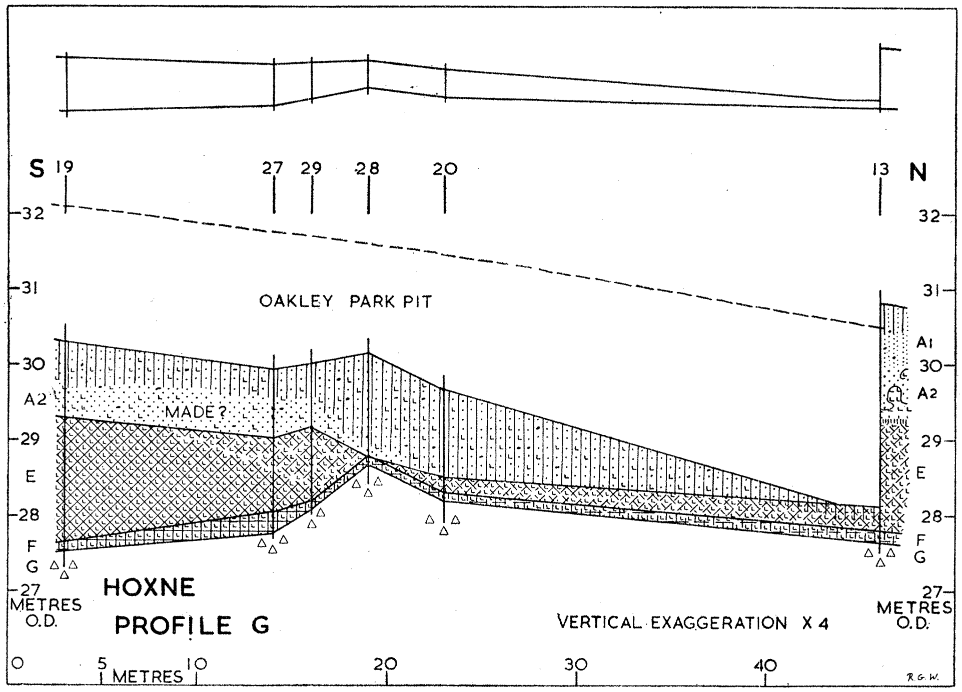

FIGURE 12. Profile showing the relation of weathered to unweathered strata E and F.

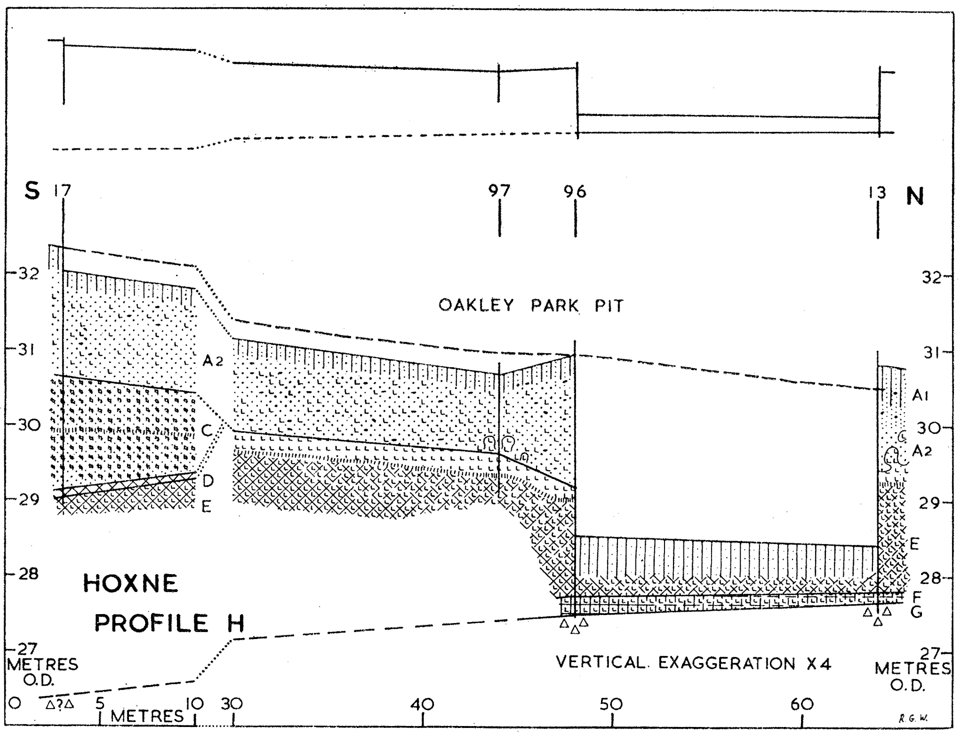

FIGURE 13. Profile along the northern part of the east face of the Oakley Park pit.

no sign of any unsorted or sorted material between the boulder clay and the lake deposits which might have been debris derived from the melting of dead ice (except perhaps in borehole no. 50). Such material might be expected if the hollow was formed by the melting of superficial dead ice. Possible explanations are—oriented material in dead ice retaining its orientation on deposition, dead ice beneath the ground moraine in the glacial sand recorded by Reid, which is also seen beneath the boulder clay in neighbouring pits, and dead ice being clean enough to leave no material on melting out.

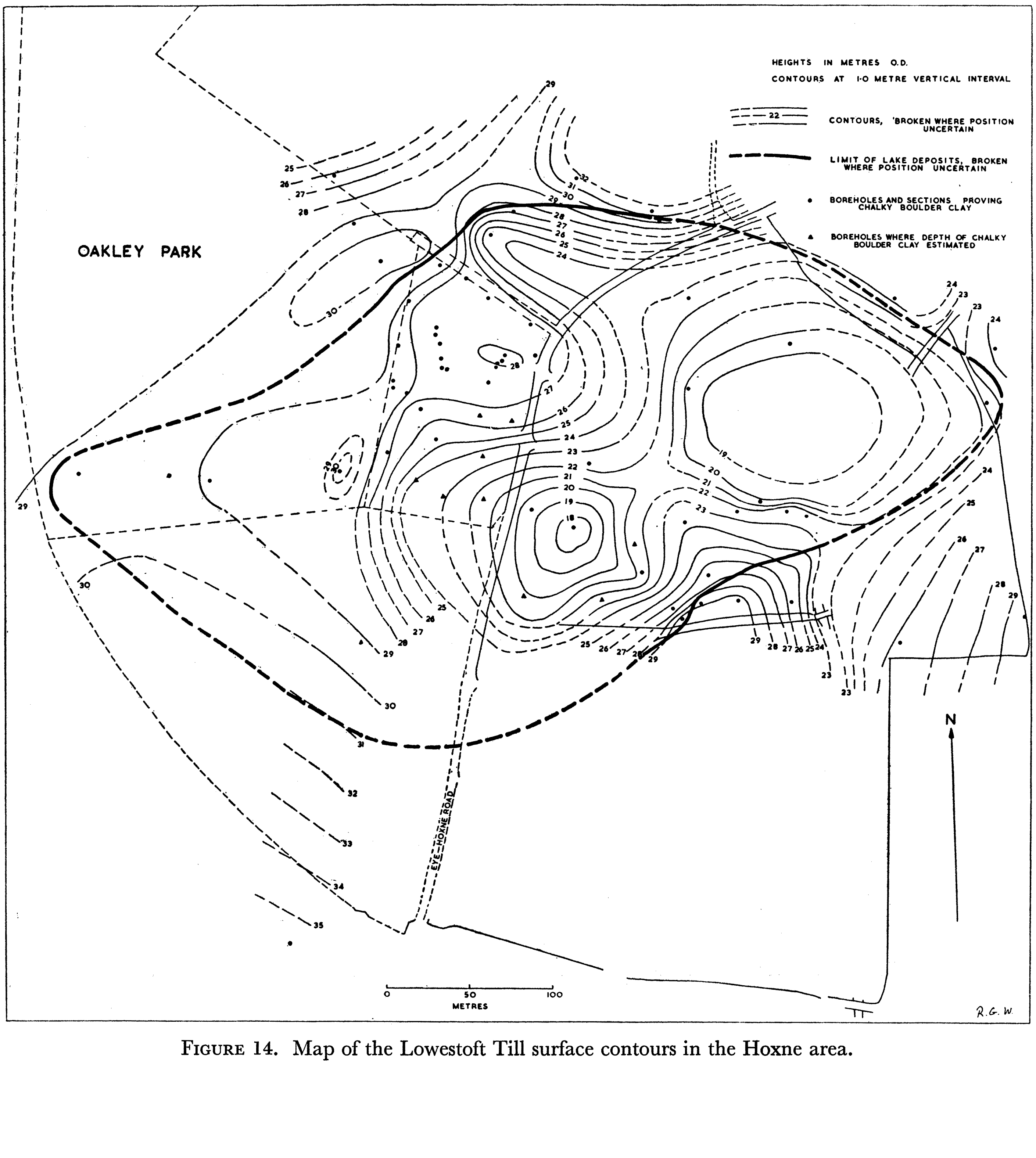

FIGURE 14. Map of the Lowestoft Till surface contours in the Hoxne area.

The absence of stratified drift, or any other deposit suggestive of retreat phenomena, in the basin between the boulder clay and the interglacial deposits suggests that a straightforward decay of the ice sheet took place in this area rather than a gradual recession of the ice.

The absence of a marked unconformity between the boulder clay and the interglacial deposits and the contours of the interglacial basin both indicate that the basin was not eroded in the boulder clay before the deposition of the interglacial sediments; sedimentation must have started soon after the disappearance of the ice, in a lake basin left on the melting out of the ice. This conclusion is supported by the pollen-analytical evidence.

It is impossible to estimate the original area of the lake basin, as large parts of it must have been removed by the later erosion. Outside the area of the lake deposits the boulder-clay surface contours are regular, and, as far as can be seen, follow the contours of the valleys, presumably a result of their erosion.

The chalky boulder clay of stratum G, known variously as the Great Chalky Boulder Clay, the Lower Chalky Boulder Clay, the Chalky Jurassic Boulder Clay and the Chalky Kimmeridgian Boulder Clay, is the Lowestoft Till of Baden-Powell (1948). Harmer (1910), from a study of the erratics, concluded that the ice which deposited this boulder clay moved in a general west to east direction in the neighbourhood of Hoxne, and this conclusion is fully supported by the more recent investigation of the erratics by Baden-Powell (1948) and by stone orientation measurements of the boulder clay (West & Donner 1956).

(ii) *Stratum F*

This stratum, mainly of grey clay-mud and marl, lies immediately above stratum G and is overlain conformably by the brown-green clay-mud of stratum E. It is separated from the latter by a thin transitional layer. The deposit was seen best in borehole no. 36 and in the excavation of section no. 100. In the borehole no. 36 its thickness was 45 cm, and it consisted of hard grey slightly sandy very calcareous clay-mud, with a 5 cm thick band containing chalk pebbles 18 cm from the base, and with irregular black laminations in the top 20 cm. This stratigraphy is made clear in the pollen diagram I*B*, figure 19. The pebbly layer in the middle of the stratum is probably the result of a minor solifluxion phase which brought coarser material into the centre of the lake basin; its lithology resembles that of the thin layer of grey sandy clay with chalk pebbles occurring at the top of the basal boulder clay.

In the section no. 100 the lithology of stratum F was slightly different from that found in the deeper part of the lake basin at borehole no. 36. Its base, seen in figure 35, plate 4, rested on the irregular surface of stratum G, and this junction was marked by a layer of non-calcareous coarse sandy detritus mud up to 1 cm thick. Above this was a layer 9 cm thick of grey calcareous shelly marl with abundant seeds, and then 20 cm of darker grey very calcareous shelly clay-mud. The pebbly layer of borehole no. 36 was absent. The fine lithological differentiation of stratum F is not shown in the profiles.

It is seen in profile D (figure 9) that the surface of the basal clay at section no. 100 is about 9 m higher than in the central part of the lake basin. The difference in the lithology of stratum F in the two parts of the lake basin is probably due to factors related to the depth of the water. The presence of the marl, and of the shells and many seeds of water plants, in the marginal facies of stratum F, and their relative absence from the deep-water facies, indicate that the lake bottom at section no. 100 was in the photosynthetic zone of the lake, with the precipitation of organic matter greater than in the deeper part of the lake.

The coarse mud at the base of stratum F in section no. 100 was slightly laminated and contained very compressed twigs and seeds of water plants. It must have been formed soon after the disappearance of the ice. Possibly this layer is in part derived from the humus formed by vegetation which was perhaps present on any ice melting out to leave the hollow; that is, it may be equivalent in origin to the Danish 'Allerød muld'. But as the mud is laminated and contains seeds of water plants and twigs, it is more probable that it is a drift mud formed under shallow-water conditions, before the water level had risen to its later height. The change in sediment from drift mud to marl to clay-mud indicates a gradual raising of the water level. Naturally this rise did not so much affect the sedimentation in the deeper part of the lake, where stratum F remains a more uniform clay-mud. The absence of a chalk-pebble layer in stratum F in section no. 100 may indicate that the water level did not reach the marginal parts of the basin at that time.

Stratum F was recognized in all the borings and sections in the lake deposits, except where weathering had obliterated its original colour (e.g. boreholes nos. 10 and 59). The profiles show the general distribution and thickness of the stratum. It was difficult to identify the different lithological types of the stratum from the auger samples. The previous conclusions regarding the lithological differences were based on borehole no. 36 and section no. 100, where the sediments could be seen uncontaminated. In general, the augering results support these conclusions. The drift mud was found, often as 'organic inclusions' at the base of the stratum in may places, including the deeper parts of the lake, but more frequently in the marginal parts. The marl was identified in three boreholes (nos. 4, 22 and 54) in the marginal parts of the lake deposits. Clement Reid also recognized it in a borehole (CR 15) in the marginal area.

It should be noted that the lithology and colour of stratum F bear a striking resemblance to a frequent type of late-glacial* sediment found resting on deposits of the Last Glaciation. That it is such a late-glacial deposit is proved by the pollen-analytical evidence.

(iii) *Stratum E*

Stratum E forms the greater part of the lake deposits, as seen in the profiles. It lies conformably between stratum F below and stratum D above. The sediment is an unstratified brown-green calcareous clay-mud, so compact that it has to be cut with a knife. There is remarkably little variation in the lithology of the clay-mud considering its occurrence in all parts of the lake basin, both shallow and deep. Conditions of deposition must have remained constant for a long time, and the lake must have been sufficiently deep to allow the deposition of profundal clay-mud both at the present margin and in the centre of the lake basin. The depth of water at the present edge of the lake deposits was probably more than 3 m.

* late-glacial, without capitals, is used here as an adjective denoting conditions just after any glaciation, not in its restricted stratigraphical sense (Late-Glacial Period) of the time just after the Last Glaciation.

The only variations in the lithology seen were: (*a*) in borehole no. 36, where two bands of a pale yellow very calcareous clay-mud were found near the base of the stratum (see stratigraphy of pollen diagram I*A*, figure 17); (*b*) towards the base of the stratum, where the clay-mud was found to be darker and more organic (e.g. borehole no. 61); and (*c*) where the clay-mud near the present surface has been weathered to a mottled red-grey or grey-blue colour and is more plastic, changes probably due to the loss of organic matter by weathering. The relation of the weathered parts of the stratum to the present surface is clearly seen in the profiles A, B, C and E (figures 6, 7, 8 and 10). In section no. 100 the transition from weathered to unweathered clay-mud showed polygonal lumps of the unweathered clay-mud separated by veins of weathered clay-mud. At first sight this looked like the result of reworking of the deposits during a time of lowered water level, but the pollen-analytical evidence described in § 5 shows that no reworking had occurred, and the effect was merely due to the appearance of the first phase of the weathering of the clay-mud.

The mineral fractions, carbonate and organic contents of five samples of stratum E were measured. The results are given in table 1. The analyses show the general constancy of the composition of the stratum. Sample no. 1 is from a band of the yellow variety of the clay-mud, and has a relatively high carbonate content. Sample no. 2, from the lower part of the stratum, has a rather higher proportion of fine sand and organic matter, the latter corresponding to the darker appearance of the clay-mud towards the base of the stratum. Samples nos. 3 and 4 from the upper part of the bed, closely resemble each other in their constitution. Sample no. 5 is from the weathered part of stratum E and shows a reduction of the organic content of the clay-mud, presumably by weathering.

TABLE 1. ANALYSES OF SAMPLES FROM STRATUM E

		percentages by weight of oven-dried samples				
sample	lithology	total carbonates ($CaCO_3$)	organic	clay (0·002 mm)	silt (0·02 to 0·002 mm)	fine sand (0·2 to 0·02 mm)
No. 1 borehole no. 36, core 16, top half	yellow clay-mud	48	18	22	11	1
No. 2 borehole no. 36, core 16, bottom half	brown-green clay-mud	18	23	24	23	12
No. 3 borehole no. 36, core 7, bottom half	brown-green clay-mud	35	17	23	22	3
No. 4 borehole no. 36, core 9, bottom half	brown-green clay-mud	36	20	18	21	5
No. 5 section no. 11, 225 to 255 cm	mottled blue clay-mud	32	10	39	15	4

At the centre of the basin stratum E is over $6\frac{1}{2}$ m thick (e.g. CR 8), but it becomes much thinner towards the edges of the basin, as seen in the profiles A, C and D (figures 6, 8 and 9). The regularity of the variation in thickness suggests that it is due to an original differential rate of sedimentation in the centre and at the edges, not to compression at a later date than deposition.

The change in colour of the clay-mud from stratum F to stratum E is probably primarily due to an increase in the organic content of the deposit as the climate ameliorated at the beginning of the interglacial period, but the change may have been assisted by the clothing of the boulder clay surface by vegetation and the subsequent reduction of calcareous matter washed into the lake.

The transition to the overlying stratum D is gradual and was only seen in one section, no. 37, where it was 15 cm thick. The clay-mud just below the transition often showed in the auger samples hard concretions (e.g. borehole no. 15). This may suggest reworking of the clay-mud during a time of lowered water level, but there was no evidence from the pollen analysis of this horizon that older material had been redeposited. It may be caused rather by post-depositional compaction and drying out of the sediment next to the more pervious overlying stratum.

It has been assumed up to now that the boulder-clay basin formed a lake and not a large river channel, mainly on the evidence of the configuration of the boulder-clay surface and its non-erosional junction with the lake sediments. The uniform nature of the sediments of stratum E confirms this conclusion. There are no variations in the lithology such as might result from the sorting action of running water. But the presence of clay, silt and fine sand in the sediment, as seen in the analyses, indicates that the water moved sufficiently to bring these fine fractions into the deposit (assuming only a small fraction blown in). Evidently there was a small flow of water through the lake, but not enough to disturb the uniform sedimentation of clay-mud.

(iv) *Stratum D*

Stratum D lies conformably on stratum E, but is overlain unconformably by stratum C. The sediment is a brown detritus mud, non-calcareous (in contrast to the calcareous beds above and below it), and easily recognizable in the auger samples. The bed was seen best in core no. 6 of borehole no. 36, where it was 27 cm thick. At the base the sediment was a brown fine detritus mud, slightly laminated, which passed upwards into a rather coarser detritus mud, still laminated, with pieces of wood; all the mud contained a very small proportion of clay and silt. The stratum was bounded at the top by a very sharp junction with stratum C.

Stratum D reaches a maximum thickness in the centre part of the lake basin, where it is up to 40 cm thick, thinning out towards the margins of the basin.

The change from stratum E to stratum D is marked by a reduction of the amount of mineral matter deposited, the sediment becoming a nearly pure mud. This reduction in the supply of clay and silt may have been caused by a halt in the flow of water through the lake, or by the prevention of mineral matter being washed into the lake by the growing over of the edges of the lake by vegetation. It is probable that at the same time the water level in the lake dropped, as the size of the mud particles is greater in stratum D than in stratum E. The increase in coarseness of the mud towards the top of the stratum, as seen in borehole no. 36, indicates a continuing change in the lake, probably dependent on the growing over of the lake and on a further drop in the water level. The edges of the lake, where the succession might have been clearer, have been completely removed by erosion, so it is impossible to say more of this change from the stratigraphical evidence. Further evidence about the change was obtained from the pollen-analytical results.

The unconformity forming the upper boundary of stratum D often cut it out completely, especially towards the edges of the basin (see profiles D and E, figures 9 and 10). The nature of the unconformity is described in the next section.

(v) *Stratum C*

This stratum lies unconformably on the lower lake deposits, but passes upwards conformably into stratum B. It is thickest (*ca.* $3\frac{1}{2}$ m) in the deepest part of the lake, and thins out towards the edges of the basin, forming a part of the series of lake deposits. The lithology of the stratum was seen best in the cores of borehole no. 36. Here, in the lower part of the stratum, the sediment was a grey-brown sandy silt, rich in organic matter, with wood fragments, occasional leaves, lenses of drift mud, and a proportion of clay-mud pebbles. Upwards this passed into yellow and grey laminated calcareous muddy silt, which alternated with compact brown-grey brecciated clay-mud, giving the kind of stratigraphy seen in figure 36, plate 5. The laminations of the muddy silt were distorted by small-scale slumping and faulting. The breccia was unstratified, slightly calcareous, and consisted of small pebbles of clay-mud with a few of clay. These pebbles were from 2 to 10 mm across, and clearly partly derived from stratum E. In places the pebbles were decalcified. Occasionally small chalk pebbles and small flints were present in the breccia and the silt, and small lenses of drift mud and wood occurred throughout the stratum. The yellow and grey silt at the top of core no. 1 passed upwards into further bands of silt and breccia and then into the gravel of stratum B.

In the auger samples from stratum C the microstratigraphy was distorted, and it was impossible to see all the structures revealed in the cores of borehole no. 36. The stratum could always be identified in the auger samples by the presence of brecciated clay-mud with interbedded sandy and silty layers.

The only variations from the lithology described above were: (*a*) in borehole no. 46, where above stratum E there was a brown-green clay-mud resembling the lower bed, but which contained chalk pebbles and drift wood and was therefore included in stratum C; (*b*) in boreholes nos. 15, 38 and 39, where there were a greater number of chalk pebbles present; and (*c*) where the deposit came to near the surface it was weathered to a greyer colour (e.g. section no. 17).

In borehole no. 36 the base of the stratum was very sharply marked off from stratum D. From the stratigraphy seen here, it appears that the change from stratum D to stratum C here took place in water, the level of which had risen since stratum D times. There must have been a period of erosion leading to the destruction in part of stratum D and to the unconformity between strata D and C, at a time of lower water level before the deposition of stratum C.

The muddy stratified silt of the stratum was evidently deposited in water, probably fairly shallow. The clay-mud pebbles of the breccia contained pollen which showed that they were derived from the marginal lake deposits, presumably by reworking when the water level had fallen. The decalcification of some of the clay-mud pebbles, described above, probably took place by weathering during the reworking. The chalk pebbles and flints must have been derived by solifluxion from the boulder clay near the edges of the lake basin, and the layers of drift mud were formed by either the reworking of stratum D or the accumulation of drifted material at the edges of the lake during times of low water level.

This stratigraphy resembles that described by Hawkins (1953) of deposits of alternating silt and chalk breccia at Ashford Hill, Berkshire. Hawkins ascribed this alternation of breccia and silt to deposition of chalk breccia from the Chalk at the edges of a basin during spring-time thaws when the ground was frozen, and then later in the summer, when the water level had risen, the deposition of varved silts occurred.

The same kind of explanation may be applied to the alternation of sediments in stratum C. At periods of relatively high water level (but probably not as high as at the time of deposition of the clay-mud of stratum E) the muddy silt was deposited; when the water level dropped the marginal lake deposits were reworked and later redeposited over the bottom of the lake. The irregularity of the alternations suggests that they were not seasonal.

The lateral movement of the marginal brecciated clay-mud towards the centre of the lake was probably due to solifluxion at times of lower water level. The presence of chalk pebbles and flints in the stratum, and the apparent increase in their number towards the edges of the basin (e.g. boreholes nos. 15, 38 and 39), indicate a lateral movement of some power, as these must have been derived from deposits beyond or below the lake deposits. The lateral movement may have been assisted by rafting on ice when the lake was frozen.

The erosional unconformity between stratum C and the lower deposits, seen well in the profiles B, D and E (figures 7, 9 and 10), suggests that the water level dropped considerably at the beginning of stratum C time. At section no. 100, and in other places in the marginal parts of the lake deposits and sometimes nearer the centre, stratum D and parts of stratum E were found to be missing from under stratum C; they were probably removed by erosion, reworking and solifluxion at times of low water level during and before the formation of stratum C. The absence of obvious silt layers in the stratum in sections towards the margins of the lake (e.g. section no. 100) may indicate that the water level at the time of deposition of the silt was too low for it to accumulate at that height.

To summarize, stratum C was formed during a period of fluctuating water level in the lake, accompanied by reworking of the marginal lake deposits and the movement of reworked material, together with stones from below or beyond the lake deposits, to the central parts of the lake by solifluxion. These processes point to a periglacial climate during stratum C time.

(vi) *Stratum B*

This stratum of stratified clay, sand and gravel lies conformably on stratum C, from which it is separated by a transitional layer, and is overlain unconformably by stratum A 2. The stratum reaches a greater thickness in the central part of the lake basin than elsewhere, and it is clearly seen in the profiles to belong to the series of lake deposits, representing the latest preserved stage of the infilling of the lake basin.

Section no. 18 (figure 34, plate 4) was in the central part of the lake basin, and showed the nature of the stratum in that area. It consisted of roughly stratified clay, sand and gravel, with seams of chalk pebbles, obviously sorted and in part waterlain. Fresh-water shells were occasionally present in the deposit, but no other organic remains were seen in the section, nor was there any brecciated clay-mud. The gravel passed down into the brecciated clay-mud and silt of stratum C, and it was overlain by blue-yellow clayey sand of stratum A 2.

This kind of deposit was identified in borings near the centre of the lake (e.g. boreholes nos. 2, 14 and 47). In the southern part of the Oakley Park pit, however, it disappeared west of borehole no. 2, and was replaced by a much less stony deposit of clay and sand, non-calcareous at the top but containing chalk pebbles at the base. The clay and sand were roughly stratified and the dip of the beds was in accordance with the shape of the lake basin. The stratum was cut across unconformably at the top by stratum A 2, and it rested conformably on the brecciated clay-mud and silt of stratum C. This succession is made clear in the profile C (figure 8), in the region of borehole no. 15. The roughly stratified sand and clay contained occasional wisps of brecciated clay-mud, but no other traces of organic matter. The deposit differed from the gravelly part of the stratum chiefly in the lack of stones, but also in being non-calcareous at the top. The latter was probably caused by post-depositional leaching.

It was difficult to ascertain the exact relations of the gravelly to the non-gravelly parts of the stratum, but their general similarity in being stratified mineral deposits, and in their conformity with stratum C and unconformity with stratum A 2, indicates that they should be included in the same phase of deposition.

The clay, sand and gravel of the stratum may either have been brought into the lake from a distance by running water or have been the result of solifluxion from the ground surface at the edges of the lake. It is unlikely that the former explanation is correct, as this surely would have produced better sorted deposits lying in a channel cut in the lake deposits, with an unconformity between strata C and B. Although some mineral matter may have been brought into the lake by slow running water, it is more probable that solifluxion introduced the material into the lake, where it was to some extent sorted by the water. Such a process would have been assisted by rafting on ice when the lake was frozen.

The water level of the lake at this time appears to have been higher than in the previous episode of deposition, because of the comparatively well-stratified appearance of the deposits and the scarcity of the breccia, the latter indicating that there was little or no reworking of the older deposits during this period.

It may be concluded that during the deposition of stratum B a periglacial climate, perhaps more severe than previously, continued.

(vii) *Stratum A 2*

This stratum of clay, sand and hoggin* (the last shown later to be till) lies unconformably on the lake deposits and the chalky boulder clay of stratum G. Upwards it

* Hoggin—a deposit of sand and gravel as occurring in nature and containing a proportion of clay which is sufficient to hold the mass together. This definition is given by the Road Research Laboratory of the Department of Scientific and Industrial Research.

merges with the surface deposit, stratum A1. The deposit reaches a thickness of about $2\frac{1}{2}$ m in the southern part of the Oakley Park pit, and it thins out towards the present boulder-clay surface to the north and south. To the east and west it is cut out by the valleys (profile B, figure 7). It is very thin in the northern part of the Oakley Park pit, and it is here mixed with the weathered clay-mud of stratum E by cryoturbation (profile F, figure 11). The stratum was found mainly on the lake deposits and no great thickness was proved on the boulder clay, although some of Reid's boreholes (CR16 and 17) show that quite a thickness may rest on it. The stratum is seen in figures 32, 33 and 34, plate 4.

Deposits rather similar to stratum A2 were found in the valleys (e.g. boreholes nos. 49 and 77), but these were not included in it, for, as seen in profile C (figure 8), they must post-date the cutting of the valleys, while the deposits of stratum A2 on the saddle between the valleys were evidently formed before the present valleys were excavated.

The sediments of stratum A2 vary from clay to sand and hoggin, all of them unsorted and non-calcareous. The three main variants seen were: (*a*) red or mottled red-grey sandy clay and clayey sand with a few small stones (e.g. sections nos. 17 and 97); (*b*) red and brown sand with a few small stones (e.g. section no. 95 and the sections disturbed by cryoturbation at the northern end of the Oakley Park pit); and (*c*) reddish sandy hoggin (e.g. sections nos. 81 and 100 and the stony raft at the southern end of the Oakley Park pit).

In many of the sections more than one of these types were present. For example, in no. 81 mottled red-grey sandy clay was overlain by red sandy hoggin. The interdigitation suggests that the stratum can be considered as one unit, in spite of its diversity of sediment.

Although the different types of sediment making up the stratum are unstratified and unsorted, they occur distinct from one another. This suggests that the deposits are of more than one origin. The clays and sands have few features which might be used in evidence of their origin, apart from their lithology suggesting an agency which excludes the action of water. Such an agency might be ice, solifluxion or wind, or a combination of these. Some of the cleaner sand at the top of the stratum certainly appears to be aeolian in origin. The structure of the hoggin layers, however, gave some evidence of their origin. The hoggin is unstratified and unsorted. Measurements made by West & Donner (1956) of the orientation of the long axes of the stones in it, in three different exposures, gave long-axis maxima in a general north-north-westerly direction, indicating that the forces responsible for deposition moved parallel to that direction. There are two possible modes of deposition giving such a structure in unsorted material, by solifluxion and from ice. The stone diagrams from solifluxion deposits usually show a dip in the direction of the solifluxion slope, but the diagrams obtained from the hoggin show that many of the stones were level and the dip of the remainder was at random. Moreover, the direction of preferred orientation is conformable to the direction of movement of the ice of the Gipping Glaciation (West & Donner 1956). The evidence suggests it was ice rather than solifluxion which deposited the hoggin, and that this is therefore probably a till.

Baden-Powell has made a study of the erratics in the hoggin (with the results given in appendix 2), and has shown that it contains a suite characteristic of his Gipping Glaciation. He concluded from the erratics that the ice of this glaciation moved into the area from the north-west, a direction agreeing with that obtained by measurement of the preferred orientation of the stones.

From the lithological evidence it may be concluded that the deposition of the stratum was due to more than one cause, the clays and sands being deposited by ice, solifluxion or wind, and the hoggin by ice.

The stratigraphical evidence for the origin of the hoggin supports the conclusion that it was deposited by ice. The following considerations make this clear:

(*a*) There is a clear unconformity between stratum A 2 and the lower beds. The latter were therefore eroded prior to the deposition of the stratum.

(*b*) There is no sign of disturbance in the beds just below the unconformity, except where the stratum is thin enough to allow mixing with the lower deposits by the later cryoturbation phase. Thus the beds below the unconformity were not disturbed by the deposition of stratum A 2.

(*c*) The unconformity takes no account of the lake basin, indicating that the erosion which occurred between the deposition of stratum A 2 and the lower beds was very considerable and must have changed the landscape enough to obliterate the lake basin as a feature. Also, compression of the lake beds must have been complete by the time of the erosion, probably taking place chiefly during the deposition of strata C and B.

(*d*) The lake deposits are found beneath the highest part of the local land surface in the neighbourhood (borehole no. 101). There is therefore at present no source for solifluxion in the area adjacent to the lake basin.

(*e*) The stony raft is roughly horizontal. The top surface of the raft was levelled in thirty-five places along the outcrop; the results showed no consistent differences in level. This position of the raft indicates that it did not move down the slope of unconformity (also suggested by the random dip of the long axes of the stones in the raft).

The evidence against solifluxion as the agent of deposition is considerable. If the overlying material originated by solifluxion, the unconformity would have been in the freeze and thaw zone above the permafrost (assuming this type of solifluxion involves low temperatures), and would have been distorted by the movement of the overlying material. The base of solifluxion deposits is usually characterized by a transition to the lower deposits, and by disturbance of the latter, but there was no sign of such disturbance, nor did there appear to be any incorporation of the lower beds into the stratum. It is also difficult to explain the horizontal position of the stony raft by solifluxion.

Supposing that solifluxion caused the deposition of stratum A 2, the following sequence of events must have occurred: the erosion of the lake basin after the solifluxion processes responsible for depositing stratum B, then a recommencement of solifluxion from a source containing erratics typical of the Gipping Glaciation, a source which has since disappeared. It would be difficult to argue the plausibility of such a sequence from the existing evidence.

On the other hand, if ice was responsible for deposition of the hoggin, the above observations would be explained and the sequence of events would be simpler. The ice, advancing from the north-north-west direction indicated by the erratics and the preferred orientation of the stones, rode over the lake basin and then deposited the hoggin. The clear unconformity is quite possible under these conditions, as shown by the numerous East Anglian sections with a level contact between lodgement till and the sand below it.

It is not possible to say whether there was a long interval of time between the deposition of strata A2 and B. The unconformity between them may be due to a period of erosion, or it may have been caused by the erosion of the ice.

Thus both the lithological and stratigraphical evidence indicate that the hoggin of stratum A2 is a till.* This does not mean that the other lithological variations of the stratum were deposited in the same way. For example, the clayey sand found on top of the hoggin in some places may have been deposited by wind action or by other periglacial agencies later in the same glaciation that brought till to the area or in a later periglacial phase.

It is impossible to say whether the stratum was primarily calcareous or not. Although Moir (1926, 1935) described chalky patches, it was found to be non-calcareous wherever it was proved in the investigations described here, except sometimes at its very base (e.g. section no. 18). The sandy nature of the stratum would certainly aid the processes of decalcification.

The question of the deposition of the stratum in terms of the landscape changes is important. It is evident from the profiles that the stratum is thickest on the saddle between the river valleys, and that the unconformity between stratum A2 and the lower beds is cut off by the valleys. It follows that the stratum was chiefly deposited before the excavation of the valleys (the east-west section given by Reid (1896) suggests the same). The superficial sandy parts of the stratum may have been formed later, perhaps during the valley formation. It is impossible to say how much the stratum has been altered by the later periods of erosion, and whether its thinness in the north face of the Oakley Park pit is due to deposition or erosion.

It is not possible to date more accurately the valley erosion. Such a topographical change must have required considerable forces, and it seems more likely that it took place in a periglacial climate after the retreat of the ice than during a subsequent warm period. The erosion may be related to the formation of Lopham Gap, as described in the summary of the geological history.

(viii) *Stratum H*

The deposits forming this stratum lie in the valleys, and are covered by stratum A1. They consist of mottled clay, sand and gravel, muddy in the flood-plains of the present streams. The deposits were not bottomed, the borings being stopped by stones at a depth of about 2 m. They probably lie on the chalky boulder clay of stratum G. The sandy parts of the stratum near or on the flanks of the valleys (e.g. nos. 49, 50 and 77) may be partly deposited by hill-wash down the slope from stratum A2 during or after the erosion of the valleys, but in general the stratum must be a fluvial deposit.

(ix) *Stratum A1*

This stratum overlies all the other deposits and forms the surface of the whole area, both on the divide and in the valleys, except for the flood-plains of the River Dove and the Gold Brook. The deposit consists of grey or brown fine sand with occasional stones up to 5 cm across. Most of the stones are flints, and they are generally frost-shattered and wind-

* This conclusion differs from Baden-Powell's opinion on the nature of the hoggin, given in appendix 2.

polished. The thickness of the deposit averages about 60 cm; it is thicker in the lower parts of the terrain (e.g. borehole no. 76) than on the higher parts (e.g. section no. 101). The sand resembles a blown sand (Flugsand) and it must have been formed by wind action from strata A2 and H. The stones in it were probably derived from the same beds.

The lithology suggests that the deposit was formed during a periglacial climate, when wind and frost action were active. The top of the sands would be reworked by wind and stones introduced into the blown sand by frost-heaving. The cryoturbation seen in the north face of the Oakley Park pit (profile F, figure 11) and of the chalky boulder clay near the surface (e.g. section no. 24) probably took place at the same time, as it is parallel to the present surface.

(*d*) *Weathering of the deposits*

Besides the decalcification of the surface deposits noted previously, the clayey deposits, such as the chalky boulder clay and the clay-muds of strata F, E and C, are weathered where they rise to near the surface to the mottled grey-blue-red colour characteristic of the gley horizon of waterlogged soils. Evidently a fluctuating water table has caused alternating conditions of oxidation and reduction which have destroyed a proportion of the organic content of the clay-mud, as seen in the analyses of the sediment of stratum E (table 1). The depth of mottling varies from 1 to 2 m, presumably dependent on the amount of movement of the water table and the thickness of the sandy covering deposits. The relation between the mottling and the present surface, seen well in the profiles, shows that the weathering took place after the present topography was formed.

The top 10 or 20 cm of the clay-mud where it is weathered is leached (the rest is calcareous though mottled), and at the base of the leached zone a purple layer, up to 5 cm thick, is usually present (e.g. section no. 11). This is probably a layer of accumulation of iron and manganese, both in a mobile state under conditions of impeded drainage. Race is often present at the base of the leached zone (e.g. section no. 11). Both the leached zone and the purple layer follow the surface disturbed by cryoturbation, so the weathering must have been proceeding since the time of cryoturbation.

(*e*) *Summary of the geological history*

The Lowestoft Till (stratum G) at the base of the lake deposits was laid down by ice of the Lowestoft Glaciation advancing from west to east. On the melting out of the ice a kettle-hole was formed, and in this, after a short solifluxion phase, a series of lake sediments was deposited. First, late-glacial sediments were laid down (stratum F). In the deepest part of the lake these consisted of a grey very calcareous clay-mud, and at the margins of the lake, a drift mud, then a marl, and finally a grey very calcareous clay-mud were deposited. The latter sequence suggests that the water level was rising during this period. During the late-glacial time, there was a reversion to the previous severe climate and a solifluxion deposit in the central part of the lake basin resulted.

After the formation of the late-glacial deposits, the amelioration of the climate caused an increase in the organic content of the clay-mud, which became darker in colour (stratum E). A long period ensued, during which the deposition of this brown-green clay-mud continued. The water level must have remained fairly constant, with a considerable depth of water in the lake (probably over 3 m at the present edges of the lake basin) during the

TABLE 2. SUMMARY OF THE STRATIGRAPHY AND OF THE LAKE, VEGETATIONAL AND CLIMATIC HISTORY OF THE HOXNE INTERGLACIAL

stratum	sediment	mode of deposition	lake history	stage	sub-stage	vegetation	archaeology	climate
A2	Glacial deposits unrelated to the lake basin				—	—	Derived artifacts	Glacial
			Erosion					
B	Stratified clay, sand and gravel	Severe solifluxion into lake	Compression of lake sediments completed. High water level?	—	—	—	Derived artifacts	Periglacial, arctic
C	Silt, drift mud and brecciated clay-mud	Solifluxion into lake and reworking of lake deposits	Fluctuating water level. Rise in water level	Early-Glacial stage IV	—	Park-tundra with arctic willows and *Betula nana*; oceanic heaths (?); forest distant or very scattered, mainly with *Betula*, *Pinus*, *Picea*, *Abies* and *Alnus*	—	Periglacial, arctic or sub-arctic Oceanic?
			Erosion					
D	Detritus mud	Normal lacustrine	Shallow water, and growing over at lake edges	Late-Temperate stage III	—	Decline of mixed-oak forest. Rise of *Pinus* and *Picea*; immigration of *Carpinus* and then *Abies*; local alder carr	—	Continuing deterioration
E	Clay-mud	Normal lacustrine	Drop in water level? Deep water	Early-Temperate stage II	*d*	Forest returns to previous state Deforestation phase. *Betula* and *Pinus* rise; *Ulmus*, *Quercus* and *Corylus* decline; high non-tree pollen Mixed-oak forest continues. *Ulmus* replaces *Tilia*; *Betula* and *Pinus*, low at first, rise slowly towards the end; *Fraxinus* rises and declines; culmination of *Corylus*	(Charcoal) Hand-axe Flakes (Bones)	Beginning of climatic deterioration Mild and oceanic
					c	Mixed-oak forest continues. *Betula* and *Pinus* decline; *Quercus* high; *Tilia* and *Alnus* rise; *Corylus* rises slowly; in latter half, *Picea* and *Ilex* begin to appear consistently	—	Thermal optimum?
					b	Mixed-oak forest rises to dominance. *Betula* and *Quercus* high; *Pinus* culminates; *Fraxinus* with a small maximum; *Corylus* low; *Hedera* immigrates	—	Mild and oceanic
					a	Formation of closed forest with *Betula* dominant and low *Pinus*; immigration of thermophilous trees	—	Rapid amelioration
F	Clay-mud at centre, and clay-mud, marl and drift mud at edges of lake	Normal lacustrine, with one phase of solifluxion (in substage I *d*)	Water level rising	Late-Glacial stage I	*e*	Open parkland with *Betula* copses	—	Less severe than sub-arctic
					d	Open *Hippophaë* scrub		
					c	Open *Hippophaë* scrub with scattered *Betula*		
					b	Open *Hippophaë* scrub		
G	Formation of lake in boulder-clay basin on disappearance of ice			I *a* in periglacial areas		—	—	Glacial

whole of this period. Some water probably flowed through the lake, but very slowly, during the deposition of strata F and E.

After stratum E was formed, the mud of stratum D was deposited. The reduction in mineral matter in the sediment may reflect either the decrease in the flow of water through the lake or the growing over of the vegetation at the edge of the lake and the consequent prevention of the washing of mineral matter in the lake. The water level in the lake was probably lowered slightly in stratum D times, but rose again later before the next episode of deposition.

Next, the deposition of stratum C took place during conditions of fluctuating water level, causing the reworking and brecciation of the marginal lake deposits, with solifluxion of reworked material and mineral matter from the adjacent drift deposits towards the centre of the lake. An unconformity formed between strata D and C was probably caused by erosion through changing water level and solifluxion.

The deposition of stratified clay, sand and gravel of stratum B then followed conformably. This sediment was probably derived from the flanks of the lake basin by solifluxion, with subsequent sorting in water. Brecciated clay was rarely deposited; probably the water level had risen and the reworking at the margins had ceased. Both strata C and B were evidently deposited under periglacial conditions.

After the deposition of stratum B the topography changed completely. The compaction of the lake sediments must have been accomplished by this time. The lake basin as such was destroyed by erosion. The deposition of unsorted clay and sand, and till, followed the erosion. The till was deposited by the ice of the Gipping Glaciation coming from the north-north-west; the clay and sand may have been deposited similarly or by other means during a later period of the same glaciation.

After the retreat of this ice, valleys were excavated on either side of the lake basin. This erosion is probably associated with the formation of Lopham Gap, an overflow channel which joins the sources of the Little Ouse and Waveney Rivers, 7 miles up the Waveney Valley from Hoxne. This channel must have been an outlet for water ponded up in the Fens, perhaps during a later glaciation or in a later phase of the Gipping Glaciation.

Following the erosion the clay, sand and gravel of stratum H were deposited in the valleys. A wind-blown sand was then distributed over the whole area, probably under periglacial conditions and at probably the same time, cryoturbation occurred where a sand and clay interface was near enough to the surface.

Since then there have been no changes in the topography, but the weathering of the clayey deposits near the surface has taken place.

Table 2 summarizes the lake history.

3. The interpretation of previous stratigraphical research

(a) *Introduction*

Detailed stratigraphical studies of the deposits at Hoxne were made by Prestwich (1860), Reid (1896) and Moir (1926, 1935); sections were also described by Frere (1800), Belt (1876) and Woodward (1887).

All the earlier data from borings and sections fit in with the interpretation of the stratigraphy given here. This interpretation, however, differs from that given by Clement

Reid and Reid Moir with regard to the position in the succession of the marginal lake deposits. This difference and its origin are described in detail, as the matter is important in relation to the placing of Palaeolithic artifacts in their correct stratigraphical position. The discussion, although mainly concerning stratigraphy, makes some mention of the biological evidence for climatic changes during the formation of the deposits. It thus anticipates to a small extent the evidence described later, but this is unavoidable if all aspects of the previous interpretation of the stratigraphy are to be considered together.

(*b*) *Frere*

John Frere described a section in the old pit to the east of the Eye–Hoxne road in a letter written in 1797 to the Society of Antiquaries. The section was:

	1.	Vegetable earth	$1\frac{1}{2}$ ft.
A2	2.	Argill	$7\frac{1}{2}$ ft.
B	3.	Sand, mixed with shells, and other marine substances	1 ft.
B	4.	A gravelly soil, in which the flints are found generally at the rate of five or six in a square yard	2 ft.

Beneath no. 4 Frere observed 'boggy earth'.

The column on the left of the section gives the probable attributions of the deposits to the strata recognized in the present work. Frere described shells and bones from his bed no. 3, so this layer was presumably calcareous and must belong to stratum B. Frere also mentioned that the bed no. 4 was stratified, so that it probably belongs to the same stratum. The 'boggy earth' must then be stratum C. Both Clement Reid and Reid Moir considered that Frere's beds nos. 3 and 4 belonged to the gravelly layer identified here as stratum B.

Frere said about the origin of the deposits: 'It may be conjectured that the different strata were formed by inundations happening at distant periods, and bringing down in succession the different materials of which they consist; to which I can only say, that the ground in question does not lie at the foot of any higher ground, but does itself overhang a tract of boggy earth, which extends under the fourth stratum; so that it should rather seem that torrents had washed away the incumbent strata and left the bog earth clear, than that the bog earth was covered by them, especially as the strata appear to be disposed horizontally, and present their edges to the abrupt termination of the high ground.'

Frere thus realized that much erosion had taken place since the deposition of the strata, and this suggested to him the great antiquity of the implements found in the bed no. 4.

(*c*) *Prestwich*

The first detailed investigations of the stratigraphy were made by Prestwich in 1859 and 1860, soon after he returned from his examination of Boucher de Perthes's sections in the Somme Valley. Prestwich had several trenches and boreholes made. The most complete sequence of strata was seen in a section exposed at the south-west corner of the old pit at the time of Prestwich's first visit. The section showed:

	a.	Surface soil	1 to 2 ft.
A2	*b.*	Brown and grey non-calcareous clay	12 ft.
B	*c.*	Flint gravel with small chalk pebbles	$\frac{1}{2}$ to 1 ft.
B or C	*d.*	Blue and grey calcareous clay	3 to 4 ft.
B or C	*e.*	Gravel like *c*	1 to $2\frac{1}{2}$ ft.
C (and E?)	*f.*	Calcareous grey clay, not bottomed at	17 ft.

The letters on the left show the attribution of the different deposits to the strata described in the present work. The two layers of gravel at the base were not seen recently, but an intercalated bed of clay in the gravel is the kind of variation to be expected in solifluxion deposits.

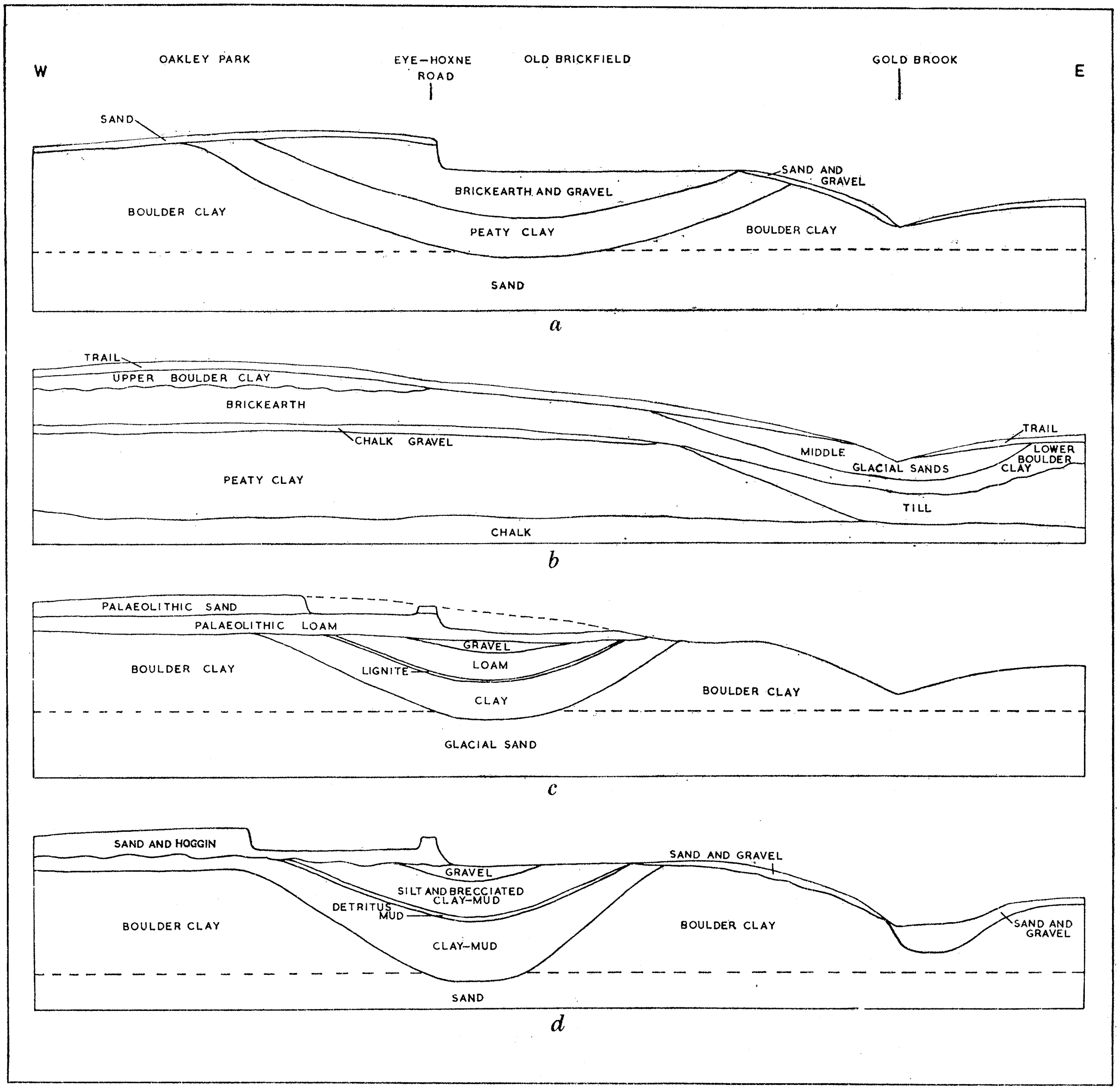

FIGURE 15. Diagrammatic profiles showing various interpretations of the stratigraphy at Hoxne. *a*, Prestwich; *b*, Belt; *c*, Reid; *d*, the author.

Prestwich's results conform with the present interpretation of the stratigraphy. He concluded that the deposits lay in a hollow in the boulder clay, and that they all originated in a fresh-water lake, except for the superficial patches of sand and gravel, which he believed were a part of the general drift of the area and not of local origin. He also saw that valley formation had taken place after the filling up of the lake. Prestwich's interpretation of the stratigraphy is shown in figure 15*a*, which is a simplified reproduction of the east-west section given in his paper.

(*d*) *Belt*

Thomas Belt made an investigation of the deposits in 1876. He regarded the overlying sand and clay which he saw in a pit in Oakley Park as boulder clay, and concluded that all the beds below it were interglacial, or perhaps preglacial, as boulder clay had never been proved beneath the basal peaty clay of Prestwich's deep section described above.

Belt's interpretation of the stratigraphy, given in figure 15*b*, is very complicated and rather obscure, and is thought not worth further consideration here.

(*e*) *Woodward*

A section in the old pit was recorded by H. B. Woodward in 1878. It showed:

Gravel and sand	3 ft.
Brown loam passing down into blue sandy clay, with a seam of gravel that merged in the eastern part of the pit into the overlying gravel. In this seam of gravel Mr Reid found a Palaeolithic implement	6 ft.
Chalky boulder clay	

This section is of interest because it shows merging of gravel, probably belonging to stratum B, with superficial gravel on the flanks of the valley of the Gold Brook. This is presumably due to the cutting of the valley and subsequent incorporation of the lake deposits into the hill-wash on the sides of the valley.

Woodward also mentioned that small pockets of boulder clay had been found lying on the 'brickearth', above the interglacial deposit.

(*f*) *Clement Reid*

The next investigation of the stratigraphy was made by a Committee of the British Association for the Advancement of Science in 1895 and 1896. The object of the Committee was to 'ascertain by excavation at Hoxne the relations of the Palaeolithic deposits to the Boulder Clay, and to the deposits with Arctic and Temperate plants'. Clement Reid supervised the work at Hoxne and wrote the Report of the Committee.

Twenty borings were made in a line roughly east-west across the deposits, and a trial pit was dug where the deposits were supposed to be deepest (figure 2 gives the positions of most of these boreholes and sections). The interpretation of the stratigraphical data obtained from this work was given in an east-west section, shown in figure 15*c*.

The following sequence of beds was recognized:

A1 and A2	Palaeolithic sand	A
E	Palaeolithic loam	
B	Palaeolithic gravel	B
C	Black loam with arctic plants	C
D	Lignite with temperate plants	D
E and F	Clay with temperate plants	E
G	Boulder clay	
	Glacial sand	G

The Committee's lettering of the beds is given on the right of the list, and on the left is the correlation of these beds with the strata described in the present work. In the following discussion the words 'bed' and 'stratum' refer to the Committee's and the author's naming of the strata respectively.

The conclusions of the Committee about the history of the deposit were: 'After the disappearance of the ice which deposited the Chalky Boulder Clay—how long after we do not know—the land stood somewhat higher than at present, so that the Hoxne channel could be excavated to a depth slightly below that of the present main channel of the river Waveney. Then gradual subsidence turned this channel into a shallow freshwater lake, in which 20 feet of the lacustrine clay E was deposited. After the lake had silted up it was overgrown by a dense thicket of alders, which by their decay formed the lignite D, containing a temperate flora like that of Bed E. Next a further slight subsidence, or perhaps an irregular silting up of the lower part of the channel, caused lacustrine conditions to reappear, and another 20 feet of lacustrine strata (C) to be deposited; but the climate had again become colder—in fact it was an Arctic or sub-Arctic one. Then followed the floods which deposited the Palaeolithic Beds B and A, only parts of which seem to be truly fluviatile; and finally the strata became sandy and perhaps of aeolian origin.'

The Committee was not able to form any conclusions about the climate prevalent during the deposition of the beds A and B, as the fossil assemblages contained no species characteristically northern or southern.

The author's interpretation differs from the Committee's in two main respects. First, the assumed excavation of a channel in the boulder clay and the subsidence of this channel before the deposition of the lake sediments is disproved by the evidence given previously. Secondly, the unconformable covering deposits of bed A, the Palaeolithic sand and loam, are now interpreted as including parts of strata A1, A2, E and F, as seen in figures 15*c*, *d* and 16.

This second modification is a fundamental one. The Palaeolithic sand agrees in its distribution with strata A1 and A2, but the position of the Palaeolithic loam in the two interpretations is obviously very different. The Palaeolithic loam, considered by the Committee to lie unconformably on the beds B, C, D and E, is described as stretching into Oakley Park (e.g. CR13, CR14), but in the profile C (figure 8) it is seen to be the same as the weathered part of stratum E, dipping down under beds B, C and D (equivalent to strata B, C and D) towards the east of Oakley Park.

In four borings (CR6, CR13, CR14 and CR15) the Committee found the Palaeolithic loam lying directly on the boulder clay. These borings are all in the marginal part of the lake basin, and the deposit is in fact weathered stratum E clay-mud. CR21, described as a section in the Palaeolithic sand and loam on the north face of the Oakley Park pit, shows a very similar succession to the recent sections on the north face (e.g. no. 11), in which the sands of strata A1 and A2 are seen overlying weathered clay-mud of stratum E, as shown in profile A (figure 6). It is clear that the Palaeolithic loam of these borings and the section is the weathered clay-mud of stratum E.

The Committee evidently separated the weathered from the unweathered part of stratum E, calling the former the Palaeolithic loam of bed A and the latter bed E. They were probably led to do this by the difference in appearance between the weathered and the unweathered clay-mud.

The Committee's correlation of the weathered deposits at the edge of the lake basin with the superficial deposits in the central parts of the lake basin, on which depends the theory that the Palaeolithic loam overlies unconformably the lower lake beds, rests on this evidence: first, on the assumption that the sections on the north face of the Oakley Park pit were similar to the sections in the superficial deposits in the old pit on the other side of the road; and secondly, on the identification of the Palaeolithic loam above the lower lake deposits in the central parts of the lake basin.

Regarding the first point, that this assumption was made is easily seen by referring to the Committee's description of bed A: 'This is the only deposit usually exposed in the brickyard, and from it the Palaeolithic implements are obtained. Hoxne Brickyard for many years seems to have been worked mainly for this upper brickearth, from which are

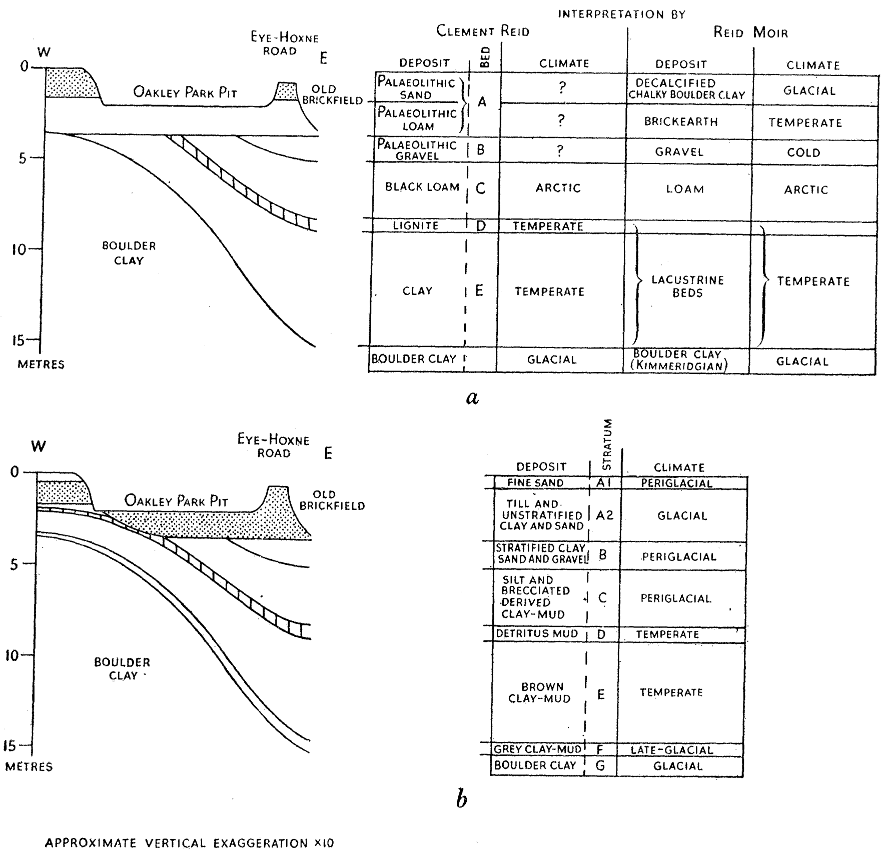

FIGURE 16. Diagrammatic profiles through the western part of the deposits showing the interpretation of the stratigraphical and climatic succession by Clement Reid and Reid Moir (*a*) and the author (*b*).

made the red bricks. It thus happens that over an extensive area nearly the whole of bed A has been removed, and the sides of the pit are so overgrown that it is difficult to obtain detailed measurements. There are clear sections, however, on the opposite side of the road in the new pit in Oakley Park where this brickearth is now worked; the material from which were obtained the fossils given in the list was therefore taken from that pit. The sections in the old yard, as far as they can now be examined, are similar, and fossils and flint implements occur there in the same manner.'

The succession of beds described by the Committee is therefore a composite one, taken partly from the old pit and partly from the new pit in Oakley Park. The section in the latter pit, CR21, in fact exposed weathered stratum E clay-mud, as explained above, so that stratum E clay-mud was superimposed on the gravel of bed (or stratum) B in the composite section. Thus many of the fossils ascribed to bed A come from stratum E.

Regarding the second point mentioned above—the identification of the Palaeolithic loam in the central parts of the lake basin—blue loam, identified as Palaeolithic loam, was found in four borings: twice on the gravel bed B (CR 1 and CR 2), once on the lignite bed D (CR 12) and once on the loam of bed C (CR 19). The identification of the blue loam in CR 12 and CR 19 was qualified by question marks.

In the recent investigations no trace of any deposit resembling weathered stratum E (= Palaeolithic loam) was found in the central parts of the lake basin. The Committee may have mistaken the weathered parts of stratum C for it, as weathering causes the two to look somewhat similar. This would explain the presence of a blue loam in CR 12 and CR 19. It is difficult to explain it in CR 1 and CR 2. In borings and sections close to these (e.g. nos. 2 and 14), no such deposit was seen overlying the gravel of stratum B.

Thus the error made by the Committee in dissociating the Palaeolithic loam from stratum E and considering it to lie unconformably on the lake beds resulted from the use of a composite section and from the misidentification of deposits in the central part of the lake basin.

Figure 16*a* summarizes the Committee's interpretation of the stratigraphical and climatic sequence of the deposits, and shows how this differs from the author's interpretation.

(*g*) *Reid Moir*

The next investigation into the stratigraphy of the deposits was made during the years 1924–6, also on behalf of a Committee of the British Association. The work was superintended by Reid Moir, who drew up the report of the excavations for the new Committee.

This Committee agreed with the previous interpretation of the stratigraphy. In the marginal parts of the lake deposits many sections were opened, some (RM 4 and RM 5) showing what must have been the weathered part of the clay-mud of stratum E resting directly on the boulder clay, others (RM 6 and RM 7) showing weathered clay-mud passing down into unweathered clay-mud (stratum E), then into grey clay-mud (stratum F) and the basal boulder clay (stratum G). Where possible the positions of the sections are given on the map (figure 2). None of these sections led the Committee to question the stratigraphical interpretation of the previous Committee. These deposits above the boulder clay in Oakley Park were correlated with the Palaeolithic loam, and they were referred to as 'brickearth' in the report.

A number of remains of temperate plants and animals were found in this 'brickearth' (= Palaeolithic loam = stratum E), and so it became established that it was a temperate deposit.

The finding of remains of mammoth and reindeer in the gravel of stratum B suggested to the Committee that this deposit was formed in a cold climate.

The hoggin of stratum A 2 was exposed during these investigations. It was described as a partially decalcified chalky boulder clay.

This series of excavations thus added to the previous Committee's findings evidence that the 'brickearth' was formed in a temperate climate, that the gravel of stratum B was formed in a cold climate and that a partially decalcified boulder clay overlay the whole.

Figure 16*a* summarizes the Committee's stratigraphical and climatic sequences of the deposits.

In Moir's 1934 excavations two sections were opened, RM8 and RM9. In RM8, a section in the old pit, a very chalky boulder clay was found overlying 'brickearth'; the latter evidently corresponds to stratum A2, and it overlaid a chalky stratified sand referable to stratum B. No deposit like a chalky boulder clay was found in the overlying deposits in the recent investigations. In RM9, a section apparently right next to the author's section no. 100 in the Oakley Park pit, the succession was that seen in no. 100, with weathered clay-mud lying on unweathered clay-mud, then the basal boulder clay. In the paper describing these excavations Moir kept to the previous interpretation of the stratigraphical and climatic succession.

Moir's work thus perpetuated the error concerning the stratigraphical position of the marginal deposits made by the 1896 Committee. The origin of the error is now clear, and the true succession of deposits is proved by the stratigraphical work described here.

Figure 16 summarizes the stratigraphical and climatic succession described by the two British Association Committees, and compares them with the interpretation made by the author.

4. The relation of the finds of Palaeolithic artifacts to the stratigraphy

No attempt is made here to describe or classify the Palaeolithic artifacts which have been found at Hoxne. The aim is to describe the provenance of the artifacts. The culture names used are repeated from the sources under discussion.

Frere (1800) first recorded the presence of Palaeolithic hand-axes at Hoxne. The section in which the hand-axes were found has been given in § 3 (*b*); the implementiferous horizon was evidently stratum B.

Prestwich (1860) recorded the positions of six implements, all hand-axes. Three were found in the grey-brown and grey clay, Prestwich's layer *b* in his deep section (= stratum A2); one in the gravel, Prestwich's layer *c* (= stratum B); one in the gravel (stratum A2 or H?) overlying the brown and grey shelly clay (= stratum E) of Prestwich's section no. 6, and one in a deposit of unknown identity overlying the gravel in Prestwich's section no. 5. The places where these were found are marked in Prestwich's section across the deposits.

Reid (1896) found one worked flake in the gravel of his bed B (= stratum B), and he and Woodward found an implement which probably came from the same stratum (see Woodward's section given in § 3 (*e*)). Reid also referred to three flint implements found during the working of the north face of the Oakley Park pit, at a depth of 5 to 7 ft. It is not possible to say whether these came from stratum A2 or stratum E, both of which are now exposed on the north face, which itself is not far distant from its position in Reid's time. Transferring the depth to the present north face (profile F, figure 11), the horizon of the finds would be at about the junction of the strata.

Moir (1926) described three implementiferous horizons, each with a different class of artifacts. These horizons were as follows:

(*a*) 'Gravel seam overlying the Arctic Bed in the Old Brickfield', that is, stratum B. 110 artifacts, mostly flakes, were obtained from this deposit. In addition to the finds in the gravel, the workmen found two hand-axes in a dark-coloured sandy layer in section

RM 6, which Moir included with those from the gravel, as he thought this sandy layer could be correlated with the gravel of stratum B. In fact, in the region of RM 6 no stratum B is seen, and from the details of the section it appears that the hand-axes came from stratum C or stratum E. Moir classified these artifacts as Late Acheulian.

(*b*) 'Floor in brickearth overlying the gravel', that is, stratum A2 in the old pit and stratum E in the Oakley Park pit, which two deposits Moir equated according to the old scheme of the stratigraphy. These artifacts (111 in all) were described as Early Mousterian.

(*c*) 'Glacial deposit overlying brickearth', that is, stratum A2 gravel. Fifty-four artifacts were found in this deposit. They ranged from pre-Chellian to Mousterian.

In Moir's (1935) later excavation two archaeological horizons were found in lacustrine 'brickearth' in the Oakley Park pit (section RM 9); Moir called the lower horizon Late Acheulian and the upper one Early Mousterian or, what he considered equivalent, Clactonian III. The Late Acheulian 'floor' occurred just above the grey clay-mud of stratum F, and Moir connected this layer with the gravel of stratum B, because both contained Late Acheulian artifacts. In an excavation in the old pit (RM 8), an Early Mousterian 'floor' was found in the 'brickearth' between stratum B and a chalky boulder clay, that is, in stratum A2.

In 1948, Dr K. P. Oakley found a rough core in material excavated from stratum E on the north face of the Oakley Park pit. Pollen analysis of sediment found on the core confirmed that it came from stratum E.

During the excavation of the pit (figure 34, plate 4) at sections nos. 40 and 100, two very fresh flakes, a piece of flint with signs of flaking, and some broken bones were found at the same horizon, marked in profiles D and E (figures 9 and 10). 10 cm higher a piece of charcoal was found. These were the only objects of archaeological significance found in the whole excavation, which removed approximately 7·5 cu. m of lake sediment, covering the whole depth of stratum E except a small part missing by erosion at the top. The pit was placed next to Moir's section RM 11, and the 'floors' he described from this section were searched for, with the results given above.

A single hand-axe was later found by the workmen at the interface of the gravel of stratum A2 and the clay of stratum C on the south wall of the same pit.

At the beginning of 1953 five hand-axes, all in a fresh condition, were found in an area of about 5 m square immediately north-west of section no. 96 (north-east corner of the Oakley Park pit, see profile H). They were found by the workmen, and as far as can be ascertained came from close to the junction of stratum A2 and stratum E. One of the implements was encrusted with race, and it is probable that it came from the top of stratum E, where, in this area, race is present at the base of the leached zone at the top of the clay-mud. The results of pollen analysis of the clay-mud from this hand-axe confirm that it came from the top of stratum E.

It should be noted that these hand-axes came from where stratum A2 overruns the same level in stratum E (shown by comparative pollen analyses) that contained flakes in section no. 100.

An Upper Palaeolithic core was found in 1953 in the top part of stratum A2 near section no. 96. It was worn and abraded, unlike the hand-axes from lower down in the deposits in the same area.

The stratigraphical positions of all these finds are summarized in table 3.

The following sequence of events explains the distribution of the artifacts: the archaeological horizon in stratum E of section no. 100 (and the 'floors' in stratum E described by Moir) represent Palaeolithic habitation on the lake shores during the interglacial period. At the end of the interglacial, artifacts on the surface around the lake were moved into the centre of the lake by solifluxion, with the material of stratum B. During the subsequent glaciation artifacts from the older deposits were incorporated into stratum A2, and a further incorporation of artifacts into stratum A2 may have occurred in the later cryoturbation phase.

TABLE 3. SUMMARY OF THE STRATIGRAPHICAL POSITIONS OF PALAEOLITHIC ARTIFACTS OF KNOWN OR REASONABLY CERTAIN PROVENANCE

	stratum		
author	A2	B	E
Frere (1800)	—	hand-axes	—
Prestwich (1860)	hand-axes	—	—
Reid (1896)	—	hand-axe, flake	—
Moir (1926)	hand-axe, flakes, scrapers, etc.	flakes, scrapers, points, etc. (Acheulian)	hand-axes, flakes, points, etc. (Acheulian and Mousterian)
Moir (1935)	scraper	—	hand-axes, scrapers (Acheulian and Mousterian or Clactonian III)
recently found	hand-axe (at base of till), core (Upper Palaeolithic)	—	hand-axe, flakes, core

Thus, although Palaeolithic artifacts have been found in strata A2, B and E, the only ones that must be in their original place of deposition and not secondarily derived are those from stratum E. From this stratum there are the implements described by Moir (from his Oakley Park 'brickearth'), the flakes found *in situ* during the recent investigations, and the hand-axe dated to the same level as the flakes by pollen analysis.

There is therefore no doubt that Palaeolithic man was contemporaneous with a part of the stratum E lake deposits. According to Moir (1935) first a Late Acheulian and then an Early Mousterian (or Clactonian III, as he later called the artifacts of this type) culture were present in stratum E times. In the recent excavations only one culture horizon was found, which was near the top of stratum E.

A recent re-examination by West & McBurney (1955) of the artifacts from Hoxne, including those described by Moir, suggests that only one culture contemporaneous with the lake deposits can be distinguished. This culture is Acheulian. According to Baden-Powell (1951 *a*), the hand-axes from Hoxne are to be considered 'Late Middle' Acheulian. The archaeology of the Hoxne Interglacial is described elsewhere in more detail (West & McBurney 1955).

5. PLANT REMAINS AND POLLEN DIAGRAMS FROM THE HOXNE INTERGLACIAL

(*a*) *Introduction*

The palaeobotany of the deposits was very thoroughly investigated by Reid (1896). From the different lake beds he collected large samples which were washed for macroscopic remains. The resulting plant list is given in §5 (*b*). Moir (1926, 1935) gave the results of

Erdtman's pollen analyses of a few samples from the interglacial deposits. Those in the later paper came from the section RM 11, and they conform in general to the fuller results now recorded.

During the recent investigations it was only possible to collect bulk samples from strata E and F. The intractability of the clay-mud of stratum E made it very difficult to extract fossils from it, and the only samples washed were from stratum F, which was not distinguished by Reid. These samples were obtained from the excavations in the Oakley Park pit. Macroscopic remains were also collected when found in the auger samples and the 4 in. cores of borehole no. 36.

The largest part of the palaeobotanical investigations was based on the technique of pollen analysis. Samples for analysis from strata F, E, D and C—the other deposits had no pollen—were taken from boreholes and sections. The positions of the sites where the samples for the pollen diagrams were taken is marked in figure 2.

The samples from the trial borehole no. 36 were obtained by sawing the 4 in. cores lengthways in half and taking the samples at intervals down the centre of the cores. During the trial boring some sediment was lost between each core. The general conformity of the pollen diagrams from the borehole shows, however, that no large gaps are present between one core and the next.

The results of the pollen analyses are expressed as follows. Where the ratio of tree to non-tree pollen is high, the percentages are based on counts of 150 tree-pollen grains. Where the ratio is low, they are based on total pollen and spores excluding water plants (the spores never rise to a frequency which would disturb the ratio). *Corylus* is excluded from the tree-pollen total and from the AP/NAP ratio. The massulae of *Azolla filiculoides* were counted as one unit. The *Sparganium* curves include all *Sparganium* and *Typha* pollen types, except for the tetrads of *T. latifolia* which are recorded separately.

The derived pollen and spores have been divided in some of the diagrams into three classes. '*Haploxylon*' is pollen comparable to *Pinus haploxylon*, and '*Hystrix*' refers to brown spore-cases with projecting hooks.

The tree-pollen frequency is expressed as the number of traverses required to count 150 tree-pollen grains. This is only a rough estimation, but the general conformity of the results shows it to be a valid method. It is, of course, a purely relative measure. The frequencies shown in the tree-pollen diagram I *A* (figure 17) are average values for the samples from half of each core.

Figure 4 explains the symbols used in the stratigraphical columns of the pollen diagrams.

The main aims of the pollen-analytical investigation were to demonstrate from the deepest part of the lake deposits the full succession of the interglacial vegetational changes (pollen diagrams I *A*–I *G*, figures 17–24), and to determine whether the marginal lake deposits separated by Reid from the lower lake deposits are similar pollen-analytically to these lower lake deposits (pollen diagrams II, III and VI, figures 25–27 and 31). In addition, other stratigraphical points were clarified by the diagrams IV (figure 28)—from weathered and unweathered parts of stratum E—and V (figures 29 and 30)—from the transition from stratum E to stratum D.

The pollen diagrams cannot be related, as may be those of the Post-Glacial period and the Last Interglacial, to an already established pattern of vegetational change. It was therefore necessary to devise a new scheme of subdivision. The macrofossil list and the pollen diagrams from the trial borehole no. 36 form the foundation for this division of the interglacial period into stages. These stages are based on the general aspect of the vegetation and therefore probably represent periods which have a regional as well as a purely local significance; as such they may have a permanent value for the designation of the interglacial succession.

Each stage is subdivided on the basis of its vegetational history. These substages, unlike the stages, are in no way to be considered as having more than a local significance. They are based on the results from one site only, and merely indicate the vegetational succession in the area around Hoxne.

The nomenclature is based on the *Flora* of Clapham, Tutin & Warburg (1952), and for mosses, on the *Check-list* of Richards & Wallace (1950). The author is grateful to Mr M. C. F. Proctor for making the identifications of the mosses found in the recent investigations and for revising the nomenclature of the mosses.

(*b*) *Macroscopic plant remains*

This list of macroscopic plant remains from the interglacial deposits is divided into two parts, the first giving Reid's (1896) identifications, the second the identifications of remains found during the investigations described here.

(i) *Reid's plant list*

The identifications refer to fruits and seeds except where otherwise stated. Strata E and F were not differentiated by Reid, who included them both in his bed E. The records from the Palaeolithic loam, the lower part of Reid's bed A, are given in the E and F column, as the loam in fact belongs to these strata. The comments on derivation are Reid's.

	stratum		
	C	D	E and F
Alisma plantago-aquatica L.	×	×	.
Alnus glutinosa (L.) Gaertn.	× (derived?)	×	×
Ajuga reptans L.	×	.	.
Betula nana L.	× (leaves)	.	.
Bidens tripartitus L.	×	×	.
Blysmus rufus (Huds.) Link	×	×	.
Caltha palustris L.	×	.	.
Carex sp.	×	.	×
C. rostrata Stokes?	.	×	.
C. distans L.?	.	×	.
C. maritima Gunn.?	×	.	.
Carpinus betulus L.	× (derived)	×	.
Ceratophyllum demersum L.	×	×	×
Corylus avellana L.	.	×	.
Eleocharis acicularis (L.) Roem. & Schult.	.	×	.
E. pauciflora (Lightf.) Link	×	×	.
Eriophorum angustifolium Honck.	.	×	.
Eupatorium cannabinum L.	×	×	.
Frangula alnus Mill.	× (derived)	×	.
Hippuris vulgaris L.	×	.	×
Isolepis setacea (L.) R.Br.	×	×	.
Lycopus europaeus L.	×	×	.
Mentha aquatica L.	.	×	.
Menyanthes trifoliata L.	×	.	.

	stratum C	stratum D	stratum E and F
Montia fontana L.	×	×	.
Myriophyllum spicatum L.	×	.	.
Oenanthe aquatica (L.) Poir.	×	×	.
Potamogeton sp.	.	.	×
P. alpinus Balb.	×	.	.
P. crispus L.	×	.	.
P. pectinatus L.	×	.	.
P. pusillus L.	×	×	.
P. trichoides Cham. & Schlecht.	×	×	.
Ranunculus aquatilis L.	×	×	.
R. lingua L.	.	×	×
R. repens L.	× (derived?)	× (cf.)	×
R. sceleratus L.	×	×	.
Rosa canina L.	.	×	.
Rubus idaeus L.	×	×	×
Rumex acetosella L.?	.	×	.
R. crispus L.	× ?	×	.
R. maritimus L.	×	×	×
Salix herbacea L.	× (leaves)	.	.
S. myrsinites L.	× (leaves)	.	.
S. polaris Wahlb.	× (leaves)	.	.
Sambucus nigra L.	× (derived?)	×	.
Sanguisorba officinalis L.	×	.	.
Schoenoplectus lacustris (L.) Palla	×	×	×
Sorbus torminalis (L.) Crantz?	.	×	.
Sparganium ramosum Huds.	×	×	×
Stachys sp.?	.	×	.
Stellaria media (L.) Vill.	×	.	.
Taraxacum officinale Web.	×	.	.
Taxus baccata L.	× (derived)	×	.
Urtica dioica L.?	×	×	.
Viola palustris L.	×	.	.
Zannichellia palustris L.	.	.	×
Chara sp.	×	.	×
Acrocladium cuspidatum (Hedw.) Lindb.	× ?	×	.
A. sarmentosum (Wahl.) R. & W.	×	.	.
Brachythecium populeum (Hedw.) B. & S.?	.	×	.
B. rutabulum (Hedw.) B. & S.	× ?	.	.
Bryum sp.	.	×	.
B. pallens (Brid.) Rohl	× ?	.	.
Camptothecium sericeum (Hedw.) Kindb.	.	×	.
Campylium stellatum (Hedw.) Lange & C. Jens.	×	.	.
Dicranum scoparium Hedw.?	.	×	.
Drepanocladus fluitans (Hedw.) Warnst.	×	.	.
Eurhynchium sp.	.	×	.
E. striatum (Hedw.) Schp.	.	×	.
Hypnum cupressiforme Hedw.?	.	×	.
Mnium sp.	×	×	.
M. punctatum Hedw.	× ?	×	.
Philonotis fontana (Hedw.) Brid.	× ?	.	.
Pohlia albicans (Wahl.) Lindb.	× ?	.	.
Rhytidiadelphus squarrosus (Hedw.) Warnst.	×	.	.
Thuidium tamariscinum (Hedw.) B. & S.	.	×	.

(ii) *Found during the recent investigations*

The numbers in the list under stratum F refer to fruits and seeds unless otherwise stated. The sizes of the different samples of stratum F were approximately the same. The mosses were all fragments of leaves and branches, and the identifications (by Mr M. C. F. Proctor) are tentative.

Stratum C

Abies sp., wood; 235 cm, borehole no. 6.

Betula cf. *verrucosa* Ehrh., 1 fruit; core 5, borehole no. 36.

Salix cf. *myrsinites* L., 3 leaves; core 5, borehole no. 36.

Azolla filiculoides Lam., massulae and megaspores common in cores 1–6, borehole no. 36.

Drepanocladus fluitans (Hedw.) Warnst.; core 3, borehole no. 36.

Sphagnum sp. subg. *Inophloea*; core 3, borehole no. 36.

Sphagnum sp. subg. *Litophloea*, sect. *Acutifolia*; core 1, borehole no. 36.

Sphagnum cf. *rubellum* Wils; core 3, borehole no. 36.

Stratum D

Alnus glutinosa (L.) Gaertn., many fruits, female cones and pieces of wood; core 6, borehole no. 36.

Bidens tripartitus L., 2 fruits; core 6, borehole no. 36.

Ceratophyllum demersum L., 1 fruit; core 6, borehole no. 36.

Rumex cf. *obtusifolius* L., 1 fruit; core 6, borehole no. 36.

Azolla filiculoides Lam., massulae and megaspores in large numbers; core 6, borehole no. 36.

Stratum E

Alnus sp.?, charcoal; 290 cm, section no. 100.

Quercus sp., leaves and an acorn; 390 cm, section no. 100.

Azolla filiculoides Lam., massulae and megaspores occasional throughout the middle and upper part of stratum E in borehole no. 36.

Stratum F

(*a*) From section no. 100.

	469–470 cm (drift mud)	460–469 cm (marl)	450–460 cm (clay-mud)
Carex sp.	48	11	4
Carex cf. *acutiformus* Ehrh.	.	.	1
Hippophaë rhamnoides L. (leaf scales)	.	×	×
Potamogeton sp.	3	2	4
Potamogeton cf. *acutifolius* Link	1	.	2
P. filiformis Pers.	.	.	1
P. pectinatus L.	64 and 5 tubers	12 and 2 tubers	11
Potamogeton cf. *praelongus* Wulf	.	1	1
Potamogeton cf. *obtusifolius* Merg. & Koch	.	1	.
Ranunculus cf. *flammula* L.	15	1	.
Ranunculus cf. *lingua* L.	.	.	1
Ranunculus cf. *repens* L.	1	.	.
Salix sp.	9 bud scales	.	.
Monocotyledonous cuticle	×	×	.
Chara sp. oospores	×	× abundant	×
filaments	.	×	.
cf. *Campylium stellatum* (Hedw.) Lange & C.Jens.	.	×	.
Drepanocladus sp.	.	×	.
Drepanocladus cf. *sendtneri* (Schp.) Warnst.	×	.	.
Scorpidium scorpiodes (Hedw.) Limpr.	.	×	.

(*b*) From borehole no. 36, core 18.

Chara sp., oospores common in the lower clay-mud of this core.

(c) *Pollen diagrams*

(i) *Hoxne I*

The results of the pollen analyses from the cores of borehole no. 36 are given in the following diagrams:

I*A*. Cores 6–19, strata C, D, E and F (tree and non-tree pollen diagrams, figures 17 and 18).

I*B*. Core 18, stratum F (figure 19).

I*C*. Cores 7 and 8, stratum E (figure 20).

I*D*. Core 6, stratum D (figure 21).

I*E*. Cores 5 and 6, strata C and D (figure 22).

I*F*. Cores 3 and 4, stratum C (figure 23).

I*G*. Cores 1 and 2, stratum C (figure 24).

The main series from the undisturbed lake sediments is given in the pollen diagrams I*A*. The diagrams I*B*, I*C* and I*D* give more detailed results from part of this long sequence. The diagrams I*E*, I*F* and I*G* are from the reworked deposits above the undisturbed lake sediments.

These diagrams are the basis of the division of the interglacial period into stages. Broadly, the diagrams are divisible into the following four stages, starting at the base:

Stage I. *The Late-Glacial stage*,* characterized by a low ratio of tree to non-tree pollen, with *Betula* the dominant tree, and with very high percentages of *Hippophaë*.

Stage II. *The Early-Temperate stage*, characterized by the immigration and dominance of the mixed oak forest trees.

Stage III. *The Late-Temperate stage*, showing the beginning of the replacement of the mixed oak forest trees by *Carpinus* and conifers, including *Picea* and *Abies*.

Stage IV. *The Early-Glacial stage*, with *Betula*, *Alnus* and conifers dominant (the naming of this stage does not depend entirely on the pollen-analytical evidence, but also on the macrofossil evidence).

These stages and their subdivisions are now defined, with reference to the pollen diagrams I*A–G*.

Stage I. *The Late-Glacial stage* (pollen diagrams I*A* and *B*, stratum F, 1080 to 1124 cm).

The base of this stage is where pollen-containing sediments are first found. The top boundary is taken where the amount of tree pollen begins to exceed that of the non-tree pollen. The boundaries of the stage coincide with the limits of stratum F.

Stage I is clearly divisible into four substages, labelled I*b* to I*e*; I*a* has been omitted to provide for any arctic flora immediately predating this stage which may be found in the future. The substages of stage I are as follows, starting at the base:

I*b*. 1113 to 1124 cm. *Pinus* generally with higher values than *Betula* but both low, high *Hippophaë* (69 %), Gramineae rising; much derived pollen and spores.

I*c*. 1106 to 1113 cm. *Betula* up to 14 % with *Pinus* remaining low, fall of *Hippophaë*, Gramineae fall slightly; decrease of derived pollen and spores.

* The term late-glacial to describe a stage may be thought to lead to confusion with the Late-Glacial Period after the Last Glaciation. Late-glacial is used here because it is the only satisfactory descriptive term available.

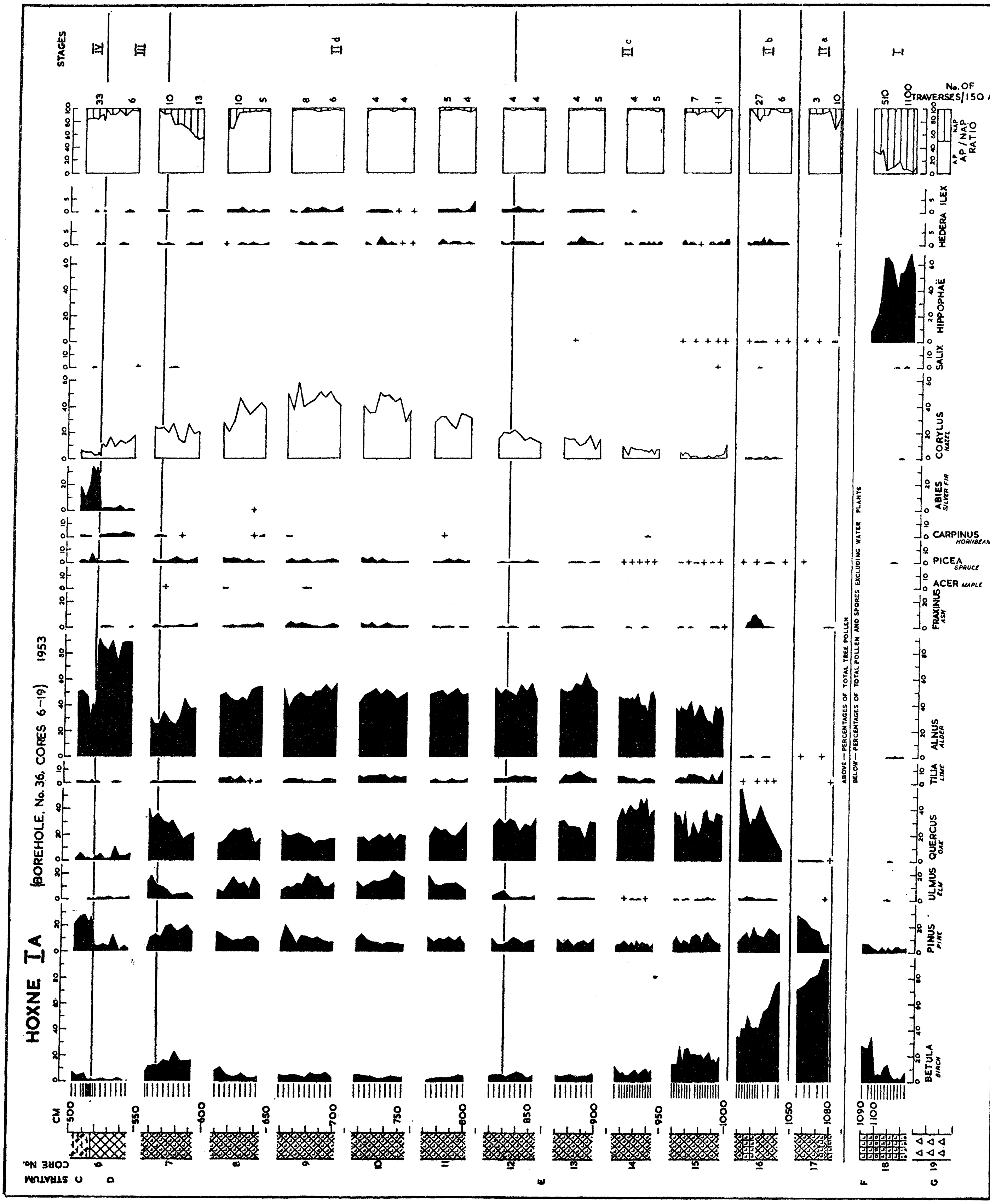

FIGURE 17. The main tree-pollen diagram from the centre of the lake basin.

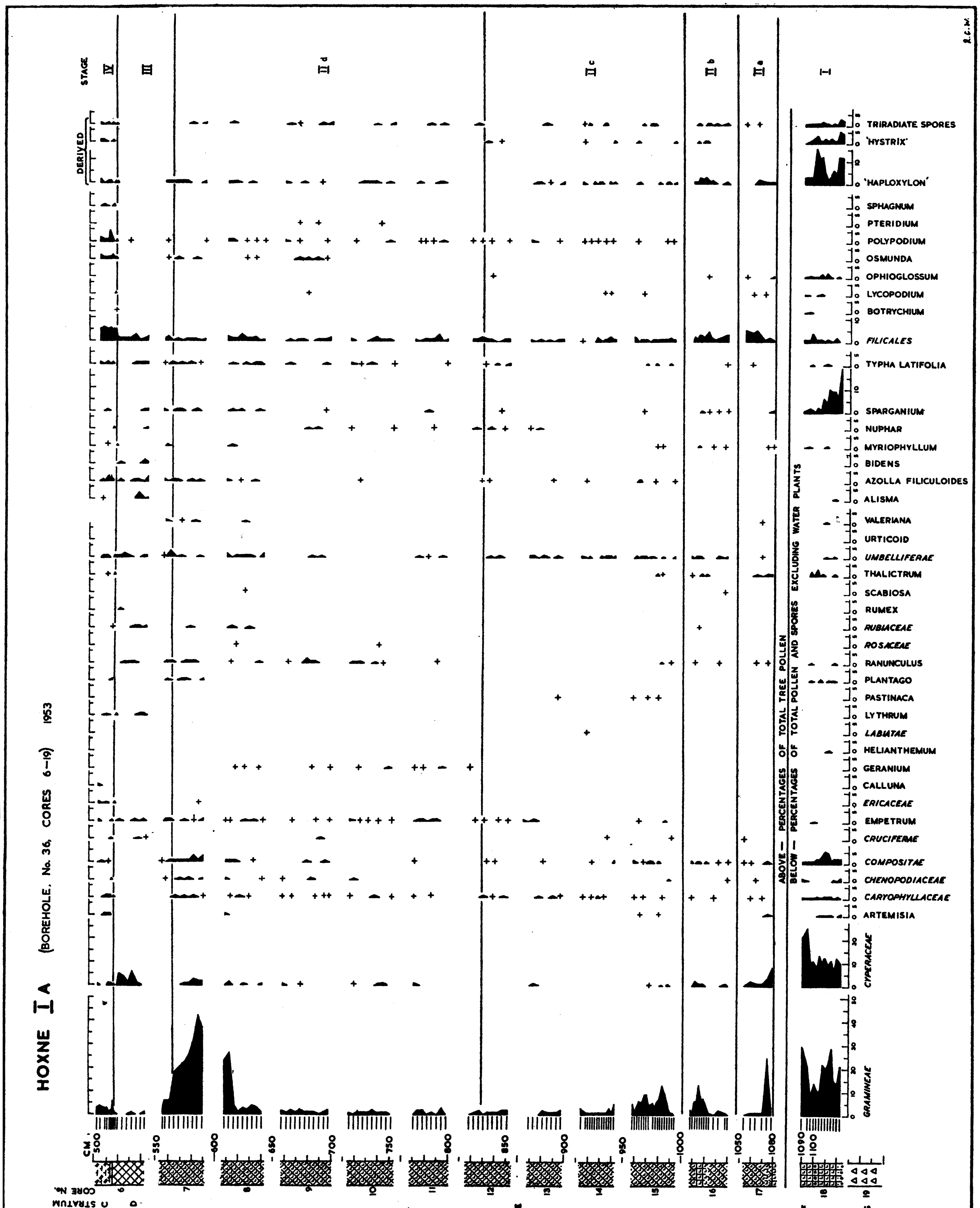

FIGURE 18. The main non-tree pollen diagram from the centre of the lake basin.

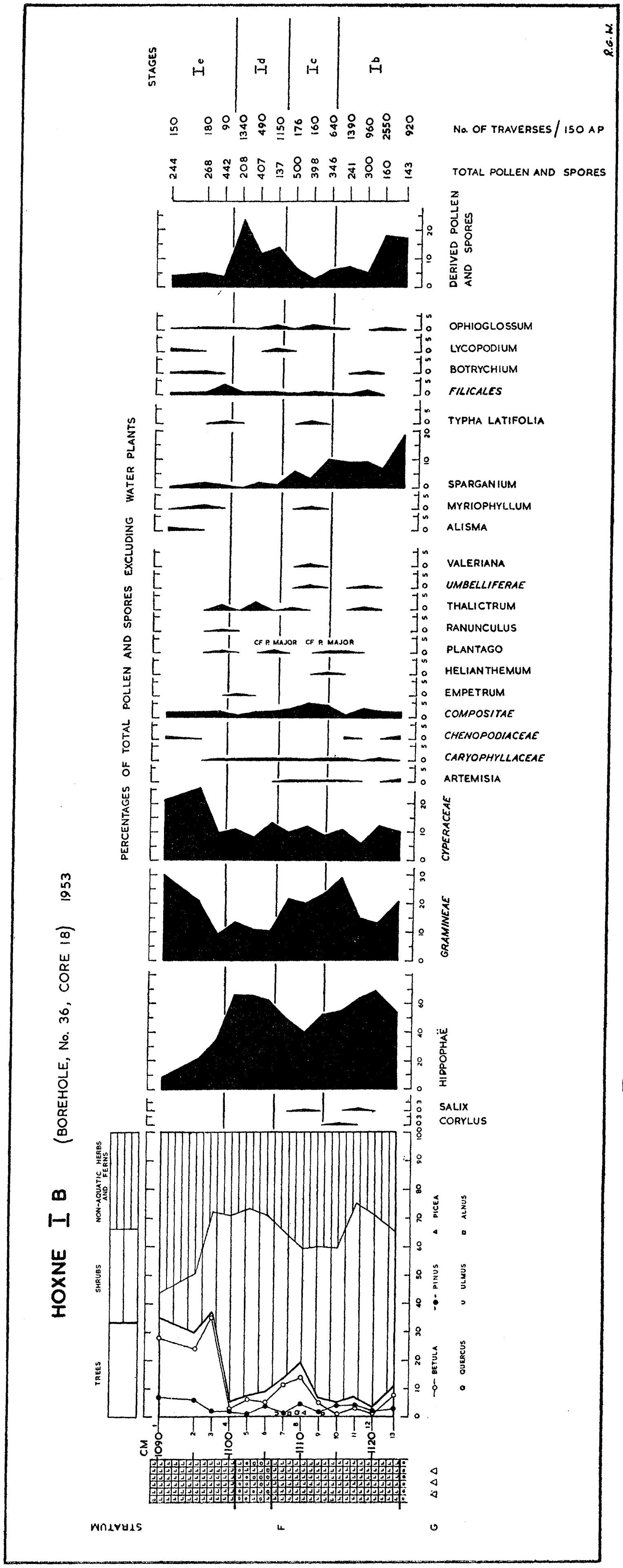

FIGURE 19. Pollen diagram of the Late-Glacial stage, stage I.

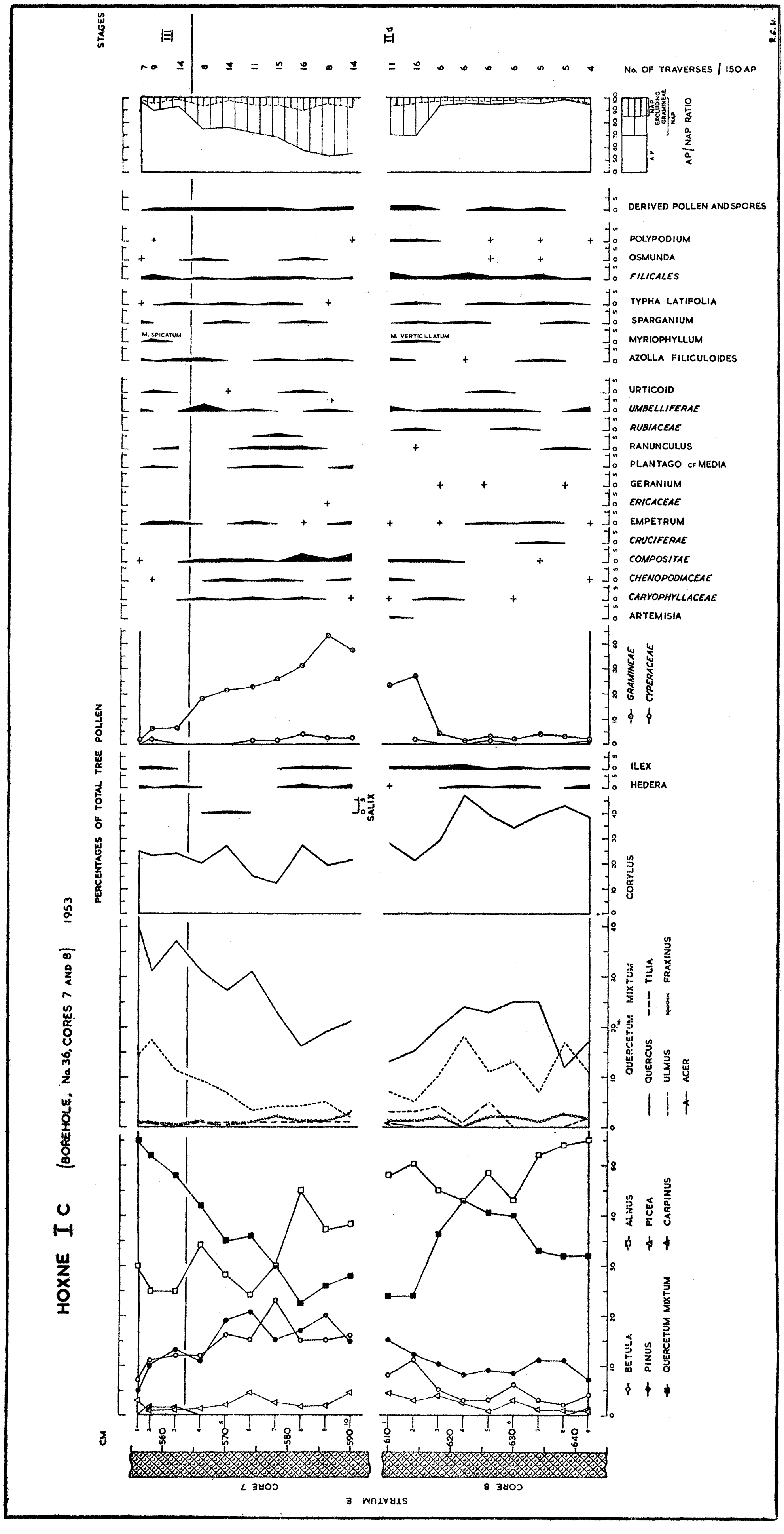

FIGURE 20. Pollen diagram of the high non-tree pollen phase of stage II.

I*d*. 1101 to 1106 cm. *Betula* falls, *Hippophaë* increases, decrease of Gramineae; increase of derived pollen and spores.

I*e*. 1080 to 1101 cm. Increase of *Betula* and *Pinus*, great decrease in *Hippophaë*, rise of Gramineae and Cyperaceae; decrease of derived pollen and spores.

It should be noted that substage 1*d* corresponds to the layer of clay-mud with chalk pebbles.

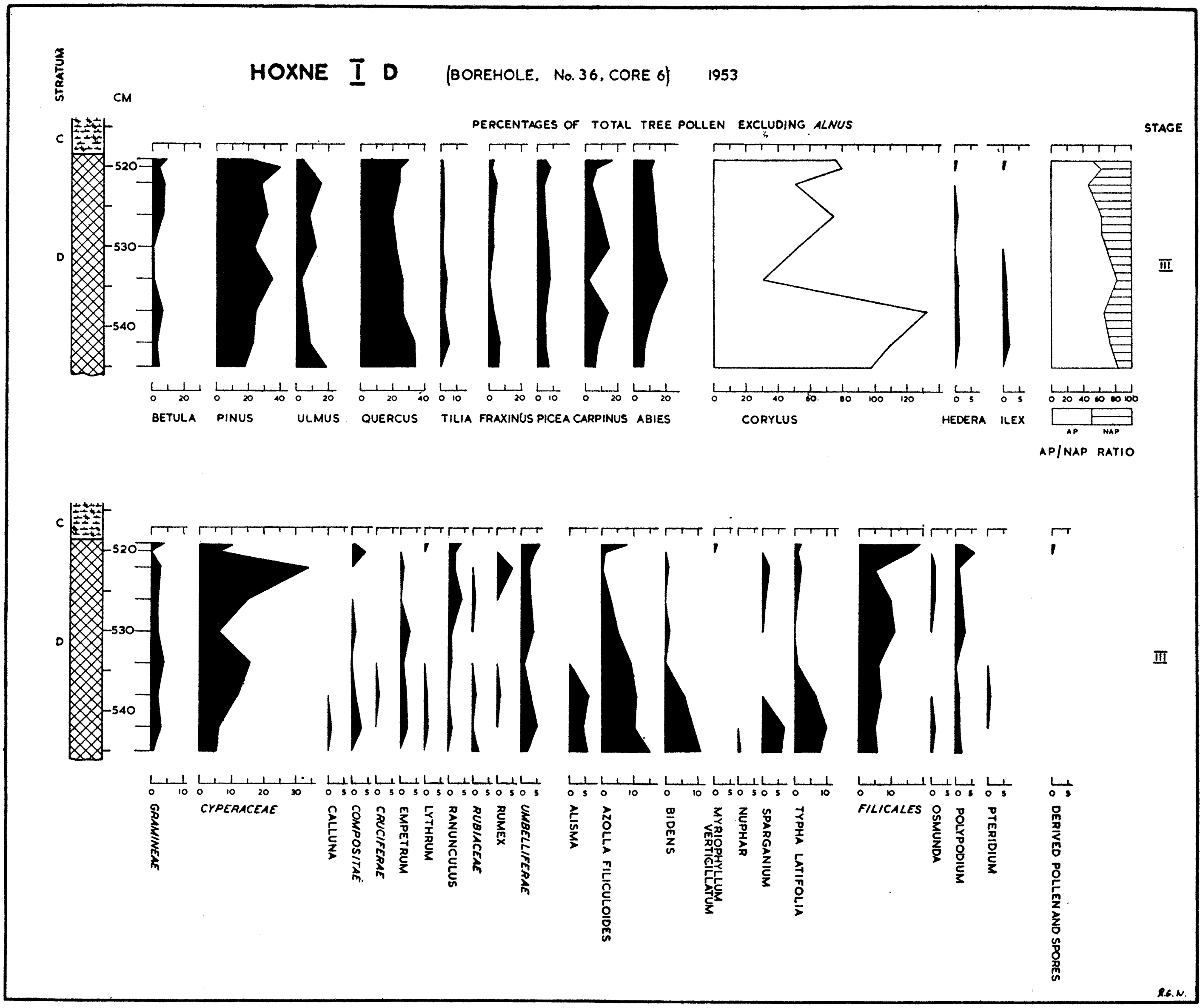

FIGURE 21. Pollen diagram excluding *Alnus* from stratum D (stage III).

Stage II. *The Early-Temperate stage* (pollen diagrams I*A* and *C*, stratum E, 550 to 1080 cm).

The lower boundary of this stage is where the tree pollen first exceeds the non-tree pollen. At the same time there is a great increase in the tree-pollen frequency. The upper boundary of the stage is where *Carpinus* first forms a continuous curve. The whole stage is included in stratum E.

The following substages are distinguished, starting from the base:

II*a*. 1050 to 1080 cm. *Betula–Pinus substage*. *Betula* dominant and at very high values. The *Pinus* curve culminates.

II*b*. 1000 to 1050 cm. *Betula–Quercus–Pinus substage*. The base of the substage is at the rise in *Quercus*. *Betula* and *Pinus* fall throughout the substage.

II*c*. 830 to 1050 cm. *Alnus–Quercus–Betula–Tilia substage*. The base of this substage is where the rise of *Alnus* and *Tilia* occurs. *Betula* falls throughout the substage. *Corylus* begins to rise.

II*d*. 550 to 830 cm. *Alnus–Quercus–Ulmus–Tilia substage*. This substage commences where *Ulmus* rises and *Tilia* declines. *Betula* and *Pinus* rise slowly and the *Corylus* curve culminates during the substage.

Stage III. *The Late-Temperate stage* (pollen diagrams I*A* and *D*, strata E and D, 518 to 550 cm).

This stage begins at the rise in *Carpinus*. *Abies* immigrates soon after this. The changes in this stage are masked by the high values of *Alnus*, a local effect. These changes may seem too insignificant to separate this stage from the last, but evidence from the pollen diagram V confirms that they differ enough to merit a separation. The stage covers a small part of stratum E and the whole of stratum D.

Stage IV. *The Early-Glacial stage* (pollen diagrams I*E*, I*F* and I*G*, stratum C, 305 to 518 cm).

The base of this stage is at the sudden rise of *Abies* and *Pinus*. These, with *Alnus* and *Betula*, remain high to the top of the stage. The stage is coincident with stratum C.

Having defined the subdivisions of the interglacial period, as shown by the pollen diagrams I*A*–*G* from borehole no. 36, it remains to consider the peculiar nature of the pollen curves in the diagrams I*E*, I*F* and I*G* from stratum C. Throughout the whole of this stratum the curves of the tree species undergo pronounced changes, which are correlated with the sediment type. The most obvious change of this type is the change from the clay-mud breccia to the silt and vice versa. The former is usually marked by an increase in *Betula*, *Pinus*, the mixed-oak forest species, *Corylus* and Gramineae, and by a decrease in *Abies* and *Alnus* (see pollen diagrams I*E*, I*F* and I*G*: core 3, sample 3 to 2; core 2, sample 2 to 1; core 1, sample 11 to 10). The reverse stratigraphical change is marked by the opposite behaviour of the curves (core 4, sample 2 to 1; core 3, sample 6 to 5; core 2, sample 6 to 5). In general the breccia has high values of *Abies* and *Alnus*, and in the silt *Betula* and *Pinus* supersede *Abies*, although *Alnus* remains dominant.

Several clay-mud pebbles of the breccia were analyzed for pollen and the results for three of these are given in table 4. The spectrum from sample no. 3 shows that this pebble came from deposits of substage II*d*. No spectra like those from the other two were obtained from undisturbed lake sediments. The spectra may have been changed by weathering, or they may represent deposits of age between strata D and C, partly eroded away during the formation of the unconformity between these strata. Other clay-mud pebbles analyzed contained only traces of *Alnus*, *Pinus* and *Abies* pollen, all very eroded. Presumably weathering of the deposits from which these pebbles were derived had taken place during the reworking.

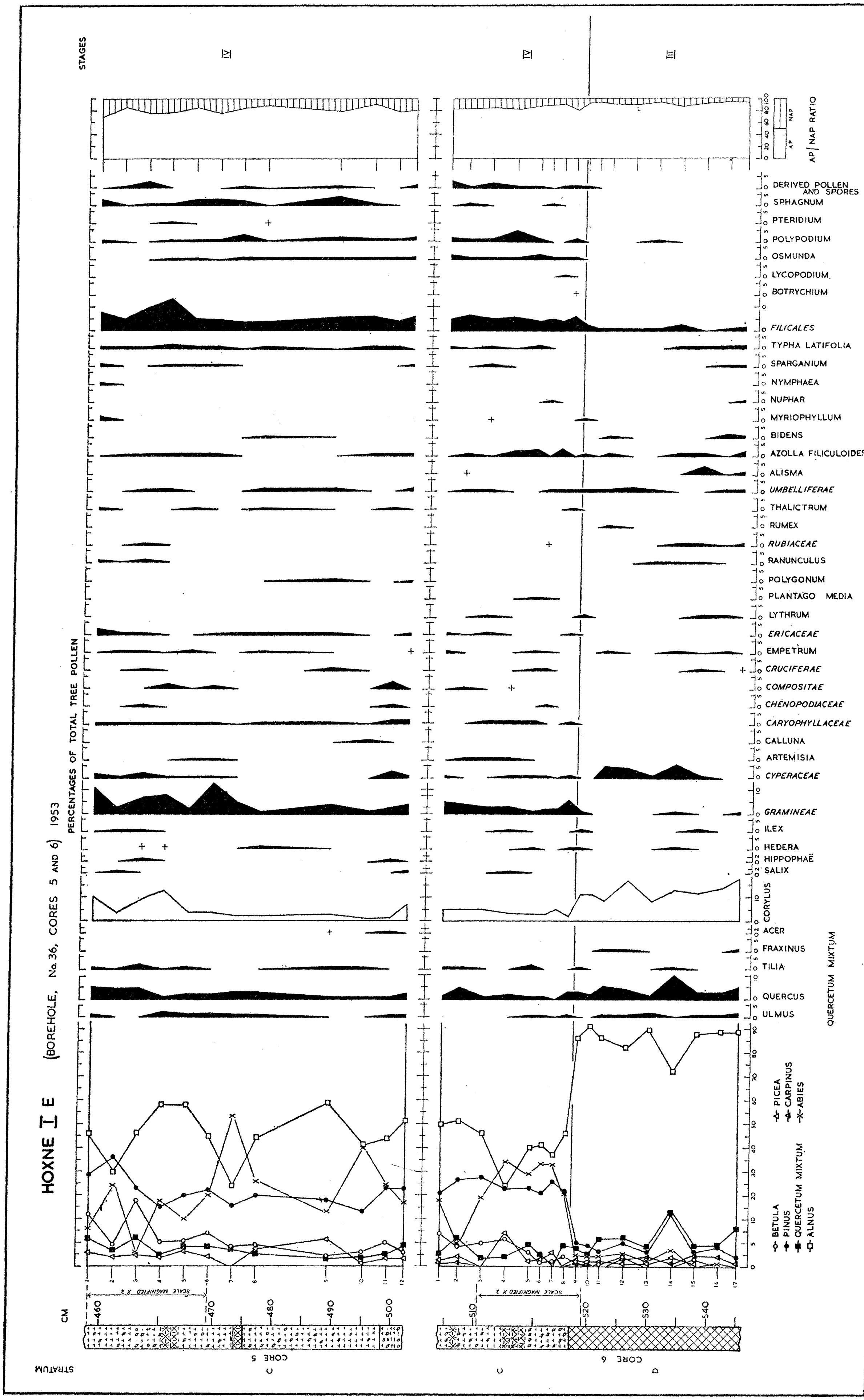

FIGURE 22. Pollen diagram from stratum C (stage IV).

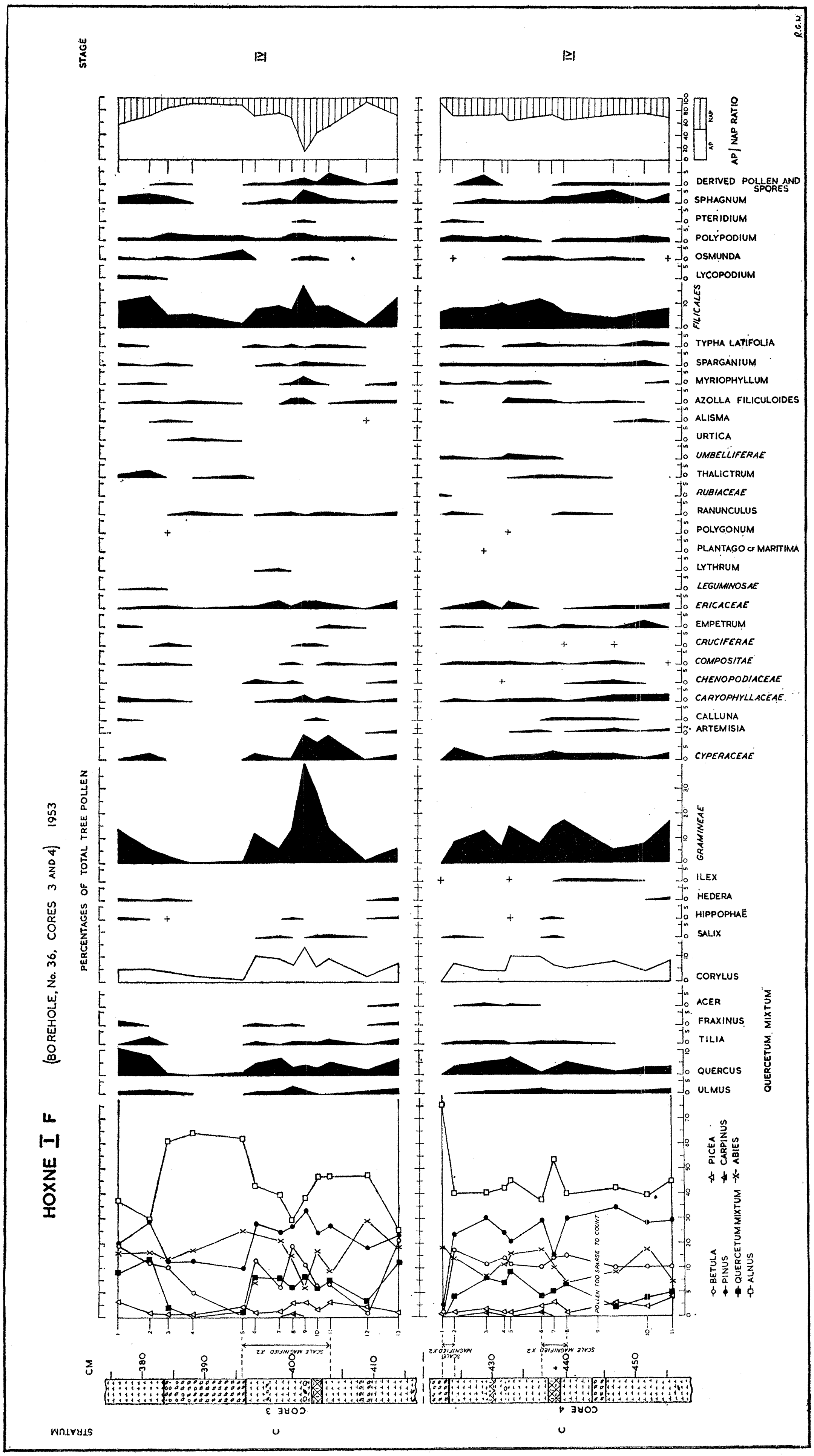

FIGURE 23. Pollen diagram from stratum C (stage IV).

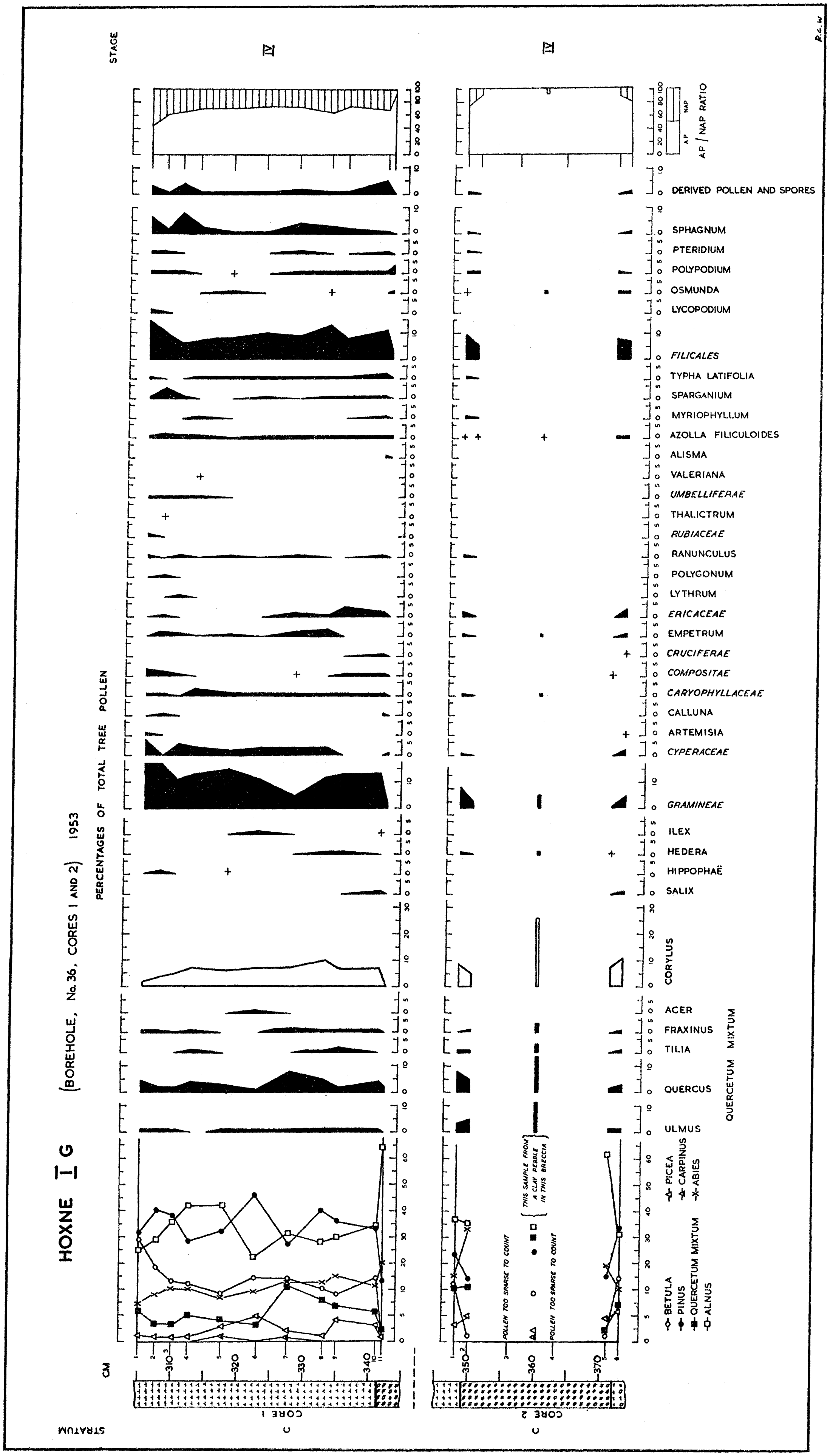

FIGURE 24. Pollen diagram from stratum C (stage IV).

It is evident from these results that much of the pollen from stratum C must be derived. It is impossible to separate the derived and underived pollen, so the various peaks of the different pollen curves remain meaningless in terms of a vegetational succession; they merely reflect the deposition of different amounts of derived pollen. It may be suggested that those pollen types showing a rise on the transition to the silt—perhaps a more 'autochthonous' deposit than the breccia—i.e. *Betula*, *Pinus*, mixed-oak forest species, *Corylus* and Gramineae, are the contemporary parts of the pollen flora. But even in the silt much derived pollen must be present, as the fluctuating water level of stratum C times would disturb the older deposits and keep derived pollen in suspension.

Certain trends, however, are seen in the pollen curves of stratum C. In particular, *Betula* and *Pinus* increase towards the top, and *Alnus* and *Abies* drop.

TABLE 4. POLLEN ANALYSES OF CLAY-MUD PEBBLES FROM STRATUM C, BOREHOLE NO. 36

sample no. ...	1	2	3
Betula	+	1	9
Pinus	10	20	24
Ulmus	.	.	11
Quercus	1	1	13
Tilia	1	1	3
Alnus	7	60	34
Fraxinus	.	.	3
Picea	+	3	2
Carpinus	.	.	1
Abies	81	14	.
Corylus	1	5	26
Hedera	.	.	1
Ilex	1	.	.
Gramineae	.	1	5
Cyperaceae	1	.	.
Caryophyllaceae	.	.	1
Cruciferae	1	.	.
Empetrum	.	.	1
Ericaceae	.	1	.
Azolla	1	1	+
Filicales	2	.	.
Osmunda	2	.	1
Polypodium	2	1	.

Percentages of total tree pollen. +Seen in screening.

Key to samples:
1. Pebble from silt with breccia, core 5, 490 cm.
2. Pebble from breccia, core 3, 395 cm.
3. Pebble from breccia, core 2, 372 cm.

(ii) *Hoxne II*

These tree and non-tree pollen diagrams (figures 25 and 26) are from section no. 100, exposed during the excavations on the west face of the Oakley Park pit. The zoning of the diagrams follows that of the main diagrams described above. The substages of stage I are not clear, because of the few samples, and it is impossible to relate this part of stratum F to the same stratum in the central part of the lake basin. The low values of *Sparganium* indicate that only the upper part of stratum F was present in the section. Above 390 cm the clay-mud is slightly weathered, but this seems to have had little effect on the pollen

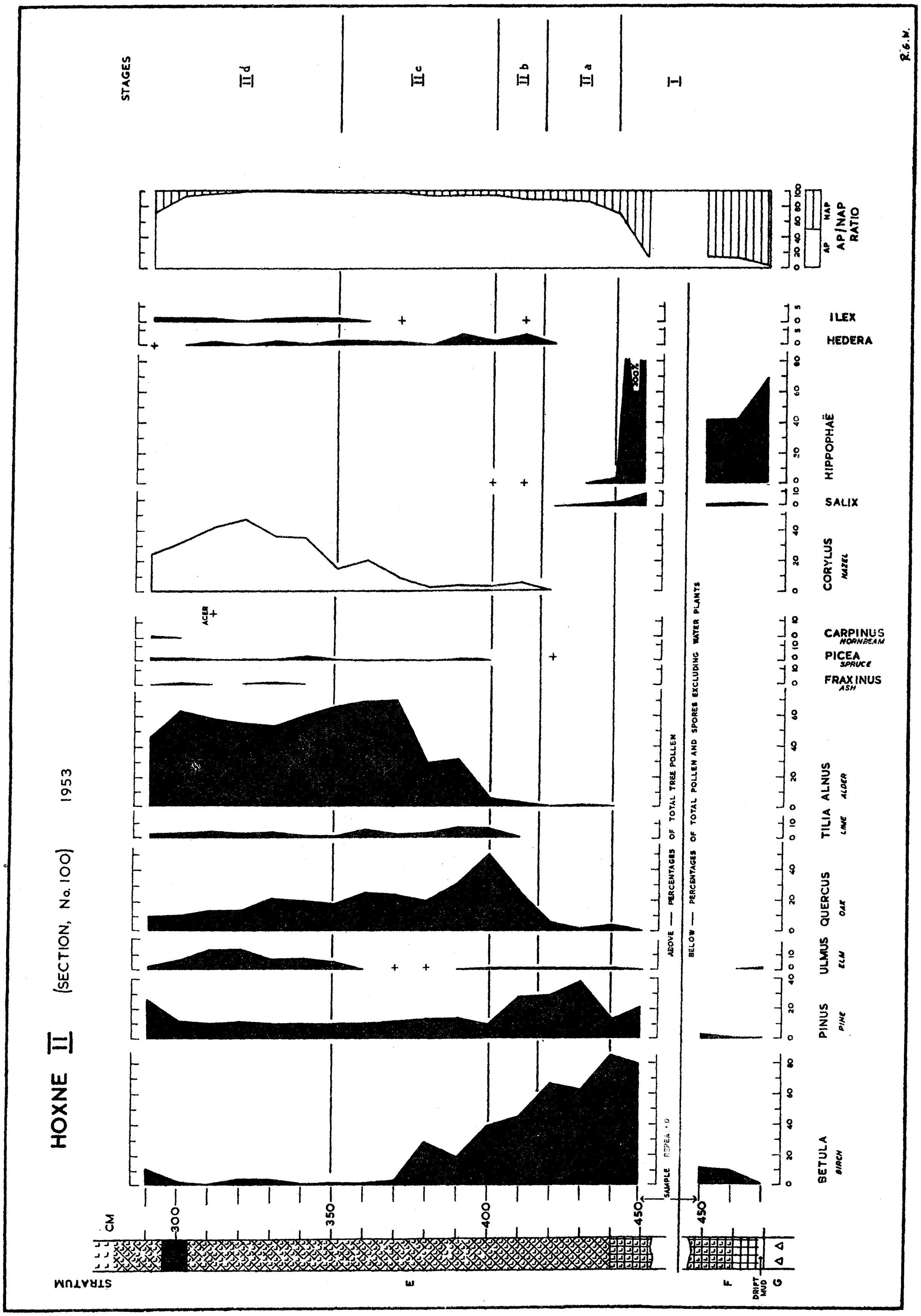

FIGURE 25. Tree-pollen diagram from the marginal lake deposits.

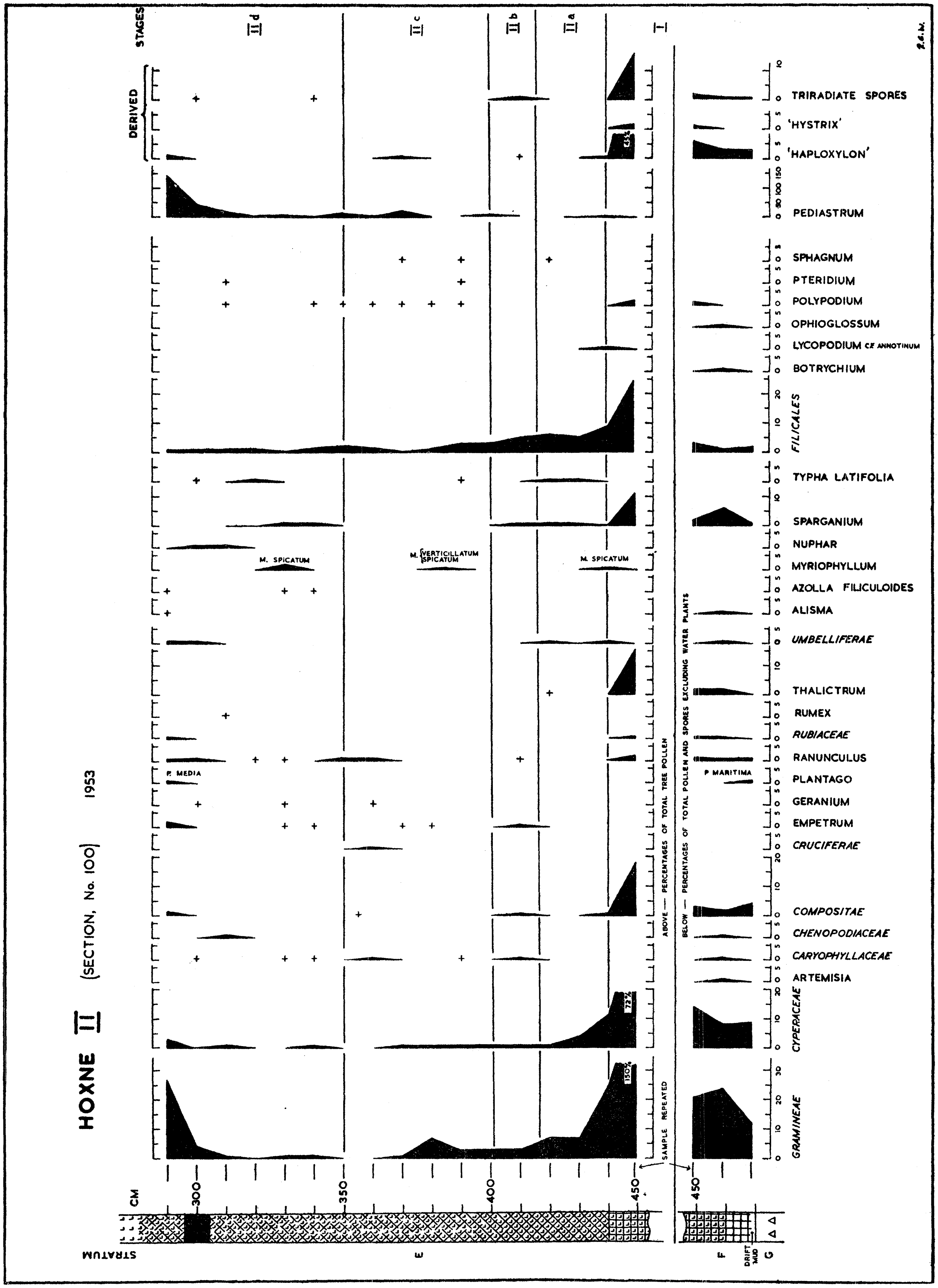

FIGURE 26. Non-tree pollen diagram from the marginal lake deposits.

Table 5. Pollen analyses of clay-mud from artifacts, bones and charcoal

sample no. ...	1	2	3	4	5	6	7	8	9	10
Betula	5	5	9	12	6	4	5	4	15	14
Pinus	16	11	14	15	15	10	13	13	14	2
Ulmus	10	10	6	8	3	15	10	13	10	.
Quercus	10	14	11	11	1	13	11	9	10	.
Tilia	3	7	5	4	8	4	3	5	2	.
Alnus	55	51	52	43	64	53	57	52	46	.
Fraxinus	.	.	.	4	1	.	.	.	.	.
Picea	1	2	3	2	1	1	1	4	3	.
Carpinus	.	.	.	1	1	.	.	.	.	.
Corylus	49	45	16	17	31	38	38	38	21	+
Salix	.	.	.	1	.	.	.	.	.	1
Hippophaë	.	.	.	15	.	.	.	.	.	39
Hedera	1	.	.	1	.	1	1	1	.	.
Ilex	+	1	.	.	.	1	1	1	+	.
Gramineae	2	+	17	23	.	1	1	1	12	19
Cyperaceae	.	.	.	4	.	.	1	.	1	17
Artemisia	.	1	1	1	.	.	.	.	.	+
Caryophyllaceae	.	+	.	.	.	.	+	+	+	.
Chenopodiaceae	.	.	.	.	.	+	.	1	+	.
Cruciferae	.	.	.	.	.	1	.	.	.	.
Compositae	.	.	1	1	.	.	.	.	1	3
Empetrum	.	.	.	.	.	.	.	.	+	.
Geranium	.	+	.	.	.	.	.	.	.	.
Pastinaca	.	.	.	1	.	.	.	.	.	.
Plantago cf. *lanceolata*	.	.	2	1	1	.	.	.	.	.
Plantago cf. *major*	.	.	.	.	.	.	.	.	.	.
Plantago cf. *media*	.	.	.	3	.	.	.	.	+	.
Ranunculus	.	.	.	1	.	.	.	1	.	1
Rubiaceae	.	.	1	.	.	.	.	.	.	1
Thalictrum	.	.	.	1	.	.	.	.	.	1
Umbelliferae	.	.	1	.	.	.	.	.	.	1
Urtica	.	.	.	12	.	.	.	.	.	.
Azolla	.	+	.	.	.	.	.	.	.	.
Myriophyllum	.	.	.	1	1	1	1	.	.	.
Nuphar	.	.	.	.	.	.	+	.	.	.
Sparganium	.	.	1	1	.	+	.	1	.	4
Typha latifolia	.	.	.	1	.	1	+	.	.	.
Filicales	2	1	10	.	1	+	1	1	1	1
Osmunda	.	.	.	.	.	1	1	.	.	.
Polypodium	+	+	1	.	1	.	1	.	+	.
Sphagnum	.	+	.	1	.	.	1	.	.	.
derived	.	.	.	1	.	.	.	.	.	4

Nos. 1–9: Percentages of total tree pollen.
No. 10: Percentages of total pollen and spores excluding water plants.
+ Seen in screening.

Key to samples:

1. Flake at 300 cm, section no. 100.
2. Flaked flint at 300 cm, section no. 100.
3. Hand-axe found by workmen near section no. 96.
4. Hand-axe found by workmen near section no. 96.
5. Flint core, British Museum (N.H.) no. E. 1272, found by Dr Oakley, from stratum E on north face of Oakley Park pit.

6, 7, 8. Bone fragments found at 300 cm, section no. 100.

9. Charcoal found at 290 cm, section no. 100.
10. Radius of *Cervus elaphus* found by workmen in stratum F (see Appendix 4).

content, except near the top of the diagram, where there are distinctly lower percentages of *Quercus* than in the main tree-pollen diagram I *A*.

It is clear that the pollen stages in these diagrams from section no. 100 at the margin of the lake deposits are exactly similar to those of the long diagrams from the borehole no. 36 in the central part of the lake basin. This is in accordance with the conclusion, made on the stratigraphical evidence, that the marginal lake deposits, described by Reid as the Palaeolithic loam, are of the same age as the central deeper-lying deposits of strata E and F, called by Reid bed E.

The pollen diagrams II are cut short at the top by the leaching of the clay-mud. They stop just where *Betula* and *Pinus* rise at the expense of the mixed oak forest trees. This is the beginning of the high non-tree-pollen phase which occurs towards the end of substage II *d* in the long diagrams Hoxne I *A*. The pollen analyses of clay-mud taken from the flints, bones and charcoal found in the excavation of the pit at section no. 100 are given in table 5. They show that the charcoal is from the high non-tree-pollen phase and the others from slightly below this. The analyses conform with those from the depth in section no. 100 at which the occupation traces were found.

(iii) *Hoxne III*

This pollen diagram (figure 27) is from section no. 11, at the north face of the Oakley Park pit. It differs from the other diagrams chiefly in the very low percentages of *Quercus* and the relative increase in the other trees, except *Betula*, and in the absence of *Hippophaë* and the low values of Gramineae and Cyperaceae at the base of the diagram. Nevertheless, the pollen stages identified in the other diagrams are still recognizable in this diagram, as would be expected from the stratigraphical evidence that the lake deposits of the section belong to strata E and F.

At section no. 11 the clay-mud is heavily weathered and the organic content reduced (see analyses in table 1). The difference of this pollen diagram from the others must be ascribed to the differential destruction of pollen by the weathering. *Quercus* in particular has suffered destruction, and the percentages of the other trees have changed as a result.

The section from which this diagram was taken is in Reid's Palaeolithic loam (his bed A). The similarity of the pollen diagram from the section to those from the deeper-lying lake sediments reinforces the conclusion that the Palaeolithic loam is, in fact, part of strata E and F (Reid's bed E). This is again shown by the pollen analysis of a sample of weathered clay-mud collected by Reid from the north face of the Oakley Park pit and placed in the Museum of the Geological Survey (collection no. M.R. 25706). The sample is labelled 'Bed A, lower part, Oakley Park Pit, clay with freshwater shells, B. Assn, 1896.' Pollen analysis of part of this sample gave the following result:

Betula	47	Filicales	6
Pinus	51	Gramineae	1
Alnus	2	*Ophioglossum*	1

(Percentages of total tree pollen).

This spectrum fits into the lower part of the diagram III.

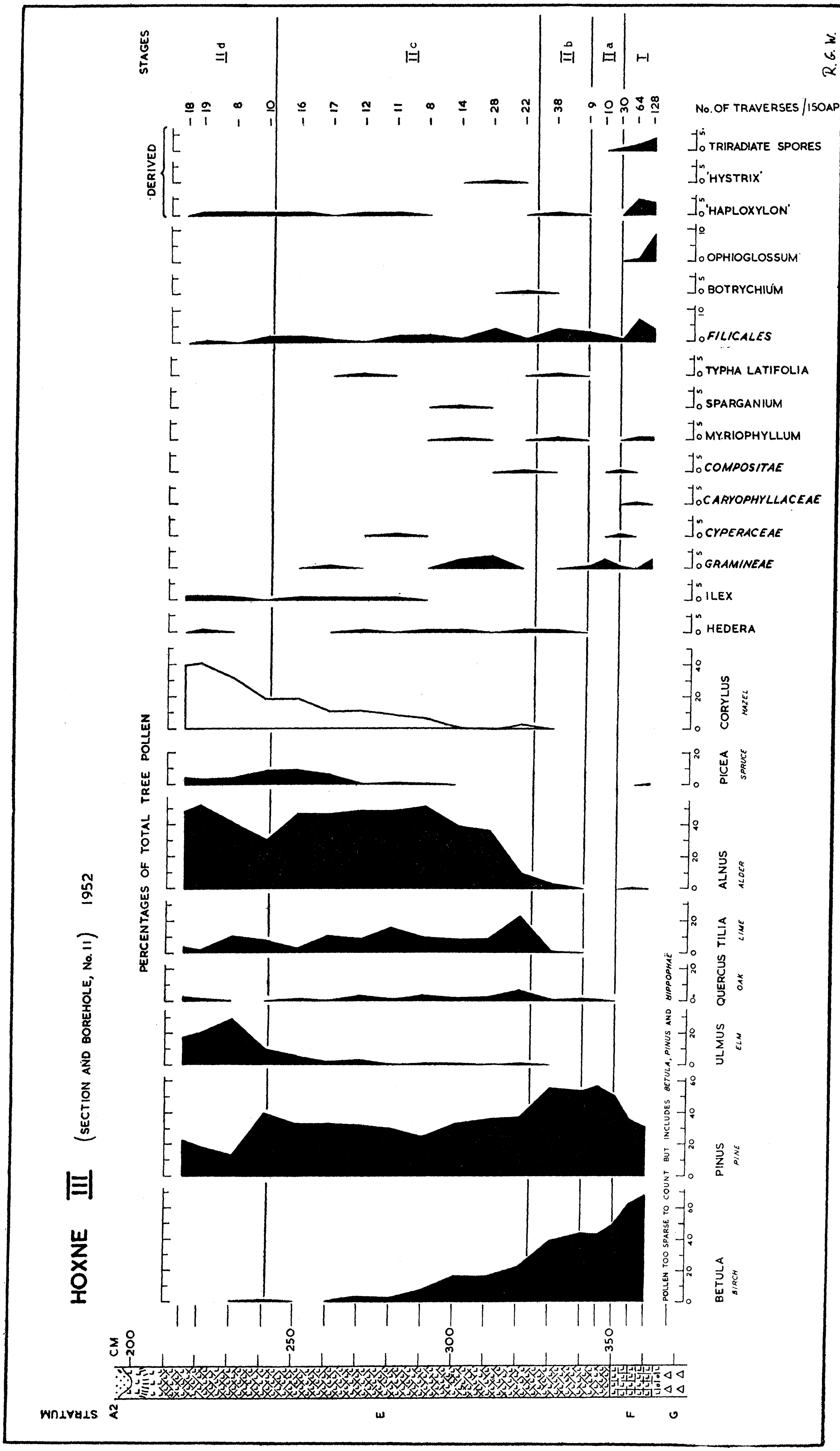

FIGURE 27. Pollen diagram from the weathered marginal lake deposits.

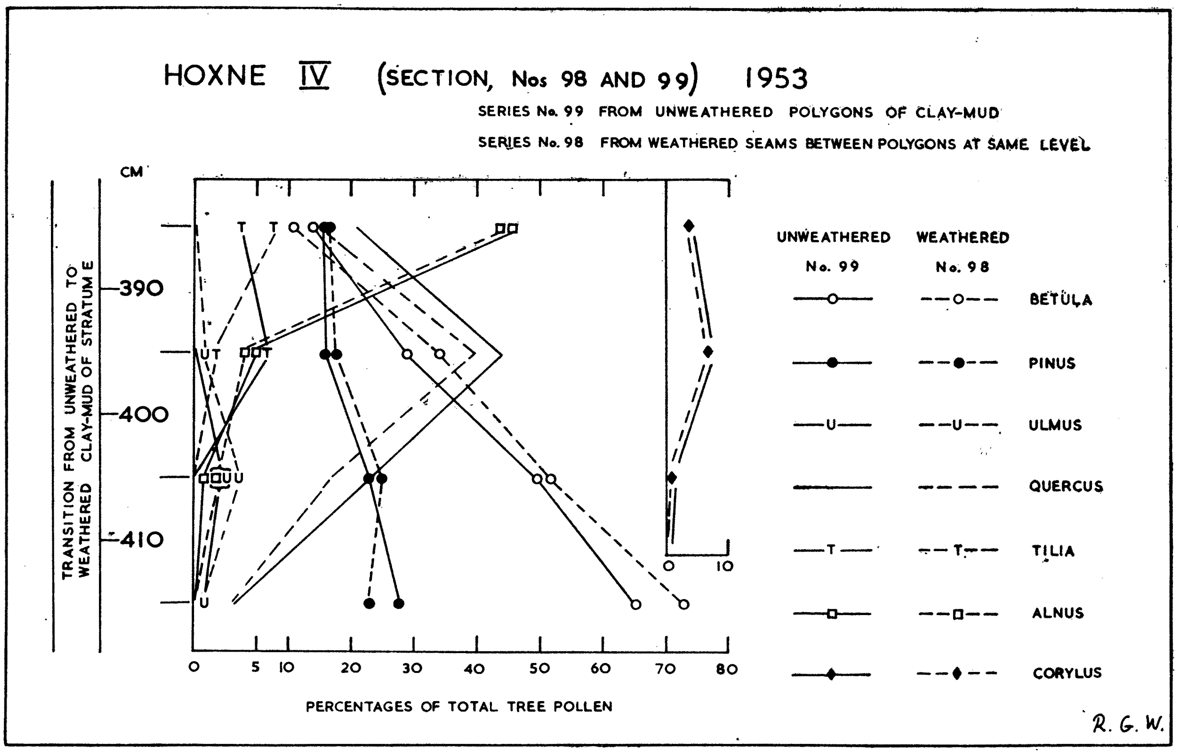

FIGURE 28. Pollen diagram from weathered and unweathered stratum E.

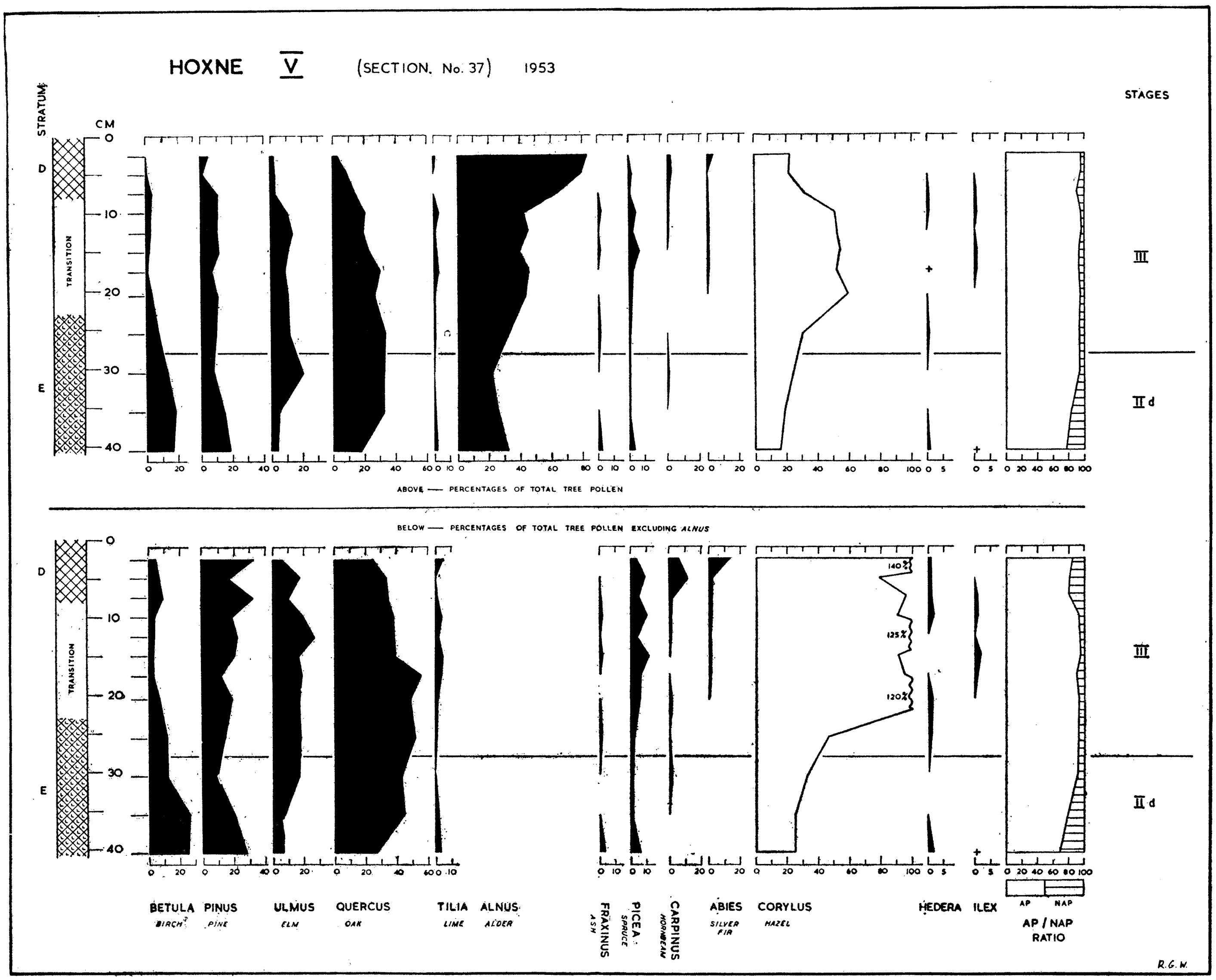

FIGURE 29. Tree-pollen diagram of the transition from stratum E to stratum D.

(iv) *Hoxne IV*

This short pollen diagram (figure 28), from next to section no. 100, is taken through the part of the section containing polygonal lumps of unweathered clay-mud set in a matrix of weathered clay-mud. The similarity of the curves from the weathered and unweathered clay-mud indicates that this structure is caused by the onset of weathering rather than by the reworking and redeposition of older deposits.

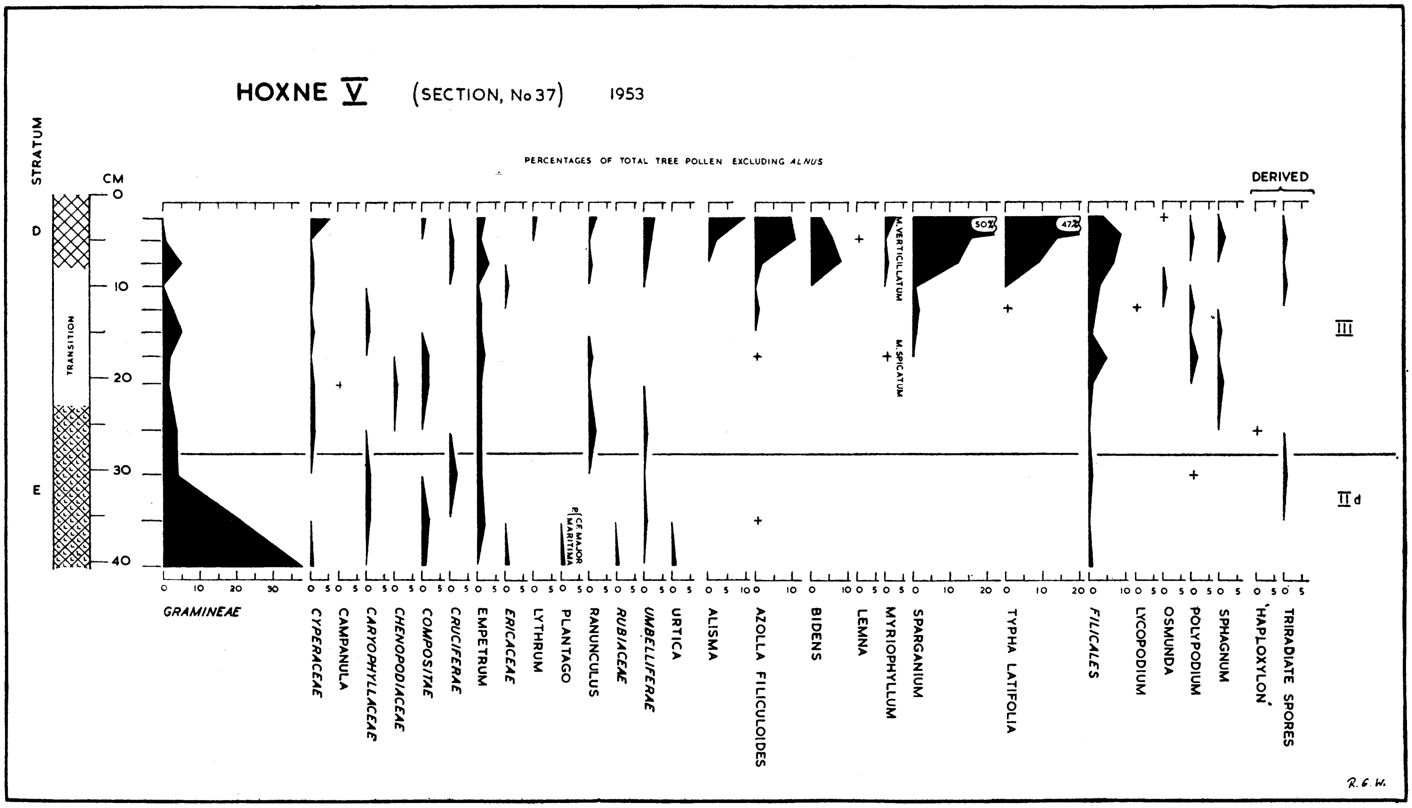

FIGURE 30. Non-tree pollen diagram of the transition from stratum E to stratum D.

Too few pollen grains were counted to decide whether the onset of weathering affected the pollen percentages. The curves in this diagram nevertheless suggest the same tendencies towards differential destruction that are seen in diagram III from the very much more weathered clay-mud of section no. 11.

(v) *Hoxne V*

These tree- and non-tree-pollen diagrams (figures 29 and 30) are from section no. 37, which showed the transition from stratum E to stratum D. This transition was not found in the cores of borehole no. 36. The diagram shows the transition from stage II to stage III, marked by the rise in *Pinus* and *Picea*, and the appearance of *Carpinus* and *Abies*.

(vi) *Hoxne VI*

This pollen diagram (figure 31) is taken from the marginal lake deposits found in borehole no. 16. The conformity of the diagram to the pollen stages found in the deeper-lying deposits shows that the clay-mud belongs to strata E and F, as concluded from the stratigraphy. The borehole is close to Reid's borehole CR 13, which proved Palaeolithic loam. The result again substantiates the conclusion that Reid's Palaeolithic loam is of the same age as the author's strata E and F.

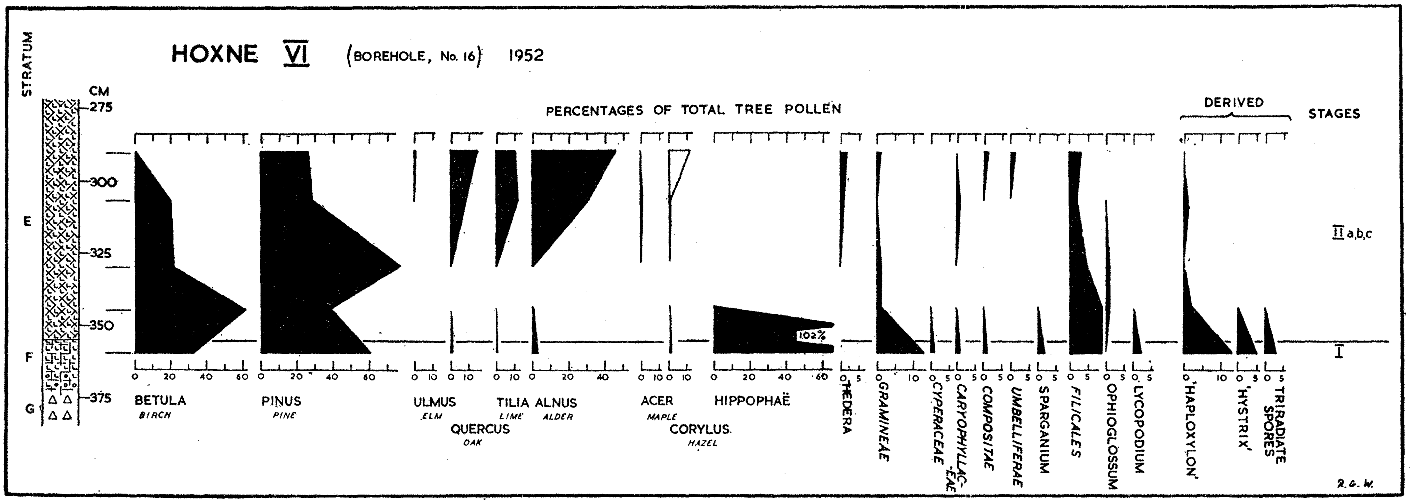

FIGURE 31. Pollen diagram from the marginal lake deposits.

6. The vegetational and climatic history of the Hoxne Interglacial

The results of the botanical investigations may now be used to reconstruct the vegetational and climatic history of the interglacial period. Table 2 summarizes the conclusions reached in this section.

(a) *Stage I. The Late-Glacial stage*

The Late-Glacial stage is the period between the disappearance of the ice which laid down the chalky boulder clay of stratum G (Lowestoft Till) and the closing in of the forests which took place at the beginning of the Early-Temperate stage (stage II),

The vegetation of this stage must have been dominated by *Hippophaë rhamnoides*, for even though the pollen production of this species is low (Firbas 1934), high pollen percentages are found throughout most of the stage. *Hippophaë* must have occurred in thick stands on the newly exposed chalky boulder clay, the calcareous soil of which would be particularly favourable to the growth of the plant. The stands may either have been confined to the margins of the lake, or have been scattered over the surface of the surrounding land. The latter seems the more likely, for although *Hippophaë* is frequently found on gravels of fast-flowing rivers, it is not usually seen around the kind of lake suggested by the interglacial sediment. Conditions favourable to *Hippophaë* near lakes would surely permit the growth of *Betula* in the hinterland, and such a situation is not suggested by the pollen diagram. The replacement of *Hippophaë* by *Betula* at the end of the stage also supports this interpretation.

The only important tree of the stage was *Betula* (no pollen distinguishable as *B. nana* was found). The low and uniform values of *Pinus* during all parts of the stage except the final substage suggest that its pollen was blown in from a distance.

At the beginning of the stage (substage I*b*) we may deduce a *Hippophaë* scrub, with very little *Betula*, and with herb communities consisting mainly of grasses and sedges. There were also present such plants as *Artemisia*, Compositae, *Helianthemum*, *Plantago* and *Thalictrum*. These herbs persisted throughout stage I with little change in their frequency. Many of them are considered to be characteristic of the Late-Glacial Period after the Last Glaciation. Towards the end of substage I*b*, *Hippophaë* started to decline and the grasses rose, perhaps because of a release from the restriction of their growth by the *Hippophaë* scrub.

In substage I*c*, birch to some extent took the place of *Hippophaë*, and probably formed isolated copses in the scrub. The herbaceous vegetation was little affected by the change, except that the grasses declined. The spread of *Betula* at this point is the first sign of the immigration of trees into the area after the glaciation. In the same substage traces of thermophilous trees appeared for the first time.

But this change was short-lived. The *Betula*-rich period of substage I*c* ended with the return of vegetational conditions similar to those of substage I*b*. *Hippophaë* replaced the birch, and the grasses declined.

This substage (I*d*) coincides with the layer of clay-mud with chalk pebbles, a layer ascribed in §2(*c*) to the recurrence of solifluxion. It is probable that both these changes—the decline of birch in favour of *Hippophaë* and the solifluxion—were responses to the same climatic change. Possibly they were both the result of a temperature drop, but, in view of the fact that the tree birches extend both farther north in Scandinavia and to higher altitudes in the Alps than *Hippophaë*, it is possible that the edaphic conditions caused by solifluxion favoured *Hippophaë* at the expense of *Betula*. The solifluxion may have been due to an increase in the precipitation. Perhaps wind had some effect, for *Hippophaë* appears to be more resistant to wind than many trees, and Jahn (1951) describes wind as a characteristic feature of the contemporary periglacial climate.

In the final part of the stage, substage I*e*, the *Hippophaë* scrub declined. Amelioration of the climate must have allowed successful competition by the birch, which again formed scattered copses. *Pinus* also spread at the same time. The grasses were again favoured by the decline in *Hippophaë*, and the sedges also increased. However, the low tree to non-tree pollen ratio of substage I*e* shows that the closure of the birch forest was delayed by a still severe climate.

The stratigraphical evidence suggested that during the Late-Glacial stage (stratum F) the water level in the lake rose. This rise is reflected by the change in the macrofossil content of stratum F at the base of section no. 100. The majority of the seeds and fruits belong to aquatics; they decrease in number towards the top of the stratum, being most abundant in the drift mud at the base. Here the presence of drift wood (possibly referable to *Salix* sp. but too squashed to identify certainly), together with monocotyledonous cuticles and abundant remains of water plants, indicate shallow-water conditions at the very beginning of the interglacial period. The abundance of fresh-water Mollusca (see Appendix 3) in the deposit also points to the same conditions. The cosmopolitan species *Potamogeton pectinatus* is especially well represented (tubers and fruit-stones). The other *Potamogetons* are all circumboreal in distribution, except *P. acutifolius*, which is more continental and is the only species with a southern distribution found in the deposits of this period.

The present behaviour of *Hippophaë rhamnoides* may offer a means of establishing the nature of the climate during stage I. To-day, *Hippophaë* has a wide but discontinuous distribution, from the Atlantic (north to 67° in Norway) and Baltic coasts and Portugal and Spain, eastwards through central Europe and temperate Asia to Japan. In the Alps *Hippophaë* does not rise higher than the forest-limit (Hegi 1926), and in Scandinavia it is mainly confined to the coastal districts, but may ascend valleys up to the birch-limit (Palmgren 1912; Nordhagen 1940). Thus *Hippophaë* is found only in climates less severe than arctic* (or alpine) and usually in those less severe than sub-arctic (or sub-alpine). Apart from this, the wide distribution suggests that *Hippophaë* has little preference for special conditions of rainfall or temperature. It is a plant intolerant of shade and is characteristic of open habitats, where it may escape competition from trees. Thus it is most commonly found in such temporary habitats as dunes and river gravels, where it behaves as a pioneer plant. It appears that the chief common factor of *Hippophaë*'s present distribution is avoidance of competition.

From these facts it may be inferred that the climate of stage I was less severe than arctic and probably less severe than sub-arctic. Also, it is apparent that the interglacial behaviour of *Hippophaë* closely resembles its present-day behaviour. It was a pioneer plant on the chalky boulder clay exposed by the disappearance of the ice, but was driven out by competition on the immigration of the trees.

Of the other plants found in the stage, only *Typha latifolia* is useful as an indicator of climate. Iversen (1954) considers this plant to be distinctly thermophilous, for to-day it is not found beyond the 14° C July isotherm in Scandinavia and in the Alps it rarely rises above an altitude of 1000 m, well below the tree-limit. The presence of the species again suggests the clement nature of the stage I climate.

It may be concluded that during the first part of the stage there was *Hippophaë* scrub open enough to allow much herbaceous vegetation (substages I*b* to *d*), and that during the last part of the stage this gave way to scattered birch woods (substage I*e*). The climate during the stage was certainly less severe than arctic, and was dry and/or warm enough to prevent solifluxion except in substage I*d*. Yet it was severe enough to allow *Hippophaë* to remain dominant during the greater part of the stage.

It is impossible not to draw comparisons of stage I with the Late-Glacial Period after the Last Glaciation. The general similarity both in pollen types and in stratigraphy is most striking. The chief difference is the abundance of *Hippophaë* and the length of time of its dominance. A peak of *Hippophaë* characterizes the end of the woodless zone I in the area of the Alps, just before the spread of the trees (Firbas 1949). Here it is only a transitory peak, representing the initial colonization of the newly exposed soils. In the interglacial period, *Hippophaë* plays a dominant role for a much longer period, but it occurs in the same way, just before the spread of the trees.

The presence of *Hippophaë*-rich communities stresses the difficulty of comparing late-glacial communities in general to any present-day communities. The nearest floristic equivalents to the stage I communities seem to be some of the *Hippophaëta* on Åland

* Arctic (or alpine) and sub-arctic (or sub-alpine) have the meanings attached to them by Hustich (1953); sub-arctic (or sub-alpine) refers to the region between the forest-limit and the tree-limit, the latter marking the beginning of the arctic (or alpine) zone.

described by Palmgren (1912), but it is pointless to make climatic inferences from such a comparison.

(b) *Stage II. The Early-Temperate stage*

The amelioration of the climate, first shown towards the end of stage I when *Hippophaë* was replaced by scattered birch copses, continued during this stage. The boundary between stage I and stage II is at the great increase of tree-pollen frequency and the drop in non-tree pollen, both of which represent the closure of the birch forest and the consequent disappearance of open habitats.

The whole of this stage is characterized by high forest made up principally of deciduous trees. The non-tree pollen is at low values once the forest has developed. Amongst the non-tree pollen, it may be noted that Umbelliferae and Caryophyllaceae persist throughout the stage, plants of these families probably forming part of the herb layer of the forest; others, e.g. Chenopodiaceae, Compositae and *Ranunculus* disappear at the beginning and reappear later.

(i) *Substage IIa. The* Betula–Pinus *substage*

The vegetation of this time consisted of a birch forest, at first with only a small amount of pine, later with more. The first of the thermophilous trees to immigrate was *Quercus*, and small amounts of its pollen are found throughout the substage.

The decline in the non-tree pollen during this substage reflects the continuing disappearance of open habitats, but there was still enough open ground to allow a fair representation of *Hippophaë*, grasses, sedges, ferns and other herbs. The peak of non-tree pollen (mostly grasses) at the beginning of the substage corresponds to a bed of very calcareous clay-mud. The possible origin of such a variation is discussed in the next section.

(ii) *Substage IIb. The* Betula–Quercus–Pinus *substage*

Quercus, the only thermophilous tree present in the previous substage, became the dominant tree of the forest during this substage. The amelioration of the climate must have been rapid, for the oak forest immediately followed the birch forest, with no intervention of a pine stage. Probably the climate was too oceanic, and the soil of the chalky boulder clay too base-rich, to allow the successful competition of pine against the oak.

The pollen values of *Quercus* reach 56 %, a high value considering the pollen production is low compared with that of *Pinus* and *Betula*. The species is almost certainly *Quercus robur*, which would have grown well on the basic and heavy soils of the chalky boulder clay. This species was found in the interglacial deposits at Clacton (Reid & Chandler 1923), shown later to be of the same age as the Hoxne Interglacial.

The continuous low values of *Ulmus* found in the substage show that this was the next thermophilous tree to immigrate, and it must have formed part of the forest at this time. *Fraxinus* also occurs in some quantity, the pollen curve forming a peak towards the end of the substage. *Tilia*, *Alnus* and *Picea* are represented sparsely in the substage.

Upon the formation of the oak forest, *Corylus* and *Hedera* appeared in small frequencies. *Hedera* must have been a fairly common constituent of the forest by this time, the pollen frequencies being as high as 3%; this frequency is maintained throughout the rest of stage II. Assuming that the species is *H. helix*, a not unlikely supposition in view of the similarity of this interglacial vegetation to that of present British woods on a similar chalky boulder-clay soil, valuable climatic inferences can be drawn from its presence at this stage. Iversen's (1944) deduction of the 'thermosphere' of this species from its present distribution shows that it will not tolerate an average temperature of the coldest month of below $-1\cdot5^\circ$ C, and that it also requires an average temperature of the warmest month of over 13° C. In any event, the presence of *Hedera* in such abundance must indicate a climate of considerable oceanicity.

Amongst the non-tree pollen, *Hippophaë* and *Thalictrum* are still found, testifying to the continued presence of a small area of open habitats.

The fluctuation of forest conditions towards the end of the substage is shown in the pollen diagrams I*A* by the alternation of *Quercus* and *Betula*, a rise in *Fraxinus* and the grasses, and a drop in the tree-pollen frequency. These changes correspond to the layer of very calcareous clay-mud of core 16, borehole no. 36. A similar fluctuation (without the mixed oak forest species), allied to a stratigraphical change, was observed in the previous substage. These changes in sedimentation were only seen in borehole no. 36.

At these times the forest cover must have decreased, to give open habitats favourable to the growth of herbs. If this were due to a climatic change, then this was not severe enough to influence *Hedera*, and it allowed an increase in *Fraxinus*, which, indeed, reached its highest values at the time. It is possible that these phases are the results of natural forest fires causing a depopulation of the forest. The rapid regeneration of birch would accompany such a deforestation, and *Fraxinus*, usually considered a light-demanding tree, and which is already present in the forest in small quantities, would also respond in the same way. *Quercus*, with a longer generation time, would recover its dominance later. Until there are further detailed pollen diagrams from other sites of the same age, it is impossible to say whether these are minor local fluctuations or not.

(iii) *Substage IIc. The* Alnus–Quercus–Betula–Tilia *substage*

Alnus, already present in small amounts in the previous substage, spread rapidly at the beginning of this period. The species is probably *A. glutinosa*, the fruits of which were found in stage III (stratum D). As in the Post-Glacial Period, this sudden expansion of *Alnus* may have been caused either by an increase in the summer warmth or by a general increase in the soil moisture, or perhaps both. It is difficult to say how far this apparent spread was caused by local over-representation. The margins of the lake might have yielded evidence on this point, but they have been destroyed by erosion. It is probable that *Alnus* did play some part in the mixed-oak forest; nowadays it is often found in damp oakwoods.

The increase of *Alnus* was accompanied by a rise in *Tilia* (cf. the end of zone VI in the Post-Glacial Period in south and east England (Godwin 1940)), and during this substage *Tilia* must have been common in the forest. The pollen is all of the *T. cordata* type. *Tilia* is usually considered characteristic of the Post-Glacial climatic optimum, being favoured by the increased warmth of that period (Godwin 1940). Such an increase of warmth seems to have taken place at this point in the interglacial period, and the climatic optimum (thermal optimum) may well have been in this substage. The presence of *Tilia* in such frequency certainly signifies a climate just as warm in both summer and winter as in the early part of the Atlantic Period of the Post-Glacial Period.

The declining pollen values of *Ulmus* show that it largely disappeared from the forest during this period, although it was present to a small extent in substage II*b*. *Fraxinus* remained a component of the mixed-oak forest. *Betula* and *Pinus* both declined in this period and must have been very nearly completely ousted from the forest by the dominance of the mixed-oak forest species. Leaves and an acorn of *Quercus* were found in deposits of this substage in section no. 100.

The gradual rise of *Corylus* occurs in this substage. The species is probably *C. avellana*, the fruits of which were found by Reid in stage III (stratum D). It appears that *Corylus* slowly became dominant in the shrub layer of the mixed-oak forest. The slow rise is very different from the rapid rise of *Corylus* before the spread of the mixed-oak forest in the Post-Glacial Period. Perhaps its late immigration in the interglacial period, after that of the mixed-oak forest, accounts for this difference.

As the mixed-oak forest achieved dominance, so the non-tree pollen fell to its lowest values soon after the beginning of the substage. *Hippophaë*, *Thalictrum* and others were still present at the beginning but they soon disappeared. *Pastinaca* (cf. *sativa*) may be noted from this period; *P. sativa* was also found in the interglacial deposits at Clacton (Reid & Chandler 1923), of the same age as the Hoxne Interglacial. In general, the non-tree pollen shows its smallest variety during this substage.

During the second part of the substage *Ilex* appeared as a constituent of the forest, and *Ulmus*, *Picea* and *Empetrum* increased their frequencies.

Ilex, probably *I. aquifolium*—a species found in the deposits of the same age at Clacton (Reid & Chandler 1923)—must have formed a part of the lower tree layer characteristic of *Quercus robur* woods. Again using Iversen's (1944) evidence of the thermal toleration of this species, it may be concluded that the average winter temperature of the coldest winter month did not fall below $-0{\cdot}5^\circ$ C. This climatic condition must have lasted to stage III at least, since *Ilex* persisted till that time.

Empetrum (cf. *nigrum*) occurs in small frequencies from this substage onwards, suggesting the presence of oceanic heath communities at some distance. Perhaps these developed on outwash deposits of the previous glaciation. The rare occurrences of *Sphagnum* spores may be associated with the same vegetation type.

Azolla filiculoides first appears in this substage. The value of *Azolla* as a climatic indicator is doubtful, for it has a very wide distribution in the Americas, and its behaviour in western Europe at the present day is erratic. It has been observed to survive the winter under ice and to be killed by winter frosts. An account of the identification of *A. filiculoides*, the ecology of the species, and its present and past distribution has been given by West (1953).

The beginning of this substage is complicated by a repetition of the changes of *Quercus* and *Betula* seen in the previous substage. These changes are again accompanied by a rise in the non-tree pollen and a fall in the tree-pollen frequency, but there is no rise of *Fraxinus* nor is there a change in the stratigraphy. The explanation of the changes may be the same as that offered for the earlier ones. It is clear that the general decline of *Betula* is delayed by these changes.

(iv) *Substage IId. The* Alnus–Quercus–Ulmus–Tilia *substage*

At the beginning of this substage *Ulmus*, already present in the forest to a small degree, increased in frequency rapidly. At the same time *Tilia* declined. These changes must have been caused by an alteration in the climatic conditions; possibly decrease in summer warmth, perhaps accompanied by an increase in moisture. More cannot be said whilst the identity of the species of elm remains unknown.

The mixed-oak forest remained dominant throughout this substage, except for a period towards the end, when the non-tree pollen increased rapidly and then declined again. This high non-tree pollen phase is not discussed in detail in this section, but in §7, as its importance merits a separate examination. In the following description the changes belonging to this phase are therefore omitted, and they may indeed be regarded as an interruption or temporary disturbance of the natural vegetational evolution of the interglacial period.

The mixed-oak forest of substage II*d* covers half the depth of stage II in borehole no. 36. It thus persisted for a great length of time. Besides *Quercus*, *Ulmus*, *Alnus* and *Tilia*, *Fraxinus* still formed a component of the forest; it became more important in the middle of the substage and fell away again towards the end. Towards the end of the substage, both *Tilia* and *Fraxinus* must have been only sparingly present in the forest, for during the high non-tree pollen phase at the end of the substage, when *Quercus* and *Ulmus* decline, no effect is seen on *Tilia* and *Fraxinus*.

Betula and *Pinus* both become more prominent towards the end of the substage (neglecting the high non-tree pollen phase, which occurred after they started rising), and so does *Picea*.

These changes may partly reflect a gradual deterioration of the climate, or partly a change in the edaphic conditions, such as leaching of the soils. *Fraxinus* and *Ulmus*, both trees which prefer fertile base-rich soils, are found throughout the substage, and it is therefore more likely that a climatic change took place during this substage, perhaps in the form of a decrease of summer warmth. The presence of *Hedera* and *Ilex* in this period indicates that there was not much change in the average winter temperatures. There is some suggestion in the *Hedera* curve of a decline of this plant, and *Ilex* also declines slightly. Such changes could have been brought about by a decline in the summer temperatures.

The curve for *Corylus* indicates that this plant reached its maximum frequency during this substage, and its decline set in towards the end of the period. This decline corresponds to the increase of *Betula* and *Pinus*, and to the fall of *Fraxinus*, *Hedera* and *Ilex*, and it was therefore probably conditioned by the changing climate.

Taking all these changes into account, there is a definite impression of the phenomenon of revertence during the substage II*d*. It is seen in the behaviour of the curves of *Betula*, *Pinus*, *Alnus*, *Fraxinus*, *Corylus*, *Hedera* and *Ilex*. The real behaviour of these plants is partly masked by the high non-tree-pollen phase at the end of the substage and by the great increase in *Alnus* in stage III (an effect of local over-representation), but in general, the reversal of the curves starts before the disturbance by the high non-tree-pollen phase, and it therefore seems probable that deterioration of the climate started during this substage.

Throughout the substage the tree-pollen frequency remains high and the non-tree-pollen low (with the exception at the end of the substage). The pollen of *Geranium* cf. *sylvaticum* was found; it may represent plants which lived in the herb layer of the mixed-oak forest. Caryophyllaceae *Ranunculus* and Umbelliferae occur throughout the period, and amongst the ferns *Pteridium* and *Osmunda* occur for the first time here.

The *Osmunda* spores are not comparable with those of *O. regalis*, but closely resemble spores of *O. claytoniana* (photographs of the spores are given in plate 6). *O. claytoniana* is a species now found in eastern North America and (a different variety) in east and south central Asia (Fernald 1950). It has been found by Szafer (1952) in the older Polish interglacials. The present disjunct pattern of distribution of *O. claytoniana* resembles that of other genera now common to Asia and North America but which had a much wider distribution in Tertiary times. The interglacial occurrence of the species in intermediate areas is presumably a stage of the change from a former wider to a present disjunct distribution.

Towards the end of the substage there is an increase in *Azolla* and *Sparganium*, and there is also a layer of clay-mud with the mollusc *Valvata piscinalis* Müller (at *ca.* 610 cm in borehole no. 36). *Pediastrum* also rises at this point (see pollen diagram II). It is evident that towards the end of the substage the lake was undergoing some change, which, however, did not affect the deposition of profundal clay-mud, even at the present edge of the lake basin.

(*c*) *Stage III. The Late-Temperate stage*

The vegetational history of this stage is masked by the great increase of *Alnus* which took place at the time of the stratigraphical change from stratum E to stratum D. Pollen diagrams V show this transition. The *Alnus* pollen belongs to *A. glutinosa*, the fruits of which were found in stratum D. The increase must represent the growing-over of the edges of the lake by alder carr. It is accompanied by a rise of the pollen of aquatics and semi-aquatics —*Alisma*, *Azolla filiculoides*, *Bidens*, *Sparganium*, *Typha latifolia* and sedges. *Lythrum* (cf. *salicaria*) probably also belongs to this group. The macrofossil list from stratum D shows that the pollen types may be referred, in part at least, to *Alisma plantago-aquatica*, *Bidens tripartitus* and *Sparganium ramosum*. In addition, many of the fruits and seeds found in stratum D are those of fen plants, e.g. *Eleocharis*, *Eupatorium*, *Isolepis*, *Lycopus*, *Montia*, *Oenanthe*, *Ranunculus* and *Schoenoplectus*.

The rise of *Alnus* and aquatics does not correspond exactly to the transition from stratum E to stratum D, but takes place suddenly at its end (see pollen diagrams V). The change in lithology from a clay-mud to a coarser detritus mud started earlier, and it probably signifies a gradual drop in water level and the stoppage of any streams whose water might have brought clay and silt into the lake. Later the vegetation responded and the alder carr grew out over the edge of the lake, with the aquatic plants colonizing the more central parts of the lake.

In the pollen diagram from the upper part of stratum D—diagram I*D*—the aquatics all decline, except for the sedges, which rise to high values. The detritus mud becomes coarser towards the top of the stratum, and contains abundant cones and fruits of *Alnus*. These changes probably represent a final stage of the growing-over of the lake, but the succession is unfortunately truncated by the unconformity which separates stratum D from the next stratum.

The non-tree pollen (excluding water plants) is low at the beginning of the period but rises at the transition to the detritus mud. This is largely due to the inclusion of the sedges in the total; these show a response to the growing-over of the lake and therefore probably belong to aquatic or semi-aquatic species. There may also have been the creation of new habitats suitable for herbs in the alder carr formed at the edges of the lake; the rise in Filicales may have been caused by this. It is important to note that the grasses show no such changes during this period as they do in the high non-tree-pollen phase shortly to be described (§7).

The mosses of this stage, according to Mitten, who identified them for Reid, point to a 'sylvan country in a temperate region of low elevation' (Reid 1896).

To clarify the forest history of this period, it was necessary to make tree-pollen counts excluding *Alnus* (diagrams I*D* and V). At the beginning of the stage, which starts where *Carpinus* forms a continuous curve, the mixed-oak forest resembled that of the previous stage. Gradually, however, *Pinus* and *Picea* both increased their frequencies and the mixed-oak forest species declined slightly.

The curves of *Pinus* and *Picea* begin to rise when the level of the water in the lake starts to drop, as shown by the beginning of the transition from stratum E to stratum D. Perhaps the same climatic effect caused both these changes; for example, a decrease in precipitation or a change to a more continental climate.

The expansion of *Pinus* and *Picea* is followed by a rise in *Carpinus* and then the immigration of *Abies*. Fruits of *Carpinus betulus* were found by Reid in stratum D, so that the species must have been present in the immediate neighbourhood at this time. Measurements by Firbas (1949) relate the pollen percentages of *Abies* to the distance from the border of its distribution; he showed that a 10 % value occurred at the border itself, 2 % 20 km away and 1 % 70 km away. This suggests that *Abies* was nearby during stage III. The presence of *Abies* in the area at some time previous to stage IV is proved by the presence of *Abies* wood in stratum C. This wood must have been derived from previously existing deposits at the edge of the lake. It is not possible to identify the *Abies* species. It may be *A. pectinata* or possibly *A. fraseri*; both have been found in continental interglacial deposits (Szafer 1952). The presence of *Picea* in the neighbourhood is not proved by the occurrence of macroscopic remains.

Taxus was also present during this period, as shown by Reid's identification of the seeds of *T. baccata*.

During this stage *Hedera* and *Ilex* still persisted, showing, with *Taxus*, that the winter climates were not particularly severe. What caused, then, the general decline of the mixed-oak forest? A general climatic change may be assumed, but it may have been accompanied by the deterioration of soil conditions as leaching proceeded, and this would also have caused vegetational changes.

The same situation is seen towards the end of the Last Interglacial in Denmark (with which, of course, no correlation is suggested). Here, in the *Carpinus* zone *g* of Jessen & Milthers (1928), *Ilex* is still present, with *Trapa natans* and *Picea*. *Ilex* apparently even survives to the next two zones, the *Picea* and *Pinus* zones (*h* and *i*) (Iversen 1944). Jessen comments on this (Jessen & Milthers 1928): (in zone *g*)...'Here we find the turning point between the climatic optimum and the subsequent cooler conditions. As a general definition of the climate in the time of the *g*-zone we may say that the summers were still warm, but the winters nevertheless cold enough to favour the conifers at the expense of deciduous trees; it is in the nature of a transitional period, as shown by the fact that such species as *Ilex aquifolium*, *Picea excelsa* and *Trapa natans* were living simultaneously in Jutland at this time immediately before the more thermophile species were exterminated altogether from the region in question. Such a coincidence is not known from regions so far north in post-glacial times.'

This statement exactly applies to the forest history of stage III. On the one hand, there is the oceanic climate suggested by *Taxus*, *Hedera*, *Ilex* and possibly *Abies*; on the other hand, a more continental climate is indicated by *Carpinus* and *Picea*. Of course, the species of some of these genera are not known, and knowledge of this might explain what appears to be an unnatural association.

It is therefore difficult to deduce what the climatic changes of this stage were. In view of the scarcity of evidence, it seems best only to say, as Jessen does, that this type of vegetation represents a transitional period between the climatic optimum (which it has already been suggested was in substage II*c*) and the later severer climate of stage IV.

(*d*) *Stage IV. The Early-Glacial stage*

The confusing nature of the macrofossils in stratum C was pointed out by Reid (1896). He found leaves of such arctic and arctic-alpine species as *Salix herbacea*, *S. myrsinites*, *S. polaris* and *Betula nana* with the seeds and fruits of *Carpinus*, *Taxus* and *Sambucus*. The seeds and fruits were worn, and Reid suggested that they were derived from the breaking up of the older deposits, while such fragile fossils as the leaves represent the flora contemporary with the deposition of stratum C.

The evidence from the pollen analyses of the stratum (diagrams I*E*, I*F* and I*G*) give a similar confusing picture, showing rapid changes in the pollen percentages corresponding to changes in lithology. *Ilex*, *Hedera*, *Azolla*—in fact, nearly all the species found in the lower beds—occur with spectra yielding little other evidence of a temperate climate. As pointed out in §2 (*c*), the pollen is to a large extent derived from the older deposits, as must be many of the macrofossils.

The botanical evidence agrees with the deduction from the stratigraphical evidence that there was a periglacial climate during this stage. The contemporary flora is represented by plants which are characteristic of an arctic climate, the dwarf willows and birch. *Salix herbacea* is a plant typical of regions where the soil is subject to solifluxion movements (Wilson 1952). We may quote from Mitten (in Reid 1896) the evidence of climate given by the mosses found by Reid in stratum C. These are also such fragile fossils that they may be considered contemporary. Mitten said of the mosses: 'all these seem to point to an origin in open moorland. *Acroceratium* (*Acrocladium*) *sarmentosum* is not now found on our plains, but is montane or sub-alpine; they are known to go very far into Arctic regions.'

In the recent investigation leaves of *Salix* cf. *myrsinites* were found. The few leaves made it difficult to make a convincing separation from *S. phylicifolia*, but they lacked the more regular venation and acuter shape of the leaves of the latter species, and they very probably belong to *S. myrsinites*, which they resemble in all respects. This was the only one of the arctic or arctic-alpine species recorded by Reid that was found, but only the cores of borehole no. 36 were examined for leaves, whereas Reid looked through large quantities of stratum C.

The leaves of *Salix myrsinites* occurred near the base of stratum C, in core 5 of borehole no. 36, and therefore the climate must have changed considerably between the deposition of stratum D (stage III) and stratum C (stage IV). If this change was not a rapid one, then there must have been a considerable time gap between the two strata, represented by the unconformity between them. The cause of the unconformity was discussed in §2(*c*).

It is difficult to reconstruct the vegetation of this period accurately, because of the difficulty of distinguishing contemporary from derived fossils. Some further idea may be gained by supposing that the plants occurring more abundantly or for the first time in this period belong to the contemporary flora. The facts that *Sphagnum* leaves first appear here, that spores of *Sphagnum* and pollen of *Calluna* and Ericaceae, all rare in the previous stages, become much more common, and that the values of *Empetrum* also increase, suggest that an oceanic heath type of vegetation developed at some time after the deposition of stratum D. The identifications of *Sphagnum*, as far as they go, suggest acid soil conditions. There may have been a spread of the communities with *Empetrum* previously referred to, and a development of *Sphagnum* communities after the fen stage of the growing-over of the lake (note the finds of *Eriophorum angustifolium* and *Sphagnum* spores in stratum D). Both these changes are consonant with the climatic deterioration at the end of the interglacial period, and agree with Mitten's suggestion of open moorland.

It is impossible to say how much forest, if any, was still present in the neighbourhood in stage IV. *Betula*, *Pinus*, mixed-oak forest species, *Alnus*, *Picea*, *Abies* and *Corylus* are all well represented by pollen, even in the silt layers of stratum C. *Betula*, *Pinus*, *Picea* and *Abies* are all more frequent than in the previous stage, and there is a corresponding decline in the mixed-oak forest species and *Alnus*, *Carpinus* and *Corylus*. These changes may well represent a real change in the forest composition, for the climatic deterioration would certainly affect the forest in this way.

The increase in non-tree pollen, especially the grasses and ferns, also probably reflects the deforestation at the end of the interglacial period. It is unfortunate that it is not possible to separate derived from contemporary pollen with such plants as *Artemisia*, *Hippophaë*, *Plantago* and *Thalictrum*. These, all present in the Late-Glacial stage, may well have returned with the Early-Glacial flora, but then they might also have come from the erosion of the Late-Glacial deposits exposed round the lake margins during stage IV.

To summarize, we may say that the vegetation of stage IV, the Early-Glacial stage, was growing under arctic or sub-arctic conditions. *Salix herbacea*, *S. myrsinites*, *S. polaris* and *Betula nana* were all growing around the lake and were brought into it by solifluxion. Probably oceanic heaths with *Sphagna*, *Calluna*, *Empetrum* and Ericaceae were also present. The forest under these conditions must have been very poor and scattered, and perhaps distant from the neighbourhood. *Betula*, *Pinus*, *Alnus*, *Picea* and *Abies* may all have been present. Certainly they predominated over the more thermophilous trees. The whole assemblage suggests the presence of a park-tundra.

The differences between the vegetation of the Late-Glacial stage and the vegetation of the Early-Glacial stage now become apparent. While the Early-Glacial flora portrays arctic or sub-arctic conditions, the Late-Glacial flora appears to be more temperate.

This difference presumably reflects, first, the lag in the reaction between the retreat and advance of the ice and the climatic conditions causing the changes, and secondly, the differences in the ecological processes of immigration on the one hand and of extinction on the other.

Thus the amelioration of the climate causing the retreat of the ice had proceeded so far by the Late-Glacial stage that no arctic flora was present; but the onset of periglacial conditions in the Early-Glacial period caused the appearance of park-tundra vegetation before the ice advanced into the area.

Finally, we may note that a comparison of the peculiar macrofossil list found in stratum C with the lists from the upper temperate horizons of the Danish Herning type interglacial deposits (Jessen & Milthers 1928) suggests that the latter might be similar in origin to stratum C. This is an important point, because the Herning oscillation is taken to be of stratigraphical significance in the Quaternary succession of north-west Europe.

7. The high non-tree-pollen phase of substage II*d*, and the relation of the Palaeolithic artifacts to the forest history

At the top of substage II*d*, where both the tree-pollen frequency and the tree- to non-tree-pollen ratio fall and then later rise again, the mixed-oak forest must have suffered a temporary setback (the effect is seen in the pollen diagrams I*A*, I*C*, II and V). This deforestation apparently led to the increase of *Betula* and *Pinus* at the expense of *Quercus* and *Ulmus*, especially the latter. The increase of grasses and the appearance of herbaceous plants absent since the beginning of the interglacial period, e.g. *Artemisia* and *Plantago*, show that at this time there was opportunity for open-ground communities to thrive.

The following subdivisions are discernible within the phase, as shown by the pollen diagram I*C*:

(*a*) 610 to 620 cm. Increase of *Betula* and *Pinus*; sharp decline of *Ulmus*, *Quercus* and *Corylus*; increase in grasses and other non-tree-pollen types; fall in tree-pollen frequency.

(*b*) 585 to 610 cm. *Betula* and *Pinus* still rising; *Ulmus* and *Quercus* at low values, especially the former; *Alnus* starts to fall; *Corylus* decreasing; grasses and other non-tree pollen types reach maximum values.

(*c*) 577 to 585 cm. *Betula* reaches maximum; *Pinus* high; *Quercus* and *Ulmus* remain low; *Alnus* and *Corylus* falling; grasses and other non-tree-pollen types falling.

(*d*) 572 to 577 cm. (see also basal part of pollen diagram V). *Betula* and *Pinus* falling; *Quercus* rising; *Ulmus* and *Corylus* remain low; *Alnus* falling; grasses and other non-tree-pollen types falling.

(*e*) 550 to 572 cm (see also basal part of pollen diagram V). *Betula* and *Pinus* falling; *Ulmus* rising; *Quercus* high; *Alnus* and *Corylus* steady; grasses and other non-tree-pollen types falling; rise in tree-pollen frequency. Later (at 25 cm in pollen diagram V) both *Alnus* and *Corylus* rise again.

These subdivisions may be interpreted to represent the following vegetational phases (lettered as above):

(*a*) The sudden opening out of the forest and the decline of *Quercus* and *Ulmus*.

(*b*) The rapid spread and maximum frequency of the herbs.

(*c*) The regeneration of *Betula* and *Pinus* and the start of the closure of the forest (*Betula* and *Pinus* both have a shorter regeneration time than the mixed oak forest species concerned here (Iversen 1941)).

(*d*) The recovery of *Quercus* and the consequent decline of *Betula* and *Pinus*, and the continued closing in of the forest.

(*e*) The return to the original forest type, at first with lower values of *Alnus* and *Corylus*, which rise later.

These vegetational changes may be considered to be a natural succession following on a sudden destruction of the forest which occurred towards the end of substage II*d*. This, together with the temporary nature of the vegetational change and the continuation of the pollen curves of plants sensitive to climatic change (e.g. *Tilia*, *Hedera* and *Ilex*), makes it improbable that a long-term climatic change caused the deforestation.

Perhaps a sudden and short-lived climatic catastrophe caused the deforestation, but, it is equally possible, and perhaps more probable, that a forest fire was the cause, especially in view of the find of the piece of charcoal from deposits of the phase in section no. 100 (charcoal was found in no other place in the section). A forest fire would bring about the sudden destruction of the forest and the subsequent recovery which is seen in the phase.

Although certain changes took place in the lake during the deforestation phase (as described in §6(*c*)), it is improbable that they caused the appearance of the high non-tree-pollen phase. The growing-over of the lake, which took place in stage III, shows a totally different effect on the pollen curves than that which is seen in this phase, and, in addition, there is no change of sediment during the phase.

The relation to the forest history of those artifacts and other remains which have been dated by the stratigraphy and pollen analysis to a particular phase of the forest history may now be described.

The flaked flints and broken bones from the excavation by section no. 100 all came from the same level, immediately below the deforestation phase (as seen in pollen diagrams II, and described in §5(*c*)). The pollen analysis of samples taken from the crevices of a hand-axe found by the workmen in the deposits near section no. 96 (see §4) is given in table 5, no. 3. The samples were obtained from crevices on either side of the hand-axe within two weeks of its discovery, one sample from each side, and each of these samples gave a similar count, aggregated to give the result in table 5. The resemblance of this analysis to the spectra from the deforestation phase leaves no doubt that the axe came from this level; in particular may be noted the high *Betula*, *Pinus* and grasses, low *Ulmus*, and the presence of *Artemisia* and *Plantago*.

A sample from another hand-axe found with the previous one was also analyzed for pollen. The sample was scraped from it some months after it was found. The spectrum is given in table 5, no. 4. It is evidently distorted by contamination, for it bears no resemblance to any other pollen spectra from the interglacial deposits. Except for the high percentages of *Hippophaë* and *Urtica*, the spectrum is close to the one obtained from the other hand-axe. This hand-axe may have come from the same level as the first one, but there must have been contamination before it was sampled.

Sample no. 5 in table 5, from a flint core obtained by Dr Oakley from the highly weathered clay-mud of the north face of the Oakley Park pit, gave a pollen spectrum distorted by weathering. The high *Betula* and low *Ulmus* (not the result of the weathering, as seen from comparison with spectra in pollen diagram III from highly weathered clay-mud), and the presence of *Carpinus*, suggest that the core came from a late part of substage II*d*.

The evidence just described makes it certain that Palaeolithic man was present around the interglacial lake towards the end of substage II*d*. The flint flakes and broken bones found *in situ* came from a horizon just before the deforestation phase, or from it if they sank more than 10 cm into the clay-mud on being deposited, and one hand-axe at least appears to have been thrown into the lake during the deforestation phase.

Although the evidence indicates that Palaeolithic man was contemporaneous with the deforestation, this does not necessarily imply a relation between the two, that is, that the forest was burnt on purpose or that Palaeolithic man cut down or otherwise destroyed trees. Forest fires can occur easily in virgin forest, as pointed out by Iversen (1941), and they could be caused by natural, not human means. Some deforestation effects were noted from the early part of the interglacial; these have not been associated with artifacts.

The deforestation may be a regional or a local phenomenon, and to decide which would give further evidence about its origin; other sites must be investigated before this can be determined. Neither is it possible to estimate the duration of the deforestation phase. Taken in relation to the total depth of the lake sediment in borehole no. 36, it would appear to cover rather a long period.

Nevertheless, in many respects the deforestation phase is similar to the Neolithic clearance phases described first by Iversen (1941). Both show a return of herbs absent since the respective late-glacial times, an advance of *Betula* and a depression of *Ulmus*, and a succession of vegetation similar in outline. But whereas the Post-Glacial *Ulmus* curve never recovers, in the interglacial period there is a full recovery to the previous state of the forest. The *Ulmus* decline in the Post-Glacial Period is usually ascribed to climatic change or to Neolithic activity or to both these. In the interglacial period the decline is a part of the deforestation, probably not caused by climatic change. The behaviour of *Corylus* is also different; in the interglacial period there is no sudden rise of this plant as there is in Iversen's forest clearance phases.

Whatever the meaning of the deforestation phase, it still retains its importance in showing that phenomena correlated with the Neolithic forest clearance are not confined to that period. Any estimate of the effect of Neolithic activity should take into account possible causes of the changes during the Hoxne deforestation phase.

8. Comparisons and correlations with other Quaternary deposits

(*a*) Palaeobotany

(i) *Vegetational history and pollen diagrams*

Introduction

In the Late- and Post-Glacial Periods in north-west Europe, the vegetational history of different areas, as shown by the pollen diagrams, is strikingly similar. There is a pattern of vegetational history which has emerged through the examination of a large number of sites throughout the region.

In the study of interglacial deposits, however, the basis for comparison is much more slender. Not only are there fewer pollen diagrams, but there is uncertainty as to the age of the deposits from which they come.

The best known of the interglacial periods in north-west Europe is naturally the Last Interglacial.* Deposits of this interglacial have been found in many places (over 200 sites are known), mainly in Jutland and north-west Germany, but also in the Netherlands. The majority of these deposits may be dated on stratigraphical evidence alone, so that it has been possible to build up for this period a pattern of vegetational history. This pattern has been described by Jessen & Milthers (1928) and Woldstedt (1954), and it appears to be characteristic of this period and no other, differing markedly, for example, from that of the Post-Glacial Period. Valid comparisons may therefore be made with the vegetational history of the Last Interglacial in north-west Europe.

In the older interglacial periods, however, there is no such body of evidence, either about the deposits themselves or about their position in the geological succession. Long-distance comparisons can hardly be made because of these difficulties. But even if there is little geological evidence of the relative age of interglacial deposits, it is permissible to compare their pollen diagrams and draw conclusions from the comparison if they lie within a small area. The closer are the sites from which the pollen diagrams are taken the more significant is the comparison between them, for the wide dissemination of pollen causes a uniformity of the pollen rain in the same area at the same time. A local approach to the problems of correlation is therefore the most valuable one.

Comparison with other British and Irish interglacial pollen diagrams

Three pollen diagrams from other British interglacial deposits are available for comparison. They are from the Cromer Forest Bed, the Clacton Interglacial, and interglacial deposits at Cambridge.

The pollen diagram from the Cromer Forest Bed (Woldstedt 1950*a*) shows no similarity to the diagrams from the Hoxne Interglacial. *Pinus* and *Picea* are relatively high throughout most of the period represented by the Forest Bed, *Corylus* remains low, and *Abies* is absent. The vegetational histories of the Cromer and Hoxne Interglacials are very unlike, and this difference cannot be ascribed to their distance apart (41 miles). These two interglacial deposits must be of different age. Woldstedt (1950*a*) correlated the Cromer Forest Bed with the First Interglacial.

* General names for the interglacial periods are substituted for the local names whenever possible. The following table, based on the writings of Woldstedt (1950*b*, 1954) and van der Vlerk (1953), shows how these general names are correlated with the local interglacial names. The East Anglian name for the Great Interglacial anticipates the conclusion reached here regarding the age of the Hoxne Interglacial; this conclusion has already been published by the author (West 1954).

			North Germany		
general name	East Anglia West & Donner (1956)	Netherlands	Woldstedt (1950*b*)	Woldstedt (1954)	Alps
Last Interglacial	—	Eemian	Saale/Weichsel	Eem	Riss/Würm
Great Interglacial	Hoxnian	Needian	Elster/Saale	Holstein	Mindel/Riss
First Interglacial	Cromerian	—	pre-Elster	Cromer	Günz/Mindel

The glaciations are referred to by their local names, except for the Last Glaciation, as this is recognizably of the same age in all parts of north-west Europe.

The pollen diagram from the Clacton Interglacial (Pike & Godwin 1953), a site 38 miles south of Hoxne, resembles an upper part of the diagrams from the Hoxne Interglacial. In the Clacton diagram *Picea* and *Carpinus* are present in small frequencies, and *Abies* rises to high values in the upper part. The mixed-oak forest species, which decline towards the top of the diagram, are *Quercus*, *Ulmus* and *Tilia*, in that order of abundance. The values of *Alnus* are high, declining towards the top, and *Corylus* is declining throughout. *Hedera* and *Ilex* are both present. In all these respects the diagram resembles those from Hoxne. Points of difference are the extended *Abies* and *Carpinus* curves and the low values of *Betula* at Clacton.

The rate of sedimentation, usually considered to be rather high under the conditions reflected by the Clacton deposits, may account for some of these differences. It is also possible that they may be partly explained by the Clacton Interglacial showing a part of the interglacial period missing between strata D and C at Hoxne.

The diagram from Clacton thus shows the decline of the mixed-oak forest and the rise of coniferous forest in which *Abies* plays an important part. This forest development exactly parallels that of stage III at Hoxne, with the component trees the same. It is therefore very probable the interglacial deposits at Clacton and Hoxne belong to the same interglacial period. Pike & Godwin (1953) suggested that the Clacton Interglacial was to be correlated with the Great Interglacial.

The pollen diagram described by Walker (1953) from the interglacial deposits at Histon Road, Cambridge (45 miles south-west of Hoxne) shows no resemblance to any part of the diagrams from Hoxne. The most striking feature of the diagram is the high value of *Carpinus* in the lower part of the diagram. *Abies* is only present in very small percentages. The mixed-oak forest is mainly represented by *Quercus*, with very rare *Tilia* and *Ulmus*. *Hedera* and *Ilex* are absent. In these respects the diagram differs from those from Hoxne.

The Histon Road diagram represents a phase of declining mixed-oak forest at the end of an interglacial period, and the sequence of the change does not resemble that seen in the Hoxne Interglacial. It is possible that the diagram could be fitted into the part missing between strata D and C.at Hoxne, but this is very unconvincing in view of the differences noted above. The Histon Road deposits were tentatively correlated by Walker (1953) and by Hollingworth, Allison & Godwin (1950) with the Last Interglacial.

Mitchell (1948) has described pollen-analytical results from Irish interglacial deposits ar Ardcavan, Co. Wexford, and Kilbeg, Co. Waterford. The pollen diagram from Ardcavan bears no resemblance to the diagrams from the Hoxne Interglacial. The few pollen spectra from the deposit at Kilbeg resemble those from stage IV of the Hoxne Interglacial; they show a predominance of *Betula*, *Pinus*, *Alnus* and *Abies*, but have no *Picea*. Mitchell (1951, 1953) concluded from the geological evidence that the Ardcavan and Kilbeg deposits were probably of Last Interglacial and Great Interglacial age respectively.

Comparisons with continental interglacial pollen diagrams

The pollen diagrams from the Hoxne Interglacial are only compared with interglacial pollen diagrams from north-west Europe. Polish interglacial deposits, though thoroughly studied, are too distant to be used; the climatic differences between north-west Europe and Poland, which cause differences between the Late- and Post-Glacial pollen diagrams from both areas, must have also been present in the interglacial periods, and thus a direct comparison for the purposes of correlation would be useless.

The pollen diagrams from Hoxne bear no resemblance to those from the Last Interglacial in north-west Europe. The main points of difference are as follows:

(*a*) The *Pinus*-dominant phase at the beginning of the Last Interglacial is absent in the Hoxne Interglacial.

(*b*) In the Last Interglacial the rapid rise and culmination of the *Corylus* curve occurs at the same time as the expansion and culmination of the mixed oak forest, but in the Hoxne Interglacial there is a slow rise and a much later culmination of the *Corylus* curve.

(*c*) The *Corylus* values are much larger in the Last Interglacial than in the Hoxne Interglacial.

(*d*) The length, relative to the changes seen in the vegetational history, of the period of mixed-oak forest dominance is much shorter in the Last Interglacial than in the Hoxne Interglacial.

(*e*) In the Hoxne Interglacial the characteristic *Carpinus*- and *Picea*-dominant zones of the Last Interglacial are absent.

These differences may be considered individually explicable in terms of possible ecological and climatic differences between the site of the Hoxne Interglacial and the various sites recording the Last Interglacial. But the conformity of Last Interglacial vegetational history in north-west Europe, stretching west at least to the Netherlands (van der Vlerk & Florschütz 1953), and probably to Cambridge if we accept the dating of the Histon Road interglacial deposits by Walker (1953), combined with the great differences between the pollen diagrams of the Hoxne Interglacial and the Last Interglacial, lead to the conclusion that the Hoxne Interglacial cannot be correlated with the Last Interglacial.

Next the continental pollen diagrams considered to be of Great Interglacial age are compared with those from the Hoxne Interglacial. The few continental Great Interglacial deposits with pollen diagrams showing a fairly complete interglacial are of limited use for comparison, because their pollen samples are spaced too far apart to give a complete picture of the vegetational change (e.g. Ummendorf (Selle 1941), Berlin *Paludina* Beds (Heck 1930)). None of them shows the same complete vegetational development that is seen at Hoxne.

There are, however, certain pollen diagrams from deposits placed in the Great Interglacial which show a resemblance to the diagrams from stage IV of the Hoxne Interglacial. It has been shown previously that part at least of the pollen of the stage IV deposits (stratum C) was derived from the older deposits. Nevertheless, the similarity between the stage IV diagrams and certain continental diagrams must be noted.

These continental pollen diagrams have *Pinus* and *Alnus* dominant, with fluctuating values of *Carpinus*, *Picea*, *Abies* and the mixed-oak forest trees. Such diagrams have been obtained from sites dated to the Great Interglacial in the Netherlands at Neede (van der Vlerk & Florschütz 1953), Spannenburg and Bantega (Brouwer 1949), and in Germany, in the Lower Rhine Valley near Krefeld at Hülser Berg (Karrenberg & Rein 1951) and Heideck (Bertsch, Steeger & Steusloff 1931). It will be remembered that similar pollen spectra, but without *Picea*, were found in the interglacial deposit at Kilbeg (Mitchell 1948), probably also of Great Interglacial age (Mitchell 1951).

There are two further points of similarity between the pollen diagrams of the Hoxne Interglacial and those of continental deposits of Great Interglacial age.

First, they show a slow rise and low values of *Corylus*, in which they differ from the pollen diagrams of the Last Interglacial, where the rise of *Corylus* to high values takes place rapidly. The same difference extends to Last and Great Interglacial pollen diagrams from Poland (Szafer 1952). We may note here that the behaviour of *Corylus* appears to differ in the Post-Glacial, Last Interglacial and Great Interglacial Periods in north-west Europe. In the Post-Glacial *Corylus* rises rapidly before the spread of the mixed-oak forest, in the Last Interglacial a rapid rise takes place at the same time of the spread of the mixed-oak forest, and in the Great Interglacial there is a slow rise to a lower maximum, which occurs long after the spread of the mixed-oak forest. Possibly these differences result from different rates of migration from glacial refuges of *Corylus* and of the mixed-oak forest trees, coupled with differences in the proximity of the glacial refuges to the areas left bare by the disappearance of the ice of each glaciation.

Secondly, the behaviour of *Abies* in the Hoxne Interglacial and continental Great Interglacial deposits is similar. Although *Abies* is found in Last Interglacial deposits in north-west Europe, it seems that it was present for a longer period and more abundantly in the Great Interglacial than in the Last Interglacial. The *Abies* curves of many Last Interglacial pollen diagrams from north-west Europe are low and short, whilst in the Great Interglacial diagrams from the same area the curves reach higher values for longer periods.

The pollen diagrams from the Hoxne Interglacial bear no resemblance to any continental pollen diagrams older than the Great Interglacial.

Conclusions

The similarities noted between the pollen diagrams of the Hoxne Interglacial and those of some continental deposits of Great Interglacial age, and the difference of the vegetational history of the Hoxne Interglacial from that of the Last Interglacial and the First Interglacial (represented by the Cromer Forest Bed), lead to the conclusion that the Hoxne Interglacial is to be correlated with the Great Interglacial.

Such a correlation agrees with the dating already described of the British and Irish interglacial deposits which have been shown to bear a resemblance to the Hoxne Interglacial—those at Clacton and Kilbeg.

(ii) *Species*

We may now consider whether any of the species found in the Hoxne Interglacial are of use as 'zone fossils' for the purposes of correlation.

Of the species which are supposed to be confined to certain parts of the Quaternary Period in north-west Europe, only one, *Azolla filiculoides*, was found in the Hoxne Interglacial.

In the Netherlands, *A. filiculoides* is described by van der Vlerk & Florschütz (1953) as characteristic of the Needian Interglacial, which is correlated with the Great Interglacial, but it has been found very rarely in the Taxandrian, the period before the Needian. In Germany, *A. filiculoides* has been found in the *Paludina* Beds of Berlin (Florschütz 1941), in deposits at Wunstorf bei Hannover (von Rochow 1953), in the Krefelder Schichten at Hülser Berg and Dachsberg (von Rochow 1953; Hiltermann 1954) and in deposits on the Isle of Norderney. The *Paludina* Beds of Berlin and the Krefelder Schichten are placed by Woldstedt (1950*b*) in the Great Interglacial and the deposits at Wunstorf are very probably the same age (von Rochow 1953). The age of the Norderney deposits is uncertain (Hiltermann 1954). In Polland, Szafer (1952) has described *A. filiculoides* from beds at Syrniki of Masovian I age (correlated with the Great Interglacial).

Thus *A. filiculoides* has been found in many deposits of Great Interglacial age and in a few of greater age than this (e.g. Taxandrian of the Netherlands), but not in deposits of the Last Interglacial. The presence of the plant at Hoxne indicates that the Interglacial is older than the Last Interglacial, and perhaps suggests a correlation with the Great Interglacial.

(*b*) Stratigraphy

(i) *The relation of the position of the Hoxne Interglacial to the surrounding topography*

For those interglacial deposits which, like the Hoxne Interglacial, are associated with glacial deposits but whose age cannot be determined either by that association or by their position in a series of valley deposits, the results of Jessen & Milthers's (1928) analysis of the relation of the position of interglacial deposits to the surrounding topography may be used to make an approximate determination of the age of interglacial deposits.

Jessen & Milthers demonstrated that the most common type of Last Interglacial deposit in Jutland and north-west Germany (the Brørup type) was found outside the edge of the Last Glaciation in enclosed hollows, which were visible on the surface, and in which there might still be lakes at the present day. These interglacial deposits were formed in hollows in the landscape left by the retreating ice of the previous glaciation, and were covered, but not so much as to fill the hollows, by solifluxion deposits during the Last Glaciation. There has not been sufficient time since the Last Glaciation for erosion to change the landscape enough to obliterate these hollows.

On the other hand, the older interglacial deposits outside the edge of the Last Glaciation generally occupy positions in relation to the topography which indicate that the landscape has changed completely between their deposition and the present time, so that they may even occur on the tops of hills. Unlike the Brørup type, they leave no trace in the topography, for they are essentially a part of the old landscape associated with the glacial deposit on which they lie and which has long since disappeared.

The Hoxne Interglacial, itself outside the edges of the Last Glaciation, clearly occupies a position of the second type, suggesting a greater age for it than the Last Interglacial.

(ii) *The relation of the Hoxne Interglacial to the East Anglian Quaternary succession*

Baden-Powell (1950, 1951*a*) has described the Hoxne Interglacial as lying between the Lowestoft and Gipping Glaciations. Such a position in the East Anglian Quaternary succession is confirmed by the stratigraphical results described here and by the stone orientation measurements of the tills at Hoxne by West & Donner (1956).

The Hoxne Interglacial is demonstrated by its overlying the Lowestoft Till to be younger than the interglacial represented by the Cromer Forest Bed, for the Forest Bed

Series is covered by the Cromer Till, and the Corton Beds and Lowestoft Till successively overlie the Cromer Till as shown in figure 3 (Baden-Powell 1950).

The Hoxne Interglacial is, however, older than the Gipping Glaciation. The ice of this glaciation advanced far beyond the edge of the Newer Drift, south-west to Moreton-in-Marsh, south to Hertford and south-east to Ipswich (West & Donner 1956), and its deposits form part of the Older Drift. The Gipping Glaciation must therefore be older than the Last Glaciation, so that the Hoxne Interglacial is older than the Last Interglacial and the glaciation which preceded the Last Interglacial.

In the East Anglian succession, therefore, the Hoxne Interglacial can occupy no other position than that between the Last Interglacial and the Cromerian Interglacial.

(iii) *Correlation with the continent*

The Cromer Forest Bed or Cromerian Interglacial is considered to be equivalent to the pre-Elster or Günz/Mindel Interglacial of Europe (Zeuner 1945; Woldstedt 1954), that is, to the First Interglacial of the terminology used here. There is at present no direct evidence of an interglacial period intervening between the Cromerian and Hoxne Interglacials. If the Hoxne Interglacial is older than the Last Interglacial, as indicated by the evidence given above, then, if a correlation with north-west Europe is to be made, there is no alternative but to correlate the Hoxne Interglacial with the Great Interglacial.

(*c*) Conclusions

Both the palaeobotanical and stratigraphical evidence for correlation point to the same conclusion, namely, that the Hoxne Interglacial should be correlated with the Great Interglacial. It follows that the Lowestoft and Gipping Glaciations must be correlated with the north German Elster and Saale Glaciations respectively.

Such a correlation agrees with other recent correlations made of English Quaternary deposits which have been related to the East Anglian succession.

First, Shotton (1953) has correlated the chalky boulder clay of the East Midlands with the Saale Glaciation of north Germany. As this chalky boulder clay is a product of the Gipping Glaciation (West & Donner 1956), such a correlation of this glaciation agrees with the dating of the glaciation following from the correlation of the Hoxne Interglacial. It should also be noted that the time of topographical change in the area described by Shotton took place soon after the chalky boulder-clay (Gipping) ice had retreated, and thus at approximately the same time as the valley erosion in the Hoxne district.

Secondly, Oakley (1952) has summarized the evidence for correlating the Swanscombe Interglacial with the Great Interglacial. Baden-Powell (1951 *b*) concluded that this interglacial deposit is of the same age as the Hoxne Interglacial, being younger than the Lowestoft Glaciation, but older than the Gipping Glaciation. Oakley's correlation therefore agrees with that of the Hoxne Interglacial.

Neither does the archaeological evidence appear to disagree with this correlation of the Hoxne Interglacial. Baden-Powell (1951 *a*) considered that the Palaeolithic implements of the Hoxne and Swanscombe Interglacials indicated that their ages were similar. He suggested that the Acheulian culture common to both deposits was 'Late Middle' Acheulian. Such a culture would not be out of place in the Great Interglacial.

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Appendix 1. Records of boreholes and sections

The relation of the numbers of Clement Reid's and Reid Moir's boreholes and sections referred to in this paper to those used in the original papers are as follows:

(*a*) Reid. Nos. 1–20 are the boreholes and section so numbered in Reid (1896). No. 21 is the section described on p. 405 of that paper.

(*b*) Moir. Nos. 1–7 are the sections so numbered in Moir (1926). Nos. 8 and 9 are the sections described by Moir (1935), the former the section in the old pit and the latter the one in the Oakley Park pit.

The details of a selection of boreholes and sections made during the investigations described here are given below. The records of all borings and sections made have been deposited with the Nature Conservancy, London.

The capitals on the left of the descriptions relate the different deposits to the strata described. All heights are given in metres O.D. The grid references give the positions of the boreholes and sections on the map, figure 2. Abbreviations used in the descriptions are as follows:

NC No visible reaction with 10% HCl (non-calcareous).
C Reaction with 10% HCl (calcareous).
G.R. Grid reference on the map, figure 2.
'Made' means that the deposit has been disturbed in recent times.

11. Height 31·26 m. G.R. 747675. Borehole and section.

A1	0–100 cm	NC. Soil, then grey fine sand with small flints.
A2 and E	100–210 cm	NC. Mottled blue clay with flints, with pockets of red sand with flints, and with race and a layer of purple clay at the base.
E	210–350 cm	C. Mottled blue clay-mud with shells.
F	350–365 cm	C. Mottled grey-brown clay-mud with shells.
G	365–380 cm	C. Blue sandy clay with chalk pebbles and flints.