E Watson

Quaternary Research Association

Clacton
April 1973

QUATERNARY RESEARCH ASSOCIATION

EASTER FIELD MEETING 1973

CLACTON

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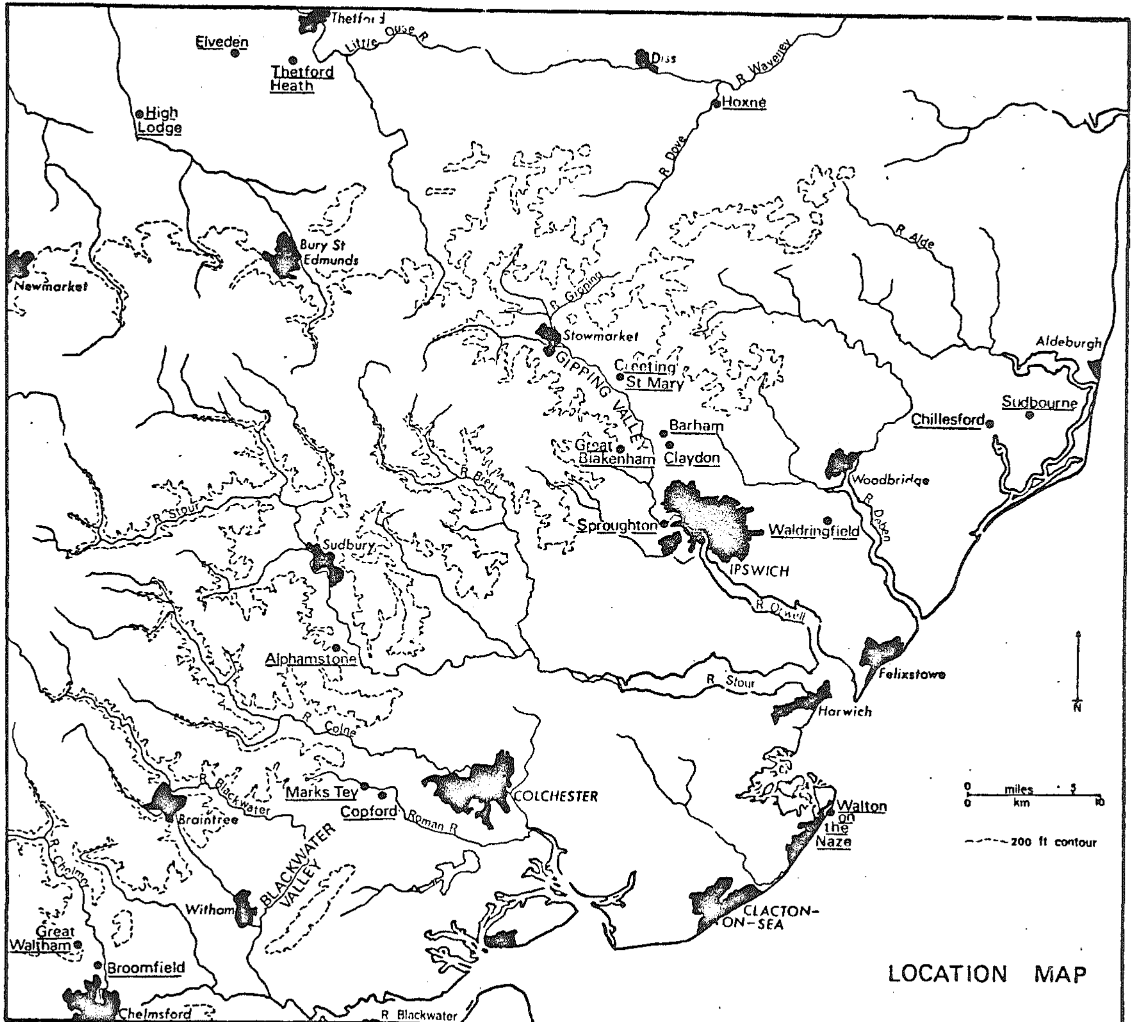
INTRODUCTION

At Easter 1970 the Association held a very successful field meeting in the Norwich region which, beside stimulating a great deal of discussion, demonstrated that major problems remained unsolved in the Quaternary stratigraphy of the area despite the great wealth of literature and many years of investigation. The same is equally true of the southern part of East Anglia, and therefore the objectives of the excursions will be again to demonstrate some of the "classic" localities of the area, where these are still accessible, but particularly to visit sites where recent work has led to a renewal of controversy.

On the first day we shall be concerned largely with the Lower Pleistocene Crag deposits which have not been visited by the Association before, including the type locality for the "Waltonian" stage, which requires discussion. Because of shortage of time and of the distances involved, it is only possible to visit a very small selection of sites, unfortunately not including the Norwich Crag exposures in the Blyth Valley which would have provided a further link with the 1970 excursion. We will, however, branch out to see the Pliocene Coralline Crag.

The remaining three days have as a connecting thread the nature and stratigraphy of the chalky boulder clay and its relationship to the underlying gravels, to interglacial deposits and to archaeological horizons. On Sunday we propose to visit South-East Essex, where the glacial and interglacial deposits have recently been reinvestigated by Bristow (Bristow & Cox 1973) and Turner (1970). On Monday our main objective is the Gipping Valley, where a number of workers are active, although nothing new has been published recently. Clearly these important sections demand reconsideration in the light of work in adjacent areas. On Tuesday a longer coach journey takes us into West Suffolk to consider lacustrine deposits there, their relationship to glacial events and to prehistoric man.

C. TURNER



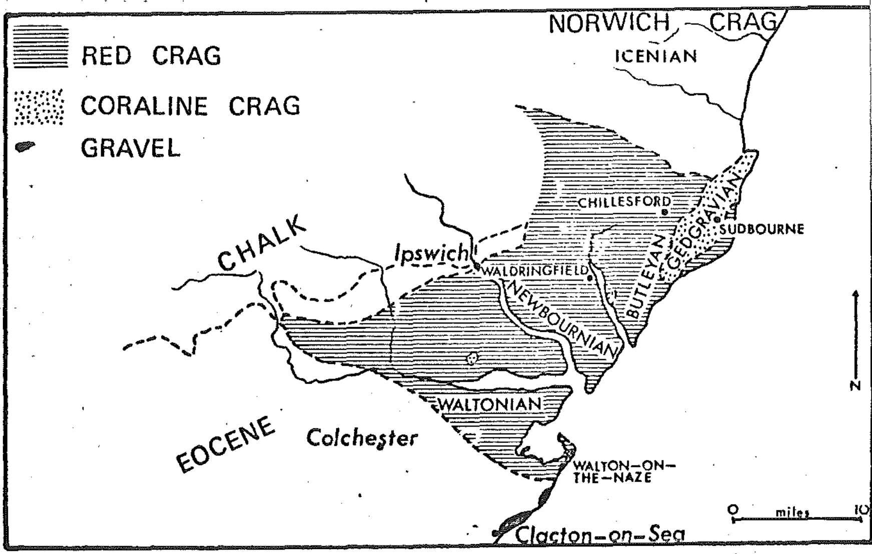
LOCATION MAP

THE CRAGS OF EAST ESSEX AND EAST SUFFOLK

Localities

Walton-on-the-Naze.
Sudbourne.
Chillesford.
Waldringfield.

THE CRAG MOLLUSCA



Map showing distribution of Crag Stages. Based on Harmer

Traditionally the Crags of East Essex and Suffolk have been studied in terms of their Mollusc content. From an analysis of the relative frequency of northern, southern, 'living-in-British-seas', and extinct types Harmer identified stages characterised by a particular Mollusc species and a limited geographical distribution. More recently Boswell has summarised this observation quantitatively.

Harmer's Stage	Characteristic Mollusc Species	% Northern	% Southern	% Not Known Living	Total Number of Species
Icenian (Norwich Crag)	*Astarte borealis*	26	0	28	98
Butleyan (Red Crag)	*Cardium groenlandicum*	21	2	40	163
Newbournian (Red Crag)	*Mactra constricta*	12	7	53	226
Waltonian (Red Crag)	*Neptunea contraria*	16	11	48	352
Gedgravian (Coralline Crag)		4	12	57	303

Basically Harmer concluded that the Coralline Crag contained a warm fauna with a large number of extinct species, and the Red Crag contained a colder fauna with fewer extinct species. Within the Red Crag he identified three Stages which displayed a progressive increase in northern species from the south to the north.

On the assumption that these deposits were laid down just before the glacial period, at a time when the climate suffered a progressive deterioration Harmer concluded that the Red Crag sediments became younger in a northerly direction in association with a northward migration of the shoreline due to a gradual uplift of the land from the south.

The Red Crag and Coralline Crag are believed to be separated by an unconformity but at no point are any of the Stages of the Red Crag seen in vertical succession. In view of this fact, the non-statistical approach to the Mollusc assemblages, and the fact that his climatic assumptions must now be considered oversimplified, this classification must be considered with great caution.

More recently Norton (1967, 1970) has begun a reappraisal of the Lower and Middle Pleistocene Mollusca on a palaeoecological basis. This approach attempts to reconstruct palaeoenvironments from the frequency distribution of Molluscs at any one point in space. The death assemblage is used to recognise species indicative of present day ecotones. From the changing representation of these groups in vertical succession, inference can be made about changes in the life-environment and deposition-environment. The chronology of the sequence is established by relation to existing pollen zones.

From the work carried out so far on the Norwich Crag and Cromer Forest Bed Series it appears that the Crag Mollusca represents the temperate Stages between the Ludhamian and Pastonian. The lack of cold molluscs may be due to a relative fall of sea level.

Mollusc assemblages tentatively suggest that part of the Red Crag may be Ludhamian in age. Recent analysis of pollen and foraminifera from Stradbroke (TM 122738) by Beck, Funnell and Lord (1972) indicates that the Red Crag at Walton and Neutral Farm (Butley) is Pre-Ludhamian which, according to palaeomagnetic investigations corresponds to the Gilsá Normal Event with a geomagnetic age of about 1.60 million years.

References

Beck R.B., Funnell B.M., and Lord A.R. 1972, Correlation of Lower Pleistocene Crag at depth in Suffolk. Geol. Mag. Vol. 109, pp. 137-139.

Boswell P.G.H. 1952, The Pliocene-Pleistocene Boundary in the East of England. P.G.A. Vol. 63, pp. 301-312.

Harmer F.W. 1902. A sketch of the Later Tertiary History of East Anglia. P.G.A. Vol. 17, pp. 416-479.

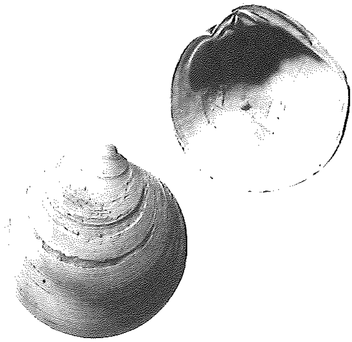
Norton P.E.P. 1967. Marine Molluscan Assemblages in the Early Pleistocene of Sidestrand, Bramerton, and the Royal Society. Borehole at Ludham, Norfolk. Phil. Trans. Roy. Soc. Lond. B. Vol. 253, pp. 161-200.

" 1970. The Crag Mollusca - A Conspectus. Bull. Soc. belge Géol., Paléout., Hydrol. Vol. 79, pp. 157-166.

J. ROSE

On the following two pages are reproduced some photographs of typical Crag Molluscs, kindly supplied by R.A.O. Markham of Ipswich Museum.

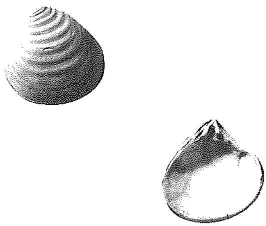
RED CRAG FOSSILS



Dosinia exoleta
Wa S

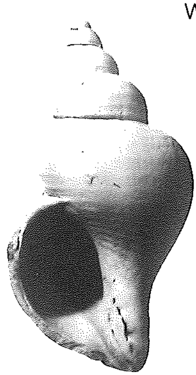
Spisula
Su

Macoma obliqua
Bu N

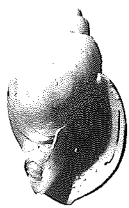


Astarte omalii
Wa

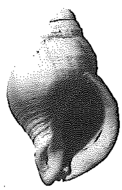
Cardium angustatum
? N



Neptunea contraria
Wa S



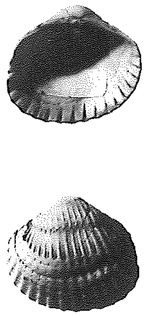
Liomesus dalei
Wa S



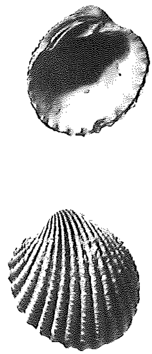
Nucella lapillus
Ba N

Turritella incrassata
Wa S

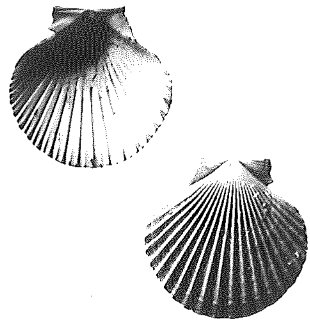
Wa Walton, Ra Ramsholt, Ba Bawdsey, Su Sutton, Bu Butley.



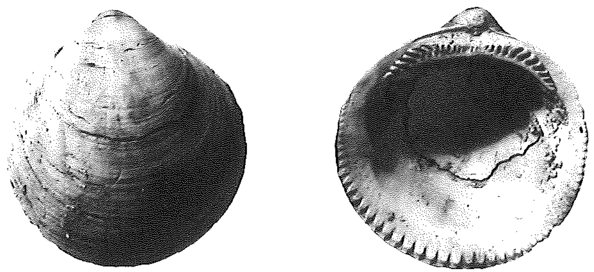
Cardium edule
Ra N



Cardita senilis
Ra



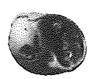
Chlamys opercularis
Ba



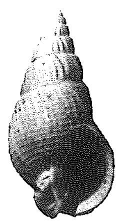
Glycymeris
Ra S

Nucella tetragona
Wa S

Natica multipunctata
Wa S



Polinices hemiclausus
?



Hinia reticosa
Wa S

N,S Fossil typical of north (south) part of Red Crag outcrop.

SEDIMENTARY CHARACTERISTICS OF THE RED CRAG

The term Red Crag was originally applied to the iron stained unconsolidated shelly sands of North East Essex and South Suffolk. The Red Crag is now known to include non-shelly iron coated sands, clean sands and clay. The deposit occurs in a triangular shaped area having a base line along the coast between Walton-on-Naze and Orford and then extending inland to an apex near Lavenham in Suffolk. The base of the Red Crag lies at about 17 metres above present day mean sea level. Over most of their extent the beds are buried by later sediments and exposures are confined to coastal cliffs, river banks and pits. In North East Essex the deposits occur as isolated outcrops but north of the River Stour the Red Crag forms a more continuous deposit.

The whole basin of deposition was a shallow near-shore depression with water depth of about 30 metres. Except in a few isolated localities the floor of the basin was on London Clay. The general surface of this clay floor undulated gently with slopes not exceeding 11^{o} but near to the Red Crag shore line, small cliff features occasionally occur in the clay, with the Red Crag banked up against them. The surface of the clay shows minor depressions similar to those found in London Clay where this forms a present day sea floor. In what is believed to be in-shore areas, the clay surface shows pitting to a depth of about 2 cm. All other features relating to the surface of the Red Crag sea floor, such as iron oxide deposits, are considered to be post-depositional.

In overall composition the Red Crag deposits show a considerable degree of uniformity. However, within closely defined limits, micro-variation is considerable both laterally and vertically. The chief factors affecting variation are the amount and size of shell debris, the proportions of iron coated and uncoated materials, overall size distribution and sorting.

The two major components of the Red Crag are quartz grains and shell debris. The degree of iron coating on each of the components depends largely on the conditions in the earlier source areas. Within the matrix are also found small numbers of pebbles composed of quartz, quartzite and chert, mud balls and also muscovite, glauconite and other minerals. Locally clay forms a major component but it is not wide-spread. Away from the Red Crag shoreline and appearing at different levels are very thin laminae of micro-crystalline iron oxide.

Sedimentary structures within the Red Crag are best considered separately in each of the three units into which the deposit can be sub-divided. These are the basal beds occurring in isolated pockets, the Lower Red Crag consisting of the characteristic steeply cross-bedded shelly sands and the Upper Red Crag composed of non-shelly sands.

The basal unit, which varies from 5 - 20 cm in thickness, usually consists of a mixture of iron coated and non-iron coated quartz grains. The amount of shell debris present varies from a trace to heavy concentrations of small size fragments in localized pockets. Frequently the beds in this unit are almost horizontal. These beds can incorporate small lenses showing Flaser bedding and also slump and 'roller' structures. In some localities where finely comminuted shell debris occurs in quantity, the beds show an internal flow structure and contain the cylindrical shaped 'rollers'. The latter vary from 1.5 - 4 cm in diameter and are about 5 - 10 cm long. They consist of a dense matrix of iron cemented mud containing an abundance of quartz grains and also shell fragments arranged in concentric bands. Other areas with abundant large size shall debris contain phosphatic nodules, sharks teeth and predominantly coarse sand. These are generally interpreted as condensed beds. Very small sand diapirs do occur in this horizon but they are comparatively rare.

The Lower Red Crag shows two main types of structures, cross-bedded shelly sands representing migrating dunes and also units consisting of alternating horizons of fine sand and silt containing well developed ripple trains. The former are occasionally bipartite in structure, consisting of an upper unit with large scale cross-bedding overlying a smaller unit with oppositely dipping cross-bedding. Sometimes they show post depositional pseudo-stratification. Locally small trough cross-bedded units occur within the dunes and were probably formed contemporaneously with them. Ice wedges are to be seen in some localities but these are again post-depositional. The individual units of the Lower Red Crag vary from a few centimetres to 5 metres in thickness. Available evidence suggests that the whole of this sub-division had a maximum thickness of about 9 metres.

The Upper Red Crag consists essentially of medium and fine grain size iron coated sands. Some parts of this unit appear to be in situ decalcified Lower Red Crag beds and other parts reworked sands. Cross-bedding occurs where the unit appears to be altered Lower Red Crag, but the dip of the foreset beds is usually less than that in the unaltered Lower Red Crag. The reworked sands contain ripple trains in some beds while other beds show an abundance of sand diapirs.

An analysis of the sedimentary structures indicates that they are mainly tidal in origin. The direction of the tidal currents was predominantly to the west between south-west and north-west. On the basis of median grain size and height of dunes, near-shore deposits appear to have been laid down in water that varied from 1 - 3 metres in depth by currents with velocities from 10 - 50 cm/sec. Off-shore, where the larger dunes formed, the waters had an estimated depth of 3 - 30 metres with currents from 10 - 75 cm/sec. The considerable thicknesses of mud sediments laid down as layers or found in Flaser bedding, would indicate as suggested by McCave et al (1970) that there were periods of increased suspended sediment concentrations. These were probably caused by storms and were followed by periods of minimal wave activity especially close to in-shore areas and shoals. Small pockets of large size material, 5 - 20 cm diameter, found on the leeside of dunes, indicates that the larger dunes were well within reach of wave action.

Electronmicrographs show well rounded non-iron coated quartz grains from Walton-on-Naze with a high density of V-shaped patterns with en echelon orientation. This indicates that the last phase in the history of transportation and deposition of the sand grains had been in a zone of medium to low energy.

Reworked sands of the Upper Red Crag are generally well sorted. Some beds consist of nearly single size sands having a median diameter of 0.18 mm. In these beds an abundance of sand diapirs have formed. These structures represent a post-depositional de-watering phase. Since the quartz grains in the beds containing the diapiric structures are very well rounded, random settling would produce a fabric with unstable equilibrium and low bulk density. Slight re-orientation of the grains to produce a tighter packing would be sufficient to displace water. The precise nature of the stress causing re-orientation of the grains cannot be determined but the spacing of the structures is of the same order as the wavelength of ripples. It is possible therefore that differential compaction of sands in which ripples are formed might be sufficient to initiate the lateral migration and upward movement of water which would accompany the re-orientation of the sand grains.

The tidal currents in late Crag times were still towards the west but had slackened in velocity to 10 - 30 cm/sec.

<u>References</u>

Allen J.R.L., 1970, Physical Processes of Sedimentation.

McCave I.N., 1970, Deposition of Fine-Grained Suspended Sediment from Tidal Currents.

Terwindt J.H.H. and Breusers H.N.C., 1971, Experiments on the Origin of Flaser, Lenticular and Sand-Clay Alternating Bedding.

A.R.C. BOATMAN.

WALTON-ON-THE-NAZE

TM 2623

The Naze at Walton is the most easterly part of the Essex coast and forms a promontory stretching northwards from the town of Walton-on-the-Naze; it is bounded by the North Sea to the east, Walton Channel (a narrow inlet) to the west, and terminates in extensive saltings to the north.

The upper part of the cliff forms a vertical face of pleistocene sediments, below this is a hummocky area of slipped material, while the lower seaward part of the cliff format is of London Clay and presents a steep face to the beach.

R.A.D.M.

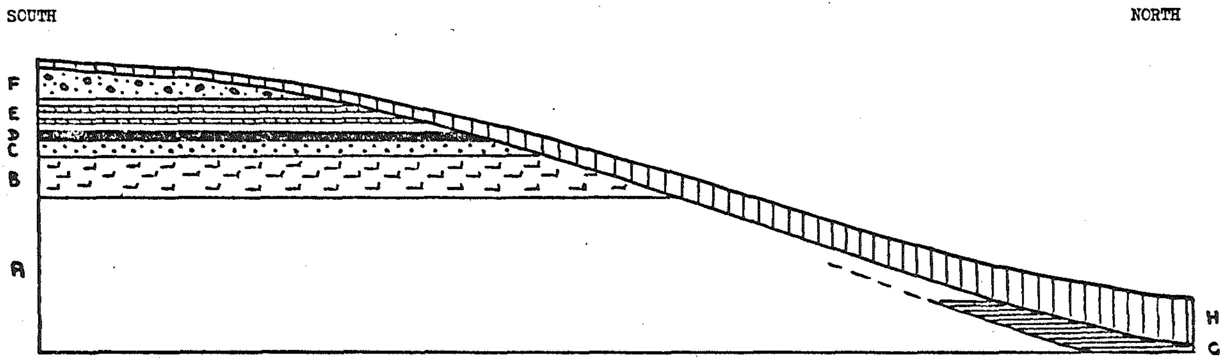
STRATIGRAPHICAL TABLE

Modified from J.R.Hails & White,P.C.S (P.G.A.,81,2,1970)

H	LOESS	Thin loess cover on higher ground, locally occupying open wedges in gravels. Deeper and more pebble-free in northern low cliff sections, with very distinct vertical jointing.
G	RED-BROWN CLAY	Wedge of red-brown, loamy clay thickening downslope to north, where it forms a more resistant base to loess cliffs a few feet high. Stratigraphical relations to beds other than the loess obscured by scree material, but possibly a colluvial deposit of mixed origin derived from London Clay and overlying beds
F	GRAVELS	Fluvio-glacial gravels, locally stratified into beds of sand and gravel at base, but generally very mixed, sandy gravel, with many of larger stones on edge. Maximum thickness about 1.50 m.
E	ALTERNATING SANDS/SILTS	Alternating beds of grey, silty clay and fine orange sand, ranging from thin streaks to 0.6 m. in thickness. Beds are often contorted and sometimes totally disrupted by complex involutions, with occasional sandy inclusions. Maximum overall thickness about 1.50 m.
D	CARBONACEOUS SILTY CLAY	Bed of purplish-grey silty clay, with pebbles of flint and quartzite locally at base, and a considerable content of sooty carbonaceous material, including plant roots and twigs. Occasional lenses of organic material. Up to 0.45 m. thick.
C	SANDS	Grey-green silty sand, with scattered pebbles of flint and quartzite, above a coarse red-brown sand, which is locally current bedded, and appears to be decalcified Red Crag. Maximum thickness of combined sand beds up to 1.15 m.
B	RED CRAG	Mixed sand and comminuted shell debris (crag), strongly current bedded, with quasi-horizontal colour zonation from red-brown (above) to pale buff. Locally, thin band of near-intact Mya arenaria valves. Maximum thickness about 2.20 m.
		UNCONFORMITY
A	LONDON CLAY	Strong blue-grey clay, with occasional septaria. Clearly defined and well spaced joint and bedding planes at base of cliffs, but highly disintegrated above. Brown weathered layer appears locally immediately below unconformity.

NAZE CLIFFS, WALTON-ON-NAZE

GENERALISED SECTION



Capitals refer to the Stratigraphical Table

H. Loess
G. Red-brown clay
F. Gravels
E. Sands and Silts
D. Carbonaceous Silty Clay
C. Sands
B. Red Crag
A. London Clay

Modified from J.R.Hails & White,P.C.S. (P.G.A.,81,2,1970)

P.C.S.W.

At a section south of the Tower, and north of the groyne (TM 26552345) the following stratigraphy was recorded in July 1972:

Upper Beds - loam, gravel, sands		
Very coarse sand		57 cm.
Large-scale cross-bedded 'Crag'	red sand	39 cm.
		limit of decalcification (these lines cut across bedding)
	shelly red sand	128 cm.
		limit of iron staining
	shelly grey sand	80 cm.
Red sand, small channels, ferruginous bands		35 cm.
Grey shelly crag		22 cm.
Brown comminuted crag		39 cm.
London Clay		

- a band of <u>Glycymeris</u> and <u>Spisula arcuata</u> occurs on or in the upper (cross-bedded) division of the Crag a short distance to the north.

Crag Molluscs

The character of the Red Crag at Walton is as follows:

a) horizontal lines of decalcification and secondary iron-staining sometimes cut across the cross-bedding, giving a rather confused appearance.

b) comminuted shell material and complete shells are common; horizontal bands of shells (usually of <u>Glycymeris</u> with one or two other species only) occur.

c) some of the commonest fossils recorded are:

Bivalve molluscs:	<u>Glycymeris glycymeris</u>
	<u>Astarte obliquata</u>
	<u>Cardium parkinsoni</u>
	<u>Spisula arcuata</u>
Gastropods:	<u>Hinia granulata</u>
	<u>Hinia reticosa</u>
	<u>Natica multipunctata</u>
	<u>Leiomesus dalei</u>
	<u>Neptunia contraria</u>
	<u>Nucella tetragona</u>
Echinoderm:	<u>Echinocyamus pusillus</u>

R.A.D.M.

Sedimentary Structures

TM 267235

The structure of the Red Crag at this location suggests that this area was a near-shore to inshore environment. Generally the section slopes gently from the north towards the south. The minor variations in the level of the London Clay - Red Crag boundary are due to the section cutting across a roughly north-south cliff in the London Clay.

The dominant structures that show in this cliff section are the dunes composed of shelly sands. These are most clearly seen in the southern and central areas although traces of them extend into the northern part. In some places the upper parts of these dunes have become decalcified while in other areas post-depositional leaching has resulted in pseudo-stratification. Flaser bedding occurs at intervals over most of the length of the section beneath the Lower Red Crag. At the northern end of the deposit some of the lower beds show internal flow structures, and a few contain 'rollers'. Blocks of crag cemented by calcite are occasionally to be found wedged in the side of the cliff. Evidence of periglacial activity is seen in the form of ice-wedge casts exposed at the northern end of the section.

Complete fossils that were once found in abundance are now comparatively rare but pockets of Glycimeris can sometimes be found, with the convex side upwards, near to the base of the crag.

A.R.C.B.

Pollen spectra from Naze cliffs.

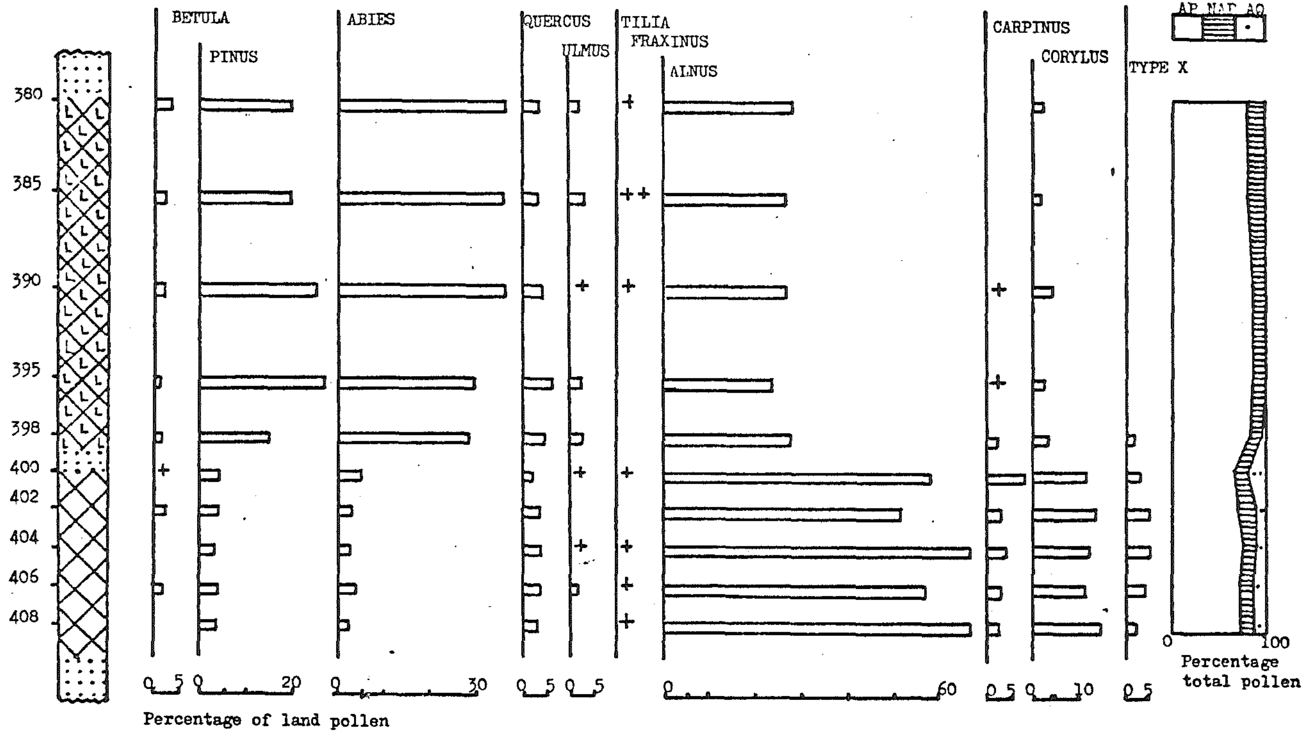
Pollen has been recovered from a small lens of compressed detritus mud 4 m from the top of the Naze cliff section 2.5 km north of Walton pier. This deposit appears to have been laid down in a freshwater environment and forms part of the carbonaceous layer (Horizon D, Hails and White 1970) which occurs with varying thickness throughout the Walton coastal sections. The pollen diagram is characterised throughout by high AP to NAP ratios, and on the basis of the tree pollen falls readily in to two parts. The lower (410-400 cms) is dominated by high Alnus values (max. 66%), and Abies, Pinus, Quercus, Ulmus, Carpinus, and 'Type X' are all present in values not exceeding 7/8%. In the upper part, where there is a stratigraphic change to a more silty layer (398-380 cms), Pinus and Abies show a marked increase, Alnus a relative fall, and Carpinus and Type X virtually disappear. Corylus also diminishes to low values. Here, pollen was rather sparse, and aquatic pollen almost non-existent.

On the evidence of the abundance of Abies and the presence of Type X, there seems little doubt that this horizon is Hoxnian; moreover, the decline of Carpinus and Corylus, followed by a rise in Pinus and Abies, points to a Late-Hoxnian age - cf. Zone III at Marks Tey (Turner 1970). This dating might afford some bearing on the various periglacial structures in the cliffs at Walton which appear to both pre- and post-date the organic layer.

R.H.B.

Palynological investigations by R.H. Bryant have shown that this stratum contains a well-preserved pollen flora, dominated by Alnus and Abies. Such an assemblage is known only from the latter part of the Hoxnian and Cromerian interglacials so far in Britain. Since the reticulate pollen 'Type X' is also found and this is not known from the Cromerian, the deposits are provisionally ascribed to zone Ho IIIb. This means that they are of approximately the same age as the Estuarine Beds of the Clacton Channel. Nevertheless, investigation of the macroflora (C. Turner) shows abundant remains of freshwater swamp plants including Azolla filiculoides, Eupatorium cannabinum and Typha latifolia and here at Walton the facies was not estuarine.

C. T.

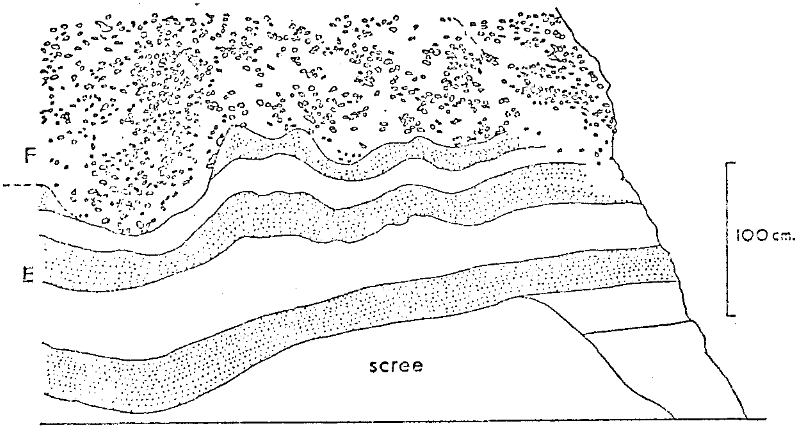


TREE POLLEN DIAGRAM, NAZE CLIFFS, WALTON

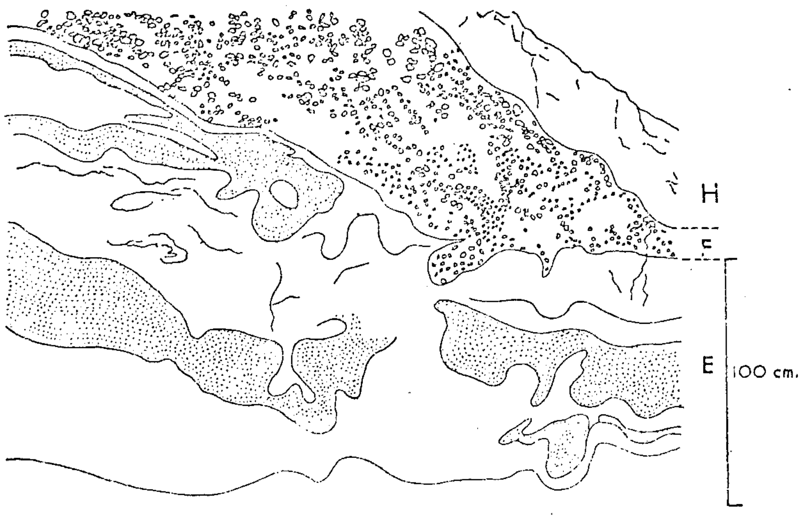
RHB

Crag Structure

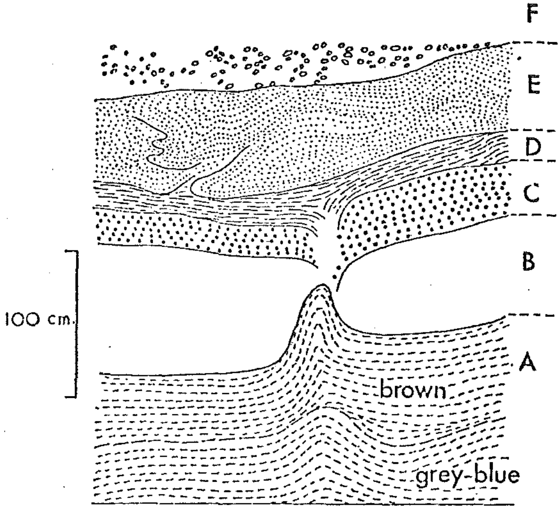
Periglacial structures in the upper part of the cliff have been described by Hails and White (1970). The following diagrams describe some of these features:



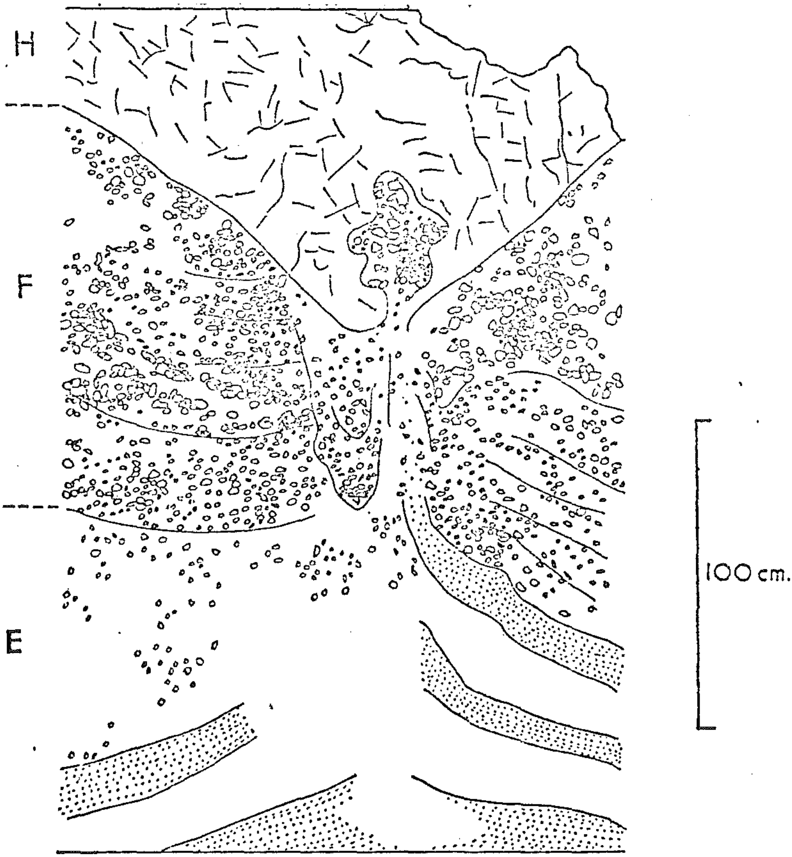
Simple involutions in sand- and silt-beds below disturbed gravels



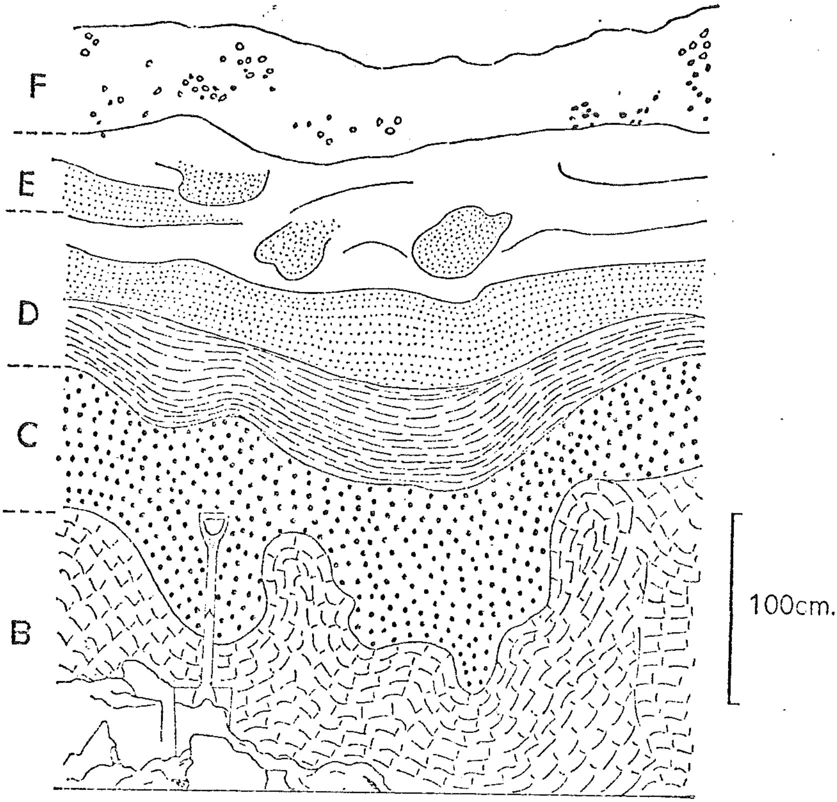
Complex involutions in sands and silty clays below disturbed gravels.



Fossil ice wedge penetrating Red Crag, with associated diapir of London Clay.



Open wedge with associated ice vein feature penetrating gravels and underlying sands and silty clays. Gravels extruded into loam which infills the wedge. Crudely stratified gravels upturned at margins of vein, with indications of later subsidence as ice melted.



Open wedge and lobe in Red Crag. At least two phases of periglacial activity seem to be represented in this section.

P.C.S.W.

A.R.C. BOATMAN.
R.H. BRYANT.
R.A.D. MARKHAM.
C. TURNER.
P.C.S. WHITE

SUDBOURNE - CRAG FARM

TM 428523

About 10 feet of the upper part ('Bryozoan Rock Bed') of the Coralline Crag (Pliocene). This division is a soft limestone which hardens on exposure to air; it has been used as a local building stone, as in the tower of Chillesford Church.

The 'Rock-Bed' is a changed form of the lower shelly sands of the Coralline Crag; the aragonite fossils have been dissolved leaving calcite fossils (Chlamys. bryozoa) cemented by reprecipitated calcium carbonate. Occasional moulds of aragonite molluscs are found and, rarely, patches of shelly (unaltered) crag; the junction of the shelly sands and rock-bed slopes from south to north.

Fine examples of cross-bedding may be seen, and reef-like masses of cheilostome bryozoa, often several feet in length, may be seen on the lower parts of the foresets and in horizontal positions.

The alteration of the shelly sands to 'rock-bed' is pre Red Crag, as pieces of rock-bed are found in the Pleistocene Crag.

On some faces in this pit, comminuted Pleistocene Crag coats the walls; whether this has occurred since the pit was dug (no shelly Pleistocene Crag may be seen on top here, although it does occur only a few yards up the slope behind the pit) or it is a form of 'Neptunean dyke' remains a problem.

R.A.D. MARKHAM.

CHILLESFORD CHURCH PIT

TM 383522

This pit and the Bullockyard pit of Church Farm, adjacent, are described by Prestwich (1871), Funnell (1961a,b) and others. These authors describe a section through "Chillesford Beds" into "Lower Division Red Crag" by combining the sections in the two pits. In 1968 the U.S.A.A.F. excavated the Church Pit to more than 10 m depth and a section from Red Crag upwards became visible.

Succession

Unit	Lithology	Thickness
	Soil then Till	2.4 m
E	Grey Silty Clay interbedded with brown sand and grey laminated silt	3.6 m
D	*Mya* Bed (local)	0.3 m
C	Brown sand, level bedded, often silty, with 'tube casts', shell beds and scattered shells (all broken)	3.4 m
B	Oblique bedded sands with comminuted shells and inclined clay partings dipping West	0.6 m
A	Red Crag with *Neptunea contraria*	base not seen

Discussion

Unit

A Red Crag (Prestwich's Lower Division) with *Neptunea contraria* and other ferruginous shells.

B,C Correlation uncertain, "Chillesford Sands" and "*Scrobicularia* Crag" of authors. Pastonian Crag in part. A mixed oak forest pollen assemblage, with *Carpinus*, suggesting a Pastonian age, was found at a level equivalent to the upper part of unit C by West (1972). Appears to contain shells mainly derived from the Red Crag, forming shell grit (not ferruginous) with a very few 'indigenous' shells (less than 10 per kg); perhaps beach-bar deposits. Just above base of B the shells have a (?chemical) polish. In places at the top of C are patches with more Scrobicularia (but not in my counts forming more than 1% of the assemblage). The commonest identifiable shells are Spisula c.f. subtruncata, Abra c.f. alba, Cardium edule, Corbula gibba, Macoma spp, Mytilus sp, Astarte sp, Venerupis sp.

The tube casts in this unit were suggested by de Heinzelin to be from Balanoglossus burrows (Cambridge & Norton 1970). Dixon (1972) has attributed them to tubicolous Polychaetes.

D Mya bed similar to that at Aldeburgh Brickyard but far richer in shells, many of which are in the life position and not reduced to casts. The commonest are Mya truncata, Yoldia lancolata, Y. myalis (Y. oblongoides Wood), Acila cobboldiae, Abra sp, Mytilus edulis, Macoma spp (incl. obliqua & calcares), Serripes groenlandicus, Calyptraea chinensis. This is similar to Norwich Crag Series assemblages not in situ from Pastonian or Antian crag elsewhere. Paleoecological assessment is in progress.

E Chillesford Clay of Prestwich (1871) who reports a whale backbone found in this layer.

P.E.P.N.

Conclusion

The deposits, with those of Norwich Crag type at Leiston, Thorpe Aldringham and Aldeburgh, appear to represent an embayment of the Southern Crag Sea of Pastonian times, silting up towards Chillesford, reworking older Red Crag, with shallow marine deposits at Sizewell and Aldringham north to Wangford.

R.G.W.

References

Cambridge. P. & P.E.P. Norton 1970 An account of the field meeting of the Colloquium for the study of the Northern Neogene: Norwich 1970. Bull. Soc. belge Geol. Pal. Hydr. 79 103-114.

Dixon, R.G. 1972 A review of the Chillesford Beds. Bull. Ipswich Geol. Group, No. 11, 2-9.

Funnell, B.M. 1961a Paleogene and early Pleistocene of Norfolk. Trans. Norfolk Norw. Nat. Soc. 19 326-342.

Funnell, B.M. 1961b The climatic and stratigraphic significance of the early Pleistocene Foraminifera of the North Sea Basin, Cambridge, Ph.D. Thesis.

Norton, P.E.P. 1970 The Crag Mollusca; a conspectus. _Bull. Soc. belge Geol. Pal. Hydr._ _79_ 157-166.

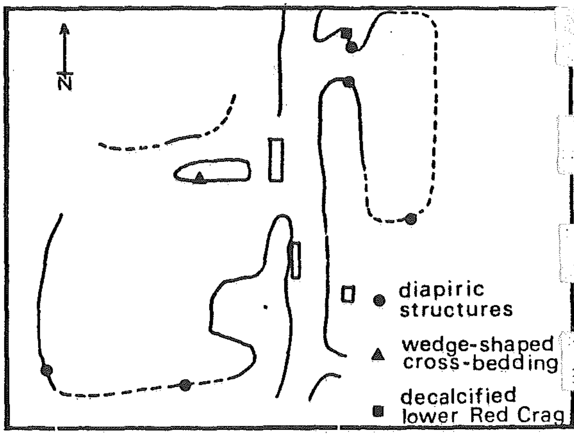
Prestwich, J. 1871 On the structure of the Crag-Beds of Norfolk and Suffolk. _Q. Jl Geol. Soc. Lond._ _27_ 325-356.

West, R.G. 1972 The stratigraphical position of the Norwich Crag in relation to the Cromer Forest Bed Series. _Bull. Geol. Soc. Norfolk_ _21_ 17-23.

P.E.P. NORTON
R.G. WEST

WALDRINGFIELD

TM 259448



In this pit both Lower and Upper Red Crag beds are exposed. Parts of the Lower Red Crag are firmly cemented by iron oxide and show wedge-shaped sets of cross-bedding. As with Walton-on-Naze, some of the upper parts of the Lower Red Crag have become decalcified but still show the characteristic cross-bedding. Of special interest are the diapiric structures which are interpreted here as a late phase in Upper Red Crag times.

Fossils are abundant in this pit but some difficulty may be experienced in obtaining the large in situ whole specimens from cross-bedded units.

A.R.C. BOATMAN.

The lower part of the Crag is strongly current-bedded and contains many phosphatic nodules. The mollusc fauna is characterised by Arctica islandica, Glycymeris, Astarte, Spisula, Cardium, Neptunea contraria, and Nucella lapillus.

The upper part of the Crag is a deep brown decalcified ferruginous sand. The decalcification junction between shelly and non-shelly sand is usually clean cut, but moulds of shells sometimes occur in ironstone in the upper beds.

The upper part of the Crag in this pit also contains numerous vertical ferruginous tubes; they may be 6 inches or more in length, they taper downwards and some are curved at the base. They generally descend from definite horizons. Plant, animal, and inorganic origins have been suggested for these structures.

R.A.D. MARKHAM.

PLEISTOCENE STRATIGRAPHY OF SOUTH-EAST ESSEX

Localities:

Alphamstone
Great Waltham
Broomfield
Rivenhall and the Blackwater Valley (no exposures)
Marks Tey
Copford

The basic stratigraphy of the glacial deposits of the area to be visited has been known for over 100 years. Here, extensive areas of chalky boulder clay overlie glacial sand and gravel. Since that time no systematic areal study was published until the work of Clayton (1957). He thought that the following stratigraphical sequence and chronological interpretation could be recognised in the area:

6	Springfield Till	Saale Glaciation
5	Chelmsford Gravels	
4	Maldon Till	
3	Period of erosion	Hoxnian Interglacial
2	Danbury Gravels	
1	Hanningfield Till	Elster Glaciation

He later revised this interpretation as follows (Clayton 1960, p.73):

	Essex area	Suffolk-Norfolk (West & Donner 1956)
Third glaciation	Springfield Till	Gipping Till
Second interglacial	Chelmsford Gravels	Hoxne Interglacial
Second glaciation	Maldon Till	Lowestoft Till
First interglacial	erosion & leaching	Corton Beds
First glaciation	Hanningfield Till & Danbury Gravels	Cromer Till and Norwich Brickearth

Both Turner (1970) and Bristow and Cox (1973) maintain that only the upper three units are valid. On the basis of six-inch geological mapping of the Chelmsford area Bristow and Cox conclude:

"The Springfield Till has a wide outcrop on the plateau area to the north-west of the Blackwater valley, where it has an average thickness of some 8 m, although locally thicknesses exceeding 18 m have been proved. Almost invariably the Springfield Till overlies the Chelmsford Gravels on the plateau, where the gravels average 6 to 7.5 m in thickness. The Maldon Till is only developed locally and in general is restricted to the sides of the present day valley system (see Two-and-a-half-inch

Sheet TL81 (Witham 1972)). Within the area of this sheet the Maldon Till has been mapped on the west bank of the River Brain and proved in one borehole (TL 8451 1758), where it was 4.5 m thick beneath Chelmsford Gravels and Springfield Till, on the north side of the Blackwater valley. Where seen in sections, boreholes and auger-holes the Maldon Till appears lithologically indistinguishable from the Springfield Till.

The division of the gravels of the Danbury-Tiptree area into upper Chelmsford and lower Danbury gravels, separated on the basis of the percentage of angular and sub-angular flints (Clayton 1957) is necessarily tenuous, and in the absence of stratigraphic proof of the relationships to the Maldon Till, is not accepted by the authors."

We shall unfortunately not be visiting any outcrop of the disputed Hanningfield Till, which the later authors regard as consisting in part of Head deposits and in part as an extension of the Springfield Till sheet (for discussion see Bristow and Cox 1973, pp. 5-6).

At various sites close to the southern margin of the Chalky Boulder Clay outcrop lacustrine deposits have been shown to overlie this glacial sequence. The lacustrine deposits lie in basins, floored by till and associated with the presence of tunnel-valley features cut deeply into the sub-drift surface. These are essentially similar to the tunnel-valleys elsewhere in East Anglia described by Woodland (1970), but in these cases there is little doubt that till actually occurs within the valley system. It is generally agreed that these tunnel-valleys were cut by meltwater under pressure beneath the ice sheet that deposited the Chalky Boulder Clay. Turner (1970) has shown that at Marks Tey (TL912242), Copford (TL926242) and Rivenhall End (TL840166) these deposits belong to the Hoxnian interglacial, a similar deposit at Witham (TL829153) has not yet been studied palynologically.

Younger series of terrace deposits occur in the Colne valley and in the Blackwater valley. Virtually nothing is known of the dating of these, because they are nowhere exploited. It is presumed that at least the floodplain terraces are of Weichselian age. At Lexden near Colchester (TL978253) a terrace deposit (peat and brickearth) was worked in the nineteenth century and re-evaluated, but not re-exposed, by Shotton, Sutcliffe and West (1962). It now seems likely that this belongs to the latter part of the Ipswichian interglacial, but otherwise no deposits of this age have been demonstrated in the area to be visited on this day. Further south, on the Essex coast, the Hippopotamus bed of East Mersey can probably be assigned an Ipswichian age, but belongs genetically to the Lower Thames terrace system.

Areas of controversy for discussion

1. **The stratigraphical succession**

There is broad agreement over the actual succession of deposits in the south east Essex area, exclusive of the coastal zone where there appears to be a very complex interdigitation of Thames and glacial gravels which has received little critical attention so far. Nevertheless Clayton (1957, 1960) believes that an earlier Hanningfield Till, resting on an older, higher sub-drift surface is present in southern Essex.

2. **The Glacial Gravels**

Clayton established the name Chelmsford Gravels for the sand and gravel deposits underlying the Springfield Till. The gravels on the slopes of the Danbury ridge he regards at least in part as older. The Institute of Geological Sciences (Bristow & Cox 1973, Haggard 1973) regard all this glacial gravel as outwash from the glacier which deposited the Chalky Boulder Clay and call it all Chelmsford Gravels. Hey (see notes on Locality 5) believes from fabric analysis of the gravels that glacial gravels of two different ages are present. The earlier consist of a series of pale whitish sands and gravels, often locally known as white ballast, which have a distinctive erratic content, and a later series consisting of outwash from the Lowestoft (equals Springfield and Maldon) ice advance. Gravels of both ages are widespread in Essex and Suffolk. Until recently the two gravels were well exposed at Bures (TL895340) with one superimposed upon the other, but unfortunately sections are too poor and too difficult of access to be worth visiting on this excursion. In the Chelmsford area Hey believes the picture to be confused at some pits because of the upper gravel becoming locally heavily admixed with the lower.

3. **The dating of the glacial and interglacial deposits**

This is the major area of controversy. On palaeobotanical evidence Turner (1970) showed that the lacustrine deposits belonged to the Hoxnian interglacial and therefore regards the Springfield Till as the equivalent of the Lowestoft Till at Hoxne. The Maldon Till is regarded as the product of a minor advance of the same ice sheet. No evidence could be found of a "Gipping" (Wolstonian) ice advance into this part of East Anglia although floral and sedimentary evidence from early-glacial clays overlying the Marks Tey interglacial deposit suggested a severe arctic climate. Because the Hoxnian interglacial yields a fauna and flora of Middle Pleistocene aspect, it is generally correlated with the Holsteinian interglacial and the Anglian, therefore, with the Elster glaciation of the Continental sequence.

Bristow and Cox have recently suggested a radically different alternative - namely that the Anglian glaciation represents the Saale of the Continent and in consequence that both the Hoxnian and the Ipswichian interglacials belong within the Eemian. This is an extension from their observation that nowhere in East Anglia can Chalky Boulder Clay be demonstrated to overlie or convincingly post-date deposits of Hoxnian age. It also involves their apparent view that river terraces in East Anglia have evolved in an orderly fashion without major interruptions, and that Hoxnian deposits are stratified within the terrace sequence.

Finally there is the view of Woodland (1970) that the Chalky Boulder Clay of East Anglia is in fact the product of the Last Glaciation.

Clearly a lot of informal discussion should take place about this issue, which is a major reason for holding the QRA meeting at Clacton. On this excursion useful points for discussion would be:

(a) The precise biological evidence for the traditional correlation of Hoxnian and Holsteinian stages (Flora, Mollusca, Ostracods, Vertebrates in particular).

Is the problem that the ranges of species in time are imperfectly known or, on the other hand, that almost all British Quaternary workers simply do not know in depth or do not even read Continental literature, either stratigraphical or palaeoecological, but rely on occasional brief summaries in English and a tradition of unread cross-references? Should the QRA have a special meeting on correlation with the Continent?

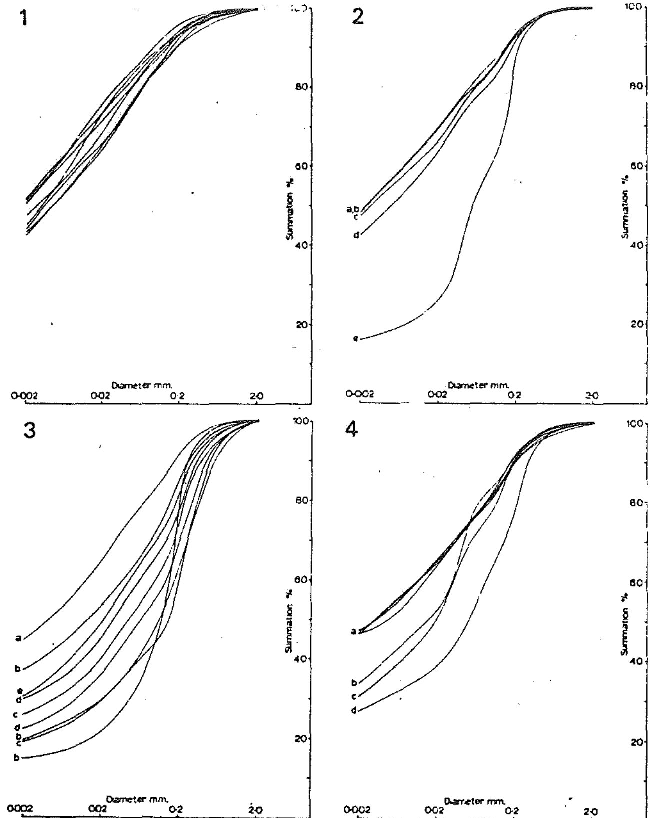
(b) The nature of terrace development.

(c) The geomorphological position of the local Hoxnian deposits visited.

C. TURNER

THE CHALKY BOULDER CLAY OF EAST ANGLIA

As part of a study of soils overlying the Chalky Boulder Clay of East Anglia and the East Midlands, the till was sampled at 234 sites. It was found to have a remarkably uniform mechanical and mineralogical composition (Tables I and II) and to be clearly differentiated from the Cromer Tills.



1. Typical cumulative mechanical composition curves of Lowestoft Tills from eight counties.

2. Section at Great Blakenham, Suffolk. a,b,c) Till at depths from 6.0 to 1.3 m. d) Weathered till at 0.4 m with minor incorporation of sand and silt. e) Topsoil at 40 mm showing major addition of sand and silt.

3. Range of compositions of deposits in the Gipping Valley which have been regarded as Gipping Till. a) Lowestoft Till at Great Blakenham for comparison. b) Creeting St. Mary. c) Barham. d) Claydon. e) Great Blakenham.

4. Deposits in the Breckland which have been regarded as Chalky Boulder Clay. a) High Lodge (two from top of section, two from base). b,c) Warren Wood brickpit, Elveden. d) Culford brickpit.

TABLE I

MEAN COMPOSITIONS OF CHALKY BOULDER CLAYS

County	No. of samples	$CaCO_3$ in < 2 mm matrix %	Mechanical composition: Effective diameter (mm) 2–1	1–0.5	0.5–0.210	0.210–0.105	0.105–0.063	(µ) 63–20	20–6	6–2	< 2
S. Lincs/Leics	8	23(2.0)	0.5(0.16)	0.9(0.20)	2.6(0.32)	4.5(0.49)	3.6(0.40)	11.8(0.53)	11.6(0.44)	12.1(0.49)	49.5(1.11)
Northants	19	24(3.5)	0.5(0.08)	0.9(0.11)	4.1(0.36)	7.1(0.40)	4.6(0.27)	12.5(0.71)	12.9(0.42)	11.0(0.30)	46.3(0.89)
Beds/Bucks	6	31(3.7)	0.5(0.05)	1.5(0.19)	6.2(1.11)	8.2(0.90)	4.3(0.17)	12.9(0.55)	12.4(0.36)	9.8(0.42)	44.1(1.18)
Hunts	10	33(2.9)	0.5(0.06)	1.2(0.20)	3.4(0.34)	6.3(0.29)	4.1(0.30)	10.6(0.37)	11.4(0.20)	11.3(0.50)	51.0(0.81)
Cambs	39	41(2.2)	0.9(0.20)	1.2(0.14)	3.8(0.26)	6.2(0.26)	4.2(0.16)	11.5(0.30)	11.5(0.23)	10.3(0.25)	50.4(0.84)
Norfolk	41	42(2.3)	0.5(0.05)	1.1(0.08)	3.2(0.43)	6.9(0.39)	3.8(0.16)	10.5(0.41)	10.9(0.24)	10.1(0.33)	51.1(0.88)
Suffolk	83	43(1.5)	0.6(0.05)	1.3(0.07)	4.7(0.23)	6.7(0.27)	4.2(0.14)	11.8(0.28)	10.9(0.17)	10.0(0.24)	49.8(0.64)
Essex/Herts	28	38(3.0)	0.5(0.06)	1.4(0.13)	6.9(0.61)	8.0(0.38)	4.1(0.15)	11.4(0.43)	10.5(0.29)	9.0(0.32)	48.2(1.13)
Total	234										

Standard errors are given in parentheses

TABLE II

Heavy mineralogical composition of the 105-63μ sand fraction of the Chalky Boulder Clay (33 samples)

	Mean	Standard Error
Heavy Minerals in 105-63μ fraction (wt % of fraction)	2.5	0.25
Opaques % of total heavy minerals	85.0	1.08
Rutile group % of non-opaque heavy minerals	2.9	0.65
Staurolite " " "	3.3	1.08
Tourmaline " " "	5.5	0.84
Garnet group* " " "	21.0	1.40
Zircon " " "	9.5	0.92
Epidote group " " "	19.7	1.44
Mica group " " "	12.3	2.24
Amphibole group " "	23.8	1.78
Others " " "	<1	

*A preliminary investigation by electron probe microanalysis shows that all the garnets in East Anglian Tills belong to the almandine group. The depth of colour is related only to the thickness of the grain. Garnets cannot therefore be used to distinguish Lowestoft from Gipping or Cromer Tills.

The sites investigated included Hoxne and the type site for the Lowestoft Till at Corton. It is therefore recommended that the name Lowestoft be used for the vast spread of Chalky Boulder Clay until such time as it can be fitted reliably into other established sequences.

As eleven of the exposures had been allocated to the Lowestoft glaciation and twelve to the Gipping by West and Donner (1955), special attention was paid to sites where some workers had claimed the existence of Gipping Till above Lowestoft:

(i) At Hoxne, Suffolk, it was confirmed that the deposits overlying the interglacial strata did not resemble any known till in their mechanical composition.

(ii) At Barrington, Cambridgeshire, although the till near the surface was weathered, the entire thickness was mineralogically and mechanically identical and the same as the Lowestoft Till at Corton.

(iii) At Great Blakenham, Suffolk, this was also found to be true for a deep continuous section of till in which co-existence of Lowestoft and Gipping facies had previously been claimed. The presence of thin sandy and silty surface drifts in this weathered till may have contributed to the illusion of an upper till in this section.

Nevertheless at a few sites deposits do occur, which though resembling the main mass of the Chalky Boulder Clay, possess a somewhat different composition. These appear to be a relatively low-lying sites, either near the presumed margins of the Boulder Clay as in the Gipping Valley, including other sections at Great Blakenham , or at sites where the till is associated with lacustrine deposits (still of unknown age) as at Warren Wood, Elveden and Culford brickpit . These deposits do not have a constant mechanical composition, suggesting a local mode of deposition in each case. Mineralogically some are closely similar to the Lowestoft Till but others are significantly rich in zircon in the sand fraction.

It is concluded that some at least of these deposits consist of Lowestoft Till, which has been soliflucted downslope, incorporating variable amounts of other drift. The examples rich in zircon probably contain sand derived from a continuous sheet which has been shown to cover much of East Anglia.

R. M. S. Perrin
H. Davies

ALPHAMSTONE

TL 871357

The Alphamstone pits have recently shown about 6 m. of pebbly sand and sandy gravel beneath a roughly equal thickness of Chalky Boulder-clay; the underlying London Clay has not been exposed. Classified as Glacial on the One-inch Geological Survey map (O.S. Sheet 47), the sands and gravels nevertheless contain a higher proportion of rounded flints than the overlying till, and a much greater abundance, though a more limited range, of erratics. A representative pebble-count, on material between 16 and 32 mm. in diameter, is as follows:

Rock Type	Percentage
Flints, rounded	29
" , angular and subangular	38
Quartz	16.5
Quartzite	13
Chert	3
Volcanic	0.5

Some of the quartzite pebbles are purple or red, the great majority partially or completely colourless. It is thought that almost all are Bunter pebbles, the former in their original state, the latter bleached. The most abundant type of chert is grey and spicular, often with impressions of crinoid ossicles or shells, and probably comes from the Derbyshire Carboniferous. The volcanic rocks are acid and intermediate lavas, ignimbrites and tuffs, mostly pale green or white. A collection of these has been examined by Dr. P.J. Brenchley, who suggests North Wales as the most likely source-area.

The poor sorting and the presence of much sharply angular flint suggest fluviatile deposition rather than marine, and cross-bedding directions indicate a palaeoslope towards the north-east (19 observations, vector mean 55°). From electron microscope studies of the surface textures of quartz grains, Prof. D.H. Krinsley has concluded that the sand is of glacial origin.

Very similar deposits, some included by Prestwich in his Westleton Beds, are exposed at many other localities in a belt of country extending from Bishop's Stortford to Norwich. In north-east Suffolk they overlie the Westleton Beds s. str., in the Norwich area they underlie the Norwich Brickearth. It is suggested that all may belong to a single unit of outwash sediment, of Beestonian or earliest Anglian age.

R.W. HEY.

GREAT WALTHAM

TL 687120

Here deep excavations show c.17 m of Chalky Boulder Clay (Springfield Till) overlying 7 m+ of sand and gravel (Chelmsford Gravels). The upper 7 m of till is chalky-buff in colour, the lower 10 m grey to dark grey. Data on the mechanical and mineralogical composition of this till at different horizons should be available by the time of the meeting. The gravels contain a high proportion of roundel flints and erratics such as quartz and quartzite, below the till they are heavily iron-stained, but pale and whitish at depth.

Only rarely are such good sections of till exposed inland. Points for discussion might include the weathering of till and the implication of colour changes within the section, the nature of till deposition here, the nature of the gravels and to what extent they are the same unit as seen at Alphamstone.

C. TURNER

BROOMFIELD

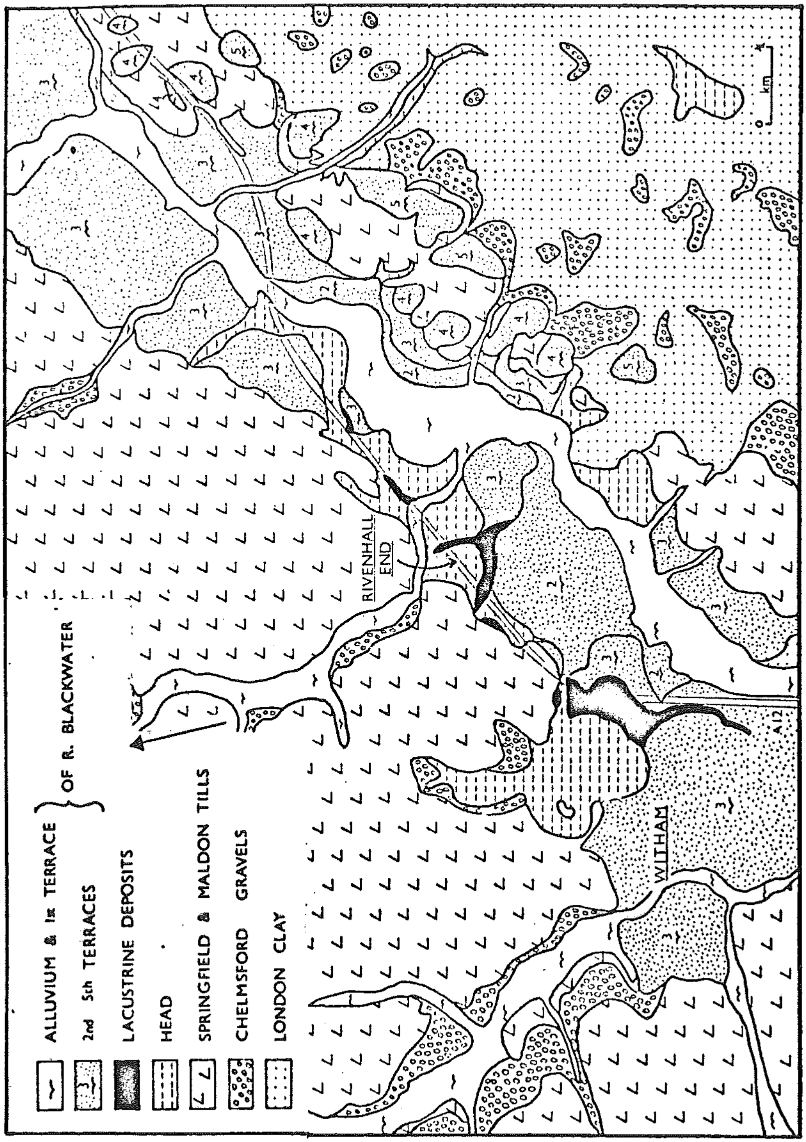
TL 722112

This site will only be visited briefly, if time allows. It lies within the type area of the Springfield Till which is exposed here. The overall section is very similar to Great Waltham. At present c.9 m of Chalky Boulder Clay overlie c.6 m of pale sand and gravel. Occasionally contorted ridges of London Clay protrude through the gravels at the base of the pit. Here the till is buff-brown in colour and the unweathered grey colour characteristic of the Great Waltham section is virtually absent. The main points of interest here are again the weathering of the till and also the surface structures of the London Clay beneath the gravels.

C. TURNER

The BLACKWATER VALLEY

The terraces of this valley and their stratigraphy are critical in the current debate on the correlation of East Anglian Pleistocene deposits. There are no exposures available at present, but our route follows the valley from Witham to Kelvedon (A12), and a stop will be made at a suitable viewpoint.



The main features of the area are described by Bristow and Cox (1973,p.6) who put forward the following interpretation :

"Between Kelvedon and Witham the River Blackwater flows in a north-east to south-west direction and follows the course of a deep drift-filled glacial channel. This channel has been proved to a depth of -54.2 m at Witham and to -44.6 m at Kelvedon. There is no evidence for a buried channel in the area north of Kelvedon nor to the south of Witham where the River Blackwater flows approximately north-south. However, there could be a drift-filled depression north-eastwards of Kelvedon in continuity with a similar channel known at Marks Tey and Copford.

The lower part of the channel at Witham is infilled with boulder clay, but at Kelvedon the lowest 14.7 m consisted predominantly of dark grey silts and silty clays, with or without small chalk pellets and locally laminated. These laminated clays are succeeded by boulder clay. In a later stage the introduction of much coarser detritus completely filled the depression with sand and gravel. The base of the sand and gravel appears very irregular with a maximum proven depth of -3.7 m near Kelvedon. Subsequent river erosion and aggradation established a terrace sequence within the depression area. Terraces 5 and 4, with bases approximately 18 m and 12 m above present day Alluvium level, form well defined deposits on the Chalky Boulder Clay south-east of the river. The widespread irregular third terrace surface ranges in height from 3 - 12 m above Alluvium level. A channel has been cut into this terrace surface, to a maximum recorded depth of 9.1 m O.D. near Kelvedon and subsequently infilled with interglacial deposits which have been dated as Hoxnian (Turner 1970, p.377). Overlying the interglacial deposits at Rivenhall End and Witham are up to 4.3 m of solifluxion material. Terraces 2 and 1 have upper surfaces about 1.5-3.0 m and 1.5 m respectively above the Alluvium level.

In this part of the Blackwater valley there is therefore a period of post-Chalky Boulder Clay sand and gravel deposition, which was probably initiated as outwash and later terraced by river action. Interglacial deposition within the terrace sequence was followed by one cold period and then the formation of terraces 2 and 1. There have clearly been no major interruptions to the terrace sequence such as would have occurred during conventional post-Hoxnian times (two glaciations and two interglacials). "

Turner's views on this differ on the following points:

a) At Hoxne and at Marks Tey the onset of lacustrine sedimentation followed directly on the melting of the Lowestoft-Springfield ice-sheet. In this valley Bristow and Cox propose the formation of three separate river terraces and the erosion of a vast amount of gravel in the interval between the melting of the ice sheet and the development of Hoxnian lakes.

b) The geomorphology of these Hoxnian channels is not sufficiently explained. Were they formed under glacial or temperate conditions? How were they carved into the gravels of Terrace 3 as long narrow structures, but survived long into the interglacial period ?

c) It is highly unlikely that river terraces in any valley in East Anglia have undergone no major interruptions. The intense Devensian erosion of the Gipping Valley (as seen at locality 14) demonstrates how difficult it is to interpret terrace sequences without deep open sections.

In consequence of this, Turner advocates the following sequence of events to explain the stratigraphy of the valley:

1) Melting of the main Springfield ice-sheet.

2) Deposition of <u>kame</u> terraces at two successive levels (Terraces 5 and 4) during melting of an ice mass stranded within the Blackwater Valley. Subglacial deposition of till and gravel on the valley floor.

3) Development of a broad lake within the valley during the Hoxnian interglacial (cf. Copford).

4) Scouring of the valley by meltwater floods during Wolstonian times (no local ice sheet); dissected fragments of lacustrine deposits survive along the northern flank. Deposition of Terrace 3, which abuts against these fragments (i.e. the interglacial deposits are not channelled into this terrace).

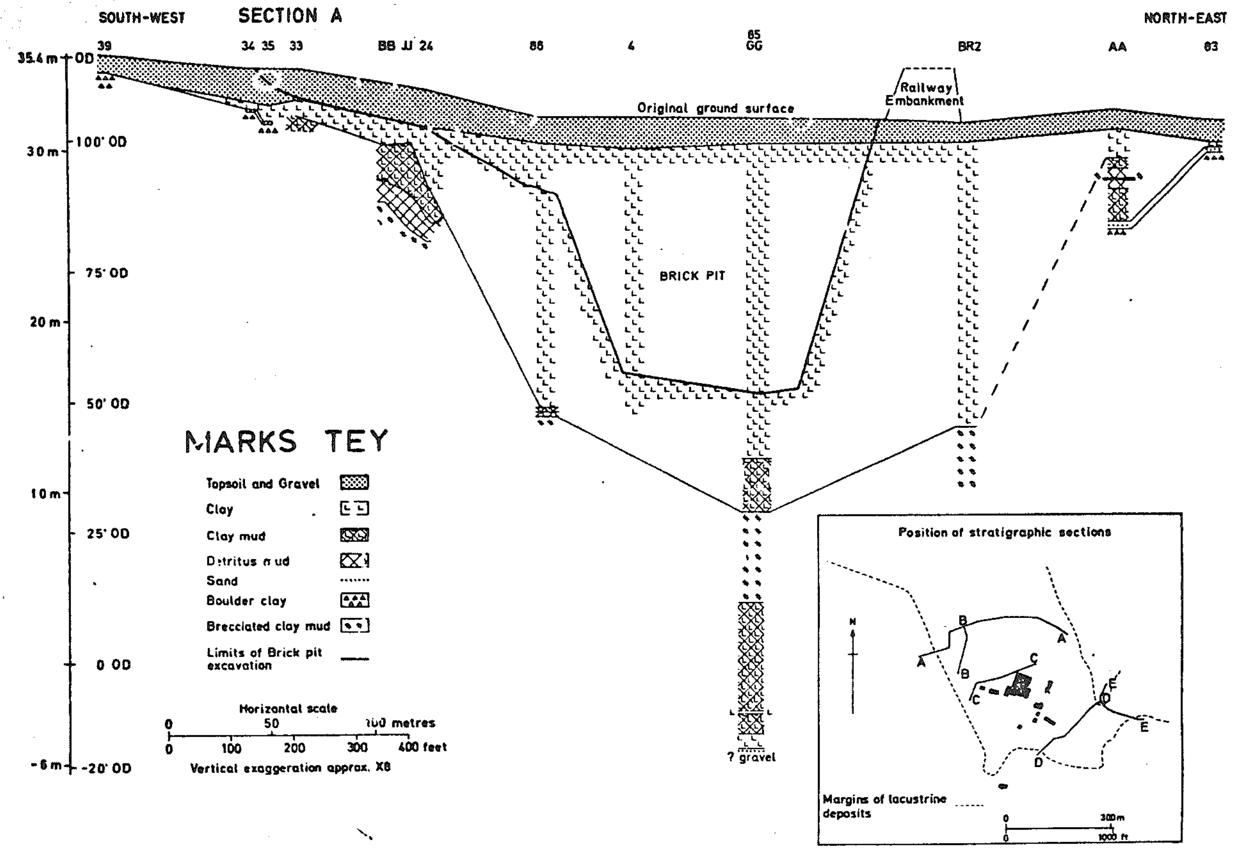
5) Renewed scouring of the valley during Devensian times. Removal of Ipswichian alluvium, as in most other valleys in this area. Deposition of Terraces 2 and 1.

C. TURNER

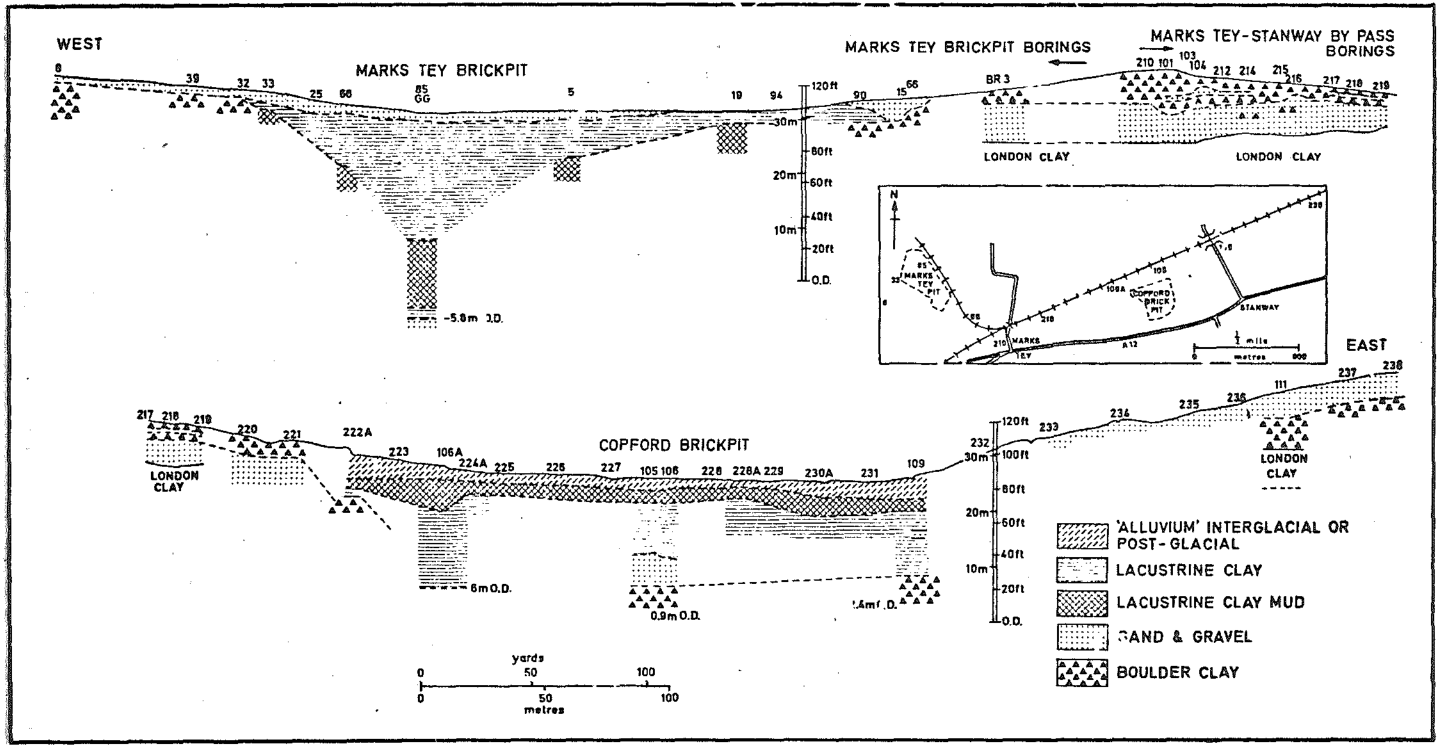
MARKS TEY

TL 912242

At Marks Tey Pleistocene lacustrine sediments rest on chalky boulder clay and occupy a deep narrow trough cut into the sub-glacial surface (Turner 1970).



Stratigraphic section A across the lacustrine deposits at Marks Tey.



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

The central deposits of the former lake basin consist of laminated clay muds, partly brecciated, overlain by laminated grey clay, which is at present exploited for brickmaking. Together these strata have a maximum proved thickness of at least 35 m. The marginal sediments of the basin are thinner and more organic and indicate some fluctuation of water-level during deposition

Palaeobotanical evidence suggests that the basin was formed during the Anglian glaciation, probably by subglacial erosion, and was gradually infilled during the course of the entire Hoxnian interglacial and the earliest part of the ensuing Wolstonian glacial period. The vegetational history can be traced from the Anglian Late-glacial through to the Wolstonian Early-glacial.

Generally all the deposits exposed in the present commercial workings belong to the Wolstonian Early-glacial, but an excavation has been carried out to reveal the uppermost part of the interglacial strata.

a) The present pit is worked at a series of levels. In total some 20 m of grey to grey-brown silty clay is exposed, the lower part finely laminated, the upper containing seams of fine chalky gravel ("race") and brecciated fragments of clay mud and detritus mud derived from the reworking of older (interglacial) strata along the slightly higher margins of the former lake basin.

This means that the sediment is full of derived interglacial pollen, but a macroflora of glacial aspect has also been recovered. This includes Armeria maritima, Oxyria digyna, Linum perenne, Silene cf. wahlbergella (now confined to the Arctic) and abundant remains of Gramineae and Cruciferae; the delicate fruit valves of the latter could certainly not have withstood reworking. There is a sparse fauna with occasional bands of freshwater molluscs and fish remains (Salmonidae). A large fine Acheulean handaxe has also been found in the clay.

The uppermost levels of the clay contain occasional isolated large flints which can only have been rafted into position by ice. The deposit is overlain by a thin discontinuous gravel and by soliflucted hillwash deposits which show festooning and other cryoturbation structures.

b) Along the margins of the former lake basin the interglacial strata lie at a much shallower depth. A section has been exposed in an old pit on the south-western margin of the workings, close to the site of borehole BB.

Here some 3.5 m of clays, becoming increasingly organic with depth, rest on detritus mud. In the adjacent borehole BB the following stratigraphy was recognised:

30 - 175 cm	mottled grey/brown clay
175 - 400 cm	silty grey-brown clay mud
400 - 525 cm	dark brown medium-fine detritus mud with some bands of clay mud
525 - 675 cm	brecciated grey-brown clay mud with occasional layers of detritus mud
675 - 685+ cm	grey sandy clay passing into sand

Neighbouring boreholes suggest the boulder clay lies immediately beneath.

From palynological evidence a conformable Hoxnian-Wolstonian boundary was proposed at c. 300 cm depth, defined on a vegetational transition from boreal forest to more open conditions with grassland characterised by *Artemisia* and also indications of the onset of mass soil movements.

The detritus mud exposed at the base of the new excavation is believed to belong to zone Ho IVa.

Deposits from the earlier part of the interglacial were recovered for investigation from a 21 m deep borehole at the lowest part of the brickpit. These are nowhere exposed but include clay muds with diatomaceous laminations which are believed to be annual.

C. TURNER

COPFORD

TL 926242

The old brick-pits at Copford were a classic locality of nineteenth century Quaternary palaeontologists, yielding faunas of Mollusca, ostracods and vertebrates. The latter included "Elephas", "Bos", "Cervus", *Ursus* and a beaver recently redetermined as *Trogonotherium*. Molluscan lists from the site show a mixed assemblage, as some collections appear to have been made from mid-Flandrian deposits overlying the earlier strata.

Trial borings for the Marks Tey - Stanway by-pass showed that the organic strata of the deposit thickened northwards, and they were finally revealed in excavations for the new road, particularly in the culvert dug to divert the small brook known as the Roman River. Part of this section is still visible and comprises:

Topsoil and silty clay with Flandrian freshwater and land shells	50 cm
Orange brown sandy gravelly clay	65 cm
Grey-brown mottled clay and clay mud	80 cm
Dark brown wood peat	50 cm
Shelly pale brown clay mud	30+ cm

Boreholes suggest that several more metres of organic sediments, then grey clay, gravels and finally chalk boulder clay at a depth of 24 m underlie the site. The deposits extend for nearly half a mile in an east-west direction. They appear to occupy a similar trough to the similar sequence at Marks Tey, a mile to the west. A spread of boulder clay separates the two interglacial basins.

Palynological investigation of the site is uncompleted, but clearly the organic deposits belong to the Hoxnian interglacial. The clay mud strata exposed in the culvert are of zone Ho IIIb age, the marl of the brickpit slightly earlier. The occurrence of *Trogonotherium* in these deposits (as at Clacton, Ingress Vale Swanscombe, and Hoxne) is important, because this genus became extinct during the Middle Pleistocene and is unknown from any post-Saalian deposits. This emphasises that the Hoxnian can only be correlated with a pre-Saalian interglacial.

Recently samples of the organic deposits from the by-pass section have yielded finite radiocarbon dates (Quaternary Newsletter no.9 and Bristow & Cox 1973).

IGS C14/94 (St 3846)	28,170 ± 170 26,220 B.C.
IGS C14/95 (St 3864)	32,500 + 1240 - 1080 30,550 B.C.

The stratigraphically younger specimen (IGS C14/95) yielded the older date. It has been concluded that both samples had been contaminated by humic solutions.

C. TURNER

THE GIPPING VALLEY

Localities

Barham, Sandy Lane Pit.
Creeting St. Mary.
Claydon, Church Pit.
Great Blakenham.
Sproughton.

The objectives of today's excursion are to examine the glacial sequences in a comparatively restricted area along the slopes of the Gipping Valley.

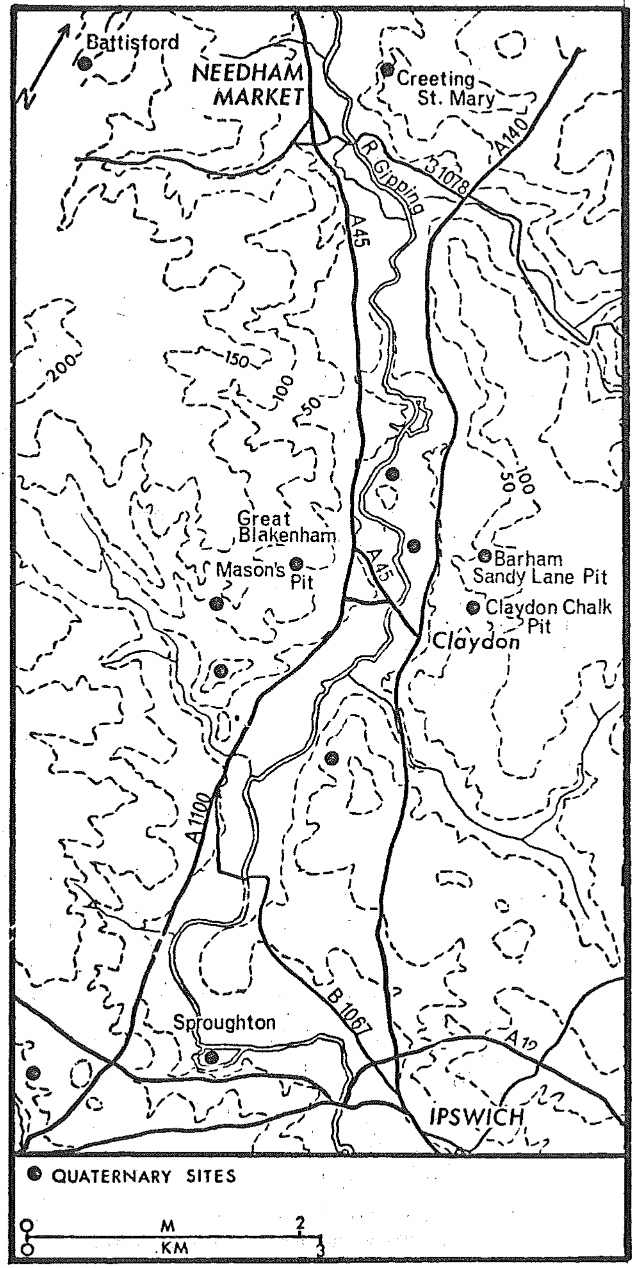
Many authors since the nineteenth century have postulated the existence of more than one major glaciation of East Anglia, but in 1948 this concept was crystallised by Baden-Powell in his subdivision of the chalky boulder clay into Gipping and Lowestoft tills formed during separate glacial advances. Later West and Donner (1956) placed these tills into a stratigraphic framework around the Hoxnian interglacial period. Virtually all Baden-Powell's detailed investigation on Gipping Till was carried out in pits in the Gipping Valley, particularly at Great Blakenham, but the concept was extended less critically to cover tills "very like the Gipping type" in other parts of East Anglia, some of which are now certainly believed to be of Lowestoft type.

Naturally sections in these pits change or are obscured very quickly. At Great Blakenham certain critical sections have gone, nevertheless we shall see tills reputed to be of both types and have the opportunity of hearing of new analytical work on the fabric of the tills and on glacial tectonics, and be able to discuss the validity of the criteria on which the original distinctions were made (colour, consistency, erratics, heavy minerals, superposition). From the glacial tectonic angle at least, it is clear both from these sections and from literature on the tills of the Sudbury area in the Stour Valley, that the till sequence in the valleys is far more disturbed than that on the plateau. Why should this be so?

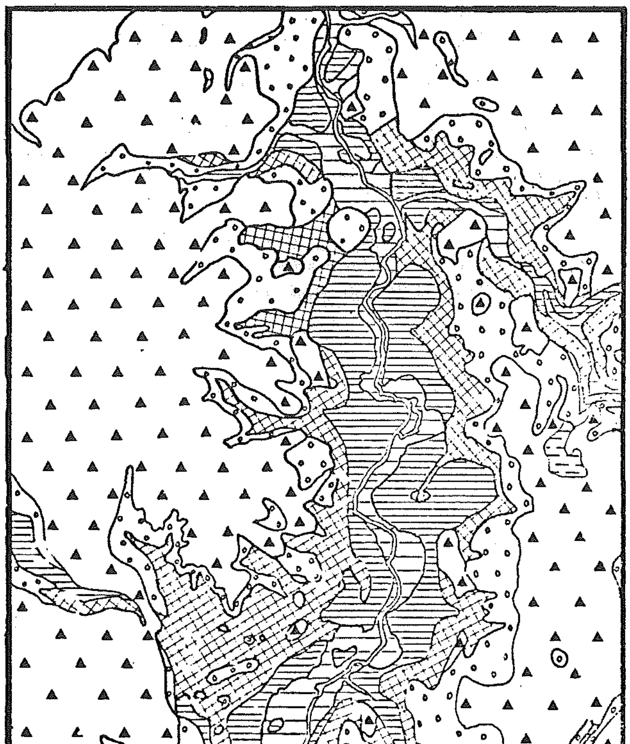
On the dating of the stratigraphy the following possibilities are open to consideration:

1) The traditional view of two tills, one predating, the other post-dating the Hoxnian interglacial. What local evidences exist for deposits between the tills?

2) Only one glacial advance is demonstrable and is of Anglian age, as in Essex.



Relief and Locations


CHALK
ALLUVIUM
READING & THANET BEDS, & LONDON CLAY
GLACIFLUVIAL SAND & GRAVEL
TILL
BRICKEARTH
TERRACE GRAVEL

Geology

3) Two advances occurred in the Gipping Valley during the Anglian. If so, can deposits of the two advances be separated by fabric analysis? (i.e. does the Gipping type till actually belong to such a readvance even if it occurred?)

The Valley itself is aligned along a sub-glacial trough, one of the tunnel-valleys described by Woodland (1970). There seems to be general agreement that this was carved out during Anglian times.

Finally a pit in the floodplain terrace of the River Gipping is visited, to demonstrate that even in Devensian times considerable erosion and sedimentation were taking place.

C. TURNER.

BARHAM, SANDY LANE

TM 133515

The general succession at Sandy Lane is:

6 COVER SANDS

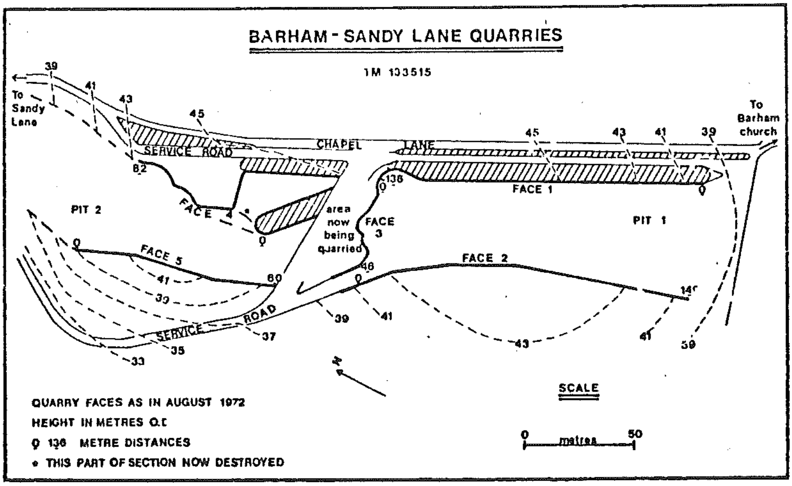
5 HEADS

4 TILL (GIPPING TILL)

3 UPPER SANDS AND GRAVELS

2 UNCONFORMITY, ASSOCIATED WITH CALCAREOUS LENSES

1 LOWER GRAVELS, SANDS AND CLAYS



THE LOWER GRAVELS, SANDS AND CLAYS

This unit is summarised in Table I and best seen in faces 1 and 5. It is disturbed by a frost wedge at the south end of face 1, by gently folded and contorted clay bands and by minor faulting around the frost wedge and near the disturbances. The major disturbance involves gravels as well as clay bands and is concentrated in a single horizon which is truncated at the upper surface. A similar structure is seen also at Kesgrave (TM 2246) and Valley Farm (TM 1143). The form, position and recurrence of this disturbed horizon suggests that the disturbance is due to cryoturbation. This is in contrast to the lower, disturbed clay bands which appear to represent loading effects.

The widespread nature of the deposit, found at at least 3 sites, its angularity and sorting indicate an outwash plain with a palaeoslope to the north-east. The environment was cold and saturated for frost-wedges, involutions and load structures occur.

TABLE I.

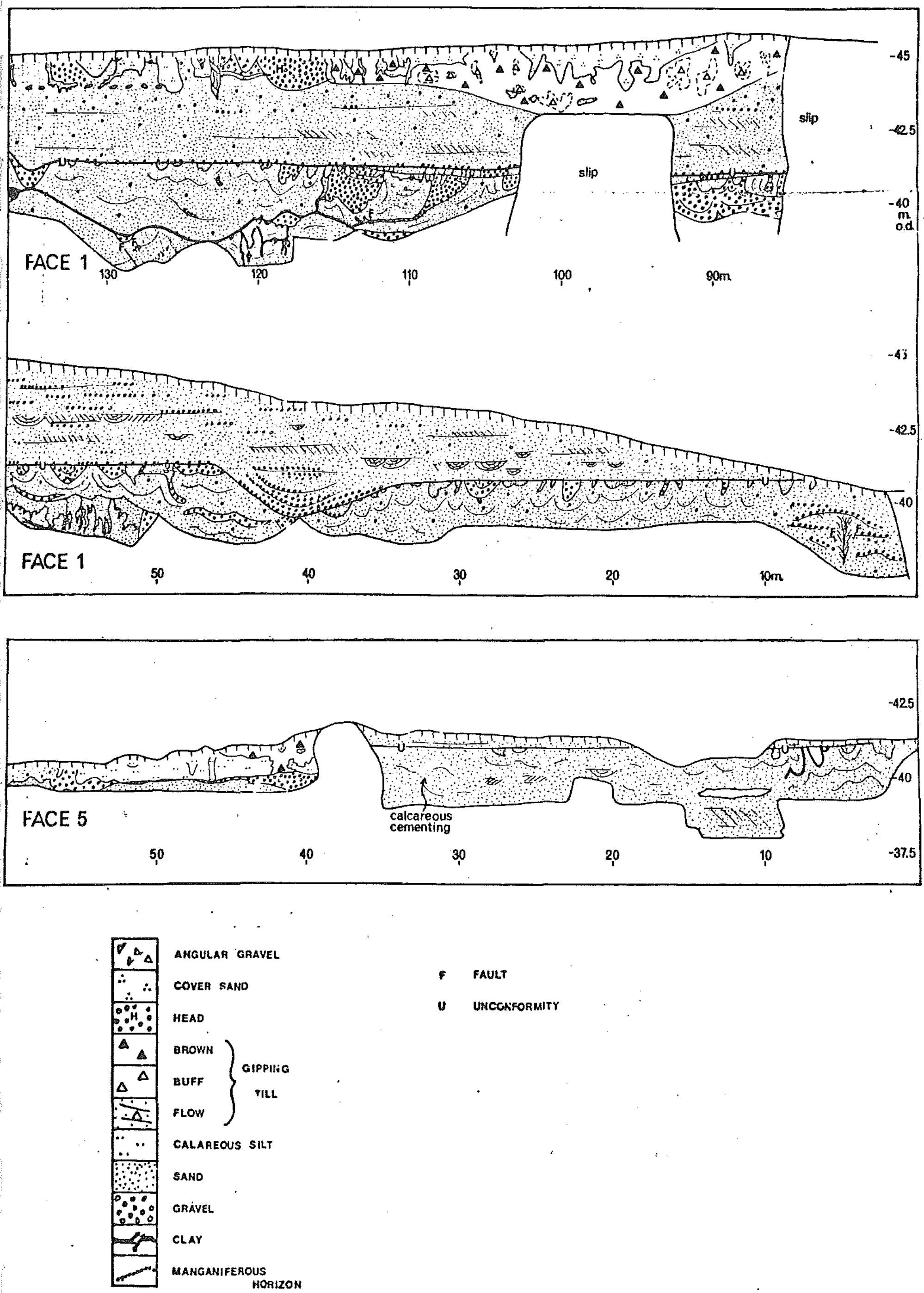
THE GRAVELS		
	LOWER GRAVELS	UPPER GRAVELS
COMPOSITION -3ø (8 mm)		
FLINT & CHERT - angular " - rounded QUARTZ/ITE & SANDSTONE OTHER	56.00% 13.00 31.00 0.18 n = 3345 pebbles	54.00% 11.00 34.00 1.37 n = 2478 pebbles
SORTING (after Friedman, 1962)		
GLACIOFLUVIALTYPE FLUVIAL/GLACIOFLUVIAL TYPE FLUVIAL TYPE	47% 26 26 n = 47 samples	33% 31 35 n = 48 samples
PALAEOSLOPE VECTOR MEAN	N 47.5°E n = 48 observations	N 62.0°E n = 67 observations

THE UNCONFORMITY

The unconformity is best seen in face 1 and to a lesser extent in face 5. It forms an almost planar surface which varies in height between 41.00 m and 41.85 m O.D. in face 1, with an asymmetric channel towards the north end cutting down to 39.80 m O.D. Several factors suggest that the unconformity represents a periglacial land surface:

a) Immediately below are periglacial involutions (described above), features normally associated with surfaces subject to freeze-thaw.

b) The involutions are associated with iron-staining and clay bonding, and in face 5, calcareous cementing, indicating oxidisation and mobility of sesquiexides and/or fines, in keeping with the presence of a land surface. The calcareous cementing is restricted to face 5 where, associated with the unconformity, there is a large lens of calcareous silt. As the gravels do not contain chalk pebbles, the source of the cement is extraneous, e.g. lenses such as just described.



FACE 1
130
120
110
100
90m.
slip
slip
-45
-42.5
-40
m.
o.d.
FACE 1
50
40
30
20
10m.
-42.5
-40
FACE 5
calcareous
cementing
50
40
30
20
10
-42.5
-40
-37.5
ANGULAR GRAVEL
COVER SAND
HEAD
BROWN
BUFF
FLOW
GIPPING
TILL
CALAREOUS SILT
SAND
GRAVEL
CLAY
MANGANIFEROUS
HORIZON
F FAULT
U UNCONFORMITY

c) The calcareous deposits are very fine grained, two lenses showing means of + 4.32 Ø (c 53 mic) and + 6.07 Ø (c 15.6 mic). The sorting is poor, being +/- 1.57 Ø in the first case and +/- 1.49 Ø in the latter, which together with its bedded nature in parts suggests that it was deposited in very low energy conditions such as a pool, or possibly it is aeolian, subsequently reworked and deposited in water.

Thus it is suggested that the unconformity represents a near planar periglacial land surface on which calcareous aeolian silts collected in pools.

THE UPPER SANDS AND GRAVELS

This unit is summarised in Table I, and best seen in face I. As the composition of this unit is not significantly different from the lower gravels and sands and as the upper is not derived from the lower, otherwise the involutions would have been removed, the two units are derived from a similar source. The angularity and sorting indicate glacial outwash, hence a return of an environment similar to that prevailing when the lower unit was deposited, but differing in that sorting was better and there are no obvious signs of cold conditions, such as frost wedges.

CORRELATION OF THE SANDS AND GRAVELS

Based on the gravels, from units 1 and 3, retained between the 16 and 32 mm sieves, correlations can be made with Hey's (1967) lithologies from the Westleton area.

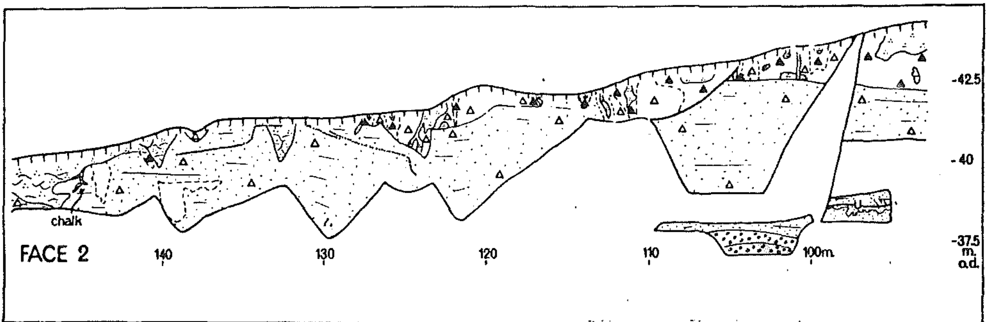
The variability of the angularity of the flints does not allow comparisons to be made, except that the Barham gravels seem more angular, though this might be due to operator variation. However, the composition of the upper gravels of the Westleton area is distinctive and the Barham gravels appear to correlate with them.

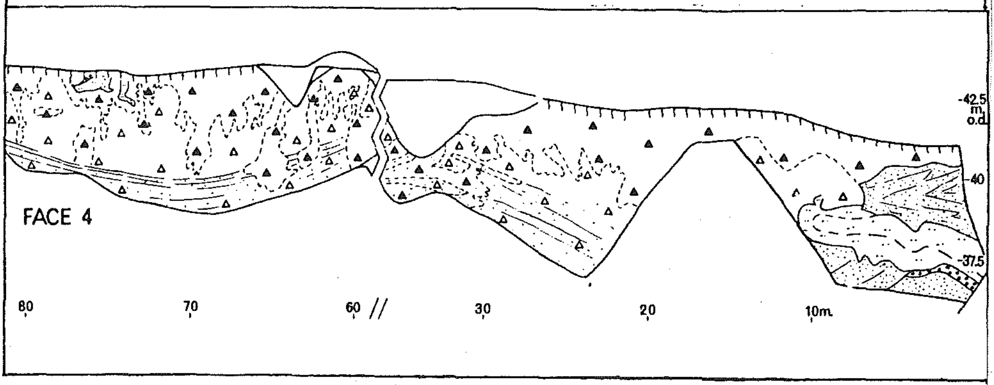
THE TILL

The till is chalky and buff in colour (10YR5/6 to 5/8 moist, 10YR6/6 to 8/3 dry), with brown, decalcified lobes (10YR3/4 moist, 10YR 4/6 dry), fitting descriptions of the Gipping Till. In places the till appears to be massive; for instance in face 1 and the upper parts of faces 2 and 4. Fabric analyses on 4 samples, each of 50 stones, shows a weakly defined preferred orientation (vector magnitudes of less than 25% with approximate trends NE - SW). Thus there appears to be little directional control, which, if original, might suggest a melt-out till, but the lack of control may indicate disturbance. In contrast, the till in the lower parts of faces 2 and 4 is crudely bedded and sandier. Fabrics (4 X 50 stones) show a strongly preferred orientation (vector magnitudes 60 - 80%) with most of the pebbles dipping towards the NW. The bedding and strong orientation suggest a flow till, with either liquid or semi-plastic flow (Boulton, 1971). Within the till sequence are occasional sand pockets, very lightly, calcareously cemented. This sand has a mean size of 2 Ø and a sorting coefficient of +/- 1 Ø, suggesting a cover sand.

TABLE II

	FLINT		FLINT and CHERT	QUARTZ QUARTZITE SANDSTONE
	ANGULAR	ROUNDED		
WESTLETON AREA				
WESTLETON	42.0%	54.0%	(96.0%)	4.0%
HOLTON	20.0	78.0	(98.0%)	2.0
HADDISCOE	35.0	61.0	(96.0%)	4.0
COVEHITHE	46.0	53.0	(99.0%)	1.0
COVEHITHE-UPPER GRAVELS	39.0	39.0	(81.4%)	18.6
HOLTON - " "	21.0	60.0	(84.0%)	16.0
BARHAM				
LOWER UNIT (1)	56.0	13.0	(84.0%)	16.0
UPPER UNIT (3)	54.0	11.0	(80.0%)	20.0





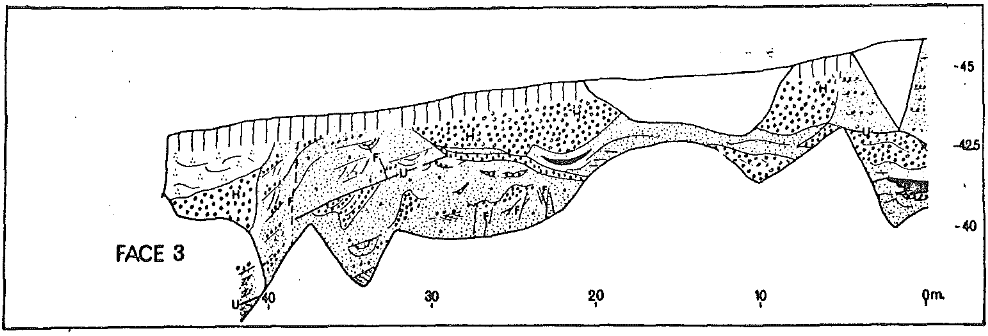
THE HEAD

Coarse unsorted deposits of rounded and angular pebbles and cobbles set in a matrix of brown clay, occupy a linear area between the two pits and dip westwards at approximately the same rate as the present hillslope. The macrofabric of the deposits are characterised by a mean orientation of 80° at some sites and 145° at others with a high indirectional dip towards the hillside. It is suggested from the unsorted and linear nature and general dip of the deposits that they are heads, though the "upstream" dips of the pebbles are not satisfactorily explained.

TECTONICS

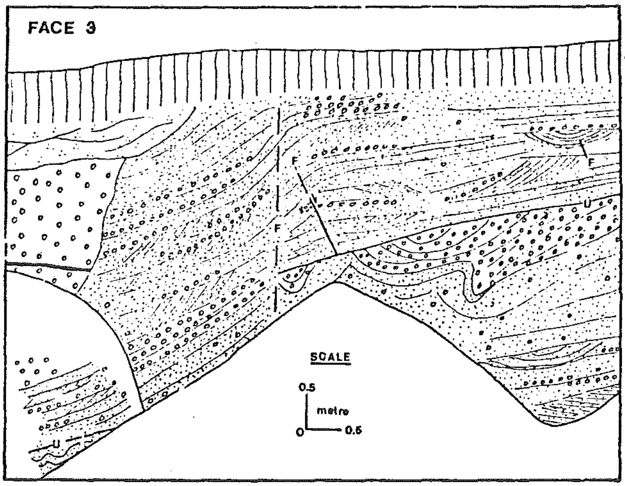
An overfold at the south end of face 4 suggests ice disturbance and the closure of the fold to the north indicates that the stress came from that direction, and that the ice was moving southwards. The flow till of that face also shows folding, though of a gentler nature. Thus some of the folding, at least, occurred after the deposition of the till.

A normal fault with a downthrow of approximately 2 metres, apparently to the west, involves the sand and gravel units of face 3. The faulting could be associated with the glacier tectonics for the overfold is only 5 m away. However, the head occurs at a lower level west of the fault, so the faulting could be later, post-dating that deposit.



THE COVER SANDS

At the top of the succession is a sandy deposit covering both till and head and at times it occurs in the cores of the decalcified lobes. These deposits have a mean size of +2 Ø (250 mic) and a sorting coefficient of +/- 1 Ø when the unit is well developed, but often angular flints up to -5 Ø (32 mm) occur, discordant with the rest of the deposit. The mean size and sorting indicate a cover sand and it is suggested that the flints are working their way through the deposit to the present ground surface.



REFERENCES

Boulton, G.S. 1971. Till Genesis and Fabric in Svalbard, Spitsbergen in Goldthwait R.P. (Ed.) Till Symposium Ohio State University Press.

Friedman, C.M. 1962. On sorting, sorting coefficients, and the lognormality of the grain-size distribution of sandstones. Jl. Geol. 70 737-753.

Hey, R.W. 1967. The Westleton Beds Reconsidered. Proc. Geol. Ass. 78 427-445.

P. ALLEN.

BARHAM

The lowest gravels exposed are similar in composition to those at Alphamstone. Cross-bedding denotes a palaeoslope to the N.E. (9 observations, vector mean 48^{o}).

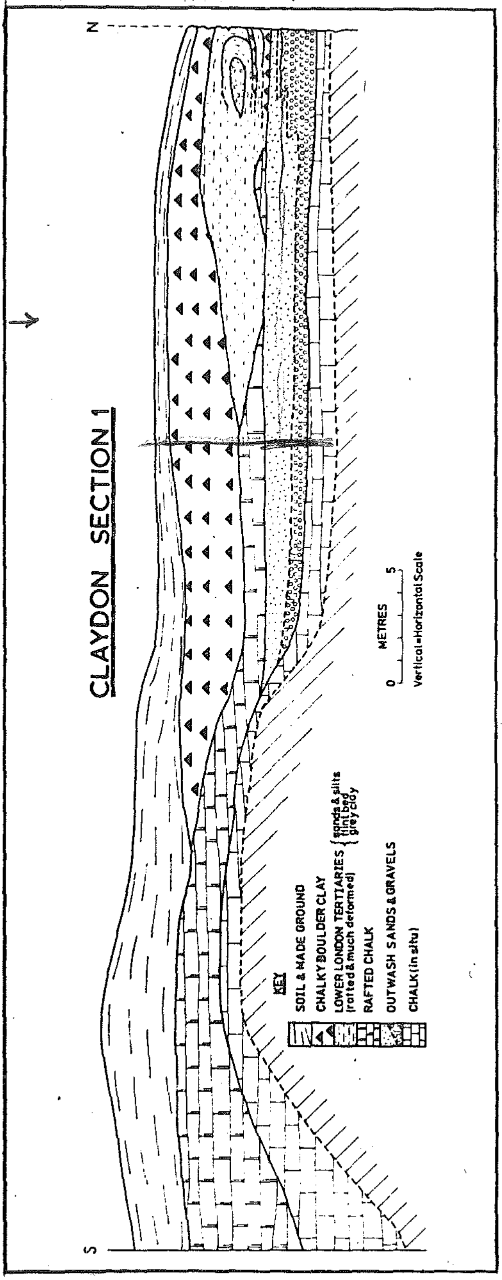
R.W. HEY.

CLAYDON CHALK PIT

TM 133498

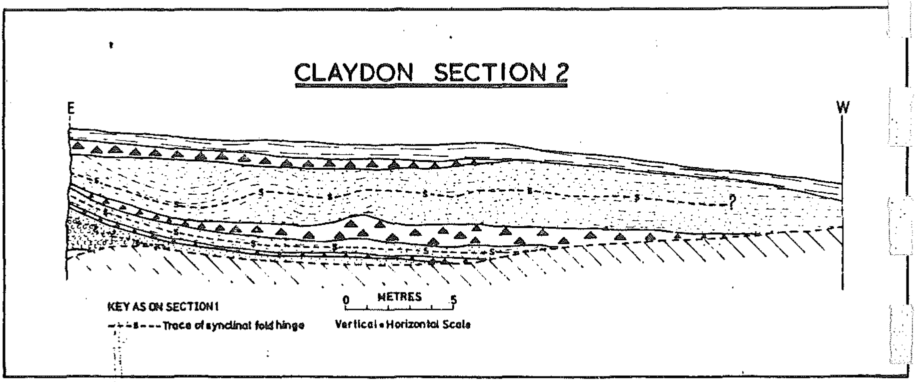
A deformed sequence of chalk, lower London Tertiaries (LLT) and chalky boulder clay (push-moraine ?) is overlain by chalky boulder clay (Lowestoft? Gipping? Till).

16 – 8 →



Section 1 - points of interest from S to N.

1. Cryoturbation festoons developed in chalk raft where it is intersected by the modern land surface.
2. Sharp, planar, generally flat and undisturbed lower surface of chalk raft.
3. Thin bed of grey clay and rolled flints (LLT) on upper surface of chalk raft under chalky boulder clay.
4. Steep-sided channels (trending approx. WSW) within the outwash sands; these contain numerous sub-angular chalk fragments and are generally laminar bedded within channels, although meander core cross-sets may be seen.
5. Detached, daughter (?) raft to north of large raft and at the same level.
6. Chalky boulder clay, laminated, with many flat, tight folds
7. Highly deformed LLTs; folding and thrusting may be seen. Sedimentary structures in the limbs of the large, tight fold at the north end of this section show younging towards the axial plane. Thus, this detached closure is synclinal (plunge 15° to 230° approx).



Section 2 - points of interest from E to W.

8. This fold (see 7 above) can be traced along the hinge in this section.
9. Two essentially synclinal slices of LLTs are found underlain overlain and separated by dislocations marked by sometimes thin, but persistent beds of chalky boulder clay.
10. Many minor folds and thrusts can be seen in the lower LLT slice (plunges at low angles to W. approx; 258° - 296° spread recorded).
11. The major synclinal hinge of the upper LLT slice is "wavy" (plunges at low angles to SW approx; 214° - 230° spread recorded).
12. Sedimentary structural evidence for way-up of fold limbs can be examined in the inner core of the upper syncline at two points in this section.

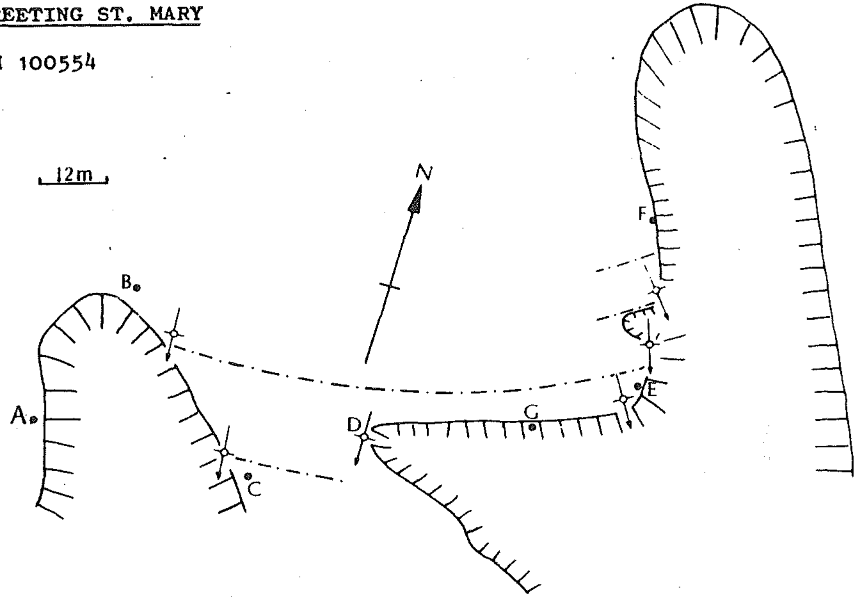
Sequence of Events - basis for discussion

1. Removal of LLTs and some chalk by incorporation into ice (moving from N - NW?).
2. Deposition of flint (etc.) gravels and chalk-bearing sands; permafrost (sub-ice?) conditions indicated by steep channel margins.
3. Emplacement of chalk raft by melting out (from ice moving from N - NW).
4. Emplacement of multiple rafts of LLTs from N - NW.
5. Continued over-riding by ice and deposition of upper (3 m+) chalky boulder clay.

P.H. BANHAM

CREETING ST. MARY

TM 100554



Site map showing the eastern part of the quarry at Creeting St. Mary.

The dashed lines show inferred positions of anticlinal crests. The arrows show the direction of tectonic transport.

A large sand and gravel working occupies much of the hill top on the eastern flank of the river Gipping. In the eastern part of the working is to be found the following sequence:

5. A highly variable series of sands, gravels and silts.

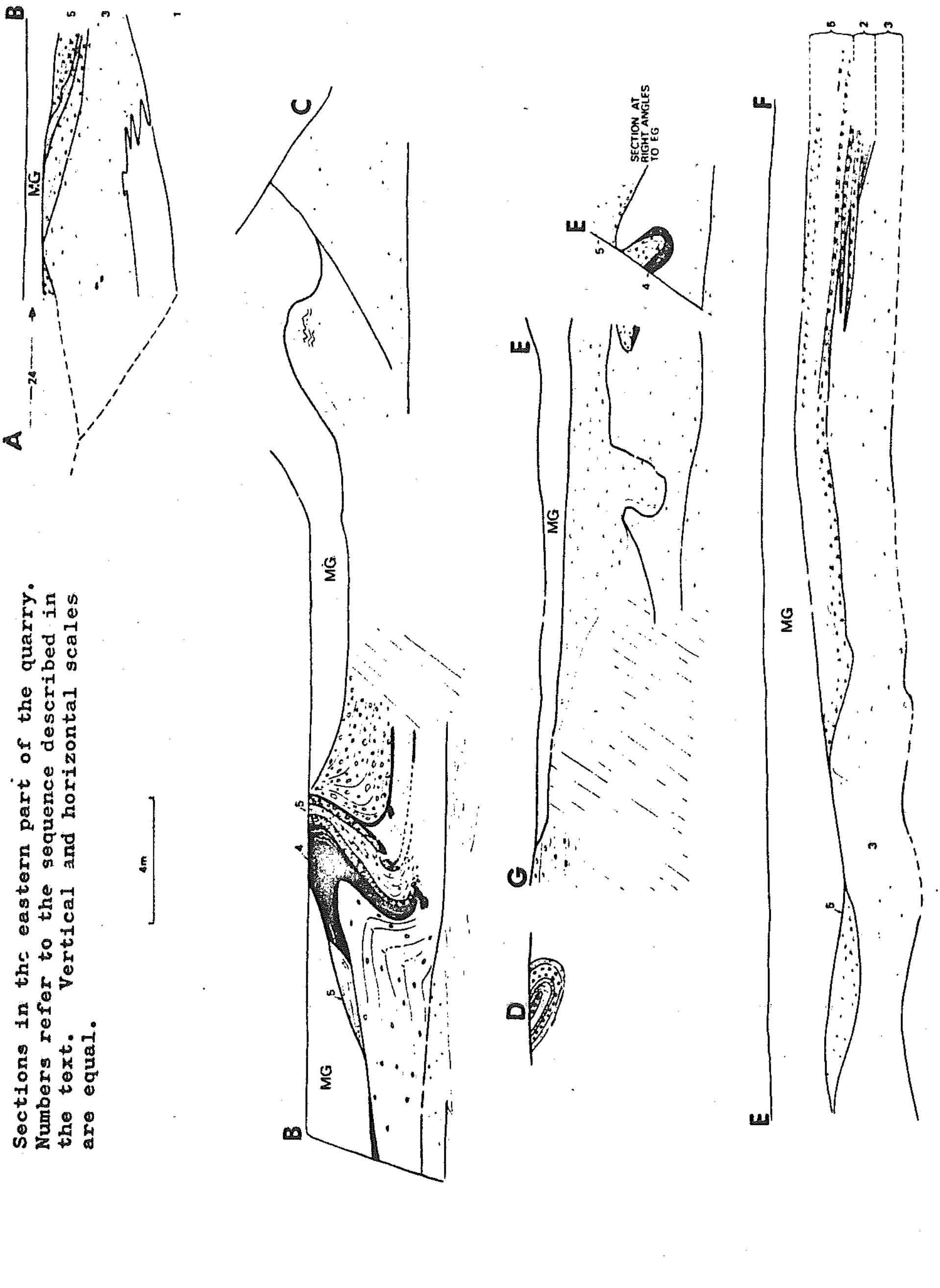
4. Till. Grey-brown with chalk and flint clasts. Crushing and streaking out of chalk clasts has produced a series of chalk-rich bands.

3. Brown medium-poorly sorted sand with occasional pebbles. Laminated but general absence of more complex current-produced structures. This unit appears to be partly contemporaneous with 2. with which it interdigitates.

2. Yellow-brown sand and gravel. Partially derived from 1. Spatially highly variable in grain-size and sorting.

1. Fine-medium grained well-sorted grey, green-white sands showing low angle cross-stratification and probably of Tertiary or lower Pleistocene age. 11m to 9m exposed.

The base of unit 5 is an important erosion surface, it cuts down through the underlying sequence (unit 4, the till, is only preserved in two localities), and to the west of point A only unit 1 is preserved below the surface. Over much of the rest of the extensive quarry workings to the west only units 5 and 1 are to be found.



Sections in the eastern part of the quarry. Numbers refer to the sequence described in the text. Vertical and horizontal scales are equal.

Genesis of the sedimentary sequence 2-5.

Unit 2 was clearly deposited from rapidly moving water currents.

Unit 3 with which it interdigitates is a very interesting sediment. The range of grain sizes is similar to some of the gravels of unit 2, but the relative magnitudes of the various components are very different, there merely being occasional pebbles set in a sandy matrix. The bedding is planar without ripples or dune structures.

The sediments of unit 3 are problematical. The laminar bedding and occasional large clasts might suggest an upper flow regime, although the apparent absence of ripple or dune structures is unusual. An alternative explanation would be that they were laid down rapidly by a series of highly turbid flows into a lake basin to which the sediments of unit 2 were marginal. It is also possible that the large clasts may have been dropped in from glacier-derived icebergs, although this would require deep water; alternatively they may have been derived during the break-up period of lake ice, from that ice which had been attached to the gravelly lake shore.

Streaking-out of chalk pebbles in the till (unit 3) suggests that this was probably deposited as subglacial lodgement till.

The variability of grain-size and sedimentary structures in unit 5, together with the considerable erosion at its base suggests proglacial outwash.

Tectonic Structures.

A series of assymetric, often monoclinal, folds and associated joint systems occur in the sequence. The intensity of folding attenuates downwards and signs of disturbance are not found more than 2-3m below the top of unit 1.

The strikes of folds and the direction of tectonic transport are marked on the map. A systematic pattern is clearly present, and if the axes of folds are projected laterally they appear to correlate over a large area, suggesting a series of persistent folds trending roughly east-west.

From the section B-C, it is clear that the period of folding was not associated with the deposition of the till (unit 4) but post-dated the whole of the sequence. The form of the folds, their assymetry towards the south, and their continuity, is very similar to certain contemporary glacitectonic features. Where glaciers advance into unlithified and only partially frozen sediments (even in polar areas there is rarely complete freezing in zones of active outwash and lacustrine activity), materials may be pushed and folded into a series of very regular "Jura-type" folds for 3-4 kilometres beyond the advancing ice margin. The surface expression of these folds is a series of ridges parallel to the ice margin. It is suggested that such an event was responsible for the tectonics at this locality.

Sequence of Quaternary events.

1. Some reworking of Tertiary Crag sediments in a fluviatile environment, and possibly the development of a lake, probably in a near-glacial environment.

2. Glacier advance over the site (unit 4) followed by retreat.

3. Fluviatile phase during which much of the pre-existing Quaternary sediments were eroded, and in which gravels of unit 5 were deposited.

4. Glacier readvance from the north, during which phase the most southerly position of the ice front lay to the north of the site.

There is no evidence from this site of the age of the sediments described above, nor is it possible to say whether the glacier readvance phase was merely a small scale event during retreat of the ice which produced the till, or whether it was a much later, and major, readvance. The fluviatile phase (3) was probably close in time to the readvance phase (4) and may have been outwash activity associated with readvancing ice. If the readvance were merely a small scale pulse during general retreat then the fluviatile phase probably spans both episodes.

G.S. BOULTON.

CREETING HILL

The gravel interbedded with the uppermost Creeting White Sands is similar in composition to that at Alphamstone. At this horizon, the cross-bedding denotes a palaeoslope to the E.N.E. (24 observations, vector mean 72°), and surface textures of sand-grains show evidence for glaciation (D.H. Krinsley). For the stoneless sands below the pebble-beds, cross-bedding indicates currents towards the S.S.W. (19 observations, vector mean 202°); no data available on surface textures of sand-grains.

R.W. HEY.

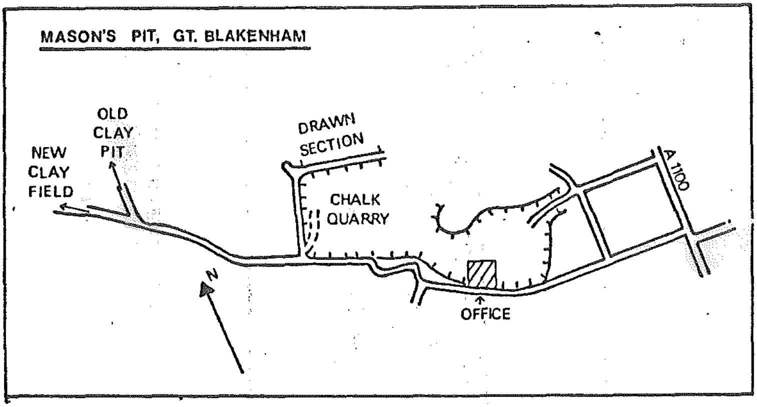
7 = pseudo-wedge

GREAT BLAKENHAM   MASON'S PIT

TM 115499

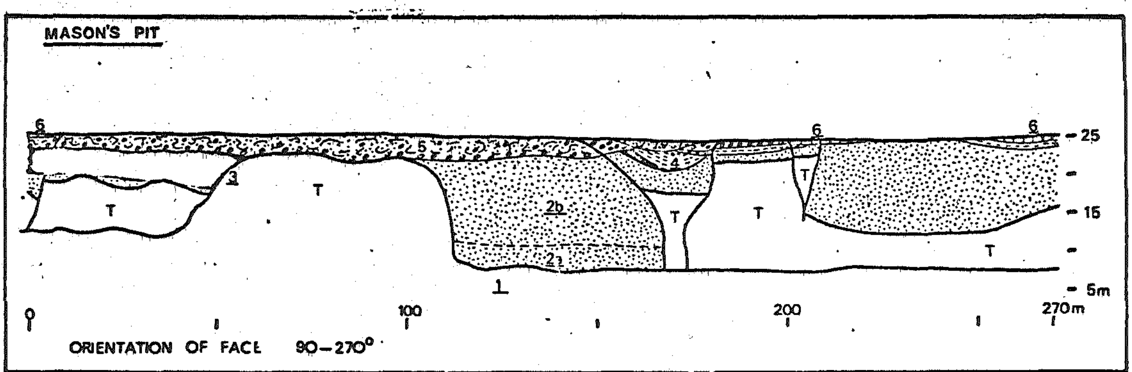
SEQUENCE (derived from direct observation and from the literature)

8 BUFF TILL (GIPPING TILL)
7 OCCASIONAL GRAVELS AND LAMINATED CLAYS
6 BLUE TILL (LOWESTOFT TILL)
5 SANDS AND GRAVELS
4 BROWN SANDS
3 CLAYS
2 MICACEOUS SANDS
1 CHALK



Reddish sands containing phosphatic nodules and phosphatised bones sometimes occur in depressions in the top of the chalk (1). This phosphatic nodule band is characteristic of the Red Crag and shows the former extension of this deposit.

Units 1 - 5 are shown in the figure. The micaceous sands have quartzose pebble bands towards their base, above which are current-bedded, clean sands (2a). The main part of the sandy body (2b) is notable for including clay flakes, which are particularly concentrated in certain areas and in sedimentary structures such as channels. Particle size analysis shows that the sands are generally well sorted in much the same way as the finer sand units from other pits working the glacial sands and gravels in the area, e.g. Foxhall Road (TM 235440), the lower unit at Kesgrave (228465), Valley Farm (116431), Westerfield (178476), and Waldringfield (258447). They are not as well sorted as the fine sands from Creeting (097556). These sands, at Great Blakenham, were regarded as possibly being outwash associated with the Lowestoft glaciation (Spencer 1966, p. 300).



6	TILL	2a	CLEAN, MICACEOUS SANDS WITH QUARTZOSE PEBBLY HORIZONS TOWARDS BASE
5	SANDS AND GRAVELS, MOSTLY CRYOTURBATED	1	CHALK
4	DARK SANDS IN CHANNELS		
3	CLAY	T	TALUS
2b	MICACEOUS SANDS WITH ABUNDANT CLAY FLAKES, SOME HORIZONS RELATIVELY CLEAN		

At the beginning of the drawn section is a thick clay horizon (3) extending approximately 50 metres along the face. The clay is blue-black in colour in its upper and lower sections with a grey horizon between. This clay differs from the clays found in the sands below in that it is not obviously micaceous.

Towards the other end of the section are brown sands (4) occurring in channels. These are lightly cemented, lacking in clay flakes and darker in colour than unit 2. Their relationship to unit 3 is not clear, except that at 160 metres one of the channels overlies a lens of clay which may be related to unit 3.

Above this are gravels and sands (5). Possibly more than one unit is present for in places the gravels are over 1 metre thick and undisturbed, but mostly they are cryoturbated.

Mason's Pit is best known for its till. Boswell, although aware of the possibility of there being two tills in the area (e.g. Boswell & Slater 1912 and Boswell & Double 1922), describes only one till at Great Blakenham, the blue-grey chalky boulder clay (Boswell 1915 and 1927). On a visit by the Geologist's Association in 1938 (Boswell 1938), a separation of the till at Great Blakenham into upper and lower units was discussed by Reid Moir. A decade later, the Association again visited the pit and recognised a yellower, chalkier Upper Boulder Clay overlying the blue-grey Chalky Jurassic Boulder Clay and separated from it by a somewhat sandy gravelly bed a few inches thick (Ovey & Pitcher 1948). In the same year, Baden-Powell (Baden-Powell 1948) definitively separated out the chalky boulder clay of East Anglia into a lower, dark clay, for which he proposed the name "Lowestoft Boulder Clay", and an upper pale one, the "Gipping Boulder Clay". The two could be seen in superposition at Mason's Pit (p. 283). The two tills were separated not only on the basis of colour and superposition, but also on differing petrological properties. From a study of the erratic content of the tills, the Lowestoft Till was shown to relate to an ice advance from the NW and the Gipping Till to one from the N - NNW down eastern England. These directions of ice advance were confirmed by West and Donner (West & Donner 1956), on the basis of stone orientations, though at Great Blakenham it was difficult to separate the two tills using this approach. Another difficulty concerns the separation of the two tills on the basis of petrological differences. The lithologies outlined by Baden-Powell show not dissimilar lists for the two tills, the differences coming more in the frequencies at which the erratics occurred. The Red Chalk is listed as being rare in the Lowestoft Till, but now it is quite common in that till at Great Blakenham.

Spencer also confirmed the view that there were two tills. "In the older clay pit, the base of the Lowestoft Till has never been exposed and its thickness must exceed fifty feet. It is covered with Gipping Till and morainic gravel has been noted intervening at a few places" (Spencer 1966, ibid.). Varved clays also have been noted between the two tills. "Remains of a deposit of varved clay were pointed out at intervals; reference was made to having passed over about twenty feet of this deposit on the outskirts of Ipswich where it occurred between the Lowestoft Till and Gipping Till" (Spencer 1967a). This twenty feet thick deposit occurred at Bramford Road (TM 133457) (Spencer 1966, ibid.) A possible complication is that "erratic rafts of varved grey and blackish clays have been observed within the Lowestoft Till at Great Blakenham of which the parent deposits are so far undiscovered" (Spencer 1967b).

At present buff till can be seen overlying grey-blue clay adjacent to the drawn section (see map) and in both the clay pit and the newly opened clay field, but it is difficult to find any deposits between the two. Current opinion suggests that there is only one till body in East Anglia (Cox & Bristow 1973). It is certainly true that much of the buff till of the area is merely a weathered form of the Lowestoft Till, but attention should be drawn to the fact that the earlier workers point out that the Lowestoft Till weathers slightly differently from the Gipping Till (Baden-Powell 1948, ibid. and Spencer 1967, ibid.). It should also be noted that if the Gipping Till is a weathered version of the Lowestoft Till, the weathering has not been accompanied by much, if any, decalcification for the former is remarkably chalk rich. This problem needs further investigation before all the buff tills can be assigned to their proper stratigraphic position.

References

Baden-Powell, D.F.W. 1948. The Chalky Boulder Clays of Norfolk and Suffolk. Geol. Mag. Vol. 85, pp. 279-296.

Boswell, P.G.H. 1915. Report of an Excursion to Ipswich and Claydon. Proc. Geol. Ass., Vol. 26, pp. 327-330.

1927. The Geology of Ipswich. Mem. geol. Surv. U.K.

1938. Whitsun Field Meeting, 3rd June to 7th June, 1938. Proc. Geol. Ass., Vol. 49, pp. 410-414.

& Double, I.S. 1922. The Geology of the Country round Felixstowe and Ipswich. Proc. Geol. Ass., Vol. 33, pp. 285-305, 306-312.

& Slater, G. 1912. Report of an Excursion to Ipswich and the Gipping Valley. Proc. Geol. Ass., Vol. 23, pp. 229-

Bristow, C.R. & Cox, F.C. 1973. The Gipping Till: a reappraisal of East Anglian glacial stratigraphy. Jl. geol. Soc. Lond., Vol. 129, pp. 1-37.

Ovey, C.D. & Pitcher, W.S. 1948. Observations on the geology of East Suffolk. Proc. Geol. Ass., Vol. 59, pp. 23-34.

Spencer, H.E.P. 1966. A Contribution to the Geological History of Suffolk. Pt. 2. Trans. Suffolk Nat. Soc., Vol. 13, pp. 290-313.

1967a. Field Meeting in the Quaternary of East Suffolk. Proc. Geol. Ass., Vol. 77, pp. 371-380.

1967b. A Contribution to the Geological History of Suffolk. Pt. 3. Trans. Suffolk Nat. Soc., Vol. 13, pp. 366-389.

West, R.G. & Donner, J.J. 1956. The glaciations of East Anglia and the East Midlands: a differentiation based on stone orientation measurements of the tills. Quart. Jl. geol. Soc. Lond., Vol. 112, pp. 69-91.

P. ALLEN

SPROUGHTON

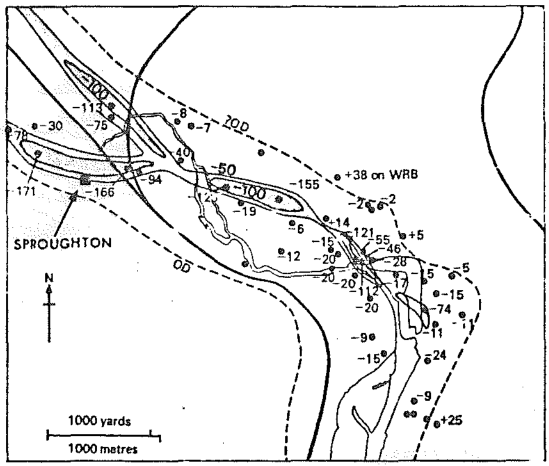
TM 133443.

Gravel workings in the base of the Gipping Valley reveal the following general succession.

7) Soil.
6) Peat, gyttja, shells, sand and gravel lenses.
5) Gravel.
4) Unconformity.
3) Chalk head.
2) Laminated organic silt.
1) Chalk mud.

Site

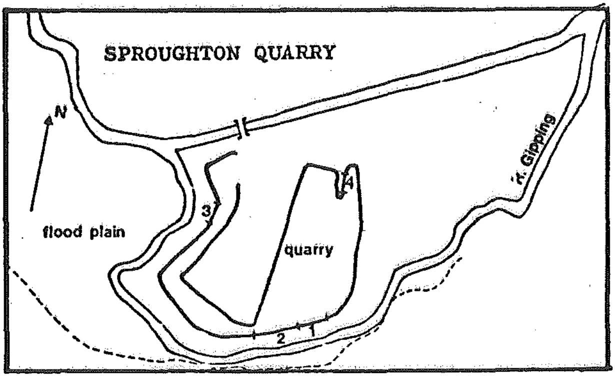
This succession forms the upper part of the sediments which fill the buried valley of the Gipping. The form of the buried valley has been described by Woodland (1970) who attributed its formation to sub-glacial glacifluvial erosion.

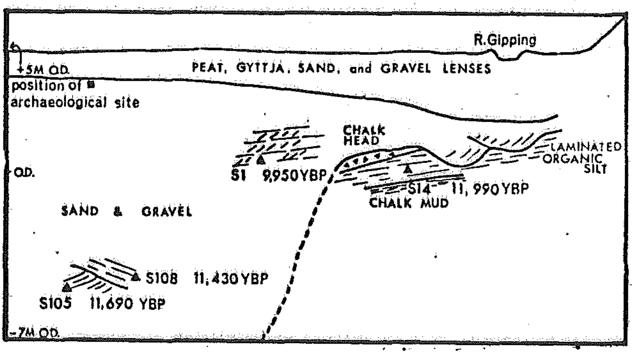


Sketch map of Ipswich area showing detailed configuration of buried channel. The wells indicated by black dots show the level of top of Chalk beneath drift: in one case the drift rests on Woolwich and Reading Beds (WRB). Chalk surface contours for O.D., —50 ft and —100 ft are shown.

Chalk Mud, Laminated Organic Silt, and Chalk Head.

These sediments are preserved at the south side of the valley. Their base is not visible, but the upper margin is truncated by channels infilled by the overlying gravel. The mud and head appear to represent mudflow deposits of comminuted and fractured chalk, transported to the site by gravitational slope processes.

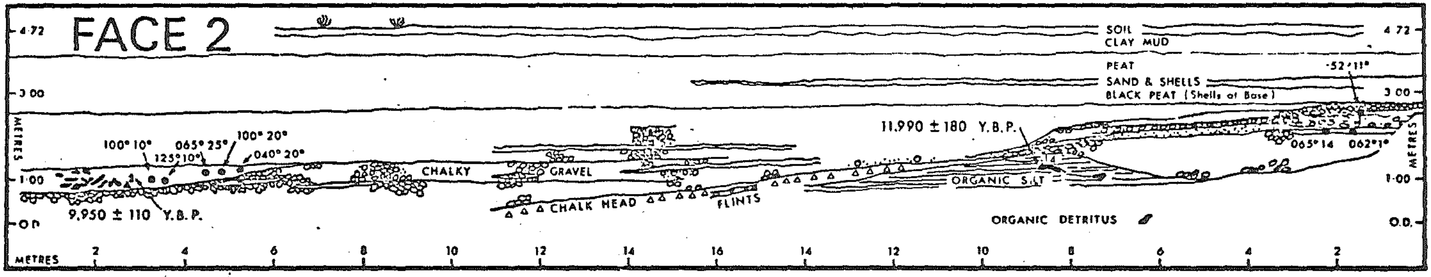




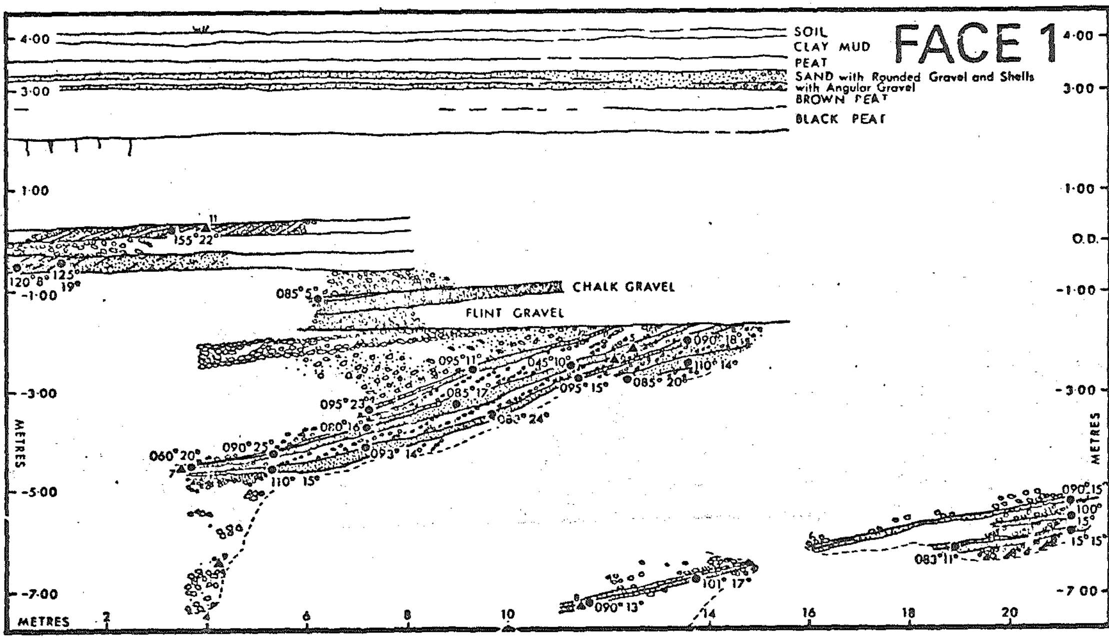
Diagrammatic representation of stratigraphy at Sproughton.

The laminated organic silts represent organic and inorganic fines accumulated in a low energy depositional environment, such as a shallow lake. Most of the organic detritus is sand and silt size, but some large twigs and branches are preserved. One branch enclosed in the middle of the silt gave a C^{14} date of 11,980 ± 180 Y.B.P. (Ha 260).

The variable organic content and lithostratigraphic character of this sequence may indicate a climatic fluctuation from cold through to less cold back to cold again. However it is also possible that it may represent nothing more than changing topographic conditions associated with the development and degradation of mud flows of chalk detritus.



FACE 2
SOIL
CLAY MUD
PEAT
SAND & SHELLS
BLACK PEAT (Shells at Base)
4.72
3.00
1.00
O.D.
METRES
100° 10°
065° 25°
100° 20°
125° 10°
040° 20°
CHALKY
GRAVEL
CHALK HEAD
FLINTS
9,950 ± 110 Y.B.P.
11,990 ± 180 Y.B.P.
ORGANIC SILT
ORGANIC DETRITUS
065° 14
062° 1°
52° 11°
2
4
6
8
10
12
14
16
14
12
10
8
6
4
2

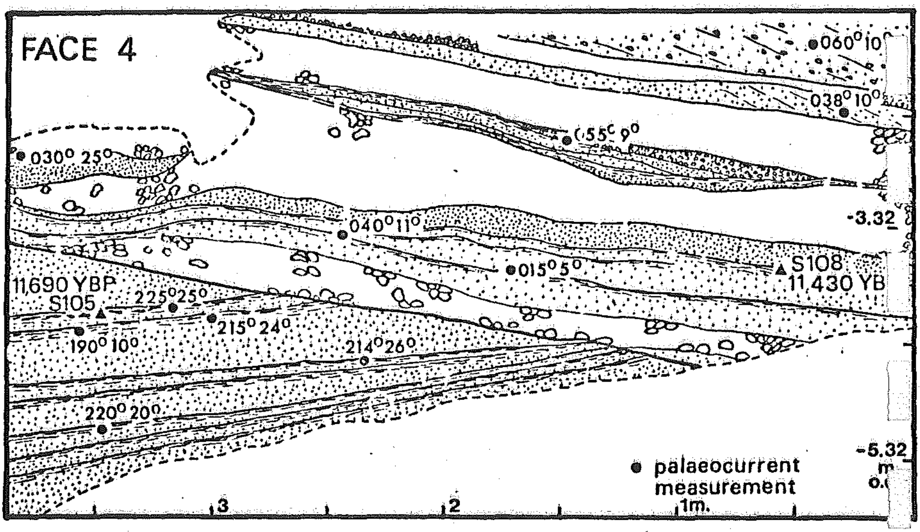


FACE 1
SOIL
CLAY MUD
PEAT
SAND with Rounded Gravel and Shells
with Angular Gravel
BROWN PEAT
BLACK PEAT
4.00
3.00
1.00
O.D.
-1.00
-3.00
-5.00
-7.00
METRES
155° 22°
120° 8°
125° 19°
CHALK GRAVEL
FLINT GRAVEL
085° 5°
095° 11°
045° 10°
090° 18°
110° 14°
095° 15°
085° 20°
085° 17°
095° 23°
080° 16°
083° 24°
060° 20°
090° 25°
093° 14°
110° 15°
090° 13°
101° 17°
090° 15°
100° 15°
15° 15°
083° 11°
2
4
6
8
10
14
16
18
20

Sands and Gravels.

The bulk of the material filling this part of the Gipping Valley is sand and gravel. It extends to at least 7 metres below sea level at the water level at the base of the pit.

At the south side these deposits form alternating, tabular, gravel and sand large-scale cross-sets with a vertical range of at least 3 metres. The sand bed decreases in mean particle size from the top to the bottom of the cross-set. These structures appear to represent fluvial deposition into relatively still water with a depth of at least 3m. The upper part of these beds is truncated, and succeeded by sands and gravels forming low angle and small scale (vertical range less than ·25 m) tabular cross-set structures. The structures and the particle size distribution (Visher 1969) suggest that these represent the traction and saltation population associated with shallow water channel flow.



In the centre of the Valley, exposed over much of the quarry, the sand and gravels form large-scale, trough, cross-set structures infilled bv small-scale tabular cross-sets. These appear to represent the path of the main fluvial channels.

Palaeocurrent measurements indicate that the currents which deposited the gravels flowed southwards and eastwards, although one major channel at Face 4 has a slope towards the west and is infilled by depositional tabular cross-sets with a slope towards the west.

The stone content of the gravels (16-32 mm fraction) is summarised below.

	Flints	Quartz	Chalk	Others
Locations at Centre of Valley	91.78	7.36	0.00	0.86
Locations at South Side of Valley	78.77	7.11	13.27	0.85

The higher chalk content from the valley side gravels indicates erosion of existing chalk or head deposits.

In summary these sediments represent upper flow regime, fluvial sediments, deposited at the base of a wide network of shallow channels, and at the valley side, in deep, relatively still water. This probably represents a braided channel complex progressively filling the Gipping Valley with a general slope away from the channel, down valley and towards the valley side.

The gravel contains rafts of peat and the sands contain seams of organic detritus, some of which is twigs. Many twigs still retain their bark which indicates limited rolling. C^{14} dates have been obtained from two samples at Face 4 and 1 sample from Face 1.

S 1	9,950 ± 110 Y.B.P.	(Ha 259)
S 105	11,690 ± 500 Y.B.P.	(Ha 261)
S 108	11,430 ± 210 Y.B.P.	(Ha 261)

This suggests that organic material accumulated in the laminated organic silts was being eroded from positions on the valley side, and redeposited among the gravels.

Peat, Gyttja, shells, sand and gravel.

The growth of topogenous peat and the deposition of fine organic and inorganic detritus indicates low relief, high water table, and a low energy depositional environment such as the backswamp area of a floodplain formed by a river flowing in a well defined channel. The gravels and sands represent higher energy conditions such as associated with a temporary shift of channel or drainage of surface water from the floodplain area. The small lenses of sand indicate that low energy conditions were dominant, that the bulk of the inorganic detritus carried by the river remained within the channel, and that flooding and the transport of sand and gravel across the floodplain by the River Gipping occurred only rarely.

J.R.

Organic Material.

The plant macroremains consist largely of wood, twigs, budscales, and leaves of willow (<u>Salix</u> spp), including both tall and dwarf shrub species, leaves and occasional fruits of <u>Betula nana</u> are present. Abundant moss fragments are preserved together with fruitstones of <u>Potamogeton</u> and <u>Chara</u> oospores. Otherwise the flora from any of the horizons so far examined is not rich. A sparse pollen flora occurs in the finer organic sediments and from preliminary analysis appears to be too cold to represent Allerød assemblage.

C.T.

Age of the Deposits.

The C^{14} dates suggest that the laminated organic silts accumulated during the Late Weichselian Thermal Maximum, which includes the Allerød, and that the gravels accumulated after this time until at least 9,950 C^{14} years ago. On this basis it seems most probable that the chalk mud was deposited in Zone I, that the chalk head and sand and gravels were deposited in Zone III. This does in fact support the simple climatic interpretation of the lithostratigraphy. If the gravels were formed in Zone III it is interesting to note that they continued to be deposited into the early Flandrian. The peat, gyttja, sands, and gravel lenses most probably represent the products of fluvial activity during most of the Flandrian. It should be noted however that the preliminary investigation of the pollen does not support this interpretation and the whole chronology may be subject to revision.

Some General Considerations.

1) The hydrological factors responsible for the contrasted fluvial regimes of the Gipping catchment during 1) the formation of the sands and gravels and 2) the formation of the upper peats and gyttja.
2) The origin of the chalk mud and chalk head. The 1" Geological Survey map indicates that London Clay outcrops on the adjacent hillside.
3) The high flint content in the gravels. This is as much as 12% higher than that in the adjacent glacial gravels.
4) The abundance of organic sediments. This is exceptional, whether the site is Late or Middle Weichselian.

J.R.

References

Spencer, H.E. 1971. A Contribution to the Geological History of Suffolk. Trans Suffolk Naturalists' Society. Vol. 15, pp. 517-519.

Visher, G.S. 1969. Grain size distributions and depositional processes. J. Sed. Petrol. Vol. 39, pp. 1074-1106.

Woodland, A.W. 1970. The Buried Tunnel-Valleys of East Anglia. P.Y.G.S. Vol. 37, pp. 521-578.

J. ROSE.
C. TURNER.

SPROUGHTON

TM 133443

Rescue excavations in November-December 1972 produced a rich flint industry in situ, on and slightly into the sane at the top of the deposits filling the buried channel of the River Gipping. The date of the industry is thus unlikely to be earlier than the latter part of the Last Glaciation. The industry is Upper Palaeolithic in type and may confirm some of the claims made in the past for the presence of Upper Palaeolithic industries in the Ipswich area. Three factors, apart from the typology, show that it is earlier than Neolithic:

i) Associated Neolithic artifacts on the same surface (scrapers, leaf-shaped arrowhead) are fresh and unpatinated in contrast to the worn, white patina of the Upper Palaeolithic type industry.

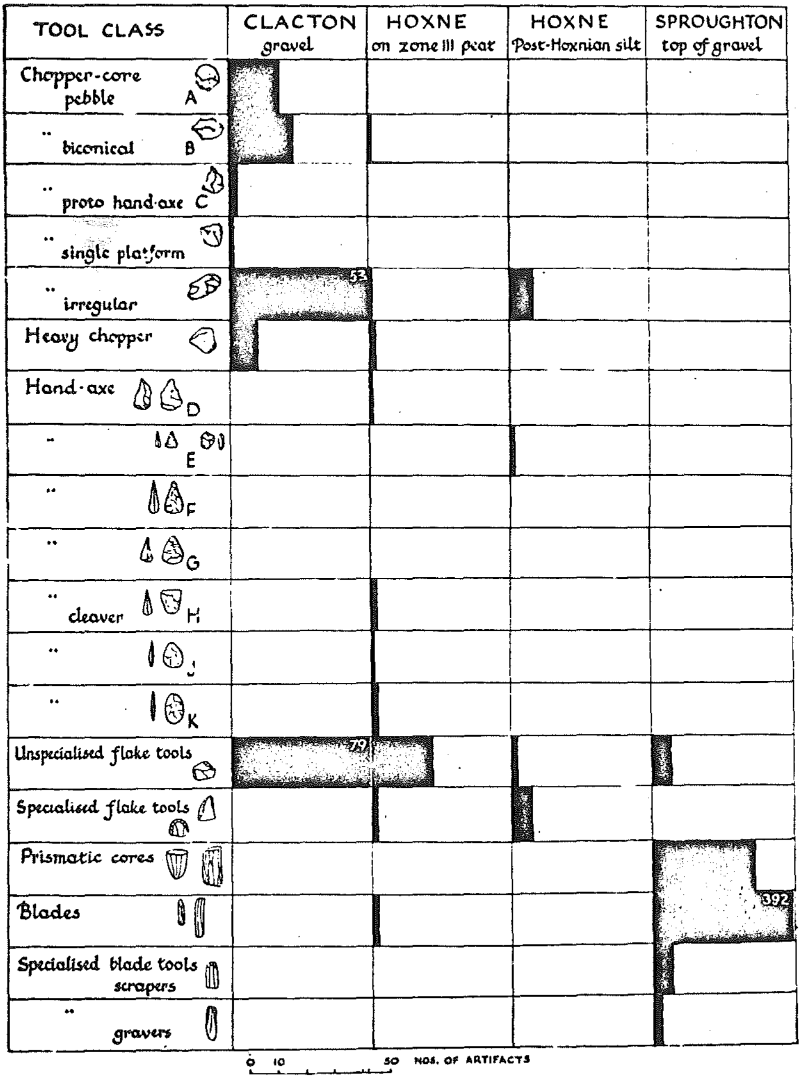
ii) Some of the white, patinated flints are in clean sand, which must have been disturbed prior to the formation of a soil above it.

iii) Reindeer bones have come from what appears to be the same horizon elsewhere in the pit.

Two minute, scalene microliths (assumed to be Late Mesolithic) are in a less weathered condition than the Upper Palaeolithic type industry. Another, tanged microlith probably belongs with the earlier industry. There is no suitable material for radiocarbon dating but pollen analysis may substantiate the date.

There are similar Upper Palaeolithic type flints in Ipswich Museum from Hadleigh and Bramford Roads, together with a few fragments of leaf-shaped blades for which Solutrean parallels have been claimed. They are all somewhat rolled and apparently come from gravel comparable to that at Sproughton which fills the buried channel.

Small cordiform and "bout coupe" hand-axes, in rolled condition, also come from Bramford Road. One was recently found at Sproughton, apparently from the chalky clay at the base. Elsewhere in the Gipping valley, Levallois material and rhino remains are said to come from loams at the base of the gravel.



Histograms to show classes of tools found at Clacton, Hoxne and Sproughton. Chopper-cores and hand-axes classified as per Wymer, 1968*. Numbers indicate totals of artifacts found during recent archaeological investigations. Excluded are flakes, trials and failures and shatter-pieces.

* Wymer, J. 1968. Lower Palaeolithic Archaeology in Britain, as represented by the Thames Valley. John Baker, London.

J.J. WYMER.

HOXNE AND THE SUFFOLK BRECKLAND

Localities

Hoxne
Thetford Heath
Warren Wood, Elveden (*swine disease restrictions permitting)
High Lodge, Mildenhall

Driving northwards from Ipswich to Hoxne, we pass over an almost continuous broad plateau covered by a thick mantle of chalky boulder clay. At Hoxne the interglacial deposits rest on what is universally accepted as Lowestoft Till. However, attention here should be centred on the recently exposed deposits which overlie the lacustrine strata. Under what circumstances were these beds laid down here ? Passing westwards we enter a very different tract of country, the Breckland, a few miles east of Thetford. Not only the topography but also the drift stratigraphy form a startling contrast with the plateau to the east and to the south beyond the River Lark. Here thin spreads of sandy chalky gravel (erroneously labelled till by some authors in the past) and blown sand overlie the Chalk. Only occasional isolated patches of chalky boulder clay, some very restricted in extent, prove that the area has been glaciated like the plateau. Nevertheless these outcrops of boulder clay are also associated with a scatter of small lacustrine deposits, which have received little attention since the days of Skertchly (Miller & Skertchly 1878, p.549). Irrespective of the age of these deposits, which is not yet clear, though some of them are polleniferous, the question must be asked, why is this area so different to the plateau country we have been studying, and likewise why, if a thickness of till has simply been eroded, should any lacustrine deposits survive since they are exceedingly few and far between on the plateau surface elsewhere?

C. TURNER

6, 5 (wedges); 4, 3, 2, 1 (Head in sands)

HOXNE-OAKLEY PARK PIT

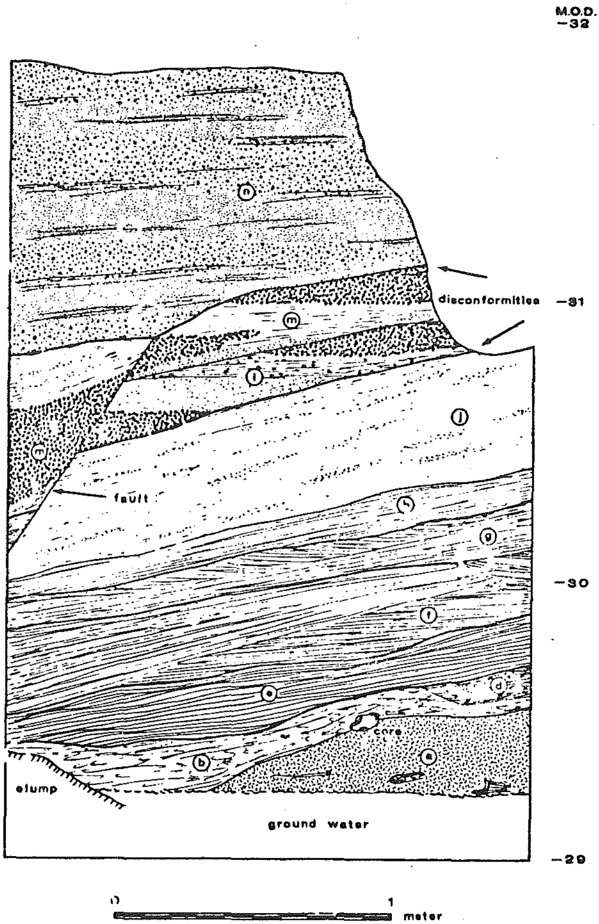
TM 175767

This type site for the penultimate interglacial has been visited on numerous occasions by organised parties, including the 1970 excursion of the Association. The stratigraphic sequence established by West (1956) is summarised in Table 1 . The present excavations, under the direction of J. Wymer, now permit the complete upper part of the sequence to be seen in section for the first time. Units of the sequence are briefly described in Table 2 .

Table 1. Summary of Sequence at Hoxne, Suffolk, According to West (1956)

Bed	Max. Thick.	Deposit	Pollen	Archeology
A1	0.6 m	Grey or brown fine sand with stones up to 5 cm. This stratum overlies the entire Hoxne sequence and except for floodplains, comprises the surface mantle of the entire area; "derived from A2" and includes frost shattered and aeolian polished flint.	No pollen recovered.	Derived artifacts.
A2	2.5 m	Clay, sand and till. Unsorted non-calcareous including water laid deposits and unstratified, unsorted gravel ("hoggin") interpreted as till and not part of the lacustrine sequence.	No pollen recovered.	Current excavations yield artifacts (Layer 7).Equivalent of West's A2.Industry?
B	2.0 m	Stratified clay, sand and gravel. The final lacustrine infilling preserved but includes clastic deposits brought into the lake by fluvial activity and solifluction; little brecciation of deposits, little or no organics.	No pollen recovered.	Derived artifacts.
C	3.5 m	Grey-brown sandy silt, brecciated clay-mud and pebbles. A highly variable series of interlayered lenses of clastics reaching considerable thickness (3.5 m). Interpreted as deposits of a fluctuating lake level with aperiodic introduction of larger clastics by solifluction from the lake margin.	Early glacial IV	
D	0.4 m	Brown non-calcareous detritus mud. A richly organic layer up to 40 cm thick with profuse macroflora and well preserved wood chunks. Superceded by pollen disconformity, with drying up of lake and erosional unconformity.	Late - temperate III (Ho IIIa)	Some artifacts.
E	6.5 m	Brown-green calcareous lacustrine clay-mud, deposited in thickness at both the center and margins of the lake without evidence of addition of older or reworked material, although water currents and channels may have moved across this stratum. Upper zone is "weathered" (decalcified).	Early - temperate II (Ho I and HoII)	Major archeological horizon at top.
F	0.5 m	Grey lacustrine clay-mud and marl. Contains some "laminae" near top and "drift mud" or thin clastic layers near the bottom interpreted as solifluction debris.	Late - glacial I (11)	
G		Chalky Boulder Clay. A blue-grey sandy clay with many chalk pebbles and erratics, usually as pebbles. Comprises the subsurface and attains thickness in excess of 20 m. Equivalent of the Lowestoft Till of Baden-Powell (1948, 1951).	Glacial No pollen	

CUTTING XXIII WEST FACE



The interpretation of this succession necessarily is preliminary, since laboratory analyses have yet to be done and the excavation is still in progress. However, the critical points now apparent are: (1) the mixed lacustrine, deltaic and fluvial character of the entire sequence overlying West's Stratum D, (2) ice wedge casts developed in the upper beds, and (3) the local and extra-local significance of the pebbly sand deposit (A1 of West).

Table 2. Upper Sequence at Hoxne[1]

Bed	Thick. in cm.	Preliminary Description	Origin	Comment
3	30-35	Sorted, crossbedded sands with silts. Bedding direction: ±120°E	Fluvial	
4	3-10	Fine-med. pebbly coarse sand. Angular pebbles up to 10 cm. Laterally variable being replaced by a seam of buff sand or clay.	Fluvial	
5	120-140	Subhor., inclined or crossbedded buff to brown sand. Thin (2-5 cm) subhor. lenses of brown or grey clay may occur throughout sequence, deformed and mottled near ice wedge. Seams of fine pebbles interlayered with sand. Bedding direction: ±145°E.	Fluvial	West's A2
6	20-35	Crudely stratified, coarse gravel in sandy matrix with silt-clay pockets. Boulders up to 23 cm, mostly flint but with erratics. Strata sampled by previous workers for heavy minerals and till fabric analysis.	Fluvial	West's "hoggin" in A2 Strata.
7	50	Brown sandy silt, more clayey near base. Well sorted but with some 2-5 cm pebbles or pebble pockets or clay zones. Mottled.	Flood-plain?	Bone clusters & artifacts
n	100	Subhor. bedded, interlayered grey chalky clay, buff sands and chalk gravel. Small uncrushed shells abound. Basal disconform.	Fluvial	Disconformity at base
m	65	Inclined, interlayered buff or grey clay, sandy layers and chalk gravel. Abundant shell. Greater thickness on downthrown block. Erosional truncation after faulting.	Fluvial	
l	15-20	Interlayered grey clay and chalk pebbles as in Beds M and N; subhorizontal bedding.	Fluvial	Disconformity at base
j	40-45	Interlayered buff brown sand, dark grey clay and massive very fine chalky gravel. Tilted, strat. bedding; some inclined or foreset bedding.	Fluvial	West's C
h	8-13	Laminated dark grey or black organic clays and dark buff sands (without chalk pebbles).	Lacustrine	
g	10-16	Interlayered sand and clay. Sandy at top with few chalk pebbles, more organic clays at bottom with wood fibre and fragments.	Deltaic	
f	22-32	Stratified sands with topset and foreset bedding.	Deltaic	
e	12-24	Stratified buff sand with shells. Thin lenses of black organic clays at top, bottom. Clay peds in the sand.	Lacustrine & Fluvial?	
d	11	Laminated sand with occasional pebble lenses.	Fluvial	
b	5-20	Dense organic grey clay with layers of peat.	Lacustrine	
a	45	Dark brown peat with abundant wood fragments up to 35 cm.	Lacustrine	West's D; ^{14}C dates

[1]Preliminary description based on Cuttings XXIII (Beds a-n) and XXIX (Beds 3-7), 1972.

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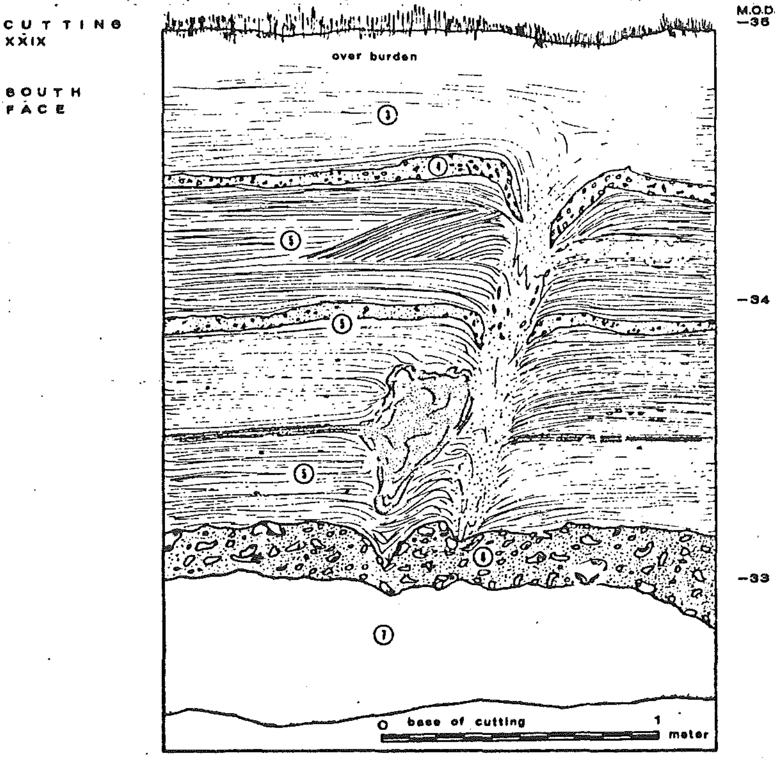


The series of Pleistocene sediments preserved here once again assumes paramount significance because of the reappraisal of the East Anglian sequence by Bristow and Cox (1973). As yet pollen has not been obtained from the upper sequence, (Beds a-n, 3-7) but post-late temperate cold conditions are documented by the several ice wedges. The coarse gravel (Bed 6) was originally interpreted as till ("hoggin") by West (1956) and as Gipping outwash (Baden-Powell in West, 1956); the present interpretation assigns fluvial origins to this sediment. Origin of the surficial deposit at this site (West's A1) is of special interest; it is recorded elsewhere in the Hoxne - Waveney Valley area and needs to be related to the deposits studied in Essex and Norfolk by Bristow and Cox respectively.

REFERENCES

Bristow, C.R. and F.C. Cox. 1973. The Gipping Till: a reappraisal of East Anglian glacial stratigraphy. Journal of the Geological Society 129: 1-37.

West, R.G. 1956. The Quaternary deposits at Hoxne, Suffolk. Philosophical Transactions of the Royal Society, B, 239:265-356.

B.G. GLADFELTER.

HOXNE.

Situation of archaeological material found in 1971-1972.

Stratigraphy after West, 1956		Pollen	
Bed F	Lacustrine clay	I	No archaeological material found.
Bed E	Lacustrine clay	II	A few mint flakes from near the top of this bed, apparently the equivalent horizon for the material recorded by West.
Bed D	Detrital mud and peat	III	Flint artifacts, faunal remains and flecks of charcoal considered in situ. An area c. 5 x 5 m, found intact, missed by previous commercial diggings. Elsewhere dug away. Industry contains evolved cordate/ovate hand-axes. Fauna: mainly horse, ox and deer Covered by 10 to 2 cm of unstratified clay and chalk pellets containing the same industry and fauna. Considered to be material contemporary with that in situ below it, but slightly moved from nearby lakeside.
Bed C	Sandy silt, clay-mud and pebbles	IV	No archaeological material found.
Bed B	Stratified clay, sand and gravel		This bed not seen in recent excavations.
Bed A2	Brown, sandy silt		Three lines of evidence indicate human occupation contemporary with the formation of this silt: i) Flint artifacts throughout the body of the deposit ii) Isolated clusters of broken animal bones iii) A localised 2 x 1 m. concentration of natural flints
	Coarse gravel		Derived artifacts including hand-axes

The typology of the artifacts is shown in the accompanying diagram. N.B. Neither of the two industries recovered in situ appear to be the same as that represented by the long, acutely pointed hand-axes of early discoveries, including those found by John Frere. These probably belong to Bed C. Examination of some of these artifacts show that some of them are slightly water-worn.

J.J. WYMER.

THETFORD HEATH

TL 850795

Chalkland patterns

The giant polygons and stripes at this locality were the first of their kind to be discovered in Britain (Watt 1955) and they still rank as some of the most remarkable examples known, being conspicuously picked out by the heathland vegetation. The gentle slopes north of the road are covered in stripes; there are limited numbers of polygons on flat ground in the centre of the Heath. A shallow valley crosses the Heath and stripes run down both its sides joining up on its floor to create a pattern that from the air resembles a herring-bone.

Calluna and other lime-hating plants grow on the borders of the polygons and alternate stripes; they are rooted in deep sand. Lime-tolerating species, principally grasses, mark the centres of the polygons and intervening stripes, occurring only where chalk is close to the surface. Excavations here and elsewhere have shown that the patterns possess a highly complex underground structure (Williams 1964, 1973; Watt, Perrin and West 1966).

No patterns exactly like the chalkland forms have been found in the Arctic and their mode of development is a matter for conjecture. They are confined to the chalk and mostly to the eastern part of the country where they cover many hundreds of square kilometres. The patterns are greatly affected by the slope of the ground. Polygons are limited to slopes of less than $\frac{1}{2}$ to $\frac{3}{4}$ degrees. Stripes occur on slopes steeper than this but less than 4 degrees. Above this angle, solifluction was apparently sufficiently rapid to prevent their formation.

R.B.G. WILLIAMS

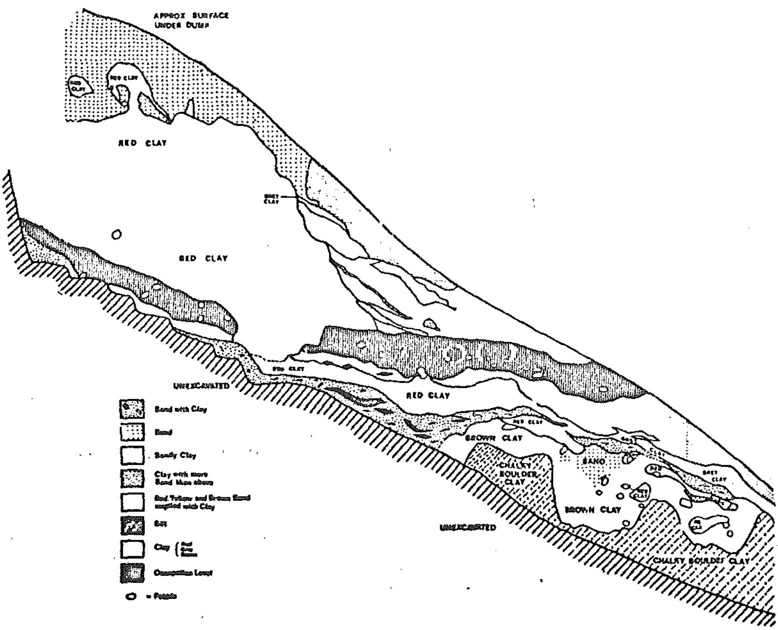
ELVEDEN

TL 809804

Warren Wood brick-pit

This is one of several sites in the Breckland area, where small deposits of lacustrine sediments rest in hollows in the surface of the chalky boulder clay. The pit was worked until 1914 and was the source of many bifacial Acheulean handaxes, and excavations have been carried out by Paterson and Fagg (1940) and more recently for the British Museum under the direction of G. de G. Sieveking.

The steep section on the west face of the pit shows a series of stratified deposits banked up against a sloping cliff of chalky boulder clay. The following sequence of deposits occurs:



ELVEDEN 67. Section 3, North Face

Below this an auger hole at the base of the pit showed at least another 6 m of silts and clays. Slightly organic bands yielded pollen spectra dominated by Betula, suggesting either interstadial or zone I interglacial conditions. No nearer diagnosis can yet be made.

Paterson and Fagg regarded the site as an infilled river channel and beds - as fluvial in origin. It seems more likely to be a kettle-hole or sink-hole deposit, but further investigation is needed.

C. TURNER

HIGH LODGE, MILDENHALL

TL 739753

The Pleistocene deposits at High Lodge, Mildenhall, lie isolated from other exposures of the Chalky Boulder Clay on the west flank of one of a small line of hills along the Fenland-Breckland margin. The site is important both geologically and archaeologically; brickpits here yielded abundant artefacts during the last century. The stratigraphy of the site is notoriously controversial. Investigations by Skertchly (in Whitaker et al. 1891), Marr (1921) and Harrison (1938) produced conflicting views on the relationship of glacial and archaeological horizons. To resolve this, recent excavations were carried out on behalf of the British Museum, under the supervision of G. de G. Sieveking and a brief account of the results has been published (Anon. 1968). Various aspects of the site and the surrounding area have been examined by E. A. Francis, R. W. Hey, S. C. A. Holmes, R. M. S. Perrin, C. Turner and R. G. West.

Although there is now general agreement on the actual stratigraphy of the site, the interpretation of its geological history has roused as much controversy as ever. The full sequence of deposits is now known to be as follows:

Bed

L Sandy topsoil

K Orange sand (sand of the Breckland)

J Pale brown Chalky Boulder Clay

H Pale brown current-bedded sand with bands of silt and gravel

G Coarse gravel, abundant flint and chalk, bands of sand

F Orange-brown sand with chalk 'flecks' and sporadic gravel seams

E Coarse cross-bedded sand

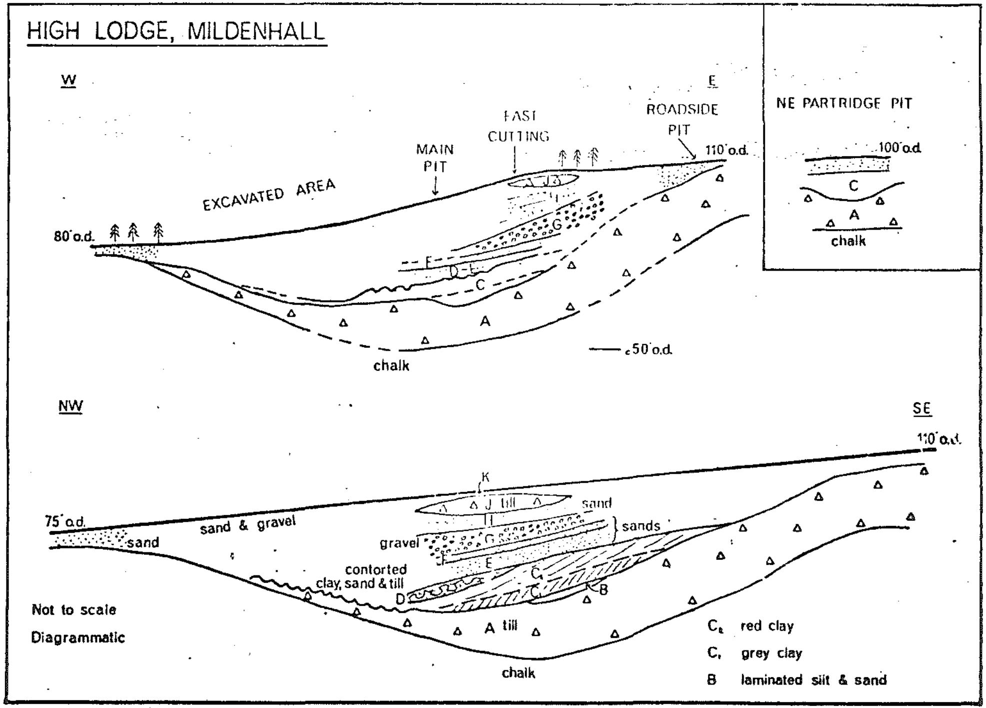
D Interbedded and interlaminated silt sand and clay

C_2 Reddish-brown clay, rare thin sand partings

C_1 Black, dark grey and light grey clays, the darker clays highly organic

B Interbedded and interlaminated sand and silt

A Grey brown to light brown chalky boulder clay with occasional seams of gravel


HIGH LODGE, MILDENHALL
W
E
ROADSIDE PIT
EAST CUTTING
MAIN PIT
110' o.d.
EXCAVATED AREA
80' o.d.
G
F
D
C
A
c50' o.d.
chalk
NE PARTRIDGE PIT
100' o.d.
C
A
chalk
NW
SE
110' o.d.
K
J till
sand
sands
75' o.d.
sand & gravel
sand
gravel
G
E
contorted clay, sand & till
D
B
A till
chalk
Not to scale
Diagrammatic
C₂ red clay
C₁ grey clay
B laminated silt & sand

Archaeological horizons

Flake industries occur in both Beds C_1 and C_2. "The flake tools of the characteristic High Lodge industry are stylistically related to Mousterian tools of the Weichsel and to ancestral types found in the Eemian interglacial, but they appear to have been made some 50,000 years earlier. On the other hand they are quite distinct from and more sophisticated than the Clactonian flake tools found at Swanscombe." (Anon. 1968)

A handaxe industry occurs above this, at the base of sands and silts of Bed D which rest on an eroded and channelled surface of the red clay, Bed C_2. The industry contains groups of flint waste flakes, which can be fitted together, and so tools were apparently being manufactured on site on a living surface.

We hope to be able to see two principal exposures (A) the "East Face" section where Beds F-L are exposed, (B) an excavation in the present floor of the site, re-exposing the trench in which Beds A-C were recorded. Some of the intervening beds may or may not be seen. The site is now under the protection of the Suffolk Trust for Nature Conservation, so disturbance must be minimised.

A number of general points may be made before listing the different points of controversy.

(i) The upper and lower boulder clays J and A are lithologically indistinguishable from Lowestoft Till in other parts of East Anglia (see Fig.) as is the boulder clay in the roadside pit near the summit of the hill. The upper clay appears to be of very limited lateral extent.

(ii) The clays C_1 and C_2 contain pollen assemblages with abundant _Pinus_ and _Picea_ and some _Betula_ and _Alnus_, they do not resemble either Hoxnian or Ipswichian pollen spectra but are believed to represent interstadial vegetation conditions (broadly cf. Chelford). Plant macrofossils (_Potamogeton_, _Stratiotes_, _Oenanthe aquatica_) suggest shallow lake and marsh conditions. There is also an elephant tooth from the clays.

(iii) Boreholes and pit sections have shown that the grey clay C_1 (all samples with similar pollen spectra) overlies till in isolated pockets at a wide variety of altitudes, particularly at the former Partridge Pit on the higher slopes of the hill, well above the level of the excavation site.

(iv) The clays C_1 and C_2 are decalcified and their surface eroded, the beds from D to H are increasingly calcareous.

Points of controversy

1) Is the upper boulder clay (J) in situ or not? If not, has it been pushed by ice or solifluced downslope?

2) Are the underlying beds F-K in situ or not?

3) Are the lower beds A-D in situ or have they been moved? E. A. Francis writes:

"The top of this till together with overlying sand lies locally in recumbent folds, and silt and clay also referred to Bed B has suffered small-scale post depositional deformation. All these structures indicat drag in which the direction of over-riding was from points between west and south. Bed C_1 contains numerous shear-planes whose three-dimensional orientation clearly demonstrates lateral pressure directed also from points between west and south-west. The stress-field indicate by these various structures is not consistent with formation as a result of subsidence or down-slope mass-movement - the only satisfactory explanation at present is that the structures are glacio-tectonic in origin. The long axes of flakes extracted from Bed C_1 also showed a preferred orientation with a maximum aligned WSW - ENE. This is somewhat divergent from the preferred orientation of long-axis azimuths in the underlying till micro-fabric, which trends NW - SE, but during excavation it was noted that one particularly prominent thrust-shear near the margin of Bed C_1 dipped at 47° towards 311°. Collectively, the structural evidence strongly suggests that Beds A-D form a single composite depositional unit, which is clearly glacial in character. Since Bed C contains pollen and flakes indicative of a non-glacial environment, the best conclusion would seem to be that this has been transported glacially by ice."

Interpretations

I The in situ theory

Anon (1968) and Holmes (1971) regarded the whole sequence of deposits as basically in situ. Holmes from wider geological mapping concluded "two series of Glacial Sand and Gravel indicate two clearly separated erosional phases, each following an ice advance represented by a strong till. In the interval between the two tills the glacial lake muds were deposited and the locality .... was at that time a centre for Mousterian man". Anon. regarded both ice-advances as "Gipping" (Wolstonian) in age.

II Glacio-tectonic theory Type A

The lower part of the section has been moved by ice, the upper part is in situ but the upper till soliflucted onto a gravel surface. This in general is the view of Francis.

III Glacio-tectonic theory Type B

All the glacial and interstadial deposits have been pushed by ice. This theory was first proposed by Sollas (in Sturge 1909)

Clearly a number of combinations of these theories can be created.

Chronology

This is as controversial as the stratigraphy:

(a) Most theories accept that an ice advance has taken place at least since the time of the flake industries.

(b) The till appears to be Lowestoft type. If it has been moved by ice with the interstadial deposits, is it a) the deposit of that ice sheet or b) the deposit of an earlier ice sheet being pushed by a readvance (? of Wolstonian age ?).

(c) Most archaeologists regard the High Lodge flake industry as post Swanscombe and Clacton (and therefore presumably post-Hoxnian).

PLEASE VOICE YOUR THOUGHTS.

C. TURNER

References

Allen, J.R.L. 1970. Physical Processes of Sedimentation.

Anon. 1968. High Lodge Palaeolithic Industry. Nature Vol. 220, p. 1065.

Baden-Powell, D.F.W. 1948. The Chalky Boulder Clays of Norfolk and Suffolk. Geol. Mag. Vol. 85, p. 279.

Beck, R.B., Funnell, B.M. and Lord, A.R. 1972. Correlation of Lower Pleistocene Crag at Depth in Suffolk. Geol. Mag. Vol. 109, p. 137.

Boswell, P.G.H. 1915. Report of an excursion to Ipswich and Claydon. Proc. Geol. Ass. Vol. 26, p. 327.

1927. The Geology of Ipswich. Mem. Geol. Surv. U.K.

1938. Whitsun Field Meeting, 3rd June to 7th June 1938. Proc. Geol. Ass. Vol. 49, p. 410.

1952. The Pliocene-Pleistocene Boundary in the East of England. Proc. Geol. Ass. Vol. 63, p. 301.

& Double, I.S. 1922. The Geology of the Country round Felixstowe and Ipswich. Proc. Geol. Ass. Vol. 33, p. 285.

& Slater, G. 1912. Report of an Excursion to Ipswich and the Gipping Valley. Proc. Geol. Ass. Vol. 23, p. 229.

Boulton, G.S. 1971. Till Genesis and Fabric in Svalbard, Spitsbergen in Goldthwait R.P. (Ed.) Till Symposium. Ohio State University Press.

Bristow, C.R. and Cox, F.C. 1973. The Gipping Till: a reappraisal of East Anglian glacial stratigraphy. Jl. geol. Soc. Lond. Vol. 129, p. 1.

Brown, J. 1852. On the Upper Tertiaries at Copford, Essex. Quart. Jl. Geol. Soc. Lond. Vol. 8, p. 184.

Cambridge, P. & Norton, P.E.P. 1970. An Account of the Field Meeting of the Colloquium for the Study of the Northern Neogene: Norwich 1970. Bull. Soc. belge Geol. Pal. Hydr. Vol. 79, p. 103.

Clayton, K.M. 1957. Some aspects of the glacial deposits of Essex. Proc. Geol. Ass. Vol. 68, p. 1.

Clayton, K.M. 1960. The Landforms of parts of Southern Essex. Transactions and papers, Inst. Brit. Geographers No. 28, p.55.

Dalton, W.H. 1880. Geology of the Neighbourhood of Colchester (Quarter Sheet 48 S.W.) Mem. Geol. Surv. U.K.

Dixon, R.G. 1972. A Review of the Chillesford Beds. Bull. Ipswich Geol. Group. No. 11, p. 2.

Friedman, C.M. 1962. On Sorting, Sorting Co-efficients, and the Lognormality of the Grain-Size Distribution of Sandstones. Jl. Geol. Vol. 70, p. 737.

Funnell, B.M. 1961a. Palaeogene and Early Pleistocene of Norfolk. Trans. Norfolk Norw. Nat. Soc., Vol. 19, p. 326.

1961b The Climatic and Stratigraphic Significance of the Early Pleistocene Foraminifera of the North Sea Basin, Cambridge, Ph.D. Thesis.

Haggard, H.J.E. 1972. The Sand and Gravel Resources of the Country round Witham, Essex (Description of 1:25,000 Resource Sheet TL 81). Rep. No. 72/6 Inst. Geol. Sci.

Harmer, F.W. 1902. A Sketch of the Later Tertiary History of East Anglia. Proc. Geol. Ass. Vol. 17, p. 416.

Harrison, K. 1938. A note on High Lodge, Mildenhall. Proc. Prehist. Soc. Vol. 4, p. 326.

Hey, R.W. 1967. The Westleton Beds Reconsidered. Proc. Geol. Ass. Vol. 78, p. 427.

Holmes, S.C.A. 1971. The Geological Mapper and the Employment of his Results, as illustrated in some areas of Southern England. Proc. Geol. Ass. Vol. 82, p. 161.

McCave, I.N. 1970. Deposition of Fine-Grained Suspended Sediment from Tidal Currents.

Marr, J.E. 1921. Excavations at High Lodge, Mildenhall in 1920 A.D. Proc., Prehist. Soc. East Anglia Vol. 3, p. 35?.

Miller, S.H. & Skertchly, S.B.J. 1878. The Fenland, Past and Present. London.

Norton, P.E.P. 1967. Marine Molluscan Assemblages in the Early Pleistocene of Sidestrand, Bramerton, and the Royal Society Borehole at Ludham, Norfolk. Phil. Trans. Roy. Soc. London. B. Vol. 253, p. 161.

Norton, P.E.P. 1970. The Crag Mollusca; A Conspectus. Bull. Soc. belge Geol. Pal. Hydr. Vol. 79, p. 157.

Ovey, C.D. & Pitcher, W.S. 1948. Observations on the Geology of East Suffolk. Proc. Geol. Ass. Vol. 59, p.23.

Paterson, T.T. & Fagg, B.E.B. 1940. Studies on the Palaeolithic succession in England No. 11. The upper Brecklandian Acheul (Elveden). Proc. Prehist. Soc. Vol. 6, p. 1.

Prestwich, J. 1871. On the Structure of the Crag-Beds of Norfolk and Suffolk. Q. Jl. Geol. Soc. Lond. Vol. 27, p. 325.

Shotton, F.W., Sutcliffe A.J. and West, R.G. 1962. The Fauna and Flora from the Brick Pit at Lexden, Essex. The Essex Naturalist Vol. 31, p.15.

Spencer, H.E.P. 1966. A Contribution to the Geological History of Suffolk Pt. 1 Trans.Suffolk Nat.Soc., Vol. 13, p.197.
1966 Pt. 2 13, p.290.
1967b Pt. 3 13, p.366.
1970 Pt. 4 15, p.148.
1971 Pt. 5 15, p.279.
1972 Supplement 15, p.517.

1967a. Field Meeting in the Quaternary of East Suffolk. Proc. Geol. Ass. Vol. 77, p. 371.

Terwindt, J.H.H. & Breusers, H.N.C. 1971. Experiments on the Origin of Flaser, Lenticular and Sand-Clay Alternating Bedding.

Turner, C. 1970. The Middle Pleistocene deposits of Marks Tey, Essex. Phil. Trans. Roy. Soc. B. 257, p.373.

Visher, G.S. 1969. Grain Size Distributions and Depositional Processes. Jl. Sed. Petrol. Vol. 39, p. 1074.

Watt, A.S. Stone stripes in Breckland. Geol. Mag. Vol.92, p.173.

Watt, A.S., Perrin, R.M.S. & West, R.G. 1966. Patterned ground in Breckland: Structure and composition. J. Ecology Vol. 54, p. 239.

West, R.G. 1956. The Quaternary Deposits at Hoxne, Suffolk. Phil. Trans. Roy. Soc. B. 239, p. 265.

& Donner, J.J. 1956. The glaciation of East Anglia and the East Midlands: a differentiation based on stone-orientation measurements of the tills. Q.J.G.S. Vol. 112, p. 69.

1972. The Stratigraphical Position of the Norwich Crag in Relation to the Cromer Forest Bed Series. Bull. Geol. Soc. Norfolk. Vol. 21, p. 17.

West, R.G. & Donner, J. J. 1956. The Glaciations of East Anglia and the East Midlands: a differentiation based on stone orientation measurements of the tills. Q. Jl. Geol. Soc. London. Vol. 112, p.69.

Whitaker, W., Woodward, H.B., Bennett, F.J., Skertchly, S.B.J. and Jukes-Browne, A.J. 1891. The geology of parts of Cambridgeshire and of Suffolk (Ely, Mildenhall, Thetford). Mem. Geol. Surv. U.K.

Williams, R.B.G. 1964. Fossil Patterned Ground in Eastern England. Biul. Peryglacjalny. Vol. 14, p. 337.

1973. Features that may be mistaken for works of Man. Antiquity (March number).

Woodland, A.W. 1970. The buried tunnel-valleys of East Anglia. Proc. Yorks. geol. Soc. Vol. 37, p. 521.

Wymer, J. 1968. Lower Palaeolithic Archaeology in Britain, as represented by the Thames Valley. John Baker, London.

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