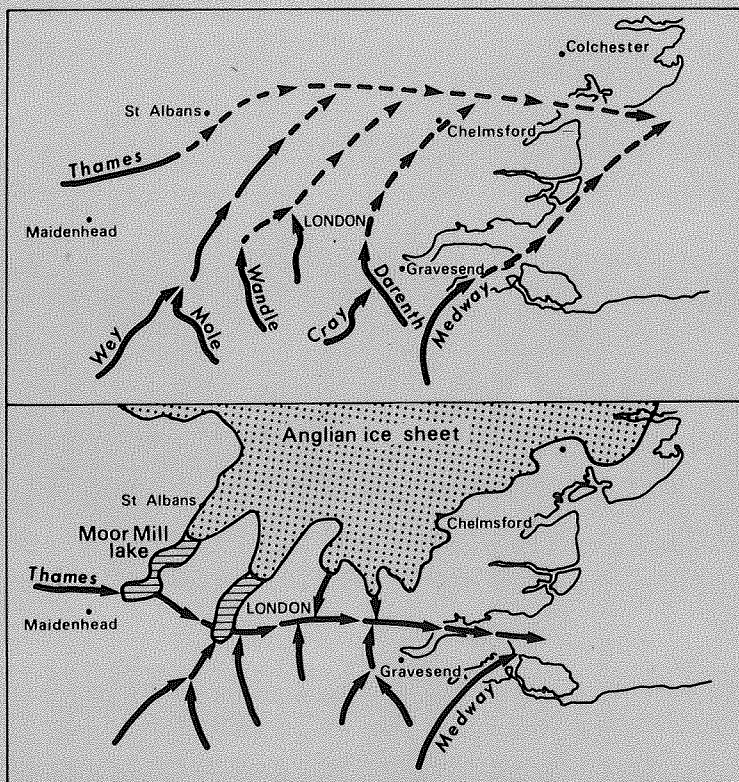


QUATERNARY RESEARCH ASSOCIATION

FIELD GUIDE



Diversion of the Thames

APRIL 1983

QUATERNARY RESEARCH ASSOCIATION

FIELD GUIDE

Annual Field Meeting 1983

The Diversion of the Thames

Hoddesdon
April 1983

QUATERNARY RESEARCH ASSOCIATION

Annual Field Meeting 1983

Hoddesdon, Hertfordshire, April 4th to 7th 1983

THE DIVERSION OF THE THAMES

Field Meeting Organiser:	P.L. Gibbard
Field Meeting Local Secretary:	D.A. Cheshire
Field Guide Editor:	J. Rose

Typing:	Marian Thomas
Cartography:	Lorraine Rutt
Photographic reproduction:	Andrew Hilton
Printing:	Gemprint, Leighton Buzzard, Bedfordshire.
Copyright:	Quaternary Research Association 1983

ISSN 0261-3611

QUATERNARY RESEARCH ASSOCIATION

Field Guide for Annual Meeting, Hoddesdon, 1983THE DIVERSION OF THE THAMES

Contents:

1-7	Introduction, by J. Rose
8-23	The Diversion of the Thames - A Review, by P.L. Gibbard.
24-28	Lithology of the Thames Gravels, by C.P. Green and D.F.M. McGregor.
39-49	Glaciation and Thames Diversion in the Mid-Essex Depression, by C.A. Baker.
50-59	Till Lithology in Hertfordshire and West Essex, by D.A. Cheshire.
61-62	The Middle Thames Region, by P.L. Gibbard.
63-68	Nettlebed, by A. Horton and C. Turner.
69-76	Highlands Farm, by P.L. Gibbard and J.J. Wymer.
77-79	Winter Hill, by P.L. Gibbard.
80-84	Gerrards Cross, by D.F.M. McGregor and C.P. Green.
85-91	Slade Oak Lane, by P.L. Gibbard.
92-93	East Hertfordshire and the Scene of the Thames Diversion, by D.A. Cheshire.
94-95	Ferneux Pelham, by R.W. Hey.
96-101	Northaw Great Wood, by B.W. Avery, J.A. Catt and D.A. Cheshire.
102-109	Harper Lane, by D.A. Cheshire and P.L. Gibbard.
110-119	Hatfield Polytechnic (Roe Hyde Pit), by P.L. Gibbard and D.A. Cheshire.
120-132	Westmill, by D.A. Cheshire.
133-134	East Hertfordshire and the Essex Region, by J. Rose.
135-139	Early and Middle Pleistocene sediments and Palaeosols in West and Central Essex, by J. Rose.
140-148	Hoddesdon, by D.A. Cheshire.
149-161	Stebbing, by C.A. Whiteman, R. Kemp and D. Wilson.
162-169	Great Waltham, by C.A. Whiteman.
170-180	Eastern Essex, by D.R. Bridgland.
181	Bovill Uplands, by D.R. Bridgland.
182-184	Southminster, by D.R. Bridgland.
185-191	References.

ADDRESSES OF CONTRIBUTORS

- B.W. Avery Soil Survey of England and Wales,
Rothamsted Experimental Station,
Harpenden, Herts., AL5 2JQ.
- C.A. Baker 5, Salisbury Ave., Broadstairs,
Kent, CT10 2DT.
- D.R. Bridgland Geography Department, City of London
Polytechnic, Old Castle St., London,
E1 7NT.
- J.A. Catt Department of Soils and Plant Nutrition,
Rothamsted Experimental Station,
Harpenden, Herts., AL5 2JQ.
- D.A. Cheshire School of Natural Sciences,
Hatfield Polytechnic, P.O. Box 109,
College Lane, Hatfield Herts., AL10 9AB.
- C.P. Green Department of Geography, Bedford College,
University of London, Regent's Park,
London, NW1 4NS.
- P.L. Gibbard Sub-Department of Quaternary Research,
Botany School, Downing St., Cambridge,
CB2 3EA.
- R.W. Hey The Old School House, Upton Bishop,
Ross-on-Wye, Herefordshire.
- A. Horton Natural Environment Research Council,
Polaris House, North Star Avenue,
Swindon, Wilts., SN2 1EU.
- R. Kemp Department of Geography, Birkbeck College,
University of London, 7-15 Gresse St.,
London W1P 1PA.
- D.F.M. McGregor Department of Geography, Bedford College,
University of London, Regent's Park,
London, NW1 4NS.
- J.E. Robinson Department of Geology, University College,
University of London, Gower St.,
London, WC1E 6BT.
- J. Rose Department of Geography, Birkbeck College,
University of London, 7-15 Gresse St.,
London, W1P 1PA.
- C. Turner Department of Earth Sciences, The Open
University, Walton Hall, Milton Keynes,
MK7 6AA.
- C.A. Whiteman Department of Geography, Birkbeck College,
University of London, 7-15 Gresse St.,
London, W1P 1PA.
- D. Wilson Institute of Geological Sciences, Bryn
Eithyn Hall, Llanfarian, Aberystwyth,
Dyfed, SY23 4BY.
- J.J. Wymer The Vines, The Street, Great Cressingham,
Norfolk, IP25 6NL.

ACKNOWLEDGEMENTS

Professor D.W. Rhind of the Department of Geography, Birkbeck College, University of London, for making available cartographic and photographic assistance at a time when there was great pressure on these services.

Lorraine Rutt of the Cartographic Unit, Department of Geography, Birkbeck College for so ably drawing the maps and diagrams.

Andy Hilton of the Joint Geography/Geology Photographic Unit Birkbeck College, for for so tolerantly printing a never-ending number of correct-size prints for pasting into the manuscript.

Marian Thomas for providing such excellent typing in such a very short time.

PREFACE

The 1983 Annual Field Meeting of the Quaternary Research Association has been organised to examine the topic of the 'Diversion of the Thames'. This came about in response to the interest generated by a large body of research recently carried out on this problem and published in a range of journals. The meeting was proposed, therefore, as a forum where those involved could come together, outline their views and demonstrate, as far as is possible, the evidence upon which views are based. Inevitably, with so many individuals involved conclusions vary, and it will be apparent by just reading this Guide that there are many points of disagreement. However, it will also become apparent that as far as the subject is understood at the present time there is agreement that the diversion occurred during the Anglian Glacial Stage of the Middle Pleistocene and was caused by the presence of ice in the Vale of St. Albans.

The activity of the Thames after it became established along its present route following diversion is not the concern of this meeting and will not be discussed in this Guide.

This Field Guide is divided into two parts. The first part consists of a series of studies that review evidence for, and associated with, the diversion in a systematic fashion. The second part consists of site descriptions. These are reasonably comprehensive in order that analytical evidence can be discussed in the field. All references are combined into a single section at the back of the Guide for ease of access and to avoid duplication.

One of the problems of studying a thematic topic dealing with a subject that is geographically extensive, is the large distances that must be travelled in order to visit the relevant sites and the ensuing waste of time and discomfort. We have done our utmost to minimize these problems and kept the journeys down to the shortest possible distances. Nevertheless the excursion will still involve travel as far west as the Reading area to study the Middle Thames region unaffected by the diversion, and eastwards to Essex and the Southend region where the diversion caused the greatest geographical displacement. Fortunately these days are separated by a study of the evidence in the Vale of St. Albans which is close to the accommodation at Hoddesdon.

J. Rose

This Guide contains unpublished material which should not be quoted without the permission of the author.

INTRODUCTION

by J. Rose

Regional characteristics

The area to be studied is outlined on Figure 1 which also shows the present drainage system and the sites to be visited. Bedrock geology in the area consists of Cretaceous and Tertiary rocks arranged in the form of a basin with an axis extending southwest-northeast across the region, roughly coincident with the route of the pre-diversion Thames (Fig. 2). The general distribution of Pleistocene sediments related to the diversion is shown on Fig. 3. This figure must be used with some caution as it has been drawn for the purpose of this Guide on the basis of the information included in the Guide and personal field observations, rather than systematic survey which is not available due to the inaccurate representation of sand and gravel deposits on most drift maps of the area published by the IGS.

Problems of significance and controversy

The general pattern of the diversion of the Thames is shown on Figure 4, illustrating the extent of the river system before and after the event, and the most likely extent of the Anglian ice sheet and the contemporaneous proglacial lakes. However, despite the agreement over this major event many points of controversy or additional significance remain: lakes (Gibbard, this Guide). However, despite the agreement over this major event many points of controversy or additional significance remain:

i) The age of the Thames river deposits. While the Thames' river deposits associated directly with diversion are accepted as Anglian the age of the earlier deposits is far from clear. As illustrated in Fig. 5 much of the time the Thames flowed along its pre-diversion course must fall within the notorious 'hiatus' of Zagwijn (1975). It is most probable that further study of the Thames deposits will provide the best evidence for filling this gap.

ii) The age of the first glaciation to affect the Thames drainage system. The occurrence of volcanic rocks in the Westland Green Gravels (Hey, 1965), possibly from as far distant as Ogwen in Snowdonia (Whiteman, this Guide) suggests that ice invaded the Thames catchment long before the Anglian glaciation. By relation to biostratigraphically defined units in East Anglia this glaciation can be shown to have occurred later than the Bramertonian temperate stage (Funnell et al. (1979) but before the Pastonian of north Norfolk (Hey, 1980)

iii) The number of glaciations in the region of the Thames diversion. Whilst most opinion seems to support the view that the only unequivocal glacialigenic sediments in the region of diversion are of Anglian age (Gibbard, this Guide) there

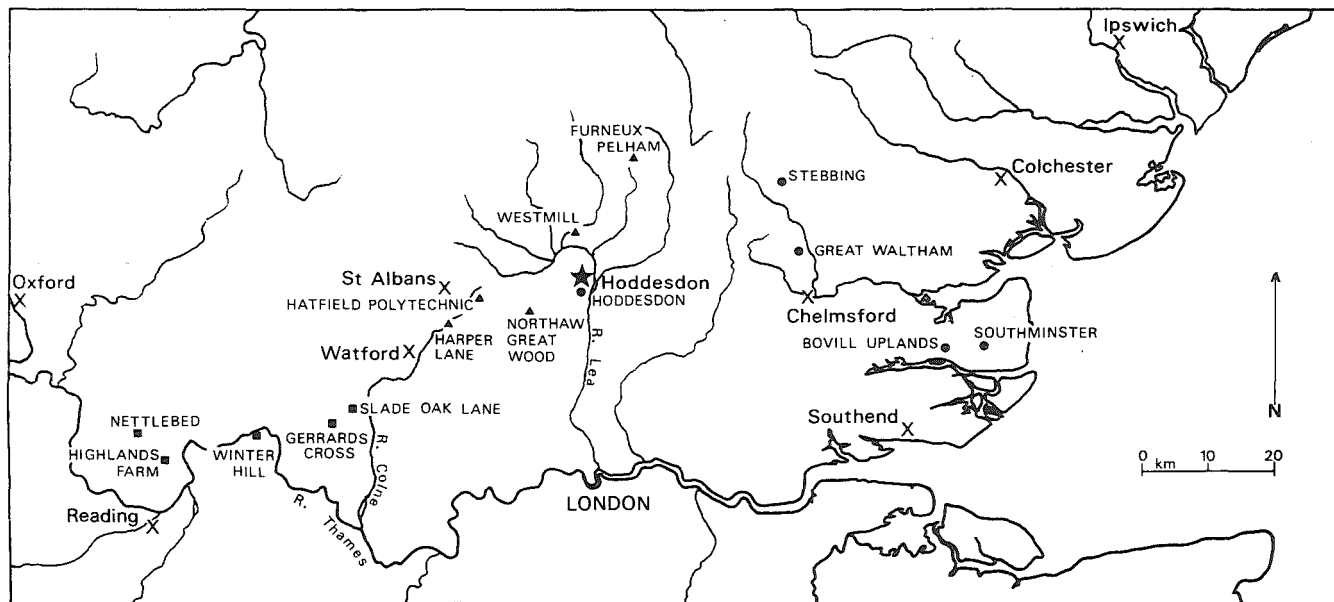


Figure 1. Location of sites to be visited during Q.R.A. Field Meeting to study the diversion of the Thames. ■ Day 1; ▲ Day 2; ● Day 3.

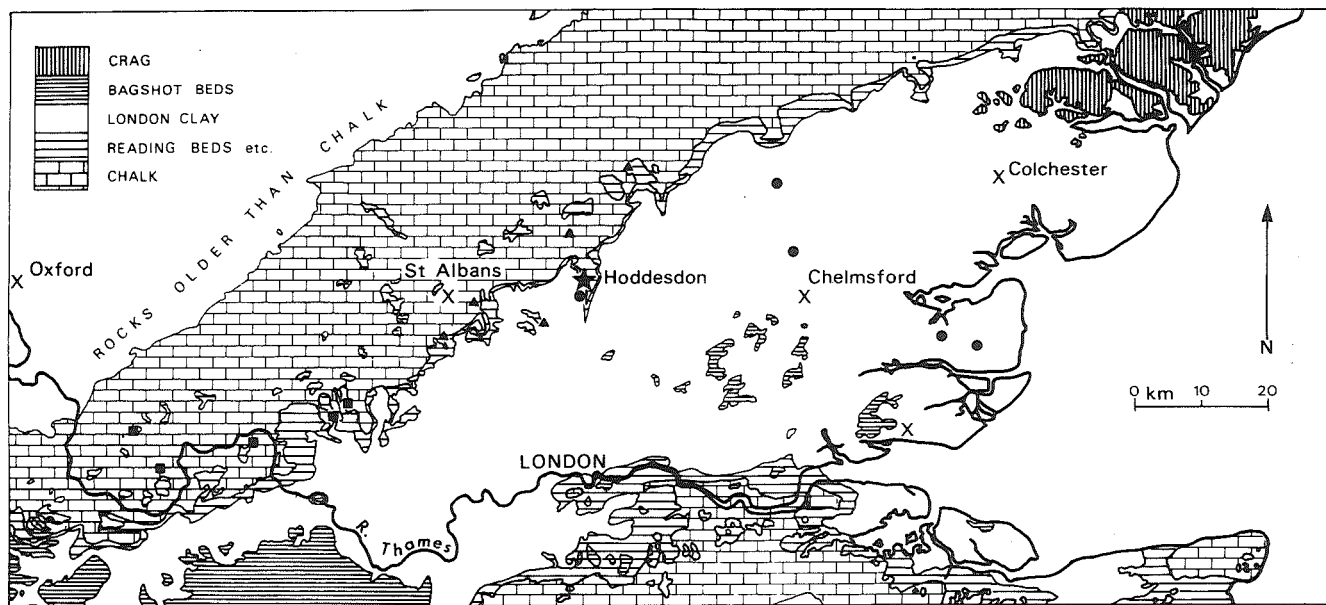


Figure 2. Bedrock geology of the area to be visited during the Q.R.A. Field Meeting to study the diversion of the Thames. : Day 1 localities, : Day 2 localities, : Day 3 localities.

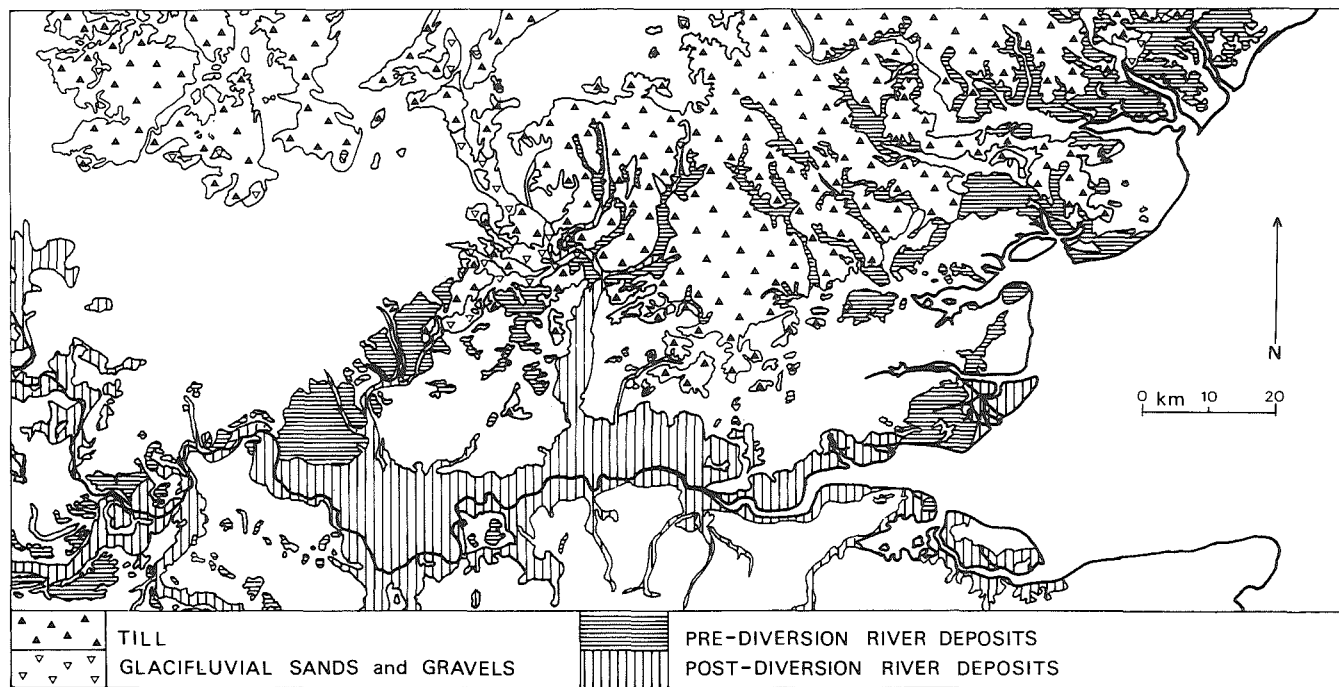


Figure 3. Glacial and glaciocuvial deposits, and Thames river deposits formed before and after diversion. The area covered is identical to that on Figs. 1 and 2.

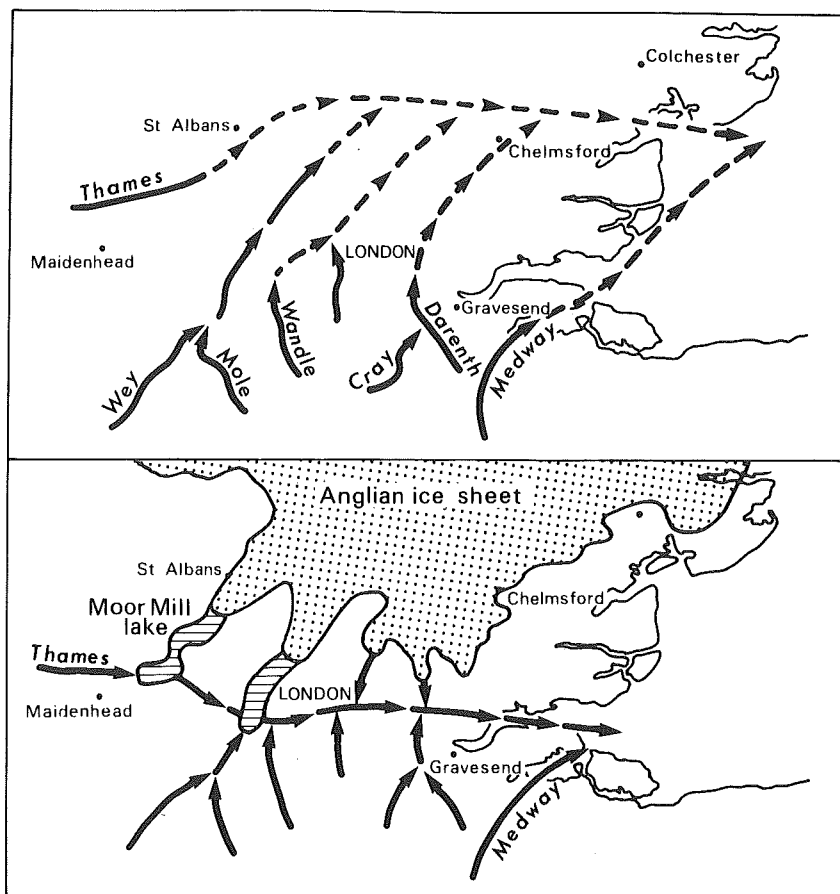


Figure 4. The patterns of Thames drainage before, and at the time of diversion (based on data provided by Gibbard in this Guide).

remains the problem of the origin of the Chiltern Drift (Wooldridge, 1938) and the Pebbly Clay Drift (Thomasson, 1961) both of which have been interpreted as glacial deposits. Attention given to these sediments by McGregor and Green (1983b) and Avery and Catt (this Guide) respectively suggest alternative origins due to periglacial and soil forming processes and shed doubt on the likelihood that the area of diversion was occupied by ice at any time other than during the Anglian glaciation.

iv) The event of diversion. It will become apparent as the Guide is studied and the meeting progresses that the cause of diversion in the Vale of St. Albans has been attributed to the Anglian ice which deposited either the Eastend Green Till (Gibbard, 1974) or the Ware Till (Cheshire, this Guide).

vi) Pre-Anglian diversion of the Thames in Essex and East Anglia. Although this meeting will give most attention to the diversion of the Thames in the Vale of St. Albans the distribution of the buried terrace deposits and landform fragments in Essex and East Anglia indicates that the river had begun to shift its course south and eastwards before the Anglian stage (Rose *et al.*, 1976), perhaps reflecting a tectonic control towards the North Sea Basin.

vii) The extent of pre-diversion Thames deposits. An examination of the evidence presented in this Guide and the distribution of Quaternary sediments shown on most maps of the IGS shows almost complete disagreement about the origin of the sands and gravel deposits throughout much of the region. Evidence presented in this Guide suggests that most of the sand and gravel was deposited by the pre-diversion Thames and glaci-fluvial sediments are restricted in their distribution, being extensive only in the area around, and to the north of the Vale of St. Albans. The interpretation shown on the IGS maps indicates that the majority of the deposits are glaci-fluvial associated with the ice which deposited the 'chalky boulder clay'. A shift of opinion by the IGS seems to be in progress as recent studies by the IMAU tend to differentiate the sands and gravels according to a glacial or fluvial origin (Marks, 1982), and a similar approach has been taken on the recently published 1:50,000 Epping Sheet (Ellison *et al.*, 1982).

viii) The role of palaeosols in the interpretation of Thames deposits. Buried and relict palaeosols have been discovered on the abandoned surfaces of Thames terraces throughout the region (Rose *et al.*, 1976) although their origin is not universally accepted (Wilson and Lake, 1983). Assuming the pedogenic origin of the Valley Farm Geosol (Catt, 1980) there exists the possibility that a soil stratigraphy based primarily on micromorphology may be developed. This would be particularly applicable to the palaeosols buried beneath the Lowestoft Till where it may be possible to identify characteristic sequences of interglacial illuviation disrupted by cold climate disturbance on terraces of particular ages. An approach of this type, and some of the problems involved are illustrated at Stebbing (Kemp, this Guide). Palaeosols are also of significance in defining the actual surface of buried aggradations.

ix) Relationship of man to the diversion of the Thames. Evidence from the abandoned channel of the Thames between Reading and Henley indicates that artefacts exist in association with the Black Park Terrace, suggesting that man occupied the region shortly after the diversion of the Thames, although the presence of hand-axes in the Wallingford Fan Gravels suggests occupation before the main advance of the Anglian ice (Wymer, this Guide). The stratigraphic variability of the the Clactonian and Acheulian industries illustrates the problem of using artefact assemblages as stratigraphic indicators.

THE DIVERSION OF THE THAMES - A REVIEW

by P.L. Gibbard.

Introduction

The Thames Valley has long been regarded as one of the most important regions for British Pleistocene geology. This valley together with its extensions into the south Midlands, central Hertfordshire and southern Essex contains the longest and most complex sequence of Pleistocene deposits outside East Anglia. However, its unique position marginal to these areas means that whilst not being totally inundated by ice during at least one glaciation, its deposits can potentially be linked to glacial sequences during two or possibly even more stages. The deposits preserved in the London Basin provide a record from the earliest Pleistocene marine phases, through initiation and development of the Thames drainage system, to the river's diversions in the Middle Pleistocene and its subsequent evolution up to the present day.

In order to examine the River Thames' evolution and events that culminated in its diversion to its present valley through London, we will be visiting four key areas on this excursion: the Middle Thames Valley, the Vale of St. Albans, central Essex and south eastern Essex.

The first of these areas is defined as that which extends from the Goring Gap, a gorge-like valley through the Chiltern Hills near Reading, to Rickmansworth and the Colne Valley. The Vale of St. Albans extends from the Colne Valley to Ware in Hertfordshire and trends southwest-northeast parallel to regional bed-rock structures. Central Essex continues due east of the Vale of St. Albans and includes the wide till covered plateau between Harlow and Chelmsford. South-east Essex consists of the region between the Thames and Blackwater estuaries from Southend-on-Sea to Bradwell.

Previous research

The Pleistocene geology of the Thames Valley has been studied since the early nineteenth century, but the most famous work was by Wooldridge and his co-workers (Wooldridge, 1927, 1938, 1960; Wooldridge and Henderson, 1955; Wooldridge and Linton, 1955). Later studies undertaken up to the early 1960's attempted to build on his model using geomorphological mapping of terrace surfaces (Hare, 1947; Sealy and Sealy, 1956; Thomas, 1961) and the study of glacial deposits (West and Donner, 1956; Clayton, 1957; Clayton and Brown, 1958; Brown, 1959).

Wooldridge, following the conclusions and suggestions of earlier workers such as Salter (1905), identified the initial Thames' course through the Vale of St. Albans and into Essex along the Chiltern dip-slope. The first modern lithostratigraphical study by Hey (1965) demonstrated that these techniques could be successfully applied to the early Thames deposits.

Recent modern work throughout the region (Gibbard, 1974, 1977, 1979; Rose, Allen and Hey, 1976; Rose and Allen, 1977; Rose, Sturdy, Allen and Whiteman, 1978; Green and McGregor, 1978; McGregor and Green, 1978; Baker and Jones, 1980; Cheshire, 1981) has demonstrated that Wooldridge's basic models were in general correct, but incorrect in detail. For example, he suggested that the Thames was diverted at an early stage from the Vale of St. Albans into the Finchley Valley (Middlesex Depression) by an early, Chiltern ice advance. We now believe this to be incorrect and can find no conclusive evidence for such a glaciation. However, his conclusion that the Thames was diverted by the Chalky Till (Anglian) ice to its present course has received much independent support.

Detailed litho- and biostratigraphical investigations have now been undertaken in all the areas to be visited on this excursion and some are already published, or will be published shortly. However, much of the work summarized here is new and has not yet been published in detail. It includes work in preparation by Gibbard, Green and McGregor in the Middle Thames; Cheshire, in the Vale of St. Albans; Bridgland in south eastern Essex and Kemp and Whiteman in central Essex.

Pleistocene Geology of the early Thames deposits

The deposits comprising the Pleistocene sequences in the areas to be examined on this excursion fall into two broad groups. In the extra-glacial regions of the Middle Thames and southeast Essex the deposits are arranged into altitudinally separable aggradations consisting predominately of gravels and sands. These deposits are thought to result from a series of progressive river incisions followed by river aggradations. This series of alternate downcutting and aggradational events leads to the preservation of progressively younger deposits down a valley side. The surfaces preserved on these deposits may present a stairway-like sequence which can be geomorphologically mapped. Such surfaces are conventionally termed terraces.

By contrast in the glaciated areas of the Vale of St. Albans and Central Essex no such stairways are preserved in the landscape. This arises partially from glacial erosion and partially from burial of pre-existing deposits beneath till and other glacial sediments.

The need to adopt critical stratigraphical methods for within and between region correlations is therefore vital if the Pleistocene history of the country is to be properly understood. It is for this reason that the use of correct stratigraphical procedure as recommended in the International Stratigraphic Guide (Hedberg, 1976) has been applied throughout the Thames region by the modern workers. The view that Pleistocene deposits cannot be classified using a formal geological system is demonstrably incorrect since such a system is already applied to sedimentary deposits throughout the geological column whether they are of terrestrial or marine origin. It is suggested that ultimately there can be no substitute for such an approach.

Pleistocene history and palaeogeography

The stratigraphical position of the deposits described below is summarised in the the correlation table (Table 1). The sequence described is divided as far as possible into formally-defined lithostratigraphical members or formations following the recommendations of Hedberg (1976). These members in the Middle Thames region form part of the Middle Thames Valley Gravel Formation, and in central Essex form part of the Kesgrave Sand and Gravel Formation (Rose and Allen, 1977; Rose, *et al.*, 1978). Pebble lithological counts described are based on the 33-8mm size range. The altitudinal arrangement of the terraces and sedimentary units is shown in the form of a schematic long profile (Fig. 6).

Pebble Gravels and the Nettlebed Gravel The highest and oldest deposits, with the exception of the gravels containing blocks of Red Crag type at Netley Heath and Rothamstead, occur on the dissected Chiltern dip-slope and south Hertfordshire plateau as far east as Epping. They consist of well rounded unfossiliferous gravels and sands mainly composed of flint with some quartz and quartzite pebbles. Locally, in the Hertfordshire area, pebbles of Lower Greensand chert (Wooldridge, 1938; Hey, 1965) from south of the present Thames Valley are present. These Pebble Gravels have been subdivided into two broad groups on the basis of altitude; the higher being the so-called '500 foot' (152m) Pebble Gravels and the lower, the '400 foot' (122m) Pebble Gravels (Wooldridge, 1960).

There is some evidence that the former may be partly marine and partly fluviatile in origin, but on the basis of sand grain surface texture the latter are definitely fluviatile. The altitudinal distribution of these deposits strongly suggests that they represent early aggradations of the Thames along a course from the Goring Gap into Essex.

At Nettlebed, gravel containing high frequencies of rounded flint (32-39%) and low frequencies of vein quartz (10-15%) appears to be the lateral equivalent of the '400 ft' Pebble Gravel of Hertfordshire on the basis of a gradient comparable to that for lower aggradations and of lithology. This aggradation pre-dates the Nettlebed interglacial channel deposits.

The evidence of southern tributaries, such as the Mole, the Wey and possibly the Wandle (Macklin, 1980), shows that the Thames drainage system was already fully established by late Early or early Middle Pleistocene time.

Westland Green Gravel and Stoke Row Gravel The occurrence of a division of the Pebble Gravels richer in vein quartz and quartzite than the higher main spread has been recognised by several writers. However, a detailed re-examination of the quartz-rich gravels led Hey (1965) to assign them to a separate lithostratigraphical member, the Westland Green Gravels (type section TL 422 215). He recognised this subdivision from Goring to Essex, their main area of outcrop being south Hertfordshire and eastern Essex. He has subsequently extended the unit northeast into East Anglia (Hey, 1980) (Fig. 75). The sedimentary structures, gradient and SEM studies of sand grains (Hey, Krinsley and Hyde, 1971) have shown that these gravels were laid down by the early River Thames under a cold climate. The course of the river at this time is shown in Fig. 7.

Upper Thames	Middle Thames	Vale of St. Albans	West Essex	East Essex	Stage
Freeland Terrace Gravel	Black Park Gravel	Smug Oak Gravel	-	-	Anglian
Coombe Terrace Gravel	Winter Hill Gravel	Upper Eastend Gravel Till	Springfield Till	Lowestoft Till	
		Moor Mill Laminated Clay			
		Lower Westmill Gravel	Upper Ware Till Lower Chelmsford Gr.	Barham Sand and Gravels Barham Arctic Structure Soil	
	Gerrard Cross Gravel	Leavesden Green Gravel	Widdington Sands		
				Valley Farm Temperate Soil	Crom-erian
?Northern Drift	Beaconsfield Gr.			Kesgrave Sands and Gravels and Palaeosols	pre-Crom-erian
	Satwell Gravel				
	Westland Green Gravel				
	Stoke Row Gravel				
	Nettlebed inter-glacial deposit				Nettlebedian
	Nettlebed Gravel	'400 ft' Pebble Gravel			pre-Nettlebedian.
		'500 ft' Pebble Gravel			

Table 1. Correlation of the lithostratigraphic units and their interpreted ages.

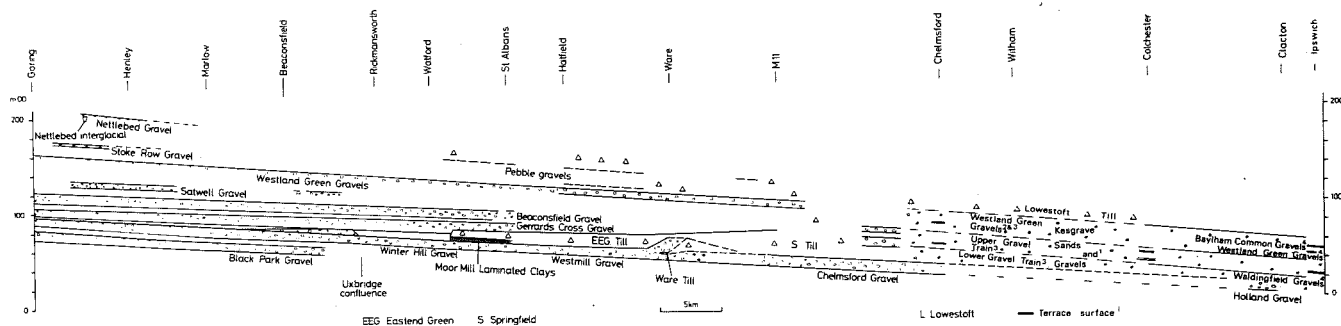


Figure 6. Schematic long profile of the terraces and sedimentary units of the pre-diversion Thames. 1: Rose et al., 1976; 2: Hey, 1980; 3: Green et al., 1982; 4: Allen, 1983.

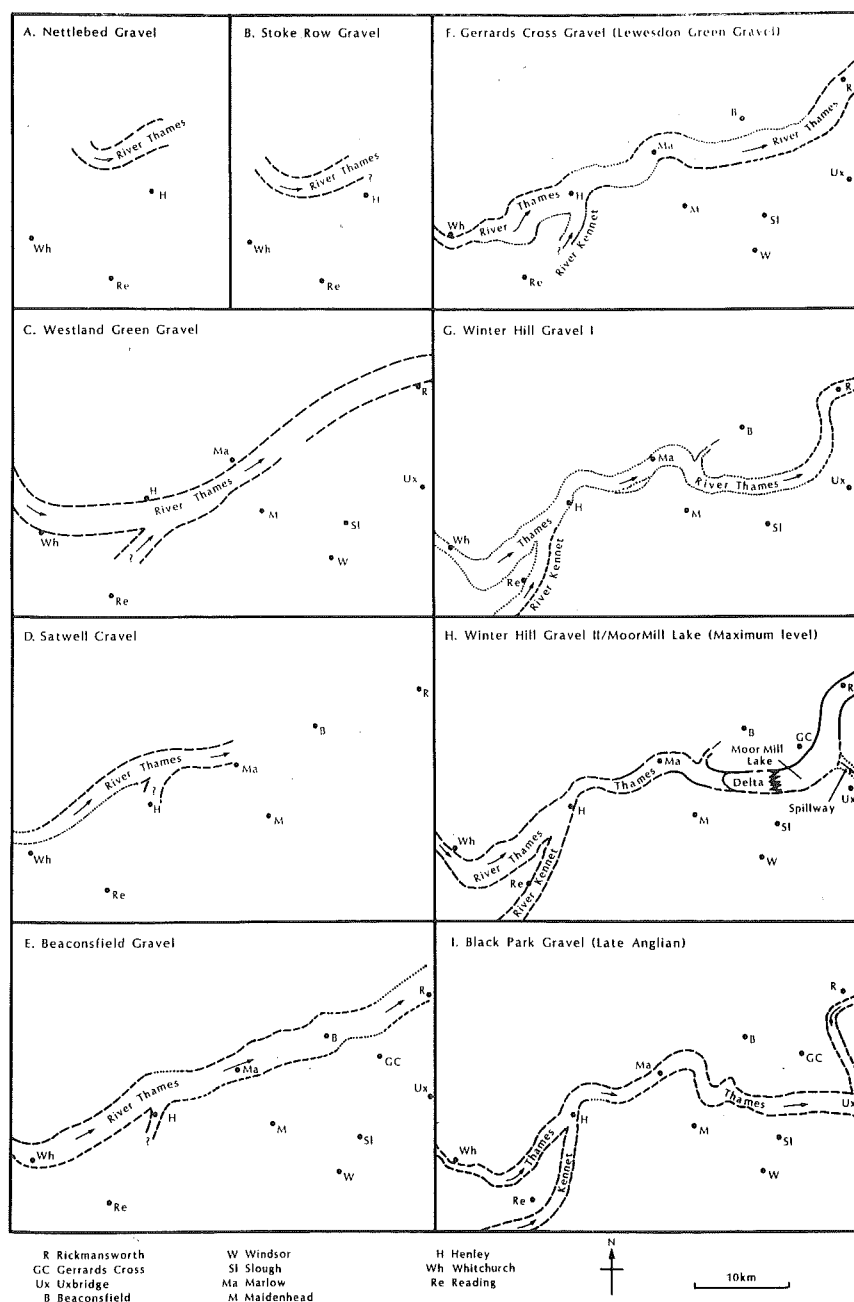


Figure 7. Drainage routes in the Middle Thames region between the formation of the Nettlebed Gravel and the Black Park Gravel.

The gravels contain high frequencies of far-travelled rock types notably vein quartz, quartzite, sandstone and Palaeozoic chert. The origins of the gravel lithologies have been recently discussed by Hey (1965); Hey and Brenchley (1977); Green and McGregor (1978) and Green, Hey and McGregor (1980). All agree that the materials represent a mixture of locally derived rocks (predominantly flint) and far-travelled material from the north of the London Basin.

Recent studies by Gibbard indicate that one locality, Stoke Row (SU 686 834: 174m O.D.) included by Hey (1965) in the Westland Green member is probably the remnant of an older quartz-rich aggradation. This, the most westerly outlier of Hey's Westland Green Gravel, requires a gradient of 1m/km to link it with Ashley Hill, the next nearest outlier. This gradient is much steeper than that found downstream (0.5m/km). If this latter gradient, is extended upstream it intersects perfectly with a large gravel outlier of comparable composition at Cray's Pond (SU 637 505: 168m O.D.) and Coldharbour (SU 635 800). The latter is therefore thought to be the correct upstream continuation of the Westland Green Gravel. The outlier at Stoke Row is therefore 6m higher than the Westland Green deposits. It must represent a remnant of an earlier aggradation termed here the Stoke Row Gravel.

Pebble counts from the Stoke Row Gravel show that it contains 30% angular flint, 15% rounded flint, 50% vein quartz and 3.75% quartzite. There are few other localities that might be equivalent to this stage, although Green and McGregor (1978) do record sites that might represent downstream correlates.

The recognition of the Stoke Row Gravel demonstrates the presence of an aggradation intermediate in age between the Nettlebed Gravel and the Westland Green Gravel. It also represents the earliest influx of quartz-rich gravel into the Thames system, yet identified.

Satwell Gravel Terrace-like surfaces at Satwell (type section: SU 706 839: 131m O.D.) and at Kingswood Common (SU 694 825: 132m O.D.) are underlain by quartz-rich gravels. Sections at the former revealed 2m of stratified gravel, whilst White (1896) recorded over 6m of gravel at the latter. Further gravel patches at comparable altitudes occur at Bromsden Farm (SU 716 847: 130m O.D.) at Bix (SU 729 846: 129m O.D.) and downstream at Hulton's Farm, Hambleton (SU 794 870: 128m O.D.).

Plotting these deposits shows that they fall on a gradient of 0.6m/km, which is very similar to that of lower units. The course of the river at this stage is shown in Fig. 7.

Pebble counts from this unit indicate that the gravel includes 34% rounded flint and 42% vein quartz. It is therefore distinct from other higher or lower members.

This member has not been previously recognised.

Beaconsfield Gravel This unit was originally recognised by Wooldridge (1938) and was later mapped by Hare (1947) as the so-called Higher Gravel Train from heavily dissected and disturbed gravel spreads around Beaconsfield. Green and McGregor (1978) showed that the deposits had a characteristic lithological assem-

blage including high frequencies of quartz and quartzite and to a lesser extent Palaeozoic chert and sandstone. The formal term Beaconsfield Gravel (type section: SU 940 192) was first applied by Gibbard (1978) to describe the gravel and sand deposits as distinct from the terrace-like form. Recent stratigraphical studies demonstrate that this aggradation can be recognised as a discrete unit throughout the Middle Thames region from Goring Heath to St. Albans (Fig. 7). Between Goring and Henley the Beaconsfield member is aligned along the Caversham Channel. Downstream of St. Albans it is apparently absent because of glacial erosion. However, Green, McGregor and Evans (1982) have suggested that a lithologically similar aggradation in a comparable altitudinal position may be present as a division of the Kesgrave Sand and Gravel Formation (Rose, *et al.*, 1978) beneath Lowestoft till (Anglian) in eastern Central Essex.

The deposits of this unit are heavily decalcified and iron-stained. In the Middle Thames area they are frequently much disturbed by collapse into chalk bedrock solution hollows. Where undisturbed they comprise a series of horizontally stratified gravels predominantly with a sand matrix. The gravels are interbedded with current bedded sand channel fills (10-14cm thick). Near contemporary valley sides, lenses of brown pebbly clay up to 1.7m thick interdigitate with the gravels. These lenticular deposits are thought to represent soliflucted debris from the valley slope. Similar sediment is also present in younger deposits.

Lithologically the gravels comprise 23-43% vein quartz, 8-17% quartzite, 8-12% rounded flint and 34-51% angular flint, together with minor erratic lithologies. Down valley increase in angular flint content and a proportional decrease in non-local lithologies is found in the Middle Thames region.

Gerrards Cross Gravel The gravels of this member were first recognised by Wooldridge (1938). However, because of the degraded nature of the surface and the possibility that more than one stage might be represented, he assigned the deposits to the Lower Gravel Train, rather than a terrace. Morphological mapping enabled Hare (1947) to rename this unit, the Harefield Terrace after its type locality near Rickmansworth. Extension of this work upstream by Sealy and Sealy (1956) showed that the terrace could be recognised as far west as Kidmore End.

Following Wooldridge (1938), Hare (1947) traced the terrace eastwards into the 'Finchley Valley'. Gibbard (1974, 1977) however, showed that gravel and sand at Leavesden Green and at the western end of the Vale of St. Albans are altitudinal and lithological equivalents of those beneath the Harefield Terrace. This was recently supported by Green and McGregor (1978). Gibbard (1977) termed this unit the Leavesden Green Gravel, but since the type section was only temporary and was within the Vale of St. Albans, it was thought necessary to redefine the unit from a well studied, open section in the Middle Thames region itself. It is therefore proposed that the deposits be included in a new member the Gerrards Cross Gravel (type section SU 968 557).

The deposits of this member comprise a series of stratified gravels and sands. The gravels are massive to horizontally-bedded and form elongate bodies 1-2m in thickness. Then are interbedded with lenses of coarse to medium sand often forming small

scale channel fills in gravel bodies. Near the original valley sides the gravel and sand may contain interbedded lenses of brown pebbly clay exactly similar to those in the Beaconsfield Gravel. On the basis of their composition, fabric and relation to other sediments these lenses appear to represent soliflucted slope material.

Also as in the Beaconsfield Gravel, where the gravels and sands rest on Chalk there is considerable evidence of collapse by bedrock solution. The deposits often show normal step faulting and locally oversteepened bedding. In places, the gravels are cut through by funnel-shaped hollows up to 10m across and filled with brown clayey silt. Occasionally, palaeosol development is visible in deposits immediately underlying the present surface.

The pebble lithological composition of this unit comprises 38-61% angular flint, 3-19% rounded flint, 18-30% vein quartz and 7-15% quartzite. The gravels also contain Palaeozoic chert, sandstone, Greensand chert (in the eastern part of the area) and minor amounts of igneous and metamorphic rocks. Most of the material is of local derivation. The lower content of rounded flint compared to higher units may result from the smaller area of Tertiary rocks and older gravels available for erosion at this time. This interpretation is supported by the fact that with each successive gravel aggradation there is a decline in the frequency of rounded flint. The abundance of far-travelled material as in previous units indicates a continued link with a source area distant from the Goring Gap. Green and McGregor (1978) have recorded comparable pebble assemblages and in particular noted characteristic igneous rocks. These include rhyolitic tuffs and other acidic lithologies of Welsh origin. To account for this McGregor and Green, (1978) have followed Hey (1965) and Hey and Brenchley (1976) in suggesting possible glacial transport into the Thames catchment from north Wales.

Attempts to test this hypothesis using SEM of quartz sand grains (200 μ) have been undertaken. However, only one glacially type textured grain was found out of a total of 30 grains examined. The case for lowland glaciation in the catchment at this time, must therefore remain undemonstrated.

On the basis of sedimentary structures, facies and association with solifluction debris, the deposits are thought to have aggraded under a cold climate regime. Because the deposits pre-date the Anglian Winter Hill Gravel (see below) they have been thought to be of pre-Anglian age (Gibbard, 1974, 1977; Green and McGregor, 1978), the latter authors actually suggesting a Beestonian age. It should be stressed that no Cromerian deposits or palaeosols that can be ascribed to the Cromerian Interglacial have yet been identified in the Middle Thames region. It is therefore not possible to unequivocally demonstrate the age of this unit at present. Moreover, there is no reason why the Gerrards Cross Gravel should not be of earlier Anglian age (e.g. Gunton stadial: sensu Mitchell et al., 1973) since the Winter Hill Gravel is presumably only of Lowestoft stadial age, based on its association with Chalky Till in the Vale of St. Albans. If the Gerrards Cross Gravel is early Anglian, it would explain the possible glacial component without having to resort to unfounded pre-Anglian glaciation to explain the exotic rock types present. Resolution of this problem may be achieved by correlation with neighbouring areas, particularly central Essex as attempted recently by Green, McGregor and Evans (1982).

Fragments of surface referred to Rassler Terrace, intermediate between the Harefield and Winter Hill Terraces by Sealys (1956) have been shown to represent either degraded remnants of the former or surfaces developed on mass flow deposits. The latter is the case at Rassler Wood (SU 822 854). No evidence for a separate Rassler stage has been found and therefore, it is suggested that the name should be abandoned.

Winter Hill Gravel and downstream equivalents. The term 'Winter Hill Terrace' was first used by Ross (1931) to describe the surface developed on gravel covering chalk on high ground south of Bourne End. Wooldridge (1938) discussed the extent of this feature from Goring to the Colne. Hare (1947) refined Wooldridge's work and subdivided the Winter Hill into two units: the Winter Hill Terrace *sensu stricto* and the lower, Black Park Terrace (see below). Hare showed that the former could be subdivided into lower and upper subfacets in the Bourne End - Colne Valley district. Sealy and Sealy (1956) extended Hare's work to Goring and suggested that the 'lower' Winter Hill Terrace floored the Caversham Channel, north of Reading. This was recently shown to be incorrect by Clarke and Dixon (1981).

Both Wooldridge (1938, 1960) and Hare (1947) thought that the River Thames flowed through the 'Middlesex Depression' across northwest London during the Winter Hill stage. However, Gibbard (1974, 1977) showed that the Westmill Gravel underlying the Chalky Till in the Vale of St. Albans was the downstream equivalent of the Winter Hill Gravel. The river therefore continued to flow through the Vale of St. Albans during this stage. This conclusion was also supported by Green and McGregor (1978). The Finchley valley in north London was shown by Gibbard (1979) to have been occupied by a Mole/Wey stream which was confluent with the Thames near Ware.

Middle Thames. The Winter Hill Gravel can be traced throughout the Middle Thames region. Upstream from Burnham the gravels comprise 'normal' fluvial deposits showing structures of typical braided river facies and with a gradient of 0.5m/km. However, east of Burnham two subunits of the gravel diverge downstream. These lithologically indistinguishable units can be separated by their different gradients. The Winter Hill Lower Gravel continues with the same gradient as further upstream and can be followed eastwards as far as Fulmer. Downstream it turns north-east towards Denham and Rickmansworth where it becomes the Westmill Gravel beneath Watford. However, the Winter Hill Upper Gravel diverges from the Lower and remains almost horizontal at 80-82m O.D.. Hare (1947, p.329) noticed this originally and remarked that it 'has little slope, and this fact may be due to prolonged aggradation in a ponded-up valley'. Gibbard (1974, 1977) showed that his ponding was equivalent to the deposition of the Moor Mill laminated clays in an ice-dammed lake. The lake was formed when the Anglian (Eastend Green Till) ice blocked the Thames in the Vale of St. Albans (Fig. 8). This upper subunit of the Winter Hill Gravel is well developed, but is only present between Burnham and Oak End Wood, Denham. Upstream it merges with the lower subunit, downstream it is absent.

In view of the evidence it appears that when the ice blocked the valley to form the ice-dammed Moor Mill Lake, a delta developed at the upstream end (Fig. 8). That this happened is sup-

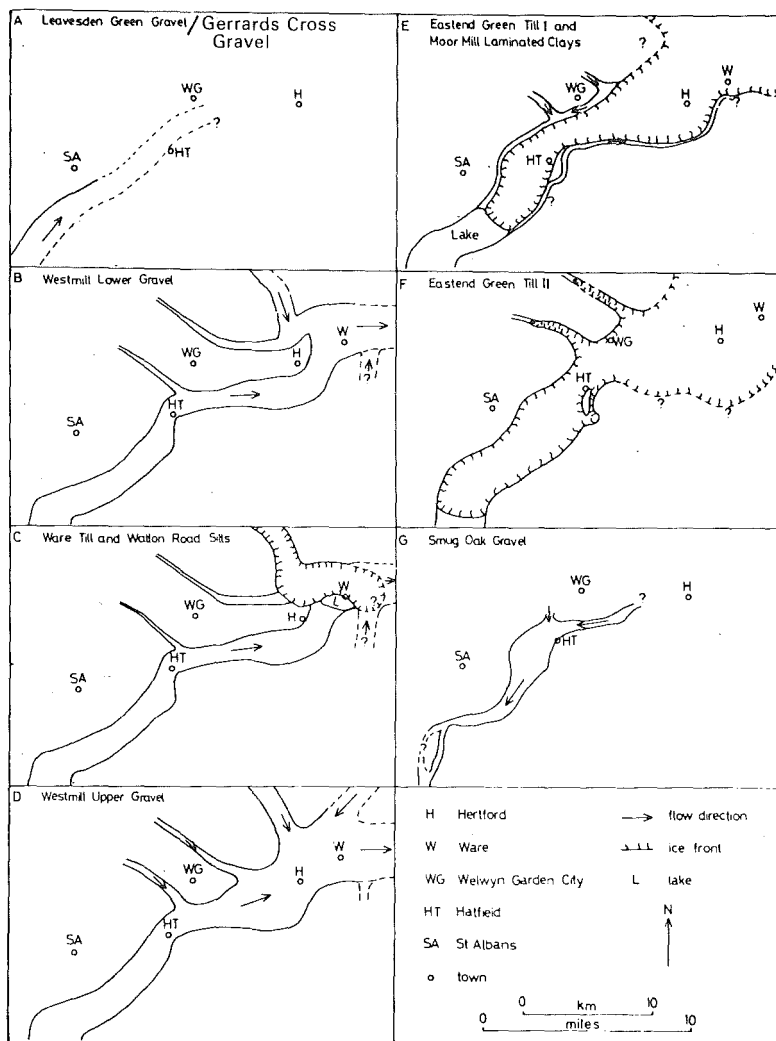


Figure 8. Thames drainage routes and glacier development in the region of the Vale of St. Albans.

ported not only by the flat upper facet terrace surface and underlying gravel distribution, but also by large scale delta foreset bedding exposed at Stoke Common. At Denham, laminated clay (? Moor Mill Laminated Clay) has been found locally overlying Winter Hill Gravel. The level of the upper subunit surface, presumably the delta topset surface, therefore records the actual lake water level (80-82m O.D.).

Projection of the gradient of the Winter Hill Gravel upstream from Goring into the Upper Thames Valley demonstrates that this member is equivalent to the Coombe Terrace gravel (Arkell, 1947).

Vale of St. Albans. Downstream the laterally equivalent Westmill Gravel (type section TL 342 162) can be traced the full length of the Vale of St. Albans to Ware. Around Hertford and Ware the Thames was confluent with a glacial outwash stream from the Hitchin - Stevenage Gap, which deposited gravels with a high chalk and erratic rock content. Advance of ice along the Hitchin - Stevenage Valley brought an end to Westmill Lower Gravel deposition in the east. This ice advance was strongly controlled by bedrock topography, so that it travelled south to Waterford then turned southeast as shown by till fabric studies (Fig. 8). In the confluence zone around Hertford and Ware the ice continued across the Vale to the southeast and dammed the Thames. The Watton Road laminated Silts (overlying the Westmill Lower Gravel and underlying the Ware Till) attest to the presence of a lake northwest of Ware. The extent of the lake is unknown although shallow water sediments at Watton Road (type section: TL 341 149) indicate that the shore was nearby. Over 485 varve-like couplets were counted and indicate that supply of sediment was uniform for this period. From this it can be concluded that the ice was stationary in the vicinity. No outflow for this lake has been firmly identified, but it seems likely that a spillway near Little Amwell (not the Amwell Gorge) carried waters southwards to join the Mole-Wey stream near Hoddesdon (cf. Cheshire, 1981). The river seems to have rejoined its preglacial course east of Ware.

Finally, the ice overrode the Watton Road lake and continued to the east and southeast. The maximum extent of this advance is not known, but to judge from the great thickness of Ware Till between Ware and Much Hadham proved in boreholes for the A10 road, it probably terminated locally. The Ware Till is notably absent from the M11 section across the Mid Essex Depression (Baker, 1971). Baker & Jones (1980), and Baker (this volume) extend this ice limit further south to Hoddesdon (see below), but there is little evidence for this at present. There is at present no evidence to support an extension of this ice lobe to the southwest along the Vale of St. Albans itself (see Cheshire. pp. 50 - 59).

After a period the ice stagnated and decayed. Fluvial sedimentation returned, marked by the deposition of the Westmill Upper Gravel (type section: TL 342 162). The Thames in the Vale, which had been flowing throughout the preceding period did not resume its easterly course beyond Ware because of the till barrier. Instead it followed the spillway into the Mole-Wey valley at Hoddesdon, whence it rejoined its earlier course immediately east of Ware. Suggestions have been made by Cheshire (1981) and Baker and Jones (1980) that the Thames was diverted into the Lower Lea Valley at this time. It should be clearly stated that there are no deposits south of Hoddesdon of either the lithology or thickness which can be unequivocally demonstrated to be of Thames origin. Indeed there is no evidence that the Lower Lea Valley even existed until possibly the latest Anglian or more probably early Wolstonian time. Further, the earliest deposits aligned along the Lower Thames Valley, of which the Lea is a tributary, are the Dartford Heath Gravels. These have been shown to be equivalent to the late Anglian Black Park Gravel of the Middle Thames (Gibbard, 1979).

During the period between the ice advances into the Vale, the Hitchin - Stevenage tributary continued to flow along its earlier course. Ice decay in situ resulted in post-depositional collapse of sediments into kettles. Ablation debris coating upstanding ice blocks flowed onto the gravel and sand forming tongues

of flow till. These deposits can be seen at various levels in the fluvial sediments. The migrating channels of the braided rivers deeply dissected the Ware Till, reworking the glacialigenic sediments.

Subsequently a new powerful outwash stream from the approaching ice sheet began to flow from the northeast. There is no evidence of its presence earlier. The new stream quickly gained strength and overwhelmed both the Thames and the Hitchin - Stevenage tributary. This stream caused southwards migration of the Thames in the confluence region as shown by palaeocurrent data from the Hertford and Ware area. At Westmill and elsewhere the river cut deeply into earlier deposits and introduced quantities of erratics and chalk derived from glacial debris and local bedrock.

The ice sheet advanced on a broad front from the north-east. It advanced along the Vale towards the west and southwest to deposit the Eastend Green Till (type section: TL 297 106) dam the Thames and from the Moor Mill Lake. On reaching London Colney, the ice halted and the lake was stabilized.

Evidence for this stationary event is recorded at Waterhall Quarry, by the presence of meltout till and subglacially-formed laminated deposits. Nearby at Bunkers Hill, after a period of ice stagnation, a temporary ice retreat was followed by the deposition of glacialfluvial sediments by an eastward flowing marginal stream.

The Moor Mill ice-dammed lake was extensive. Despite subsequent erosion its deposits still cover an area of 4 x 1.5 km west of London Colney. The varve-like laminar couplets indicate that the lake existed for a minimum of 342 years. The lake probably drained east and fed the ice marginal stream that cut the Harefield - Flatfield meander. The ice in the Vale presented a barrier to the northern tributary valleys, and drainage was deflected around the ice margin.

Finally, the ice again advanced towards the southwest. At Waterhall and Bunkers Hill it laid down further lodgment till. Further west, the ice continued to the present line of the M1 Motorway and Aldenham where it halted. The ice overrode the Moor Mill lake deposits. This apparently forced the lake water to spill over the London clay interfluvium near Uxbridge into the neighbouring Mole-Wey valley to the East. Here a similar ice-dammed lake, the Coldfall Wood lake was ponded in front of the Finchley Till ice lobe (Gibbard, 1979). The initial overspill appears to have triggered a chain of events during which spillways were formed from the Thames to the Mole-Wey and from there into the neighbouring valley (? Wandle) until the river reached the unglaciated Medway system (Fig. 4). As has been shown by Bridgland (1980, 1983a) the Thames was confluent with the Medway near Southend-on-Sea from where the Thames-Medway flowed northeast along the pre-existing valley to re-join the original Thames course near Clacton.

Essex Within the central trough of the Mid-Essex Depression a sequence of gravels and sands up to 11m thick occurs (Baker, this volume). These gravels are the altitudinal equivalent of the Westmill Gravel of the Vale of St. Albans (Baker, 1971; Gibbard, 1977; Baker and Jones, 1980) and the Chelmsford Gravel of the Harlow area (Clayton, 1957, Baker and Jones, 1980) although deposits of this name have been shown by Rose, et al. (1978) to include sediments of diverse origin and ages. As mentioned above, the first advance of the Lowestoft Till ice, represented in this

area by the Maldon Till, is thought to be equivalent to the Ware Till (Clayton, 1957; Baker and Jones, 1980). During this phase the ice may have extended towards the southwest as far south as Ongar and Hoddesdon, although evidence for the latter is unsubstantiated. The Maldon Till, where present, subdivides the Chelmsford Gravels into upper and lower subunits thought by Baker and Jones (1980) to be equivalent to the Westmill Upper and Lower Gravels of the Vale. These gravels are overlain by the substantial thickness of Springfield Till (Clayton, 1957; Baker and Jones, 1980) or Lowestoft Till (Perrin *et al.*, 1979) that represents the so called main advance of the Anglian glaciation. This till sheet buries all earlier deposits including fragments of older gravel aggradations thought by Green, McGregor & Evans (1982) to be equivalents of the pre-Winter Hill deposits of the Middle Thames including the Westland Green Gravel (Hey, 1965) and the downstream equivalents of the Kesgrave Sand and Gravel Formation of Rose *et al.* (1976, 1978).

In the Bishops Stortford area of Eastern Essex, southward trending buried channels cut by meltwater beneath the Anglian ice incised into earlier deposits filled with gravels of immature erratic-rich composition. They are thought to represent proximal outwash and are very similar in composition to the Barham Sands and Gravels of Rose *et al.* (1976).

Some stratigraphical problems arise in Eastern Essex because of the discovery of the Valley Farm palaeosol of apparent interglacial type developed on gravel beneath Lowestoft Till. This palaeosol has been assigned to the Cromerian stage and where it is present it indicates that the gravels beneath must pre-date the Cromerian. For this reason Rose and his co-workers (1976, 1978) have suggested that the Thames did not pass near Chelmsford during the Anglian. Baker and Jones, (1980), however, suggest that the palaeosol does not reflect interglacial conditions and at least some of the gravels might be Thames deposits of Anglian age. They further suggest that the first ice advance (Maldon Till) could have diverted the river on to the so-called 'Romford River' line, but offer no lithological evidence to support this interpretation.

At Ongar the ice lobe dammed the northward flowing Roding stream (Baker and Jones, 1980) forming a sequence analogous to that in the Vale of St. Albans, and Finchley Valley. Whilst the Roding stream may have only been a local tributary, it is possible that it represents the northward extension of the Wandle. This is supported by the similar gravel overlain by a till sequence that occurs at both Loughton and Chigwell Row (Dines and Edmunds, 1925). This sequence provides further evidence of drainage reversal arising from glaciation of the Thames south bank tributary valleys.

Black Park Gravel. The Black Park Terrace was first recognised as a discrete well-developed stage by Hare (1947, p.314-6). Following Hare, the Sealy's (1956) extended the Black Park surface upstream to Henley, but then through the modern Thames Valley to Caversham where they proposed it merged with their 'Lower' Winter Hill Terrace. Walder (1967, p.118) also noted this merging of the two stages. However, a reconstruction of terrace gradients led Clarke and Dixon (1981) to suggest that the deposits flooring the Caversham Channel, north of Reading, should not be correlated with the 'Lower' Winter Hill, but with the Black Park, and this has been supported by my own stratigraphical studies in the area.

In the Vale of St. Albans, Gibbard, (1974, 1977) showed that ice stagnation resulted in post-depositional collapse and slumping of till in places (Rose, 1974). Westward flowing meltwater derived from the ice front some distance to the east eroded the underlying till and deposited the Smug Oak Gravel (type section TL 144 026). This river turned southward at Rickmansworth to flow over the newly drained valley incised into the Moor Mill Lake floor (Fig. 8), later to be occupied by the River Colne, to join the Thames at Uxbridge during the Black Park Gravel stage (type section: TL 006 832) Gibbard (1974, 1977, 1979) (Fig. 7). Investigations in the London area led Gibbard (1979) to propose an extension of the Black Park Gravel to Richmond, Wimbledon and to Dartford in East London. This confirmed Hare's (1947) conclusion that the Black Park was the first terrace aligned along the present Thames Valley. Bridgland (1980) has extended this line into southeast Essex using detailed lithostratigraphical analyses. Here the Thames was confluent with Medway. The correlation of the late Anglian Smug Oak Gravel with the Thames Black Park Gravel (Gibbard, 1974, 1977, 1979) means that the latter provides an invaluable marker horizon throughout the Thames Valley.

Recent work has shown that a similar southwest flowing stream was present in the Finchly Valley after drainage of the Coldfall Wood ice dammed Lake. This ancestor of the River Brent is represented by erratic-rich gravels at Hanger Hill, Ealing, (type section: TL 182 819: Hanger Hill Gravel), originally described by Brown (1883). The stream was probably confluent with the Thames near Richmond.

Baker and Jones (1980) have suggested that the Lower Lea Valley may have been in existence at this time. To the author's knowledge no deposits equivalent to the Thames' Black Park Gravel have been discovered in this valley.

Lithologically, the Black Park Gravel may be easily separated from earlier Thames aggradations. The gravel in the Middle Thames is rich in angular flint (75-89%), poor in rounded flint (3-9%), poor in vein quartz (2.5-10%) and poor in quartzite (1.8-5%). This is the first solely fluvial, flint-rich gravel aggradation in the Thames sequence. This phenomenon was also noted by Walder (1967) in the gravel flooring the Caversham Channel. It is evident from these assemblages that the source of the quartz and quartzite component that was so important in the older gravels was no longer linked to the Thames catchment. Glacial drainage diversion in the south Midlands must be the explanation for this dramatic change.

Upstream correlation through the Goring Gap by projection of the gradient (0.5m/km) of this aggradation shows that it is altitudinally equivalent to Arkell's (1947) Freeland Terrace gravel.

Hoxnian interglacial deposits. In the Vale of St. Albans and inside the glaciated area of neighbouring districts partially buried ice blocks melted following climatic amelioration at the end of the Anglian stage to form kettle hole pools and small lakes. Sedimentation in these shallow basins began during the late Anglian

and continued into the Hoxnian interglacial. The progressive inward migration of boreal and then mixed oak forest woodland clearly indicates the development of fully interglacial conditions.

Throughout this period, the pools filled with sediment and may at times have dried-up completely as a result of changing water table levels (Gibbard and Aalto, 1977). A regional rise in water table is thought to account for the sequence preserved in the collapsed doline at Slade Oak Lane, Denham (see below).

There is no evidence for fluvial activity in the Vale of St. Albans at this time. However, within the Thames Valley, the fossiliferous deposits in the Upper and Lower Thames at locations such as Sugworth and Swanscombe, indicate that the river had occupied its present course by the Hoxnian stage.

LITHOLOGY OF THE THAMES GRAVELS

by C.P. Green and D.F.M. McGregor

Introduction

The evolution of the Thames drainage system has been a subject of scientific enquiry since the mid 19th century. Fig. 9 shows development of ideas concerning the terrace stratigraphy since about 1900. The following notes are based on studies of the proto-Thames in the area between the Goring Gap and Ipswich (Fig. 10). The main aim of these studies has been to differentiate successive depositional stages and to trace the early course of the Thames and its tributaries across the region. These aims require, above all, the identification in the depositional record of features having recognisable lateral continuity. Only in this way can isolated fragments of the record be related to one another either spatially or in stratigraphic succession. This requirement was clearly explained by Wooldridge and Linton (1955) who indicated three possible strategies for the geomorphological and stratigraphical reconstruction of the Thames record - palaeontological, lithological, morphological. Their work is based on an interpretation of the morphological evidence. While acknowledging the pre-eminent value of the palaeontological evidence, they dismissed it as a general basis for reconstruction because of its scarcity. They also dismissed the lithological evidence on the grounds that only a very crude subdivision of the record into three stages could be achieved.

Work on the composition and shape of pebbles in the gravels of the proto-Thames (Green and McGregor, 1978) showed that these features can be used as the basis for a lithostratigraphical scheme to differentiate depositional stages at a relatively refined level; and that units differentiated in this way can be widely traced in scattered and discontinuous outcrops throughout the area investigated. In particular it has proved possible to trace terrace complexes identified in the middle Thames and Vale of St. Albans area into Essex and southern East Anglia (Green McGregor and Evans, 1982), and to demonstrate the continuity of down-valley gradients between these areas (Fig. 11). In Essex and Suffolk subdivision of the Kesgrave Formation (Rose and Allen, 1977) is indicated. The same method was used (McGregor and Green, 1983a) to differentiate adjacent gravel outcrops exposed along the line of the M1 Motorway between Hemel Hempstead and Watford.

In total, 151 samples of gravel have been analysed from over 100 sites. Composition has been determined for the half ϕ size fraction 16.0 - 11.2mm. The roundness of flint pebbles in this size fraction has been investigated for many samples, using the nine point visual chart of Krumbein (1941).

Lithological Types.

The following lithologies can be recognised:

Flint: invariable the largest single component; derived either directly from the Chalk, or from Tertiary pebble beds.

Lower Greensand chert and cherty sandstone: probably largely derived from outcrops in the Weald,

Pliocene							Lenham Beds	Pliocene
	1927						Rothamsted Sandstone	Waltonian
Pebble Gravels	500 foot Pebble Gravels						500 foot Pebble Gravels	
	400 foot Pebble Gravels						400 foot Pebble Gravels	
		1938	1947	1956	1965	Westland Green Gravel	Westland Green Gravel	
Plateau and Glacial Gravels		Higher Gravel Train					Higher Gravel Train	
		Lower Gravel Train					Lower Gravel Train	
	1929	1932	1945				Harefield	
		Binfield					Rassler	
			Finchley Leaf			Upper Winter Hill	Upper Winter Hill	
		Winter Hill				Lower Winter Hill	Lower Winter Hill	
			Kingston Leaf			Black Park	Kingston Leaf	? Late Cromerian
		1936					Black Park	Late Anglian
Boyn Hill		v L. Barnfield and viii M. Barnfield					Boyn Hill	Hoxnian
		L. Boyn Hill or U. Taplow or Furze Platt or Iver					Lynch Hill	Hoxnian or Wolstonian
Taplow		xi Taplow					Upper Taplow	Ilfordian or Ipswichian
	1921						Lower Taplow	
Floodplain		Upper Floodplain	xiv Ponders End				Upper Floodplain	Ipswichian
		Lower Floodplain	xvi Hailing				Lower Floodplain	Devensian
Alluvium			xvii Tilbury				Alluvium	Flandrian

Figure 9. The terrace sequence: the development of the nomenclature since 1912. Dates indicate the following sources: 1921, Dewey and Bromehead; 1927, Wooldridge; 1929, Saner and Wooldridge; 1932, Ross; 1936, King and Oakley; 1938, Wooldridge; 1945, Zeuner; 1947, Hare; 1956, Sealy and Sealy; 1965, Hey. Dashed lines indicate subdivisions which are either of local significance only, or are disputed, or superceded. P: relationship of Ponders End sediments in Zeuner (1945); 1st: first sunk channel of Zeuner (1945); 2nd: second sunk channel; 3rd: third sunk channel. Roman numerals signify the stages of King and Oakley (1936). An attempt is made to show the position in the terrace sequence, as supposed by King and Oakley, of the sediments from which the stages are named. Pre-Boyn Hill stages (i-iv), brickearths (vii, xii), periglacial deposits (x, xvb) and certain erosional stages (vi, ix, xiii) are omitted. The correlations in the final column reflect the authors present opinion.

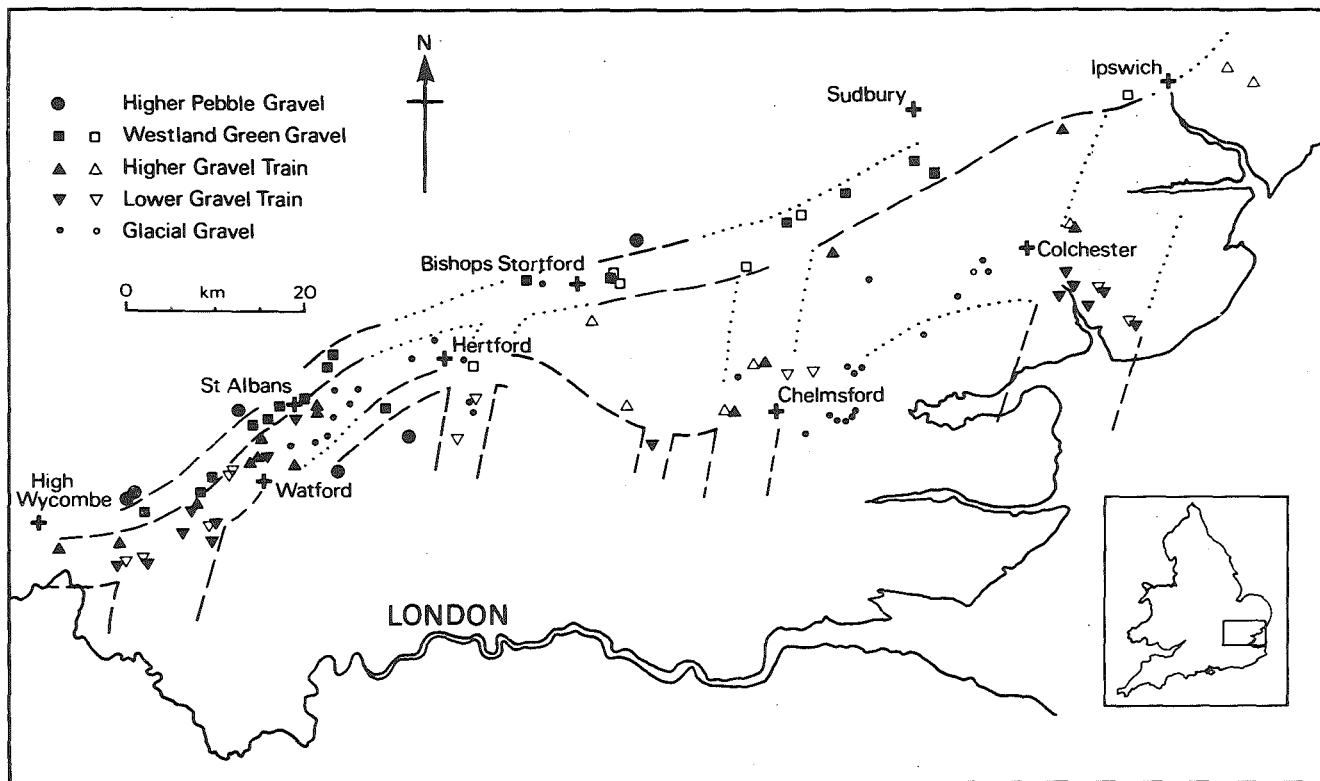


Figure 10. Distribution of gravel groups, indicating the approximate alignment of successive courses of the river and its right-bank tributaries. The separate distribution of the Higher and Lower Gravel Trains is not shown west of Hertford (broken lines: boundaries based on relief and gravel distribution; dotted lines: boundaries inferred). Open symbols indicate substantial Lower Greensand content (100chert/flint ratio > 2.5). In this and the following figure, due to limitations of scale, the number of symbols at each stage is not equal to the number of samples shown on Fig.

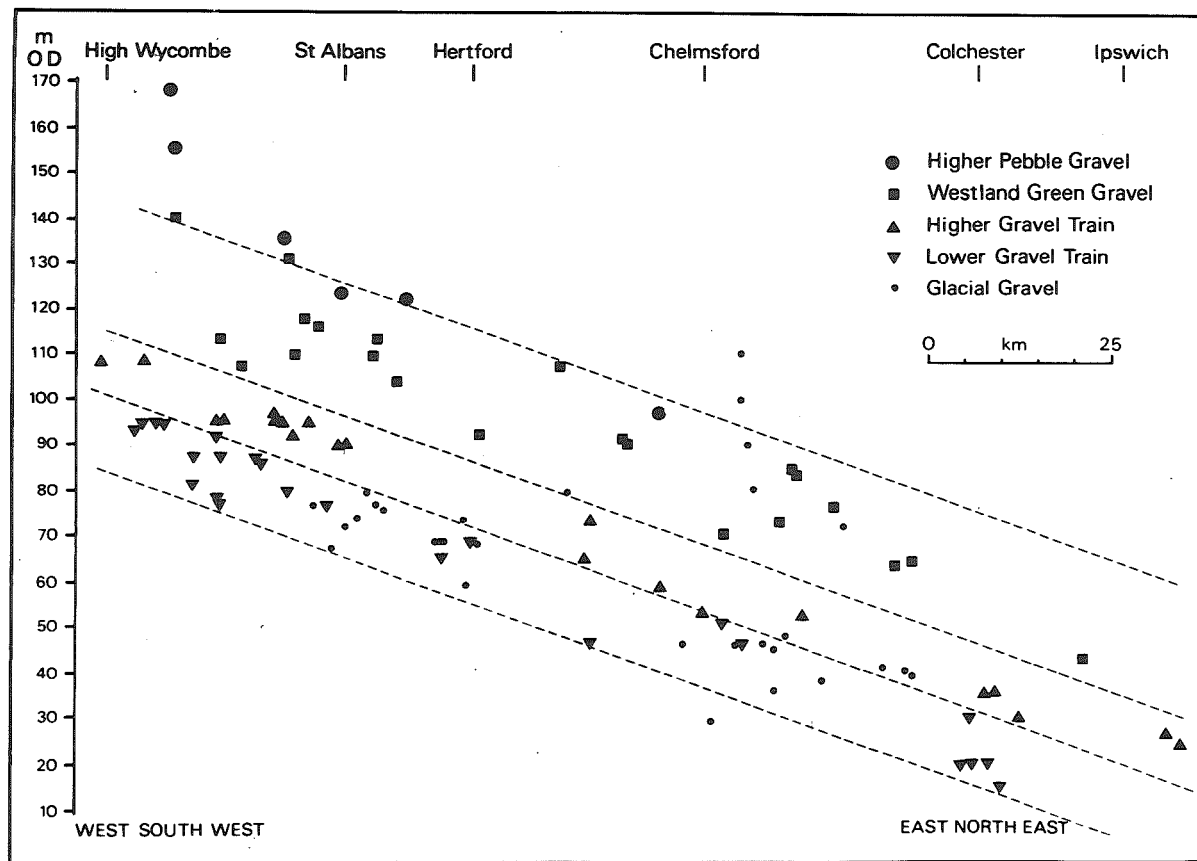


Figure 11. Distribution of gravel groups according to schematic terrace profiles. Samples as in Fig. 10.

although durable lithologies are present to the north of the Chilterns.

Quartz: commonly the second largest component; undoubtedly from a variety of sources but mainly far-travelled.

Sandstone: a diverse category, ranging from hard quartzites to soft micaceous sandstones.

Volcanic: this term refers to a suite of fine grained acid igneous rocks ('rhyolites') and vitric and lithic tuffs, probably originating in North Wales (Green, Hey and McGregor, 1980); mainly green in colour due to the presence of chlorite. Fig. 12 shows the broad distribution of volcanic pebbles in the Thames/proto-Thames basin. Fig. 13 shows detailed distributions in a group of sites in the Middle Thames and Vale of St. Albans areas.

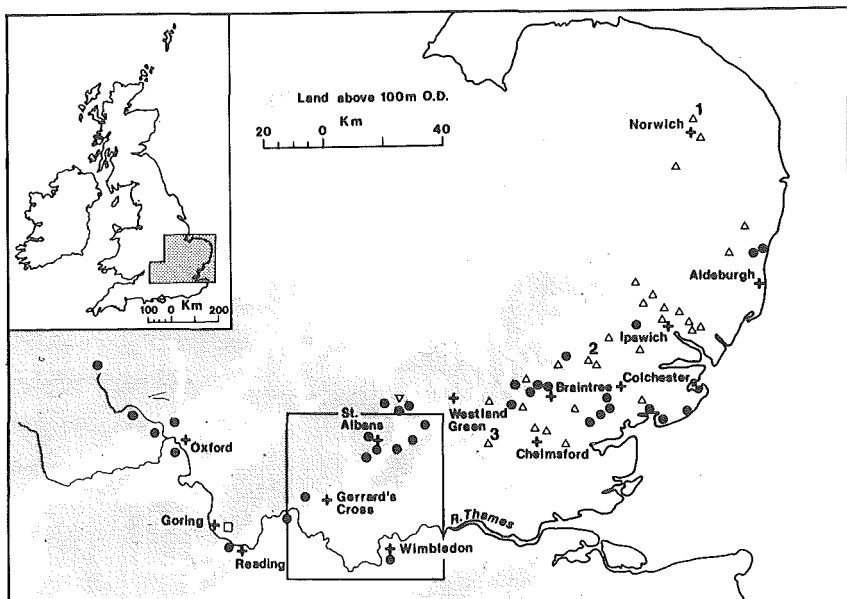


Figure 12. Site where volcanic pebbles have been reported. ●, Salter (1905); □, Hawkins (1923); ▽, Wooldridge (1958); Δ, 1-3 sites of petrographic investigation (Hey and Brenchley, 1977); Δ, other sites recorded by Hey and Brenchley. Outline of Fig. 13 indicated.

Rhaxella chert: composed largely or exclusively of the minute (0.1-0.2mm) globular spicules or the sponge *Rhaxella perforata*; derived from a relatively restricted outcrop in the Corralian of North Yorkshire.

Others: a wide range of rock types, most of which are represented only once or twice each among all the far-travelled material examined.

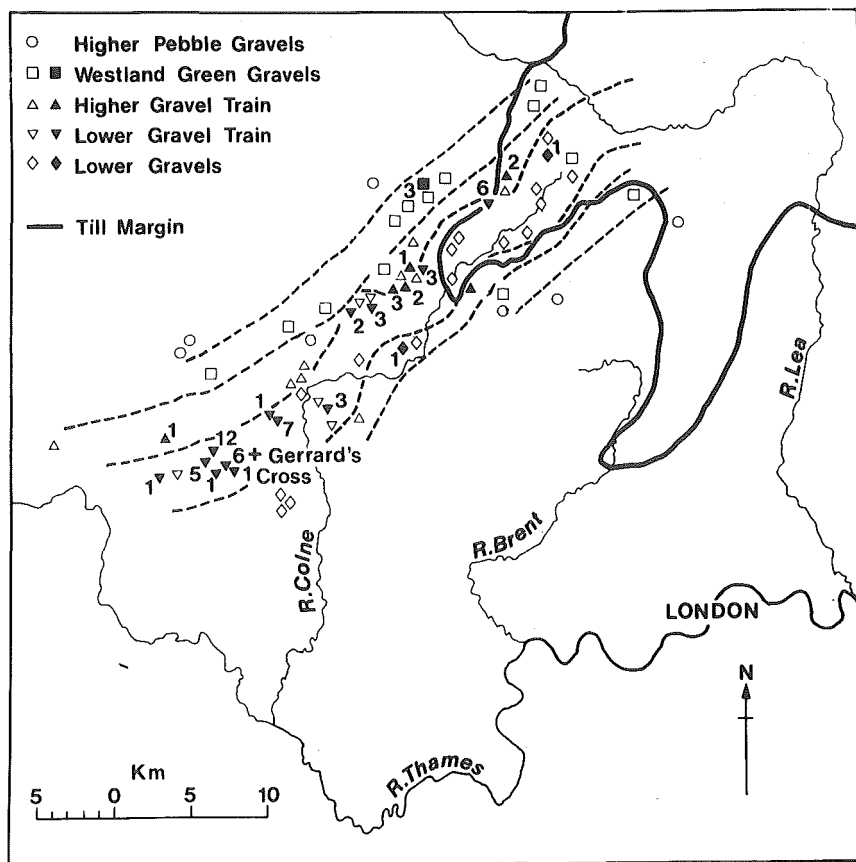


Figure 13. Volcanic pebbles in the Middle Thames and Vale of St. Albans areas. Closed symbols indicate samples yielding volcanic pebbles, with number of pebbles.

Interpretation is based largely on the use of internal ratio values (Table 2 and Fig. 14). In Table 1 which presents details of a group of 130 samples, the sandstone and other categories are amalgamated.

Lithological assemblages

Five main gravel suites are recognised.

Higher Pebble Gravels: this group includes the '400 foot' and '500 foot' Pebble Gravels and some 'Calabrian gravels'. At the highest levels, well-rounded flint pebbles are overwhelmingly predominant. At lower levels quartz becomes increasingly common in the smaller size fractions, and Lower Greensand material appears in small amounts in some samples. Other far-travelled material is very scarce and there is no indication of components

derived from western source areas outside the present catchment. Rhaxella chert has however been found, but no further than Watford.

Gravel set	Numbers of pebbles										Numbers per cent				Ratios			
		<i>fl</i>	<i>c</i>	<i>qz</i>	<i>V</i>	<i>R</i>	<i>s</i>	Total	<i>loc</i>	<i>far</i>	<i>loc</i>	<i>far</i>	<i>V</i>	<i>R</i>	<i>loc/far</i>	<i>qz/f</i>	100 <i>c/fl</i>	<i>n</i>
HPG	W	1727	1	237	—	—	94	2059	1728	331	83.9	16.1	0.00	0.00	5.22	2.52	0.06	5
	E	193	△	19	—	—	14	226	193	33	85.4	14.6	0.00	0.00	5.85	1.36	—	1
	T	1920	1	256	—	—	108	2285	1921	364	84.1	15.9	0.00	0.00	5.28	2.37	0.05	6
WGG	W	1926	6	817	3	1	641	3394	1932	1462	56.9	43.1	0.46	0.15	1.32	1.27	0.31	11
	E	3335	86	1502	24	3	1017	5967	3421	2546	57.3	42.7	2.30	0.29	1.34	1.44	2.57	11
	T	5261	92	2319	27	4	1658	9361	5353	4008	57.2	42.8	1.60	0.24	1.34	1.37	1.75	22
HGT	W	2183	10	553	4	1	724	3475	2193	1282	63.1	36.9	0.55	0.14	1.71	0.76	0.46	11
	E	4440	100	1005	28	1	1158	6732	4540	2192	67.4	32.6	2.36	0.08	2.07	0.85	2.25	11
	T	6623	110	1558	32	2	1882	10207	6733	3474	66.0	34.0	1.67	0.10	1.94	0.81	1.66	22
LGT	W	2419	61	1004	32	—	1192	4708	2480	2228	52.7	47.3	2.61	0.00	1.11	0.82	2.52	16
	E	6396	147	1063	27	—	919	8552	6543	2009	76.5	23.5	2.85	0.00	3.26	1.12	2.30	10
	T	8815	208	2067	59	—	2111	13260	9023	4237	68.0	32.0	2.72	0.00	2.13	0.95	2.36	26
AGG	W	3897	56	288	—	3	471	4715	3953	762	83.8	16.2	0.00	0.63	5.19	0.61	1.44	19
	E	11909	150	1613	36	48	1684	15440	12059	3381	78.1	21.9	2.04	2.71	3.57	0.91	1.26	29
	T	15806	206	1901	36	51	2155	20155	16012	4143	79.4	20.6	1.61	2.27	3.86	0.85	1.30	48

HPG, Higher Pebble Gravel. WGG, Westland Green Gravel. HGT, Higher Gravel Train. LGT, Lower Gravel Train. AGG, Anglian glacial gravels. W, western area. E, eastern area. T, total area. △, present in set but not in this size range. *fl*, flint. *c*, Lower Greensand chert and sandstone. *qz*, quartz. *V*, volcanic. *R*, Rhaxella chert. *s*, sandstone and other. *loc*, local. *far*, far-travelled. *f*, far-travelled other than quartz. *n*, number of samples in set. Under 'Numbers per cent', *V* and *R* are given as percentage of *f*.

Table 2. Summary of gravel assemblages from 11.2 to 16.0 mm size fraction.

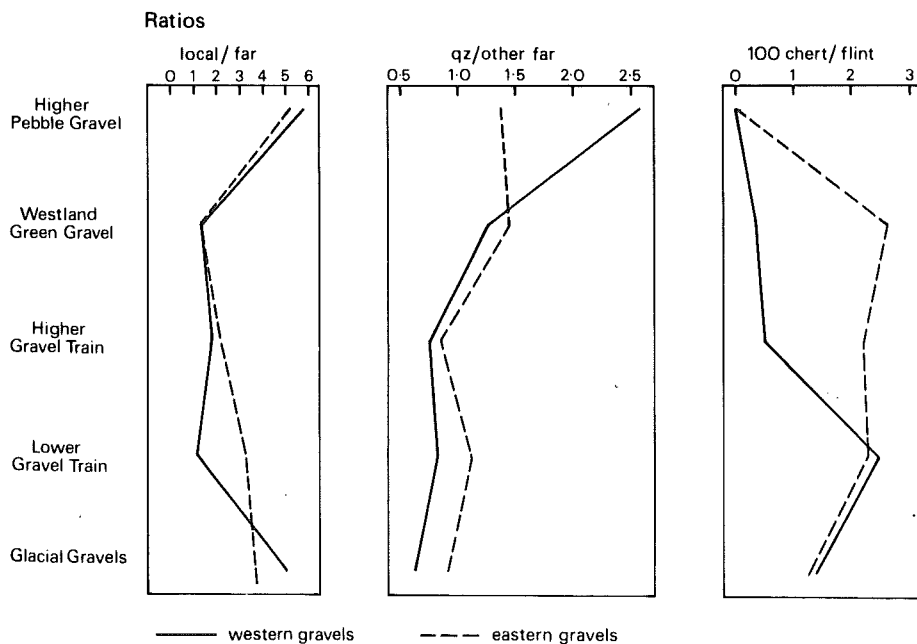
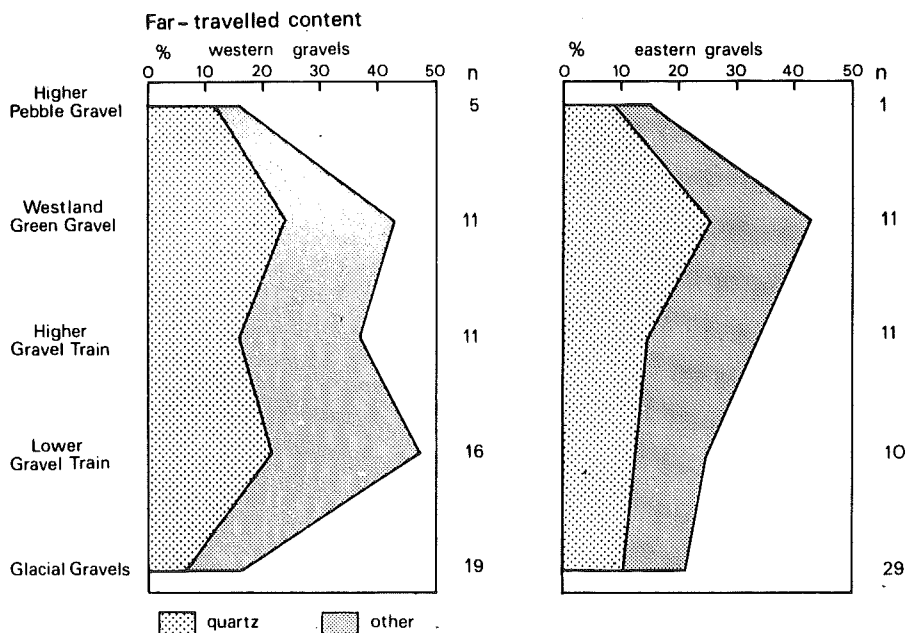


Figure 14. Gravel composition. Samples as in Figs 10 and 11.

Westland Green Gravels (Hey, 1965, 1980): In these gravels far-travelled material appears in larger amounts, forming up to 58.5% of individual samples.

Higher and Lower Gravel Trains: Composition suggests that these depositional stages reflect two further and separate influxes of far-travelled material into the Thames basin.

Anglian Glacial Gravels: In these gravels material of northern and eastern provenance, represented by Rhaxella chert, increases at the expense of components of southern and western provenance. Proximal outwash is distinguished from distal by the inclusion of large amounts of non-durable material - mainly Chalk and limestone pebbles, and derived Jurassic fossils.

The patterns of Thames drainage

The distribution of components in the gravels suggests a number of major changes in the organisation of the proto-Thames drainage system in pre-Anglian times.

In Higher Pebble Gravel times there is no direct evidence for the existence of the Goring Gap, but there are traces of south bank tributaries draining the weald.

In Westland Green Gravel times far-travelled material was obviously entering the Middle Thames area via the Goring Gap. There is however no evidence of downstream modification of gravel characteristics between the Middle Thames and East Anglia. Material may therefore have been reaching the proto-Thames by more than one route across the Chalk escarpment. The separate existence of proto-Mole/Wey, proto-Darent and proto-Medway is suggested by the distribution of Lower Greensand material. Such material is scarce but not absent to the west of the proto-Mole/Wey confluence.

In Higher Gravel Train times downstream modification of gravel characteristics can be traced from the Middle Thames area into southern East Anglia. In Essex, gravels of the Higher Gravel Train lie to the south of the Westland Green Gravels.

In Lower Gravel Train times a pattern of downstream modification of gravel characteristics is clearly established, and for the first time a substantial input of Lower Greensand material occurs to the west of the proto-Mole/Wey confluence apparently along the line of the present Colne valley. In Essex, the Lower Gravel Train Thames has not been traced north of Colchester.

After Lower Gravel Train times there is no evidence of the Thames in Essex, although later gravels of Thames Type (Lower Westmill Gravels of Gibbard, 1977) are found in the Vale of St. Albans passing eastward beneath the chalky till. Diversion of the Thames into the lower Lea valley may be indicated.

Post-formational modification of the Thames terraces

The recognition of structures and materials unrelated to the original floodplain processes of terrace formation is essen-

tial for an understanding of terrace morphology and stratigraphy. Two groups of processes have modified the early terraces of the Thames since their formation: non-fluvial deposition; and subsidence consequent on solution of the Chalk bedrock. Non-fluvial deposits comprise solifluction gravels and brickearths.

Solifluction gravels are usually compact clayey gravels resting on top of sands and gravels of fluvial origin. The junction is usually sharp, and interdigitation has not been seen. As much as 8m of solifluction gravel may be present, but depths of 2 to 3m are more usual, or such deposits may be lacking. Diagnostic structures within the solifluction gravel are not conspicuous. It is often massive, or shows a crude horizontal bedding which marks variations in matrix texture and stone size. Seams and beds of sand or loam are frequent, but evidence in these of deposition from running water is absent. Stone orientation fabrics in solifluction gravels differ significantly from those in river deposits and confirm their different origin (Fig. 41).

The composition of solifluction gravels has been examined (McGregor and Green, 1978), and it has been shown that it is often significantly different from the composition of underlying river gravels. Table 3 shows the mean composition of gravels forming the main depositional stages of the proto-Thames between High Wycombe and Hertford. Table 4 and Fig. 15 show that by comparisons many solifluction gravels contain much larger proportions

N	n	D	Per cent loc	qz	o	Ratio loc/far	qz/f
5	2059	HPG	83.9	11.5	4.6	5.2	2.5
11	3394	WGG	56.9	24.1	19.0	1.3	1.3
11	3475	HGT	63.1	15.9	21.0	1.7	0.8
16	4708	LGT	52.7	21.3	26.0	1.1	0.8
19	4715	AGG	83.8	6.1	10.0	5.2	0.6

n = number of pebbles; N = number of samples; D = depositional stage (HPG-Higher Pebble Gravels; WGG-Westland Green Gravel; HGT-Higher Gravel Train; LGT-Lower Gravel Train; AGG-Anglian Glacial Gravels); loc = local (flint + Lower Greensand); qz = quartz; o = other; far = far-travelled; f = far-travelled other than quartz.

Table 3. Mean gravel composition (% and ratio values) of the main depositional stages of the proto-Thames between High Wycombe and Hertford (Green *et al.*, 1982).

T	n	D'	per cent loc	qz	o	Ratio loc/far	qz/f
102	505	WGG	85.6	6.5	8.6	5.9	0.8
103	514	WGG	85.0	8.2	6.8	5.7	1.2
84	384	HGT	90.4	4.7	4.9	9.4	0.9
85	612	HGT	97.7	0.7	1.7	42.7	0.4
13	167	LGT	74.3	14.4	11.3	2.8	1.3
26	228	LGT	89.5	5.7	4.8	8.5	1.2
43	330	LGT	93.9	2.7	3.4	15.5	0.8

T = sample number.

Table 4. Colluvial gravels with a large bedrock component showing the depositional stage with which they are now associated. Abbreviations as in Table 3.

of local bedrock (flint). Table 5 shows that at some sites, solifluction gravels consist largely of pre-existing superficial deposits transferred downslope without significant change of composition.

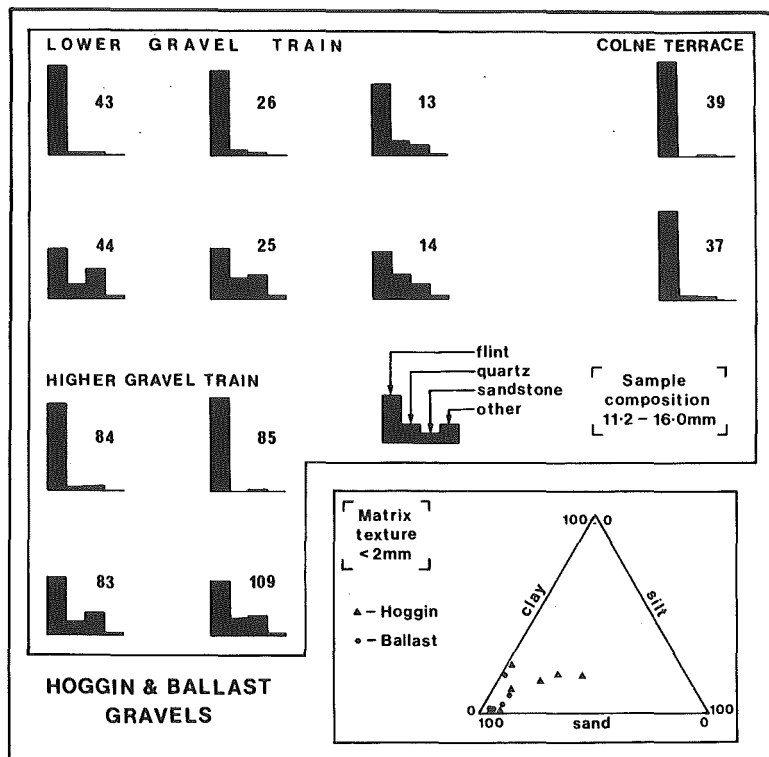


Figure 15. Composition and matrix texture of gravels. Hoggin indicated in the upper histogram of each pair.

T	n	D'	Per cent loc	qz	o	Ratio loc/far	qz/f	D
40	143	HGT	82.5	7.0	10.5	4.7	0.7	HPG
93	307	LGT	88.3	10.7	1.0	7.5	11.0	HPG
110	344	HGT	54.1	25.0	20.9	1.2	1.2	WGG
92	220	LGT	58.6	21.4	20.0	1.4	1.1	WGG
9	213	AGG	59.2	24.9	15.9	1.4	1.7	WGG

Table 5. Displaced river gravels showing the depositional stage with which they are now associated (D') and their original affinity. Abbreviations as in Tables 3 and 4.

Matrix textures also distinguishes between solifluction and river gravels (Fig. 16). The fine component of the river gravels is very sandy. The matrix of solifluction gravel is variable and generally loamy. In addition, solifluction gravel may contain

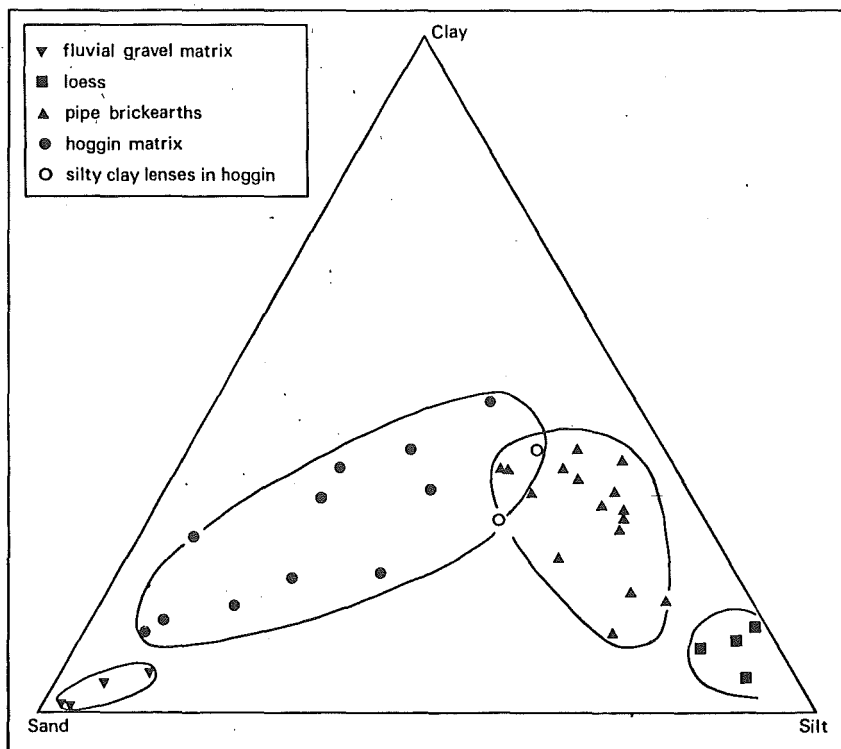


Figure 16. Textural characteristics of sediment types discussed in text.

seams and lenses of brickearth-like material which is seen to fall texturally into a field of overlap between solifluction gravel matrix and brickearth.

The term brickearth has been applied to a wide range of fine-grained deposits used for brickmaking. The main common characteristics are scarcity of stones and substantial proportion of silt. On the older terraces of the Thames, brickearth is found in two main situations, either as a discontinuous surface layer, or in pipes that penetrate the terrace deposits. Brickearths are often massive, but may be laminated or show evidence of reworking. Where they occur in solution pipes, catenary structures are often visible, marked by stonelines or variations of colour or texture. Texturally brickearths are mainly silty clay loams tending towards silt loams (Fig. 16). They correspond closely with deposits described by Avery *et al.* (1982), who regard them as mixtures of Tertiary Reading Beds with reworked loess.

Beneath the older terraces of the Thames, terrace deposits have in many places subsided into the Chalk in steep-sided pipes. At the surface such pipes are usually circular in plan, and range in diameter from 1 or 2m to more than 12m across. The relationship of the pipes to the terrace deposits is not uniform.

Pipes can be grouped into three classes (Fig. 17).

1. Truncated pipes beneath terrace deposits.
2. Truncated pipes in river deposits beneath solifluction gravel.
3. Pipes extending to the ground surface through river and solifluction deposits.

Structural disturbance associated with individual pipes may extend over an area with a diameter of up to 100m. Within this area, vertical faults occur, sediments are separated by slip planes, and may be intensely disturbed.

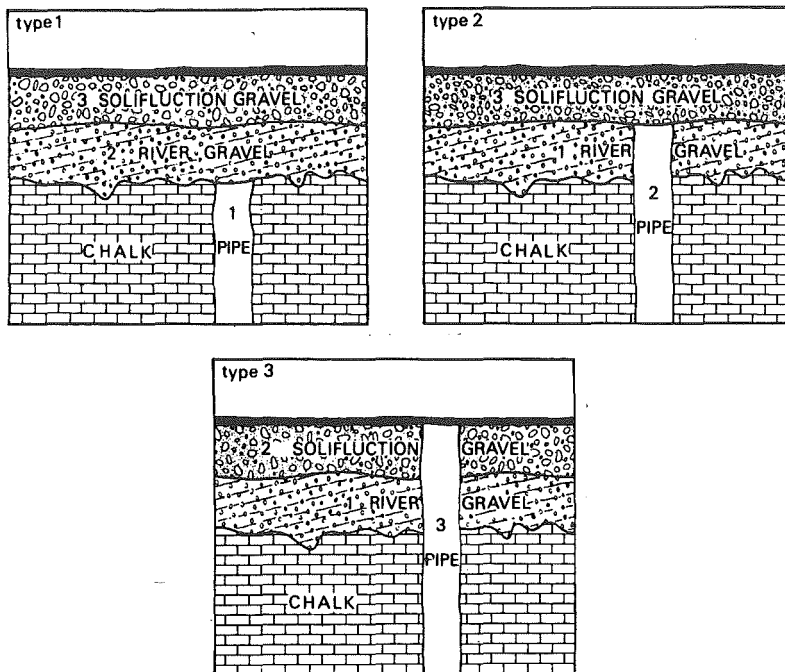


Figure 17. Possible stratigraphical relationships of solution pipes. For explanation see text.

Features typically encountered in the early terrace deposits of the Thames are illustrated schematically in Fig. 18. The following scheme of development may be traced.

1. Deposition of river gravel on an erosional bench.
2. Deposition of solifluction gravel on terrace.
- 3-6. Deposition of loess/formation of solution pipe.

The developing pipe incorporates river deposits (a) and solifluction gravel (2a) and a succession of loess deposits (3-6). Avery et al. (1982) show that heavy mineral assemblages typical of Anglian, Wolstonian and Devensian loess are present in the Chiltern brickearths.

7. Periglacial disturbance of upper horizons of solifluction gravel and any overlying patches of brickearth.
8. Reworking of surface layers.

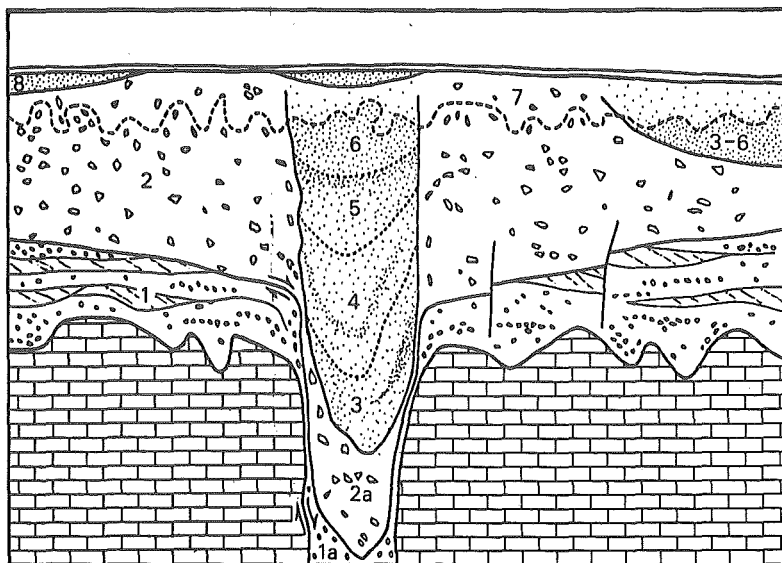


Figure 18. Post-depositional modification of terrace deposits. This shows an idealised sequence. For explanation see text.

The re-examination of the superficial geology of the Chiltern dip slope, described in the preceding paragraphs makes possible a re-evaluation of the enigmatic Chiltern Drift. The term was first applied by Wooldridge (1938) to supposed till occurring at relatively high levels (Fig. 19) on the Chilterns dip slope. Till-like structures were described in deposits at Mardley Heath by Wooldridge and Cornwall (1964), while as early as 1919, Barrow suggested a glacial tectonic explanation for thrust-like structures at Cowcroft.

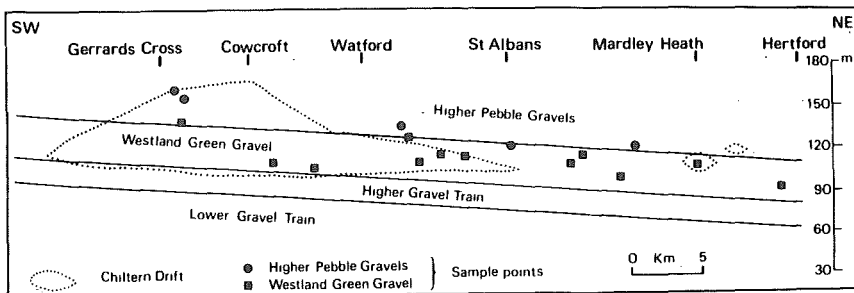


Figure 19. Chiltern Drift in relation to schematic terrace profiles.

Figure 19 shows that the height range of the Chiltern Drift as mapped by Wooldridge and Linton (1955) coincides with the height range of the Higher Pebble Gravels and Westland Green Gravels. All gravels within the main Chiltern Drift envelope, analysed during the investigations described here have Higher Pebble Gravel or Westland Green Gravel characteristics. At Mardley Heath, the deposits appear to be an association of brickearth and solifluction gravel (Table 4, T102, T103). Structures within the Chiltern Drift are similar to subsidence structures seen at Gerrards Cross, and it is not necessary to invoke glacial processes to explain their origin.

In an article in the 'Shaping of Southern England' edited by D.K.C. Jones (1980), Colin Baker and David Jones proposed a history of glaciation and Thames diversion based on Baker's fieldwork in the region around Harlow and Saffron Walden. The following is a summary of these views giving emphasis to the sediments in the area and the main elements of the interaction between glaciation and river development. The ages proposed for these events, which are different from those given elsewhere in this guide, are also listed.

GLACIATION AND THAMES DIVERSION IN THE MID-ESSEX DEPRESSION

by C.A. Baker.

Introduction

Whilst great progress has been made in recent years in deciphering the sedimentary sequences of Hertfordshire and Mid-Essex and the Essex-Suffolk border, doubts still linger about the intermediate ground of West Essex and the probable proto-Thames course east of Ware. Obscured by up to 35 metres of chalky till, the area between Harlow and Chelmsford affords few exposures of 'stratified drift'. Furthermore, the critical ground of the lower Lea valley has lost its glacial imprint through considerable postglacial erosion.

North of Hoddesdon, the confined valleys of the glaciated Chiltern dip slope first converge and then broaden out into the open aspect of the lower Lea. This particular valley is remarkable for its width and well-preserved terraces. It is a discordant valley in respect of the synclinal structure which links Hampstead Heath to Epping Forest. A misfit river in appearance, the lower Lea also does not fit comfortably into our various models of drainage evolution for the lower Thames. It demands explanation. An early hypothesis (Hawkins, 1923) postulated that the Pleistocene Thames flowed "up the Colne and down the Lea". Sherlock (unpublished; Wooldridge and Linton, 1955) originally concurred with Hawkins, but later abandoned the idea in favour of a more northerly route (Sherlock, 1924). Whereas Hawkins considered the Lea route to be 'pre-glacial'. This contribution inclines to the view that it was formed in mid-Anglian time, and occupied briefly but significantly by the combined force of glacial outwash and diverted Thames. In the regrettable absence of direct stratigraphic evidence in the lower Lea, four lines of circumstantial evidence have to be advanced in support of such a hypothesis.

Chronological difficulties

According to Gibbard (1977) the continuous passage of the proto-Thames through the Vale of St. Albans persisted until the Westmill Upper Gravel stage. Gibbard (1979) has further shown that the Finchley depression was almost certainly occupied by the proto-Mole-Wey, on the evidence of the Dollis Hill Gravels. The implications of these reconstructions, as clearly stated by Gibbard (1979) is that the proto-Thames flowed eastwards of

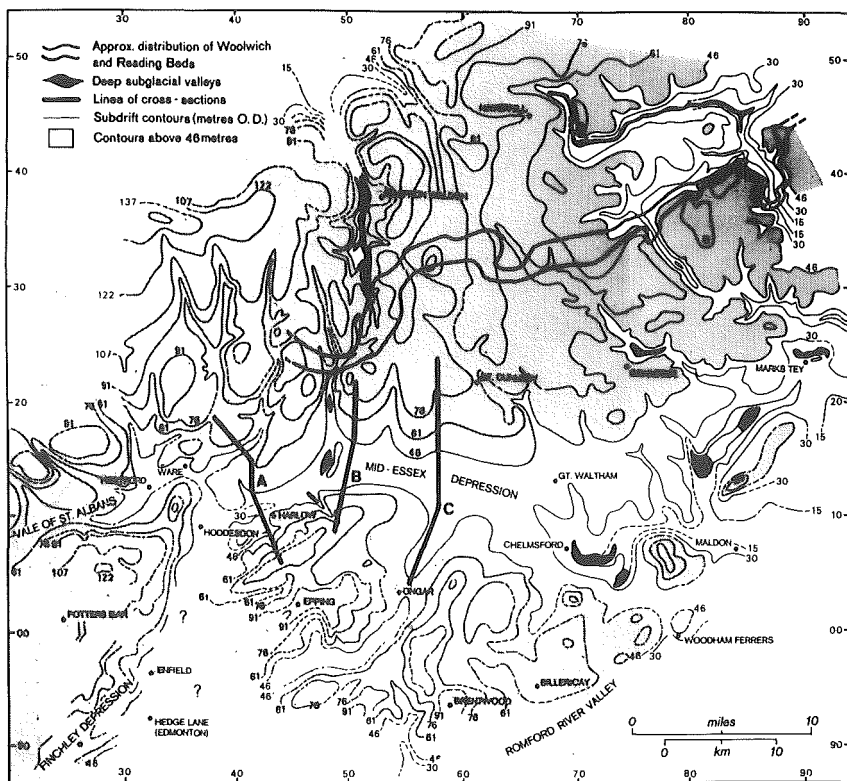


Figure 20. Contour map of the sub-drift surface in east Hertfordshire and Essex.

by the pro-Mole-Wey, on the evidence of the Dollis Hill Gravels. The implication of these reconstructions, as clearly stated by Gibbard (1979) is that the proto-Thames flowed eastwards of Ware into the mid-Essex depression in the Anglian stage, and that at that time the "Lower Thames valley did not then exist". The post-diversion course can only be traced along the present Lower Thames valley in the Black Park Terrace.

Further to the east, in mid-Essex and the Essex-Suffolk border, the course of the proto-Thames has been examined by Rose *et al.*, (1976). The Kesgrave Sands and Gravels beneath chalky till, occupy much of Essex and southeast Suffolk and partially infill the mid-Essex depression. These deposits were considered to have been laid down as a series of terraces under periglacial conditions in the Beestonian stage, prior to the Cromerian Interglacial. A north-eastward flowing major river was indicated, migrating progressively south-eastwards. By the Cromerian, the river, according to Rose *et al.*, (1976) must have adopted a route south and east of a line from Chelmsford to Colchester. This conclusion is somewhat difficult to reconcile with Gibbard's (1979) view which has a mid-Essex route as late as

the Westmill Gravel phase as the mid-Essex depression runs unequivocally north of Chelmsford. Three possible explanations might be considered. Firstly, the proto-Thames "migrated" southwards by a non-glacial mechanism (e.g. river capture), precluding the need for a glacial diversion hypothesis. We must conclude then that 35 metres of chalky till were emplaced in an all but vacant depression, abandoned by the Thames long before the Anglian stage. Secondly, the diversion was indeed glacial, but took place in partial stages; the mid-Essex route need not have been abandoned at the same time as the Vale of St. Albans. Thirdly, a revised date for the Kesgrave Sands and Gravels could be considered. Indeed some stratigraphers are of the opinion that these sediments constitute glacial outwash of Anglian age (Allender and Hollyer, 1973; Bristow and Cox, 1973; Baker, 1977; discussions in Rose *et al.*, 1978a, 1978b). The considerable height range of the Kesgrave Formation and the large volume of sediment involved suggests a glacifluvial origin, rather than a fluvial terrace laid down under periglacial conditions (Baker, 1977; Green, in Rose *et al.*, 1978a). Much hinges on the environmental significance attached to the Valley Farm palaeosol. Divergence of opinion on the chronology of the pre-chalky till drifts is summarised in Table 6.

Stage	Sediments and palaeosols in Essex and W. Suffolk	
	After Rose <i>et al.</i> (1976)	Alternative chronology
Anglian	Lowestoft Till (glacial)	Lowestoft Till (glacial)
	Barham Sands and Gravels (fluvio-glacial)	Barham Sands and Gravels (fluvio-glacial)
	Barham Loess (periglacial)	Barham Loess (periglacial)
		Valley Farm Rubified Sol Lessivé (interstadial)
		Kesgrave Sands and Gravels (fluvio-glacial)
Cromerian	Valley Farm Rubified Sol Lessivé (interglacial)	
Beestonian	Kesgrave Sands and Gravels (periglacial)	

Table 6. Sediments and palaeosols in Essex and west Suffolk.

The Mid-Essex Depression

Weak though the evidence may seem, the morphological form of the sub-drift surface provides further circumstantial evidence. The form of the surface (Fig. 20) is believed to broadly approximate to the pre-Anglian topography, though interpretation of the surface can be misleading (Baker and Jones, 1980).

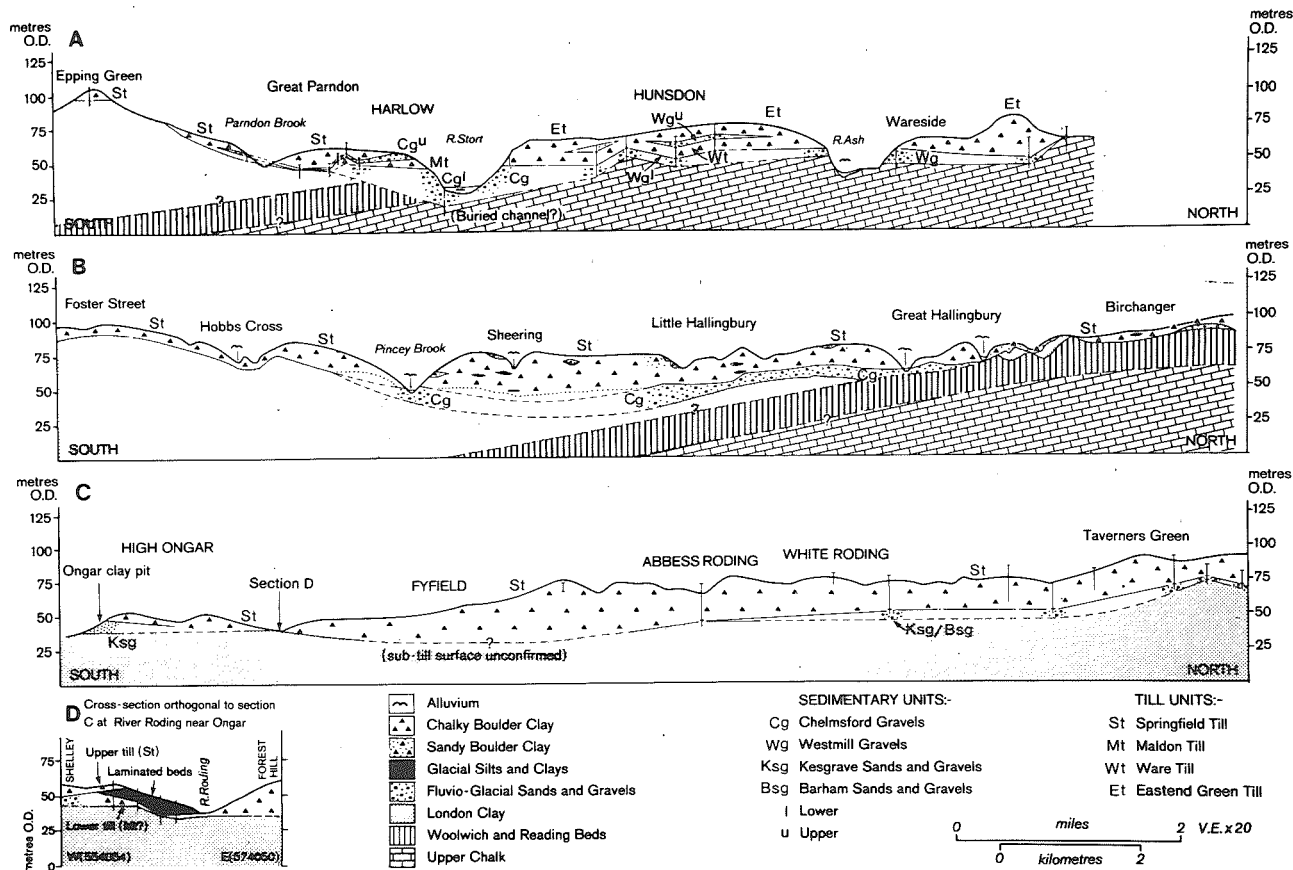


Figure 21. Sections across the Mid-Essex Depression. For locations see fig .

The mid-Essex depression (Fig. 20) is a notable west-east trough which cuts diagonally across the structural grain of the Tertiary rocks. Near Hertford bedrock surfaces lie at about 50m and decline progressively eastwards to 46m at Harlow, 40m at The Rodings and 30m around Chelmsford. At the 61m level, the depression broadens eastwards from 3.5km at Hertford, to 5.5km at Harlow, 7km in the Pincey Brook area, 11km in The Rodings and 19km through Chelmsford. The depression is buried beneath up to 35m of chalky till, and up to 11m of stratified sands and gravels. Tributary valleys enter the depression from both north and south. There seems little doubt, therefore, that a major river (the proto-Thames) occupied this route at a pre-diversion stage. To the south, the sub-drift surface rises to a watershed of about 91m between Epping and Brentwood. From Brentwood, the surface falls rapidly to less than 24m at Hornchurch and 30m at Woodham Ferrers. A second and more southerly valley is implied, and to this Holmes (1892) applied the term "Romford River" valley. The origin of this is far from clear as it could be correlated with the proto-Thames in mid-Essex, the downstream route of a partially-diverted Thames, or perhaps the track of the proto-Darent.

The sub-drift surface is dissected along all principal river valleys (Fig. 20) showing that much of the relief is, at least in the local sense, pre-glacial (i.e. pre-Anglian). Glacial overdeepening is evident in many of these (Rib, Ash, Upper Cam, Stort, Chelmer, Upper Stour, Blackwater) indicating that sub-glacial meltwater paths were largely controlled and directed by these palaeodrainage lines. The Stort valley, with its deep sub-glacial elements, is particularly noteworthy, directed as it is south-westwards into the lower Lea, rather than south-eastwards into the mid-Essex depression.

North-south cross-sections across the depression reveal the main morphological and stratigraphic relationships (Fig. 21). A significant section (Section D, Fig. 21) lies in the Roding valley north of Ongar, where drainage reversal is strikingly evident. Proglacial lacustrine sediments here suggest a former watershed between Epping and Brentwood of at least 62m elevation. The proglacial lake was subsequently overridden by ice and covered by thick chalky till, and the middle section of the Roding was reversed. This site provides strong confirmation of the independent catchment of the mid-Essex depression.

Stratified deposits in the Mid-Essex Depression

The broad nature and distribution of the stratified drifts at the solid-drift interface is mapped in Fig. 22. While the higher margins of the depression are drift-free, the central trough is seen to contain up to 11m of sands and gravels, though 4-6m is more typical. These consist of various units - the Westmill Gravels (Upper and Lower), the Chelmsford Gravels (Upper and Lower), the Kesgrave Sands and Gravels, and the Barham Sands and Gravels. The lowest units are sometimes overlain by thin lower tills (the Ware Till of Gibbard (1977), or the Maldon Till of Clayton (1957).

It is likely that the lowest units of sand and gravel would show palaeocurrents consistent with a continuous eastward passage (the Westmill Lower Gravel phase). In the upper Cam-Stort watershed, detailed drift mapping has revealed the pre-

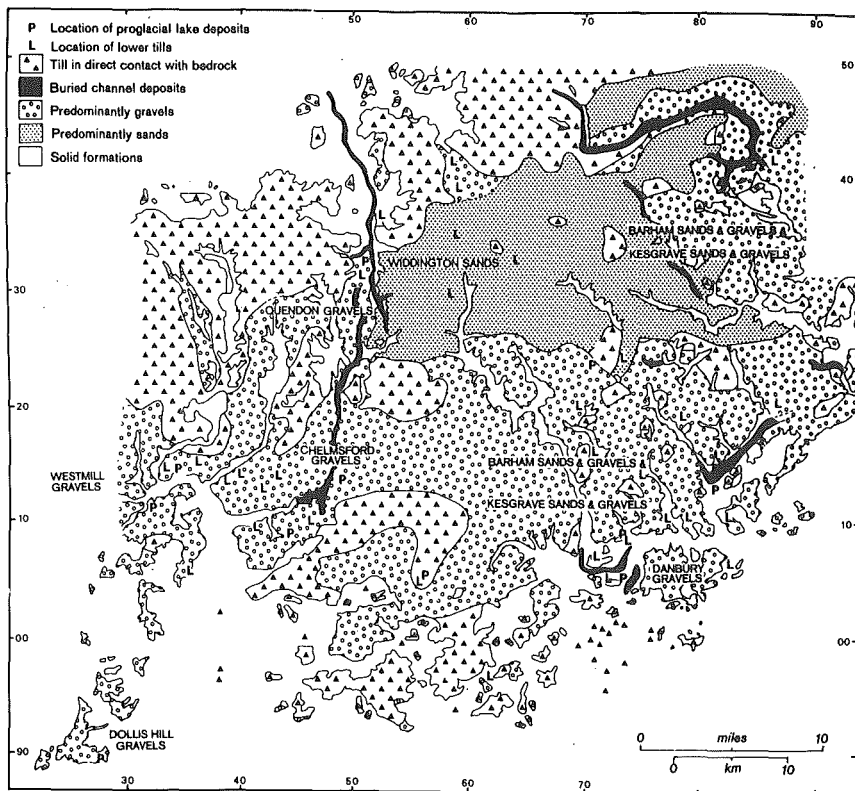


Figure 22. The nature of the basal drift unit at the solid-drift interface (area as for fig. 20)

sence of two distinct outwash formations (Baker, 1976, 1977) - the Widdington Sands and the Quendon Gravels. The older (Widdington Sands) consist of up to 13m of well-sorted, cross-bedded sands, culminating in a rubified palaeosol and leached coversand. Their correlation with the Kesgrave Sands and Gravels (Rose *et al.*, 1976) seems likely. The distribution of Widdington-type sands (Fig. 22) suggests that they are continuous and widespread to the east and south-east of the upper Cam, consistent with their preferential direction southeastwards into the Chelmer valley. This interpretation is consonant with Rose *et al.*, (1976) in so far as their work suggests an eastward-flowing proto-Thames in the mid-Essex depression at the Kesgrave phase, but is in disagreement, however, with their chronology for the Kesgrave Formation. We prefer to regard it, at least in part, as early Anglian in age and glacifluvial in character.

The younger formation in the upper Cam (Quendon Gravels) consists of medium to coarse-grained, poorly-sorted gravels (5m to 24m thick) with a coarsening sequence upwards and an irregular gravel-till contact. There seems little doubt that this repre-

sents high-energy proximal outwash emanating from the advancing ice-sheet. A close parallel with the Barham Sands and Gravels is thus evident. The distribution of Quendon-type gravels (Fig. 22). is confined to the west of the upper Cam, as if preferentially directed south-westwards into the Ash and southwards into the Stort. From Bishop's Stortford, outwash gravels are directed south-westwards in sympathy with the sub-drift contours and the alignment of the buried channel. At Harlow, these gravels were identified by Clayton as Upper Chelmsford Gravels (Fig. 22), and these would appear to correlate with the Westmill Upper Gravels at Hertford. These considerations imply that the lower Lea valley was open at this stage, allowing free passage for outwash, and that the mid-Essex depression had been abandoned. Palaeocurrent analyses of upper and lower gravel units at Harlow would provide valuable data to confirm or modify this belief.

The Lower Till

At Ware and Harlow, the basal gravels are overlain by a lower till - the Ware Till and Maldon Till respectively. A similar succession occurs in the intervening Ash-Stort watershed (Fig. 21), apparently confirming the correlation. Some stratigraphers attach little significance to these lower tills, preferring to regard them as products of ephemeral fluctuations in the position of the Anglian ice-sheet. It should be noted, however, that appreciable thicknesses of lower tills are recorded throughout Essex and east Hertfordshire separated from the main chalky till sheet by up to 13m of stratified sediments. The concentration of lower till units in the Harlow-Hunsdon-Ware area is a notable feature (Figs. 21 & 22), and the most southerly occurrence of lower till is at Hoddesdon, 9km south of Ware. Exposures of lower till are not good, but a temporary exposure at Quendon allowed fabric analysis which showed a north-west to south-east trend with high vector magnitudes and strong up-glacier dip. This is markedly different from fabrics in the upper till body (Baker, 1976), but accords with the general direction of ice movement detected in the Ware Till around Hertford (West and Donner, 1956; Gibbard, 1977).

Data are too scarce at present to confirm a separate and widespread ice advance prior to the main Anglian advance; the duration of time between the two tills is debatable. However, it is clear from these considerations, that the ice front was oscillatory, and may well have occupied the mid-Essex depression on more than one occasion. Consequently the events surrounding drainage diversion in and around the mid-Essex depression must have been anything but simple.

Synthesis

As a working hypothesis, we may envisage a double deflection model (Fig. 23). In Fig. 23A, the proto-Thames is shown as having excavated the mid-Essex depression at the Lower Gravel Train stage; the depression was separated from a "Romford River" valley by a watershed connecting Hampstead, Epping and Brentwood. At the early Anglian stage (Fig. 23B) the Thames catchment came under the influence of advancing ice; the Widdington Sands and Kesgrave Sands and Gravels were laid down. At the mid-Anglian stage (Fig. 23C), an ice advance blocked the mid-Essex route and deposited lower tills; the proto-Thames was partially diverted,

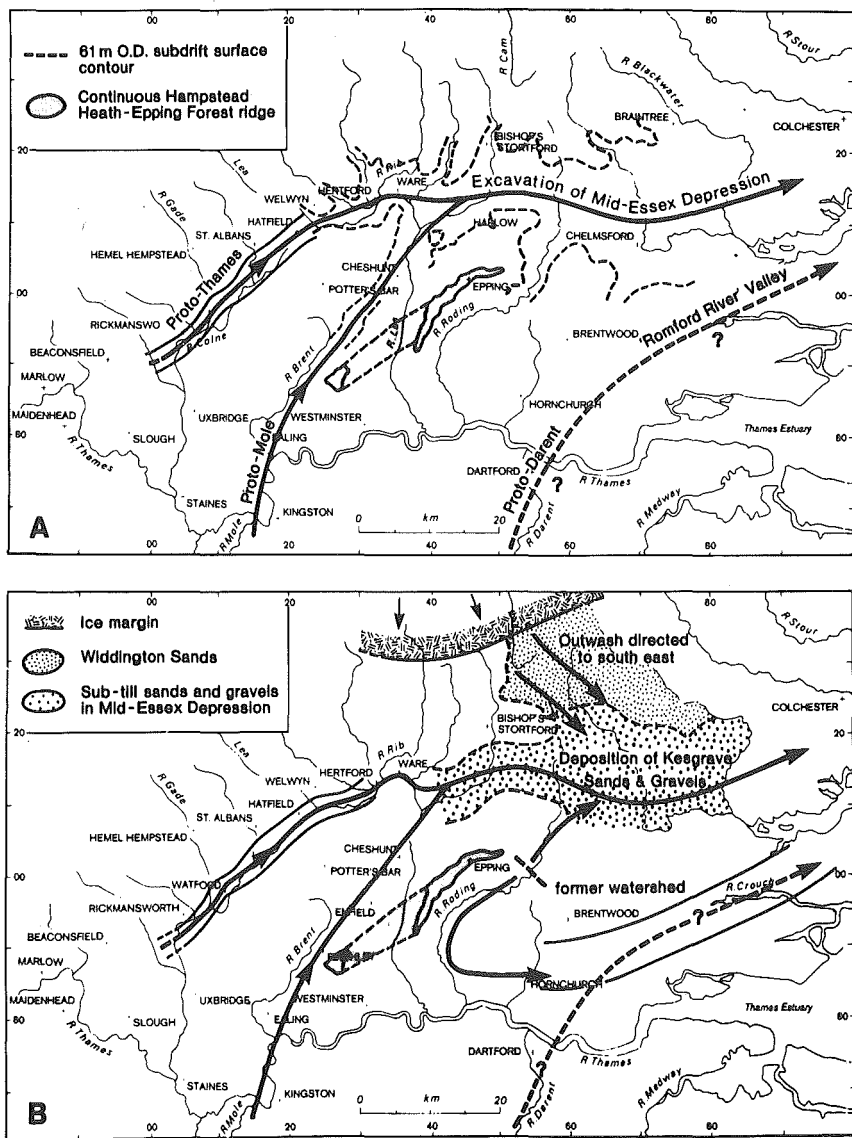


Figure 23. Evolution of the Thames and Lea drainage systems.

A) Lower Gravel Train stage (early Anglian).

B) First ice advance (early stage): Westmill Lower Gravel, Dollis Hill Gravel, Lower Chelmsford Gravels, Widdington Sands, Kesgrave Sands and Gravels (Anglian)

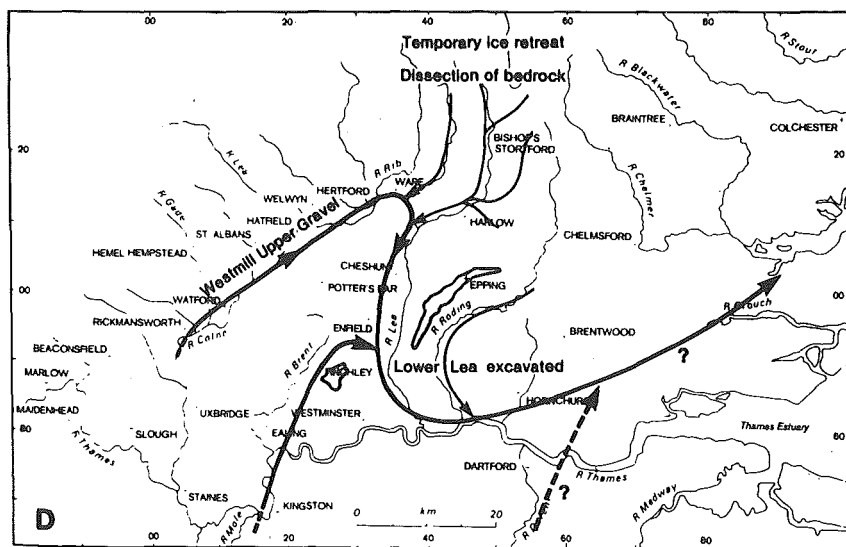
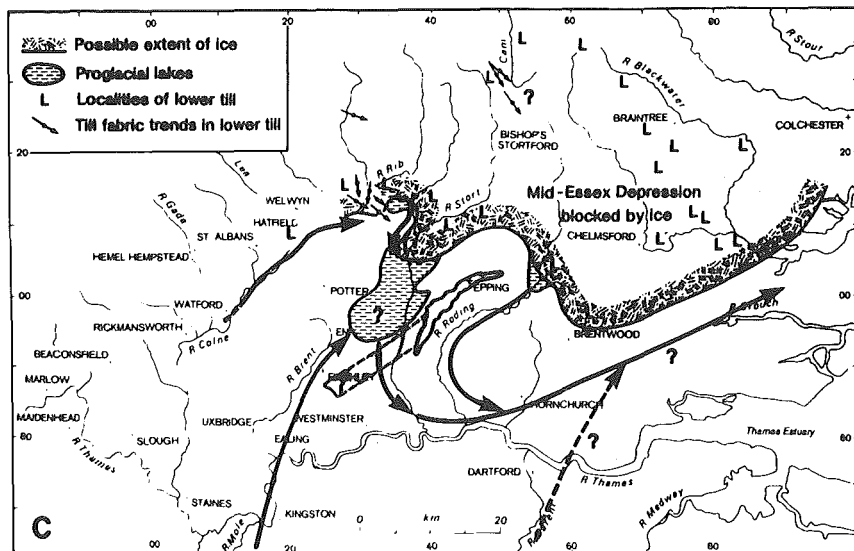


Figure 23 continued.

C) First ice advance (late stage): Quendon Till, Maldon Till, Ware Till, Watton Road Silts, Ongar Laminated Clays (Anglian).

D) Temporary ice retreat: Westmill Upper Gravel (Anglian).

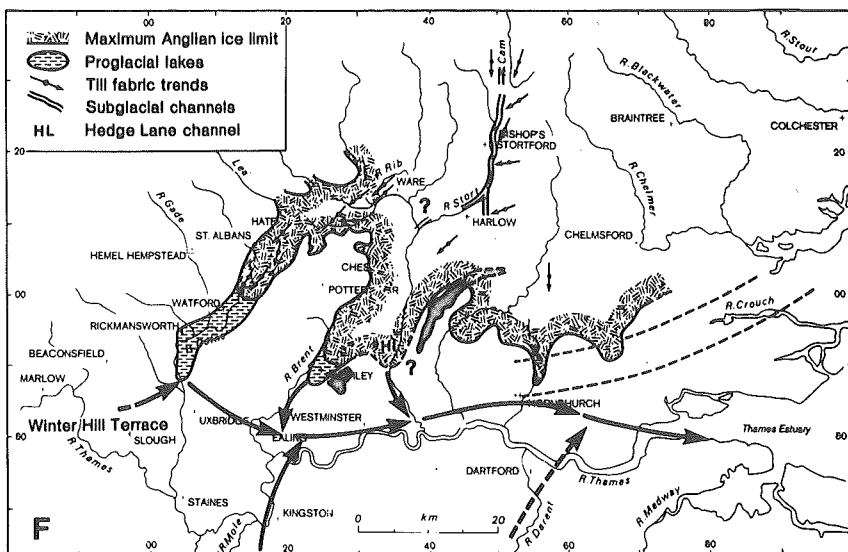
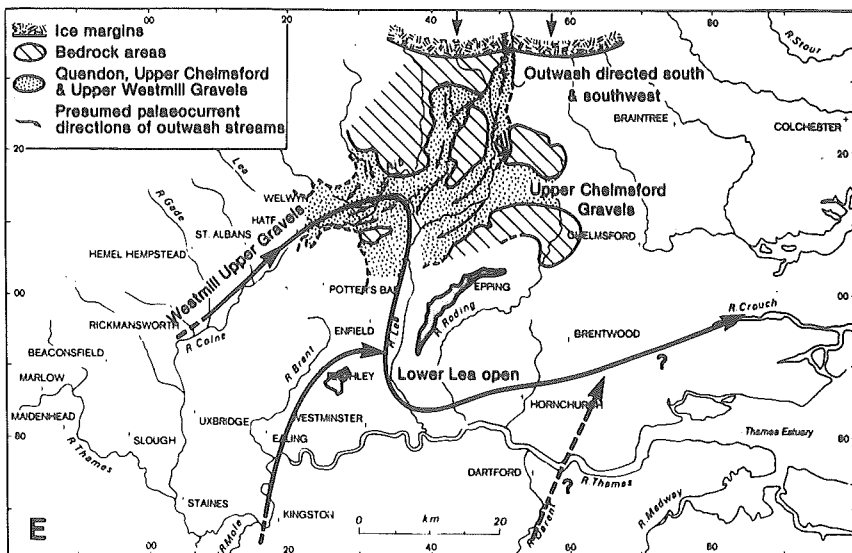


Figure 23 continued.

E) Second ice advance (early stage): Quendon Gravels, Upper Chelmsford Gravels, Westmill Upper Gravels (Anglian).

F) Second ice advance (late stage): Widdington Till, Eastend Green Till, Finchley Till, Moor Mill Laminated Clay, Coldfall Wood Laminated Clay, Winter Hill Terrace (Anglian).

from the mid-Essex depression, but not from the Vale of St. Albans. At this stage also, the Hampstead-Epping ridge was breached and the lower Lea valley initiated. This position was consolidated in a period of ice retreat (Fig.23D). In the late Anglian stage (Fig.23E) ice readvanced, depositing first outwash of Quendon/Barham type, and second (Fig.23F) chalky till. This major ice advance expelled the proto-Thames finally from the Vale of St. Albans, the lower Lea and the 'Romford River' valley. This stage was by the Black Park Terrace route.

TILL LITHOLOGY IN HERTFORDSHIRE AND WEST ESSEX

by D.A. Cheshire

Introduction

These results are part of on-going research project and this contribution should only be considered as an interim report, which may be modified at a later date. The work is based on 142 samples from 37 sites in the Lea basin and adjacent areas, which have been analysed for particle size distribution and lithological composition. Although the work is incomplete some apparently significant patterns have emerged concerning the distribution of recognizable till types.

It is convenient to regard Westmill as a key site for several reasons: (i) it is the stratotype of Ware Till, the Westmill Lower Gravel and the Westmill Upper Gravel (Gibbard, 1977), (ii) it possesses a more complete and better exposed stratigraphy than any pit currently being worked in the area, and (iii) it lies in the general confluence area of sediments derived from the south-west, south and north. At present three parameters, particle size, solubility in hydrochloric acid and small clast lithology have been examined for the Ware Till and upper till at Westmill, and these results form the basis of comparisons with other tills in the area. It has been shown that fabrics in the same till vary widely over distances of several kilometres (Gibbard, 1977), partly as a glacial response to local palaeorelief (Cheshire, 1981). Hence fabric observations, unless spaced at intervals of less than the palaeorelief amplitude, can not form a satisfactory basis for till correlation.

Particle size distribution

Distinct patterns emerge in non-cumulative particle size characteristics if Figs. 63 and 68 of the Westmill description are compared. These signatures may be identified in exposures of till throughout the area, sometimes with modified modal amplitudes, but in each case the internal consistency of the distribution remains approximately constant. The areal distribution of tills which may be associated on grounds of particle size are shown in Fig. 24, where three zones may be identified. It must be emphasised that the lines separating each zone have no precise significance, and will alter in the light of further results. An approximate ice margin is shown, beyond which no till has been identified. In Zone I tills of a Ware Till type occur either at the surface, or shallowly buried but with no till conforming to the upper till at Westmill above them. This zone, the most southerly of the three, includes the Tills of Vale of St. Albans southwest of Welwyn Garden City, Bayfordbury (southwest of Hertford), Potters Bar, Northaw Great Wood the lower Lea valley near Cheshunt, and all the M25 sections south of Epping. In Zone III only tills conforming to the upper till at Westmill are found. Within the area of Zone III (Fig. 24) no Ware Till type is found, probably as the result of the absence of deep exposures. However, further north-east at Ingham and Acton in Suffolk, and at Coggeshall in Essex,

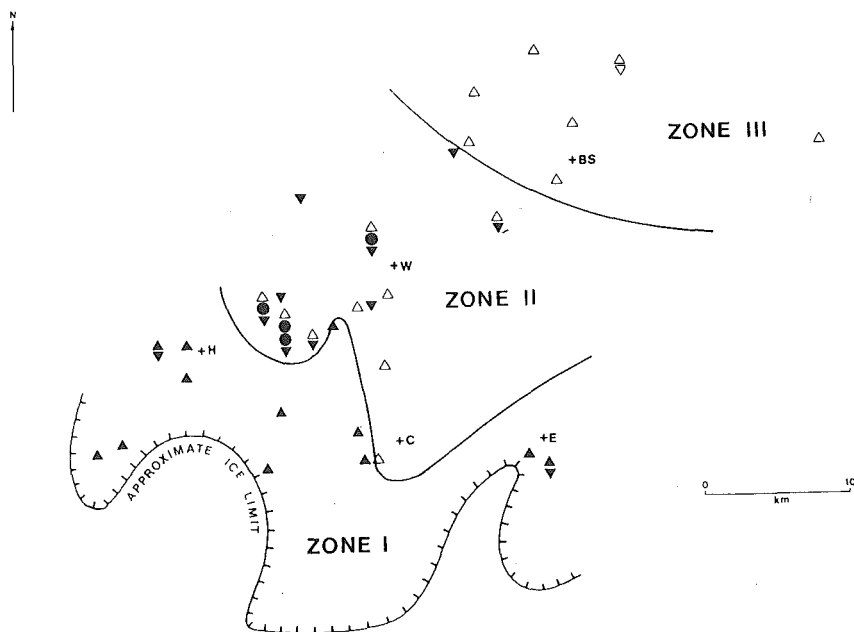


Figure 24. Areal distribution and stratigraphic position of till types identified by particle size analysis. Black symbols: Ware Till type, white symbols: upper till type. Triangles on base: uppermost till in succession (often at surface), triangles on apex: lowermost till in succession. Circles: middle tills. Towns: BS: Bishop's Stortford, C: Cheshunt, E: Epping, H: Hatfield, W: Ware.

the Ware Till type is observed. In the intervening Zone II tills of both types occur, Ware Till particle size types always lie below those conforming to the upper till at Westmill. At Holwell Hyde and Holwell Court the Upper Westmill till directly overlies the Ware till. At Bunkers Hill, Foxholes, Westmill and Hadham Towers, they are separated by sand and gravel. The relationships can only be established by stratigraphic extrapolation. Watton Railway Station, where erosion and quarrying respectively have removed the Group B till.

Solubility in hydrochloric acid

Data produced from the solubility determinations (using 1N HCl) demonstrate that in the range +1 to +40 the insolubles dominate the solubles totally in both groups of till. The discriminating range, in which differentiation between till types is possible, is -2.50 to +10. Soluble percentages in this fraction range from 13.0% at Moor Hill, near Harper Lane, to 86.2% Little Dunmow, Essex. When all tills in the area are considered, the acid soluble proportion in this fraction is seen to be divided into two overlapping populations, with the intermodal overlap

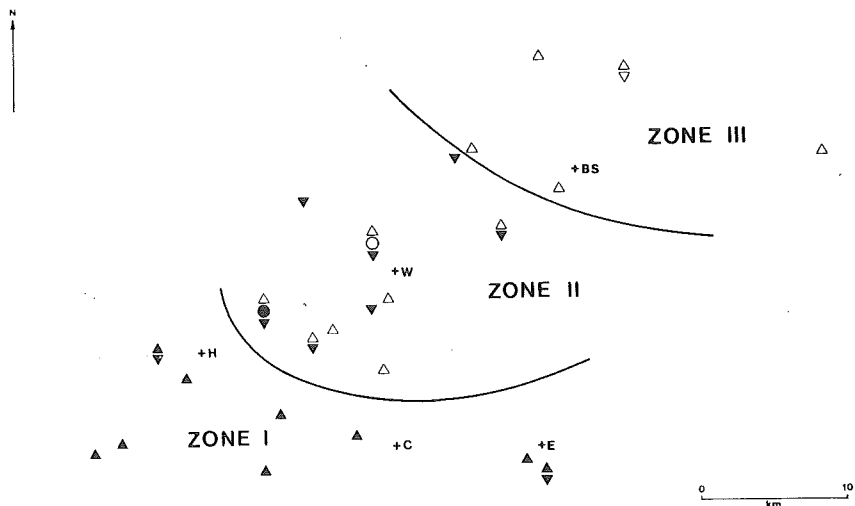


Figure 25. Areal distribution and stratigraphic position of till types identified by solubility in the -2.50 to +1.0 fraction. Black symbols: Ware Till type, white symbols: upper till type. Triangles on base: uppermost till in succession (often at surface), triangles on apex: lowermost till in succession. Circles: middle tills. Towns: as Fig. 24.

occurring at 63% acid-soluble. The Ware Till falls into the lower solubility mode, while the upper till at Westmill occurs in the higher solubility mode.

In Fig. 25 the areal distribution and stratigraphic position of tills discriminated solely by acid solubility is shown. Three zones emerge. In Zone I tills of low solubility (Ware Till type) lie either at the surface, or shallowly buried but with no other tills above them. In Zone III only tills of high solubility (upper till, Westmill type) are found, while in Zone II the low solubility tills lie below high solubility tills, in a manner identical to that displayed by particle size discrimination.

Small clast lithology

The main emphasis in interpreting the patterns of lithologies in the -2.0 to +1.50 fraction has been to employ the ratio between quartz and flint. The selection of these components results from their presence in sufficiently large quantities to give statistically reliable and reproducible ratios. The proportions of other major components, such as pyrites, nodules of various iron oxides, loosely bonded shales, are not sufficiently stable to justify comparison between sites with very different conditions of exposure to weathering and other processes.

The quartz: flint ratios for the Ware Till and upper till at Westmill are shown comparatively in Fig. 26. The Ware Till is seen to possess a greater spread of values compared with

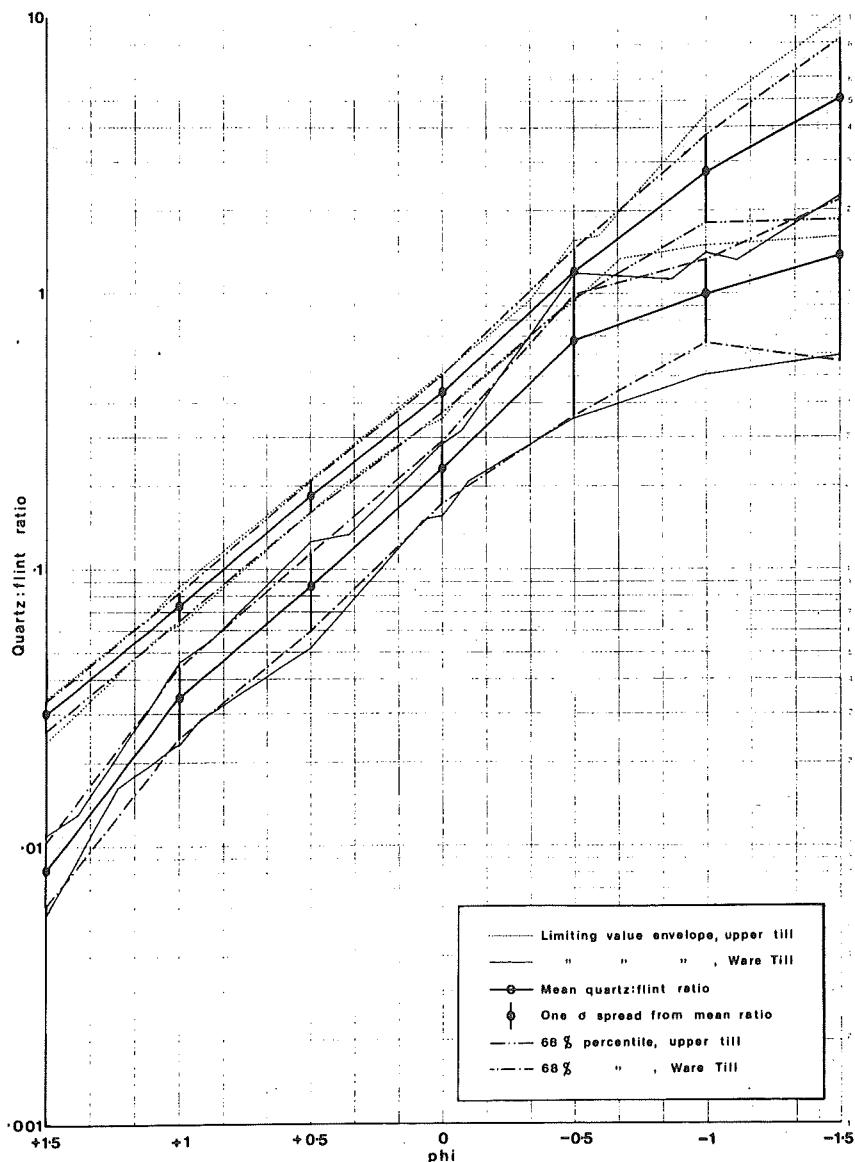


Figure 26. Comparative properties of the quartz: flint ratio of the Ware Till and upper till at Westmill.

the upper till, which has a remarkable uniformity of quartz to flint. The mean ratio for each 0.50 class in the Ware Till is consistently lower by a factor of between 1.8 and 3.7, with a mean value of 2.6. That is, the upper till contains on average 2.6

times the flint of the Ware Till with respect to quartz. Fig. 26 compares the means, standard deviation, 68% percentiles and limiting value envelopes for the samples studied at Westmill. It can be seen that the ratio bands are largely discrete, with small overlaps in the two 0.50 classes only.

Tills from other sites are plotted against the Westmill data, and can be correlated with the Ware Till or the upper till at Westmill. The areal distribution and stratigraphic position of tills discriminated by quartz: flint ratio is shown in Fig. 27.

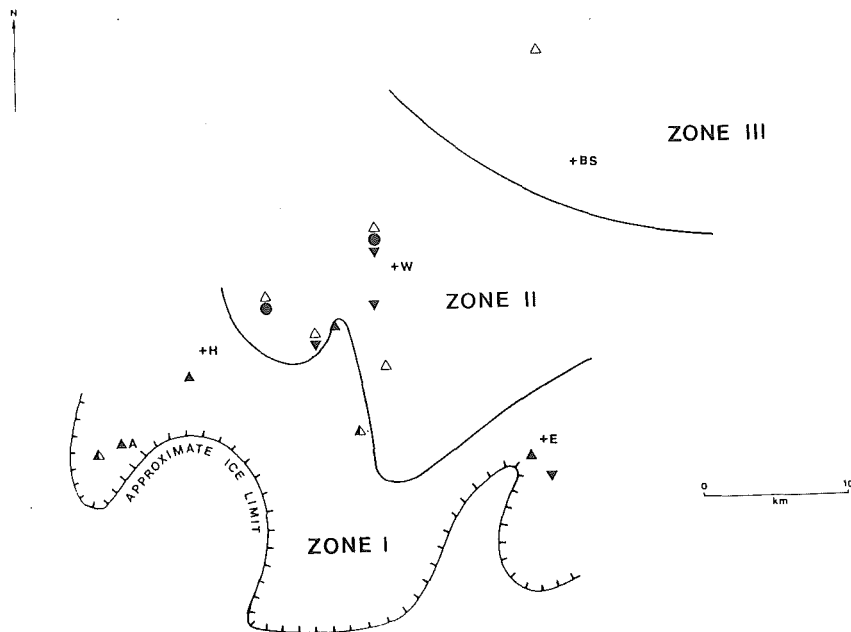


Figure 27. Areal distribution and stratigraphic position of till types identified by quartz: flint ratios in the -2ϕ to $+1.5\phi$ fraction. Black symbols: Ware Till type, white symbols: upper till type, black/white symbols: indeterminable type. Triangles on base: uppermost tills in succession (often at surface), triangles on apex: lowermost tills in succession. Circles: middle tills. A: anomalous result at Harper Lane. Towns: as Fig. 24.

In only two cases has no clear correlation proved possible. These are at Moor Mill (near Harper Lane) and Goffs Lane, Goffs Oak. At the latter site the till is not demonstrably *in situ*. An anomalous result was obtained for Harper Lane, sample HL4, which is discussed in the Harper Lane site report in this Guide.

Comment

When comparing the areal and stratigraphic distribution of till types it should be born in mind that spatial resolu-

tion reflects the density of samples analysed, which is greatest for particle size and least for small clast lithology. Of the 59 samples common to particle size and acid solubility parameters, 56 are in agreement. The exceptions are Bayfordbury, the middle till at Westmill and Coggeshall, Essex. These three have over 63%, but not more than 68.3% acid solubles, and occupy the inter-modal overlap range. It is the Bayfordbury case which causes the northward swing in the Zone I/II boundary in Fig. 24, but not in Fig. 25. Of the 33 samples analysed for small clast lithology, 29 are in agreement with particle size characteristics. The exceptions are at Moor Mill and Goffs Lane where the quartz:flint ratios fall partially between the 68 percentiles, and sample HL4 at Harper Lane, which has been noted as in many respects anomalous.

Interpretation

Zones I, II and III, though very approximately delineated, indicate a generally northeast-southwest transgression from zone to zone. The Ware Till and upper Westmill Till types may be interpreted as reflecting 1) till facies of one or more ice advance, or 2) lithostratigraphic variations between till sheets possessing strong intraformational homogeneity.

Till type variations attributable to facies changes near the ice margin. Fabrics reflecting the dominant ice movement from the northeast exclude the possibility of the observed zones resulting from sub-parallel ice streaming. Zone II demonstrates that at least two ice advances occurred, so that two variants of the facies model need consideration.

Model 1a. If a situation existed where a second ice advance was less extensive than the first, the first "ortho facies" Y_1 (Fig. 28) must have been completely overridden in Hertfordshire, as there is no observed change of till type within the single till south west of Welwyn Garden City. Thus, the marginal facies X_2 of the second advance must lie above either X_1 or Y_1 in Zone II where two or more tills are present. Further northeast one should expect Y_2 to lie above Y_1 . In critical Zones I and II the model predicts an "ortho facies" (Y_1) occurring only as the lower till while marginal facies X_1 and X_2 occur respectively peripherally and above. The observed relationship in Zone II though is the reverse, with the Group A till (lower till) having a peripheral equivalent in Zone I, as shown in Fig. 28.

Model 1b. If a situation existed where a second ice advance was more extensive than the first, the till in peripheral zone (Zone I of the observed tills) would be of the marginal facies X_2 , while till of the "ortho facies" Y_2 , would lie above X_1 in the zone of two or more tills, Zone II, as shown in Fig. 29.

Providing the lateral relationships between tills are unproven this model could account for the observed disposition in Zone I and II. In both 1a and 1b "ortho facies" tills would be expected to lie in upper and lower positions further northeast in Zone III.

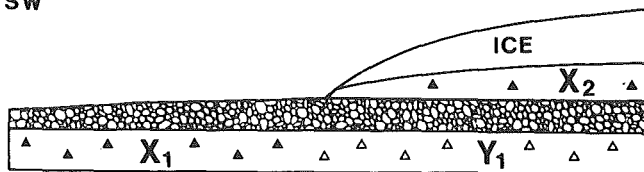
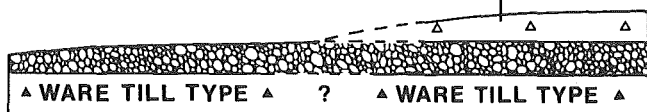
Model 1a **ZONE I****ZONE II** **NE****SW****Observed** **ZONE I****ZONE II****UPPER TILL TYPE**

Figure 28. Till type variations attributable to a facies change near the ice margin when the first ice advance is more extensive than the second, compared with observations.

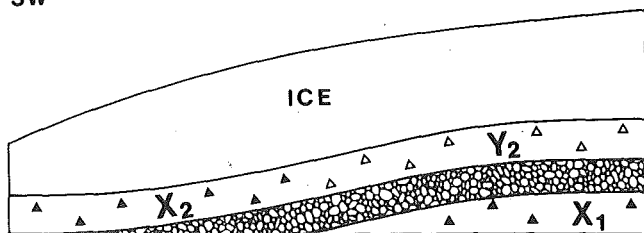
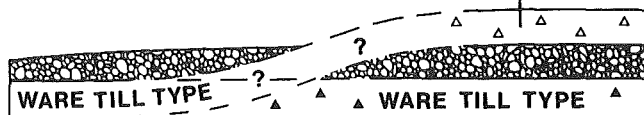
Model 1b **ZONE I****ZONE II** **NE****SW****Observed** **ZONE I****ZONE II****UPPER TILL TYPE**

Figure 29. Till type variations attributable to a facies change near the ice margin when the second ice advance is more extensive than the first, compared with observations.

Till type variations owing to stratigraphic succession of different tills possessing strong intraformational homogeneity. According to this model each successive glacial episode is required to deposit till with little lithological variation vertically or horizontally. Some small variation is inevitable owing to stochastic factors or upstream bedrock geology, but on the scale of the study area the model requires the retention of the dominant lithological and mechanical parameters of each till sheet.

Models 1b and 1b could both account for the observations, hence criteria other than spatial are required to identify which model closely reflects these observations. Three further properties may aid interpretation of the spatial patterns:

i) Vertical variability within a till sheet. During advance of a margin-dependent facies change, the ortho facies would succeed the marginal facies vertically as the terminus moved further away. During a dynamic retreat a marginal facies would be deposited above the ortho facies, resulting in the sequence of facies changes within a till sheet, shown in Fig. 30.

Section through till sheet:

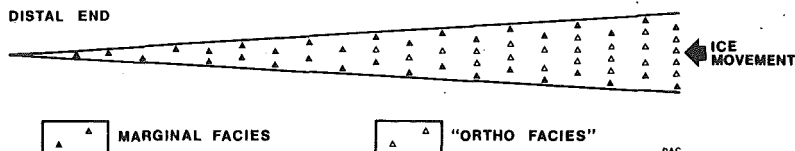


Figure 30. Scheme of till facies variation associated with dynamic glacial advance and retreat.

The upper marginal facies would be absent in the case of ice sheet stagnation. If lithological variability is stratigraphically dependent, vertical intraformational variability should be minimal. With the exception of Holwell Hyde, where upper till directly overlies Ware-type till, and the anomaly noted elsewhere at Harper Lane, no vertical change of till type is observed within one stratigraphic unit at any site in the study area. Tills at any one site invariably possess a remarkable degree of intraformational homogeneity.

ii) Stratigraphic relations: In the Vale of St. Albans much new detailed borehole information is available, chiefly from the proposed Al(M) through Hatfield and from Mineral Assessment Report 69, also new quarry sections are exposed. It is possible to trace till units between bores and quarry sites from south Hatfield to near Hertford with intervals averaging about 400m, as seen in Fig. 31.

The tills below the Hatfield organic deposits can be seen as continuous lower till unit leading towards Foxholes and the Ware Till at Westmill, and underlying an upper till in the east of the area.

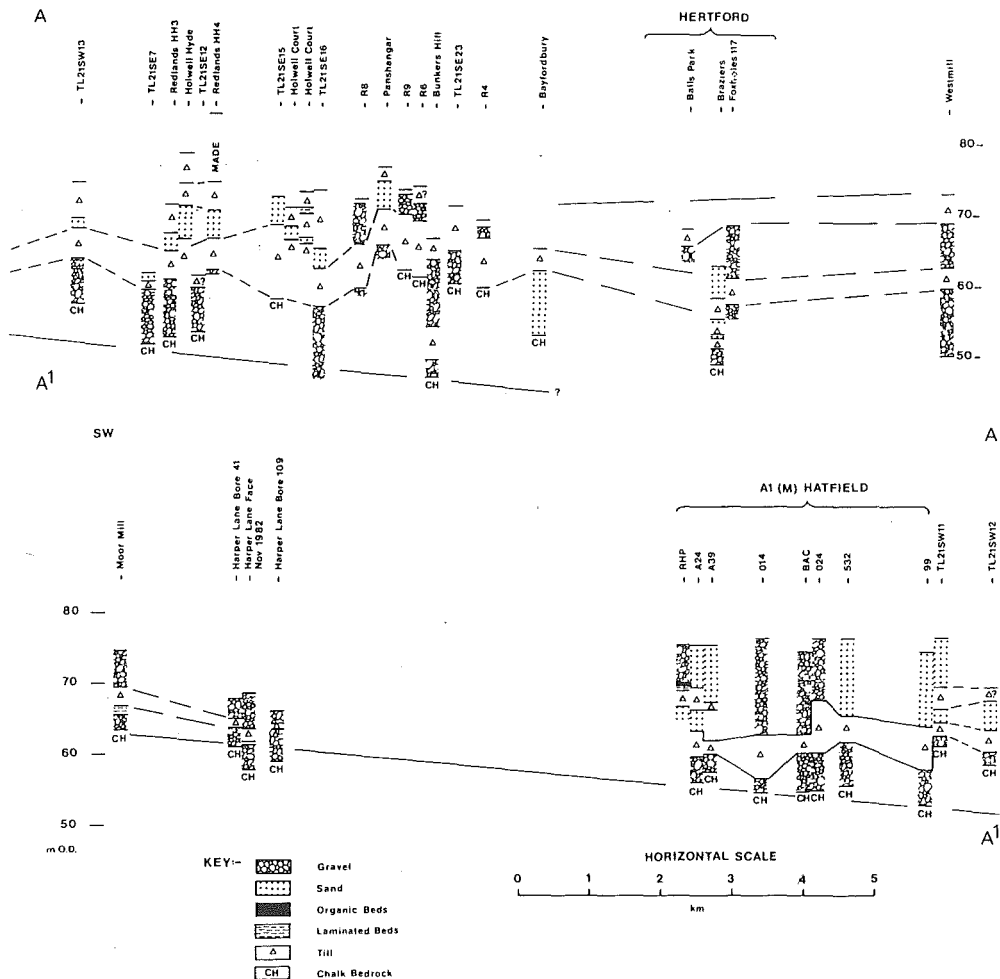


Figure 31. Section through Quaternary sediments from Moor Mill to Westmill. The sections join at A - A1. Data from Redland Aggregates is gratefully acknowledged.

iii) Palaeogeographical viability. All the past evidence favours ice advancing up the Vale of St. Albans against the flow of the Anglian Thames. Only the Ware Till can maintain an ascending basal gradient, albeit gentle, of 13cm/km from Westmill to Moor Mill (or 11cm/km from Foxholes to Harper Lane). An extension of the upper till from Westmill towards Moor Mill is on a gently declining gradient, -6cm/km from Westmill to Moor Mill and -17cm/km from Westmill to Harper Lane.

On the basis of the three characteristics, it would seem that the available evidence favours a stratigraphic rather than a facies-dependent model to account for the observed distribution of till types.

Implications for the Anglian Thames.

The interpretation advanced here is that the Ware Till ice extended well south of the Vale of St. Albans to maximal positions near Moor Mill, to at least the line of the M25 motorway, and possibly to Finchley. The ice clearly overtopped elevations of 113m at Potters Bar, 122m at Northaw Great Wood, and 109m at Bell Common on the Epping Forest Ridge. The Ware Till ice is believed to have achieved thicknesses at the very least of 100m within the former Thames valley in the Vale of St. Albans, and it is difficult to escape the conclusion that this ice advance was responsible for diverting the Thames into its present valley through London through the creation of the Moor Mill Lake. More than one pulse of the advance is observed in the Vale of St. Albans at Holwell Hyde, Holwell Court and Westmill (Ware Till and middle till). If the Moor Mill lake marks the diversion of the Thames, then the drainage southwards in the lower Lea drainage southwards in Westmill Upper Gravel times must have been essentially Lea drainage. The later and lesser ice advance would have effected fewer, if any, permanent drainage changes.

MIDDLE THAMES REGION

The object of the first day of the the excursion is to demonstrate the deposits of the Thames in the extra-glacial Middle Thames region. This is the classic area from which the terraces were first recognised and named. With the exception of the diversion from the Caversham Channel, the River Thames has remained on the same general course through this region for much of Pleistocene time.

The excursion will begin by visiting the oldest Pleistocene river deposits in the region at Nettlebed, Oxfordshire. These were deposited in both cold and temperate climates and provide a basal 'fixed-point' from which to build the succession. After leaving Nettlebed, the party will descend into the Caversham Channel passing over progressively younger, dissected terrace deposits en route to Highlands farm, near Henley. The famous sections at this site will offer an opportunity to examine the deposits and their contained artefacts which floor this abandoned valley of the Thames.

From Henley the party will cross the river and climb Winter Hill. This hill offers a unique vantage point from which to view the terrace surfaces on the left bank of the Thames and a possibility of examining the Winter Hill Gravel at its type locality.

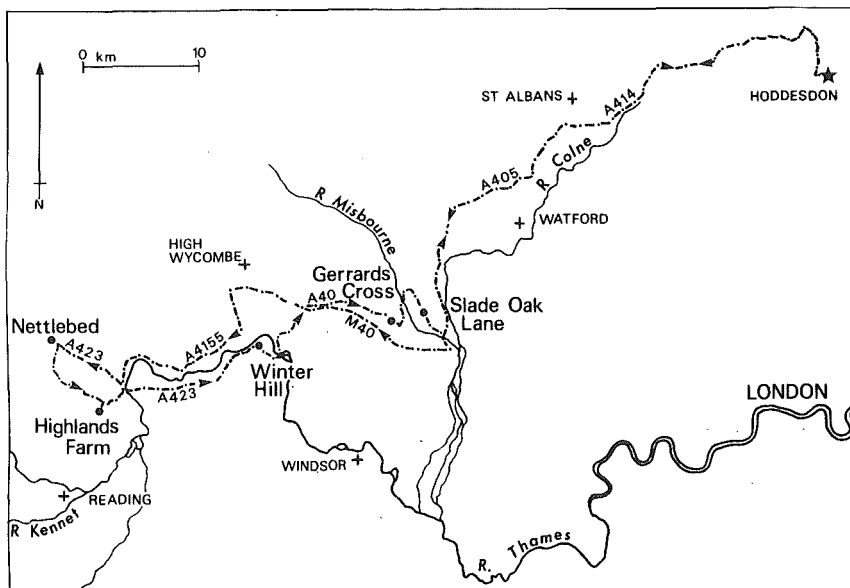


Figure 32. Location of sites and route for day 1.

The journey to Gerrards Cross will take the party up onto the classic Middle Thames ancient 'Gravel trains' in the region around Beaconsfield. The sections at Gerrards Cross provide a typical example of these ancient deposits.

The last stop will be to examine the recently discovered doline filling including interglacial sediments at Slade Oak Lane, Higher Denham, and the origin and stratigraphical importance of this sequence will be discussed.

P.L. Gibbard

NETTLEBED

SU 6996 8716

Site description

The surface elevation of the Nettlebed site is c.203m. The following succession was observed in July, 1975.

Soil: pebbly loam	0.20m	
Gravel; poorly sorted pebbles with grey sandy clay matrix and occasional pockets of very pale grey well-sorted sand of Reading Beds type. Proportions of pebbles about 5% at top, but increasing downwards (Sample CC9).	1.35m	
Sand: very pale grey almost white, with orange mottling.	0.04m	
Clay: medium humic and pebble free, passing up.	0.025m	} INTERGLACIAL BEDS
Organic horizons: Dark-brown humic silt with grey mottling. Scattered plant debris. Poorly sorted, ranging from clay to sand with scattered pebbles which are not concentrated in bands. Quartz and flint are dominant pebble lithology, some chert. Some flints are angular whilst others show chatter marks. Becomes sandy at top 0.05m. Abrupt base.	0.66m	
Sand: white, with some orange-brown mottling. Silty with scattered pebbles upto 40mm diameter. Well-rounded flints with chatter marks and some sub-angular pebbles. Well rounded quartz pebbles. Sand in quartzose and fine to medium grade.	0.93m	
Base of trench	3.205m	
Laterally the organic horizons increases to at least 1.30m.		

Samples were collected at intervals from the profile as indicated on Figure 33. and the lithological composition of Sample CC9 is given below.

Sample CC9	42% gravel	n = 383
Flint	74.2%	
Quartzite	18.5%	
Chalk	4.6%	
Others	2.6%	

General comments

This important early Pleistocene site at Priest's Hill, Nettlebed, Oxfordshire, was discovered by chance. During the survey of the Henley Geological 1:50,000 map a trench was dug to

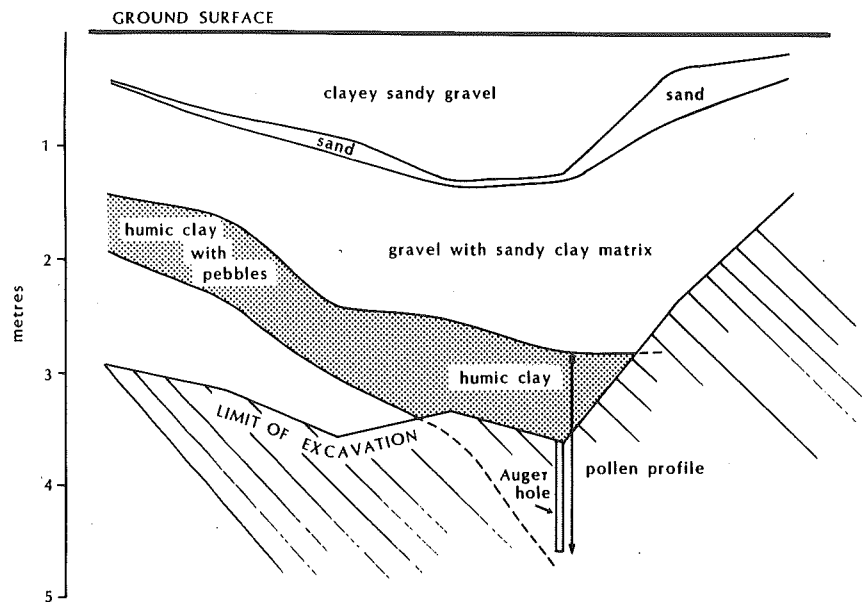


Figure 33. Temporary section, Priest's Hill, Nettlebed.

attempt to investigate, and hopefully disprove the concept of a Calabrian raised beach or shoreline at this site.

Priest's Hill forms a small subsidiary summit to the main peak of this part of the Chiltern Hills. Gravel deposits occur on both summits and rest upon the basal London Clay which in turn overlies Reading Beds. Priest's Hill rises to 203.1m O.D. and a trench was dug at the summit. The section is shown in Figure 33, and consisted of a bed of humic clay interbedded with sandy gravel. The humic bed contained pebbles at the margin, but increased in thickness, and the pebbles disappeared towards the centre of the original depression. Other trenches were dug close by and suggested that the gravel deposit itself infilled a depression in the Tertiary sediments. The humic clay extended from about 201.7m down to at least 199.6m O.D.

The fluvial deposits at Priest's Hill are of great significance due to their topographic position on the summit of the Chiltern Hills. These deposits indicate that during early Pleistocene times the locality was a valley floor position, and that since that time the relief has been totally inverted and erosion has removed the original valley slopes (Fig. 34).

N.W.

Near
Nuffield

S.E.

Sonning

Crowsley
Park 82m

Binfield
Heath 94m

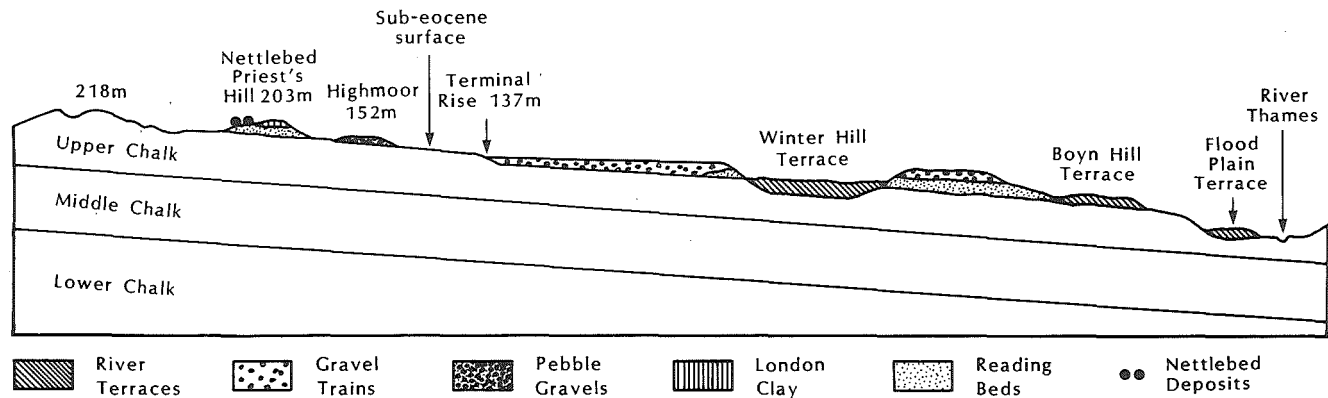


Figure 34. Schematic representation of topographic position of the Nettlebed site.

NETTLEBED

SU 702 872, SU 701 872

Nettlebed gravel

On the western side of Windmill Hill, Nettlebed, up to 1.5m of gravel with a sandy matrix rests on Reading Beds. The gravel reaches a maximum height of 206m O.D., which is 5m below the gravel-free London Clay hilltop.

The gravel, previously described by White (1896), Jukes-Brown and White (1908) and Horton (1977) lacks bedding structures and may not be *in situ*. However, it probably has not moved far, to judge from the lack of gravel on the summit. The gravel comprises a high proportion of 'Tertiary type' rounded flint (32-39%), together with angular flint (42-53%), vein quartz (10-15%) and quartzite (4%). The abundance of rounded flint, in comparison with its lower frequency in lower altitude deposits, clearly separates this deposit lithologically from the latter. The presence of quartz and other far-travelled lithologies indicates that the link with the Midlands existed at the time of deposition. White (1896) suggested that all the constituents could have originated from the Reading Beds, but this seems rather unlikely in view of the abundance of quartz. The source of rounded flint is, however, probably the underlying Tertiary strata.

SEM studies of quartz sand grains (200µm) from the gravel showed that the sand predominantly derived from the Tertiary strata. This conclusion is based on the presence of secondary diagenetic quartz and V-shaped notches on the surface of the grains, indicating a pre-diagenetic marine history. Other grains lacking notches suggest fluvial transport (Hey, *et al.*, 1971).

As part of a widespread sequence of well-rounded flint gravels, this deposit was included in the Pebble Gravel of the Chilterns and mapped as such by earlier workers. The origin of these gravels has long been a subject of controversy. Jukes-Brown and White (1908, p. 79-80) believed that they were derived from Lower Eocene Pebble-beds which had been 'fitfully dispersed and re-grouped in a progressive movement down the Chalk dip slope'. Wooldridge (1927) believed that the Nettlebed gravels were equivalents of the Lenham Beds and had been laid down on the wave-cut platform of the Pliocene Diestian Sea. He concluded that the deposit was higher and thus older than the Hertfordshire Pebble Gravels which he recognised as fluvial. Subsequently he modified this view by suggesting an early Pleistocene Calabrian age (Wooldridge, 1960).

The present interpretation is that the gravels are fluvial. Possible lateral equivalents of the Nettlebed Gravel occur at Russell's Water (SU 714 889) and Kimble Farm (SU 749 888). In spite of the unsatisfactory nature of the locality and the distribution of the Pebble Gravel in general, it is clear that plotting the outcrops suggest a gradient of c.0.90m/km. This gradient is comparable, if slightly steeper, to that of the lower gravel units in the Middle Thames (0.45-0.60m/km). It suggests that the Nettlebed Gravel was laid down, as proposed by Horton

(1977) by the river Thames flowing from Oxfordshire north-eastwards across the Middle Thames region.

Nettlebed interglacial deposits

During the resurveying of the area by the IGS, temporary excavations were made at Priest's Hill, a small hillock lying just below Windmill Hill on the north side of the village. The objective was to re-examine the series of pebbly sands and silts recorded as overlying the Reading Beds in abandoned clay-pits. It shown that these deposits fill a channel cut into the Reading Beds and that, unexpectedly, the major silt bed was highly organic. (Horton, 1977, and above).

A resistivity survey and further boreholes carried out by I. Bryant, P.L. Gibbard and C. Turner have shown that the channel trends north northeast-south southwest. The lowest sediments comprise a white to orange-brown pebbly sand at least 1m thick. This is overlain by a sequence of dark brown, highly organic bedded sandy and clayey silts with occasional pebbles which attain a thickness of at least 2m towards the centre of the channel. This bed is overlain by c. 1.6m of grey-brown clayey gravel which passes laterally into pebbly clay. The sequence is capped by further 1.3m of sandy clayey gravel that reaches to the ground surface.

The organic silts have been shown to contain abundant, well-preserved pollen although no plant macroscopic remains or fossil insect remains have yet been found. The pollen diagram (Figure 35) demonstrates a characteristic Pleistocene interglacial vegetational succession, beginning with a Pre-temperate zone (I), passing through an Early-temperate zone (II) and just recording the onset of a Late-temperate zone (III). The Pre-temperate zone is characterised by dominance of Betula (birch) with subsidiary Pinus and small amounts of Picea (spruce). Quercus (oak) dominated the Early-temperate forest, though small amounts of Ulmus (elm) were present. The onset of Late-temperate conditions was heralded by the immigration of Carpinus (horn-beam) and marked expansion of Corylus (hazel). Alnus (alder) was present in small quantity during the temperate zones.

This pollen diagram contains no 'exotic' pollen taxa, the only non-native tree being Picea. Nevertheless, it is very unlike other Middle and Upper Pleistocene pollen diagrams in several respects. One of the most striking features is the total absence of temperate elements such as Hedera (ivy) and Ilex (holly). Likewise Tilia (lime) appears to be absent. Corylus expands late, and Picea occurs early in the interglacial. No trace of Tsuga or Pterocarya has yet been found, although a further sequence is now awaiting investigation and might hopefully provide additional information about the Post-temperate zone, when such late-immigrating trees might be expected to arrive.

From its position in the terrace sequence, this interglacial deposit must be considerably older than Sugworth. Although doubts have been expressed about the Cromerian age of the latter site, surely Nettlebed must be pre-Cromerian. The early appearance of Picea and the late expansion of Corylus are both features which suggest an early Middle Pleistocene, if not Lower

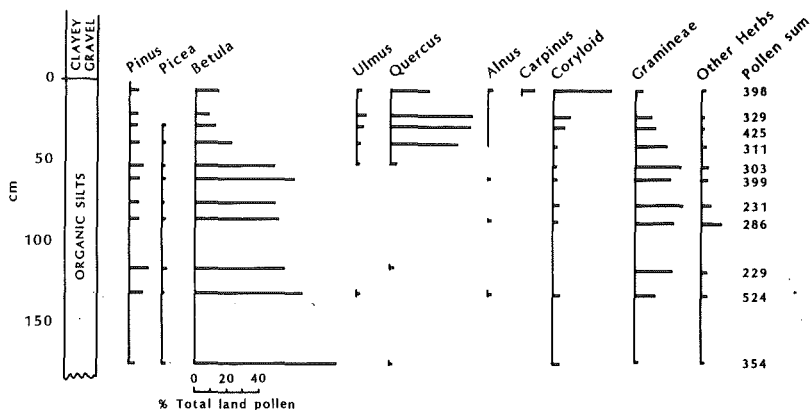


Figure 35. Preliminary pollen diagram from the Nettlebed interglacial site.

Pleistocene age. Likewise the pollen diagram differs distinctively from those of the Hoxnian and Cromerian interglacials and indeed from the Pastonian also. Comparisons with more fragmentary diagrams from the Bramertonian marine sediments are difficult, and the probability is that the Nettlebed deposit represents an interglacial period hitherto undefined in the British Isles.

The lower part of the sequence appears to be of fluvial origin, the organic deposits probably accumulated in an abandoned river channel. The lithology of the upper gravels which overlies the organic deposits is identical to that of the Nettlebed Gravel described above, although it has a clay-rich matrix and in parts may be described as pebbly clay. Although there is little difference in altitude between the base of the Windmill Hill gravel spread and the base of that capping the Priest's hill channel (4.7m), the mode of occurrence of the latter deposit suggests that it may have originated by solifluction of Nettlebed Gravel mixed with Reading Beds over the top of interglacial sediments, which to some extent also become incorporated. Alternatively it is possible that the two gravel units were once continuous and that the channel containing the interglacial deposits pre-dates the Windmill Hill spread. On balance the former explanation seems more plausible in view of the altitudinal separation and the local bedrock lithology which would produce slopes very susceptible to solifluction. Further investigations are in progress to try and resolve this point, since the Nettlebed interglacial deposits form an extremely important marker horizon in the high-level sequence of the Middle Thames region.

C. Turner.

HIGHLANDS FARM

SU 744 813

Introduction

The gravel and sand exposed at Highlands Farm represents part of a deposit that floors a former valley of the River Thames between Caversham and Henley. This valley is separated from the present rivers' course through Reading and Shiplake by a dissected Chalk ridge capped by higher level Gerrards Cross and Winter Hill Gravel remnants. The Caversham Channel was originally described by Treacher, Arkell & Oakley (1948) and more recently re-evaluated by Wymer (1961).

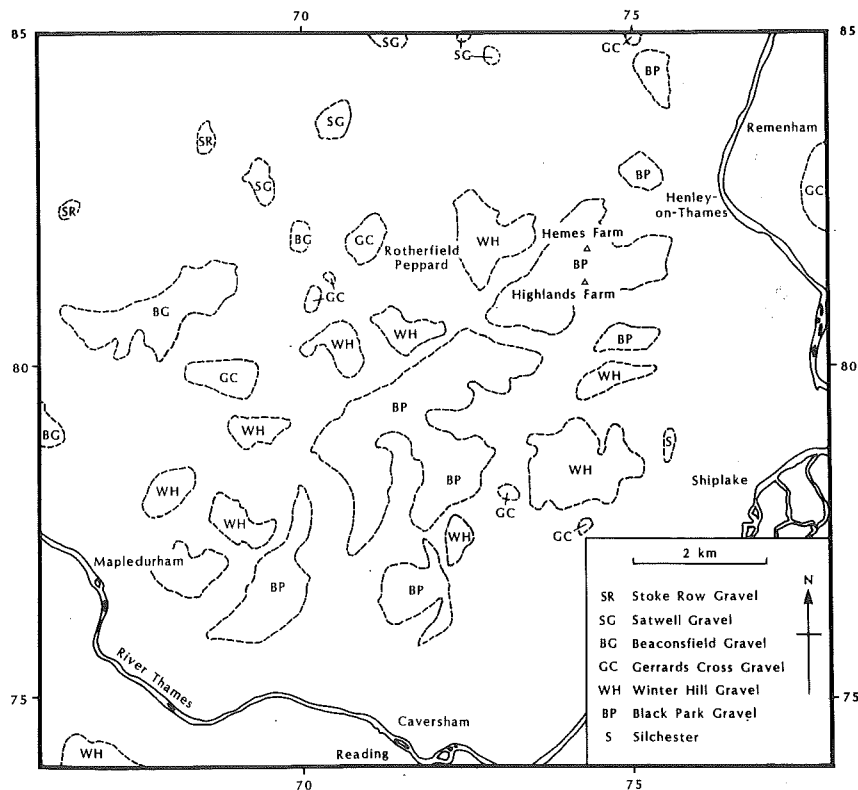


Figure 36. Distribution of terrace gravel fragments in the area between Caversham and Henley.

Historical Background

The ancient channel of the Thames between Caversham and Henley was first recognised by Llewellyn Treacher

of Twyford early in this century. He collected palaeoliths from numerous gravel pits in the Thames valley between Burnham and Reading, and his vast collection is now in the University Museum at Oxford. The first published reference to the Ancient Channel was in the account of a Geologists' Association excursion to Ship-lake on June 26th, 1926. Treacher (1926) referred to the Tertiary outliers extending from Caversham to Henley-on-Thames which "divided the present Thames Valley from another parallel valley to the north-west, the floor of which, where not cut through by more recent transverse valleys, is at about 270 ft. O.D."

Fig. 37 records the positions of the main pits within this Ancient Channel of the Thames in which Mabel and Llewellyn Treacher discovered considerable numbers of palaeolithic artifacts, mainly hand-axes. Their significance was apparent to the late Dr. K.P. Oakley who, on the grounds of the altitude of the gravels and parallels in the Somme Valley, considered them the "largest and most valuable geologically-dated assemblage of Abbevillian and Early Acheulian culture yet brought to light in Britain". Llewellyn Treacher died in 1943 but, in collaboration with Mrs. M.S. Treacher and Dr. W.J. Arkell, Oakley published an account of the geology of the Ancient Channel and its contained palaeoliths (Treacher, Arkell and Oakley, 1948).

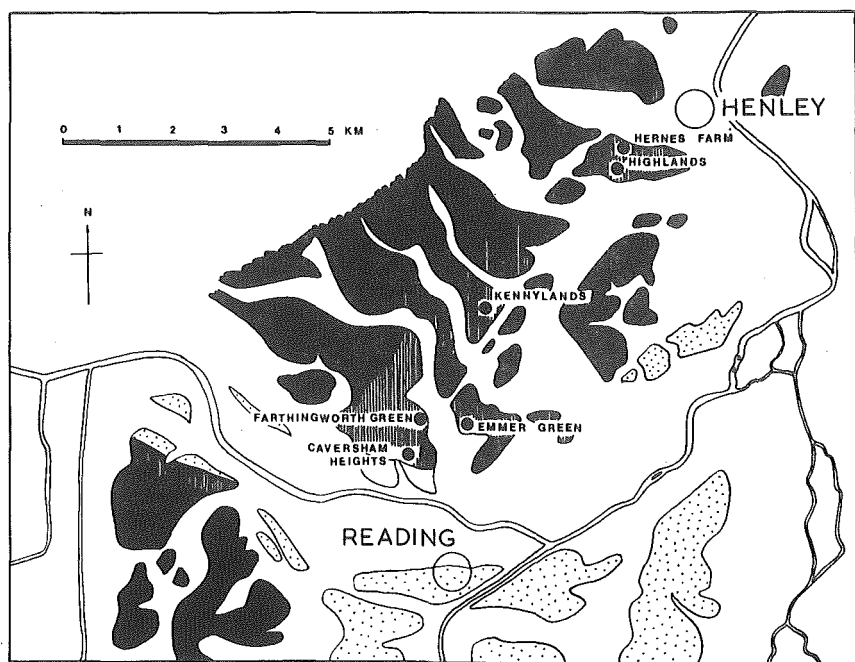


Figure 37 . Location of major palaeolithic sites in the ancient channel of the Thames between Caversham and Henley. The channel is shown by vertical shading. The land above 76 m O.D., including the gravel terraces is shown solid black. Lower terraces are stippled. (Reproduced for X INQUA Congress Guidebook for Excursion A5, 1977)

By 1950 most of the gravel pits had ceased working, but in 1955 the old pit at Highlands Farm, Rotherfield Peppard, was re-opened, and a new opportunity arose for examining the deposits and collecting palaeoliths (Wymer, 1958). The latter were numerous and it was apparent that at least two flint industries were present: Clactonian in a mainly rolled condition, and Acheulian in relatively fresh condition. Excavation and controlled collecting showed that the great majority of the artifacts of both of these industries were in basal 1-2m of fluviatile sandy gravel with no stratigraphical or vertical separation. Such was the elegance of many ovate and cleaver-like forms of the hand-axes that, mainly on the basis of the Swanscombe archaeological sequence, a much later date was suggested for the Acheulian industry and, hence, a later date for the deposition or reworking of the gravel (Wymer, 1961). It was suggested that the Ancient Channel was an early Thames feature, but the gravels had been reworked at some later date, possibly contemporary with the Boyn Hill Terrace Gravels, at which time the Acheulian Industry became incorporated. The Clactonian Industry was perhaps a relic of the earlier period.

Sediments

The deposits comprise a lower coarse gravel unit 3m in thickness containing irregularly-shaped coarse flints and sarsen boulders. This is frequently overlain by a finer upper sub-unit about 1.5m thick of medium to fine gravel. Both horizontally stratified subunits are interstratified with current bedded sand. The latter are present as narrow tabular cross-bedded lenses 2-20cm in thickness. The upper 40cm of the deposits are disturbed by cryoturbation and are overlain by 30cm of faintly-banded, red stained light brown silt.

The gravel lithology comprises 81% angular flint, 5% rounded flint, 6.5% vein quartz and 6% quartzite. Pebbles of igneous and metamorphic rocks, Palaeozoic chert, sandstone and sarsen are also found. These counts are similar to those of Walder (1967) and indicate that the gravels are of Thames origin.

Steeply dipping strata are very common in these sections and have been described by R.R. Inskeep (personal communication) and Wymer (1961, 1968). They record large scale collapse into Chalk bedrock solution cavities. This collapse has been predominantly post-depositional since large funnel-shaped hollows penetrate the full thickness of the gravels and sands and are infilled by the silt, mentioned above. The largest hollow observed was at least 3m deep and 6m wide.

Archaeology

The gravels and sands at this site have yielded a prolific assemblage of Palaeolithic artefacts.

The Clactonian industry is mainly rolled condition (Fig. 38). It consists of chopper-cores of pebbles (1), bi-conical (2) or irregular form, and heavily struck flakes with (3) or without (4) non-standardised secondary working.

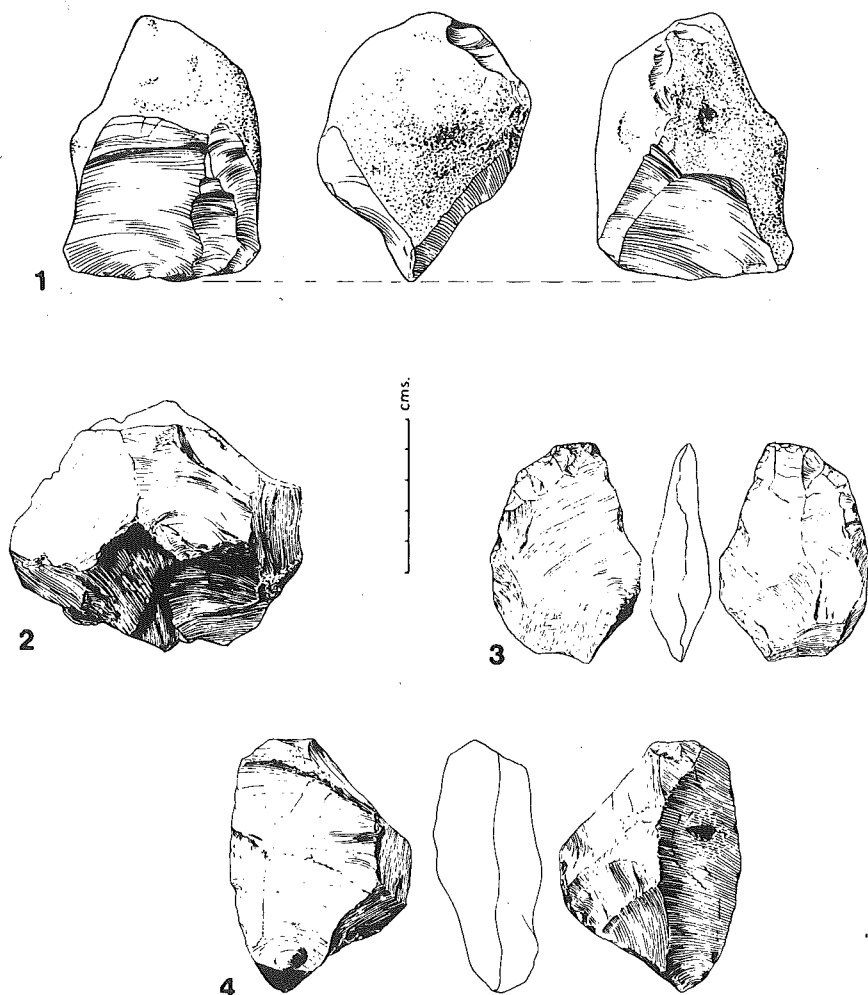


Figure 38. Artefacts of the Clactonian industry from the Highlands Farm pit. 1, Pebble chopper core; 2, Biconical chopper core; 3, Flake with secondary working; 4, Flake.

The Acheulian industry is mainly relatively fresh (Fig. 39). It consists of elegant ovate and cordate hand-axes often sharpened with a final flake removed transversely (tranchet flake) (1), and rarer cleavers (2). Hand-axe finishing flakes (3) and scrapers of standardised forms (4). Cruder, stone-struck hand-axes (5-6) may represent a different Acheulian industrial group.

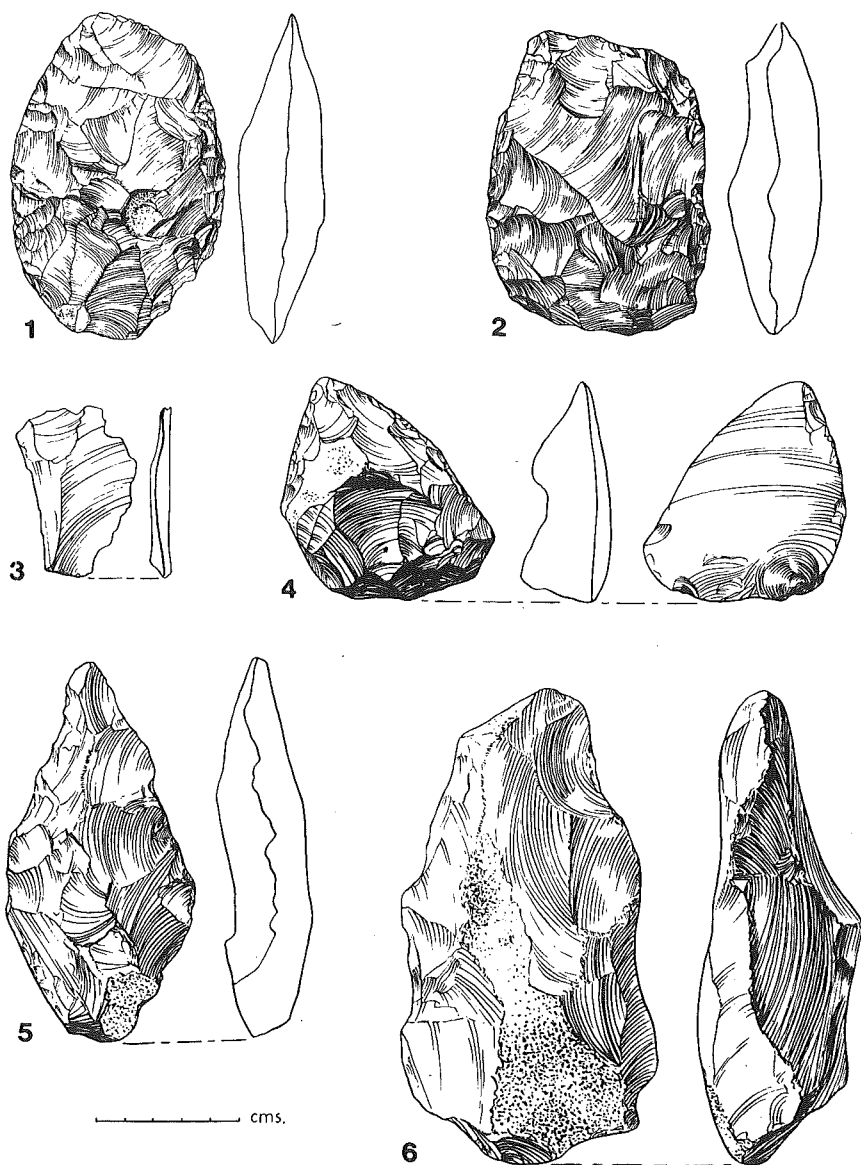


Figure 39. Artefacts of the Acheulian industry from the Highlands Farm pit. 1, Ovate hand-axe sharpened with tranchet flake; 2, Cleaver; 3, Hand-axe finishing flake; 4, Convergent scraper; 5 and 6, Crude, stone-struct hand-axes.

These brief descriptions pertain to assemblages found in the other pits within the Ancient Channel, Farthingworth Green and Kennylands being the most prolific sites. However, Clactonian type artifacts had only previously been recorded in small numbers, possibly because their crudity did not attract attention. From a negative aspect of typology, it seems significant that there are no twisted ovate/cordate hand-axes, no refined pointed forms as at Toot's Farm or Furze Platt (both in terrace gravels at a lower altitude) and no Levalloisian flakes or cores.

Current interpretation correlates the gravels of the Ancient Channel with the Black Park Terrace (Clarke and Dixon, 1981) and the Black Park Terrace with the Late Anglian Stage (Gibbard, 1979). Thus the Acheulian industries of elegant hand-axes are attributed to a time earlier than the Acheulian of the Swanscombe Middle Gravels, although the latter are, in turn, overlain by the Upper Loam which contains an Acheulian Industry with ovate and cordate hand-axes of similar form and elegance to those of the Ancient Channel. This apparent inversion now seems of little consequence in view of the unequivocal nature of the evidence from Hoxne, where pointed hand-axes overlie an industry of elegant cordate and ovate hand-axes, although twisted forms are present.

Age of the gravels

The terrace surface developed on the gravels at Highlands Farm and indeed throughout the Caversham Channel was correlated by Sealy & Sealy (1956), following Wooldridge (1938), with their 'lower' Winter Hill Terrace. The gravels beneath were later shown by Walder (1967) using pebble counts from several sites to represent a single unit with a characteristic assemblage. This is borne out by recent results. In her discussion of the area Walder notes that the Sealy's Black Park and 'lower' Winter Hill Terraces appear to be one and the same in the Caversham Channel. More recently, Clarke & Dixon (1981) using altitudinal evidence reaffirmed this observation, noting that the deposit flooring the Caversham Channel seemed to be of Black Park Terrace elevation. Stratigraphical studies by Gibbard confirm Walder's and Clarke & Dixon's proposals and demonstrate that the deposits should be correlated lithologically and altitudinally with the Black Park Gravel.

The Black Park Gravel is known to be of Late Anglian age (Gibbard, 1977, 1979) and this provides a maximum date for the Thames' occupation of the Caversham Channel. The first aggradation aligned along the modern course is the Boyn Hill Gravel. On the basis of altitudinal relationships east of London (Bridgland and Gibbard, in press) this cold stage unit almost certainly of early Wolstonian age (*sensu* Mitchell *et al.*, 1973). The modern course was therefore occupied at this time.

The gravels at Highlands Farm contain an intermixture of Clactonian and Acheulian material. At Swanscombe, the lower gravel and lower loam have yielded exclusively a Clactonian industry. The overlying gravel and sands contain an Acheulian industry, the appearance of which therefore post-dates the former. The lower loam and the upper part of the lower gravel are correlated with the Hoxnian interglacial stage (Wymer, 1974). This correlation is reinforced by the late Anglian-early Hoxnian age

of the Clactonian industry at Clacton itself (Wymer, 1977; Singer; et al., 1973). The evidence from Hoxne demonstrates that the Acheulian industry first appeared in biozone HoII (West & McBurney, 1955), that is, later than the industry at Clacton. Wymer (1977) therefore concludes that 'there is reasonable evidence to place the Clactonian industries in the time range of the Anglian to the early temperate zone of the Hoxnian'.

The Black Park Gravel is known to be of late Anglian age (Gibbard, 1988, 1979). In view of the dating evidence stated above, the Caversham Channel filling would appear to include both late Anglian and Hoxnian artefact elements. Wymer (1961) suggested that the gravels having been deposited in the Anglian may have been reworked after the Hoxnian, to account for the Acheulian material. The latter closely resembles that from the local Boyn Hill Gravel. He therefore concluded that a small remnant stream on the floor of the Caversham Channel may have been responsible for reworking the gravel after diversion of the Thames. This explanation seems extremely plausible. The Thames appears to have been captured from the Caversham Channel by the Kennet during a down-cutting phase subsequent to deposition of the Black Park Gravel. The latter stream joined the Thames at Henley probably before the Black Park stage (Gibbard, 1982). Later solutional collapse followed lowering of the water table during subsequent phases. The infill of the hollows may represent surface wash possibly including material blown in by wind or slumped from the sides.

A note on the Palaeolithic evidence in relation to the diversion of the Thames

The original correlation of the Ancient Channel between Caversham and Henley with the Winter Hill Terrace (Treacher, Arkell and Oakley, 1948) conflicted with the evidence downstream, for no palaeoliths have ever been found in gravels of the Winter Hill Terrace at its type site or elsewhere east of Henley. This problem is resolved if the identification of the Ancient Channel with the Black Park Terrace of the Thames is accepted, for palaeoliths are known from Black Park Terrace gravels at Hillingdon (Gibbard, 1979) and Dartford Heath (Gibbard, 1979) although at neither site are they plentiful. They are Acheulian hand-axes. An Acheulian occupation of the Middle and Lower Thames Valley during the Late Anglian Stage, after the diversion of the Thames, would appear to be demonstrated, with no occupation during the time of the deposition, or prior to, the Winter Hill pre-diversion gravels. This conclusion is somewhat at variance with the evidence west of the Ancient Channel, for hand-axes have been found in fair numbers at Hampstead Marshall, Berkshire, in gravels of the Silchester Stage which is usually equated with the Winter Hill Terrace. There are and have been many large exposures of the Silchester Stage gravels between Newbury and Silchester and yet no palaeoliths have ever been found in them. Those that do occur, as at Wasing, Sulhampstead and Mortimer have been found on the surface and have thus been interpreted as of later date. However, nearer Reading, at Englefield and Tidmarsh, hand-axes have come from gravel which is at the height of the Winter Hill Terrace. A further suggestion that Acheulian occupation does pre-date the diversion and the maximum advance of the Anglian ice is the presence of hand-axes in the Wallingford Fan Gravels.

There are two little-understood sites in the Rickmansworth area which must be very relevant to the Thames diversion and the question of human occupation: Croxley Green with a rich Clactonian Industry, and Mill End with an Acheulian one.

P.L. Gibbard

J.J. Wymer

WINTER HILL

SU 880 863

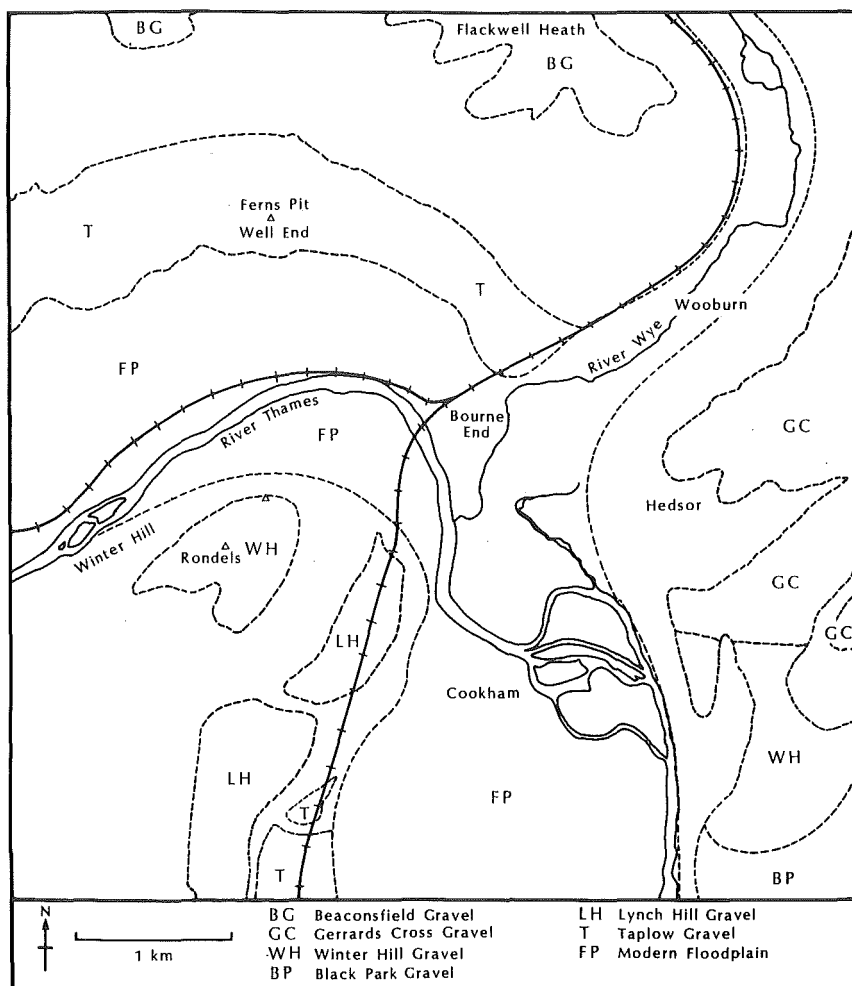


Figure 40. Thames gravels in the region of Winter Hill.

The triangular shaped bench-like feature at the eastern end of Winter Hill at 75-77m O.D., was regarded by Ross (1931) and later Wooldridge (1938) as representing a major terrace of the Thames. Later investigation of the surface by Hare (1947) convinced him that the surface was somewhat degraded.

Hare's mapping revealed that the Winter Hill could be divided into two sub-facets between Bourne End and the Colne Valley. Sealy and Sealy (1956) extended this work upstream to the Goring Gap and suggested that the surface at Winter Hill itself was a fragment of Hare's lower facet. Re-examination of the area indicates that Hare's lower and upper sub-facets do exist, but the intervening gravels underlying them are indistinguishable and can be demonstrated to be continuous. The upper gravel sub-unit apparently diverges from the lower near Burnham and can be followed only as far as Oak End Wood, Denham. This upper subunit appears to be a deltaic deposit formed when the Thames was dammed to form the Moor Mill Lake by Eastend Green Till ice in the western part of the Vale of St. Albans. Upstream of Burnham only one unit, the Winter Hill Gravel can be found. This is a 'normal' fluvialite aggradation with a gradient of 0.35-0.40m/km, i.e. comparable to both higher and lower aggradations.

The deposits temporarily exposed at Winter Hill comprise a sequence of massive to coarse gravels with occasional narrow sand bands. The gravel and sand rests on Chalk and shows considerable variation in thickness, for example near Rondels (SU 880 863) it is 2.5m thick, whilst a borehole at SU 879 863, 75.5m O.D.) recorded 5.9m gravel. The most likely explanation of this variation is probably solution of Chalk bedrock or perhaps post-depositional downslope movement of sediments. The upper 1-2m of the deposits are frequently disturbed by periglacial cryoturbation.

Sedimentary structures observed both here and at other localities upstream indicate that the Winter Hill Gravel aggraded in a braided river environment.

Pebble lithological counts from the Winter Hill Gravel show that it has a characteristic assemblage distinct from both higher and lower members. The gravels comprise a transitional assemblage between the former, rich in quartz and quartzite and the latter rich in angular flint. At Winter Hill (type section) the 33-8m size fraction of the gravel comprises:

74.5% angular flint	} 81.0% total flint
6.5% rounded flint	
10.0% vein quartz	
2.5% quartzite	
3.5% chert	
3.0% minor lithologies	

The gravels have never yielded any Faunal or arthaeological material (Wymer, 1968).

Winter Hill is located above the River Thames where it makes a substantial right-angled bend at Bourne End. The hill affords extensive views of the modern Thames where it occupies a valley deeply incised into the Chalk Terrace surfaces on the northern and eastern sides of the River can be seen.

To the north at Warren Wood (SU 873 900) and at Flackwell Heath (SU 905 894) extensive spreads of Beaconsfield Gravel upon which the Higher gravel train surface is developed at about

110m O.D. can be seen. North of the present floodplain at 38-40m O.D. are Taplow Gravel deposits. The Taplow Terrace surface is here developed upon local head deposits comprising reworked quartz-rich gravel. The deposits are well-exposed at Ferns quarry (SU 883 883). To the east the considerable spread of Gerrards Cross Gravel beneath the Harefield Terrace flat can be seen around Hedsor at 92-95m O.D. The large gravel workings in the present floodplain are also visible. Exposures in these workings are rare because of the high water levels. The Shepperton Gravels which underlie the floodplain sediments (Flandrian continuously floor the modern valley and can be shown to be of Late Devensian age by correlation with tributary valley aggradations.

P.L. Gibbard

GERRARDS CROSS

SU 980 887 Surface elevation: 90m O.D.

The Chalk surface is not exposed at present, but has been seen to be very uneven, with numerous pipes and other, shallower, indentations. A variable thickness of Tertiary Reading Beds sands and clays overlies the Chalk. The upper surface of the Reading Beds is itself uneven, and exhibits many erosional contacts.

Up to 4m of bedded sands and gravels ("ballast") overlie the Reading Beds, and display structures suggestive of a braiding environment. The frequent occurrence of large (30cm) erratic boulders may indicate ice-rafting in cool climatic conditions. The ballast is overlain, or, towards the western margins of the pit replaced by a variable thickness of compact, clayey, relatively structureless gravel ("hoggin").

The hoggin is locally overlain by a relatively thin sandy laminated deposit, the laminations of which become less distinct upwards. The origin of this material is obscure, though occasional clay-lined cavities at the junction with the underlying hoggin suggest very slow flow of material, possibly in a frozen condition.

Composition of Ballast.

The composition of 11.2 - 16.0mm fraction suggests an origin in the Lower Gravel Train (Green & McGregor, 1978), and the close proximity of glacial ice in the upper catchment of the Thames is indicated by the substantial proportion of far-travelled material (Table 7). Local flint forms the largest single compon-

	T19	T20	T21	T52	T148
Flint	37.3	39.4	41.9	34.5	47.7
Quartz	33.6	25.5	17.5	26.3	20.6
Sandstone	25.2	28.4	34.4	34.8	25.8
Chert	1.5	4.2	3.4	2.2	3.8
Volcanic	1.9	0.6	0.0	1.3	1.0
Other	0.4	1.8	2.7	0.9	1.0

Table 7. Lithological properties of 11.2 - 16mm size fraction of the gravels at Gerrards Cross.

ent in all samples. Quartzite and hard sandstone together comprise the largest percentage of erratic material in 4 of the 5 samples. Much of this material is derived from the Bunter Pebble Beds of the Midlands. A substantial proportion of quartz is also present, though this can be derived from a variety of sources both within and without the present catchment of the Thames. The chert includes material from the Lower Greensand of the Weald.

Volcanic pebbles. The petrography of volcanic clasts found at Gerrards Cross is examined in detail in Green, Hey & McGregor (1980). A collection of 41 non-sedimentary clasts of

long axis 32mm or more was made from in situ gravel for thin section examination. Thirty-six of these proved to be volcanic (28 pyroclastic and 8 rhyolitic), 4 granitic or granophyric and 1 metamorphic. In hand specimen, the volcanic pebbles usually have a pale green or buff appearance, due to the presence of chlorite associated with various degrees of bleaching. They are generally easily broken by hand. The rhyolites characteristically contain phenocrysts of feldspar, both plagioclase and orthoclase. No quartz phenocrysts have been seen. With regard to the pyroclastics, vitric and lithic tuffs are present in approximately equal proportions.

The Gerrards Cross collection differs from that recorded from Kesgrave Sands and Gravels in Essex and Norfolk by Hey & Brenchley (1977) in that pyroclastics are more abundant than rhyolites at Gerrards Cross, whereas the opposite pertains in the Kesgrave deposit. Also, lithic tuffs are virtually absent from the Kesgrave beds. These differences may be due to differential abrasion rates, the vitric tuffs having been more resistant to transport than the lithic tuffs, and rhyolites more resistant than either.

The distribution of these volcanic pebbles in the Gerrards Cross ballast is very uneven. Much of the ballast contains only very small numbers of these easily-recognised pebbles, while pockets of volcanic-rich gravel are found. This, coupled with the relatively low durability, suggests that ice-rafting may have protected relatively large clasts, or concentrations of broken clasts, for all but the last phase of transport, and that these are then quite rapidly broken up during a relatively brief depositional phase.

Composition of hoggin

The composition of hoggin gravels has not been examined at this site, but results from other sites in the Lower Gravel Train where this material is present (McGregor & Green, 1978) shows that it contains a much larger proportion of angular flint than underlying ballast gravel, together with material reworked from ballast gravels on the valley flank.

Fabric

Detailed studies of ballast and hoggin fabric at Gerrards Cross and at Westwood Quarry (TQ 072 990), also assigned to the Lower Gravel Train, have been reported in McGregor & Green (1983b). As Fig. 41 shows, the orientations of ballast imbrication and sand foresets are strongly developed and are consistent with the regional trend of the ancestral Thames, to the northeast along the Vale of St. Albans. In the hoggin gravel, preferred orientation is seldom significantly developed. At Gerrards Cross, preferred orientation, though very weak, is consistent with an origin on existing higher ground. This suggests formation as a very low-angle, slow-flowing solifluction sheet.

Post-depositional modification

The upper horizons of the hoggin gravels exhibit many

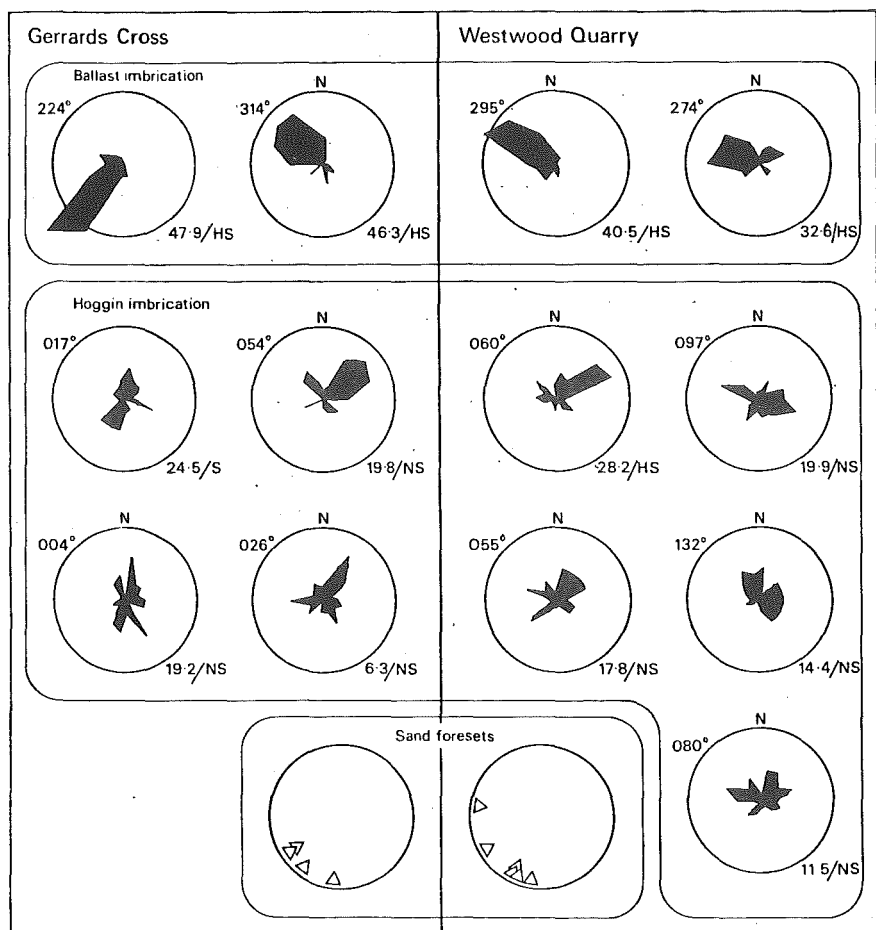


Figure 41. Orientation data for ballast and hoggin gravels. Figures show the resultant vector in degrees; vector strength and level of significance (HS = highly significant, 99%; S = significant, 95%; NS = not significant).

of the features typical of small-scale periglacial disturbance. At Gerrards Cross, however, the larger-scale effects of piping due to differential solution of the underlying Chalk, are particularly well-developed. The regional distribution of piping appears to be uneven, and pipes are particularly numerous at Gerrards Cross. Mapping of identifiable pipe remnants indicates a density of 4.0 pipes per hectare (Fig. 42). Study of aerial photographs plus instrumental surveying indicate no obvious systematic local pattern. Tonal contrasts on the aerial photographs do, however, show circular and linear features which are presumably related to ground moisture contrasts, and which may be associated with the incidence of piping.

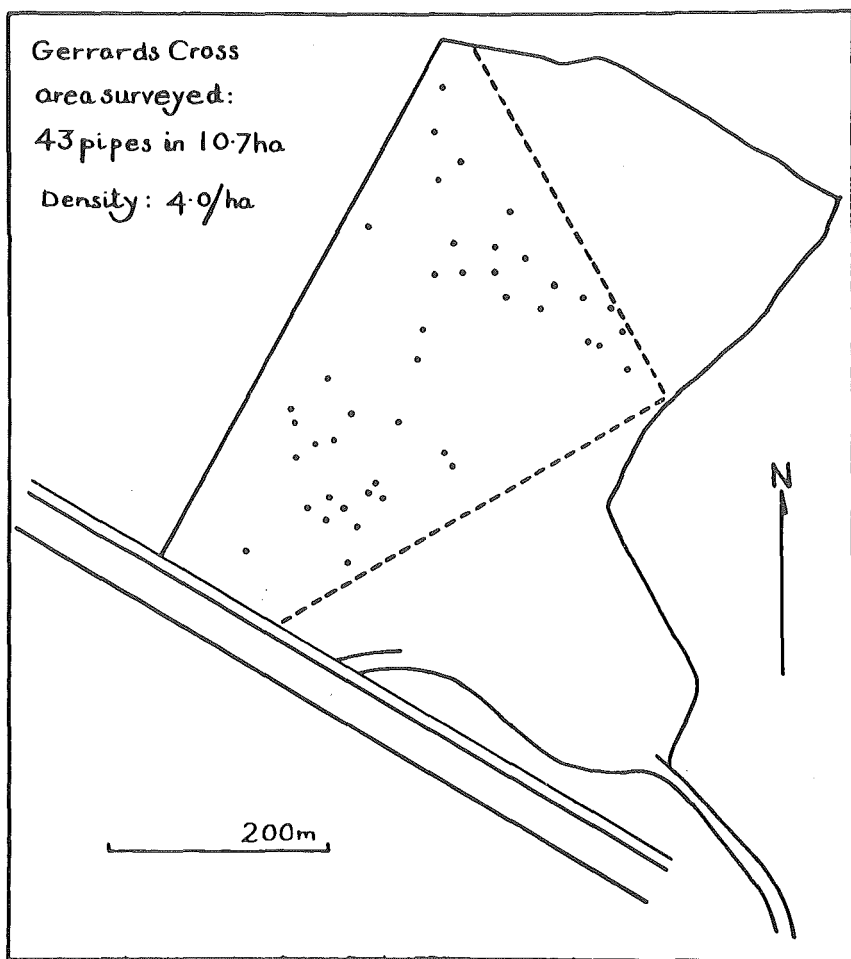


Figure 42. Distribution of pipe remnants at Gerrards Cross, based on detailed topographic survey.

The pipes at Gerrards Cross almost invariably penetrate both solifluction gravel and river deposits, and are occupied in their upper part by brickearth. Disturbance of the Reading Beds deposits adjacent to these pipes is often intense, and the Reading Beds deposits are often brecciated. Steeply-inclined bedding is often seen in close proximity to the pipe wall. Within the brickearth, stones are commonly present immediately adjacent to the pipe wall and exhibit a preferred orientation to it. The pipe wall itself is often a smooth, polished and fluted surface.

Textural variations are apparent in pipe profiles. Fig. 43 illustrates typical variations in particle size with depth in one Gerrards Cross pipe. In several pipes an upper hori-

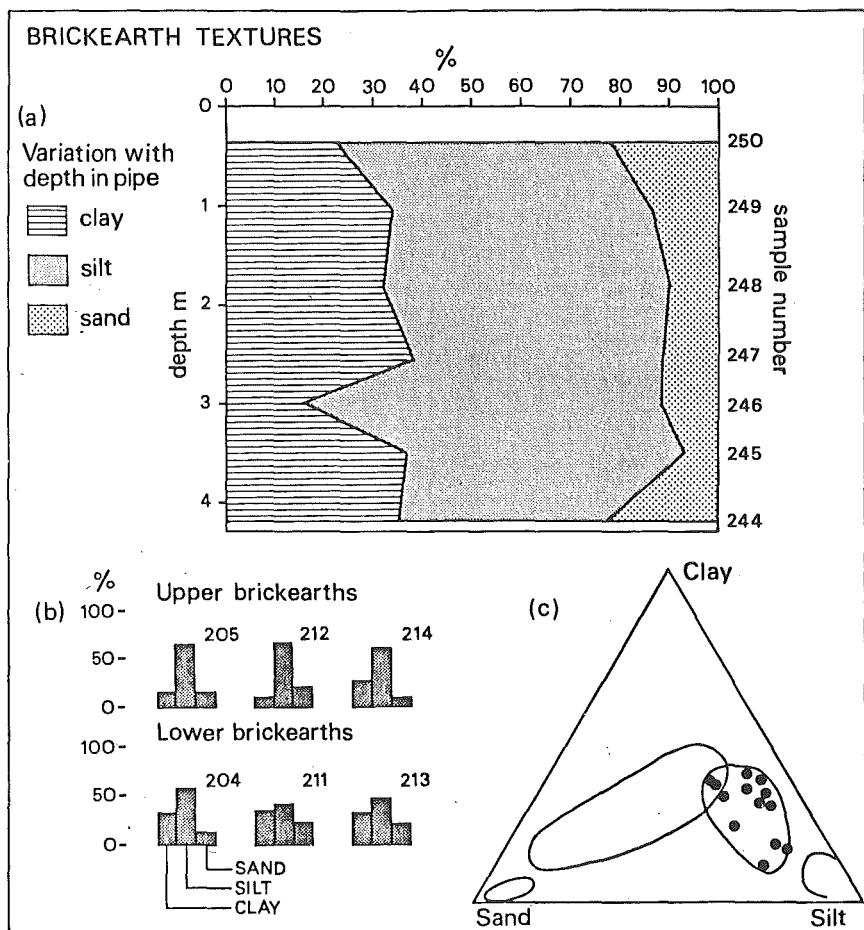


Figure 43. Pipe brickearths. A: particle size profile of sediments in pipe; B: textural differentiation of upper and lower brickearths.

zon can be differentiated in the brickearths in terms of particle size. Fig. 43 shows that in three typical pipes from Gerrards Cross, this upper horizon is more silty and less clayey than brickearths at greater depths. With many piped brickearths passing downwards into hoggin gravels, the idealized succession of materials and events present throughout the early terraces of the Thames, and illustrated on p. of the present volume, is easily recognised at Gerrards Cross.

D.F.M. McGregor
C.P. Green

SLADE OAK LANE

TQ 019 897

During the site investigations for the M25 Motorway, boreholes for a bridge at Slade Oak Lane, Higher Denham penetrated anomalously great depths of sediments resting on Chalk. The sediments were sampled in June 1980. The complete investigations of the deposits are being prepared for publication by P. Gibbard, I. Bryant and A. Hall.

The deposits underlie a small, seasonally dry valley trending east to east-south-eastwards (Fig 44). This valley dissects the plateau, the Misbourne-Colne interfluve, which is underlain by gravels and sands of the Gerrards Cross Gravel Members. The surface developed on the gravels is the degraded Harefield Terrace (Hare, 1947). The gravels overlie 14-16m of Reading Beds clays, which in turn rest on Chalk. The valley is underlain by a very steep-sided, funnel-shaped basin with a minimum diameter of 20-25m and a maximum observed depth of 37.5m (Fig.44).

The sequence filling the hollow can be divided broadly into three units:

Basal sands, clays and gravels.

This unit comprises a highly complex succession of sorted and non-sorted sediments. The lowest sediment is highly compact yellow sand with brown silty clay partings and is up to 8.20m thick. The sands are succeeded by as much as 10.80m of very compact angular to subrounded sandy gravel in a light grey clay matrix. The gravel is rich in frost-shattered, but otherwise unweathered flint, it also contains rounded and rolled flint, vein quartz, quartzite and sandstone pebbles. The gravels are overlain by predominantly massive light grey, green of buff sandy silty clay, with angular pebble concentrations at some levels. Occasional beds of sorted buff sand also occur (up to 20cm thick). This unit is commonly disturbed by high angle, near vertical normal faults with throws of several centimetres.

Organic silty clay.

Fossiliferous dark grey to black silty clay overlies the previous sediment. The sediments are finely laminated throughout much of their depth and contain irregularly distributed wood and clasts.

The microstratigraphy of this unit in borehole Q is: in metres below ground surface (82.8m O.D.).

<12.70m	Light grey-brown silty clay, grades into
12.70-12.81	Interstratified grey-brown sandy silt and dark grey silty clay.
12.81-13-29	Massive dark grey silty clay with scattered clasts and narrow sand bands
13.29-13-47	Black sandy clayey silt with small stones
13.47-13-67	Grey clayey silt with small stones, clay clasts and plant remains.

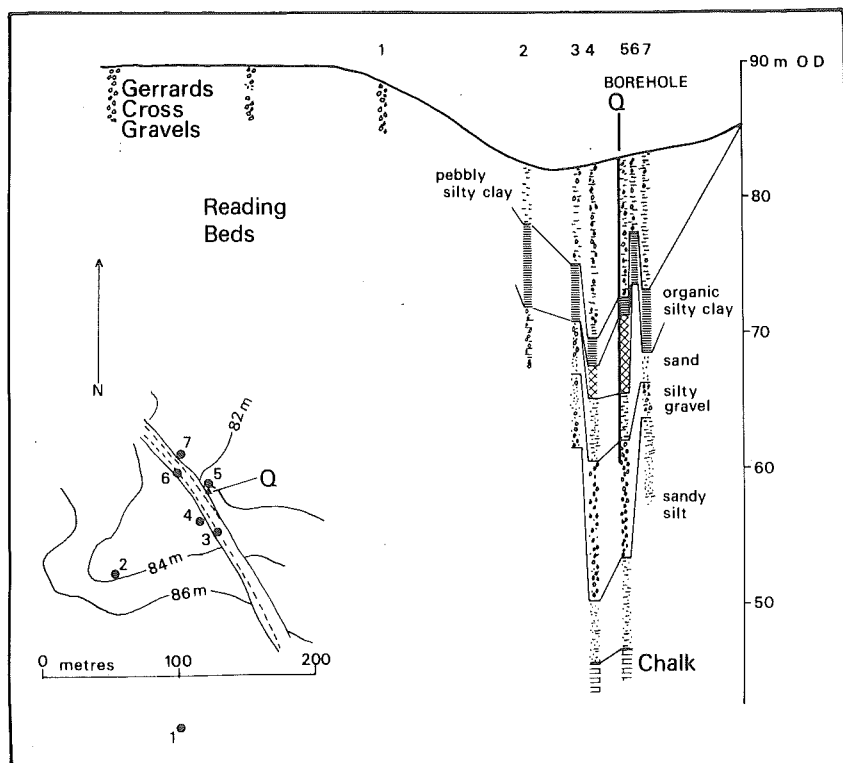


Figure 44. Location and stratigraphy of Slade Oak Lane.

13.67-13.85	Indistinctly stratified grey clayey silt with clay clasts and plant remains.
13.85-13.89	Black organic clay mud with plant remains.
13.89-16.51	Indistinctly stratified dark grey brown clay mud with a few plant remains. Wood,

- small pebbles and grey silt clasts.
- 16.51-16.58 Interstratified dark brown silty clay and sand.
- 16.58-17.03 Finely interstratified light grey silty clay, becoming siltier with depth. Some plant remains. Base very sharp and irregular. Small scale loading structures at base.
- 17.03-17.21 Light grey silty clay with coarse sand interbeds.
- 17.21> Grey silty clay with pebbles and angular flints.

Pebbly silty clay.

There is an upward transition from the organic clay-muds into light brown silty clay between 12.70-12.81m resulting from interbedding of the sediments. Above 12.70m the brown silty clay continues up to the surface, becoming progressively more orange-brown with secondary iron oxide and black manganese dioxide precipitation above 12.00m. Pebbly horizons are common. Some fine lamination (laminae 1-2mm thick) is present, consisting of an alternation of orange sand and grey silt and clay. In the upper part of the sequence the sediment is highly fissured. Its maximum thickness is 15.15m.

In order to establish the three dimensional shape of the basin a geophysical resistivity survey was undertaken. A series of eight traverses using a terrameter with the 'Wenner Configuration' producing a low frequency, high voltage current was adopted. These investigations indicated that the deposits are absent to the east and south-east of the borehole sites and therefore that the hollow is an enclosed basin.

Palaeobotany

Detailed investigation of the fossil pollen and macroscopic plant remains were carried out from a continuous sample series at locality Q (Fig. 44). Pollen samples were taken from the centres of sediment sample blocks so that the two types of analyses could be directly related.

The pollen diagram is shown in Fig. 45. Throughout most of the deposits the pollen was extremely well preserved, particularly between 13-16.50m below the surface. The sequence obtained has been divided into four pollen assemblage biozones (p.a.b's) which have been correlated with the regional p.a.b's of the Hoxnian stage (West, 1956; Turner, 1970).

The biozones recognised are as follows:

- (a) 16.00-17.05m: Corylus-Quercus-Fraxinus p.a.b.

The basal organic sediments comprise stratified light grey silty clays becoming more organic and richer in plant remains upwards. Throughout the zone, the spectra indicate the total dominance of temperate deciduous mixed oak forest, including Corylus, Quercus, Ulmus, Betula, Alnus, Fraxinus and small amounts of Tilia. The occurrence of fully temperate conditions is confirmed by the presence of pollen of frost susceptible Ilex (Holly) and Hedera (Ivy). The pollen of Carpinus and conif-

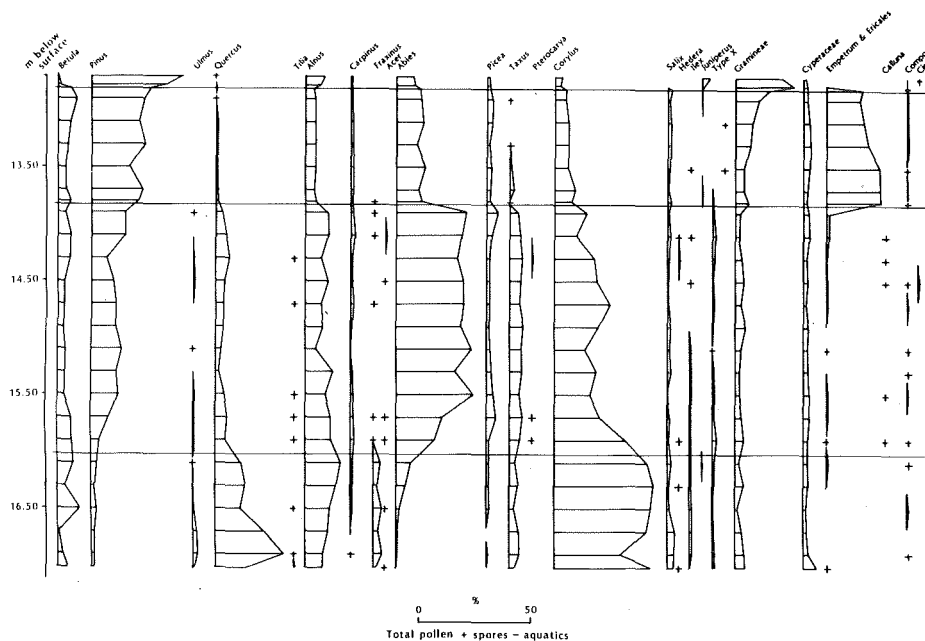


Figure 45. Pollen diagram, Slade Oak Lane, 1980.

erous trees become increasingly important through the zone. There is a marked rise in frequency of Abies and Picea pollen whilst Taxus and to a lesser extent Pinus are well represented.

The occurrence of the unknown pollen Type X in this and the subsequent zone confirm the Hoxnian age of this deposit. This pollen type is at present known exclusively from the Hoxnian stage (Turner, 1970).

Herb pollen is poorly represented at this time. The decline in the basal 10-20cm of the aquatic Sparganium Type, accompanied by Ranunculaceae (including subgenus Botrachium) implies a rise of water level.

(b) 13.84-16.00m Abies-Picea-Corylus-Pinus p.a.b.

The sediments deposited during this zone are extremely organic clay muds formed under eutrophic conditions in a shallow pool with periodic low energy inflow, probably slope wash. They include many pieces of wood and comminuted plant fragments. This is by far the best represented zone in the sequence. It is marked by the continued dominance of forest, the decline of the pollen of mixed oak forest taxa and the expansion to its acme of conifer pollen, in particular Abies (silver fir). The closed forest appears to have prevented the extensive growth of herbs although a slight rise in Umbelliferae and Ranunculaceae pollen does occur. The pollen of aquatic taxa is also more abundant and diverse than during the previous zone, possibly indicating an opening of the forest canopy over the pool.



(c) 12.80-13.84 Pinus-Ericales - Sphagnum p.a.b.

This zone occurs in the grey silty clay containing scattered clasts including clay pebbles and narrow sand bands. The sediments therefore record inwashing of inorganic detritus from the sides of the hollow around the pool. The abrupt decline in the pollen of both deciduous and coniferous Late temperate (sensu Turner and West, 1968) forest trees, accompanied by an expansion of Pinus pollen is very marked. The temperate taxa are replaced by an expansion of Empetrum and Ericales pollen, the increase in the pollen of herb taxa characteristic of open ground conditions and the increased frequency of spores of the moss Sphagnum. All these features record a deterioration of the soil and climate accompanying opening of the vegetation typical of the end of the Hoxnian interglacial stage (HoIVa).

(d) 12.70-12.80 Pinus - Gramineae-herb p.a.b.

The remaining sediments are grey-brown to grey silty clays. They continue without a break into the overlying silty clays which contain a few broken, mostly unidentifiable pollen grains. The contemporary spectra in this zone are characterised by a further abrupt increase in Pinus pollen and the continued decrease of the remaining temperate trees. Pollen of the latter may have been washed into the pool from the steep sides to judge from the poor preservation of pollen at this stage. Of note is the occurrence of Pterocarya pollen. This waterside tree has been characteristically found only in Hoxnian biozone HoIVb in the British Middle Pleistocene (Turner, 1970). The pollen of

Juniperus increase at this time and is accompanied by Gramineae pollen. Diverse plants of unshaded habitats appear in this zone. The expansion of Rubiaceae and Artemisia pollen is particularly interesting.

Taking the biozones together, there can be no doubt that this sequence represent the second half of the Hoxnian stage (Late and Post Temperate biozone). It is possible not only to match the broad assemblages with those at Hoxne (West, 1956) and Marks Tey (Turner, 1970), but individual curves from Slade Oak are so similar that they could be superimposed on the Marks Tey spectra.

Water level fluctuation

The occurrence at Slade Oak Lane of a continuous sequence of deposits representing only the second half of the Hoxnian Stage is very important. Lack of weathering in the sediments beneath those yielding temperate pollen indicates that they must have been moist, but not submerged for much of the first half of the interglacial. The rise of water level early in biozone Hox1a, which must have taken place to permit deposition of the fossiliferous sediments, has important implications. This rise is contemporary with water level rises recorded at sites in Hertfordshire (Gibbard and Aalto, 1977) and at Marks Tey (Turner, 1970) (see section on Hatfield Polytechnic). That the rise in water level also occurred at this site underlines that it was brought about by a regional water table rise. Such a phenomenon may record increased precipitation in the second half of the Hoxnian stage.

Origin of the basin

To judge from its form, position and size it seems most likely that the basin originated by bedrock solution. The funnel-like shape and proportions closely resemble those of dolines (Sweeting, 1974, p.44), although it is rather larger than solution features previously described from the Chalk, with the exception of the Breckland Meres. Smaller examples are common in the neighbouring district. For example around Burnham Beeches (Hare, 1947), and from High Wycombe and Beaconsfield (Higginbottom and Fookes, 1971). Sperling et al., (1977) in a discussion of Dorsetshire dolines, show that these structures are concentrated where a thin cover of Palaeogene rocks or plateau deposits overlies Chalk. This is precisely the situation at Slade Oak Lane. Dolines are thought to form by intense solution activity along joint planes or fissures in the rock. Materials enter either by an 'hour glass' effect or by streams flowing into them and the filling may be highly variable.

Timing of the formation and infilling

Since organic sediments representing the second half of the Hoxnian stage occur within the doline, its formation must pre-date this phase. No earlier Hoxnian sediments are present and the sediments beneath lack fossils and are unweathered. This suggests that the sediments beneath the organic deposits accumulated under a cold climate. The interfluvies immediately adjacent to the valley are capped by Gerrards Cross Gravel, however only 400m to the south beneath Oak End Wood (TL 019 891: 82m O.D) is the Winter Hill Upper Gravel up to 7m thick overlain by 1m of laminated clay (possibly equivalent to the Moor Mill laminated clay:

Gibbard, 1977). Both the Winter Hill Upper Gravel and the clay were laid down in the lake formed when the Anglian chalky till ice dammed the Thames near St. Albans. Drainage of this lake led to a sharp fall in the local water table level (c 15m). Such a change in level could have triggered collapse which may then have continued periodically through remaining Anglian time.

The hollow was initially filled by sorted sand, possibly washed in by a stream. The overlying clayey gravel seems to represent detritus that slipped or flowed by solifluction directly into the hollow from the sides during subsidence. The material was probably derived from a mixture of Reading Beds and the overlying gravel. The interbedded clay and sand bands may represent periodic inwash or accumulation in standing water. The faulting present suggests that the basin was actively subsiding.

The lack of sediments from the first half of the Hoxnian suggests that no subsidence took place at this time. The rise of water table level in the second half of the Hoxnian led to the development of a pool in which the organic sediments accumulated.

During the latter part of Hoxnian biozone HoIV the deteriorating climate decreased the vegetation cover, and soil erosion began. Slope wash of sediment into the pool brought about the transition to inorganic sediment. Continued deterioration of climate led to the return of periglacial processes. The latter caused solifluction of soil and regolith into the basin presumably early in the Wolstonian.

There is no evidence of subsidence of the hollow after the organic deposition began. The Slade Oak Valley and other valleys in the area were excavated in the sedimentary fill and therefore post-date it.

P.L. Gibbard.

EAST HERTFORDSHIRE AND THE SCENE OF THE THAMES DIVERSION

The proposed itinerary is as follows:

1. Furneux Pelham
2. Northaw Great Wood
3. Harper Lane quarry
4. Hatfield Polytechnic pit
5. Westmill quarry

The route is indicated on Fig. 46.

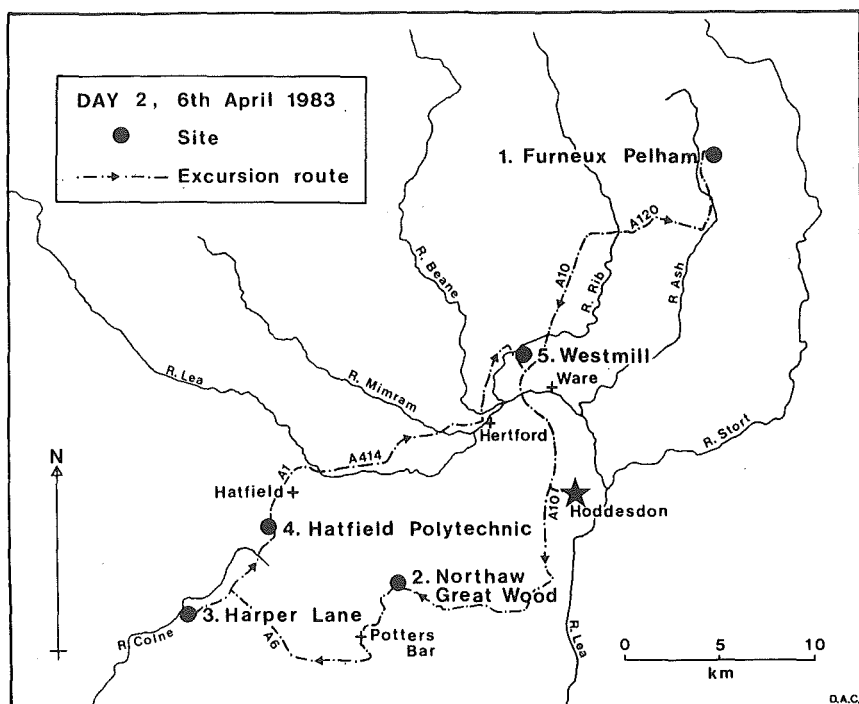


Figure 46. Location of sites and route.

All sites visited on this occasion lie within the limits of the Anglian glaciation, though the southern sites are clearly close to the distal margin. The first two sites demonstrate that the pre-Anglian course of the Thames lay well north of the South Hertfordshire Plateau. In the north-east, at Furneux Pelham, evidence for the Westland Green Gravels will be examined as course of the Thames from Goring to Norwich. At Northaw Great Wood in the south-east, Pebble Gravels will be seen.

These represent some of the earliest deposits of the ancestral Thames system of uncertain pre-Anglian age. The theme of pre-Anglian glaciation will be discussed on the basis of the "pebbly clay drift" and other sediments at Northaw Great Wood, although it will be suggested that the till here can be correlated with Anglian till further north.

The remaining three sites lie within the relatively thick accumulations of the Vale of St. Albans, and provide evidence for the history of the early Anglian Thames diversion from the Vale, to the south of the South Hertfordshire Plateau, and along the present Thames valley through London. At Harper Lane laminated silty clays (unfortunately rather thin at this site compared with the now-abandoned Moor Mill quarry) rest upon Thames gravels and are overlain without a break in sedimentation by till. The Moor Mill lake, created by ice advancing up the ancestral Vale of St. Albans from the north-east is believed to have overspilled into a pre-existing valley system approximately along the line of the present lower Thames. At the Hatfield Polytechnic pit a lower till and a slumped till, which can both be correlated with that at Harper Lane and Moor Mill, is overlain indirectly by late Anglian and early Hoxnian silts and peat, thus dating palynologically the Thames diversion to pre-late Anglian times.

At Westmill pre-diversion early Anglian Thames gravel (Westmill Lower Gravel) demonstrates a course towards mid-Essex. The succeeding Ware Till (underlain by laminated silts at the neighbouring Watton Road quarry) and its associated ice clearly dammed the Thames. The problem of the extent of the Ware Till and its parent ice sheet will be examined. The problem arises from the fact that if the Ware Till ice is regarded as a lobe of limited extent near Ware, of an age earlier than the till at Harper Lane and Hatfield, then permanent diversion of the Thames by the Ware Till ice is unlikely and unnecessary, and the upper till at Westmill, correlated with the Eastend Green Till and with the till at Harper Lane and Hatfield, may be seen as the cause of the Thames diversion. Alternatively, if the Ware Till ice is seen as of greater extent, reaching on to the South Hertfordshire Plateau and south-westwards up the Vale of St. Albans, then the Ware Till may be regarded as instrumental in diverting the Thames, and the Eastend Green till would be regarded as of more limited extent, with a provenance from the north-east and having relatively little permanent effect upon the gross drainage pattern of the area.

D.A. Cheshire.

FERNEUX PELHAM

TL 442 267

The north west corner of the pit provides the only available good exposure of the Westland Green Gravels in their type-area. The type-site itself, 5km to the south southwest is now waterlogged and overgrown.

The following units can be distinguished, the three lowest being separated by channelled erosion surfaces:

4. Wind-blown sand: 1m or less.
3. Coarse poorly sorted gravel, the uppermost beds clay -enriched and red (10R 4/8) to dark brown (10YR 3/3) in colour: 6m.
2. Yellow sand, with one band of flint pebbles; 2m.
1. Dark purplish-brown clayey sand. About 1m exposed, base not seen.

The clayey sand probably belongs to the Reading Beds which are recorded in the area. The yellow sand may also be Tertiary, perhaps even decalcified Crag. The lowest 2m of the coarse gravel consist almost entirely of flint pebbles, but the

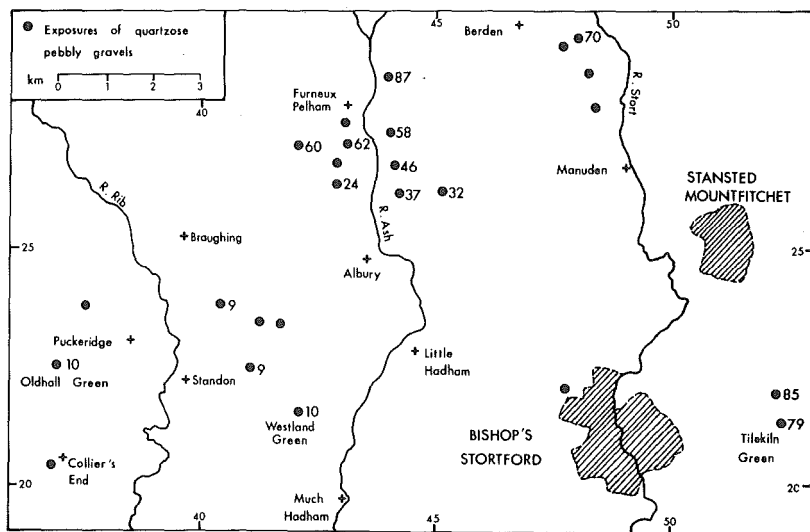


Figure 47. Exposures of quartzose pebbly gravels near the Hertfordshire-Essex border. Numbers against the sites refer to the ratio of colourless quartzites to total quartzites (reproduced from Proceedings of the Geologist's Association, 1980, 91).

higher beds contain, in addition to flints, some 19% of quartz pebbles and 6% of quartzites, with a few pebbles of miscellaneous chert and even fewer of decomposed volcanic rocks. The unit is assigned to the Westland Green Gravels because: (i) the upper beds are almost identical with those formerly exposed at the type-site; (ii) the maximum level of the gravels, about 107m. O.D., is nearly the same as at the type-site; (iii) similar gravels have been seen at many intermediate points. No basal flint-pebble gravel was seen at Westland Green, but a similar bed is present at some sites on Tertiary outcrops in Essex.

About 50% of the quartzites at Furneux Pelham are completely colourless, as compared with only 10% at Westland Green. This is part of a regional trend, the percentage 2km further north being nearly 90. Westland Green Gravels with abundant colourless quartzites are widespread to the east and north of Bishop's Stortford, and were at one time thought to belong to a different formation. The discovery of this transition near Furneux Pelham provided the first real evidence that they were nothing more than Westland Green Gravels bleached after deposition (Fig. 47).

Small faults have affected both gravels and yellow sands. In most parts of the section both units dip eastwards, at angles ranging from 10° to 30° , but there are indications of westerly dips on the west face of the pit. It is thought that these dips are not original but may be of diapiric origin.

R.W. Hey.

NORTHAW GREAT WOOD

TL 28 04

Introduction

This site provides evidence that may have a bearing on the problem of pre-Anglian glaciation. It is located in Northaw Great Wood which is 537 acres in extent, and is scheduled as an SSSI because of its rich fauna and flora. It is open to the public for scientific and recreational purposes. It belonged to St. Albans Abbey from Norman times, but became Crown property at the dissolution in 1539, was granted to the first Earl of Warwick in 1576, and held by various private owners until bought by Hertfordshire County Council in 1937. It is typical of the deeply dissected London Clay outcrop of south-east Hertfordshire, though the Chalk and Reading Beds are brought closer to the surface than usual by an ENE-WSW anticlinal flexure, and swallow holes consequently occur in the valley of the Cuffley Brook on the northern margin of the wood.

Description

From a detailed soil survey of the area, Thomasson (1961) inferred the following Quaternary succession in higher parts of the wood and adjacent interfluvial areas:

Chalky Boulder Clay

Pebbly Clay Drift

Pebble Gravel

though none of these beds is laterally continuous, and he found no clear section with Chalky Boulder Clay overlying Pebbly Clay Drift. He suggested that the non-calcareous Pebbly Clay Drift, which was once exposed to a depth of 3.3m near the south-east corner of the wood (TL 291 035), is a deeply weathered pre-Chalky Boulder Clay till, because its stone content and sand mineralogy show it is not a purely local mixture of Pebble Gravel and London Clay, and the characteristic brightly mottled subsoil horizons were nowhere found to overlie Chalky Boulder Clay or to extend appreciably below the general level of the plateau. However, Sturdy et al. (1979) recently described deep, red mottled soils on Chalky Boulder Clay in Essex, and similar soils have since been found in other parts of East Anglia and at Moreton-in-Marsh. So the possibility remains that the Pebbly Clay Drift represents either a deep interglacial (Hoxnian or later) in situ soil on Chalky Boulder Clay or a downslope accumulation of such soil material. The latter would account for Thomasson's observation, based on shallow augering, that in places the Pebbly Clay Drift seemed to crop out on slopes below interfluvial cappings of Chalky Boulder Clay but above the sandy-gravelly soil materials which he referred to as Pebble Gravel, thus giving the impression of a layered tripartite succession. Similarly the Pebble Gravel soils commonly show evidence of having developed in loamy slope deposits rather than in coarse waterlaid sands and gravels (Pebble Gravel sensu stricto), which they locally overlie.

Moffat and Catt (1982) tried to prove Thomasson's suc-

cession by drilling through the Chalky Boulder Clay at several plateau sites in south-east Hertfordshire; a thin bed resembling Pebbly Clay Drift was encountered between the Chalky Boulder Clay and Pebble Gravel at only one of the sites, and laboratory analyses suggested that this was a Bt horizon (enriched by illuvial clay) of a palaeosol formed in the Pebble Gravel. Other features suggested correlation with the Valley Farm rubified sol lessivé of Rose and Allen (1977) in areas further east.

In the wood three pits will be visited. Pit 1 shows Pebble Gravel overlain by loamy slope deposits derived partly from weathered deposits upslope, Pit 2 shows Pebbly Clay Drift over loamy gravel (probably a mixture of glacial and Pebble Gravel), and Pit 3 shows the following succession:

Pebbly Clay Drift

Chalky Boulder Clay

Gravel similar to that in Pit 2

Depth (cm)	Horizons
0-3	Black (10YR 2/1) stoneless humose silt loam
3-28	Brown (10YR 5/3) slightly stony clay loam; rounded flint and quartz pebbles, subangular flint and sandstone
28-55	Prominently mottled light brownish grey (10YR 6/2), strong brown (7.5YR 5/8) and yellowish red (5YR 5/6) very slightly stony clay; mainly small subangular flints
55-84	Prominently mottled light grey (10YR 7/1), brown (7.5YR 5/6), yellowish red (5YR 5/6) and locally red (2.5YR) very slightly stony clay; mainly small subangular flints
84-126	Prominently mottled dark yellowish brown (10YR 4/6) and grey (10YR 5/1) very slightly stony clay; mainly small subangular flints
126-136	Dark yellowish brown (10YR 4/4) gravelly sandy clay loam; mainly subangular flints up to 8cm, some Tertiary-derived flint pebbles, quartz pebbles and quartzite/sandstone.

Figure 48. Description of Proline core from Northaw Great Wood, Pit 2 (TL 279 039)

Detailed field descriptions of Proline cores taken from the sites of Pits 2 and 3 are given in Figs. 48 and 49. Analytical data (Table 8 and Fig. 50) show that the Pebbly Clay Drift can be interpreted as weathered Chalky Boulder Clay covered by a very thin intermixed layer of (Devensian ?) loess.

Depth (cm)	Horizons
0-2	Black (10YR 2/1) stoneless humose silty clay loam
2-8	Brown (10YR 5/3) slightly stony clay loam; rounded flint and quartz pebbles, subangular flint and sandstone
8-23	Yellowish brown (10YR 5/4) slightly stony clay loam; small angular flints and Tertiary-derived flint and quartz pebbles
23-39	Yellowish brown (10YR 5/4), pale brown (10YR 5/3) and strong brown (7.5YR 5/6) finely mottled slightly stony clay loam; stones as above
39-73	Prominently mottled light brownish grey (10YR 6/2) and strong brown (7.5YR 5/6) very slightly stony clay; angular flints often with thick white patina, and a few flint and quartz pebbles
73-93	Prominently mottled dark yellowish brown (10YR 4/4) and grey (5Y 5/1) very slightly stony clay; angular flints and rare quartzite pebbles
93-170	Prominently mottled dark yellowish brown (10YR 4/4) and light brownish grey (10YR 6/2) very calcareous slightly stony clay; common rounded chalk fragments and a few angular flints and flint pebbles, mainly <6 cm
170+	Dark yellowish brown (10YR 4/4) gravelly sandy clay loam; stones mainly flints up to 8cm and Tertiary-derived flint pebbles, with some quartz pebbles and quartzite/sandstone

Figure 49. Description of Proline core from Northaw Great Wood, Pit 3 (TL 278 039)

Ø divisions	µm equivalent	Profile 2, 3-28cm	Profile 2, 28-55cm	Profile 2, 55-76cm	Profile 2, 84-126cm	Profile 2, 126-136cm	Profile 3, 8-23cm	Profile 3, 23-39cm	Profile 3, 39-73cm	Profile 3, 73-93cm	Profile 3, 93-170cm (Chalky till)	Pit 1, Pebble Gravel
0 to -1	1000-2000	2.2	1.0	0.7	1.6	17.7	3.5	1.5	1.5	0.9	0.7	1.7
+1 to 0	500-1000	4.6	1.9	2.0	2.6	25.2	5.5	3.7	3.1	2.6	2.4	3.2
+2 to +1	250-500	7.7	4.4	4.6	6.5	16.3	9.7	7.5	7.2	6.0	7.0	29.2
+3 to +2	125-250	9.6	6.8	7.3	10.5	6.4	11.5	9.7	10.2	9.6	10.8	50.6
+4 to +3	63-125	6.6	5.5	5.3	7.4	3.8	6.7	6.4	5.9	6.8	7.5	6.2
+5 to +4	32-63	11.9	7.1	6.2	6.9	3.0	11.0	9.7	5.6	5.2	5.3	1.0
+6 to +5	16-32	13.8	7.8	7.2	5.4	2.2	10.8	10.6	4.7	5.0	5.5	0.4
+7 to +6	8-16	10.0	6.6	5.7	4.7	1.4	9.4	8.8	4.9	5.0	4.5	0.2
+8 to +7	4-8	7.1	4.8	4.6	4.8	1.4	6.1	5.4	3.7	5.3	5.0	0.4
+9 to +8	2-4	6.1	5.0	4.6	5.0	1.5	5.5	5.2	4.6	5.4	5.0	0.3
>+9	<2	20.4	49.1	51.8	44.6	21.1	20.3	31.5	48.6	48.2	46.3	6.8

Table 8. Particle size distribution at Ø intervals (Ø = -log₂ mm) of samples from profiles 2 and 3, Northaw Great Wood, and Pebble Gravel from pit 1 (decalcified, <2mm, oven-dry basis).

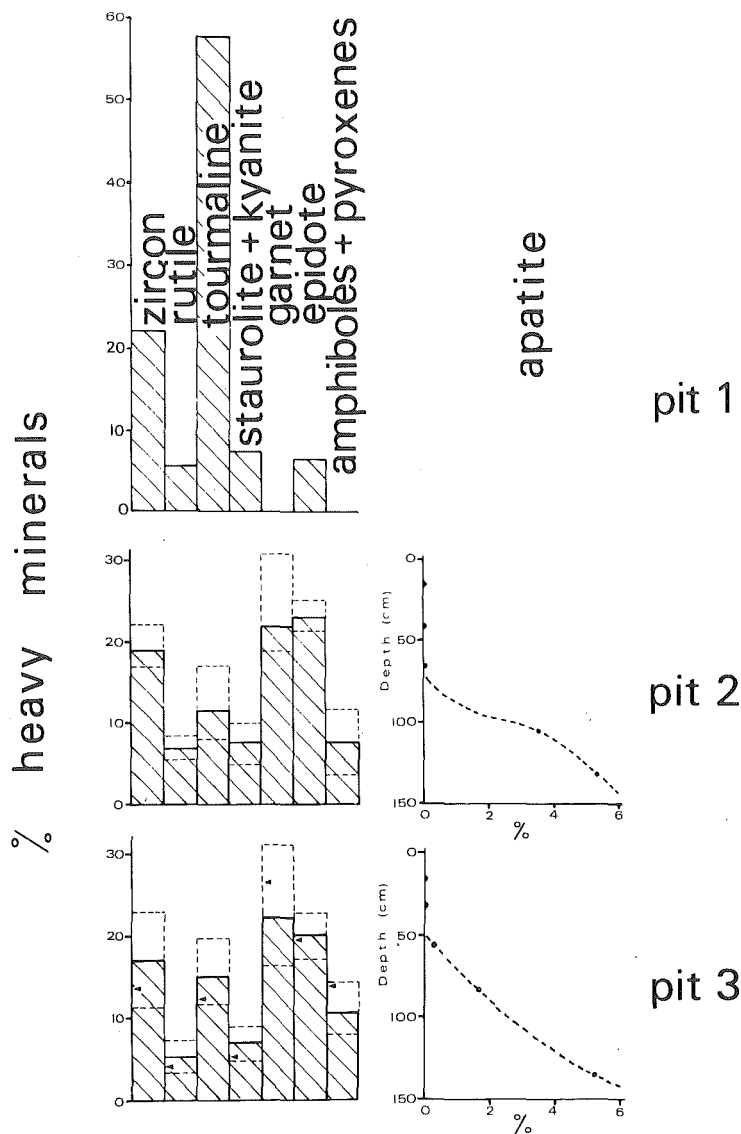


Figure 50. Amounts of major non-opaque heavy minerals (as percentages of total non-opaque heavy fraction) in Pebble Gravel from Pit 1, and five horizons of each profile at Pits 2 and 3 (solid lines indicate means, dashed lines the full ranges). Arrowheads indicate the composition of chalky till (93-170 cm) in Pit 3. Amounts of apatite plotted against depth to show effects of weathering.

	% > 2mm	Flint	Chert	Quartz	Quartzite	Other
Pit 1, Pebble Gravel	14.7	87.8	0.2	11.9	-	0.1
Pit 2, 126-136cm	67.6	91.7	-	7.9	0.5	-

Table 9. Percentage weight of stones (>2mm) and types of stones (>4mm) in samples of Pebble Gravel (Pit 1) and gravel beneath Pebbly Clay Drift (Pit 2).

Conclusion

In Northaw Great Wood and at the sites investigated by Moffat and Catt (1982) materials corresponding to the Pebbly Clay Drift of Thomasson (1961) have originated by soil development at two different times, one before and one after deposition of the Chalky Boulder Clay. In neither of these areas can the Pebbly Clay Drift be interpreted as the till of a pre-Anglian glaciation, though this possibility should perhaps still be considered for Pebbly Clay Drift elsewhere in south-east Hertfordshire and west Essex.

The evidence for a pre-Anglian glaciation of the proto-Thames valley may be stronger in the Oxford area (Shotton, et al., (1980) and on the lower dip slope of the Chilterns around Chorleywood and Chalfont St. Giles, where Barrow (1919) recorded a reddish sandy clay containing Tertiary-derived flint pebbles and numerous far-travelled stones, including large angular fragments of vein-quartz. This deposit, part of the "Chiltern Drift" of Woodridge and Linton (1955), is not exposed at present. At least there is no possibility of confusing it with Chalky Boulder Clay, as it lies outside the Anglian limit, well beyond any known remnant of chalky till. However, it could be interpreted as Westland Green Gravel overlying Reading Beds, the two having been disturbed, incompletely mixed and weathered during later Quaternary stages.

B.W. Avery and J.A. Catt.

Fabric analysis from Pit 3, Northaw Great Wood

Macrofabrics taken at 0.85m (very slightly stoney clay, i.e. "pebbly clay drift") and at 1.35m below the surface (very calcareous slightly stoney clay, i.e. chalky till) yield the following results.

Sample No.	Depth	Resultant vector	Vector Magnitude	Rayleigh test	Mean dip
HW2	0.85m	40/220°	48.6%	.99999	21.8°
HW1	1.35m	37/217°	55.4%	.99999	13.9°

D.A. Cheshire

HARPER LANE

TL 16 02

The sequence exposed in the Redland Aggregate's quarries in 1971/74 was as follows:

	maximum thickness
4. Brown clayey silt	2.3 m
3. Dark grey Chalky Till	5.5 m
2 Laminated silty clays	1.1 m
1 Current bedded sand and gravel	4.2 m

The Pleistocene deposits rest on an irregular floor of weathered, brecciated Chalk, which is poorly exposed.

Sand and gravel

Buff coloured medium gravel overlies the chalk showing little evidence of bedding, although imbrication may be seen indicating a south-westerly derivation. Sand lenses are absent from the lower horizon and are rare near the top of the bed. When they do occur, they reach a thickness of up to 0.6m and a lateral extent of some 3m. Further horizontally bedded medium gravel occurs associated with the sand lenses, the gravels being strongly stained by iron, and in places, manganese compounds.

Infrequently, small lenses of yellow tabular cross-bedded coarse sand are found between 0.25 and 0.7m thick. Narrower lenses of yellow ripple marked silty sand up to 0.3m are also seen immediately underlying the succeeding unit. However, in most parts of the exposure the overlying deposit rests directly upon the medium gravels with a sharp junction. The entire gravel unit is 4.2m thick. Current bedding from the gravel and sand gives a direction towards 70°.

The gravels contain a number of small scale monoclinical flexures and some larger scale shallow open folding, all of which has a similar north-west/south-east trend. Two structures resembling ice wedge casts occur in the upper part of the deposit, the tops of which are concordant with the surface of a gravel horizon. They are small, up to 75cm long, the infill having a pebble fabric parallel to the walls of the structure.

Laminated clays

These overly the gravel and have a markedly sharp base. They are 1.1m thick, grading upwards into the overlying till, making this measure rather arbitrary. The clays are well developed and very uniform over the entire pit area, although they thin and become more silty eastwards. In places, they are cut out and replaced by till. Throughout the exposure they are seen to be gently undulating; the fold axes, corresponding with those of the gravel beneath, strike in a north-west/south-east direction.

The lowest sediment is very silty consisting commonly of contorted or partially distorted laminae mainly of a reddish brown (5YR) colour. Although parts of the basal sediment show some laminar pairs, the couplets become much more apparent immediately above a dark red band. Above this, dominantly buff silt (7.5YR) and dark brown clay laminar pairs, up to 2mm in thickness, occur. The individual laminae are variable in colour and thickness. Each shows a gradation from silt to clay and then truncation by the following silt.

Progressing upwards the clays become relatively darker. However, between the horizons of buff undisturbed couplets are dark brown massive units. These horizons show contortion of silt laminae and mixing of sediment which is considered to be evidence of slumping. The bases of such units are often highly irregular resting on a number of different laminae and on occasions showing minor load casts where clay sediment is overlain by coarser material. Such 'slump' horizons alternate with the laminated beds to produce a cyclic sequence. Higher in the section (upper 30cm) the sediments become darker (10YR) and display small scale faulting, both normal and reverse, with throws up to 2cm. Towards the top, the laminae become progressively less distinct and finally are replaced by structureless clay horizons. The uppermost sediment consists of sandy silt in angular blocks closely packed into a dark clay matrix. This material is related to the gradation into the till above. A minimum total of 342 laminar pairs was counted in the vertical sequence.

The till

This reaches a maximum of 5.5m. It has a defuse base, grading through 1.5m of sediment. It comprises dark grey silty clay with few Chalk clasts or other pebbles at the base. Pebbles become much more abundant in the upper 3m of the section. The till is massive and shows no evidence of slumping. The basal 2m contains lenses of a material similar in grain size and colour to that beneath the clays, although these show no evidence of structure. These irregularly shaped bodies vary in size, the largest being 35cm at its widest point. A macrofabric measured in unweathered till in a neighbouring pipe trench at TL 164 020 yielded a resultant vector of $38/218^{\circ}$, see Fig. 54.

Brown clayey silt

In the section described this unit overlies and is separated from the till by a marked unconformity. It does not form part of the glacial sequence. However, some 75m to the south, a second exposure shows similar, although undisturbed, orange medium gravel. Here the gravel is capped by 1.5m of brown silty clay. The base of this deposit consists of cream and brown stratified clay 0.8m thick. The upper part consists of unbedded, brown silty clay except for a narrow horizon of medium gravel in a clayey matrix.

More recent exposures in November, 1982 at TL 168 027 revealed the following succession:

Surface 68.86m O.D.

Observed thickness

- | | |
|-------------------------------------|--------|
| 4. Sand and gravel, current bedded. | 5.39 m |
| 3. Chalky till | 1.7 m |
| 2. Silty clays | 0.56 m |
| 1. Sand and gravel, current bedded. | 3.39 m |

Chalk bedrock 57.82m O.D.

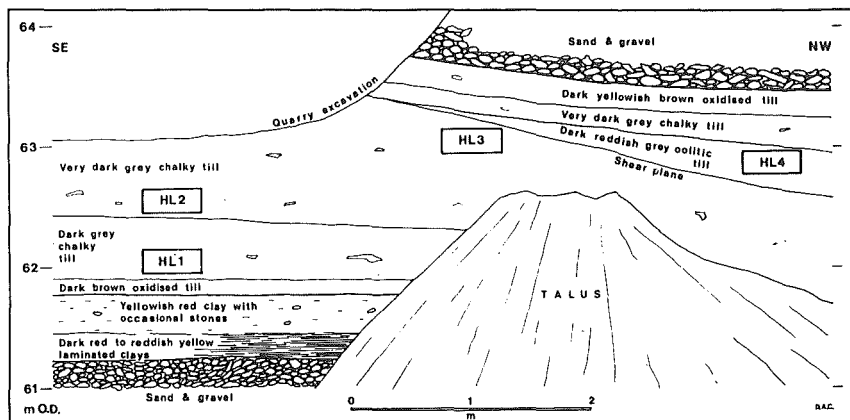


Figure 51. Southwest face of Harper Lane quarry, November 1982, showing silty clays and chalky till. Macrofabric measurements are from HL1, HL2 and HL4. Particle size analyses are from HL1, HL2, HL3, HL4. Acid solubility and small clast lithology are from HL2 and HL4.

Sand and gravel (1)

This unit is identical to the lowest unit described above. Owing to the high water level, only the upper 0.5 to 1m of this unit was visible.

Silty clays (2)

The clays overlie the gravel with a sharp junction. Only the basal 24cm show laminations, which vary from dark red (2.5YR 3/6, moist) to reddish yellow (7.5YR 6/6, moist). The upper 32cm is structureless, yellowish red (5YR 4/6, moist), with occasional stones, but with no chalk clasts visible.

Chalky till (3)

The base of this deposit shows on a narrow transition a few centimetres thick. It possesses a range of colours, at

least one of the colour boundaries being accompanied by clear signs of shearing (Fig. 51). With the exception of oxidised zones top (10YR 4/4, moist) and bottom (10YR 4/3, moist), the till matrix is generally dark grey (10YR 4/1, moist) to very dark grey (10YR 3/1, moist), and contains clasts of chalk and flint. Samples taken at HL1, HL2 and HL3 (Fig. 51) yield a particle size distribution shown by samples 1, 2 and 3 on Fig. 52. 'S' is an

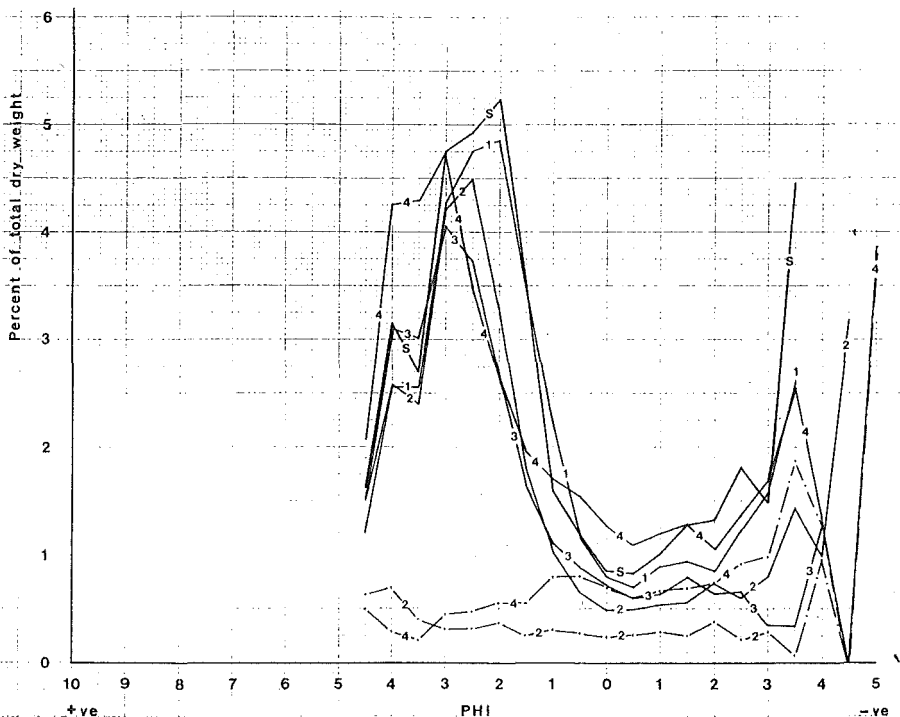


Figure 52. Particle size distribution of the till at Harper Lane from the fraction coarser than +4.5 ϕ . Sample S was taken 0.5m from the base of the till 80m northeast of the section shown on Fig. 51. Solid lines: total of lithologies including acid solubles. Broken lines: acid soluble fraction. Note the anomalous distribution of HL4.

earlier sample taken near the base of the till. These all show a mode in the +2 to +3 ϕ fraction with a diminutive mode at +4 ϕ . This distribution will be noted elsewhere. The acid soluble content, mainly chalk, in the diagnostic -2.5 ϕ to +1 ϕ fraction at HL2 is 44.5%, and quartz: flint ratios are shown in Fig. 53.

In marked contrast in all respects is the dark reddish grey (5YR 4/2, moist) oolitic till at HL4. This till type has not been encountered at any other locality in Hertfordshire or West Essex. It has an anomalous particle size distribution (Fig. 52, curve 4), an acid soluble content in the -2.5 ϕ to +1 ϕ

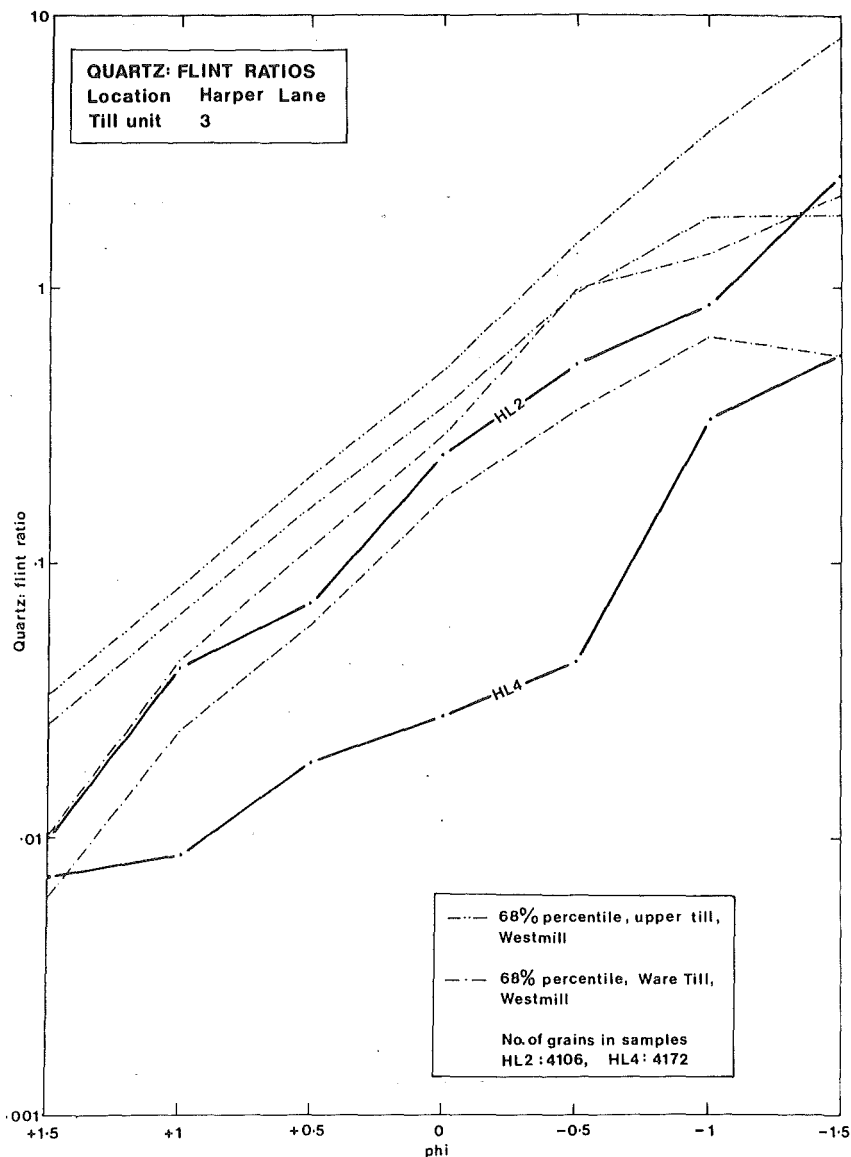


Figure 53. Quartz:flint ratios for the till at Harper Lane.

fraction which is composed of 52.2% oolites (determined in the -2.50 to -1.0 fraction). The quartz: flint ratios (HL4 in Fig. 53) are also clearly anomalous. Small clast lithology analysis (-2.0 to +1.50) shows the proportion of black shale to be about an order of magnitude greater than in the most shaley tills of the area. Though encountered once only, this till, whether lodgement

or flow, clearly has a provenance different from the other tills of the area, which, on grounds of solid geology, presumably lies to the west of the main ice stream. Its contemporaneous deposition with till of recognisable composition suggests either a localised concentration of shaley oolitic debris within the till mass, or the proximity of a mixing zone between sub-parallel ice streams of different till lithologies.

Macrofabric samples yield a generally northeast/south-west preferred orientation, but inconsistencies in the pattern of deposition (Fig. 54) suggest that the process was less dominated by regional dynamics than by complex local conditions in an area very close to the ice sheet maximum.

Upper sand and gravel (4)

This unit, not present in the 1974 exposure described above, consists of over 5m of medium gravel containing tabular and trough cross bedded sands with fining-upwards sequences characteristic of braided river sedimentation. These structures give a strong palaeocurrent vector towards 270° in marked contrast to the lower sand and gravel palaeocurrent direction towards 70°. This unit, the Smug Oak Gravel, marks the onset of southwestward "Colne" drainage in the Vale of St. Albans.

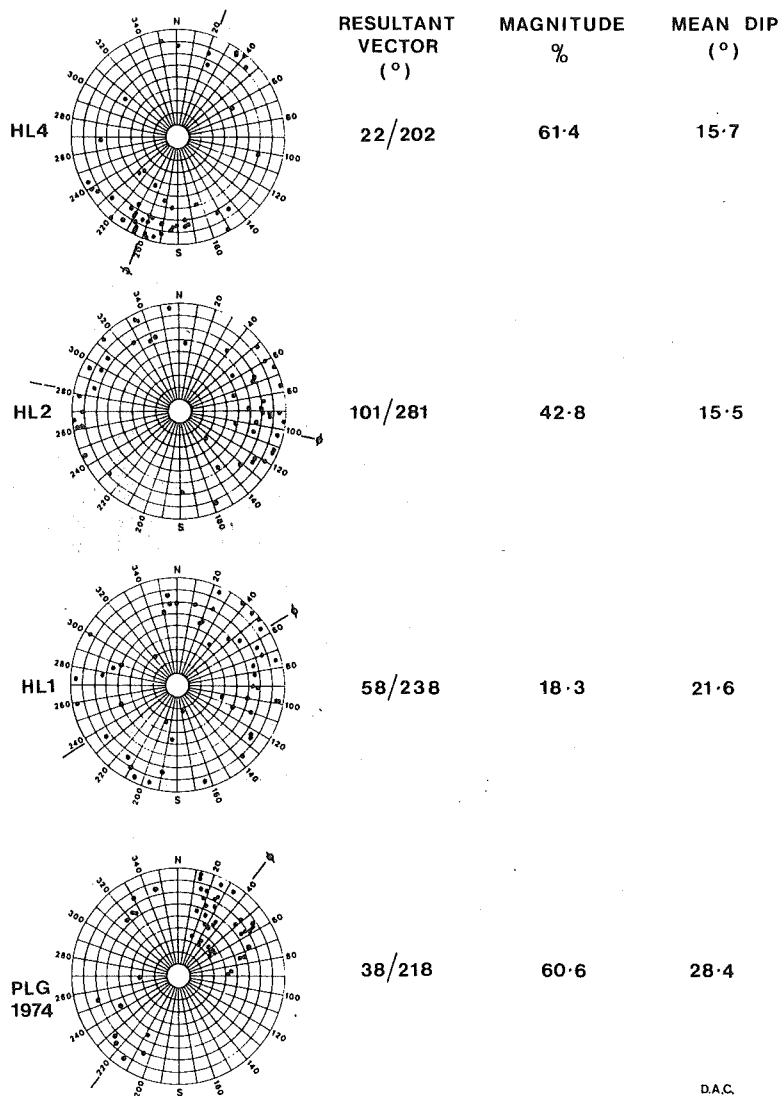
Summary and Interpretation

The lower gravels and sands were probably deposited in a river as a gravel bar in a permafrost environment under broadly similar conditions to those at the Westmill Quarry. Current bedding shows a derivation from the west-south-west, and ice wedge casts in the gravel suggest temporary subaerial exposure.

The laminated clays indicate deposition in still-water, with the laminar pairs suggesting a 'varve-like' periodicity of deposition. If the laminae are annual, the lamination would result from a freezing of the lake in winter and its melting in summer. In this case the coarse silt laminae would correspond to the summer horizon. Early deposition of coarse sediment was followed by finer material, possibly reflecting increased water depth. The depth of the water cannot be determined, but the margin was probably to the east.

The massive horizons probably indicate slumping of material. Erosion of the laminated clays beneath suggests that the material entered the area as a turbidity flow. This alternation implies that sediment built up until no longer stable, then slumping occurred. The increase of structureless horizons near to the top of the sequence suggests the influence of approaching ice, which eventually overrode the clays. The relation of the clays to the till suggests that they were deposited in a proglacial lake, and the concentration of faulting in the upper levels of the clays supports the suggestion of glacial overriding.

The gradation into the till indicates that sedimentation must have been continuous. The lack of stratification may result from large scale slumping or continuous sediment supply.



D.A.C.

Figure 54. Till macrofabrics from Harper Lane. Sample PLG 1974 is from a neighbouring pipe trench (Gibbard, 1974).

The ice, therefore, must have been initially floating on the lake. However, normal massive till was deposited after the disappearance of the lake. On grounds of particle size, carbonate content and small clast lithology the till may be correlated with that exposed near Hatfield Polytechnic and other tills further east. Contortion of the gravel and clays below indicates ice push. The alignment of the axes suggests a thrust from the northeast. The till exposed at HL4 suggests the possibility of ice with a more westerly provenance.

The Smug Oak Gravel marks the commencement of the drainage reversal caused by the obstruction of the Proto Thames in the Vale of St. Albans.

The brown clayey silt is believed to be late Devensian age.

P.L. Gibbard

D.A. Cheshire

HATFIELD POLYTECHNIC (ROE HYDE PIT)

TL 212 075

The sections at this locality were first described by Sparks *et al.*, (1969) who recorded the stratigraphy; Rose (1974), who described aspects of the till lithology, and Gibbard (1978) who provided a review for the 1978 Quaternary Research Association Meeting.

This is the type section for the Hatfield organic deposits and the Roe Green Gravel, and the general stratigraphy is summarized in Fig. 55. At the present time the only section visible is HA. The quarry in which the section described by Rose (1974) was located is completely infilled. The following descriptions and discussion are concerned primarily with the Hoxnian organic deposit and the underlying till. It should be noted at this stage that there is disagreement between the two contributors (D.A.C. and P.L.G.) about the designation of the lower till unit as either the Eastend Green Till (Gibbard, 1977, 1978) or the Ware Till (Cheshire, this Guide).

The succession at locality HA (Fig. 55) is:

Roe Green Gravel	glacial beds	L 0-90cm	Pebbly sand, cryoturbated into the bed below in irregular tongues-reach a depth of approximately 180cm.
		H 90-220cm	Grey silty mottled clay, orange when weathered and grey where unweathered.
Hatfield Organic Deposit	Inter-glacial beds	G { 220-340cm	Black detritus mud, clayey towards the top, and containing coarse sand grains in the lower part.
		{ 340-360cm	Dark sedge peat, with some small gypsum crystals.
		F 360-415cm	Grey silty marl with abundant <i>Chara</i> and Mollusca. Thin peat seams (0.5-1.0cm. thick) occur at 400 and 407cm. There are other very thin peat seams and the beds appear much disturbed.
	Late glacial beds	E 415-500cm	Whitish silty marl with abundant <i>Chara</i> and Mollusca. In the basal 15cm. merges, by close alternations, into:
		D 505-?600cm	Dark grey silty clay with few Mollusca and plant remains. Thickness is uncertain as lower limit obscured by talus.
Smug Oak Gravel	glacial beds	C?600-850cm	Dark grey till with chalk and flints in dark clay matrix.
		B 850-1100cm	Current-bedded sand with pebble layers. At 1000cm is a layer with many blackened wood fragments.
Till		A 1100-1400cm	Till, apparently identical with that of bed (C) extending down below level of water table.

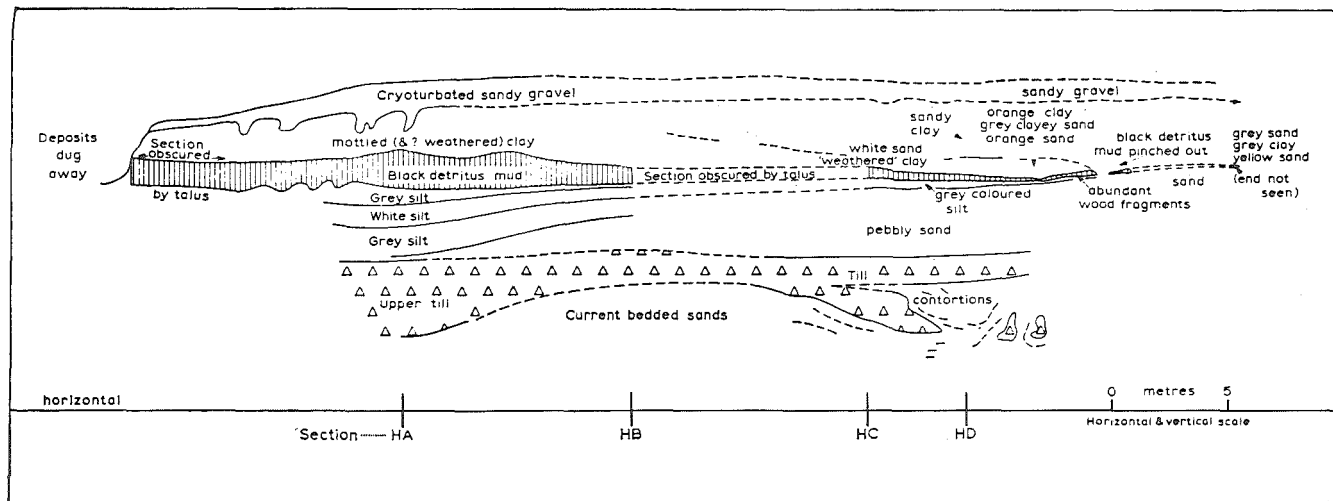


Figure 55. Hatfield Polytechnic Quarry, east face. (Reproduced from Proc. Geol. Ass., 1969, 80).

Glacigenic Deposits

Figure shows that the biogenic deposits at Hatfield lie in a shallow depression in the lower glacial beds. The latter consist of till, overlain by sand and gravel which is step-faulted in places. Both of these units were exposed in a neighbouring pit now infilled. The deposits were correlated by Gibbard (1977) with the Eastend Green Till and the Smug Oak Gravel respectively, on the basis of their height, stratigraphical position, pebble lithology and the palaeocurrent direction in the gravel and sand. The till was previously investigated by Rose (1974) and shown to be a disturbed body of slumped till, which accounts for the presence of a till lens (bed C) immediately beneath the late-glacial beds. This till probably slumped off an upstanding stagnant ice block nearby into the neighbouring kettle hollow. Sections in the adjacent quarry showed that the sub-horizontally stratified sands and gravels were disturbed by a series of low angle normal faults. These release structures support the ice-melt hypollaxis and confirm that *in situ* melting of buried ice continued during deposition of the overlying sand and gravel.

P.L. Gibbard.

Bed A of Sparks *et al.* (1969) is no longer exposed. Two macrofabric analyses by Sparks *et al.* from this bed gave orientations of 50/230° to 60/240° and 75/255° to 80/260°. A similar till has been detected by a large number of Al(M) boreholes at elevations of 57m to 67.7m O.D. The same till can be shown to extend along the Vale of St. Albans northeastwards to Westmill and, southwestwards to Moor Mill and Harper Lane (Fig. 24). No recent samples have been obtained from the present site at Hatfield, but those bores at the British Aerospace factory, 1.7km to the north, show this till to be dark grey (10YR 4/1, moist) to very dark grey (10YR 3/1, moist) and to have particle size characteristics of the Ware Till type (see pages 50-59). Samples obtained from the same till at the Holwell Hyde quarry (southeast of Welwyn Garden City) also show particle size and acid solubility characteristics of the Ware Till type.

The till now exposed at the Hatfield site is Bed C of Sparks *et al.* It lies at 66.9m to 69.0m O.D. and is dark grey (10YR 4/1, moist) at the base, through dark greyish brown (2.5Y 4/2, moist), to brown (10YR 4/3, moist) at the top. The discontinuous nature of the till shown by Al(M) bores supports the view (Rose, 1974; Gibbard, 1978) that the till is in the form of lenses or lobes of a slumped or flow origin. The till has been sampled at 0.5m intervals, the upper 80cm showing clear signs of disturbance and incorporation of chalky sand stringers. This is reflected in the particle size distribution for sample 4 (Fig. 56). The three lower samples yield consistent distributions which conform to the pattern of the Ware Till type (see Westmill site description) and possess low proportions of acid solubles, 33.6 - 35.5% in the -2.50 to +10 range, comparable with the Ware Till at Westmill (mean value 29.1%), but contrasting with the Westmill upper till (mean value of 77.1%). The small

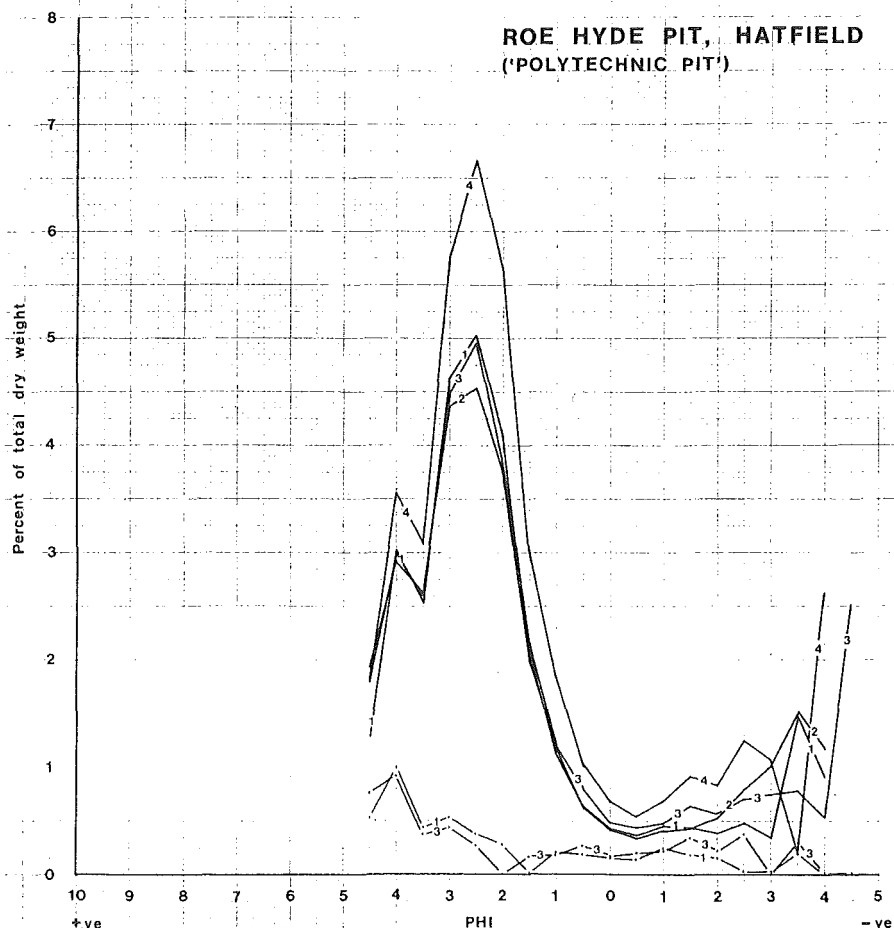


Figure 56. Particle size distribution of till from Bed C (Sparks *et al.*, 1969) in the fraction coarser than $+4.5\phi$, sampled at 0.5m vertical intervals. Solid lines: total of lithologies including acid solubles. Broken lines: acid soluble fraction.

clast lithologies in the -2ϕ to $+1.5\phi$ size range show a reduction in shale and pyrites from the base upwards and increase in the iron oxides and hydrated oxides. The quartz: flint ratios are shown in Fig. 57 and fall largely within the 68 percentiles for the Ware Till at Westmill.

It is of interest to note that although no higher till is observed at this section, about 1.5km north at the British Aerospace airfield a non-calcareous till has been mapped by the Soil Survey within 1m of the level surface at a height of 74m O.D. (R.G.O. Burton, pers. comm. 1982). The nature of the stratigraphic relationship of the Hatfield organic deposits with the

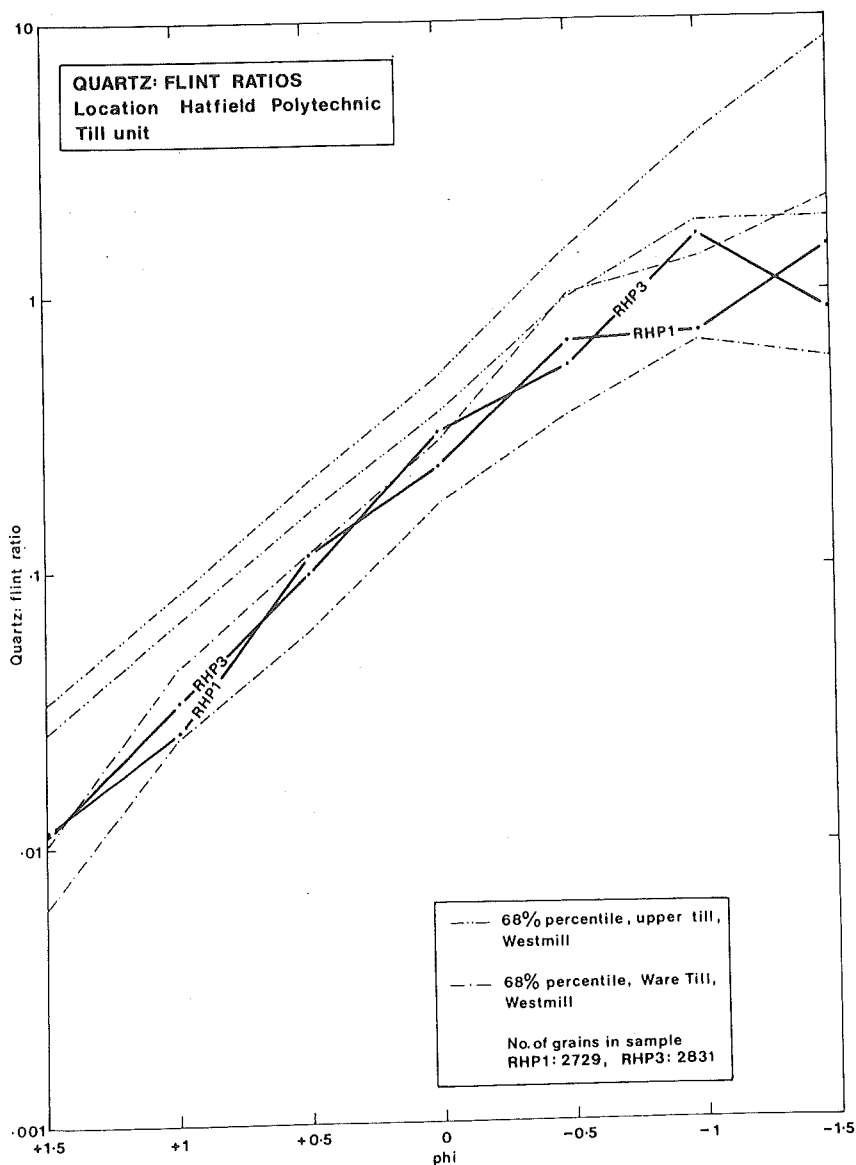


Figure 57. Quartz: flint ratios for the till of Bed C (Sparks et al., 1969) at Hatfield.

non-calcareous till and other surface tills a few km further north may be clarified by the proposed Al(M) cut and cover tunnel through Hatfield, due to start later this year.

Hatfield Organic Deposits

The biogenic deposits are divisible into two separate units, the lower marl and silty clay (beds D and F) and the upper organic peat and detritus mud horizons (F and G), between which there is a substantial non-sequence.

The pollen diagram from the sample sequence HA is shown in Figure 58. The samples also contain macroscopic plant remains, fresh water mollusca and ostracods. The pollen is of very local origin and is not continuous record. The non-sequence between the detritus mud and the marl is shown by the abrupt change in pollen spectra. Other breaks may occur in the disturbed upper marl sediment. The local nature of the pollen record results in over-representation of vegetation at or near the site.

The lower grey clay at 390cm contains only a few remains of sedges (Carex sp.) and Scirpus lacustris, but no pollen.

Zone a 345 - 375cm Hippophae - Salix - Betula - Herb p.a.b.

The sediments of this zone are Chara marls formed under shallow water base-rich conditions. The pollen spectra are dominated by non-tree pollen (NAP) and the vegetation indicated was open, with grassland, Hippophae (sea buckthorn) scrub and Betula (birch) copses. A wide variety of open ground herbs are represented whilst herbs of wet ground are also abundant. The vegetation is of a characteristic late-glacial type, similar to that recorded from beneath Hoxnian interglacial deposits and elsewhere in East Anglia. (West, 1956, 1970; Turner, 1970). It can therefore be correlated with the late Anglian regional pollen assemblage biozone (p.a.b.).

Zone b 285 - 345cm Betula - Juniperus - herb p.a.b.

Deposition of Chara marls continued into this zone. The change in vegetation, shown by the pollen and macroscopic plant remains from zone a to b is associated with the seral change on the transition to interglacial conditions. Betula copses expanded in this zone and Hippophae shrubs were greatly reduced. Open ground plants such as Artemisia were present, but their variety and frequency was less than in the previous zone.

Zone c 245 - 285cm. Betula - Juniperus - herb - p.a.b.

Chara marl with disturbed mud layers was deposited at this time. The abrupt changes in lithology and pollen content of this zone may be attributed to reworking, and bioturbation by molluscs. A hiatus may be present between zone b and c covering the development of mixed oak forest since Pinus (pine), Quercus (oak) and Alnus (alder) were growing around the pool at this time. A large number of aquatic plants are recorded.

Zone d 225 - 245cm. Betula - Pinus - Alnus p.a.b.

Chara marl continued to be deposited in this zone. By

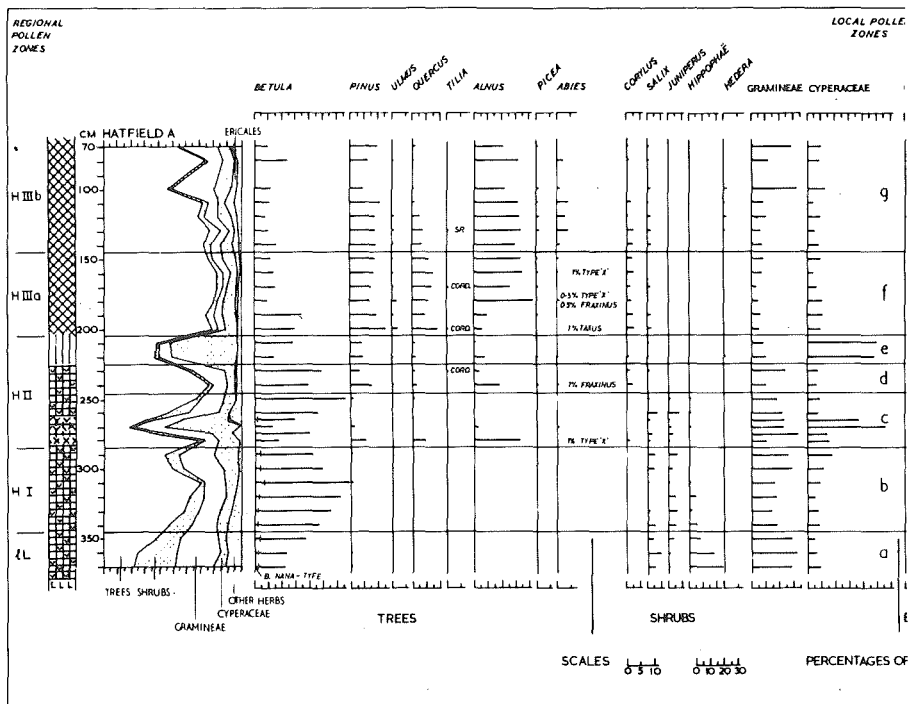


Figure 58. Pollen diagram from sample sequence HA at Hatfield

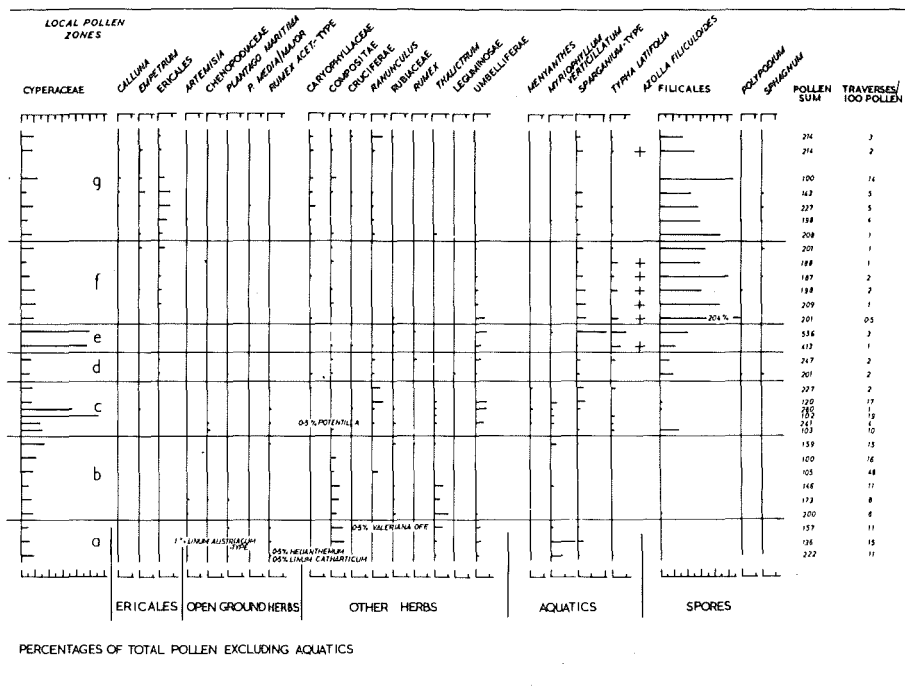
this time there is a clear development of forest with local Betula and Alnus and regional mixed oak forest including Pinus, Ulmus (elm), Tilia (lime), Quercus and Corylus (hazel). Local fen woods supported large numbers of Polypodium ferns.

Zone e 205 - 225cm. Betula - Pinus - Alnus - Cyperaceae p.a.b.

The sedge peat forming the sediment of this zone contains a rich flora of aquatic and fen plants. During this zone sedge communities spread over the shallow lake and fen wood with Betula occupied the margins. Mixed oak forest was present regionally.

Zone f 145 - 205cm. Betula - Pinus - Quercus - Alnus p.a.b.

In this zone, black detritus mud was laid down which at its base shows a transition from sedge peat. The water fern Azolla filiculoides is found throughout the zone. A rise in water level during this time accounts for the decline in Betula and the expansion of Alnus pollen frequencies. Otherwise tree genera represented are of mixed oak forest communities.



Polytechnic Quarry, east face (Reproduced from Proc. Geol. Ass., 1969).

Zone g 70 - 145cm. Betula - Pinus - Alnus - Abies - Ericales
p.a.b.

The black detritus mud continues into this zone becoming more clayey towards the top. The pollen spectra show the continued dominance of forest, though rising grass pollen values in the upper part of the zone indicate increased opening of the tree vegetation. The forest assemblage shows the decline of the thermophilous mixed oak forest taxa and an increase in conifer pollen, especially Abies (silver fir). This is associated with expansion of Ericales (heath) pollen. These taxa are characteristic of the second half of interglacial forest development in the Hoxnian stage.

The deposits can therefore be clearly correlated with the Hoxnian interglacial stage on the basis of their pollen flora.

Roe Green Gravel

The transition from detritus mud (bed G) to the upper silty clay (bed H) indicates a flooding of the mud by water rich in fine inorganic sediment. The pebbly sand overlying the silty

clay has been shown to have a similar particle size distribution to that overlying biogenic silty clays at Bell Lane. The gravels, termed Roe Green Gravel by Gibbard (1977), originated by solifluction of glacial gravel into hollows early in the Wolstonian cold stage. It is this period during which the horizontal inter-fluve surface of the Vale of St. Albans apparently developed. The cryoturbation may date from a later period.

General significance

Similar biogenic kettle hole fills resting on Smug Oak Gravel occur at six localities under the A1 road, at Colney Heath and at Bell Lane, London Colney (Gibbard, 1977). These Hatfield organic deposits are therefore important stratigraphical marker horizons since they demonstrate the pre-Hoxnian, i.e. Anglian, age of the underlying glacial deposits.

The discontinuous sequence recorded in the biogenic kettle infills is thought to result from water level fluctuations during the interglacial (Figure 59). These changes may reflect

Regional pollen assemblage biozone	Slade Oak Lane	Hertfordshire sites (combined)	Marks Tey (after Turner, 1970).
Ho IV	? deposition ends		temporary fall in lake level
Ho III		? infill of basins deposition ends	
Ho II	rise in water level	rise in water level fluctuating water level	rise in water level
Ho I		fall in water level	? drop in water level
LAn	? continued collapse of basin	deposition begins Melting of stagnant ice blocks	

Figure 59. Comparison of the water level changes at the Hertfordshire and Buckinghamshire sites with those at Marks Tey.

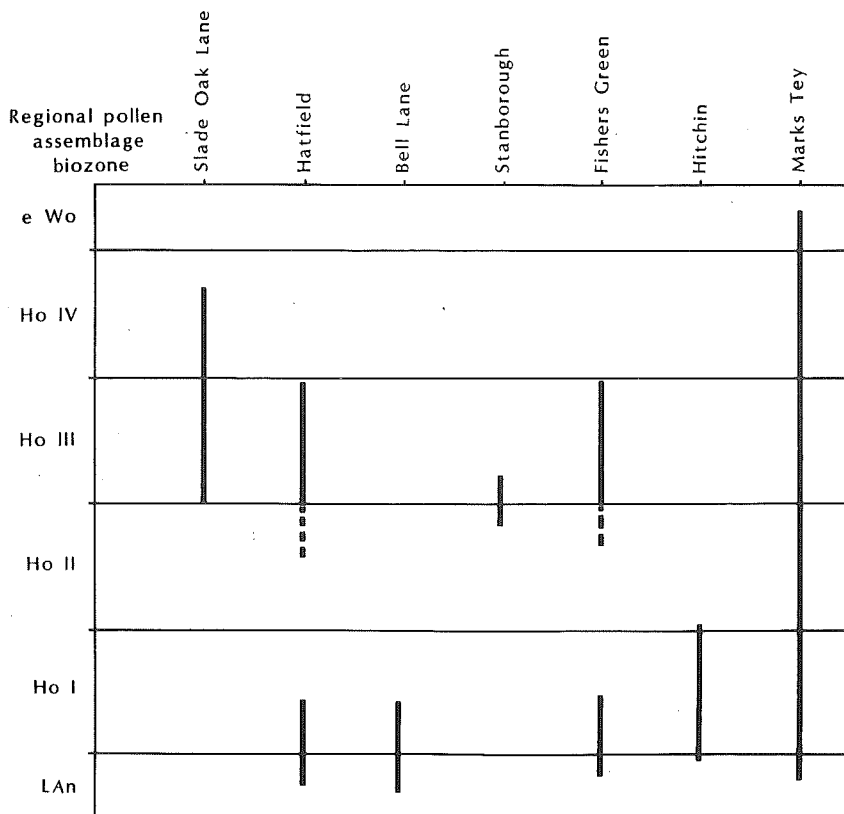


Figure 60. Comparison of the timespan of the Hoxnian interglacial sequences at sites in Hertfordshire and Buckinghamshire with Marks Tey, Essex.

periods of alternately drier and wetter climatic conditions. Such shallow water pools are particularly susceptible to minor changes in ground water level and are useful for establishing these fluctuations (Gibbard and Aalto, 1977). The relationship of this site, and other sites in the area to the complete pollen spectra from Mark Tey is shown in Figure 60.

P.L. Gibbard.

WESTMILL

TL 344 158

The quarry, owned by the St. Albans Sand and Gravel Company, is situated on a level north-south interluve at 73.0m O.D. The Chalk bedrock floor declines from c. 58m O.D. to the northwest of the quarry to 48-50m O.D. at the A10/B1001 interchange. Bedrock contours interpolated between boreholes in the area confirm the site's position on the northern side of an extensive depression from the Vale of St. Albans into western Essex.

The following sediments and respective thicknesses are represented in the quarry:

- | | | |
|-----|------------------------------------|------------|
| 4. | Chalky till (Westmill upper till) | Up to 4.1m |
| 3 | Westmill Upper Gravel (stratotype) | 7 to 11m |
| 2b. | Chalky till (Westmill middle till) | 0 to 3.5m |
| 2a. | Ware till (stratotype) | 0 to 2.8m |
| 1. | Westmill Lower Gravel (stratotype) | Up to 8.8m |
| | Chalk bedrock at 48-54m O.D. | |

The sequence of deposits and sedimentary structures are shown in Fig. 61, from drawings made in June 1981, when the full sequence was well displayed.

Westmill Lower Gravel

The following is taken from (Gibbard, 1978): 'The basal deposits rest on an irregular bedrock surface at 48m O.D. and consist of orange-brown gravel and sand. The gravels are not generally current bedded, but show imbrication indicating a derivation from the southwest. Tabular or trough cross bedded sand lenses are present in the gravel and an alternation of gravel and sand beds is often present. Cross-cutting channel fills are occasionally seen and fining upward sequences from gravel into sand fill the channels. The wide variety of sedimentary structures, and their lateral variability indicates that these sediments accumulated under variable energy conditions in the migrating channels of a braided river. Palaeocurrent measurements indicate a mean current flow towards 039°. Within the upper 3m of the deposit pale buff silt lenses between 0.3m and 2m thick are frequently observed. These carbonate-rich silts are interpreted as deposits which accumulated in backwater channels within a braiding river regime, in which Robinson (1978) found abundant Chara and a fauna of Middle Pleistocene ostracods of cold aspect (see below).

Ware Till

This till overlies the gravel upon a base which must be partially, at least, erosional. Gibbard (1974) recorded the base at 55m O.D., whilst in the 1981/82 exposures the base lay between 59.6 and 60.2m O.D. Occasionally present at the base of the till however, is a yellowish brown (10YR 5/6, moist) lami-

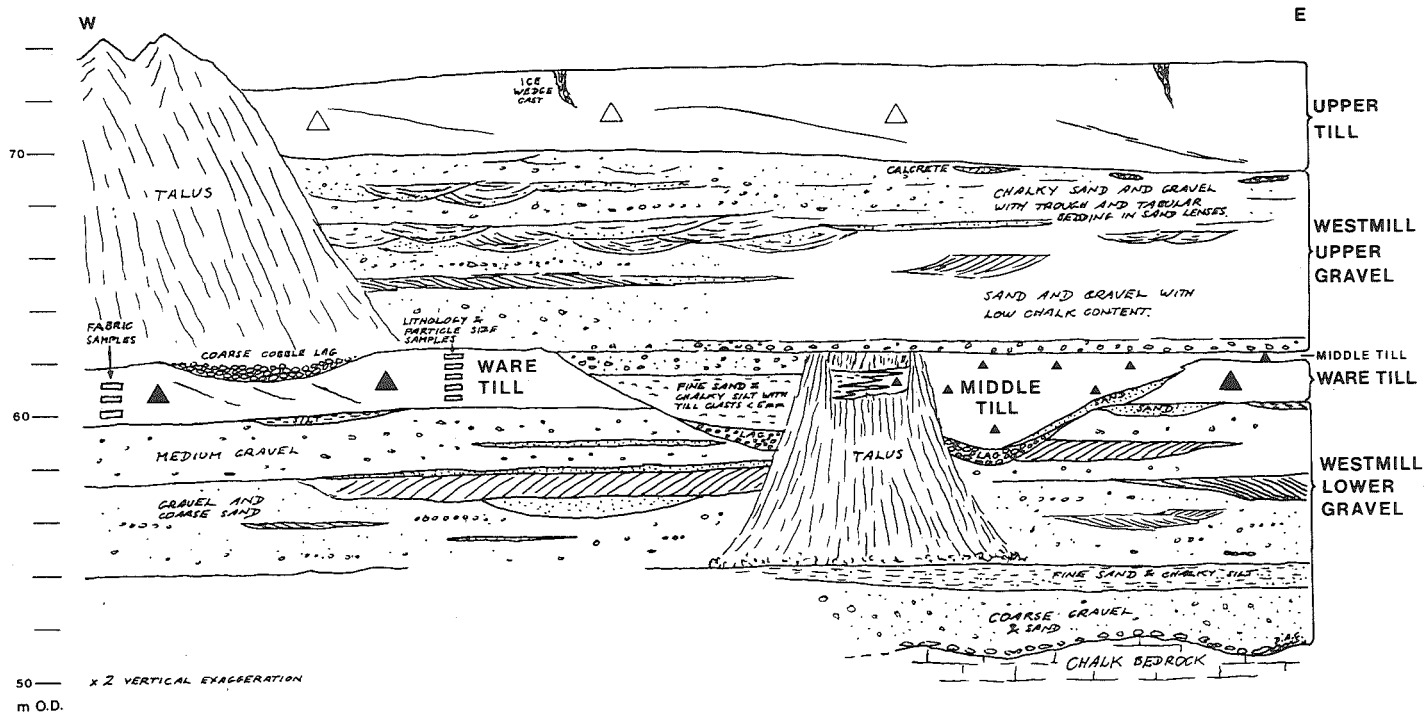


Figure 61. Westmill Quarry, north face, west end, showing sequence exposed in June 1981

nated very silty clay about 15cm thick, which probably accumulated in ephemeral pools either immediately adjacent to the ice margin or beneath the advancing ice.

The till is greyish brown (10YR 5/2, moist) to dark greyish brown (10YR 4/2, moist) with a chalk content markedly lower than the other two tills at Westmill. The matrix of dark Mesozoic clays/shales is partially oxidised, with pyrites now largely absent from the till, though small quantities of pyrites nodules with a limonitic coating have been found 1.7m above the base. Exposures of basal till in 1971/73 yielded shear planes and a strong fabric indicating advance from the northwest (Gibbard, 1977), but more recent exposures, sampled at 0.5m vertical intervals have yielded much weaker macrofabrics possessing resultant vectors orientating from $177/356^\circ$ in the lowest sample to $48/228^\circ$ in the highest (Figure 62). Gibbard's strong basal fabric possesses a mean clast dip of c. 24° , and is interpreted as lodgement till. The mean clast dip of the upper three samples, though, reduces from 15.4° to 12.5° at the top. Lawson (1979) shows that subglacial melt-out till possesses lower clast mean dips ($7-8^\circ$) and lower vector magnitudes than those normally associated with clasts in the glacier ice from which they are deposited. Lodgement till properties from Waterhall Farm, Hertford (Rose, 1974) contrast markedly, possessing mean clast dips of 21° and a mean vector magnitude of 48%. It is clear that the Ware Till, whilst deposited by lodgement from the northwest at the base, exhibits properties tending towards subglacial melt-out and progressive reorientation of the ice from the northeast in the upper and major part of the till. Melt-out is supported by the presence of washed surfaces overlain by laminae in the upper part.

Particle size and acid solubility characteristics in the $> +4.5\phi$ fraction, derived from samples at 0.5m vertical intervals are shown in Fig. 63. The particle size distribution has a mode in the pebble grades, a distinct mode in the $+2.5$ to $+3\phi$ classes, and a subsidiary mode at $+4\phi$ which is partly an artifact of higher acid-solubility in this fraction. Analyses of the small clast lithology in the 4mm to $355\mu\text{m}$ fraction (minus carbonates) shows the proportion of quartz increasing as size diminishes, contrasted with flint which decreases to a point possibly approaching its terminal grade. Oxides of iron and aggregates, whilst constituting 30-40% in the largest grade, reduce to 2.5-8.7% in the finest. The ratio of quartz: flint against particle size is shown in Fig. 64. The upper surface of the till is eroded, and in several places has been considerably thinned or cut out by channel or channel-like structures.

Middle till

This pale brown till (10YR 6/3, moist) has come to light in recent years, and is well exposed only from time to time. It lies upon a strongly erosional base, resting variably upon a coarse gravel up to 0.8m thick above the Ware Till, on the Ware Till itself, and in channel-like structures cut through the Ware Till on the Westmill Lower Gravel. This till is notably more chalky than the Ware Till (68% solubles in the -2.5 to $+1\phi$ fraction, contrasting with 23-40% in the Ware Till), and possesses large pebble-sized sub-rounded and striated chalk clasts. The

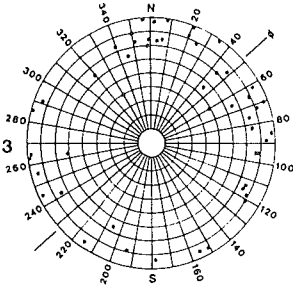
TOP OF TILL

RESULTANT
VECTOR
(°)

MAGNITUDE
%

MEAN DIP
(°)

WMW3

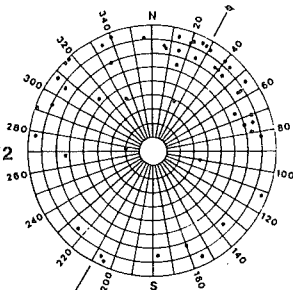


48/228

13.3

12.5

WMW2

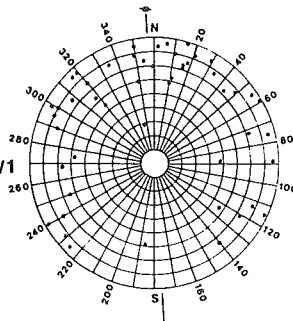


29/209

17.1

15.1

WMW1

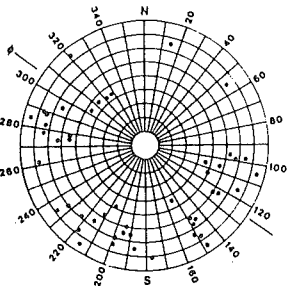


357/177

9.0

15.4

PLG
1974



306/126

—

c24

BASE OF TILL

D.A.C.

Figure 62. Macrofabrics from the Ware Till taken at 0.5m vertical intervals. The lowest fabric is from Gibbard (1974).

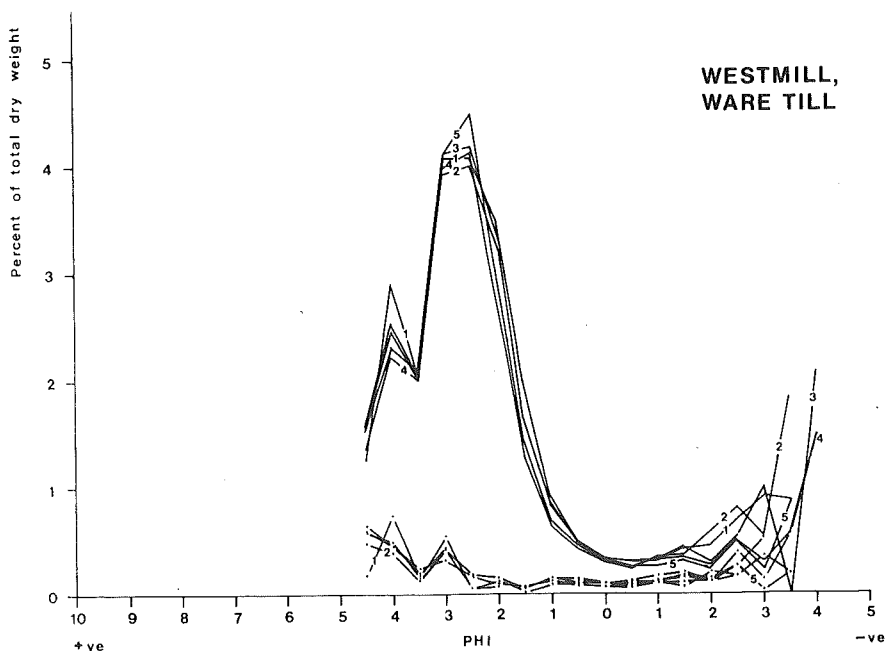


Figure 63. Particle size distribution of the Ware Till, sampled at 0.5m vertical intervals. Solid lines: total of lithologies including acid solubles. Broken lines: acid soluble fraction.

high proportion of solubles in the very fine sand and coarse silt fraction creates a mode at +4 ϕ masking a particle size distribution which is internally consistent (though with a lower sand mode) with that of the Ware Till below (Figure 65). The quartz: flint ratios (Fig. 66) are also similar to those of the Ware Till. However, this till, with a higher proportion of fines and striated chalk clasts than the Ware Till is clearly not re-mobilised and redeposited Ware Till per se. A glacially induced flow till of supraglacial origin can not be ruled out on these grounds.

Fabric data demonstrate that where the till lies in a channel a low magnitude vector results from a basically bimodal distribution. One mode is aligned with the channel axis, and the other approximately northsouth. Where the till lies upon a level surface a strong (magnitude 48.3%) northsouth vector is observed, attributed to a lodgement process. As a result, this till is interpreted as being of generally lodgement origin from the north, but with initial deposition of till in scour channels either by a process of lodgement where glacial dynamics at the base have been weakened by depression of the ice/till interface zone below the zone of optimum lodgement, or by ice advance and partial fabric imprinting over flow till lobes occupying pre-existing channels. The upper surface of the middle till is clearly eroded.

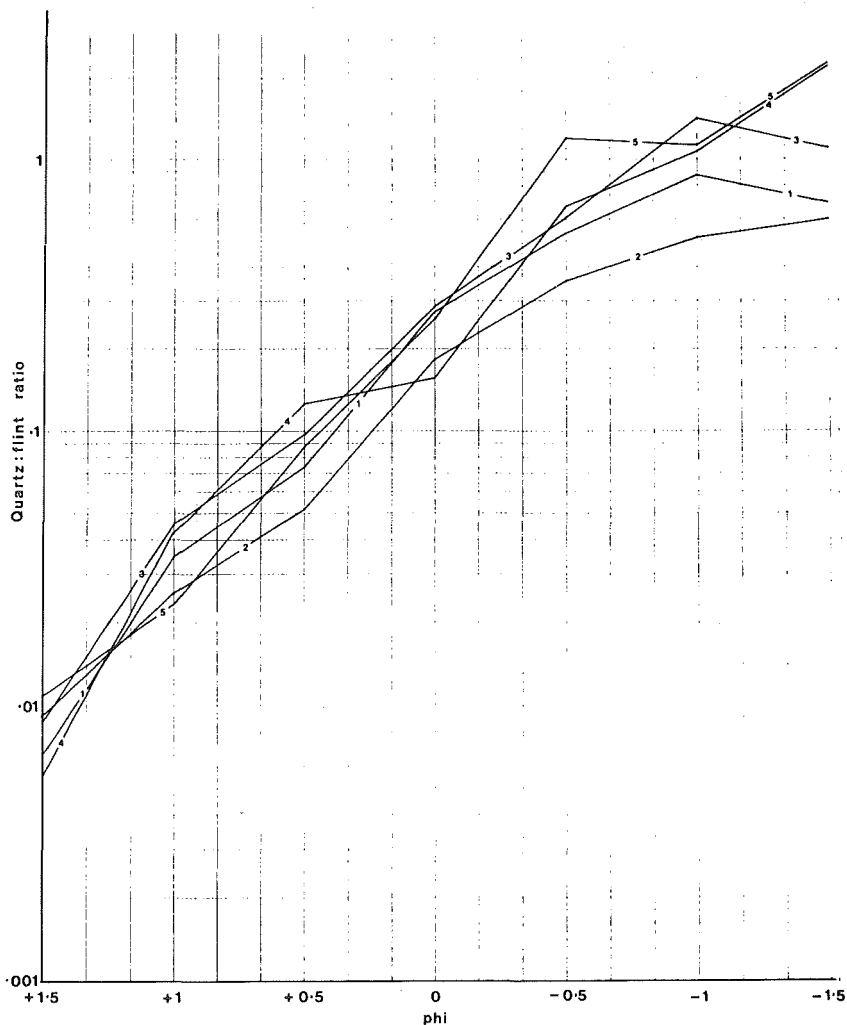


Figure 64. Quartz: flint ratios for the Ware Till, Westmill.

Westmill Upper Gravel.

The following description is taken from Gibbard (1978). 'Large scour channels up to 10m across dissect the underlying tills and the gravel and sand fill rests, in places, directly on the lower gravel. Partially fining upward sequences fill the channels, whilst current-bedded sand and fine gravel lenses are common. Both tabular and trough cross-bedded sands occur. The lower 4m of the unit give a mean palaeocurrent direction towards

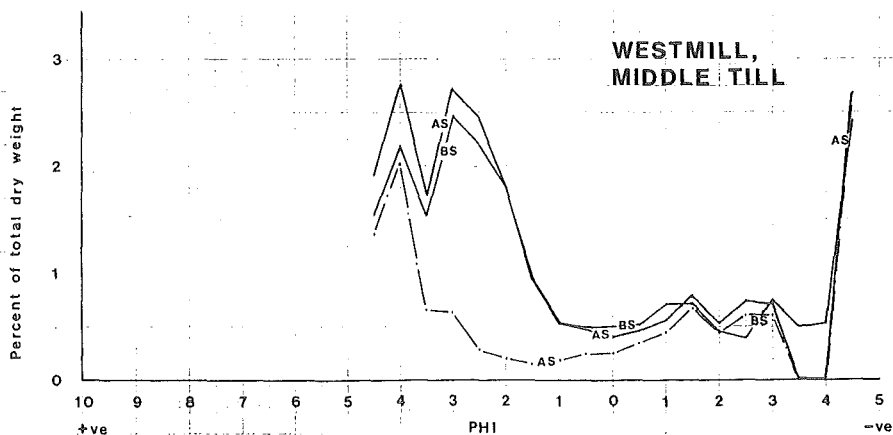


Figure 65. Particle size distribution of the middle till, Westmill. Solid line: total of lithologies including acid-solubles. Broken lines: acid-soluble fraction.

067°, showing that after the retreat of the ice which deposited the Ware Till, the braided rivers returned to the course followed when the Westmill Lower Gravels were deposited.

However, these are overlain by lenses of coarse gravel of variable thickness, which are succeeded locally by trough, cross-bedded sand beds and interstratified gravels. These units give a mean palaeocurrent direction of 228°. This change in palaeocurrent direction records a migration of river confluence in the Hertford - Ware area, caused by outwash from ice advancing from the northeast.

The sedimentary structures and their lateral variability indicates that these sediments were laid down by a braided river under variable energy conditions in a periodically migrating channel system'.

Pebble counts from this unit, (Gibbard, 1978) show an increase in chalk and other exotic lithologies (compared with the Westmill Lower Gravel) immediately above the Ware Till and middle till. This has been ascribed to local erosion of the tills (Gibbard, 1974, 1978), though succeeding deposits contain reduced proportions of these lithologies, suggesting ice retreat and/or burial of the till source below river deposits. The change in current direction, noted above, at c. 68m O.D. is accompanied by a very marked increase in chalk and other exotic lithologies, and probably marks the appearance of further ice to the north of the area.

In the upper 50cm of the gravel Gibbard (1978) observed a sandy gravel bed showing vertical clast alignment, and may be described as an arctic structure soil (Rose and Allen, 1977). Also

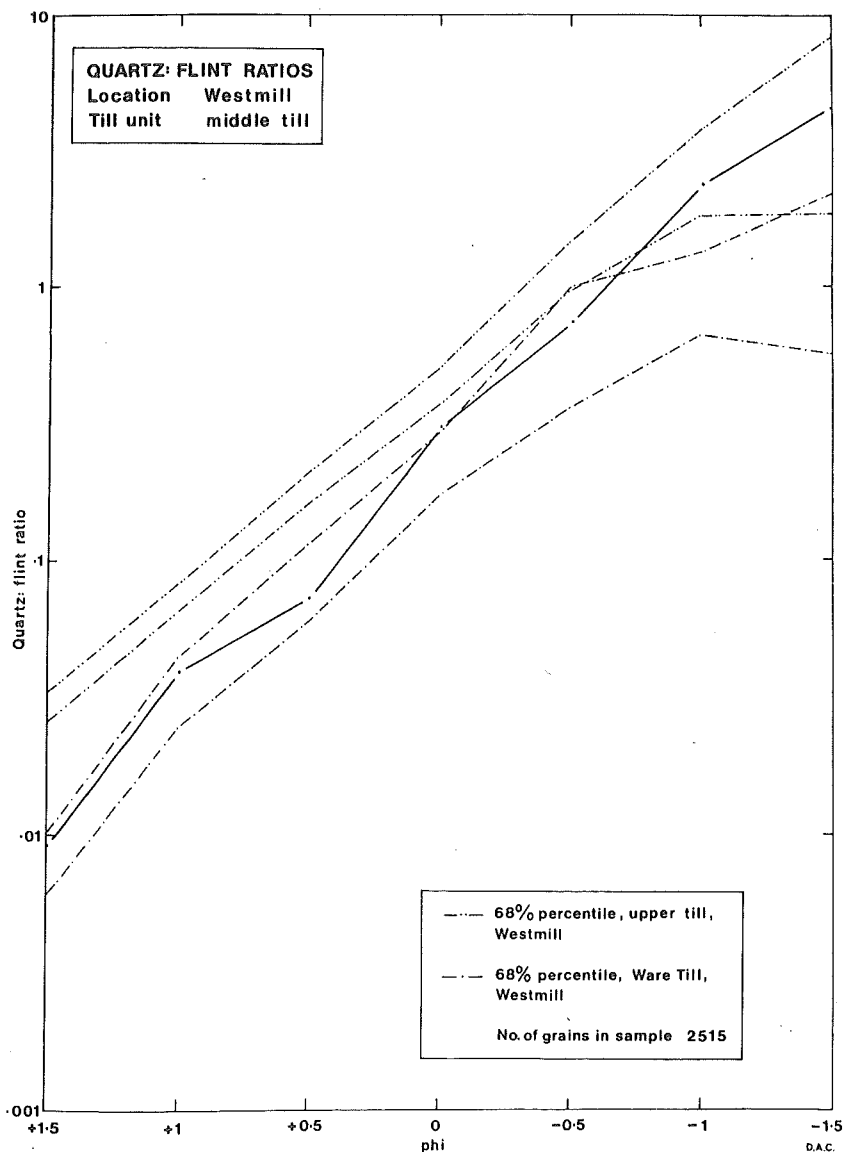


Figure 66. Quartz: Flint ratios of the middle till, Westmill, compared with the Ware Till and upper till.

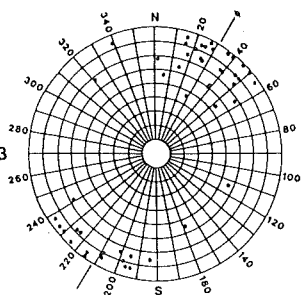
within the upper 1m or so localised cementing of the gravel by carbonate deposition has formed calcrete blocks varying from 30cm to over 5m in length. Quarry staff confirm the periodic recurrence of calcretes at this horizon.

TOP OF TILL

RESULTANT
VECTOR
(°)MAGNITUDE
%

MEAN DIP

WMU3

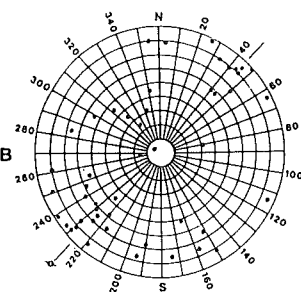


31/211

74.8

13.5

WMU2B

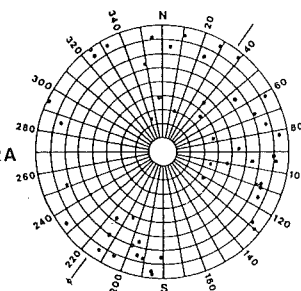


45/225

36.7

24.0

WMU2A

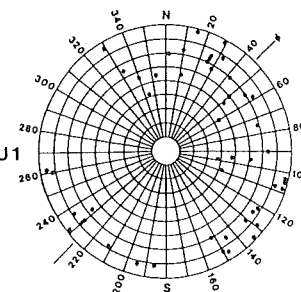


37/217

11.1

20.6

WMU1



46/226

9.4

17.7

BASE OF TILL

D.A.C.

Figure 67. Macrofabrics from the upper till, Westmill. Fabric WMU2B is 4cm vertically above and 25m to the north of fabric WMU2A. The remaining analyses are at 0.5m vertical intervals from WMU2A.

Upper till

This till is lighter in colour than the Ware Till and of greater chroma than the middle till, being generally light yellowish brown (10YR 6/4, moist) in the lower half and brownish yellow (10YR 6/6, moist) to yellowish brown (10YR 5/4, moist) in the upper half. In places the till is stratified in the basal 10-15cm.

The till contains discontinuities such as curvilinear shears and streaking from 0.5m to 20m in length, though most are 1 to 3m. They are most noticeable in the middle and upper part of the till. The shear planes are frequently stained with limo-

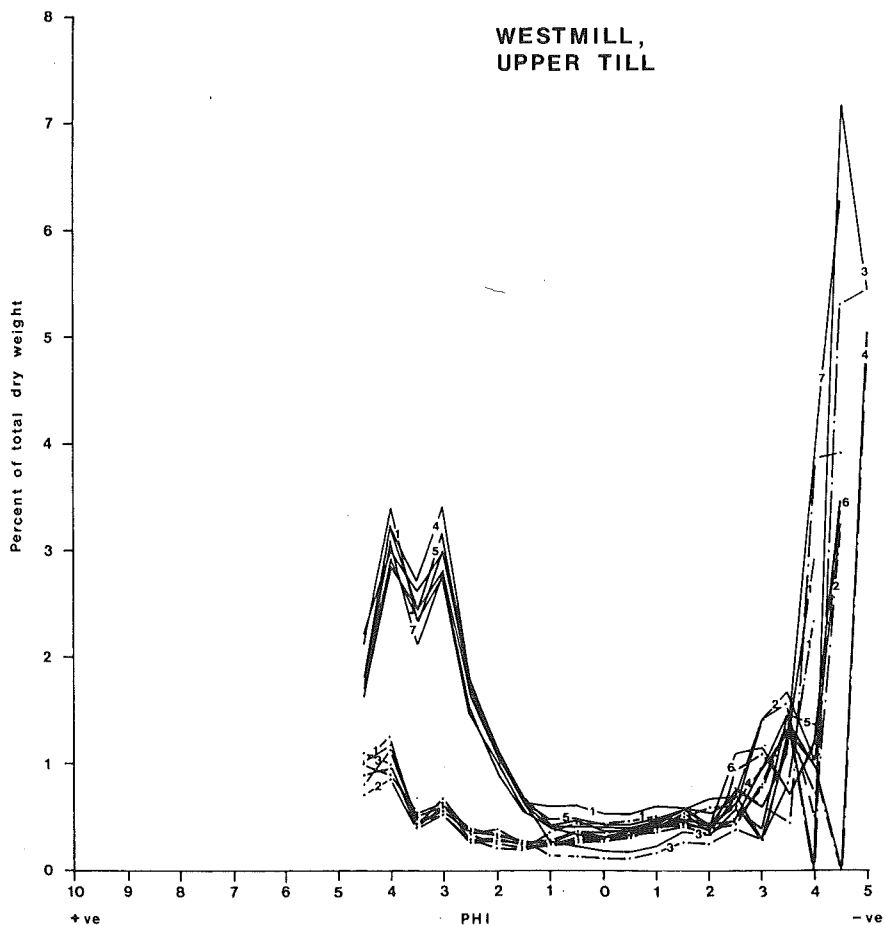


Figure 68. Particle size distribution of the upper till, Westmill, sampled at 0.5m vertical intervals. Solid lines: total of lithologies including acid-solubles. Broken lines: acid-soluble fraction.

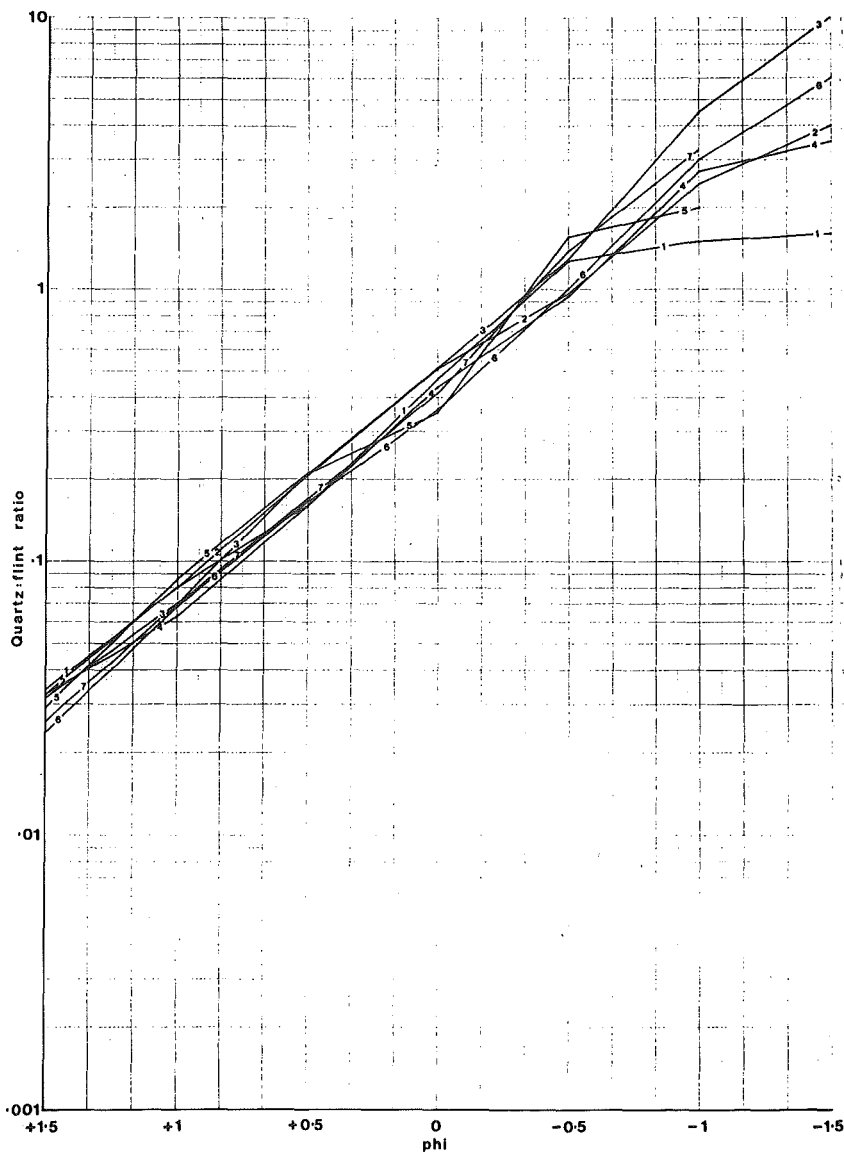


Figure 69. Quartz: flint ratios for the upper till, Westmill.

nite, and sand, only a millimetre or two thick, is common along the plane. Waterlain silt has been found in some cases, and slickensides have been observed. The down dip resultant vector or the planes is towards 32° , with a mean dip of 20° .

The lower part of the till is weakly orientated (Fig. 67) while stronger fabrics are encountered near the top. Resultant vectors fall between $31/211^{\circ}$ and $46/226^{\circ}$ and suggest derivation from the northeast. Mean dips vary from 13 to 24° , with the lowest dip occurring in the strongest fabric. Shear planes and fabrics together indicate lodgement in the upper part, but in the lower part the manner of deposition is less clear.

Particle size characteristics in the $> +4.5\phi$ fraction are quite distinct from those of the Ware Till, as shown in Fig. 68. The till possess three modes: in the large pebble grade, and at $+3\phi$ and $+4\phi$. This till is markedly deficient in medium sand compared with the Ware Till. Analyses of the acid soluble content reveal 2.65 times more carbonate than the Ware Till in the diagnostic -2.5ϕ to $+1\phi$ range. Small clast lithology shows quartz increasing as size diminishes, though flint is in larger proportion throughout than the Ware Till. The ratio of quartz: flint against particle size is shown in Fig. 69.

Ice wedge casts to a depth of c. 1.5m, usually with a mixed sand/clay fill, often iron stained occasionally cut the upper part of the till.

The writer thanks J. Little for supplying the macro-fabric WMU2B used here.

D.A. Cheshire.

Ostracods from the Westmill Lower Gravel, Westmill

In the course of the Quaternary Research Association field meeting to the Westmill Pit (TL 342 162) in the Vale of St. Albans (June 2nd-4th, 1978), a number of samples were taken from sands and silty horizons within the prevailing gravels, and an ostracod fauna was recovered from the Westmill Lower Gravel.

At the time of the visit, a 30-40cm pale coloured bed was prominent within the lower gravels below the platform formed by the Ware Till. In discussion, the bed was described as "fines accumulated in a backwater channel within the regime of a braided river system". The bed owed its pale colour to abundant debris of Chara and reworked fragments of Chalk fossils. Other than this derived fauna, however, the sample also contained an "in situ" assemblage of Pleistocene ostracods, which together constitute a fauna of a cold climate. The list includes:

- Candona levanderi Hirschmann 1912
- Candona neglecta Sars 1887
- Candona cf. triticatrica Diebel & Pietrzeniuk 1969
- Eucypris pigra (Fischer 1851)
- Eucypris cf. dulcifons Diebel & Pietrzeniuk 1969
- Herpetocypris reptans (Baird 1835)
- Ilyocypris cf. monstrifica (Norman 1882)
- Paralimnocythere compressa (Brady & Norman 1889)

From the list, Paralimnocythere compressa is probably the most significant species, being essentially a Middle Pleistocene form recorded from the Cromerian sites of Süssenborn (East Germany), Presletice (Czechoslovakia) and Tiraspol (U.S.S.R.). In Britain, it has been found in the late Beestonian at West Runton by Patrick De Dekker in a study which analysed the changing ostracod fauna from fluviatile, through intermittent flow, to stagnant fen pool environments in Cromerian 1A and 1B. I am grateful to Patrick De Dekker for drawing my attention to this species, which promises to be useful in identifying fluviatile settings in a cold steppe or tundra climate, as well as a broad Middle Pleistocene age. Such conditions seem to have prevailed during the late Beestonian in Norfolk, and likewise could have been a feature of early Anglian times in the proto-Thames valley at Ware on the basis of the ostracods found at Westmill. It is the environment which is being stressed rather than the age, but this discovery does lend biostratigraphical weight to Gibbard's interpretation (1978), particularly his chronology for the Westmill Gravels.

J.E. Robinson.

EAST HERTFORDSHIRE AND ESSEX REGION

The third day of the field meeting aims to examine the evidence for the drainage of the Thames east of the Vale of St. Albans. Attention will be given to three elements of this problem: i) the drainage route immediately east of the Vale, immediately before and after the time of diversion, and the evidence for the relationship with the Lea Valley; ii) the course of the Thames in central Essex, where the river deposits were overridden by Anglian ice and extensively buried beneath Lowestoft Till, iii) the course of the Thames in east Essex and its relationship with the pre-diversion Medway. The sites in this area include evidence for all stages of Medway drainage and the earliest stages of Thames drainage immediately following diversion.

The sites to be visited are:

Hoddesdon
 Stebbing
 Great Waltham
 Bovill Uplands
 Southminster

the locations of which, and the route to be followed, are shown on Figure 70.

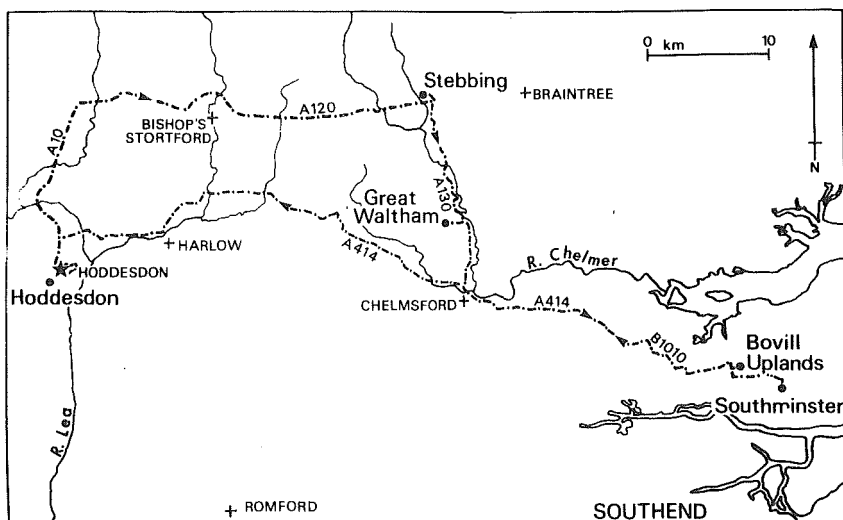


Figure 70. Location of sites to be visited and route to be followed on Day 3 of excursion.

The journey will begin by visiting the quarries at Hoddesdon, just south of our accommodation at High Leigh, and evidence will be examined for Thames drainage in the area, particularly in relation to glaciation and the initiation of the Lea Valley.

This will be followed by a visit to the gravel pit at Stebbing, just east of Great Dunmow, where sands and gravels of the Kesgrave Formation outcrop in a small north-south trending valley. The upper part of the Kesgrave Sands and Gravels shows a very well developed example of the multi-phase Valley Farm Palaeosol. This site is also of interest in revealing large structures that disturb the gravels and the palaeosols layer. The origin of these structures is far from clear, and in places they include a complex stratigraphy. If time permits the next stop will be at Great Waltham where pre-diversion Thames deposits are shown in their typical position beneath a great thickness of Lowestoft Till. At the present time the exposures show the Kesgrave Formation, the Valley Farm Palaeosol in its typical buried and disrupted state, the early Anglian coversand, and the Lowestoft Till including examples of the several till facies that exist in the area.

The excursion then continues eastward beyond the limit of Anglian ice, to the region around Southminster. At Bovill Uplands, exposures show Mayland Gravel which accumulated as the highest deposit of the pre-diversion Medway. Particular attention will be given to the lithological evidence for a catchment area that extended into the region of the Central Weald. The meeting will conclude by visiting the gravel pits at Southminster which are developed in the Asheldham Gravel deposited by the combined drainage of the Thames and Medway. These deposits therefore represent evidence for the earliest path of the Thames after its diversion by Anglian ice. This was a time when the lower part of the Thames followed the existing route of the Medway from the region of Southend to Clacton, before eventually adopting its final route towards the east, in the location of the modern Crouch estuary.

J. Rose.

EARLY AND MIDDLE PLEISTOCENE SEDIMENTS AND PALAEOOLS IN WEST AND CENTRAL ESSEX.

East of the Vale of St. Albans, the Pleistocene succession younger than the Crag and Creeting Formation (Allen, 1983) can be described, from the base upwards, in terms of three main stratigraphic units:

- Lowestoft Formation -Anglian glacigenic and windblown sediments.
- Valley Farm Palaeosols-Weathering profiles on Thames terraces
- Kesgrave Formation -Pre-diversion Thames river deposits.

The stratigraphic and geographical relationships are summarized in Figure 71. Within the Pleistocene succession

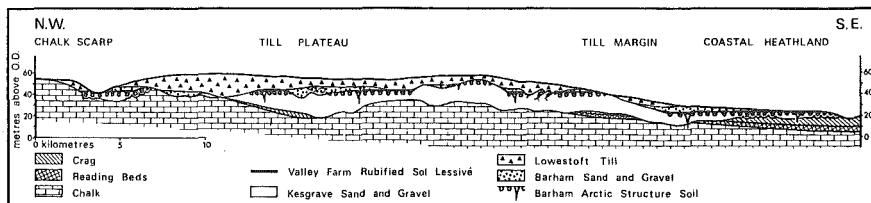


Figure 71. Schematic representation of Pleistocene sediments in Essex and south Suffolk (Reproduced from Journal of the Geological Society, 133, 1977)

the Kesgrave Sands and Gravels and Valley Farm Palaeosol were formed between the Bramertonian temperate Stage and the Anglian glaciation, covering a period of about 1.2 million years (Thompson, 1977).

The Kesgrave Formation comprises a complex sedimentary body deposited as a series of progressively lower terraces by the Thames at a time when it flowed through Essex and East Anglia. It can be subdivided lithologically into the Westland Green (high level gravel) Member and the low level gravel (Hey, 1980) the lower of which has been correlated with the Higher and Lower Gravel Trains of further west (Green *et al.*, 1982). The lithological characteristics used to identify the various members are shown in Figures 72, 73, 74, and 75. In Suffolk, Allen (1983) has recognised the Westland Green Member, an upper unit known as the Baylham Common Gravels, and a lower unit known as the Waldringfield Gravels.

The Valley Farm Palaeosol consists of a series of weathering profiles developed on the low relief terrace surface after it had become abandoned by the river. Thus, this palaeosol is a very complex feature represented in the case of the highest and oldest terrace by a very long period of temperate and cold climate weathering. On the intermediate terrace surfaces the palaeosol has an intermediate degree of complexity,

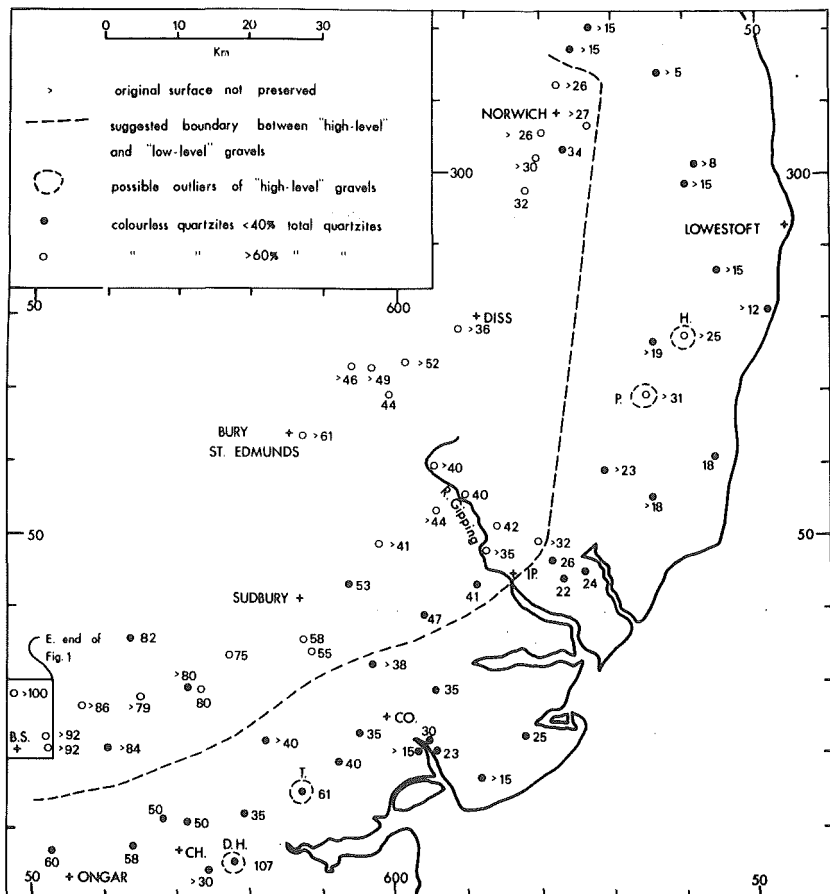


Figure 74. Surface elevations and percentage total quartzites of the Kesgrave Sands and Gravels in Essex and East Anglia. B.S., Bishop's Stortford; CH, Chelmsford; CO, Colchester; D.H., Danbury Hill; H, Holton; IP, Ipswich; P: Peasenhall; T: Tiptree. (Reproduced from Proceedings of the Geologists' Association, 91, 1980).

and in the case of the lowest terrace level (for instance the Waldringfield Terrace of southeast Suffolk (Allen, 1983, Kemp pers. comm.)) it is relatively simple showing evidence of formation during a single temperate (Cromerian) stage and the early part of the Anglian. Typical stratigraphical sequences showing the terraces and palaeosols in southeast Suffolk are shown in Figure 76.

The palaeosols are very important also because they identify the original surface of the terrace rather than a later surface formed by glacial or other erosional processes. The terrace levels identified in this way and recorded by Rose *et al.*,

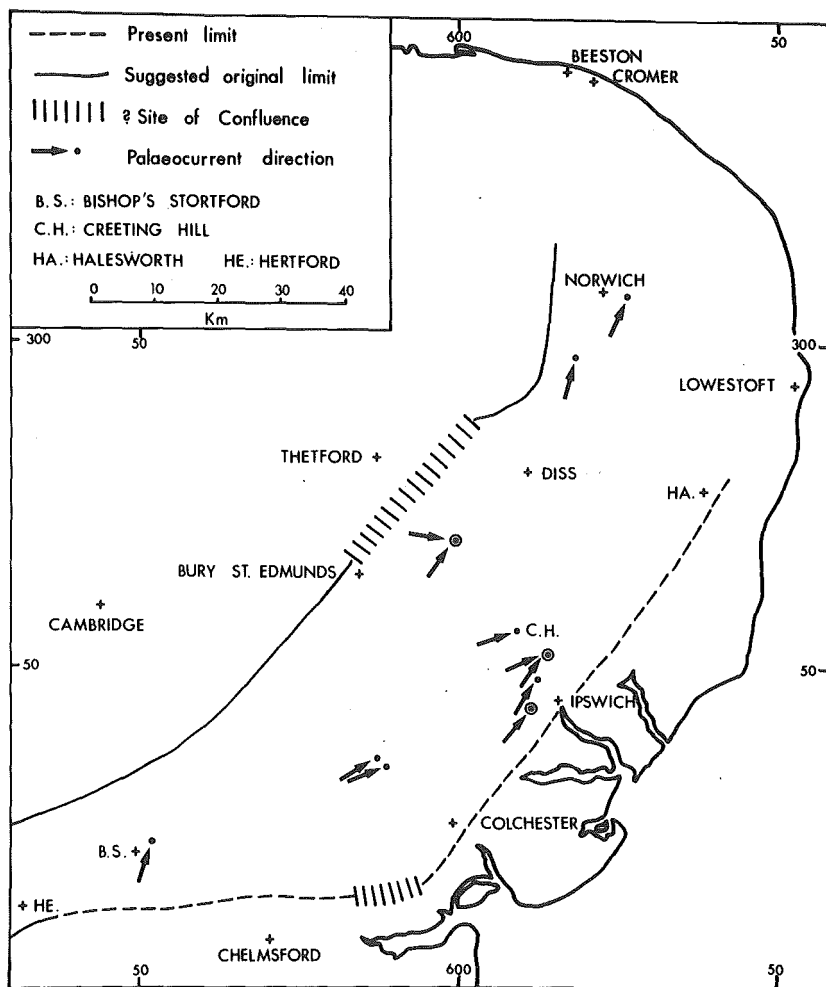


Figure 75. Limits of the Westland Green Gravel Member, with palaeocurrent measurements. The limits are drawn to include the probable outliers at Tiptree, Peasenhall and Holton. Reproduced from Proceedings of the Geologists' Association, 91, 1980.

(1976), Rose and Allen (1977) and Hey (1980) do not appear to coincide with the upper levels of the sediment bodies of Green *et al.*, (1982) and suggest a greater degree of complexity than indicated solely by the lithological properties. This is perhaps to be expected in view of the time span involved and the position in the lower, less confined parts of the drainage basin.

The south and eastward displacement of the terraces before the Anglian glaciation may possibly indicate tectonic

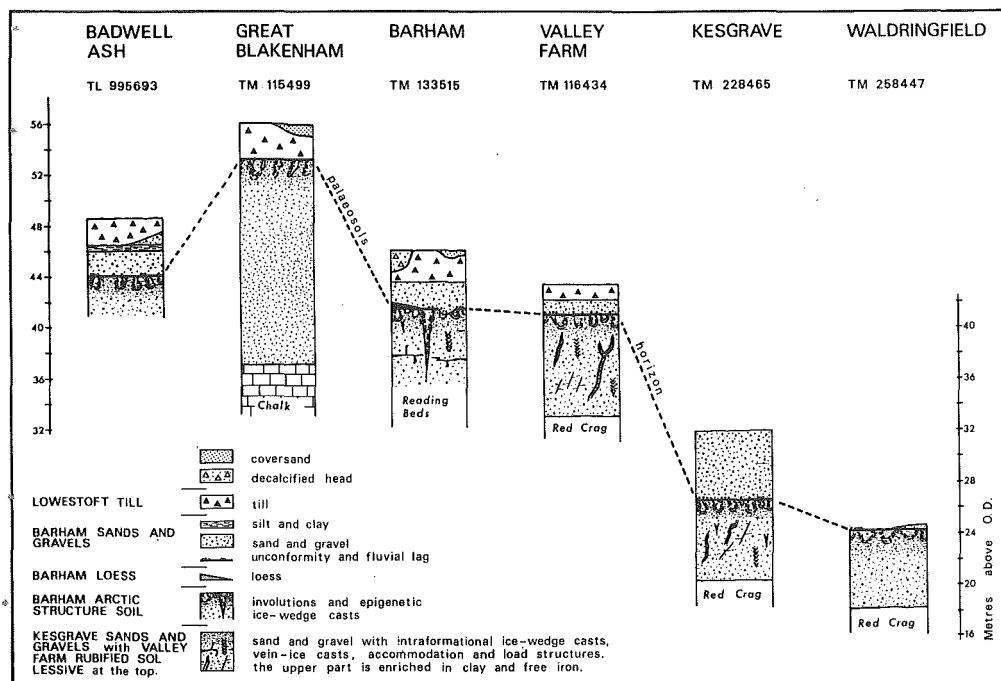


Figure 76. Pleistocene sediments and palaeosols in southeast Suffolk and their relation to Thames terraces. (Reproduced from Journal of the Geological Society, 133, 1977).

depression towards the North Sea Basin. Such an explanation could account for the diversion of the Thames/Medway at the Asheldham stage, from the Southend - Clacton route, to an easterly route parallel to that in use at the present time.

The Anglian deposits begin with loess and coversand. These wind blown sediments were derived from glacial material of the Anglian glaciation and deposited across a wide proglacial region of East Anglia. Contemporary periglacial soil formation resulted in their inclusion in sediment wedges and other arctic soil structures such as involutions (Rose *et al.*, 1976, 1978). The Anglian glaciation resulted in the burial of much of the terrace deposits either extensively by Lowestoft Till or locally by outwash.

J. Rose.

HODDESDON, ST ALBANS SAND AND GRAVEL CO. QUARRY.

TL 354 077

St. Albans Sand and Gravel Co. Quarry is situated on a level east-west interfluvial at about 65m. O.D. Four lithostratigraphic units may be identified.

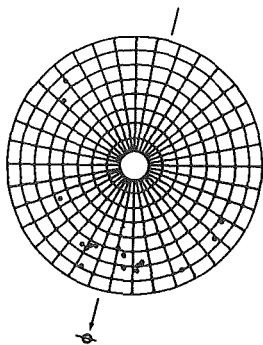
Surface 65.7m O.D.

	<u>Lithology</u>	<u>Thickness</u>	<u>Regional correlation</u>
4.	Clay-bound sand and gravel	Up to 3.5m	Localised, lower Lea gravel
3.	Chalky till	0 to 2.55m	Upper till at Westmill
2.	Chalky gravel and sand	4.2m	Westmill Upper Gravel
1.	Sand and gravel	4.4m	

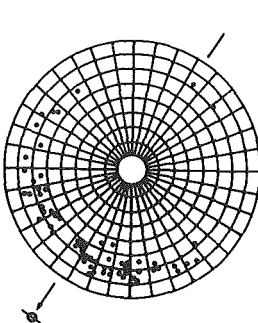
London Clay bedrock at 53.95m O.D.

Sand and gravel. The lowest 1.5m of this unit have never been exposed, lying below the pumped water level during extraction. Amongst a variety of structures of variable lateral geometry, well sorted tabular and trough bedded sand and fine gravel lenses are common. The channel fills often show fining-upward sequences with lags at the base, and less frequently coarsening-upward sequences are seen. The structures suggest frequent lateral migration in a braiding palaeoenvironment. Indifferent exposure, through talus accumulation, enabled only 17 palaeocurrent measurements to be taken, yielding a vector towards 194° (Fig.77). The

Hoddesdon, St.A Unit 1



Hoddesdon, St.A Unit 2



Hoddesdon, St.A Unit 4

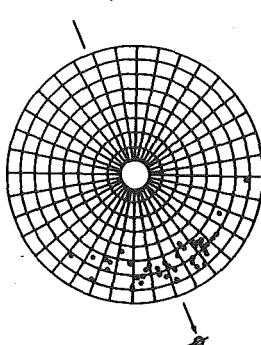


Figure 77. Palaeocurrent scattergrams for the gravel units at Hoddesdon, St. Albans Sand and Gravel Co. Quarry. \emptyset = resultant vector: unit 1 = 194° , unit 2 = 213° , unit 3 = 158° .

unit is dominated by angular flint (55.5 - 67.5%). Chalk and calcareous lithologies are completely absent, whilst rounded and broken rounded flints range from 7.5 to 16.2% of the stone counts. Quartz ranges from 6.7 to 10.1% and Lower Greensand chert from 2.6 to 3.1%.

Chalky gravel and sand. This unit is differentiated from the sand and gravel below on the grounds of clast lithology. In the -3, -4 and -5 phi range angular flint dominates (42.7 to 67.5%). Rounded and broken rounded flints are markedly fewer than in the underlying sand and gravel, decreasing in proportion upwards from 11.6 to 3.1%. Quartz is also less frequent, ranging from 8.2% at the base to 2.8% at the top, and Lower Greensand cherts are fewer (1.4 to 2.0%). The most apparent change from the unit below is the presence of Chalk (5.9 to 16.3%) and a wide range of calcareous lithologies including Jurassic limestones and fossils. Calcareous lithologies, including Chalk, range from 13.7% to a maximum of 23.6% 1.5m below the till. Structures are similar to the lower sand gravel unit but with tabular and trough cross bedding better defined, yielding a palaeocurrent vector of 213° . (Fig. 77).

Chalky till. This varies in thickness from 45cm to 2.55m. It is largely decalcified where less than 0.5m thick or where divided by intraformational gravel. Where exceeding 60cm in thickness, large sub-rounded chalk clasts survive in a soft condition at the base of the unit and preserve striations on their underside. There is generally little evidence of erosion on the upper surface of the till, but scour channels cut it out in the south of the pit. It lies on an irregular eroded base of sand and gravel. Three macrofabrics give an overall vector of $21/201^{\circ}$ with a magnitude of 38% (Fig.78). The particle size character-

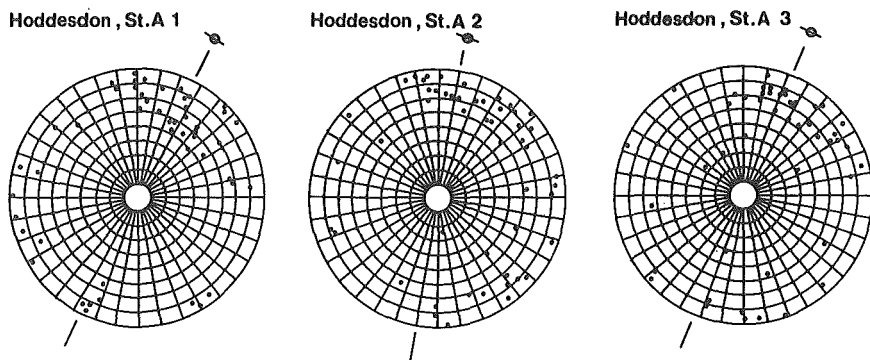


Figure 78. Till macrofabric scattergrams for unit 3 at Hoddesdon, St. Albans Sand and Gravel Co. quarry. Ø = resultant vector. Overall vector = $21/201^{\circ}$, overall vector magnitude = 38.2%, Rayleigh test $>.999$.

istics of the till fraction finer than $+4.5\phi$, at 0.5m intervals are shown in Fig. 79. The insoluble: soluble ratio for the -2.5ϕ to $+1\phi$ fraction is 1:2 (i.e. 67.5% solubles), and the quartz: flint ratios for the -2ϕ to $+1.5\phi$ fraction are shown in Fig. 80.

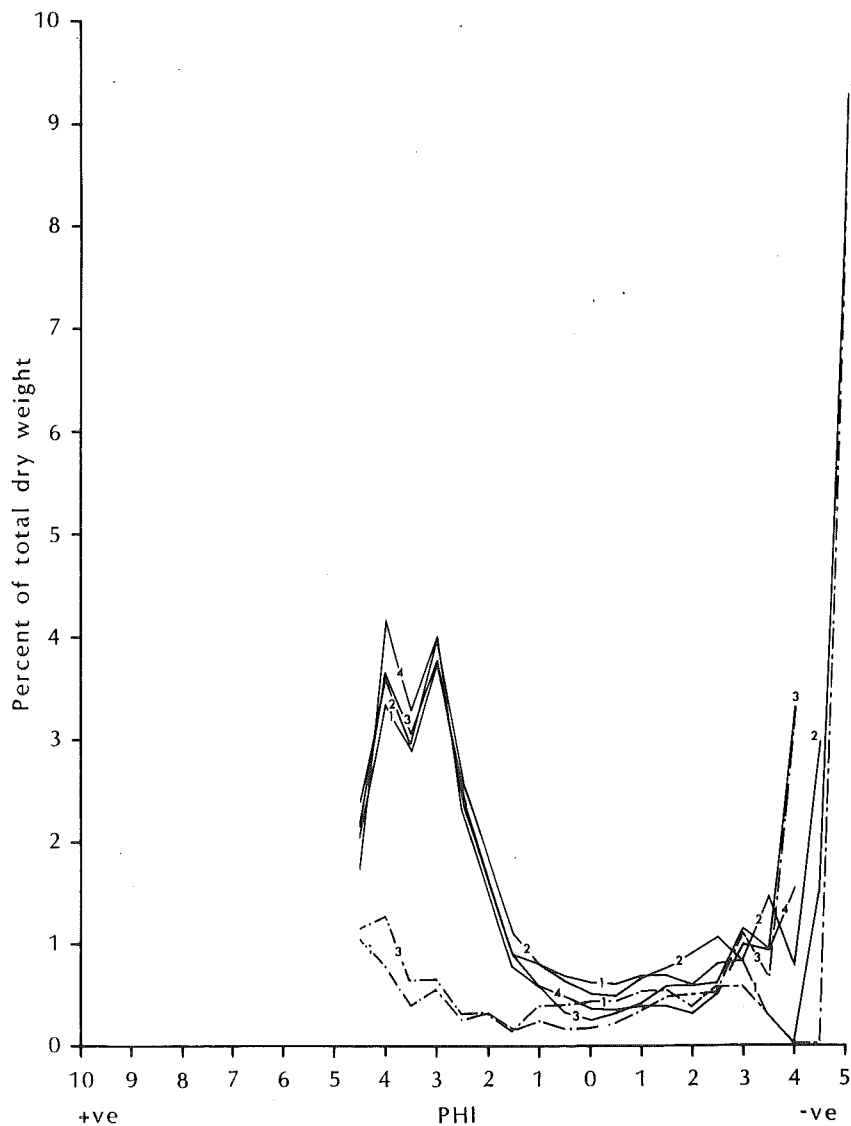


Figure 79. Particle size distribution of the till at Hoddesdon, sampled at 0.5m vertical intervals. Solid lines: total of lithologies including acid-solubles. Broken lines: acid-soluble fraction.

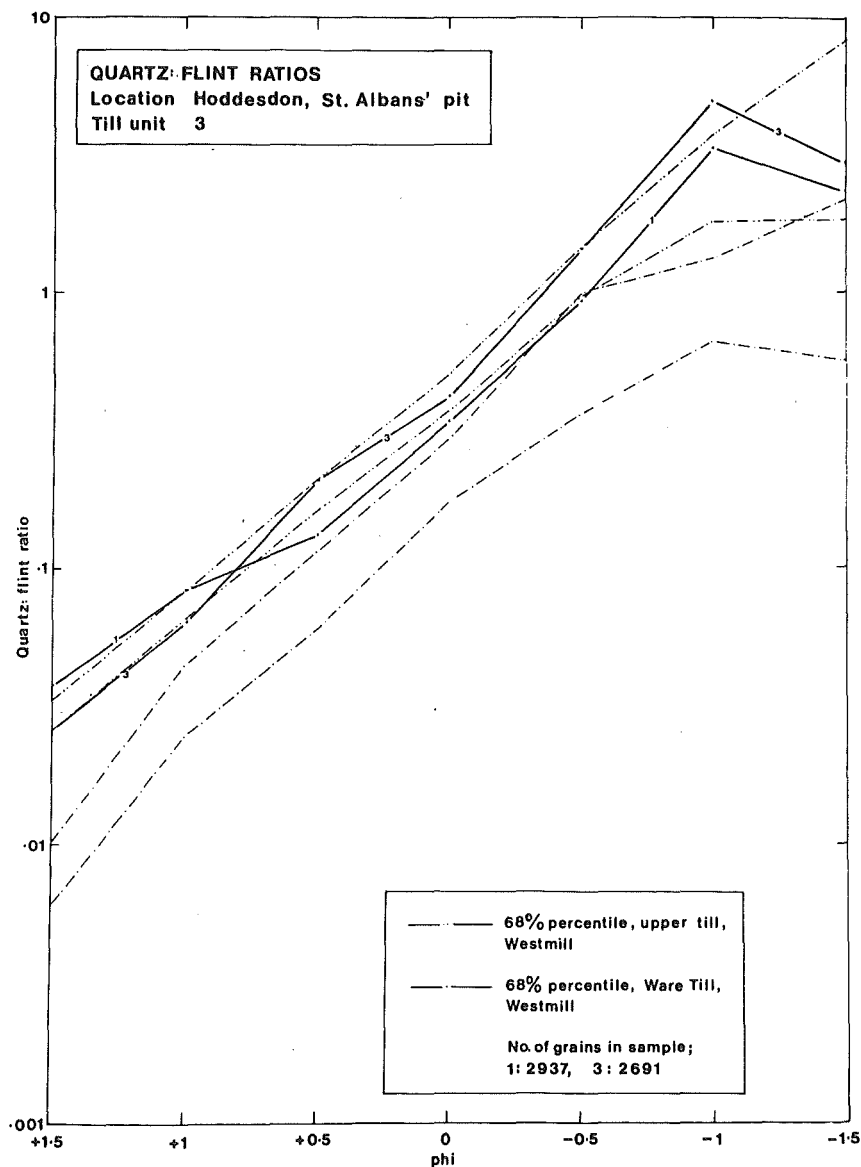


Figure 80. Quartz:flint ratios for the Hoddesdon till compared with the Ware Till and upper till at Westmill.

Clay-bound sand and gravel. The maximum observed thickness is 3.5m. Attenuated sand lenses contain cross-bedding giving palaeocurrents towards 158°. The sediment is iron-stained and non-calcareous, with an angular flint content approaching 89%.

HODDESDON, NURSERY GROVE PITS

TL 353 077

These shallow abandoned workings are located on a broad bench 140m west of the St. Albans Sand and Gravel Co. quarry at 70.4 to 72.8m O.D. Here the gravel is quite distinct from any of the units seen in the St. Albans Sand and Gravel Co. quarry, possessing the following lithologies in the -3, to -5 phi range:

	Nursery Grove Hoddesdon %	Aggregate of Dollis Hill Gravel (Gibbard, 1979) %
Angular flint	27.47	
Broken rounded flint	26.17	58.48
Rounded flint	24.51	32.04
Quartz	6.33	1.82
Quartzite	2.18	
Lower Greensand chert	9.66	7.37
Others	3.69	0.29
Total clasts in sample	1926	1442

Interpretation and general discussion.

The lithology of the gravel at Nursery Grove suggests an association with the Dollis Hill Gravel, which has been shown by Gibbard (1979) to correlate with the St. George's Hill Gravel of the Mole-Wey. If the gradient between St. George's Hill and Dollis Hill (Gibbard, 1979, Fig.3) of 20cm/km is projected northwards to the Hoddesdon area, the gravel should be at one elevation between 59 and 64m O.D., which is too low for the deposits at Nursery Grove. However, Gibbard has shown that in the Finchley depression gravels of a similar lithology occur up to 8m above the projected profile (points 3 and 6, Fig.2). A parallel gradient of 20cm/km through these higher Dollis Hill Gravels at Finchley, when projected northwards, reaches the Hoddesdon area at 72m O.D., which is good agreement with the Nursery Grove gravel at 70.41 to 72.81m O.D. There is no reason to believe that the sediments at Nursery Grove are not in situ. The site is nearly level, and higher gravels on the flanks of the South Herts Plateau have a different lithology. Thus the gravel at Nursery Grove lends support to the suggestion for a pre-Anglian or early Anglian S.-N. drainage in the lower Lea valley, probably the Mole-Wey, possibly augmented by tributaries such as the proto-Wandle (Peake, 1982). It should be noted that this gravel, if projected to the Ware area, would be at 70m O.D., an elevation exceeded by the later Westmill Upper Gravel aggradation.


Lower, and presumably younger, Mole-Wey gravel occurs further south on benches near the M25 at South Osiers (TL 332


003, 54.32m to 57.26m O.D.) and at the former borrow pit at Bullscross Farm (TL 340 006, 54.20m to 56.95m O.D.). Mean compositions of this gravel in the -3, to -5 range are:


	South Osiers	Bullscross Farm
	%	%
Angular flint	26.54	25.36
Broken rounded flint	34.17	39.04
Rounded flint	27.44	25.26
Quartz	1.84	1.45
Quartzite	0.45	0.25
Lower Greensand chert	8.62	7.37
Others	0.94	1.27
Total clasts in sample	2227	4073

The composition of this gravel is similar to, and suggests correlation, with the Dollis Hill Gravel. However, the gradient from the lowest known point in the Finchley depression col at 63m O.D. (Gibbard, 1979) to the base of the M25 gravel at 54.2m O.D. is 76cm/km, considerably steeper than the gradient upstream of Finchley (20cm/km, Gibbard, 1979). If this gradient extended northwards it would reach Hoddesdon at 48.5m O.D. and near Ware at 43.8m O.D., below the bedrock floor of pits such as the St. Albans Sand and Gravel Co. quarry at Hoddesdon, and the Westmill and Foxholes quarries near Ware. The South Osiers gravel can be shown to lie *in situ* by the presence of cross bedding yielding a palaeocurrent from 25 measurements towards 60°. This orientation and the increased gradient suggest that the South Osiers/Bullscross Farm stream did not follow the former northwards route towards the Thames. Limitations of rockhead confirm this view and permit only two routes, i) north east to join the Thames in the Sawbridgeworth/Harlow area, or ii) south east and south of Epping Forest ridge into the present basin of the lower Thames/Medway. The Westmill Lower Gravel aggradation in the Thames valley would sooner or later increasingly favour the second alternative for the Mole-Wey.

The bedrock surface in the Hoddesdon area (Fig. 81) is genetically composite in that part of the surface overlain by Anglian glacial and glaci-fluvial sediments forms a well-defined western flank of a valley declining southwards. The sediments at Hoddesdon (St. Albans Sand and Gravel Co. quarry) rest upon a bench on this surface at about 54m O.D. On this basis of clast lithology, the lower sand and gravel units may be correlated with lithological units 3 and 5 at Foxholes South and 1, 2 and 3 at Bullscross Farm (Fig. 82). At each site an upper facies can be differentiated from a lower facies on grounds of carbonate content, although at all sites some laterally variable carbonate removal has taken place, particularly where the overlying till is absent. The downvalley increase in rounded (Tertiary) flint in the lower unit probably reflects progressive reworking of the earlier Mole-Wey gravel.


Preglacial
and solid
sediments
(Geological
Survey)


Contours on
sub-glacial
surface


Contours on
sub-drift
surface

Contours in
m O.D.

Towns:
H : Hertford
Ho : Hoddesdon
W : Ware
WX: Waltham Cross

Sites:
(B) Bullscross Farm
(F) Foxholes S.
(H) Hoddesdon
(N) Nursery Grove
(S) S. Osiers
(W) Westmill

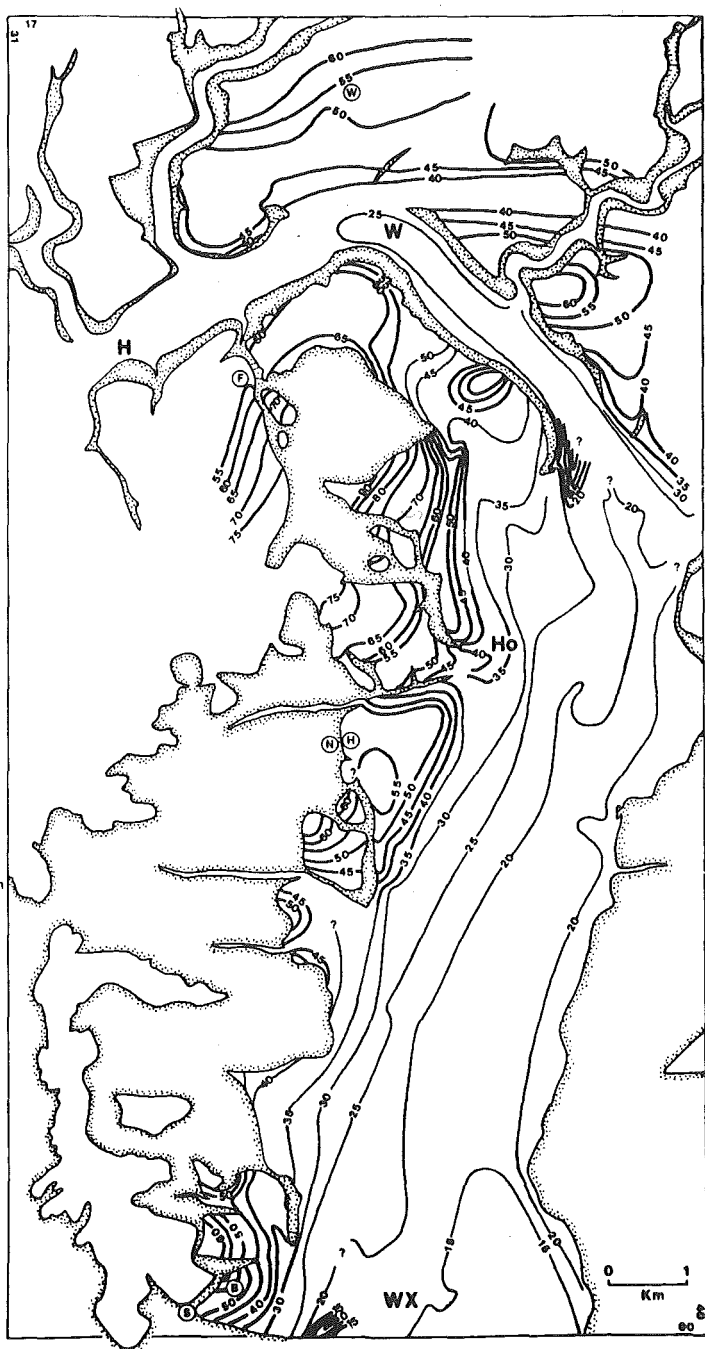


Figure 81. The rockhead surface in south east Hertfordshire. Based on over 600 borehole records and intersection points between the glacial/rockhead junction and map contours.

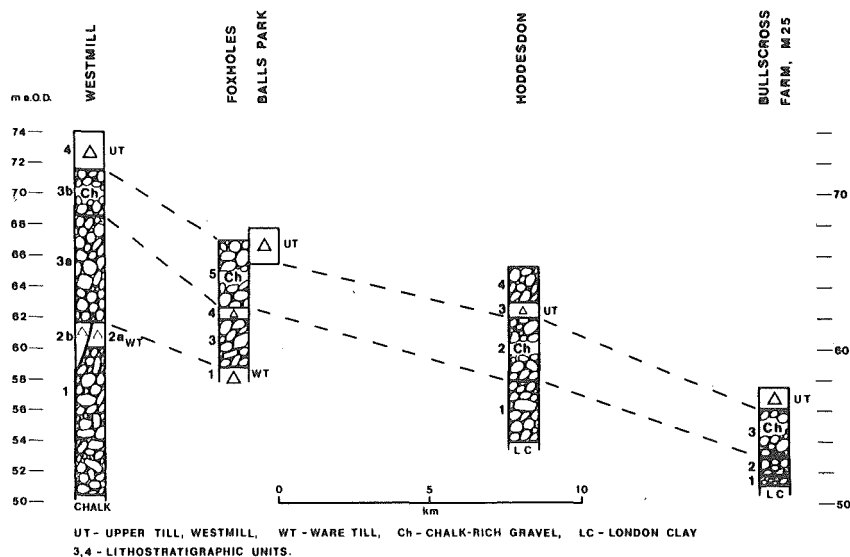


Figure 83. North-south section along part of the lower Lea valley showing the altitudinal relationships of the Westmill Upper Gravel and associated sediments.

dammed by a less extensive Ware Till ice sheet, creating a lake in the Hoddesdon-Ware area, spilling southwards along the line of the present lower Lea and into the Thames/Medway basin. The ice sheet depositing the upper till at Westmill appears to have had little permanent effect on the main drainage alignments in the Lea basin.

D.A. Cheshire.

STEBBING

TL 669 233

A shallow quarry in the east flank of the valley of the Stebbing Brook 0.75km north of Stane Street, shows two faces revealing the following simple stratigraphy throughout most of their length (Fig. 84).

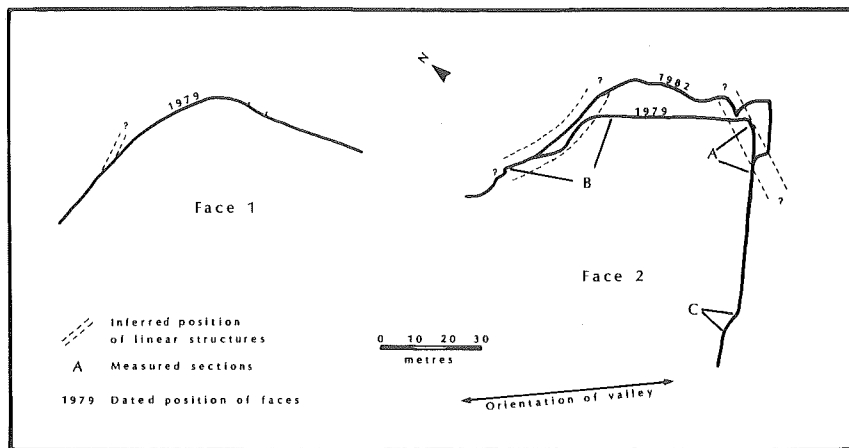


Figure 84. Exposures at Stebbing, 1979.

The stratigraphy at Stebbing is given below:

	Silty sand in which current Ap horizon is developed up to 0.30m thick.
Kesgrave Sands and gravels with palaeosols horizon.	Gravels sands and silts, strongly rubified in the upper 1-2m 3.75m thick.
London Clay	Occasionally seen at base of the quarry.

Kesgrave Sands and Gravels

Iron stained, clast supported gravel dominates the lower part of the face (Fig. 85) as large scale, relatively low angle gravelly cross sets dipping towards the north-east representing channel bars. The fluctuating energy regime is shown by the particle size distribution of the beds which varies from well sorted, washed gravels through sandy gravel to thin sand beds with only rare stones. Occasional cross-bedded sand units occur within the gravel. A noticeable drop in iron oxidation occurs above the lower third of the exposure at a fairly uniform level, probably related to the local water table.

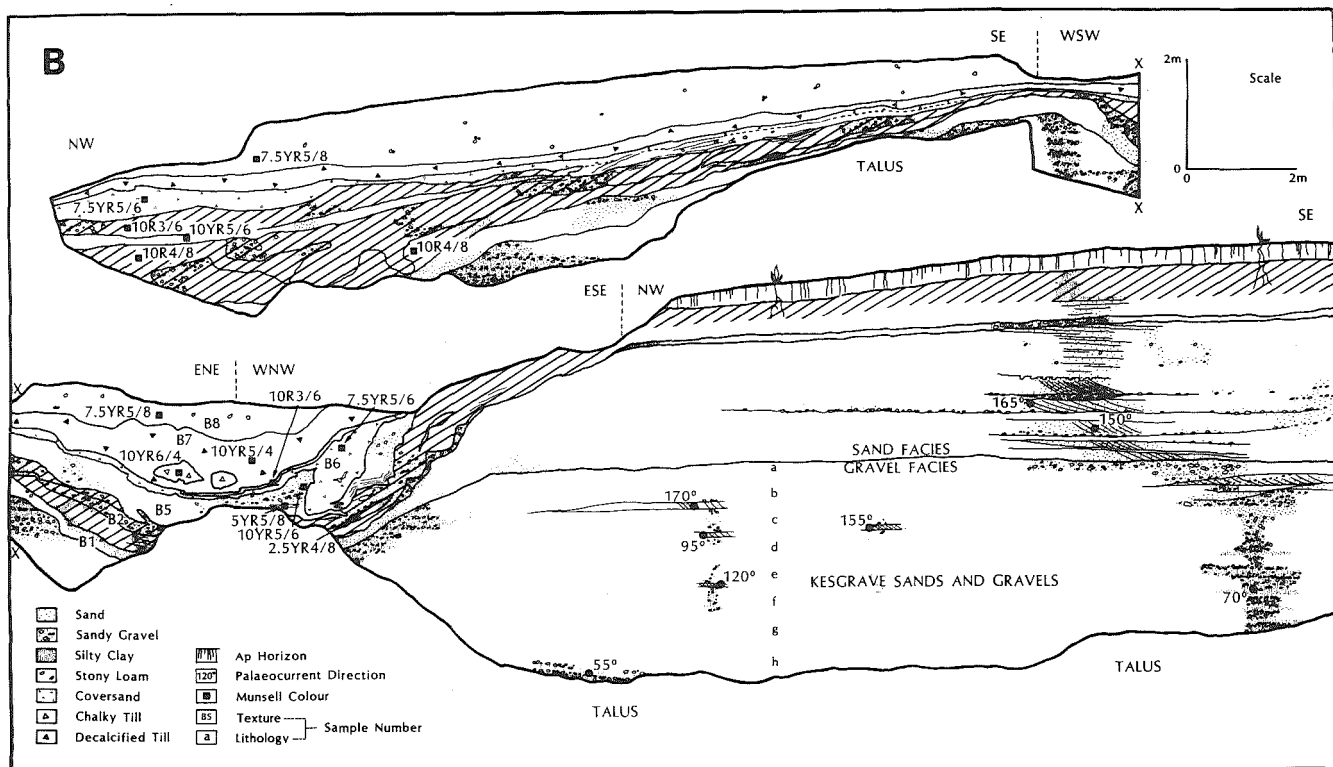


Figure 85. Section B, Face 2 at Stebbing, 1979. The diagonal shading indicates areas of rubification.

Half way up the face the gravel dominated facies change to a series of sand dominated beds in which gravel occurs as occasional channel fills or lags, loose clusters or stringers. High lateral variation of beds occur in the lower part of the sandy facies but this is replaced upwards by laterally more persistent beds of sand, silt and gravel that can be traced across both faces. It suggests that a single large stream replaced many smaller streams.

The Kesgrave Sands and Gravels are dominated by flint and quartz and quartzite with subsidiary chert and rare volcanic rocks (Table 10). There is a significant break across the textural boundary, with the upper facies showing a higher angular: rounded flint ratio (3.4 to 1.95) and a higher flint: quartzite ratio (1.19 to 0.85) relative to the underlying gravel unit.

Sample	Number of clasts	Flint	Quartz	Quartzite	Percentage		Volcanics
					Chert		
					L.G.S.	Mics.	
a	664	44.6	37.5	13.7	0.8	3.5	0.0
b	564	46.1	38.7	13.3	0.4	1.4	0.0
c	642	45.5	39.9	13.4	0.3	1.1	0.2
d	516	45.2	39.2	13.8	0.8	1.2	0.0
e	607	43.3	40.5	14.2	0.5	1.5	0.0
f	587	42.1	40.6	15.5	0.2	1.7	0.2
g	559	37.9	47.4	12.9	0.0	1.8	0.0
h	784	45.3	38.5	14.3	0.6	1.7	0.0
Mean		43.8	40.3	13.9	0.5	1.7	

Table 10. Lithology of 8-16 mm clasts at 0.5 m vertical intervals through the Kesgrave Sands and Gravels at Stebbing. Sample locations are given on Fig 85.

Palaeocurrents measurements on the large scale gravel

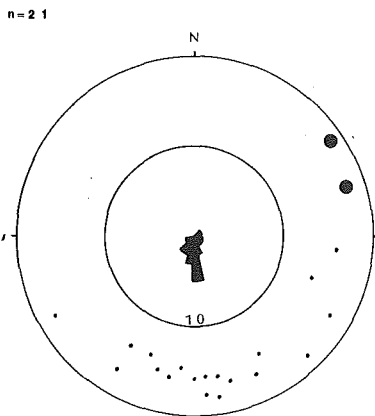


Figure 86. Palaeocurrent measurements on the Kesgrave Sands and Gravels, Stebbing. The large dots refer to measurements on large-scale cross-sets.

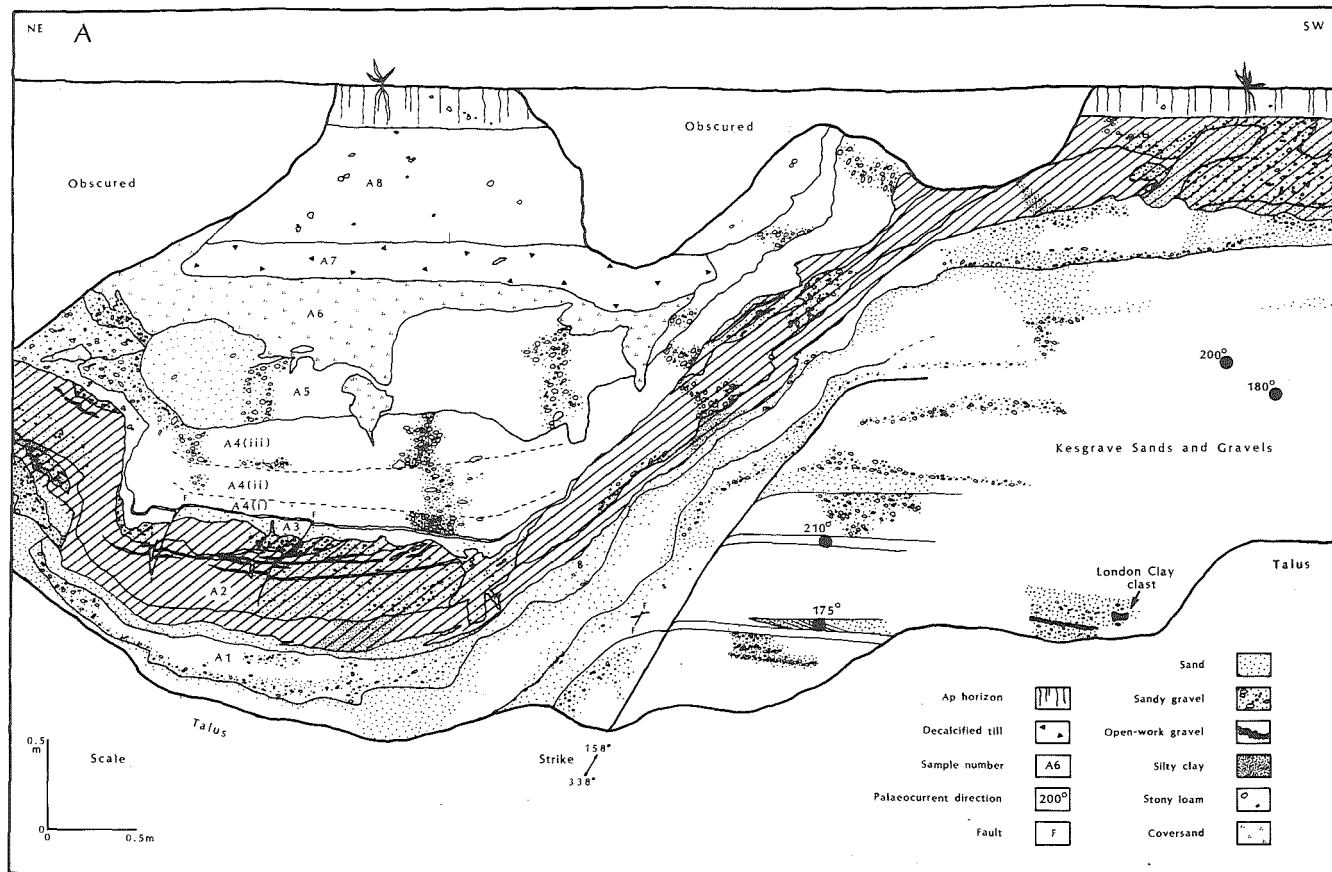


Figure 87. Large scale deformation structure at Stebbing. The diagonal shading indicates rubification.

cross-sets suggest flow to the east-northeast, while the small scale sandy sets give a flow to the south (Fig. 86), probably reflecting minor flow paths controlled by bed topography.

The upper 1-2m of the gravels, sands and silts are prominently rubified. This phenomenon will be discussed more fully in the succeeding section on palaeosols.

Large-scale deformation structures.

The gravels, sands and silts are prominently truncated in places by large V - shaped linear depressions (Figs 87 and 88). Their origin is far from obvious. Explanations

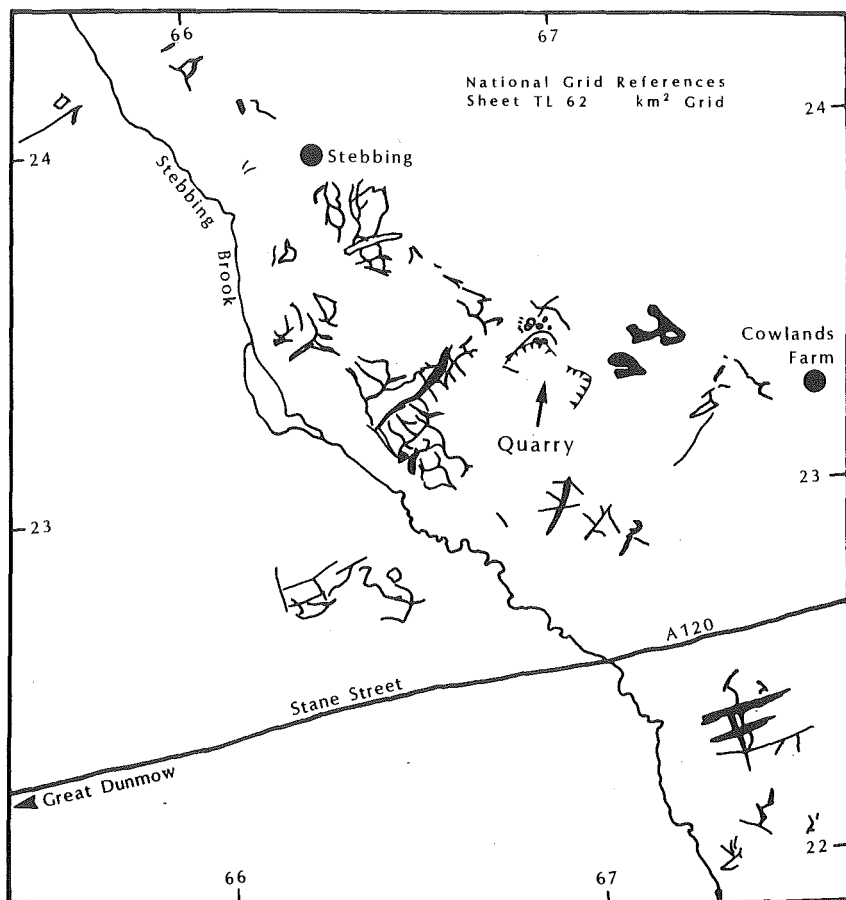


Figure 88. Surface pattern shown by large-scale deformation structures in the region of Stebbing. Based on air photo interpretation.

may include: a) gulls produced by lateral movement of competent beds over less competent units during periglacial conditions.

b) thermal contraction cracks associated with intense and rapid cooling in permafrost conditions. Such a pattern would be that of non-sorted polygonal ground. Figure 88 produced by air photo interpretation tends to support this explanation.

Much smaller scale deformation structures exist within the large features involving both coarse and fine grained materials. Again the explanation is far from clear and may be due to either loading during the development of the large structures or periglacial cryoturbation associated with a periglacial land surface.

C.A. Whiteman

Valley Farm Palaeosols Layer

The Valley Farm Palaeosol is particular well illustrated along the north-facing section of Face 2, at Stebbing. (Fig. 84). Here, it occurs beneath about one metre of coversand in which the present surface soil has largely formed. The palaeosol, which varies in thickness between two and three metres, is virtually continuous for over 100 metres.

Morphologically, the soil is distinguished by its intense red colours (hues of 10R or 2.5YR) and associated grey mottles (Fig. 89). Field evidence for the pedological movement of clay into the Kesgrave Sand and Gravel parent material is provided by the prominent clay coats around gravel clasts (Table 11). These characteristics, combined with the micromorphological evidence for over 20% illuvial (translocated) clay, are sufficient for the soil to be considered as paleoargillic (Avery, 1980). The absence of an overlying clay-depleted horizon implies the soil has been truncated. The numerous involutions and preferred sub-vertical stone orientations (Fig. 89) are presumably indicative of periods of disturbance such as cryoturbation under a cold climate.

The palaeosol shows considerable horizontal and vertical variation in texture and colour (Fig. 89; Table 11). Although there is an expected vertical decrease in the amount of illuvial clay the texture varies irregularly with depth. This appears to be due to the dominant influence of primary sedimentary structures and sorting. Beds of fine and coarse material are frequently associated with particular colour changes and appear to have some influence on the degree of rubification in the profiles.

Sedimentary heterogeneity is confirmed by the considerable variation in relative abundances of very fine sand size minerals throughout the soil and parent material, although all appear to be derived from a common source area. Quartz makes up nearly 90% of the fraction, with alkali feldspars, flint, quartzite and glauconite, contributing most of the rest. The non-opaque heavy minerals, which generally amount to less than 0.2% of the total fraction consist mainly of tourmaline and/or zircon with variable minor quantities of rutile, staurolite, epidote and kyanite. This heterogeneity of a limited suite of minerals makes it difficult to establish weathering trends within the palaeosol. However, in situ distintegration of flint pebbles and micromorphological evi-

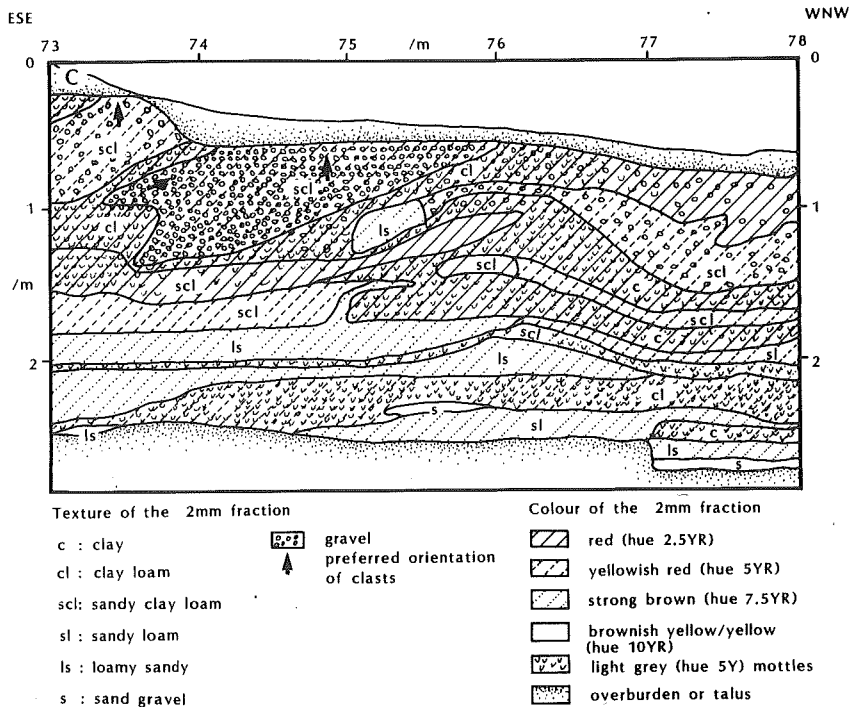


Figure 89. Profile drawing of part of the north facing section of Face 2 at Stebbing, illustrating the variation in colour and texture of the palaeosol.

Table 11.

Ap 40-0cm.	Very dark greyish brown (10YR 3/2); slightly stoney sandy clay. Disturbed or removed by plant machinery. Sharp irregular boundary to
2b Bt(g) 0/10-25/55cm	Red (2.5YR 4/6) with common medium prominent clear stony brown (7.5YR 5/8) mottles; a prominent sharp light olive grey (5Y 6/2) channel zone (2.5cm thick) with many fine roots (which continues into 2Bt1 where it branches into two sub-horizontal and two sub-vertical channels, the latter terminating at the base of 2Bt2); moderately stony sandy clay loam; mainly sub-rounded weathered flints; moderate medium sub-angular blocky; moderately weak; slightly sticky; moderately plastic; few medium roots; common continuous prominent argillans around stones; clear irregular boundary to
2Bt1 25/55-60/67cm.	Yellowish red (5YR 4/6); moderately stony sandy clay loam; mainly medium sub-rounded weathered flints; weak medium sub-angular blocky; moderately weak; slightly sticky; moderately plastic; few medium roots; common continuous prominent argillans around stones; clear smooth boundary to

- 2bBt2
60/67-75/93cm. Yellowish red (5YR 4/6); moderately stony sandy clay loam; mainly medium sub-rounded weathered flints; moderate medium sub-angular blocky; very weak; non-to slightly sticky; moderately plastic; no roots; common discontinuous distinct argillans around stones. Yellowish red (5YR 5/8) prominent sharp lens (3Bt: 60-69/72cm (30cm long)); very slightly stony sandy clay loam; mainly small rounded stones. Clear wavy boundary to
- 4bBtg
75-93/90-101cm. Red (2.5YR 4/6) and light olive grey (5YR 6/2) coarse prominent clear mottles (the latter commonly channel-shaped); clay; weak medium sub-angular blocky; moderately strong; moderately sticky; very plastic; very few fine roots; abrupt wavy boundary to
- 5bBtg
90/101-100/115 cm. Yellowish red (5YR 4/6) with few medium prominent clear light olive grey (5Y 6/2) mottles; sandy clay loam; weak fine platy; moderately weak to firm; slightly sticky; moderately plastic; clear to gradual wavy boundary to
- 6bBtg
100/115-117/122 cm. Red (2.5YR 4/6) and light olive grey (5Y 6/2) coarse prominent clear mottles (the latter commonly channel-shaped); clay; weak medium sub-angular blocky; moderately strong; moderately sticky; very plastic; abrupt wavy boundary to
- 7bBct
117/122-130/132 cm. Yellowish red (5YR 5/8); sandy loam; massive; very weak and moderately firm; slightly sticky; moderately plastic; abrupt wavy boundary to
- 8bBct
130/132-132/140 cm. Strong brown (7.5YR 5/6); sandy clay loam; weak fine sub-angular blocky to massive; moderately firm; slightly sticky; very plastic; clear broken boundary to
- 8bBctg
132-140-140/146 cm. Strong brown (7.5YR 5/6) with common medium prominent clear light olive grey (5Y 6/2) mottles; sandy clay loam; massive; moderately firm slightly sticky; very plastic; abrupt irregular boundary to
- 9bBctg
140/146-155/168 cm. Yellowish red (5YR 5/8) with many medium prominent clear pale olive (5Y 6/3) mottles; clay loam; massive; very firm; slightly sticky; very plastic; sharp irregular boundary to
- 10bBct(g)
155/168-171/180 cm. Strong brown (7.5YR 5/6) with many medium prominent diffuse yellow (10YR 7/8) mottles; sandy loam; weak fine sub-angular blocky to massive; very weak; non-to slightly sticky; slightly plastic; sharp irregular boundary to
- 11bBctg
171/180-180cm. Yellowish red (5YR 5/8) with few medium prominent clear light olive grey (5Y 6/2) mottles; clay; massive; moderately firm; slightly sticky; moderately plastic; abrupt wavy boundary to
- 12bBCu
180-190 cm. Strong brown (7.5YR 5/6) with many fine faint strong brown (7.5YR 4/6) mottles; loamy sand; weak fine platy to massive; very weak to loose; non-sticky; non-plastic; abrupt wavy boundary to

136bCu
190 -

Yellow (10YR 7/8); sand; single grain; loose;
non-sticky; non-plastic.

Table 11. Description of a one-metre wide profile at the west-northwest end of the section shown in Fig. 89 (770-780 m).

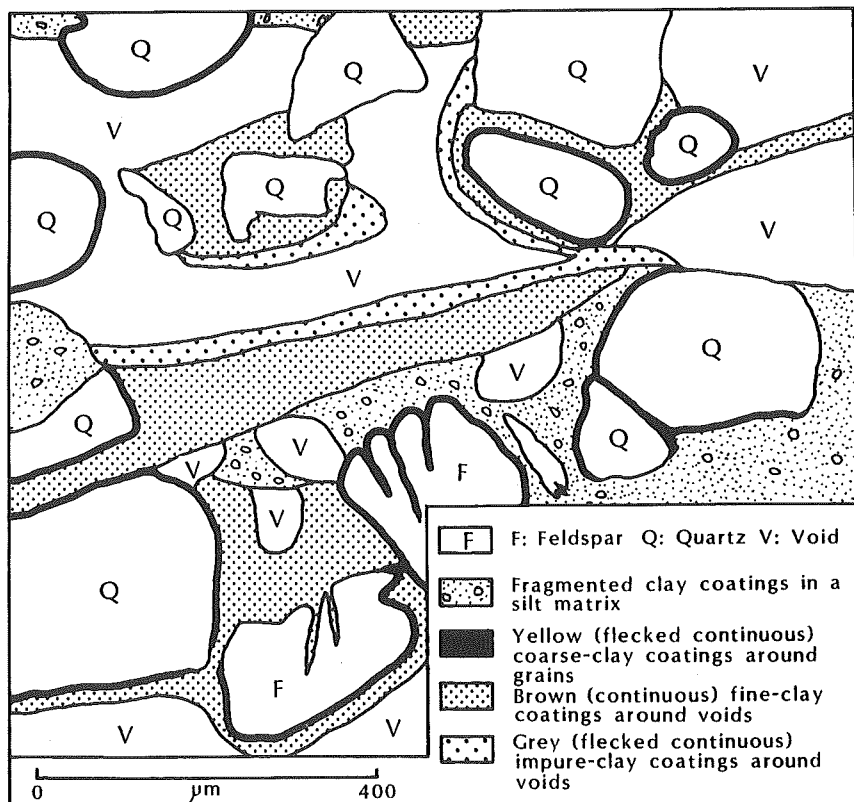


Figure 90. Schematic drawing of part of a thin section from the Valley Farm palaeosol at Stebbing. A number of pedofeature-associations are present in the palaeosol. One of these, involving at least three separate phases of illuviation, is illustrated in the diagram. The fragmented clay coatings (papules) indicate an initial period of clay translocation followed by disruption (possibly due to cryoturbation) and incorporation of the fragments into the matrix. The yellow grain coatings, which may be contemporaneous with the initial illuviation phase, clearly pre-date the brown fine-clay coatings. The latter are in places sharply bounded by impure-clay coatings, indicating an abrupt change from fine clay to coarser clay and fine-silt translocation.

dence for the alteration of sand-size alkali feldspar and glauconite grains confirm that severe weathering has occurred. Frequent pitted and fractured tourmaline grains could be due to in situ weathering, although there remains the possibility of them being derived from a pre-existing soil.

Micromorphological analysis of particular horizons in the paleosol reveals a complex pedogenic history. A number of associations of pedofeatures (Fig.) can be identified which help to elucidate the types of soil processes responsible for its development. Several phases of illuviation of fine and coarse clay, silt and sesquioxides have already been identified. These are sometimes interrupted by periods of disruption which may be related to macromorphological evidence for cryoturbation. Rubification and gleying, as recognised by mottles, were other important processes.

R. Kemp.

Stebbing - Face 2B (Fig. 85).

Along the north side of Face 2 the simple stratigraphy revealed elsewhere is replaced by the following:

- h. Stony loam
- g. Till
- f. Coversand
- e. Sandy, silty grave with laminated, rubified inclusions.
- d. Coarse, weakly bedded clayey, sandy gravels, strongly iron oxidized.
- c. Coversand
- b. Rubified palaeoargillic horizon.
- a. Gravels and Sands.

This stratigraphy is attributed to local disturbance within one of the large-scale structures. The lithology and particle size distribution of these beds is given in Tables 12 and 13 respectively. Certain features require particular attention:

1. The upper beds of the gravels, sands and silts can be traced into the base of the large scale structures. In the largest section (Fig. 87), the right hand margin is faulted (trend 160° - 340°) and the gravel and sand beds are sharply truncated. In (Fig. 87) the edge of the bedded gravel and sand appears to have been drawn down into the structure.

2. Several prominently reddened (10R hue) beds of variable texture can be traced laterally upwards into the top of the south face. A few faults with a throw of only 3cm effect this and the overlying units. This rubification is not associated with the margins of the structure, as has been suggested by Wilson and Lake (1983, p.78). There seems no reason to suggest that the rubification and the structures are penecontemporaneous.

Sample	Number of Clasts	Percentage										
		Flint	Quartz	Quartzite	Chert		Volcanic	Fe Nodule	Ironstone	Shell	Chalk	Calc. Nod.
					L.G.S.	Mics						
B8	169	55.6	28.4	8.3	0.6	3.6	-	3.0	0.6	-	-	-
B7	102	6.9	2.0	-	-	-	-	-	-	1.0	82.4	7.9
A5	832	48.6	35.8	8.9	0.0	4.3	-	2.6	-	-	-	-
B5	222	49.1	34.2	10.4	2.3	4.0	-	-	-	-	-	-
A4(iii)	966	47.1	38.2	9.6	1.3	2.8	-	0.8	-	-	-	-
A4(ii)	832	49.0	32.9	9.6	2.6	3.7	-	2.0	-	-	-	-
A4(i)	973	44.4	39.3	9.3	2.3	2.8	-	2.1	-	-	-	-
B2	226	44.2	38.1	12.0	4.0	1.8	-	-	-	-	-	-
B1	556	45.9	39.4	11.5	2.0	1.3	-	-	-	-	-	-

Table 12. Lithology of the 8-16 mm clasts from beds within the large scale structures at Stebbing (sample locations given on Figs. 85 and 87)

Sample	% Gravel	% Sand		% Silt		% Clay	
		Bulk	<2mm	Bulk	<2mm	Bulk	<2mm
B8	16.5	26.9	32.2	31.8	38.1	24.8	29.7
A7	29.4	7.2	10.0	18.4	26.3	45.0	63.7
A6	3.9	76.7	77.7	8.6	9.9	10.8	12.4
A5	51.3	24.7	50.6	17.1	34.8	6.9	14.6
A4(iii)	59.5	30.3	75.1	1.1	4.8	8.1	20.1
A4(ii)	59.7	34.2	84.8	1.3	3.2	4.8	12.0
A4(i)	63.5	30.6	83.7	1.5	4.2	4.4	12.1
A3	8.9	66.8	71.5	12.8	15.0	11.5	13.5
B2	27.0	47.7	65.1	4.9	6.8	20.4	28.1
B1	60.1	38.0	95.2	0.5	1.3	1.4	3.5

Table 13. Particle size distributions of units within the large scale structures at Stebbing (sample locations given on Figs 85 and 87).

3. A thin bed (up to 12cm) of medium to fine sand which projects downwards into the rubified sediment as a distorted wedge is probably coversand.

4. 75cm of coarse, weakly bedded reddish brown clayey gravel and sand overlies the coversand, followed by up to 75cm of silty sandy gravel of variable texture and, colour banded (10YR to 2.5YR with occasional prominent 10R mottles).

5. A thick bed of coversand penetrates the underlying bed in the form of a wedge.

6. A bed of largely stone-free decalcified till forms a distinct unit generally only 25cm thick although where it reaches greater thickness (c 50cm) some calcareous pockets remain.

7. The uppermost unit is stony loam (7.5YR 5/8, 6/4) with sandier pockets, some of which are strongly rubified (10R). Weak bedding within this deposit may indicate the reworking of former aeolian sediments. The top 20cm of this bed is the Ap horizon of the present soil.

Points for discussion include:

- (a) the origin of the large scale structures.
- (b) the nature of the sediments contained within them and their mode of emplacement. There appears to be a repetition of the palaeosol - coversand sequence within the section.
- (c) the age of formation. Was there a single episode post-dating the till which is assumed to be Anglian or does the repetition within the sedimentary sequence suggest at least 2 stages of infilling?

C.A. Whiteman.

Periglacial structures

In the summer of 1979 and 1980 I had the opportunity to visit the Stebbing Pit near Cowlands Farm, which exposes Kesgrave Sands and Gravels. At that time a complete section through a large periglacial structure had been uncovered in the south-eastern corner of the working pit (Fig. 91) (TL 6700 2325) and there was evidence of similar structures in the older degraded parts of the pit. On a subsequent Geologists Association meeting (Wilson and Lake, 1983) I postulated that these structures were gulls formed by periglacial cambering processes. Four main elements support this hypothesis.

1. The gulls are periglacial structures because locally, in their upper part, they contain a horizontal layer of blue-grey and brown mottled silty clay, recognised as a penecontemporaneous periglacial solifluction deposit (Wilson and Lake, 1983).
2. In true cross-section the gulls appear tight, v-shaped and steep sided.
3. A small fault with a displacement of about 1.5m occurs in the sands and gravels adjacent to the large gull in the south-east corner of the pit (Fig. 91). Its inclination and sense of movement are clearly attributable to the contemporary collapse of competent strata in the steep unstable face of the gull wall.
4. An oblique section through one of the gulls in the northern part of the working face revealed that hereabouts they are aligned approximately north-south. This alignment coincides with that of the present day valley of Stebbing Brook. Recent IGS mapping has shown that Stebbing Brook is typical of a number of small rivers in the district which has re-excavated along the line of earlier shallow boulder clay-filled channels. It is inferred that these

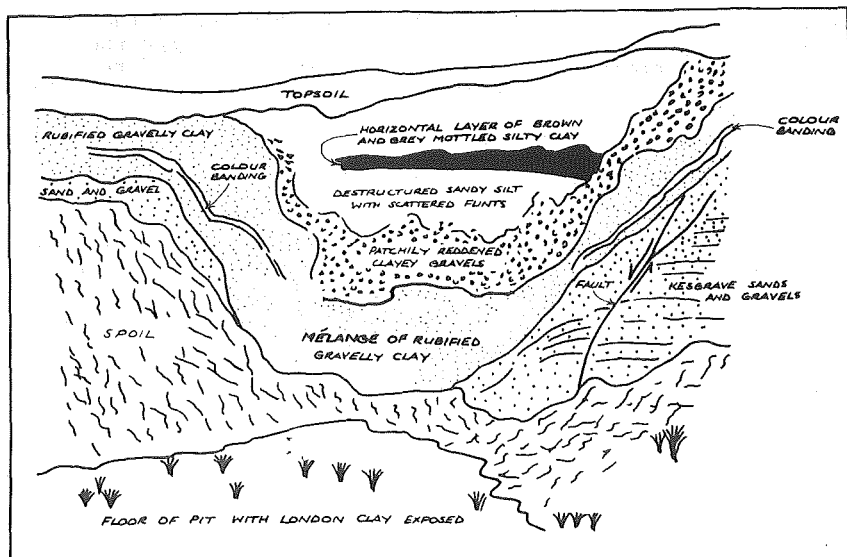


Figure 91. Periglacial structures in the southeast face of Stebbing gravel pit, August 1980. An oblique view drawn from IGS photograph A 13557.

north-south channels formed part of an early Anglian drainage system which was subsequently overridden by the ice, and the configuration of the structures in the Stebbing Pit is typical of faults or cracks in cambered strata related to this earlier valley system. In this context, the IGS mapping also revealed that the base of the Kesgrave Sands and Gravels falls gently towards the valley axis and whilst this may be the result of relatively recent mass movement processes, the possibility that it is related to earlier periglacial cambering effects should not be overlooked.

It is unlikely that the structures are due to icemelt-out or to solution collapse, because firstly the site is flooded by London Clay, secondly there is no evidence of large scale collapse or sagging of the sands and gravels into the structures, and thirdly the introduction of large masses of ice results in space problems which are difficult to resolve.

The involuted, clay-enriched rubified horizon, which has been thought to represent a stratigraphically important warm temperate palaeosol (Rose, Allen and Hey, 1976; Rose and Allen, 1977), is well developed in the Stebbing Pit. The involutions are regarded as the overprint of an arctic soil structure and incorporate the red and grey colour banding of the sol lessivé.

At Stebbing however, doubt is thrown on the palaeoclimatic interpretation of the rubified sol lessivé. In the south-east corner of the working pit the rubified material lines the walls of a large gull. The core of the gull contains a basal mélange of rubified sandy loam and flint gravel which appears to have been derived from the walls. However, it is difficult to envisage all of the rubified material as having slumped because,

in the upper part of the gull, the colour banding of the rubified material is planar and concordant with the walls, and the rubified zone is continuous, with a thickness little different from that outside the gull. The amount of rubified material lining the sides of the gull is thus greater than the amount which could collapse by a tensional opening of the gull. There is also no evidence that the minor faulting associated with the formation of the gull disturbed the base of the rubified material or its colour banding.

Previous authors have regarded the rubified material as the illuvial horizon of a sol lessivé. The complete absence of an eluvial horizon of this soil profile has been ascribed to erosion during the early Anglian glaciation (Rose, Allen and Wymer, 1978). The structures at Stebbing provide an ideal site for the preservation of such a horizon, and its absence throws doubt on the gentic interpretation of the rubified material.

These observations lead to the conclusion that the rubified material lining the walls of the gulls formed in situ and is not the result of slumping into structures. It follows that this would have taken place in a periglacial environment, penecontemporaneously with, or postdating the opening of the gulls.

Acknowledgement

This short communication is published with the permission of the Acting Director, Institute of Geological Sciences (N.E.R.C.).

D. Wilson.

GREAT WALTHAM

TL 687 117

These notes refer to the now abandoned quarry south of Broad Green Lane. Similar sections can be seen in the currently active quarry north of the lane. The general stratigraphy is given below:

Lowestoft Till	Dull yellow brown (2.5Y 5/4), very calcareous till (4.4m).
	Olive grey (5Y 4/2), calcareous till (1.45m).
	Brown (7.5YR 5/6) sandy banded till (1.44m).
	Deformation till/gravel, sands and silts
	Coversand
Kesgrave sand and gravel and Palaeosols horizon.	Lower sand and gravel with palaeo-argillic horizon or calcrete in upper metre.
	London Clay

London Clay

This silty clay underlies both quarries. It is rarely exposed during mineral extraction but is sometimes revealed as small ridges up to c 2m high and 2-3m wide above its general surface level. These linear structures are usually associated with collapse features in the overlying sediments including the tills.

Kesgrave Sands and Gravels

Fig. 92 illustrates the main characteristics of this unit. It possesses considerable structural and textural variability with common erosional surfaces, especially channel scours. Several depositional facies have been recognised. Large scale, steeply dipping, poorly sorted, channelled, gravel cross-sets, probably representing a meandering river point bar are overlain by small sand dunes shown by cross laminated sands, and further gravel. All are truncated by a deep (at least 1.47m) channel subsequently infilled by a series of poorly sorted, massive or weakly bedded sandy gravel beds with occasional small scale cross bedded sand units and a silty clay draped channel. Occasional massive, very coarse, poorly sorted, matrix supported gravel beds suggestive of debris flood deposition were recorded. In general bed thickness decreases upwards.

The sedimentation above the large erosion surface equates well with Miall's (1977) Scott Type braided river system but with a slowly moderating flow regime. Palaeocurrent measurements indicate flow towards the east-northeast (Fig. 93).

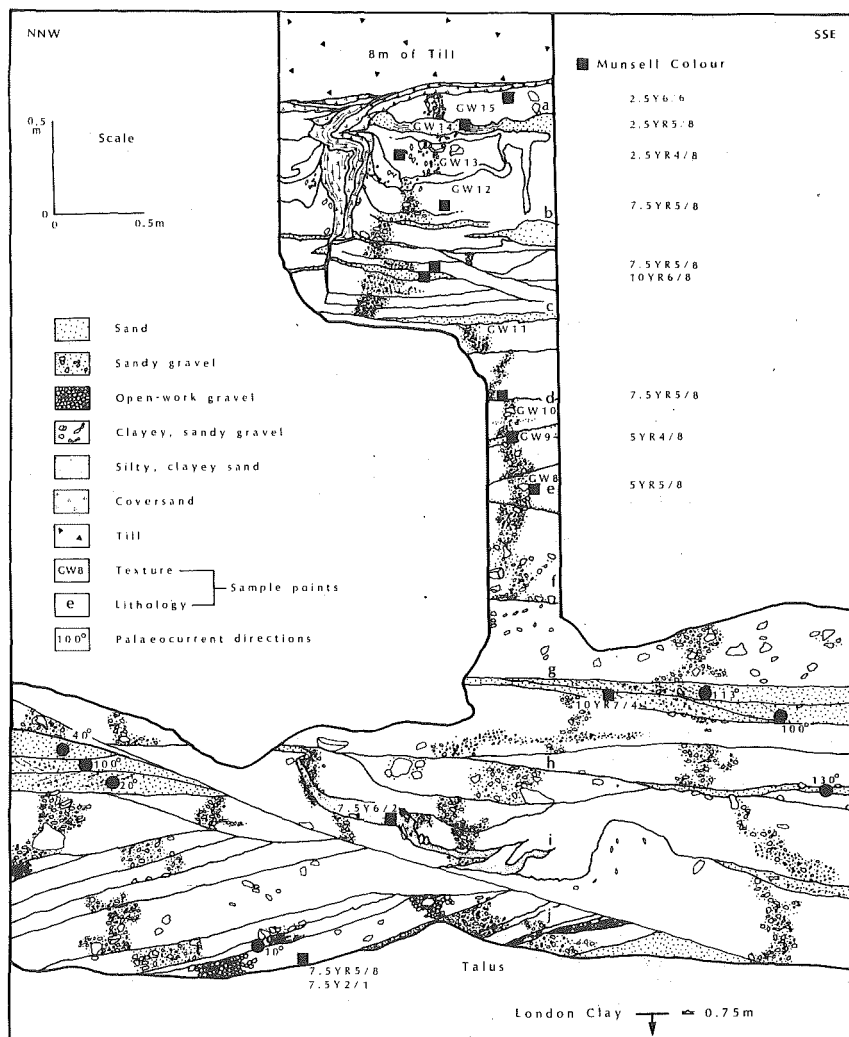


Figure 92. Kesgrave sands and gravels at Great Waltham, south quarry. The upper part of the section shows rubification associated with the Valley Farm palaeosol and a sand wedge of the Barham Arctic Structure Soil.

Samples of the 8-16mm clasts at 0.5m vertical intervals indicate the uniformity of the clast lithology (Table 14) dominated by flint (69%) and quartz and quartzite (28%) with small but significant amounts of Greensand chert, and volcanic rocks. Many large clasts (up to c 30cm) of volcanic tuff have been discovered in this quarry. Similar rocks have already been discussed by Hey and Brenchley (1977) and Green, Hey and McGregor (1980). Noteworthy is a small clast of accretionary lapilli tuff which bears a very close textural and mineralogical similarity to an in situ sample obtained from Ogwen in Snowdonia, North Wales.

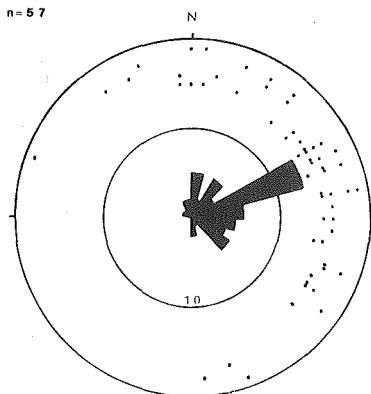


Figure 93. Palaeocurrent measurements from the Kesgrave Sands and Gravels, Great Waltham.

Rubification and clay enrichment in the upper metre of the sand and gravel (Table 15) meets the soil survey of England and Wales criteria (Avery, 1980) for a palaeoargillic horizon interpreted as a warm temperate, interglacial soil. Retention of the primary sedimentary bedding in these pedogenic horizons suggests that only the B/C and B horizon of the soil have survived subsequent erosion.

In places, the upper part of the sands and gravels is irregularly, but strongly, cemented (sufficient to tear the bottom out of a digger bucket!) with calcium carbonate to a mean thickness of 5-10cm and maximum thickness of 49cm. The matrix is dull brown (7.5YR 5/4). Pebble sockets show coats of calcaeous crystals sometimes stained black by Fe/Mn oxidation. Fine sand or clay occupies pockets in the upper surface of the calcrete. A thin section revealed angular to sub-angular fairly coarse quartz sand and flint with occasional sandstone fragments in a very dense brownish grey mass of fine calcium carbonate crystals. Coarse crystals are orientated around the sand grains. There is evidence of the filling of voids and channels by translocated CaCO_3 . A Zone of vertically striated brownish material could represent ferriargillans. It is open to discussion whether this deposit is pedogenic in origin, or the result of ground water movements operating after the emplacement of the chalky till. In at least one site in this quarry the chalk rich, olive grey till was seen to be downfaulted adjacent to the lower sand and gravel.

Coversand

A thin discontinuous, very well sorted bright brown (7.5YR 5/6), medium to fine sand with occasional small sometimes polished pebbles overlies the Kesgrave sand and gravel. It is interpreted as a coversand, on the basis of its sorting and mineralogy (Rose, et al., 1978). It often occupies wedge shaped structures penetrating the underlying sediments. Fine, vertical, textural laminations parallel the sides of these structures. The surrounding horizontally bedded sediments show the classic upturning adjacent to the structure, typical of a sand wedge. The in-

SAMPLE	NO. OF CLASTS	PERCENTAGE						VOLCANICS
		FLINT ANG.	ROUNDED	QUARTZ	QUARTZITE	CHERT L.G.S.	MISC.	
a	1323	78.2		12.9	6.3	6.3	1.9	0.1
b	1088	74.4	3.8	22.1	10.9	1.9	1.0	-
c	1584	64.3		17.4	8.7	2.3	1.0	00.1
d	1191	70.6		20.4	9.4	2.7	0.8	-
e	1239	66.7		18.1	11.7	1.9	1.1	0.2
f	1437	67.1		20.0	9.3	2.0	0.6	0.1
g	1161	68.1		19.3	10.2	1.8	1.2	0.2
h	1246	67.4		19.4	9.0	3.0	0.7	0.1
i	1011	67.8		17.2	8.3	3.1	1.1	0.1
j	1014	70.2		19.3	10.3	2.0	0.9	0.1
MEAN (EXCL. SAMPLE a)		67.7		19.2	9.7	2.3	0.9	0.1
		62.0	5.7					

Table 14. Lithology of the 8-16 mm clasts at 0.5m vertical intervals through the Kesgrave Sands and Gravels, Great Waltham (sample locations are shown on Fig.).

SAMPLE NUMBER G.W.	DEPTH BELOW KESGRAVE S/G SURFACE (CM)	% SAND	% SILT	% CLAY
15	5-15	55.1	14.8	30.1
14	18-28	63.0	8.9	28.1
13	37-52	64.6	22.3	13.2
12	59-72	74.5	-	-
11	129-142	87.3	3.9	10.8
10	172-182	89.3	-	-
9	183-190	85.8	5.2	9.0
8	219-229	93.8	2.6	3.6

Table 15. Particle size distribution of the palaeoargillic horizons and Kesgrave Sands and Gravels at Great Waltham (sample locations given on Fig. 92; analyses are based on the fraction finer than 2mm).

creased percentage of flint, especially angular flint, at the top of the Kesgrave Sands and Gravels (Table 14) may reflect frost shattering during periglacial conditions. Unidirectional deformation of the upper part of the wedge is probably related to the action of the overriding ice.

Tills

Several till units have been distinguished. Some of their characteristics are summarized in Table 16 and Fig. 94.

Depth Below Sur- face (M)	Sample No.	Colour	Particle size Properties				Lithology, 8 -16m Clasts												CaCO ₃ %	
			Gravel	Sand	Silt	Clay	Flint	Quartz	Quartzite	Chert	Chalk	Jurassic S&T	Shell	Permo-Trias.S&T	Oolite	Shale	Carb.lst.	Igneous	Calc. Nods.	Calc.
0.5	28	2.5Y 5/4	8.3	13.2	45.3	33.3	1.2	-	3.6	1.2	86.9	1.2	-	1.2	-	-	-	-	4.8	46.5
	27		12.6	18.3	39.4	29.8	13.3	-	1.2	-	80.7	3.6	1.2	-	-	-	-	-	-	45.2
	26		12.7	16.4	38.6	32.4	10.4	1.8	1.8	3.7	77.4	2.0	0.6	-	-	0.6	0.6	-	-	42.8
	24		13.4	16.6	36.4	33.6	11.3	1.3	1.3	2.0	77.5	4.0	2.0	-	0.7	-	0.7	-	-	42.6
4.9	23	5Y 4/2	9.2	19.8	37.4	32.6	8.3	2.3	3.0	1.5	77.4	6.1	0.8	-	0.8	-	-	-	-	39.7
	22		7.0	18.7	37.1	36.3	11.8	1.5	1.5	1.5	75.0	3.0	-	-	-	5.9	-	-	-	37.4
	21		8.5	20.7	37.0	33.7	26.3	2.2	3.2	3.2	55.8	2.2	1.1	1.1	-	4.2	-	1.1	-	33.1
6.35	20	7.5YR 4/4	17.1	34.5	23.0	25.7	68.8	7.5	5.6	3.1	9.4	3.2	1.3	0.6	0.6	-	-	-	-	13.2
	19	7.5YR 5/6	37.2	41.4	13.2	8.2	74.3	15.1	5.1	5.5	-	-	-	-	-	-	-	-	-	1.5
7.79	18		26.9	30.1	20.1	11.3	71.6	16.2	7.7	3.7	-	-	-	-	-	-	-	0.7	-	3.6
7.99	17	10YR6-7/8 10YR 3/2	15.1	36.1	30.4	18.5	75.3	12.7	6.7	3.3	-	-	-	-	-	-	-	-	-	5.2

Table 16. Lithology, calcium carbonate, colour and particle size properties of the till units at Great Waltham. Description of the lithologies is given on Fig. 94.













Depth below surface (m)	True North	Description	Sample number	Resultant Vector	Vector Magnitude	Significance	Mean Dip	Dip to Ice %
0.5			G.W.					
			28	171	55	99.99	30	42
		Yellowish-grey, (2.5Y5/4) structureless, silty-clay, chalk-rich till	27	148	17	NS	25	52
			26	154	10	NS	25	58
		Fine chalky gravel/sand lense	24	150	30	98	23	60
4.9		Gradual Boundary						
			23	175	35	99.0	20	62
		Greyish-olive, (5Y4/2) very compact, structureless, silty-clay, chalk-rich till	22	2	41	99.9	21	82
			21	18	25	95.0	25	74
6.35		Clear Boundary						
			20	94	33	99.0	13	26
		Brown, (7.5YR4/4) sandy, banded till	19	102	57	99.99	13	52
			18	109	69	99.99	12	48
7.79		Sharp Boundary						
		Yellowish-brown, (10YR6-7/8) sandy, deformation till	17	116	63	99.99	15	82
7.99								

Figure 94. Till macrofabric properties, Great Waltham.

The lowest unit (Sample G.W.17) is about 20cm of gently flexed medium to fine, laminated sand with some stones and lenses of brownish black (10YR 3/2) silty clay. It shows a well defined, preferred orientation which trends west-northwest - east-southeast. Lithologically it reflects the subjacent sands and gravels with the addition of modules of calcareously cemented sand. Particle size distribution suggests derivation from the coversand and London clay. It is likely that this unit represents deformation and reworking of very local sediments, possibly with a stoney glacial fluvial contribution.

This unit is overlain by about 1.5m of brown (7.5YR) sandy till (GW 18, 19, 20) interbedded with thin (<5cm) well sorted clay silt and sand laminations which tend to decrease upwards. At some points several fining upward units are overlain by well developed till and the interbedding of water lain and glacial material is reduced to a minimum. The preferred orientation is again west-northwest - east-southeast in this brown sandy till. Several systematic trends are discernable within this and the underlying unit. The till becomes stonier, sandier and less calcareous through GW. 17, 18 and 19. Orientation trends rotate from west-northwest - east-southeast towards west - east and the vector magnitude decreases. Lithology remains like the Kesgrave Sands and Gravels. In sample GW 20 some of these trends remain but the till becomes more calcareous, clayier and the lithology begins to show characteristics, especially the frequency of chalk clasts, that typify the main body of overlying till.

This overlying till (GW 21, 22, 23) is a uniform greyish olive (5Y 4/2), compact, clay- and chalk-rich, structureless diamicton typical of a lodgement till. Where it impinges directly onto the Kesgrave Sands and Gravels the bottom 20-30cm is oxidized (10YR 5/4). Lithologically the erratics are dominated by far travelled chalk and Jurassic rocks. It has a general north - south preferred orientation, mostly strongly developed in the middle of the unit.

A gradual boundary separates it from the uppermost till unit. At or just above this boundary a discontinuous lense (up to 20cm thick) of fine chalky gravel and sand occurs (GW 25). The till (GW 24, 26, 27, 28) is 4.4m of dull yellowish brown (2.5YR 5/4), structureless, but less compact, silty clay with abundant chalk clasts, similar lithology and particle size distribution to the underlying unit. Preferred orientation is similar, to but generally much weaker than the olive grey till. Strongly weathered clasts are more common and occasional sand pockets occur. The characteristics of these two till units suggest a lodgement till overlain by a supra-glacial melt-out till. The higher vector magnitude of sample 28 may reflect an element of flow in its formation, although there was no evidence of flow banding in the till.

C.A. Whiteman.

EASTERN ESSEX

Introduction

This area between the estuaries of the Thames and Blackwater is predominantly one of low-lying land, with the highest ground in the west and a succession of gravel covered terraces, showing various amounts of dissection, falling eastwards, culminating in coastal marshes and mudflats (Fig. 95). The local bedrock is predominantly London Clay, although Bagshot Beds cap the Rayleigh Hills in the south, and Claygate Beds outcrop widely on higher ground in the western parts of the area.

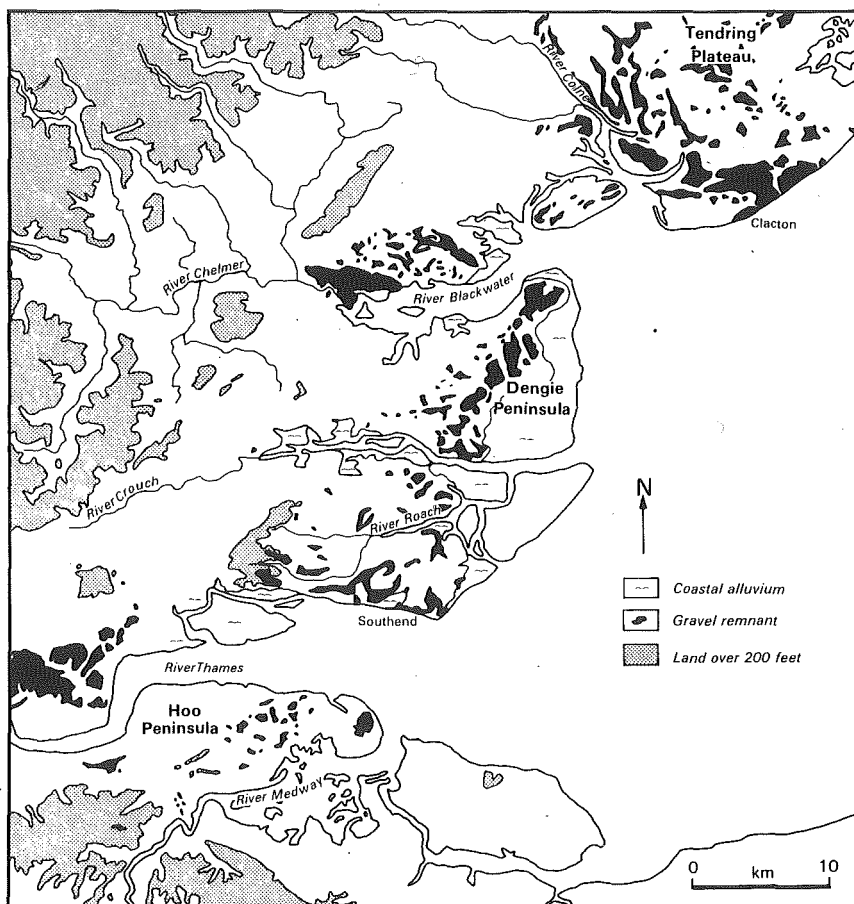


Figure 95. Topography, drainage and extent of gravel remnants in eastern Essex.

The earliest description of the gravels was by Wood (1866), who regarded them as marine. Whitaker (1889) considered them to be a continuation of the Thames Valley gravels and suggested that the Thames and Medway flowed together across the area. Gregory (1922), however, was impressed by the presence of large quantities of Lower Greensand chert in the gravels and formed the opinion that they were deposited, in late Tertiary times, by rivers flowing down an extended northern slope of the Weald. In a more recent study, Gruhn and Bryan (Gruhn *et al*, 1974) confirmed the strong southern affinities of the gravel and suggested that the Medway was the main agent in their deposition. These authors recognised a number of terraces in the area, correlating their remnants by elevation and from borehole data. The area has recently been resurveyed by the Institute of Geological Sciences, as a result of which four named terraces and a number of drift-filled channels have been recognised (I.G.S. sheets 241 and 258/); Lake *et al*, 1977; Hollyer and Simmons, 1978; Simmons, 1978).

During the period 1977 - 1980, the various gravels were sampled, predominantly from trial holes, and identified according to lithological types in the 16 - 32mm and 11.2 - 16mm size ranges (Tables 17 and 18). The elevations of the surface of the gravel bodies were surveyed, enabling the subdivision of the deposits into a number of aggradation stages. Stone counting showed that the composition of the higher members of this series differs considerably from that of the lowest four aggradations. The two distinct types of gravel recognised in this way were collectively termed High and Low Level East Essex Gravels.

The High Level East Essex Gravel

The High Level East Essex Gravel comprises almost entirely local (35 - 68%) and southern (13 - 65%) rock types. The local material being made up of flint from the chalk and rounded flint (often broken) from the Tertiary deposits of the London Basin. The southern component is made up largely of chert from the Folkestone and Hythe Beds (Lower Greensand), supplemented by sandstones, siltstones and ironstones from the Hastings Beds of the central Weald, and rare arenaceous lithologies from the Lower Greensand (Bridgland, 1980; 1983 a; b). Occasional 'exotic' material (derived from outside the London Basin and the Wealden area) was also encountered, mainly cherts of Jurassic or Palaeozoic origin and quartzose lithologies (Tables 17 and 18).

These deposits have a composition virtually indistinguishable from that of Medway gravels which have been recognised in north Kent (Table 18), although they generally contained slightly less southern material, particularly the predominantly soft Hastings Beds lithologies. This probably reflects the dilution of the southern component by addition of local material picked up directly, or by way of tributaries, north of the Hoo Peninsula.

The High Level East Essex Gravel aggradations are therefore attributed to the river Medway, which is considered to have been a south bank tributary of the Thames, and flowed across central Essex prior to the Anglian glaciation (Rose, *et al*.,

Sub-division	Location	Sample No.	Height m O.D.	% Flint	% Medial Flint *	% Non-tertiary	% Tertiary Flint	% Sarsen	% Local	% Lgsd chert	% Total gsd	% Hastings Beds	% Southern	% Qtz & Olivine	% Rhazella chrt	% Carb chrt	% Igneous/Met	% Enactics	Ratio Tertiary: Non-Tertiary 1:2	Ratio Southern: Local 1:2	Ratio Southern: Enactics 1:2	Total count	Grid Reference
Mayland Gravel	Bovill Uplands	1A	11.7	85.5		25.3	60.3		85.5	14.0	14.0	—	14.2	—				—	0.42	6.02	—	380	TQ 9252 9998
	Bovill Uplands	1B	11.7	79.5		26.7	52.8		79.5	19.5	19.5	1.0	20.5	—				—	0.51	3.87	—	307	TQ 9252 9998
	Bovill Uplands	1C	11.4	74.4	13.3	27.8	46.6		74.4	24.1	25.0	0.6	25.6	—				—	0.60	2.90	—	324	TQ 9252 9998
	Bovill Uplands	1C	21.4	72.8	3.7	22.5	50.3	—	73.0	25.6	25.9	1.1	27.0	—				—	0.45	2.70	—	644	TQ 9252 9998
St Lawrence Gravel	St. Lawrence	1	30.3	36.4		25.1	11.3		36.4	62.5	63.2		63.2	—				0.4	2.21	0.40	0.01	469	TL 9677 0408
	St. Lawrence	1(c & d)	30.3	34.6	1.9	24.8	9.8		34.6	65.1	65.4		65.4	—				—	2.52	0.53	—	1069	TL 9677 0408
Badnock's Gravel	Badnocks Farm	1A	34.5	66.1		38.0	28.0		66.1	32.3	32.9	1.1	33.9	—				—	1.36	1.95	—	560	TL 9498 0189
	Badnocks Farm	1A	34.4	70.2	5.2	22.2	38.0		70.2	28.6	28.8	0.9	29.7	—				0.2	0.85	2.36	0.01	1277	TL 9498 0189
	Badnocks Farm	1B	34.1	64.0	10.1	34.0	29.4		64.0	35.2	35.2	0.9	36.0	—				—	1.16	1.78	—	347	TL 9498 0189
	Badnocks Farm	2	31.8	76.8	5.5	24.3	52.5		76.8	22.2	22.5	0.8	23.2	—				—	0.46	3.30	—	383	TL 9526 0181
Caidge Gravel	Caidge Farm	1	30.4	74.6	10.3	29.8	44.7		74.6	23.7	23.9	1.3	25.2	—				—	0.67	2.96	—	389	TL 9471 9940
	Caidge Farm	1	30.3	69.1	5.9	30.7	38.4		69.1	29.4	29.8	1.2	30.9	—				—	0.80	2.23	—	524	TL 9471 9940
Asheldham Gravel	Ratsborough Farm Pit	1	13.5	90.3		33.9	56.5		90.3	7.7	7.9		7.9	1.1	—	0.5		1.8	0.60	11.47	0.24	623	TQ 9531 9833
	Goldlands Road Pit	1A	20.2	84.0		42.5	41.6		84.3	12.8	13.5		13.5	0.9	—	0.4		2.3	1.02	6.25	0.17	445	TQ 9609 9901
	Goldlands Road Pit	1B	19.8	88.8		37.0	57.1		88.8	9.5	9.6		9.9	0.7	—	0.3		1.4	0.72	9.00	0.14	862	TQ 9609 9901
	Goldlands Road Pit	2	19.7	88.0	11.9	41.3	46.8		88.0	10.0	10.2		10.2	1.4	—	—		1.8	0.88	8.64	0.18	834	TQ 9608 9897
	Asheldham	1A	20.3	87.2		32.1	55.1	—	87.4	9.9	10.1		10.1	1.3	0.4	0.4	—	2.5	0.58	8.64	0.25	554	TL 9715 0173
	Asheldham	1B	19.4	74.3		28.3	46.1		74.3	25.1	25.1		25.1	0.6				0.6	0.61	2.96	0.02	354	TL 9715 0173
	Asheldham	1B	19.4	78.0	3.0	31.0	46.9		78.0	20.7	21.0	—	21.1	0.3	—	0.4	—	1.0	0.66	3.70	0.05	1025	TL 9715 0173
	Asheldham	1C	20.5	87.4		38.1	42.3		87.4	10.6	10.9	0.5	11.4	1.0	—			1.2	0.77	7.67	0.31	404	TL 9715 0173
	Asheldham	2	19.6	77.3	12.7	42.6	34.7		77.3	22.0	22.3		22.3		—	0.5		0.5	1.23	3.47	0.02	427	TL 9728 0190
	Tillingham	1A	14.7	92.9	9.8	25.7	67.2		92.9	5.4	5.4		5.4	1.5	—			1.7	0.38	17.32	0.32	522	TL 9846 0352
	Tillingham	1B	14.4	90.3	10.6	32.7	57.6	—	90.4	8.0	8.0	—	8.2	1.0	—			1.4	0.57	11.06	0.17	576	TL 9846 0352
	Tillingham	2A	14.6	90.3		21.8	68.6		90.3	8.0	8.2		8.2	1.1	—			1.5	0.32	11.05	0.18	538	TL 9851 0334
	Tillingham	2B	14.9	87.7		25.1	62.6		87.7	10.9	11.0		11.0	0.9	—			1.3	0.40	7.95	0.11	563	TL 9851 0334
	Tillingham	2B	14.0	84.9	2.3	32.9	52.1	—	85.0	12.2	12.3	—	12.4	1.6	0.3	0.3	0.2	2.6	0.63	6.85	0.21	1281	TL 9851 0334
	Bradwell	1	15.4	88.7		25.5	63.2		88.7	9.8	10.0	0.4	10.3	0.6	—			1.0	0.40	8.58	0.10	813	TL 9935 0580
	Bradwell	2	16.3	86.0		33.0	53.0		86.0	13.1	13.1		13.3	0.7	—			0.8	0.62	4.99	0.06	619	TL 9938 0577
	Bradwell	4A	12.6	89.3		29.2	60.0		89.3	9.3	9.3	0.4	9.7	0.6	0.4			1.0	0.49	9.16	0.10	503	TL 9938 0532
	Bradwell	4B	11.6	79.9	9.3	34.8	45.1		79.9	19.5	19.8	—	20.0					—	0.77	4.00		581	TL 9938 0532
	North Wick	1A	6.6	85.6	6.9	38.1	47.5		85.6	12.2	12.8		12.8	0.8	—			1.6	0.80	6.68	0.12	507	TL 9710 0010
	North Wick	1B	5.8	89.8	8.0	33.6	56.2		89.8	8.4	8.4	0.4	8.8	1.0	—			1.4	0.60	10.19	0.16	772	TL 9710 0010
	North Wick	1C	5.3	93.0		31.7	61.3		93.0	5.7	5.7		5.7	0.8	—			1.2	0.52	16.41	0.21	511	TL 9710 0010
Marsh Road Gravel	Marsh Road	1	12.0	88.9	8.0	32.9	56.0	0.5	88.4	8.7	8.9		8.9	1.2	—			1.7	0.59	10.00	0.19	414	TM 0024 0388
	Marsh Road	1	12.0	89.1	3.8	36.0	53.1	—	89.2	8.5	8.5		8.5	1.7	0.2			2.3	0.68	10.54	0.28	898	TM 0024 0388
Dammer Wick Gravel	Dammer Wick	1	2.7	86.3	14.5	36.3	52.0		86.3	10.6	10.9		10.9	0.8				0.8	0.70	8.07	0.07	256	TQ 9614 9268
	Dammer Wick	1	2.7	87.8	2.4	40.8	46.9		87.8	9.8	10.0		10.0	1.3	0.4	0.3		2.3	0.87	8.80	0.23	752	TQ 9614 9268
Hond-gravel	Skimmers Wick	1	14.2	85.5		18.1	70.9		85.5	9.8	9.8		9.8		—			0.7	0.26	9.13	0.07	306	TQ 8413 9813
	Skimmers Wick	1	14.2	85.5	4.1	22.5	64.0		85.5	13.3	13.3		13.3		—			—	0.35	6.51	—	564	TQ 8413 9813
Crouch gravel	Little Hayes	1	6.5	91.8		34.5	57.3		91.8	1.8	1.8		1.8	5.7	0.3	0.3		6.4	0.60	49.92	3.46	767	TQ 7980 9588
	Little Hayes	2	7.8	93.2	3.4	31.8	61.2		93.3	0.7	0.7		0.7	5.1		0.3	—	6.0	0.52	143.00	9.25	613	TQ 7981 9597
	Little Hayes	2	7.8	91.7	2.5	42.4	49.3		91.7	1.5	1.7		1.7	5.2	0.2	0.4		6.7	0.87	55.50	4.05	1211	TQ 7981 9597

Table 17. Lithological properties of the gravel units from the Dengie Peninsula. - indicates that a single example was found. * indicates that data were not recorded for all 16-32 mm analyses.

Hoo Peninsula																								
	Location	Sample No.	Height m O.D.	% Flint	% Modular Flint %	% Non-Tertiary	% Tertiary Flint	% Sarsen	% Local	% Gsd cht	% Total gsd	% Hastings Beds	% Southern	% Qtz & Qtzite	% Rhazella cht	% Carb cht	% Igneous/Met	% Exotics	Ratio Tertiary: Non-Tertiary 1:n	Ratio Southern: Local 1:m	Ratio Southern: Exotics 1:n	Total count	Grid reference	
	High Halstow Gravel	High Halstow	1	56.0	62.8	9.0	32.4	30.4		62.8	36.3	36.5	0.7	37.2					1.07	1.69	—	566	TQ 7831 7508	
	Clinch Street Gravel	Clinch Street Farm	2B	50.3	68.8		35.4	33.4		68.8	28.4	29.3	1.7	30.9	—			—	1.06	2.23	—	359	TQ 7911 7622	
	Dagenham Farm Gravel	Dagenham Farm	2	37.7	72.8	25.5	49.2	23.6		72.8	25.3	25.5	1.4	27.0		—		—	2.08	2.70	—	423	TQ 8277 7770	
	Shakespeare Gravel	Shakespeare Farm Pit	2B	28.3	74.2	20.8	38.4	35.8		74.2	24.3	24.6	0.8	25.6	—			—	1.07	2.90	—	745	TQ 8136 7731	
	Newhall Farm Gravel	Newhall Farm	2	21.1	70.8	26.8	45.8	25.0		70.8	28.8	29.0		29.2				—	1.84	2.42	—	493	TQ 8297 7664	
	Stoke Gravel	Stoke	1A	15.1	72.6	17.1	42.6	30.0	—	72.8	25.6	25.9	0.9	27.0	—			—	1.42	2.69	—	636	TQ 8218 7479	
	Binney Gravel	Binney Farm	1	5.5	70.4	19.0	49.1	21.3		70.4	28.4	29.1	0.5	29.6				—	2.30	2.38	—	652	TQ 8484 7743	
Tilbury area																								
	Orsett Heath Gravel	Unford	1	32.2	96.0	11.6	31.4	64.6		96.0	2.2	2.4		2.4	1.2		—	1.7	0.49	40.70	0.70	424	TQ 6681 8028	
	Barvills Gravel	Barvills Farm Pit	1	11.0	92.9	11.8	35.0	67.9		93.1	3.3	3.3		3.3	2.8		0.3		3.6	0.61	28.00	1.08	722	TQ 6811 7774
	Mucking Gravel	Mucking	1A	4.2	97.0	9.3	33.1	64.0		97.0	1.1	1.1		1.1	1.3	—		1.8	0.53	85.88	1.63	708	TQ 6892 8154	
	E. Tilbury Msh Gravel	East Tilbury Marshes	1	-1.1	96.2	9.9	37.3	58.9		96.2	0.9	1.1		1.1	1.6	0.3	0.4	0.3	2.7	0.63	89.63	2.68	745	TQ 6880 7843
Southend area																								
	Daws Heath Gravel	Daws Heath	1	72.4	86.1	8.3	22.7	63.5		86.1	13.2	13.4	0.3	13.7			—	—	0.36	6.29	—	613	TQ 8068 8887	
	Oakwood Gravel	Oakwood Reservoirs	1	63.6	73.1	6.8	20.3	62.9		73.1	26.7	26.7	—	26.9				—	0.98	2.72	—	558	TQ 8234 8639	
	Ashington Gravel	Ashington (Mount View)	1	53.7	80.3		37.1	43.2		80.3	19.7	19.7		19.7				—	0.86	4.08	—	620	TQ 8545 9339	
	Bellairs Gravel	Bellairs Park	1	8.1	65.2	8.4	25.8	39.5		65.2	34.1	34.1	—	34.5			—	—	0.65	1.89	—	299	TQ 8336 8764	
	Canewdon Gravel	Canewdon Hall Farm	1A	38.0	75.0		25.6	49.4		75.0	24.7	25.1		25.1				—	0.52	3.00	—	776	TQ 8973 9468	
	Chalkwell Gravel	Chalkwell Park	1	36.5	84.4	7.7	25.5	58.9		84.4	15.2	15.4		15.4			—	—	0.43	5.49	—	494	TQ 8579 8636	
Southchurch Gravel	Cecil Jones School		1	25.4	76.2		42.6	33.6		76.2	20.9	21.2		21.2	0.8	1.1	0.5	—	2.6	1.27	3.59	0.12	613	TQ 8962 8750
	Canewdon Wick		1A	19.4	91.2		26.0	65.3		91.5	7.0	7.0	—	7.2	0.8	—	—	1.3	0.40	12.72	0.19	599	TQ 9107 9468	
	Moats and Springs		1	14.9	93.4	9.4	22.8	70.6	—	93.6	5.0	5.3	0.3	5.6	0.3		—	0.8	0.32	16.65	0.15	605	TQ 9088 9197	
Rockford Gravel	Rockford		1	12.3	86.6	14.2	44.4	42.2		86.6	10.7	11.2		11.2	1.0	—	1.0		2.2	1.05	7.72	0.20	410	TQ 8803 9155
	East Canewdon		1A	8.9	85.2		46.0	39.2		85.2	13.5	13.5		13.5	0.7		0.6		1.3	1.17	13.49	0.10	541	TQ 9220 9416
Barking Gravel	Barking Hall		1	2.8	80.4		46.7	33.7		80.4	18.6	18.6		18.6	1.0			1.0	1.39	4.32	0.05	308	TQ 9318 9018	
	Hampton Barns		1	5.9	91.1		43.8	47.3		91.1	7.4	7.4		7.4	1.3			1.5	0.93	12.29	0.21	459	TQ 9026 9161	

Table 18. Lithological properties of selected 16-32 mm samples from the Hoo Peninsula, the Tilbury area, and the Southend area. - indicates that a single example was found. * indicates that data were not recorded for all 16-32 mm analyses.

1976; Gibbard, 1977; Bridgland, 1980). The exotic material has probably been derived from pebble-beds within the Hastings Beds and Lower Greensand of the Weald (Bridgland 1983 a; b). Six aggradation stages have been recognised within the High Level East Essex Gravel (Table 19), although subdivision and correlation

Southend area	Dengie Peninsula	Projected surface elevation in the region of the Crouch Estuary.
Daws Heath Gravel		66m O.D.
Oakwood Gravel		57m O.D.
Ashingdon Gravel	Gravel at Stamfords Hill and Althorne?	50m O.D.
Belfairs Gravel	Mayland Gravel	45m O.D.
Canewdon Gravel	St. Lawrence Gravel	37m O.D.
Chalkwell Gravel	Caidge Gravel	33m O.D.

Table 19. Aggradation stages in the High Level East Essex Gravel.

proved difficult in a number of cases, due to the much dissected nature of the deposits, and the tendency for the altitudinal ranges of successive aggradations to overlap, particularly towards the northern part of the area (Fig. 96). Additional stages may therefore exist (Bridgland, 1983a).

The correlation of these much dissected aggradations across the Crouch Estuary is based largely on the assumption that they are more or less parallel with the highest Low Level East Essex Gravel stage, the downstream gradient of which can be determined with some precision, due to its considerably better preservation.

The Low Level East Essex Gravel

The composition of the Low Level East Essex Gravels differs from the higher aggradations in a number of ways. They contain a greater proportion of local material (74 - 94%) and a significantly smaller proportion of southern rock-types (5 - 25%). The most marked change, however, is the presence of a small but consistent exotic component (0.5 - 3%), comprising vein quartz, ortho- and metaquartzite, Carboniferous chert, Rhaxella chert and igneous rock-types (Tables 17 and 18; Bridgland, 1983 a; b). This exotic suite is identical to that recognised in the Lower Thames gravels of the Tilbury area (Bridgland, 1980; 1983 a), although it also occurs occasionally in Medway gravels of all ages (Bridgland, 1983 a), due to derivation from the Cretaceous rocks of the Weald. The consistent presence of Rhaxella chert in the Low Level East Essex Gravel is taken to indicate an Anglian or post-Anglian age, since this rock-type, from the Corallian of north Yorkshire, was apparently carried in some quantity into the London Basin by Anglian ice (Bridgland, 1980; 1983 a; b).

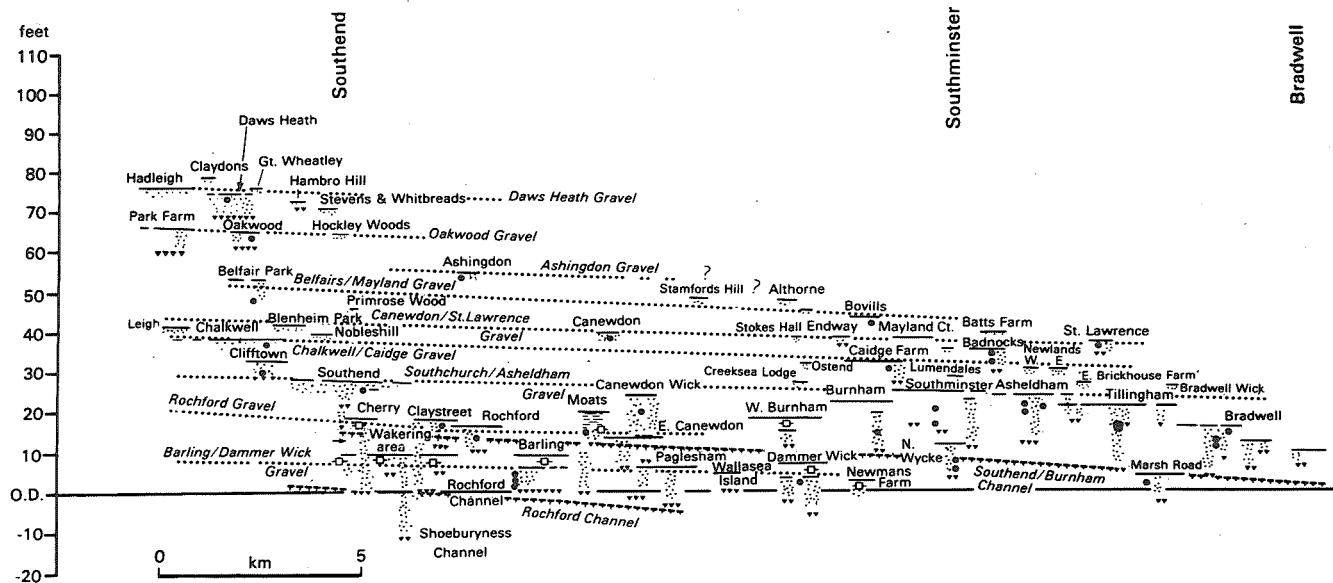


Figure 96. Long profile diagram of the east Essex gravels.

The presence of this characteristic exotic component, and the continued occurrence of fairly abundant southern material, including occasional soft Hastings Beds lithologies, suggests that the Thames and Medway have both contributed to the Low Level East Essex Gravel, and they are defined as Thames-Medway deposits laid down by the Thames downstream from its confluence with the Medway, as first envisaged by Whitaker. Four aggradation stages have been recognised within these deposits, which are associated with a number of drift filled channels (including those described by Lake, *et al.*,) (Table 20).

Southend area		Dengie Peninsula		Projected surface elevation (base of channel) in the region of the Crouch Estuary
aggradation	associated channel	aggradation	associated channel	
Southchurch Gravel	Southend Channel	Asheldham Gravel	Burnham Channel	25m O.D. (c10m O.D.)
Rochford Gravel	Rochford Channel	(Marsh Road Gravel)		16m O.D. (c-3m O.D.)
Barling Gravel	Shoeburyness Channel	Dammer Wick Gravel		5m O.D. (<-12m O.D.)

Table 20. Aggradation stages in the Low Level East Essex Gravel.

The highest of these Thames-Medway aggradations, represented by the Southchurch and Asheldham Gravels, remains relatively intact north of the Crouch, although it has been largely removed between Southend and Canewdon by a 'meander loop' of the later Rochford Channel and associated aggradations (Figs. 96 and 98). The Asheldham Gravel, north of the Crouch, appears to represent a complete floodplain and buried valley, which suggests, along with general lack of later deposits, that the river's course north of the Crouch was abandoned at the end of Asheldham Gravel times.

Later deposits are limited on the Dengie Peninsula. A few small spreads of lower gravel are found east of Tillingham (Marsh Road Gravel, TM 000 040), but do not appear to represent the main Thames-Medway (Bridgland, 1983 a). The Dammer Wick and Barling Gravel occur only in the south-east corner of the Dengie Peninsula. (Figs. 96 and 97). The distribution of these various Low Level East Essex Gravel aggradations suggest that, following Southchurch Asheldham Gravel times, the main river turned eastwards to flow more or less along the line of the modern Crouch Estuary. The origin of this anomalously large estuary, fed only by a small river, may therefore lie in the past activity of the Thames-Medway rather than the Crouch itself.

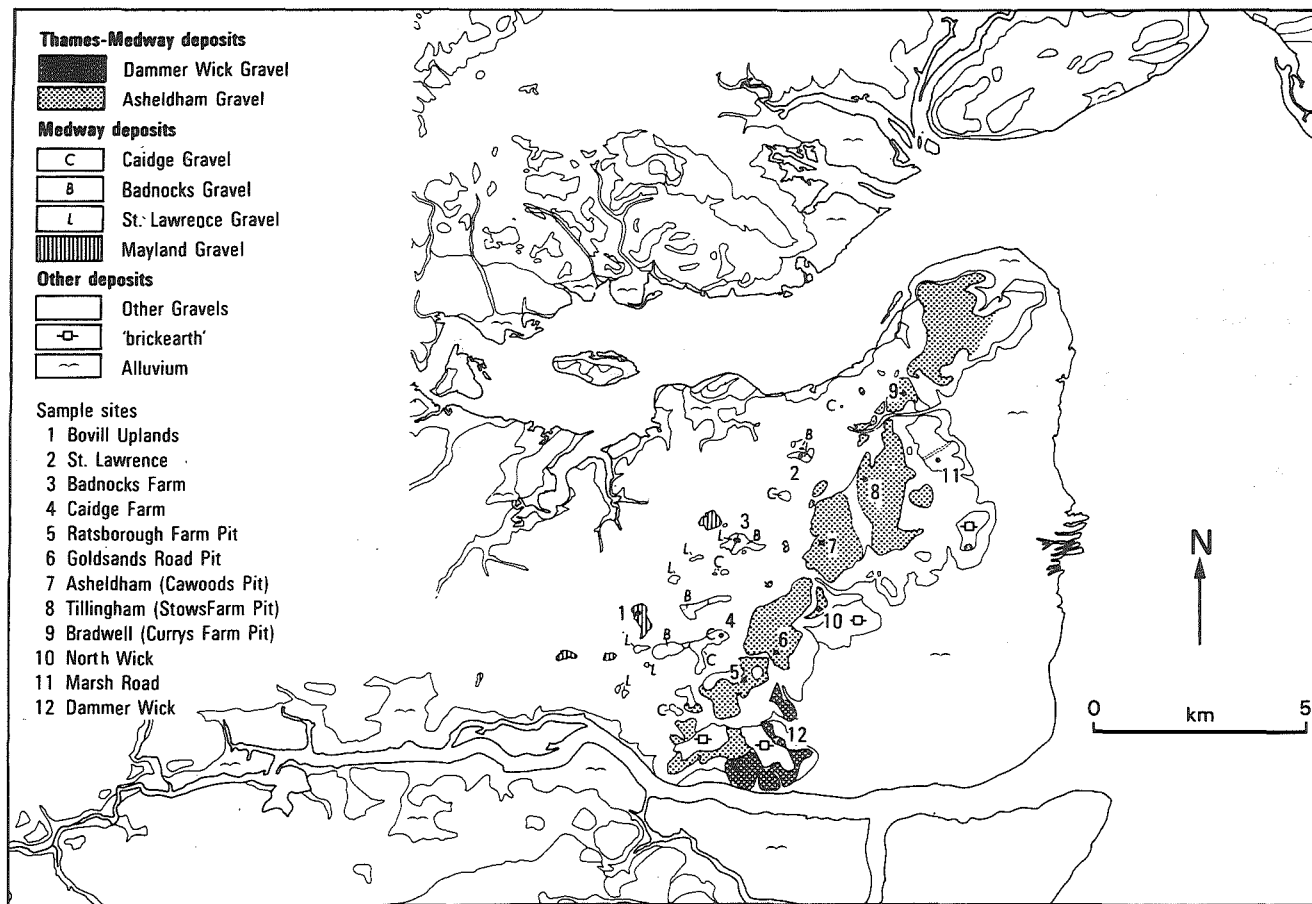


Figure 97. Gravels of the Dengie Peninsula

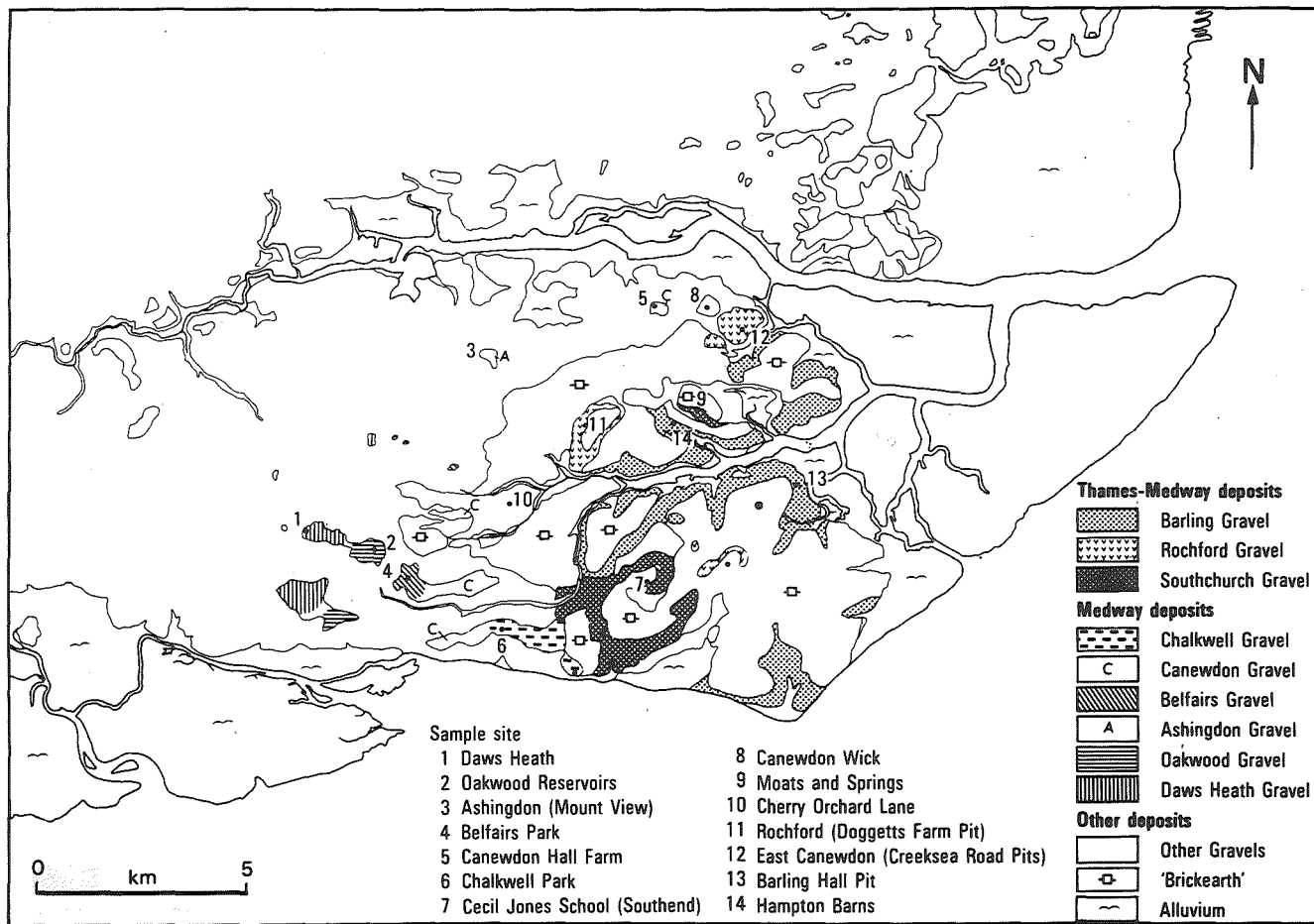


Figure 98. Gravels of the Southend area.

The Pleistocene History of the area

Study of the earliest deposits of eastern Essex has shown that the River Medway once flowed across the district prior to the existence of the modern Thames Estuary. The influence of the Thames catchment is indicated by a marked change in gravel composition due to the diversion upstream by Anglian ice (Gibbard; 1977; 1979). At this stage the combined river appears to have adopted the former course of the Medway across eastern Essex suggesting that the Thames was actually diverted into the Medway, possibly by way of an existing tributary in the position of the present Lower Thames Valley (Bridgland, 1980; 1983 a). At first this diversion merely served to re-route the Thames between Slough and Clacton where the river rejoined its original route, but at a fairly early stage, this northern part appears to have been abandoned in favour of a easterly course, in the region of the modern Crouch Estuary.

Correlation with the Pleistocene sequence in the Thames Valley

The abrupt change in gravel composition with the appearance of the Thames in eastern Essex gives rise to a distinct marker horizon which can be traced as the Southchurch/Asheldham Gravel from Southend to the Blackwater, enabling the downstream gradient of the river to be determined with some accuracy. (Fig. 96). This greatly facilitates correlation both within the area and with other regions. Upstream to Tilbury it is correlated with the Orsett Heath Gravel, which appears to be equivalent to the Boyn Hill Gravel of the Middle Thames. It is perhaps surprising that the highest Thames-Medway aggradation in eastern Essex should correlate with the Boyn Hill gravel, when the Black Park Gravel was the earliest aggradation laid down by the Thames in its post-diversion route through London (Gibbard, 1979). However, the Black Park aggradation has a steeper downstream gradient than the Boyn Hill, and it is thought to have sloped below the level of the latter before reaching eastern Essex (Bridgland, 1980).

Correlation of later and earlier stages is based largely on long profile relationship with the Southchurch/Asheldham Gravel, although in the case of the Barling Gravel additional evidence is available in the form of mammalian remains. The proposed correlations are given in Table 21. The important Southchurch/Asheldham Gravel aggradation can be traced north of the Blackwater to Mersea Island and the Clacton area, where it is represented by the lowest of a series of Thames and Thames-Medway deposits, the higher members of which pre-date the diversion of the Thames (Bridgland, 1980; 1983 a).

Conclusion

A study of gravel composition in eastern Essex has facilitated both the subdivision of the deposits into those pre-dating and those post-dating the Anglian diversion of the Thames into the area and correlation within the area and with the sequence in the Thames Valley. It appears from this work that the Thames, when diverted into its modern valley through London, flowed into the former valley of the River Medway and thereby

Middle Thames (Gibbard, in prep.)	Lower Thames (Bridgland & Gibbard, in prep.)	Southend area (Bridgland, 1983a)	Dengie Peninsula (Bridgland, 1983 a)
Winter Hill Gravel & earlier stages		High Level East Essex Gravels	
Black Park Gravel	Dartford Heath Gravel ?	within South- church Gravel ?	within Asheldham Gravel ?
Boyn Hill Gravel	Orsett Heath Gravel	Southchurch Gravel	Asheldham Gravel
Lynch Hill Gravel	Barvills Gravel	Rochford Gravel	Marsh Road Gravel
Taplow Gravel	Mucking Gravel	Barling Gravel	Dammer Wick Gravel
later stages	sub-floodplain deposits	submerged	submerged

Table 21. Proposed correlation of gravel bodies in East Essex with the lower and middle Thames.

rejoined its old course in the Clacton area. The northern part of this new route, inherited from the Medway, was, however, abandoned by 'Lynch Hill times', the river turning eastwards in the region of the modern Crouch Estuary. Post 'Taplow' aggradations are below modern sea-level in this area, but may be represented in the submerged terraces described by D'Olier (1975).

D.R. Bridgland.

BOVILL UPLANDS

TL 926 000

A newly excavated section south of Bovill Uplands, near Mayland, provides an exposure of Mayland Gravel, the highest established fluvial aggradation on the Dengie Peninsula. Gravel samples have previously been collected up to 41 O.D. at this site from a trial pit (Fig. 99). Stone counts of these samples showed 14%, 20.5% and 25.5% of southern material in the 16-32mm size fraction of samples A, B and C respectively. The only exotic material encountered was a veined quartzitic rock in sample A, the remaining clasts being of local origin (flint). Hastings Beds material was present in all three samples. The occurrence of this predominantly soft rock-type from the central Weald, the high southern content in general, and the similarity of the composition to that of known Medway deposits in north Kent (Table 18), suggest that the Mayland Gravel formed by aggradation of the River Medway.

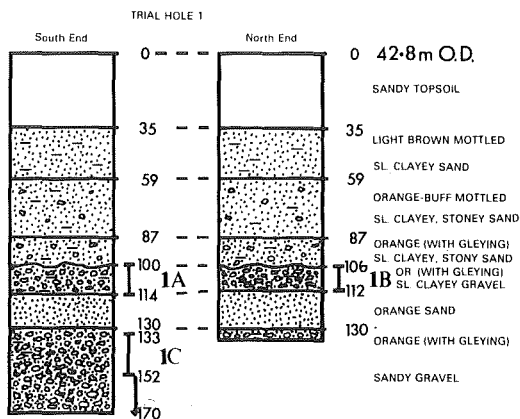


Figure 99. Sedimentary sequence and location of sample points, Bovill Uplands.

D.R. Bridgland.

GOLDSANDS ROAD PIT, SOUTHMINSTER

TQ 961 991

Exposures at Goldsands Road Pit, Southminster, show the Asheldham Gravel, which is largely equivalent to both the Southminster and Asheldham Terraces of Gruhn *et al.* (1974) to the '3rd Crouch Terrace' of Lake *et al.* (1977). Over 4.5m of Pleistocene sediments overly London Clay at 15.5m O.D. Gruhn and Bryan, who worked here at a time of more extensive quarrying, reported a sloping bench, ranging between 9.7 and 10.7m O.D., with the highest clay level in the north-east (Gruhn, *et al.*, 1974, unpublished appendix). Three I.G.S. boreholes in the vicinity add to the general picture of variable relief. A borehole to the north-west of Goldsands Road pit showed 3.8 m of sandy, silty clay and soil, overlying 2.4m of gravel; the London Clay being reached at 14.4m O.D.: Another section 350-400m to the south-west showed only 3.0m of Pleistocene sediments overlying the London Clay at 16.3m O.D.. The third borehole, near Newmoor to the north of Southminster (TL 9964 0035), revealed 10.5m of gravel overlying London Clay at 10.8m O.D., (Simmons, 1978). The range and distribution of London Clay surface suggests a buried channel underlying part of the Asheldham Gravel. The implication, from I.G.S. sub-drift mapping (Lake, *et al.*, 1977; Simmons, 1978), that the eastern side of the channel has been entirely removed by later erosion, is not supported by the higher level recorded near the eastern edge of the gravel spread nor by the sloping bench recorded by Gruhn and Bryan in Goldsands Road Pit. The original land surface in the vicinity of the pit was probably between 20 and 21m O.D., rising north-westwards to 25m O.D. in the middle of Southminster (TQ 956 998), well within the mapped extent of the Asheldham Gravel.

The exposures in this pit show mainly matrix supported, massive and cross-stratified sandy gravel, interbedded with sands and clayey sands (Fig.100). Palaeocurrent measurements from the sands, indicate flow to the east-north-east (Fig. 101) Small areas of clast supported gravel were observed. Over much of the pit the sands and gravel are overlain by 1.5m of clayey 'brickearth', containing scattered pebbles. This may be either a floodloam (overbank) deposit or a colluvial accumulation and, except for the pebbles, has an appearance similar to weathered London Clay. These deposits, with the exception of the clayey 'brickearth', are typical of the products of a braided river environment (Miall, 1977) indicating deposition as longitudinal bars and linguoid bars.

The samples of Asheldham Gravel from the Southminster exposures showed the combination of local, southern and exotic lithologies which characterizes the Low Level East Essex Gravel. Local material (84 - 81%) comprises a rather larger proportion than in the High Level gravels, while the southern component is distinctly smaller, ranging between 7.8 and 13.5%. The occurrence of a number of pebbles of Ightham Stone (Bridgland, 1983 a; b) and Hastings Beds material suggests a continued Medway influence, but the appearance of 1.4% to 2.25% of exotics, including all the types characteristic of the Lower Thames gravels of the Tilbury area (Bridgland, 1983 a), marks the initiation of Thames drainage in this part of eastern Essex.

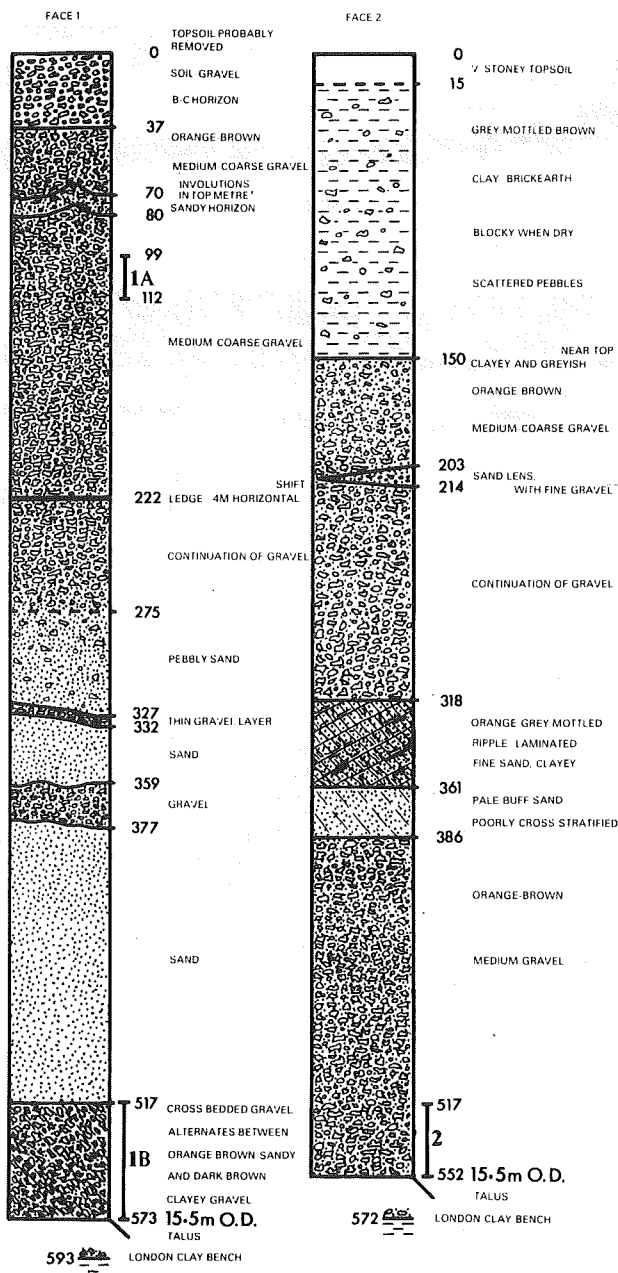


Figure 100. Sedimentary sequence from the Goldsands Road pit, Southminster.

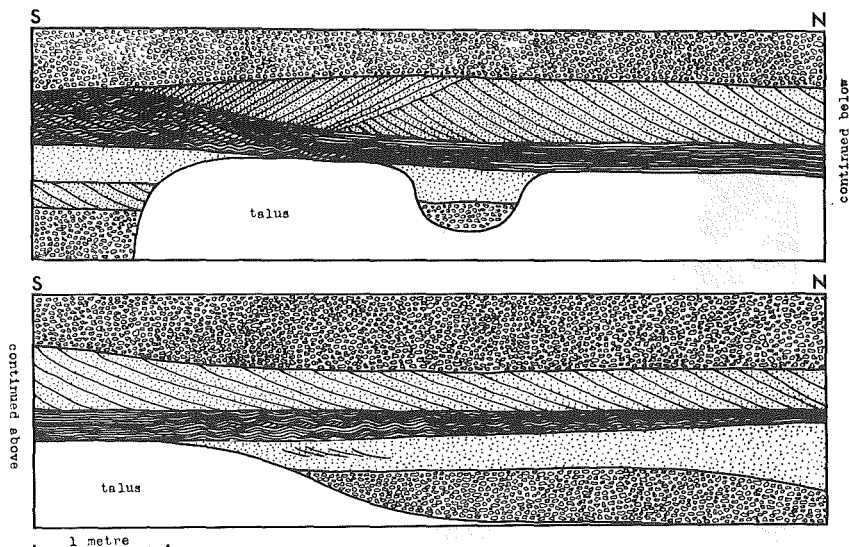


Figure 101. Sedimentary structures at Goldsands Road pit, Southminster.

No archaeological finds have been reported from Southminster, but Warren (1932) reported a few flakes and a heavy Clactonian chopper from gravel at Burnham-on-Crouch, at about 18m O.D.. According to Oakley and Leakey (1937) these were "exactly comparable with those from the Lower Gravel" at Swanscombe. Wymer (pers. comm) noted that these artifacts have been slightly rolled. The elevation of the deposit from which they were recovered clearly places it within the Asheldham Gravel aggradation. The occurrence of Clactonian artifacts in the Asheldham Gravel is in keeping with its interpretation as a late Anglian or early post-Anglian deposit.

D.R. Bridgland

REFERENCES

- Allen, P. 1983. Middle Pleistocene Stratigraphy and landform development in southeast Suffolk. University of London Ph.D. Thesis, to be submitted.
- Allender, R., and Hollyer, S.E., 1973. The sand and gravel resources of the country around Shotley and Felixstowe. Description of 1:25000 resource sheet TM23. Rep. Inst. Geol. Sci., 73/13.
- Arkell, W.J., 1947. The geology of Oxford. Clarendon Press: Oxford.
- Avery, B.W., 1980. Soil Classification for England and Wales, Soil Survey Technical Monograph No.14.
- Avery, B.W., Bullock, P., Catt, J.A., Rayner, J.W. and Weir, A.H., 1982. Composition and origin of some brickearths on the Chiltern Hills, England. Catena, 9, 153-174.
- Baker, C.A., 1971. A contribution to the glacial stratigraphy of West Essex. Essex Nat., 32, 318-330.
- Baker, C.A., 1976. Periglacial phenomena in the Upper Cam Valley, North Essex. Proc. Geol. Ass., 87, 285-306
- Baker, C.A., 1977. Quaternary stratigraphy and environments in the Upper Cam Valley. unpublished. Ph.D. Thesis, Univ. of London (unpublished).
- Baker, C.A., and Jones, D.K.C., 1980. Glaciation of the London Basin and its influence on the drainage pattern; a review and appraisal. In: The shaping of Southern England (Ed. by D.K.C. Jones). Inst. Br. Geogr., Sp. Publ. 11. Academic Press;
- Barrow, G., 1919. Some future work for the Geologists' Association. Proc. Geol. Assoc., 30, 1-48
- Bridgland, D., 1980. A reappraisal of Pleistocene stratigraphy in north Kent and eastern Essex and new evidence concerning the former courses of the Thames and Medway. Quat. Newsletter, 32, 14-24.
- Bridgland, D.R., 1983a. The Quaternary fluvial deposits of north Kent and eastern Essex. Unpublished Ph.D. thesis, City of London Polytechnic.
- Bridgland, D.R., 1983b. The rudaceous components of the East Essex Gravels; their characteristics and provenance. Quat. Studies in press.
- Bristow, C.R., and Cox, F.C., 1973. The Gipping Till: a reappraisal of East Anglian glacial stratigraphy. J. Geol. Soc. Lond., 129, 1-37.
- Brown, J.A., 1883. On probable glacial deposits or evidence of the action of ice near Ealing. Proc. Geol. Ass., 6, 172-181.
- Brown, J.C., 1959. The sub-glacial surface of east Hertfordshire. Trans. Inst. Brit. Geogr., 26, 37-50.
- Catt, J.A., 1980. Soils and Quaternary Geology in Britain. J. Soil Sci., 30, 607-642.

- Cheshire, D.A., 1981. A contribution towards a glacial stratigraphy of the Lower Lea Valley and its implications for the Anglian Thames. Quat. Studies, 1, 27-69.
- Clayton, K.M., 1957. Some aspects of the glacial deposits of Essex. Proc. Geol. Ass., 68, 1-19.
- Clayton, K.M., and Brown, J.C., 1958. The glacial deposits around Hertford. Proc. Geol. Ass., 69, 103-119.
- Clarke, M.R., and Dixon, A.J., 1981. The Pleistocene braided river deposits in the Blackwater Valley area of Berkshire and Hampshire, England. Proc. Geol. Ass., 92, 139-158.
- Devey, H., and Bromehead, C.E.N., 1921. The geology of south London. Mem. Geol. Surv. U.K.
- De Dekker, P., 1979. The Middle Pleistocene ostracod fauna of the West Runtun Freshwater Bed, Norfolk. Paleontol., 22, 293-316.
- Dines, H.E., and Edmunds, F.H., 1925. The geology of the country around Romford. Mem. Geol. Surv. U.K.
- D'Olier, B., 1975. Some aspects of late Pleistocene-Holocene drainage of the River Thames in the eastern part of the London Basin. Phil. Trans. R. Soc. Lond., A 279, 269-277.
- Funnell, B.M., Norton, P.E.P. and West, R.G., 1979. The Crag at Bramerton, near Norwich, Norfolk. Phil. Trans. R. Soc. Lond., B 287, 489-534.
- Gibbard, P.L., 1974. Pleistocene stratigraphy and vegetational history of Hertfordshire. Ph.D. thesis University of Cambridge.
- Gibbard, P.L., 1977. Pleistocene history of the Vale of St. Albans. Phil. Trans. R. Soc. Lond., B, 280, 445-483.
- Gibbard, P.L., 1978. Quaternary geology and landform development of the Vale of St. Albans. In: Quaternary geology of the Vale of St. Albans. (Ed. by J. Rose and P.L. Gibbard). Field guide Quat. Res. Ass., 9-29.
- Gibbard, P.L., 1978. Westmill. In: Rose, J. and Gibbard, P.L., Quaternary Geology of the Vale of St. Albans. Quat. Res. Ass., Field Excursion Guide.
- Gibbard, P.L., 1979. Middle Pleistocene drainage in the Thames Valley. Geol. Mag., 116, 35-44.
- Gibbard, P.L., and Aalto, M.M., 1977. A Hoxnian interglacial site at Fishers Green, Stevenage, Hertfordshire. New Phytol., 72, 505-523.
- Gibbard, P.L., and Stuart, A.J., 1974. Trace fossils from proglacial lake sediments. Boreas, 3, 69-74.
- Green, C.P., and McGregor, D.F.M., 1978. Pleistocene gravel trains of the River Thames. Proc. Geol. Ass., 89, 143-156.
- Green, C.P., Hey, R.W., and McGregor, D.F.M., 1980. Volcanic pebbles in Pleistocene gravels of the Thames in Buckinghamshire and Hertfordshire. Geol. Mag., 117, 59-64.
- Green, C.P., McGregor, D.F.M., and Evans, A.H., 1982. Development of the Thames drainage system in early and middle Pleistocene times. Geol. Mag., 119, 281-290.

- Gregory, J.W., 1922. Evolution of the Essex rivers and of the Lower Thames. Benham, Colchester.
- Gruhn, R., Bryan, A.L., and Moss, A.J., 1974. A contribution to Pleistocene chronology in southeast Essex, England. Quat. Res. 4, 53-71.
- Hare, F.K., 1947. The geomorphology of a part of the Middle Thames. Proc. Geol. Ass., 58, 294-339.
- Hawkins, H.L., 1923. The relation of the River Thames to the London Basin. Rep. Br. Ass., 1922, 365-72.
- Hawkins, H.L., 1923. Excursion to Goring Gap. Proc. Geol. Ass., 34, 56-65.
- Hedburg, H.D., 1976. International stratigraphic guide. Wiley Interscience: New York.
- Hey, R.W., 1965. Highly quartzose Pebble Gravels in the London Basin. Proc. Geol. Ass., 76, 403-420.
- Hey, R.W., 1980. Equivalents of the Westland Green Gravels in Essex and East Anglia. Proc. Geol. Ass., 91, 279-290.
- Hey, R.W., and Brenchley, P.J., 1977. Volcanic pebbles from Pleistocene gravels in Norfolk and Essex. Geol. Mag., 114, 219-225.
- Hey, R.W., Krinsley, D.H., and Hyde, P.J.W., 1971. Surface textures of sand grains from the Hertfordshire Pebble Gravels. Geol. Mag., 108, 377-382.
- Higginbottom, I.E., and Fookes, P.G., 1970. Engineering aspects of periglacial features in Britain: Quart.J.Engng. Geol., 3, 85-117.
- Hollyer, S.E., and Simmons, M.B., 1978. The sand and gravel resources of the country around Southend-on-Sea, Essex. Miner. Assess. Rep. Inst. Geol. Sci., No. 36.
- Holmes, T.W., 1892. The new railway from Gray's Thurrock to Romford, Q.J. Geol. Soc. Lond., 48, 365-72.
- Horton, A., 1977. Nettlebed. In: South east England and the Thames Valley (Ed. by E.R. Shepherd-Thorn and J.J. Wymer) Guidebook for Excursion A5. INQUA X Congress.
- King, W.B.R., and Oakley, K.P., 1936. The Pleistocene succession in the lower part of the Thames Valley. Proc. Prehist. Soc., 2, 52-76.
- Krumbein, W.C., 1941. Measurement and geological significance of shape and roundness of sedimentary particles. J. Sediment. Petrol. 11, 64-72.
- Lake, R.D., Ellison, R.A., Hollyer, S.E., and Simmons, M., 1977. Buried channel deposits in the south-east Essex area; their bearing on Pleistocene palaeogeography. Rep. Inst. Geol. Sci., 77/21.
- Lawson, D.E., 1979. Sedimentological analysis of the western terminus region of the Matanuska Glacier, Alaska. CRREL Report, 79-9.
- Macklin, M.G., 1980. Prestwich's Southern Drift in South East London: a re-evaluation. Quat. Newsletter, 34, 19-26.

- Marks, R.J., 1932. The sand and gravel resources of the country around Clare, Suffolk. Description of 1:25,000 sheet TL 74. IGS Mineral Assessment Report No 97, 73 pp.
- McGregor, D.F.M., and Green, C.P., 1978. Gravels of the River Thames as a guide to Pleistocene catchment changes. Boreas, 7, 197-203.
- McGregor, D.F.M., and Green, C.P., 1983a. Lithostratigraphic subdivisions in the gravels of the proto-Thames between Hemel Hempstead and Watford. Proc. Geol. Ass., 94, 83-85.
- McGregor, D.F.M., and Green, C.P., 1983b. Post-depositional modification of Pleistocene Terraces of the River Thames. Boreas, 12, 23-33.
- Miall, A.D., 1977. A review of the braided river depositional environment. Earth Sci. Rev., 13, 1-62.
- Millward, D., 1981. 1:50,000 Map. Geological Survey of England and Wales, Epping, Sheet 240.
- Mitchell, G.F., Penny, L.F., Shotton, F.W., and West, R.G., 1973. A correlation of Quaternary deposits in the British Isles. Geol. Soc. Lond. Special Report 4.
- Moffat, A.J., and Catt, J.A., 1982. The nature of the Pebbly Clay Drift at Epping Green, south-east Hertfordshire. Trans. Herts. Nat. Hist. Soc., 28, Part 6, 16-24.
- Oakley, K.P., and Leakey, M. 1937. Report on excavations at Jaywick Sands, Essex (1934), with some observations on the Clactonian Industry, and on the fauna and geological significance of the Clacton Channel. Proc. Prehist. Soc., 3, 217-260.
- Peake, D.S., 1982. The ground upon which Croydon was built - A reappraisal of the Pleistocene history of the River Wandle and its basin. Proc. Croydon nat. Hist. Scient. Soc. 17, 89-116.
- Robinson, J.E., 1978. Ostracods from deposits in the Vale of St. Albans. Quaternary Newsletter, 25.
- Rose, J., 1974. Small scale spatial variability of some sedimentary properties of lodgement and slumped till. Proc. Geol. Ass., 85, 223-237.
- Rose, J., and Allen, P., 1977. Middle Pleistocene stratigraphy in southeast Suffolk. J. Geol. Soc. Lond., 133, 85-102.
- Rose, J., Allen, P., and Hey, R.W., 1976. Middle Pleistocene stratigraphy in southern East Anglia. Nature, 263, 492-494.
- Rose, J., Allen, P., and Wymer, J.J., 1978. Weekend Field Meeting in South-east Suffolk. Proc. Geol. Ass., 89, 81-90.
- Rose, J., and Gibbard, P.L., 1978. Quaternary geology of the Vale of St. Albans. Field guide. Quaternary Research Association.
- Rose, J., Sturdy, R.E., Allen, P., and Whiteman, C.A., 1978. Middle Pleistocene sediments and palaeosols near Chelmsford, Essex. Proc. Geol. Ass., 89, 91-96.
- Ross, B.R.M., 1931. The physiographic evolution of the Kennet-Thames. Rep. Brit. Ass. Lond., 1931., 368.

- Salter, A.E., 1905. On the superficial deposits of central and parts of southern England. Proc. Geol. Ass., 19, 1-56.
- Saner, B.R., and Wooldridge, S.W., 1929. River development in Essex. Essex Nat., 22, 244-250.
- Sealy, K.R., and Sealy, C.E., 1956. The terraces of the Middle Thames. Proc. Geol. Ass., 67, 369-392.
- Simmons, M.B., 1978. The sand and gravel resources of the Dengie Peninsula, Essex. Miner. Assess. Rep. Inst. Geol. Sci., No. 34.
- Sherlock, R.L., 1924. On the superficial deposits of South Herts. and South Bucks., etc. Proc. Geol. Ass., 35, 1928.
- Shotton, F.W., 1973. The English Midlands. In: A correlation of Quaternary deposits in the British Isles. (Ed. by G.F. Mitchell et al.) Geol. Soc. Lond., Special Report. 4.
- Shotton, F.W., Goudie, A.S., Briggs, D.J., and Osmaston, H.A., 1980. Cromerian interglacial deposits at Sugworth, near Oxford, England, and their relation to the Plateau Drift of The Cotswolds and the terrace sequence of the Upper and Middle Thames. Phil. Trans. Roy. Soc., B 289, 55-89.
- Sparks, B.W., West, R.G., Williams, R.B.G., and Ransom, M., 1969. Hoxnian interglacial deposits near Hatfield, Herts. Proc. Geol. Ass., 80, 243-267.
- Sperling, C.B.H., Goudie, A.S., Stoddart, D.R. and Pode, G.G., 1977. Dolines in the Dorset Chalklands and other areas in southern Britain. Trans: Inst. Br. Geogr., NS2, 205-223.
- Sturdy, R.G., Allen, R.H., Bullock, P., Catt, J.A., and Greenfield, S., 1979. Paleosols developed on Chalky Boulder Clay in Essex. J. Soil Sci., 30, 117-137.
- Sweeting, M.H., 1972. Karst Landforms. MacMillan: London.
- Thomas, M.F., 1961. River terraces and drainage development in the Reading area. Proc. Geol. Ass., 72, 415-436.
- Thomasson, A.J., 1961. Some aspects of the drift deposits and geomorphology of south-east Hertfordshire. Proc. Geol. Assoc., 72, 287-302.
- Thompson, R. 1977, Stratigraphic consequences of palaeomagnetic studies of Pleistocene and Recent sediments. J. Geol. Soc., 133, 51-59.
- Treacher, M.S., Arkell, W.J., and Oakley, K.P., 1948. On the Ancient Channel between Caversham and Henley, Oxfordshire, and its contained flint implements. Proc. Prehist. Soc., 22, 29-36.
- Treacher, L., 1926. Excursion to Shiplake. Proc. Geol. Ass., 37, 440-442.
- Turner, C., 1970. The Middle Pleistocene deposits at Marks Tey, Essex. Phil. Trans. R. Soc. Lond. B, 257, 373-440.
- Turner, C., and West R.G., 1968. The subdivision and zonation of interglacial periods. Eiszeitaler Gegenwart. 19, 93-101.

- Walder, P.S., 1967. The composition of the Thames gravels near Reading, Berkshire. Proc. Geol. Ass., 107, 107-179.
- Warren, S.H., 1933. The Palaeolithic industries of the Clacton Dovercourt districts. Essex Nat. 24, 1-29.
- West, R.G., 1956. The Quaternary deposits at Hoxne, Suffolk. Phil. Trans. R. Soc. Lond., B., 239, 265-356.
- West, R.G., 1970. Pleistocene history of the British Flora. In: Studies in the vegetational history of the British Isles (Ed. by D. Walker and R.G. West) University Press. Cambridge.
- West, R.G., and Donner, J.J., 1956. The glaciations of East Anglia and the East Midlands; a differentiation based on stone orientation measurements of the tills. Quart. J. Geol. Soc. Lond., 112, 69-91.
- Whitaker, W., 1889. The geology of London and of part of the Thames Valley. Vol. 1. Mem. Geol. Surv. G.B.
- White, H.J.O., 1896. On the distribution and relations of the Westleton and glacial gravels in parts of Oxfordshire and Berkshire. Proc. Geol. Ass., 14, 11-30.
- Wood, S.V. Jnr., 1866. On the structure of the valleys of the Blackwater and the Crouch, and of the East Essex Gravel, and on the relation of this gravel to the denudation of the Weald. Geol. Mag., 3, 348-354 and 398-406.
- Wooldridge, S.W., 1927. The Pliocene history in the London Basin. Proc. Geol. Ass., 38, 49-132.
- Wooldridge, S.W., 1938. The glaciation of the London Basin and the evolution of the Lower Thames drainage system. Q. J. Geol. Soc. Lond., 91, 627-667.
- Wooldridge, S.W., 1958. Some aspects of the physiography of the Thames valley in relation to the ice age and early man. Proc. prehist. Soc., 23, 1-19.
- Wooldridge, S.W., 1960. The Pleistocene succession in the London Basin. Proc. Geol. Ass., 71, 113-129.
- Wooldridge, S.W., and Cornwall, I.W., 1964. A contribution to a new datum for the pre-history of the Thames Valley. Bull. Inst. Archeol. Univ. Lond., 4, 223-232.
- Wooldridge, S.W., and Henderson, H.C.K., 1955. Some aspects of the physiography of the eastern part of the London Basin. Trans. Inst. Br. Geogr., 21, 19-31.
- Wooldridge, S.W., and Linton, D.L., 1955. Structure, surface and drainage in south-east England. George Philip: London.
- Wymer, J.J., 1956. Palaeoliths from the Gravels of the Ancient Channel between Caversham and Henley at Highlands, near Henley. Proc. Prehist. Soc., 22, 29-36.
- Wymer, J.J., 1961. The Lower Palaeolithic Succession in the Thames Valley and the date of the Ancient Channel between Caversham and Henley. Proc. Prehist. Soc., 27, 1-27.
- Wymer, J.J., 1968. Lower Palaeolithic archaeology in Britain. John Baker: London.

- Zagwijn, W.H., 1975. Variations in climate as shown by pollen analysis, especially in the Lower Pleistocene of Europe. In Wright, A.E. and Moseley, F. (eds) Ice Ages: Ancient and Modern, Seel House Press, Liverpool, 137-52.
- Zeuner, F.E., 1945. The Pleistocene period: its climate, chronology and faunal successions. Ray Soc. Pub., No. 130.