QUATERNARY RESEARCH ASSOCIATION

Field Guide to the East Midlands Region.

LEICESTER

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QUATERNARY RESEARCH ASSOCIATION

FIELD HANDBOOK

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Edited by T D Douglas

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PREFACE

This handbook has been compiled for the 1981 Annual Field Meeting of the Quaternary Research Association at Leicester. It contains descriptions of the sites to be visited on the excursions as well as some additional sites of interest and background material of the region. Fig 1 is a location map for the excursion routes and sites, whereas Table 1 presents an outline stratigraphy of the Leicester area.

The editor would like to thank the contributors for the preparation of their manuscripts and Mrs Oonagh Grassie of the School of Geography, Newcastle Polytechnic for drawing the text figures.

It should be noted that a description of a site in this handbook does not imply that access is open to the public. Permission to visit sand and gravel pits and quarries must be sought from the operators.

Table 1 A Simplified Stratigraphy of the Quaternary of Leicester and environs. (See text for further correlations and comment)

Stage	Representative deposits
FLANDRIAN	Alluvium; Fen peats
DEVENSIAN	Many terrace gravels; remains of coversands
IPSWICHIAN	Wing interglacial beds
WOLSTONIAN	Dunsmore Gravel Upper and Lower Oadby Tills Wolston Sand Bosworth Clays and Silts Thrussington Till Bagington Sand Bagington-Lillington Gravel
HOXNIAN	Woodston Beds
ANGLIAN	Bubbenhall Clay; Chalky Boulder Clay of Peterborough area

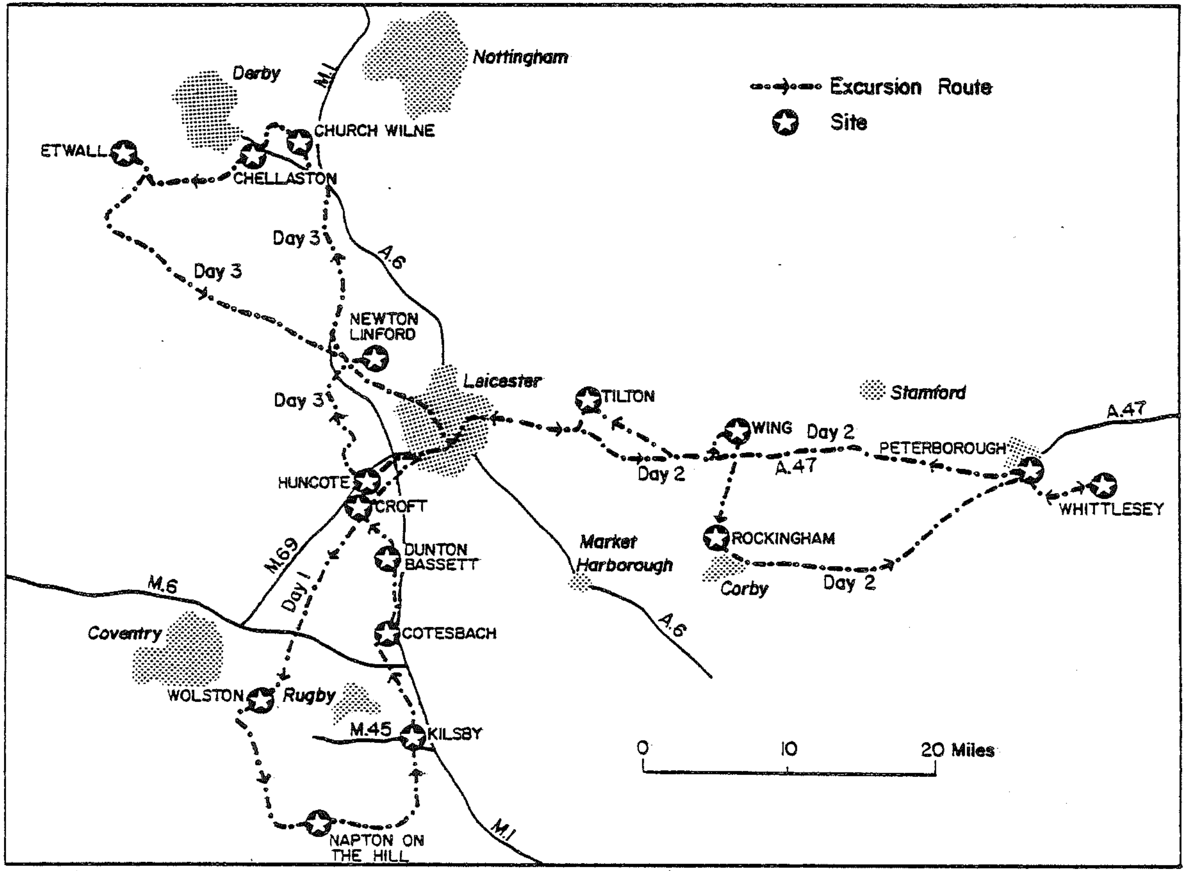


Fig. 1 Map of excursion routes and sites.

EXCURSION TO THE TYPE AREA OF THE WOLSTONIAN AND SOUTH LEICESTERSHIRE

This excursion explores much of the area which can be tied in to the Wolstonian type sequence by lithostratigraphic continuity. From Coventry to Loughborough there is a nearly continuous mantle of drift which carried the main England watershed between the Severn (via the Warwickshire Avon) and the Trent (via the Soar) (Shotton 1953). In many places this plug of drift exceeds 50m in thickness. Crucial to the interpretation of Quaternary events in the area is the recognition of the bedrock surface of the proto-Soar (fig 2). Early Wolstonian drainage was to the northeast and it was in this large catchment that Lake Harrison was impounded as Wolstonian ice moved from the north.

Correlation within the region if facilitated by the strong lateral persistence of many of the members, notably the glaciolacustrine Bosworth Clays and Silts and the overlying glaciofluvial Wolston Sand. Thus the correlations between the areas which have been mapped in detail (fig 2) are well-founded although it should be noted that as these members are defined on lithostratigraphic grounds, boundaries may be diachronous as glacial, glaciofluvial and glaciolacustrine environments shifted in response to an oscillating ice front.

Correlation of Wolstonian deposits

Dunsmore Gravel	Flinty Gravel	
Upper Oadby Till Lower Oadby Till	Chalky Till Pennine Till	Upper Oadby Till Lower Oadby Till
Wolston Sand	Cadeby Sand and Gravel	Wigston Sand and Gravel
Bosworth Clays and Silts	Bosworth Clay	
Thrussington Till	Basal Till	Thrussington Till
Baginton Sand		Thurmaston Sand and Gravel
Baginton-Lillington Gravel		
Wolstonian nomenclature (Shotton 1976)	West Leics. (Douglas 1980)	Central Leics. (Rice 1968)

T D Douglas

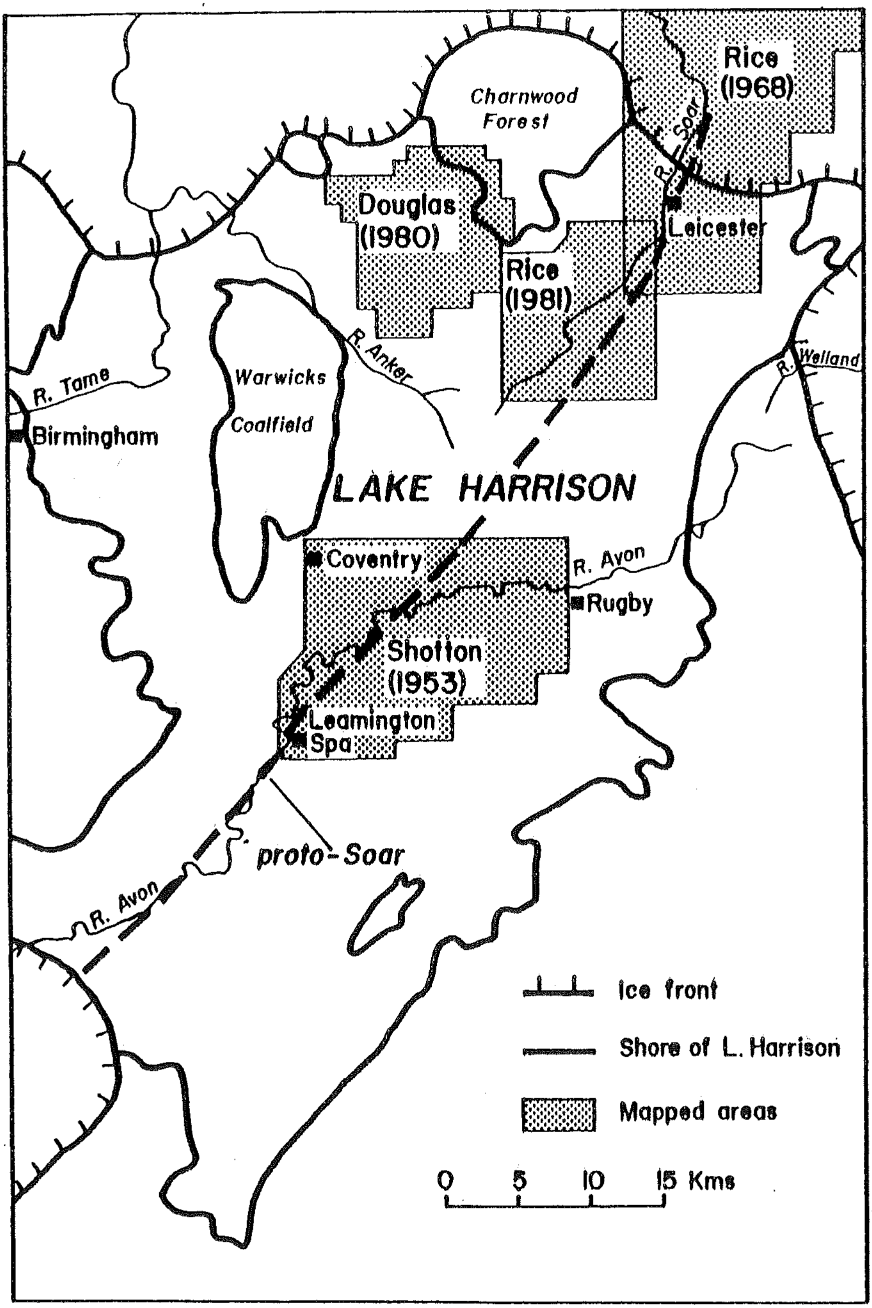


Fig. 2 The Lake Harrison basin showing areas of detailed mapping.

The Wolstonian in its Type Area

The subdivisions of the Wolstonian now recognised are as follows (Shotton 1976):

7. Dunsmore Gravel
6. Oadby Tills. Dominantly chalky boulder clay (Upper Wolston Clay)
5. Wolston Sand
4. Bosworth Clays and Silts
3. Thrussington Till
2. Baginton Sand
1. Baginton-Lillington Gravel.

Although the southern end of the Wolston pit (now a tip) is preserved as an SSSI, it shows only formations 2, 3 andpart of 4 and needs extensive cleaning up before it is worth examining. A working pit somewhere close to Ryton Wood (SP 3772) will be visited but gravel working changes its location so rapidly that it is impossible to localise a site at this time of writing. We can expect to see formations 1-4. Higher beds, having little or no economic value, can only be seen in temporary exposures.

Note: (a) The Baginton-Lillington Gravel (on Mercian Mudstones) c.3m thick and entirely composed of "Bunter" pebbles.

(b) The Baginton Sand (c.4m) strongly cross-bedded except in its highest part where it is more argillaceous and level bedded.

(c) The undisturbed and in some places interdigitated contact of the sand with the Thrussington Till.

(d) Thrussington Till (c.3m) a typical lodgement till with Permian and Triassic erractics and rare (but often large) erratics of Leicestershire Igneous rocks.

(e) The overlying Wolston Clay is usually devoid of clasts except for an occasional dropstone, and it may be varved. It is interpreted as glaciolacustrine.

Cryoturbation may be observable in the middle of the Baginton-Lillington Gravel, and on two past occasions a frost wedge has been seen in the Baginton Sand, truncated by the Thrussington Till.

F W Shotton

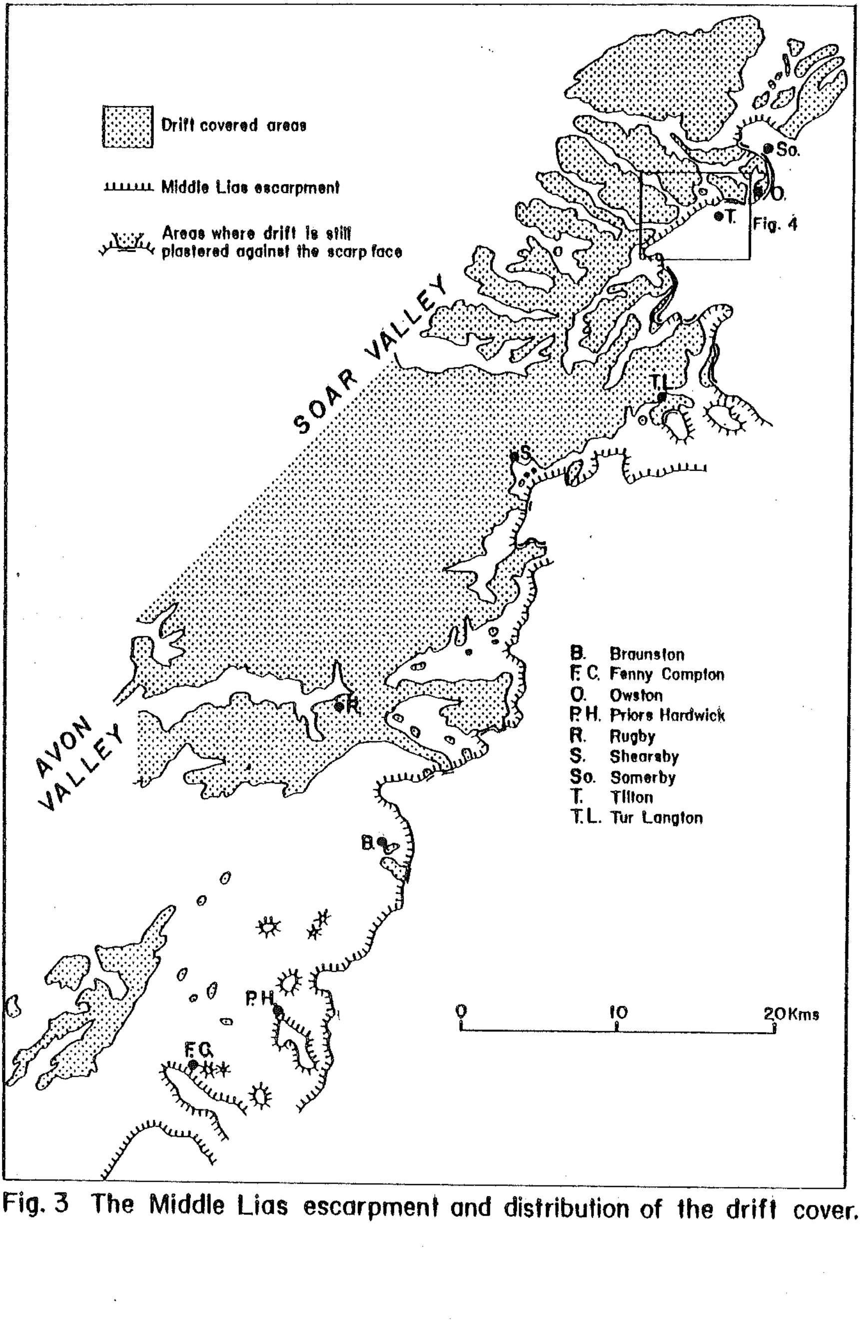


Fig. 3 The Middle Lias escarpment and distribution of the drift cover.

The Lake Harrison Shoreline Bench and other Scarp-Foot features

In 1951 Dury drew attention to a narrow bench, lying with its front edge at 122m and its rear edge close to 125m, which he claimed to be traceable for a distance of 65km from near Ilmington (212434) in the south-west to near Braunston (542662) in the north-east. Dury described the bench as being "well seen near Fenny Compton and north of Priors Hardwick, standing some fifteen to twenty feet (4.5 to 6m) above the vale floor" (p.167). Although at the time of his original article little detailed work had been published on the Pleistocene deposits to the north, Dury suggested that the morphological feature is "due to wave erosion along the shore of a pro-glacial lake" (p.168). This interpretation appeared to receive powerful support when Shotton in 1953 ascribed many of the fine-grained Pleistocene sediments in the area between Rugby, Coventry and Leamington to deposition in ice-dammed Lake Harrison. The relationship between the erosional and depositional evidence for this lake was further investigated by Bishop (1958) who showed that the bench locally truncates the glacial succession up to and including the most recent chalky till; he therefore concluded that the lacustrine sediments accumulated in Extra-Morainic Lake Harrison during the ice advance whereas the bench was eroded by Inter-Morainic Lake Harrison during the ice withdrawal.

Since these studies in the 1950s the bench has received little detailed attention. The Officers of the Geological Survey in 1965 examined the field evidence on the Banbury 1" sheet (no. 201), concluding that "from Wormleighton to the Dassett gap this erosional feature is plainly developed ... however, south-westwards along the Middle Jurassic (sic) scarp to Brailes the evidence is less conclusive" (Edmonds et al p.109). In the view of the present writer (R.J.R.) the existence of the bench can scarcely be doubted, particularly around Fenny Compton where the waters of the impounded lake apparently overspilled into the Cherwell valley. Bishop (1958) equated the period of overspill with accumulation of the Wolvercote terrace gravel in the Oxford region.

The preservation of the bench has important implications for the post-Wolstonian evolution of the Middle Lias escarpment. This latter topic merits closer examination than it has so far received, since there are well defined landform assemblages detectable elsewhere along the scarp face. As fig 3 illustrates, there are striking regional contrasts between the areas south and north of Rugby. To the south of Rugby, and broadly corresponding with the tract over which the shoreline bench has been identified, there is a zone, several kilometres wide, in which there are only small vestigial traces of drift. To the north, on fig 4

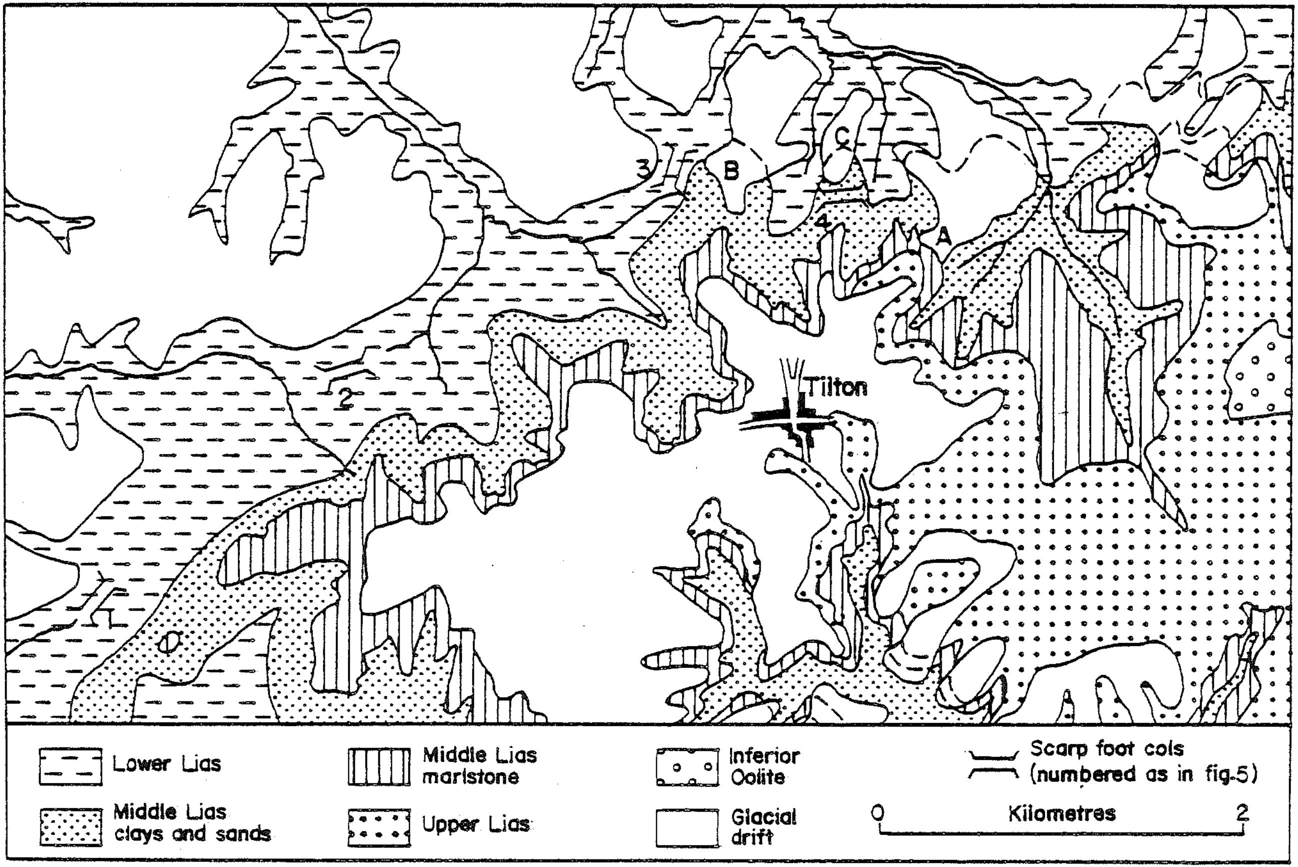


Fig. 4 The distribution of glacial drift in the vicinity of Tilton (drift areas left blank).

the other hand, the thick drifts extend very much closer to the foot of the scarp and along a number of sections are actually banked against the scarp face. The latter situation is especially characteristic of the broad embayments of the escarpments such as exist, for instance, around Tur Langton and Owston. The intervening promontories, as near Shearsby, Tilton and Somerby, exhibit scarp forms unencumbered with drift. A recurrent feature of these promontories is a succession of scarp-foot cols that run parallel to the Middle Lias outcrop and together form a strip of country, a few hundred metres wide, that has apparently been divested of its drift cover. The feature is probably best seen west of Tilton (fig 4) where it forms a virtual gutter flanked on the east by the Middle Lias marlstone escarpment and on the west by the blunt ends of a succession of till-capped interfluves that separate the regularly spaced tributaries of the Soar. Clayton (1959) in alluding to the cols, suggested two possibilities for their origin; the first is that they were formed as part of a lateral meltwater gutter during final decay of the Wolstonian ice sheet, the second that they result from scarp retreat by sub-aerial processes since the close of that glaciation. Fig 5 is an attempt to analyse the height relationships of seven of these cols. This reveals a consistent northward slope whose regularity might be held to support a meltwater origin. If the cols be viewed as constituting an "aligned sequence" it requires that the meltwater was flowing northwards in the direction of presumed ice thickening. Such a relationship is by no means impossible but there appear to be alternative explanations for the northward decline in height. For example, there is firstly the general northward slope of the Soar catchment to be taken into account, and secondly the overall but more erratic fall in height of the marlstone outcrop in the same direction. It is also noteworthy that nowhere does the modern drainage follow the "gutter" for any distance; it is a morphological feature that, at the present time, is seemingly being etched out by the headwaters of a wide variety of streams. This is particularly conspicuous around Shearsby where various parts of the scarp-foot depression are drained south-westwards via the Swift to the Avon, north-westwards via the Sence to the Soar, and eastwards to the Welland.

The view that the drift-free depression along the foot of the scarp is the result of post-Wolstonian stream erosion receives support from a number of sites where exhumation of the scarp face, although actively in progress, appears to be incomplete. North of Tilton three adjacent spurs illustrate stages in the process of exhumation. At the first (A on fig 4) a narrow neck of till joins the main mass of drift to a long salient of cambered Middle Lias marlstone. The sides of the neck are steep and are being actively sapped where springs emerge from sandy

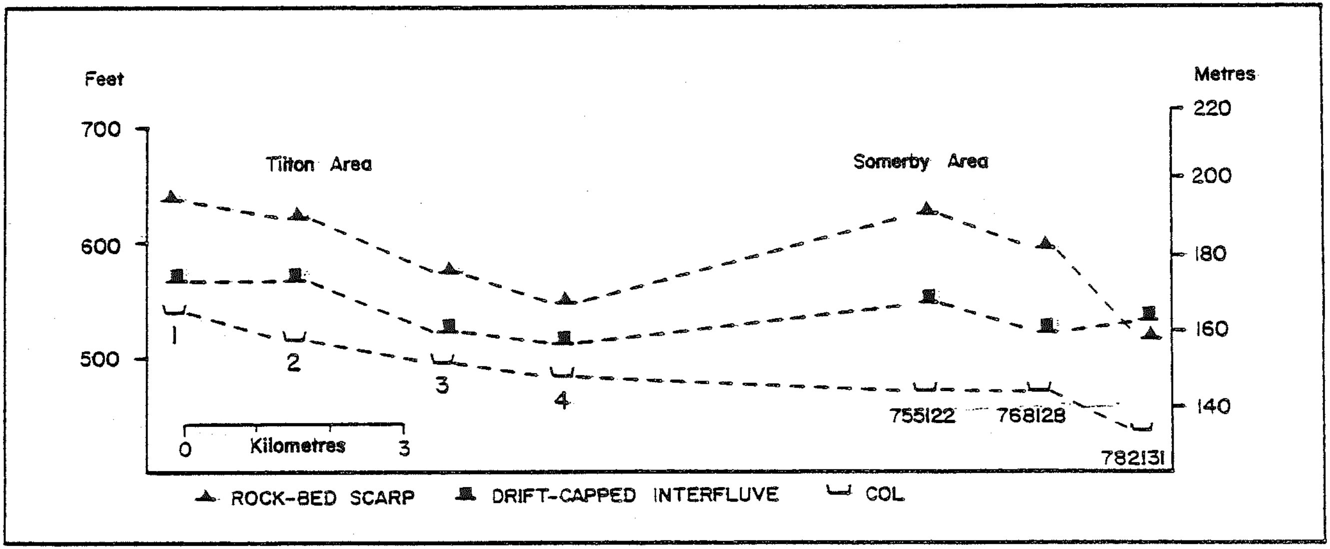


Fig. 5 The height relationships of the scarpfoot cols in the vicinity of Tilton and Somerby.

horizons within the Middle Lias clay. One kilometre to the west (B) a further stage is reached where the marlstone salient has been divested of its till cover and a slight depression is beginning to develop on the Middle Lias clay. Even later evolution is seen on the intervening salient (C) where a prominent col has been cut in the Middle Lias clay, almost down to the level of the Lower Lias.

If the foregoing arguments are accepted, the drift-free depression along the face of the scarp promontories provides a crude measure of the amount of local erosion that has taken place since the end of the Wolstonian glaciation. The width of the depression between scarp face and drift-capped Lower Lias can be attributed to the combined recession of both marginal elements, and it is not easy to apportion the total between them. Around Owston where the scarp is being uncovered at the present day the initial col is normally formed in the Middle Lias clay. The fact that around the Tilton and Somerby promontories no Middle Lias is found beneath the till on the western side of the depression suggests that significant recession of that margin has taken place. On the other hand, the scars of landslips and mudflows, some of which are patently unstable, leaves little doubt that the main scarp face has also receded. If one simply assigns half the total distance between the scarp face and the till margin to scarp recession, the edge of the marlstone would appear to have retreated by about 200m since the close of the Wolstonian glaciation.

The apparent conflict which the foregoing discussion has sought to highlight - namely the preservation of a bench along the foot of a scarp that has elswhere undergone substantial retreat - may perhaps be reconciled by one or more of the following considerations:

(i) the lack of drift deposits in front of the scarp south of Rugby reflects a sudden almost catastrophic, draining of Inter-Morainic Lake Harrison. Bishop (1958) invoked this hypothesis to explain the absence of any lacustrine deposits dating from the Inter-Morainic stage.

(ii) The drift-free zone along the scarp foot north of Rugby may owe its width much more to recession of the drift edge than to retreat of the actual scarp.

(iii) The so-called Middle Lias escarpment is, in practice, a multiple feature of highly complex form. Much of the shoreline bench where best preserved is cut in Lower Lias clays and limestones some distance in front of the nearest Middle Lias outcrops. Where substantial scarp recession has been inferred, the strata consists of a permeable caprock resting on clay; spring sapping appears to be a primary mechanism whereby slope retreat has been effected.

R J Rice

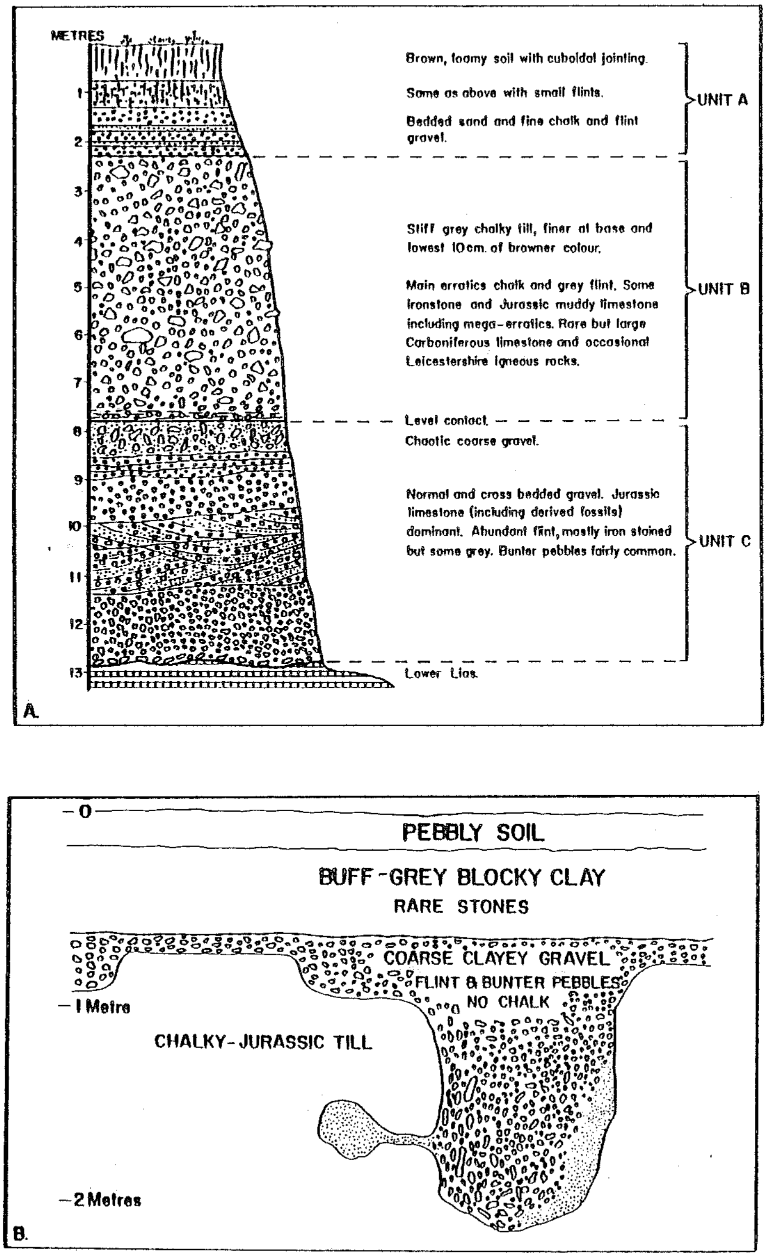


Fig. 6 Kilsby sand and gravel pit. A - measured section. B - decalcification pocket.

Kilsby sand and gravel pit(SP 569696)

Examination of the Geological Survey Sheet 185 shows an extended strip of sand and gravel running from the north-west corner south-eastward for several km, passing into a more complicated and widespread pattern of till and gravel around Kilsby. This elongated gravel outcrop is at first glance suggestive of an overflow to the east from the Proto-Soar valley, but this is misleading. Contouring on the base of the Drift shows the sub-Pleistocene levels to be declining to the west and the linear outcrop of the gravel is due to its preservation on the interfluve between two parallel streams flowing into the Avon system.

The fullest exposure at the pits in June 1980 exhibited a three-fold series illustrated in Fig. 6. Unit A varies rapidly in its detail of fine and coarser beds and elsewhere on higher ground is not obviously represented. Its sedimentology and mineralogy have been examined by Dr J Catt who found no clear loessic element and inclined to the opinion that it was a late-Wolstonian wash into hollows in the underlying till.

Unit B is a grey chalky till, here 5-6m thick, massive except for the lowest 10cm which is much finer. It lies with little or no disturbance on the underlying gravels. Principal erratics of the till are chalk and grey flint, less commonly Jurassic limestones, some Bunter pebbles and ironstone. Rare constituents are Carboniferous Limestone (sometimes with confirmatory fossils) and Leicestershire igneous rocks.

Unit C, about 5m thick, is extremely coarse and unsorted at the top but passes downwards into well-bedded (but often cross-bedded) gravels. Jurassic clasts including separated fossils are dominant, there is plenty of ironstained flint and much less grey flint, and Bunter pebbles are fairly frequent. When a contact with the underlying Lower Lias can be seen, there is usually a concentration of boulders.

Correlation: Unit B is ascribed to the Oadby Till and C is regarded as proglacial outwash of Wigston Gravel type (= Wolston sand and gravel). The sub-Pleistocene surface is too high for the Bosworth clays and silts of Lake Harrison to be present.

Another pit being opened up in August 1980 showed a similar sequence of chalky till on gravel, with no important changes of lithology or thickness. The till here, however, was overlain by a coarse clayey gravel, itself covered by an almost stoneless clay similar to the uppermost bed of Unit A. The upper gravel differed from any bed of

Unit A in its larger pebble size and absence of Chalk clasts. In several places the gravel descended into pockets in the till, (a complicated one is shown in Fig. 6) and these appear to be examples of decalcification of the till rather than cryoturbation. There is clearly an unconformity between the disturbed gravels and the overlying clay, indicating an appreciable lapse of time. Was decalcification an interglacial process?

It should be pointed out that within 1.5km of these exposures between SP 56037065 and 56647069, a cutting in the M45 revealed a section described by Shotton (1963, 1966). It provided a fuller sequence than at the Kilsby pits, as follows:

Grey chalky till	7.6+	m
Pink-grey chalky till	1.5-3.0	m
Boulder gravel with Jurassic limestone ironstone, Bunter pebbles, <u>No chalk or flint</u>.	1.8-6.0	m
Calcareous sand and fine gravel	0-3.+	m
Dark grey chalky till	6.5	m
Red Trias-rich till	4.5	m

There are some intriguing difference between this and the Kilsby sequence. The basal Trias-rich till could be the Thrussington Till but it could be older. If the lower chalky till is the same as in the Kilsby pit, nothing resembling the Wigston Gravel lies under it. There are clearly two major chalky tills but the intervening very coarse gravel cannot be due to melt-out from either as there is no flint in it and this must involve a major ice retreat.

Finally, the motorway section was disrupted by 5 faults with throws in excess of 9 metres. Such complication has not yet been observed in the nearby Kilsby pits.

F W Shotton

Cotesbach sand and gravel pit (SP 525820)

Situated on a bluff overlooking the valley of the River Swift, this relatively recent excavation affords an opportunity to examine a section in undisturbed Wolston sand and gravel. The exposure lies at an elevation of approximately 120m OD and displays the following succession:

Lithology	Thickness	Regional correlation
Grey chalky till	Up to 2m exposed	Oadby till
Fine grey sand, silt and clay	Irregular, but up to ? 1.5m	Upper Wolston clay of Shotton (1953)
Sand and gravel	4 - 4.5m	Wolston sand and gravel
Grey bedded silts and clays	Up to 1.5m exposed	Bosworth clays and silts

The lowermost bed is composed of a deep bluish grey clayey silt and silty clay. In places the material is prominently laminated, but elsewhere it displays little clear structure. Augering on the hillsides downslope from the level of the pit strongly suggests that, at a lower stratigraphic horizon, the water-lain sediment interdigitates with, and is largely underlain by, chalky till. Observations by Eastwood et al (1923) and by Poole et al (1968) suggest that, at an even lower horizon, there is red clayey till largely derived from the Keuper Marl.

The sand and gravel tends to be more sandy at the base and to become more gravelly towards the top. This is characteristic of the Wolston sand and gravel as observed elsewhere, although in the Cotesbach pit the distinction is less marked than, for instance, at Dunton Bassett. Many of the sand layers are cross-bedded but the directions assumed by the cross-bedding units are very varied and do not point consistently to any single direction of flow. The gravel is generally fine, with a very low percentage of the constituent pebbles exceeding 5cm in maximum axial length. An analysis of lithological composition (based on a sample of 474 pebbles) yielded the following results: Middle Jurassic limestone 31%, flint 27%, Bunter pebbles 15%, Carboniferous material. The results may be compared with those from the Wolston sand and gravel sampled at Dunton Bassett and quoted below. So far no unequivocal periglacial structures have been observed affecting the bedding of the sand and gravel. However, in this same general area Poole et al (1968 p 50) report the occurrence of cryoturbation in the top of what appears to be the equivalent bed.

The sand and gravel passes abruptly upwards into a variable thickness of mottled rusty brown and grey clayey silt, silt and fine sand. Pebbles are almost totally absent but the bed contains a great deal of "race" (calcareous nodules). Locally this water-lain material reaches 1.5m in thickness, but it is truncated above an irregular sloping (and probably erosional) junction by grey chalky till. It is noteworthy that in the Lutterworth area there are several reports (eg Poole et al 1968) that the advance of the ice responsible for the upper till disrupted the topmost layer of the earlier sediments. However, the scale of the preserved disturbances is small when compared with that affecting the Wolston sand and gravel at Dunton Bassett (see below,).

The sand and gravel exposed at the Cotesbach pit is traceable over a wide area, its presence being attested both by abandoned pits and also by a number of deep boreholes where the overburden of later sediments is too thick to allow commercial exploitation. It was encountered in many of the exploratory boreholes along the line of the M6, although where that motorway crosses the river Swift 3.5km south-west of the Cotesbach pit, it was not very clearly developed. The boreholes for the M1 and M6 revealed a complex sub-drift relief pattern in the area between the Swift and the M1. At the M6 crossing over the Swift, Lower Lias was encountered at elevations of at least 122m OD; and in the vicinity of Lutterworth the same bedrock occurs at elevations of 99m OD. Yet just west of the bridge that carries the M6 over the A5 a borehole was sunk to an elevation of 65m without striking bedrock. In other words, evidence exists for a deep depression, filled primarily with a brown and grey silty clay containing occasional chalk fragments and laminated at several horizons, penetrating to a substantially greater depth than the regional pattern of rockhead relief would lead one to expect, and indeed extending to an elevation as low as that along the axis of the proto-Soar valley (which is believed to lie some 12km away to the north-west). There is as yet inadequate information either to trace the limits of this depression or to place its development firmly in the sequence of Pleistocene events so far deciphered. However, it appears reasonable to suppose that the depression may be related to an old record of a deep, drift-filled valley on the north-eastern outskirts of Rugby. Here Wilson (1870) reported that he drilled through 17.4m of sand with chalk lumps near the base before entering bedrock at 69m OD. There is also a record of 44m of drift being encountered near Hillmorton (at 542736 - see Bishop 1958 p. 299) which would yield a rockhead elevation of c.70m OD. Surface exposures of sand and gravel then lead directly towards the Middle Lias eescarpment a short distance east of Kilsby, but the crucial stratigraphic relationships remain obscure.

R J Rice

Dunton Bassett Sand and Gravel Pit (SP 539900)

During the mid 1970s the main face at this pit provided an unusually fine display of glaciotectonic structures. However, working of the sand and gravel ceased in 1979-80 and the exposure has since been steadily deteriorating. It is still possible to discern the basic lineaments of the disturbance to which the sand and gravel has been subject although some of the finer detail has inevitable been lost. At the time of writing (October 1980) a new pit is being developed about a kilometre to the south east (SP 546889) and since exploratory boreholes have revealed what the quarry manager terms "clay banks" within the ballast, it is anticipated that this fresh working may shortly display further glaciotectonic structures.

The structure at the Dunton Bassett pit consists of the following main members:

Lithology	Thickness	Regional Correlation
Mottled reddish brown till	Up to 4m visible	Oadby till
Buff laminated silt and fine sand	0 - 0.5m	Very localised - ? Upper Wolston clay (Shotton)
Gravel	5m	Wolston sand and gravel
Sand	8m	Wolston sand and gravel
Grey laminated silt and clay	0 - 2.5m	Bosworth clay and silt
Grey chalky silt	5.9m proved in	Thrussington till (chalky facies)

The earliest bed is a deep grey lodgement till studded with innumerable fragments of chalk, flint, colitic limestone and other clasts of a general north easterly provenance. Stratigraphically it clearly underlies the Wolston sand and gravel and is therefore correlated with the Thrussington till which, further west, consists predominantly of Trias-derived material.

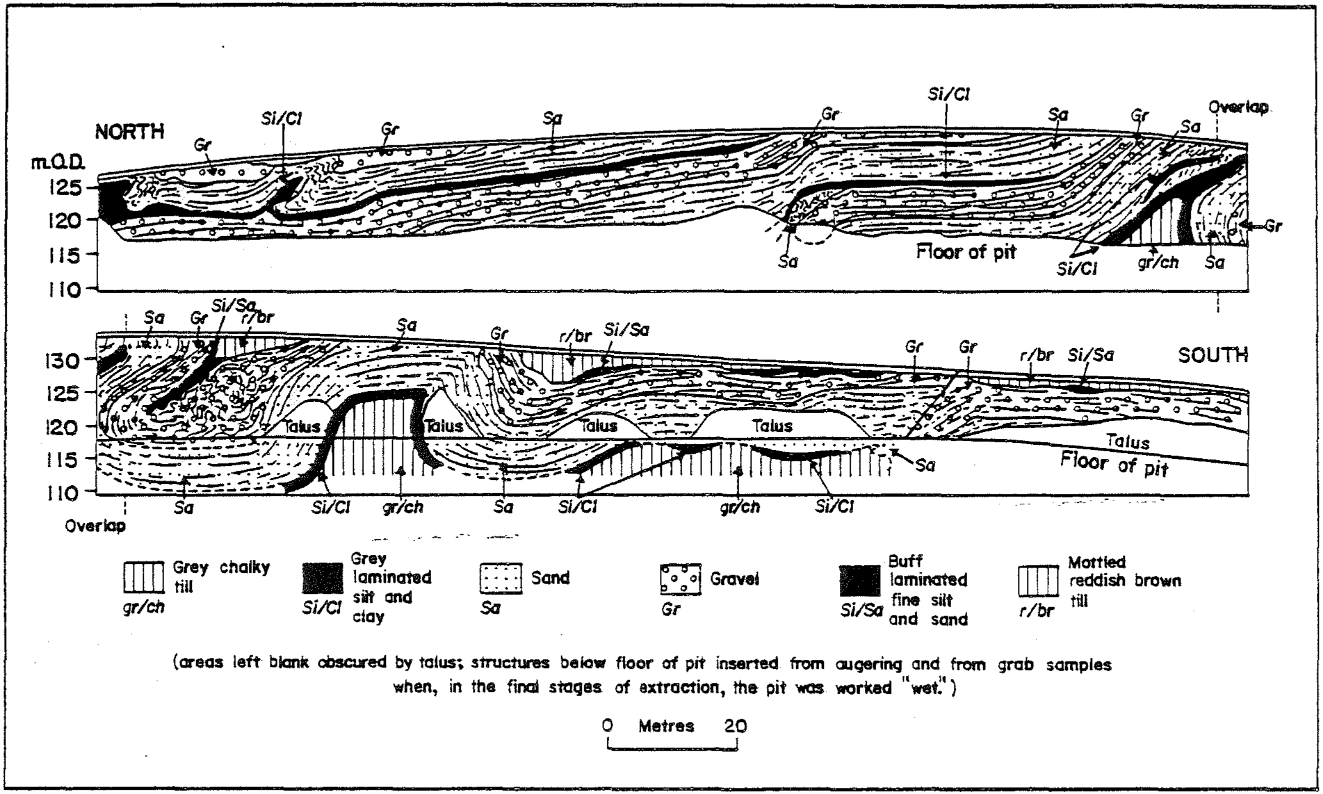


Fig. 7 Dunton Bassett sand and gravel pits showing glaciotectonic structures

The grey laminated silt and clay is a bed of variable thickness that, along part of the section is totally absent. However, hand augering on the hillslopes one to two kilometres further west shows that the silt and clay thickens very rapidly and attains values in excess of 16m.

The sand is highly calcareous (17.8% weight loss on treatment with HCl) and in places has been cemented into massive sheets of calcrete. Cross-bedding units indicate a south westerly direction of flow for the depositing water. The sand passes up into a fine to medium regularly bedded gravel in which the major components, based upon a sample of 763 pebbles, are as follows:

Bunter pebbles 35%, middle Jurassic limestones 23%, Carboniferous material 16%, Lias limestone 8%, and flints 7%.

It is noticeable that there is a much larger proportion of "north westerly" debris than in the underlying chalky till, the match being rather closer with the overlying reddish brown till; if the gravel is interpreted as part of an outwash sandur another important factor may well be contrasts in the resistance to abrasion of the various till clasts.

The thin buff coloured silts and fine sands are only irregularly present and may be no more than deposits of shallow local ponds that developed prior to advance of the ice depositing the Oadby till. The latter is only preserved in the core of a few of the downfolds where it is seen to be crudely bedded; the stratification is visibly deformed in conformity with the adjacent till-gravel junction.

The whole sequence from Thrussington till below Oadby till above has been dislocated by a series of folds, faults and low angle slide planes that all indicate powerful compressive stresses directed from slightly east of north. The structures are illustrated in fig.7. It is now recognised that the glaciotectonics displayed at Dunton Bassett are merely one part of a much more extensive zone of deformation traceable across a wide area of southern Leicestershire.

R J Rice

Croft Quarry (SP 512963)

This very large stone quarry is opened in an outcrop of diorite (or tonalite - see Le Bas 1968 for petrological description) that extends over an area of approximately 0.37 km^2. The most prominent topographic feature that it forms is Croft Hill which rises to a height of 128m or some 60m above the surrounding country. An associated but less obvious topographic form is a shallow, rock-walled gorge by which the river Soar traverses the southern edge of the diorite; the simplest explanation for this drainage pattern appears to be superimposition from a former cover of glacial deposits. Whilst this explanation may be true, it is also worth noting that the Soar around Croft pursues a curious angular course and that both upstream and downstream from the gorge it follows the line of a deep, drift-filled depression scoured not only through the Baginton-Lillington sand and gravel but also 10m or more into the underlying Keuper Marl.

For many decades Leicestershire has been the foremost English county for the production of stone, and the large quarries working the igneous rocks of the Charnwood and south west Leicestershire districts have afforded valuable sections in the over burden of Pleistocene sediments. Today the number of active quarries is much reduced from its peak earlier in the century, but of those that remain several are undergoing substantial enlargement. Croft is one such quarry and the preliminary stripping of overburden has provided new sections in the drift deposits. The most significant exposure (fig 8) lies on the eastern slopes of Croft Hill at between 90 and 100m OD. Here the exposed till displays translocated masses of Keuper Marl up to a metre thick and five metres in visible length. This evidence of powerful sub-glacial stresses is supplemented by the occurrence of low angle shear planes traversing both the till and the displaced marl. Slickensides on one shear plane were measured at an orientation of N35 E implying compression from a little east of north as is also inferred from the glaciotectonics at Dunton Bassett.

The stratigraphy of the till sequence is extremely complex, and difficult to relate with any confidence to drift sections in the surrounding area. A very obvious feature of the exposure is the presence of repetitive delicate banding as illustrated in fig 9. The depositional mechanism by which such banding is produced remains uncertain. Douglas (1980) has suggested that successive flow tills of contrasting composition may be involved, but the remarkable regularity, combined with the absence of any clear indication of flow movement, does not make this hypothesis entirely compelling. Moreover, in the example at Croft, the banding slopes at an angle of

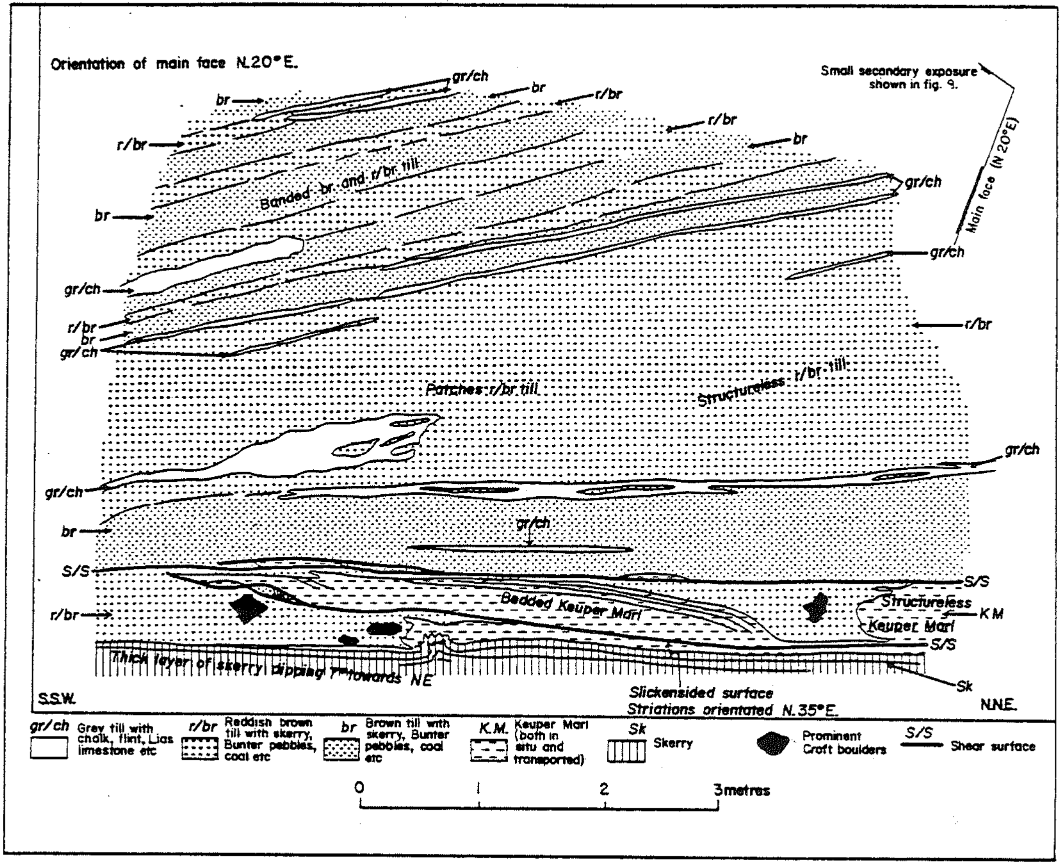


Fig. 8 Croft quarry. Measured section exposed in the eastern end of Croft Hill, recorded in June 1978.

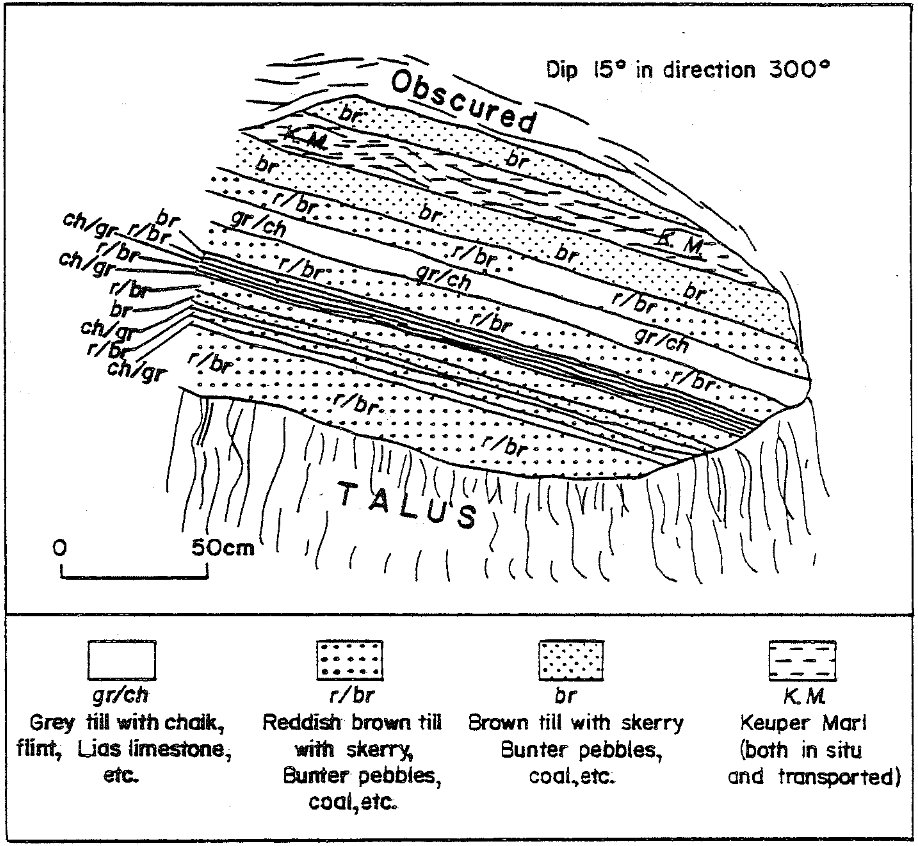


Fig. 9 Croft quarry. Small secondary exposure of banding in till.

15° without any sign of the downslope thickening that might be anticipated if low viscosity flow tills were involved. Although comparable banding is relatively common in Leicestershire, an unusual aspect of the phenomenon at Croft is the incorporation of a layer of pure Keuper Marl that does not appear to have been disaggregated.

The sections exposed at Croft quarry merit attention for one further reason. The working of the igneous rock affords an opportunity of examining the weathering profiles in three different circumstances, firstly where the diorite is overlain by Keuper Marl, secondly where it is overlain by glacial drift, and thirdly where it is actually exposed at the surface. Beneath the Keuper Marl the rock is sound and shows little sign of chemical alteration. Similarly, beneath the glacial drift only limited decomposition has taken place. Both these circumstances exhibit a striking contrast with the modern outcrops where the uppermost 1.5 - 2m of the diorite are so thoroughly rotted that they can easily be crushed in the hand. Chemical alteration has been greatly facilitated by the development of prominent sheeting structures which are largely missing where there is an overburden. The unmeasured but seemingly large volume of Croft-type erratics in the Wolstonian tills, much of it little weathered, argues for significant glacial degradation of the dioritic outcrops of south Leicestershire and implies that the observed weathering profiles are post-Wolstonian in age. Much less certain is the relationship of the profiles to the changing environmental conditions of the Ipswichian, Devensian and Flandrian periods.

R J Rice

EXCURSION TO EAST LEICESTERSHIRE AND THE PETERBOROUGH DISTRICT

This excursion leads eastwards from the Soar valley where Wolstonian drifts are relatively plentiful, across the Jurassic scarplands where tills have a more patchy distribution, to Peterborough on the Fen margin.

In the context of the debate on the age of the chalky tills of the region, the interglacial site at Wing in Rutland and the Woodston Beds near Peterborough assume considerable importance. Much recent work has stressed the lithological homogeneity of the Chalky Boulder Clay throughout East Anglia and the East Midlands (Perrin, Davies and Fysh, 1973; Perrin, Rose and Davies, 1979) and the argument has been advanced that the Chalky Boulder Clay is the product of one glaciation. Such an interpretation clearly conflicts with established schemes identifying separate Wolstonian and Anglian chalky tills (Shotton, Banham and Bishop, 1977). Much relies on the interpretation of related interglacial beds and the idea that temperate stages can be separated on the basis of palaeobotanical evidence, notably pollen. At Wing, Ipswichian deposits overlie the chalky till in a deeply incised basin, whereas the Woodston Beds, also stratigraphically above chalky till, show a Hoxnian assemblage.

Much else of interest is to be found in the region. Chandler (1971, 1976) has identified several landslide sites on Lias clays near Rockingham and in the vicinity of Rutland Water. The importance of periglacial conditions in the evolution of these slopes has been demonstrated. The Welland Valley is also noted as classic terrain for valley bulging and cambering. At Tilton, Leicestershire (see p.9 , fig 4), Rice has described the distribution of drift in relation to the Marlstone escarpment and has discussed the significance of this pattern in the development of the landscape.

T D Douglas

Wing Interglacial site

The unusual drift deposits at Wing were first encountered during a site investigation by Ground Engineering (Messrs J Laing) on behalf of the Anglia Water Authority, whose Water Treatment Plant now dominates this hilltop site. Boreholes revealed a sequence of till, peat and lake clays within a restricted area at the eastern edge of the proposed Plant, the maximum depth of drift proved being some 17m. It was clear from these boreholes, and from hand-augering, that the Pleistocene deposits occupied a basin, probably closed, some 100m

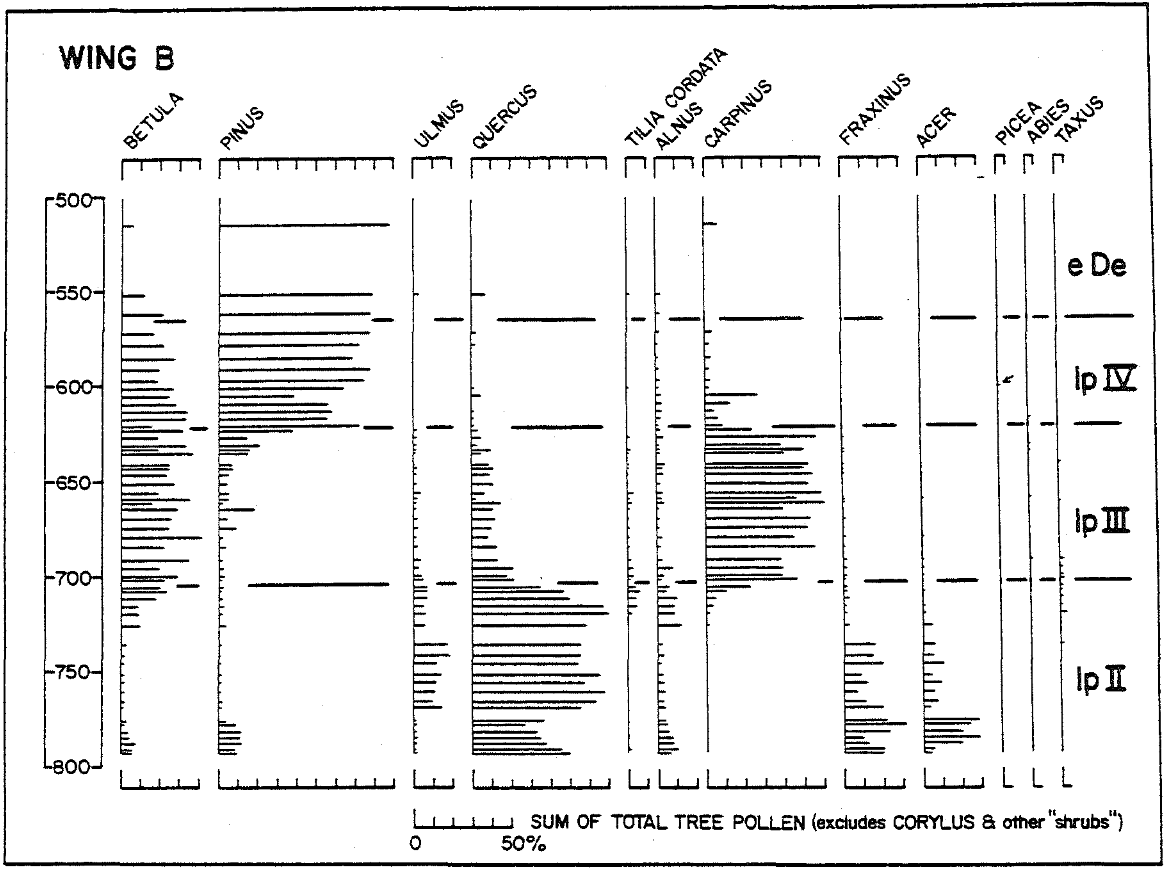


Fig. 10 Pollen diagram, Wing.

across and deeply incised into the underlying solid rocks (here about 3-4m of Northampton Sand Ironstone overlying Lias Clay). The sequence from the only continuous core available for study (from near the centre of the basin) was as follows:

0-0.60m	red brown sandy clay topsoil
0.60-5.40m	silty clay, red-brown above, becoming brown/grey-mottled, then grey-brown with laminations marked by colour and particle size. Increasingly rich in fine organic detritus with depth
5.40-5.80m	interbedded silty peaty clay and silty clay peat with a streaked appearance in vertical section
5.80-6.35m	well humified silty Sphagnum peat becoming less silty with depth; strongly compressed throughout
6.35-6.55m	the same, though without mineral component and with an increasing wood component
6.55-7.84m	strongly compressed, well humified wood peat with a distinct moss-rich horizon at 6.95-7.20m; sharp contact at 7.84, with only a few thin laminations of alternating woody detritus and silty clay to
7.84-8.20m	stiff, silty, calcareous grey clay with some obscure laminations through 8.10-8.20m.
8.20-9.90m	a series of very heterogeneous sediments including (?slumped) chalky Jurassic till (stiff grey to blue-grey clay with abundant chalk fragments and occasional Jurassic fossils), (?unweathered) Northampton Sand Ironstone and a stiff grey clay (8.40-8.90m), clearly waterlain.

From other boreholes it appeared that, below this, there was a considerable depth (perhaps 6-7m) of unsorted deposits derived from, or composed of, till. This till probably forms a blanket across the floor of the basin and certainly extends to the surface at the north-eastern margin where it can be proved by augering, although it is very well weathered and brown in colour. The Geological Survey drift map for the area shows this to be a very small remnant of a till sheet which evidently once covered most of Rutland.

At the margins of the basin, there appears to be a condensed form of the same sequence as at the centre, with highly humified peats resting on bright blue sand and clay, and overlain by mottled silty clays.

Sediments from the upper 7.84m of the sequence described above were subjected to detailed pollen and plant macrofossil analyses, and the pollen stratigraphy (Fig 10) reveals that the organic deposits and upper silty clays record a long period of interglacial and early glacial time. The first countable pollen spectra clearly represent mixed oak forest and the very local nature of the pollen catchment is evident from the high frequencies (as much as 20% total land pollen) of normally rather poorly represented taxa such as maple (*Acer*), ash (*Fraxinus*) and elm (*Ulmus*). Similarly high levels of ivy (*Hedera*) are also noteworthy here and the sum of tree and shrub pollen at these levels is little short of 100%. From the macrofossils, it appears that the forest grew close to, and indeed probably overhung the basin, for the high pollen values for these trees are reflected in the macrofossil records for buds and bud-scales, and in some cases also fruits, of themajor m.o.f. taxa. These were deposited in a lake, which was eventually overgrown with a mat of vegetation marking the beginning of a *Verlandung* or "terrestrialization" in which *Sphagnum*, and later birch (*Betula*) and cotton-grass (*Eriophorum vaginatum*), grew on an acid raised bog across the basin. The late stages of the interglacial are marked by the decline of trees, (notably hornbeam, *Carpinus*) and the massive, and apparently rather sudden, increase in grass and herbs.

Climatic deterioration or some other change affecting local hydrology, appears to have led to the re-establishment of a lake within the basin at this time, and to the inundation of the peats by a five and a half metre thickness of silty clays,laminated in parts, ensured their survival at depth during the ensuing cold stage.

The dating of the deposits by pollen stratigraphy indicates that the peats are Ipswichian (Eemian) (pollen zones IpIIb to IV inclusive) and the upper clays Early Devensian (pollen zone eDe). Despite problems of correlating this, the longest Ipswichian sequence to date, with others recorded from Britain, from sites with mainly "regional" spectra, there are some striking similarities between the diagram from Wing and published accounts from N. Germany where small basins (some showing the same *Verlandung* and *Versumpfung*) have been investigated. Furthermore, assuming this correlation to be correct, there seems little doubt that the chalky Jurassic till underlying the interglacial deposits is Wolstonian in date.

The location of these deposits raises a number of questions about the formation of the basin of deposition and about the evolution of the present topography in the vicinity of Wing. Ice action must surely be invoked to explain the excavation of a basin of such dimensians in solid (albeit rather easily eroded) rock, and it has been suggested that a subglacial stream may have been the agency responsible. The area is one noted for the development of cambering and gulling in the ironstone and limestone mantling the Lias clay, but the apparently non-linear form of the basin indicates that it is probably not a gull.

Drift deposits are, unfortunately, poorly preserved over much of this area of the East Midlands; they are confined for the most part to spreads of chalky Jurassic till mantling the hill-tops and interfluves of the predominantly eastward-flowing streams of the Welland. It is thus difficult to reconstruct much of the Pleistocene history, and in particular to suggest when the present drainage pattern was established.

A more detailed site record, together with the results of the palaeobotanical analyses and a discussion of some particular plant records, are given by Hall (1979, 1980).

A R Hall

The Peterborough area - glacial deposits

Peterborough lies at the very margin of the Fens, the limit of which runs broadly north-south in this district. The limit coincides approximately with the outcrop of the harder Middle Jurassic and basal Upper Jurassic formations. To the west are the Jurassic uplands with broad plateaus covered by glacial deposits.

In the Fens the outcrop of the Jurassic rocks and glacial deposits gives rise to small islands rising above the Flandrian sediments. Within the city of Peterborough the River Nene passes through a shallow and narrow valley caused by the outcrop of the Cornbrash. In contrast the River Welland has a broad valley which opens out into a broad plain at Market Deeping. The drift sequence includes glacial, marine, estuarine and fluviatile phases of deposition:

FENLAND	NENE VALLEY	STAGES
Terrington Beds		
Nordelph Peat	Alluvium	FLANDRIAN
Barroway Drove Beds		
Lower Peat		
Crowland Bed Marine Gravel and Sand	Ist Terrace Gravel	DEVENSIAN
Marine Gravel and Sand and ? March Gravel	2nd Terrace Gravel	?
	3rd Terrace Gravel	?
	Woodston Beds	HOXNIAN
Chalky Boulder Clay with Glacial Sand and Gravel and Glacial laminated deposits		ANGLIAN

Glacial deposits, mostly Chalky Boulder Clay, occur on the Jurassic uplands as remnants of a much dissected sheet. Narrow localised depressions or buried valleys extend below the basal surface of this sheet. A depression infilled with bedded Glacial Silt and Clay and overlain by Chalky Boulder Clay, has been traced from Norman Cross (TL 161909) to Stanground (TL 210970), south-east of Peterborough, where it passes beneath the Fen deposits. Extensive sheets of Chalky Boulder Clay extend beneath the Fen deposits in the Crowland area and in the Billingborough-Bourne-Spalding area. Between Billingborough and Bourne the sheet of Chalky Boulder Clay which outcrops on the uplands is in places co-extensive with the sheet which underlies the Fen deposits. Although the upland and Fen sheets appear to lie at quite distinct topographic levels, there are narrow outcrops of boulder clay which connect the two sheets. The modern erosional slope intersects the almost parallel palaeoslope on the base of the boulder clay. Similar situations occur in Norfolk.

Lithologically the Chalky Boulder Clay of the Peterborough areas is indistinguishable from that mapped by the author along the Waveney valley, between Norfolk and Suffolk, in Huntingdonshire, Warwickshire, Leicestershire and Northamptonshire. When fresh it consists of dark grey silty clay with abundant chalk and flint pebbles, with derived Jurassic fossils and rock debris.

Woodston Beds and River Terraces

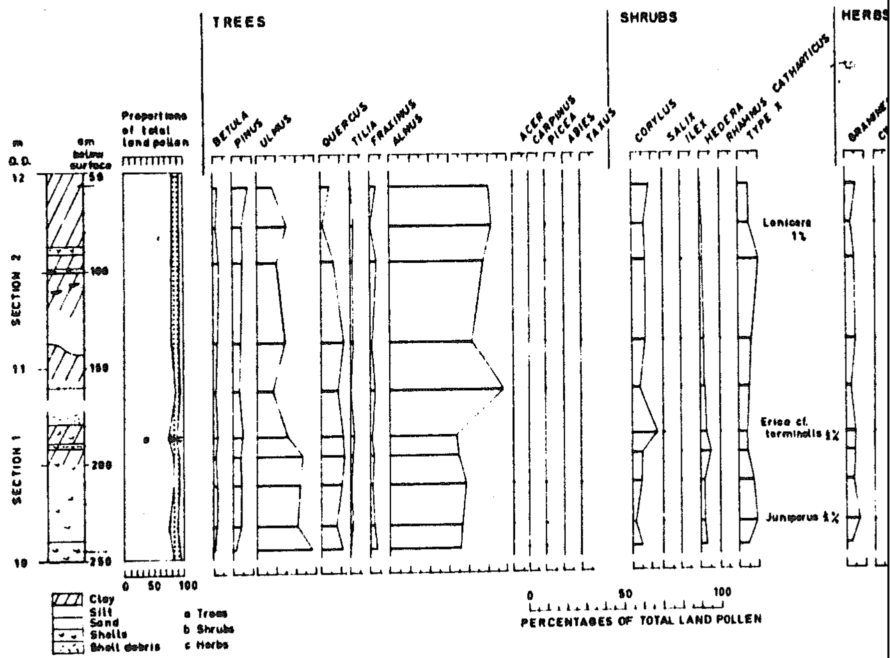
Throughout its outcrop the Woodston Beds, a series of estuarine, lacustrine and fluviatile deposits, rest upon Oxford Clay or Kellaways Beds. They consist of clays, silts and sands with seams of coarse sand and gravel, which commonly occur at the base. The Woodston Beds crop out in the Hicks No.2 Brick Yard (TL 18999564) and the Central Electricity Generating Boards Dust Disposal Terminal (TL 188954), south of Fletton, Peterborough. The formation extends westwards beneath gravels of the Third Terrace of the River Nene. The importance of the Woodston Beds is that they are of interglacial origin and thus provide a stratigraphic marker horizon within the local drift sequence.

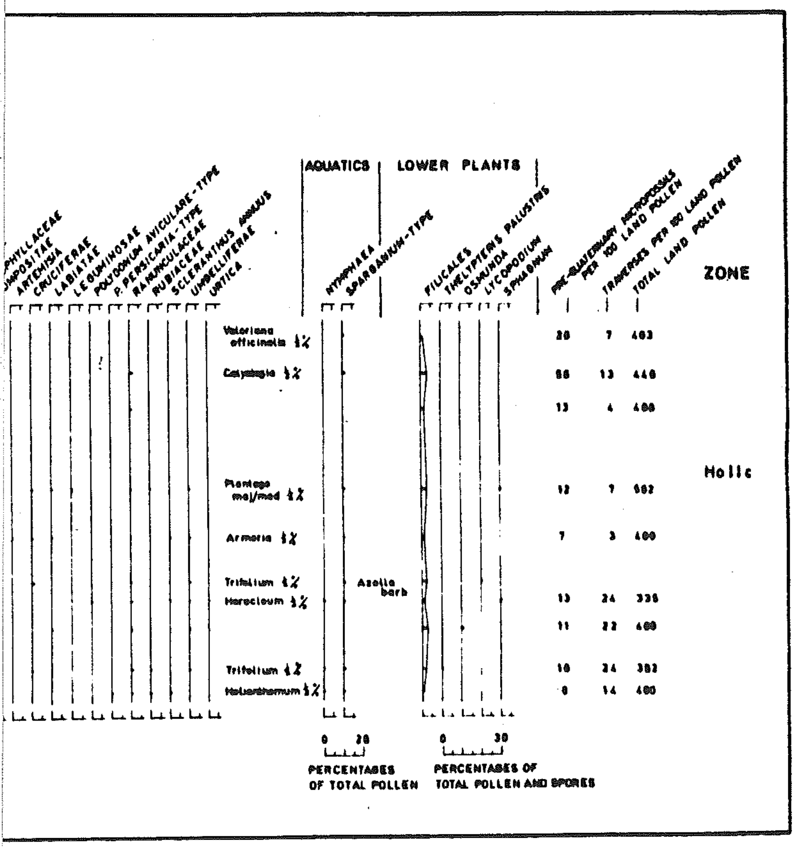
The Woodston Beds have a maximum proven thickness of 7m in a borehole at Cow Pastures Farm (TL 18349582). The base of the formation ranges in altitude from +5.2 to +14.7m OD whilst the top lies at about 13 to 16.3m OD. Outcrops of Third Terrace gravel have a surface level of about 15m OD in the vicinity of the Woodston Beds outcrop, but this increases upstream to at least 21m at Alwalton, or up to 12-14m above the Nene alluvium.

The Woodston Beds were first recognised in a shallow railway cutting at the Hicks No 2 Brick Yard (TL 18999564). The only other exposure was in the adjacent Dust Disposal Terminal, but this was already seeded at the time of discovery. All the information of the Woodston Beds has been obtained from trenches and boreholes. For the purpose of the QRA meeting the London Brick Co Ltd has agreed to re-open the section in the Hicks No 2 Brick Yard. The original trench proved 3.35m of beds resting on Oxford Clay (Fig 11). In the Peterborough "Type" trench (TL 17999609) the thickness of the formation was 3.1m and in the Peterborough "L" trench (TL 18019594) it was about 5.1m thick. In all three sections a basal coarse sandy gravel was overlain by a variable sequence of sands, silts and silty clays. Other boreholes suggest that the basal gravel may be absent locally. The overlying finer-grained sediments are generally weathered, but three sections have yielded plant remains.

Miss Lynda Pilips reports that the pollen spectra obtained from the fine-grained sediments at the Hicks Brick Yard are relatively uniform, the assemblage being characterised by a high level of tree-pollen

HICKS BRICK YARD, PETERBOROUGH




AQUATICS
LOWER PLANTS
PHYLLACEAE
MPOSITAE
ARTEMISIA
CRUCIFERAE
LABIATAE
LEGUMINOSAE
POLYGONUM AVICULARE-TYPE
P. PERSICARIA-TYPE
RANUNCULACEAE
RUBIACEAE
SCLERANTHUS ANNUUS
UMBELLIFERAE
URTICA
NYMPHAEA
SPARGANIUM-TYPE
FILICALES
THELYPTERIS PALUSTRIS
OSMUNDA
LYCOPODIUM
SPHAGNUM
PRE-QUATERNARY MICROFOSSILS PER 100 LAND POLLEN
TRAVERSES PER 100 LAND POLLEN
TOTAL LAND POLLEN
ZONE
Valeriana officinalis ½%
Calystegia ½%
Plantago maj/med ½%
Armeria ½%
Trifolium ½%
Heracleum ½%
Trifolium ½%
Helianthemum ½%
Azolla barb
20 7 403
56 13 448
13 4 400
12 7 502
7 3 400
13 24 335
11 22 400
10 24 382
8 14 400
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0 20
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PERCENTAGES OF TOTAL POLLEN
PERCENTAGES OF TOTAL POLLEN AND SPORES

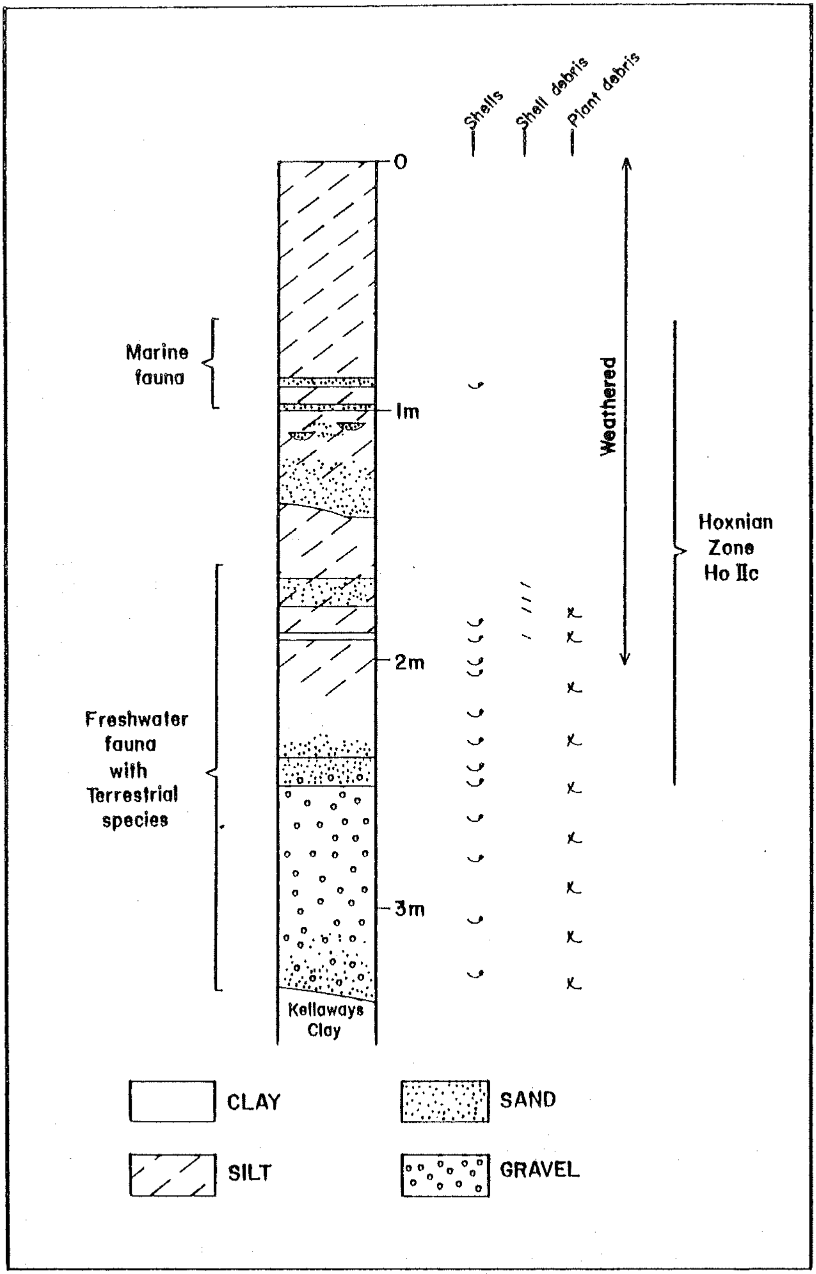


Fig. 11 Composite section in the Woodston Beds, Hicks no. 2 Brickyard.

which does not fall below 72% of the total land pollen. The principal pollen taxa represented are Ulmus, Quercus, and Alnus, whilst amongst the shrubs Corylus and Type X are the most important. The vegetation indicated by the pollen diagram is an almost complete mixed oak forest cover. Pollen from the Peterborough "Type" and "L" trenches was poorly preserved, probably as a result of weathering. Miss Philips concludes that the pollen assemblage falls within the Hoxnian Early-temperate zone (Zone Ho. II).

Molluscan faunas have been collected from all three of the trench sections in the Woodston Beds and have been described by Dr D K Graham. In all three sections the basal lithology is gravel which has yielded a diverse fauna dominated by freshwater species which include Anodonta complanata, Pisidium amnicum, P henslowanum and P nitidum, Ancylus fluvia talis, Armiger crista, Bithynia tentaculata, Lymnae peregra and Valvata piscinallis with some terrestial species including Carychium tridentatum. In the Hicks Bricks Yard sequence the freshwater species persist up into the sands and clays overlying the basal gravel. However, the overlying sands and silty clay contain a brackish to marine fauna which includes Cardium edule, Mytilus edulis, Scrobicularia plana, Spisula elliptica and Hydrobia truncata. In the Peterborough "L" sequence the basal gravel is overlain by clays and sandy clays with a mixed freshwater and terrestrial fauna which are in turn succeeded by sands containing lenses of shells consisting almost entirely of Littorina saxatalis. This species is present throughout the sand unit and is associated with Cerastoderma edule, Ostrea edule, and Scrobicularia plana and probably freshwater and terrestrial species. The topmost interbedded sands and clays and silty clays with a restricted brackish to freshwater fauna. In the Peterborough "Type" section the basal gravels are overlain by sands which have yielded a predominantly freshwater fauna although brackish species occur at at least two levels. The fauna becomes more restricted upward and is of freshwater or marsh aspect. It is impoverished but this may be partly the result of subsequent weathering. Here the highest bed is a gravel, which traced laterally overlaps the fine grained sands and silts, which pinch out, and rests on and is indistinguishable from, the basal gravel.

Ostracods washed from the finer-grained sediments of the Woodston Beds include a mixed freshwater and brackish water assemblage. A solitary indeterminate mammalian rib fragment was collected from the basal gravel in the Hicks Brick Yard.

Thus the Woodston Beds were deposited in a marginal environment. At first fluviatile conditions were widespread and gravels accumulated.

The rivers abated; although quiet-water fluviatile conditions persisted in some areas and estuarine environments existed nearby; probably an intermingling of the facies occurred; the Woodston Beds transgression extending at least into the Fletton-Orton Longueville area. In time fluviatile conditions were re-established, the initial quiet-water sedimentation being replaced by the higher energy environment with the accumulation of the gravels of the Third Terrace. Climatic conditions during the accumulation of the Woodston Beds were comparable to those of the present day.

There are currently no sections in undisturbed deposits of the Third Terrace. Temporary exposures have shown up to 3m of well-sorted gravel with seams of clay and coarse sand. No fossils have been found by the present author in these deposits. A very rich mamalian fauna was obtained from a long disused gravel pit at Orton Longueville probably excavated into gravel of the Third Terrace.

The gravels of the second terrace form a bench some 4.6 to 7m above the alluvium in the Peterborough district. The gravels consist largely of limestone gravel and may contain seams of sand and rarely clay. Boreholes at Orton Waterville (TL 14989675) have proved a lens of dark grey humic silty clay. This has yielded a poor molluscan fauna which Mr D K Graham reports includes abundant Pisisium nitidium, with Bithynia tentaculata, Valvata piscinallis and Sphaerium corneum. The fauna is indicative of a sluggish shallow freshwater environment such as a pond within the higher energy fluviatile environment. Ostracods are also present and Miss D Gregory has recorded Ilocypris gibba, I biplicata, Canodona neglecta, C albicans, Cyprinotus salinus and Gytherissa lacustris. The molluscs and ostracods suggest that the temperature at the time of deposition of this clay was comparable to that of the present time.

Marine Gravels, Fen-edge Gravels and Flandrian deposits

The term Fen Gravel has been applied to gravel deposits which outcrop at the margin of the Fen deposits or locally enclosed by them. Resurvey of the Fenland margin north of Peterborough has shown that the extensive Fen-edge gravels at the mouth of the River Welland form part of broad spread of gravel of First Terrace age. These gravels can be traced out into the Fenland where they are partly obscured by Flandrian sediments. At the margin of the Fenland they undoubtedly are fluviatile and contain freshwater molluscs and mamalian bones, but traced seaward they become thinner, more sandy and yield a sparse marine fauna, including Cerastoderma and Littorina. These marine sediments lie on the projected base-level surface of the

First Terrace gravels. North of the Welland towards Billingborough spreads of gravel are associated with several of the small streams which flow into the Fenland. These gravels extend laterally along the margin of the Fenland. They are probably of comparable age to the First Terrace deposits of the Welland and Nene and also originate as debouchment aprons as the fast flowing streams left the narrow valleys and entered the low-lying Fenland. As in the south these Fen-edge gravels appear to pass into finer grained deposits with marine shells, and in one example east of Billingborough into chenier (lumachelle) deposits.

Deposits of gravel of the above type are buried beneath Flandrian sediments, but a second type caps the ridges or islands which are enclosed within the Flandrian sediments. These higher level deposits generally rest on Jurassic clays whose outcrop although largely obscured by cryoturbation and solifluction can be traced around the edges of these Fenland islands, for example Whittlesey and March. These gravels contain a very poorly preserved fauna which is probably residual after intense leaching and oxidisation. Although the projection is much greater, these marine gravel, which include the March Gravels, lie on the extended base level surface of the Second Terrace of the River Welland. The limited marine faunas of the two ages of Fen gravel are similar and may be compared to the present day fauna of The Wash.

Thus the fluviatile history appears to have been one of progressive downcutting interrupted by at least three stages of aggradation. During each stage, there appears to have been a transition from river gravels into pebbly sands with marine shells. (Eg: the Third Terrace gravels pass into the Woodston Beds.) During each stage, fluvial gravel appears to have transported into a marine or estuarine environment where marine to brackish water mollusca were either growing <u>in situ</u> or were swept by storms into the marginal inter-tidal zone.

The Fenland is underlain by a variable series of shallow water and salt-marsh clays, silty clays, silts and fine sands with inter-bedded peat horizons. The oldest sediments, the Crowland Bed, are of uncertain age and origin. The Bed is generally less than 1m thick. Its basal boundary is commonly unclear, the bed forming a blanket between the Flandrian sediments and the underlying formations which vary from Jurassic in age to glacial deposits or marine pebbly sands and silts. The Bed is of variable lithology, which reflects, but is not entirely derived from the underlying formation. Since its accumulation it has been altered by the development of a soil profile and weathering during the formation of the overlying Flandrian deposit. In parts it resembles a solifluction deposit, but there are only negligible slopes present. It probably developed in situ by cyroturbation associated with only minimal lateral movement of sediment.

The oldest Flandrian deposit, the Lower Peat, is present througout the Peterborough district, but may be absent locally. It is diachronous, the zone of growth and accumulation migrating progressively, but discontinuously, shoreward as the marine transgression proceeded. It is overlain by the Barroway Drove Beds (Fen Clay) which consists of silty clays (saltmarsh) silty sands and clays (shallow water sandflat) and silts and silty sands (tidal creek deposits). These are succeeded by the Nordelph Peat which crops out over much of the adjacent Fenland. Towards the margins of the Fenland the Barrowoy Drove Beds thin and rarely the Nordelph Peat may rest directly upon the Lower Peat. Elsewhere either or both may split with the development of locally persistent peat seams. The sea retreated from the area before the accumulation of the Nordelph Peat but further transgression as far as the Spalding-Wisbech area was followed by the accumulation of the Terrington Beds, salt-marsh and sandflat deposits comparable to the Barrowy Drove Beds.

Alluvium accumulated on the main valleys contemporaneously with the marine and estuarine sedimentation in the Fenland. Near Peterborough an alluvial channel extends out into a complex series of estuarine clays and silts with peats which are intermediate in character to the typical Fenland deposits.

The Peterborough area - stratigraphic problems

a) The age of the Chalky Boulder Clay.

The Peterborough District is intermediate between the Midlands and East Anglia. In both areas the most widespread glacial deposit is the Chalky Boulder Clay. In East Anglia it is assigned to the Anglian Stage whereas in the Midlands it is assigned to the Wolstonian Stage. Although local variations in lithology occur there is no major contrast between the Norfolk, sub-Fenland and Peterborough types of Chalky Boulder Clay. They appear to form part of a single stratigraphic and morphological unit. There is no direct proof of the age of the local Chalky Boulder Clay. The Woodston Beds are assigned to the Hoxnian

Interglacial Stage. So far they have only been found overlying Oxford Clay. However, they contain well-preserved Jurassic and Cretaceous foraminifera and ostracods and Mesozoic pollen. Cretaceous formations do not outcrop in the Nene Valley. The nearest Chalk outcrops are in Lincolnshire, Cambridgeshire and Norfolk. Derivation from these areas would involve very long transportation by longshore drift in the Hoxnian "estuary". An alternative source would be the chalk-rich boulder clay outcrops within a kilometre. This would mean that the Chalky Boulder Clay of Peterborough is of pre-Hoxnian, ie Anglian age. An inference supported by the association of the Woodston Beds with Third Terrace gravel deposits which morphologically post-date the Chalky Boulder Clay.

b) The absence of deposits contemporaneous with the Hunstanton Till.

Hyothetical reconstruction of the Hunstaton Till environment suggests that the ice-sheet from which it was deposited closed the mouth of The Wash and thus formed a lake. No lacustrine deposits associated with such an ice-dam have been found so far in Norfolk nor in the present district. The glacial lacustrine and marginal deposits described to date, all belong to the Chalky Boulder Clay Glaciation.

A Horton

EXCURSION TO CHARNWOOD FOREST AND THE MIDDLE TRENT VALLEY

This excursion begins with a visit to Huncote sand and gravel pit which lies just to the northern side of the recorded limit of the Bosworth Clays and Silts. It shows the Wolstonian succession of the Leicester area to good effect. The Charnwood Forest and Middle Trent areas both to the north of Lake Harrison display a rather patchy drift cover which can frustrate lithostratigraphical correlations. Wolstonian ice must have covered the area for a period of time sufficient to maintain the empoundment of Lake Harrison and the deposition of up to 40m of clays (often varved) to the south. The recognition of two distinctive till lithologies throughout the area (red Pennine tills and chalky boulder clay) is no longer interpreted as the product of two cold stages. As has been shown elsewhere (Rice 1968, Douglas 1980), the Wolstonian tills indicate both northwestern and northeastern provenance.

T D Douglas

Huncote Sand and Gravel Pit (SP 513981)

This is the sole surviving example of a whole series of pits that have, during the last hundred years, been opened in a bed which Rice (1968) termed the Thurmaston sand and gravel and which he traced along the middle Soar valley from a little north of Huncote to the village of Thurmaston at the confluences of the rivers Wreake and Soar. Further work has os strengthened an original correlation suggested in 1968 with the Baginton Lillington sand and gravel, that it now appears justifiable to employ that term to describe the material currently being worked at the Huncote pit.

The succession exposed at Huncote may be divided into four main units:

Lithology	Thickness	Regional Correlation
Chalky till and associated water-lain sands, silts and clays	Up to 6m	? Oadby till
Red and reddish brown till derived mainly from Triassic source rocks	Variable 1 - 5m	Thrussington till
Reddish sand with a few gravel stringers	6m	Baginton sand
Fine-to-medium gravel	up to 5m	Baginton-Lillington gravel

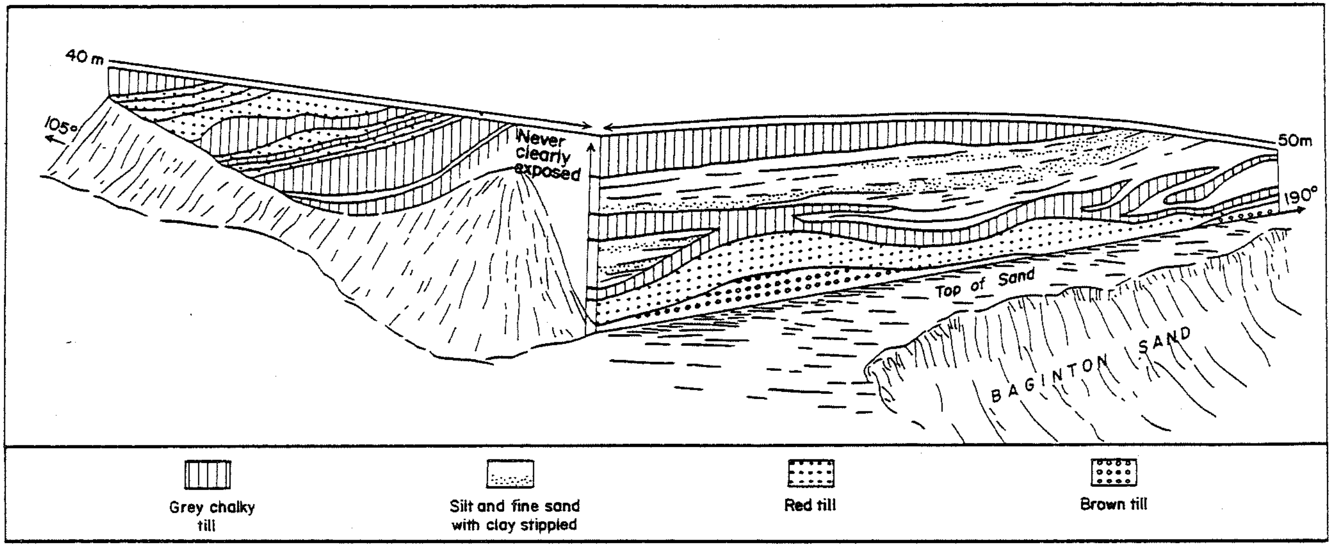


Fig. 12 Schematic representation of the overburden at Huncote sand and gravel pit. The face on the left is almost certainly cut by a number of shear surfaces.

The basal gravel rests directly on undisturbed Keuper Marl. As the bedrock floor of the pit rises gently eastwards, the thickness of the level-bedded gravel gradually diminishes. Analysis of a sample of 1913 pebbles showed the following composition:

Bunter pebbles 77%, Keuper skerry 9%, Carboniferous sandstones, limestones and coal 7%, Keuper or Bunter sandstones 3%, Lias limestone 1%, others 3%.

There is a rapid upward transition from the gravel into the sand. This latter bed is 6m thick and consists predominantly of well sorted, medium- fine sand arranged in a series of cross-bedded units that testify to deposition by northward-flowing water. Towards the top of the sand the dominant grade of material becomes appreciably finer and the bedding largely horizontal. So far as is known no organic materials have been recovered from either the sand or the gravel at Huncote - nor, for that matter, at any of the other sites in central Leicestershire where the Baginton-Lillington sand and gravel has been worked - and the best evidence for climatic conditions prevailing during the accumulation comes from the presence of ice-wedge casts. Most of these are intra-formational, although at least one has been seen extending to the top of the sand.

The dominantly Trias-derived till is divisible into two parts. At the base is a reddish brown horizon, commonly a metre or so thick, which is succeeded by a reddish till of rather greater thickness. The boundary between the different hues is sharp, and in places streaks of the brown till can be seen to pass up at a shallow angle into the basal layers of the red. Counts to establish the provenance of the clasts in the two tills show very little difference, as do geochemical analyses of the matrices. Fabric studies, on the other hand, reveal marked contrasts in the alignment of the erratics, with a south-westerly orientation being characteristic of the brown till and a south-easterly orientation characteristic of the red till. The reason for the two differently coloured tills remains uncertain. It is conceivable that there were localised changes in the direction of ice movement, or alternatively the basal layer may be a flow till that was later covered by a lodgement till. One aspect of the upper till is its occasional incorporation of masses of Keuper Marl that may attain 5-10m^3 in volume. This evidence of disruption of the surface across which the ice moved is in sharp contrast to the contact between the brown till and the underlying sand. This is a planar surface below which the delicate depositional structures in the sands and silts remain almost entirely intact.

The upper surface of the red till is irregular, and in the small basins so formed there lie complex sequences of sand, silt, clay and till. Occasional fragments of chalk, flint, colite and Lower Lias limestone can be found in all the water-laid sediments, and the thin till horizons are almost invariably rich in Cretaceous debris. The ice-marginal sedimentation, which these diverse sequences are believed to represent, was terminated by a glacial re-advance which deposited an overlying sheet of unbedded chalky till. This final event induced significant disruption of the earlier drift deposits. Folds and shears attest to compression from the north-east, with the earlier chalk-bearing debris being the most affected but with at least one sheet of reddish Trias-derived till being thrust towards the south-west over the top of chalky sediments.

Correlation of the sand and gravel with the Baginton-Lillington sand and gravel in the Avon catchment near Coventry is supported by numerous similarities in both depositional structures and compositional characteristics. The evidence strengthens Shotton's original contention that the sediments were laid down by a north-flowing proto-Soar river that had its source to the south of Coventry. The deposits can be traced down the present Soar valley to the vicinity of Thurmaston, but beyond that point considerable uncertainty remains. Two possibilities exist. The first is that the proto-Soar continued along the line of the modern river to a confluence with the Trent. There is no continuity of the sand and gravel in this direction, but this might be explained by the constricted valley between Mountsorrel and Barrow on Soar where post-Wolstonian erosion by the Soar would rapidly destroy any earlier fluvial sediments. The second possibility is that the proto-Soar originally flowed along the line of the Wreake valley (although in the reverse direction to the present river) and that it ultimately debouched into the Fenland region by way of the large drift-filled valley that crosses the Lincolnshire limestone plateau near South Witham (Rice 1965). There is no known bedrock outcrop which precludes this hypothetical reconstruction; on the other hand, there is also no direct evidence that the Baginton-Lillington sand and gravel extends eastwards along the route of the proposed valley from Thurmaston to the Fens. There are exposures around Castle Bytham in Lincolnshire that might be equated with the sections in the middle Soar valley, but in the intervening area near Melton Mowbray there are boreholes which, at the appropriate elevation, encountered till rather than water-laid sediments. Such occurrences do not necessarily rule out the possibility of a former sand and gravel suite along the floor of the proposed valley, since even around Huncote later glacial erosion has undoubtedly removed this material and scored a furrow into the underlying bedrock. This was disclosed by excavations and boreholes along the line of the M69 only a few hundred metres west of the Huncote pit. Sections revealed the sand being abruptly truncated by bedded till along a junction sloping at an angle of 30°, and trial bores showed the till and associated fine-grained sediments to descend well below the depth at which the gravel normally occurs. This furrow can be traced along the western side of Croft Hill after which it apparently merges with the similar feature that fringes the eastern side of Croft Hill (already mentioned on p.19).

R J Rice

Charnwood Forest - stratigraphy

Charnwood Forest lies approximately 15km to the south of the Trent-Soar confluence. Forming some of the highest ground in Leicestershire it has the underlying structure of a breached, south easterly plunging, Precambrian anticline with igneous intrusions. These ancient rocks are unconformably over-lain by the remnants of a formerly, more extensive cover of Triassic strata. For many years drift was believed to be of restricted occurrence, a misunderstanding related to the difficulty of distinguishing amongst Keuper Marl, Keuper-rich till and their soliflucted derivatives. Recent, temporary sections, particularly those exposed during the construction of the M1 motorway, have shown, unquestionably, that both glacial and periglacial deposits are widely distibuted over Charnwood Forest (Ford 1967; Poole 1968; Bridger 1972 and 1975).

Some progress towards the establishment of a Pleistocene succession has been possible in the south of Charnwood Forest and here it has been divided into the following members:

7. Upper Head

6. Anstey Till

5. Newtown Linford Till

4. Markfield Clay with Middle Head

3. Cliffe Hill Sands and Gravels

2. Raunscliffe Till and White Hill Clays and Silts

1. Lower Head.

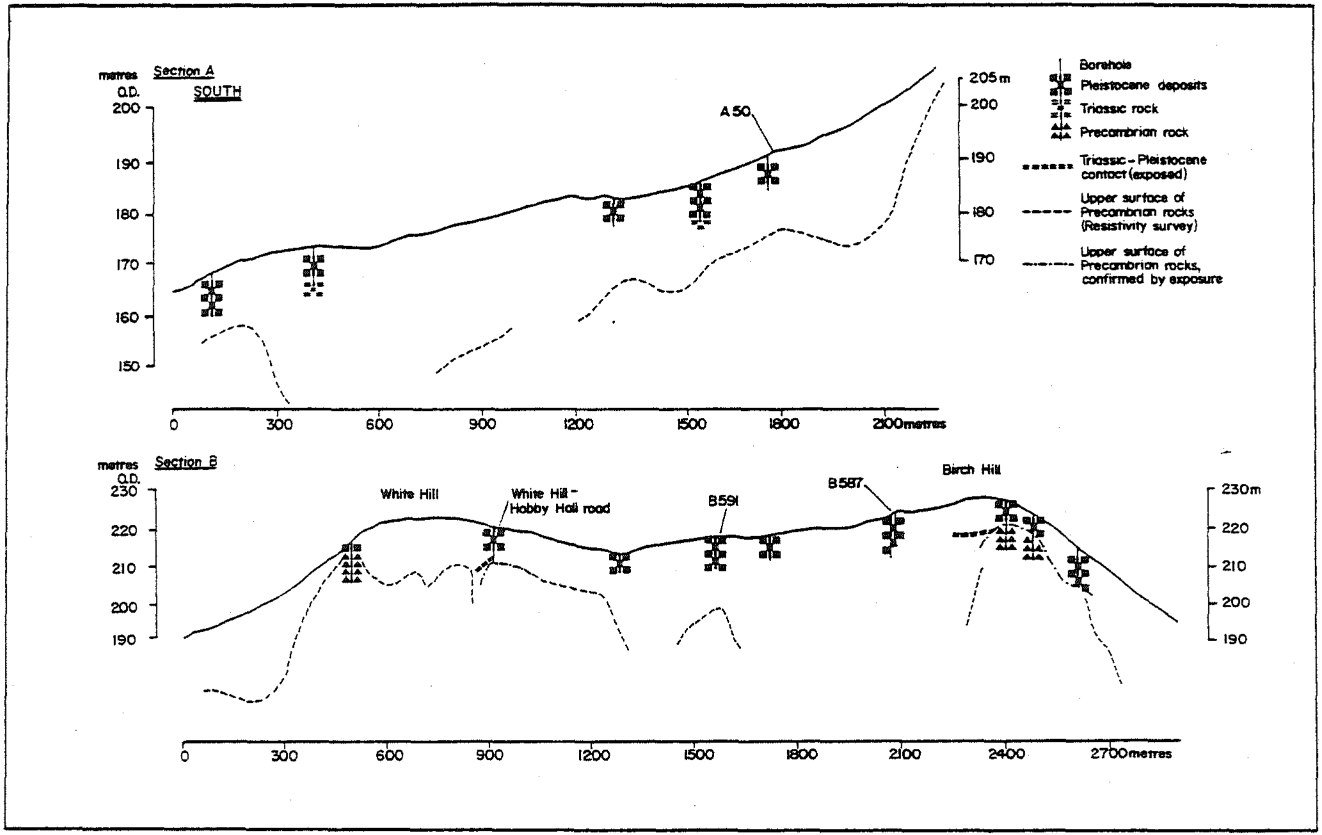
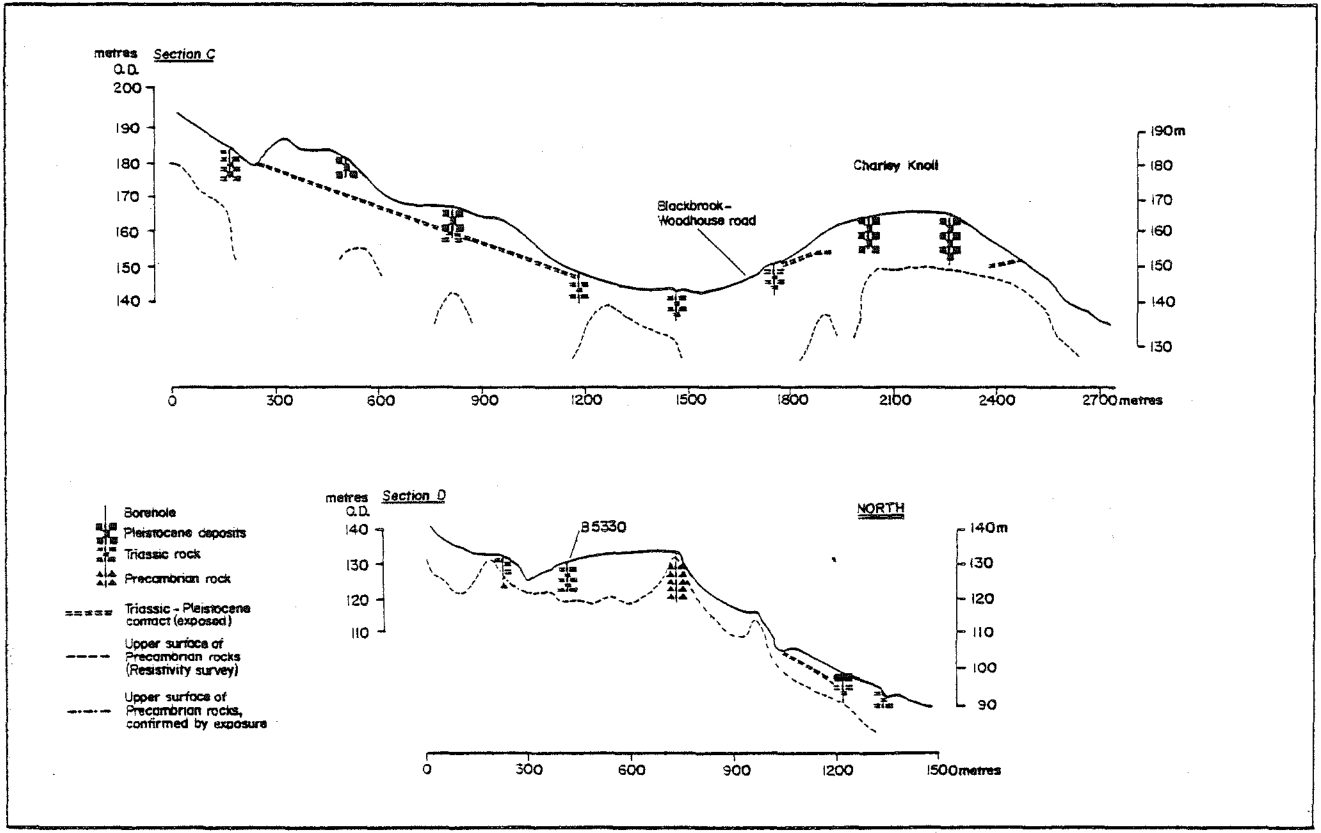


Fig. 13 Composite section across Charnwood Forest, following the line of the M.1 motorway.


metres O.D.
Section C
200
190
180
170
160
150
140
190m
180
170
160
150
140
130
Charley Knoll
Blackbrook-Woodhouse road
0
300
600
900
1200
1500
1800
2100
2400
2700 metres
Borehole
Pleistocene deposits
Triassic rock
Precambrian rock
Triassic - Pleistocene contact (exposed)
Upper surface of Precambrian rocks (Resistivity survey)
Upper surface of Precambrian rocks, confirmed by exposure
metres O.D.
Section D
B5330
NORTH
140
130
120
110
140m
130
120
110
100
90
0
300
600
900
1200
1500 metres

Differences between the lithologies of the Newtown Linford till characteristically containing Coal Measure erratics and the overlying chalky Anstey till, may be considered as local reflections of the well established pattern of Midland ice-movements related to the Wolstonian formation of Lake Harrison. Associated with this Wolstonian episode are the underlying non-calcareous Markfield clay and Coal Measur-bearing Cliffe Hill sand and gravel, interpreted respectively as proglacial lake sediments and outwash deposits, formed as ice from the north-west advanced towards Charnwood Forest.

Difficulties arise, however, when consideration is given to the lowest glacial member of the succession. If the Liassic-rich Raunscliffe till is though of as being Anglian in age there is the problem of reconciling this date with the widely agreed view that Midland Anglian tills are either of Welsh or of north western provenance (eg Shotton 1953 and 1973). Poole (1968) has argued that an Anglian age is applicable to a lower till with Cretaceous erractics near Market Harborough but here, as in Charnwood Forest, an absence of related Hoxnian deposits means that unequivocal evidence for dating early north-eastern tills as Anglian is missing.

The alternative of placing the Raunscliffe till in the pre-Lake Harrison phase of the Wolstonian is preferred, although this again raises difficulties. Acceptance of this age for the till would require revision of the generally accepted Wolstonian glacial sequence in the Midlands to accommodate the implied advance of north eastern ice before the ponding of Lake Harrison. It is possible that such a revision might also provide a satisfactory explanation for the other pre-Lake Harrison tills with eastern erratics recorded elsewhere in the Midlands by Bishop (1958) and Douglas (1980).

The Raunscliffe till has not been recorded away from the Markfield area and although the situation of the related proglacial White Hill clays and silts in south Charnwood indicates a minimum height of 215m OD for the associated ice, the extent of its penetration into the area remains obscure.

It should be borne in mind that there in uncertainty about the Pleistocene succession in north Charnwood Forest and the mixture of north-eastern and north-western erratics in certain tills (Bridger 1972) suggests that ice movements here did not necessarily follow the pattern recorded in the area to the south. Nevertheless, the distribution of drift which may be confidently attributed to the following Wolstonian (Lake Harrison) glaciation implies that the whole of Charnwood Forest was ice covered.

An impression of the magnitude of glacial deposition and its geomorphological impact may be gained from the composite section along the line of the M1 motorway (Fig. 13) which runs north-south almost centrally through Charnwood Forest (resistivity and borehole data kindly made available by Sir Owen Williams and Partners). Although the resistivity results do not separate Pleistocene from Triassic deposits, it is clear from the bore holes that the southern half has a virtually continuous and locally very deep cover of drift. In the north, the section shows that drift is variable in both thickness and extent. Its almost complete absence on northern peripheral slopes, in contrast to the depth of cover in the south, is thought to be the result of differences in local rates of post-glaciation fluvial erosion rather than reflecting inequalities in the original drift thicknesses. If the latter view is corret it follows that, after deglaciation, the topographical profile would have approximated to an inverted saucer.

Discordant drainage of Charnwood

The two features of Charnwood Forests scenery which have attracted most geomorphological attention are its crags and discordant drainage.

The crags, which display a wide range of tor-like forms, are composed of either igneous rock or various types of Charnian strata and occupy a variety of topographical situations. Surrounding, surface-spreads of clitter are not always apparent but sectional slopes have almost invariably exposed a layer of head running down-gradient from the sides of crags. In the case of the Altar Stones, near Raunscliffe (SK 488107), two layers of head have been recorded.

The drainage of Charnwood Forest (Fig. 14) is unexceptional on the highest ground where it has produced an approximately radial network with an ill-defined watershed running north-east to south-west. On the lower slopes, however, notably in the northern and eastern areas, many streams change direction to follow routes which frequently take them discordantly across outcrops of pre-Triassic rock. Several instances of such stream behaviour are located at heights of around 122m OD but this phenomenon is also to be found at lower altitudes. There is no consistency in the angles of deflection and minor discordancies may occur without any perceptible deviation of the stream. The morphology of the valleys, developed in discordant sections, is not uniform and by no means all the examples strictly justifiy being described as gorges. There are a few cases where discordantly flowing streams have achieved little more than incipient valley development. Apart from recent sediments, evidence of infilling deposits has not been observed within the gorges although both Triassic and Pleistocene material has been recorded in contiguous locations.

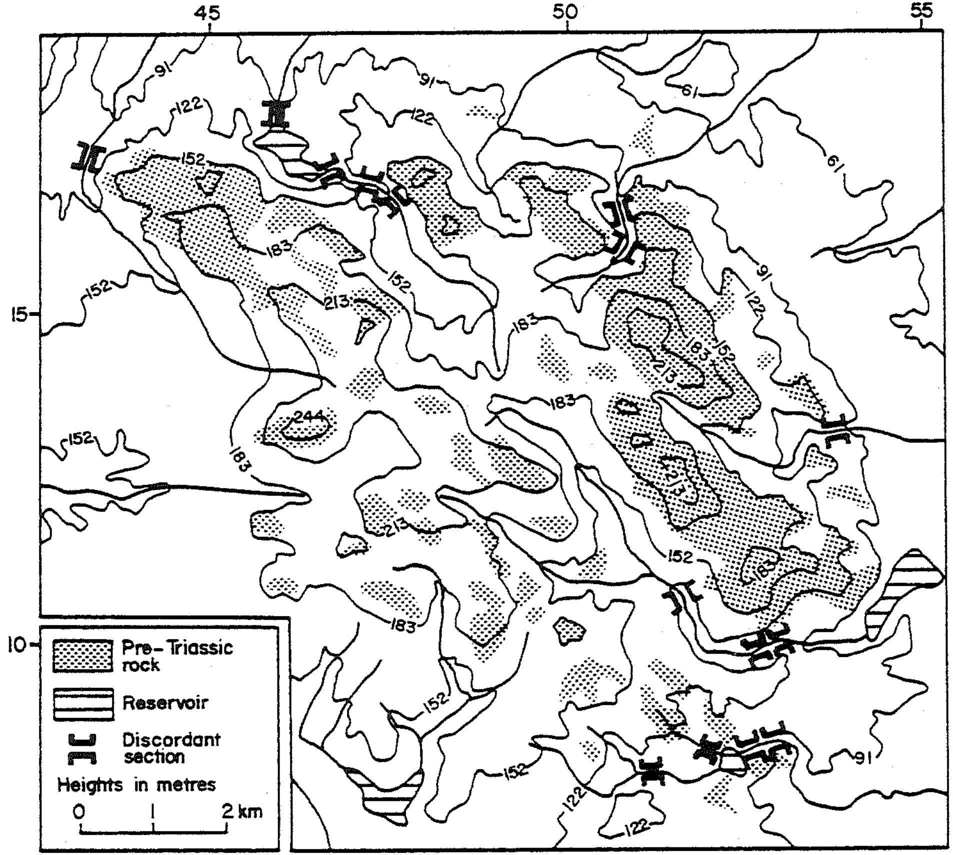


Fig. 14 Discordant drainage of Charnwood Forest.

Throughout the first half of this century, a widely accepted interpretation of these features was put forward by W W Watts (1903, 1905, 1947). Neglecting the evidence of drift in Charnwood Forest plotted on Geological Survey maps, he took little account of Pleistocene events and argued that the crags and, at least, some of the gorges were "uninjured" Triassic landforms which had been exhumed from a protective cover of Keuper Marl. He went on to explain the stream pattern and the remainder of the gorges in the context of uninterrupted drainage evolution upon a one-time, complete cover of Mesozoic rocks. Watts believed that streams had "unconsciously" wandered, to follow courses taking them over buried ridges of ancient rock onto which they were eventually superimposed through Keuper Marl to produce discordant drainage.

Support for Watts views on the origin of the discordant drainage was given, for example, by F W Bennett (1928) who advocated superimposition from a Triassic cover to explain the small but complex section at Ulverscroft Mill (SK 514108).

Against a background of the new understanding of glacial and periglacial history in Charnwood Forest, any account of landform evolution not taking into consideration Quaternary events is clearly in need of revision.

Ford (1967), in discussion of the crags, agreed that the lineaments of the landscape had a Triassic heritage but concluded that the formation of the "tors" also involved Quaternary weathering processes including periglacial activity and probably a measure of glacial plucking. The identification of three periods of head formation in south Charnwood Forest reinforces the significance of cold-climate weathering in their formation.

Recent opinion (Bridger 1968; in press) on the genesis of the discordant drainage stresses the importance of the Wolstonian glaciation. The present stream network is thought to be essentially the imprint of the major meltwater routes with the deflections attributed to glaciological factors such as the influence of crevasses. An environment of deglaciation may, additionally, explain the formation of the discordant features by epigenesis through ice. It is possible that some of the gorges were initiated in this way, but widespread distribution of drift presents a further medium through which epigenesis could operate after the ice had finally melted. The development of the discordant drainage phenomenon within a Quaternary time-scale, of course, allows the possibility of a stream cutting progressively through ice, drift and Keuper deposits before making contact with underlying Charnian strata.

The explanantion for the concentration of the discordant sections in the northern and eastern parts of Charnwood Forest may be related to special conditions in those areas during the deglaciation but supporting evidence for this view has not been found. It is, however, possible that factors associated with the contracting Upper Pleistocene histories of the Proto-Trent and Proto-Soar valleys were involved. While to the south of Charnwood Forest the valley of the Proto-Soar has remained largely buried under drift since the Wolstonian glaciation, the River Trent to the north probably re-occupied the middle reaches of the Proto-Trent valley from the beginning of the Ipswichian stage. The erosional advantage so gained by the tributaries of the River Trent would locally be reflected by an increase in their chances of forming discordant sections and thus lead to an asymmetrical distribution of the phenomenon in Charnwood Forest.

In so far as superimposition was probably the mechanism responsible for Charnwood Forest's discordant drainage, Watts' interpretation is almost certainly correct but, as in his explanation of the crags, it is unsatisfactory owing to his failure to take into account the geomorphological significance of Quaternary environments.

Newtown Linford

This locality displays features characteristic of discordant drainage in Charnwood Forest. Above Newtown Linford (SK 520100) the Ulverscroft stream flows generally southward in a valley developed almost exclusively in Pleistocene deposits. However, in the immediate vicinity of the village, the route to the south is blocked by till and the stream swings north-westwards through Bradgate Park (SK 530100) where it has cut a 300m long gorge in igneous rock. A map of the sub-Triassic surface by Watts (1947) shows an unobstructed valley running southwards from Ulverscroft Mill (SK 515108) as far as Newtown Linford from where it continues in a south-westerly direction to Anstey (SK 550085). A seismic traverse has confirmed a buried valley to the south of Newtown Linford but whether its infilling is totally of Pleistocene origin remains uncertain. Both drift and Keuper Marl have been recorded close to the entrances of the Bradgate Park gorge but within it, where there has been much disturbance by the construction of weirs, neither of these deposits has been observed.

J F D Bridger

Middle Trent - introduction

The currently accepted Pleistocene chronology for the Middle Trent Basin is based largely on the morphological investigations of Clayton (1953) and the various attempts at interpreting the sequence of deposits established almost a century ago by Deeley (1886). Particularly notable are the reviews by Clayton (1953), Posnansky (1960), Straw (1963), King (1966) and Rice (1968). The interpretation given by Posnansky is the most recent composite picture of the sequence of events.

Deeley recognised a succession of lithologically distinct "boulder clays" separated by sands and gravels. The "boulder clays" were attributed to successive deposition by ice sheets or northern and eastern (Chalky) derivation. Subsequent authors have tended towards a simpler glacial chronology and it has been inferred by some that all the "boulder clays" belong to a single (Wolstonian) glacial stage.

Terrace deposits which apparently post-date the Chalky Boulder Clay have also provoked considerable controversy. Disagreement has persisted over the age, origin and even the number of terraces. Several workers have followed Clayton (1953) in differentiating the Hilton, Beeston and Floodplain on a decreasing height and age basis. However, Clayton's suggestion was questioned by Stevenson and Mitchell (1955) and Posnansky (1960) who regarded the Hilton deposit as being wholly or partly of fluvioglacial origin. The Beeston Terrace has yielded mammalian remains indicative of the Ipswichian interglacial (Jones and Stanley 1974) even though morphological evidence suggests a later (Devensian) age (Stevenson and Mitchell, 1955). The age of the Floodplain Terrace is also uncertain, although it has been correlated with the Tame Low Terrace which is dated as late Middle Devensian (Shotton 1973).

Church Wilne (SK 449318)

Recent alluvium, floodplain gravels and associated organic deposits; pre-Devensian (Wolstonian?) glacial deposits.

At Church Wilne 10km south east of Derby, extensive gravel workings have revealed a complex assemblage of glacial deposits which underlie the fluvial sediments making up the wide floodplain of the River Derwent near to its confluence with the Trent.

The general sequence for the first 3m below the floodplain is:

6. Brown silty alluvium 1.0m, Flandrian.

5. Black organic silty clay, up to 0.5m in sinous channels running across the underlying gravels. Contains insects and seeds including Corylus indicative of the Flandrian. One channel has yielded fragments of Mediaeval pottery. The channels have little or no surface expression being obscured by deposit 6.

4 Coarse sandy gravels, with large scale cross bedding, 1.5 - 2.0m. These are normally equated with the Floodplain Terrace which passes beneath the alluvium upstream of Beeston (Clayton 1953). Late Devensian to early Flandrian.

3. Thin lenses of dark organic silt at base of gravels. Biota indicates Late-Glacial, Pollen Zone III, confirmed by radiocarbon date Birm 818, 10 320 ± 160.

Over large areas such a sequence rests directly on Keuper Marl but elsewhere channels are found beneath the floodplain gravels filled with older Pleistocene deposits. These take two forms:

2. Gravels and red pebbly clays with occasional lenses or organic silt and at the base a stoneless red clay. Max 2.5m. Strongly cryoturbated, with the involutions truncated by Bed 4 or 3. The organic material has not yet been dated.

1. Glacial deposits including tills and glacigenic gravels with associated glacifluvial and glacilacustrine sediments (base not seen, except at channel margin).

The glacial deposits occupy a buried channel up to 1km wide cut in the Keuper Marl bedrock. Although the deposits are highly variable in composition and structure, two distinct groups may be recognised on the basis of provenance. In general, dark grey tills and associated gravels derived largely from Carboniferous rocks contrast strongly with the reddish brown (Trias-derived) deposits containing Jurassic and Cretaceous erratics. The former are consistent with an ice stream of northern (Pennine) origin whereas the latter may be attributed to an ice stream crossing Lincolnshire from the E or NE (cf. Posnansky 1960). At several localities the contact between the two groups has been seen to be disturbed but sharply defined. In every case the Trias-derived deposits rested on top of, or abruptly against, a Pennine till. This relationship suggests that a "northern" ice stream entered south Derbyshire before one of "eastern" origin. However, the regional stratigraphy is complex and elucidation of the glacial chronology must await further study.

The "eastern" glacial deposits show considerable variation in their structure and lithological composition and include numerous sand and gravel lenses. A notable feature is the abundance and wide variety of derived fossils including Gryphaea, Cardinia, Lima, Nuculana, Dactilyoceras, Amalthens, Schlotheimia, Montlivaltia, Pentacrinus and belemnites. Also of interest is the presence of tills rich in chalk debris, since it has been stated previously (eg Clayton 1953) that the so called "Chalky Boulder Clay" contains only flints west of Nottingham. In places the tills are exclusively chalky and have matrix carbonate contents in excess of 40%. Similar deposits have been observed in an almost identical context at Boulton Moor (7km W). Here the chalky till was associated with large "rafted" blocks of Jurassic mudstone and gravels containing a wide variety of Mesozoic rock fragments.

The "Pennine" deposits, in contrast, are relatively homogeneous with uniform lithologies and little discernible variation in structure over a wide area. The most significant member is a matrix dominated till which comprises an overconsolidated stiff grey clay with a sporadic content of predominantly small clasts (15mm). The overall characteristics of this till are consistent with formation by lodgement. The very low frequency of clasts has precluded a statistically valid clast fabric analysis. However, the erratic content strongly indicates an ice flow direction from the N or NNW. An unusual feature displayed by the till in recent workings 50m S of the church was the presence of a conspicuous set of sub-vertical curving fractures. These have been interpreted as due to point loading of the frozen till surface by englacial (basal) boulders which provided periodically high compressive stresses and induced tensional failure (Derbyshire and Jones 1980).

The age of the Church Wilne glacial deposits in uncertain. They are unusual because of their freshness, their high content of chalk and their sub-alluvial context. Equivalent deposits at Boulton Moor (7km W) are overlain by Beeston Terrace gravels containing Ipswichian faunal remains (Jones and Stanley 1974). This supports the Wolstonian date normally attributed to the South Derbyshire tills. However, correlation of the sub-alluvial tills with those capping the interfluves to the north is not easy. The latter are deeply dissected, contain little or no chalk (although sometimes rich in flint) and are almost totally decalcified. These higher level patches may well prove to be of Anglian age.

Thulston-Chellaston Road (SK 405315)

Vantage point; Beeston Terrace feature.

This vantage point, 6km SE of Derby, affords a view over the Beeston Terrace at its widest extent. At this locality the terrace is a broad, well developed feature with an average height of about 42 m OD. It lies approximately 5.4m above the present Derwent floodplain from which it is separated by a marked break-of-slope. The terrace is shown on the IGS map (Sheet 141) as terminating to the SW against higher ground composed of Keuper Marl with a capping of "boulder clay". However, the terrace margin is obscured by a veneer of solifluction which also appears to extend over the entire terrace surface. The terrace deposits themselves are underlain by a thick and complex sequence of glacial materials. Recent pipetrench excavations on Boulton Moor (1.5 km NW) has enabled the following stratigraphical sequence to be established:

5. Pebbly clay, 0.25 -1.0 m; solifluction.

4. Ochreous sands and gravels; 1.0 - 2.0 m; well developed cryoturbation structures truncated by deposit 5.

3. Black silty clay; up to 0.25 m in lenses; insect fauna suggests mid-Devensian date, possible equivalent to Upton Warren interstadial (G R Coope, personal communication).

2. Cross bedded sands and coarse sandy gravels with large scale cross-stratification; occurring in channels over 4m deep; abundant memmalian remains including Hippopotamus suggests Ipswichian date for the channel deposits.

1. Glacial deposits of eastern derivation overlying Pennine till. The glacial deposits occur in a 1km wide channel cut in Keuper Marl bedrock. Borehole evidence suggests that this channel is over 20m deep.

Etwall Gravel Pit (SK 275309

Hilton Terrace (upper level), fluvial and/or glacifluvial gravels, periglacial involutions.

The Hilton Terrace is a composite and complex feature which has been the subject of much debate. Its component patches of sand and gravel flank the valleys of the major rivers at heights in excess of 40ft(12m) above the alluvium. These are particularly extensive along the northern margin of the lower Dove, where they form conspicuous flats between Uttoxeter and Willington. Smaller, but morphologically similar patches occur along the valley of the lower Derwent downstream of Derby, and may be traced up the River Trent as far as Rugeley.

Clayton (1953) regarded all these deposits as of fluvial origin and considered the overall feature to be a "true river terrace" which he named after the type area at Hilton and attributed to the "Main (Ipswichian) Interglacial". Deeley (1886) and also Pocock (1929) had already recognised the existence of "high-level" river terraces, but whereas Pocock found evidence for at least four, Clayton identified only a "Lower" and an "Upper" level. In contrast, Stevenson and Mitchell (1955) maintained that the gravels at Hilton were fluvioglacial deposits, and could be equated with outwash from the Irish Sea Ice. These conflicting opinions were partly reconciled by Posnansky (1960) who argued that the Hilton deposits represented "outwash aggradation terraces", initiated during the retreat stages of the "Eastern (Wolstonian) Glaciation" and completed during the ensuing interglacial. It is notable that when the deposits were originally mapped by the Geological Survey (Sheet 141) they were described by Fox-Strangeways (1905) as being "intimately associated both with the glacial beds and with the modern river terraces", thus forming "a passage between Glacial and Post-glacial times."

The quarry at Etwall is the only major exposure of the Hilton gravels in existence at the present time. Sections described by previous authors are no longer available for study. The present working face is located on the "Upper" terrace feature, 1 km S of Etwall village and 3 km E of the type locality. Approximately 3m of coarse ochreous gravels rest on Triassic bedrock. The gravels are poorly stratified and highly disturbed in a form suggestive of severe periglacial disruption. Lumps of included "boulder clay" were reported by Posnansky (1960) from a nearby site (2km SE) but have not been recorded here. Borehole and geophysical investigations in connection with earlier workings on Eggington Common (1.5 km S) showed that the gravels in that area occupy a series of sinuous channels. These are over 5m deep and form a dendritic pattern with an apparent drainage direction of E - W (ie opposite to the flow of the modern river). The borehole logs also record the occasional presence of pebbly red clays at different horizons within the gravel sequence. While the origin of these deposits is not clear, discontinuous surficial layers of pebbly clay exposed in shallow pits on Eggington Common have been interpreted as solifluction earths. Such records do not support the view that the Hilton Terrace had a conventional fluvial origin.

Recent temporary exposures have shown that the gravel patches along the lower Derwent valley are fequently very thin (1.5m) despite the relatively broad outcrops portrayed on the Geological Survey map (Sheet 141). In all exposures, the gravels show little sign of stratification and are invariably highly disturbed. They generally rest on an irregular surface of stiff red clay which itself contains isolated pebbles or small pockets of steeply inclined clasts in a zone up to 2m thick. Although the pebbly clay could represent a residual layer of "basal" till, its overall characteristics tend to indicate formation by intense cryoturbation of the Keuper Marl bedrock and overlying gravel.

The disturbed nature of the Hilton gravels appears to be a widespread characteristic. Disruptions at Hilton were reported by Deeley (1886) to descend "several feet". In this area, Armstrong (1939) noted the presence of "mushroom-shaped" intrusions of underlying gravel into an excessively contorted upper zone containing intensely fractured flints. These structures presumably correspond to the "festooning" that Stevenson and Mitchell (1955) noted in the top 1.5 - 3.0m at an adjacent locality and which may be interpreted as periglacial involutions. Further contortions have been described from the Lower Hilton Terrace at Willington by Posnansky (1960) but this site appears to have been somewhat unusual in that only the lower half of the section was affected. It is possible that the upper 2.5m of undisturbed even-bedded sand and gravel resulted not from interglacial fluvial activity as implied by Posnansky, but through the combined action of periglacial solifluction and seasonal meltwater in the Devensian cold stage. Such an interpretation would also explain the rather paradoxical absence of contortions from the Upper (ie older?) Hilton Terrace at an adjacent locality (Posnansky 1960) and the "obliteration" of the terrace edges described by Deeley (1886) and attributed by him to subsequent glacial action.

The available evidence strongly suggests that the Hilton Terrace is not merely the result of fluvial aggradation in a waning glacial episode. In contrast, the relatively level surfaces and simple morphology of the terrace gravels testifies to significant cryonival modification under

Devensian periglacial conditions. The "terraced" form is therefore midleading, and the features should no longer be regarded as simple morphostratigraphical units. The internal stratigraphy of the terrace sediments awaits further study.

P F Jones

REFERENCES

ARMSTRONG A L (1939) Palaeolithic man in the North Midlands. Mem. Proc. Manchr. Lit. Phil. Soc. 83, 87-116.

BENNETT F W (1929) Remarkable features in the Ulverscroft Valley. Trans. Leic. Lit. Phil. Soc. 30, 40-45.

BISHOP W W (1958) The Pleistocene geology and geomorphology of three gaps in the Midland Jurassic escarpment. Phil. Trans. Roy. Soc. Lond. B241. 255-305

BRIDGER J F D (1968) Remarkable features in the Ulverscroft valley; a reappraisal of the drainage history. Trans. Leic. Lit. Phil, Soc. 62, 73-77.

BRIDGER J F D (1975) The Pleistocene succession in the southern part of Charnwood Forest. Mercian Geol. 5, 189-203.

BRIDGER J F D (in press) The problem of discordant drainage in Charnwood Forest, Leicestershire. Mercian Geol.

CHANDLER R J (1971) Landsliding on the Jurassic escarpment near Rockingham, Northamptonshire. In IBG Special Publication no 3 (ed D Brunsden), 111-128.

CHANDLER R J (1976) The history and stablity of two Lias clay slopes in the Upper Gwash valley, Rutland. Phil. Trans. Roy. Soc. Lond. A 283, 463-492.

CLAYTON K M (1953) The denudation chronology of part of the Middle Trent Basin. Trans. IBG 19, 25-36.

CLAYTON K M (1953) The glacial chronology of part of the Middle Trent Basin. Proc. Geol. Assoc. 19, 198-207.

CLAYTON K M (1959) The geomorphology of the area around Melton Mowbray. E Midl. Geogr. 12. 3-8.

DEELEY R M (1886) The Pleistocene succession in the Trent Basin. Quart. Jnl. Geol. Soc. Lond. 42, 437-80.

DERBYSHIRE E & JONES P F (1980) Systematic fissuring of a matrix-dominated lodgement till at Church Wilne, Derbyshire, England. Geol. Mag. 117, 243-254.

DOUGLAS T D (1980) The Quaternary deposits of western Leicestershire. Phil. Trans. Roy. Soc. Lond. B 288. 259-286.

DURY G H (1951) A 400 foot bench in southeast Warwickshire. Proc. Geol. Assoc. 62, 167-73.

EASTWOOD T et al (1923) Memoir of the Geological Survey, Coventry sheet.

EDMONDS E A & WILSON V (1965) Memoir of the Geological Survey, Banbury and Edge Hill Sheet.

FORD T D (1967) Deep weathering, glaciation and tor formation in Charnwood Forest, Leicestershire. Mercian Geol. 2, 57-62.

FOX-STRANGWAYS C (1905) Memoir of the Geological Survey, the country between Derby, Burton on Trent, Ashby and Loughborough.

HALL A R (1979) Some new palaeobotanical records for the British Ipswichian integlacial. New Phytologist 81, 805-812.

HALL A R (1980) Late Pleistocene deposits at Wing, Rutland. Phil. Trans. Roy. Soc. Lond. B 289, 135-164.

JONES P F & STANLEY M F (1974) Ipswichian mammalian fauna from the Beeston Terrace at Boulton Moor near Derby. Geol. Mag. 111, 515-520.

KING C A M (1966) Geomorphology. In Edwards K C (ed) Nottingham and its region. Brit. Assoc. Adv. Sci. 41-59.

LE BAS M J (1968) Caledonian Igneous Rocks. In Sylvester-Bradley, P C & Ford T D (eds). The geology of the East Midlands. 41-58.

PERRIN R M S, DAVIES H & FYSH M D (1973) Lithology of the Chalky Boulder Clay. Nature 245, 101-104.

PERRIN R M S, ROSE J &DAVIES H (1979) The distribution, variation and origins of pre-Devensian tills in eastern England. Phil. Trans. Roy. Soc. Lond. B287, 535-570

POCOCK T J (1929) The Trent Valley in the glacial period. Zeit. fur Gletscherkunde 17. 302-318.

POOLE E G (1968) Some temporary sections seen during the construction of the M1 motorway between Enderby and Shepshed, Leicestershire. Bull. Geol. Surv. G.B. 28, 137-151.

POOLE E G et al (1968) Memoir of the Geological Survey, the geology of the country around Market Harborough.

POSNANSKY M (1960) The Pleistocene succession in the Middle Trent Basin. Proc. Geol. Assoc. 71 285-311.

RICE R J (1965) The early Pleistocene evolution of north eastern Leicestershire and parts of adjacent counties. Trans. I B G 37, 101-110.

RICE R J (1968) The Quaternary Era. In Sylvester-Bradley P C and Ford T D (eds). The geology of the East Midlands. 332-355.

RICE R J (1968) The Quaternary deposits of central Leicesterhsire. Phil Trans. Roy. Soc. Lond. A 262, 459-509.

SHOTTON F W (1953) The Pleistocene deposits of the area between Coventry, Rugby and Leamington and their bearing on the topographic developments of the Midlands. Phil. Trans. Roy. Soc. Lond. B 237, 209-260.

SHOTTON F W (1973) The English Midlands. In Mitchell G F et al A Correlation of Quaternary deposits in the British Isles. Geol. Soc. Lond. Special Rep. No. 4.

SHOTTON F W (1973) A mammalian fauna from the Stretton Sand at Stretton on Fosse, south Warwickshire. Geol. Mag. 109, 473-476.

SHOTTON F W (1976) Amplification of the Wolstonian stage of the British Pleistocene. Geo. Mag. 113, 241-250.

SHOTTON F W , BANHAM P H & BISHOP W W (1977) Glacial - inter-glacial stratigraphy of Quaternary in Midland and eastern England. In Shotton F W (ed) British Quaternary Studies. 267-282.

STEVENSON I P & MITCHELL G H (1955) Memoir of the Geological Survey, the geology of the country between Burton on Trent, Rugeley and Uttoxeter.

STRAW A (1963) The Quaternary evolution of the lower and middle Trent. E. Midl. Geogr. 3, 171-189.

WATTS W W (1903) A buried Triassic landscape. Geog. Jnl. 21, 623-636.

WATTS W W (1905) Buried landscape of Charnwood Forest. Trans. Leic. Lit. Phil. Soc. 9, 20-25.

WATTS W W (1947) Geology of the ancient rocks of Charnwood Forest.

WILSON J M (1870) On the surface deposits in the neighbourhood of Rugby. Quart. Jl. Geol. Soc. Lond. 26, 192-202.

WILSON J M (1875) On the probable existence of a considerable fault in the Lias near Rugby and of a new outlier of oolite. Quart. Jl. Geol. Soc. Lond. 31, 355-356.