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The Quaternary Deposits of Western Leicestershire

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THE QUATERNARY DEPOSITS OF WESTERN LEICESTERSHIRE

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CONTENTS

The Quaternary sequence of an area of 120 km^2, centred on Market Bosworth in Leicestershire, is described. The entire sequence is regarded as the product of the Wolstonian stage. The bedrock surface of the area shows the buried Hinckley valley, which opened southwards into the proto-Soar basin. The first evidence of sedimentation onto this surface in western Leicestershire is the Basal Till which betokens an ice advance prior to the accumulation of the extensive glacio-lacustrine member, the Bosworth Clays and Silts. This proglacial lake is interpreted as being the northern continuation of lake Harrison, which was initiated on the retreat and stagnation of ice, following the deposition of the Basal Till. A readvance of ice led to the deposition of a large sandur represented by the Cadeby Sand and Gravel and followed by a till sequence comprising the Pennine and Chalky Tills of northwestern and northeastern provenance, respectively.

The Quaternary members of western Leicestershire can readily be correlated with those described by Shotton in the Avon valley and have been matched with Rice's succession in the central Leicestershire area, thus extending the area over which the Wolstonian stratigraphy can be applied.

1. Introduction

A programme of field mapping was undertaken between 1973 and 1975 to determine the Quaternary succession in an area of 116 km² centred on Market Bosworth in the western part of Leicestershire.

Apart from the mapping of the Geological Survey officers (Fox-Strangways 1900; Eastwood *et al.* 1923), only the work of Harrison (1898) and, to a lesser extent, Deeley (1886) and Wills (1937) cast much light on this area, where considerable drift thicknesses are encountered. Harrison pointed to the loams in the Hinckley area as being direct evidence of a Lake Bosworth:

> 'The district mainly to the southwest of Charnwood in northwest Leicestershire and north Warwickshire...was surrounded in such a way by ice dams and high land that a considerable lake was formed in northwest Leicestershire extending from Hinckley to Market Bosworth and Ashby-de-la-Zouch.'

In the light of this present work, Harrison's findings were remarkably perceptive. While Deeley and Fox-Strangways interpreted the complex series of drifts as being the product of several cold periods, Harrison felt that there was no proof of any interglacial period and that the glacial deposits fell into one 'continuous but not unvarying period of cold, during which fluctuations of the ice front took place'.

The most significant development in the study of the Quaternary of the English Midlands was Shotton's 1953 paper, which demonstrated that the bedrock surface of much of the area indicated a very different topography from the present one. The considerable thicknesses of drift in northeast Warwickshire and southern Leicestershire conceal a buried sub-drift surface, which confirms that the main watershed of England (separating drainage towards the Seven *via* the Warwickshire Avon in the southwest from the eastward and northeastward draining Soar–Trent system and the rivers flowing to the Wash) has been displaced northeastwards by as much as 65 km during and after the period when these Quaternary sediments were deposited. The implications of this displacement were recognized in the reconstruction by Shotton of glacial Lake Harrison. Shotton (1953) mapped the Quaternary sequence in the Avon valley, which was later chosen as the type site for the Wolstonian stage (Shotton & West 1969). To the north of the main watershed in the Leicester area, Rice (1963, 1968) mapped a succession which he was able to match with the Wolstonian type area although this was largely beyond the northern limits of Lake Harrison as defined by Shotton (figure 1).

It was against this background that the investigations reported in this paper were set. First, it was felt that the Lake Harrison model proposed by Shotton should be tested by detailed mapping in the area near Market Bosworth, where Harrison (1898) first identified sedimentological evidence for his Lake Bosworth. Secondly, it was hoped to set up a lithostratigraphy for western Leicestershire, which could complement those of Rice and Shotton and thus extend the area in the English Midlands over which well-stratified Quaternary deposits could be recognized and an environmental reconstruction attempted for the northern part of the Lake Harrison basin.

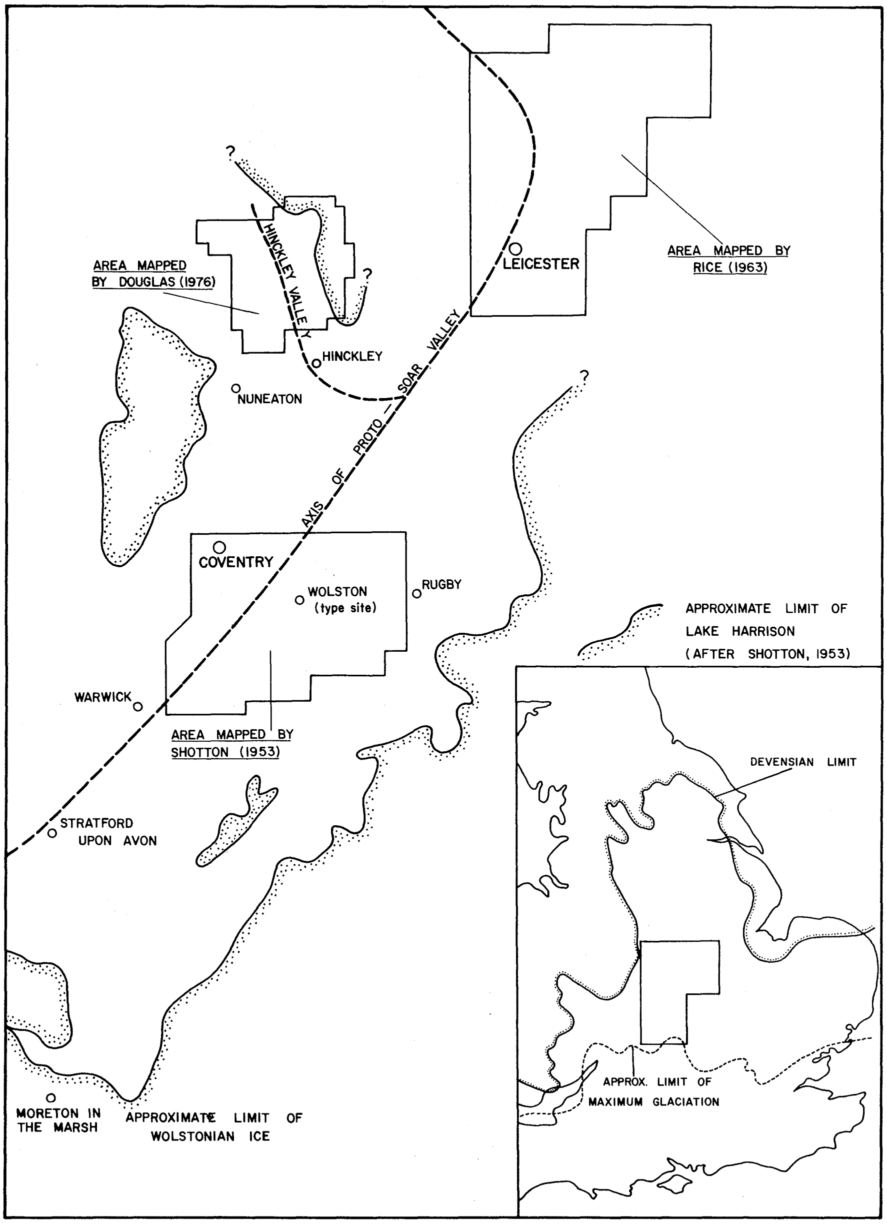

FIGURE 1. Location map.

Western Leicestershire south of Charnwood Forest exhibits a gently rolling, rural landscape. The area studied has a relative relief of less than 100 m and falls entirely within the Trent watershed. The majority of the area to the west is drained by the Sence and the Sence Brook, which head westwards into the Anker and thus via the Tame into the Trent. To the east, streams drain to the Soar. The drainage has been incised into the Quaternary beds, which are best preserved on the interfluves, with bedrock (almost entirely Mercian Mudstone) exposed in the valley bottoms of the lower reaches of the streams. This pattern has resulted in a fairly full succession of the drift being exposed on many hillslopes. The mapping has been accomplished by means of augering with a hand operated Dutch auger. This has permitted sampling of the drift to a depth

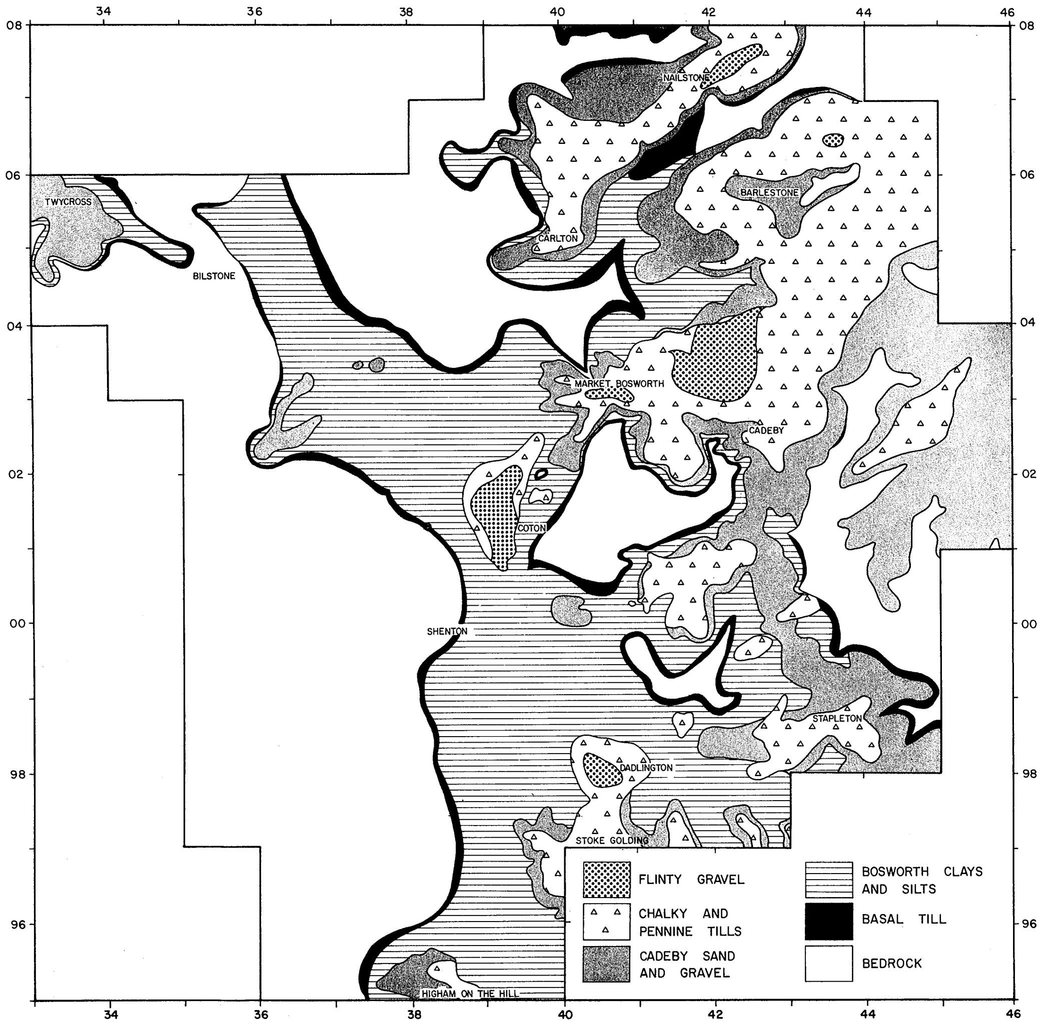

FIGURE 2. Map of the Wolstonian members of Western Leicestershire.

of 5 m, but by far the greatest number of holes were only drilled to about 1 m. The mean density of auger holes exceeded 20/km^2. Other information was provided by the only satisfactory sections in western Leicestershire, at the Cadeby sand and gravel pit, adopted as the type site (Douglas 1974) and at the recently opened pit at Kirkby Lodge, 2 km southeast of Cadeby. The borehole cover within the district is relatively sparse, but N.C.B. logs and mechanical auger records undertaken by the I.G.S. in connection with the re-mapping of the Atherstone sheet (155) proved useful (Ambrose & Brewster 1976). The original maps of the I.G.S. were surveyed by Fox-Strangways and often proved to be unreliable when subjected to close scrutiny in the field, particularly with regard to the outcrop of the glacial lake clays, which were grossly under-represented. Figure 2 is the result of field mapping and shows the distribution of the Quaternary beds.

2. The bedrock surface

A reconstruction of the bedrock surface is an essential preliminary to the meaningful description and analysis of the drift succession, for it represents an approximation to the surface at the start of the cold period during which the drifts were deposited. Shotton (1953) presents a regional map of the Avon valley and adjacent catchment areas, and Rice (1972) has compiled a map for the county of Leicestershire. In western Leicestershire, Shotton identifies a Market Bosworth arm to Lake Harrison, which occupies the Hinckley Valley, a major left-bank tributary to the proto-Soar (figure 1).

The detailed evidence is in close agreement with these earlier reconstructions (figure 3). Many auger holes passed through drifts into bedrock, thus fixing the position of the interface. Other subsurface information was obtained from borehole records. Where postglacial stream incision has resulted in valleys with a narrow strip of bedrock exposed in the valley floor, it is a relatively simple matter to interpolate the bedrock surface. However, where stripping of the drift cover has been more extensive, as in the western part of the study area, and the amount of bedrock surface lowering is unknown, such reconstructions are much more tentative, although there is sufficient information to establish the general pattern of the surface.

The geometry of the reconstructed surface is relatively simple but radically different from the present land surface (figure 3). The col at the head of the Hinckley valley lies near Shackerstone, where bedrock is encountered near and at the surface at marginally over 90 m (300 ft). To the north, a valley, now occupied by the Mease, trends northwestwards towards the Tame. The Hinckley valley is aligned from north–northwest to south–southeast, its floor shelving gently at a mean gradient of 2.4 m/km over the 13 km between Shackerstone and Stoke Golding; it then assumes a rather gentler gradient near its confluence with the proto-Soar. A boring at Stoke Golding proved 41 m of drift, and places the rockhead at 66 m (317 ft) O.D. Some of the well records and boreholes near Hinckley show similar thicknesses of drift as the buried Hinckley valley widens to merge with the trunk proto-Soar (Pickering 1916). Several shallow valleys are tributary to the Hinckley valley, notably on the eastern side.

The pattern of the bedrock surface describes an integrated system of drainage, with one isolated anomaly, which is termed here the Kingshill depression. Fox-Strangways (1907) quotes an old boring which was put down at Kingshill Spinney (SK 383016) to investigate the southern edge of the concealed coalfield. On the manuscript six inch geological map, the position of the borehole is marked and the following record is annotated:

	thickness	
	m	ft
soil	1	4
brickclay	28	93
sand	2	7
red marl		

The problem arises in reconciling the level of rockhead (about 53 m O.D.) recorded by this boring with any bedrock surface that could be regarded as supporting an integrated drainage system. The bedrock floor of this depression is 24 m below the minimum level to the general surface at this point. Only 590 m from the site of this boring, field mapping has revealed bedrock at the surface, indicating that at least one side of the depression must have steep bedrock sides. Whatever the origin of the depression, whether it be an example of subglacial glaciofluvial activity or of direct glacial scouring, it provides the only known example in western Leicestershire of modification of the bedrock surface prior to the depositional events recorded in the following section.

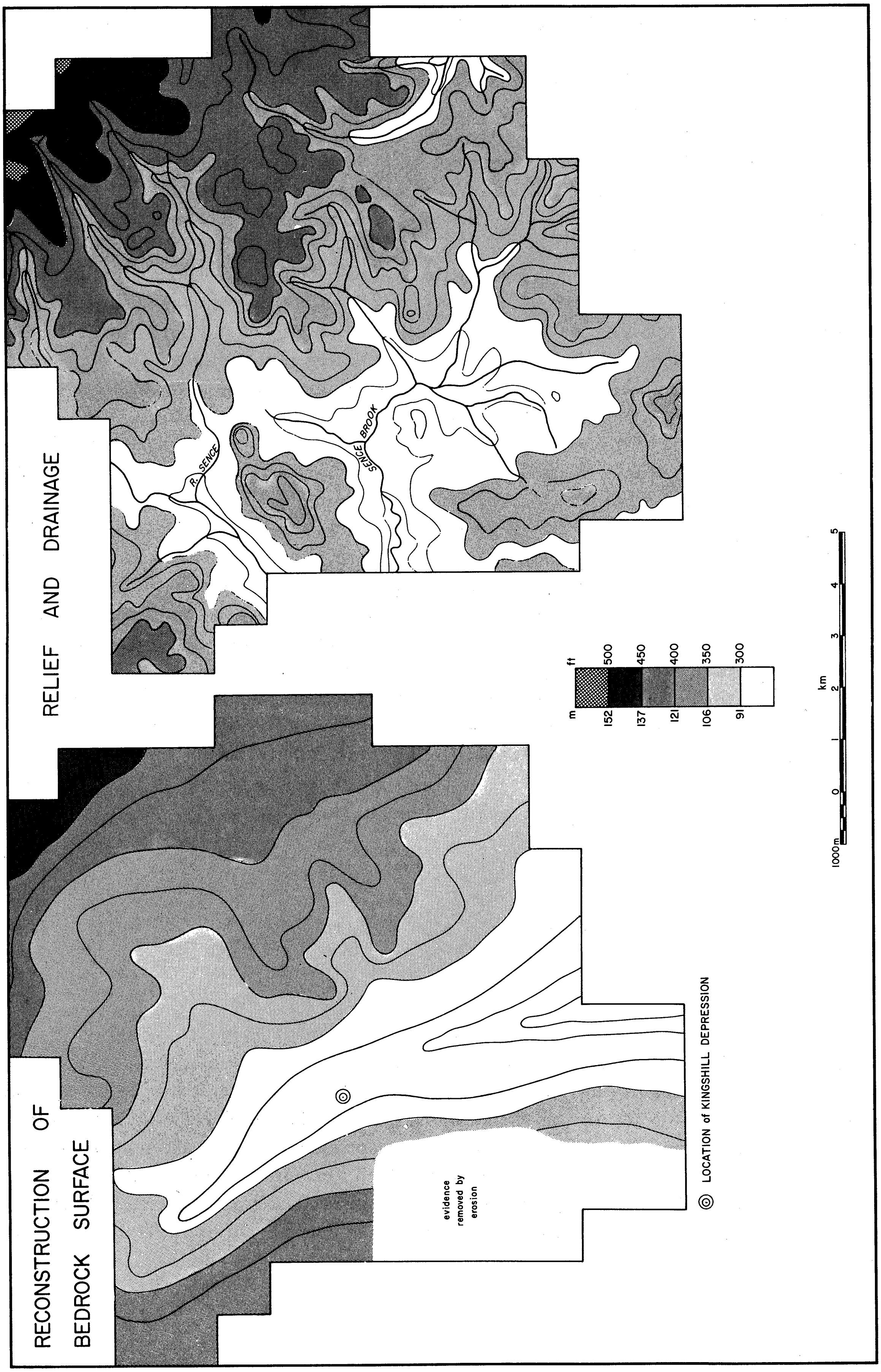

FIGURE 3. Bedrock surface and present relief.

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3. The lithostratigraphy

The pattern of the drift types in western Leicestershire demonstrates a markedly stratified sequence, which is particularly well developed in the vicinity of Cadeby. Six members have been recognized on lithostratigraphic grounds:

(*f*) Flinty Gravel,
(*e*) Chalky Till,
(*d*) Pennine Till,
(*c*) Cadeby Sand and Gravel,
(*b*) Bosworth Clays and Silts,
(*a*) Basal Till.

As only members (*c*), (*d*) and (*e*) are exposed in the Cadeby pit, a traverse of auger holes was run from the adjacent interfluve crest downslope until bedrock was reached. The height relation of the beds is shown in figure 4.

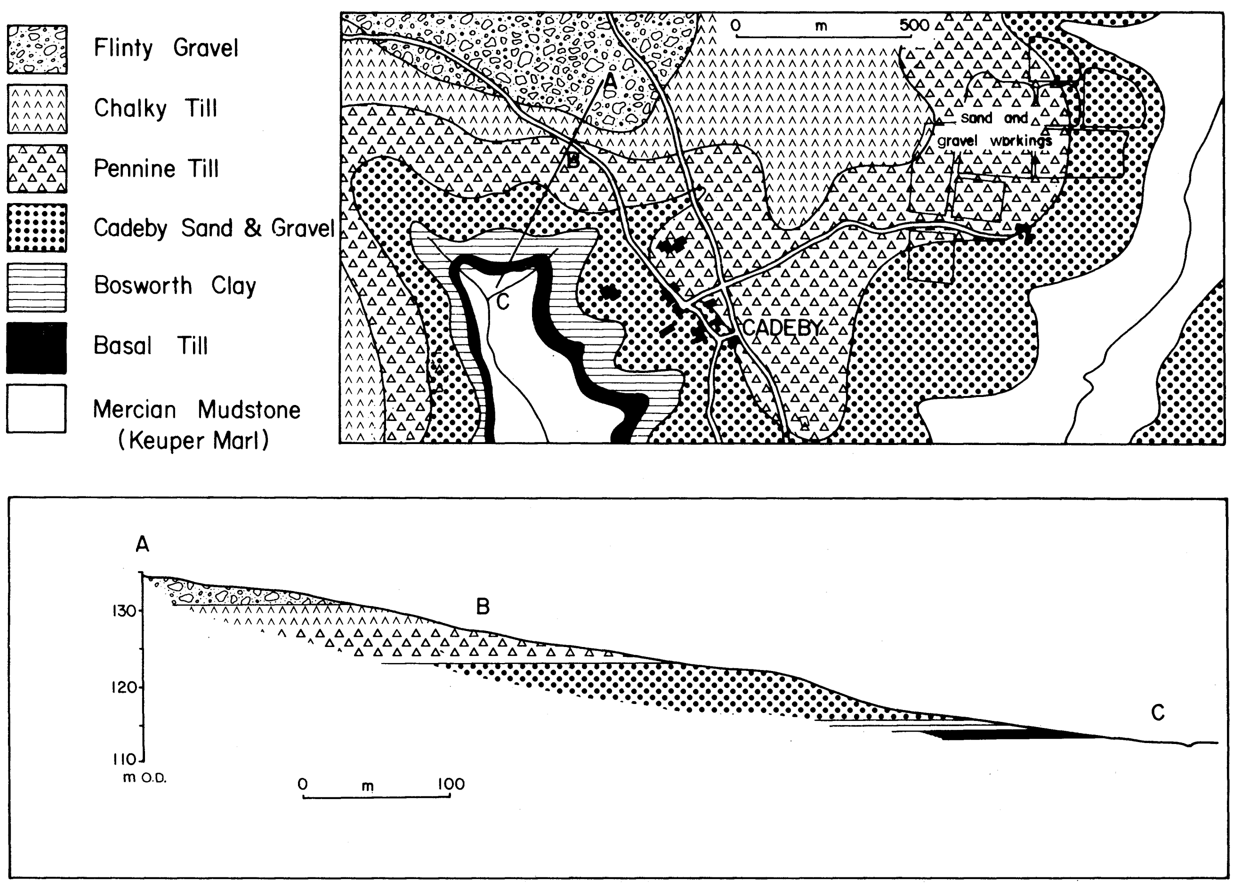


Figure 4. Cadeby type site: map of drifts and augered section.

(*a*) *The Basal Till*

At the type site, the Basal Till is represented by a thin band no more than 1 to 2 m thick, which rests with a sharp junction on Mercian Mudstone. No good sections are known to show the till in the study area, but some drainage ditches show its contact with the bedrock and enable its thickness to be measured. Where the till is thin, as it frequently is, auger holes have to be closely spaced to detect it. The sides of one such ditch at Sutton Wharf (SP 432994) exposed the junction between drift and bedrock at about 100 m O.D. The Basal Till was 2 m thick and rested on a sharp contact of undisturbed marl. Some few metres downslope, beds of skerry within the red mudstones showed no disturbance. The till matrix was brown (7.5YR 4/2), probably indicating a high proportion of reconstituted marl. The contained clasts included Bunter Pebbles and Triassic sandstones and siltstones with smaller amounts of Carboniferous material. The Basal Till is here overlain by brown, stoneless lake clays. At Stapleton Fields (SP 424991) an overgrown stream section revealed about 4 m of till, floored by Mercian Mudstone and overlain by stoneless clays. The till is unbedded and packed with erratics, coal fragments being particularly numerous, as are other clasts of a generally local or 'northern' provenance. An auger hole sunk upslope from the stream section showed that the junction with the stoneless clays was not a very sharp one, clasts increasing in frequency through a depth of 1 m between the completely stoneless clay and the fully developed till.

There would appear to be two facies of the Basal Till; the most widespread is that with a red–brown matrix which has been mapped as the basal member of the drift succession in the central and western parts of the study area. However, occupying the same stratigraphic position in the vicinity of Nailstone and Osbaston Hollow, chalk fragments are contained within a till of variable matrix type, which ranges from a Trias-rich colour to the grey–brown associated with the chalky boulder clay. This latter facies is very restricted.

Mechanical analyses of the Basal Till are summarized below (figure 5). The fraction finer than 2 mm shows poor sorting, which readily differentiates the till from the well-sorted lacustrine material which frequently overlies it (the Bosworth Clays and Silts). The Basal Till is the first indication of sedimentation onto the bedrock surface in the area. Its outcrop shows that it drapes the preglacial relief as a veneer of variable thickness. The numerous erratics within it would strongly suggest that it was not a solifluction deposit, for even if such erratics could have been provided by the dissection of an earlier drift sheet, there is no recorded remnant of such a deposit anywhere in Leicestershire. Further, its textural similarities with the Pennine Till (figure 5), which the most widespread facies closely resembles, argue for interpretation as till. Confirmatory evidence of the till is provided by borehole logs from Stoke Golding and Hinckley, which figure red stony clays immediately above bedrock. Near Hinckley, records indicate that the till is between 1 and 10 m thick (Eastwood *et al.* 1923).

(*b*) *The Bosworth Clays and Silts*

The Basal Till is succeeded by a series of nearly stoneless clays and silts, which locally can constitute the thickest member of the series in western Leicestershire. The thickest records of the deposit have come from sites near the axis of the Hinckley valley, where 35 m have been proved in boreholes and a total thickness of 48 m can be estimated from auger traverses and interpolation between boreholes. These lake deposits thin against the rising bedrock slopes away from the centre of the Hinckley valley. The highest points where the clays are encountered are at Twycross (119 m), Wellesborough (115 m) and, on the opposite side of the basin, along a line that curves southeastwards from Barton-in-the-Beans through Osbaston to Cadeby and Stapleton, where they commonly reach 110–115 m (figure 6). Above these limits the Basal Till is overlain by the Cadeby Sand and Gravel.

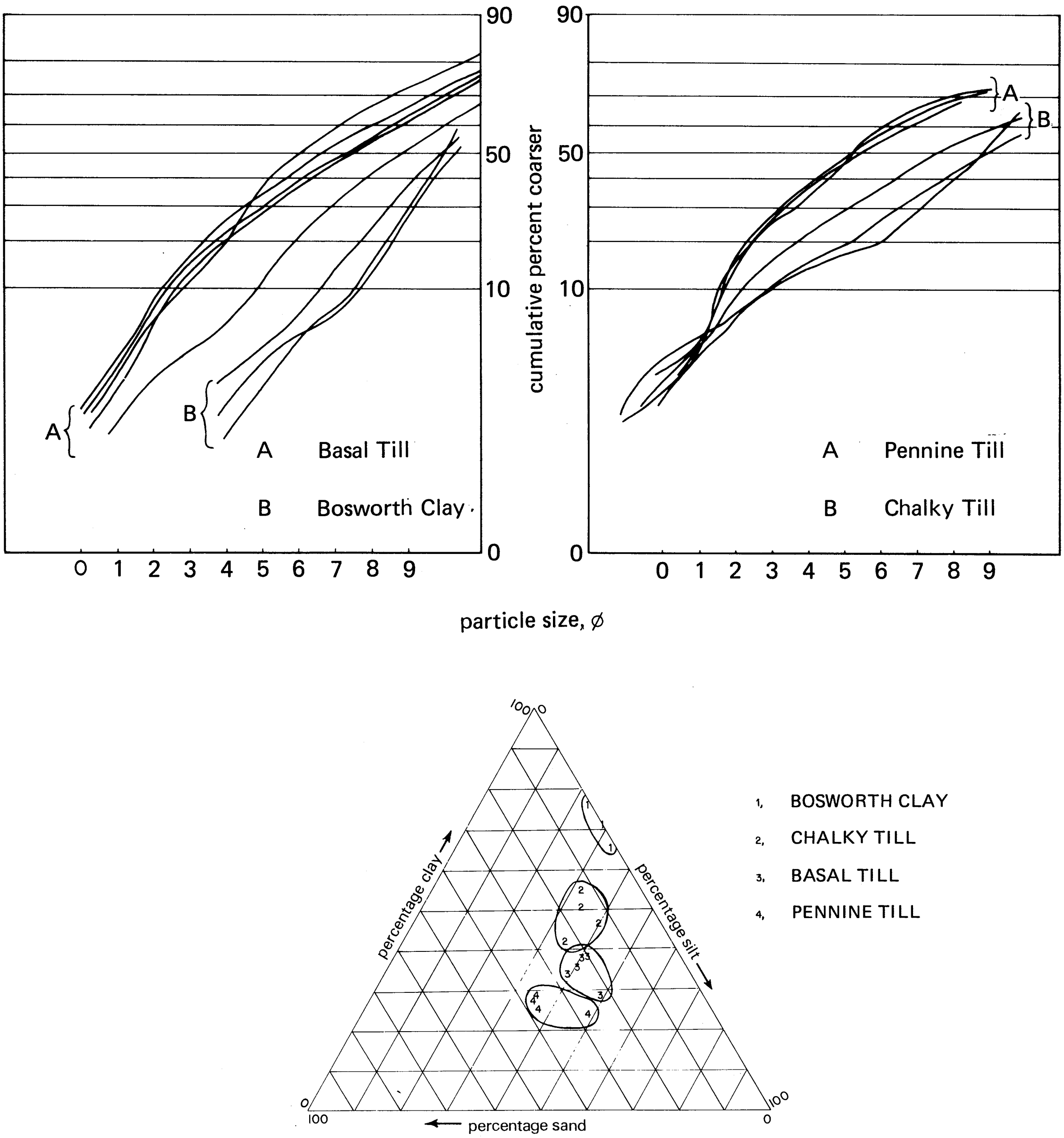


FIGURE 5. Results of mechanical analyses.

The name of Bosworth Clays and Silts has been adopted as a suitable local one which also recalls the Lake Bosworth of Harrison, subsequently refined by Shotton (1953) and renamed Lake Harrison. It was Harrison (1898) who originally recognized 'loams' in the area and was the first geologist to attribute a lacustrine origin to them. In the Geological Survey memoir to the Atherstone sheet, Fox-Strangways (1900, p. 38) noted that: 'At Bosworth Wharf, Shenton, Stoke Golding and further south a great part of the clay is free from stones and is more the character of a brickearth, containing sandy and loamy bands and a great profusion of the small calcareous lumps known as "race". The mapping of the lake deposits by Fox-Strangways does, however, underestimate their true extent, which has been revealed by augering. Eastwood *et al.* (1923) reported brown laminated silts and clays in the Hinckley and Bedworth areas, but mapped them as boulder clay.

The cutting of the abandoned railway line to the west of Higham on the Hill station (SP 377957) exposes the lower edge of the Bosworth Clays and Silts resting on Basal Till. The clays are plastic and completely stoneless, with no clear signs of laminations. They are brown (7.5 YR 4/2). Further north at Shenton, where the railway cuts through the western slopes of Ambion Hill, the east wall of the cutting displays up to 10 m of brown plastic clays. In places the clays are laminated with silt partings, elsewhere they are more massive and structureless. No dropstones or other inclusions were found here, but this overgrown exposure demonstrates the consistent texture and undoubted stillwater origin of the deposit.

The thickest recorded Bosworth Clays and Silts were found at a boring at Basin Bridge Farm near Stoke Golding (SP 395961).

	thickness/m	depth/m
soil	0.30	
red clay	1.83	2.13
dark red clay	1.52	3.65
sand and gravel	1.83	5.48
blue clay	2.59	8.07
dark red clay	2.44	10.51
sand and gravel	2.29	12.80
red clay	1.30	14.10
red sand	2.21	16.31
soft red clay	6.55	22.86
soft blue clay	9.75	32.61
soft brown clay	2.44	35.16
stiff red clay	3.05	38.21
Mercian mudstone		

The height of rockhead in this boring is estimated to be 69 m (225 ft) O.D. Although two minor beds of sand and gravel are recorded, this is not regarded as being inconsistent with the interpretation of the top 35 m (125 ft) as being Bosworth Clays and Silts in view of the interstratified sands and gravels encountered within the formation at other locations. The 'stiff red clay' immediately above rockhead may be Basal Till. Prominent beds of sand within the clays have been recorded at Harpers Hill, between Dadlington and Stapleton, at Lodge Farm (SP 398989), Greenhill Farm (SP 407992), where the sands form a gentle knoll, and less than 0.5 km away, where sands are exposed, at the same height above O.D., in the canal cutting near the Poplars (SP 412987). In the northern part of the study area similar sandy beds have been recorded at Hill Farm, Bilstone (SK 362053) and Sibson. Nevertheless, clay is by far the dominant lithology and samples have yielded the results of mechanical analyses presented in figure 5.

More recent mechanical auger holes confirm the widespread nature of the lake deposits (Ambrose & Brewster 1976). At Hoo Hills (SK 371037) 17 m of dark chocolate clays were recorded below terrace gravels. The base of the clays was not found.

(*c*) *Cadeby Sand and Gravel*

On top of the Bosworth Clays and Silts lies the very extensive Cadeby Sand and Gravel. The member has been worked in many small sand pits, now obscured, but the most illuminating sections are in the larger pits, near Cadeby, operated by Tilcon.

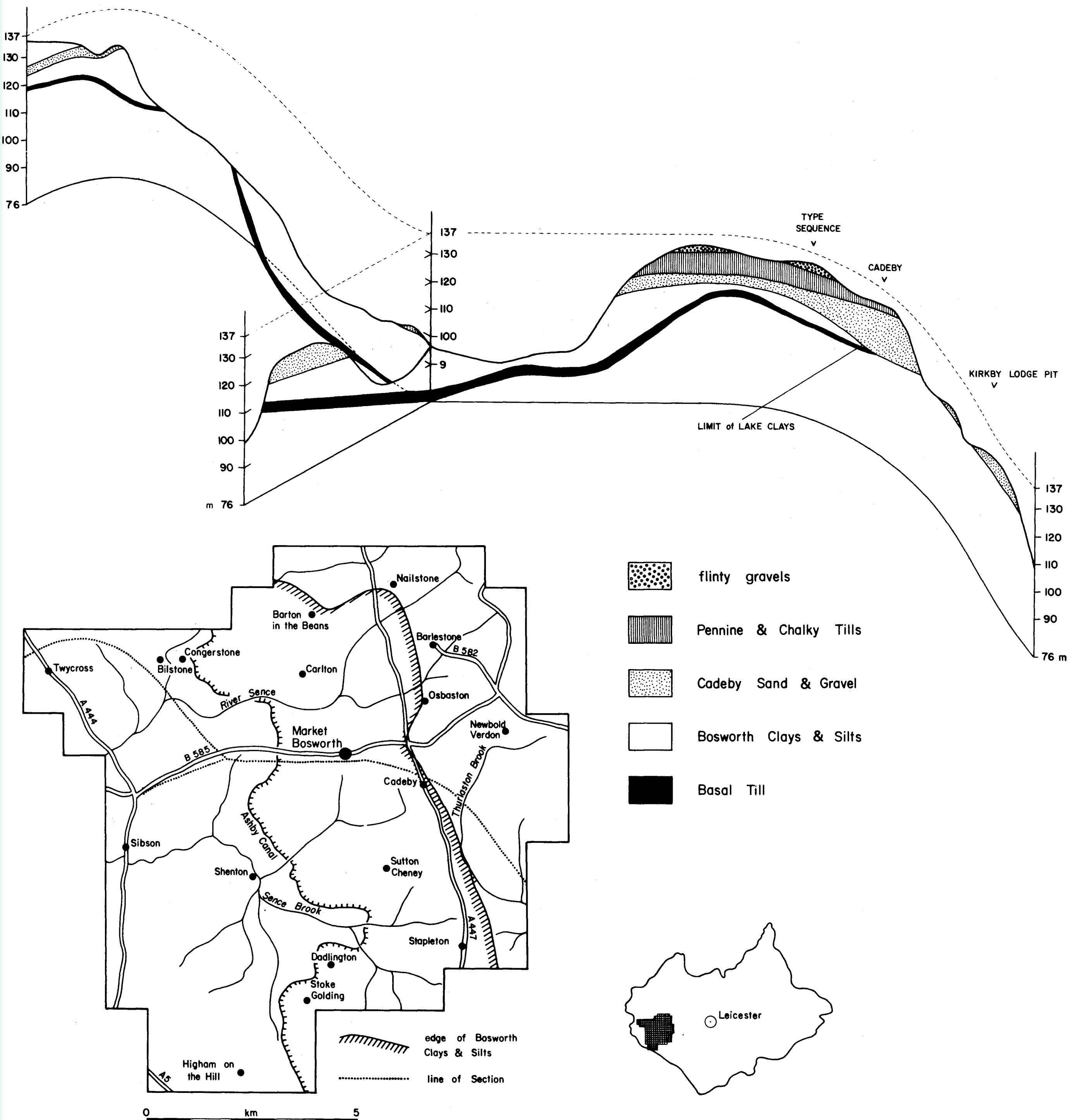


Figure 6. Calculated section through the Wolstonian members.

Previous authors have distinguished several beds of gravel and have differentiated them, along with the remainder of the drifts, on the basis of the provenance of the constituent clasts. The division has usually been drawn between drifts containing Jurassic and Cretaceous rocks and those in which only pre-Jurassic rocks are prominent. On this basis it is possible to identify the gravel facies as either 'flinty' or 'pebbly' (quartzose), the latter referring to Bunter pebbles. There are clear difficulties in applying these terms quantitatively, for those beds that have often been described as 'flinty' gravels may reveal a dominance of Bunter pebbles, the diagnostic feature being whether or not flints occur in significant numbers. As the classification here is a lithostratigraphic one, the Cadeby Sand and Gravel formation is defined as a nearly continuous horizon of sand and gravels; their composition is variable, but in most cases it is the 'pebbly' gravel described by other workers.

The sequence exposed at Cadeby in 1974 has been described by Douglas (1974). Subsequently, the working faces have shifted to Kirkby Lodge, where essentially similar sections have

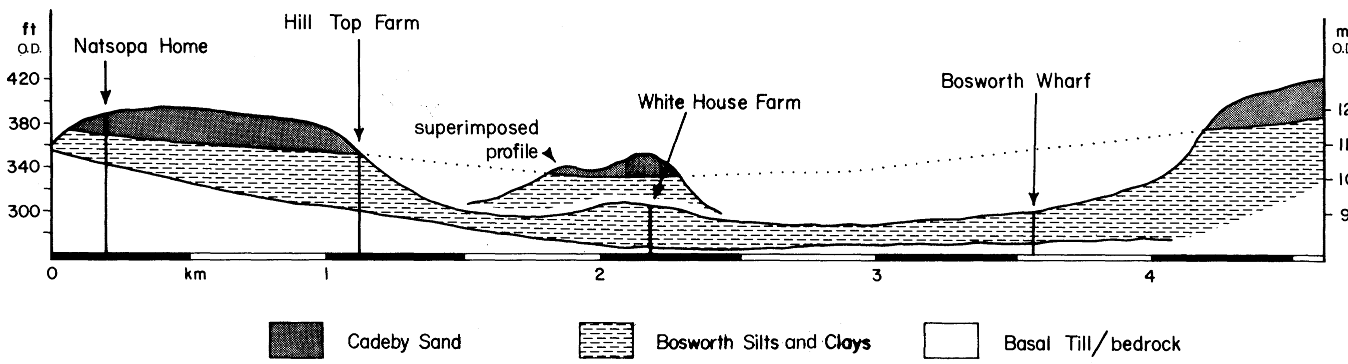


FIGURE 7. Section from Wellesborough to Market Bosworth to illustrate the compaction of the Bosworth Clays and Silts.

been revealed. The lowest beds exposed are brown silts and fine sands. Layers of coal fragments pick out level-bedding. Some of the sandy layers are cross-bedded. These silty sands are followed by a well marked series of medium and coarse sands, each bed showing laminar cross-stratification. The sands average 3 m in thickness, are free from inclusions of till or other heterogeneous material and grade upwards into gravels that in places are cross-bedded but tend to be poorly bedded and ill sorted. This coarse-up sequence is a characteristic of this member throughout western Leicestershire and is traceable with a hand auger and apparent from borehole records.

In those areas where the surface rises above the limits of glacial Lake Harrison to the north and east of the study area, the sands and gravels overlap the Bosworth Clays and Silts onto Basal Till and in some places bedrock; thus in many places the feather-edge of the Bosworth series is buried (figure 6). Along the valley of the Thurlaston Brook, hillslope auger traverses revealed a narrow outcrop of the Bosworth Clays and Silts overlain by sands, whereas to the east the sands rest on Basal Till and bedrock, the valley incision having removed the feather-edge. The relation between the Cadeby Sands and Gravels and the underlying Bosworth Clays and Silts is important because the height of the interface has been largely controlled by post-depositional compaction of the lake clays. Borehole and augering data have been used to draw a section (figure 7) which illustrates the form of the compaction between Wellesborough and Market Bosworth.

In an attempt to explore the shape of the surface given by the top of the lacustrine material, 64 points, at which the height of the Bosworth Clays and Silts/Cadeby Sand and Gravel interface had been measured, were used to compute trend surfaces that could model the characteristics of this horizon. (figure 8). The level of significance for the increment of variance explained by the cubic surface over the quadratic was less than that for the same quantity for the quadratic over the linear surface; thus the quadratic surface was used as the most appropriate model. Although the pattern of residuals from the quadratic surface displays some autocorrelation, the significance of the quadratic surface is great enough to enable meaning to be attached to the trend model (Unwin 1975). The effects of compaction are clearly likely to have been greatest where the lake basin was deepest; this relation is borne out by the quadratic surface, the axis of the trough almost exactly paralleling the centre of the reconstructed bedrock valley.

The outcrop of the Cadeby Sand and Gravel is shown in figure 2. From Nailstone in the north to Stoke Golding in the south, the outcrop parallels the valley sides. To the west, this member is found as a number of small outliers at Twycross, at Wellesborough and Hoo Hills and at Higham on the Hill. The outcrop is usually marked by a small scarp, which makes field mapping somewhat easier. A spring line is characteristic of the lower edge of the outcrop, but in some areas a veneer of sandy, washed material masks the clays downslope from the sand and gravel outcrop. Good examples of the morphological control exercised by this sub-horizontal sheet of sand and gravel are the north-facing slopes of Ambion Hill (SK 403002), where the scarp is quite pronounced, and the caps of sands on the Hoo Hills (figure 7).

A stone count taken from the gravels exposed at the Cadeby pit revealed a dominance of Trias-derived materials with smaller admixtures of Carboniferous and Jurassic/Cretaceous clasts (table 1). The latter are represented by flints, oolite, ironstone and Liassic limestones. This pattern is characteristic of the Cadeby Gravels, but there are patches within the formation that yield distinctly higher percentages of flints and associated 'eastern' material (notably to the west of Nailstone Village). The continuity of the member within the study area and its demonstrable continuation outside it make it a particularly valuable interstratified marker horizon to which other drifts may be related as either inferior or superior; thus, as will be seen below, its identification is critical in any regional correlation.

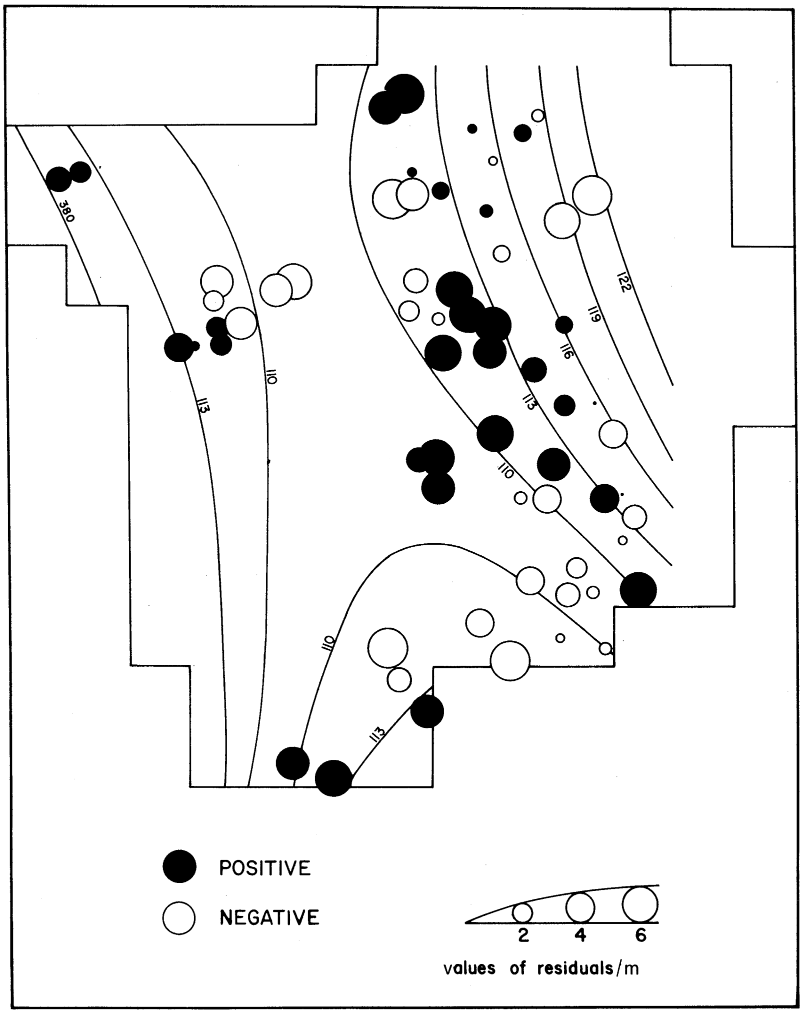
TABLE 1. STONE COUNTS (PERCENTAGES)

	Cadeby Gravel	Pennine Till	Chalky Till
Carboniferous	6	5	0
Bunter pebbles	32	53	13
Triassic sandstone	34	26	5
Jurassic and Cretaceous	7	15	81*
others	1	1	2

* This total can be subdivided: chalk, 38; flint, 12; Jurassic (mainly oolite, ironstone and Lias limestone), 31.

(*d*) *The Pennine and Chalky Tills*

Capping the higher ground along the watershed between the Soar and Anker are tills that rest on the Cadeby Sand and Gravel. Fox-Strangways recognized several spreads of boulder



TREND SURFACE STATISTICS

	surface order			
	1	2	3	4
variation explained by surface (%)	32.7	55.4	65.7	85.0
variation not explained by surface (%)	67.3	44.6	34.4	15.0
coefficient of correlation	0.572	0.774	0.811	0.922

FIGURE 8. Map of quadratic trend surface and residuals.

clay. Much of this material has been interpreted here as being Bosworth Clays and Silts, but undoubted tills are present. He observed that 'the clay principally consists of local materials mixed with well-rounded quartzite and other pebbles: and generally contains, but not always, some fragments derived from the Jurassic rocks and chalk, the latter being in many places so numerous as to form a regular Chalky Boulder Clay'.

Two till lithologies are readily differentiated in the field: a till with a reddish-brown matrix, similar in characteristics to the Basal Till but occupying a much higher stratigraphic position

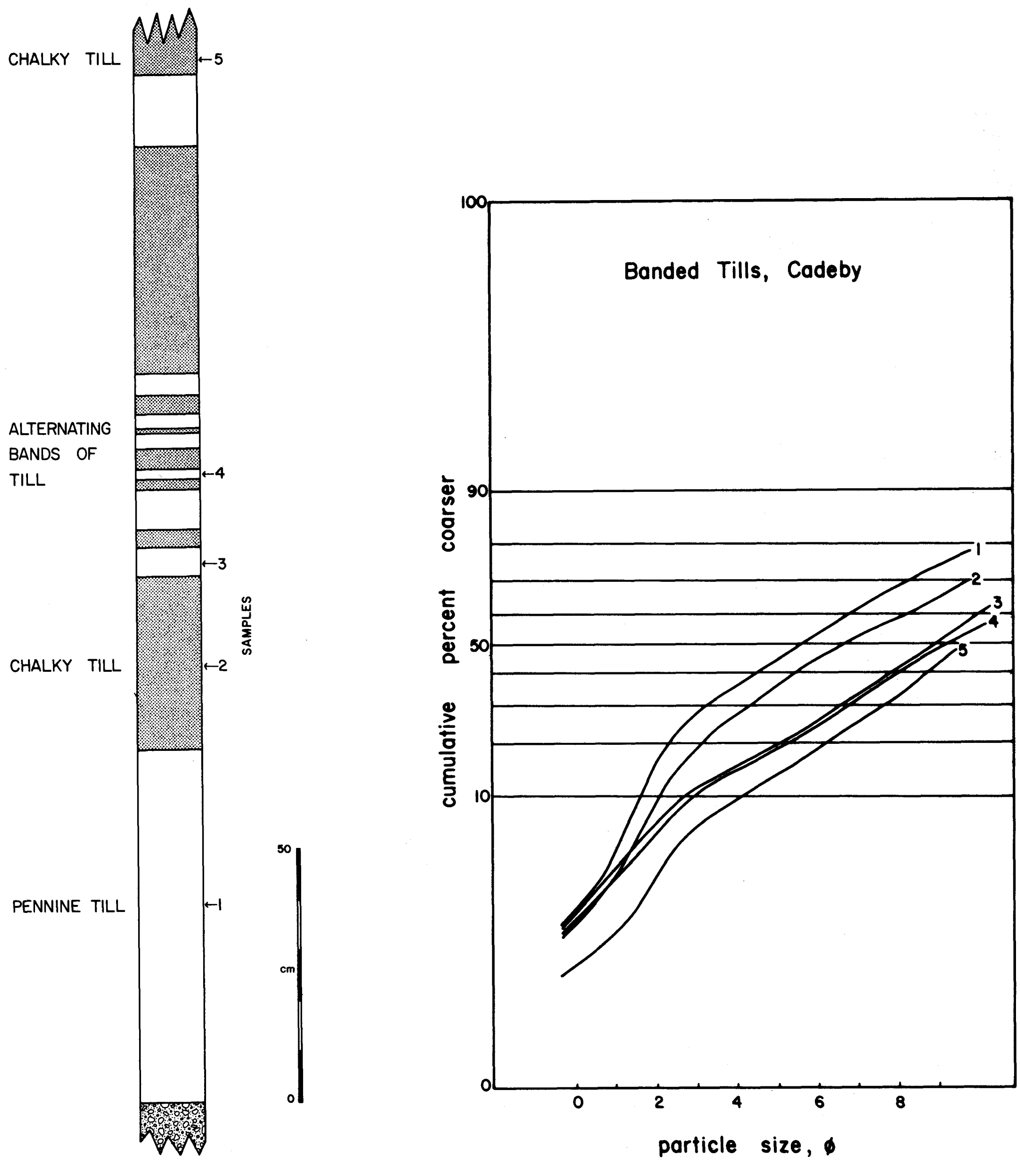


FIGURE 9. Column to show the banding of the tills at Cadeby.

and a till with a grey–brown matrix, packed with chalk and other 'eastern' erratics. The former has been given the name Pennine Till, following Deeley (1886), and the latter is the Chalky Boulder Clay described by other workers (Harmer 1928; Clayton 1953). Notwithstanding the marked differences between the counts of erratics (table 1), the tills are frequently interdigitated and exhibit a complex relationship with each other, which makes mapping them as separate formations problematical.

The Pennine Till is found consistently as a relatively thin outcrop to the north and east of Market Bosworth. It can be traced continuously from west of Cadeby, near the headwaters of the Sence Brook (SK 415022), to the higher ground east of Barlestone, at the extremity of the study area. Covering the Pennine Till in this area is an extensive sheet of Chalky Till. At Barlestone, a well record showed 12 m (40 ft) of till with chalk fragments; the boring was at

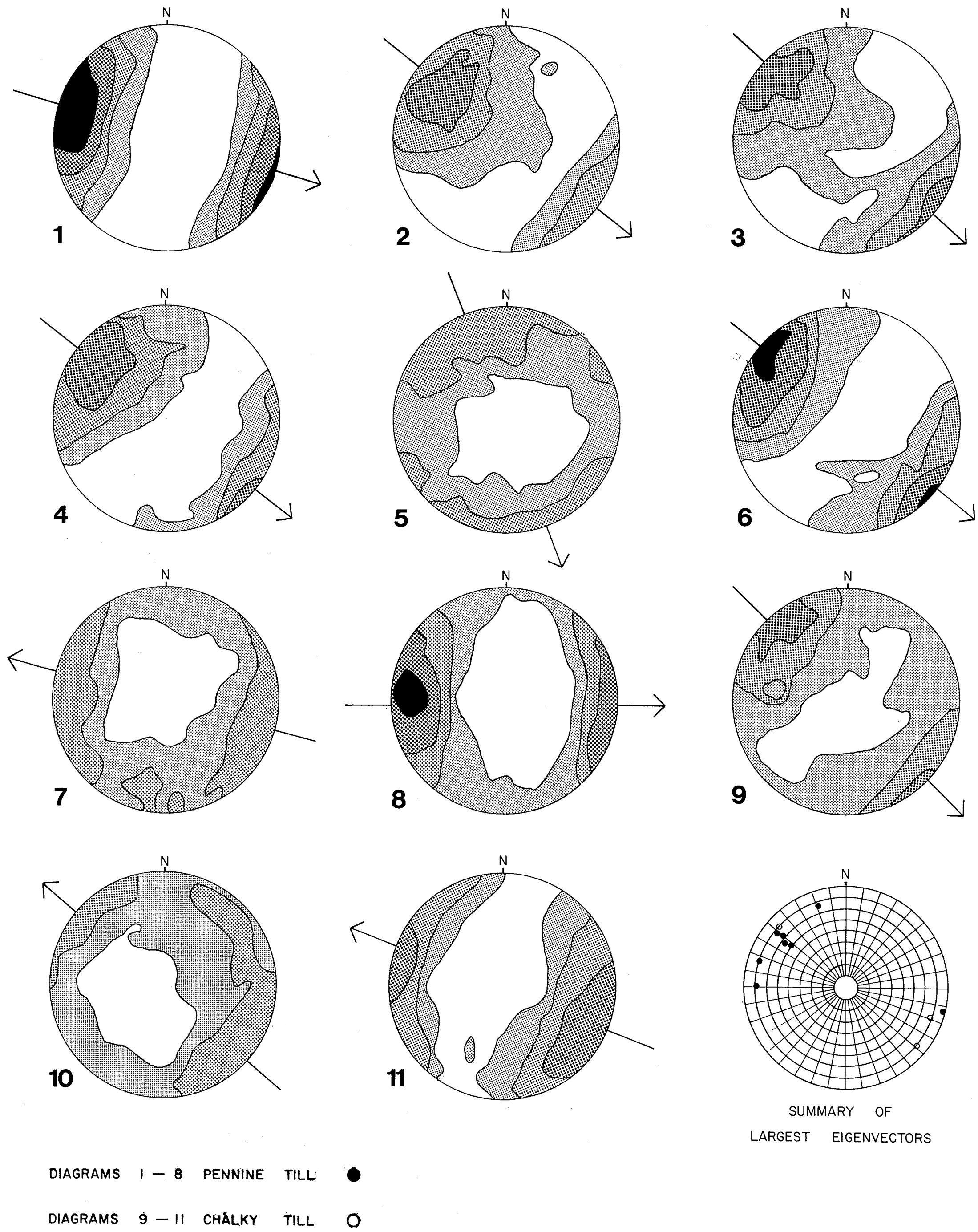


FIGURE 10. Till macrofabrics from Cadeby: upper hemisphere projections. Diagrams 1–8, Pennine Till; 1–9, Chalky Till. The arrows denote fabric preferred orientation (largest eigenvector). The contour interval is two standard deviations.

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139 m O.D. (455 ft) and was entirely within this till. The presence of the Chalky Till is indicated by plentiful flints in the topsoil and can be confirmed by augering. In a few areas, the tills extend well below the level of the Cadeby Sand and Gravel and rest unconformably on the Bosworth Clays and Silts. At Stoke Golding the Cadeby Gravel is followed by the Pennine and Chalky Tills, but near Dadlington the tills are found to rest on Bosworth Clays and Silts at relatively low heights. Closely spaced augering around Dadlington has revealed the pattern of this apparent overstep of the tills onto successively younger beds. The plane at the base of the Pennine Till truncates the sands immediately to the south of Dadlington village at a height of 104 m (340 ft). From the point at which the Ashby Canal is carried over the Tweed River (SP 411985), to the Manor House (SP 405980), the shortened sequence, with the sands and gravels missing, is displayed.

To the east, at Stapleton, Chalky Till is found on the highest point of the interfluve (SP 436987), where augering has shown that it rests on gravels. The same till sheet is found much lower down the slopes near Elms Farm (SP 429989) and the Bradshaws (SP 427981), where it appears to lie in a shallow trench that has been cut through the sands and stoneless clays. Isolated patches of till at Stapleton Wood (SK 430002) and Hangmans Hall (SP 427981) provide further examples of the till resting on members older than the Cadeby Sand and Gravel.

The two tills exposed in the Cadeby pit provided the data for the stone counts (table 1), macrofabric (figure 10) and particle size analyses (figure 5).

The complexity of the till sequence is demonstrated by the measured section taken from the northwest corner of a pit that has not been worked since 1975 (figure 9). The lowest layer of Pennine Till is compatible with that recorded elsewhere, and rests with a sharp junction on gravels which are, in places, cemented. Above this, in a zone extending for 1–2m, the tills appear to be stratified, with alternating thin bands of predominantly chalky and predominantly red till. The measured section depicts fifteen alterations between the two till lithologies. Some of these bands of till can be traced for 15m along the face of the pit and show a surprising degree of lateral persistence. One or two of the narrower bands thin out until they become almost imperceptible streaks. The banding is picked out by the alternating colours of the matrices, and, on inspection, the clasts contained within the till bands are consistent with those that would be expected from the two till types, very little chalk or flint being found in the red bands. Elsewhere in temporary sections at Cadeby these banded tills are associated with thin layers of laminated silts and sands.

Particle size analyses of samples from the measured section are shown in figure 9. The sample from the Peninne Till at the base of the sequence showed the characteristically low clay content (less than 30%) associated with this member of the succession. Samples from thin red bands of till, which were inter-stratified with the Chalky Till, showed a larger, more variable clay content, so that, in terms of mechanical composition of the matrix, differentiation between the bands was not possible, although, as has been established above, the colouration and erratic content of the bands indicate a different ultimate source. That the red colour of some of the bands is not so pronounced as that of the Pennine Till may be indicative of a limited mixing of the two matrix types. Nevertheless, the boundaries between individual bands are very sharp indeed and the grey chalky bands are not affected, in respect of colour and particle size, by mixing with the red material.

Suitable sites for till fabric analysis were few at the Cadeby pit. The thickness of till exposed here is generally no more than 3 m. The effects of weathering and cryoturbation can be observed to a depth of 2 m below the surface; consequently, only a limited layer near the base of the till sequence provided undisturbed samples. This constraint severely limited the samples of Chalky Till that could be used for macrofabric analysis. Furthermore, the nature of the clasts within the till is such that very low a/b axis ratios had to be accepted. Few blade- or rod-shaped particles occur in an erratic suite which has a large component of Bunter pebbles, skerry and subrounded chalk and limestone fragments. The macrofabric data were processed by means of the programs of Andrews & Shimizu (1966) to yield a mean vector, and of Mark (1973) to give the largest eigenvector. The results are presented in figure 10.

The eight Pennine Till fabrics show a preferred orientation that differs significantly from random at the 90% confidence level or greater, although there is variation between the fabric strengths of individual samples as measured by the largest eigenvalue. The distribution of sample preferred orientations is plotted in summary form on a polar equidistant net, which shows a clustering about 130 °. A very similar pattern emerges in the plot of resultant vectors from the vectorial analysis performed, as a check, on the same data. The horizon of Pennine Till from which samples 1–6 were taken shows no stratification, is unaffected by any banding of the tills, and no flow structures can be identified in it. Furthermore, five of the six fabrics show highly preferred orientations (greater than 99%), all of which trend in the same direction. Rose (1974) has employed similar reasoning to suggest that a till at Hertford is the product of lodgement. This would seem to be true at Cadeby for the majority of the Pennine Till which displays a consistent fabric type. Mark (1974) has proposed a scheme that relates fabric-forming processes and hypothetical fabric types, with a view to interpreting the results of three dimensional fabric studies. The Cadeby fabrics 1–6 show similarities to type A, which is regarded as the product of lodgement at the ice–till interface. As the independent evidence at Cadeby of the physical character of the Pennine Till does not accord with the structures that would be expected with flow or melt-out processes, it is concluded that the overwhelming evidence implies a dynamic subglacial depositional environment with an energy source acting from the northwest sector. If the alternative, that the ice movement could have acted from the southeast, is discounted, the mean dip of the pebbles is down-glacier. This is a somewhat unusual situation, but Saunders (1968) discovered a similar tendency for till macrofabrics in the Lleyn Peninsula. The variability shown by the Pennine Till fabrics 7 and 8 and by those taken from the Chalky Till is difficult to interpret. It would seem unlikely, however, that the banded tills and upper Chalky Till figured in the section at Cadeby were emplaced by lodgement. The associated sedimentological evidence of the banded tills strongly supports an interpretation of a complex ice sheet carrying debris of the Chalky and Pennine Till types and suggests that the complete sequence of tills, while being the product of a single ice advance, reveals evidence of melt-out and flow as well as lodgement.

(*e*) *Flinty Gravels*

A few patches of gravel lie above the Chalky Till. These are stratigraphically distinct from the Cadeby Sand and Gravel and contain numerous flints. Nowhere are they well exposed. North of Cadeby, at Bull in the Oak, a considerable spread of gravels caps the interfluve. At Dadlington, Fox-Strangways (1900) noted that a pit, now overgrown, contained a high proportion of flints, chalk fragments and oolite. The site is surrounded by outcrops of Chalky Till and thus the Flinty Gravels might once have been more extensive, having been largely removed by postglacial erosion.

4. Correlation of the Quaternary Deposits

Before turning to the environmental reconstructions which follow from the lithostratigraphical evidence outlined above, a consideration of the stratigraphic links with adjacent regions is provided. These correlations place the western Leicestershire evidence in a more meaningful general context of the Wolstonian of the English Midlands.

The west Leicestershire sequence observed at the Cadeby type site, although not everywhere fully developed, contains no major erosional unconformities and each member normally rests conformably on the subjacent one. Each member can be matched with a particular event and the implication of this unbroken sequence is that it provides a continuous record of the series of events from the ice advance which was responsible for the Basal Till to the deposition of the water-lain Flinty Gravels. Nowhere within this sequence are found any interglacial deposits and it is concluded that the whole sequence is the product of one cold period.

Table 2. Correlation of Wolstonian deposits

Stour and Evenlode	Itchen Valley	Wolstonian (revised nomenclature)	western Leicestershire	central Leicestershire
—	—	Dunsmore Gravel	Flinty Gravel	—
Chalky Till	Grange Clay	{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
—	Wolston Series	Bosworth Clays	Bosworth Clays and Silts	—
Purple Clay	Hodnell Clay	Thrussington Till	Basal Till	{Thrussington Till Glen Parva Clay
—	—	Baginton Sand	—	—
Quartzose and Paxford Gravels	—	Baginton–Lillington Gravel	—	Thurmaston Sand and Gravel
(Stretton Sands?)	—	—	—	—
Briggs (1973)	Bishop (1958)	Shotton (1976)	Douglas (1976)	Rice (1963)

(a) *Correlation with the Wolstonian type area of Shotton*

The equivalence of the Cadeby Sand and Gravel and the Wolston Sand underpins the correlation between the northern part of Lake Harrison and the sequence exposed by the Warwickshire Avon. In both areas this horizon is readily mapped and the formation has been preserved over much of its original extent (figure 11). The co-extension of the underlying clays is proven by the M69 bores (Shotton 1976) and thus the Bosworth Clays and Silts and the upper part of the Lower Wolston Clay can be correlated, as can the Basal Till and the lower part of the Lower Wolston Clay. Similarly, the Upper Wolston Clay and the Pennine and Chalky Tills can be regarded as approximate equivalents. It must be stressed that the correlation figured here is lithostratigraphic rather than chronostratigraphic. The boundaries between the members are almost certainly diachronous as glaciogenic, glaciolacustrine and glaciofluvial modes of deposition shifted across the Midlands. The amplified Wolstonian strarigraphy by Shotton (1976) can now be equated with the local succession in western Leicestershire (table 2).

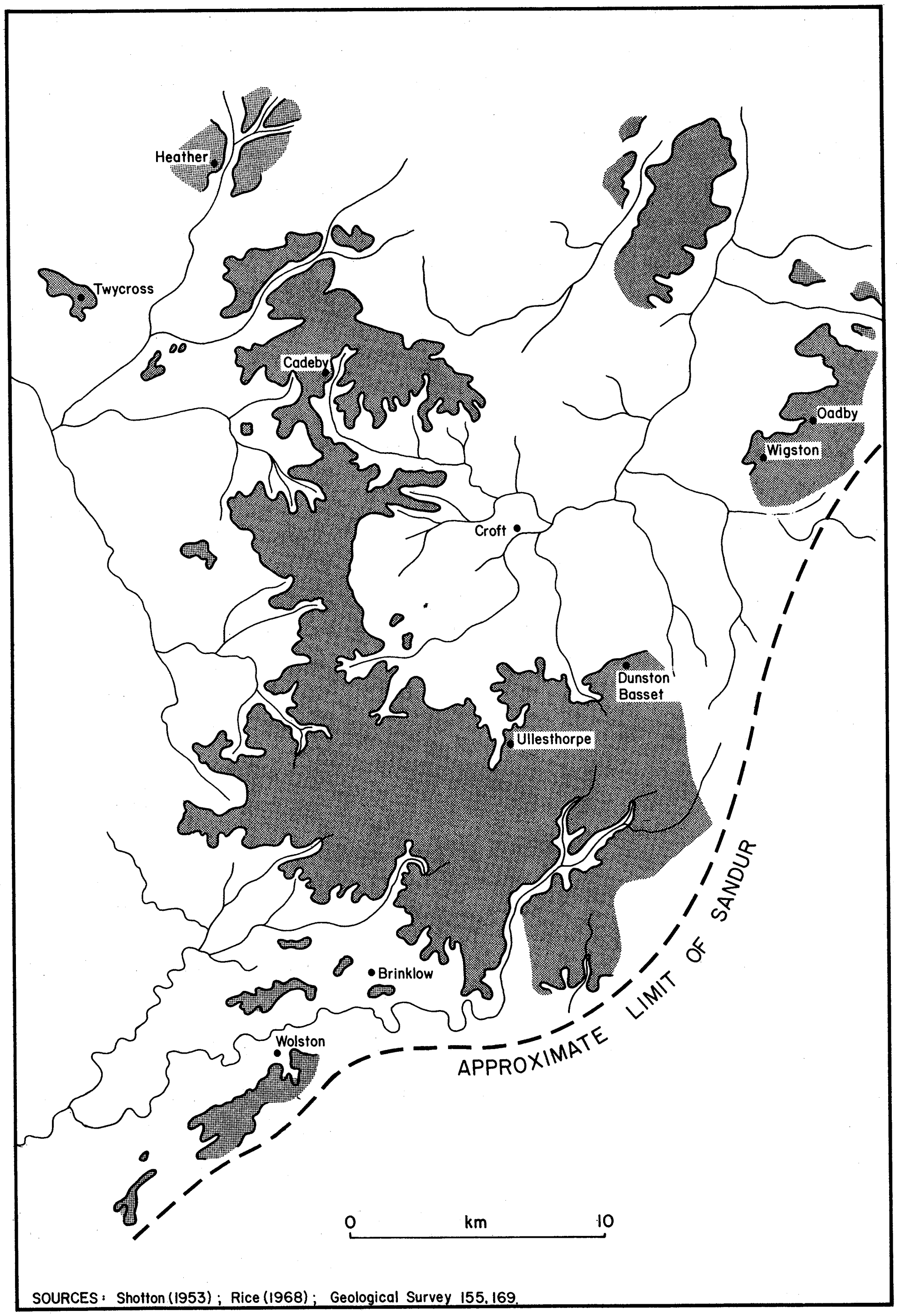

FIGURE 11. Remnants of the Cadeby sandur.

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(b) Correlation with the central Leicestershire area of Rice

The revision of Shotton's nomenclature incorporated several members that had been named by Rice (1968) as comprising the drift succession of central Leicestershire. The Wigston Sand and Gravel, which Rice has correlated with the Wolston Sand, can be shown to be the equivalent of the Cadeby Sand and Gravel. On the Beaumont Leys interfluve, which separates the Rothley Brook from the Soar Valley, Oadby Till rests on patches of Wigston Sand and Gravel. This till can be traced southwestwards beyond the western edge of Rice's map (Rice 1968, fig. 14), towards Leicester Forest East and Cross Lanes (SK 506019), where the till overlies the sand and gravel horizon that can be traced via Desford to the study area, where it has been mapped as the Cadeby Sand and Gravel. Thus the correlation of the main formations in the triangle between Leicester, Coventry and Market Bosworth is firmly based and it is possible to apply the revised Wolstonian nomenclature, with considerable confidence, to the area from Melton Mowbray in the northeast (Rice 1968) to the Anker valley in the northwest (Douglas 1976), across the main English watershed to the Warwickshire Avon (Shotton 1953). The significance of the western Leicestershire sequence in this regional context lies in the exceptional evidence of the glaciolacustrine event provided by the Bosworth Clays and Silts and the regular interstratified nature of the drifts, which is not so apparent in southern Leicestershire, where glaciogenic and glaciolacustrine beds show intricate relations of some complexity.

(c) Correlations with other areas

The internal consistency of these correlations within the Midlands cannot be extended, with the same certainty, outside the region, for, as Wills observed as long ago as 1937, 'the weakest links in the chain of evidence are those that connect the Midlands with other glaciated areas'. More tentative correlations can be made with those areas in the south of the Lake Harrison basin and immediately beyond it. For instance, the similarity between the sequences presented by Bishop (1958), for the Itchen valley, and by Briggs (1973), for the Stour/Evenlode area, leads to the links suggested in table 2.

The classic East Anglian succession has recently been the subject of renewed enquiry, with the suggestion that the Chalky Boulder Clay, which has traditionally been divided into the Lowestoft Till (Anglian) and Gipping (Wolstonian), may be the product of only one glaciation (Perrin *et al.* 1973; Bristow & Cox, 1973). If this view is accepted on stratigraphic grounds, then the palaeobotanic evidence is difficult to resolve. At the type site of Hoxne, the interglacial deposits overlie chalky boulder clay, whereas at Quinton and Nechells in the west Midlands tills that can be linked stratigraphically with the chalky tills of Warwickshire and Leicestershire overlie deposits of Hoxnian age (Kelly 1964). Yet, if the chalky boulder clay at Hoxne is regarded as Anglian, there is, by implication, a boundary, as yet unspecified, that represents an interglacial somewhere between the tills of East Anglia and that of the Midlands. This viewpoint seems to contradict the conclusion that 'the remarkable constancy of composition of its (chalky boulder clay) matrix over a considerable area makes it difficult to believe that the Chalky Boulder Clay could be the product of more than one glaciation' (Perrin *et al.* 1973, p. 102). The recent find of an Ipswichian site at Wing in eastern Leicestershire (Hall 1978) does not resolve the question as to the age of the underlying chalky till as either Wolstonian or Anglian. Given the variance of some of these interpretations, no attempt has been made to relate the Wolstonian deposits of Leicestershire with those of East Anglia, although the author inclines to the view of Shotton *et al.* (1977) that the Wolston (and therefore the entire west Leicestershire) sequence is post-Hoxnian and is therefore not the correlative of the Lowestoft Till, despite the similarities of the Chalky Boulder Clay, which is common to both.

5. Environmental Reconstruction and Chronology

(*a*) *The first ice advance*

The Basal Till is the first indication of sedimentation onto the sub-drift surface in the area. Although this Till is relatively thin in western Leicestershire, its discovery at several points, both within the area subsequently inundated by Lake Harrison and on the higher ground outside, leaves no room for doubt about the ice advance which it represents.

The sedimentology of the deposit indicates that it is texturally different from the Bosworth Clay, with which it could be confused in terms of colouration and stratigraphic position. The distribution of the deposit as a veneer draped over the sub-drift surface could lead to the view that it was a solifluction deposit and not the result of deposition from ice. The thickness attained by the deposit locally, i.e. at Nailstone, would seem to be too great for head, and the numerous erratics within it would argue against such a proposal. Even if such erratics could have been provided by the dissection of an earlier drift sheet, there is no recorded remnant of such a deposit anywhere within Leicestershire, and only very limited evidence within the Midlands as a whole.

There appear to be two facies of the Basal Till. The most widespread is that with a reddish matrix which incorporates Bunter pebbles, Triassic sandstone and a few Carboniferous erratics. At Nailstone, Osbaston Hollow and Stapleton, in the east of the study area, chalk fragments are included in a variable matrix which ranges from a Trias-rich red colour to the grey-brown associated with the Chalky Boulder Clay. The latter facies is restricted and patchy and can be compared with its correlative in central Leicestershire, the Thrussington Till, which contains lenses of chalky till and occasional flints (Rice 1968, p. 484). The provenance of erratics within the Basal Till is dominantly northern or northwestern and it is from this sector that the ice sheet is thought to have moved. The limited admixture of chalk and flint, attesting an eastern or, more probably, northeastern provenance, can perhaps be associated with a stream of ice moving across eastern Yorkshire and merging with the northwest ice in the middle Trent valley, where both chalky and red tills have been recorded at low points in the stratigraphic succession near Derby (P. Jones, personal communication). That the ice advance was a complex one, involving the transport of material of diverse provenance, there can be little doubt. The banding of the Basal Till, detected by augering at Nailstone Gorse, shows the interdigitation of the two till types and several exposures near Leicester indicate that chalky material was introduced to the area at an early stage in the till sequence.

A consideration of the bedrock topography of the Hinckley Valley shows that any ice advancing from the northern sector would be moving down-valley and the drainage of meltwaters in the direction of the proto-Soar would be unimpeded (figure 3). These meltwaters would be channelled towards the axis of the Hinckley Valley, but only in the log of a borehole at Stoke Golding is there a record of any material that could be interpreted as glaciofluvial immediately above bedrock (2 m of sand and gravel below Bosworth Clays and Silts). Although similar patches of sand and gravel, relating to the outwash of this ice sheet, could remain buried at depth, it may be that the overriding ice incorporated them within the Basal Till. It is worthy of mention that the Thurmaston Sands and Gravels, which represent an aggradation of water-lain sediments in the proto-Soar Valley, near Leicester, contain no Cretaceous material. Thus, any input of glaciofluvial material via the Hinckley tributary at this stage was strictly from an ice front producing 'non-eastern' material.

The progress of this Basal Till/Thrussington Till ice sheet is convincingly demonstrated, as far south as Leamington and Warwick, by the occurrence of till immediately above the Baginton Sand at the Wolston type site and elsewhere (Shotton 1976). It is probable that the chalk-rich Hodnell Clay of Bishop (1958) is also a product of the same advance, as it pre-dates the bedded deposits ascribed to Lake Harrison. Thus, this initial Wolstonian ice advance penetrated to a minimum of 140 km beyond the mapped area of western Leicestershire.

(*b*) *The establishment of Lake Harrison*

Where the Thrussington Till ice sheet moved contrary to the line of the pre-glacial drainage, local ponding of meltwaters would be expected. For instance, Tomlinson (1935) recorded laminated clays near Snitterfield, Warwickshire, and Rice (1968) identified the Glen Parva Clay in the Soar Valley below Leicester. Clearly, the free drainage to the south, along the Hinckley Valley, did not permit any such ponding in western Leicestershire, but the Bosworth Clays and Silts show, in the most dramatic fashion, the substantive nature of glaciolacustrine sedimentation that followed the withdrawal of ice.

The contact between the Bosworth Clays and Silts and the Basal Till is inadequately exposed, but at Stapleton Fields (SP 424991) the junction was not a sharp one: clasts increase in frequency through a depth of 1 m between the completely stoneless clay and the fully developed till. It can be reasoned that the lake was established as the ice stagnated and withdrew from the region, and that no lengthy period of time elapsed between the ice withdrawal and the initiation of the lake, which would have resulted in the erosion of the till. The relation between the Basal Till and the overlying drifts is instructive on this point. Where the till has been covered by the Bosworth Clay series, its preservation seems almost complete; its present distribution in this area is a thin sheet that gives a narrow, almost unbroken outcrop around the Bosworth Clays. Outside the lake basin, however, at heights above 116 m (280 ft) the Basal Till is patchy and, where it is still preserved, as at Stapleton, it is overlain by a stratigraphically higher bed, usually the Cadeby Sand. This pattern indicates that the lake deposits acted as a protective blanket covering the Basal Till, and that the till above the shores of the lake underwent erosion, which, in many instances, was sufficient to effect its complete removal.

The nature of the glacial conditions that enabled this ponding to take place is clearly significant in this environmental reconstruction. As the ice withdrew from the limit, well to the south of Leicestershire, reached by the Thrussington Till advance, Lake Harrison itself would have been established and maintained so long as withdrawal did not extend beyond the lower reaches of the proto-Soar and thus allow the water to escape northwards. This condition clearly limits the oscillation of the ice front to a position to the south of the present Trent Valley. If the lake was drained for any length of time by such an unblocking, it is surprising that there is evidence neither of significant dissection of the Basal Till beneath the Bosworth Clay nor of any lacustrine sediments extending further north in central Leicestershire. Shotton's reconstruction of the basin in which the clays accumulated necessitates a similar front of Severn Valley ice plugging the head of the proto-Soar valley, which has been reconstructed at a height slightly below 91 m (300 ft) between Church Lench and Bredon Hill (Shotton 1953, fig. 11).

The continuity of the Bosworth Clay and Silts, demonstrated above, and the firmness of the correlation with the Wolstonian type site confirm the reality of Lake Harrison and point to its extent. The significance of the massive thicknesses of this member recorded in western Leicestershire lies in its northern location within the Lake Harrison basin. In order that glacio-lacustrine sedimentation could occur in the Market Bosworth area, the whole of the Lake Harrison basin as defined by Shotton (1953) must have been simultaneously inundated; the Hinckley Valley is tributary to the larger proto-Soar basin. The lacustrine beds of western Leicestershire must therefore have chronostratigraphic, as well as lithostratigraphic, equivalence with part of the lake clays further to the south. Although the lake developed progressively as the ice withdrew northwards, and was subsequently extinguished upon a later readvance (see below), the record of the lake, in the form of deposits, is arguably best evidenced in western Leicestershire, where the deposits are thicker than elsewhere. This apparent anomaly can have several possible explanations. The deposits have been relatively well preserved from dissection, whereas in the lower valley of the Warwickshire Avon there has been widespread removal of the glacial drifts. Towards the northern, ice-dammed limit of the lake, rates of sedimentation would undoubtedly have been more rapid, allowing a thicker build-up of sediment. It is difficult to place the ice margin during this maximum phase of Lake Harrison. Rice (1969) has adduced evidence to show that the record immediately to the east of the region under consideration underwent a predominantly glacial style of sedimentation. The ice front must have curved northwards between central and western Leicestershire to accommodate the Bosworth Clays and Silts to the south. In view of the proximity of the ice front, it is perhaps surprising to record the sparse number of dropstones within the laminated clays and silts. Even as far north as Twycross and a few isolated sites north of the Hinckley Valley in the Mease catchment, the Bosworth Clays and Silts are noteworthy by the absence of inclusions and coarse material; neither is there any evidence of proglacial deltaic sedimentation.

Careful sedimentological study of the Bosworth Clays and Silts is frustrated by the paucity of exposures. Nevertheless, the material that has been retrieved from Leicestershire shows that an interpretation other than that of annual varves may be admissible. The sediment is predominantly clay- or silt-sized and is usually laminated, although massive beds of clay have been noted. Couplets of grey–brown or brown clay often alternate with red–brown silty bands. On examination under a binocular microscope, each lamina was found to be graded fine-upwards and occasionally the more silty bands showed small-scale, but unmistakable, cross-bedding. Each couplet is typically 2–3 mm in thickness; an interpretation as a varve would imply an annual regime of sedimentation. This annual rate of sedimentation would appear to be extraordinarily low for sites which may be no more (and often considerably less) than 20 km from the ice front. An origin as turbidity currents would not only allow each graded lamination to be the product of one sedimentary event of substantially less than one year, but could also explain the small-scale cross-bedding indicating moving water (Harrison 1975). On the basis of varves, Shotton (1976) calculated an approximate duration of 9600 years for the lake. Although it is felt that the arithmetic by which lake sediment thickness and varve thicknesses are used to compute the duration of glaciolacustrine conditions may be inappropriate to western Leicestershire, it is believed that the lake lasted for a considerable period.

The reconstruction of Lake Harrison by Shotton indicated a maximum lake level of 125 m (410 ft), based on the altitude of marginal deposits. Similar evidence in western Leicestershire accords well with that estimate. The feather-edge of the Bosworth Clays has been accurately

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recorded at 119 m at Twycross and between 110 and 115 m elsewhere. The controls of the lake height have been reviewed by Bishop (1958), but it is worthwhile noting that a further spillway at Saddington may have been operative at the maximum retreat of the ice. The break in the Jurassic escarpment between Saddington and Smeeton Westerby (SP 662929) carries the Grand Union Canal between the Sôar and Welland Catchments. The bedrock in the col is at 119 m (390 ft).

There is limited evidence to suggest that the lake deposits were built-up almost to water level even away from the edge of the lake. The boundary between the Bosworth Clays and Silts and the Cadeby Sand and Gravel is a transitional one from clays, through silts, to current-bedded sands, which represent the start of the outwash phase. Nowhere do these sands show the deltaic bedding with steeply dipping foresets that would be expected if the outwash was released into a deep lake. Rather, the sands show trough cross-sets such as would be associated with the braided channels of the sandur extending across the infilled lake. Subsequently, this horizon has been deformed by compaction of the Bosworth Clays and Silts to an extent estimated at 30–40% of the original thickness of the lake beds (Douglas 1976, p. 105; see above, 3(*c*)).

(*c*) *The deposition of the Cadeby sandur*

The shift from glaciolacustrine to glaciofluvial deposition was almost certainly not synchronous throughout the region, as the outwash was built out over the Bosworth Clays and Silts from the north. The continuity of the Cadeby Sand and Gravel with the Wolston Sand has been demonstrated and the extent of this sandur has been mapped (figure 11).

At Cadeby, the member can be subdivided into the lower sand and the upper gravel. There is borehole evidence to suggest that this division can be recognized elsewhere and pits to the north at Heather (SK 399108), to the east and at Dunton Bassett (SP 539901) show similar coarse-up sequences. This has been interpreted as signifying the greater competence of the meltwater streams to shift material as the ice front pressed southwards. The sedimentary structures within the sands and gravels consistently indicate deposition by moving water rather than into ponded water. The general lack of inclusions of till and glacio-tectonic structures in this outwash signifies a subaerial rather than subglacial or submarginal mode of deposition.

The lateral extent and continuity of this member is impressive; that such a wide sandur could develop is testimony to the nearly horizontal landscape of the infilled lake that the meltwater streams would have traversed. Yet the outwash was not only deposited onto the lake clays, for, at Cadeby and elsewhere, the sands rest directly on the Basal Till or bedrock above the level of the lake. Against the higher ground that fringes Charnwood Forest, the sands and gravels thin out and are overlapped by the tills east of Barlestone and towards Bagworth at a little over 125 m (425 ft). At Cadeby the mean direction of streamflow (as reflected by the bedding) responsible for the sand conforms to the gentle bedrock slope westwards towards the margins of the lake. A similar situation obtains at Heather, where the gravels are much thicker than indicated by the Geological Survey map and palaeocurrent directions have been estimated by the writer that indicate flow towards the south. The configuration of this sandur is rather different from that of the outwash that preceded the Basal Till and was almost totally confined to the valley floors; but the contrast seems wholly consistent with the differing topographies, the preglacial one showing greater relief and more pronounced lines of drainage than that which immediately followed the lengthy empoundment of Lake Harrison.

(*d*) *The readvance of ice*

The tills that cover the Cadeby Sand and Gravel represent the second major ice advance, the earlier advance being represented by the Basal Till. As Lake Harrison was progressively extinguished by the extension of the sandur, so the sandur was buried by a variable thickness of till comprising both Pennine and Chalky types. At the start of this readvance, there is ample evidence to indicate that the ice sheet that framed western Leicestershire to the north and east was already a compound one. The outwash deposited in front of it, while normally dominated by material of northern provenance (table 1), contained an admixture of Jurassic and Cretaceous material which locally can account for as much as 30% of the clasts.

The till sequence at the Cadeby type site can be divided into three parts: the Pennine Till, an intervening sequence of banded tills of contrasting lithologies and, finally, the Chalky Till. There are no major erosional unconformities in this sequence, which is regarded as the product of a single, if complex, ice advance. The Pennine Till is massive in nature, contains few structures and displays, at Cadeby, a consistent strength and direction of macrofabric (figure 10).

Table 3. Glacial deposits and provenance

schematic sequence of events	western Leicestershire	central Leicestershire	M69 motorway
readvance of ice	Pennine and Chalky Tills often banded at junction	Upper Oadby Till: chalky Lower Oadby Till: red	largely, but not entirely chalky tills
outwash	Cadeby S. and Gr.: predominantly non-eastern	Wigston S. and Gr.: great diversity in provenance	generally non-eastern
Lake Harrison	Both red and bluish-brown lacustrine material	Thrussington Till: largely northern with local inclusions of eastern material	lake clays subdivided into upper (blue–brown) and lower (red) types
ice advance	Basal Till: largely northern material with patches of eastern		both till types with at least one example of chalky till at base
outwash	—	Thurmaston Sand and Gravel: *no* Cretaceous material	*no* Cretaceous material

These properties are taken as being evidence of deposition by lodgement; the strong northwest to southeast preferred orientation of the contained clasts would thus broadly reflect the direction of ice movement which is supported by erratic provenance. The intimate relation between the alternating bands of Trias-rich and chalky type tills demonstrated that the parent ice sheet contained both kinds of debris, possibly as a result of re-working of earlier material or of the establishment of a complex ice sheet at the confluence of northwesterly and northeasterly streams. It seems, therefore, that the initial movement of ice, as it advanced across the Cadeby sandur, was from the north or northwesterly direction and that this ice was eventually overridden by chalk-bearing ice, producing a layered ice sheet, the deposits of which hint at a variety of modes of deposition, but which were ultimately characterized by the Chalky Till, for above the banded tills there is no reversion to a Trias-rich till.

The character of the tills described here is essentially similar to that of their correlatives immediately to the east: the Upper and Lower Oadby Tills. Rice (1972) has concluded that 'no major discontinuity in sedimentation' exists between the Trias-rich and Chalky tills in central Leicestershire. The evidence from the west of the country certainly confirms that they were the product of a single event, and it seems that earlier schemes which linked each till lithology with a separate glacial advance can no longer be sustained (Deeley 1886; Fox-Strangways 1900; West & Donner 1956). Throughout the entire sequence of Pleistocene deposits in Leicestershire, only in the basal sands and gravels have no Cretaceous materials been found, and only in the uppermost part of the till complex (the Chalky Till of western Leicestershire, the Upper Oadby Till) do Trias-rich deposits appear to be infrequent. Table 3 attempts to summarize the evidence from western Leicestershire and some of the other sites regarding the ultimate provenance of the drift materials and shows that, from the advance prior to the existence of lake Harrison, during the ponding of the lake and during the readvance of the ice, the ice sheet was a composite one. Thus, although erratic content may be at best an unreliable guide to stratigraphic position, the dominance of northwestern and northeastern sources does shift in favour of the latter during the Wolstonian. The different lithologies represented by the Cadeby Sand and Gravel and the Flinty Gravel confirm this trend. Whereas the Cadeby Sand and Gravel forms the outwash which preceded the advance, the Flinty Gravel was the product of the final decay of Wolstonian ice in the region. The Flinty Gravel is not represented in central Leicestershire but can be equated with the Dunsmore Gravel, which caps the succession near Rugby (Shotton 1953). The ice readvance between these two glaciofluvial events is regarded by Shotton (1976) as extending to Moreton-in-the-Marsh where the Wolstonian limit is placed.

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