THE PHYSIOGRAPHIC EVOLUTION OF CENTRAL

LEICESTERSHIRE DURING THE PLEISTOCENE PERIOD

by

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A thesis submitted to the University of Leicester for the degree of Doctor of Philosophy - September, 1963.
The research I describe in this thesis was undertaken in the years from 1959 to 1963 with the aim of elucidating the physiographic history of central Leicestershire during the Pleistocene period. I have directed relatively little attention to the phases of erosion, albeit of the Pleistocene age, which preceded the deposition of the earliest drift, for to have done so adequately would have involved study of a much wider area than is now encompassed. Instead attention has been concentrated on the events leading firstly to the accumulation of the drifts and secondly to their dissection. These are the two major themes of the thesis, but they are preceded by a brief introductory chapter outlining the present physique of the area, its solid geology, and the history of previous research.

Such is the complexity of the glacial drifts that I can lay no claim to have made either an exhaustive or a definitive study; "the balance of probability" is liable to be an over-worked phrase. It is believed that much of the value of the thesis lies in bringing together descriptions of a large number of sections
in the Pleistocene deposits. To this end Chapter two is largely descriptive, and as far as possible interpretation has here been eschewed. A further aspect of the thesis stemming from this is that the area considered in Chapters two, three and four is sharply circumscribed. The boundaries are artificial, and certain topics are discussed in two parts; considerable cross-referencing is the result, and for any inconvenience to the reader I apologize. The justification lies in the obvious risks arising from not differentiating clearly between areas known in vastly different detail.

In pursuing the research I have received assistance from individuals and organizations too numerous to list. I am particularly indebted to the Geological Survey, Stewarts and Lloyds Minerals Ltd., Owen Williams and Partners Ltd., and Leicester City Engineer for access to numerous borehole records. I should especially like to acknowledge the help of Dr. T.D. Ford who has always been ready to assist in any way he could. To all others, unnamed, I tender my grateful thanks.
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CHAPTER ONE

INTRODUCTION

(a) Relief and drainage.

The area studied in detail (fig. 1) covers some 135 square miles and comprises the central section of the Soar river basin. The two main rivers, the Soar and the Wreak, are incised to a depth of 100 feet or more below the adjacent ridge tops, and since they have cut down along almost their entire lengths into solid rock, the glacial drifts are largely confined to the interfluves. The drainage pattern of the main rivers divides the area of study into three:

(i) The Eastern Uplands. Tributary to the Soar and Wreak from the east is a series of approximately parallel streams which have eroded into bedrock and so further broken the continuity of the drift cover. The spacing of the streams at intervals of a mile or more leaves broad drift-capped interfluves which, in cross section, have a concave-convex form lacking in sharp breaks of slope. In long profile the interfluves slope very gently westwards before terminating in relatively steep bluffs overlooking the Soar-Wreak valley.
(ii) The Western Plateau. In contrast to the Eastern Uplands, this area west of the Soar is drained by two streams, the Rothley and Swithland Brooks, which flow for several miles parallel to the main river. They are separated therefrom by a broad, steep-sided and relatively flat-topped plateau which extends from south of Leicester to the upstanding hills of the Mountsorrel district, and which is broken only where crossed by the Rothley Brook on its way to join the Soar. Again the plateau top is formed of glacial drift, with solid rock exposures confined to the valleys.

(iii) The Leicestershire Wolds. The third physiographic region is the gently undulating plateau lying north of the Wreak valley and known locally as the Leicestershire Wolds. In the vicinity of Six Hills the plateau is little dissected, but elsewhere the tributaries of the Soar and Wreak have bitten back into its edge to form a series of short radiating valleys. Whilst the upper reaches of many of these valleys are excavated entirely in drift, the lower reaches once again penetrate into solid rock.

These three regions, together with the Soar and Wreak valleys, have been employed in Chapter 2 as convenient units for the description of the glacial drifts. Their boundaries, however, have not been rigidly defined
in order to permit greater flexibility in the description.

(b) Solid geology.

It has been no part of the intention in the present research to map the solid geology, and most of the following account is based upon published work, notably that of Fox-Strangways (1903). Nevertheless, augering and recording of temporary sections has afforded an opportunity of verifying, and in one or two places amending, the outcrops as depicted on the Geological Survey one-inch sheets (Nos. 142 and 156).

The succession of sedimentary rocks consists of five main members:

<table>
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<th>Rock Type</th>
<th>Description</th>
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<tr>
<td>Middle Lias</td>
<td>Marlstone with shales below</td>
</tr>
<tr>
<td>Lower Lias</td>
<td>Shaly clay with limestones near base</td>
</tr>
<tr>
<td>Rhaetic</td>
<td>Shales with nodular limestone</td>
</tr>
<tr>
<td>Keuper</td>
<td>Marl with lenticular sandstone beds</td>
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<td>(?) Swithland Slate</td>
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There are in addition the major igneous intrusions of the Mountsorrel district which have recently been dated as Caledonian (Miller and Podmore, 1961 p. 87).

There are three recorded outcrops of rocks older than the Mountsorrel granite, all of them situated close to Swithland Reservoir (fig. 2). Each exposure reveals, in contact with the granite, a slate so altered that it is not possible to state with certainty whether it is part
Fig. 2
part of the accepted Charnwood sequence; if it is, then it is probably part of the Swithland Slate group (Watts, 1947 p. 75).

Topographically the slate is of little consequence, for the outcrops are small and the relief in their vicinity tends to be dominated by the upstanding granite masses. The granite crops out in at least twenty isolated knolls ranging in size from those which are only a yard or two across, to Buddon Hill nearly half a square mile in area. The rock itself is normally a pink or white granite with its degree of basicity increasing from the eastern exposures towards the western.

Approximately half the area studied is underlain by the Keuper Marl. The characteristic red and grey-green marls are well exposed at a number of brickpits both north and south of Leicester, and in addition there are numerous disused, and now overgrown, workings. Inter-leaved with the marls are many thin beds of flaggy grey sandstone, known locally as "skerry", and occasional beds of gypsum. Of more localized occurrence are massive false-bedded sandstones; the best example of these is to be seen in the rock cutting for the old Leicester and Burton Railway on Shoulder of Mutton Hill, but other considerable beds of sandstone have been noted at Birstall, Rothley and Ratcliffe. Towards the top the Keuper Marl
is characterized by some twenty to thirty feet of soft, tea-green marls. Formerly exposed at South Wigston and at Spinney Hills, Leicester, these beds can be traced as a relatively continuous stratum northwards to Queniborough. Beyond this their outcrop is both faulted and obscured by superficial deposits, but north of Barrow they are again in evidence.

The only clean exposure of the Rhaetic beds observed during the present investigation was in a temporary section about one mile north of Barrow, where some four feet of black paper-shales were visible. Elsewhere the outcrop is now obscured, but from the descriptions of sections opened at South Wigston and Spinney Hills at the end of last century it appears that the Rhaetic beds are typically about twenty five feet thick and consist of shales interbedded with nodular limestones.

The Lower Lias beds occupy an area almost as large as that of the Keuper Marl, but are poorly exposed at the present time. An abandoned pit north of Sileby retains a clean face of limestone interbedded with blue-grey shaly clay, a sequence characteristic of the lower part of the Lower Lias, but of the great thickness of overlying clay little is to be seen other than in small sections along the brooks. The Middle Lias outcrops only in the extreme north-east where it consists of some ten feet of ironstone,
now very largely worked out, overlying a few feet of "Sandrock", which in turn rests upon shale. Owing to the restoration of the land after ironstone working, little is now to be seen of the Middle Lias.

At first sight the basic structure of the district may appear simple, with both Triassic and Jurassic strata exhibiting a slight but fairly persistent regional dip towards the east. There are, however, two complicating features. The first is the great relief amplitude of the basement on which the Triassic strata rest. This has been shown by a number of deep boreholes in Leicester (fig. 2) and although outside the city boundary the exact height of the sub-Triassic surface remains uncertain, Hallimond (1930) concluded after a geophysical survey that the pre-Triassic rocks probably approach relatively close to the surface in the vicinity of Thrussington. He gave reasons for believing there is a mass of igneous rock at about -250 feet O.D. at Thrussington, whereas in the Melton Mowbray district the sub-Triassic floor may well decline to -900 feet O.D.

The second complicating feature is the presence of folds and faults affecting the Mesozoic strata. Owing to the widespread drift cover and the rapid facies variations within the Keuper Marl, the precise delineation of these structures is not easy. However, a conspicuous datum plane
is afforded by the base of the Rhaetic, and contouring of
this (fig. 2) suggests the presence in the vicinity of
Barrow of an important downfold terminated on its southern
side by a fault, or series of faults. The downfold has
been linked by Kent (1937) and Clayton (1959) with a simi-
lar structure affecting the Middle Lias near Grimston;
both writers believe it to be a Tertiary structure, and
Clayton has termed it the Holwell Syncline. The bounding
dislocation on its southern margin appears more complex
than the simple arcuate fault postulated by Fox-Strangways.
A fault which cuts out the Rhaetic beds and brings the
Lias directly against the Keuper Marl can be traced with
some precision from the spurs immediately north of Sileby
to the point where it crosses Sileby Brook. To the south-
east a new sewage trench in 1962 revealed undisturbed Lias
limestones interbedded with blue shaly clay within 150
yards of Ratcliffe Road, Sileby, and it seems clear from
the alignment of the fault that close to where it crosses
Sileby Brook it has been shifted about 200 yards to the
south-west. Since the only solid rock outcrops in the
next valley to the south are of Keuper Marl, the fault zone
must either swing very sharply to the east-north-east or,
more probably, meet another fault running west-south-west

\[ \text{There may have been some late Triassic and infra-Rhaetic}
\text{flexuring but the effect is too slight to negative the}
\text{use of the base of the Rhaetic as a datum plane. See}
\text{Kent (1937).} \]
from Hoby. The line of the latter fault is largely obscured by drift, although in sections along the brook half a mile north of Thrussington church its position can be very closely determined, and its general effect of suppressing the Rhaetic outcrop and displacing the Triassic and Liassic outcrops is immediately apparent from the geological map. Until detailed mapping of the Lower Lias has been completed, it will remain difficult to trace the fault eastwards from Hoby, but that it probably continues in this direction is indicated by a number of observations.

On the southern side of the Wreak valley the base of the Lias appears to be not far below river level. In the railway cutting at Kirby Bellars Judd (1875 p. 58) recorded limestones belonging to the lower part of the A. planorbis zone, and a borehole at Frisby is reputed to have entered Keuper Marl at about 175 feet O.D. In contrast a borehole south-west of Asfordby was still in Lower Lias at 110 feet O.D., and a borehole at Melton Mowbray proved the base of the Rhaetic at -25 feet O.D. On the basis of magnetic surveys Cox (1919 p. 112) argued that the Hoby fault continues at least as far as Asfordby, while Hallimond (1930 p. 20) suggested that it may be linked with a major fault at Sproxton, seven miles east-north-east of Melton Mowbray. Without fuller mapping of the Lower Lias the throw of the Sileby and Hoby fault system is largely in-
determinate, but at Sileby it cannot be less than 50 feet and is probably much more, while at Hoby Hallimond estimated it as about 300 feet.

South of the Hoby fault the sub-Rhaetic contours trend south-south-west, and there is little evidence of transverse folding or faulting until Humberstone is reached. Three-quarters of a mile south-east of Barkby Thorpe the Rhaetic outcrop as depicted on the Geological Survey one-inch map would seem to betoken an anticlinal flexure, for Rhaetic beds are shown as occurring at over 275 feet O.D. However, during the present survey no support for this interpretation could be found, and a borehole less than four hundred yards east of the supposed Rhaetic outcrop still had not reached the Keuper Marl at an altitude of 190 feet O.D. Just north of the Humber Stone a small fault which displaces the Rhaetic beds has a throw of some 25 feet.

At Humberstone village the sub-Rhaetic contours disclose the presence of a synclinal axis\(^x\) trending at right angles to the strike. The downwarping is manifest in the presence of Rhaetic beds at 200 feet O.D. close to Humberstone station, and in the fact that the Crown Hills borehole one and a quarter miles to the south-east reached Keuper Marl at 105 feet O.D. Further south at Oadby and Wigston the

\[\text{X}\]The available evidence could also be interpreted as indicating trough faulting.
relatively gentle dip to the east is resumed.

(c) History of previous research.

The purpose of this section is to outline briefly previous systematic accounts of the glacial drifts of central Leicestershire. No attempt is made to encompass the numerous descriptions of individual sections as, where appropriate, these will be incorporated in later chapters of the thesis.

The earliest significant account of the glacial drifts is that in W.J. Harrison's "Geology of Leicestershire", originally published as part of White's Gazeteer for 1877, and reprinted in the same year as a separate book. Harrison recognized a four-fold division of the drifts:

- Forest Drift
- The Northern Drift
- Eastern Drift
- Mid-Glacial Beds.

Harrison argued that the oldest glacial beds, mainly composed of sand, are probably not as old as some of the drifts of East Anglia, and he consequently termed them mid-glacial. Of the true "Glacial Beds" he remarked that in the main they came from either the north or the east, that the two types are much intermingled, but that there is reason to believe that the eastern derivation is the earlier. The Forest Drift was deposited by a local Charnwood ice-cap at a late stage in the glaciation.
It is rather surprising that Harrison should have regarded the earliest drift as of eastern derivation (the detailed evidence on which he based this view is not disclosed), since nearly all later workers have regarded it as of northern or north-western derivation. Thus in 1886 R.M. Deeley advanced the following classification of the drifts which he believed applicable to much of the Trent river basin:


Apart from an area of some 70 square miles south-east of Derby, Deeley did not produce a map of the glacial deposits, and his succession was based upon examination of sections at widely scattered localities. For the first time considerable attention was directed to the water-laid deposits interbedded with the boulder clays, and although the criteria by which Deeley ascribed a bed

\[X\]Harrison later changed his mind. In Kelly's Directory for 1900 he described the drift succession as

(c) Northern and Forest Drift
(b) Eastern Drift
(a) Pre-Glacial or Mid-Glacial Beds

but in the same directory for 1908 he described it as

(c) Eastern Drift or Great Chalky Boulder-clay
(b) Northern and Forest Drift
(a) Pre-Glacial or Mid-Glacial Beds.
to a particular place in his succession are not always clear, in general a sand bed succeeded by a "Pennine Boulder-clay" was regarded as part of the Quartzose Sand, whereas a sand bed immediately succeeded by chalky boulder clay and containing pebbles similar to those in the chalky boulder clay was described as Melton Sand. By this criterion, Deeley believed, the extent of the Melton Sand is very limited, and he recorded it in only two districts, around Melton Mowbray and at Chellaston Hill just south of Derby; the Quartzose Sand, on the other hand, is a very extensive deposit and most of the glacial sands of central Leicestershire can be ascribed to this horizon. Nevertheless it is difficult to equate the Quartzose Sand of Deeley with the Mid-Glacial Beds of Harrison, since Deeley maintained that the Quartzose Sand is underlain by boulder clay.

One further aspect of Deeley's article merits note at this point. Like Harrison, he postulated a late-stage recrudescence of glaciers, in this instance to explain an extensive but thin veneer of boulder clay which is composed of an amalgam of local solid rock and previously deposited glacial drift. The late date of this boulder clay, he argued, is indicated by its occasional superposition on what are clearly river-laid terrace gravels.

In 1901 J.D. Paul advanced a less elaborate classifi-
cation of the drifts in the Soar valley, recognizing four main members:

Upper Sand and Gravel
Chalky Boulder Clay
Lower Boulder Clay
Lower Sand

The Lower Sand was described as current-bedded, relatively continuous and often ten to twelve feet thick; it is succeeded, above a clearly defined junction, by a chocolate-coloured boulder clay with quartz pebbles, Millstone Grit and Carboniferous Limestone. The Chalky Boulder Clay comes on gradually and irregularly with lumps of chalk and flint, and is in turn capped by sand and gravel with abundant chalk and flint.

Two years later the publication of the Geological Survey one-inch sheet (No. 156) provided the first detailed map to show the distribution of glacial drift (although, with minor differences, various sections of the map had previously been published by the Leicester Literary and Philosophical Society to illustrate excursions led by Fox-Strangways). The accompanying memoir by Fox-Strangways provided yet another interpretation of the drift succession:

Valley Drift.
Great Chalky Boulder-clay with intercalated beds of sand and gravel.
Older Boulder-clay (upper part).
Quartzose Sand.
Older Boulder-clay (lower part).
Older Sand and Gravel. (?)
The Older Sand and Gravel is a bed outcropping along the Wreak valley where it appears to be the oldest of the superficial deposits; the query in the above table is occasioned by a possible confusion with river terraces which occur at approximately the same altitude. It consists of false-bedded sands and gravels, composed chiefly of quartzite pebbles and other rocks derived from the north and west. It is succeeded at Thrussington by a variegated red and bluish grey boulder clay containing both quartzite pebbles and Lias limestone. Overlying this boulder clay is the Quartzose Sand, a deposit of false-bedded sand with much coal detritus, and of gravel which is often cemented into a hard conglomerate. The typical Quartzose Sand is best seen in the Soar valley, since in the Wreak valley it tends to be replaced, in part at least, by a red laminated brick-clay which covers an area of about 25 square miles. Above the Quartzose Sand comes another boulder clay which is similar to that already described in that it does not contain any fragments of chalk or oolite. This is in turn capped by the Chalky Boulder-clay which is characteristically blue or grey in colour and contains chalk and chalk flints in greater numbers than all other erratics together. This distinctive member of the drift succession is still preserved on most of the higher interfluves where it is not infrequently associated with lenticular patches
of sand and gravel composed almost entirely of chalk, oolite and Lias fragments.

Like both Harrison and Deeley before him, Fox-Strangways postulated a final glacial episode during which ice of a local character deposited along certain tributary valleys a drift which is usually not more than five feet thick and largely made up of pre-existing boulder clays. Fox-Strangways remarked that the most noteworthy fact in connection with this glaciation is that the Lias strata on which the drift reposes are nearly always more or less disturbed and frequently violently contorted, with patches of gravel thrust into them for some depth. In 1909 G.W. Lamplugh in the Geological Survey memoir on the Melton Mowbray district suggested that the Valley Drift is "mainly the result of 'creep' and down-wash from the clayey slopes of the valleys, mingled and contorted with the old gravelly sediments of the streams." (p. 85).

The work of Fox-Strangways was the culmination of a 30-year period during which four investigators had attempted to perceive some pattern in the succession of glacial drifts; for the next fifty years (1903-1953) little systematic field study was undertaken in central Leicestershire, and attention was concentrated on fitting the succession as it had already been described, especially by Deeley and Fox-Strangways, into the broader context of British Pleistocene chronology. Analysis of the
many diverse opinions expressed during this half century is beyond the scope of the present chapter, but there remains for consideration the published work of the last ten years.

Outstanding among this is the study by F.W. Shotton of the drift deposits of eastern Warwickshire. Although the area mapped by Shotton lies within the Avon catchment basin some 16 miles to the south-west of Leicester, his reconstruction of a "proto-Soar valley" extending from Bredon Hill northwards to beyond Leicester gives to the whole region a unity which it might otherwise appear to lack. In the Warwickshire section of this valley Shotton recognized the following succession:

Dunsmore gravel
Wolston Series  (Upper Wolston clay
   (Wolston sand
   (Lower Wolston clay
Baginton sand
Baginton-Lillington gravel
   Long time interval
   Bubbenhall clay

The Bubbenhall clay, which was found at only three localities in eastern Warwickshire, may in part be a true till but some of it is undoubtedly water-deposited. The original extent and thickness may well have been considerable, but a long period of erosion has left only disconnected small relics. The Baginton-Lillington gravel and the Baginton sand are much more extensive deposits laid down
in a cold climate by normal land streams. The gravel generally consists of rounded pebbles, mainly below three inches in diameter, set in a rusty brown sandy matrix. Two distinct facies may be discerned, a northern one in which the gravel is almost wholly composed of Bunter pebbles, and a southern or south-western one in which there are, in addition, a large number of Jurassic fragments. The sand is typically rusty brown in colour, rarely more than half a millimetre in grain size, and extremely cross-bedded. Toward the top the sand commonly becomes level-bedded and is succeeded above an undisturbed junction by the Wolston Series. The dominant material of this series is a red or pinkish grey, stoneless, very plastic clay, or a similar material with rare small scattered stones; near the base the stones tend to be either Bunter pebbles or Keuper sandstone, but near the top flints become equal in importance to the Bunter pebbles. Although patches of undoubted till do occur, most of the clay can only be interpreted as due to the settling of fine detritus in an ice-ponded lake. The Wolston clays are divided into two separate members by a bed of sand which covers at least 250 square miles and varies in thickness from less than five feet to about fifty feet; the latter thickness is attained near Hinckley where the sand passes into sandy gravel. Resting on the Upper Wolston clay is a deposit
of gravel with subordinate beds of sand. This Dunsmore gravel with pebbles up to about three inches in diameter and composed mainly of flint, seems to be the local equivalent of the Chalky boulder clay further north.

In 1956 West and Donner described the fabric of tills at various sites in East Anglia and the East Midlands, including several in the Soar valley. They concluded that in central Leicestershire there is evidence for at least two ice advances, an earlier one from the north-west and a later one from the north-east.

The most recent classification of the drifts is that advanced by Posnansky who, in a review of work in the middle Trent basin, recognized the following succession:

- **Lower Hilton Terrace**
- **Upper Hilton fluvio-glacial terrace gravels**
- **Outwash gravels of retreating Pennine Ice** (Chalky boulder clay)
- **Deposits of Eastern Glaciation** (and associated outwash gravels) (Middle Pennine boulder clay)

**Long time-interval**

- **Pennine Drift** (Skegby outwash gravels) (Early Pennine boulder clay)

The scantily preserved Early Pennine boulder clay is of local derivation and generally red in colour; it has been recorded both in the Wreak valley and at Kilby Bridge south of Leicester. A plateau gravel encountered north of the Trent at Skegby, Kirk Ireton and Blackwall, is probably the outwash gravel of the retreating Pennine ice.
Following a prolonged period of interglacial erosion, ice readvanced first from the Pennines to deposit a boulder clay similar to that of the earlier glaciation; later this ice was pushed aside by a sheet from the north-east which deposited a thick spread of Chalky boulder clay. During the withdrawal of these competing ice sheets, patches of outwash gravel were laid down, but the most distinctive feature was the formation of a series of aggradation terraces along the line of the middle Trent. These Hilton terraces show considerable variation in height, ranging from about 100 feet to little more than 30 feet above modern alluvium. They are the youngest deposits of the Older Drift.

It will be noted that in this summary of previous research almost no reference has been made to the river terraces. The reason is simple: apart from brief descriptions by officers of the Geological Survey, there has been no systematic account of the Soar terraces. Fox-Strangways (1903) remarked that along the valleys of the Soar and Wreak there are well-marked terraces of river gravel flanking the modern alluvium. They are commonly about 20 feet above the present river flats, and near the confluence of the two rivers at Syston, form considerable spreads of flat gravelly soil. In many places the terraces extend up the tributary valleys, and in their
upper part join on to the alluvium of those streams so that it is difficult to separate one from the other. Fox-Strangways concluded his description with a list of mammalian remains recovered from the terrace deposits. In the Geological Survey memoir on the Melton Mowbray district, it is recorded that gravel terraces rise over 35 feet above the river flats along part of the Wreak valley, and also that the Valley Drift described by Fox-Strangways appears to merge into the higher terraces of the Soar at the mouths of the tributary valleys.
CHAPTER TWO
DESCRIPTION OF THE GLACIAL DRIFTS

(a) Methods of investigation.

The gently rolling slopes of much of central Leices-
tershire present a challenge to the student wishing to study the glacial drifts. Not only is there a general lack of clean sections, but the hillsides are often covered by a layer of orange or brown gravelly loam which effectively conceals the nature of the drift materials, even along ditches and streams. After an abortive attempt to map solely from natural and artificial sections, it was decided that augering was essential, and the information on which the following account is based was obtained in five ways:

(i) Examination of natural and artificial sections. Good natural sections in the drifts are virtually non-existent, since the unconsolidated nature of much of the subsoil results in rapid downwash and concealment. Artificial sections tend to be infrequent since much of the drift succession consists of economically unimportant boulder clay; at the time of writing (June 1963) there are only two working faces in glacial deposits, a sandpit at Rothley
Station and a brickpit at Blaby, the latter working both Keuper Marl and boulder clay. In addition disused sandpits at Ratcliffe, Thurcaston, Rothley Station and Blaby retain faces which are still sufficiently clean to yield valuable information. Another factor militating against frequent artificial sections in the drifts is the pattern of settlement and economic development which has concentrated activity along the major valleys, and these, as indicated in Chapter I, are incised through the drift into solid rock. The one exception is in the neighbourhood of Leicester where suburban growth has spread far on to the cover of glacial deposits.

(ii) Collation of historical records of drift sections.
The paucity of modern sections emphasises the need to collate the observations of earlier workers, and this aspect of the present study is of considerable importance. Two sources are particularly fruitful, the Transactions of the Leicester Literary and Philosophical Society, and the writings and field maps of the officers of the Geological Survey. Both have been systematically perused, while further information has been gleaned from sundry other sources, published and unpublished.

(iii) Compilation of borehole records. A list of about 150 wells and boreholes in central Leicestershire has been compiled, and the logs of many of these provide valuable
data regarding the nature and thickness of the drift deposits. However, the sites are so unevenly distributed that for extensive areas there is still little guidance as to the exact thickness of the drift. A further problem is occasioned by the doubtful reliability of some of the logs, a not surprising circumstance where one often has a clayey till resting on a "solid" clay. In the following pages wherever there are reasonable grounds for doubting the accuracy of a borehole record, attention is drawn to the fact; no re-interpretation of any record has been made without a statement to that effect.

(iv) Traverses with a bucket auger. In order to establish the basic succession in the Wreak valley, four short traverses with a four-inch bucket auger were undertaken. A total of 61 holes was put down to an aggregate depth of 363 feet, and the greatest depth reached at any one hole was 16'3". Difficulty was experienced in attempting to bore through boulder clays, especially when boring to a depth of much over 6 feet; beyond that point the greater torque required and the remoteness of the auger blades from the operator mean that the removal or by-passing of erratic pebbles is increasingly troublesome. As a consequence many holes were put down to a depth of only a little over 6 feet and the vertical interval between successive holes was restricted to 5 feet. Clearly such a procedure would not be satis-
factory on a slope masked by thick down-wash, but the consistency of records from adjacent holes suggests that an accurate picture of the drift succession was obtained in the particular traverses undertaken. Although boring through sand and silt was relatively easy, the "washing in" of sand by groundwater often limited the depth which could be reached with the implements at hand.

The horizontal and vertical distances between holes were measured by tape and Abney level, and the most convenient hole in each traverse was then tied in to a bench mark or spot height by means either of a level or of a surveying aneroid. When an aneroid was used the operation was repeated at least twice, and as the interval between corrections to the instrument never exceeded ten minutes, an accuracy of \( \pm 4 \) feet is thought to have been achieved.

The great advantage of the bucket auger is that a reasonably bulky sample is obtained which normally permits of little doubt about the nature of the material penetrated. Its main limitations, apart from the purely physical ones already mentioned, are that the sample is composed of shavings in which minor structures are often so distorted as to be difficult to interpret, and that the sample from any particular level may easily be contaminated by material falling from higher in the hole. Consequently it is unwise to attach too much importance to individual erratic
pebbles, especially where these might have been in the soil or subsoil and carried down to a lower level by the borer.

(v) **Mapping by means of a screw auger.** The standard mapping technique for the present study was to run a line of screw auger holes up a hillside, using for the purpose an instrument composed of a 1-inch diameter, 8-inch long soil-auger bit welded to a 52-inch stem. Normal practice was to penetrate at each hole to a depth of between four and five feet and to allow an estimated vertical interval of about eight feet between adjacent holes. The distance between lines of holes was commonly three to four hundred yards. However, in practice considerable variations from this norm were employed, notably in utilising ditches and other excavations which often permitted penetration to seven feet or more. In addition a uniform vertical interval was not strictly adhered to, especially when it was desired to locate a boundary very precisely, nor were the holes invariably arranged in lines. During survey with the screw auger, heights of significant holes were determined by means of an aneroid; less stringent precautions were taken than in the case of the post-hole borer traverses, but it is believed that the vast majority of the measurements have an accuracy of $\pm 6$ feet.

The great advantage of the screw auger is its speed and facility in use. Little difficulty was experienced in
putting down twenty five holes in one day, and during the present study several thousand holes were put down. Against this the sample brought up by the auger is small and much disturbed, and is not necessarily entirely representative of the material penetrated. The space between the whorls are so small that large erratics cannot be recovered whole, and only those sufficiently soft to be crushed by the auger will be brought to the surface. Nevertheless, with experience the major types of drift deposit may be readily distinguished, and the boundaries accurately plotted. The other limitation is that of the depth reached, and there are undoubtedly a few sites where a longer-stemmed auger would be beneficial. This is especially true on certain gentle slopes where there is a cover of sandy or gravelly loam exceeding five feet in thickness. On the other hand, at by far the greater number of localities the consistency of the results obtained argues in favour of in situ drift deposits having been penetrated.

The use of data derived from such varied sources brings with it a number of problems which it would be wrong to minimize. A large clean section permits a relatively thorough analysis of the erratic content of a boulder clay - and if necessary a search for one particular type of erratic - whereas the sample obtained with a bucket or screw auger is so small as to indicate only the general
nature of the boulder clay. For example, an excavation at Leicester University disclosed a discontinuous seam of grey chalk-bearing till only nine inches thick in a 25-foot mass of red Trias-derived till in which no Cretaceous erratics were visible; only extremely thorough augering could have revealed the presence of this seam. It must be stressed therefore that the mapping which has been completed shows only the general character of the drift, and no claim is made to have defined, for example, beds from which Cretaceous material is totally absent. Where reliance has to be placed upon historical records of old sections, a similar problem arises for it is usually uncertain how thorough the examination of the section has been. Again it is only safe to regard the record as describing the general character of the drift.

Despite these limitations it is believed that the methods employed during the present investigation are adequate to sustain the interpretations put forward in this thesis. Further significant advances seem likely to depend upon the recording of temporary sections systematically pursued over a period of many years.

(b) Description of the members of the drift succession.

For purposes of description the glacial drifts will be divided into the following six members:
Narborough beds.
Oadby till.
Wigston sand and gravel.
Glen Parva and Rotherby clays.
Thrustington till.
Thurmaston sand and gravel.

(1) Thurmaston sand and gravel (Map A).

Over much of the mapped area the basal deposit is a cross-bedded, well sorted sand, occasionally resting upon a few feet of fine gravel. The sand and gravel are best exposed in pits at Thurmaston and Rothley (fig.3). At the former the reddish sand is at least 20 feet thick and normally ranges in grain size from \(0.02\) to \(0.005\) inches.

One of the most distinctive features of the sand is its high content of fine coal fragments which have been so sorted as to render the cross-bedding particularly conspicuous. The bedding appears to be mainly foreset delta deposition but with a few scour-and-fill channels.

In an attempt to determine the preferred orientation of the foreset bedding the dip of ninety separate depositional wedges was noted as they appeared on the working faces of the pit. Obviously by this method one does not obtain a true direction of dip, but it does provide some guide to the movement of the depositing water. On the faces of the Thurmaston pit orientated almost due north-south, sixty of the depositional wedges dipped northwards and only six southwards; on faces orientated approximately
(A) THURMASTON SANDPIT

Section line gravel on Keuper Marl

Disused sandpit, now completely obscured by tipping

Length of arrow proportional to number of foreset wedges exposed on pit faces (shown by thick line on map on left)

Fig. 3.
E5°S seventeen wedges dipped eastwards and six westwards. These results are shown diagrammatically in fig. 3. On the basis of these measurements it is suggested that the depositing water flowed in a direction between north and east, probably with a stronger northward component. It may be noted that this conclusion agrees with that of Fox-Strangways who recorded on his 6-inch field sheet that the sand in a nearby pit, now largely concealed, showed "bedding directed towards the north." One final aspect of the sand at the Thurmaston pit deserving brief mention is the selective calcration which it has undergone. Pillars of the resultant sandstone are frequently ten yards or more across, and it would seem probable that the consolidation is due to percolating water enriched with calcium carbonate dissolved from an overlying calcareous boulder clay.

Beneath the sand in the Thurmaston pit there is at least six feet of fine gravel. The junction between the different grades is a transitional one and there is no reason to suspect any unrepresented time interval. The great majority of the pebbles in the gravel are under two inches in diameter, and in an attempt to establish their provenance a sample of 205 pebbles was analysed (Appendix A No.4). Virtually all the far travelled material is derived from sources lying to the north and west; the local material might have been derived from the same direction,
but this cannot be proved and should not be assumed. A search was made for Middle Jurassic and Cretaceous pebbles, but none was found. The base of the gravel is not exposed in the sandpit, nor could it be reached by means of the bucket auger owing to the rapid washing in of debris by groundwater. However, at the nearby northern end of the Thurmaston by-pass a shallow cutting reveals a similar gravel resting directly on Keuper Marl.

The Rothley sandpit is excavated in a deposit exhibiting many similarities with that at Thurmaston. A working face up to 22 feet high displays cross-bedded sand with much coal, while underlying this, and exposed in a small secondary pit 150 yards further north, there is at least 14 feet of medium to fine gravel. The false bedding of the sand was examined in the same way as at Thurmaston and yielded a direction of movement lying between east and north, but with a relatively strong easterly component. A representative sample of 174 pebbles from the gravel was analysed, and again it was found that the vast majority were of northern and western provenance (Appendix A No.2). But one of the most important aspects of the Rothley sandpit is the clear demonstration it affords that the sand and gravel is banked against a hillslope of Keuper Marl. Near the railway cutting at Rothley Station Keuper Marl was formerly exposed at a level of 238 feet (Tucker, 1896
p. 213), and screw augering has shown its presence along Top Road around Sandfields Farm at over 230 feet. These levels are some 15 feet above the sand exposed in the working face of the pit, and the pit owner reports that the southward extension of the face is limited by the existence at floor level of "red and bluish green clay", presumably the Keuper Marl. The owner also reports that below the small gravel pit "red clay" has been proved at a depth of about ten feet, that is, at about 192 feet O.D.

The fact that the Thurmaston sand and gravel is banked against irregularities of the solid rock surface makes variations in thickness inherently likely, and it is found that where the bedrock floor rises above 250 feet the deposit is normally very attenuated or completely missing. Nevertheless, the bed can be traced over a wide area, and some of the more significant temporary exposures and historical records of earlier exposures must now be described.

(a) Soar Valley and Western Plateau. Westwards from the Rothley pit screw augering indicated that the sand is intermittently present but relatively thin. North-westwards there is probably a local extension of the sand towards Swithland (1) where Fox-Strangways records on his six inch field sheet an exposure of "Dirty sand and

In the account of the Thurmaston sand and gravel, beds described as sand may also contain seams of gravel.

The numbers in brackets refer to the numbered sites on the accompanying map, e.g. in this instance Map A.
gravel with some coaly stuff. Pebbles. No Chalk flints."
Northwards on Rothley Plain and southwards at Thurcaston the bed is virtually absent and the earliest till rests directly on the Keuper Marl. It is to the east that the sand continues as a thick stratum, being exposed in an abandoned and partially over-grown pit 350 yards north-north-east of Rothley Station (fig. 3) where it is overlain by some four feet of boulder clay. A second abandoned pit (2) 550 yards east of Rothley Station was described by Fox-Strangways on his field sheet as displaying "Sand with a few quartz pebbles and gravel boulders. No Chalk. Sandy boulder clay over." The sand is present but apparently rather thinner around the village of Rothley, whence its outcrop can be traced with only a few gaps southwards along the left bank of the Soar. Two exposures (3 and 4) were noted during improvements to the A6 road north of Birstall. In each case medium red sand with much coal was overlain by a red boulder clay, the junction between the two deposits being horizontal and apparently undisturbed. A similar succession was noted along Loughborough Road in the village of Birstall (5), whilst a quarter of a mile further south (6) extensions to an electricity sub-station revealed, beneath 2'6" of made ground, a mixture of fine gravel and coarse sand. The gravel contains Bunter pebbles, chert, Carboniferous
sandstone and skerry, and in general appearance is almost identical with that at Thurmaston two miles away to the north-east. The interbedded seams of sand are characteristically darkened by their high content of coal. At both ends of this 20-yard section the sand and gravel was overlain by red boulder clay with Bunter pebbles, coal and skerry, but unlike the exposures already described the junction in this instance was disturbed, the beds beneath the boulder clay having apparently been arched into an anticline, the top of which has since been removed by erosion.

For a distance of 1400 yards to the south the Thurmaston sand and gravel appears to be either absent or thin and discontinuous. However, in the valley of the small stream flowing east past Beaumont Leys there were formerly several sandpits, and although these have now been completely obscured by tipping and the building of new housing estates, some information about the succession can be gleaned from an article entitled "Geology of Beaumont Leys" by Montagu Browne published in 1902. The sand was revealed in a number of shallow trial holes, and was described at various sites as generally red in colour, containing a few subangular quartzite pebbles, and stained by bands of carbonaceous matter. It should be pointed out that Browne interpreted the deposit as "Post-glacial river terrace", 
but there seems little doubt that it is in fact at the base of the glacial drifts. Indeed, Browne himself records (p. 15) that below a boulder clay mainly of Keuper derivation, a borehole (7) appears to have been carried on into red sand for twenty feet or so. Half a mile further south there is another old sandpit, the Leicester Abbey pit (8), but once again housebuilding and the work of earthmoving equipment have rendered it of little assistance in its present state. Fortunately there are several accounts of the deposits formerly exposed. Harrison (1877 p. 44) refers to "about 11 feet of pinkish sands, the false bedding of which is displayed in perfection by streaks of coal or lignite. Bits of red marl, Triassic pebbles, etc. occur." Deeley (1886 p. 446) describes the sand as resting directly on the Keuper Marl, and as being "light in colour, splendidly false-bedded by currents from the south-south-west, and almost free from erratic pebbles of any size. The lower nine feet is false-bedded, but in the upper portion the bedding becomes horizontal, and the deposit finally changes abruptly into brown sandy boulder-clay." Paul (1891 p. 407) adds the information that partial cementing of the sand has produced pillars of sandstone several feet across and about eight feet high.

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Lewis (1894 p. 322) postulates currents from the north-west, but this is probably erroneous.
The parallelisms with the sand and gravel at Thurmaston need no stressing.

From the site of the Leicester Abbey pit the outcrop of the sand can be readily traced to the eastern end of the Glenfield railway tunnel, where there seems to have been another small working of the sand (9). Within a further mile to the south, however, the sand thins and temporarily disappears, being absent both at Shoulder of Mutton Hill and at some of the old sandstone workings in the Dane Hills district (see for instance Browne, 1893 p. 131). Near Rowley Fields Fox-Strangways (1903 p. 45) records a cemented gravel at the base of the drift, but during the present study no clean section in such a gravel could be found. The final site on the left bank of the Soar at which the Thurmaston sand and gravel was observed lies at the rear of the works of Jones and Shipman on Narborough Road, Leicester (10). Whilst the stratigraphical position and the lithology are characteristic of the deposit as already described, the structure is not (fig. 4). There is up to six feet of the usual red, cross-bedded sand with its high coal content, and there is a fine to medium partially calcareted gravel of northern or western derivation (Appendix A No.5). Both materials seem, however, to have been much disturbed during emplacement of the overlying boulder clay. The junction of the sand and boulder clay
at the south-western end of the section has a scalloped appearance, with one particularly sharp contortion where gravelly sand appears to have been thrust towards the south-west. But the greatest disturbance occurs where two patches of sand have been incorporated in the base of the boulder clay (for detail see annotation of fig. 4).

Before proceeding to describe the exposures on the right bank of the Soar, it is necessary to examine the extension of the sand beneath the interfluve separating the Soar from Rothley Brook. Only a few deep boreholes have penetrated this spur of higher land. At Beaumont Leys a well was sunk through "Blue clay 97 feet into gravel." No exact location for this well is recorded but it seems almost certain that it was situated near the summit of the interfluve at a height of over 300 feet O.D. Paul (1891 p. 405) mentions that a well at Leicester Frith, again near the summit of the interfluve, proved a drift succession consisting of 90 feet of clay resting upon a bed of sand. A further source of evidence is the Glenfield Tunnel on the Leicester-Swannington Railway, the eastern entrance to which is situated on the outcrop of the Thurmaston sand and gravel. Fox-Strangways (1903 p. 45) records that the whole of the tunnel was cut through sand, and as it was originally perfectly level (Clinker 1954 p. 79), unless one has the improbable
circumstance of two sands banked one against the other, it provides a valuable stratigraphical link between the Soar valley on the east and the Rothley Brook valley on the west.

The above observations give good reason for believing that the Thurmaston sand and gravel is fairly continuous beneath the later drifts in that area lying between Birstall, Anstey and the Glenfield Tunnel. Further north towards Thurcaston the evidence is very slight, but the lack of any clear outcrop suggests that the sand may be very thin or entirely absent. Similarly, south of the Glenfield Tunnel the limited borehole data indicates that the sand thins and disappears.

On the right bank of the Soar the most southerly observed exposure is at Blaby brickpit (11) where the assemblage of sand, pebbles and boulder clay is extremely confused (fig. 4). Within a distance of two or three yards the arrangement of the materials may alter completely, so making any descriptive generalisation very difficult. The characteristic cross-bedded red sand, blackened by layers of coal fragments, is intimately associated with the overlying red boulder clay. At some points within a vertical distance of less than a foot, three or four thin seams of pebbly boulder clay are interleaved with the sand. The junction between the sand and the
till is often irregular, and the stratification of the sand quite clearly disturbed. This was best seen on an isolated face, not illustrated in fig. 4, where over 10 feet of sand was exposed and where the bedding round the lower edge of an included boulder clay lens six feet long and less than eighteen inches thick was seen to be sharply contorted. Two other aspects of the deposits at this site call for brief reference. The first is the presence of a basal breccia composed in the main of angular fragments of skerry, many of them over 3 inches across and bearing pronounced glacial striae. A sample of 71 pebbles was analysed (Appendix A No. 6) and was found to bear some resemblance in derivation to the Thurmaston gravel. The second feature of note is the appearance on face 3 of a mass of transported Keuper Marl within the cross-bedded sand. The Marl, horizontally banded in red and green, would excite no comment if seen as part of a solid rock succession, the only distinctive feature being the presence of concretionary "balls" of soft red marl. On face 4 there is a 2'6" bed of red marly material, but as this contains a few small erratic pebbles it appears to be intermediate between the pure transported Keuper mass, and the typical red boulder clay which overlies the whole section.

Immediately north of Blaby brickpit the Thurmaston
sand and gravel is very irregularly developed, but it re-
appears as a prominent bed around Aylestone. Formerly
there were two sandpits south-east of the village centre,
but one has now been filled by tipping and the other is
occupied by cultivated gardens. However, around the turn
of last century they were much frequented by geologists and
several descriptions were published. Paul (1883a p. 25)
records one pit (12) as showing "a bed of fine sand, vary-
ing from nine to fifteen feet in thickness, false-bedded
throughout, marked with streaks of lignite and containing
a few fragments of Gryphiaea and Belemnites. The sand
lies on a flattish surface of Keuper Marl." Moore (1888)
mentions that immediately above the Marl there is a thin
stratum of fine gravel, and he quotes the thickness of the
sand as fifteen to twenty feet. In a report on a field
excursion organised by the Leicester Literary and Philo-
sophical Society Browne (1901 p. 31) describes the sec-
tion in the pit as follows:

Humus and rainwash with pebbles............. 1'6"
Boulder-clay, consisting chiefly of a matrix
of tough reconstructed Keuper red marls, in-
cluded in which are quartzites, pieces of
coal and coalbinds, Keuper sandstone and
"skerries", "chert" (probably quartz rock),
altered Millstone Grit, Syenite, "chalk"
nodules, a few Carboniferous and Lias
boulders and fossils, and still fewer flints 16'0"
Clean yellow sand ("Quartzose sand") false-
bedded, with not only stainings of carbona-
ceous matter, but with bands, nearly a foot
in thickness, of coal dust and small rolled
pieces of coal, Gryphaea and other fragment-
ary fossils from the Lias.................. 14'0"
Upper Keuper not proved....................

In view of the earlier observations quoted above the failure to prove the Keuper is both surprising and unexplained. Browne also describes the section in the adjacent pit (13):

Humus and rainwash...................... 1'6"
Boulder-clay................................ 17' to 18'
Sand (false-bedded)...................... 14'0"
Silt and Gravel composed of small Quartzites, etc., and fragments of Liassic shells, 1 ft. to 3 ft. average 2'0"
Upper Keuper red and grey marls.... 6'0"

Between Aylestone and Thurcaston the distribution of the sand and gravel is very sporadic. On both sides of the Saffron Brook valley exposures noted during the present study, and others described in the past (e.g. Browne 1893 p. 182, and Fox-Strangways on his 6-inch field sheets), indicate the virtual absence of the sand. A section in 1962 on the site of new offices for the East Midland Gas Board (14) revealed, resting directly on the Keuper Marl, a one-foot bed of fine red sand, grading up into two feet of hard brown or purplish clay with thin but continuous seams of fine sand and silt. These two beds show signs of slight disturbance either in gentle sagging or in very small faults with throws of about one inch. Whereas the sand grades up into the clay, the contact of the latter with an overlying till
is extremely abrupt. A comparable thin bed of sand has been recorded in the nearby cemetery (15) and also on the site of Leicester Museum (16 (Browne 1893 pp.197 and 144). The writer is also informed that the foundations for Lillie House near London Road Station (17) were dug in sand underlying boulder clay. But the finest section in this vicinity was undoubtedly that seen during widening of the Midland Railway cutting in 1893. Browne (1893 pp. 195-198) records that this section (18), several hundred yards long, was remarkable for the rapid variations displayed by the drift, although one of the more persistent beds is a basal sand averaging fifteen feet in thickness. In disposition and lithological characteristics the sand is described as precisely similar to that at Aylestone, being "quartzose, yellowish, clean and also false-bedded, with bands of small coal grit of the same extent, with inclusions of Gryphaeae and fragments, quartzite pebbles and one or two flints." Interstratified with the sand is a thick seam of clay, gutta-percha-like in colour, toughness and tenacity, which is contorted to such an extent that in places, together with the sand, it has been thrust into an almost vertical position. The one puzzling aspect of this description is the reference to flints, but unfortunately the accuracy of this observation is at present beyond verification. It may be
appropriate to note at this point that Browne was frequently the centre of heated argument, and that the absolute reliability of some of his records may be open to question. He was, for instance, very reluctant to admit that there was much chalk in the drifts of central Leicestershire (see for instance the discussion in the Transactions of the Leicester Literary and Philosophical Society for 1902, pp. 36-41).

At Humberstone a well is reputed to have passed through 66 feet of boulder clay before entering nine feet of fine (grey pink) sands, which from their stratigraphical position may well constitute part of the Thurmaston sand and gravel. Three hundred yards north of the Towers Hospital screw augering demonstrated the presence of a two-foot bed of coaly silt with occasional Bunter pebbles, and similar occurrences were noted at isolated points northwards as far as Barkby. It is clear that from a thickness of over 20 feet at Thurmaston the sand thins rapidly south-eastwards against the rising bedrock surface formed by the Rhaetic beds. Tongues of sand extend up some of the valleys, notably at Humberstone and west of Hamilton, but in the latter locality there seems to be much intermixing of sand and boulder clay.

(b) The Wreak valley. In the Wreak valley the Thurmaston sand and gravel covers an extensive area, especi-
ally to the south of the river, but is poorly exposed. Threequarters of a mile south-west of Rearsby a sloping spread of terrace gravel was excavated during 1962 in a series of trial holes (19) to test the soil preparatory to the erection of new buildings. The site had previously been occupied by the army as a supply depot, and much artificial disturbance of the ground had obviously occurred. However, the trial holes were up to twelve feet deep and in most instances penetrated into undisturbed sediments. The succession exhibited in the holes was as follows:

- Flint-bearing yellow sand and gravel... Up to 8'0"
- Red coaly sand, generally level-bedded... Up to 6'0"
- Medium gravel........................................... Up to 5'0"
- Keuper Marl.............................................. 3'0" exposed

The boundary between the flinty gravel and the red sand is sharply defined, and there seems little doubt that the former is a comparatively recent terrace deposit, the latter part of the Thurmaston sand and gravel. An analysis of 134 pebbles from the bed immediately above the Keuper Marl yielded results entirely consonant with this interpretation (Appendix A No.3).

Screw augering demonstrated that the sand half a mile north of Rearsby is only a few feet thick, but towards Brooksby it thickens once more and fine gravel becomes a significant component. On his 6-inch field sheet Fox-Strangways records a shallow excavation (20)
revealing gravel composed mostly of quartz and quartzite, with few if any flints, while less than half a mile away (21) a well 18 feet deep was sunk entirely in gravel. Fox-Strangways also notes that the foundations of new buildings at Brooksby were in a "great quantity of sand." North-east of Rotherby (22) use of the bucket auger demonstrated a thickness of over 13 feet of sand and gravel, the detailed record at this point being:

Medium red sand ....................... 4'0"
Coarse reddish sand with seams of gravel, the proportion of gravel increasing with depth ..................... 6'0"
Coarse gravelly sand rendered black by its very high coal content ............... 3'0"

From the lower nine feet of this succession 321 pebbles were recovered, and on analysis the vast majority proved to be of northern or western derivation and so typical of the Thurmaston sand and gravel (Appendix A No.1).

Five hundred yards to the east-north-east (23) a borehole has proved about 30 feet of sand and gravel resting directly on solid rock:

G.L. c.230 ft.  Clay ....................... 3'0"
              Red sand .................... 8'0"
              Sand and gravel ............. 9'0"
              Red sand .................... 1'6"
              Sandy gravel ................ 6'6"
              Clay ......................... 2'0"
              Sand and gravel ............. 4'6"
              Lower Lias.

In the village of Frisby a borehole is said to have
proved 40 feet of sand and gravel resting on bedrock. Unfortunately there are now no exposures, but an old sandpit (24) close to Frisby Mill was described by Deeley (1886 p. 446) as being dug in "a light, clean, bedded sand, with occasional pebbly beds; it much resembles the Aylestone sand. The false-bedding indicates currents from the west." Immediately east of Frisby screw augering showed that the sand thins once more, but at Ash Tree Farm it is present in considerable quantity. The farm is reputed to be built on the site of an old sandpit, and the farmer reports that a trial bore encountered 14 feet of clean sand before entering blue (Lias) clay; as screw augering demonstrated that the bore started at least 10 feet below the top of the sand, the total thickness is almost certainly over 20 feet. At the nearby Kirby Hall Farm a windpump probably draws water from the base of the drift and has a local reputation for being exceptionally reliable, never having run dry. Yet the borehole log makes no reference to "sand", and certainly does not lend support to any contention that there is a continuously thick bed of basal sand and gravel:

G.L. 296 ft.

Brown marl clay................. 3'0"
Yellow boulder clay........... 12'0"
Blue clay........................ 2'0"
Brown clay...................... 57'0"
? brown sandstone............. 5'0"
Lower Lias Clay.
Screw augering in the vicinity of Kirby Bellars located a thin and apparently impersistent basal sand, and it is only further to the east, notably near Eye Kettleby Mill, that the basal sand and gravel again becomes conspicuous. Five hundred yards west-south-west of the mill, Wedd records on his 6-inch field sheet an old sand-pit (25) displaying "false bedded sand with streaks of coaly stuff, rather clayey in places." He also notes that there are Chalk flints lying about, and a pit section (26) 300 yards closer to Eye Kettleby Mill is described as follows: "Stony boulder clay on yellow wavy-bedded sand with pinkish loamy seams. Boulders of Carboniferous sandstone and grit, Lower Lias limestone, flint, Lincolnshire Limestone, Bunter quartzites, dolerite, syenite, green slate, etc." Deeley (1886 pp. 456-7) describes this pit in the following terms: "... stratified sand, about 8 feet thick, rests upon flinty gravel. The sand is false-bedded, and contains carbonaceous seams. Brown Chalky Clay rests unconformably upon it." Since the Melton Mowbray Memoir in a reference to this pit (p. 68) also mentions gravel containing stones which occur in the Chalky boulder clay, there seems reliable evidence for an important change in the lithology of the basal drift deposit. Whether the material at Eye Kettleby Mill is the true equivalent of the Thurmaston sand and
gravel remains uncertain, but it will be so classed for the present. Fuller discussion of this question is deferred until Chapter Four.

The extent of the Thurmaston sand and gravel on the right bank of the Wreak is so limited as to require only brief mention. Close to Sysonby Grange there is a deposit of sand which appears to be the equivalent of that at Eye Kettleby Mill. A temporary exposure (27) showed five feet of coarse flinty gravel, almost certainly alluvial, resting on eight feet of coarse reddish sand, which in turn rests on blue Lias clay. Further downstream there is no clear evidence of the Thurmaston sand and gravel until Hoby is reached, although the bed may possibly be concealed beneath later terrace deposits. At Hoby a basal sand and gravel is capped by boulder clay, and in an old pit (28) just south of the village Fox-Strangways records on his field sheet a gravel composed mainly of Bunter pebbles. Westwards from this there is again no conclusive evidence of the bed, and it is only downstream from Ratcliffe that it reappears. A cutting on the A46 road (29) displays a poor section in red coaly sand, while screw augering in an abandoned pit immediately to the west (30) showed that the sand is by no means homogeneous, being frequently interbedded with bright red boulder clay.

The description of the Thurmaston sand and gravel
may be concluded by very short references to two other localities. The first is the valley of Rearsby Brook, south of the Wreak, where screw augering proved the existence of the sand and gravel as a continuous stratum, but where no clean exposure was seen during the present study and the deposit does not seem to have been worked on any large scale in the past. A farmer reported to the writer that the material when seen in temporary sections is "red running sand with many black patches." The second lies north of the Wreak (31), where bucket-auger traverse AA' (fig. 5) disclosed a bed of red coaly sand over nine feet thick. Although this deposit probably rests directly on the Lias, no southward extension linking it with the main mass of the Thurmaston sand and gravel could be found. At present the significance of this isolated occurrence is not understood.

(ii) Thrussington till. (Map B).

North of the latitude of Leicester the Thurmaston sand and gravel is generally succeeded by a till which, although by no means uniform in composition, is characterized by the comparative rarity of chalk and flint erratics. Good sections in the till are infrequent since they are normally restricted to temporary excavations or the overburden in pits working the earlier sand. One of the criteria employed in selecting the lines for the bucket-auger
traverses in the Wreak valley was the information likely to be yielded about the Thrussington till, and it is appropriate therefore to begin the description by reference to these traverses, especially as in them the till approaches its maximum thickness.

(a) The Wreak valley. In Traverse AA' (fig. 5) the Thrussington till is about 20 feet thick and consists of mottled brown and red boulder clay with Bunter pebbles, coal, skerry, Lias limestone, yellow sandstone and ironstone. In Traverse BB' just over a mile to the south, it has thickened to 55 feet (although when quoting such thicknesses it must be remembered that the boulder clay may be banked against an irregular bedrock surface so that only deep bores can prove the actual thickness) and has become more diverse in character, with alternating beds of red and blue boulder clay. Although the matrix clay changes from Keuper to Lias the erratic content as brought to the surface by the bucket auger is more stable with Bunter pebbles, coal, Lias limestone (including many *Gryphaea*), skerry and soft yellow sandstone nearly always present. In Traverse CC' the boulder clay, although much thinner, is of almost identical composition. Finally, in Traverse DD' the Thrussington till is about 30 feet thick and is quite sharply divided into a lower red and an upper blue boulder clay; in this instance there is also a clear preponderance of skerry and Bunter pebble erratics in the
Fig. 5. Bucket-auger traverses AA' & BB'

FOR LINES OF TRAVERSES SEE FIG. 9 & MAP B
red, and of Lias limestone erratics in the blue boulder clay.

In the Wreak valley east of the zone investigated by the above traverses, screw augering on the right bank of the river proved that the Thrussington till retains its mixed character with beds of both Trias-based red boulder clay, and Lias-based blue boulder clay. No consistency in the sequence of these two types could be detected, and locally they are so intermixed as to be inseparable. There is a marked tendency for the proportion of Lias-derived boulder clay to increase in a northeasterly direction, until beyond Asfordby, the Thrussington till may locally thin and even disappear. However, to the north of Asfordby, Lamplugh (1909 pp. 69-70) mentions the presence of two boulder clay types, one greyish and full of oolite, chalk and flints, the other blue or purplish with much Jurassic detritus and very little oolite and chalk. The latter could well be the local equivalent of the Thrussington till. On the left bank of the Wreak, the glacial material is very similar, but an important addition to the erratic content was noted east of Kirby Bellars. A fragment of chalk was here (1) brought to the surface by the screw auger, and although at first it was thought this might have been derived from a down-washed soil horizon, recovery of other fragments of both chalk and oolite from at least half a dozen nearby deep
screw-auger holes led to the conclusion that these erratics are actual constituents of the boulder clay. The presence of the Wigston sand and gravel overlying the boulder clay confirms that one is here dealing with the Thrussington till and that there has been an important lateral change in this bed. However, as chalk, flint and Lincolnshire Limestone erratics in appreciable quantity are diagnostic elsewhere of the Oadby till, mapping the boundary between the Thrussington and Oadby tills east of Kirby Bellars is extremely difficult unless a stratified deposit intervenes; as a consequence some of the mapped boundaries in the Melton Mowbray district must be regarded as provisional until further work is completed. West of Kirby Bellars, a borehole at Kirby Hall Farm (see p. 45) proved over 70 feet of Thrussington till. Screw augering on the hillside below the windpump showed that the "brown clay" of the record is actually a mottled purplish brown boulder clay with a large number of small Lias limestone fragments and a few Bunter pebbles. On the hillslopes above Frisby the alternation of red and blue boulder clays once more becomes very pronounced, with the screw auger at several points having penetrated an unusually bright red till with numerous skerry, coal and Bunter pebble erratics.
In the Wreak valley downstream from the zone of bucket-auger traverses, the pattern of intermixed boulder clays continues, but there is a distinct tendency for the boulder clay of Triassic derivation to increase in amount. Two brickpits in this area, both now completely overgrown, were described by Deeley and Fox-Strangways, whose accounts furnish some guide to the appearance of the Thrussington till when seen in section. At Thrussington itself (2) the boulder clay is described by Deeley (1886 p. 444) as "at least 30 feet of fine, tough, silty Boulder-clay, with included masses, streaks, or irregular beds of unstratified moraine. These morainic masses have been forcibly intruded or even dropped into the surrounding clay. Though the main mass of the deposit is a tough silty clay, it is thickly studded with very small fragments of rock and occasional boulders. The boulders are well striated, especially the Lias limestone. Keuper Marl, green marl, quartz pebbles, and a few Pennine rocks also occur. The quartz and quartzites are most plentiful in the intruded morainic portions. Oolitic and Cretaceous rocks are quite absent." Such a description must be interpreted in the light of Deeley's claim to differentiate between "aqueous" and "morainic" boulder clays, and Fox-Strangways (1903 p. 45) seems to have entertained no
doubt that the deposit is a normal till. He alludes to the bed, under the head of "The Older Boulder-clay", as a "stiff marly clay of variegated red and bluish-grey colour, with small pebbles of quartzite and other rocks, but containing few, if any, large boulders, nor any derived from the Chalk or Oolite. It however contains a considerable amount of limestone derived from the Lias, which is usually well striated, as also are most of the harder rocks." On the opposite bank of the Wreak at Rotherby brickyard (3) Fox-Strangways (1903 p. 46) mentions that a boring into the floor of the pit proved 12 feet of hard, tough, red boulder clay with small quartzite pebbles and a few bits of limestone.

Bucket-augering through the floor of Ratcliffe sand-pit (4) disclosed a characteristic red boulder clay with Bunter pebbles, skerry and coal. Between this site and the village of Ratcliffe lines of screw-auger holes penetrated an almost identical till, but also patches of relatively stoneless clay. In Ratcliffe during 1960 a deep roadside trench (5) displayed red boulder clay resting directly on Keuper Marl, while for a mile to the south-west numerous screw-auger holes revealed almost the entire thickness of the Thrussington till as a bright red boulder clay. Of 25 erratics collected from a small section (6) 450 yards west of Lewin Bridge fifteen were
Bunter pebbles, seven skerry, one coarse grit (probably Carboniferous), one Charnwood ash, and one much weathered black fine-grained igneous rock (?dolerite). Northwards from this site the Thrussington till becomes progressively thinner until around Sileby the only possible equivalent is an occasional stratum of red boulder clay, two or three feet thick, at the base of the Oadby till. This is too thin and discontinuous for accurate mapping. The attenuation of the Thrussington till is also demonstrated in the record of a well at Ratcliffe College. In 1893 during repairs to the well, samples of the strata at intervals of 11 feet yielded the following succession:

- Clayey sand with small pebbles and specks of chalk......... at 11 ft.
- Clayey sand with small pebbles and specks or rather coarser.. at 33 ft.
- Grey clay, probably dark when wet..... at 44 ft.
- Gritty sand with clayey partings and small stones............. at 55 ft.
- Grey (blue) clay with sandstone, chert, etc................... at 66 ft.
- Grey (blue) clay with chalk, etc...... at 77 ft.
- Coarse sand with fragments, little marl at 88 ft.
- Red marl with a grey patch............... at 99 ft.
- White quartzose sandstone............. at 102 ft.
- Red marl streaked with grey............ at 110 ft.
- Red sandy marl with grey specks......... at 121 ft.

The Thrussington till is either entirely lacking, or at least less than eleven feet thick.

(b) The Soar valley. Although exposures of the Thrussington till in the Soar valley are limited in number, they do provide in the vicinity of Leicester a
further indication of the nature of the deposit. On the site of the Percy Gee building at Leicester University (fig. 7) West and Donner (1956 p. 75) noted, beneath a chalk-bearing till, three metres of red boulder clay from which a sample of 50 erratics yielded a preferred orientation of 325° (Grid) North. Recent excavations have permitted a further study of the till on and near the University campus. Deep foundations for the new Bennett building exposed over 25 feet of the till which is predominantly red in colour although with a certain amount of blue mottling, and has as its most numerous erratics Bunter pebbles, Lias limestone and skerry. There are in addition larger boulders derived from Charnwood and Mountsorrel. However, at a depth of 20 feet below surface level there occurs a discontinuous lens, under one foot thick but over 10 yards in visible length, composed of blue boulder clay thickly studded with chalk and flint. One of the flints was of exceptional size for such an erratic, measuring 19 x 15 x 8 inches. The lens is quite discrete, and stone counts from the lens itself and from the till above and below emphasise the contrast in erratic content (Appendix A Nos. 7, 8, 9). The complexity of the drift in this neighbourhood was further underlined by a section exposed on the site of the East Midland Gas Board offices. The basal strati-
Fig. 7.
fied deposits are here succeeded by a boulder clay which has a predominantly blue Lias clay matrix, and Lias limestone as the most common erratic material. Other erratics include Bunter pebbles, skerry, coal and Millstone Grit. Such is the contrast with the red boulder clay on the University campus that it was decided to test the preferred orientation of the stones in this Lias-based till. A sample of 102 stones was measured, and they were found to have a preferred direction of S 30°W.

In fig. 7 the sites of other sections in the till are shown, and it will be seen that the Lias-based and chalky boulder clays are the exceptions in a mass of Trias-derived till. These observations may be compared with the descriptions of the drift revealed during widening of the nearby railway cutting in 1893. Browne (1893 pp. 195-6) records that the boulder clay is red in colour with patches and stainings of blue clay, and contains flints, quartzite, Lias limestone, white sandstone and (?) chert. The flints, though few, are equally common at the bottom as at the top. Fox-Strangways (1903 p. 47), in a figured diagram, confirms that chalk and flint occur within 10 feet of the base of the drift.

In the circumstances it is extremely difficult to know where to draw the upper boundary of the Thrussington till. Wherever it is drawn, one stratum of till will
inevitably be included within a member of the drift succession of which it is not typical. After much hesitation the boundary has been placed at the base of the red chalk bearing boulder clay described by West and Donner. The grounds for this decision are that West and Donner seem satisfied that a major stratigraphical break occurs at this level, and the present writer is informed that a large pocket of sand was visible at this horizon. Such pockets of sand are not unusual at the junction of the Thrussington and Oadby tills. But undoubtedly the most important conclusion to be drawn from all the observations around the University site is the absence of any sharp boundary line between the different tills.

One other occurrence of the Thrussington till in the Soar valley, that is as the overburden in the old Aylestone sandpits (7), requires close attention. In this instance reliance has to be placed upon the descriptions of earlier observers, and as the following account shows, they express several conflicting views. Paul (1883 a pp. 24-5) distinguishes two boulder clays: the lower consists of eight feet of tolerably uniform chocolate coloured clay, in places stratified, containing chert, quartz, yellowish flint, Keuper sandstone, and Mountsorrel granite; the upper is a tough, dark blue boulder
clay. Deeley (1886 pp. 452 and 461) also recognizes two boulder clays, the lower being reddish in colour and containing Charnwood, local and Pennine rocks, the upper blue in colour and containing flints. Moore (1888 pp. 22-3) notes only one boulder clay which he describes as "... a stratum of stiff blue clay, in places weathering brown in colour, and varying in thickness to about 12 feet... This clay contains numerous fragments of coal, some chalk pebbles, pieces of sandstone, millstone grit, with numerous boulders of syenite." Browne (1893 pp. 188-9) also contends that there is only one boulder clay, although he does note the presence, near the base, of compact clay formed from "almost pure or washed Keuper", and locally inclined to lamination. Lewis (1894 p. 326) seems in no doubt that two drifts can be distinguished. He writes, "A second visit here showed clearly two separate clays. An under one, red without glaciated stones as a rule, sedimentary, with no chalk flint, but with large angular blocks of Charnwood Forest granite. On this is the blue and brown clay containing more stones, among which are occasional chalk flints and chalk pebbles, more till-like in aspect, but without large blocks of granite, etc. Chalk flints are very scarce in it. A sharp line, well seen at some distance, separates the two clays." By analogy with the
section now visible at Blaby brickpit (see below) the present writer believes that there were almost certainly two drift deposits exposed, although the difference between them was only slight. The lower one was the Thrussington till, probably intermixed with beds or patches of stoneless clay, the upper one the Oadby till.

Other exposures in the Soar valley may be treated more summarily. At Blaby brickpit (8) there is a basal boulder clay, predominantly red in colour but with some blue mottling, in which more than three-quarters of the erratics consist of Bunter pebbles and skerry. No flints were observed at the time the section was recorded. This bed terminates upwards (fig. 4) in a sharply defined but not particularly conspicuous boundary, above which there is a boulder clay of similar general appearance, but with rather more blue clay in the matrix and a few scattered flints among the erratics. The boundary is believed to separate the Thrussington till below from the Oadby till above. In Knighton a number of excavations up to 10 feet deep were observed in the course of the present study, and virtually all displayed the typical Trias-derived boulder clay with few if any flints. This is in accord with the records of Browne (1893 pp. 175-182) for the same area. It was noted, however, that as one passes eastwards into Stoneygate the proportion of Lias clay and limestone
in the till gradually increases. On the opposite bank of the Soar at the works of Jones and Shipman (9) it is characteristic red boulder clay, with Bunter pebbles and skerry in abundance, but also large fragments of Lias limestone, that overlies the disturbed Thurmaston sand and gravel (fig. 4). Downstream at Thurmaston the overburden of the sandpit (10) is formed by up to five feet of purplish brown, much weathered till containing numerous fragments of Lias limestone which frequently exceed six inches in diameter. Lastly, several of the long spurs east and north of Barrow are capped by red boulder clay with the characteristic assemblage of Bunter, Keuper and Lias erratics.

(c) The Eastern Uplands. It is only where continuous stratified drift intervenes, as in the Wreak valley, that the boundaries of the Thrussington and Oadby tills can be mapped with confidence. It is evident from what has been written in the foregoing paragraphs about the Soar valley that even with reasonable exposures it is not always easy to draw the boundary between the Thrussington and Oadby tills. In the Eastern Uplands stratified deposits are only intermittently developed, and during the period of the present investigation there was a general paucity of good sections. The criterion employed in the mapping was that whilst the basal layers of the Oadby till may be ex-
pected to contain at least a few chalk, flint or oolite fragments, these are either absent or extremely rare in the Thrussington till. It cannot be denied that a one-inch screw auger is not an entirely satisfactory instrument for making such a fine distinction, and in places the boundary between the boulder clays remains uncertain.

On this basis the outcrops of the Thrussington till are very limited in extent, being confined in large measure to a narrow strip on the lower slopes of the valley sides. As along the Wreak valley, there is an alternation of red and blue boulder clays, with a corresponding predominance of Triassic and Liassic erratics respectively. An exposure in a stream bluff west of Gaddesby (11) displays 4'-6" of purplish red, rather shaly boulder clay resting directly on Lower Lias clay. A sample of 82 pebbles from the boulder clay was analysed (Appendix A No.10); over three-quarters were found to be of Triassic provenance, and none from beds later than the Lower Lias. A second series of exposures illustrating the character of the Thrussington till is to be seen in bluffs along the southern side of the Barkby Brook valley (12). The till is here at least 15 feet thick and varies in colour from deep blue to bright red; it has scattered all through it fragments of coal, skerry, Lias limestone and Bunter pebbles. In the succeeding valleys to the south shallow sections and the use of the
screw auger confirmed the heterogeneous character and variable thickness of the Thrussington till.

It is, however, at the western ends of the spurs between the Soar tributaries that the Thrussington till is most extensively found. This is notably true around Barkby Thorpe where screw augering showed that the predominately red boulder clay must locally attain a thickness of at least 25 feet. A thinner but continuous strip of the till outcrops along the middle slopes of the spur north of Humberstone, and a still thinner bed has been observed on the spur around Leicester General Hospital. In Leicester itself several exposures of the Thrussington till have been recorded by earlier workers. Selecting two examples which incorporate relatively full descriptions of the drift, reference may first be made to the excavations on Spinney Hills in 1886 where, according to Bates and Hodges (1886 p. 23), the drift is up to 10 feet thick and consists of "Glacial drift clay with numerous rolled pebbles of quartz and quartzite, and boulders of Lias limestone, smooth and occasionally striated, with two small boulders of syenite. Matrix a coarse mixture of red and blue clay, where the pebbles are most numerous, elsewhere of a yellowish colour with many ferruginous streaks." Browne (1893 p. 169) describes the drift in Mere Road (13) as composed of "reconstructed Lias clay in
greater part, with some Keuper Marl and quartzite pebbles, and with pieces of Rhaetic nodular limestone very common."

(d) The Western Plateau. In the north of this region, no continuous stratum which could be equated with the Thrussington till was detected between Rothley and Mountsorrel, but to the west of Swithland Reservoir there is a considerable area of red boulder clay, apparently lacking in Cretaceous erratics, which may well be the equivalent bed. Resting upon the Thurmaston sand and gravel at the disused sandpit north of Rothley station (14) there is up to five feet of reddish brown till characterized by numerous large boulders of Mountsorrel granite arranged as a layer near its base. A sample of 120 erratics from this site showed that the vast majority have travelled from the north or west (Appendix A No.11). In the area between Swithland, Cropston and Thurcaston shallow sections indicate that there is probably a red boulder clay containing Cretaceous and Middle Jurassic rocks, resting upon a red Thrussington till lacking these constituents, but in the absence of better exposures the boundary between the two tills can only be tentatively mapped.

South of Thurcaston along the Rothley Brook valley the Thrussington till thickens so that its outcrop occupies much of the lower hillslopes. A 10-foot excavation one thousand yards north-north-east of Anstey (15) re-
revealed red boulder clay in which the only visible erratics were Bunter pebbles, skerry and coal, but a nearby sewage trench was dug through a mottled red and blue till containing, in addition to the materials mentioned above, several blocks of Lias limestone. Use of the screw auger established that a similar deposit is to be found on the right bank of the Rothley Brook, although the construction of numerous channels for the Beaumont Leys Sewage Farm has much disturbed the surface layers (which in any case are not very pleasant for augering into!). Browne (1902 pp. 20-22) describes the drift exposed in a series of trial holes in the same locality, referring at one site (16) to a "very tough Boulder-clay composed chiefly of Keuper and Lias clays with pea-sized limestones, quartzites, Lias limestones, Granites."

East of Thurcaston the Thrussington till was traced by means of the screw auger to the bluffs overlooking the Soar valley, and from there was noted in trenches during improvements to the A6 road at Wanlip (17). Reference has already been made to the red boulder clay exposed in the neighbourhood of Birstall (see p. 33), but immediately south of this few sections were seen and the Thrussington till appears to be relatively thin. The overburden at Leicester Abbey sandpit (18) was described by a number of writers who are in general agreement about the succession
of strata. Deeley (1886 pp. 452 and 461) refers to brown or reddish brown boulder clay passing up into chalky boulder clay, Paul (1891 p. 405) adds the information that the lower deposit contains well rounded stones of materials which are only to be found to the north and west, while Fox-Strangways (in discussion of Browne, 1902) mentions that the two boulder clays are separated by a clear and distinct division. Use of the screw auger demonstrated the southward continuation of the red till, and although generally less than 20 feet thick it outcrops over a wide area apparently because it is draped across an undulating bedrock topography. However, the outcrop narrows south of Braunstone and finally disappears south of Lubbesthorpe Brook.

(iii) Glen Parva and Rotherby clays.

During the present investigation deposits of stoneless clay and silt, in places clearly laminated, were noted at a number of sites, but the only localities in which these are of wide extent is in the Soar valley south of Leicester and in the Wreak valley upstream from Rearsby. Whilst the existence of the clays is beyond dispute, it has not proved practicable to map them as separate strata; in both localities the clay grades without sharp break into Wigston sand and gravel, and in one it also interdigitates with the Thrussington till. Nevertheless, in view of their importance the clays will be described under
separate headings.

(a) Glen Parva clay. (fig. 8). In his account in 1893 of the Midland Railway section (1) Browne (p. 196) refers to a constant seam of stratified dark chocolate silt, with sandy partings but entirely free from stones, attaining a thickness of about 3‘6”. Above this comes a discontinuous chocolate, blue or red clay in which there are but few quartzites, etc. Fox-Strangways (1903 p. 47) figures a section on the Midland Railway (2) a couple of hundred yards south of that described by Browne in which a laminated clay six to eight feet thick and with only a very few small stones is sandwiched between two boulder clays. Fox-Strangways does not comment upon the significance of this occurrence, but examination of his 6-inch field sheets shows that southwards from this point he frequently refers to a deposit of marly clay rather than boulder clay. A good illustration is afforded by his description of the railway cutting at Aylestone Lane (3). From north to south his record of this section reads: "Red marly clay with pebbles; red marly boulder clay; very like red marl – small pebbles, no chalk; red marly clay in upper part of cutting; boulder clay 20 feet; reddish clay on top." Similarly, a short distance to the west he alludes to "Red marly drift over Keuper" and "Red marly clay with a few stones," and in Oadby to "Sand
GLEN PARVA CLAY

Fig. 8.

- Narborough Beds
- Oadby Till
- Wigston Sand & Gravel
- Thurmaston Sand & Gravel
- Bedrock
- Alluvium & Terraces
over clean clay." The last is descriptive of a pit (4) which had previously been recorded by Deeley (1886 p. 446): "9 or 10 feet of light reddish sand rests upon brick-earth, which separates it from the early Pennine Boulder-clay below. The change from Boulder-clay to brick-earth with morainic masses of Boulder-clay, then to brick-earth with sandy seams, and through a series of interstratified sand and loam-beds into clean false-bedded sand, indicate (sic) clearly the changes which occurred between this and the previous stage." Deeley also mentions that sand and brick-earth were formerly exposed at Wigston. Lastly, it is worth noting that the views of Paul and Lewis quoted on pp. 57-58 may indicate the possibility of there being relatively pure clay intermixed with till in the overburden of the old Aylestone sandpits (6).

All the records quoted above suggest that there are, within the drifts south of Leicester, deposits of relatively stoneless clay quite different from the typical tills. This was amply confirmed during the present investigation. A deep section on University Road proved, under the Thrussington till, over two feet of laminated reddish silt and clay, while on the nearby site of the East Midland Gas Board offices two feet of clay with partings of fine sand was seen. Screw augering in the railway cutting at Aylestone Lane (3) disclosed a virtually stoneless plastic clay, generally red in colour but
with some blue and purple mottling, passing down into intermixed clay and till. In August 1962, following heavy rain, a small rotational slip took place within the cutting and the resultant poor exposure showed the two types of deposit to be interbedded in very irregular fashion. Trenches in Manor Street, Wigston (7) revealed purplish red clay with seams of sand, while screw augering about quarter of a mile to the south-east (8) demonstrated very clearly that the plastic stoneless clay abuts against a buried slope of solid Lias clay. To the west of the Aylestone Lane railway cutting, four occurrences of the drift clay deserve mention. The first is on a new housing estate quarter of a mile north-east of Glen Parva barracks (9) where trenches up to seven feet deep were entirely in mottled purplish red and blue clay with scarcely any rock fragments visible. Some 600 yards to the north-west almost identical material formed the spoil heap when deep excavations were made for a new petrol station (10). In the autumn of 1962 four parallel east-west trenches were dug in an extension of the Eyres Monsell housing estate (11), and all were in plastic mottled red and blue clay with only the occasional Bunter pebble or fragment of skerry and Lias limestone. In the highest trench a seam of orange sand up to 6 feet thick was exposed, but this appeared to thin rapidly towards both
east and west. Finally three boreholes were sunk in 1953 on the Eyres Monsell estate (12,13,14), and the following logs were supplied by Leicester City Engineer:

G.L. of all three boreholes c.285 feet O.D.

<table>
<thead>
<tr>
<th>Description</th>
<th>Footage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>3'0&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>1'0&quot;</td>
</tr>
<tr>
<td>Sand</td>
<td>1'6&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>3'6&quot;</td>
</tr>
<tr>
<td>Hard marl, mainly blue</td>
<td>11'0&quot;</td>
</tr>
<tr>
<td>Top soil</td>
<td>3'0&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>1'0&quot;</td>
</tr>
<tr>
<td>Sand</td>
<td>1'0&quot;</td>
</tr>
<tr>
<td>Wet sandy clay</td>
<td>13'0&quot;</td>
</tr>
<tr>
<td>Blue marl</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Top soil</td>
<td>3'0&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>1'0&quot;</td>
</tr>
<tr>
<td>Sand</td>
<td>1'6&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>3'6&quot;</td>
</tr>
<tr>
<td>Hard red marl with small pockets of sand</td>
<td>11'0&quot;</td>
</tr>
</tbody>
</table>

It is thought most unlikely that any of these boreholes penetrated to the Keuper Marl, although in the absence of samples from the beds one cannot be absolutely certain.

It may be noted that to treat the 11 feet of "marl" in the first and third holes as Keuper Marl requires that the bedrock surface rises to over 275 feet O.D., and not only would this be much higher than the known outcrops of Keuper Marl in this locality, but it would actually represent the greatest altitude attained by the Keuper Marl in the mapped area except where it is buttressed by thick sandstone on Shoulder of Mutton Hill and by granite in the Mountsorrel district. Equally
unusual would be the presence of a hill of Keuper Marl rising above the level of the Rhaetic and Lias outcrops immediately to the east. In the circumstances there can be little doubt that the deposits penetrated by the boreholes are entirely superficial, and they probably represent just about the maximum thickness reached by the Glen Parva clay.

It will be noted that thus far no reference has been made to the precise relationship between the Thrussington till and the Glen Parva clay. The reason is that the relationship is difficult to determine and is almost certainly very complex. The difficulty is occasioned by the fact that so much of the area in which the clay occurs is built over; the complexity arises from the interbedding of the clay and till as seen in the Aylestone Lane railway cutting, and as recorded by Deeley at Oadby. It can be argued that there must be at least two horizons at which the clay is found, one underlying the Thrussington till as around the University and the other overlying it as at Oadby; but it can scarcely be doubted that between these extremes there is much interdigation of clay and till and that the two deposits are broadly contemporaneous.

(b) Rotherby clay. (fig. 9). Description of the Rotherby clay may appropriately begin with an account of the exposure formerly visible at Rotherby brickpit (15)
and recorded by a number of observers. Harrison (1877 p. 43) refers to fifteen feet of reddish sandy brickearth, finely laminated, and appearing to be recomposed red marl. Deeley (1886 p. 446) describes the deposit at the same site as "a reddish stratified, silty, or tolerably clean sand. It contains beds of strong clay in the upper portion and passes down into silty sand or brickearth." But the most comprehensive account is that given by Fox-Strangways (1903 p. 46):

Loamy soil, with Chalk fragments.
Boulder-clay, containing mostly Lias fragments and quartzite pebbles, but with one or two Chalk fragments... 8'0" to 12'0"

Stratified clayey sand with coaly matter and a few pebbles. Thin seam of clay in upper part...... 4'9" to 5'0"

Laminated brick-clay or sandy loam of a reddish colour, with a pebble here and there (lower part proved by boring)... 21'0"

Hard, tough red Boulder-clay, with small quartzite pebbles and a few bits of limestone, etc. (bored into)... 12'0"

"This brick-clay has a red Keuper-looking appearance, as if it had been deposited from tranquil water largely charged with the debris of that formation." Fox-Strangways (1903 p. 45) also mentions that laminated clay or brickearth was exposed on the opposite bank of the Wreak at Thrussington brickyard (16).

Today both these pits are completely grassed over,
but similar deposits were discovered at a number of other sites in the Wreak valley. Two thousand yards west-southwest of the old Rotherby pit a drainage trench (17) disclosed soft, red, poorly laminated silt and clay resting upon typical red Thrussington till. The same succession was proved by screw augering half a mile closer to Rearsby (18), while an old pit southwest of that village (19) is recorded by Fox-Strangways on his field sheet as displaying "sandy brickearth - sand with coaly fragments." Screw augering in the valley of Rearsby Brook revealed the stratum of stoneless clay at a number of points, frequently interbedded with sand. North-east of the old Rotherby pit, the clearest indication of the clay was obtained in Traverse DD' with the bucket auger (fig. 6). The clay here is 15 feet thick and tends to be predominantly blue in colour, but with some red and purple mottling. It is virtually stoneless, although a very few fragments of Lias limestone and Bunter pebbles were recovered with the bucket auger. At one point purplish shavings in the auger were clearly laminated, but elsewhere the clay is hard, structureless and often almost indistinguishable from solid Lias clay. Further up the Wreak valley the bed appears to decrease in thickness and to grade into a stratum in which silt and sand are more common than clay.
On the right bank of the Wreak the clay reaches its fullest development in the vicinity of Hoby. Screw augering at intervals along the tributary valleys north-west of Hoby demonstrated the presence of red clay and silt approaching 20 feet in thickness. However, beyond a distance in this direction of about one mile from the village the fine grade of material tends to give place to sand and even gravel as was revealed by Traverse CC with a bucket auger. Further south-west around Thrus-sington a similar pattern prevails, although the clay extends at least as far north as Thruslington Grange, and one of the very few places where it is exposed is along the banks of Sileby Brook above Seagrave (20). Here it is a red or chocolate brown plastic clay with rare Bunter pebbles and skerry fragments; in places it is rudely laminated. In the Wreck valley above Hoby, Traverse BB with the bucket auger proved up to eight feet of red sand silt and clay, interbedded with thin seams of red and blue boulder clay which yielded at two horizons much weathered fragments of oolite. Further north, Traverse AA encountered a similar succession of bright red, almost pure silty clays, some beds of silt, and occasional patches of more stony clay and sand which are probably best interpreted as sandy till. Lastly, screw augering on the hillslopes north-west of Asfordby
(21) demonstrated the presence of thin beds of red silt locally passing into stoneless red and purple clay.

From the foregoing account, and especially from numerous other observations made in the course of the present study, it is clear that within the drifts of the lower Wreak valley there exists an almost continuous stratum of clay and silt, somewhat variable in character but normally resting upon the Thrussington till. The extent of the bed as determined during the present investigation conforms remarkably closely to that postulated by Fox-Strangways (1903 p. 46): "The area over which the brick-clay has been deposited is about five miles across in either direction, and consequently covers about 25 square miles, of which the village of Hoby is nearly in the centre."

(iv) Wigston sand and gravel. (Map C).

The Rotherby clay is frequently succeeded by a bed of sand. This was formerly visible in the Rotherby brickyard (1) (see p. 71) and was encountered during Traverse DD' with the bucket auger (2). However, the sand and associated sediments extend far beyond the outcrop of the Rotherby clay, and constitute a horizon which may be mapped over much of central Leicestershire. The material is very varied, including not only sand but also silt and gravel; frequently lenses of till are found within these stratified sediments. Further work will
almost certainly show that two separate facies can be
distinguished, the first consisting of red cross-bedded
silt and sand resembling the Thurmaston sand, and the
second of much coarser sand and gravel. However, it
has not proved feasible in the present study to map such
sub-divisions, and the Wigston sand and gravel is treated
as a single unit. The bed is particularly significant in
that it is the earliest of the drift deposits to contain
Cretaceous rocks in any quantity.

(a) The Wreak valley. In the Wreak valley numerous
small pits have been opened in the Wigston sand and gravel,
but today most of these are grassed over and the sections
appear to have gone unrecorded. While the present study
was in progress a pit at Ratcliffe (3) was worked inter-
mittently and provided valuable information about the
deposit. The section (fig. 10) disclosed up to 15 feet
of generally fine red or buff-coloured sand which is some-
times structureless but often displays excellent false
bedding, made particularly conspicuous by thin seams
composed almost entirely of comminuted coal fragments.
Measurement of the directions assumed by the bedding fail-
ed to yield any statistically significant orientation.
At two or three points the cross-bedding is sharply con-
torted, while a further noteworthy feature is the presence
of a few seams of red stoneless clay up to about three
Fig. 10.
inches thick. But undoubtedly the most striking characteristic of the section is the inclusion within the sand of lenses of boulder clay, and the inclusion in the overlying boulder clay of pockets of the sand. Two major lenses of till were noted, the larger running diagonally down the western face of the pit and varying in thickness from 18 inches where in contact with the overlying till, to only an inch or two at its lower end at a depth of nine feet below the top of the sand. The total length of this lens was just over 20 feet. The second lens, ten feet long and less than nine inches thick, was observed at a depth of ten feet below the top of the sand and as far as could be determined had no direct connection with the overlying till. In each case the boulder clay had a greenish grey matrix with erratics of Lias limestone, chalk, flint, and Bunter pebbles. In contrast a much smaller seam of reddish brown boulder clay, also entirely surrounded by the sand but situated only one foot from the top of the bed, contained only Bunter pebbles, skerry and coal.

The junction of the sand with the overlying boulder clay is sharp but extremely irregular. Pockets of sand, elliptical in cross section with horizontal long axes of 1-2 feet, are common near the base of the boulder clay and on clean faces are extremely conspicuous since around
them, as elsewhere at the contact of the till and sand, the boulder clay is stained white by secondary deposition of calcium carbonate. At many points the junction is "faulted" with wedges of sand projecting upwards several feet into the boulder clay. On the western face of the pit where an attempt was made to dig out the junction it was found that the base of the till slopes westwards at an angle of $35^\circ$.

The only other clean sections observed during the present study were in drainage trenches 300 yards east of Ragdale church (4). These revealed material ranging in grade from coarse brown sand to fine silt and even clay. The sorting of the deposit is far from complete and yet is sufficient to indicate deposition by water, an interpretation confirmed by the presence in places of rudimentary foreset bedding. Among the very few pebbles visible in the trench sections were small fragments of flint and ironstone, whilst another feature was the presence of an interbedded two-foot seam of blue boulder clay with Lias limestone erratics. Screw augering has shown that material similar to that at Ragdale is widely distributed in the Wreak valley, but is particularly common at sites marginal to the area covered by the Rotherby clay; the distribution suggests it is probably the lateral equivalent of the clay. Yet the rapidity
with which the Wigston sand and gravel changes character is also well illustrated at Ragdale. Between the trench sections just described and the village itself there was formerly a small sand and gravel pit (5). No clean exposure remains, but the gravel appears to consist mainly of Lias limestone and Bunter pebbles, with a distinctly smaller proportion of oolites. Not far distant (6) Traverse CC' with the bucket auger revealed beds of fine red sand, coarse yellow sand, brown silt with coal fragments, and at the base gravelly sand with much oolite and other Jurassic materials.

The few sections described by earlier workers in the Wreak valley include one "on the west side of the wood, near Shoby Scholes," (7) which is said by Deeley (1886 p. 447) to have shown eight or nine feet of red stratified sand free from pebbles. Further to the north-east the same writer records (p. 456) a temporary section at Grimston in gravelly sand with Cretaceous and oolitic pebbles. Half a mile north of Asfordby Fox-Strangways notes on his 6-inch field sheet a pit (8) with gravel of mostly oolite, chalk and Lias pebbles resting on sand stratified from the south. Deeley (p. 456) adds the information that the sand is 15 feet thick and shows signs of great disturbance. Finally, on the south side of the Wreak a borehole at The Hall, Kirby Bellars, is said to have pene-
trated 27 feet of clay before entering sand; from examination of the ground, the clay is almost certainly boulder clay and the sand part of the Wigston sand and gravel.

(b) The Eastern Uplands. In the Eastern Uplands the Wigston sand and gravel outcrops intermittently along many of the valleys sides. Exposures are poor, but as the following account shows, some impression of the varying nature of the bed can be gathered.

On the northern side of the Gaddesby valley, several pits have been opened in the sand but today all are overgrown. On his field-sheet Fox-Strangways records two of them as follows: coarse reddish sand and gravel with lumps of white sand, a few pebbles and coaly fragments (9); and oolitic and chalky gravel (10). Close to Harborough Cottage north-east of Gaddesby another old pit (11) at about the same horizon appears to have been worked for gravelly sand full of chalk, oolite and flint. On the southern side of the Gaddesby valley the Wigston bed has been worked near Barsby (12) where it seems to consist of gravelly sand with oolite pebbles much in evidence. Along the small tributary valley quarter of a mile of Barsby (13) closely-spaced screw-auger holes demonstrated the presence immediately beneath chalky coulder clay of red sand

\[X\]In the description of the Wigston sand and gravel, the word sand may be used to include both sand and gravel.
and silt with streaks of coal and at least one flint chip. Westwards from here the outcrop widens rapidly, but the material becomes so heterogeneous that it is difficult to map any precise boundaries. Considerable masses of red boulder clay with Bunter pebbles and skerry are included within beds of red sand, silt and clay, with the last-named at one locality quite clearly laminated. Towards the top the material becomes more like that at Ragdale (p. 77), with patches of blue boulder clay derived from the Lias increasing in frequency. West of Barsby Spinney the outcrop narrows once more and the bed does not appear again as a conspicuous feature on the southern side of the Gaddesby valley.

On the northern side of the Queniborough valley (14) screw augering proved the presence of orange sand inter-leaved with a blue boulder clay containing predominantly Lias limestone erratics but also a little chalk and oolite. Eastwards the nature of the bed changes with red silt and stoneless clay becoming much more characteristic. Beyond South Croxton the apparent thickness of the silt and clay increases and the junction with the overlying chalky till becomes extremely irregular. The mapped boundary at one place runs almost directly down the valley side, and on the summit of the spur (15) two screw-auger holes, 3'6" apart, were put down to five feet, the one entirely in red
sand and silt, the other entirely in till. Further confirmation of the irregularity of the sand-till junction is afforded by the presence of an old sandpit (16) described by Fox-Strangways on his 6-inch field sheet as showing "Sand stratified to the north. Chalk, coal, etc.," while only one hundred yards away and at approximately the same altitude a sewage excavation (17) in 1961 revealed over eight feet of bluish brown boulder clay with Liassic limestone, ironstone, chalk and flint. North towards Barsby the sand which forms a single stratum at South Croxton appears to be split into two by a 20-foot bed of chalky boulder clay. The upper part of the sand was formerly worked in a shallow pit in Barsby (18) and was proved by a well in that village which is said to have penetrated 30 feet of sand. On the hillside south of the village there was once a large pit (19) which is now completely grassed over. On his field sheet Fox-Strangways records "Old sand pit with patches of clay," and screw augering in the course of the present study clearly demonstrated that some at least of the clay patches are seams of blue till studded with abundant Cretaceous fragments. On the left bank of Queniborough Brook near Baggrave Hall, a disused pit (20), devoid of any clean face, yielded gravelly sand with rounded fragments of Liassic limestone, oolite and Bunter pebbles. Downstream from here the outcrop of the
sand can be traced to another old pit (21) where, according to the field sheet of Fox-Strangways, four feet of coarse gravel composed mainly of chalk flints rests upon Lower Lias clay. Further west the same horizon seems to be marked by a thin, intermittent stratum of red sand and silt, but threequarters of a mile from Queniborough the deposit thickens again and a third pit (22) has been opened for the working of sand and gravel. As so often, no clean face survives, but screw augering demonstrated an abundance of chalk and oolite in the gravel.

In the Beeby valley the area of the Wigston sand and gravel outcrops is very small, although the usual contrast between beds of red sand and silt, and beds of chalk- and oolite-bearing gravel is again in evidence. North-east of Beeby the gravel has been worked on a small scale (23), while screw augering close to Little Beeby (24) proved over 10 feet of fine red and orange sand.

Even more illustrative is the Keyham valley. Three hundred yards west of Keyham (25) screw augering demonstrated a drift succession composed of purplish red till at the base, then interbedded red sand, silt and stoneless clay, and finally at the top chalky blue till. On the opposite side of the valley the succession is the same apart from the intercalation immediately below the chalky till of a stratum of gravel. An old working in the gravel (26) yielded enough material for a pebble count (Appendix A
No. 12). Most of the stones are of Triassic or Liassic origin, but there are also a few from the Middle Jurassic; to nearly all of them there adheres a considerable amount of coarse sand fixed by a calcareous cement. A short distance downstream screw augering (27) revealed at least 20 feet of red sand but with many included lenses of red Trias-derived boulder clay. Opposite Scraptoft Lodge there are in addition some lenses of chalky boulder clay, and a nearby pit (28) is described by Fox-Strangways on his field-sheet as showing "Loam and gravel with chalk flints." The gravel was also worked south of Scraptoft Lodge (29) where Fox-Strangways records "Pebbles and chalk flints," a description amply confirmed by examination of the site today. Further downstream the Wigston sand and gravel is probably missing, although close to Hamilton Grounds (30) another patch of flint-bearing gravel occurs. Capping the top of a prominent spur, it is uncertain whether this is inter-bedded with the drift or simply resting on top of it; since augering failed to locate any point where till could be shown to overlie the gravel, the latter seems the more likely.

In the vicinity of Humberstone the Wigston sand and gravel consists of reddish coaly sand and silt, temporarily exposed during the present study in a six-foot trench (31) which needed shoring up to prevent collapse of the sides.
Traced eastwards the bed thins and becomes impersistent so that it could not be detected beyond Humberstone Garden City. It reappears as typical reddish sand east of Scraptoft, but here it also contains a large mass of chalk-bearing gravel. As usual the gravel appears to overlie the red sand, although the relationship between the two is not entirely clear. A trench (32) in the gravel provided a sample for a pebble count (Appendix A No.13), and this showed a very high proportion of the constituents to be of either Cretaceous or Middle Jurassic origin. Not only is the association clearly with the chalk-bearing till, but on the west the gravel seems to be interleaved with such till. It should perhaps be mentioned that, as the deposit caps a hill, its exact stratigraphical position is a little uncertain, and it could conceivably be later than the chalky till on a site where that bed is virtually absent. The writer, however, regards this as unlikely.

Around the village of Thurnby the glacial drift is draped over a hill composed of Lower Lias clay, and attains no great thickness. Such is the variability of the drift that resting on the solid rock one finds in some places boulder clay, in others sand and in yet others quite coarse gravel. Within a distance of 300 yards east of Thurnby station, Fox-Strangways on his 6-inch field sheet twice records stratified sediments (sand, gravel and brick-earth)
and once boulder clay resting on the Lower Lias. In the
course of the present study, a deep excavation near the
top of Thurnby Hill (33) revealed six feet of loamy sand
mixed with patches of blue boulder clay containing Lias
limestone erratics, resting directly on four feet of
Lower Lias clay. But the most instructive section was
seen 100 yards south of Thurnby church (34) where compara-
tively coarse gravel lies upon a contorted surface of the
Lias clay (fig. 10). A sample of the gravel was analysed
(Appendix A No. 14) and this showed that over two-thirds
of the pebbles are of Bunter derivation; none was found
indicating a provenance from east of north. Such consti-
tuents are not normally associated with the Wigston sand
and gravel, and their true place in the drift succession
is debatable. So far as could be ascertained, the strati-
fied deposits at Thurnby are directly overlain by chalky
boulder clay, and the Thrussington till is missing. Whe-
ther it is missing from below or above the Bunter rich
gravel one cannot be sure; further reference to this
question is made on p. 181. The extreme irregularity of
the drift-solid junction at this site is almost certainly
due to post-depositional disturbance under periglacial con-
ditions.

On the northern side of the Evington Brook valley,
an old gravel pit in Evington (35) is described by Fox-
Strangways on his field-sheet as showing "Chalky boulder
clay over sand, gravel and brick earth." Discontinuity of these stratified sediments was well illustrated during the present investigation by a shallow excavation half a mile to the north-east (36) where the chalky boulder clay could be seen resting directly on Lias clay. However, the stratified material reappears at Stoughton where it was formerly worked at a site 250 yards north-west of the church (37). Today the sections are very poor, but a gravel composed mainly of Lincolnshire Limestone with a few flints and pieces of chalk seems to be the most abundant constituent. This accords with the note by Fox-Strangways on his field-sheet "Stratified sand and gravel, mostly oolite, some quartz, some Chalk flint." As at Scraptoft, it is difficult to determine the precise horizon of this sand and gravel, for in part at least it rests directly on solid rock and in available exposures is not capped by any later deposit. Yet analogous occurrences elsewhere argue strongly in favour of the Stoughton bed being situated at the base of the chalk-bearing till. On the southern side of the Evington Brook valley, the Wigston sand and gravel seems to be almost entirely absent.

Reference has already been made (p. 67) to Deeley's description of the old pit near Oadby race-course (38), where the facies represented was that of the clean reddish sand. The same material was seen at two other sites
during the present study. In the course of road improve-
ments at Oadby Hill (39) over 10 feet of medium reddish
sand with coal lenses was visible beneath a capping of
chalky boulder clay. As observed in trenches the junc-
tion between the sand and till is usually sharp and un-
disturbed, although at a few points pockets of sand have
been incorporated in the base of the till. Another note-
worthy aspect is the existence of large fragments, many
of them nine inches or more across, of Lias limestone,
colite and chalk flint in the base of the till, so that
locally it approaches the composition of an extremely
course gravel. The second site was in the centre of
Oadby where the foundations for the Leicester Cooperative
Society store (40) disclosed six feet of weakly current-
bedded red sand. The interest of this exposure was much
enhanced when a deep trench was dug higher on the same
slope close to Oadby by-pass (41). At the lower western
end of this trench a basal red sand, although rather clayey,
is not dissimilar to that at the Cooperative store, but
resting upon this and separated from it by a sharp, sloping
boundary is a melange of chalk-bearing gravel, sand, till,
clay and silt, the last two being clearly laminated at
one point and elsewhere showing a tendency towards lami-
nation. Such is the confused mixture of deposits that it
is almost impossible to provide a brief description and
the annotation of fig. 10 must suffice. On the southern side of the valley at Oadby there was formerly a sand and gravel pit (42) which has been completely obscured by tipping. No description of the pit has been found, but from shallow cuttings in the locality (now a housing estate) it is evident there is much gravel composed of Bunter pebbles, Lias limestone, oolite and flint.

The nature of the Wigston sand and gravel around Wigston itself is equally varied. Deeley (1886 p. 446) records the presence of sand and brick earth, both much disturbed, probably exposed in an old working north of the village (43). North-east of the village shallow trenches (44) in 1962 disclosed brown sand and silt, probably at the same horizon. In contrast deep foundations for new buildings in the centre of Wigston (45) revealed coarse, yellow, false-bedded sand resting upon a gravel composed almost exclusively of flint, oolite and chalk. At one point the sand was seen to contain a lens of blue chalky till two feet thick and over four feet long. The last section to be noted lies south of Wigston (46) where a hole was excavated on a building site especially for the benefit of the writer. Owing to the depth of the hole and the nature of its sides, it was impracticable to sample the material in situ, so that the following description is based upon observation from the surface and examination of the spoil heap:
An extremely varied deposit - reddish brown till with Bunter pebbles, coal, flint and chalk, completely mixed up with numerous patches of dirty brown sand - no apparent pattern in the distribution of the sand... 5'6"
Relatively pure red sand.................. 2'6"
Blue till with Bunter pebbles, Lias limestone, and small pieces of chalk...... 2'0"
Purplish brown coarse sand................ 2'0"

Both beds of sand yielded water profusely, rendering the sides of the hole very unstable. From a depth of 12 feet the excavator brought to the surface scrapings of a compact deep blue clay, almost certainly Lower Lias clay.

(c) The Soar valley. The Wigston sand and gravel does not occur extensively in the Soar valley, and only three widely separated localities merit note. The most southerly is at Saffron Hill cemetery where a hill rising to just over 300 feet O.D. is capped by a small patch of gravelly sand, which in newly dug graves was seen to consist of reddish sand with Bunter, skerry and Lias limestone pebbles in great number, and just a few of flint and oolite. There is no conclusive evidence that the deposit is part of the drift succession, for it could be a fragment of a high-level terrace, but its height, position and composition all accord with the probability that it is an outlying remnant of the Wigston sand and gravel. It certainly lies close to an outlier of the chalk-rich boulder clay.
The second area where possible Wigston sand and gravel has been located lies between Braunstone and Rowley Fields. Screw augering demonstrated the existence of a considerable mass of flinty gravel west of the Foss Way (47), while near the railway cutting three-quarters of a mile due east (48) almost identical material was noted in shallow exposures. It was here that Fox-Strangways (1903 p. 45) recorded the gravel as cemented. It must be admitted that there is some doubt regarding the correct interpretation of these deposits. Their level is the same as that of many of the post-glacial terraces, and the eastern spread has the surface form of a terrace. The western, on the other hand, seems to pass beneath, or at least be interbedded with, chalky till and thus to be part of the drift succession. Even so, it might equally be considered as part of the Narborough beds which seem to fill a channel trending southwards from this vicinity. Further work is necessary before these points can be settled, but for the present it will be assumed that the gravel spread overlooking the Soar is a terrace deposit, that to the west is part of the Wigston sand and gravel.

The third locality is at Thurmaston where the thin stratum of Thrussington till is succeeded by intermixed chalky gravel and boulder clay. Today exposures are poor, but on his 6-inch field sheet Fox-Strangways records
near the En-Tout-Cas works (49) exposures of a "Thin seam of gravel with much Chalk between boulder clay with little or no Chalk," and "Boulder clay, mostly pebbles with one or two Chalk flints overlaid by gravel."

(d) The Western Plateau. As in the regions already described, the Wigston sand and gravel does not here form a continuous stratum, but seems to consist mainly of a series of separate masses of gravel. Two of these were encountered in the digging of cuttings on the Great Central Railway. The southern one (50) was recorded and figured by Fox-Strangways (1903 p. 48), and it is clear that variability constitutes one of the most striking aspects of the deposit. Fox-Strangways gives no precise dimensions for the section, but in a depth of about fourteen feet the materials include, among others, "gravelly, chalky boulder clay," "chalky gravel," "loamy sand" and "stiff drab clay." The northern one, at Birstall Hill (51), was not recorded in such detail but seems to have consisted mainly of flinty gravel. Roechling (in discussion of Browne, 1902) contrasts the deposit with that seen in the sandpits at Thurcaston, Aylestone and Leicester Abbey. Further west in the valley of Rothley Brook, a thin and discontinuous bed of reddish sand and silt was traced southwards from near Thurcaston by means of the screw auger. Around Anstey Pastures the bed becomes
gravelly, and on his field sheet Fox-Strangways records an old pit (51) as showing "Sand with Chalk flints." On the western side of the valley a sewage trench north of Anstey (52) revealed a four-foot bed of red sand which can be followed northwards towards Cropston.

(v) Oadby till. (Map D)

The Oadby till is distinguished from the Thrussington till by its much higher content of chalk, flint and Lincolnshire Limestone erratics. The matrix is normally blue or grey Lias clay, although isolated occurrences of a Keuper Marl matrix have been noted. The till is not homogeneous, for some layers within it possess far fewer Lias than Middle Jurassic or Cretaceous erratics, while in others the proportions are reversed. The till of more local derivation is particularly common near the base, and although there is no sharp dividing line it is possible to recognize a lower stratum in which Liassic and even Triassic erratics are in the majority, and an upper in which Cretaceous and Middle Jurassic erratics far outnumber all others. These two strata are sufficiently distinct to allow for the depiction of the intervening boundary by a dotted line on the drift map, and for their separate treatment in the following account. A further point worthy of note is that whilst the upper Oadby till is quite unmistakable, even in the small
quantities recovered with the screw auger, the lower is not always easy to separate from the Thrussington till, especially where there is no intervening horizon of stratified sediments.

**Lower Oadby till.**

(a) **Wreak valley and Eastern Uplands.** The lower Oadby till is only found extensively in the area between Beeby and Shoby. Nowhere is it well exposed, although in the old Rotherby brickyard (1) Fox–Strangways (1903 p. 46) notes what seems to be lower Oadby till: " Boulder clay, containing mostly Lias fragments and quartzite pebbles, but with one or two Chalk fragments."

Material fitting this description was encountered in each of the bucket-auger traverses at the base of the chalk-bearing boulder clay. Screw augering demonstrated the lower division of the Oadby till close to Barrowcliffe Farm (2), but southwards from here it thins rapidly with the result that the upper division comes to rest either directly on solid rock or on one of the earlier members of the drift succession.

(b) **The Soar valley.** Three sites merit brief reference. The first is Leicester University campus (described on p. 55) where the boulder clay containing lenses of red chalky till exposed in the foundations of the Percy Gee building is deemed to belong to the lower Oadby till.
The lenses were studied by West and Donner (1956 p. 75) who found the erratics to have a preferred long-axis orientation of \(35^\circ\) (Grid) North. It may be noted that this is one of the relatively few localities where plentiful Cretaceous erratics are set in a Keuper Marl matrix. The second site worthy of mention is the old Aylestone sandpit (3). Accounts (quoted on pp. 57-58) of the overburden at this pit indicate the presence, above the Thrussington till, of typical lower Oadby till, blue in colour and with Cretaceous rock fragments outnumbered by those of more local derivation. This description also applies very well to the upper boulder clay exposed at Blaby brickpit (4), the last important site in the Soar valley. It should be added, however, that without better exposures than existed in the course of the present study, it is almost impossible to delimit precisely the occurrences of the lower Oadby till in the built up area of south Leicester, and there may well be isolated patches which have been omitted from the map.

(c) The Western Plateau. The only locality in this region where the lower Oadby till attains any considerable thickness is between the villages of Swithland, Thurlaston and Anstey. Much of the spur running north-east from Cropston is capped by boulder clay with a Keuper Marl matrix and erratics which include Bunter pebbles, skerry,
Lias limestone and oolite. Examples of all these constituents were obtained by use of the screw auger, while shallow trenches on the summit of the spur yielded in addition several flints; whilst these last are probably part of the boulder clay, the sections were too shallow for certainty. On the other side of the Rothley Brook valley at Thurcaston, foundations up to six feet deep for a new house (5) disclosed bright red boulder clay with Bunter pebbles, coal, skerry and at least half a dozen fragments of chalk. South-westwards from here the lower Oadby till apparently occurs as a very thin bed overlying the Wigston sand and gravel; it was exposed as a red chalk-bearing boulder clay on a new housing estate north of Anstey (6).

The Upper Oadby till.

This, one of the most distinctive and easily mapped beds in the drift succession, was the subject of detailed study in the foundations for a new office block for Leicester Permanent Building Society, 900 yards south-east of Oadby parish church (7). The excavation varied between 12 and 16 feet in depth, and disclosed a till with a bluish grey Lias clay matrix conspicuously studded with numerous small fragments of chalk, Lias limestone and oolite. Small irregular patches of gravel, less than six inches in diameter, and one undulating streak of red
plastic clay, three feet long and three inches thick, were the only notable variations. A sample of 141 erratics was analysed and this showed over half to be of Cretaceous origin, and almost threequarters to be of Cretaceous and Middle Jurassic origin (Appendix A No. 15). In addition the orientation of 132 rock fragments was measured. In the course of the measurement it was noted that the strength of the preferred orientation appeared to vary slightly according to the alignment of the face from which the fragments were drawn (fig. 11). The probable reason is that, in dressing a section preparatory to making the measurements, those erratics lying with their long axes parallel to the face are much more easily displaced than those with long axes normal to the face. Consequently there is a selective factor operating to produce an artificially large proportion of undisturbed erratics with normal long axes. This factor is likely to be more important when a high percentage of the rock fragments are small; at the Oadby site many were only about two cms in diameter. By making measurements at differently aligned faces, the effect of the selective factor may be minimised, and the orientation illustrated in fig. 11c is believed to be a true indication of the preferred direction of the erratics at this section in the Oadby till.
Fig. II. Excavation at Leicester Permanent B.S. offices, Oadby.

A & B - Preferred orientation as measured at differently aligned faces
C - Overall orientation
D - Composition of erratics
Although the proportion of local to far-travelled material may vary slightly from section to section, the general character of the upper Oadby till is sufficiently constant throughout central Leicestershire to make detailed description of each individual exposure unnecessary.

(a) The Eastern Uplands and Wreak valley. Upper Oadby till caps all the interfluves northwards from the site just described to the Wreak valley, its presence being readily demonstrable by use of the screw auger. The thickness varies considerably but is known to be great in the south around Oadby and Scraptoft. Before the foundations for the Leicester Permanent Building Society offices were excavated, nearby trial bores (8) had proved 30 feet of grey chalky till without the base being reached, and as the bores commenced over 50 feet below the summit of the adjacent hill the total thickness may well approach 100 feet. Two other holes near Oadby are said to have encountered a considerable thickness of till, probably the upper Oadby till: the first (9) lies two miles south-east of Oadby G.L. 405 feet O.D.

Chalky boulder clay................. 41'0"
Sand with coal fragments and clayey gravel, said to cross well at an angle. 1'0"
Blue boulder clay with chalk fragments.. 8'0"

The second is situated half a mile further south and just outside the boundary of the mapped area
G.L. c.390 feet O.D.

Yellow clay and stones......................... 3'6"
Yellow clay and bed of sandstone......... 12'0"
Blue boulder clay.......................... 66'0"

The Geological Survey in an unpublished note has queried the accuracy of the latter record, suggesting that the lowest 66 feet are probably Lias clay. This view seems to be based upon supposed outcrops of Lias clay on the floors of adjacent valleys, but as will be shown below there is much evidence that in preparing the Geological Survey map Fox-Strangways frequently overestimated the extent of the solid-rock outcrops, and the present writer sees no reason to doubt the veracity of the record quoted above. One other site where a comparable thickness of upper Oadby till has been demonstrated is at Ingarsby tunnel, one and a quarter miles east-south-east of Scraptoft (10). Paul (1883b p. 51) records that in construction of the tunnel about 90 feet of greyish blue clay containing lumps of chalk and flint a foot in diameter was proved. Other erratics included oolite, Keuper sandstone and lumps from the Marlstone rock-bed. Northwards from Scraptoft, although the outcrop of the upper Oadby till is still very extensive, the thickness of the deposit probably declines. There is little direct evidence in the form of reliable borehole records, but mapping by means of the screw auger suggests that the till often forms only a thin
capping on the interfluve crests. Support for this view comes from the log of a borehole at Barrowcliffe Farm where only the top 8'6" of the drift is described as containing chalk. On the other hand it should be mentioned that at a few isolated points the mapped base of the chalk-rich till descends abruptly from the spur crests to the valley floors; discussion of the significance of such occurrences is deferred until Chapter four.

(b) The Leicestershire Wolds. The Leicestershire Wolds are the site of an extremely thick cover of upper Oadby till. Although very few deep sections were available during the present study, numerous shallow sections testified to a composition similar to that already described from Oadby. At a number of sites, especially in the east, the till is characterized by the large size of its erratics. North of Shoby a deep ditch section (11) revealed numerous pieces of oolite exceeding one foot in diameter, while about four miles further east (12) Fox-Strangways (1903 p. 52) records a mass of oolitic limestone which "appears to be at least 300 yards long and 100 yards across." In this vicinity the till often contains more Middle Jurassic than Cretaceous erratics, and Lamplugh (1909 p. 69) has described a deep section visible in 1906 at a point 600 yards east-north-east of Welby House (13) in the following terms:
Yellowish brown clayey soil .......... 1'0"
Pale yellowish boulder clay, full of
big lumps of oolitic (Lincolnshire)
limestone, some large flints, a few
blocks of sandstone, etc.............. 5' to 7'0"
    passing into, wedged into and
    mixed with -
Dark blue Liassic boulder clay, with
fewer stones, including some big
blocks of oolitic (Lincolnshire)
limestone, sandstone, etc. and
plentiful crumbs of chalk; also
with wedges of gravelly loam in
places................................. 10'0" plus

The exact thickness of the upper Oadby till on the
Leicestershire Wolds remains uncertain. The failure of
the streams to dissect more than the fringe of the
boulder-clay mass makes any assessment from the mapped
drift boundaries extremely hazardous. It is stated in
the Melton Mowbray Memoir (p. 79) that numerous wells
have been sunk to depths of 60 to 70 feet in boulder
clay, and it is estimated that the maximum thickness
probably exceeds 100 feet. At Ratcliffe College
(see p. 54) there appears to be at least 77 feet of
chalk-bearing drift, while at the Durham Ox Hotel, Six
Hills, a borehole is reputed to have penetrated the
following strata:

G.L. c. 440 feet O.D.

Soil................................. 3'0"
Blue clay with limestone boulders,
flints................................. 178'6"
Gravel and sand..................... 14'6"
Red marl............................. 2'6"

It is uncertain how much of the boulder clay, here
apparently totalling 178'6", is attributable to the upper Oadby till, but it seems likely to be a high proportion. One justification for this statement is that a well on the floor of a valley just over 1½ miles to the west (14) was sunk through the following drift deposits before the Lower Lias was entered:

G.L. c. 290 feet O.D.

Brown chalky boulder clay....................... 10'0"
Bluish grey chalky boulder clay.............. 3'0"
Chalky gravel................................. 0'2"
Chalky gravel much mixed with boulder clay................................. 5'0"
Lower Lias clay................................. 3'0"

As the interfluves to north and south rise fully 100 feet above the site of the well, a probable thickness of about 125 feet for the upper Oadby till is indicated; and if the base of the till were approximately horizontal between the well and the Durham Ox, the whole 178'6" of boulder clay at the latter place would be upper Oadby till. Corroboration that on much of the south-western Wolds virtually all the boulder clay belongs to the Oadby till is afforded by a well at Lodge Farm, Seagrave\(^x\), which is said to have been sunk through 46 feet of "Chalky boulder-clay, rather darker, with less chalk towards the bottom" before the Lower Lias was entered.

(c) The Western Plateau. On Rothley Plain, directly across the Soar valley from the Wolds, the cover of

\(^x\)There is some doubt about which farm is referred to in this record; the one indicated on Map D seems the most likely.
upper Oadby till is extensive but relatively thin. About 10 feet of grey boulder clay studded with numerous chalk fragments is exposed at the top of one face in the Mountsorrel Granite quarry (15), and this is probably representative of the whole Rothley Plain area. Cuttings along the Mountsorrel Railway, described by Fox-Strangways on his field sheet, generally revealed Keuper Marl at the base capped by irregular patches of sand and boulder clay. The basal boulder clay does not invariably contain chalk; at the Broad Hill cutting (16) Fox-Strangways notes "Apparently no Chalk in basement clay." But elsewhere chalky boulder clay actually rests on solid rock; at the Nunckley Hill cutting (17) he notes "Chalky boulder clay on Marl" and "Chalky boulder clay with thin seams of sand on granite." Southwards the upper Oadby till thickens appreciably, and immediately west of Rothley village (18) the base descends to the level of the post-glacial stream terraces. Unfortunately there are no recorded wells or boreholes in this vicinity, but augering suggests that the upper Oadby till may here reach 50 feet in thickness.

The summit of the Beaumont Leys spur between the Soar and Rothley Brook is covered by an excellent example of the upper Oadby till. This was demonstrated during the present study by use of the screw auger, but may also be inferred from the description by Browne of trial
holes on the Beaumont Leys estate. One 5'3" section (19) is recorded by Browne (1902 p. 23) as "yellowish for half its distance, and for the remainder bluish grey. It contains quartzites, flints, and one or two small pieces of Granite and pieces of Lias throughout, and is crowded with pieces of 'chalk', and something which may be soft chalk." Harrison (1877 p. 44) mentions that in Anstey Lane (20) lumps of hard chalk are very numerous, while Paul (1891 p. 405) in his account of the Leicester Abbey sandpit (21) refers to a clay "stuffed with pieces of chalk, Gryphaea, ironstone and other materials all from the east." Finally, in a railway cutting north-east of Thurcaston (22) Fox-Strangways details on his 6-inch field sheet a "stiff grey and blue clayey boulder clay with some Chalk fragments. Few boulders about 1'0" diameter. Patches of chalky gravel. A good deal of Lias and small pebbles. Several patches of sand."
The thickness of the upper Oadby till on the Beaumont Leys spur remains uncertain. On the testimony of the levels at which the base of the till is exposed on the hillsides overlooking the Soar and Rothley Brook valleys, a thickness varying between 50 and 100 feet seems probable. There are, however, a number of enigmatic borehole records which suggest that the till may locally be thicker than the outcrop levels indicate. These records are enumera-
ted and their significance discussed on pp. 185-186.

(d) The Soar valley. The cover of chalky boulder clay on the Beaumont Leys spur can be traced south-westwards into the New Parks district of Leicester. Here (23) a deep ditch revealed Keuper Marl capped by boulder clay containing several large boulders of Mountsorrel granite in addition to skerry, Lias limestone and Bunter pebbles, and this in turn passing up at about 295 feet into typical chalk-bearing, brown-weathering boulder clay. Further south the base of the chalky till falls rapidly in height. Use of the screw auger proved upper Oadby till in Braunstone Park (24) at below 250 feet, while a section (25) in extensions to Lubbesthorpe Brook sewage works revealed the same bed at well below 225 feet. At the time the sewage works were visited, only eight feet of bluish grey boulder clay studded with numerous chalk fragments in addition to such erratics as Lincolnshire Limestone, Lias limestone and Bunter pebbles, was visible; but the engineer in charge reported that the full 25 feet of the excavation was in identical material. Confirmation was forthcoming in a trench, 100 yards to the south-west and at a lower altitude, which passed through eight feet of dirty alluvial sand and then entered six feet of typical upper Oadby till. Screw augering showed that the till outcrops on both sides of the Lubbesthorpe Brook alluvial cover downstream as far
as the Osiers, but further south is so mixed with gravel, sand, and soft grey silty clay that it is better regarded as part of the Narborough beds.

On the right bank of the Soar, an outlier of upper Oadby till was noted on a new housing estate south of Saffron Hill cemetery. The deposit is here comparatively thin, and post-glacial erosion has produced a very crenulate southern margin.

(vi) Narborough beds. (fig. 12) (see Addendum)

The Narborough beds outcrop at two separate localities, both south-south-west of Leicester, and both close to the margin of the mapped area. The beds are distinctive not only in their lithology, but more especially in their relationship to the other drift deposits. They are very varied in composition, ranging from clayey silt to coarse gravel, and from well sorted sand to boulder clay; and they seem to fill deep channels cut into, and even completely through, earlier drifts. There is little guide as to the precise age of the Narborough beds, and the fact that they are being described last must not be regarded as indicative of a view that they are necessarily the youngest of the glacial drifts.

The easterly occurrence lies due north of Blaby on the right bank of the Sence. The deposit has here been worked in a large and now abandoned pit (1), described by
Fig. 12.

NARBOROUGH BEDS

- ALLUVIUM
- TERRACE GRAVEL
- NARBOROUGH BEDS
- EARLIER DRIFT
- KEUPER MARL
- BOREHOLE

Fig. 12.
Deeley (1886 p. 463) in the following terms: "At Blaby Wharf about twenty-one feet of false-bedded Chalky Gravel rests upon Chalky Clay; it contains great quantities of hard chalk, flint, and other easterly rock-debris, derived from the Chalky Clay. Small grains of chalk form no inconsiderable portion of the sand. Many of the beds are blackened by carbonaceous matter, and small lumps of decomposed coal are numerous. The false-bedding indicates currents from the east and west. Rolled boulders of pebble-covered Chalky Clay are of frequent occurrence." Lewis (1894 pp. 327-8) mentions two pits in this vicinity, one showing "clay full of limestone, sandstone, and a Lake District felsitic ash erratic, also Charnwood granite; the limestone is striated. This has all come down the valley. Over the clay is 20 feet of flinty gravel, sharp flints forming the most of it," and the other showing "fine sand false-bedded from the north-west, then a thin stratum of chalky boulder clay, and finally 20 feet of flinty and chalky sand false-bedded from the east." Lewis concludes "The gravel flood has washed the boulder clay away here and the chalky boulder clay and Pennine clay run into each other." Fox-Strangways (1903 p. 51) figures a sketch section, but this adds little to the accounts given above. At the present day there remains one clean face in the pit, and a
number of others which are partially overgrown. The clean face confirms much of what Deeley wrote, although measurement of the direction of the false bedding yields a very high proportion indicative of flow towards the south. Other poorer sections display large lenses of Oadby till incorporated in the sand and gravel. Analysis of pebbles in the gravel confirms the affinity with the Oadby till (Appendix A No. 16). However, the most distinctive aspect of the pit is the way in which the Narborough beds appear to occupy a deep and steep-sided channel cut into the Thrussington till. On the northern and eastern sides of the pit, screw augering and examination of shallow sections proved red boulder clay to outcrop at the same level as the top of the Narborough beds, while on the western side screw augering in an old working (2) (probably the one described by Lewis) revealed the junction between the flinty sand and gravel and a red clayey till to slant very steeply towards the former.

The second occurrence of the Narborough beds was first detected by screw augering, and was later confirmed by a number of borehole and well records. Augering on the left bank of the Soar south of Lubbesthorpe Brook revealed a surprising amount of sand and gravel, more than seemed consistent with the interpretation offered by Fox–Strangways of terrace gravel resting on Keuper Marl.
Moreover, no trace of the Keuper Marl could be found, and to take one example augering through the floor of a ditch north-east of Cottage Farm (3) proved interbedded chalky boulder clay and sand extending down to over eight feet below natural ground level. More evidence on the nature of the deposits in this vicinity was obtained by enquiry at three nurseries. At the most northerly, Barton's Nursery (4) a borehole has been sunk to a depth of 39 feet and is said to have passed through 26 feet of sand and gravel resting on 13 feet of sand; at the second, Palmer's Nursery (5), a borehole is said to have penetrated the following strata:

- Gravel.............................. 15'0"
- Blue pebbly marl.................... 30'0"
- Sand.................................... 5'0"

while at the most southerly (6), a well has been dug through nine feet of dirty gravel into two feet of red running sand. Since the contractor who had sunk the two boreholes refused to divulge his records, all the above information was supplied by the nursery owners. There can be little doubt about the general accuracy of the information, for the contrasts between the strata at the two holes excited much interest at the time of the drilling. The writer was also fortunate in that the owner of Palmer's Nursery had retained a sample of the material described as "blue pebbly marl" which was thus shown to be typical chalk-rich boulder clay. It
is the presence of this boulder clay, together with the content of Cretaceous pebbles in the sand and gravel as proved by screw augering, that invites comparison with the deposits exposed north of Blaby. Yet the fullest detail about the nature of the Narborough beds was provided by the sinking of boreholes in preparation for the building of the M1 Motorway across central Leicestershire. The sites of these boreholes (7 to 20) are shown on fig. 12, and the following selected logs illustrate the variability of the strata:

<table>
<thead>
<tr>
<th>G.L. 268' O.D.</th>
<th>(No.8 on fig. 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil........</td>
<td>0'6&quot;</td>
</tr>
<tr>
<td>Stiff mottled brown and grey chalky boulder clay..........</td>
<td>10'0&quot;</td>
</tr>
<tr>
<td>Stiff grey chalky boulder clay..........................</td>
<td>19'6&quot;</td>
</tr>
<tr>
<td>(At 17'6&quot; described as &quot;laminated (?)&quot; and at 24'0&quot; as &quot;laminated&quot;)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G.L. 270' O.D.</th>
<th>(No.15 on fig. 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil........</td>
<td>2'3&quot;</td>
</tr>
<tr>
<td>Stiff reddish brown sandy clay and stones including chalk.</td>
<td>31'9&quot;</td>
</tr>
<tr>
<td>Stiff red sandy silty clay with green specks.............</td>
<td>6'6&quot;</td>
</tr>
<tr>
<td>Dark slightly reddish brown silty clay and stones.........</td>
<td>0'6&quot;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G.L. 202' O.D.</th>
<th>(No.20 on fig. 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil, clay and stones........</td>
<td>3'3&quot;</td>
</tr>
<tr>
<td>Firm brown silty clay and stones passing down into Stiff brown sandy clay and stones..</td>
<td>9'0&quot;</td>
</tr>
<tr>
<td>Stiff greyish brown very silty clay</td>
<td>4'9&quot;</td>
</tr>
<tr>
<td>Firm reddish silty fine sand........</td>
<td>1'3&quot;</td>
</tr>
<tr>
<td>Stiff grey brown very silty clay with one or two stones and with seams of fine sand...........</td>
<td>8'9&quot;</td>
</tr>
<tr>
<td>Stiff brown silty clay with a few stones................</td>
<td>6'6&quot;</td>
</tr>
</tbody>
</table>
One of the features revealed by the Motorway boreholes is that close to their western margin the Narborough beds consist predominantly of boulder clay, whereas a few hundred yards further east sand and silt are more abundant. This is indicated both by the boreholes at the nurseries, and by a series of geophysical surveys carried out for the Motorway contractors (fig. 13). The most instructive of these is that along the line AB on fig. 12. Here a deep borehole proved over 50 feet of sand with minor bands of chalky clay, and an electrical resistivity survey was undertaken to trace the lateral extent of the sand. The following are the pertinent points abstracted from the report submitted to the Motorway contractors. A Wenner configuration expanding depth probe was used, but only a low resistivity contrast between the sand and adjoining boulder clay was obtained. It appears, however, that where the sands persist in depth resistivity values of over 20 units are obtained, whereas in clay areas values of the order of 10 units are obtained. On this basis the lateral limits of the sand may be defined as shown in fig. 13.

Other geophysical surveys were undertaken one and a half miles to the north but these did not add greatly to what was already known about the lithology of the
Fig. 13.
Narborough beds. They did, however, show that the beds occupy a deep, steep-sided channel just as they do north of Blaby. As the channel is cut in solid rock rather than in earlier drift deposits, discussion of its form is deferred until Chapter three.
CHAPTER THREE

THE FORM OF THE BEDROCK SURFACE

(a) The bedrock surface stripped of superficial deposits.

Before proceeding to discussion of the drift deposits it is necessary to outline the relief of the solid rock surface, so that the relationship of this relief to events in the deposition of the drift may be assessed. Map E is an attempt to depict the relief as it would be if all the drift and all the later fluvial materials were stripped away. In constructing the diagram, the first stage was to draw the contours across the known outcrops of solid rock; the second, to contour the base of the fluvial deposits; and the third, to contour the base of the drift. Since the thickness of the river gravels can generally be assessed with reasonable accuracy, it is only the last stage which presents major problems. The evidence to be used consists of known outcrops of the solid-drift junction, supplemented by all the available borehole records. The latter are so irregularly distributed, and the drift thicknesses so uneven, that the reconstruction of the bedrock surface where masked by drift is necessarily the most tentative part of the diagram.
One principle followed in the contouring has been to assume wherever feasible that the bedrock configuration is such as might have been produced by normal stream erosion, that is, without enclosed hollows. In one instance there patently is an enclosed hollow, and in a number of others the writer believes such hollows to be probable but has no indisputable proof. In the latter cases the doubts which the writer entertains have been ignored and a stream-eroded relief has been assumed.

Whilst it would be tedious to detail all the evidence on which Map E is based, discussion of some of the more critical aspects is required, especially as the map locally conflicts with the published Geological Survey one-inch sheets.

(i) Eastern Uplands. The Rhaetic and Lower Lias beds form an undulating sub-drift surface between Wigston and Gaddesby. East of Wigston the extent and thickness of the glacial deposits, together with the paucity of borehole records, precludes any attempt at precise delineation of the bedrock surface. As already indicated (pp. 97-8) two boreholes in this area failed to reach the Lower Lias at heights of 310 and 355 feet, while screw augering along the floors of the adjacent valleys did not locate solid rock at heights of more than 305 feet. At Wigston itself, a building contractor reports that on the southern edge
of the village an 18-foot excavation (1) reached a compact pure blue clay, almost certainly Lower Lias clay, at 290 feet, and on the northern edge of the village bedrock was observed in temporary sewage trenches (2) at exactly the same height. From here the sub-drift surface undoubtedly declines westwards, for in the Aylestone Lane railway cutting (3) it was not encountered much above a level of 250 feet, and is at the same altitude in South Wigston. There is a record dating from 1878 of a well at the "New Barracks, Glen Parva" (4) which penetrated the following strata:

- Drift .................................................. 10'0"
- Lower Lias with thin limestone .......... 40'0"
- Rhaetic (mostly tea-green marl) .......... 20'0"
- Chocolate marls ................................. 30'0"
- Red marls, chocolate colour ............... 150'0"

The anomalous feature of this record is that the ground level is quoted as "About 300 feet above O.D." but there seems no doubt that the actual level is about 265 feet, with the base of the drift at 255 feet.

A similar westward fall in height is also apparent around Oadby. Lower Lias clay was noted in excavations at the sewage works (5), where the solid-drift junction must be at just over 275 feet, while at the eastern end of the village a six-foot sewage trench (6) just touched the solid rock at a level of 308 feet. Further east screw augering failed to locate any Lias outcrop, and
although at several points the alluvium on the valley floors was passed through, the material then entered was typical upper Oadby till. This finding conflicts with the Geological Survey one-inch map, but it seems noteworthy that Fox-Strangways on his six-inch field sheet does not record any actual exposure of the Lias. His only reference to solid rock in this locality is at Oadby Lodge, where he describes the material thrown out of a borehole (7) as "Lias and drift." Confirmation for the view that the Geological Survey one-inch map overestimates the area of the Lias outcrop comes from two boreholes on the site of the Leicester Permanent Building Society offices (8). Both these 30-foot boreholes were sited on the Lias outcrop as depicted on the Geological Survey map, but both were entirely in Oadby till.

All the evidence quoted so far is consistent with a gently undulating Lower Lias plateau sloping from over 300 feet in the east to about 250 feet in the west. Immediately north of Oadby complication of this relatively simple pattern becomes apparent. A borehole (9) commencing at a ground level of 288 feet penetrated 25 feet entirely in Oadby till; the reliability of this record is beyond dispute, for the writer was able to examine the core and found abundant chalk fragments even at a depth of 25 feet. According to the Geological Survey one inch map, the site of this borehole is on an
outcrop of Lower Lias clay which fingers up a minor valley half a mile further east to an altitude of almost 350 feet. It might be assumed that this Lias outcrop is non-existent, but at its eastern extremity a deep borehole (10) is reputed to have penetrated the following strata:

- **Lias (Shale)**.......................... 130'0"
- ?Rhaetic.................................. 3'0"
- **Keuper Marl**............................. 130'0"

If the record is correct, the bedrock surface must here have a relief amplitude in excess of the present day surface. Whilst this is by no means impossible, or even unlikely, the writer has some hesitation in accepting the record as it stands. Screw augering within five yards of the borehole site proved at least eight feet of chalky boulder clay, and it seems almost certain that some drift should have figured in the log. The height of the sub-drift surface must remain in doubt. A second problem arises from the proven level of under 263 feet for the drift base. This is an instance where the assumption of a stream-eroded topography can be maintained, but only just. The borehole is sited on the floor of a valley which less than 1000 yards to the west is cut in solid rock at a level of over 250 feet, so that if the modern valley is coincident with an earlier drift-filled one, the downstream gradient of the latter must be relatively very gentle; yet there is no obvious alternative course
for a valley accommodating the level of less than 263 feet.

In Knighton the base of the drift is at just over 240 feet, Rhaetic beds having been recorded at this level close to Knighton Hall (Browne 1893 pp. 181-2). Northwards for over a mile the Rhaetic beds are obscured by an unknown thickness of drift, but when they re-emerge at Spinney Hills they form a prominent scarp about 50 feet high. On the summit of Spinney Hills the bedrock surface reaches an altitude of at least 262 feet (Bates and Hodges, 1886), but this is an isolated eminence being bounded on the west and north by the valley of Evington Brook. On the far side of Evington Brook lies the northward continuation of the Lower Lias plateau already described from south of Oadby. The gentle westward slope of the plateau is again in evidence, with the drift base being detected at about 300 feet on Horston Hill (11), and at almost 350 feet near Stoughton (12); similarly in the Bushby Brook valley the drift base is at about 275 feet in the railway cutting crossed by Uppingham Road (13), and rises to over 350 feet south of Thurnby (14). But one of the most significant aspects of the interfluve between the Evington and Bushby Brooks is the proof it affords that the bedrock surface here resembles in subdued form the present day relief. On the
summit of the interfluve an eight-foot section (15) revealed Lower Lias clay at an altitude of over 330 feet, while to both north and south drift is found in situ at substantially lower levels (16 and 17). This is the first of several examples in the Eastern Uplands where the core of an interfluve seems to be formed by a ridge of solid rock over which the drift deposits are draped.

The Rhaetic beds cap a 50-foot scarp rising to at least 250 feet at the western end of the spur between Bushby and Hamilton Brooks. Along the southern edge of this spur the drift base can be shown to rise eastwards, reaching 275 feet southwest of Scraptoft where the Lias was exposed in deep house foundations (18), and 350 feet southeast of that village where the drift-solid junction was located with the screw auger (19). Whilst the base continues to climb further east, it apparently fails to reach 400 feet within the limits of the mapped area since Ingarsby tunnel at that altitude was cut entirely in Oadby till (Paul 1883b). Along the northern margin of the spur a comparable eastward rise in the drift base can be demonstrated, but there is also an undoubted gradient from the centre line of the spur towards the Hamilton Brook valley. One indication of this is provided by the occurrence of drift downstream from Hamilton at a level lower than that at which the Rhaetic beds out-
crop on the western extremity of the spur. Another is provided by the results of screw augering summarized in fig. 14. The slope of the drift base evidence by the heights shown thereon is unlikely to be due to post-glacial solifluxion, for close to Scraptoft Lodge the Wigston sand and gravel has been worked in an old pit, and 400 yards south-west of Keyham screw augering proved over 10 feet of uniform and seemingly undisturbed drift resting on Lias clay.

On the spur between Hamilton and Beeby Brooks the pattern of solid rock outcrops is very similar, the Rhaetic beds forming a prominent scarp in the west near Barkby Thorpe, and the level of the drift base showing an overall rise towards the east. On the summit of the scarp bluish green marly clay was encountered with the screw auger at an altitude of 263 feet (20); at Keyham blue grey Lias clay is exposed in the banks of Hamilton Brook at 310 feet, and was located by screw augering upstream from Beeby at 306 feet (21). Whilst these heights indicate an overall trend, there are considerable irregularities in the drift base which demand closer attention. On the right bank of Hamilton Brook upper Oadby till can be found descending to floodplain level at heights below 240 feet (22). In like manner, on the floor of Beeby Brook valley Thrussington till can be

xThroughout this thesis pre- and post-glacial are used in the purely local sense.
Fig. 14. Heights of drift-base
found below stream level for a distance of 600 yards, and here the drift base again descends below 250 feet (23). In neither of these instances is there sufficient evidence to eliminate solifluction as a possible explanation of the low altitude of the till. However, it is worthy of note that on the southern side of the spur the till at floodplain level is at least six feet thick, and is in part separated from the higher slopes by a small gulley running parallel to the main valley; and that on the northern side the decline in the base of the drift is mirrored on the opposite side of the Beeby valley. On the other hand, the Geological Survey one-inch map shows an outcrop of Rhaetic and Lias beds high on the southern side of the spur, and if accurate this betokens a very steeply sloping bedrock surface which might be regarded as particularly favourable for solifluction. During the present study no outcrop of the solid strata could be found by screw augering, and examination of the 6-inch field sheet of Fox-Strangways failed to yield any clue as to an actual exposure. Yet a borehole (24) close to the southern corner of Barkby Thorpe Spinney is reported to have passed through "135 feet of Lower Lias clay and shale, into Rhaetic (sand).'' No mention is made of any drift, although screw augering around the base of the wind-
pump where the borehole was sunk encountered only chalky boulder clay. Yet even if solid rock does outcrop at this point, it does not necessarily indicate that the till on the lower slopes has been soliflucted, since it might equally point to the tendency noted elsewhere for the solid rock surface to resemble that of the present day.

At the western end of the spur between Beeby and Queniborough Brooks the Rhaetic beds are almost completely obscured by drift, but outcrops of Keuper Marl can be found at up to 255 feet (25), and the steeply rising slope of Keuper Marl probably constitutes the lower part of the Rhaetic scarp. As mentioned in the preceding paragraph, not far upstream from Barkby the base of the drift descends to below brook level, but further east it rises well above the valley floor, reaching over 300 feet close to Little Beeby (26). Outcrops of solid rock have been located at even greater heights along some of the small valleys tributary to Beeby Brook. In the tributary joining the main valley at Beeby itself the screw auger penetrated weathered blue clay at 350 feet (27), and undoubted Lower Lias clay at almost exactly the same altitude a short distance further east (28). Even further east the solid rock rises above 375 feet (29). These occurrences provide more evidence of the tendency for the base of the
drift to be lowest along the main valleys and to rise gently towards the centres of the spurs.

At the western extremity of the spur between Queniborough and Gaddesby Brooks the bedrock outcrops are less conspicuous, and 218 feet is the greatest height at which Keuper Marl was located (30). Eastwards from here the level of the bedrock surface rises only slowly, the drift base remaining close to stream level until Barsby is approached. Moreover, a borehole (31) at Barrowcliffe Farm reached the Lias at 217 feet, so that in this vicinity the solid rock surface does not rise appreciably towards the centre of the spur. Yet in the neighbourhood of Barsby there is ample reason for believing that much of the core of the spur is composed of Lower Lias beds. Half a mile north of the village, Wigston sand has been worked in a small pit at under 300 feet (32), while near the centre of the village a 30-foot well (33) which is reputed to be entirely in glacial sand and gravel would indicate a level of less than 350 feet for the drift base. On the other hand, screw augering demonstrated that the Lias directly underlies the alluvium of the small stream immediately south-east of Barsby, and near the source of this stream a six-foot excavation in 1961 penetrated the Lower Lias at a height of 385 feet (34). Thus on every spur in the Eastern Uplands from Evington north to Gaddes-
by there is a suggestion that the bedrock surface, at
least in general outline, resembles the present-day relief.

(ii) The Wreak valley. North of Gaddesby Brook the con-
ditions alter considerably, for there is an extensive
area over which no outcrop of solid rock has been located.
Along the right bank of Gaddesby Brook the Lias can be
found outcropping at, and a little above, stream level,
but in those valleys converging on Rearsby no such out-
crop occurs. On the intervening spur two boreholes
(35 and 36) have been sunk, but neither of the records
can be regarded as definitive. The records are as
follows:

<table>
<thead>
<tr>
<th>G.L. c.240 feet (No.35)</th>
<th>G.L. 274 feet (No.36)</th>
</tr>
</thead>
</table>
| Soil.................. 1'0" | Soil.................. 1'6"
| Yellow clay........... 11'0" | Light brown clay.... 4'0"
| Reddish brown clay... 10'0" | Dark brown clay.... 19'6"
| Light blue clay....... 9'0" | Dark grey clay..... 15'0"
| Red marl clay......... 13'0" | Blue clay........... 17'0"
| Light blue clay....... 3'0" | Red clay............. 18'0"
| Red marl clay......... 73'0" | Blue clay........... 15'0"
|                         | Red marl clay....... 31'0"
|                         | Stone bed........... 0'3"

In an unpublished discussion of the second record, the
Geological Survey admits there is much doubt about the
correct interpretation. Three alternatives are briefly
considered: (a) boulder clay to 25 feet, then 15 feet
of Rhaetic beds and the rest Keuper Marl; (b) boulder
clay to 57 feet, the rest Keuper Marl; and (c) boulder
clay to 90 feet, the rest Keuper Marl. On the avail-
able information it is difficult to justify preference
for any one particular interpretation, but in the contouring of Map E interpretation (a) has been adopted. The reasons are that the "blue clay", and the "light blue clay" of the preceding record, could well refer to the Tea-green Marl (although the splitting of this bed into two is rather puzzling), that the level of the "Dark grey clay" is consistent with its being the Rhaetic and with the presence of a small Rhaetic scarp such as occurs on most of the spurs to the south, and finally that the absence of any bed representative of the Thurcaston sand and gravel is most likely where the bedrock surface rises relatively high.

The lack of exposure of the Lias in those valleys which drain westwards to Rearsby may be taken to imply a fall in the level of the solid rock surface. This is confirmed in the log of a deep borehole (37) at Highfields Barn which is said to have encountered the following strata:

G.L. 336 feet.

<table>
<thead>
<tr>
<th>Clay</th>
<th>119'0&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>0'4&quot;</td>
</tr>
<tr>
<td>Gravel</td>
<td>0'5&quot;</td>
</tr>
<tr>
<td>Red marl and gravel</td>
<td>35'3&quot;</td>
</tr>
<tr>
<td>Blue clay</td>
<td>5'0&quot;</td>
</tr>
</tbody>
</table>

A minimum thickness of 119'9" for the drift is indicated by this record, and an actual thickness of 155 feet seems highly probable. Although discretion must be exercised as possible disturbances associated with the Sileby fault
are approached, the site of the borehole is such that at a level of 181 feet O.D. the solid strata would almost certainly be of Liassic age, and as a consequence the "Red marl and gravel" is to be interpreted as wholly of drift origin.

An altitude of 181 feet for the drift base at Highfields Barn poses the problem of possible outlets for such a low level valley. There is no evidence to preclude the assumption that the valley declines very gently westwards and joins the Wreak valley north of Syston. On the other hand, the drift base seems to rise above 181 feet in all other directions. Data is very scarce east of Highfields Barn, but it appears unlikely that the valley floor can decline in this direction. Just outside the mapped area and two miles east-south-east of Highfields Barn, a well and borehole at Pick's Lodge (38) is said to have encountered the following strata:

<table>
<thead>
<tr>
<th>G.L.</th>
<th>Strata Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>401 feet</td>
<td>Dark grey clay with fragments of limestone and chalk. At the base a deposit of fine grey sand, 6 inches thick, was encountered. A heading 40 feet long, by 4 feet by 5 feet (in places 11 feet high) proved this lenticle of sand to be locally 6 feet thick. 73'0&quot;</td>
</tr>
<tr>
<td>52'0&quot;</td>
<td>Dark grey shaly clays with occasional lumps of limestone.</td>
</tr>
<tr>
<td>40'0&quot;</td>
<td>Shales</td>
</tr>
</tbody>
</table>

If, as the Geological Survey suggests, the drift is here 73 feet thick the solid rock surface rises to 328 feet.
One mile further east and again just outside the mapped area, a well at Great Dalby police station (39) is said to have passed through the following beds:

G.L. 375 feet

<table>
<thead>
<tr>
<th>Description</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil and bluish clay</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Reddish boulder clay and stones</td>
<td>10'0&quot;</td>
</tr>
<tr>
<td>Bluish clay with chalk and flints</td>
<td>7'6&quot;</td>
</tr>
<tr>
<td>Bluish clayey gravel</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Blue boulder clay</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Bluish shale</td>
<td>1'6&quot;</td>
</tr>
</tbody>
</table>

Against the lowest bed the Geological Survey has written "? Lower Lias" and this suggestion accords with the fact that a short distance to the east the Lower Lias was formerly worked at a level considerably above 300 feet.

Unfortunately there are no known records of boreholes in the area between Great Dalby and the Wreak valley. The Lower Lias was formerly exposed in two railway cuttings (40 and 41) close to Kirby Bellars, and it has been located by use of the screw auger in the lower half of the valley running north from Great Dalby to the Wreak. There is some evidence that solid rock outcrops at a higher level on the western than on the eastern side of this valley, for it has been encountered at up to 261 feet on the left bank (42), but at only 250 feet directly opposite on the right bank (43). Similarly, the solid rock first appears from beneath the alluvial cover further downstream on the right bank than on the left. Along the middle reach of the valley, no actual
outcrop of the Lower Lias could be detected, but screw augering indicated that the alluvial cover probably rests directly on bedrock. On the left bank the auger passed through five feet of alluvium into Lias clay at a level of 251 feet (44), while augering through the actual bed of the stream proved four feet of sand and gravel overlying pure blue clay (45). A short distance higher up the valley, the same instrument encountered what seemed to be no more than slightly disturbed Lias clay, although in this instance nothing that was indubitably solid rock was recovered. All the evidence therefore makes it most unlikely that there exists any substantial drift-filled valley running east-west between Great Dalby in the south and the Wreak valley in the north.

Bedrock exposures, absent along the minor valleys converging on Rearsby, reappear on both sides of the Wreak valley. Close to Rearsby trial holes reached the Keuper Marl at an altitude of 184 feet (46), and from here eastwards to Rotherby there is an almost continuous outcrop, first of Keuper Marl and then east of Brooksby of Lias clay. Bucket-auger traverse CC proved the drift base at 208 feet (47), but immediately to the east it must decline, for a borehole (48) beginning at a ground level of 230 feet penetrated 36'6" of drift before entering the Lias. In the village of Frisby, from a similar ground
level, 40 feet of sand and gravel was recorded before solid rock was encountered (49). And yet only a short distance further east, screw augering located Lias clay at 231 feet (50), and a borehole (51) at Kirby Hall Farm entered it at 217 feet. The reason for the sudden fall in the drift base at Frisby is unknown, but it may possibly indicate the presence of an old drift-filled valley running south to join that situated beneath Highfields Barn. If this were so, it would mean that the lower course of the Wreak trends athwart a "pre-glacial" drainage line and is therefore not of any great antiquity. Some support for this view is to be found in the widespread occurrence of Thurmaston sand and gravel to the south of the Wreak valley, in contrast to its very sporadic distribution to the north of that valley. As already mentioned the Lower Lias was formerly exposed in railway cuttings around Kirby Bellars, but as the outskirts of Melton Mowbray are approached the solid rock outcrops disappear and the recent river gravels come to rest directly against the drift deposits.

On the right bank of the Wreak Keuper Marl is exposed in a number of river cliffs downstream from Ratcliffe, while Lias clay is to be found immediately above the floodplain around Asfordby. In the intervening section of the valley, terrace gravels mask all the
older deposits, but there is no reason at present for supposing that in this terrace zone the bedrock configuration differs radically from the modern relief. A possible exception is in the neighbourhood of Hoby, where there may locally be a deposit of Thurmaston sand and gravel beneath the terrace materials. Upstream from Asfordby the Lower Lias outcrops over a wide area flanking the floodplain, and was exposed in 1961 during extensions to Melton Mowbray sewage works (52). At this site the bedrock was reached at a level of 231 feet, and was overlain by 12 to 15 feet of sand and gravel. In the outskirts of Melton Mowbray, however, the height of the solid rock surface appears to be lower than this. Close to the railway bridge on Asfordby Road, a borehole (53) penetrated 17 feet of sand to an altitude of c. 218 feet without reaching the Lias; and on the site of the new P.E.R.A. building a borehole (54) proved 55 feet of drift again without reaching bedrock, in this instance at c. 210 feet. It thus appears that the drift base which rises up the Wreak valley from about 200 feet near Ratcliffe to over 250 feet near Asfordby, begins to fall again at a relatively rapid rate towards Melton Mowbray. This significant change can be detected along both banks of the Wreak.

It remains to note the form of the bedrock surface
beneath the Wreak floodplain. There is no evidence that within the mapped area glacial drift occurs beneath the floodplain. Information about the material underly­ing the fluvial deposits is available at five points, and is conveniently summarized in the following table:

<table>
<thead>
<tr>
<th>Site</th>
<th>Thickness of fluvial deposits</th>
<th>Underlying material</th>
<th>Height of rock surface</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>17'0&quot;</td>
<td>Keuper Marl</td>
<td>142 feet</td>
</tr>
<tr>
<td>56</td>
<td>16'0&quot;</td>
<td>Keuper Marl</td>
<td>154 feet</td>
</tr>
<tr>
<td>57</td>
<td>15'0&quot;</td>
<td>Lower Lias clay</td>
<td>192 feet</td>
</tr>
<tr>
<td>58</td>
<td>15'0&quot;</td>
<td>Lower Lias clay</td>
<td>197 feet</td>
</tr>
<tr>
<td>59</td>
<td>7'9&quot;</td>
<td>Lower Lias clay</td>
<td>222 feet</td>
</tr>
</tbody>
</table>

(iii) Leicestershire Wolds. The extensive, thick cover of drift on the Leicestershire Wolds, allied to a paucity of borehole records, confronts any attempt to contour the bedrock surface with a major problem. However, in the east where the crest of the Wolds is formed by the Middle Lias beds the general configuration of the surface may be plotted with some confidence. The Middle Lias Marlstone forms an undulating plateau at an altitude of about 500 feet with its southern edge running obliquely across the boundary of the mapped area. Southwards from this plateau, the sub-drift surface falls rapidly in height, having been located within a mile at heights of 333 (60), 359 (61) and 362 feet (62). In like manner, around Grimston the height of the Lower Lias surface quickly
falls below 400 feet, although along the line of the railway tunnel half a mile to the north the Middle Lias beds reach almost 500 feet. Having declined rapidly from the plateau edge the bedrock surface then flattens and slopes much more gently southwards. A sample of six sites at which the drift base has been located by means of the screw auger will readily demonstrate this:

<table>
<thead>
<tr>
<th>Site (Map E)</th>
<th>63</th>
<th>64</th>
<th>65</th>
<th>66</th>
<th>67</th>
<th>68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift base (ft. 0.D.)</td>
<td>295</td>
<td>325</td>
<td>330</td>
<td>292</td>
<td>300</td>
<td>270</td>
</tr>
</tbody>
</table>

The configuration of the solid rock surface thus reconstructed implies the existence of a south-facing escarpment capped by the Middle Lias Marlstone and overlooking by as much as 100 feet an undulating area of Lower Lias clay. In the vicinity of Welby House an important additional feature of the bedrock relief becomes apparent. Along a line running from just north of Welby House to Sysonby Lodge there is evidence for a considerable drift-filled valley, the floor of which slopes eastwards. As indicated in the above table, west of Welby the drift base is at a height of 295 feet, but within 250 yards it has declined to 264 feet (69), and within a further 600 yards is down to about 250 feet (70), at which level boulder clay was exposed in excavation for Holwell Iron Works (Melton Memoir p. 69). Beyond this point the general form and direction of the drift-filled
valley can only be deduced from four borehole records.
The first borehole (71) was sunk over half a century ago by Holwell Iron Company:

G.L. 324 feet
Yellow clay, easily got........... 10’0”
Yellow clay with blue cast........ 77’0”
Sandy loam.......................... 2’0”
Blue clay with very much gravel 8’6”
Lower Lias........................... 27’9”

The second (72) was sunk nearby in 1948 and proved the following drift beds:

G.L. 316 feet
Boulder clay.......................... 75’0”
Red sand with water............... 1’0”
Sand and sandy clay.............. 4’0”

Lower Lias was probably entered at 236 feet O.D., although there is some doubt whether it was solid rock in situ. Fifteen hundred yards to the east, the log of the third borehole (73) reads as follows:

G.L. 375 feet
Blue drift............................ 104’0”
Sandy clay............................ 8’0”
Dark sand............................. 1’0”
Dark stony clay..................... 13’0”

The lowest 13 feet might conceivably be Lower Lias clay, in which case the bedrock surface is at 262 feet, but more probably the surface is below 250 feet. Finally, a well at Sysonby Lodge (74) is said to have proved over 168 feet of boulder clay, and if this old but probably accurate record is accepted, the level of the drift base has here fallen below 200 feet. This seems to be but
one more instance of the tendency already noted for the base of the drift around Melton Mowbray to slope in an easterly direction.

In the western part of the Wolds centred on Six Hills the contouring of the bedrock surface is extremely tentative. The scarcity of borehole records means that considerable importance attaches to the height at which the Lower Lias outcrops can be found at the heads of the small valleys draining to the Soar and Wreak. There seems no doubt that on the Geological Survey one-inch maps the extent of the solid rock outcrops is exaggerated. An instance is afforded by bucket-auger traverse AA' which, according to the Geological Survey map, should have encountered Lias clay on the lower slopes of the valley (75). Likewise, at a number of sites screw augering through the alluvial cover on the valley floors has demonstrated the presence of boulder clay rather than the solid rock portrayed on the Geological Survey one inch maps. An examination of the Geological Survey 6" field sheets was made in order to ensure that no actual exposures of solid rock were recorded in areas which during the present study have been mapped as drift covered. A fossiliferous outcrop is noted north of Thrussington Grange (76), and although this could not be found, its existence has been taken into account in the contouring of Map E. At the
head of the Shoby valley the Lias approaches a level of
400 feet but in the other valleys west of here and tribu-
tary to the Wreak no solid rock was recovered at alti-
tudes above 350 feet, and over by far the greater part
of this area the bedrock surface does not appear to rise
above 300 feet. At the southern ends of the spurs over-
looking the Wreak valley, the drift base is generally down
to below 250 feet:

<table>
<thead>
<tr>
<th>Site (Map E)</th>
<th>77</th>
<th>78</th>
<th>79</th>
<th>80</th>
<th>81</th>
<th>82</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence</td>
<td>B.auger</td>
<td>S.auger</td>
<td>S.auger</td>
<td>Section</td>
<td>Boreholes</td>
<td></td>
</tr>
<tr>
<td>Drift base</td>
<td>(ft. O.D.)</td>
<td>241</td>
<td>236</td>
<td>249</td>
<td>232</td>
<td>221 224</td>
</tr>
</tbody>
</table>

Along those valleys draining the Wolds westwards to
the Soar, a similar pattern appertains with the Geological
Survey one-inch map depicting solid rock outcrops higher
upstream than appears to be warranted. This is especi-
ally true in the valleys of Fishpool and Walton Brooks
where augering through the alluvial cover has shown the
upper reaches to be floored by typical Oadby till. Corro-
borative evidence that this is not due simply to soli-
fluction accumulation is provided by the records of two
wells in Walton Brook valley. The first (83), on the
floor of the valley, proved 18'2" of chalky boulder clay
with a little gravel resting directly on the Lower Lias,
while the second (84) proved 16'6" of brown and grey chalky
boulder clay without reaching solid rock. One of the
important indications of these two wells, as also of the
mapping with the screw auger, is the slow rate at which
the sub-drift surface rises north-eastwards from the
bluffs overlooking the Soar. On these bluffs the
solid/drift junction occurs at the following levels:

<table>
<thead>
<tr>
<th>Site  (Map E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drift base  (ft. O.D.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Site</th>
<th>85</th>
<th>86</th>
<th>87</th>
<th>88</th>
<th>89</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>230</td>
<td>224</td>
<td>210</td>
<td>195</td>
<td>185</td>
</tr>
</tbody>
</table>

North-eastwards the junction rises at an average gradient
of 25 to 30 feet per mile, a figure which seems to be
remarkably persistent over a distance of several miles.
However, the gradient cannot be projected as far as Six
Hills if reliance is to be placed upon the record of the
borehole (90) at the Durham Ox (see p. 100). If this
borehole failed to bottom the drift, the bedrock surface
must be below 242 feet. At first sight the basal "red
marl" might appear to be part of the Keuper beds, but
the level at which it was encountered renders this un-
likely. Should there be a deep drift-filled valley be-
neath Six Hills, there seems no doubt that it must run
northwards; there is no evidence for such a low-level
valley joining either the Soar or the Wreak within the
area where detailed mapping has been undertaken.

(iv) **Western Plateau.** Over much of the Rothley Plain
region the thickness of the drift is so slight that the
sub-drift surface does not differ radically from the
present-day relief. The Mountsorrel igneous masses rise above the general level of the drift cover, while to the north around Quorndon the Keuper Marl is veneered with terrace deposits which do not seem to attain any great thickness. On the northern part of Rothley Plain itself the cover of Oadby till is so thin that during construction of the Mountsorrel mineral railway line shallow cuttings frequently disclosed the Keuper Marl (the cuttings are now much overgrown, but details of the sections are given on the 6-inch field sheets of Fox-Strangways). The Marl was formerly worked a short distance to the south at a level of up to 227 feet (91), while at Rothley Grange (92) weathered Marl was located by screw augering at precisely the same level. On the western side of Swithland Reservoir the bedrock surface continues at a level of about 220 feet.

Over the southern part of the Rothley Plain region the bedrock configuration becomes more complex and, unfortunately, more difficult to reconstruct. From the level of 227 feet in the old working just mentioned the base of the drift passes down to below 200 feet at Rothley sandpit (93), but then rises rapidly southwards to over 230 feet close to Rothley Station (94). (see also fig. 3). The form of the bedrock surface appears unrelated to the modern drainage pattern, and it is note-
worthy how the glacial deposits along both sides of Swithland Reservoir do not descend into that part of the valley which thus seems to be of post-glacial origin. It is suggested that there is probably a drift-filled valley largely occupied by Thurmaston sand and gravel trending east-west across the site of Rothley sandpit. A westward extension of this old valley is to be found in the neighbourhood of Swithland where Fox-Strangways records on his field sheet a section in drift at only just over 200 feet (95). Eastwards the line of the valley is more obscure. Beyond Rothley station an old pit in the Thurmaston sand and gravel carries the drift base down to below 200 feet (96), but screw augering showed Keuper Marl outcropping at a greater altitude within a few yards to both east and west. The gap in the continuity of the solid rock outcrop seems too small to accommodate the main drift-filled channel, and it probably signifies the presence of a small north-flowing tributary valley. The main channel is more likely to have intersected the present Rothley Brook valley close to the village of Rothley. In the village itself few exposures could be found, but the drift base seems to be only a foot or two below the 200-foot contour. A few yards to the south-west, on the other hand, screw augering showed five feet of Oadby till without any trace of the Keuper Marl at a level of below 180 feet (97). In
fact no outcrop of the Keuper Marl could be found on the valley side at this point, for the base of the drift is here obscured by the terraces of the Rothley Brook. Further east the original form of the drift-filled channel has been very largely destroyed by the more recent erosive activity of the Soar.

In the Cropston area screw augering revealed an undulating Keuper Marl surface at a general altitude of 200 to 250 feet. It is not unlikely that some of the irregularities of this surface denote small drift-filled channels originally tributary to the major east-west drainage line through Rothley; but in the absence of more complete evidence it is impossible to be specific on this point. South of Cropston along the Rothley Brook valley the level of the drift base declines. Screw augering through the floor of a ditch to a depth of 6'6" below ground level failed to bottom purplish blue Thrusington till at an altitude of 185 feet (98). Upstream from here as far as Anstey there is no exposure of solid rock along the western edge of the floodplain. The record of an old well and shaft (99) in Anstey (actually situated about 100 yards beyond the edge of the mapped area) confirms that the drift base here sinks to an unusually low level:
G.L. 225 feet.

Drift, stiff brown Boulder-clay with rounded pebbles (with lumps of black clay (shale) and pyrites).............. 70'0"
Red marl with layers of gypsum (6 inches to 12 inches) and white and blue clay (dicey) (Another account gives 80 feet red marl and 10 feet skerry)........................................117'0"

At the nearby Anstey Mill (100), Fox-Strangways records on his field sheet that a well proved 12 yards of "dark clay and stones"; here too the bedrock surface must fall below 175 feet.

These two occurrences of low-level glacial deposits lead naturally to a consideration of the Beaumont Leys spur between Rothley Brook and the Soar. Although the Keuper Marl outcrops extensively around the margins of the spur, there are a number of localities where the drift base slopes down and disappears beneath the later terrace and alluvial deposits. Along the valley side opposite Anstey, screw augering failed to reveal any trace of Keuper Marl, even in the base of a series of undercut stream bluffs. Working downstream, the first undoubted outcrop of the Marl is in an abandoned bluff (101) south-west of Thurcaston where the drift base is no lower than 203 feet. Around Thurcaston screw augering demonstrated several points where the solid rock attains a level of over 200 feet; an interesting aspect of this area is that the drift base appears to
slope not towards Rothley Brook but south-eastwards away from the brook. This is indicated by the presence of boulder clay at a level of 190 feet east of the village (102), whereas Keuper Marl occurs at over 200 feet along the bluffs overlooking Rothley Brook. Further east screw augering showed the drift base to plunge down to below 175 feet, and around the northern extremity of the Beau­mont Leys spur no outcrop of solid rock was located above the 200-foot contour.

Along the eastern edge of the spur overlooking the Soar valley, the altitude of the solid-drift junction again ranges above and below 200 feet. At Wanlip Hill it is at 204 feet (103), and for the next two miles to the south it appears to remain above 200 feet. Keuper Marl was encountered at the following sites:

<table>
<thead>
<tr>
<th>Site (Map E)</th>
<th>104</th>
<th>105</th>
<th>106</th>
<th>107</th>
<th>108</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of evidence</td>
<td>S.auger</td>
<td>S.auger</td>
<td>Section</td>
<td>Section</td>
<td>Grave</td>
</tr>
<tr>
<td>Height (ft. O.D.)</td>
<td>210</td>
<td>208</td>
<td>210</td>
<td>205</td>
<td>200</td>
</tr>
</tbody>
</table>

In the mile between sites 105 and 106, exposures are very scarce owing to the spread of Birstall housing estates across the area. However, reference to the field sheets of Fox-Strangways leaves little doubt about the continuity of the solid rock outcrop, for north of the old village he records an outcrop of Keuper Marl (109) only a little below 200 feet.
It is in the area immediately south of Belgrave cemetery that the drift base reaches its lowest point along the eastern edge of the Beaumont Leys spur. On his field sheet Fox-Strangways records that two bridges on the Great Central Railway had foundation excavations which failed to penetrate to the Keuper Marl; at the first (110) the section consisted of three feet of clay over 10 feet of sand and loam, while at the second (111) the entire foundations were in stiff boulder clay. Although the clay, sand and loam may be a post-glacial alluvial deposit, it nevertheless seems clear that in this neighbourhood the drift base falls considerably below 200 feet. Southwards the level of the Keuper Marl outcrop rises again, for close to Beaumont Leys solid rock was encountered in a trial hole (112) at a level of 209 feet (Browne, 1902 p. 12). Despite the extension of housing estates in north-western Leicester across the solid-drift junction, there remain sufficient exposures to fix quite precisely the level of the bedrock surface. There can be no doubt that it climbs steadily until it reaches an altitude of about 250 feet near the eastern end of the Glenfield Tunnel:

<table>
<thead>
<tr>
<th>Site (Map E)</th>
<th>Nature of evidence</th>
<th>Height (ft O.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>113</td>
<td>Section</td>
<td>214</td>
</tr>
<tr>
<td>114</td>
<td>Section</td>
<td>222</td>
</tr>
<tr>
<td>115</td>
<td>Section</td>
<td>226</td>
</tr>
<tr>
<td>116</td>
<td>S. auger</td>
<td>249</td>
</tr>
<tr>
<td>117</td>
<td>S. auger</td>
<td>250</td>
</tr>
</tbody>
</table>

The variations in the level of the drift base around the
margin of the Beaumont Leys spur pose a number of questions which require for their full solution information regarding the bedrock configuration beneath the centre of the spur. Unfortunately very little such information is available. There is no reliable record of any sinking which has passed through the glacial material into the underlying Keuper Marl, and as a consequence one can only refer in general terms to the maximum possible height which the solid rock surface may attain. The deepest borehole (118) is situated near the northern end of the spur, but the log of the strata encountered is so extraordinary as to nullify its value:

G.L. c.270 feet.

- Topsoil: 1'0"
- Clay: 4'0"
- Gravel: 5'0"
- Blue Lias: 176'0"

An attempt to elucidate the record by correspondence with the driller proved abortive. Two boreholes just over a mile to the south show that the bedrock surface beneath the centre of the spur can only locally rise above the level of the exposures around the margin. Fox-Strangways notes on his field-sheet "Boulder clay, 25 yards or more. Not many large stones," (119) and as the ground level is no more than 270 feet, the drift base must be below 200 feet. In the Geological Survey Memoir a boring at Mowmacre Hill is quoted as having penetrated to a depth
of 120 feet within striking Keuper Marl. The exact site of this boring is unknown, but as the maximum altitude in the Mowmacre Hill district is no more than 310 feet, the evidence again points to a level for the drift base of under 200 feet. As already demonstrated, the Keuper Marl frequently outcrops on the nearby slopes overlooking the Soar above the 200-foot contour, so that there may well be a slope not towards the Soar but away from it. On the Beaumont Leys estate a borehole is reputed to have been sunk to a depth of 100 feet without reaching solid rock. Again the precise site is uncertain, but even if, as seems probable, the borehole were situated on the highest part of the estate the bedrock surface could not be much above 200 feet. Finally Paul (1891 p. 405) records that at Leicester Frith (120) which stands at about 315 feet, 90 feet of drift clay was proved resting on a bed of sand. Here, as at Mowmacre Hill, the level attained by the Keuper Marl is lower than in the nearby outcrops along the Soar valley, so that a slight westward slope for the drift base is indicated.

To summarize, the sub-drift configuration of the Beaumont Leys spur is a gently undulating Keuper Marl plain at an altitude of around 200 feet. The variable level of the bedrock outcrop in the Soar and Rothley Brook valleys suggests a considerable discrepancy between
the modern drainage pattern and the form of the sub-drift surface. This is also borne out by the tendency, noted at three separate localities, for the altitude attained by the Keuper Marl to decline towards the centre of the spur. In Map E the contours have been drawn on the assumption that an old drift-filled valley trends east-west across the Beaumont Leys estate, and that a second channel runs north-eastwards to Rothley to join the east-west valley already postulated for that area. It must be emphasised that such a reconstruction is very tentative owing to the absence of definitive borehole evidence.

A major problem is also posed by the apparently reliable record of the drift base sinking to 155 feet O.D. at Anstey. It seems impossible to accommodate this altitude in any normal valley system tributary to the Soar, and if the record is correct it seems it must betoken glacial erosion in this neighbourhood.

To complete this account of the Western Plateau, brief reference may be made to the New Parks district. The rising level of the Keuper Marl outcrop noted at the eastern end of the Glenfield tunnel continues in this district, screw augering having located it at 287 feet (121) and a borehole having entered solid rock at over 290 feet (122). These altitudes, however, may represent a crest-line in the bedrock relief, for a well (123) at Bird's Nest Cottage at a ground level of 315 feet is said to have
been sunk to a depth of 45 feet without reaching the Trias. South-eastwards towards the Soar the drift base undoubtedly declines, for on Shoulder of Mutton Hill (124) ten feet of red marly boulder-clay overlies sandstone which is exposed at 265 feet, and in an old quarry at Dane Hills (125) a thin capping of drift was formerly visible at about 235 feet (Browne 1893 p. 131). It seems likely that in the New Parks district the glacial deposits are draped over a west-facing escarpment formed by the thick bed of sandstone exposed at Shoulder of Mutton Hill.

(v) The Soar valley. In the preceding paragraph it was shown how the base of the drift descends towards the Soar valley. As the river is approached the rate of descent slackens, and much of the nineteenth century Leicester on the left bank of the Soar was built over an undulating Keuper Marl surface lying between about 195 and 230 feet. Numerous sections described by earlier workers attest to this fact (see for instance Browne 1893), and exposures can still be seen in railway cuttings immediately above the floodplain at levels of over 200 feet. Southwards, screw augering proved red marl at 225 feet (126), and even further south shallow trenches appeared to enter the Keuper at 227 feet (127). On his six-inch field sheet Fox-Strangways records the latter point as the site of an old marl pit. Seven
hundred yards to the south-west screw augering penetrated Keuper Marl at 235 feet (128), but beyond this the drift base begins to decline instead of rise. Along the line of the spur between Lubbesthorpe Brook and the Soar the decline is at first quite gentle. Close to the works of Jones and Shipman (129) several small sections appeared to be cut into slightly disturbed Keuper Marl at a height of about 210 feet. Although there is little doubt that bedrock is here just below the surface it is nevertheless true that even with the screw auger no undisturbed marl could be recovered. On the other hand, on his six-inch field sheet Fox-Strangways records the presence of an old marl pit (130) and maps the locality as a Keuper outcrop. Today the site of the pit is completely obscured by a new housing estate. On the opposite side of Lubbesthorpe Brook no equivalent outcrop could be detected, and it seemed that the slope of the drift base had carried the bedrock down out of reach of the auger. Along the north-south line of Lubbesthorpe Brook itself, a comparable but more dramatic southward descent of the drift base may be discerned. Where Lubbesthorpe Brook enters the mapped area Keuper Marl was located by augering at an altitude of 250 feet (131), and yet 600 yards downstream two excavations (132 and 133) failed to bottom typical Oadby till at
altitudes of 209 and 212 feet. As these levels are lower than those at which the Trias outcrops half a mile to the east in the bluffs overlooking the Soar, the picture which emerges is of a low Keuper Marl ridge separating the Soar valley on the one hand from a drift-filled depression followed by Lubbesthorpe Brook valley on the other.

This conclusion, based upon field mapping, received much support when geophysical investigations were undertaken preparatory to the construction of the M1 motorway and its approach roads. A survey was made along an east-west line lying south of Lubbesthorpe Brook (CD in figs. 12 and 13), and the following are the relevant points abstracted from the report on the survey: Using a Wenner configuration expanding depth probe, observations were made at 13 points to a maximum depth of 80 feet. Along the western part of the line alluvium in the form of sandy clay, stones and some gravel rests directly on Keuper Marl (proved in a nearby borehole), but east of probe 3 it overlies glacial deposits with the elevation of the underlying Keuper Marl surface decreasing rapidly. Probes 5, 6, 7 and 8 probably indicate alluvium in the form of silty clay overlying glacial deposits. Probe 9 indicates Keuper Marl occurring near the surface, so that the solid rock acts as a division between two areas of
deep glacial deposits. Probes 10 to 13 all penetrate direct into glacial deposits. Two other shorter lines were surveyed (EF and GH), giving results which amplify those derived from the major traverse.

Three important findings emerge from this geophysical study. Firstly, the Keuper Marl ridge noted between Lubbesthorpe Brook and the Soar continues southwards at least as far as line CD. Secondly, in the area of the survey the ridge is bounded on its eastern as well as its western side by a drift-filled channel; there is no known continuation of this channel further north, although one could possibly lie hidden beneath the alluvial deposits of the Soar. And thirdly, the drift base along line CD seems to sink at two points to levels considerably below 175 feet. Such low altitudes are confirmed by a borehole (134), the record for which is quoted on p. 108, which was drilled to 160 feet O.D. without striking bedrock, and more particularly by a borehole (135) which proved 80 feet of Narborough beds and a bedrock level of under 150 feet O.D. It seems not unlikely that over quite an extensive area the drift base lies below 150 feet. The depression occupied by the Narborough beds seems to be trench-like in form, being elongated along a north-north-east - south-south-west axis and bounded by steeply sloping sides. The gradient of the sides is most clearly illustrated by taking
one example from many along the western edge of the trench. The following two boreholes (136 and 137) were drilled within 250 yards of each other:

G.L. 269 feet

<table>
<thead>
<tr>
<th>Layer</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil and clay</td>
<td>3'0&quot;</td>
</tr>
<tr>
<td>Keuper Marl</td>
<td>35'0&quot;</td>
</tr>
</tbody>
</table>

G.L. 250 feet

<table>
<thead>
<tr>
<th>Layer</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topsoil</td>
<td>0'6&quot;</td>
</tr>
<tr>
<td>Clayey sand and silt</td>
<td>2'6&quot;</td>
</tr>
<tr>
<td>Firm brown and grey chalky boulder clay</td>
<td>9'0&quot;</td>
</tr>
<tr>
<td>Grey silty clay crowded with chalk particles</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Firm-stiff grey chalky boulder clay</td>
<td>16'6&quot;</td>
</tr>
</tbody>
</table>

There is thus a minimum difference in the level of the bedrock surface of about 50 feet. The precise form of the eastern edge of the trench remains unknown since it presumably lies beneath the floodplain of the Soar; the bluffs along the right bank of the Soar reveal Keuper Marl at levels considerably over 200 feet.

It is impossible to accommodate a level of under 150 feet at the southern edge of the mapped area in any system of normal drift-filled valleys. To the west lie the igneous outcrops of the Enderby district; to the north stands the sandstone escarpment of the New Parks region rising to almost 300 feet; to the south, as Shotton (1953) has demonstrated, the sub-drift surface rises steadily above 200 feet; and to the east Keuper Marl is exposed at several points above 200 feet, notably
at Blaby brickpit (138) where it attains a height of 223 feet, while beyond this rises the low escarpment formed by the Rhaetic beds. Also precluded is any drift-filled valley following approximately the course of the present Soar, although this possibility requires closer examination. It has already been shown that flanking the left bank of the Soar around Leicester is an undulating Keuper Marl surface generally rising to a little over 200 feet. A similar surface may be discerned on the right bank around Aylestone; Browne (1893) records several exposures of Keuper beds, including one at an altitude of 229 feet (139), while a number of others were noted in the course of the present study. This leaves only the floodplain of the Soar, and there is every reason to believe that the alluvial deposits rest directly upon bedrock. At Aylestone Bridge a borehole (140) proved the following succession:

<table>
<thead>
<tr>
<th>G.L. (feet)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>190</td>
<td>Clean ballast</td>
</tr>
<tr>
<td>184</td>
<td>Light brown soft marl</td>
</tr>
<tr>
<td>168</td>
<td>A characteristic Keuper series of red marl, grey marl, siltstone and sandstone</td>
</tr>
</tbody>
</table>

It is not entirely clear whether the "light brown soft marl" is weathered Keuper or a river deposited material, but on the assumption that it is the latter, bedrock was encountered at a level of 181'6". A mile downstream on
the site of the gasworks, at least two excavations and two boreholes are reputed to have passed straight through the alluvial cover into solid rock. A pit (141) dug in 1878 revealed 10 feet of alluvial and organic matter resting on undisturbed Keuper Marl (Mott 1878); in 1888 an excavation (142) near the centre of the floodplain disclosed 11'7" of fluvial material resting on Keuper Marl (Browne 1893 p. 193); a borehole (143) sunk in 1877 proved 11'6" of alluvial beds resting on 37'6" of Keuper Marl (Fox-Strangways 1903 p. 71); and in 1948 a second borehole (144) struck Keuper Marl at a depth of 15'0" (the top 3'0" of the last record probably refers to made ground). As the natural ground level at the gas works is 185 feet, bedrock seems to floor the valley at over 170 feet.

The foregoing facts seem to exclude completely any normal drift-filled valley at under 150 feet, and it is concluded that the Narborough beds occupy an enclosed depression that is presumably due to some form of glacial scouring. The only other feasible explanation appears to be post-glacial tectonic movement, but there is no other positive evidence for this, and the Narborough beds are sufficiently distinctive for one to say that they are not simply downfaulted masses of Oadby till.

It remains to consider that part of the Soar valley

* This is no longer true. See Addendum.
around and downstream from Leicester. In the centre of Leicester there is again no evidence of a drift filled channel below the more recent fluvial deposits; indeed, the multiplicity of records around the city centre indicate that the bedrock surface does not differ radically from the present-day relief. It may be briefly noted that on occasions the records refer to "drift", "valley drift" and even "boulder clay" resting on the Keuper Marl but these are patently the terms used by certain drillers and well-sinkers to denote the clayey gravel sometimes found towards the base of the terrace deposits. Downstream from the city centre the pattern may change slightly for there are two sites where material differing in description from normal Keuper Marl has been encountered beneath the river deposits. One borehole (145) is said to have encountered the following strata before entering Keuper Marl:

G.L. 170 feet O.D.

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made ground</td>
<td>3'0&quot;</td>
</tr>
<tr>
<td>Brown clay</td>
<td>5'0&quot;</td>
</tr>
<tr>
<td>Gravel</td>
<td>4'0&quot;</td>
</tr>
<tr>
<td>Grey clay with pebbles</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Red clay with pebbles</td>
<td>10'6&quot;</td>
</tr>
</tbody>
</table>

The correct interpretation of the material lying between the base of the gravel at 12'0" and the undoubted Keuper Marl at 24'6" is uncertain, but it seems most likely that it is either the driller's description of a particular facies of the bedrock, or possibly locally disturbed bed-
rock. It is noteworthy that only 300 yards west of this borehole, Fox-Strangways records on his fieldsheet the presence of 12 feet of clay and gravel resting on red marl. Of more significance than the foregoing log is one relating to a borehole (146) at Beaumanor Brewery where the following strata were encountered:

G.L. 172 feet

- Topsoil ...................... 1'6"
- Brown loamy clay ............ 1'6"
- Clay and stones .............. 4'0"
- Gravel ........................ 5'0"
- Clay and stones .............. 10'6"
- Sandstone .................... 3'0"
- Drift and marl and stone .... 3'6"
- Drift marl and clay and gravel 3'0"
- Keuper Marl ........................ 169'0"

Again the top 12 feet appear to represent a typical succession of fluvial deposits, but it is difficult to reconcile the next 20 feet with normal Keuper Marl. Another significant aspect of this borehole is that it is sited close to the one point in this part of the Soar valley where the drift base descends to the level of the terrace gravels. There is thus some reason for thinking that the sub-drift surface may fall to the unexpectedly low level of 140 feet. On the other hand, it would be unwise to attach too much significance to one uncorroborated borehole record, and there is no evidence that further downstream any material other than Keuper Marl underlies the floodplain alluvium. At the edge of the
floodplain near Birstall a borehole (147) encountered Keuper Marl at a depth of 6'6", while around the confluence of the Soar and Wreak several sinkings have proved solid rock at about 16 feet below ground level. This latter figure seems to be representative of the thickness of the river deposits downstream to Quorndon and beyond.

Finally, excavations and boreholes which have passed through the terraces rather than the floodplain of the Soar have generally encountered no great thickness of gravel; a boring (148) at Wanlip Hall proved seven feet of gravel resting on Keuper Marl and whilst this may be a little below average it is not entirely unrepresentative. On the other hand, the terraces may just occasionally conceal a considerably greater thickness of post-glacial material; not far from Wanlip Hall Fox-Strangways notes on his field sheet that there is 20 feet of sand, and this has recently been confirmed by a borehole (149) which penetrated to a depth of 18 feet without bottoming the deposit.

(b) The pre-glacial relief.

The purpose of this chapter so far has been to survey the form of the bedrock surface as it would appear if all the superficial deposits were stripped away. It is now necessary to consider the relationship of that surface to the relief which existed at the time the
earliest glacial drifts were laid down. It has already been shown how, at a number of points, it is difficult to conceive of the bedrock morphology having been shaped other than by some form of glacial scouring. This undoubtedly applies in the south near Narborough, and may possibly apply elsewhere. But once it is admitted that glacial erosion has played some part in shaping the bedrock morphology, the question of the extent of such erosion arises. This is an extremely intractable problem in our present state of knowledge, and the practical solution adopted is to treat only proven enclosed hollows as glacially eroded. Using this criterion fig. 15 has been drawn in an attempt to portray the relief as it existed just before the Thurmaston sand and gravel was laid down. Clearly, the contouring cannot claim to be precise, and it is only the major relief features that are depicted. It must be borne in mind that the basis for much of fig. 15 is the sub-drift contouring of Map E, and it is this contouring that is the least precise part of that diagram.

Certain aspects of fig. 15 merit brief discussion:
(a) The level of the pre-glacial Soar. Apart from those localities where there is a presumption of glacial scouring, very little drift has been met with below an altitude of 200 feet. The most southerly occurrence lies one and a half miles upstream from Leicester, and
PRE-GLACIAL RELIEF

Fig. 15.
it is here that the 200-foot contour has been drawn across the floor of the valley. Higher upstream, Keuper Marl frequently outcrops close to the modern floodplain at levels up to 225 feet, so that the 200-foot contour could only be extended in this direction by keeping within the confines of the modern valley floor. Below Leicester the outlying patch of drift at Thurmaston provides another datum point where the base of the glacial deposits is at 200 feet. At this latitude the Soar must have been flowing at a slightly lower level, and its course must therefore have lain to the west of the drift outlier. Confirmation of the height of the trunk valley comes from the left bank tributaries, the Beaumont Leys and Rothley streams, both of which seem to require a confluence level of under 200 feet. Around Mountsorrel there is very little evidence by which to assess the altitude of the pre-glacial drainage, but north of Barrow drift can be found considerably below 175 feet O.D.

From this analysis it appears that the level of the pre-glacial Soar was not greatly different from that of its modern counterpart. A similar conclusion has been reached in other parts of the Trent river basin (Pocock 1929, Pickering 1957).

(b) A possible alternative course for the pre-glacial Soar. In drawing fig. 15 it has been assumed that the pre-glacial ancestor of the Soar followed the same course
as the modern river. There remains, however, the remote possibility that it diverged from that course below Thurmaston and flowed north-eastwards towards Melton Mowbray. The doubt concerning the exact form of the bedrock surface in the region south of Kirby Bellars has already been mentioned (p. 125 et seq.); and there is positive evidence that at Melton Mowbray the drift base descends some way below 200 feet. It is thus conceivable that there exists a drift-filled valley running from Thurmaston to Melton, and thence passing eastwards into Lincolnshire. Such a hypothesis has a superficial attraction in that the alignment of the lower Wreak valley continues in an unbroken curve the alignment of the middle Soar valley about Leicester. However, when examined more critically, the hypothesis becomes difficult to sustain. No significance can be attached to the alignment of the modern rivers, since any major drift-filled channel at under 200 feet would have to lie south of the Wreak valley. More importantly, the gap in which no Lower Lias outcrop has been located between Kirby Bellars and Great Dalby appears too narrow to accommodate a valley of the dimensions to be expected for the Soar. Proof will only come when the bedrock surface has been more thoroughly investigated by means of deep boreholes, but from the evidence now
at hand it seems much more likely that the pre-glacial Soar pursued a course northwards past Barrow. During this period there was probably a col near Kirby Bellars at a little under 250 feet, separating the Soar basin from streams draining eastwards past Melton Mowbray. (see p. 206 et seq.)
(c) The form of the Rhaetic scarp and Eastern Uplands. The Rhaetic scarp between Queniborough and Wigston was already in existence when the earliest drift was being laid down. This is clearly shown by the low level of the drift base at Thurmaston compared with Barkby Thorpe, while a similar relationship obtains at Spinney Hills, Leicester, where the boulder clay is virtually banked against the scarp face. From the top of the scarp the general elevation of the land continued to rise eastwards, probably reaching over 400 feet within the mapped area. It is reasonable to suppose that dissecting this upland and breaching the continuity of the scarp there would be a series of streams tributary to the Soar.
There seems no doubt that most of the modern water gaps through the Rhaetic scarp are the same as those which existed before the drift was deposited; this is clearly demonstrated by the descent of the drift base from the top of the scarp down into each water gap. In delineating the valleys further east a correspondence between pre- and post-glacial drainage patterns has been assumed.
In general this assumption appears fully justified by the evidence quoted in the earlier part of the present chapter, but there remain one or two places where the bedrock surface may fail to rise beneath the modern interfluve and where some divergence between the two patterns may occur. Only numerous extra sub-surface records can prove this.

The Rhaetic scarp between Sileby and Walton, and the area of Lower Lias to the east, might be expected to display analogous features, but for some reason which is not understood there is almost no evidence for "pre-glacial" valleys infilled with drift and now undergoing exhumation. The base of the drift is here unusually regular.

(d) Drainage changes resulting from glaciation. Reference has already been made to three substantial differences between the pre-glacial and the modern drainage patterns. These involve the "Beaumont Leys stream", the "Rothley stream" and the "Highfields Barn stream". Examination of fig. 15 will show that a fourth, minor drainage change has been invoked. This concerns Evington Brook which today begins by flowing parallel to the neighbouring Soar tributaries, but then turns abruptly northwards to join Bushby Brook before breaking through the Rhaetic scarp. It is suggested that the pre-glacial
ancestor of Evington Brook flowed westwards to enter the Soar upstream from Leicester. Two lines of evidence prompt this suggestion. The first is the absence of low-level drift in that part of Evington Brook valley where the stream is flowing northwards. The second is the admittedly fragmentary indication of a deep, drift-filled channel running from the elbow in Evington Brook westwards to the Soar. Deep trenches have shown that the drift base descends to the level of the alluvium just west of the elbow; wells in Stonygate are said to have encountered 50 feet of drift (Plant 1882 p. 34) and a borehole on the site of the University has been sunk to a depth of over 40 feet without reaching bedrock.
CHAPTER FOUR

DISCUSSION OF THE GLACIAL DRIFTS

Most previous writers on the drifts of central Leicestershire have postulated a subdivision into an earlier boulder clay derived mainly from the north and west, and a later boulder clay derived mainly from the north and east. The present study has amply confirmed the existence of these two quite distinct types of drift; the contrast in the erratic content of the Thrussington and Oadby tills as revealed by stone counts 11 and 15 in Appendix A is very great indeed. But these are end-members of a series, and there is now much evidence to show that the recognition of only two till types is an unwarranted oversimplification. Likewise it is also untrue that one particular till type invariably overlies another, although the concept of an upward change from drift of a predominantly northwestern provenance to one of a predominantly north-eastern provenance does appear well founded. Interbedded with the tills there is a widespread stratum of water-laid material which is believed to indicate an important ice withdrawal.
Within this basic pattern there exist many complications, and for purposes of the present discussion it will be most convenient to consider in turn each member of the drift succession as described in Chapter two.

(i) **Thurmaston sand and gravel.**

The likely extent of the Thurmaston sand and gravel at the time of deposition is shown in fig. 16. It flooded much of the pre-glacial Soar valley around Leicester, with the Rhaetic scarp to the east and the sandstone cuesta of the New Parks district to the west constituting limiting higher ground. Downstream between Mountsorrel and Barrow no trace of the basal stratified drift now remains, but that it was originally deposited here is suggested by the occurrence of similar material one and a half miles beyond the boundary of the mapped area at Fox Hill. Deeley (1886 p. 447) records, at an altitude of a little over 200 feet, a section showing "about 10 feet of obliquely laminated sand with carbonaceous and gravel beds." The removal of the deposit between Mountsorrel and Barrow may be ascribed in large measure to the narrowness of the bedrock valley at this point, and to the almost exact coincidence of the pre- and post-glacial river courses.

To the west of the Soar, the Beaumont Leys and Rothley valleys were the sites of extensive spreads of
Fig. 16. Probable original extent of the Thurmaston sand & gravel.
Thurmaston sand and gravel, although between them the gently undulating Keuper Marl interfluve probably rose sufficiently high to remain uncovered. To the east of the Soar very little deposition is manifest in the small valleys which drain the Eastern Uplands and the Wolds, but in sharp contrast the Highfields Barn valley was floored by an accumulation which locally attained over 30 feet in thickness and had an original width of at least one mile. This accumulation was different from that elsewhere for there was no clear division into a basal gravel and an overlying sand.

Everywhere a very high proportion of the material in the gravel must ultimately have come from the Bunter Pebble Beds. No outcrop of the Pebble Beds occurs within the area now drained by the middle Soar, nor extensively within the area likely to have been drained by any larger forerunner of the present river. Initial transportation by ice is the obvious answer, and the most probable source of the material the outcrops of the Pebble Beds to the north-west of Leicester; it is difficult, however, to exclude the possibility that some of the pebbles may have come from the north in Nottinghamshire.

Although the sand and gravel has frequently been examined for fossils, it is doubtful whether any (other than derived ones) have ever been found. In 1901 the
Leicester Daily Post carried a report that shells had been found in the Aylestone sandpits, but this was almost certainly erroneous (Browne 1901). A more problematical record refers to a find during the widening of the Midland Railway at Knighton Tunnel: "A part of a Mammoth-tusk now in the Museum is stated to have been procured from the middle of the sand" (Browne 1893 p. 197). Mr. Sizer of Leicester Museum has provided the information that this specimen disintegrated several years ago, and that there is a record of its having been obtained from "boulder clay" in the railway cutting. In the circumstances no significance can be attached to the supposed find.

The distribution of the sand and gravel along many of the pre-glacial valleys, allied to the well-sorted, false-bedded nature of much of the deposit, points to deposition by flowing water. Whether the water was proceeding from a contemporaneous ice front advancing from the north-west, or was "normal" drainage dissecting an earlier till sheet is less certain. Nowhere in central Leicestershire has till been found to underlie the Thurmaston sand and gravel, and if dissection had advanced so far that only a few residual fragments were left, it is surprising that local material forms such a conspicuously small fraction of the gravel. This is
especially true for instance at Thurmaston where one might anticipate that feeders from the Eastern Uplands would have introduced an appreciable quantity of Lias limestone, but where in fact the proportion of Lias limestone is less than that found in the adjacent post-glacial river terraces. Generally, the composition of the gravel shows a marked affinity with the overlying Thrussington till.

The statement that no till has been found beneath the Thurmaston sand and gravel requires some elaboration, for around Anstey till descends far below the level at which the Thurmaston beds normally occur. Two considerations give grounds for doubting whether this is necessarily an indication of greater age. Firstly, the sand and gravel seems to be entirely absent where the low-level till is found, and secondly, the base of the till descends to an altitude which implies that there has been substantial glacial erosion.

On the other hand, if the Thurmaston sand and gravel is outwash, the ice advancing from the northwest must have reached the upper part of the Soar basin before the lower, since what little evidence there is points to initially free drainage down the Soar valley. The only site at which a boulder clay lens has been found within the Thurmaston sand and gravel is at Blaby.
brickpit, and if the sand here is actually contemporaneous with that further north it would go far to prove that the Thurmaston sand and gravel is outwash. But the succession at Blaby is so disturbed, and in that respect so unlike the rest of the deposit, that the writer hesitates to claim contemporaneity. Nevertheless, it remains true that on the evidence of central Leicestershire the basal stratified drift along the valleys of the Soar and its left bank tributaries is more consistent with outwash than "normal drainage.

The great thickness of the Thurmaston sand and gravel along the Highfields Barn valley poses a special problem. The argument that there is surprisingly little local rock in the gravel at Thurmaston applies with even greater force at Rotherby. Here, resting directly on the Lower Lias, is a gravel which in a sample of over 300 pebbles yielded not a single Lias fragment. For this reason alone it is difficult to conceive of deposition by a normal west-flowing stream. There is also direct observational evidence that, for a time at least, water was flowing eastwards, for Deeley (1886 p. 446) states that at Frisby mill the false-bedding betokens currents from the west. The most feasible explanation is that the deposits along the Highfields Barn valley are the direct outwash from an ice front which, advancing from the north-west, had already passed across the line
of the Soar valley and so was diverting water towards the col in the bedrock surface near Melton Mowbray, whence there was a valley leading eastwards to the Wash (see p. 206 et seq.)

This sequence of events is not only consistent with the evidence of the deposits themselves, but might be anticipated from a knowledge of the pre-glacial topography. Nevertheless, there remain a number of problems to which no entirely satisfactory answer can yet be given. The first concerns the phase at which the lower Soar valley became blocked by ice. Unfortunately the best evidence on which to determine this would presumably lie in that reach of the valley around Mountsorrel, and as already indicated the deposits here have been completely removed by post-glacial erosion. The second problem is closely related for it concerns the upward change from gravel to sand along the Soar and its left bank tributaries. It is possible that this change was induced by shallow ponding of water when the ice invaded the downstream section of the Soar valley. The upper level of the sand is neither constant, nor does it show a consistent fall in any one direction; yet it is sufficiently close to the level of the bedrock col at Melton Mowbray, 240 feet, to suggest that this may have been a controlling influence. The third problem concerns the precise conditions of deposition in the Highfields Barn valley. The ice was here
advancing against the gradient of the valley and some impounding of water might be expected. The rather ambiguous record of 35'3" of "red marl and gravel" at Highfields Barn could be interpreted as favouring this view, but the writer believes that much more evidence is still required. A final problem is posed by the nature of the basal gravel encountered at Eye Kettleby mill (see p.46). Whereas in the neighbourhood of Frisby the gravel resting on the Lias is composed very largely of Bunter pebbles, at Eye Kettleby it contains in addition both flints and Lincolnshire Limestone. The affinity of the pebbles in the Thurmaston sand and gravel with the overlying till has been used as an argument for regarding the water-deposited material as outwash from an advancing ice front. A similar argument may be applied to the Eye Kettleby deposits, for the Thrussington till in this region is known to contain Cretaceous and Middle Jurassic erratics. It is therefore reasonable to suppose that meltwater issuing from the ice bearing this till would have contributed an admixture of flint and oolite to the Bunter pebbles already being carried from the west. Supporting this view is the extremely mixed character of the Eye Kettleby gravel, which suggests a provenance ranging in direction from east of north for the Lincolnshire Limestone to west for the syenite and green slate. The alternative view is to regard the Eye Kettleby gravel as a later deposit
related to the onset of ice bearing the Oadby till, but this would raise the problem of why there is no earlier drift beneath the gravel and why there appears from the recorded descriptions to be so much material of western derivation. For these reasons the Eye Kettleby deposit is tentatively classed as part of the Thurmaston sand and gravel, although final resolution of this point must await fuller study of the Melton Mowbray district.

Fig. 17 is an attempt to portray the conditions under which the Thurmaston sand and gravel was laid down. Owing to the difficulty of establishing a truly synchronous ice front it cannot be claimed that fig. 17 depicts other than very generalized conditions.

(ii) Thrussington till.

The till laid down by the ice which advanced across the Thurmaston sand and gravel is extremely heterogeneous. This is amply demonstrated by the bucket-auger traverses in the Wreak valley where there is rapid alternation of material derived mainly from the Lias with that derived mainly from the Trias. In these traverses the changes could conceivably be explained without recourse to variations in the direction of ice movement, since slices of far-travelled till of Triassic origin might be interbedded with slices of locally derived Liassic till, both types having been subject only to south-eastward transpor-
Fig. 17. Stages in the accumulation of the glacial drifts.
tation. There is, however, good reason to believe that during the time the Thrussington till was being deposited, major shifts in the direction of ice movement took place. These are most readily demonstrated in the area around the University campus (fig. 7). On the site of the East Midland Gas Board offices the basal boulder clay is of obvious Liassic derivation while the underlying bedrock is Keuper Marl. The only Leicestershire outcrop of Lower Lias both north and west of this site is in the vicinity of Barrow, and if the boulder clay were derived from the western extremity of this outcrop the overall direction of transport would have been S10°E. A much more likely direction would appear to be west of south, and this receives confirmation from the stone orientation of the till which is S25°W. At the University the overlying till is of Triassic provenance and is of the type which yielded to West and Donner a preferred stone orientation of S35°E. Yet lying within the main mass of red till is a lens containing numerous chalk fragments which must have travelled in a direction west of south. It seems an almost inescapable conclusion that significant shifts in the trend of ice movement occurred during the accumulation of the Thrussington till.

Leicester, lying at the junction of Triassic and Jurassic rocks in an area where the geological strike
trends roughly north-south, is so sited that even slight changes in the direction of ice movement about the meridional position would be conspicuously reflected in the character of the till. Nevertheless, it seems reasonable to suppose that in other areas, such as those investigated with the bucket auger in the Wreak valley, variations in the character of the till are due to changes in the direction of ice movement. Corroboration comes from the finding not only of Triassic debris to the east of the Soar, but also of Liassic debris to the west of the river in the area around Anstey. Furthermore, the recognition that even within the earliest tills of central Leicestershire there is evidence for shifts in the trend of glacier motion affords an explanation of what, during preliminary mapping, appeared an anomaly in the erratic content of the Thrussington till. Around Kirby Bellars the boulder clay which underlies the Wigston sand and gravel, and is therefore assignable to the Thrussington bed, contains both chalk and oolite. So long as one thinks in terms of an ice advance solely from the north-west, so long do these erratics defy explanation; but once it is realised that even at a very early period some ice also moved from the north-east, then these erratics become almost expectable.

The shifts in ice movement are attributable to
the interplay of two competing centres of ice dispersal. Although the resultant interbedding of dissimilar tills can be demonstrated at many separate localities, it is not possible at present to correlate one succession with another and so to disentangle what is probably an extremely complex history. It is certainly true that in the vicinity of Leicester ice from the north-west, bringing with it Trias-based till, dominated that from the north-east, and it is probably this fact which led earlier workers to conclude that a simple two-fold division of the drifts was adequate, with the lower part carried in its entirety from the north-west. Intimately associated with this idea was the view that the lower division of the drift succession represents the deposit of a separate glacial period; in the light of the evidence quoted above, the whole concept will require critical review (see p.224 et seq.)

A second factor which may locally have influenced the pattern of ice movement is the surface relief. Although the amplitude of relief as the ice advanced cannot have been great, there is a noticeable discrepancy between the thickness of the Thrussington till in the Soar valley about Leicester and in the middle Wreak valley, compared with that on the higher ground formed by the Lower Lias and by sandstones in the Keuper Marl. This is illustrated by about 25 feet of till at the University
corresponding to less than 10 feet at Evington and New Parks. These figures are in sharp contrast to the Oadby till which often far exceeds 25 feet even on the highest parts of the bedrock surface. A possible explanation is that the ice which deposited the Thrussington till was relatively thin and may not have extended far beyond the southern edge of the mapped area; the control exercised by the relief would then have been correspondingly greater, and it certainly appears that the ice front began to progress up rather than across the Soar valley and to impound a lake before it. The Glen Parva clay is testimony to this stage.

(iii) Glen Parva clay.

In the area north of Leicester the Thurmaston sand and gravel is generally succeeded by Thrussington till. This is seen in sandpits at Rothley and Thurmaston, and was demonstrated in the Wreak valley by use of the augers. At one or two isolated sites a foot of stoneless clay has been noted separating the sand from the till, and in an exposure north of Birstall lamination of the clay was clearly visible. These indications of ponded water are very localized and it is only in the area south of Leicester that the ponding reached significant proportions. Beds of stoneless silt and clay were noted during the present study at several excavations close to
the University, while Fox-Strangways (1903 p. 47) records laminated clay in the adjacent railway cutting. The probability is that until the ice front had reached this far up the Soar valley, meltwater had still managed to escape north-eastwards to Melton Mowbray, but once the pressure of ice against the Rhaetic scarp blocked this outlet a relatively deep lake was impounded. This lake is here termed Lake Glen Parva, and the conditions envisaged during the accumulation of the floor deposits are illustrated in fig. 17. The interbedding of till and stoneless clay betokens considerable fluctuations in the position of the ice front, and on occasions the whole of the site of Lake Glen Parva as depicted in fig. 17 was occupied by ice. Ice advancing across the lake ploughed up the lacustrine sediments which are consequently much disturbed. This increases the difficulty of deciphering what is certainly a complex history, but it seems clear that a Lake Glen Parva existed on two separate occasions. The first was during the ice advance and is evidenced by the stratified clays and silts which either underlie the Thrussington till or are incorporated in the base of the till. The second was during withdrawal of the ice and is evidenced by the clay and silt overlying the Thrussington till. It is impossible to assess the water level of the first
Lake Glen Parva, but during the withdrawal phase the water level may have stood at little above 300 feet O.D. The basis for this statement is that at four separate points the top of the still-water deposits lies very close to the 300-foot contour. This assumes of course that the lacustrine sediments were built up to water level and although at Wigston the sediments are banked against a gently rising slope of Lower Lias clay which has the appearance of a lake margin there is no convincing proof forthcoming on this point. If 300 feet is a reasonable estimate, there is no obvious "direct overflow" at this altitude and it seems more likely that the control was a marginal overflow between the ice front and the Eastern Uplands.

(iv) **Rotherby clay.**

Whereas the Glen Parva clay indicates ponding in the Soar valley during both the advance and withdrawal phases of the Thrussington till ice sheet, the Rotherby clay accumulated only during the withdrawal phase. As stated earlier it is possible that ponding occurred during the ice advance but more evidence is required. Lake Rotherby occupied the low ground which in the pre-glacial period had been excavated by the Highfields Barn stream, but which now had a thick cover of Thrussington till. It was impounded between higher ground to the
CONTOURS OF THE BASE
OF THE
WIGSTON SAND & GRAVEL
AND
ROtherby CLAY

Fig. 18.
north and south and the retreating Thrussington till
ice sheet to the west. Fig. 18 is an attempt to
contour the base of the stratified sediments lying
between the Thrussington and Oadby tills, and it pro-
vides an indication of the surface relief at the time
Lake Rotherby was in existence. The generalized history
of the lake is extremely difficult to decipher, for again
there is no certainty that the sediments were ever built
up to lake level. The still-water clays and silts grade
laterally and vertically into sand and gravel, and there
is no consistency in the level at which the change occurs.
Still-water sediments attain a thickness of 21 feet on
the site of the old Rotherby brickpit where their upper
surface is a little below 300 feet. On the opposite
bank of the Wreak, bucket-auger traverse BB' proved 10
feet of fine water-laid material just above the 300-foot
contour, while traverse AA' encountered very similar
material at just over 340 feet. By contrast laminated
clay just east of Rearsby outcrops at about 250 feet, and
is capped by till at well under 300 feet. The range of
heights at which materials of comparable grade occur,
allied to the rapid vertical variations in the same lo-
cality, suggests that the base of the Rotherby clay is
diachronous, and that the position of the lake shifted
westwards as the ice withdrew in that direction. Another
significant aspect of Lake Rotherby is that a water level of 300 feet, the absolute minimum demanded by the still-water sediments, requires that the former outlet eastwards past Melton Mowbray was blocked. Whilst this could be due to a thickening of the Thrussington till ground moraine beyond the boundary of the mapped area, a much more likely explanation is that ice was already beginning to advance from the north-east so that Lake Rotherby was ice-dammed at both ends. Support for this contention is to be found in two circumstances. The first is that whilst the Rotherby clay follows upon the Thrussington till without any break in sedimentation, there equally appears to be no major interval of erosion between the withdrawal of the ice to the west and the fresh advance from the north-east. The second is that at Melton Mowbray there was formerly an exposure of stoneless clay, probably lacustrine in origin, at 250 feet O.D. and this seems to require that the ponding agent should be situated not to the west but to the east. Further reference to this occurrence is made in Chapter five.

The water-laid Rotherby and Glen Parva clays betoken an ice withdrawal towards the north-west, but the maximum extent of the withdrawal remains uncertain. If the belief that the north-eastern ice passed across
the site of Lake Rotherby after a very short time interval is correct, it is difficult to see how the Soar with its ultimate debouchment into the North Sea could have come into existence again during this interstadial period. One curious aspect of the Thrussington till is its thinness and partial absence downstream from the Soar-Wreak confluence, and it is tempting to ascribe this to a phase of interstadial sub-aerial erosion; the writer, however, regards this as unlikely and prefers to treat it as one of the normal variations in the thickness of the till which are apparent from all over the mapped area. It may well be that there was originally more of the early till along the actual line of the Soar valley and that this has been removed by erosion in the post-glacial period. It is tentatively concluded that the ice did not withdraw beyond a line running from west of Seagrave to Barkby and then looping across the Soar valley to the vicinity of Anstey. This line is probably not synchronous, but it does have the effect of separating those areas in which still-water deposits and the Wigston sand and gravel occur, from those in which they are, with very few exceptions, absent. North-west of this line the ice which had deposited the Thrussington till yielded directly to increasing pressure from the north-east with the result that this region did not become ice-free. It
is uncertain whether Lakes Glen Parva and Rotherby were ever united into one open stretch of water, although there is a general accordance in the altitude of the lacustrine clays. The evidence on which to base a firm conclusion has been destroyed by post-glacial erosion along the Soar valley.

The thesis outlined in the foregoing paragraphs, that ice withdrew in a north-westerly direction, implies that small lakes were probably impounded in some other valleys of central Leicestershire. There is good reason to believe that this did happen. In the Eastern Uplands several of the valleys contain deposits of fine silt and clay, the best example being at Keyham where screw augering proved that the Thrussington till is succeeded by at least 10 feet of fine red silt interbedded with stoneless clay.

One final aspect of the pro-glacial lakes requiring brief reference is the problem of possible overflow channels. In this context it must be remembered that subsequent to the ponding of these lakes a very thick cover of till was deposited over the whole region making identification of eroded meltwater features extremely difficult. Moreover, as has already been pointed out, there is so very little guide to the precise levels of the lakes since the undoubted lacustrine deposits occur at
different altitudes and do not possess a uniform upper level. It is broadly true that while the floor deposits are testimony to the existence of the lakes, details of the extent and heights of the lakes are at present largely conjectural. It seems reasonable to assume that the meltwater escaped eastwards and the most likely course is past Melton Mowbray; further detail must await mapping of the area east of that town.

(v) **Wigston sand and gravel.**

The deposition of the Wigston sand and gravel coincides with the change from the dominance of the northwestern ice to the dominance of the north-eastern ice. It is a transitional bed partaking of some of the characteristics of the till laid down by each of these ice sheets. This is most clearly seen at Oadby, where the Glen Parva clay grades up into red, false bedded coaly sand, and this in turn is capped by coarse gravel with much chalk, flint and Lincolnshire Limestone. Such is the similarity of the sand with that formerly visible, for instance, at Aylestone sandpits, that Deeley (1886) classified it as part of the Quartzose Sand. This, the present writer believes, was the fundamental error in Deeley's classification, since it led him to postulate an additional sheet of boulder clay to explain that exposed at Oadby. In other words, the Quartzose Sand as
recorded by Deeley is at two separate horizons, and there is only one major "Pennine Boulder clay". The sand at Oadby denotes a shallowing of the ponded water in which the Glen Parva clay accumulated, and the renewal of normal stream activity. Such streams would be reworking the drifts already deposited, so that the material they laid down would have an affinity with the Thrussington till.

Locally beds of gravel occur of a composition which signifies that they are outwash from the retreating Thrussington till ice-sheet. Just occasionally where the Thrussington till is missing it is difficult to ascertain whether it was during the advance or retreat of that ice sheet that deposition took place; this is the situation at Thurnby referred to on p. 85. The vast majority of the gravel, however, is obviously associated with the Oadby till, and is outwash material from the ice which advanced from the north-east. Unlike the earlier outwash, this is very irregularly distributed and rarely can an outcrop be traced continuously for more than a mile or so. Furthermore, the deposit is much more poorly sorted than the Thurcaston sand and gravel. The cause of these contrasts is to be found in the differing alignment of the ice fronts relative to the relief pattern across which they were advancing.
During the first glacial period meltwater was channelled down the Soar valley and so deposited a continuous, well-sorted sheet of outwash. With the later ice advance no simple pattern of meltwater drainage away from the ice front could be established, and the outwash was laid down in irregular masses close to the ice margin. A further feature indicative of accumulation in proximity to the ice edge is the large number of sites where lenses of till have been noted in the gravel, or even where the gravel appears to be included within the lowest layers of the till itself. Instances of the latter relationship occur at Stoughton, Scraptoft and South Croxtton and may signify minor oscillations in the forward progress of the ice edge.

It might be anticipated that the ice which was once more advancing up the Soar valley would have ponded water before it. There is some evidence that this did occur, since at a number of localities grey stoneless silts have been located beneath the Oadby till. Two factors have militated against the widespread preservation of any still-water deposits. The first is that most of the deposits would have been in a position and at an altitude where they were particularly susceptible to erosion in the post-glacial period; very little Oadby till has been preserved along the line of the Soar valley.
Equally important is the fact that the ice sheet which spread from the north-east seems to have been particularly effective in disturbing the sediments over which it passed. The occurrences of silt that remain are too isolated to permit reconstruction of stages in the ponding.

(vi) Oadby till.

The Oadby till is not entirely homogeneous, revealing variations ranging from red, Trias-derived boulder clay to blue boulder clay studded with innumerable Cretaceous erratics. However, the amount of material of north-western provenance is small, and even some of this may be of secondary derivation from the Thrussington till. The lower Oadby till tends to contain more local material than the upper, but there is no reason to think this is due to any shift in the direction of ice movement. For the present purposes, therefore, the Oadby till may be treated as a single unit in which nearly all the rock debris has been transported in a south-westerly direction.

The surface across which the ice moved was an uneven one, for although the earlier drifts had tended to smooth out some of the irregularities of the pre-glacial relief, the process was far from complete. There is little doubt that the ice also gouged deeply into the surface across which it passed. On a small scale this was apparent in the old sandpit near Oadby race-course
where Deeley (1886 p. 446) records that Chalky Clay was forced over the sand "contorting, faulting and tearing it up. One large contortion trends north and south, representing an ice flow from the east." The same author adds that at Wigston both the sand and associated brick-earth are greatly disturbed. There is, however, reason to believe that sub-glacial erosion took place on a much greater scale. The most obvious and best authenticated example is discussed below under the heading of the Narborough beds. The writer believes that there are two other probable cases, and several possible ones although in no instance can proof yet be furnished. The two most likely occurrences are at Oadby and Birstall, and both are worthy of brief discussion. On the south-western side of the A6 road close to Oadby race-course (fig. 19) the drift succession appears perfectly normal, with interbedded Thrussington till and Glen Farva clay resting upon the Lower Lias at 275 feet, and passing up into Wigston sand and gravel at about 300 feet. On the north-eastern side of the road the succession is completely different. The Wigston sand and gravel outcrops at Oadby Hill at a little over 300 feet, but at the junction of Meadowcourt Road a bore-hole has proved 25 feet of chalky boulder clay and did not reach the Lias at 263 feet O.D. Further north-
Fig. 19

Screw augering
Trias-based till and red stoneless clay resting on Lias

Sections in Trias-based till; some red stoneless clay

Section 4 chalky till

Section chalky till

Borehole - 25' grey chalky till

Old sandpit described by Deeley

Glen Parva clay

OADBY HILL

Oadby till

Thrussington till

Lower Lias

Wigston sand

Fig. 19
west at the County Police Headquarters a nine-foot trench was still in Oadby till at a height of under 290 feet. The most likely explanation of these observations is that the A6 road runs along the south-western edge of a depression gouged out by sub-glacial erosion. The alternative view is to regard the Oadby till as occupying an old bedrock valley which earlier drift had failed to fill in, but the respective levels of the glacial deposits renders this highly improbable.

In the region of Birstall there are two points at which the base of the Oadby till is known to sink to a level of 200 feet or lower. The first is at Rothley where, on both sides of Rothley Brook, boulder clay very rich in chalk can be found at an altitude of under 190 feet, and where the base of the boulder clay has not been reached owing to the obscuring effect of the river terraces. The second is south of Birstall in the cutting on the old Great Central railway, where Fox-Strangways (1903 p. 48) records not only chalky boulder clay, but also chalky gravel, sand and stiff drab clay; the similarity of these constituents, and their seemingly haphazard arrangement, with the Narborough beds may not be lacking in significance. Between these two points there are three borehole records, each presenting a

\[\text{XSite 97 on Map E.}\]
problem but each also giving some grounds for thinking that the base of the Oadby till may descend to unusually low levels. The most northerly\textsuperscript{x} is that quoted on p. 142. As it stands the record is meaningless, but there is the possibility that much if not all the "Blue Lias" is actually chalky boulder clay. The basis for suggesting this is that elsewhere the same driller has described what is undoubtedly chalky boulder clay as "Blue Lias"; to quote but one example of several, at Wibtoft in south Leicestershire where the drift according to Shotton exceeds 100 feet in thickness, two beds of "Blue Lias" are reported, separated by a four-foot seam of sand. The second borehole\textsuperscript{xx} is noted by Fox-Strangways on his field sheet and is said to have encountered 75 feet of chalky boulder clay, which would place the base of the Oadby till below 200 feet. The most southerly borehole is situated at Mowmacre Hill, and is said to have passed through "Drift clay" into "Gravel and sand with Oolitic boulders." If the reference to oolitic boulders is reliable, the likelihood is that the drift clay is Oadby till with its base again at about 200 feet. Whilst these observations by no means constitute proof, they nevertheless indicate the likelihood of sub-glacial erosion. The mere fact that Oadby till occurs at altitudes

\textsuperscript{x}Site 118 \textsuperscript{xx}Site 119 on Map E.
of 200 feet or less is noteworthy, for it has already been shown that most of the pre-glacial valleys were filled with Thurcaston sand and gravel to above this height before the first boulder clay was laid down.

During the mapping of the Eastern Uplands, two localities were discovered where the base of the chalk-rich Oadby till descends abruptly to below stream level. The first lies in the valley of Queniborough Brook, and the second in the valley of Hamilton Brook. Screw augering in the foot of a stream bluff being undercut by Queniborough Brook proved over 10 feet of boulder clay very rich in Cretaceous erratics, but despite the proven thickness of the deposit there remains some doubt whether it is truly in situ or has been soliflucted to the position it now occupies. As will be shown in Chapter six, a cold climate supervened after the valleys of central Leicestershire had been excavated in the post-glacial period to their present level, so that accumulation at the height of the present valley floor does not exclude solifluction as a possible cause. An argument in favour of the solifluction hypothesis is the absence of the till at a similar low level on the opposite side of the valley, but doubts such as this will only be dispelled when more is known about the structures at depth.

Such is the thickness and continuity of the Oadby
till that its former complete extension across the whole of the mapped area can scarcely be doubted. It is testimony to the amount of post-glacial erosion which has taken place along the line of the Soar and its main tributary valleys that the edges of the Oadby till have been pushed so far back from the larger streams. There is no sign of thinning of the till, and the impression conveyed is of a much more massive ice sheet than that which brought the Thrussington till.

(vii) Narborough beds. (see Addendum)

Much of what is known about the Narborough beds comes from a series of relatively full and accurate bore-hole records, but even these cannot compensate for the poverty of good sections. From the disused sandpit in the easterly occurrence of the Narborough beds, certain conclusions seem clear. The composition of the gravel facies as analysed in pebble count No.16 of Appendix A, betokens an affinity with the Oadby till. The inclusion of frequent lenses of boulder clay indicates that ice must have been in the immediate vicinity during accumulation of the sand and gravel. On the evidence of the false bedding the water which deposited the sand and gravel was flowing southwards. Finally, the wide range in the grade of the water-laid sediments, apparent in the disused pit but emphasized even more strongly in the boreholes to the west, implies great variations in the
velocity and transporting power of the water.

One must, of course, recognize that the agent which laid down the Narborough beds is not necessarily that which scoured out the trenches in which they lie. The two agents which might have gouged out the trenches are ice, and meltwater acting subglacially. The steep-sided, relatively narrow form seems more consistent with meltwater activity, for it is not easy to see why a narrow tongue of ice should cut a deep gash in the subglacial surface. Moreover, the efficacy of subglacial meltwater as an erosive agent has long been recognized (e.g. Werth 1909) and has frequently been quoted by the Scandinavians to explain such features as Rinnentäler (Woldstedt 1926, Schou 1949). Recently in Great Britain the importance of subglacial stream erosion has received greater recognition. Sissons (1958, 1960) has ascribed to meltwater activity beneath an ice sheet features which had previously been ascribed to extra-glacial meltwater, and the present writer (Rice, 1959) has described from Scotland a good example of a tunnel valley. But none of these features is strictly comparable with the trough occupied by the Narborough beds, since in this case it is necessary to explain not only the excavation of the trough but also its subsequent infilling.

A number of deep, drift-filled channels more analo-
gous to that at Narborough have been described from various parts of Britain. Over a century ago Jukes (1859) drew attention to a channel at Moxley on the South Staffordshire coalfield which, he said, is filled for the most part with fine red sand containing a few thin beds of well-rounded pebbles. Jukes was unconvinced of the Pleistocene age of the deposits, but Robertson (1928 pp. 191-2) refers to the "remarkable, steep-sided channel" as filled with drift composed mainly of red clay, sand and gravel. Whitehead and Eastwood (1927) record that close to Moxley at least 10 feet of the infilling is composed of laminated loam and clay. However, it is in East Anglia that similar channels have been most commonly encountered. Boswell (1913) describes some of these and likens them to the "Föhrden" of Schleswig-Holstein excavated by subglacial streams. The same writer (1927) discusses the buried channels beneath the Brett and Gipping valleys, and whilst admitting the remote possibility that they could be normally eroded stream valleys, again likens them to the "Föhrden". Osborne White (1932) provides a relatively full account of the very deep channels underlying the Cam and Stour. The infilling is composed mainly of gravels, sands, loams and chalky tills, and although there is little guide to the age of the deposits, there
are a few borehole references to constituents found in the Chalky Boulder Clay, part of the Upper Glacial succession. The proportion of boulder clay in the infilling is small, while fine-grained sorted sediments are usually well represented. These have less the appearance of fluvial than of lacustrine sediments.

There seems little doubt that the features alluded to in the above paragraph are the true analogues of that at Narborough. Both the channels and the deposits which fill them show many points of similarity. Nevertheless, the statement that "the mode of formation of buried channels in general is obscure, and likely to remain so until we have sufficient data to indicate the actual shape of their longitudinal profiles in a few typical instances" (Osborne White, 1932 p. 52) is still true today. The form of the sub-drift floor at Narborough is indeterminate, and so does not add greatly to our understanding. Moreover, it is doubtful whether the sample of known channels is sufficiently representative to justify speculation about the factors controlling their location. In this context it may be significant that the Narborough channel lies between Charnwood Forest on the west and the Lias uplands on the east, for these may have had the effect of constricting the ice-sheet between them, or funneling meltwater towards the axis of the Soar
valley. A further aspect worthy of note is that the Blaby brickpit sections betoken contortion of drift in the same locality during the period of the Thrussington till ice sheet. Milthers (1948), in discussing Danish tunnel valleys, invokes convergence of ice sheets as a localizing factor. He asserts that at such a convergence great volumes of meltwater would collect, sink through cracks and crevasses, and then force their way to the ice margin subglacially. Yet there is less evidence of convergence during the advance of the Oadby till ice sheet than during the earlier glacial episode.

If the disposition of materials apparent in section AB (fig. 13) should prove to be true of the whole Narborough channel, it would show that a phase of glacial deposition supervened before the finer, water-laid sediments began to accumulate. The evidence, however, is still inadequate to sustain this view, although it may be concluded from the amount of till in the Narborough beds that infilling of the channel occurred subglacially. In Scandinavia the excavation of tunnel valleys was commonly followed by the formation of an esker (Madsen 1928), that is, the activity of the meltwater changed from erosional to depositional. A similar change may be inferred from the Narborough beds, although in this case relatively still-water conditions
seem to have prevailed beneath the ice. A connection with the ponded water at the ice margin further south may be suggested, but this is purely conjectural. Further surmise would be out of place, and for the moment it is better simply to add the Narborough channel to known examples of subglacial scouring.

(viii) **Summary.**

Before proceeding to discuss the correlation of the drifts with those in adjacent areas, it will be useful to state in summary form the main conclusions derived from the foregoing study. The major events recorded in the drifts of central Leicestershire appear to be:

(i) Accumulation of an extensive sheet of fluvio-glacial outwash along the major valleys of the pre-glacial surface, with meltwater at a slightly later date diverted eastwards across a col at Melton Mowbray.

(ii) Advance of an ice sheet in which the dominant direction of movement was south-eastwards, but which from a very early phase came into competition with ice proceeding from the north-east.

(iii) Ponding of water in the Soar valley as the ice front reached the neighbourhood of Leicester, but the lake sediments being over-ridden as the ice moved further south.

(iv) Partial withdrawal of the ice sheet from central Leicestershire, with ponded water occupying both the Soar...
and Wreak valleys.

(v) Readvance of the ice but with the dominant direction of movement now from the north-east. Overriding of the lake sites by an ice sheet which as it proceeded up the Soar valley induced considerable subglacial scouring.

(vi) Final withdrawal of the ice from central Leicestershire.
In this chapter it is intended to examine how far the foregoing interpretation of the drifts of central Leicestershire is consistent with published accounts of the glacial deposits in adjacent regions. Particular attention is paid to two critical areas, that to the south and south-west of the mapped area, and that to the east of Melton Mowbray, but a briefer examination is also made of contiguous districts ranging as far west as Charnwood Forest and as far east as the Middle Lias escarpment around Tilton. Much reliance has been placed upon the records of earlier workers, but these have locally been supplemented by the author's own investigations.

(i) Correlation with the succession described by Shotton.

The northern boundary of the area described in detail by Shotton (1953) lies eleven miles from the southern boundary of the area described in this thesis.
Nevertheless, the similarity of the drift succession in the two regions is such that the following correlation can be proposed with some confidence:

<table>
<thead>
<tr>
<th>Coventry Area</th>
<th>Leicester Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dunsmore gravel</td>
<td>Narborough beds</td>
</tr>
<tr>
<td>Upper Wolston clay</td>
<td>Oadby till</td>
</tr>
<tr>
<td>Wolston sand</td>
<td>Wigston sand and gravel</td>
</tr>
<tr>
<td>Lower Wolston clay</td>
<td>Thrussington till</td>
</tr>
<tr>
<td>Baginton sand</td>
<td>Glen Parva clay</td>
</tr>
<tr>
<td>Baginton-Lillington sand and</td>
<td>Thurmaston sand and gravel</td>
</tr>
<tr>
<td>gravel</td>
<td></td>
</tr>
<tr>
<td>Subbenhall clay</td>
<td>Not found</td>
</tr>
</tbody>
</table>

Among the similarities between the Thurmaston sand and gravel and the Baginton-Lillington sand and gravel the following may be mentioned:

(a) The presence of basal gravel passing up into false-bedded sands.
(b) The tendency for the sands to become level-bedded in the upper few feet.
(c) Deposition over an undulating surface with the deposits thinning out against the higher ground.
(d) The lithology of the gravel, for Shotton describes the gravel occurring north of grid-line 71 as, for all practical purposes, wholly made of Bunter pebbles.
Further support for the correlation of these two water-laid strata is to be found in the fact that Shotton himself equates the Baginton-Lillington beds with the "Older sand and gravel" of Fox-Strangways, and the "Older sand and gravel" constitutes part of the Thurmaston sand and gravel as described in this thesis. Nevertheless, the interpretation placed by the writer upon the deposit in the Leicester area differs in one important respect from that placed by Shotton in the Coventry area. In central Leicestershire one of the outstanding features of the gravel is the paucity of material from the Lias, even where it is actually resting upon the Lias. In the Coventry area, on the other hand, Shotton notes how variations in the composition of the gravel indicate feeding streams from the east. In central Leicestershire preference has been accorded to the idea that much of the gravel is outwash from an advancing ice sheet, while to the south Shotton invokes "normal land streams" acting during the cold phase immediately preceding the glaciation. Although it would be surprising if around Coventry all the pebbles came from the east derived by erosion from an earlier till, while at the same time around Leicester all came from a later ice sheet, it is still possible that both interpretations are largely correct in their respective areas.

Despite differences in the nature of the deposits,
correlation of the Thrussington till and associated lake sediments with the Lower Wolston clay is supported by analysis of the pebbles which they contain. The Thrussington till is composed in the main of material from the north and west, but there is also evidence that at a very early stage ice moving from the north-east introduced a few Cretaceous erratics. In the lower part of the Lower Wolston clay Shotton records 2% of the pebbles as flints, and in the upper part 20%; he comments that these figures may not be representative, and that they probably err in being too high. The presence of the still-water clays in the area immediately south of Leicester indicates the likelihood that what in this thesis has been termed Lake Glen Parva is in fact the northern edge of Lake Harrison in which the Lower Wolston clay accumulated. In practice, recognition of this fact does not add greatly to our knowledge of the history of Lake Harrison. In large measure it confirms what Shotton has already deduced, namely that as the ice proceeded up the Soar valley it impounded a lake by the time it reached Leicester, that it then advanced further south reaching the latitude of Croft at a very early stage, and that there was a later withdrawal accompanied by a renewal of lacustrine conditions in the vicinity of Leicester. The level of the lake when the ice front was lying across central Leicester-
shire is indeterminate, but it was almost certainly much lower than the maximum level of Lake Harrison at 435 feet (Bishop 1958). There is some reason to believe that during the withdrawal phase water level may have fallen to 300 feet.

Correlation of the Wolston sand with the sand and gravel outcrop at Wigston is implicit in the work of Shotton who appears to use the outcrop as a control point in contouring the base of the Wolston sand. Moreover, both beds occupy a horizon transitional between deposits yielding a profusion of Bunter pebbles, and deposits in which flints at least rival Bunter pebbles in number.

Correlation of the Oadby till with the Upper Wolston clay and Dunsmore gravel accords with the rapidly increasing amount of Cretaceous material to be found in the latter deposits, and Shotton himself regards the Dunsmore gravel as the local equivalent of the "eastern boulder clay". It seems that the ice from the north-east, pushing aside the weakening north-western ice and once more invading the site of Lake Harrison, ultimately spread to the distant margin of the lake (Bishop 1958 p. 293).

(ii) South Leicestershire.

It is believed that the similarities noted above are adequate to sustain the correlation given on p. 196, but additional observations in south Leicestershire make it possible to forge a closer link between the two areas
which have now been mapped in detail. A number of deep boreholes near the border between Leicestershire and Warwickshire have proved a basal sand and gravel which may safely be presumed the equivalent of the Baginton/Thurmaston deposits. Among the boreholes are those at Cloudesley Farm and Ullesthorpe (both quoted by Shotton), and at Leire and Frolesworth (fig. 20). Northwards the declining ground level means that shallower bores and wells have penetrated to the bottom of the drift, and a number of records indicate the presence of a basal sand and gravel. Among these may be instanced wells at Broughton Astley, where 17 feet of fine reddish brown sand was entered at about 250 feet O.D., at Sutton in the Elms where nine feet of loamy sand underlies red clay, and at Primethorpe where the sand underlying red clay is reported to be 50 feet thick (although this seems most unlikely if it is the equivalent of the Thurmaston deposits). At Broughton Astley the sand is said to contain pebbles of Carboniferous, Triassic and Liassic origin, which accords with the normal character of the Thurmaston sand and gravel. There is thus evidence of the continuity of the Baginton/Thurmaston beds from the Coventry district where they were mapped by Shotton to the neighbourhood of Broughton Astley. Moreover, the level of the top of the sand seems to decline
Fig. 20. Contours of the proto-Soar valley.
from about 270 feet around Rugby to about 250 feet around Broughton Astley. Between the latter village and Narborough it is probable that the beds, although originally deposited, have been largely destroyed by subglacial erosion, but the evidence for this suggestion is deferred until the link between the Glen Parva clay and the Lower Wolston clay has been examined.

Indications of the extension of the Glen Parva clay south of the Sence have been obtained at a number of localities between Blaby and Countesthorpe. In a well at Blaby Isolation Hospital the following strata were encountered:

Soil.......................... 0'6"  
Brick clay...................... 20'0"  
Bluish clay with a vein or pocket of sand at 55 feet... ?70'0"  

while nearby typical red brick clay was formerly worked in a series of large pits. On the north-eastern outskirts of Blaby deep trenches on a new housing estate revealed stoneless red clay interbedded with some sand to a depth of at least six feet. In all these instances the altitude at which the clay occurs is about 250 feet, but without any indication of the height to which the deposit may formerly have reached. In an old pit close to Broughton Astley station there was formerly an exposure of 30 feet of stiff red clay containing scattered pebbles and boulders; the clay here is at about 300 feet with
the base not exposed, but it is capped at about 325 feet by a chalky clay mixed with gravelly sand. The latter appears to be the base of the Wigston/Wolston sand, while the red clay may be the Glen Parva/Lower Wolston clay. It should be pointed out, however, that although the pebbles in the clay are "scattered" the Geological Survey Officers who examined the section refer to the deposit as boulder clay rather than as water-laid material. Around Stoney Stanton and Sapcote red and brown clays rest directly on some of the igneous rocks, while in the Hinckley and Burbage districts a number of boreholes have proved red stoneless clay and silt. There is thus an east-west zone between Countesthorpe and Hinckley in which the dominant material appears to be water- rather than ice-deposited, and which goes far to establishing the equivalence of the Glen Parva and Lower Wolston clays. The overlap of the lacustrine sediments across the basal sand and gravel on to solid rock seems to be very finely displayed, and there is the prospect that future mapping will permit the differentiation of the Thrussington till and Glen Parva clay in a way that has not been possible in central Leicestershire.

Yet at this point it is necessary to interject a cautionary note, for there are certain observations which signify that the distribution of the drifts is more compli-
cated than the foregoing paragraphs might suggest. For instance, chalky boulder clay occurs very extensively at comparatively low levels in the area between Croft, Cosby, Narborough and Whetstone. In the old pit at Broughton Astley station the red clay and stones extends up to a height of 325 feet, at which level it grades into the Wigston/Wolston sand. At Croft, on the other hand, the writer has noted nine feet of blue boulder clay very rich in chalk where the ground level is no more than 255 feet. Even more instructive is the series of boreholes sunk to test the foundations of the M1 Motorway. Fig. 21 is a section along the line of the motorway compiled from these boreholes and a supplementary geophysical survey, and it is immediately apparent how a very considerable thickness of typical north-eastern boulder clay is trenchesed down below the level at which to both east and west red stoneless clays are found. The probable explanation lies in the subglacial erosion already demonstrated at Narborough having continued at least as far south as Cosby; but this point awaits fuller investigation.

So far no mention has been made of the Bubbenhall clay which Shotton found lying beneath the Baginton-Lillington gravel in two areas south-south-east of Coventry. Shotton regarded the small patches of clay as relics of a once more extensive deposit greatly
dissected by a long period of erosion. No equivalent of the Bubbenhall clay has yet been found in the Leicestershire area. This is not surprising, for it seems more likely that small relict masses of very early drift would be preserved in the upper rather than the lower reaches of the proto-Soar valley. On the other hand, in a number of deep boreholes between Hinckley and Lutterworth as much as 30 feet of red boulder clay has been recorded at the base of the drift, and has been regarded by Shotton as the equivalent of the Bubbenhall clay. A possible alternative view meriting further enquiry is that the boulder clay signifies the early ice advance from which meltwater depositing the Thurmaston sand and gravel proceeded.

(iii) The proto-Soar valley.

In contouring the base of the drifts and thus reconstructing the proto-Soar valley, Shotton included much of central Leicestershire. The present study has shown that the base of the drift occasionally sinks much lower than Shotton envisaged, but it is believed that these "lows" are due to subglacial erosion and are therefore not relevant to the reconstruction Shotton was attempting. No reason for any radical modification to the contours of the proto-Soar valley has been found, although one or two minor refinements have been incor-
porated in fig. 20. These include carrying the 250-foot contour closer to the valley centre at Red Hill quarry, Narborough, and the 250- and 300-foot contours in the same direction in the eastern suburbs of Leicester. For reasons given on p. 156 the 200-foot contour has been drawn across the valley further downstream. The overall effect of these changes is to reduce very slightly both the gradient and the width of the proto-Soar valley. The long profile of the valley is surprisingly gentle – averaging less than eighteen inches per mile between Warwick and Aylestone – but the transverse form is clearly much influenced by the geology. In the reach between Narborough and Leicester the valley is confined between the Rhaetic scarp on the east, and the igneous and Triassic sandstone outcrops on the west; between Sileby and Barrow where the valley narrows once again it is confined between the Rhaetic scarp and the Mountsorrel igneous intrusions. It is presumably the short transverse distance separating these resistant outcrops that accounts for the valley being much narrower than it is higher upstream on the Warwickshire border. The close parallelism of the proto-Soar with the geological strike suggests that it originated as a subsequent, a point which Dury (1963) has recently elaborated. Although it is not intended to pursue the matter further in this thesis,
it is worthy of note that the relationship of the proto-
Soar to the geological structure at Mountsorrel may be
more complex than Dury implies. The width of the Keuper
outcrop cannot be much greater than the width of the
modern floodplain, and the Rhaetic base which is here
as low as 150 feet (fig. 2) might not, if projected,
clear the top of the Mountsorrel granite. Harrison
(1876) mentions that pebbles 3" - 4" long in the Rhaetic
bone bed may be referred to Charnwood Forest rocks which
probably means that Charnwood Forest was subject to ero-
sion during Rhaetic times.

(iv) North-east Leicestershire and parts of adjacent
counties.

Fig. 22 shows the distribution of glacial deposits
in the area east of Melton Mowbray. It is based upon
published Geological Survey maps, with some minor amend-
ments necessitated by recent borehole records. If, as
has been argued above, there is a valley which carried
meltwater eastwards past Melton Mowbray at a level below
250 feet, its course must obviously lie hidden beneath
the drift cover extending from Melton Mowbray to Castle
Bytham. Any other outlet in this direction is precluded
by the almost unbroken outcrop of Lincolnshire Limestone
from Croxton Kerrial to Sewstern, and from Market Overton
to Burley.
Fig. 22. Distribution of glacial drift in N.E. Leicestershire.
It has already been shown that in the immediate vicinity of Melton Mowbray the bedrock surface declines eastwards (rather than westwards in conformity with the slope of the present Wreak valley). A further indication of the great thickness of the drift is provided by a well at Thorpe Arnold:

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow clay</td>
<td>10'0&quot;</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>0'6&quot;</td>
</tr>
<tr>
<td>Blue shale and boulder stones</td>
<td>90'0&quot;</td>
</tr>
<tr>
<td>Sand</td>
<td>0'8&quot;</td>
</tr>
<tr>
<td>Lower Lias shale</td>
<td>11'0&quot;</td>
</tr>
</tbody>
</table>

At this site the bedrock surface can be only very little above 200 feet. It is most unfortunate that for about five miles east of this point there are no records providing precise and reliable information about the form of the sub-drift floor. Yet there is reason to believe that the drift cover remains thick, for at Freeby it is recorded that "a well was sunk and bored 78 feet through clay with stones only." Evidence becomes more plentiful north of Wymondham where three boreholes have been drilled deep into the glacial deposits. The first lies south-east of Coston and proved the following strata without reaching bedrock:

G.L. c. 430 feet O.D.

<table>
<thead>
<tr>
<th>Stratum</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder clay</td>
<td>147'0&quot;</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>7'0&quot;</td>
</tr>
<tr>
<td>Sand</td>
<td>3'0&quot;</td>
</tr>
</tbody>
</table>

The second lies due north of Wymondham church, and the
log reads as follows:

G.L. c. 430 feet O.D.

<table>
<thead>
<tr>
<th>Material</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder clay</td>
<td>113'0&quot;</td>
</tr>
<tr>
<td>Boulder</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Gravel</td>
<td>6'0&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>3'0&quot;</td>
</tr>
<tr>
<td>Sandstone and clay</td>
<td>2'0&quot;</td>
</tr>
<tr>
<td>Blue clay</td>
<td>4'0&quot;</td>
</tr>
</tbody>
</table>

The most likely interpretation appears to be 126 feet of drift, with the base of the hole entering four feet into Lower Lias clay. If this is correct, the level of the bedrock surface is here just over 300 feet.

The last borehole is at Garthorpe Lodge and has a more problematical record:

G.L. c. 400 feet O.D.

<table>
<thead>
<tr>
<th>Material</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay and boulders</td>
<td>50'0&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>140'0&quot;</td>
</tr>
<tr>
<td>Sand and clay</td>
<td>15'0&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>9'0&quot;</td>
</tr>
<tr>
<td>Sand</td>
<td>7'0&quot;</td>
</tr>
<tr>
<td>Clay</td>
<td>2'0&quot;</td>
</tr>
</tbody>
</table>

The Geological Survey has interpreted this as 50 feet of drift resting on 173 feet of Lower Lias. An alternative view is to regard almost the entire succession as drift. Two arguments may be adduced in support. The first is that the water obtained from the sinking is described as "full of sand and small bits of coal," which would be more consistent with derivation from the drift than from the Lower Lias. The second is that the bedrock surface undoubtedly slopes very steeply northwards from Wymond-
ham and a drift base of under 200 feet at Garthorpe Lodge would only represent a continuation of that slope. The gradient of the bedrock surface may be deduced from the fact that the Middle Lias outcrops at over 400 feet on the hillslopes above Wymondham, while less than a quarter of a mile to the north the second borehole described above proved 126 feet of drift and the drift base at about 300 feet O.D.

Whichever interpretation of the Garthorpe Lodge record is correct, and with present information it is difficult to decide between them, there remains ample evidence to show that the drift cover is locally very thick and conceals something other than a gently undulating Lower Lias surface sloping gradually from the floor of the Wreak valley to the crest of the Belvoir ridge around Waltham-on-the Wolds. The significance of this fact is much enhanced by the presence of a deep, drift-filled valley cutting across the Lincolnshire Limestone escarpment between North and South Witham. The sub-drift configuration of this region is relatively well known, since a very large number of boreholes have been sunk by the companies quarrying and mining the Northamptonshire ironstone. The sites of a selection of the boreholes are shown in fig. 23, but the contouring is based upon all available source material. Owing to the fact that
Fig 23 The form of the drift-filled valley across the Lincolnshire Limestone plateau.
the boreholes were sunk to test the potential value of the ironstone, there is much more information about the margins of the channel than about its greatest depths where it constitutes a major "wash-out". The channel sides are steeply sloping so that it is not unusual to find over 100 feet of glacial deposits within quarter of a mile of Lincolnshire Limestone outcrops. West of the Withams the edges of the valley are closely defined by the edges of the drift, but further east the till cover is more extensive and the precise limits of the valley are concealed. Nevertheless, borehole records indicate that the characteristic steep sides persist at least as far as Castle Bytham.

The exact height and form of the valley floor remains unknown. Among the boreholes which have proved either a great thickness of drift or a particularly low level for the drift base are the following:

<table>
<thead>
<tr>
<th>Borehole (fig.23)</th>
<th>Surface level</th>
<th>Thickness of drift</th>
<th>Height of drift base</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>330</td>
<td>Over 146</td>
<td>below 184</td>
</tr>
<tr>
<td>C</td>
<td>371</td>
<td>over 195</td>
<td>below 176</td>
</tr>
<tr>
<td>D</td>
<td>298</td>
<td>157</td>
<td>141</td>
</tr>
<tr>
<td>E</td>
<td>302</td>
<td>147</td>
<td>155</td>
</tr>
<tr>
<td>F</td>
<td>183</td>
<td>41</td>
<td>142</td>
</tr>
</tbody>
</table>

The only record which raises any doubt about interpretation is that of borehole D. The log of this hole reads as follows:
Brown clay ................................... 4'0"
Grey clay ....................................... 25'0"
Boulder clay .................................... 1'0"
Grey clay ........................................ 127'0"
Blue clay ........................................ 40'0"
Grey clay ........................................ 1'0"

The absence of the Lincolnshire Limestone seems to imply that the 127 feet of "Grey clay" must be a drift deposit, and the most probable interpretation appears to be 157 feet of drift resting on Lias clay.

On the evidence of the above figures, supplemented by information from numerous shallower boreholes the floor of the drift-filled valley in the vicinity of the Withams is probably several hundred yards wide and at an altitude of about 150 feet. The latter figure is also suggested by the gradient of a small tributary valley entering the main channel from the south. The form of this buried tributary valley is known in unusual detail (Rice 1962), and extrapolation of the long profile is consistent with a confluence level of about 150 feet. Another feature emerging from the contouring of the drift base is the tendency of the channel to narrow eastwards. The probable reason for this is that around the Withams where the valley floor is deeply cut into the Lias clay, spring sapping at the base of the Lincolnshire Limestone was operative for a much longer period than at Castle Bytham where the valley floor is not far below the base of the limestone. One final aspect of fig. 23 worthy of note
is that an apparent outcrop of Lincolnshire Limestone near the western end of the valley has been discounted. This occurrence of Lincolnshire Limestone was noted by the early Geological Survey Officers who mapped it as solid rock. Stewarts and Lloyds, however, possess the record of an early borehole which is said to have passed through the limestone into "boulder clay." A recent drilling right at the edge of the "outcrop" passed through 70 feet of drift and still had not reached solid rock. There seems no doubt that one here has a large raft of Lincolnshire Limestone incorporated in the boulder clay; comparable examples are very common in this region.

The very size of the buried valley at the Withams is testimony to the volume of water which must once have flowed through it. For purposes of comparison, the gap through the Lincolnshire Limestone escarpment is much larger than those now occupied by the rivers Chater and Gwash near Oakham. Allied to the presence of a watershed in the sub-drift configuration just west of Melton Mowbray, and of a possible buried valley between that town and the Lincolnshire Limestone escarpment, this fact suggests that much of the area now draining westwards down the Wreak valley formerly drained eastwards through the gap at Withams. Fig. 24 portrays the relief and drainage as it probably was just before the deposition of the
Fig. 24. Pre-glacical relief & drainage of NE Leicestershire.
earliest drift. No great precision in the contouring can be claimed since the fixed altitudes for the drift base are so irregularly distributed; but on the other hand, the contours are nowhere at variance with any borehole record which the writer has been able to locate, nor with any recent published map of the Geological Survey.

The reconstructed drainage pattern accords well with the conclusions arrived at after study of the Thurcaston sand and gravel, since the valley cutting across the Lincolnshire Limestone escarpment east of Melton Mowbray would provide a ready escape for the Soar drainage once its normal outlet below Thurcaston was blocked by ice. Presumably the diverted water would find its way to the present site of the Fens, although detail of the form of the buried channel below Castle Bytham has not yet been ascertained.

The pre-glacial drainage pattern as reconstructed in fig. 24 would help to explain the curious course of the modern Wreak, the headwaters of which rise around Cold Overton and flow for several miles in a general north-easterly direction. The curving route followed by the middle Wreak results in the direction of the flow having veered through almost 180° before the final confluence with the Soar. Kellaway and Taylor (1952)
suggest that two of the Wreak headstreams, those flowing past Langham and Ashwell, formerly continued eastwards across the Lincolnshire Limestone escarpment via drift-plugged cols south-west of Cottesmore and south of Barrow. These writers also suggest that as the bedrock cols occur at altitudes of 460 and 450 feet respectively, capture of the Langham brook was effected by a strong subsequent feeder of the Ashwell brook developing on the Lias clay. Later, but before deposition of the local chalky drift, the Ashwell brook was itself captured by the Wreak. Whilst this appears a satisfactory explanation of the courses taken by the Langham and Ashwell streams, it leaves unexplained the courses of two other Wreak headstreams, namely those rising at Cold Overton and Somerby, both of which begin by flowing for over four miles in a north-easterly direction. Two miles from Wymondham where the streams are only half a mile apart they abruptly turn through 90° towards the north-west, but in direct alignment with their upper courses is a plug of boulder clay which descends to a level not much above that of the bend in the streams. The plug of boulder clay is continuous with the main mass of drift and may well conceal the former north-eastward continuation of the Somerby and Cold Overton drainage. The bedrock surface beneath the plug is unknown but a
borehole a short distance east of Wymondham proved 58 feet of boulder clay within 300 yards of a solid rock outcrop; there is manifestly a considerable difference between the modern relief and that of the sub-drift surface. If it is true that the Somerby and Cold Overton streams formerly joined the trunk river draining through the Witham gap, then it follows that it was a tributary of these streams which diverted the Langham and Ashwell brooks. The contrasting dimensions of the Witham, Barrow and Cottesmore drift-plugged valleys makes this seem very feasible.

A further district which appears to have drained through the Witham gap is that lying north and north-east of Melton Mowbray. Two deep drift-filled valleys score the summit of the Belvoir ridge. The western or Scalford channel is incised about 100 feet below the plateau formed by the Middle Lias Marlstone, and from the available borehole records the bedrock watershed seems to lie close to the scarp face overlooking the Vale of Belvoir. The eastern or Waltham channel is probably a little shallower, and the watershed several miles from the scarp face. The continuity of the channels trenching the summit of the Belvoir ridge suggests that they may be in part the product of glacial meltwater, but discussion of this possibility involves consideration of the relatively drift-free Vale of Belvoir which is regarded as outside
the confines of the present study. It will suffice to
say that pre-glacially the valleys were occupied by
normal streams tributary to the trunk river draining
through the Witham gap. A third drift-filled valley
which probably functioned in the same way runs southwards
from Croxton Kerrial to join the main valley close to
Coston. Details of the form of this third channel are
uncertain, but it differs from those further west in that
it does not breach the crest of the Middle Lias scarp.

The reconstruction of the pre-glacial drainage
pattern indicates that an area not far short of 100 square
miles formerly drained through the Witham gap; the resul-
tant volume of water would explain the size of the gap.
It may be added that a trunk stream flowing from Melton
Mowbray to Castle Bytham would constitute another member
of the series of east-flowing consequents recognized by
Kellaway and Taylor (1952). Furthermore, the strikingly
smooth gradient of the surface which rises gently westwards
from near Colsterworth to Waltham, and continues in a more
dissected form to Ab Kettleby, is manifestly comparable with
the "East Midland surface" which those authors describe
from the area immediately to the south. As in the country
around Market Overton, Barrow, Cottesmore and Burley it is
most noticeable that the massive Lincolnshire Limestone
fails to produce a topographic feature even approaching
the dimensions which might be expected. Nothing can be added to the cogent argument deployed by Kellaway and Taylor that the "East Midland surface" is of sub-aerial origin, although the more approximately parallel consequents that are recognized the stronger appears the contention that the surface is not far removed from that on which the drainage was initiated.

Turning from the form of the sub-drift surface to the nature of the glacial deposits themselves, one must recognize that until much more work has been done any attempt to correlate the glacial deposits with those mapped in central Leicestershire will be fraught with hazards. Nevertheless, certain remarks in the Geological Survey Memoir on the Melton Mowbray district are worthy of note. It is stated that in the south-eastern portion of Sheet 142 three types of boulder clay may be distinguished: (1) a chalky boulder clay which forms the surface deposit over a very wide area; (2) a leaden-grey clay of Lower Lias or immediately local origin in which rock fragments are few and do not seem to include either Cretaceous or Oolitic materials; and (3) a red laminated silty clay apparently derived from the Keuper Marl, often much contorted, and containing still fewer stones which consist, in the one clean section where the clay is exposed, exclusively of Bunter pebbles and fragments of Keuper
skerries. The best section observed by the Officers was in the northern outskirts of Melton Mowbray, where the leaden grey clay was succeeded by red laminated silty clay, which in turn passed up into yellow current-bedded sand with at least one band of grey loam in it, and the whole succession was capped by light blue chalky boulder clay. The general similarity with the Thrussington till, Rotherby clay, Wigston sand and gravel and Oadby till is obvious. The ponding of water indicated by the red laminated clay is particularly significant for it lies east of the pre-glacial watershed. If, as seems likely, the deposit is roughly contemporaneous with the Rotherby clay, it strengthens the view that damming by north-eastern ice was an essential feature of Lake Rotherby; final proof however must await further study of the area east of Melton Mowbray, for we do not yet know the form of the surface left behind by the retreating north-western ice.

The cover of chalky boulder clay is so extensive that it tends to conceal all the earlier glacial deposits. For this reason it is impossible without very full bore-hole records to establish the drift succession along the line of the buried valley leading to the Witham gap. Regrettably, even the logs provided by the companies working the ironstone beds, although generally giving a
full and reliable account of the solid strata, pay little attention to details of the drift. It is not unusual for beds of sand and gravel to be consolidated with true till and recorded simply as "boulder clay". As a result it is only in the Castle Bytham district, where post-glacial erosion has cut down to the level of the buried valley floor that reliable guidance as to the nature of the basal drift is available. In a sand and gravel pit east of the village the lowest visible bed is a fine gravel composed mainly of Bunter pebbles with an admixture of Jurassic limestones. Such a composition agrees very well with the thesis advanced on completely independent evidence that the Soar while transporting a Bunter-rich load was diverted eastwards past Melton Mowbray. Above the gravel lies a confused assemblage of deposits generally containing north-eastern erratic material.

(v) The Tilton district.

Although the proportion of Oadby till to Thrussington till increases as one moves from the Soar valley across the Eastern Uplands, there is no reason to believe that within the mapped area of central Leicestershire the limit of the Thrussington till has been reached. It is likely that at least in isolated patches it extends as far as the foot of the Middle Lias escarpment around Tilton. Whether the north-western ice actually surmounted the
scarp is less certain. There is much drift on the scarp top, as a number of recent boreholes have shown (fig. 25). The normal succession appears to consist of boulder clay resting on a very variable thickness of sand and gravel, as the following records testify:

G.L. 692 feet O.D. (A in fig. 25)

<table>
<thead>
<tr>
<th>Soil</th>
<th>1'0&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder clay</td>
<td>9'0&quot;</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>46'0&quot;</td>
</tr>
<tr>
<td>Upper Lias</td>
<td>29'0&quot;</td>
</tr>
</tbody>
</table>

G.L. 707 feet O.D. (B in fig. 25)

<table>
<thead>
<tr>
<th>Soil</th>
<th>1'0&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder clay</td>
<td>71'0&quot;</td>
</tr>
<tr>
<td>Sand</td>
<td>5'0&quot;</td>
</tr>
<tr>
<td>Ironstone</td>
<td>22'0&quot;</td>
</tr>
</tbody>
</table>

G.L. 692 feet O.D. (C in fig. 25)

<table>
<thead>
<tr>
<th>Soil</th>
<th>1'0&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder clay</td>
<td>39'0&quot;</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>8'0&quot;</td>
</tr>
<tr>
<td>Upper Lias</td>
<td>12'0&quot;</td>
</tr>
</tbody>
</table>

Field observation indicates that the boulder clay is very rich in Cretaceous and Middle Jurassic erratics, while the sand and gravel is believed to be of similar composition. Posnansky (1960 p. 307) analysed the pebble content of a glacial gravel at Tilton and found it to contain 12% Bunter pebbles, 12⅔% flint and 61% Jurassic fragments. The inference seems to be that the drift on the summit of the escarpment is the equivalent of the Wigston sand and gravel, and the Oadby till. Should
TILTON DISTRICT

Fig. 25
further work establish that the scarp was not overridden by the earlier north-western ice, it will provide a most valuable guide to the maximum extent of that ice sheet. It is noteworthy that Shotton (1953) also regards the early ice advance as less extensive than the succeeding one, for he writes (p. 253) that "this first advance presumably halted some way north of the southern limit of the Wolston sand," a limit which is placed near Cubbington, six miles south of Coventry. It may thus be permissible to envisage a stage in the history of Lake Harrison when the ice was banked against the Middle Lias escarpment at Tilton while its southern edge swept away from the high ground and lay in the waters of the lake near Coventry. This stage would be followed by a partial withdrawal leading to the extension of the lake north to Leicester, before finally the whole region was overwhelmed by ice coming from the north-east.

(vi) The Groby district.

Fox-Strangways, in his description of the Geological Survey one-inch sheet No. 155, remarks that the glacial beds are generally not so thick, nor the sub-divisions so clearly defined, as they are along the Soar valley to the east. Nevertheless, he does distinguish between gravels composed mainly of quartzite pebbles and material from the west, and later gravels from the east. Among
those consisting mainly of Bunter pebbles are spreads at Kirby Muxloe and Ratby, and it seems likely that these are the equivalent of the Thurmaston sand and gravel. As is usual with that deposit, the gravel is banked against hillslopes of solid rock and seems to occupy the floor of a pre-glacial valley, probably that which continued downstream beneath the Beaumont Leys estate. An important tributary valley ran south-eastwards from near Groby where boreholes have proved thick beds of sand lying beneath later Trias-derived till.

Boulder clay rather than lacustrine clay appears to be characteristic of the Groby district, and it displays the usual upward change from material of Triassic provenance to material of Cretaceous provenance. Harmer (1927-30 p.144) records a large section at Leicester Forest showing "blue Chalky Boulder-clay resting on the eroded surface of purple Triassic drift which contains boulders of Mount Sorrel granite, with many blocks of Mountain Limestone, Millstone Grit and Coal Measure chert and sandstone, but no Chalk or Oolite." The detailed logs of boreholes sunk along the line of the M1 Motorway show that the change is not always an abrupt one, but that there is often a transition in which the two types of till alternate.
As described in the above paragraphs, the glacial succession of the Groby district conforms very closely to that of the Soar valley. However, reference must also be made to a complicating feature revealed by the recent M1 boreholes. Where the motorway crosses Rothley Brook the alluvium was found to rest, not on Keuper Marl as might be expected, but on thick glacial deposits; the following are representative logs:

G.L. 236 feet O.D. (Grid ref. 525054)

(Topsoil) ............................................................ 1'6"
(Stiff brown clay) ............................................. 1'0"
(Stiff reddish brown sandy clay) ............................. 4'6"
(Brown silty fine sand and silt) ... 13'0"
(Firm brown (partly laminated) )

G.L. 238 feet O.D. (Grid ref. 523056)

(Topsoil) ............................................................ 0'6"
(Sandy clay) ........................................................ 1'0"
(Firm clay) ....................................................... 1'3"
(Stiff greyish brown silty clay) ... 6'0"
(Brown silt) ....................................................... 1'0"
(Stiff brown (partly laminated) )

The discovery was the more surprising because beyond the edges of the alluvial cover the Keuper Marl either outcrops or is overlain by only a thin stratum of drift.
Two aspects of the glacial deposits call for particular comment. The first concerns their lithology which is quite unlike the normal Thurmaston sand and gravel which might have been anticipated. The second is the very low altitude of the drift base, for one of the boreholes quoted above penetrated to 192 feet O.D., and several adjacent holes reached about 200 feet O.D., all without striking bedrock. These would be surprisingly low levels for the glacial infilling of a normal valley which would presumably have been tributary to the Soar some six miles away to the north-east. Reference has already been made (pp. 138-9) to the indications that around Anstey the bedrock surface declines to abnormal levels, and although much more evidence is to be desired, the tentative conclusion is that along the middle reach of the Rothley Brook valley there is probably another instance of subglacial scouring. In this case the scouring is associated with the earlier ice advance from the north-west.

(vii) The Age of the Glacial Drifts in Central Leicestershire.

West and Donner (1956) suggest that the lower boulder clay of north-western derivation in central Leicestershire is the equivalent of the Lowestoft till in East Anglia, basing their argument primarily on the
direction of ice movement as revealed by the preferred orientation of the erratic fragments. Similarly, the chalky boulder clay is equated with the Gipping till. Between the Lowestoft and Gipping tills lie the Hoxnian deposits which West (1954, 1955) refers on palynological grounds to the Great Inter glacial. If these correlations are sound, it follows that the early drifts of central Leicestershire were deposited during the Elster glacial period, the later drifts during the Saale glacial period, and between the two there lies a long break in glacial sedimentation representing the Great Interglacial. Posnansky (1960) accepts and elaborates this chronology.

Shotton regards nearly all the glacial drifts of the Coventry area as of Saale age, maintaining that during this one glaciation the direction of predominant ice movement shifted from south-eastwards to south-westwards. The Baginton-Lillington beds were laid down in the cold phase immediately preceding the advance of the ice. The only deposits which are assigned to the Elster glacial period are the small pockets of Bubbenhall clay, although a formerly more extensive till cover of this age is invoked to explain the distribution of

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xThere is an important factual error on p. 290 of Posnansky's paper. Deeley does not record an older boulder clay lying beneath the Quartzose sand (Thuraston sand and gravel) at Aylestone.
Bunter pebbles in the Baginton-Lillington gravel. Palynological evidence in support of this dating has been obtained from the Nechells interglacial deposits (Duigan, 1956).

Shotton, in discussion of the paper by West and Donner, appears to accept those authors' correlation of the successions in the East Midlands and East Anglia. Yet there seems to the present writer to be an inconsistency between the conclusions of Shotton (1953) and West and Donner (1956). It is part of Shotton's thesis that when, at the onset of the Saale period, the ice advanced up the proto-Soar valley it invaded an area largely denuded of earlier drift by prolonged sub-aerial erosion; only very small pockets of the Bubbenhall clay survived. Yet one of the sites where West and Donner claim to have found Elster drift is at Leicester University in a bluff directly overlooking the Soar, and at a point where this old drift must be at least 30 feet thick. If this identification is correct, it means that the proto-Soar valley up which the Saale ice moved was surprisingly narrow at Leicester compared with further south, and that Shotton is not justified in his belief that the bedrock surface which he contoured corresponds without significant differences to the proto-Soar valley at the end of the Great Interglacial.
Such an analysis of recent published literature constitutes a prima facie case for believing that the dating postulated either by Shotton or by West and Donner is erroneous. The present study leads to the same conclusion. Arguments have been adduced to sustain a correlation between the drifts of central Leicestershire and those of the Coventry area, and this correlation involves equating the Thrussington till which West and Donner regard as of Elster age with the Lower Wolston clay which Shotton regards as of Saale age. The incompatibility may be summarized in tabular form:

<table>
<thead>
<tr>
<th></th>
<th>Shotton</th>
<th>West and Donner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saale</td>
<td>U. Wolston clay</td>
<td>Saale</td>
</tr>
<tr>
<td></td>
<td>Oadby till</td>
<td>Gipping till</td>
</tr>
<tr>
<td>Saale</td>
<td>Wolston sand</td>
<td>Hoxne</td>
</tr>
<tr>
<td></td>
<td>and gravel</td>
<td>Needian</td>
</tr>
<tr>
<td>Saale</td>
<td>L. Wolston clay</td>
<td>Lowestoft till</td>
</tr>
<tr>
<td></td>
<td>Thrussington till</td>
<td>Elster</td>
</tr>
</tbody>
</table>

The present writer believes that the Thrussington till is of Saale age. Three lines of reasoning conduce to this view. The first is the cogency of the arguments by which the Leicestershire deposits are related to those in Warwickshire, and by which in turn the latter are dated. The second is the lack of any convincing evidence for a prolonged interglacial interval during the deposition of the Leicestershire drifts. A temporary withdrawal does
appear likely, but there seems no reason to believe it was at all comparable in length with the Great Inter-glacial. The third is the inherent weakness of any hypothesis founded on the assumption that during one glacial period the direction of ice movement was fairly constant. Shotton showed that with the passage of time the types of pebbles accumulating in the Wolston beds changed in such a way as to suggest a shift in the direction of ice movement. In central Leicestershire certain features of the drift sequence are explicable only if it be allowed that during one glacial period there were rapid shifts to-and-fro in the direction of ice movement. Such short-term shifts, superimposed upon an overall change like that detected by Shotton, render the use of isolated sections extremely hazardous; there is no difficulty in visualizing sections in the Leicester area which would display till of Cretaceous derivation underlying till of Triassic derivation, nor till of north-western provenance as evidenced by pebble orientation underlying till of north-eastern provenance. That such sections are relatively rare is merely due to the fact that the overall change is in the opposite direction.

The view that all the mapped drift of central Leicestershire is of Saale age raises the problem of correlation with East Anglia and intervening districts. It would be
presumptuous to doubt the dating accorded to the Hoxnian deposits by West, and the most likely cause of the erroneous long distance correlation proposed by West and Donner seems to lie in the close resemblance of the Elster till to some of the basal till of the Saale period. But presumably somewhere in the area between Leicester and Hoxne this deceptive Saale till thins and disappears. In the Kettering district of Northamptonshire, Hollingworth and Taylor (1946) recognize the following succession:

Chalky boulder clay with associated gravels
Mid-glacial gravels
Lower boulder clay
Sands and gravels.

At first sight the succession of two gravels interbedded with two tills tempts one to make the straightforward correlation with the similar sequence in central Leicestershire. However, the basal sands and gravels around Kettering are characterized by material wholly of local origin, which is certainly not true of the Thurmaston sand and gravel. The Lower boulder clay is free from chalk and flint and thus bears a partial resemblance to the Thrussington till in which these erratics are scarce; yet it is only intermittently preserved in hollows beneath newer drift and this may indicate that its deposition was followed by a long period of erosion. The Mid-glacial gravels have a "local plus Bunter" composition and so resemble the Thurmaston sand and gravel (or
at least its presumed equivalent, the Baginton-Lillington gravel). The chalky boulder clay with associated gravels seems to be the equivalent of the Cadby till and Wigston sand and gravel. The correlation between Northamptonshire and central Leicestershire may be summarized as follows:

<table>
<thead>
<tr>
<th>Northamptonshire</th>
<th>Leicestershire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalky boulder clay and</td>
<td>Cadby till and Wigston</td>
</tr>
<tr>
<td>gravels</td>
<td>gravel</td>
</tr>
<tr>
<td>Not recorded</td>
<td>Thrussington till</td>
</tr>
<tr>
<td>Mid-glacial gravels</td>
<td>Thurcaston sand and gravel</td>
</tr>
<tr>
<td>Lower boulder clay</td>
<td>Not recorded</td>
</tr>
<tr>
<td>Sands and gravels</td>
<td>Not recorded</td>
</tr>
</tbody>
</table>

The probable reason for the Thrussington till finding no representation in Northamptonshire has already been suggested during discussion of the Tilton district, namely that the early north-western ice lacked the impetus to surmount the Middle Lias scarp, while at its maximum in the Soar valley it reached only to the vicinity of Coventry.

The postulated sequence of events in the East Midlands and East Anglia is therefore:

1. An ice advance from the north-west during the Elster period.
2. Complete ice withdrawal with accumulation of the Hoxne and Nechells interglacial deposits; a long period
of erosion during which almost all the early drift was removed from the proto-Soar valley.

(3) A readvance during the early Saale period with north-western ice still dominant, but reaching only as far as the proto-Soar valley.

(4) A partial withdrawal of the ice, but very shortly the whole of the East Midlands and East Anglia being covered by north-eastern ice.

The resulting correlations are shown in tabular form on p. 232.
<table>
<thead>
<tr>
<th>Central Leicestershire</th>
<th>Warwickshire</th>
<th>Northamptonshire</th>
<th>East Anglia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oadby till</td>
<td>Chalky boulder clay, Dunsmore gravel and Upper Wolston clay</td>
<td>Chalky boulder clay</td>
<td>Gipping till</td>
</tr>
<tr>
<td>Wigston sand and gravel</td>
<td>Wolston sand</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thrussington till and Glen Parva clay</td>
<td>Lower Wolston clay</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thurmaston sand and gravel</td>
<td>Baginton-Lillington sand and gravel</td>
<td>Mid-glacial gravels</td>
<td>-</td>
</tr>
<tr>
<td>Nechells deposits</td>
<td>-</td>
<td>-</td>
<td>Hoxne deposits</td>
</tr>
<tr>
<td>Bubbenhall clay</td>
<td>Lower boulder clay</td>
<td>Lowestoft till</td>
<td></td>
</tr>
</tbody>
</table>

CHAPTER SIX

DISSECTION OF THE GLACIAL DRIFTS:

THE RIVER TERRACES

(a) Deglaciation

It has not proved possible to reconstruct the sequence of events which followed immediately upon the withdrawal of the ice from central Leicestershire. There is no reason to doubt that initially there was a complete cover of Oadby till over the whole of the mapped area, and that the present drainage began to flow upon this cover. It has already been argued that the Soar and many of its tributaries are re-excavating old valleys, and it may be assumed therefore that the positions of these valleys were marked by depressions in the original drift surface. To the west of the Soar, however, the subdued pre-glacial relief was more completely masked and much of the present drainage pattern is of purely post-glacial origin. The initiation of the modern Wreak must also date from the same period; whether its course is due simply to irregularities in the surface left by the ice, or to diversion by the ice margin as it withdrew eastwards is less sure. Much of the uncertain--
ty stems from the fact that it is doubtful whether in central Leicestershire, any of the original drift surface remains.

Shotton (1953) and Bishop (1958) have shown that as the ice front withdrew northwards from the Moreton district, meltwater began to dissect the drift cover and to initiate the Avon valley. The Avon No. 5 terrace is believed to date from this period, and its absence from the Avon headwaters may yield a clue as to the position of the ice front at one particular time. Once the ice front had withdrawn north of the present Avon-Soar watershed, it is possible that meltwater was ponded in a pro-glacial lake; this would seem likely if the surface relief was akin to that of today, which is probable but unproven. The spur crests in central Leicestershire were examined to discover whether in their morphology they retain any traces of former lake strandlines. The crests are generally very even, lacking sharp breaks of slope. Nevertheless, the long interfluves between the right-bank tributaries of the Soar display a series of "flats" separated by slightly steeper "risers". Analysis of the heights at which the concave breaks of slope between flat and riser occur failed to yield a consistent pattern, and the evidence available at present does not warrant the view that the
breaks of slope are old strandlines.

A further feature of many of the spurs in the Eastern Uplands is the presence of a pronounced col at the foot of the Middle Lias escarpment (fig. 25). Clayton (1959 p. 8) has written "It is conceivable that this col could be an original ice-marginal feature, a sort of gutter lying between the ice and the Marlstone." If this were the correct explanation, the cols might yield evidence as to some of the retreat phases of the ice, and they were examined with this possibility in mind. From Billesdon Coplow the cols form a sequence which shows a gradual fall in altitude northwards: the col close to Billesdon Coplow is at about 530 feet, that close to Cold Newton at about 515 feet, and that close to Lowesby at just below 500 feet; around Maresfield where the Middle Lias scarp swings to the east in a deep re-entrant distinctive cols are absent, but they reappear further north at 470 feet below Burrough Hill, at approximately the same altitude at Home Farm, and at 440 feet at Debdale Lodge. If the features constitute an "aligned sequence" they betoken a northward flow of meltwater. Yet conditions under which meltwater would be forced to flow northwards seem intrinsically unlikely, since it would presumably require that the ice was banked higher against the scarp face around Billesdon than it
was further north near Great Dalby. An alternative explanation of the cols is that they are due to scarp recession. The floor of each col is cut in Lower Lias clay, but the upper slopes are formed on the one side by drift and on the other by Middle Lias beds. Some retreat of the Middle Lias escarpment since the deposition of the Saale drift is inherently probable, for there is evidence of two allied processes which even today are eroding the face of the scarp. The Middle Lias beds act as an important aquifer giving rise to a series of powerful springs sapping the lower scarp slopes, while general instability of the scarp face is indicated by numerous scars resulting from small rotational slips. The writer is in agreement with Clayton who thinks it "likely that the feature has formed since the ice melted, and that it has resulted from the divergent retreat of the upper edge of the boulder clay and the Marlstone scarp" (p. 8). A possible explanation of the otherwise puzzling northward fall in height of the cols is to be found in the fact that the level of the base of the Middle Lias also declines northwards, being about 550 feet near Billesdon and under 500 feet near Debdale Lodge.

The foregoing paragraphs illustrate how an examination has failed to yield convincing evidence concerning the earliest phases of deglaciation. The first decipher-
able events appear to post-date the removal of the Oadby till and are best encompassed under the general heading of river terraces.

(b) **River terraces.**

The river terraces of the Middle Soar basin (fig. 26) are not sharply defined features, for they normally possess a distinct riverward slope and the inter-terrace bluffs are much degraded. The terrace gravels frequently form a continuous spread across the bluffs so that in the absence of deep sections it is difficult to determine either the form of the basement on which the gravels rest, or the precise relationship of one suite of gravel to another. Nevertheless, it is possible to distinguish four terrace levels along the middle Soar valley; in descending order they are

- Birstall Terrace
- Wanlip Terrace
- Syston Terrace
- Quorndon Terrace

In addition to the terraces there is also a group of erosion "flats" which constitute what is here termed the Knighton Surface, while below the modern alluvium there is a considerable thickness of floodplain gravels.

The criterion employed in distinguishing the terraces has been solely that of height above modern alluvium. The altitude of the leading edge of each
FIGURE 26
THE TERRACES OF CENTRAL LEICESTERSHIRE

- Knighton Surface
- Birstall Terrace
- Wanlip Terrace
- Syton Terrace
- Quornon Terrace
terrace fragment has been measured by means of an aneroid; an accuracy of +5 feet is claimed for all the heights quoted. The pronounced gradient towards the valley centre means that the height of the leading edge is much influenced by the degree of later trimming when the river was eroding at a lower level. One result is that the fragments of a single terrace as depicted in fig. 27 do not fall on a line comparable with the modern floodplain, but occupy a zone which may have a height range of 10 feet or more. The writer has not felt justified in inserting any indication of former river levels on fig. 27.

(i) Knighton surface.

One of the most distinctive topographic features of the city of Leicester is a very gently undulating plateau which extends from a level of just over 300 feet in Stoneygate to a level of about 275 feet in Knighton where it overlooks the Soar. Much of the plateau is now built over making its form less easy to discern, but a good example of the evenness of the spur tops is afforded by the open space of Victoria Park. That this form is due to erosion is indicated by its being cut indiscriminately across Cadby and Thrusington till; and although it does not have the normal spread of terrace grevel, it is intermittently veneered with a sheet, two or three feet thick, of water-deposited
sand and gravel. This was noticed at a number of sites during the present study, and Fox-Strangways on his six-inch field sheet writes "Apparently many patches of sand over this ground."

North-east of Leicester the rising ground of the Rhaetic scarp is capped by a series of small gravel spreads. The largest of these is at Barkby Thorpe, where there is a distinctive "flat" at about 260 feet. It is unlikely that much of the gravel is a true terrace deposit, for in comparison with a normal terrace it contains a very high percentage of Bunter and Carboniferous pebbles, and a very low percentage of flint (Appendix A No. 17). The composition is more in keeping with a local bed of gravel within the Thrussington till, across which has been spread a thin sheet of flint-bearing gravel such as occurs at Knighton. No sections permitting closer examination of the deposits were noted in the course of the present study.

On the opposite bank of the Soar the remarkably smooth-topped plateau known as Rothley Plain and lying at about 240 feet may also be classed as part of the Knighton surface, although in this area there are no known water-laid deposits resting on the glacial drift.

(ii) **Birstall terrace.**

This is the highest terrace to display the normal
attributes of extensive spreads of gravel at a relatively constant level above alluvium. Also included under this heading are several isolated and irregular patches of gravel which occur at an altitude above that of the main terrace but which are so fragmentary that they do not warrant recognition as a separate stage. The only one of these meriting special mention is that at Barrow. Here a small patch of rather clayey sand and gravel caps an isolated knoll at a height of just over 200 feet. Whilst a distinctive terrace form is lacking, the writer sees no reason to doubt that the material is a post-glacial river deposit. The site is of particular interest for it is here that Plant (1859) records the finding of a complete skeleton of Elephas antiquus. Detailed location of the find is not given by Plant, but there seems little doubt that it was in the gravel on the higher ground, rather than in the spreads along the nearby valley floors.

The main level of the Birstall terrace is particularly well developed around the confluence of the Soar and the Wreak. North-east of Belgrave a series of Keuper Marl ridges is capped by flint-bearing gravel at about 200 feet, that is, at about 30 to 40 feet above alluvium. The thickness of terrace material is not great. On the Belgrave ridge it is commonly seven or
eight feet, as has been proved both in old workings (Fox-Strangways six-inch field sheets) and in more recent boreholes. On the next ridge downstream it is about the same thickness, although comparison with the Geological Survey one-inch sheet will show that what is there depicted as glacial sand and gravel is treated in the present study as a post-glacial terrace. The justification for this change lies in the abundance of flint as revealed on cultivated land and in shallow sections. In this particular area the basal drift would presumably be the Thurmaston sand and gravel in which flint is either absent or extremely rare (of stone counts Nos. 4 and 18 in Appendix A). It is of course possible that a terrace deposit overlies a thin stratum of drift, and some support for this suggestion is to be found on the next ridge south-west of Barkby. In an old brickpit working the Keuper Marl, the overburden consists of five feet of gravel in which Bunter pebbles are by far the most common constituent and in which no flint was found. This is the Thurmaston sand and gravel. Yet in the adjacent fields ploughing disclosed a gravel relatively rich in flint which is therefore to be regarded as a post-glacial river deposit. On the other ridges around Barkby the Birstall terrace deposits seem commonly to be about five feet thick.
If the terrace gravels described in the foregoing paragraph were all deposited by the main river, they would indicate that the Soar at one period flowed to the east of the Thurmaston drift outlier, and became fixed in its present course as the result of a cut-off. Although this remains a possibility, the writer inclines to the view that most of the gravels were laid down by the right bank tributaries of the Soar where they emerged from the Eastern Uplands on to the more easily eroded area of drift-covered Keuper Marl; at the stage of the Birstall terrace the Soar must have been close to regaining its pre-glacial level. A much clearer example of an abandoned meander loop is to be found on the left bank north of Birstall. Today this district is covered by housing estates, making an appreciation of the surface morphology difficult, but there appears to have been little erosion since the cut-off took place, and the level of the Soar at the time it followed this route must have been just over 190 feet.

Along the valley of the Wreak the Birstall terrace is well represented, and much of it was mapped by the officers of the Geological Survey under the title of "Older river gravel". The terrace fragments, however, are poorly shaped and rarely retain a well defined "flat". Where the Soar valley narrows to pass between
the Mountsorrel igneous outcrops on the left bank and
the Rhaetic and Lias outcrops on the right bank, rem-
ants of the Birstall terrace are missing, but they
reappear around Quorndon at a level of about 30 feet
above alluvium. So far as the writer has been able
to discover there are no reliable records of any fauna
having been obtained from the main level of the Birstall
terrace.

(iii) Wanlip terrace.

Below the base of the Birstall terrace gravels there
is usually a pronounced rock step denoting the end of
that phase of aggradation and the onset of a period of
erosion. At and below the level of the Wanlip terrace
the form of the bedrock basement is commonly concealed
by the superficial deposits, so that the sequence of
events must be deduced from deep sections and sub-
surface records. The Wanlip terrace gravels can be
shown at a number of points to rest upon a bedrock
platform the surface of which lies about 10 feet above
modern alluvium. The depth of incision following the
Birstall aggradation must therefore have been at least
twenty feet.

The Wanlip terrace deposits are generally between
five and ten feet thick, but may locally attain over
15 feet. Much of central Leicester is built upon a
fragment of the Wanlip terrace, and the many records of that city show these to be representative figures. The Leicester fragment is also characteristic in that the bluff at its back is not sharply defined. It is one of the most distinctive features of the Wanlip terrace that the concave break of slope at its rear is obscured by a gently inclined sheet of clayey sand and gravel which may extend over a vertical interval of as much as 30 feet and which grades down from the valley side into the top of the terrace. Good examples are to be seen at Wanlip itself, and on an even larger scale across the river at Cossington. One result is that flat terrace remnants are uncommon and the height of the frontal bluff is in large measure controlled by the amount of valley widening which the river has achieved at a lower level.

The melange of material that swathes the valley sides is attributable to solifluction. The fauna of the Wanlip aggradation is a "cold" one, Elephas primigenius having been recorded from a number of sites. Although only few sections were seen in the course of the present study, it is now evident that much of the contortion and disturbance of strata which earlier workers described is due to the growth of ground-ice under periglacial conditions. Fox-Strangways (1903 p. 54) refers
to five feet of "valley drift" made up of pre-existing boulder clay, containing lenticular patches of sand and gravel which seem to have been thrust into the mass of the clay, and resting upon solid strata which are nearly always more or less disturbed and frequently violently contorted. The best example of such disturbance noted in the course of the present study was just outside the mapped area in the centre of Blaby. Here a deep section disclosed violent involutions, with wisps and irregular masses of Keuper Marl thrust up into the terrace gravel. Comparable structures are not unusual in excavations in central Leicester, and they probably account for the relatively frequent references to "valley drift" and "boulder clay" in well and borehole records.

(iv) Syston terrace.

Fringing the modern alluvium and often rising only two or three feet above it, there lies a further sloping spread of gravel. The surface form is not very distinctive, for conspicuous bounding bluffs are rare. The precise age of the gravel is a little uncertain, for its relationship to the deposits beneath the floodplain is indeterminate. South of Thurmaston a series of closely spaced boreholes suggests it may rest upon a bedrock platform below the level of the modern alluvium but above the base of the floodplain gravels. Elsewhere,
however, no such platform has been detected, and the probability is that the Syston terrace represents the maximum aggradation level after the cutting of the sub-alluvial channel.

Although the records are rather inexact in fixing sites of finds, it is believed that in the Thurmaston locality a cold fauna including *Elephas primigenius* (and possibly *Tichorhinus antiquitatus*) has been obtained from the Syston terrace gravels.

(v) **Quorndon terrace.**

At Quorndon a very curious and as yet unexplained transformation of the valley floor takes place. In the reach immediately below Cossington, the Soar executes a series of large meander loops (one of which is now abandoned, but is still clearly traceable on the ground), and the floodplain attains a width of fully three-quarters of a mile. At Quorndon a gravel-covered spur some five to ten feet above the level of alluvium projects from the western side of the valley and so constrains the floodplain that for a short distance it is no more than 200 yards wide. At the constriction the gradient of the floodplain steepens perceptibly, and downstream what was evidently the former floodplain is dissected into a low terrace. This, the Quorndon terrace, rises only two or three feet above modern alluvium but may be clearly
distinguished in the field.

At first sight the features at Quorndon might seem to betoken a normal head of rejuvenation, but there are cogent reasons for believing that it is something more than that. The Soar has failed to trim back the low ridge which projects across its valley despite the fact that immediately upstream it has eroded an exceptionally wide floodplain. A rock-cored ridge is a possible answer, but this raises the question of the nature of the rock. As the ridge must have survived not only the cutting of the present-day floodplain, but also the erosion which preceded the floodplain aggradation, the resistance of the rock must have greatly exceeded that of the normal Keuper Marl. A core of Rhaetic of Lias strata is one possibility, a core of igneous rock a less likely one. An even more remote possibility is that very recent tectonic movement beneath the floor of the Soar valley has dislocated the fluvial deposits. In the context of the present study, the problem is a minor one, but is obviously worthy of further investigation.

(vi) **Floodplain gravels.**

Beneath the modern alluvium of the floodplain, there is commonly a depth of ten to twelve feet of coarse sand and gravel, although the figure decreases slightly as one moves up both the Soar and Wreak valleys. There
can be no doubt about the coldness of the fauna associated with this aggradation, for almost all the gravel pits on the floodplain have yielded *Elephas primigenius*, *Tichorhinus antiquitatus* and *Rangifer tarandus*, while recently the first occurrence of *Megaceros giganteus* has been recorded (Sizer 1962). The faunal remains are very much more common at the base of the aggradation than they are towards the top.

Resting upon the sand and gravel there is normally three or four feet of alluvial silt and clay. It is not unusual to find that the base of the clay is stained dark with organic matter, and at one or two localities there is a thin bed of peat separating the clay from the underlying sand and gravel. A preliminary examination of the organic layer at Wanlip by Dr. F. Oldfield showed a high content of *Tilia*, and it was thought unlikely that the deposit dates back to more than 5000 B.P.

(vii) The chronology of the terraces.

The terraces of central Leicestershire testify to at least three distinct phases of aggradation, namely those associated with the Birstall, Wanlip and floodplain gravels. Of these the last two undoubtedly occurred under cold climatic conditions and may be assigned to the last (Weichsel) glaciation. The assignment of the Birstall terrace gravels is much more problematical.
The terrace itself is almost certainly composite, and may cover a long span of time. The record of *Elephas antiquus* from Barrow favours a date for part of it within the last (Eemian) interglacial period, but whether this applies to the main terrace level is debatable. From fig. 27 the gravel spread at Barrow appears to lie some 30 feet above that level, although this may be misleading inasmuch as it is partly attributable to the method of constructing the diagram. In the diagram all the gravel spreads are related to the floodplain of the Soar and there is the tacit assumption that most of them were deposited by the Soar itself. This may not apply to the Barrow terrace fragment which lies within the mouth of a small tributary valley and could therefore be 10 to 20 feet higher than the contemporaneous Soar deposits. Nonetheless, the dating of the main level of the Birstall terrace must be regarded as indeterminate until further evidence becomes available.

The Knighton surface which is presumably older than the Birstall terrace may be ascribed to a stillstand in the dissection of the glacial drifts occurring either at the end of the Saale glaciation or early in the Eemian interglacial period. The Syston and Quorndon terraces probably bear witness to minor phases of down-cutting subsequent to the floodplain aggradation, although there remains the possibility that the former may denote
an aggradational phase prior to that of the floodplain gravels.

(c) Correlation with adjacent rivers.

(i) The Trent.

In order to establish a correlation with the Trent, the terraces of the lower Soar were mapped (fig. 28 and 29). During the mapping only surface morphology was taken into account and no attempt was made to determine the form of the bedrock basement. Moreover, in locating the terrace fragments much reliance was placed upon the published one-inch maps of the Geological Survey, and although additions were made in the field there may still be some small remnants which have escaped detection. The altitude of the leading edge of each terrace fragment was measured with an aneroid, and an accuracy of 1/8 is thought to have been achieved.

It is not proposed to detail here the character of the terraces along the lower Soar, for the evidence which they provide is adequately summarized in fig. 29. It will suffice to say that the accordance with the middle Soar is remarkably good, and provides a reliable guide for establishing a correlation with the Trent. Although the writer is reluctant to quote figures which suggest a greater degree of precision than the evidence warrants, the following table based upon the mapping
Figure 28
Terraces of the lower Soar

- Birstall Terrace
- Wanlip Terrace
- Syston Terrace
- Quorndon Terrace

Scale: 1/4 Mile

Locations:
- Kegworth
- Ratcliffe
- Sutton Bonington
- Hathern
- Stanford
along the lower Soar is given for purposes of comparison with the Trent:

Birstall terrace - main terrace level up to about 50 feet above alluvium; many higher fragments.

Wanlip terrace - maximum aggradation about 30 feet above alluvium.

Syston terrace - maximum aggradation about 10 feet above alluvium.

Quorndon terrace - less than four feet above alluvium.

Such diverse views have been expressed concerning the Trent terraces that correlation is by no means easy, but to facilitate discussion the following is proposed:

<table>
<thead>
<tr>
<th>Soar</th>
<th>Trent (Clayton 1953)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birstall</td>
<td>Hilton terrace</td>
</tr>
<tr>
<td>terrace</td>
<td>Upper</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Wanlip</td>
<td>Beeston terrace</td>
</tr>
<tr>
<td>terrace</td>
<td>? Beeston terrace</td>
</tr>
<tr>
<td>Syston</td>
<td>Floodplain terrace</td>
</tr>
<tr>
<td>terrace</td>
<td></td>
</tr>
<tr>
<td>Quorndon and</td>
<td></td>
</tr>
<tr>
<td>floodplain</td>
<td></td>
</tr>
<tr>
<td>gravel terrace</td>
<td></td>
</tr>
</tbody>
</table>

The position of the Hilton terrace is still very obscure. Clayton (1953) argues that the Hilton gravels constitute a "true river-terrace, though considerably affected by mass movement." (p. 201). Mitchell and Stevenson (1955) doubt the status of the gravels as a terrace and regard them as a spread of fluvio-glacial outwash. Posnansky (1960) adopts an intermediate view and terms them "fluvio-glacial gravel terraces rather than normal river terraces." (p. 301). There are of course equally divergent views.
about the age of the gravels, but both Clayton and Posnansky are agreed that they span part at least of an interglacial episode. This accords with the present writer's conclusion concerning the Birstall terrace.

Neither Posnansky nor Clayton sub-divides the Beeston terrace, although Mitchell and Stevenson recognize "First" and "Second" terraces which may be the equivalent of the Syston and Wanlip terraces. Pocock (1929) also recognizes what may be dual levels within the Beeston terrace. But the major difficulty in equating the Wanlip and Syston terraces with the Beeston terrace resides in the belief that the Beeston aggradation is interglacial. This was suggested by Swinnerton (1937, 1948) and elaborated by Posnansky. The latter author gives three reasons for regarding the aggradation as warm. One is the finding of Elephas antiquus at Barrow, but the ascription of this to the Beeston aggradation is extremely doubtful. A second is the finding at Allenton of a whole hippopotamus skeleton "in a layer of dark sand immediately above or forming the uppermost part of the Beeston gravels." (p. 301). The original description of the site (Arnold-Bemrose and Deeley, 1896 p. 505) refers to "one of the lowest of the upper series of terraces" and there seems to be the possibility that the deposit in which the skeleton was found should be ascribed to
the Hilton aggradation. If this were so, it would mean that the warm fauna of Barrow and Allenton could be assigned to the same aggradation. The third reason given by Posnansky is the contained artifacts which include rolled mid-Acheulian hand-axes and Clactonoid flakes, but fresh Levallois flakes. (Armstrong 1939). The latter are not necessarily out of place in a gravel which, the writer ventures to suggest, may belong to a phase of the last glaciation. Such a date would also be more in accord with the views of Mitchell and Stevenson who contend that the Second Terrace was contemporaneous with, or only slightly later than, the recent ice-marginal phenomena of the Irish Sea ice.

The place of the Quorndon terrace in the Trent succession is obscure, and recent writers do not appear to recognize any correlative. On the original Geological Survey one-inch sheet (No. 141) this terrace was distinguished from the alluvium by a separate symbol, and was briefly alluded to by Fox-Strangways (1905). On the edition of the map published in 1950 the differentiation was abolished.

(ii) The Avon.

A correlation with the well-established terrace sequence of the Avon (Tomlinson 1935) is suggested in the following table:
By this correlation the only evidence of warm fauna in central Leicestershire is equated with the well authenticated warm fauna of the Avon basin. On the other hand, the morphology of the terraces is not similar, for the Avon No. 4 is a well developed topographical feature, whereas the lower No. 3 is not; along the Soar valley it is the lower part of the Birstall terrace that is well formed, whereas the upper part is very fragmentary. Morphological similarity, however, does characterize the Avon No. 2 and the Wanlip terrace, for Shotton (1929, 1953) describes the former as by no means level in cross section and only on occasions forming a feature distinct from those above and below, while Tomlinson (1941) describes "fan-deltas" of sand and gravel which grade down into No. 2 terrace. Too many uncertainties attach to the Syston terrace to judge whether the correlation with the Avon No. 1 is warranted.
EPILOGUE

In this thesis much use has been made of the observations recorded by earlier workers. It is appropriate, therefore, to conclude by paying tribute to the perspicacity of these workers. Shotton has already commemorated the name of W.J. Harrison, and reference to an article by Harrison in the Proceedings of the Geologists' Association for 1897 will show how closely the conclusions outlined in pp. 193-4 of this thesis had already been anticipated by the nineteenth century observers.
ADDENDUM

Since this thesis was written, a cutting along the line of the M1 Motorway has disclosed sections which necessitate some modification of the interpretation placed upon the Narborough beds. It is now evident that part at least of the deposits mapped as Narborough beds are tectonically displaced blocks of drift each composed of beds which may be related to the general drift succession of central Leicestershire.

The cutting extends from 140 yards south of site 8 to within 60 yards of site 11 on fig. 12. At its southern end (see accompanying diagram) the cutting is almost entirely in grey chalky boulder clay, although a thin bed of water-laid material can be traced across the full width of the excavation. This sandy bed dips northwestwards but probably reappears at the first of the major faults which traverse the cutting. The effect of this fault is to expose red Trias-derived till resting upon Keuper Marl, and on the western face of the excavation the following succession was formerly exposed:

- Chalky boulder clay
- Sand
- Red Trias-derived boulder clay
- Sand (impersistent)
- Keuper Marl
- Cadby till
- Wigston sand
- Thrussington till
- Thurmaston sand

On the right of the above table is the suggested correlation.
with the drift succession of central Leicestershire.

Two normal faults crossing the line of the motorway have let down a thick bed of chalky boulder clay which was proved to a depth of thirty feet by a borehole at site 9. Further north the base of the drift is again exposed, and a succession similar to that recorded in the table above may be recognized. Part of the red Trias-derived material is here a stoneless, sandy clay with red and grey mottling which was believed from the borehole sample to be Keuper Marl in situ. The presence of drift sand beneath the deposit proves that it is part of the drift succession, and in general appearance and composition it may be compared with the material described from Blaby brickpit on the opposite bank of the Soar. Close to the northern end of the cutting a further fault brings chalky boulder clay in contact with the Keuper Marl, and a borehole at site 11 proved chalky boulder clay to a depth of over 30 feet.

On the evidence now available there seems no doubt that in the vicinity of the motorway cutting there has been Pleistocene faulting involving throws of over 50 feet. It is possible that faulting may also be responsible for other irregularities in the drift base, as well as for sites where the Cadby till is known to sink to unusually low levels. Whilst much of the material that has been described in this thesis as Narborough beds is now to be interpreted as tectonically displaced drift, there remains the thick bed of silty...
sand with clay bands and chalk specks which was proved in a borehole at the point where the motorway crosses A46 to exceed 60 feet in thickness (fig. 13). This bed cannot at present be matched with any member of the drift succession as mapped elsewhere in central Leicestershire, and it may still testify to some form of sub-glacial scouring. It is clearly important to establish the precise relationship between the bed of sand and the faulting which the motorway cutting has disclosed; whilst the juxtaposition of these two features may be fortuitous, it seems more likely that they are connected.

Finally, I should like to thank Professor F.W. Shotton for discussion of the topic raised in this Addendum, and for providing the details on which the accompanying figure is based.
APPENDIX A

Analyses of the stones in the glacial and post-glacial deposits were made at over 25 sites. All the stones included in the counts had a diameter between one and 25 cms. The following is a selection to illustrate the lithological character of the various beds described in this thesis.

THURMASTON SAND AND GRAVEL

No. 1

<table>
<thead>
<tr>
<th>Sample: 321 stones</th>
<th>Recovered by bucket auger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Page ref: 44</td>
<td>Location: Rotherby, 685172</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Carboniferous sandstone and chert</td>
<td>85</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>187</td>
</tr>
<tr>
<td>Triassic sandstone (mostly skerry)</td>
<td>40</td>
</tr>
<tr>
<td>Others (including two siliceous fragments which could be flint but are probably Carboniferous chert)</td>
<td>9</td>
</tr>
</tbody>
</table>

No. 2

<table>
<thead>
<tr>
<th>Sample: 174 stones</th>
<th>Nature of site: Gravel pit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Page ref: 30</td>
<td>Location: Rothley, 566124</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Charnwood rocks</td>
<td>7</td>
</tr>
<tr>
<td>Carboniferous sandstone and chert</td>
<td>27</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>119</td>
</tr>
<tr>
<td>Triassic sandstone (mostly skerry)</td>
<td>17</td>
</tr>
<tr>
<td>Others (provenance uncertain)</td>
<td>4</td>
</tr>
</tbody>
</table>

No. 3

<table>
<thead>
<tr>
<th>Sample: 134 stones</th>
<th>Site: Temporary excavation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Page ref: 43</td>
<td>Location: Rearsby, 643135</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Carboniferous sandstone and chert</td>
<td>4</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>126</td>
</tr>
<tr>
<td>Triassic sandstone (mostly skerry)</td>
<td>4</td>
</tr>
</tbody>
</table>
No. 4
Sample: 205 stones  Nature of site: Old sandpit
Page ref: 29  Location: Thurmaston, 616102

Vein quartz ? Charnwood 3 1%
Carboniferous sandstone and chert 21 10%
Bunter pebbles 124 60%
Triassic sandstone (mostly skerry) 46 22%
Lias limestone 3 1%
Others (inc. one metamorphic frag. with biotite and staurolite ? Bunter) 8 4%

No. 5
Sample: 179 stones  Nature of site: Temporary section
Page ref: 35  Location: Jones & Shipman, 558011

Carboniferous sandstone and limestone 20 11%
Bunter pebbles 129 72%
Triassic sandstone (mostly skerry) 19 11%
Lias limestone 9 5%
Others (inc. fine-grained lower Palaeozoic sediment and schistose sandstone ? via Bunter) 2 1%

No. 6
Sample: 71 stones  Nature of site: Blaby brickpit
Page ref: 38  Location: Blaby, 563987

Carboniferous sandstone 4 6%
Bunter pebbles 18 25%
Triassic sandstone (skerry) 30 42%
Lias limestone 19 27%

Note:– The bed from which this sample comes is better described as breccia than gravel; all but the Bunter pebbles are angular and many carry clearly striated faces.
THRUSSINGTON TILL

No. 7

Sample: 87 stones  Nature of site: Temporary excavation
Page ref: 55       Location: Bennett Building, 595032

Carboniferous sandstone and coal  4  5%
Bunter pebbles                   51  59%
Triassic sandstone (mostly skerry) 24  28%
Lias limestone                   8  9%

Note:-- Sample collected from less than three feet below chalk-bearing lens (No. 8)

No. 8

Sample: 50 stones  Nature of site: Temporary excavation
Page ref: 55       Location: Bennett Building, 595032

Sandstone (?Carboniferous)  3  6%
Bunter pebbles               3  6%
Lias limestone               4  8%
Middle Jurassic limestone    4  8%
Chalk                        27  54%
Flint                        9  18%

No. 9

Sample: 120 stones  Nature of site: Temporary excavation
Page ref: 55       Location: Bennett Building, 595032

Carboniferous sandstone, coal and chert  5  4%
Nodular ironstone (?Carboniferous)  1  1%
Bunter pebbles                      84  70%
Triassic sandstone (mostly skerry)  10  8%
Lias limestone                      20  17%

Note:-- Sample collected from less than 10 feet above chalk-bearing lens (No. 8)
No. 10

Sample: 82 stones  
Nature of site: Stream section  
Page ref: 61  
Location: Gaddesby, 677128

Carboniferous sandstone, limestone and coal 11 13%  
Bunter pebbles 34 41%  
Triassic sandstone (mostly skerry) 35 42%  
Lias limestone 2 2%

No. 11

Sample: 120 stones  
Site: Overburden of old sandpit  
Page ref: 63  
Location: Rothley, 569126

Carboniferous sandstone and chert 11 9%  
Ironstone (prob. Carboniferous) 9 8%  
Mountsorrel granite 2 2%  
Bunter pebbles 85 71%  
Triassic sandstone (mostly skerry) 9 8%  
Lias limestone 2 2%  
Others (vein quartz and volcanic ash) 2 2%

Note: Large Mountsorrel boulders are common at this site.

WIGSTON SAND AND GRAVEL

No. 12

Sample: 132 stones  
Nature of site: Old gravel pit  
Page ref: 82  
Location: Keyham, 668060

Carboniferous sandstone, chert and limestone 19 14%  
Bunter pebbles 34 26%  
Triassic sandstone (mostly skerry) 8 6%  
Lias limestone 44 33%  
Ironstone 7 5%  
Oolite 7 5%  
Others (all small sandstone fragments) 7 5%
### No. 13

Sample: 109 stones  
Nature of site: Temporary excavation  
Page ref: 84  
Location: Scraptoft, 649055

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboniferous sandstone and chert</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>Lias limestone</td>
<td>8</td>
<td>7%</td>
</tr>
<tr>
<td>Ironstone</td>
<td>7</td>
<td>6%</td>
</tr>
<tr>
<td>Middle Jurassic limestone</td>
<td>62</td>
<td>57%</td>
</tr>
<tr>
<td>Chalk</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td>Flint</td>
<td>14</td>
<td>13%</td>
</tr>
<tr>
<td>Others</td>
<td>6</td>
<td>6%</td>
</tr>
</tbody>
</table>

### No. 14

Sample: 150 stones  
Nature of site: Temporary excavation  
Page ref: 85  
Location: Thurnby, 647038

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboniferous sandstone and chert</td>
<td>17</td>
<td>11%</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>109</td>
<td>73%</td>
</tr>
<tr>
<td>Lias limestone</td>
<td>20</td>
<td>13%</td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
<td>3%</td>
</tr>
</tbody>
</table>

Note: The stratigraphical position of this deposit is uncertain.

### OADBY TILL

### No. 15

Sample: 141 stones  
Nature of site: Temporary excavation  
Page ref: 96  
Location: Oadby, 631999

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone (prob. Carboniferous)</td>
<td>5</td>
<td>4%</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>6</td>
<td>4%</td>
</tr>
<tr>
<td>Lias limestone</td>
<td>21</td>
<td>15%</td>
</tr>
<tr>
<td>Middle Jurassic limestone</td>
<td>26</td>
<td>18%</td>
</tr>
<tr>
<td>Chalk</td>
<td>64</td>
<td>45%</td>
</tr>
<tr>
<td>Flint</td>
<td>13</td>
<td>9%</td>
</tr>
<tr>
<td>Others</td>
<td>6</td>
<td>4%</td>
</tr>
</tbody>
</table>
### NARBOROUGH BEDS

**No. 16**

Sample: 137 stones  
Nature of site: Old gravel pit  
Page ref: 107  
Location: Glen Parva, 570988

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandstone (prob. Carboniferous)</td>
<td>12</td>
<td>9%</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>11</td>
<td>8%</td>
</tr>
<tr>
<td>Triassic sandstone (skerry)</td>
<td>7</td>
<td>5%</td>
</tr>
<tr>
<td>Lias limestone</td>
<td>14</td>
<td>10%</td>
</tr>
<tr>
<td>Middle Jurassic limestone</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>Chalk</td>
<td>47</td>
<td>35%</td>
</tr>
<tr>
<td>Flint</td>
<td>41</td>
<td>30%</td>
</tr>
</tbody>
</table>

### POST-GLACIAL DEPOSITS

**No. 17**

Sample: 134 stones  
Nature of site: Temporary excavation  
Page ref: 239  
Location: Barkby Thorpe, 637085

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboniferous sandstone and chert</td>
<td>32</td>
<td>24%</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>91</td>
<td>68%</td>
</tr>
<tr>
<td>Lias limestone</td>
<td>1</td>
<td>1%</td>
</tr>
<tr>
<td>Ironstone</td>
<td>5</td>
<td>4%</td>
</tr>
<tr>
<td>Flint</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>Others</td>
<td>2</td>
<td>1%</td>
</tr>
</tbody>
</table>

Note:— Probably a mixture of outwash from the Thrussington till and thin post-glacial gravel spread.

**No. 18**

Sample: 110 stones  
Nature of site: Temporary excavation  
Page ref: 241  
Location: Rearsby, 643135

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboniferous sandstone and chert</td>
<td>7</td>
<td>6%</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>39</td>
<td>35%</td>
</tr>
<tr>
<td>Lias limestone</td>
<td>7</td>
<td>6%</td>
</tr>
<tr>
<td>Ironstone</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td>Middle Jurassic limestone</td>
<td>20</td>
<td>18%</td>
</tr>
<tr>
<td>Flint</td>
<td>33</td>
<td>30%</td>
</tr>
</tbody>
</table>

Note:— From an undifferentiated terrace gravel.
No. 19

Sample: 76 stones  
Nature of site: Temporary excavation  
Location: Melton Mowbray, 743189

<table>
<thead>
<tr>
<th>Material</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carboniferous sandstone and chert</td>
<td>10</td>
<td>13%</td>
</tr>
<tr>
<td>Bunter pebbles</td>
<td>16</td>
<td>21%</td>
</tr>
<tr>
<td>Lias limestone</td>
<td>10</td>
<td>13%</td>
</tr>
<tr>
<td>Ironstone</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>Middle Jurassic limestone</td>
<td>21</td>
<td>28%</td>
</tr>
<tr>
<td>Flint</td>
<td>16</td>
<td>21%</td>
</tr>
</tbody>
</table>

Note:— From the floodplain gravel.
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