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The Quaternary Deposits of Central Leicestershire

R. J. Rice

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THE QUATERNARY DEPOSITS OF CENTRAL LEICESTERSHIRE

By R. J. RICE

Department of Geography, University of Leicester

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A programme of mapping and augering has shown the glacial drifts of central Leicestershire to consist of a basal sand and gravel overlain by a complex succession of tills and interbedded water-laid sediments. The tills display a transition from materials of predominantly north-western derivation to those of north-eastern derivation. Arguments are adduced by which the succession is correlated with that described by Shotton in Warwickshire, and it is concluded that the vast majority of the drifts belong to the Saalian glaciation. A widespread but discontinuous horizon of sand and gravel is believed to denote a temporary melt phase in the middle of the glaciation, while more limited beds of stoneless silt and clay betoken still-water sedimentation which, south of Leicester, is regarded as the local equivalent of the lacustrine Wolston clay of Warwickshire.

Although the bedrock surface over most of central Leicestershire has a form consistent with an origin by normal stream erosion, there remain a number of areas where it is difficult to sustain such an interpretation. At Narborough excavations and augering have revealed virtually the full drift succession cut by a series of normal faults traceable over a distance of at least a mile. Near these faults there is evidence of an enclosed depression scored into bedrock and filled with water-laid drift.

Although subsequent to the deposition of the drift, the faults have no surface expression at the present time, the structures being truncated by an early post-glacial erosion surface. Later phases in the post-glacial evolution of the Soar and Wreak valleys are associated with a suite of river terraces which, from their included fauna, span the period of the Eemian interglacial and the Weichselian glaciation.

1. Introduction

Within the area discussed in this paper, comprising some 135 square miles of the central section of the Soar river basin (figure 1), a twofold division of the Quaternary deposits may be recognized: the glacial drifts which generally occupy interfluvial positions as a result of post-glacial dissection, and the later river terraces which fringe the modern streams. Before proceeding to an account of these deposits, it is desirable to outline briefly the solid geology, history of previous research, and methods employed in the present study.

(a) Geology

The sedimentary succession comprises five main members:

Middle Lias:	marlstone with shales below
Lower Lias:	shaly clay with limestones near the base
Rhaetic:	shales with nodular limestones
Keuper:	marl with lenticular sandstone beds
Pre-Cambrian:	slates (? Swithland Slates)

There are in addition the Mountsorrel igneous intrusions of Caledonian age.

Among the pre-Triassic rocks the slates are of little consequence for there are only three small recorded outcrops; much more significant is the Mountsorrel granodiorite exposed in at least twenty rocky knolls ranging in size from those only a few yards across to Buddon Hill nearly $\frac{1}{2}$ sq. mi. in area. Interleaved with the red and green Keuper Marl which underlies the western half of the area are many thin beds of flaggy grey sandstone or 'skerry' and, of much more localized occurrence, beds of gypsum and massive false-bedded sandstones. By virtue of the greater resistance to erosion offered by their included limestones, the Rhaetic and Lower Lias beds form higher ground fronted by a low escarpment traceable intermittently from the vicinity of Barrow to south of Leicester. The Middle Lias outcrops only in the extreme north-east and does not here form a prominent escarpment as it does along the strike to both north and south.

The Triassic and Jurassic strata exhibit a slight but fairly persistent regional dip towards the east. Contouring of the base of the Rhaetic indicates the presence near Barrow of an important downfold with a faulted southern limb which has been linked by Kent (1937) and Clayton (1959) with the Holwell syncline affecting the Middle Lias near Grimston. The bounding dislocation is a complex structure whose general effect of suppressing the Rhaetic outcrop and displacing the Triassic and Liassic outcrops is evident from the geological map; that it extends eastwards beyond Hoby may be inferred from a number of observations, and has already been suggested by Cox (1919) and Hallimond (1930). South of the Hoby fault the sub-Rhaetic contours trend south-south-east with little sign of transverse folding or faulting except in the neighbourhood of Humberstone.

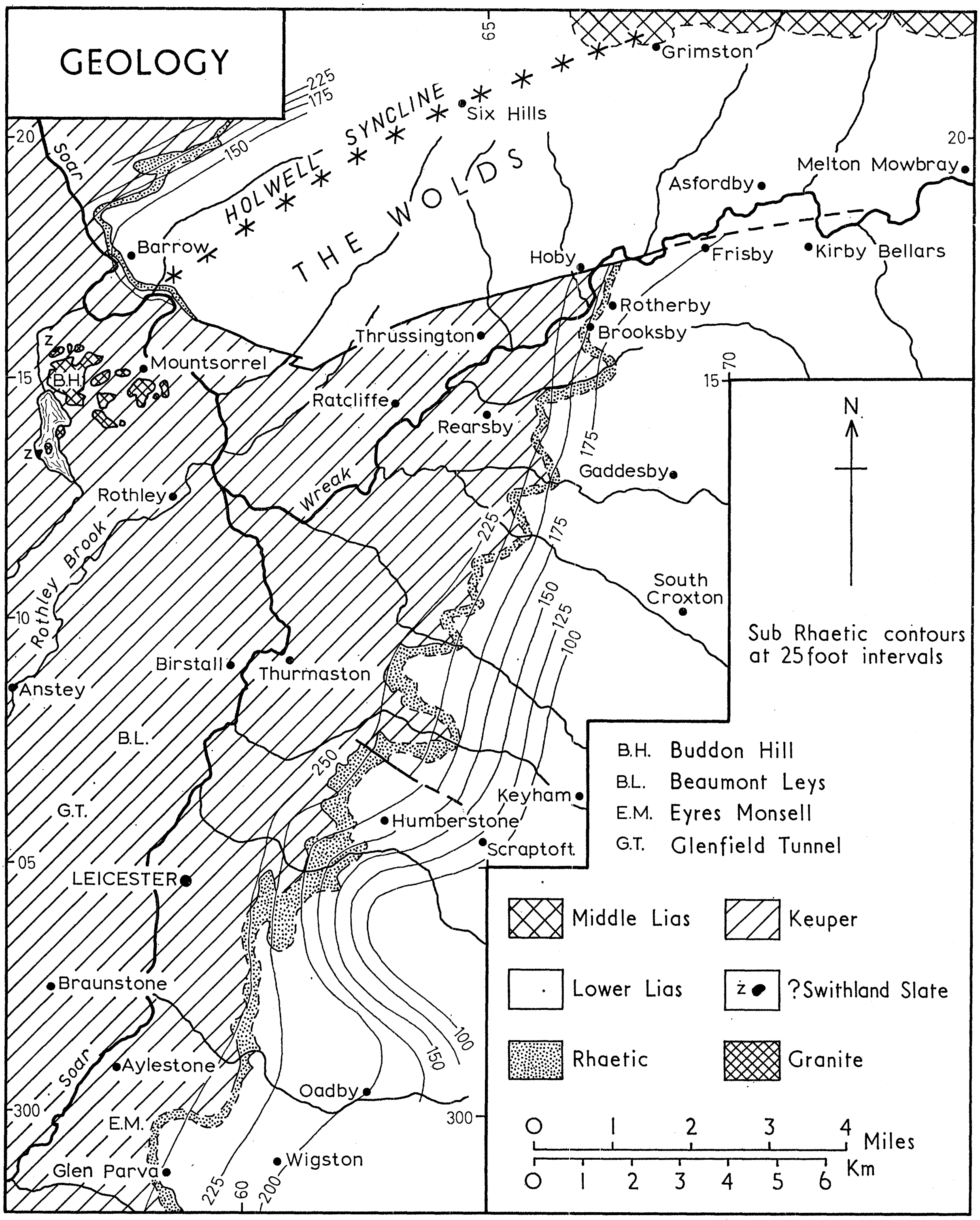

FIGURE 1. The bedrock geology of central Leicestershire.

(*b*) *History of previous research*

The earliest significant account of the glacial drifts is that of Harrison (1877) who recognized a fourfold division:

(*d*) forest drift (*b*) eastern drift
(*c*) the northern drift (*a*) mid-glacial beds.

In the light of observations presented below, it is interesting that Harrison regarded the eastern drift as earlier than the northern (his detailed evidence for this view is not disclosed) for nearly all writers have maintained the contrary. A quarter of a century later Harrison changed his mind, as comparison of his accounts in *Kelly's Directory* for 1900 and 1908 shows.

In 1886 Deeley proposed for much of the Trent basin a more elaborate classification which envisaged three sheets of boulder clay separated by two of sand. Considerable attention was directed to the water-laid material interleaved with the tills, and although the criteria for assigning a bed to a particular place in the succession are not always explicit, in general a sand succeeded by 'Pennine Boulder Clay' was assigned to the lower, Quartzose, sand, and one succeeded by chalky boulder clay to the upper, Melton, sand. On this basis the majority of the water-laid sediments belong to the Quartzose sand, but it is difficult to equate this with the Mid-Glacial Beds of Harrison since Deeley maintained that it is normally underlain by an earlier till.

In 1901 Paul postulated a simple fourfold division of the drifts in the Soar valley:

(*d*) upper sand and gravel (*b*) lower boulder clay
(*c*) chalky boulder clay (*a*) lower sand.

Two years later Fox-Strangways in the memoir on the Geological Survey one-inch sheet no. 156 amplified this succession and indicated his belief that the lower boulder clay of north-western provenance is divided into two parts by a sheet of sand for which he adopted Deeley's term, the Quartzose Sand.

The work of Fox-Strangways was the culmination of a thirty-year period of attempts to perceive some pattern in the sequence of glacial drifts; for the next fifty years little systematic field study was undertaken, attention being concentrated on fitting the succession as already described, particularly by Deeley and Fox-Strangways, into the broader context of British Pleistocene chronology. Recently there has been a revival of work in the East Midlands. Outstanding is the account by Shotton (1953) of the drifts in eastern Warwickshire, and while these lie within the Avon catchment some 16 miles south-west of Leicester, Shotton's reconstruction of a 'proto-Soar valley' stretching from Bredon Hill northwards to beyond Leicester gives the whole region a unity it might otherwise appear to lack. Other recent contributions include those by West & Donner (1956) who numbered in their till-fabric studies a group of sites in the Soar valley, and by Posnansky (1960) and Straw (1963) who together have reviewed much of the literature on the East Midlands.

(*c*) *Methods employed*

The paucity of clean exposures over much of central Leicestershire has necessitated the extensive use of hand augers, and the data thus derived has been supplemented by the collation of borehole records and descriptions of old drift sections. A four-inch bucket-auger was employed in a series of traverses to establish the basic succession in the Wreak valley, a total of 61 holes being sunk to an aggregate depth of 363 ft. In consequence of the difficulty in boring at depth through compact tills, many holes were sunk to only a little over 6 ft. with the vertical interval between them restricted to 5 ft. or less. The horizontal and vertical distances between the holes were measured by tape and Abney level, and the height above Ordnance Datum established by tying in to a bench mark; an accuracy of ± 4 ft. is thought to have been achieved in the height determinations. The most frequently used auger consisted of a 1 in. diameter, 8 in. long soil-auger bit welded to a 52 in. stem, the standard practice being to run lines of holes from valley floor to ridge crest at intervals of 300 to 400 yards. By using ditches and other excavations depths in excess of 6 ft. were often attained. The heights of significant holes were then determined by means of a surveying aneroid, and in view of the precautions taken the majority of these determinations are believed accurate to $\pm$ 6 ft. Occasionally, as detailed below, where the welded auger was deemed inadequate for the purpose in hand, an extending auger with a 2 in. bit was employed, and with this instrument depths in excess of 15 ft. were reached.

A list of over 200 well and borehole records giving information about the nature and thickness of the superficial deposits has been compiled. The uneven distribution of the sinkings means that for extensive areas they afford little guidance, while a further problem is occasioned by the doubtful reliability of some of the logs; in the following account no re-interpretation has been made without a statement to that effect. The collation of historical records of drift sections has involved perusal of both published and manuscript materials, but two sources which have proved particularly fruitful are the *Transactions of the Leicester Literary and Philosophical Society*, and the writings and field maps of the Geological Survey officers.

The use of data from such a variety of sources presents problems which it would be wrong to minimize. Whereas a clean section affords opportunity for a relatively detailed study of a deposit, neither an auger sample nor a description of an old exposure can be trusted to indicate more than the general character of the materials. For this reason it is stressed that the completed mapping shows only the basic nature of the drift, and no claim is made to have defined, for example, beds from which Cretaceous detritus is totally absent. Despite these limitations the methods employed are believed adequate to sustain the interpretation put forward.

2. Description of the members of the drift succession

For purposes of description the glacial drifts will be divided into the following five members:

- (*e*) Oadby till
- (*d*) Wigston sand and gravel
- (*c*) Glen Parva and Rotherby clays
- (*b*) Thrussington till
- (*a*) Thurmaston sand and gravel

(*a*) *Thurmaston sand and gravel*

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 bed is named from pits at Thurmaston (SK 615101) where it was formerly well exposed although recent tipping has

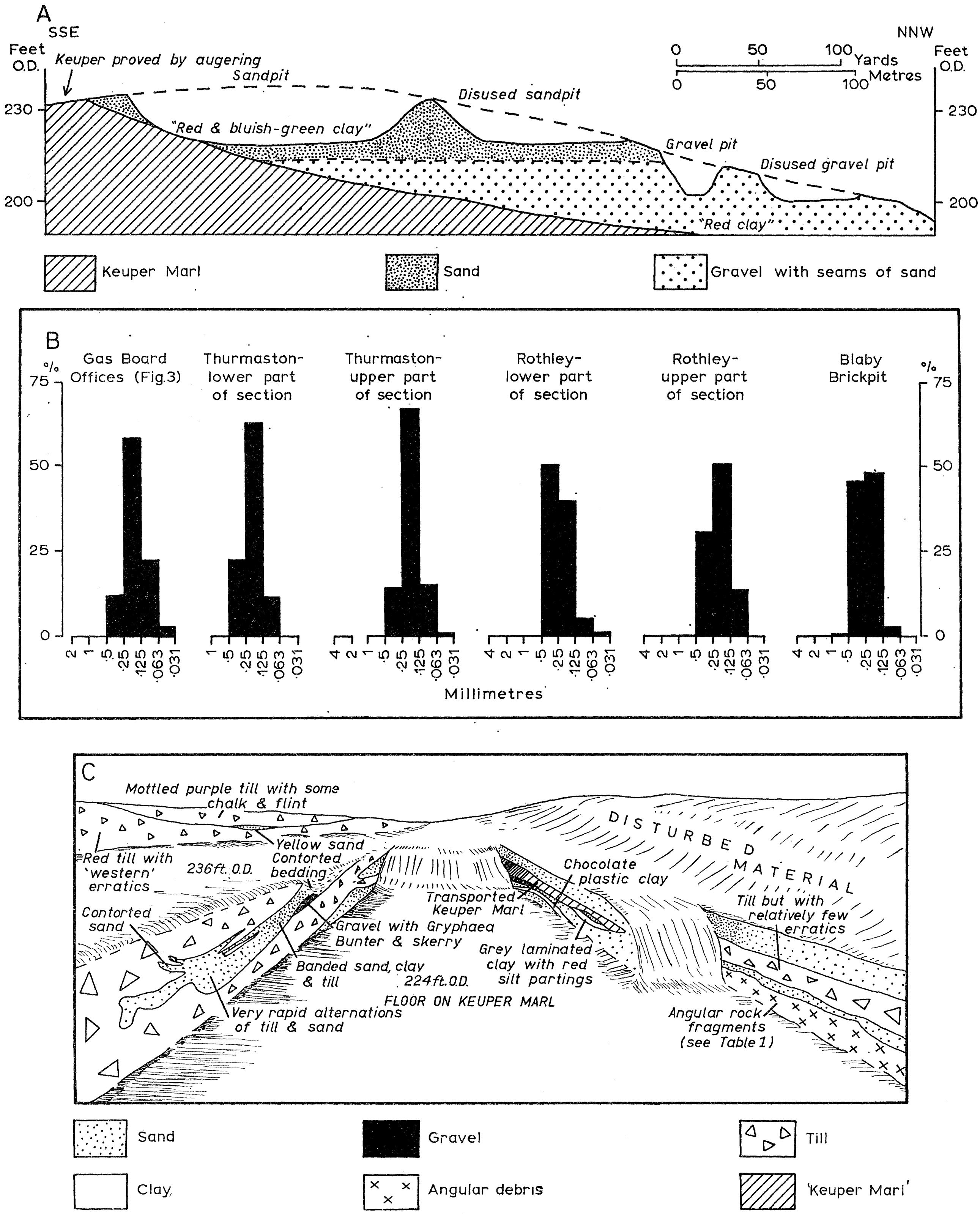

Figure 2. Diagrams to illustrate some of the characteristics of the Thurmaston sand and grave. (A) Rothley sand-pit, (B) Particle size analyses of typical foreset wedges at a variety of sites, (C) Blaby brick-pit.

completely obscured the sections. The reddish sand is here at least 20 ft. thick and of a grade predominantly between 0·25 and 0·125 mm (figure 2). Numerous sorted coal fragments delineate bedding mainly of foreset delta type dipping north-north-eastwards with a few scour-and-fill channels, but tending to become horizontal towards the top. Selective calcretion has produced several sandstone pillars. Beneath a transitional junction giving no reason to suspect an unrepresented time interval, the sand passes down into at least 6 ft. of gravel. Most of the pebbles in the gravel are under 5 cm in diameter, and as table 1 shows virtually all the far travelled material is derived ultimately from sources to the north and west; a search for Middle Jurassic and Cretaceous pebbles proved fruitless. Although the base of the gravel in the pits could not be reached by augering, a cutting on the nearby Thurmaston by-pass shows it resting directly on Keuper Marl.

The uneven bedrock floor to the deposit is most clearly demonstrated in a pit at Rothley (SK 565123) where 22 ft. of cross-bedded sand overlies at least 14 ft. of medium to fine gravel (figure 2). The sand is appreciably less uniform in grade than at Thurmaston and includes occasional seams of chocolate-coloured silt and clay, together with fine lenses of gravel; the sand composing individual foreset wedges also seems less well sorted, while analysis of the dips of the wedges indicates a flow direction north of east. The composition of the basal gravel (table 1) shows obvious affinities with that at Thurmaston. The pit owner reports 'red clay' beneath the gravel at 192 ft., and 'red and bluish green clay' limiting southward extension of the sand face at *ca.* 215 ft. No doubt both clays are Keuper Marl which outcrops on the ridge crest to the south at 230 ft. and was formerly visible in the adjacent railway cutting at 238 ft. (Tucker 1896).

Irregularity of the bedrock floor may partly explain the considerable variations in thickness of the sand and gravel, for where rockhead rises above 250 ft., the deposit is normally much attenuated or completely missing. Remnants are particularly sparse in that reach of the Soar valley constricted between the igneous hills of the Mountsorrel district and the scarp of the Rhaetic beds downwarped along the axis of the Holwell syncline, but higher upstream they constitute a relatively continuous basal stratum.

On the left bank of the Soar, sections at Birstall have shown the deposit apparently disturbed during emplacement of overlying red till, and for about $\frac{3}{4}$ mile to the south it is either absent or thin and discontinuous. It reappears, however, in the small valley east of Beaumont Leys where Browne (1902) records red sand with a few quartzite pebbles stained by bands of carbonaceous matter, and although he interpreted the material as 'Post-glacial river terrace', his description of 20 ft. of sand beneath till mainly of Keuper derivation leaves little doubt that it is part of the drift succession. Half a mile further south the old Leicester Abbey sandpit (SK 577063), now obliterated, disclosed at least 11 ft. of pinkish coal-bearing sand, partially calcreted, resting directly on Keuper Marl (Harrison 1877; Deeley 1886; Paul 1891; Lewis 1894); according to Deeley the bedding, false in the lower 9 ft. but becoming horizontal below the abrupt junction with brown sandy till, indicates currents from the south-south-west (mention by Lewis of currents from the north-west is probably a mistake). From this site the sand outcrop can be readily traced to the eastern end of Glenfield tunnel, but it then thins and disappears against an upstanding bedrock ridge. Further south only infrequent exposures have been noted. In the Braunstone district Fox-Strangways (1903) records a cemented gravel at the drift base,

TABLE 1

locality	site	size of sample	Bunter pebbles	other Triassic mostly skerry	Carboni-ferous	Lias	Mount-sorrel and Charn-wood	chalk	flint	Middle Jurassic	others
				Thurmaston sand and gravel							
Rotherby	auger sample 685172	321	58	12	26	—	—	—	—	—	3
Rothley	pit 566124	174	68	10	15	—	4	—	—	—	3
Rearsby	temp. section 643135	134	94	3	3	—	—	—	—	—	—
Thurmaston	pit 616102	205	60	22	10	1	1	—	—	—	4
Braunstone	temp. section 558011	179	72	11	11	5	—	—	—	—	1
Blaby*	pit 563987	71	25	42	6	27	—	—	—	—	—
				Thrussington till							
University†	Bennett section 595032	87	70	8	4	17	—	—	—	—	1
University†	Bennett section 595032	50	6	—	6	8	—	54	18	8	—
University†	Bennett section 595032	120	59	28	5	9	—	—	—	—	—
Gaddesby	stream section 677128	82	41	42	13	2	—	—	—	—	—
Rothley	pit 569126	120	71	8	9	2	2	—	—	—	10
Ratcliffe	temp. section	25	60	28	4	—	4	—	—	—	4
				Wigston sand and gravel							
Keyham	pit 668060	132	26	6	14	33	—	—	—	5	5
Scraptoft	temp. section 649055	109	5	—	5	13	—	2	13	57	6
Thurnby‡	temp. section 647038	150	73	—	11	13	—	—	—	—	3
				Oadby till							
Oadby	temp. section 631999	141	4	—	4	15	—	45	9	18	4

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

† These samples from the Bennett site are in stratigraphic order. The highest was collected from less than 10 ft. above the chalk-bearing lens, the lowest from less than 3 ft. below the lens.

‡ There is considerable doubt about the stratigraphic horizon of this deposit. It rests directly on bedrock but appears to be overlain by chalky till.

while the present writer has observed up to 6 ft. of red cross-bedded sand with northern or western gravel (table 1) sharply contorted beneath Trias-derived till incorporating large pockets of the sand.

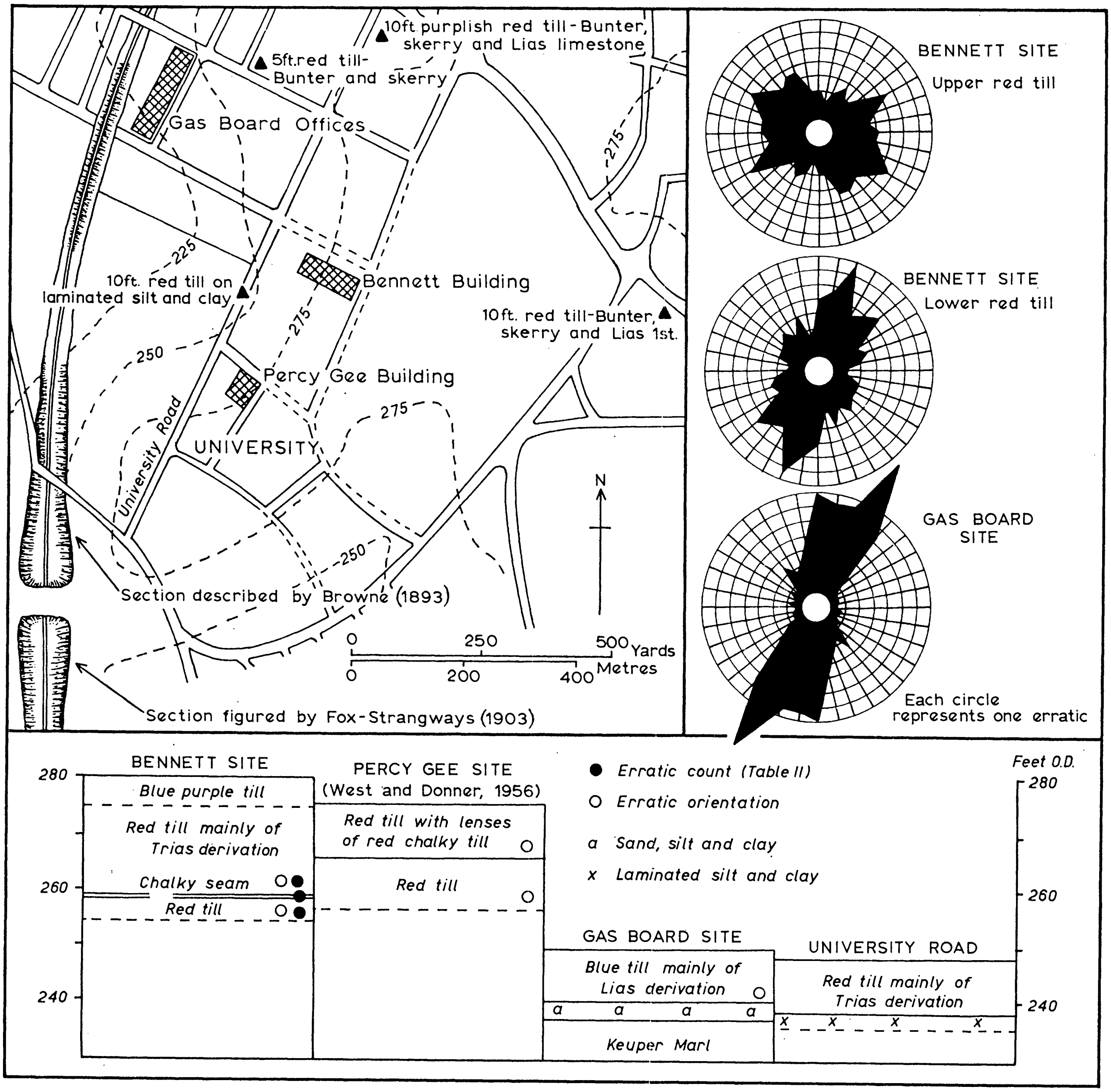

FIGURE 3. Exposures of glacial drift in the vicinity of Leicester University.

On the right bank of the Soar, a section at the Gas Board offices near Leicester University (figure 3) has displayed one foot of fine red sand resting directly on Keuper Marl and grading up into 2 ft. of slightly disturbed purplish clay with thin silt seams beneath a capping of till. A comparable sand stratum has been recorded from several nearby sites (see, for example, Browne 1893), but undoubtedly the finest exposure was that revealed during widening of several hundred yards of railway cutting in 1893. One of the more persistent beds in a remarkably varied succession is a basal sand averaging 15 ft. thick and likened by Browne (p. 19) to deposits at Aylestone in 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' (this rather surprising reference to flints is unfortunately beyond verification at present). An interstratified thick seam of tough tenacious clay is so contorted that in places, together with the sand, it lies in an almost vertical position. Although only sporadically developed south of the University, the sand with fine basal gravel was formerly worked in old pits at Aylestone (SK 575005). The gravel resting directly on Keuper Marl contains abundant quartzites and Liassic shell fragments, and is succeeded by at least 14 ft. of clean false-bedded sand with comminuted coal, capped in turn by thick red till (Paul, 1883 *a*; Moore 1888; Browne 1901). South of Aylestone this characteristic succession has not been met with again, being replaced at the drift base in Blaby brickpit (SP 563987) by a remarkable assemblage of materials whose stratigraphy may alter completely within a distance of two or three yards (figure 2C). The typical red cross-bedded sand, ranging in thickness from 20 ft. to less than 5, is not only capped by red till but locally so interleaved with it that within a vertical interval of less than 1 ft. there may be three or four seams of pebbly boulder clay. Where the sand is thickest it encloses large till lenses below which the bedding is often sharply contorted. A local basal breccia with many striated fragments over 8 cm. across is largely of Keuper derivation (table 1). A further feature of note is a large transported mass of Keuper Marl which, with its horizontal red and green banding over a distance of 75 ft., would excite no comment if seen as part of a bedrock succession.

Three main extensions of the Thurmaston sand and gravel away from the trunk valley have been located, two on the west and one on the east, each apparently occupying a depression in the bedrock surface with no exact counterpart in the modern topography. The first is at Rothley where the sand and gravel in the pit already described thins westwards but continues eastwards in abandoned workings north and east of Rothley station and probably emerges from beneath a till cover in the village itself, although here in the absence of clean exposures the material is difficult to differentiate from post-glacial terrace deposits. The second lies south of Beaumont Leys where local wells and the construction of Glenfield tunnel have shown water-laid sediment to be continuous beneath the interfluve separating the Soar and Rothley Brook valleys (Fox-Strangways 1903; Clinker 1954), whereas to both north and south such continuity seems to be precluded by till resting directly on bedrock. The third lies somewhat to the south of the modern Wreak valley. Exposures here are poor, but trial holes penetrating 8 ft. of coarse flinty terrace gravel south-west of Rearsby have exhibited a drift succession composed of up to 5 ft. of typical Thurmaston gravel (table 1) resting on Keuper Marl and grading up into 6 ft. of red, generally level-bedded sand. Records at Brooksby indicate a basal sand and gravel composed of quartz and quartzite with few if any flints, while a bucket-auger traverse north-east of Rotherby has proved four feet of red sand grading down into nine feet of northerly or westerly derived gravel resting on Lias clay (table 1). At Frisby drift sand and gravel is reputed to attain a thickness of 40 ft., and an old pit 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'. Towards Kirby Bellars the sand thins and till comes to rest directly on bedrock. A mile further east gravelly sand reappears at or very close to the drift base, but as flints here constitute an appreciable part of the material (Wedd, 6 in. field sheets; Deeley 1886) it remains a little uncertain whether the deposit is truly part of the Thurmaston sand and gravel. All the above occurrences are on the left bank of the Wreak, and while small patches are not totally absent from the right bank, having been located for instance at Hoby and Ratcliffe, the main spread undoubtedly lies south of the modern valley.

(*b*) *Thrussington till*

North of Leicester the Thurmaston sand and gravel is generally succeeded by a variable till characterized by the sparseness of Cretaceous erratics. In the Wreak valley four bucket-auger traverses (figure 4) demonstrated a thickness ranging from 20 ft. to more than 50 ft. and a constitution ranging from blue boulder clay with a preponderance of Lias limestone fragments to red boulder clay with an abundance of Bunter pebbles, coal and skerry (table 1). In some instances the contacts between these two contrasting types are sharp and virtually exclusive, but in others there is much mottling of the matrix clays and the erratics include a wide range of Carboniferous, Triassic and Liassic rock fragments. An old pit at Thrussington (SK 646162) displayed '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' (Fox-Strangways 1903, p. 45). Higher up the Wreak valley the deposit retains its mixed character and although no consistency in the sequence of till types has been detected, there is a substantial eastward increase in the proportion of Lias-derived materials. North of Asfordby Lamplugh (1909) has recorded the lower of two boulder clays as blue or purplish with much Liassic detritus and little oolite or chalk; the fact the Lamplugh does not aver a total absence of oolite and chalk accords with the belief, based upon augering, that locally in this upper part of the Wreak valley a small percentage of the erratics in the basal till may be of Cretaceous and Middle Jurassic origin.

Of the limited number of exposures in the Soar valley those in the vicinity of Leicester University are particularly important (figure 3). On the site of the Percy Gee building West & Donner (1956) recorded, beneath a chalk-bearing till, 3 m of red boulder clay yielding a preferred erratic orientation of 325° (Grid) north. More recent foundations for the Bennett building have exposed over 25 ft. of till, predominantly red in colour but with some blue mottling, and with Bunter pebbles, Lias limestone and skerry as the most common erratics, Charnwood and Mountsorrel boulders as the largest. However, at a depth of 20 ft. the excavation revealed a discontinuous horizontal lens, under 1 ft. thick but over 30 ft. in visible length, composed of blue boulder clay studded with chalk and striated flint erratics, one of the latter measuring $48 \times 38 \times 20$ cm. The lens is quite discrete and stone counts from it and from the till immediately above and below emphasise the contrast (table 1). Measurements of preferred erratic orientation suggest the till below the lens was deposited by ice moving from east of north, and that above the lens by ice moving from west of north. The measurement of the upper till was made at a depth of 15 ft., and there was no indication of solifluction on the present slope of 4° in a direction of W 20° N. Admittedly the strength of the orientation is less than is often found in tills, with statistical

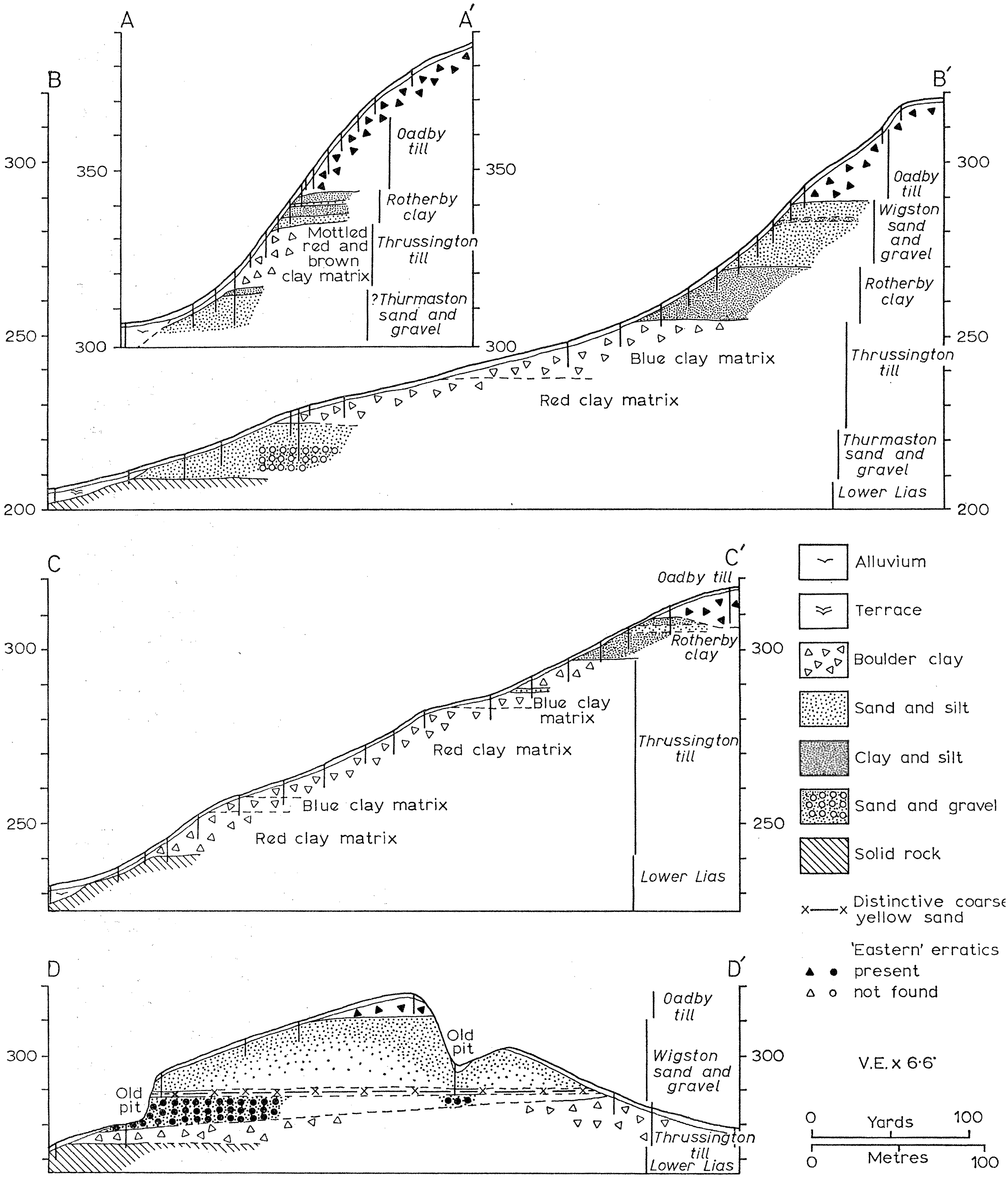

FIGURE 4. Bucket-auger traverses on the Wreak Valley. The location of the traverses is shown on figure 14, p. 509.

tests indicating significance only at the 10% level, but even if discounted on this score so that all the drift disclosed on the Bennett site might be equated with the upper chalk-bearing till of West & Donner, there remain very cogent reasons for regarding the drift around the University as much more complex than such a correlation would imply. The basal stratified deposits at the Gas Board offices are succeeded by a predominantly blue till with Lias limestone as the most abundant erratic, but also Bunter pebbles, skerry and Millstone Grit. Both the material and the preferred erratic orientation (figure 3) suggest a provenance from east of north, although in the limited section available there was no sign of Cretaceous detritus. Browne (1893) records the boulder clay in the nearby railway cutting as red with blue mottling, and containing flints, quartzite, Lias limestone, white sandstone and (?) chert. He declares the flints, though few, to be equally common at the bottom as at the top, and Fox-Strangways (1903) figures chalk and flint within 10 ft. of the drift base. Undoubtedly the most important conclusion to be drawn from these and other observations annotated in figure 3 is the variability of the Thrussington till and the absence of any single criterion for its identification; without the evidence of an intervening water-laid stratum, the differentiation of the Thrussington and Oadby tills necessarily becomes very tentative.

Other sections in the Soar valley may be treated more summarily. The overburden of the old Leicester Abbey and Aylestone sandpits probably showed two tills, although this view has been contested in the case of Aylestone (Paul 1883*a*; Deeley 1886; Moore 1888; Browne 1893; Lewis 1894). At both sites descriptions of the lower member tally with the general character of the Thrussington till, although opinions conflict on whether it contains flints; if present, they are certainly not abundant. At Blaby brickpit (figure 2) the basal red till with abundant Bunter pebbles and skerry but no observed flints, terminates upwards in a sharply defined but not particularly conspicuous boundary, above which lies material of similar general appearance but with more blue clay in the matrix and scattered flints among the erratics; the boundary is believed to separate the Thrussington till below from the Oadby till above.

On the higher ground east of the Rhaetic scarp outcrops of the Thrussington till are largely confined to narrow strips along the lower hill slopes between the solid rock of the valley floors and the Oadby till of the interfluves. The criterion employed in mapping was that whereas the basal layers of the Oadby till may be expected to contain Cretaceous material, this is either absent or much rarer in the Thrussington till. As in the Wreak valley there is often an alternation of red and blue boulder clays with a corresponding predominance of Triassic and Liassic erratics; although the proportion of Trias-derived boulder clay decreases eastwards, there is no reason to suspect that its limit in this direction has been reached.

On the left bank of the Soar between Mountsorrel and Rothley the Thrussington till is only sporadically present, and where exposed near the latter village consists of 5 ft. of reddish brown till characterized by a layer of large Mountsorrel boulders at its base and a northern or western erratic suite (table 1). Higher up the Rothley Brook valley the deposit thickens and on the western bank at Anstey is a predominantly Trias-derived boulder clay with local blue mottling and blocks of Lias limestone. On the opposite bank of the stream similar varied materials have been recorded (Browne 1902).

(c) *Glen Parva and Rotherby clays*

Stoneless clays and silts, in places clearly laminated, occur at a number of sites but are of wide extent only in the Soar valley south of Leicester and in the Wreak valley above Rearsby. Although proving impracticable to map as separate stratigraphic units, they merit individual description for the evidence they yield about the changing depositional environment.

(i) *Glen Parva clay*. From the railway cutting near Leicester University Browne (1893) describes a constant seam of dark stratified silt succeeded by a discontinuous chocolate, blue or red clay with but few stones, while Fox-Strangways (1903) figures a section in which laminated clay 6 to 8 ft. thick is sandwiched between two tills. South of this point the latter author frequently records on his 6 in. field sheets a drift deposit which he calls marly clay rather than boulder clay. Deeley (1886) alludes to brickearth exposed at Wigston and describes a pit at Oadby (SK 617007) displaying Pennine boulder clay grading up into brickearth with morainic masses, brickearth with sandy seams, and finally false-bedded sand. Lastly several accounts of the overburden in the Aylestone sandpits allude to a compact stratified red clay (Paul 1883*a* Browne 1893; Lewis 1894).

The suggestion in these records of a relatively stoneless, fine grade material distinguishable from the typical tills was amply confirmed during the present study. Two exposures near the the University (figure 3) disclosed at least 2 ft. of stratified purplish clay and silt underlying Thrussington till. Augering and temporary sections around Wigston showed a stratum of virtually stoneless red and purple clay locally abutting against a bedrock slope and elsewhere passing down into the same material interleaved with till. Deep trenches at Glen Parva and Eyres Monsell displayed mottled red and blue clay with scarcely any rock fragments visible, and at the latter place three 20 ft. boreholes all recorded interbedded sand and clay passing down into 'hard marl', either blue, red or mottled. To interpret this marl as bedrock would require not only that Keuper Marl here rise higher than at any known outcrop in the vicinity, but also that it overtop the Rhaetic scarp immediately to the east; there seems little doubt that the deposits penetrated by the boreholes are entirely superficial and represent just about the maximum thickness reached by the Glen Parva clay.

The precise relation between the Thrussington till and Glen Parva clay is complex and difficult to determine. The clay certainly occurs at more than one horizon, being found both beneath the till, as around the University, and also above it, as at Oadby; but it can scarcely be doubted that between those extremes there is much interdigitation of clay and till in such a way as to suggest that the two deposits are broadly contemporaneous.

(ii) *Rotherby clay*. A brickpit at Rotherby (SK 678163) formerly displayed at least 15 ft. of laminated clay passing up into stratified sand and then into sand with seams of clay (Harrison 1877; Deeley 1886; Fox-Strangways 1903). Fox-Strangways records the deposits as sandwiched between two tills, the lower from his description being typical red Thrussington till, the upper the basal part of the Oadby till. The clay is said to have a red Keuper-looking appearance as if deposited in tranquil water charged with debris of that formation; similar material was at one time exposed on the other bank of the Wreak at Thrussington brickyard.

Augering has demonstrated these two sections to be in a clay and silt stratum having a wide distribution in the lower Wreak valley. Bucket-auger traverse BB′ (figure 4) proved 15 ft. of almost stoneless blue or mottled purple clay with at least one clearly laminated horizon. Traced laterally the materials tend to become coarser with thinly stratified silts characteristic of wide areas on the north bank of the river as, for instance, in traverses AA′ and CC′. Locally, as in traverse DD′, and more particularly the further one moves from Rotherby, sand and gravel become dominant. The extent of the Rotherby clay as determined by the present study conforms very closely to that postulated by Fox-Strangways, namely, an area about 5 miles across in either direction, centred on the village of Hoby.

(*d*) *Wigston sand and gravel*

The sands seen to overlie the Rotherby and Glen Parva clays in a number of old pits constitute part of an extensive but discontinuous horizon compounded of two separate facies, the first resembling the Thurmaston sand, the second much coarser sand and gravel. The bed is particularly noteworthy as the earliest to contain Cretaceous rocks in quantity.

Augering has shown the bed to be widely distributed in the Wreak valley, although subject to rapid variations in thickness and lithology. As exposed in a small pit at Ratcliffe (SK 635155), it consists of 15 ft. of red coaly sand with thin clay seams. The cross-bedding lacks a statistically significant orientation and is sharply contorted at two or three points. Included in the sand are till lenses over ten feet long and up to 18 in. thick; two of the lenses studied were of typical chalky boulder clay while one nearer the top of the sand was of reddish Thrussington till. The sharp but very irregular contact between the sand and an overlying till sheet is rendered conspicuous by secondary calcium carbonate deposition; 'faulted' wedges of sand project several feet into the till and elliptical pockets of sand 1 or 2 ft. across are incorporated in the lower layers of the till. Elsewhere in the Wreak valley coarse gravel becomes dominant and yields abundant flint, chalk and oolite. An old gravel pit near Asfordby showed signs of great disturbance (Deeley 1886) and contorted structures seem typical of this member of the drift succession.

Four examples illustrate the variability in other areas east of the Soar. Around South Croxton 20 ft. of red stoneless clay, silt and sand with occasional masses of red till, is divided north of the village into two separate horizons by a 20 ft. bed of chalky boulder clay. At Keyham a basal red till passes up into interbedded red sand, silt and clay capped in turn by chalky boulder clay; on the opposite side of Hamilton Brook valley the succession is the same apart from the intercalation below the chalky till of a gravel which is of mainly Triassic or Liassic origin with a small Middle Jurassic admixture (table 1), but which towards the north-west also yields chalk and flint. At Scraptoft reddish coaly sand and silt is capped by a gravel composed largely of Cretaceous and Middle Jurassic pebbles (table 1) occasionally interleaved with chalk-bearing till. The final example comes from Oadby where the red sand described by Deeley (1886) is capped by chalky boulder clay whose base locally approaches the composition of a very coarse gravel with 9 in. subangular fragments of Lias limestone, oolite and flint. At one site this gravelly material was also seen to contain contorted beds of laminated clay and silt.

Along the Soar valley it is not always easy to differentiate remnants of the Wigston sand

and gravel from later terrace materials of similar composition. However, a gravel spread at Thurmaston preserves till lenses within the water-laid sediments, and a second spread north of Glen Parva is assigned to the drift succession on the basis of its height, composition and proximity to an outlier of chalk-rich till. West of the Soar drift gravels with abundant chalk and flint have been recorded at several localities (Fox-Strangways 1903), and along Rothley Brook valley they are associated with a stratum of reddish sand and silt seen in a number of temporary sections to be sharply contorted and studded with lenses of red Trias-derived till.

(*e*) *Oadby till*

Distinguished from the Thrussington till by its much higher content of chalk, flint and oolite, the Oadby till normally has a matrix derived from the Lias clay, but very locally near the base a Keuper Marl matrix has been noted. Although there is no sharp dividing line, a lower subdivision may be recognized in which Cretaceous and Middle Jurassic erratics are usually outnumbered by those of Liassic or even Triassic origin, and an upper much thicker one in which the Cretaceous and Middle Jurassic erratics are in the majority.

(i) *Lower Oadby till*. At Rotherby the Wigston sand and gravel is overlain by a till containing mostly Lias fragments and quartzite pebbles, but with a few pieces of chalk (Fox-Strangways 1903). Similar material was encountered in each of the bucket auger traverses, but to both north and south it thins so rapidly that the upper Oadby till comes to rest directly on bedrock. In the Soar valley accounts of the overburden in the old Aylestone sandpits refer to typical lower Oadby till while the same material was well exposed at Blaby brickpit (figure 2). West of the Soar the only extensive outcrop is around Thurcaston where till with a Keuper Marl matrix yields as its most common erratics Bunter pebbles, skerry, coal, Lias limestone, oolite and flint.

(ii) *Upper Oadby till*. This subdivision was studied in a 16 ft. excavation at the Oadby offices of the Leicester Permanent Building Society (SP 631999). Bluish grey in colour, it yielded an erratic sample of which over half was derived from Cretaceous strata and over three-quarters from Cretaceous and Middle Jurassic strata (table 1). Measurement of erratic orientation gave a preferred alignment of W 30° S. So far as yet determined, the bed is more constant in character than the other tills and description of individual sections seems unnecessary. Even a short auger readily demonstrates the capping on all the interfluves northwards from Oadby to the Wreak, and although the thickness varies considerably it is known to be great in the south. Boreholes at the building society offices in Oadby proved at least 30 ft. of chalky till, and as they commenced over 50 ft. below the summit of the adjacent plateau the thickness may well approach 100 ft. A borehole 2 miles to the south-east is said to have penetrated 66 ft. of 'blue boulder clay' beneath $15\frac{1}{2}$ ft. of yellow clay and stones, and although the Geological Survey in an unpublished note has queried the veracity of the record the writer sees no reason for such doubt. A comparable thickness of upper Oadby till has been encountered at Scraptoft where Paul (1883 *b*) reports 90 ft. of greyish blue clay with lumps of chalk and flint a foot in diameter, together with fragments of oolite, Keuper sandstone and Marlstone rock-bed. Further north, although the outcrop remains extensive, the thickness probably declines with the material draped over earlier interfluve crests (see p. 477).

Numerous shallow sections on the Leicestershire Wolds testify to a till composition similar to that at Oadby, although in the east the proportion of Lincolnshire Limestone seems to increase appreciably and many of the erratics are of unusually large size (Fox-Strangways 1903; Lamplugh 1909). The relatively undissected nature of the till sheet makes any assessment of thickness based upon mapped drift boundaries very hazardous. Sinkings in the east have encountered at least 60 ft. of chalky till, while near Ratcliffe at least 77 ft has been proved. At Six Hills a borehole is reputed to have penetrated the following strata:

	ft.	in.
ground level *ca.* 440 ft. O.D.		
soil	3	0
blue clay with limestone boulders, flints	178	6
gravel and sand	14	6
red marl	2	6

It is thought that a high proportion of this material is ascribable to the upper Oadby till for a well in a deeply incised valley $1\frac{1}{2}$ miles to the west proved 18 ft. of chalky boulder clay mixed with a little gravel resting directly on Lower Lias clay at 272 ft. O.D. As the adjacent interfluves rise fully 100 ft. above the site of the well, a thickness of over 100 ft. for the upper Oadby till is not unlikely; and if the till base were approximately level from the well to Six Hills, virtually all the blue stony clay of the above record would belong to that bed.

South of Mountsorrel the Oadby till cover is extensive but relatively thin, 10 ft. being a representative figure, but as the village of Rothley is approached the base of the chalky till descends to the level of post-glacial terraces and augering indicates the thickness may reach as much as 50 ft. Across the Rothley Brook valley on the summit of the Beaumont Leys spur a spread of typical bluish grey upper Oadby till crowded with chalk fragments contains in addition quartzites, flints, a few small pieces of granite and Lias limestone (Browne 1902). The thickness is estimated as varying between 50 and 100 ft., although a number of enigmatic borehole records suggest that it may locally exceed the figure inferred from outcrop levels. Further south in the Braunstone district the drift capping to the spur thins as the bedrock surface rises in response to a thick sandstone bed within the Keuper Marl.

3. The bedrock surface

(*a*) *The form of the bedrock surface*

Figure 5 is an attempt to depict the relief as it would be if all the superficial deposits were removed, the contouring inevitably being most tentative on the areas of extensive drift cover. One principle followed in the contouring has been to assume that, unless there is definite evidence to the contrary, the bedrock relief is such as might have been produced by normal stream erosion. While it is unnecessary to detail all the data on which figure 5 is based, certain critical features do require closer examination.

Around Wigston and Oadby the Lower Lias forms a gently undulating plateau sloping from over 300 ft. in the east to about 250 ft. at the crest of the low Rhaetic escarpment in the west. Immediately north of Oadby, however, trial holes have been carried to

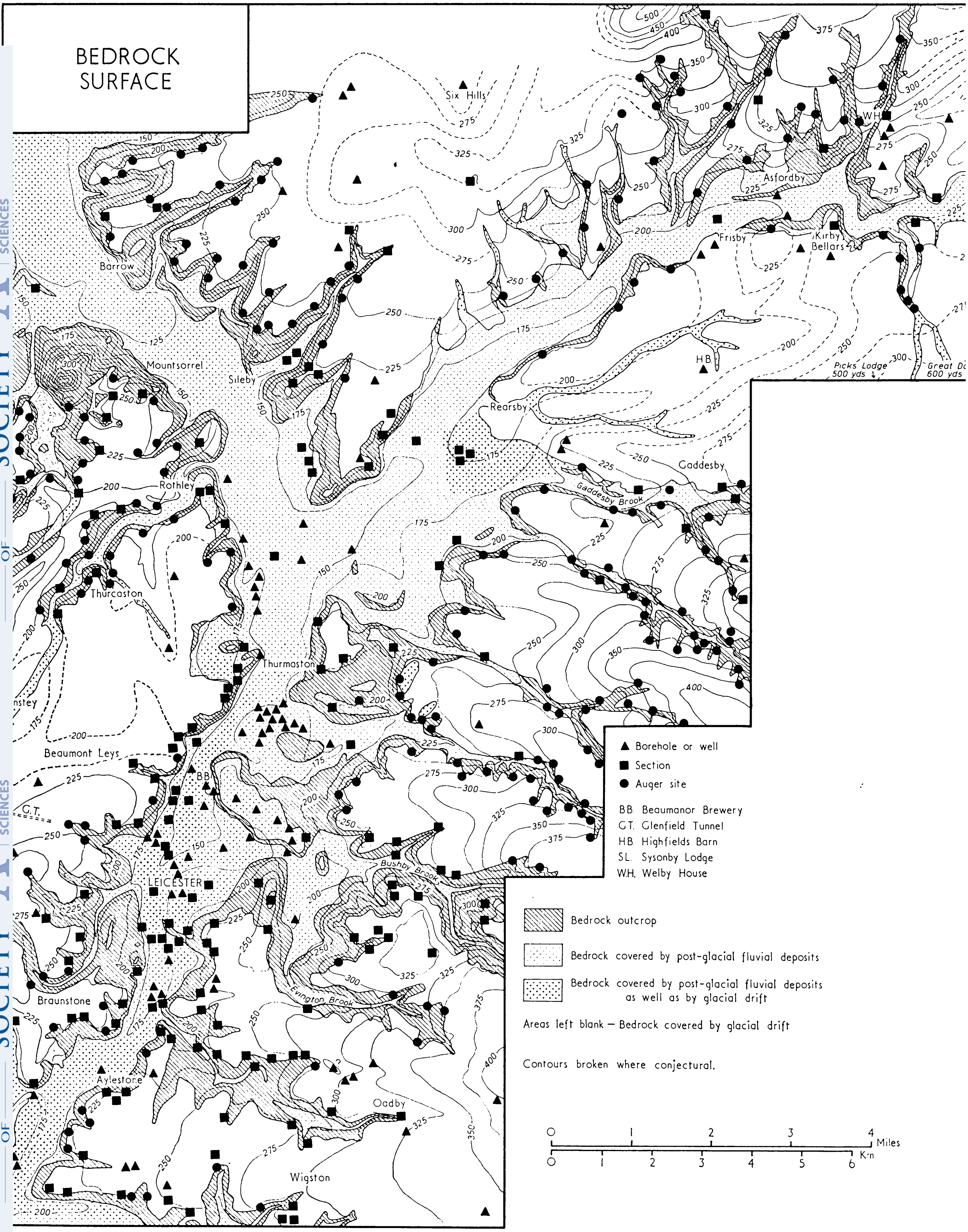

FIGURE 5. An attempted reconstruction of the bedrock surface as it would appear if all superficial deposits were removed. The contour interval is 25 ft. and the contours are pecked where the evidence is very scanty.

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elevations of less than 270 ft. without striking rockhead, and a borehole starting at a level of 288 ft. penetrated 25 ft. entirely in upper Oadby till. The significance of these records in terms of the drift stratigraphy is discussed below (p. 493 and figure 10), but they also have important implications in the reconstruction of the bedrock surface. The borehole at 288 ft. lies on the floor of a small valley which heads $\frac{1}{2}$ mile to the east at a height of almost 350 ft. where a deep sinking is reputed to have started in 'Lias (Shale)'. This seems to imply a bedrock relief exceeding that of the present day, but local augering which has proved at least 8 ft. of chalky till casts doubt upon the reliability of the log. The resulting uncertainty about the height of the sub-drift surface is the more regrettable in that this is one of the localities where the assumption of a normal stream-eroded topography is extremely difficult to maintain. The valley floor with the proven drift base of under 263 ft. is cut in solid rock at over 250 ft. $\frac{1}{2}$ mile downstream; if the modern valley is coincident with an earlier drift-filled one, the gradient of the latter can at most have been a third of its modern counterpart, and yet there is no apparent alternative course for a valley accommodating the level of under 263 ft.

Between Oadby and Gaddesby the bedrock relief resembles in subdued form the present pattern of parallel north-west trending valleys and intervening ridges. The resemblance is most clearly demonstrated in the case of the interfluve between Bushby and Evington Brooks where a temporary section on the ridge crest has revealed Lower Lias clay at an altitude substantially above that at which drift is found *in situ* along the adjacent valleys. Two arguments may be adduced that a similar relationship holds for most of the other interfluvial ridges. First, most of the ridges terminate westwards in a prominent Rhaetic scarp whose summit is at a greater height than the drift base further east. Secondly, the solid-drift junction regularly rises and falls in conformity with gullies scored into the valley sides, and although solifluction may be a contributory factor to this outcrop pattern, it is most unlikely to be the sole cause.

Although Lias clay is exposed along Gaddesby Brook, to the north there lies an extensive area where no bedrock outcrop has been located. The record of a well at Highfields Barn (SK 691152) reads as follows:

ground level 336 ft.	ft.	in.
clay	119	0
sand	0	4
gravel	0	5
red marl and gravel	35	3
blue clay	5	0

To interpret any save the lowest 5 ft. as bedrock encounters insuperable objections, and it is therefore concluded that rockhead probably lies at 181 ft. O.D. This is consonant with the apparent descent of the drift base northwards from Gaddesby, but it also poses the problem of possible outlets for any such low-level valley. There is no evidence to preclude the assumption that its floor declines very gently westwards and joins the Wreak valley south of Rearsby; in all other directions the rather inadequate data suggest a drift base rising well above 181 ft. Wells at Pick's Lodge (SK 724145) and Great Dalby are reputed to have entered Lower Lias at over 300 ft., while the same rock was formerly exposed near Kirby

Bellars at 225 ft. Unfortunately boreholes are absent from the area between Great Dalby and Kirby Bellars, and although bedrock has been proved by augering at the lower end of the valley running from Great Dalby to the Wreak, it was not located along the middle reaches of that valley at depths of over 12 ft. There thus remains the possibility of a very narrow east–west channel in this position, although the interval between known bedrock outcrops seems to preclude any broad drift-filled valley.

Bedrock outcrops on both sides of the Wreak valley, but the drift base, especially on the left bank, is undulatory. Rockhead has been reached near Rearsby at 184 ft. and in bucket-auger traverse DD′ at 208 ft., but upstream around Frisby it declines below 200 ft. before rising above 225 ft. near Kirby Bellars. The reason for the fall at Frisby is unknown, but its association with a local thickening of the Thurmaston sand and gravel may indicate an old drift-filled valley running transverse to the modern drainage towards Highfields Barn. East of Kirby Bellars the height of rockhead declines once more so that in the outskirts of Melton Mowbray recent river gravels come to rest directly against drift. On the right bank of the Wreak the only area where there is reason to suppose that the bedrock configuration differs radically from the modern relief is upstream from Asfordby. East of the village Lower Lias outcrops at over 250 ft., but as Melton Mowbray is approached the drift base declines, one 55 ft. borehole in the town failing to bottom the drift at 210 ft.

On the eastern Wolds the 500 ft. marlstone plateau terminates southwards in a buried scarp rising more than 100 ft. above an undulating area of Lower Lias clay. Today the region drains southwards to the Wreak, but the bedrock configuration discloses a considerable drift-filled valley sloping eastwards in the direction of Melton Mowbray. Augering shows that from 295 ft. near Welby House (SK 722201) the drift base sinks progressively to about 250 ft. in an old exposure $\frac{1}{2}$ mile to the east (Lamplugh 1909). Beyond this point the trend of the buried valley may be deduced from the record of four sinkings. On the ridge east of the exposure one borehole proved $97\frac{1}{2}$ ft. of drift before reaching Lower Lias clay at 227 ft., another 80 ft. of drift before entering what may be bedrock at 236 ft. At 1500 yards further east a borehole over 125 ft. deep failed to reach rockhead at 250 ft., while a well at Sysonby Lodge (SK 745209) is said to have been dug through 168 ft. of boulder clay without touching the Lias at under 200 ft. These records clearly accord with the previously noted tendency of the bedrock surface around Melton Mowbray to slope eastwards.

On the western Wolds the contouring of the bedrock surface is necessarily very tentative. Augering shows the drift base to lie between 220 and 250 ft. at the southern ends of the spurs overlooking the Wreak, and between 185 and 230 ft. at the western ends of the spurs overlooking the Soar. From these altitudes the mapped base of the drift rises very gently away from the trunk valleys, locally surpassing 350 ft. but more commonly restricted to below 300 ft. The rise north-eastwards from the Soar averages 25 to 30 ft./mile, a figure that is remarkably persistent over a distance of several miles but cannot be projected as far as Six Hills if reliance is to be placed upon the borehole record quoted on p. 475. Any deep drift-filled channel in this locality must seemingly run northwards for there is no evidence of its joining either the Soar or the Wreak valley within the area of detailed mapping.

West of the Soar the drift in the Mountsorrel district is generally so thin that the sub-drift surface does not differ greatly from that of the present day. Around Rothley, however, it becomes both more complex and more difficult to reconstruct, with the drift-filled depression seen in the Rothley sandpit (figure 2) probably debouching eastwards to the Soar valley. Southwards rockhead again rises well above 200 ft. at Thurcaston before declining towards Anstey where the absence of Keuper Marl from the base of undercut stream bluffs suggests it sinks below floodplain level. Corroboration comes from an old sinking in Anstey (actually sited 100 yards beyond the edge of figure 5) which is reputed to have encountered 70 ft. of till before entering Keuper Marl at 155 ft. Along the eastern margin of the Beaumont Leys spur the solid-drift junction again ranges above and below 200 ft., reaching its lowest point about a mile south of Birstall but then rising steadily to 250 ft. near Glenfield tunnel and almost 300 ft. west of Braunstone where a thick sandstone bed forms a buried west-facing cuesta.

The bedrock relief beneath the axis of the Beaumont Leys spur is still very inadequately known. The value of the deepest borehole is nullified by its extraordinary log of 176 ft. of 'Blue Lias' beneath 9 ft. of clay and gravel. Four further boreholes have all proved at least 90 ft. of drift without reaching rockhead at elevations ranging from 255 ft. to under 200 ft. It appears likely that the sub-drift configuration is a gently undulating Keuper Marl surface at around 200 ft. The relatively high level reached at Thurcaston suggests that Rothley Brook had no pre-glacial ancestor, and figure 5 has been drawn on the assumption that drainage from the Anstey area transected the Beaumont Leys spur to join the Soar south of Birstall. It must be emphasized that the contouring is very tentative owing to the lack of definitive boreholes, and the record of drift at 155 ft. in Anstey still poses a problem since it cannot be incorporated in any normal valley system tributary to the Soar.

In the Soar valley below Leicester indications of drift beneath river level are either absent or very rare, the post-glacial fluvial deposits normally resting directly on Keuper Marl. A number of old records allude to gravelly or stony clay at the base of the alluvial deposits, but observations suggest this usually refers to periglacially disturbed bedrock mixed with the river gravels (cf. Shotton 1954). However, at Beaumanor Brewery in north-western Leicester (SK 587071) the Keuper Marl is separated from a typical fluvial succession by 20 ft. of material described in borehole logs as 'clay and stones' or 'drift and marl and stone'. Although it is unwise to attach too much significance to such uncorroborated records, proximity to a point where the drift base has been traced down to the level of the terrace gravels gives reason for thinking rockhead may fall as low as 140 ft. There can be no doubt that the drift base descends well below river level south of Leicester. Before the construction of the M1 Motorway, two exploratory boreholes on the floodplain of Lubbesthorpe Brook failed to bottom glacial materials at levels of 169 and 179 ft., and an associated resistivity survey was deemed to show two drift-filled trenches with floors below 160 ft. separated by an upstanding ridge of Keuper Marl (for a fuller discussion see below p. 487 and figure 8). Three-quarters of a mile to the south a third borehole was still in drift at 160 ft., and the same distance beyond a fourth proved rockhead at 144 ft. It appears there is an extensive area within which the drift base, lying at about 150 ft., cannot be accommodated in any system of normal drift-filled valleys. To the west lie the igneous outcrops of Enderby, to the north the sandstone cuesta of Braunstone, to the south a sub-drift surface rising steadily above 200 ft. (Shotton 1953), and to the east several

Keuper Marl exposures above the 200 ft. contour. A drift-filled valley following the present course of the Soar also seems precluded since the Keuper Marl underlying Braunstone and Aylestone at between 230 and 195 ft. outcrops in bluffs adjacent to the river and has been proved beneath the floodplain deposits at 175 ft. near Aylestone Bridge and at 170 ft. at the gasworks a mile further downstream (Mott 1878; Browne 1893; Fox-Strangways 1903). It is concluded, therefore, that the low-level drift must occupy an enclosed depression.

(*b*) *The pre-glacial relief* (*figure* 6)

The fact that it is locally difficult to conceive the bedrock surface as shaped solely by pre-glacial stream erosion, notably near Narborough and with less certainty at Anstey, Oadby and in north-western Leicester, raises the problem of the extent to which forces other than normal stream erosion may have operated and how their effects can be recognized. At present this is an extremely intractable problem, and the practical solution adopted in drawing figure 6 is to treat only proven hollows as of abnormal origin; justification for this procedure is to be found in the consistency of the results outside the limited areas referred to above.

Outside those areas of presumed abnormal conditions, the most southerly occurrence of drift below an altitude of 200 ft. lies one and a half miles above Leicester, and it is here that the 200 ft. contour is drawn across the floor of the Soar valley; it could only be extended further upvalley by keeping within the confines of the modern floodplain. Downstream the height of the trunk river is indicated by tributaries seeming to require confluence levels of a little under 200 ft. Around Mountsorrel evidence for assessing the altitude of the pre-glacial Soar is very scanty, but since drift can be found north of Barrow considerably below 175 ft., it seems unlikely to have differed radically from that of its modern counterpart; a similar conclusion has been reached for other parts of the Trent basin (see, for example, Pocock 1929; Pickering 1957).

It is difficult to exclude completely the very remote possibility that the pre-glacial Soar diverged from the modern river course below Thurmaston and flowed instead north-eastwards towards Melton Mowbray. Doubts about the bedrock surface south of Kirby Bellars, plus the evidence of drift at Melton Mowbray well below 200 ft., make conceivable a buried valley running from Thurmaston to Melton and thence eastwards into Lincolnshire (Rice 1965). Such a hypothesis has a superficial attraction in the alinement of the lower Wreak and middle Soar valleys, but when examined critically becomes difficult to sustain. No significance can be attached to the modern river alinements since any major drift-filled depression at under 200 ft. would have to lie south of the Wreak valley. More importantly, the gap between known Lower Lias outcrops near Kirby Bellars seems too narrow to accommodate a valley of the dimensions to be expected for the Soar. Proof will only come with more thorough investigation by deep boreholes, but on the evidence now at hand it seems very much more likely that the pre-glacial Soar followed the same course as the modern river. At this time there may well have been a col near Kirby Bellars at a little under 250 ft. separating the Soar basin from streams draining towards Melton Mowbray.

The existence of the Rhaetic scarp during accumulation of the earliest drift is indicated by the banking of glacial deposits against the scarp face. Dissection by Soar

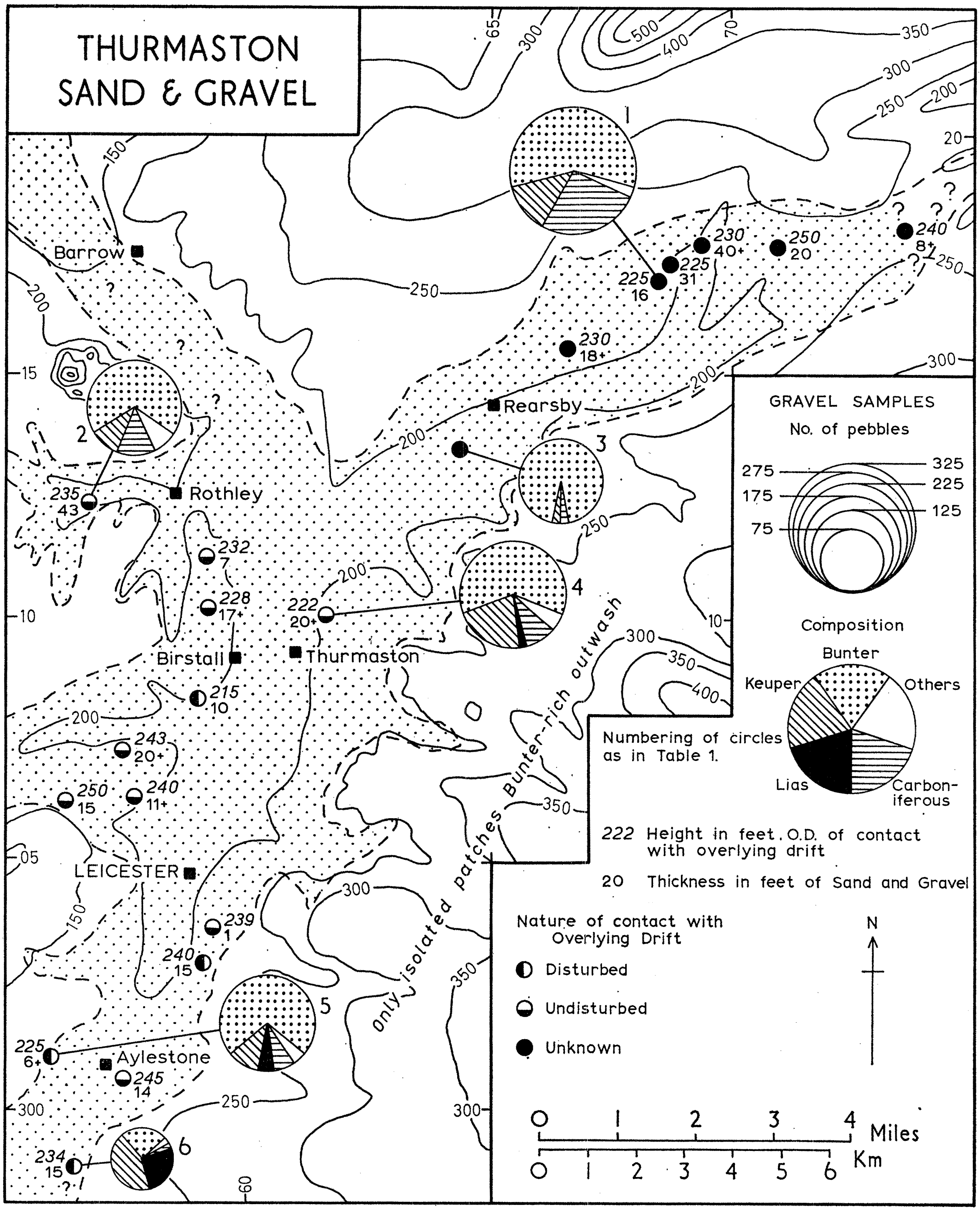

FIGURE 6. A reconstruction of the probable relief prior to deposition of the Thurmaston sand and gravel, together with an indication of the former extent of that member of the drift succession.

tributaries had already proceeded along courses closely approximating those of the modern streams, and it is only north of Sileby that this relationship is not clearly displayed. Between Sileby and Barrow, for some reason which is not understood, there is almost no evidence for pre-glacial valleys infilled with drift and now undergoing exhumation.

4. Interpretation of the drift succession

Most previous writers have postulated a subdivision into an earlier north-western boulder clay and a later north-eastern boulder clay. The present study has amply confirmed the existence of these distinctive till types, but has also shown a two-fold subdivision to be an unwarranted simplification. Likewise, it is also untrue that one till type invariably overlies the other, although the concept of an upward change from drift of predominantly north-western provenance to one of predominantly north-eastern provenance does seem well founded. Interbedded with the tills there is at least one widespread stratum of water-laid material indicative of an important change in the depositional environment. Within this basic pattern there exist many complications, and it is most convenient to consider each member of the drift succession in turn.

(*a*) *Thurmaston sand and gravel*

The major spread appears to have accumulated along the floor of the pre-glacial Soar valley (figure 6). The Rhaetic scarp on the east, the sandstone cuesta at Braunstone and the igneous outcrops at Mountsorrel constituted limiting higher ground and where the valley was particularly constricted post-glacial erosion has destroyed most of the deposit. This is especially true of the narrows around Mountsorrel, but the original continuity of the sand and gravel is suggested by the occurrence of similar material a short distance further downstream at Fox Hill (SK 536223) (Deeley 1886). Subsidiary spreads accumulated in the main tributary valleys to both east and west, but in the smaller valleys dissecting the Rhaetic scarp relatively little deposition is manifest.

Although frequently examined, it is very doubtful whether the sand and gravel has ever yielded fossils (Browne 1901). A problematical record refers to a find in the railway cutting near the University: '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). The writer is informed that the specimen disintegrated several years ago and is recorded as coming from the boulder clay in the cutting.

The distribution of the material along the major pre-glacial valleys, allied to its well-sorted, false-bedded nature, points to deposition by flowing water. Along the tributary valleys the grading appears less uniform than along the Soar, betokening a greater variability in the environment of accumulation which locally provided still-water conditions in which seams of plastic clay were formed. There seems no necessity to invoke deep and extensive ponding, the more likely conditions being those of braided river channels with local back-ponding. Whether the water was proceeding from a contemporaneous ice front or was 'normal' drainage preceding the onset of glaciation remains less certain. Whereas most of the observed disturbances in the water laid sediments can be ascribed to disruption during subsequent passage of an ice sheet, the sand at Blaby brickpit indisputably encloses till lenses which would normally be regarded as indicative of deposition in proximity to an ice sheet. It is possible that such occurrences of heterogeneous materials represent ice-contact deposits which accumulated after the main body of the Thurmaston sand and gravel had been laid down in a non-glacial environment; alternative hypotheses include the large scale translocation of frozen sedimentary masses by the ice sheet, or even 'intrusion' of the till in a manner comparable to that invoked by Yorke (1961) in Derbyshire.

The immediate derivation of the pebbles composing the gravel is also debatable. Everywhere a high proportion must ultimately have come from Bunter Pebble Beds and in the absence of outcrops within the present catchment or any likely earlier catchment, initial transport by ice may be assumed. Dissection of an earlier till sheet affords one feasible provenance, for although such till has nowhere been observed beneath the Thurmaston sand and gravel, remnants could, of course, still lie undetected on some of the interfluves. However, if dissection had proceeded so far, it is curious that local material forms such a conspicuously small fraction of the gravel. This is true, for instance, at Thurmaston where, despite feeders from the east which could introduce appreciable quantities of Liassic material, the actual amount is less than in the adjacent post-glacial terraces. It is even more true in the Wreak valley where the meagreness of the Liassic material makes it almost impossible to conceive of the deposit being laid down by a normal west-flowing stream. Moreover, there is direct observational evidence that, for a time at least, the water at Frisby Mill was flowing eastwards (Deeley 1886). The most likely explanation is that the deposits in this locality are outwash from an ice front which, advancing from the north-west, had already crossed the lower Soar valley and was diverting water towards the bedrock col south of Kirby Bellars and so eastwards past Melton Mowbray (Rice 1965).

The balance of the evidence currently available favours the view that the Thurmaston sand and gravel originated as outwash from ice advancing into the Soar basin from the north-west. Initially free drainage down the trunk valley was later obstructed, the rapid transition from gravel to sand possibly being induced by shallow ponding which lessened the gradient of the thalweg. The gravel east of Kirby Bellars (Deeley 1886), lithologically unlike the Thurmaston gravel further west but displaying an affinity with the local Thrussington till in its content of Middle Jurassic and Cretaceous detritus, could also be regarded as outwash from the earliest ice advance. The writer, however, feels it would be wiser to defer judgement on this point until much more work has been completed in the Melton Mowbray district.

(*b*) *Thrussington till*

The till deposited 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 with their rapid alternation of materials derived mainly from the Lias and the Trias. Although these changes might conceivably be explained without recourse to variations in the direction of ice transport, slices of far-travelled Triassic till being interleaved with locally derived Liassic till, there remain good reasons for believing that the accumulation of the Thrussington till was accompanied by major shifts in ice movement. These are particularly manifest in the area around the University (figure 3). At the Percy Gee site the lower Triassic till has a preferred erratic orientation of S 35° E (West &

Donner 1956), but at the Gas Board offices the basal till is of Liassic origin and even if derived from the easternmost outcrop at Barrow its direction of overall transport would have been S 10° E; a much more likely direction would seem to be west of south and this receives confirmation from the orientation of erratics. Moreover, all observers of the basal till in the nearby railway cutting agree that it contains occasional flints which seem to require an early overall movement from east of north, as do the lenses of blue chalky boulder clay at the Bennett site. Nevertheless, it remains true that the great majority of the drift around the University is of Triassic derivation and therefore likely to have come from west of north.

Lying at the junction of Triassic and Jurassic rocks in an area where the geological strike trends roughly north–south, Leicester is so sited that even slight shifts in ice movement about the meridional position would be conspicuously reflected in the till character. None the less, it is reasonable to suppose that in other areas, such as those investigated with the bucket auger in the Wreak valley, till variations are due to changes in ice movement. Corroboration comes from the presence not only of Triassic debris east of the Soar, but also of Liassic debris west of the river, as, for instance, around Anstey.

The shifts in ice movement are probably attributable to the interplay of competing centres of ice dispersal. Although interbedding of dissimilar tills can be demonstrated at many separate localities, it is not yet possible to correlate one succession with another and so unravel the complex depositional history. It is undoubtedly the early dominance of the north-western ice that has led many workers to accept the adequacy of a simple two-fold division of the drifts with the lower member derived in its entirety from the north-west. Intimately associated with this view is the idea that the north-eastern and north-western drifts represent separate glaciations; in the light of the evidence quoted above, this whole concept requires critical review (pp. 497–499). A second factor, which may have influenced the pattern of ice movement, is surface relief. Although the relief amplitude during the ice advance cannot have been great, the thickness of the Thrussington till differs markedly between the major valleys and the interfluves; illustrative is the 30 ft. of till at the University corresponding to less than 10 ft. on the higher ground at Evington and Braunstone. These figures are in sharp contrast to those for the Oadby till which often far exceeds 30 ft. even on the higher parts of the bedrock surface. A possible explanation is that the ice depositing the Thrussington till was relatively thin, in which case the control exercised by the relief may have been correspondingly greater.

(*c*) *Glen Parva clay*

In the Soar valley below Leicester indications of still-water sedimentation prior to deposition of the Thrussington till are extremely localized, and it is only south of the city that such conditions are widely evidenced. Beds of laminated silt and clay have been noted in a number of sections around the University, and the probability is that until the ice front had reached this point melt-water 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. The interbedding of till and stoneless clay betokens a fluctuating glacier margin, while the common disturbance of the lacustrine sediments is attributable to the disruptive effect of the advancing ice. It seems clear that

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ponded water existed on at least two separate occasions, the first during the initial ice advance and the second during a withdrawal phase, each being attested by stratified clays and silts below and above the Thrussington till. Assessment of the water levels is extremely difficult, but during the withdrawal phase it may have stood for a time at about 300 ft. The basis for this statement is that at four separate points the top of the still-water deposits has been located very close to the 300-ft. contour. This assumes, of course, that the lacustrine sediments were built up to water level and on this point there is no convincing proof, but if 300 ft. is a reasonable approximation there is no obvious 'direct overflow' at this altitude and it seems more likely that escape was either through the ice or marginal to ice pressing against the higher ground formed by the Lower Lias.

(*d*) *Rotherby clay*

There is at present no evidence for ponded water in the Wreak valley area before deposition of the Thrussington till, but a later widespread stratum of silt and clay seems to denote a phase of still-water sedimentation during a temporary ice withdrawal. Constant in neither thickness nor altitude, the stratum passes both laterally and vertically into sand and gravel. The height range of material of the same grade, allied to the upward passage into generally coarser sediments, indicates a diachronous base to the clay with still-water conditions probably shifting westwards in conformity to a withdrawing ice margin. A water level of at least 300 ft. is demanded by the lacustrine deposits at Rotherby brick-pit and in bucket-auger traverse BB′, and if there were originally a lower outlet past Melton Mowbray it must by this time have been blocked, presumably by a local thickening of the Thrussington till or by residual ice.

It is likely that similar impoundment occurred in some of the other minor valleys draining to the right bank of the Soar. Plastic silt and clay, located for instance in the valleys about Keyham and South Croxton, seem once more to be associated with the advance and withdrawal of the ice sheet responsible for the Thrussington till.

(*e*) *Wigston sand and gravel*

This transitional bed coinciding with the change from the dominance of north-western to north-eastern ice partakes of some of the characteristics of the till laid down by each of these ice sheets. At Oadby, for instance, the Glen Parva clay grades up into red, false-bedded sand, capped in turn by coarse gravel with much chalk, flint and oolite. The similarity of the sand to that at Aylestone led Deeley (1886) to equate it with the Quartzose Sand. This, the writer believes, was the basic flaw in Deeley's classification since it forced him to postulate an additional sheet of 'Pennine Boulder clay' to explain that exposed beneath the sand at Oadby. The succession at Oadby denotes a transition from relatively still ponded water to a resumption of deposition by flowing currents. The material laid down may derive in part from re-working of the drift already deposited and so explain the apparent affinity with the Thrussington till. The succeeding gravel is of a composition signifying outwash from north-eastern ice, and is so irregularly distributed that rarely can an outcrop be traced continuously for more than a mile or so. The sporadic occurrence and relatively poor sorting contrast with the Thurmaston sand and gravel; whereas the latter accumulated along the valley floors still largely unobstructed by ice, the Wigston sand and gravel was laid down at or even beneath the ice margin without any apparent integrated system of meltwater drainage. Proximity of the ice is clearly evidenced by the large number of sites where till lenses have been observed.

The interstratification of still-water clays, sand and gravel between two major till sheets is taken to signify a phase of melting, but the precise extent of ice withdrawal remains uncertain. The frequency of till in the water-laid sediments argues against complete disappearance of the ice, and no evidence of a relatively warm climate or of active pedogenic processes has been found. A curious aspect of the Thrussington till is its thinness and partial absence north–west of the Soar–Wreak confluence, and it is tempting to ascribe this to a phase of 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 is tentatively concluded that the melting did not reach an advanced stage beyond a line extending from Ratcliffe to Anstey, for such a line separates those areas in which the water-laid sediments are relatively common 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 north-eastern ice without a significant degree of melting.

(*f*) *Oadby till*

Although the Oadby till is not entirely homogeneous, the amount of material of north-western provenance is relatively small, and even much of this may be of secondary derivation from the Thrussington till or its associated gravels. The surface across which the ice moved was an uneven one, for although the earlier drifts had tended to smooth out the pre-glacial relief, the process was far from complete. There is little doubt that the ice disrupted the surface across which it passed. Deeley (1886, p. 446) records that at Oadby the chalky clay was forced over sand 'contorting, faulting and tearing it up', and similar disturbances have been noted at Wigston. It might be expected that as the ice sheet advanced up the Soar valley it would again have ponded water before it. Sporadic patches of grey stoneless silts beneath the Oadby till testify that this did occur, although two factors have militated against the widespread preservation of still-water deposits; the first is their position and altitude which rendered them particularly susceptible to post-glacial erosion, and the second is the effectiveness of the ice in destroying the unconsolidated sediments in its path. Such is the thickness and continuity of the Oadby till that its former complete extension across the mapped area can scarcely be doubted, and all the indications are of a thicker and more enduring ice sheet than that responsible for the Thrussington till. It is testimony to the amount of post-glacial erosion along the line of the Soar valley and its major tributaries that the edges of the Oadby till have been pushed so far back from the rivers.

5. The deposits and structure of the area around Narborough

(*a*) *Description of the deposits*

Although the drift succession of central Leicestershire cannot be treated simply as horizontal strata resting unconformably upon the bedrock relief, there is sufficient local altitudinal consistency for any pronounced deviation from the normal pattern to be immediately apparent. The first indications of an anomaly in the Narborough district came from the finding of thick beds of chalkrich drift at unexpectedly low altitudes (figure 7). Material formerly worked in the large Blaby Wharf pit (SP 570987) (Deeley 1886; Lewis, 1894; Fox-Strangways 1903) consisted of about 20 ft. of false-bedded gravel with hard chalk, flint and other easterly rock debris resting upon a thin stratum of chalky till, Lewis adding that the till is underlain by fine sand false-bedded from the north-west. At present only one clean face remains for study, and this corroborates much of what the earlier observers wrote. The sand and gravel, cross-bedded with foreset wedges indicative of flow towards the south and west, incorporates large lenses and irregular masses of Oadby till. Capping the section is 4 ft. of chocolate blocky clay overlain by 4 ft. of mottled purplish till with Bunter pebbles, skerry, Lias limestone and chalk. The chalk content is considerably under-represented in the pebble count for the till since many of the chalk fragments are too small to be counted among the normal erratics and the deposit effervesces very freely when treated with acid. However, the most distinctive aspect of the pit is the way the deposits appear to occupy a deep and steep-sided trench within a sheet of earlier drift. Although the base of the exposed section at 225 ft. corresponds to the normal altitude of the Thurmaston sand and gravel, there can be no doubt concerning the differences of the two deposits. Not only are the gravel compositions completely dissimilar, but the sand in the pit is coarser and more poorly sorted, has individual grains appreciably less well rounded, and in some samples is so calcareous that there is up to 40% weight loss on treatment with acid. While the latter figure includes secondary cementing material, it also includes a large number of individual calcareous grains; the Thurmaston sand by contrast is only rarely calcreted and may normally be regarded as devoid of calcium carbonate. Augering and shallow sections have revealed typical Thrussington till around the margins of the pit at the same level as the top of the sand and gravel, and in an old working to the west have shown the junction between Thrussington till and flinty gravel to slope very steeply towards the latter. It was probably examination of this old working that led Lewis to conclude that 'the gravel flood has washed away the boulder clay here and the chalky boulder clay and Pennine clay run into each other' (1894, p. 328).

On the left bank of the Soar low-level chalky drift was first detected along Lubbesthorpe Brook valley where excavations for sewage works disclosed at least 6 ft. of Oadby till beneath the alluvium. The engineer in charge reported that the till had not been bottomed at a depth of 25 ft. so that its base can at most lie a few feet above 200 ft. In the lowest reach of the same valley drift beneath the floodplain was confirmed by exploratory boreholes sunk in preparation for the building of the M1 Motorway:

site no. 1 on figure 7, ground level 209 ft. O.D.

	ft.	in.
topsoil		6
soft to firm mottled brown and grey silt and clay	22	6
brownish grey fine sand and silt	7	0

site no. 2 on figure 7; ground level 202 ft. O.D.

	ft.	in.
top soil, clay and stones	3	3
firm brown sandy silty clay and stones	9	0
stiff grey brown very silty clay with a few stones and seams of fine reddish sand	21	3

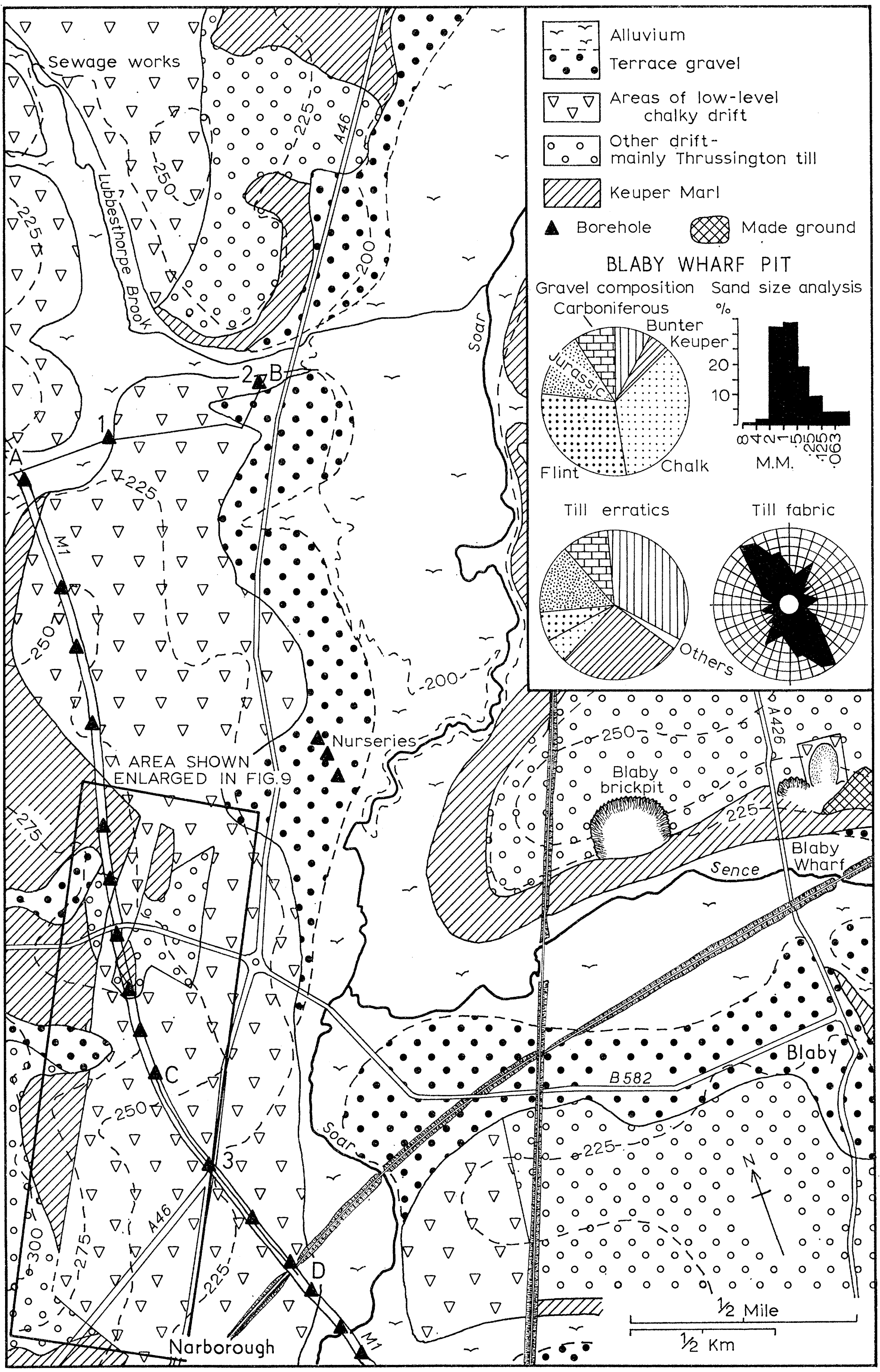

FIGURE 7. The distribution of glacial drifts in the area around Narborough.

A complementary resistivity survey was interpreted as indicating two deep drift-filled trenches separated by an upstanding ridge of Keuper Marl (figure 8). Some 1200 yards to the south sinkings reported by three nursery owners provide further information. At the most northerly a borehole is said to have passed through 26 ft. of sand and gravel resting on 13 ft. of sand; at the second a 50 ft. borehole is said to have proved 15 ft. of gravel resting on 30 ft. of 'blue pebbly marl' which in turn rests on 5 ft. of sand; at the most southerly a well was dug through 9 ft. of dirty gravel into 2 ft. of running sand. A sample of the 'blue pebbly marl' proved to be typical chalky boulder clay, with the result that material resembling the Oadby till is found at an altitude of 175 ft., or at least 75 ft. below the regional level of that member of the drift succession. Three-quarters of a mile further south where the M1 crosses A46 a borehole has encountered the following succession:

site no. 3 on figure 7, ground level 224 ft. O.D.

	ft.	in.
topsoil	2	6
firm brown sandy clay and stones	7	0
sandy clay and clayey sand passing down into reddish brown clayey silty sand	19	0
grey silt		6
reddish brown clayey silty sand	31	0
grey clayey silty sand and fine gravel with layer of stiff clay	4	6
silt	13	6
boulder	2	0
Keuper Marl	7	0

A resistivity survey by the Motorway contractors was interpreted as showing a steep-sided trench bounded by boulder clay and filled with water-laid sediments in which sand predominates and which, on borehole evidence, contain abundant chalk particles (figure 8).

(*b*) *Interpretation of the deposits*

Initially the writer interpreted the presence of chalky drift in hollows below the level of normal stream erosion as due to sub-glacial scouring by meltwater. The erosive efficacy of such meltwater has long been recognized (see, for example, Werth 1909) and has frequently been invoked to explain such forms as Rinnentäler (Woldstedt 1926; Schou 1949) and submarine trenches (Valentin 1955). More recently Sissons (1958, 1960) has stressed the role of sub-glacial meltwater in producing features previously described as overflow channels. However, in the case of Narborough it is necessary to explain not only the excavation of the hollow but also its subsequent infilling, and a number of more analogous channels have been described from various parts of Britain. Jukes (1859) drew attention to a steep-sided channel at Moxley on the South Staffordshire coalfield which later workers (Whitehead & Eastwood 1927; Robertson 1928) have shown to be full of predominantly water-laid sediments. Comparable trenches have been described from various parts of East Anglia (Boswell 1913, 1937; Larwood & Funnell 1961; Sparks & West 1965), and Osborne White (1932), in a relatively full account of the very deep channels beneath the Cam and Stour valleys, showed the infilling to consist mainly of gravels, sands, loams and chalky tills.

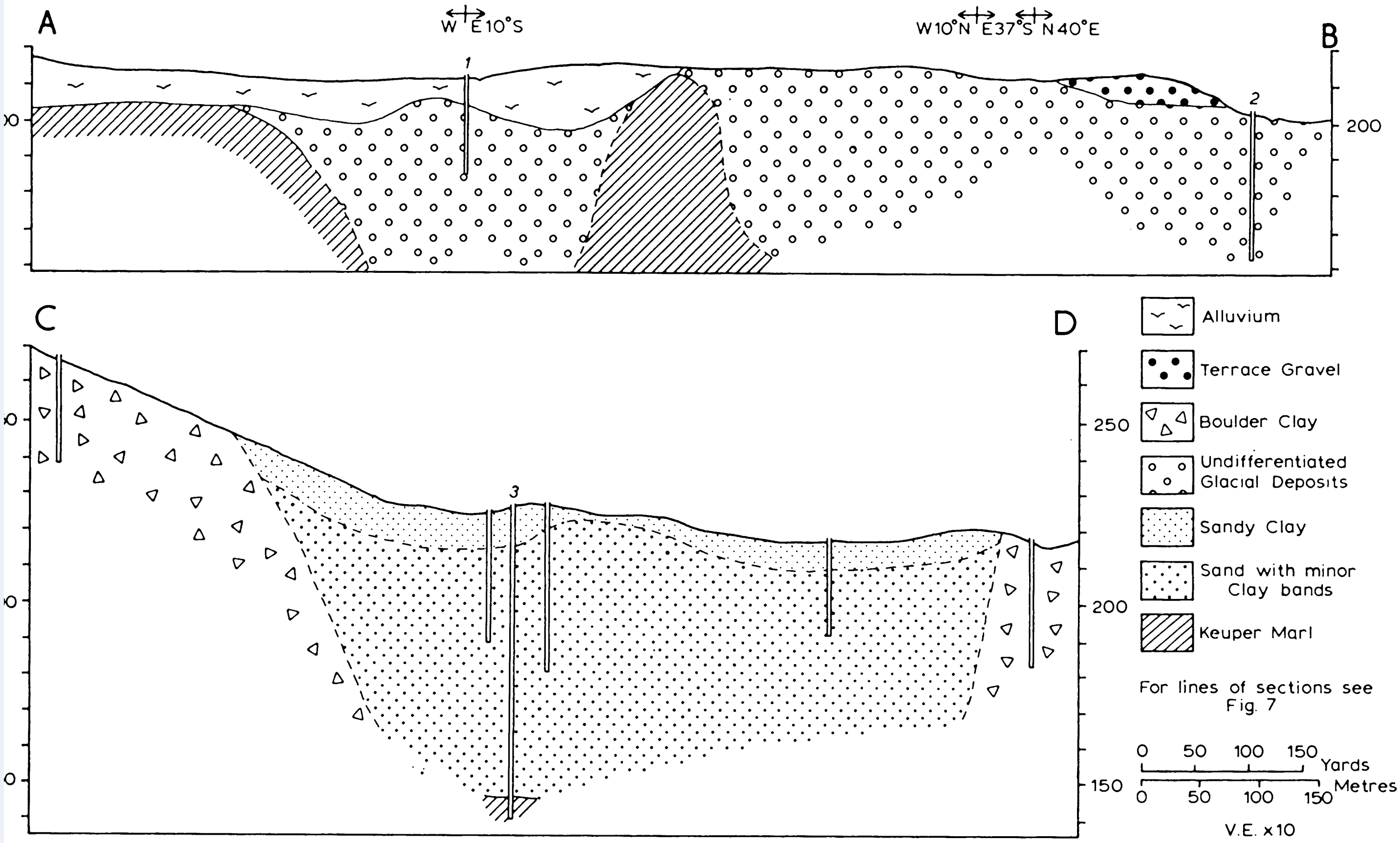

FIGURE 8. Sections along lines shown on figure 7, based upon resistivity surveys undertaken by the motorway contractors.

Realization that the above analogies may not be entirely apposite came with construction of the motorway north of Narborough. Exploratory boreholes had disclosed a very irregular bedrock surface, and excavations recorded and described by Shotton (1965) showed both Keuper Marl and drift cut by normal faults defining a series of horsts and graben. On the horsts the Keuper Marl is capped by a drift succession readily correlated with that of central Leicestershire:

chalky till	25–30 ft.	Oadby till
buff sand	3–5 ft.	Wigston sand and gravel
red triassic till	25 ft.	Thrussington till
fine buff sand	0–2 ft.	Thurmaston sand and gravel

On the graben the chalky till includes a sheet of water-laid sediments indicative of a phase during accumulation of the Oadby till not yet widely detected in central Leicestershire.

Use of an extending auger with 2 in. bit has subsequently shown the exposed faults to be part of a larger system stretching over a total distance of at least 1 mile (figure 9).

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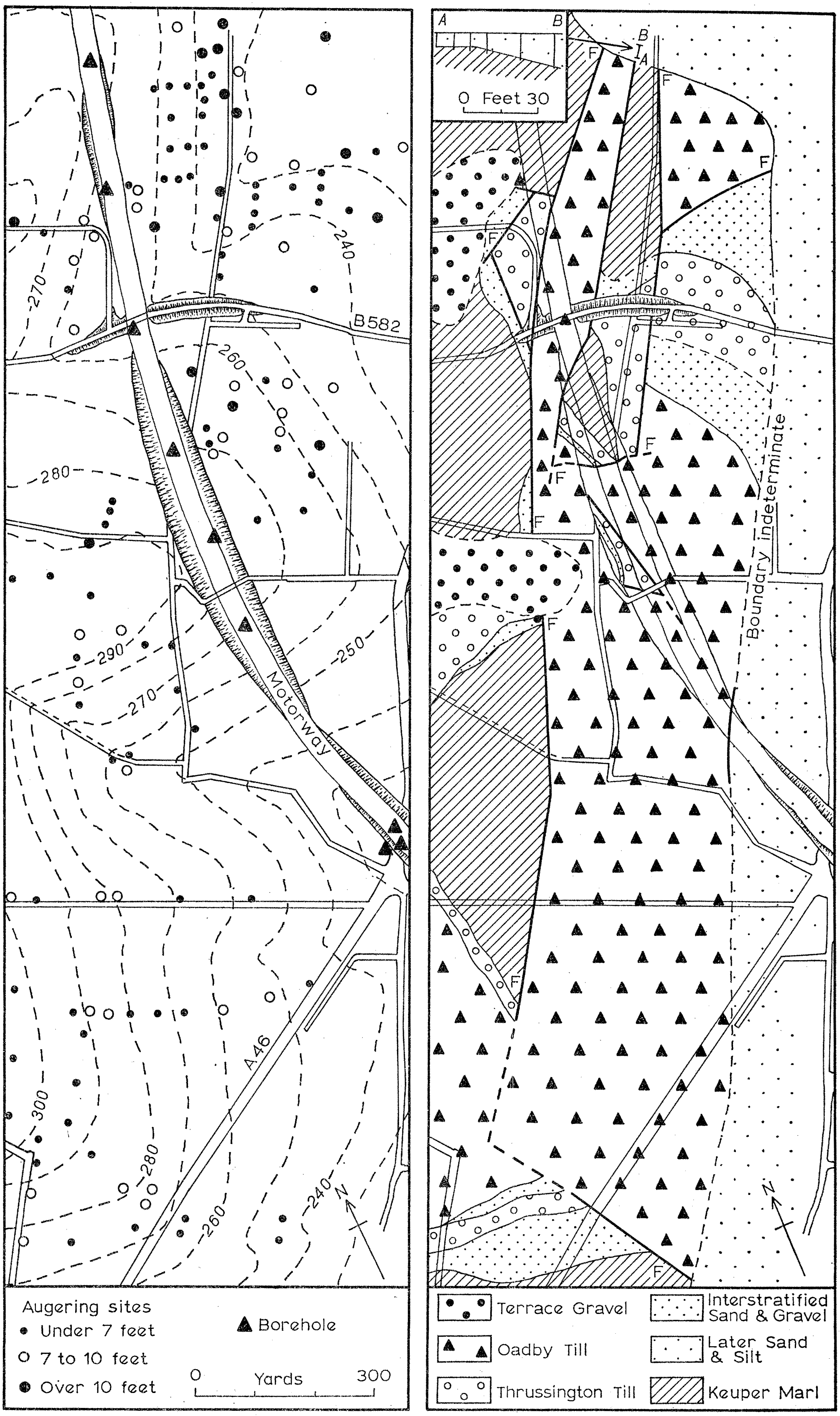

FIGURE 9. Detail of area surrounding the motorway cutting described by Shotton (1965).

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Although during augering some difficulty was experienced in differentiating between the beds of sand, and occasionally between the Keuper Marl and Thrussington till which in patches very closely resembles the bedrock, it is, nevertheless, believed that the basic fault pattern has been established. The faults traceable over the greatest distances are oriented N 35° E and appear to define a series of elongate horsts and graben cut by short transverse fractures. The displacements along the four faults exposed in the motorway cutting amount to 70, 70, 25 and 55 ft. (Shotton 1965), and the faults detected by augering have throws of a similar order. This is best illustrated by the long narrow graben near the northern edge of figure 9 where, if the drift thicknesses observed in the cutting hold true, the bounding fractures must have minimum displacements of 40 ft. The most westerly fracture is especially important for in its southward extension it appears to form the boundary of the faulted drift against the Keuper Marl; at its maximum the throw must here approach 100 ft.

The presence of faults cutting the drift in the motorway section encourages the belief that similar displacements may have occurred elsewhere in the Narborough district. The writer now regards this as the most feasible explanation of the anomalous chalk-bearing deposits at Blaby Wharf pit where the succession probably consists of Wigston sand and gravel passing up into lower Oadby till. If correct this ascription means that the Wigston sand and gravel here lies 25 to 50 ft. below its regional level, giving some measure of the possible displacement. One corollary would be that beneath the pit floor there should be a stratum of Thrussington till; no evidence is forthcoming on this point, nor has any trace of a fault extending beyond the immediate vicinity of the pit yet been found. In Lubbesthorpe Brook valley what little is known of the disposition of the strata is also consistent with the presence of faults, the sub-surface Keuper Marl ridge invoked by the geophysicists (figure 8) possibly being an elongate horst with a western bounding fault of similar trend to the main series further south.

Yet there remain certain features of the Narborough area not adequately explained by displacement along faults. A significant aspect of the drift in the motorway cutting is its evident relation to the normal succession in central Leicestershire. By contrast the thick sandy deposits where the motorway crosses A46 have no obvious counterpart and are believed peculiar to this locality. Unfortunately mapping the boundary of the sand is rendered very difficult by the spread of suburban housing and by a sheet of post-glacial fluvial materials covering much of the lower ground. Water-laid drift figures prominently in a number of the boreholes shown on figure 7, and it was found that the faulted deposits of the motorway cutting pass northwards beneath a spread of sand and silt too thick to be penetrated by a hand auger. The very gentle decline in the base of this spread compared with the hade of the typical fault (figure 9 inset) supports the view that the hollow occupied by the sandy deposits is not merely trough-faulted.

(*c*) *Other areas displaying comparable features*

Features apparently resembling those at Narborough are known in varying degrees of detail from other localities. At Oadby a 25 ft. borehole on A6 near Leicester race course was still in Oadby till at 263 ft. despite the fact that in this vicinity the undisturbed base of that deposit normally lies close to 325 ft. (figure 10). Sections on the north-eastern side of A 6 have exhibited grey chalky till at the same altitude as augering and temporary sections to the south-west have revealed bedrock capped by the normal drift succession culminating in the Oadby till at 320 ft. There can be no doubt that a steeply sloping junction closely paralleling the A 6 separates these two areas, and analogy with the Narborough district fosters the belief that it may be a fault. Recent boreholes close to, but south-west of, the junction have proved a sequence typified by the following log:

site no. 1 on figure 10; ground level 342 ft. O.D.

	ft.	in.	
firm to stiff light brown clay	17	0	Oadby till
hard dark blue clay	7	0	
loose light brown sand	7	0	Wigston sand and gravel
soft sandy silty clay	19	0	Glen Parva clay
hard dark brown clay	12	0	
hard red marl	11	0	Thrussington till

The interpretation on the right is based upon examination of samples recovered during piling operations, and two aspects of the record deserve comment. The first concerns the levels of the Thrussington till and compact Glen Parva clay which appear to be at least 15 ft. lower than in the old pit 300 yards to the south-west described by Deeley (1886). The second is the intercalation of a 19-ft. stratum of sandy silty clay which, from the available accounts, was either very attenuated or completely absent in the pit section. The material is greyish brown and very thinly bedded with a rhythmic alternation of fine sand, silt and plastic clay, but the cause of its apparently very limited distribution remains uncertain.

Other districts possess features which in certain respects resemble those at Narborough but are known in much less detail. The base of the Oadby till descends below 200 ft. at Rothley, and on the higher ground to the south several equivocal borehole logs might be interpreted as showing chalky drift at a comparable elevation; a railway cutting south of Birstall displayed chalky till, gravel, sand and stiff clay, again at about 200 ft. (Fox-Strangways 1903), while one of the few localities where drift has been reported beneath the Soar terraces lies less than a mile further south. The importance of these occurrences becomes obvious when it is remembered that the pre-glacial Soar valley seems already to have been filled to well above this altitude by the Thurmaston sand and gravel, but at present there is too little evidence to warrant discussion of the several feasible explanations. Augering in the tributary valleys east of the Soar has disclosed two points where the Oadby till, normally restricted to the interfluves, descends abruptly to stream level, although in both instances it is difficult to rule out solifluction as a possible explanation. Finally, at Anstey drift resembling the Thrussington rather than the Oadby till appears to descend to depths which cannot be accommodated in any pattern of pre-glacial valleys (see p. 479).

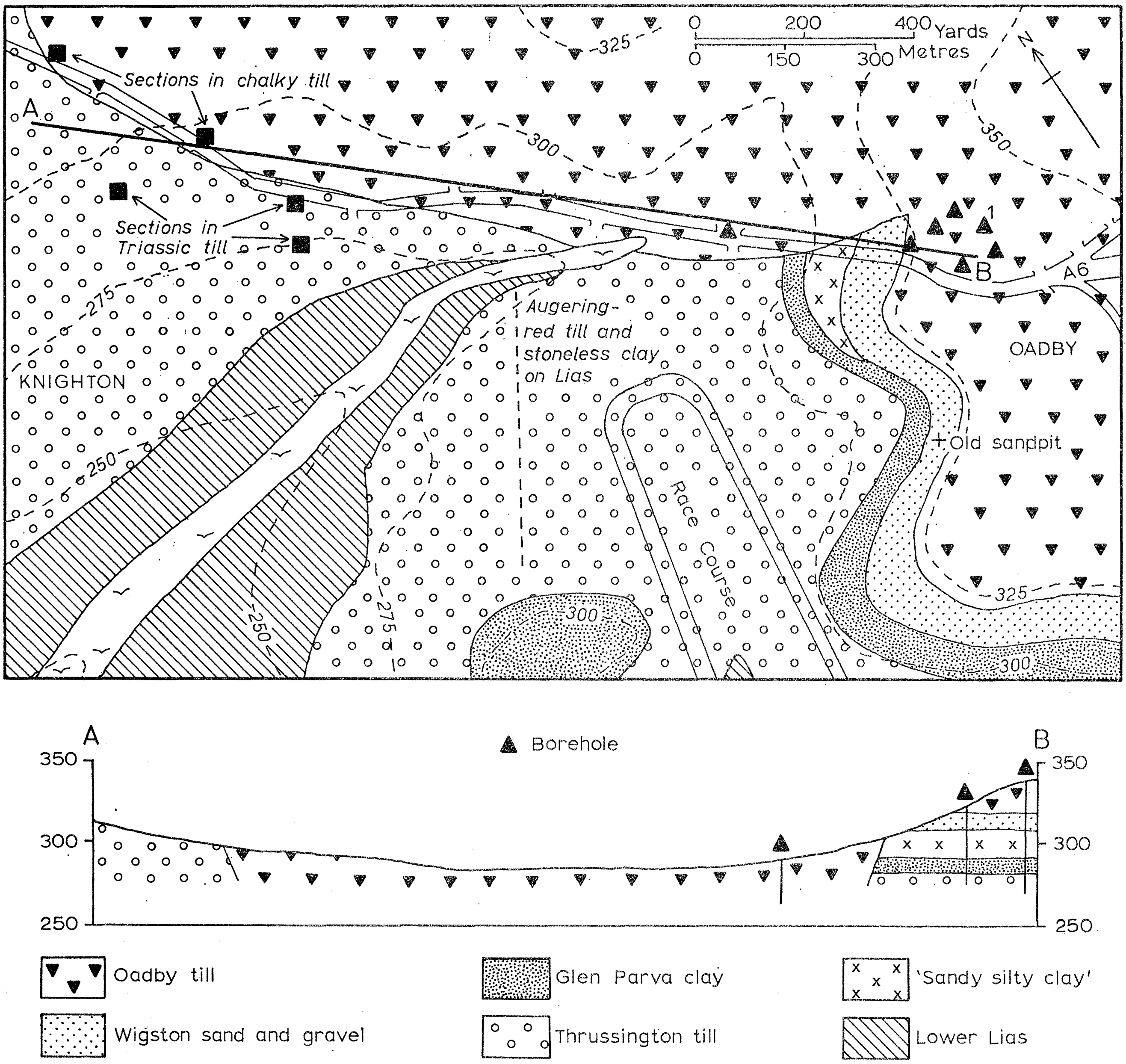

Figure 10. The drift deposits of the area north of Oadby.

6. Correlation and dating of the glacial drifts

(a) *Correlation with the succession described by Shotton*

Although the area described by Shotton (1953) lies 11 miles distant, the similarities between the two drift successions justify proposal of the following correlation:

Coventry area	Leicester area
Dunsmore gravel Upper Wolston clay	Oadby till
Wolston sand	Wigston sand and gravel
Lower Wolston clay	Thrussington till Glen Parva clay
Baginton sand Baginton–Lillington gravel	Thurmaston sand and gravel
Bubbenhall clay	not found

Among the similarities between the Thurmaston sand and gravel and the Baginton–Lillington sand and gravel are: (*a*) the presence of basal gravel passing up into false-bedded sands; (*b*) the abundance of Triassic pebbles north of grid-line 71 (Shotton 1953, p. 215); (*c*) deposition over an undulating surface with the deposits thinning out against the higher ground; (*d*) the tendency for the sands to become level-bedded in the upper few feet; and (*e*) the sorting and particle size of the sands. Microscopical examination of the sands has revealed nothing inconsistent with the proposed correlation, and Shotton himself equated the Baginton–Lillington beds with the 'Older sand and gravel' of Fox-Strangways which constitutes part of the Thurmaston sand and gravel as here described. Arguing from the paucity of local material, the writer has interpreted the Thurmaston sand and gravel as primarily outwash; on the other hand, arguing from variations in gravel composition and from the fauna, Shotton has invoked 'normal land streams' as the depositing agent. Resolution of these differing, but not necessarily incompatible, views must await further research, and it is noteworthy that a similar problem has arisen where Miss Tomlinson (1963) has correlated the Baginton–Lillington gravels with the Paxford gravels of the Cotswolds, the latter being underlain by western drift of the same glaciation as the Wolston clay.

Despite differences in the nature of the deposits, correlation of the Thrussington till and associated still-water sediments with the Lower Wolston clay is supported by analysis of the pebbles they contain. The Thrussington till is composed mainly of northern and western detritus but also includes a few Cretaceous erratics; Shotton records 2 % of the pebbles as flints in the lower part of the Lower Wolston clay, and 20 % in the upper part, but comments that these figures probably err in being too high. It seems likely that the stoneless clays immediately south of Leicester accumulated at the northern edge of Lake Harrison and thus confirm what Shotton has already deduced, namely that impoundment of the lake began when the ice front reached Leicester, and that further advance was followed by a temporary withdrawal allowing lacustrine conditions to extend back northwards.

The Wigston sand and gravel and Wolston sand are both beds transitional between deposits yielding a profusion of Bunter pebbles and those in which flints at least rival Bunter pebbles in number; the correlation is also implicit in the work of Shotton for he used the gravel outcrop at Wigston as a control point in contouring the base of the Wolston sand. The correlation of the Oadby till with the Upper Wolston clay and Dunsmore gravel accords with the rapidly increasing amount of Cretaceous debris in the highest members of the drift succession, laid down in association with an ice sheet ultimately transgressing as far as the southern margin of Lake Harrison (Bishop 1958).

(*b*) *South Leicestershire*

While the foregoing arguments are believed adequate to sustain the proposed correlation, much interest still attaches to the intervening area of south Leicestershire (see Shotton 1953). A number of deep boreholes near the county boundary (figure 11) have proved a basal sand and gravel which is the presumed equivalent of the Baginton/Thurmaston deposits. Northwards the declining ground level means that shallower boreholes bottom the drift and a number of records from such villages as Primethorpe, Sutton in the Elms and Broughton Astley indicate a basal sand and gravel which at the latter village is said to

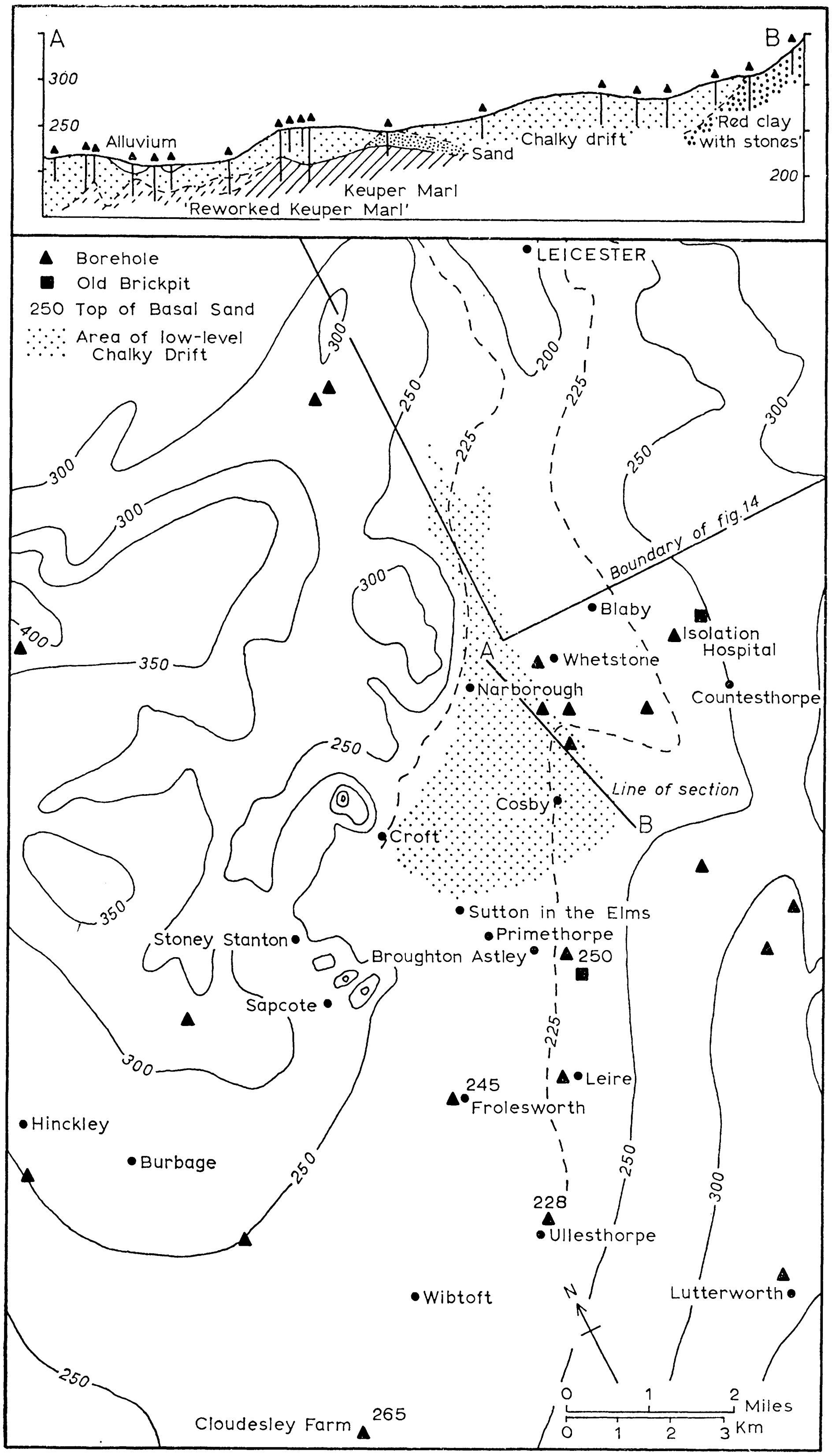

FIGURE 11. The bedrock surface of South Leicestershire, together with an indication of the area in which low-level chalky drift appears to occur.

contain Carboniferous, Triassic and Liassic pebbles. The Baginton/Thurmaston beds thus appear to continue northwards from Coventry to Broughton Astley with the elevation of the top of the sand declining from about 270 to 250 ft.

There are plentiful indications of the extension of the Glen Parva clay southward from central Leicestershire. In Blaby red stoneless clay has been exposed on several recent housing estates, and at the nearby isolation hospital 20 ft. of brickclay proved in an old well was formerly worked in a series of large pits. South of Whetstone boreholes have encountered laminated clay inter-bedded with Trias-derived till, and in an old pit at Broughton Astley station 30 ft. of stiff red clay with scattered pebbles and boulders is capped by chalky clay mixed with gravelly sand (Eastwood, Gibson, Cantrill & Whitehead 1923). The latter appears to be the base of the Wigston/Wolston sand, with the red clay the equivalent of the Thrussington till and Glen Parva clay. 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.

The above observations are consistent with the view that the infilling of the proto-Soar valley consists predominantly of till around Leicester separated from contemporaneous lacustrine sediments around Coventry by a complex diachronous boundary not yet traced in detail. Nevertheless, there are signs that the distribution of the drifts is more complicated than the foregoing paragraphs might suggest. For instance, at Broughton Astley the red clay with scattered pebbles extends up to a height of 325 ft. whereas in the area between Narborough, Whetstone, Cosby and Croft grey chalky till occurs at a relatively low level, a 9 ft. exposure having been noted at the last settlement at under 260 ft. Similarly, a section along the M1 Motorway shows north-eastern till trenched down below the normal level of the red stony clays (figure 11, inset). These examples evidently represent an extension of the features found in the Narborough area, although the relative importance of down-faulting and sub-glacial erosion remains to be determined.

(*c*) *The age of the glacial drifts in central Leicestershire*

Shotton (1953) regarded 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; only small pockets of Bubbenhall clay were assigned to the Elster glaciation. Palynological support for this dating has been obtained from the Nechells interglacial deposits (Duigan 1956; Kelly 1964). Basing their arguments primarily on ice movements inferred from erratic orientation, West & Donner (1956) correlated the north-westerly derived till of central Leicestershire with the Elsterian Lowestoft drift of East Anglia, and the north-easterly derived till with the Saalian Gipping drift. Posnansky (1960) accepted and elaborated this latter chronology.

The present writer, however, sees inconsistencies between the views of Shotton (1953) and those of West & Donner (1956). It is part of Shotton's thesis that the Saalian ice, when it first advanced into the proto-Soar valley, invaded an area very largely denuded of earlier drift by prolonged sub-aerial erosion. Yet the contention of West & Donner that they identified Elster till at Leicester University means that this old drift is at least 30 ft.

thick in a bluff directly overlooking the Soar. If correct, the identification would very seriously affect Shotton's reconstruction of the proto-Soar valley at the end of the Great Interglacial, for in the Leicester area the valley would necessarily be much narrower than further south; his reconstruction would, however, be unaffected if the University till were post-Hoxnian.

The proposed correlation between the drifts of central Leicestershire and the Coventry area 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. Three lines of reasoning favour the view that the Thrussington till is of Saale age. 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 an inter-glacial episode comparable in length with the Great Interglacial during accumulation of the Leicestershire drifts. The third is the abundant evidence of numerous shifts in ice movement, undermining the implicit assumption of relative constancy during one particular glaciation. The last argument is considerably reinforced by recent work in Lincolnshire (Straw 1966).

To argue that the mapped drift succession is of Saale age does not preclude the possibility that patches of earlier drift survive undetected beneath more recent deposits. However, the view that the vast majority of the drift is of Saalian age raises problems of correlation with the well-established East Anglian sequence (West, 1955, 1963). The most likely cause of the discordance noted above seems to reside in resemblances between the Lowestoft till and the basal Saale till of the East Midlands, but presumably somewhere between Leicester and East Anglia this deceptive Saale till thins and disappears. The following table lists the drift succession recognized in Northamptonshire (Hollingworth & Taylor 1946; Taylor 1963), and proposes a tentative correlation with central Leicestershire:

Northamptonshire	Leicestershire
chalky boulder clay and outwash	Oadby till and outwash
	Thrussington till
mid-glacial gravels	Thurmaston sand and gravel
lower boulder clay	not recorded
sands and gravels	not recorded

While at first sight it is tempting to equate directly the Northamptonshire succession of two gravels interbedded with two tills with the similar sequence in central Leicestershire, the above table may be justified on a number of grounds. The basal gravel in Northamptonshire is characterized by material wholly of local origin, which is certainly not true of the Thurmaston gravel, and although the Lower boulder clay resembles the Thrussington till in the paucity of Cretaceous erratics, its intermittent preservation in hollows beneath newer drift probably bespeaks a long period of subsequent erosion. The Mid-glacial gravels with their 'local plus Bunter' composition seem more akin to the Thurmaston gravel, while the Chalky boulder clay is presumably the equivalent of the Oadby till. The absence of the Thrussington till from Northamptonshire would be consistent with the view that the early Saalian ice sheet was thinner and less extensive than that responsible for the Oadby till. Shotton concluded that the first ice advance halted some way north of Leamington, and that it may have failed to surmount the Middle Lias scarp in eastern Leicestershire is consonant with the observed basal drift around Tilton being largely flinty outwash gravel.

A possible sequence of events is therefore (*a*) a very extensive Elsterian ice advance, mainly from the north-west; (*b*) a complete ice withdrawal with accumulation of the Hoxne and Nechells interglacial deposits, and a prolonged period of erosion during which nearly all the earlier drift was removed from the proto-Soar valley; (*c*) an early Saalian advance with north-western ice dominant but reaching only as far as the middle proto-Soar valley; and (*d*) a partial withdrawal followed shortly by a major re-advance during which the whole of the East Midlands was covered by north-eastern ice of the main Saalian glaciation.

7. 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 disappearance of the ice from central Leicestershire. The spur crests of the area were examined to discover whether in their morphology of subdued 'flats' separated by slightly steeper 'risers' they retain evidence of pro-glacial lakes, but no pattern consistent with an origin as strandlines was detected. This may indicate stagnation and in situ decay of the ice sheet. There is no reason to doubt that originally there was a complete cover of Oadby till and that the present drainage began to flow on 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. 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. But the first decipherable episodes in the dissection of the glacial drifts appear to post date local removal of the Oadby till and are best encompassed under the general head of river terraces.

(*b*) *River terraces*

The terraces of the middle Soar (figure 12) are not sharply defined features, for they normally possess a pronounced riverward slope with much degraded intervening bluffs. The gravels often 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 bedrock basement or the precise relationship of one gravel suite to another. Nevertheless, four terrace levels may be distinguished:

Birstall terrace	Syston terrace
Wanlip terrace	Quorndon terrace

Additionally, a group of erosion 'flats' constitute what is here termed the Knighton Surface, while below the modern alluvium lies a considerable thickness of floodplain gravels.

The criterion employed in differentiating the terraces was height above modern alluvium, the altitude of the leading edge of each terrace fragment being measured to an estimated accuracy of within 5 ft. The pronounced riverward slope means that the height of the leading edge is much influenced by the extent of later trimming, with the result that the remnants of a single terrace as depicted in figure 13 do not fall on a line comparable with the modern floodplain, but occupy a zone having a height range of 10 ft. or more.

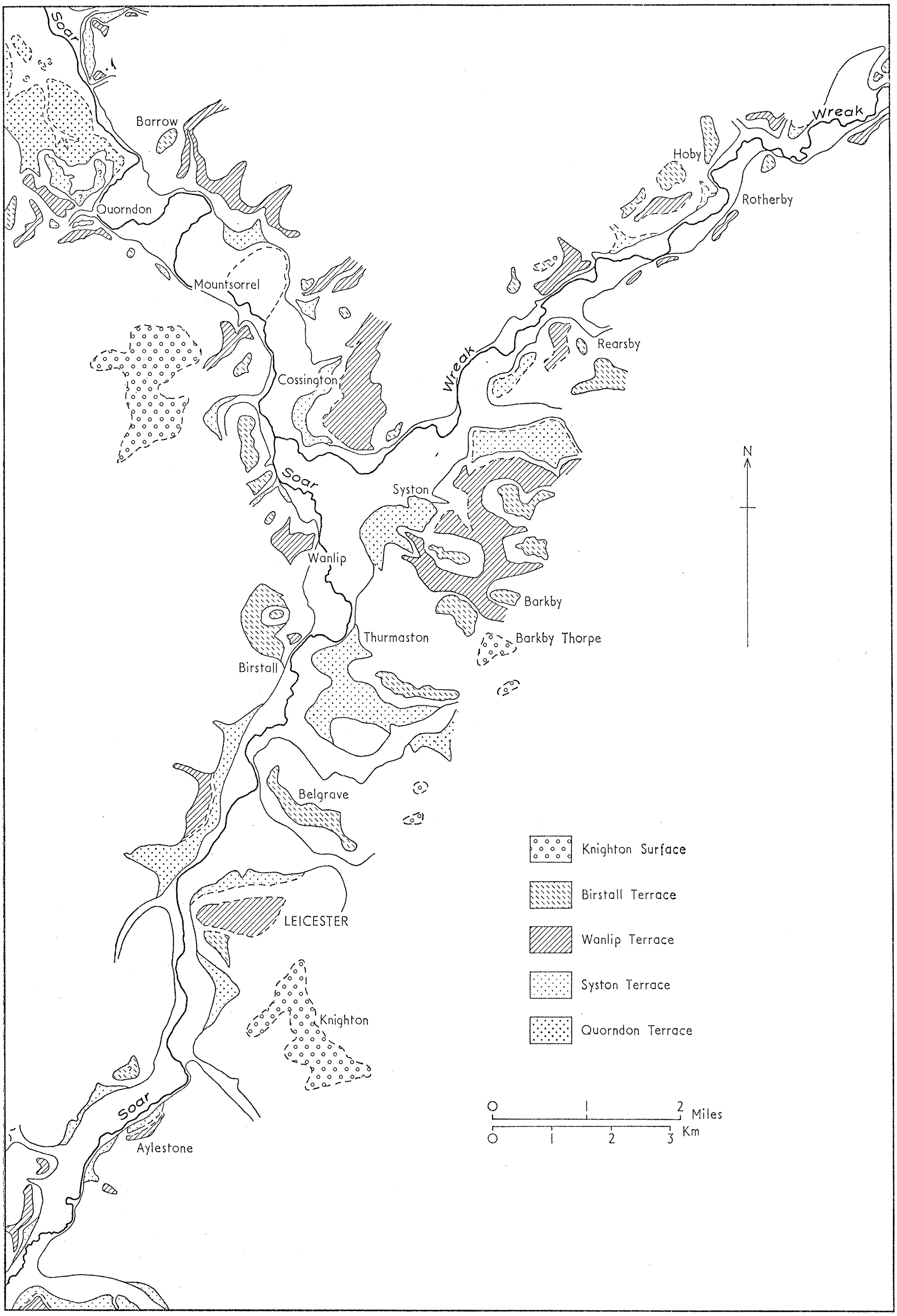

FIGURE 12. The distribution of terraces in central Leicestershire.

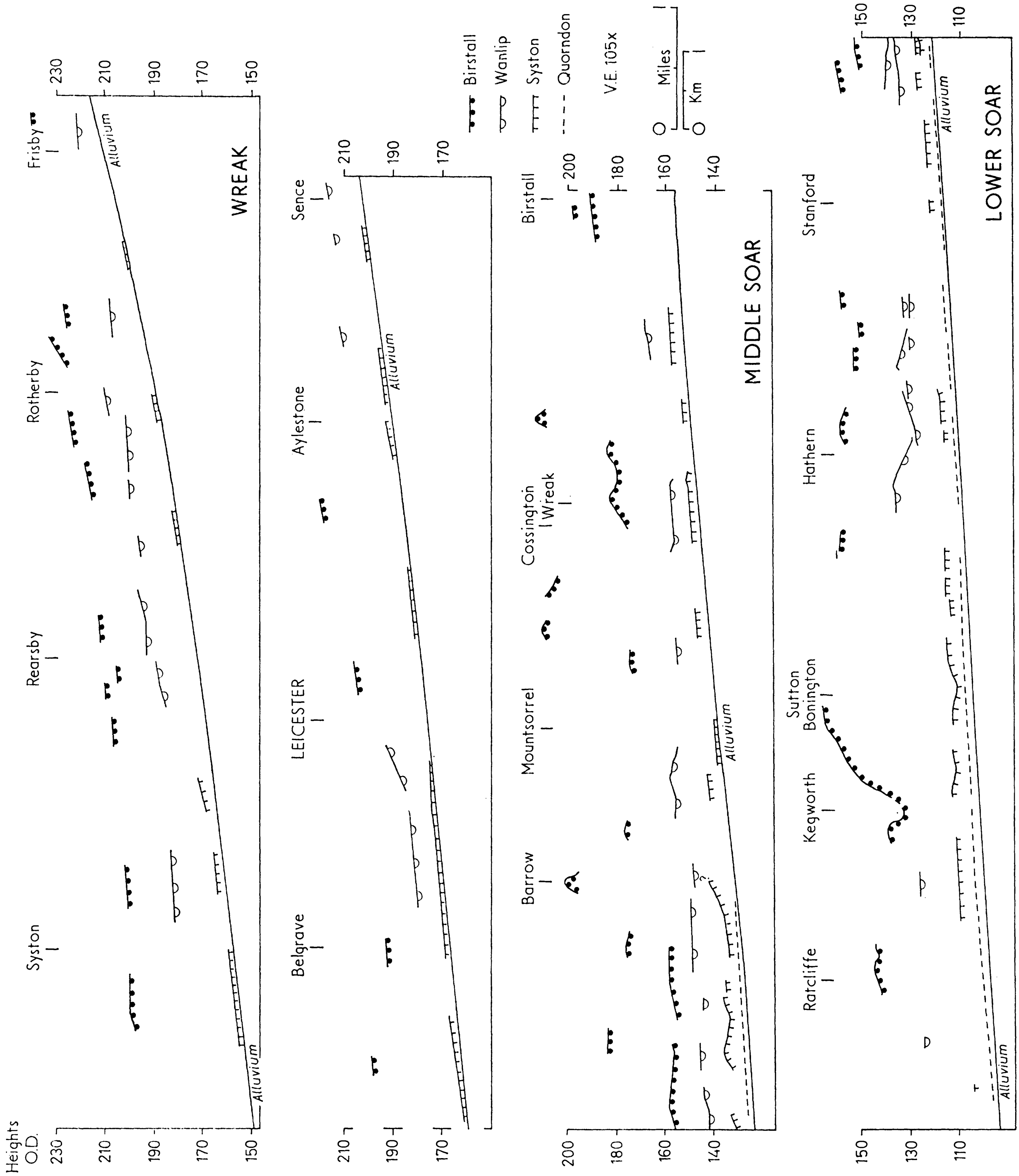

FIGURE 13. The terraces of the lower Wreak and of the middle and lower Soar.

(i) *Knighton surface*. One of the most distinctive topographic features of the city of Leicester is the gently undulating plateau at between 275 and 300 ft. in the suburb of Knighton. Its erosional origin is indicated by its indiscriminate transgression across both Oadby and Thrussington tills, even where those drifts are juxtaposed along a high-angle and conceivably faulted junction (p. 493). Although lacking a thick or continuous sheet of terrace gravel, it is intermittently veneered with 2 or 3 ft. of water-laid sand and gravel.

Among apparent correlatives one particularly interesting instance occurs west of Narborough where an extensive plateau on Oadby till at a little over 300 ft. declines very gently towards the Soar and is there covered by patches of gravel which from their composition appear to be post-glacial terrace deposits. The interest derives from the fact that these gravel patches impinge upon the area of faulted drift (figure 9) and appear to be later than any major displacements along the fractures which lack any topographic expression at the present day (Shotton 1965). The only case where a relationship between structure and topography may reasonably be suspected is in the alinement of Lubbesthorpe Brook which, for a distance of over 1 mile, flows southwards along the length of an elongate block of low-level chalky drift before turning abruptly eastwards to join the Soar (figure 7). If this is a graben, the initiation of the rather curious drainage pattern may well date from the period of active displacement.

Other fragments of the Knighton Surface occur near Barkby Thorpe at 260 ft. and on the remarkably smooth-topped plateau of Rothley Plain at 240 ft.

(ii) *Birstall terrace*. This is the highest terrace to display the normal attributes of extensive gravel spreads at a relatively constant altitude above alluvium. Also included under this head are several isolated and irregular patches of gravel which occur above the main terrace level, but which are too fragmentary to warrant recognition as a separate stage. The only one meriting special mention is at Barrow where a small patch of rather clayey sand and gravel caps an isolated knoll at just over 200 ft. O.D. While a distinctive terrace form is lacking, the writer sees no reason to doubt that the material is a post-glacial river deposit, and the locality is of particular interest for it is here that Plant (1859) records the finding of a complete skeleton of *Elephas antiquus*.

The main level of the terrace is especially well developed around the Wreak confluence where, at Birstall, an old meander loop of the Soar is preserved little dissected at 30 ft. above alluvium and on the right bank a whole series of Keuper Marl ridges is capped by flinty gravel at between 30 and 40 ft. above alluvium. The thickness of the mapped terrace deposit is not great, commonly 5 to 8 ft., but some of it was regarded by Fox-Strangways as of glacial origin. The justification for the change in interpretation lies in the abundance of flint as revealed on cultivated land and in shallow sections, for the basal drift in this vicinity is normally the Thurmaston gravel in which flint is either absent or extremely rare.

Along the Wreak valley the Birstall terrace is well represented, much of it being mapped by the Geological Survey officers as 'Older river gravel'. The terrace fragments, however, are poorly shaped and rarely retain a well defined 'flat'. Where the Soar valley narrows between the Mountsorrel igneous outcrops and the Rhaetic scarp terrace remnants are missing but they reappear around Quorndon at a level of about 30 ft. above alluvium. So far as the writer has been able to ascertain there is no reliable record 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 a pronounced rock step denotes an important phase of erosion. This terminated with the development of a Keuper Marl platform whose surface, now commonly concealed beneath the Wanlip gravels but known from a number of deep sections and sub-surface records, lies some 10 ft. above the modern floodplain. The depth of incision following the Birstall aggradation must therefore have been at least 20 ft.

The Wanlip terrace deposits, generally 5 to 10 ft. thick, may locally attain over 15 ft. Part of central Leicester is built upon the terrace, and the many records of that city show these to be representative figures. A further characteristic of the terrace is that the concave break of slope at its rear is often obscured by a gently inclined sheet of clayey sand and gravel which may extend over a vertical interval of as much as 30 ft. and which grades down from the valley sides 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 largely controlled by the extent of later undercutting.

The fauna of the aggradation is 'cold', *Mammuthus primigenius* having been recorded from a number of sites. The melange of material swathing the valley sides is attributable to solifluction, and it now seems evident that much of the contortion and disturbance which earlier workers described is due to the growth of ground-ice under periglacial conditions. The best example noted during the present study lies just south of the mapped area in Blaby where a deep section disclosed violent involutions, with wisps and irregular masses of Keuper Marl thrust up into the terrace gravel. Comparable structures probably account for the relatively frequent references to 'valley drift' and 'boulder clay' in well and borehole records in central Leicester.

(iv) *Syston terrace*. Fringing the modern alluvium and often rising only 2 or 3 ft. above it, lies a further sloping spread of gravel. At one point south of Thurmaston there are signs that the gravel rests upon a bedrock platform below the top level of the modern alluvium yet above the base of the floodplain gravels, but no such platform has been detected elsewhere and although some uncertainty must remain the probability is that the Syston terrace represents the maximum aggradation level after the cutting of the sub-alluvial channel; analogy with the Tame valley (Coope & Sands 1966) supports this view. Although the records are rather inexact in fixing the sites of finds, it is believed that a cold fauna including *Mammuthus primigenius* (and possibly *Coelodonta antiquitatus*) has been collected from the Syston terrace gravels.

(v) *Quorndon terrace*. At Quorndon a curious and as yet unexplained transformation of the valley floor takes place. In the reach immediately upstream the Soar executes a series of large meander loops on a floodplain fully three-quarters of a mile wide, but then a projecting gravel-covered spur some 5 to 10 ft. above the level of the alluvium so constricts 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 the low Quorndon terrace 2 or 3 ft. above modern alluvium. The failure of the Soar to trim back the spur not only at present river level, but also during the erosion which preceded the floodplain aggradation betokens something more than a normal head of rejuvenation.

(vi) *Floodplain gravels*. Beneath the modern alluvium there is commonly 10 to 12 ft. of coarse sand and gravel, although the thickness decreases slightly as one moves up both the Soar and Wreak valleys. The associated fauna is 'cold', almost all the gravel pits on the floodplain having yielded *Mammuthus primigenius*, *Coelodonta antiquitatus* and *Rangifer tarandus*, while more recently the first occurrence of *Megaceros giganteus* has been recorded (Sizer 1962). Resting upon the sand and gravel there is normally 3 or 4 ft. of alluvial silt and clay. It is not unusual to find the base of the clay darkened by organic matter, and locally a thin peat bed separates the clay from the underlying sand and gravel. A comparable bed in the Tame valley has been ^{14}C-dated at 4830 ± 100 years B.P.

(*c*) *The chronology of the terraces*

At least three separate phases of aggradation may be distinguished, namely those associated with the Birstall, Wanlip and floodplain gravels, and of these the last two apparently occurred under cold climatic conditions assignable to the last (Wiechsel) glaciation. The assignment of the Birstall terrace gravel, almost certainly composite and covering a long time span, is much more problematical. The record of *Elephas antiquus* from Barrow favours a date for part of it within the last (Eemian) interglacial, but whether this applies to the main terrace level is debatable. The gravel spread at Barrow apparently lies considerably above the main terrace, but this could be misleading in that it is situated within the mouth of a small tributary valley and might be 20 ft. above the contemporaneous Soar deposits; until further evidence becomes available dating of the Birstall terrace must be regarded as indeterminate.

The Knighton surface, presumably older than the Birstall terrace, may be ascribed to an episode either at the end of the Saale glaciation or early in the Eemian interglacial. The Syston and Quorndon terraces bear witness to minor phases of downcutting subsequent to the main floodplain aggradation.

(*d*) *Correlation with the Trent and Avon*

(i) *The Trent*. In order to establish a correlation with the Trent, the terraces of the lower Soar were mapped and the height of the leading edge of each terrace fragment measured with an aneroid to an estimated accuracy of ± 8 ft. (figure 13). No attempt was made to determine the form of the bedrock basement, and in locating the terrace fragments much reliance was placed on published Geological Survey maps. Although the accordance of this reconnaissance survey with the middle Soar is generally very good, correlation with the Trent remains extremely difficult owing to the wide diversity of views regarding the chronology of the Trent terraces, and the following table is proposed primarily to facilitate discussion:

Soar	Trent
Knighton surface	Hilton terrace
Birstall terrace, Wanlip terrace	Beeston terrace
Syston terrace, Quorndon terrace, Floodplain gravels	Floodplain terrace

Correlation of the Syston with the Floodplain terrace is justified on the grounds that both represent the culmination of the last major aggradational phase. It is generally acknowledged that the Floodplain terrace is a cold aggradation, and Coope & Sands (1966) describe an insect fauna from the Low Terrace of the Tame consonant with this view, and quote a ^{14}C date of 32160^{+1780}_{-1450} years B.P. for an organic horizon near the base of the gravels, thus seeming to confirm that the alluviation commenced in the latter half of the Weichsel glaciation. The place of the Quorndon terrace in the Trent succession is obscure for recent writers do not appear to recognize an exact correlative. Originally distinguished on the Geological Survey 1 in. = 1 mile map no. 141 and briefly alluded to by Fox-Strangways (1905), it was omitted from the edition of the map published in 1950.

Greater conflict inevitably surrounds any attempt at correlation with the Beeston terrace, since the conditions obtaining during that aggradation are much disputed. Mitchell & Stevenson (1955) contend that the 'Second terrace' is contemporaneous with, or only slightly later than, recent marginal phenomena of the Irish Sea ice, a view previously adumbrated by Pocock (1929) and Clayton (1951), and Straw (1963) argues that the Beeston terrace around Lincoln is contemporaneous with a Weichselian ice advance to the north Norfolk coast. By contrast, Posnansky (1960), following Swinnerton (1937, 1948), suggests three arguments which conduce to the view that the aggradation belongs to the Eemian interglacial. The first concerns the find of *Elephas antiquus* at Barrow, the second the find 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), and the third the presence of fresh Levallois flakes. The evidence of the Wanlip terrace reinforces the belief that at least part of the aggradation is glacial, but final resolution of the problems concerning the Beeston terrace must await more research in the Trent valley itself. It may tentatively be suggested that it is the higher parts of the Beeston gravel which are of interglacial age; this would then permit equation with the Birstall terrace, and it is noteworthy that the original description of the hippopotamus find at Allenton refers to 'one of the lowest of the upper series of terraces' (Arnold-Bemrose & Deeley 1896, p. 505).

Various arguments have been adduced by Armstrong (1939), Mitchell & Stevenson (1955), Posnansky (1960) and Straw (1963) to show that the Hilton gravels are predominantly fluvio-glacial and date from the decay of the Saalian ice sheet. In the Soar valley few terrace-like spreads ascribable to the same period have been mapped, but it is possible that the Knighton surface is of approximately this age. If this is the case, it appears to define very closely the period within which the dislocations at Narborough may have occurred.

(ii) *The Avon.* A correlation with the well-established terrace sequence of the Avon (Tomlinson 1925) is suggested in the following table:

Avon no. 5	Knighton surface
Avon no. 4	Birstall terrace
Avon no. 3	Wanlip terrace
Avon no. 2	Syston terrace
Avon no. 1	Quorndon terrace

Again the Knighton surface is placed at the end of the Saale glaciation, although equation with the no. 5 terrace should not be taken as implying exact contemporaneity. The evidence of the warm fauna in the two basins has been given priority over the morphological and sequential differences in correlating the Birstall and Wanlip terraces with the Avon no. 3 and 4. Recent dating of the last aggradation in part of the Trent system supports the association of the Syston terrace with the Avon no. 2 (Coope & Sands 1966).

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References

Armstrong, A. L. 1939 Palaeolithic man in the North Midlands. *Mem. Manchr. Lit. Phil. Soc.* **83**, 87–116.

Arnold-Bemrose, H. H. & Deeley, R. M. 1896 Discovery of mammalian remains in the old river gravels of the Derwent near Derby. *Quart. J. Geol. Soc. Lond.* **52**, 497–509.

Bishop, W. W. 1958 The Pleistocene geology and geomorphology of three gaps in the Midland Jurassic escarpment. *Phil. Trans.* B **241**, 255–306.

Boswell, P. G. H. 1913 On the age of Suffolk valleys; with notes on the buried channels of drift. *Quart. J. Geol. Soc. Lond.* **69**, 581–618.

Boswell, P. G. H. 1937 The geology of the country around Ipswich. *Mem. Geol. Surv.*

Browne, M. 1893 A contribution to the history of the geology of the borough of Leicester. *Trans. Leic. Lit. Phil. Soc.* **3**, pt. 4, 123–240.

Browne, M. 1901 Report on an excursion to Aylestone and Glen Parva. *Trans. Leic. Lit. Phil. Soc.* **6**, pt. 1, 29–38.

Browne, M. 1902 The geology of the Beaumont Leys estate. *Trans. Leic. Lit. Phil. Soc.* **7**, pt. 1, 5–36.

Clayton, K. M. 1951 Some contributions to the denudation chronology of part of the middle Trent basin. Unpublished M.Sc. thesis, University of Sheffield.

Clayton, K. M. 1959 The geomorphology of the area around Melton Mowbray. *East Mid. Geog.* **2**, no. 12, 3–8.

Clinker, C. R. 1954 The Leicester and Swannington railway. *Trans. Leic. Arch. Soc.* **30**, 59–114.

Coope, G. R. & Sands, C. H. S. 1966 Insect faunas of the last glaciation from the Tame valley, Warwickshire. *Proc. Roy. Soc.* B **165**, 389–412.

Cox, A. H. 1919 A report on magnetic disturbances in Northamptonshire and Leicestershire, and their relations to the geological structure. *Phil. Trans.* A **219**, 73–135.

Deeley, R. M. 1886 The Pleistocene succession in the Trent basin. *Quart. J. Geol. Soc. Lond.* **42**, 437–479.

Duigan, S. L. 1956 Pollen analysis of the Nechells interglacial deposits, Birmingham. *Quart. J. Geol. Soc. Lond.* **112**, 373–389.

Eastwood, T., Gibson, W., Cantrill, T. C. & Whitehead, T. H. 1923 Geology of the country around Coventry. *Mem. Geol. Surv.*

Fox-Strangways, C. 1903 The geology of the country near Leicester. *Mem. Geol. Surv.*

Fox-Strangways, C. 1905 The geology of the country between Derby, Burton-on-Trent, Ashby-de-la-Zouch and Loughborough. *Mem. Geol. Surv.*

Hallimond, A. F. 1930 On the magnetic disturbances in north Leicestershire. *Summ. Progr. Geol. Surv. Lond. for* 1929, pt. 1–23.

Harrison, W. J. 1877 *The geology of Leicestershire and Rutland.* Sheffield: White.

Hollingworth, S. E. & Taylor, J. H. 1946 An outline of the geology of the Kettering district. *Proc. Geol. Assoc. Lond.* **57**, 204–233.

Jukes, J. B. 1859 The South Staffordshire coalfield. *Mem. Geol. Surv.*

Kelly, M. R. 1964 The middle Pleistocene of north Birmingham. *Phil. Trans.* B **247**, 533–592.

Kent, P. E. 1937 The Melton Mowbray anticline. *Geol. Mag.* **74**, 154–160.

Lamplugh, G. W. *et al.* 1909 The geology of the Melton Mowbray district. *Mem. Geol. Surv.*

Larwood, G. P. & Funnell, B. M. 1961 Geology, in 'Norwich and its region'. *Br. Ass. Adv. Sci.*

Lewis, H. C. 1894 *Glacial geology of Great Britain and Ireland.* London: Longmans.

Mitchell, G. H. & Stevenson, I. P. 1955 The geology of the country between Burton upon Trent, Rugeley and Uttoxeter. *Mem. Geol. Surv.*

Moore, C. A. 1888 The Aylestone sandpit in the Soar valley. *Trans. Leic. Lit. Phil. Soc.* **1** pt. 6, 22–23.

Mott, F. T. 1878 Report of Section C (Geology). *Rep. Leic. Lit. Phil. Soc.* 1878, 26–28.

Osborne White, H. J. 1932 The geology of the country near Saffron Walden. *Mem. Geol. Surv.*

Paul, J. D. 1883*a* Report of Section C (Geology). *Rep. Leic. Lit. Phil. Soc.* 1883, 24–25.

Paul, J. D. 1883*b* Section exposed on the Great Northern Railway near Thurnby and Scraptoft. *Trans. Leic. Lit. Phil. Soc.* 1882–3, 50–51.

Paul, J. D. 1891 Recent geological notes. *Trans. Leic. Lit. Phil. Soc.* **2** pt. 9, 405–408.

Paul, J. D. 1901 The Soar valley in glacial time. *Trans. Leic. Lit. Phil. Soc.* **5** pt. 11, 565–570.

Pickering, R. 1957 The Pleistocene geology of the south Birmingham area. *Quart. J. Geol. Soc. Lond.* **113**, 223–239.

Plant, J. 1859 Notice of the occurrence of mammalian remains in the valley of the Soar, Leicestershire. *Geologist* **2**, 174–5.

Pocock, T. I. 1929 The Trent valley in the glacial period. *Z. Gletscherk.* **17**, 302–318.

Posnansky, M. 1960 The Pleistocene succession in the middle Trent basin. *Proc. Geol. Assoc. Lond.* **71**, 285–311.

Rice, R. J. 1965 The early Pleistocene evolution of north-eastern Leicestershire and parts of adjacent countries. *Trans. Inst. Br. Geog.* **37**, 101–110.

Robertson, T. 1928 Contributor to The geology of the country between Wolverhampton and Oakengates. *Mem. Geol. Surv.*

Schou, A. 1949 *Atlas of Denmark*, I. *The landscapes.* Copenhagen: Roy. Dan. Geog. Soc.

Shotton, F. W. 1953 The Pleistocene deposits of the area between Coventry, Rugby and Leamington, and their bearing upon the topographic development of the Midlands. *Phil. Trans.* B **237**, 209–260.

Shotton, F. W. 1954 The geology around Hams Hall, near Coleshill, Warwickshire. *Proc. Coventry Nat. Hist. Sci. Soc.* **2** no. 8, 237–244.

Shotton, F. W. 1965 Normal faulting in British Pleistocene deposits. *Quart. J. geol. Soc.* **121**, 419–434.

Sissons, J. B. 1958 Sub-glacial stream erosion in southern Northumberland. *Scot. Geog. Mag.* **74**, 163–175.

Sissons, J. B. 1960–61 Some aspects of glacial drainage channels in Britain. *Scot. Geog. Mag.* **76** 131–146 and **77**, 15–36.

Sizer, C. A. 1962 Remains of the Giant Irish Deer in Leicestershire. *Trans. Leic. Lit. Phil. Soc.* p. 56.

Sparks, B. W. & West, R. G. 1965 The relief and drift deposits, in 'The Cambridge region', *Br. Ass. Adv. Sci.*

Straw, A. 1963 The Quaternary evolution of the lower and middle Trent. *East Mid. Geog.* **3**, 171–189.

Straw, A. 1966 The development of the middle and lower Bain valley, east Lincolnshire. *Trans. Inst. Brit. Geog.* **40**, 145–154.

Swinnerton, H. H. 1937 The problem of the Lincoln gap. *Trans. Lincs. Nat. Union* **9**, 145–153.

Swinnerton, H. H. 1948 'Pleistocene and later deposits'. In *Guide to the geology of the East Midlands.* University of Nottingham.

Taylor, J. H. 1963 Geology of the country around Kettering, Corby and Oundle. *Mem. Geol. Surv.*

Tomlinson, M. E. 1925 River terraces of the lower valley of the Warwickshire Avon. *Quart. J. Geol. Soc.* **81**, 137–163.

Tomlinson, M. E. 1963 The Pleistocene chronology of the Midlands. *Proc. Geol. Assoc. Lond.* **74**, 187–202.

Tucker, W. T. 1896 On some supposed British remains from Rothley, Leicestershire. *Trans. Leic. Lit. Phil. Soc.* **4**, pt. 6, 212–218.

Valentin, H. 1955 Die Grenze der Letzen Vereisung im Nordseeraum. *Verhandl. dtsch. Geogrt. Hamburg*, **30**, 359–366.

Wedd, C. B. 1909 Contributor to The geology of the Melton Mowbray district. *Mem. Geol. Surv.*

Werth, E. 1909 Fjorde, Fjärde und Föhrden. *Z. Gletscherk.* **3**, 346–358.

West, R. G. 1955 The Quaternary deposits at Hoxne, Suffolk. *Phil. Trans.* B **239**, 265–356.

West, R. G. 1963 Problems of the British Quaternary. *Proc. Geol. Assoc. Lond.* **74**, 147–186.

West, R. G. & Donner, J. J. 1956 The glaciations of East Anglia and the East Midlands: a differentiation based on stone orientation measurements of the tills. *Quart. J. Geol. Soc.* **112**, 69–87.

Whitehead, T. H. & Eastwood, T. 1927 The geology of the southern part of the South Staffordshire coalfield, *Mem. Geol. Surv.*

Woldstedt, P. 1926 Das Problem der Seenbildung in Norddeutschland. *Z. ges. Erdk. Berl.* pp. 103–124.

Yorke, C. 1961 The pocket deposits of Derbyshire. Private publication, Birkenhead.

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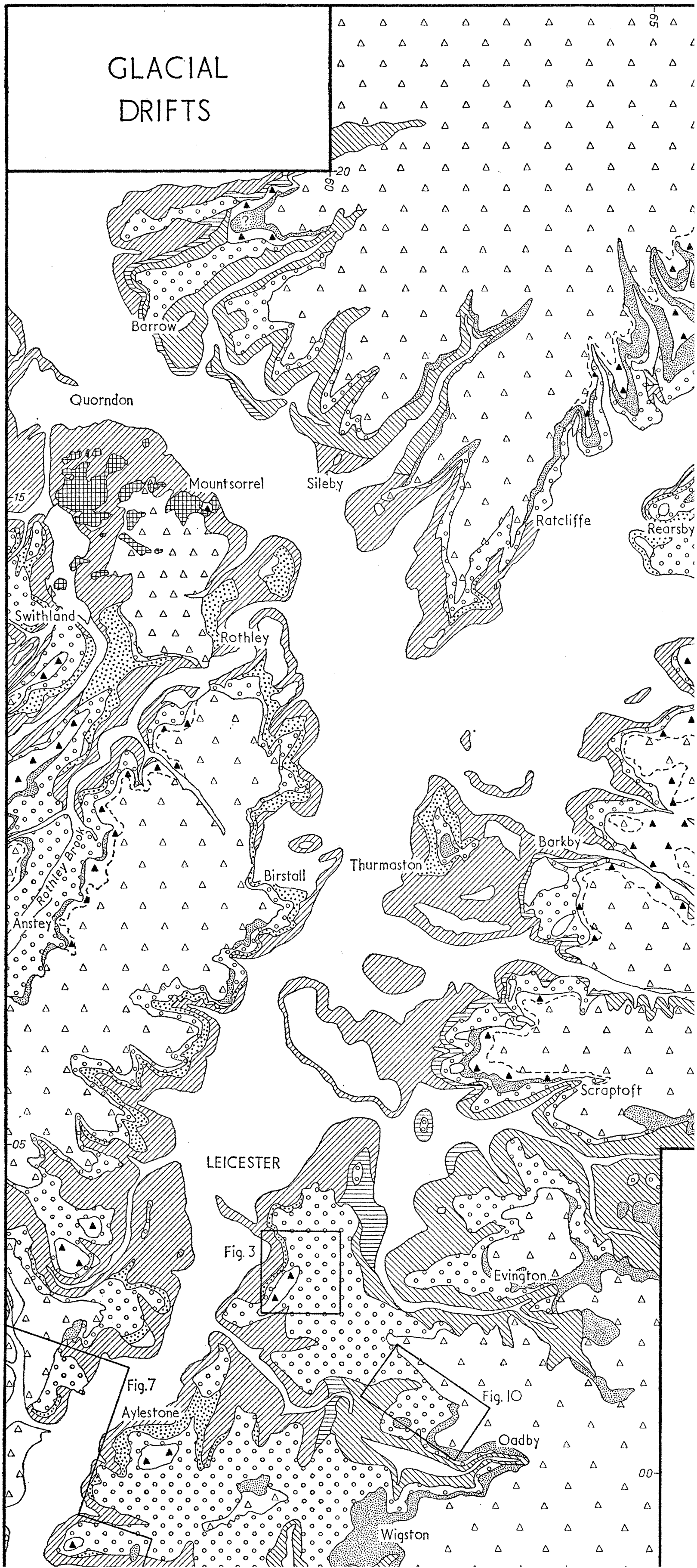
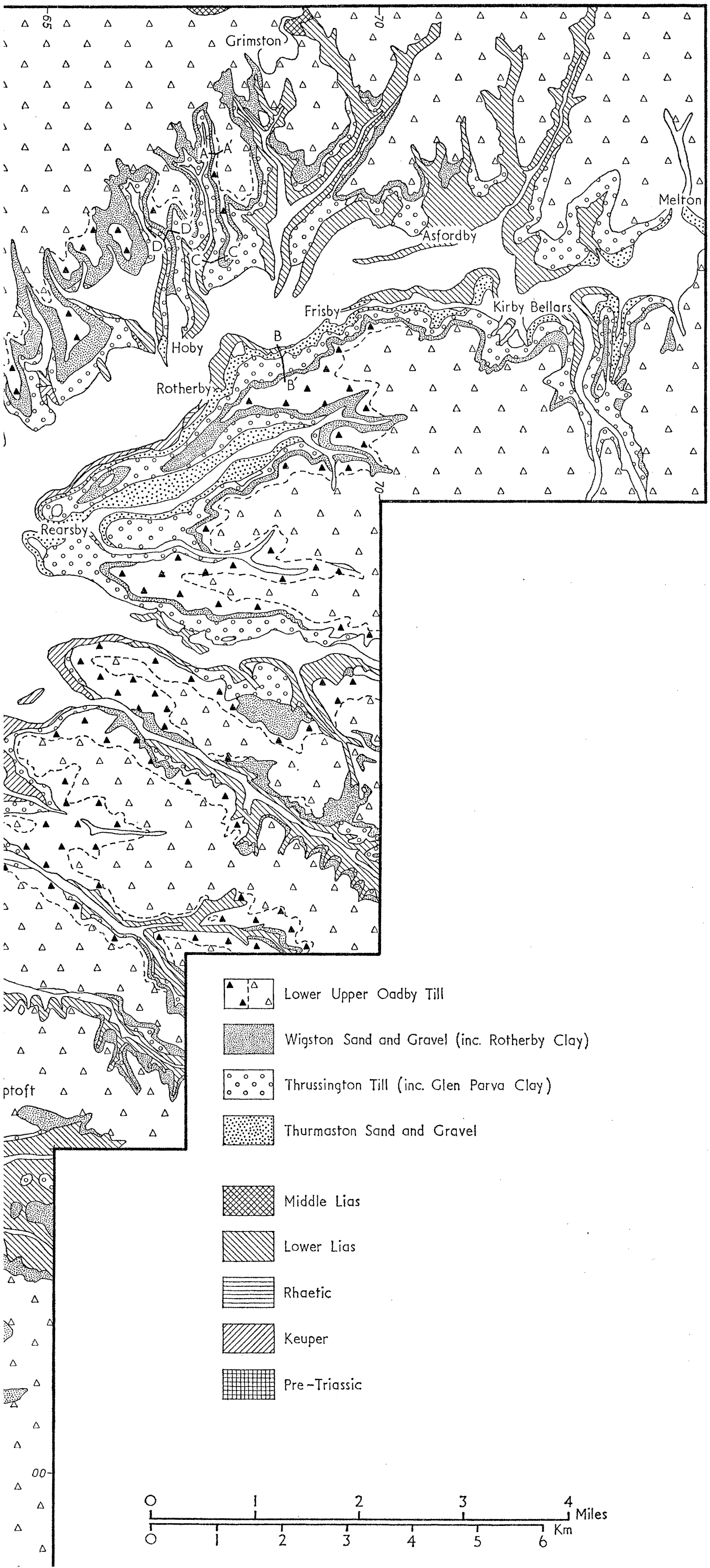

GLACIAL
DRIFTS
65
20
60
Barrow
Quorndon
Mountsorrel
Sileby
Ratcliffe
Rearsby
15
Swithland
Rothley
Rothley Brook
Anstey
Birstall
Thurmaston
Barkby
Scraptoft
05
LEICESTER
Fig. 3
Evington
Fig. 7
Aylestone
Fig. 10
Oadby
00
Wigston


Grimston
Melton
Asfordby
Frisby
Kirby Bellars
Hoby
Rotherby
Rearsby
ptoft
A A'
B B'
C C'
D D'
65
70
00
Lower Upper Oadby Till
Wigston Sand and Gravel (inc. Rotherby Clay)
Thrussington Till (inc. Glen Parva Clay)
Thurmaston Sand and Gravel
Middle Lias
Lower Lias
Rhaetic
Keuper
Pre-Triassic
0 1 2 3 4 Miles
0 1 2 3 4 5 6 Km

FIGURE

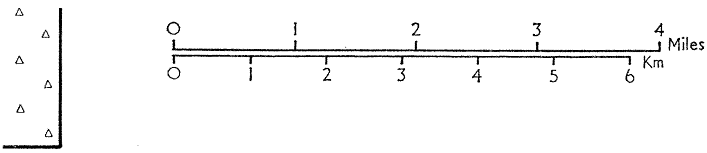


Figure 14

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

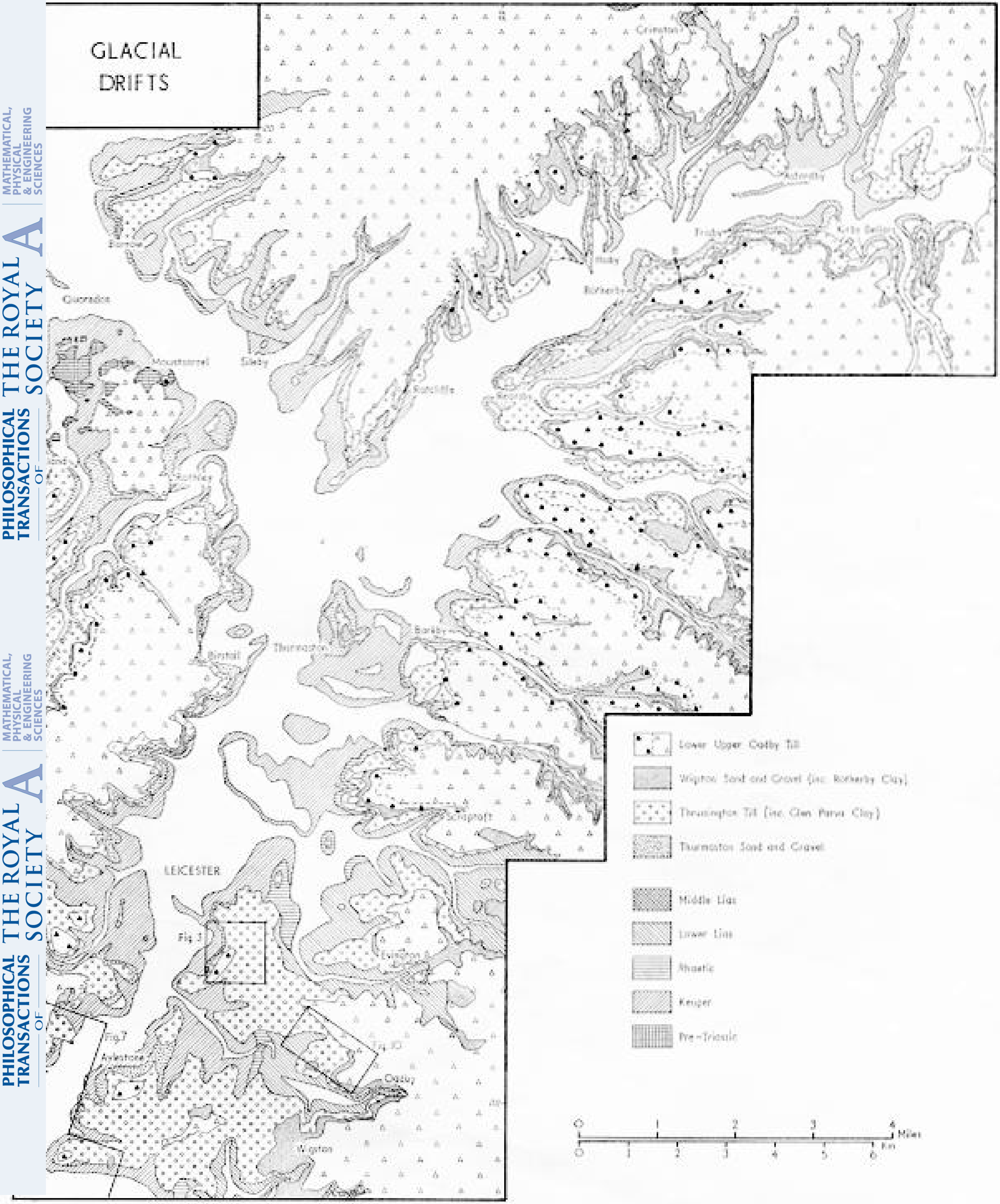

GLACIAL DRIFTS
Mountsorrel
Sileby
Ratcliffe
Rotherby
Hoby
Frisby
Asfordby
Kirby Bellars
Barkby
Thurmaston
Birstall
Scraptoft
LEICESTER
Evington
Aylestone
Oadby
Wigston
Lower Upper Oadby Till
Wigston Sand and Gravel (inc. Rotherby Clay)
Thrussington Till (inc. Glen Parva Clay)
Thurmaston Sand and Gravel
Middle Lias
Lower Lias
Rhaetic
Keuper
Pre-Triassic
0 1 2 3 4 Miles
0 1 2 3 4 5 6 Km

Figure 14