Natural Environment Research Council

British Geological Survey

Onshore Geology Series

TECHNICAL REPORT WA/97/64

Geology of the Littleover area: 1:10 000 sheet SK 33 SW

Part of 1:50,000 Sheet 141 (Loughborough)

A H COOPER

Geographical index
UK, East Midlands, Littleover,
Mickleover, south-west Derby

Subject Index
Geology, stratigraphy, Carboniferous,
Triassic, Quaternary, tunnel valley

Bibliographic reference
Cooper A H. 1997. Geology of the Littleover area:
1:10 000 sheet SK 33 SW.
British Geological Survey Technical Report WA/97/64

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available through the Sales Desks at Keyworth and at Murchison House, Edinburgh, and in the BGS London Information Office in the Natural History Museum Earth Galleries. The adjacent bookshop stocks the more popular books for sale over the counter. Most BGS books and reports are listed in HMSO's Sectional List 45, and can be bought from HMSO and through HMSO agents and retailers. Maps are listed in the BGS Map Catalogue, and can be bought from Ordnance Survey agents as well as from BGS.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Overseas Development Administration.

The British Geological Survey is a component body of the Natural Environment Research Council.

Parent Body

Natural Environment Research Council
Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU.
Telephone 01793 411500
Telex 444293 ENVRE G
Fax 01793 411501

Kingsley Dunham Centre
Keyworth, Nottingham NG12 5GG.
Telephone 0115 936 3100
Telex 378173 BGSKEY G
Fax 0115 936 3200

Murchison House, West Mains Road, Edinburgh EH9 3LA.
Telephone 0131 667 1000
Telex 727343 SEISED C
Fax 0131 668 2683

London Information Office at the Natural History Museum, Earth Galleries, Exhibition Road, South Kensington, London SW7 2DE.
Telephone 0171 589 4090
Telephone 0171 938 9056/57
Fax 0171 584 8270

19 Grange Terrace, Edinburgh EH9 2LF.
Telephone 0131 667 1000
Telex 727343 SEISED C

St Just, 30 Pennsylvania Road, Exeter EX4 6BX.
Telephone 01392 78312
Fax 01392 437505

Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS.
Telephone 01232 666595
Fax 01232 662835

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB.
Telephone 01491 38800
Telex 849365 HYDROL G
Fax 01491 25338

CONTENTS

TABLES

1. INTRODUCTION

This account describes the geology of 1:10,000 sheet SK 33 SW (Littleover) covering the area from Littleover southwards to the flank of the Trent valley. It includes the urban areas forming the south-western parts of Derby, including Normanton and Sinfin. It also includes rural areas between Derby and Findern. The rural ground in the south is fairly low-lying with an elevation of up to 60m. The ground rises to the north reaching around 105 m above OD in the central parts of Mickleover and Littleover. The central and northern part of the area is drained by Hell Brook, the south-west by Dole Brook and the eastern part by an un-named brook between Normanton and Sinfin. The map sheet lies within 1:50,000 Geological Sheet 141 (Loughborough).

The first geological survey of the area was undertaken on the one-inch to one-mile scale by E Hull during the 1850s; it was published in 1855 as part of the south-western quarter of Old Series One-Inch Geological Sheet 71 (Nottingham). No geological descriptions were published to accompany these early maps. The present area was resurveyed on the six-inch scale by C Fox-Strangways between 1901 and 1902 and published as part of the New Series One-Inch Geological Sheet 141 (Loughborough) in 1904. Based on this survey, a geological account of the Loughborough district by Fox-Strangways was published in 1905. A H Cooper re-surveyed the area in 1995-6.

The Littleover area is about half rural with pasture farming along the stream flood plains and on the rising ground bordering the urban area. The bulk of the lower land is dedicated to arable farming. The outskirts of Derby are subject to continued expansion with a considerable amount of building construction. New estates are being built at Mickleover, Littleover and Sinfin. The former Pastures Hospital area [302 334] is also destined for re-development. Industry is mainly restricted to the area between Sinfin and Normanton, but even here one large industrial site has been redeveloped for housing. Compared with the situation when the late 19th Century survey was undertaken, the loss of farmland has been considerable; approximately half of the map area has been covered by development in the last 100 years.

This report is best read in conjunction with 1:10 000 Geological sheet SK 33 SW. The map indicates the outcrop limits of deposits which are for the most part concealed beneath soil and vegetation; the geological boundary lines are mostly inferred from indirect evidence such as the form of the ground surface and soil type, or are extrapolated from adjoining ground. The map is thus the subjective interpretation of the surveyors, and all geological boundaries carry an element of uncertainty. Boundaries of solid geological formations which (in the opinion of the surveyors) can be located to an accuracy of about 10 m or less on the ground, are shown as unbroken lines on these maps; all others are shown broken. It is a reflection of the poor exposure in this area that none of the solid geological lines in this area were considered to have an accurate status.

Fully attributed, digitally-produced colour copies of the 1:10 000 maps can be purchased from BGS, Keyworth. It should be noted that copyright restrictions apply to the use of these maps, or parts thereof, and to the copying of the illustrative and text material of this report.

The ground to the north of the area was surveyed by J G O Smart in 1965-1966 as overlap from the 1:50 000 Sheet 125 (Derby), it is described in the Memoir for that sheet. All the other adjoining sheets were mapped on the 1:10 000 scale in 1995-6 as part of the Sheet 141 (Loughborough) revision project. The surveyors are: SK 23 SE, A Brandon and A H Cooper; SK 33 SE, A Brandon; SK 32 NW, A Brandon. An index to the adjacent 1:10,000 geological map sheets is given in Figure 1. Reports covering contiguous 1:10,000 sheets are:

SK 23 SE	Etwall	(Brandon and Cooper, 1997)
SK 33 SE	Lower Derwent Valley	(Brandon, 1996)
SK 32 NW	Stretton and Repton	(Brandon, 1997)

Throughout this report, National Grid References are given in square brackets and all lie within 100 km grid square SK unless otherwise stated. The borehole numbers given are those of the BGS archives where they are prefixed by SK 33 SW. Borehole depths and bed thicknesses are metricated in the report even though they may have been given in feet and inches in the original logs. Lithological descriptions from older logs have also, where possible, been transposed into modern terminology.

SK 23 NE	SK 33 NW	SK 33 NE
SK 23 SE	SK 33 SW	SK 33 SE
SK 22 NE	SK 32 NW	SK 32 NE

Figure 1. Location of the area with respect to adjacent 1:10 000 mapped sheets

2.GENERAL ACCOUNT

The Mercia Mudstone Group forms the bedrock over the entire area. It is mainly composed of red and red-brown mudstones and siltstones with thin sandstones. The Cropwell Bishop, Gunthorpe and Edwalton formations are all present in the area, but they are very poorly exposed except in temporary excavations. There is very little detailed, or deep, borehole information that helps with the stratigraphy, but just to the west of the area, one deep well borehole (see Section 8), at the old Pastures Hospital, proved possible Millstone Grit at the base of the Triassic sequence. This is overlain by red sandstones that can be attributed to the Bromsgrove Sandstone Formation of the Triassic, Sherwood Sandstone Group. It is overlain by thinly bedded sandstones, mudstones and siltstones of the Sneinton Formation and laminated mudstones of the Radcliffe Formation, two units of the Mercia Mudstone which do not occur at outcrop. Above this come the formations that outcrop or form the bedrock within the area. They are the Gunthorpe Formation, followed by the Edwalton Formation (with the Cotgrave Member at its base and Hollygate Sandstone Member at its top) capped by the Cropwell Bishop Formation.

Drift deposits cover about one quarter of the area and form two contrasting terrains, although stream floodplain alluvium and head slope deposits are common to both. In the very south of the area, between Findern and Stenson, the northern flank of the Trent valley is covered by extensive patches of sand and gravel forming a flight of terrace deposits, some of which have been worked for sand and gravel. Extending from Findern, in the south-western corner of the area, to the east-north-east towards Sinfin there are deposits of till and glaciolacustrine deposits infilling a channel carved deeply into bedrock. In the northern part of the area the drift deposits are mainly restricted to patchy till capping the higher hills; alluvium and head deposits are also present. Artificial ground is widespread in the area reflecting the urban nature of the landscape. The artificial ground is divided into worked ground, made ground and landscaped ground.

	Thickness
QUATERNARY:	
Head	up to c.3
Alluvium	up to c. 4
Terrace Deposits:	
Beeston Sand and Gravel	up to c.4
Egginton Common Sand and Gravel	up to c. 5
Etwall Sand and Gravel	up to c. 2
Eagle Moor Sand and Gravel	up to c. 1
River Terrace Deposits, Undifferentiated	
Findern Clay	up to c. 19
Oadby Till	up to c. 15
TRIASSIC:	
MERCIA MUDSTONE GROUP:	c. 190
Edwalton Formation	45
Cotgrave Sandstone Member	c. 2
Gunthorpe Formation	c. 70
Radcliffe Formation	c. 10-11
Sneinton Formation	0-24
SHERWOOD SANDSTONE GROUP:	
Bromsgrove Sandstone Formation	10-47
UPPER CARBONIFEROUS:	
MILLSTONE GRIT GROUP	more than 17

Table 1. Geological sequence proved in the vicinity of sheet SK 33 SW (Littleover), giving approximate thicknesses in metres. Strata below the Gunthorpe Formation of the Mercia Mudstone Group are known only from boreholes. (NB some of these subdivisions may be revised at a later date, and may thus appear with different names on subsequent published 1:10,000 or 1:50,000 maps).

3. UPPER CARBONIFEROUS ROCKS

Carboniferous rocks underlie the Triassic over the entire area but have only been proved in one borehole.

3.1 Millstone Grit Group

The Pastures Hospital Borehole SK23SE/19, situated 300 m west of the area [2968 3317], with a surface elevation of about 91 m AOD (Section 8), proved 17.45 m strata interpreted as part of the Millstone Grit Group. The drilling record dating from 1899-1901 recorded interbedded 'red granite', 'blue shale' and 'grey rock' below 'red sandstones' and 'marls' (Sherwood Sandstone Group) below a depth of 157.28 m, or about 66 m below OD. The descriptions are equivocal but the probable interpretation is that these strata represent red and grey, coarse-grained, arkosic sandstones interbedded with dark bluish grey, shaly mudstones.

4. TRIASSIC

4.1 Sherwood Sandstone Group

Strata belonging to this group (Warrington et al., 1980) have been proved just west of the area in the Pastures Hospital Borehole (Section 8). The dominantly red, and partly grey, sandstone sequence from 141.73 m to 157.28 m, overlying the supposed Millstone Grit Group, is non-pebbly and contains no conglomerates. On this basis it can be assigned to the Bromsgrove Sandstone Formation.

4.1.1 Bromsgrove Sandstone Formation

This unit, named by Warrington et al. (1980), was formerly referred to as 'Lower Keuper Sandstone' (e.g. Fox-Strangways, 1905), and elsewhere is usually characterised by thick-bedded, fine- to medium-grained, pebble-free, fluviatile sandstones and subordinate interbedded mudstones and siltstones. The only information relevant to this area comes from the Pastures Hospital Borehole situated just to the west of the sheet. The lower 15.55 m thick part of the Triassic sequence assigned to this formation (from 141.73 m to 157.28 m depths) is dominantly composed of 'red sandstone' with some 'grey rock' (siltstone?) and about 21% 'marl'. The Bromsgrove Sandstone is considered to be mainly of Anisian age (Oral communication, G W Warrington, 1997).

4.2 Mercia Mudstone Group

The Mercia Mudstone Group was defined by Warrington et al. (1980) with divisions based on those of Elliot (1961). These divisions were further modified by Charsley et al. (1990). The mudstone-dominated, readily degradable strata of this group form rockhead over the entire Littleover area. In the south much of the unit is overlain by superficial deposits while to the north it is covered by urban development. There is consequently little landform feature control on the geology. Information on the disposition of the strata at surface mostly comes from borehole data and temporary excavations associated with major construction projects such as the Derby Southern Bypass and Derby Hospital. These, and stratigraphical information proved elsewhere in the Loughborough district allow the stratigraphy to be delineated.

4.2.1 Sneinton Formation

The Sneinton Formation (Charsley et al.,1990) is approximately equivalent to the former Keuper Waterstones (e.g. Lamplugh et al., 1908). In the Loughborough district it comprises an heterogeneous sequence at the gradational base of Mercia Mudstone Group. This is composed mainly of reddish brown and pale green, thinly interbedded and interlaminated mudstones, siltstones and very fine-grained sandstones. Micaceous laminae, ripple marks and cross-lamination are characteristic features.

Because of the above mentioned difficulties, thickness estimates for the formation, of 0-24 m in the area, are considered unreliable. Very little insight into the nature of the formation can be gained from the nearby Pastures Hospital Borehole (Section 8). The 9.14 m thick interval most probably equivalent to the Sneinton Formation (from 141.73 m to 132.59 m depths) is recorded as 'grey rock', 'sandstone' and 'marl'. Within the Loughborough and Nottingham districts the unit is considered to range in age between Anisian and Ladinian (Oral communication, G W Warrington, 1997).

4.2.2 Radcliffe Formation

In the surrounding region this formation (Elliott, 1961) comprises laminated, reddish brown, pink and greyish green mudstones and siltstones with a few, very fine-grained sandstones. Wireline log signatures in the deeper boreholes in the Nottingham and Loughborough districts show that the formation is uniform and maintains a thickness of around 10 m. The unit is considered to be Anisian to Ladinian in age (Warrington, oral communication 1997).

Just west of the present area, the formation is tentatively recognised in the Pastures Hospital Borehole (Section 8). Here a 10.82 m thickness of 'sandstone', 'marl' and 'grey rock' with a little 'red spar' (from 121.77 m to 132.59 m depth) may belong to the formation.

4.2.3 Gunthorpe Formation

The Gunthorpe Formation (Charsley et al., 1990) is equivalent to both the Carlton and Harlequin formations of Elliott (1961) and consists of interbedded reddish brown and greyish green mudstones, silty mudstones and siltstones. These lithologies are commonly massive, but contain intercalations of fine-grained sandstone and indurated dolomitic siltstone which occur at many stratigraphical levels. Wireline log signatures of the more recent deeper boreholes across the Loughborough district establish that a fairly uniform thickness of approximately 70 m is maintained. The formation is thought to be largely of Ladinian age (Warrington et al., 1980).

In the present area the Gunthorpe Formation is inferred to form the bedrock over much of the south-western part of the sheet. The mapped boundaries, apart from where the Cotgrave Sandstone Member is tentatively identified, are faulted and entirely conjectural. There are very few noteworthy exposures, the weathered mudstone-dominant strata mostly being seen at surface as red clay. In most boreholes, the unit is recorded simply as red marl. The best descriptions are in site investigation boreholes along the new Derby Southern Bypass. The mudstones and siltstones have been excavated for marl at numerous 'marl pits' across the outcrop (see Economic Geology section).

Details: outcrop

The Gunthorpe Formation was exposed in excavations for the Derby Southern Bypass where it cuts through the hill [3257 3042 to 3410 3000] between Stenson and Stenson Fields. The strata here are disposed in an open anticline with the beds being gently eastwards-dipping in the west of the cutting, horizontal in the central part and north-east dipping in the east of the cutting. At the western end of the cutting the sequence includes a green-grey mudstone bed which acts as a marker horizon within the cuttings and ditches associated with the road. Just north of Stenson [3253 3042] the westerly dipping sequence was:

	Thickness, metres
OADBY TILL Clay, brown, with abundant rounded and sub-rounded pebbles of quartzite , quartz and a few of chert and flint.	0.4
GUNTHORPE FORMATION: Clay, red-brown, mottled green-grey in patches towards the base of the unit amalgamating into a bed about 0.2 m above the base of the unit.	1.2
Siltstone and mudstone, grey-green with one very thin 0.02-0.03 m bed of very fine-grained grey-green sandstone with salt pseudomorphs.	0.15
Mudstone, red-brown, weathered.	1.3
Siltstone, green-grey.	0.05
Mudstone, red-brown.	1-2

In the middle part of the section, the excavations for the new fly-over leading to Stenson showed the following horizontally bedded sequence in the Gunthorpe Formation that could not be examined closely:

	Thickness, metres
No exposure, concealed by supporting shuttering	5.0
GUNTHORPE FORMATION: Clay, red	1.0
Sandstone, pale green, thin-bedded	0.15
Mudstone and siltstone, red	1.2
Sandstone, green-grey with some red mudstone	0.3
Siltstone and mudstone, red, blocky	c.2.0

Between the section described above and the one described below [3313 3035 to 3322 3034], the strata dips gently with the hill and shows slight undulations, probably due to cryoturbation. The sequence here is mainly red-brown mudstone weathered to clay. The beds include three laminated to very thinly bedded pale grey sandstones.

In the eastern part of the bypass cuttings the excavation for a drain sump [3323 3033] exposed the following section dipping at about 2 degrees to the north-east;

	Thickness, metres
OADBY TILL Clay, brown with pebbles and cobbles	0.4
GUNTHORPE FORMATION: Clay, red-brown	0.4
Sandstone, pale grey, very fine-grained, laminated to very thinly bedded	0.2
Clay, grey-brown	0.3
Clay, red-brown	0.7

Lying to the north of the Derby Southern Bypass, a flat area of lacustrine deposits is drained by a small un-named drain. Along this drain the stream has cut down to bedrock and there are numerous small exposures [3368 3046 to 3435 3033]. Many of these exposures are of clay derived from weathered red-brown mudstone. Farther east [3400 3049] the mudstone includes several very thin beds of very fine-grained sandstone with signs of disturbance (cryoturbation?) and a gentle dip to the east. Nearby [3409 3043], the stream section exposes red-brown and grey mottled mudstone with numerous laminated beds of very fine-grained pale grey siltstone and sandstone. These beds have ripple-marked surfaces and numerous halite pseudomorphs. The dip of the sequence here is 2 degrees to the east, but just east of here [3421 3033 and 3435 3033] lithologically similar beds are horizontal.

During the resurvey, considerable building development was taking place to the south and west of Sinfin, within the area called Stenson Fields. In the excavations for some of the houses small temporary sections were visible. Mostly these sections exposed red-brown mudstone with numerous laminae of pale greenish grey siltstone and sandstone with salt pseudomorphs. A section for the foundations of a new church [3341 3112] showed clay with pebbles to 0.3 m resting on red-brown clay to 0.8 m. The bottom of the trench was composed of a hard stratum of laminated green-grey sandstone. In the excavations for one house [3367 3125] the trenches showed made ground on a bed of pale greenish grey sandstone with abundant salt pseudomorphs. Beneath this there was 0.4 m of red-brown clay.

Details: boreholes

The Pastures Hospital Borehole (Section 8) was drilled in the bottom of an existing well and penetrated white sand and marl possibly assigned to the Cotgrave Member. Below this, the Gunthorpe Formation comprised 73.92 m of mainly 'grey rock', 'red and grey marl' and 'marl' with subordinate amounts of 'red sandstone', 'blue shale' and 'rocky marl'; this sequence also included thin seams of white spar' (gypsum?) In the upper 15 m.

The Gunthorpe Formation was penetrated by about 90 boreholes and trial pits along the Derby Southern Bypass transect, most of these holes are 4 to 8 m deep, but a few are 15-30 m deep; reference to the BGS borehole archives should be made for details. The Gunthorpe Formation is typically composed of deeply weathered, mainly red, mottled green, thinly to thickly interlaminated, silty mudstone and siltstone with numerous very fine-grained grey-green sandstone and siltstone beds. These are generally concealed below various cryoturbated superficial deposits. Gypsum veins and crystals are also present in many of the boreholes.

One of the deeper boreholes SK33SW/164 [3293 3038] for the Derby Southern Bypass showed the following sequence near Stenson:

	Thickness, metres
Topsoil	0.30
Clay, brown	0.20
Clay, red-brown, firm (extremely weathered Mercia Mudstone Group)	1.15
Clay, red-brown, stiff, with sporadic beds of sandy grey marl and siltstone	5.35
Clay, red-brown, stiff, with beds of sandy grey marl	5.00
Sandstone, light grey-green, silty and fine-grained	0.31
Mudstone, red-brown, weak	0.69
Clay, red-brown, silty, soft	2.10
Mudstone, red-brown, very weak	0.55
Mudstone, grey-green, laminated, weak	0.77
Mudstone, red-brown, weak	1.38
Mudstone, red-brown, very soft, recovered as clay from the borehole	1.80
Mudstone, red-brown, very weak,	0.30
Mudstone, red-brown, moderately strong, some very thin gypsum veins	2.00
Mudstone, red-brown, very weathered, recovered as clay	0.30
Mudstone, red-brown, weakly laminated	1.70
Mudstone, red-brown, weak, thinly laminated	3.10

Mudstone, red-brown, weathered to clay	1.44
Mudstone, red-brown, thinly bedded	1.56
Borehole completed at a depth of 30.30 m	

4.2.4 Edwalton Formation

The outcrop of the Edwalton Formation (Elliot, 1961) extends across the northern part of the area through the Mickleover to Littleover and Normanton. It comprises mainly reddish brown and greyish green siltstone and mudstone which is typically blocky or very poorly laminated. Thin beds of fine-grained sandstone occur at many levels within the formation, but thicker sandstone beds are concentrated at the base and top of the formation where they form the Cotgrave and Hollygate Sandstone members. Wireline log signatures across the region suggest that the stratigraphy is persistent and the thickness maintains about 45 m. The formation is mostly Carnian in age, although the basal part is possibly Ladinian (Oral communication, G W Warrington, 1997).

The Cotgrave Sandstone Member is tentatively recognised forming the base of the formation between Findern and Mickleover. The Hollygate Sandstone Member is inferred to be present crossing the central part of the area. The mudstones of this formation have been dug from numerous small 'marl pits' dotted over the outcrop, and a former brick clay pit in Normanton (see Economic Geology section).

Details: outcrop

The only place where the formation was well-exposed was in the excavations for the extension to the Derby City Hospital [337 347]. Here the sequence showed red-brown silty mudstone with numerous thin grey-green sandstone beds. The total section exposed about 12 m of strata dipping to the SW at between 2 and 3 degrees towards 230- 250. The highest part of the section exposed was in the south-western corner of the site compound [3236 3468], an area designated to be a car park. Between here and the eastern part of the section [3292 3467] the sequence was:

	Thickness, metres
Made ground (western end of section), sandy clay, red-brown, with abundant pebbles and cobbles of quartzite, quartz and a few flints, (east of section), poorly exposed	0.5-1.5
GUNTHORPE FORMATION:	
Siltstone, red-brown, poorly exposed and weathered	0.5
Sandstone, pale grey, one bed up to 0.06 m with several 0.02 m thick, very fine-grained with numerous very small (1 mm) holes possibly after salt dissolution	0.11
Siltstone, red-brown, fairly hard and blocky	0.30
Sandstone, pale grey, very fine-grained laminated and very thinly bedded	0.15
Siltstone, red-brown, poorly exposed	0.14
Sandstone, pale grey, very fine-grained in beds up to 0.08 m thick, plus numerous partings and beds of red-brown siltstone forming about 20-30% of the sequence	0.39
Siltstone, red-brown, poorly exposed	0.30
No exposure	0.50
Hardstanding level at base of section 89.9 m above OD	

Below this section there was approximately 2 m of no exposure with mudstone exposed approximately in this interval nearby. Below this unexposed interval was a further section, immediately next to the new rear entrance bridge into the building [3285 3479]; this showed:

Top of section c. 87.6 m above OD	Thickness, metres
Mudstone, red-brown with abundant siltstone and sporadic very fine-grained sandstone laminae, all moderately weathered	0.99
Siltstone and mudstone, red-brown, in thin beds and laminae, some of the siltstone laminae contain voids up to 1 mm in diameter	0.57
Siltstone, grey-green	0.03
Siltstone and mudstone red-brown, in thin beds and laminae, some of the siltstone laminae contain voids up to 1 mm in diameter	0.4
Sandstone, pale greenish grey, very fine-grained, bedded in units 0.02-0.04 m thick, some cemented, some friable	0.14
Siltstone, red-brown, blocky with traces of bedding; slightly micaceous	0.69
Sandstone, pale greenish grey and brownish grey, very fine-grained, slightly lenticular bedding with cross-lamination	0.02-0.06

Siltstone, red-brown, blocky with two 0.02 m thick beds of greenish grey siltstone	0.32
Siltstone, red-brown, slightly sandy, fairly massive and homogeneous	0.14
Siltstone, red-brown, slightly sandy in places, well-laminated with a few beds to 0.04 m	0.27
Sandstone, pale grey very fine-grained with irregular cavities to 5 mm (after salt?)	0.02-0.04
Siltstone, red-brown with red-brown mudstone, weakly laminated with traces of grey-green siltstone	0.29
Sandstone, pale grey and brownish grey, very fine-grained, mainly in beds 0.03-0.06 m with about 30% of interbedded red-brown siltstone. The sandstone has numerous open voids (after salt?)	0.38
Siltstone, red-brown, laminated to very thin bedded with porous layers possibly after salt crystals; base of this section at c. 83.6 m above OD	0.20
No exposure, section extrapolated to sequence exposed in drain sump	c.0.50
Mudstone, red-brown, silty, weakly-bedded with very thin beds and laminae of very fine-grained red-brown sandstone, forming about 5% of the unit	0.70
Sandstone, pale grey, very fine-grained, in laminated and very thin beds forming 55% of the unit, interbedded with siltstone, red-brown also laminated and very thin-bedded; bottom of section	0.95

Another exposure on a new building site at Littleover [c.329 327] showed 0.6 m of sandstone and mudstone beds with salt pseudomorphs, similar to that seen at the hospital, also dipping to the SW at 6 degrees to 234.

Cotgrave Sandstone Member

The Cotgrave Sandstone is thought to form a bench-like topographical feature [c. 296 317] to the west of the area. The feature is covered in reddish brown and pale green, fine-grained sandstone brash. Some of the sandstone slabs exhibit ripple marks and hopper casts of halite. This feature is difficult to trace eastwards through the area, and the position of the sandstone is conjectural.

Details: boreholes

From the mapped position of the Cotgrave Member, and the elevation of the Pastures Hospital Borehole, just west of the area (Section 8), the position of the member in the borehole can be inferred. The strata at this level, penetrated at the bottom of the well into which the borehole was drilled, included white sand and marl that was penetrated for 1.83 m between the bottom of the well at a depth of between 46.18 m and 47.86 m.

Hollygate Sandstone Member

This member corresponds to the 'Hollygate Skerry' of Elliott (1961), and is the stratigraphically highest subdivision of the Edwalton Formation. Warrington et al. (1980) referred to the unit as a member but did not precisely define it: they tentatively assigned it a Carnian age. The thickness, lithology and age of this member invite correlation with the Arden Sandstone of the West Midlands (e.g. Old et al., 1991, p.32). Within the area the Hollygate Sandstone Member is inferred to be present across the central part of the area where it forms a capping to the flank of the rising ground occupied by the Edwalton Formation. There are no exposures of the sandstone and its position is highly conjectural.

4.3.5 Cropwell Bishop Formation

The name Cropwell Bishop Formation was designated by Charsley et al. (1990) for the single mappable formation between the top of the Edwalton Formation and the base of the Blue Anchor Formation. A probable Norian age is suggested for equivalent beds elsewhere (Oral communication, G.W. Warrington, 1996). Within the present area the Cropwell Bishop Formation is inferred to be present in a swath extending from the south-east corner of the sheet to the central part of the sheet; this outcrop is largely inferred from information derived from the adjacent maps. The formation comprises mainly red-brown mudstone and siltstone with a few very thin silty sandstone beds. Gypsum is proved in the formation outside of the area. At and near to surface most of the gypsum has been dissolved. The soft nature of the formation makes it easy to erode and it forms some of the lowest ground within the area. The full thickness of the formation is not proved within the area, but in other areas within the district the formation reaches a thickness of nearly 70 m.

Details:

North-west of Sinfin, adjacent to the railway, an inaccessible section at the south-west end of an excavation [3378 3179] for a storm overflow tank showed a temporary section. This revealed up to 1.5 m of glacial till overlying up to 3 m of red-brown mudstone with a few thin beds of grey sandstone. These beds all dipped gently to the south. At the north-east end of section the till was 2.5 m thick overlying about 2 m of red-brown and grey mottled mudstone with numerous joints and some slightly polished surfaces.

5. QUATERNARY

This introduction to the Quaternary deposits and the chronology of the Trent river terraces is largely the work of A. Brandon; it is based closely on the description of the adjacent area by Brandon and Cooper (1997).

The landscape and drainage of the area is largely a legacy of various erosional and depositional events which occurred in response to the oscillating climatic conditions of the Quaternary Period. Fluviatile sediments of the River Trent cover the southern part of the area, the older sedimentary deposits occurring as successively higher terrace remnants. Glacigenic deposits predominate in the north of the area where they mainly comprise relict patches of till on ground generally higher than 80 m above OD. Glacigenic and glaciolacustrine deposits also fill a deep palaeochannel cut into the Mercia Mudstone Group in the southern part of the area. This channel is thought to have been a subglacial tunnel valley.

5.1 'Older Drift'

The region was not glaciated during the late Devensian (Oxygen isotope stage 2) when ice sheets overran much of northern England. Instead, the glacigenic deposits which occur both as dissected cappings on the higher ground and as an infill of a palaeochannel cut through bedrock (see below) have been collectively referred to as 'Older Drift'. These deposits are currently thought to be Anglian in age (Oxygen isotope stage 12), dating back some 500 000 years BP, and indicate a greater overall amplitude of relief at the end of that glaciation than that of the present day. The ice sheets at glacial maximum overwhelmed the entire region (see below). During glacial meltout, meltwater streams deposited glaciofluvial sand and gravel along their courses. The main trunk routes developed into the rivers Trent and Dove, which have subsequently eroded and deepened their valleys to leave the glacial deposits as high level erosional remnants. The glacigenic deposits were subsequently so strongly affected by later periglacial degradational processes (frost shattering and mass movement), particularly in the late Devensian, that they now lack any constructional morphology of glacial origin.

5.1.1 Oadby Till

During the Anglian glaciation of Central England ice-flow was initially from the north-west with Pennine Ice advancing from the north. This was succeeded by ice that moved across from the snow fields of Scandinavia and eastern Scotland (e.g. Rose, 1994). These separate ice advances result in two basic types of till in the Loughborough - Derby region, namely a till of northern 'Pennine Drift' provenance, and one of eastern 'Chalky Boulder Clay' provenance, equivalent to the Thrussington and Oadby tills respectively of Leicestershire (Rice, 1968). These correspond respectively with the Early and Middle Pennine boulder clays and Great Chalky Boulder Clay of Deeley (1886). There is no Thrussington Till preserved in the Littleover area. The stone clasts in the local Oadby Till include chalk, flint, oolitic limestone, Liassic bioclastic and argillaceous limestones, Liassic fossils including pyritised ammonite fragments and bivalves (particularly *Gryphaea*), black fissile shale and calcilutite limestones from the Penarth Group, as well as abundant Triassic lithologies more typical of the northern till suite. Regardless of the ice flow direction and provenance of the farther travelled stones, the basal 1 m or so of the till typically incorporates local bedrock from the Mercia Mudstone and the matrix may have a red coloration.

During glacial advance, the local base level of the area was probably considerably higher than it is in the Trent valley at present; it may have approached 70 m above O.D. Consequently, the Oadby Till, (except for that deposited in tunnel valleys beneath the ice - see below), is generally only found capping hills above this height, where it is all considerably dissected.

Oadby Till also partially infills the Elvaston Palaeochannel, which enters the south-western corner of the map sheet and extends to the east-north-east onto sheet SK 33 SE. In tunnel valley situations, much of what has been determined as till in boreholes and poorly exposed sections may in fact be very stony, unlaminated, glaciolacustrine clay.

Details:

Small patches of Oadby Till occur scattered throughout the northern half of the area. The most extensive areas occur in the north of the area capping the hills around the central parts of Mickleover and Littleover. The till around here comprises brown and red-brown clay and sandy clay with abundant pebbles and cobbles mainly of quartzite, but with some quartz pebbles and flints. Oadby Till is inferred to occur in the basal part of the Elvaston Palaeochannel.

5.1.2 Findern Clay

The Findern Clay is the name proposed by Brandon & Cooper (1997) for the glaciolacustrine deposit infilling the Elvaston Palaeochannel. It has a low height relative to the level of Eagle Moor Sand and Gravel part of the Trent valley sandur formed during the meltout phase of the Oadby Till glacier. This relationship and the general lack of coarse-grained clastic sediments in the palaeovalleys suggest that the Findern Clay must have formed subglacially from waters ponded within tunnel valleys.

Details:

Elvaston Palaeochannel
The channel is a prominent Quaternary feature on Sheet 141 (Loughborough). It has been traced along a slightly sinuous, east - west course for about 19 km while maintaining a width of only 0.4 - 1 km. It first appears in the east a short distance to the east of the M1 crossing of the River Trent [465 310] at Sawley (Brandon, 1996, figure 5). From there it follows the Derwent valley and then crosses the Derwent/Trent interfluve from Allenton to the Findern area (Brandon, 1996; Brandon & Cooper, 1997) from where it deepens on entering the north-eastern corner of Sheet SK 22 NE and the adjoining parts of Sheet 32 NW and SK 23 SE before closing.

Data on the channel infill deposits in the present area derive from boreholes and personal observations during excavation of cuttings along the route of the Derby Southern Bypass, and from confidential site investigation boreholes at the Toyota car factory. In this area and the adjoining part of SK 23 SE, the stratigraphy of the infill deposits beneath a partial cover of Etwall Sand and Gravel, Egginton Common Sand and Gravel, Oadby Till and Lacustrine Deposits is fairly clear. The major deposit is a glaciolacustrine unit, termed the Findern Clay. This is generally underlain by a relatively thin deposit of lower Oadby Till which rests directly on bedrock. In places along the incised channel on sheets SK 23 SE and SK 22 NE, an upper Oadby Till is preserved in large pods irregularly overlying the Findern Clay.

The lower Oadby Till is generally a stiff, compact, consolidated, dull brown, stony, clay/silt-based diamict with a variable, but generally moderate, stone content. The stones include flint, chalk, Triassic quartzite, coal and sandstones from the Mercia Mudstone Group. No sections in the lower Oadby Till were seen in the Elvaston Channel during the survey of the Littleover area, nor was it penetrated by the deeper boreholes connected with the bypass route. It was proved on sheet SK 22 NE and may be present at the base of the palaeochannel in the present area.

The Findern Clay was exposed to the west of the area on sheet SK 23 SE (Brandon and Cooper, 1997), in excavations during construction of the Derby Southern Bypass. It was also penetrated in numerous boreholes within and adjacent to the present area along the bypass transect. To the west and east of the area the undisturbed, unweathered deposit comprises medium to dark grey, brownish grey or greyish brown clay and silt. The lower parts of the deposit are commonly well laminated, typically with alternating darker grey clay and paler brownish grey or brown silt laminae. The laminae are generally horizontal or subhorizontal. Other parts of the deposit are only poorly laminated and some beds, up to c. 4 cm thick, appear massive. The stone content also varies greatly. Much of the deposit is stoneless but on some levels layers of stones occur which are interpreted to be dropstones from the sole of the glacier above the tunnel valley. The stones are of the same suite as found in the Oadby Till and chalk and flint stones are abundant. The stones may occur as a single layer along one laminae or multiple layers through several metres of deposit. In the latter case, in the absence of conspicuous lamination, the deposit appears till-like. For this reason, it is commonly very difficult to separate Findern Clay from Oadby Till in the logs of the bypass boreholes. It is possible in some situations, that what has been determined to be Oadby Till is in fact very stony glaciolacustrine clay.

In the adjacent area (Brandon, 1997) noted that the uppermost c. 3- 4 m of the deposit are severely affected by post-depositional processes, particularly cryogenic involution. The clay is commonly weathered to a dull reddish brown colour mottled with pale bluish or greenish grey. Irregular domed masses or pods of the deposit, up to 15 m across, have been remobilised and extend upwards through overlying Etwall Sand and Gravel, commonly to reach as far as the surface. These upper parts are not laminated and are commonly brecciated, even when not affected by involution. The breccia comprises massive angular pieces of poorly laminated clay set in a stiff remobilised clay. Nodules of race occur sporadically in the upper parts of the deposit. This upper part is also cut by numerous sub-vertical fissures which are lined with pale grey, slickensided clay.

Lenticular bodies of generally reddish brown, fine-grained, cross-bedded, laminated sand, with conspicuous coal debris, occur within the Findern Clay at several places to the west of the area. The sand is thought to be fluvially deposited in minor channels incised into the lacustrine clay; similar sand also occurs at the top of the Findern Clay in the Findern area, both within the present area and on sheet SK 32 NW.

Details, boreholes:

Borehole SK 33 SW/159 [30671 30016]: Ground level 47.05 m above OD.	Thickness, metres
Topsoil	0.30
BEESTON SAND AND GRAVEL: Gravel, brown, fine to coarse-grained, with some quartzite and flint in a stiff brown clay matrix	0.60
Sand , fine to coarse-grained, with gravel containing clasts of quartzite, sandstone and siltstone	4.60
FINDERN CLAY: Clay, dark brown, stiff, with occasional fine to coarse gravel including quartzite and chalk	2.80
Gravel, dark brown, sandy and clayey	0.40
Sand, brown, silty, fine to coarse-grained with a little gravel	3.25
Clay, very stiff, dark brown, with some subangular to rounded fine gravel predominantly of chalk	0.55
Sand, brown, fine to coarse-grained with a little fine to medium gravel	0.95
Clay, dark brown, stiff, sandy with a little gravel	0.65
Sand, brown fine-grained and silty	0.80
Clay, brown, stiff, with fissures and sporadic partings of brown silty fine-grained sand	1.10
Clay, dark brown, hard with a few partings of brown silt and fine-grained sand	8.10
Gravel, fine to coarse-grained, angular to rounded	1.00
GUNTHORPE FORMATION: Siltstone, grey-green weak and weathered	0.40
Sandstone, pale grey-green, fine-grained, with a few beds of mudstone	2.10
Mudstone, red-brown, weak, thinly laminated with a few gypsum crystals	2.90
Bottom of borehole, terminated at a depth of 30.5	

To the east of the area exposures of the Findern Clay were recorded in the trenches associated with a new stormwater sewer scheme in the north-west of Sinfin. Here [3374 3210 and 3379 3226] the deposit consisted of smooth, stiff, greyish brown clay exposed to a depth of about 3 m. This deposit has a higher elevation than the lacustrine deposits filling in the low ground immediately to the west. The Findern Clay is stiffer and more consolidated than the lacustrine deposits. Another section in the sewer trenches at Sinfin [3404 3202] exposed very thin lacustrine clay resting on the underlying Findern Clay. This trench showed about 0.5m of soft clay (lacustrine deposits) overlying 2m of still grey-brown slightly laminated clay (Findern Clay).

5.2 River Terrace Deposits: terrace deposits of the River Trent

During mapping of the Loughborough geological sheet considerable changes have been made by A. Brandon to the nomenclature of the local river deposits in an attempt to facilitate terrace correlation within and between river valleys. In this new scheme, the terrace deposits of each of the three major river valleys, i.e. those of the Trent, Derwent and Soar, are given completely separate sequences of names. Wherever possible, these names are taken from, or are modified versions of, a formerly established nomenclature. The deposits are given lithological qualifiers, for example *Etwall Sand and Gravel*. To avoid confusion, the surfaces of river terrace deposits are named differently, as in *Etwall Terrace*. Conversely, in previous works on the deposits of the local rivers (e.g. Pocock, 1929; Swinnerton, 1937; Clayton, 1953; Posnansky, 1960; Rice, 1968), a name such as *Beeston Terrace* was applied to both the terrace feature and its underlying deposits. Moreover, the terraces/deposits of the Trent and lower Derwent generally shared a common nomenclature following Swinnerton (1937). The proposed terrace correlations of the local river valleys are shown in Table 2. The terrace names used in this report are those of Brandon (in Bowen et al., in press), but the formal member and formation names suggested by him are not adopted here, since they do not fit with the current BGS classification which employs lithological descriptors.

Quaternary stage	Approx. age of commencement in 1000 years BP	Oxygen isotope stage	LOWER DERWENT	LOWER SOAR	TRENT (above Nottingham) and LOWER DOVE	TRENT (Newark - Lincoln)
Flandrian	10 K	1	Floodplain deposits Ambaston Terrace Deposits *	Floodplain deposits	Floodplain deposits Hemington Terrace Deposits *	Floodplain deposits
Devensian	26 K	2		Syston Sand and Gravel *	Holme Pierrepont Sand and Gravel *	Holme Pierrepont Sand and Gravel *
	65 K	3				
	80 K	4	Allenton Sand and Gravel	Wanlip Sand and Gravel	Beeston Sand and Gravel	Scarle Sand and Gravel *
	115 K	5d-a				
Ipswichian	128K	5e	Crown Inn Beds *			
Wolstonian	195 K	6	Borrowash Sand and Gravel	Birstall Sand and Gravel	Egginton Common Sand and Gravel	Balderton Sand and Gravel *
'Ilfordian'	240 K	7				Thorpe on the Hill Beds *
Wolstonian	297 K	8	Ockbrook Sand and Gravel	Knighton Sand and Gravel	Etwall Sand and Gravel	Whisky Farm Sand and Gravel
Hoxnian	330 K	9				
Anglian	367 K	10	Eagle Moor Sand and Gravel (in part?)			
Hoxnian	400 K	11				
Anglian	500 K	12	Eagle Moor Sand and Gravel Oadby Till Thrussington Till	Oadby Till Thrussington Till Hathern Gravel	Eagle Moor Sand and Gravel Findern Clay Oadby Till Thrussington Till	Eagle Moor Sand and Gravel Skellingthorpe Clay

Table 2. Correlation of the terrace deposits of the rivers Trent, Soar, Derwent and Dove (from Brandon and Cooper, 1997).
* signifies that deposit is ascribed to an oxygen isotope stage on basis of biostratigraphy, absolute age determination, detailed stratigraphy and sedimentology or presence of palaeosol etc. Other deposits are ascribed to a stage mainly on the basis of altimetry.

The coarse-grained (sand and gravel), sheet-like spreads in the Trent basin typically represent successive cold stage aggradations on base level valley braid plains when deposition was optimised (see Table 2). Most incision seems to have occurred during intervening interglacial periods during single thread, meandering river regimes. For this reason, apart from those of the Flandrian, interglacial deposits are not well represented in the East Midlands river

The terraces are nearly planar surfaces much dissected by later fluvial erosion, the degree of dissection being generally related to the age of the underlying fluvial deposits. The terraces do not represent the original depositional surfaces (see Head section), rather the terrace surfaces result from modification and degradation through various post-depositional erosional, periglacial and depositional processes. Cryoplanation and general mass movement have been particularly disruptive, these presumably cumulative effects acting during all subsequent stadial stages so that their severity depends again on the age of the underlying fluvial deposit. The post-depositional processes result in head-capped terraces sloping gently away from the valley flanks with the underlying fluvial deposits cryogenically involuted to varying degrees. The three older deposits, namely the Eagle Moor, Etwall and Egginton Common sands and gravels, are typically severely and spectacularly involuted down to several metres below the terrace surfaces, and this disturbance commonly also involves the underlying bedrock. These terrace deposits are generally overlain by complex, clayey, geliflucted Head deposits, which can in turn be epigenetically deformed. In spite of the post-depositional modifications to the older terrace surfaces, each sand and gravel spread remains stratigraphically discrete; it is separated from those adjacent by a rock step, and, allowing for any post-depositional disturbance, has a more or less graded flat base which falls steadily and systematically down river, allowing a long river profile to be constructed (see Brandon, 1996, figure 6 for the Derwent terraces; Brandon 1997, figure 5 for the Trent terraces). Brandon showed that the base levels, represented by the terrace deposit thalwegs, are more or less parallel to each other over the stretches of the rivers so far studied in the Trent basin. These figures also show that base levels fell regularly by approximately 7 m between each successive cold stage.

Brandon observed that in the Trent basin, outside the limits of the Late Devensian ice sheet, terrace deposits that are older than late Devensian nearly always occur on the northern flanks of valleys. This observation accords with the presence of the numerous terraces along the southern edge of the area. No systematic lithological clast analyses of the terrace deposits has been undertaken and proportions of the various lithologies are based on field assessment. It is apparent that all the terrace deposits of the Trent contain a similar assemblage of main clast lithologies (see also Posnansky, 1960). The clasts in the terrace deposits are derived either directly from the erosion of bedrock or reworking from an older glacigenic, terrace or head deposit.

The gravels of the pre-Late Devensian terrace deposits have been subject to various cryogenic and leaching processes so that any unresistant rocks that were originally deposited in the gravels, such as calcareous lithologies and mudstones, are now rarely preserved. The most durable rock types which form the bulk of the gravels are, in order of decreasing abundance, Triassic quartzite and quartz (derived largely from the pebble beds), flint and chert. It is apparent that over time the flint clasts are increasingly frost shattered and mechanically broken down into smaller fragments relative to the exceptionally tough, unyielding Triassic quartzite and quartz clasts. Thus, the younger a pre-Late Devensian terrace deposit is, the higher the flint:Triassic clast ratio would be expected to be in counts undertaken on the small pebbles.

5.2.1 Eagle Moor Sand and Gravel

This deposit was first named by Brandon & Sumbler (1988; 1991) in the Newark - Lincoln area. It is thought to be essentially the valley sandur formed during the meltout phase of the Oadby Till sheet glacier. As such, its thalweg (Brandon, 1996, Figures 5 & 6) represents the base level during the final meltout phase of the glacier as the Trent and Dove valleys were initiated. For this reason it is dealt with in this report, and on the accompanying map, as a river terrace rather than glacial deposit. However, as in the case of the analogous Late Devensian Holme Pierrepont Sand and Gravel, it is both a river terrace deposit and a glaciofluvial sheet deposit. It generally occurs flanking valleys as isolated high level remnants, but typically at a slightly lower altitude than the relict Oadby Till outcrops. It was part of Fox-Strangways (1905) 'High Level Valley Gravel', denoted as 'Old Valley Gravel' on the original 1905 edition of the one-inch Sheet 141 (Loughborough). This was modified to 'Fluvio-glacial Gravel' on later editions of the map. The deposits at Etwall and Burnaston House (Little Derby) were included in the highest 'Hilton Terraces' (e.g. Posnansky, 1960, pp. 297-299).

Relative to the lower terrace deposits, the few isolated remnants of Eagle Moor Sand and Gravel span a greater height range. This could reflect irregularities in the immature land surface at the end of the Anglian glaciation or it might be due to more than one cold stage aggradation being represented (see Table 2).

Details:

The only remnant of the Eagle Moor Sand and Gravel in the present area is situated to the west of Findern [302 307]. In a ditch section [3037 3066 to 3044 3058] the deposit comprises up to 1m of slightly clayey orange-brown sand with abundant Triassic derived quartzite and quartz pebbles and a few flints.

5.2.2 Etwall Sand and Gravel

This deposit was part of Fox-Strangways (1905) 'High Level Valley Gravel', denoted as 'Old Valley Gravel' on the original 1905 edition of the one-inch Sheet 141 (Loughborough). This was modified to 'Fluvio-glacial Gravel' on later editions of the map. The name Hilton Terrace was introduced by Clayton (1953) for a higher river deposit than the Beeston and Floodplain terraces (Swinnerton, 1937) and he divided the deposit into a lower and upper level. Controversy surrounds the nature of the Hilton Terrace (Rice, 1968, p. 348) with former Geological Survey practice and Posnansky (1960) preferring to associate the deposits with glacial outwash. Following mapping of the Hilton terrace deposits in the area of the Trent/Dove confluence on sheets SK 23 SE (Etwall) and SK 22 NE (Stretton), they have been found to form two distinct terraces underlain by cryogenically disturbed sand and gravel and separated by a rock step (Brandon 1996, 1997). They are here divided into the Etwall Sand and Gravel and the Egginton

Common Sand and Gravel, which correspond to the Upper and Lower Hilton Terrace deposits respectively (Clayton, 1953; Posnansky, 1960).

The thalweg and long river profiles of the Etwall Sand and Gravel in the lower Dove valley are shown in Brandon and Cooper (1997, Figure 3). Correlations with the terraces of other East Midlands river valleys, based on altimetry, are shown in Table 2.

Details:

The Etwall Sand and Gravel is present in four places within the southern part of the area. In Etwall sand was reported from excavations around the Findern village green [3084 3048] and gravelly sand was augered on the south side of the village [3093 3037]. The deposit here extends to a maximum height of about 61 m above OD with a base at 51-55 m above OD. To the east of Findern [3140 3065] a deposit of brown gravelly sand caps the hill with a base at 55-58 m and a maximum height for the top at 62 m above OD. The third area of the deposit caps a small hill between Findern and Stenson [3194 3049] and comprises brown sandy gravel with pebbles of quartzite an quartz. A section for the new Derby Southern Bypass [3192 3041] showed the feather edge of this deposit which thickened to the east; the base of the deposit here was at about 52 m above OD. The most extensive deposit belonging to this terrace caps the south side of the hill that lies just to the north of Stenson [327302]. This deposit comprises gravelly, clayey sand with pebbles of sandstone, quartz and a few large flints. The base of the deposit extends down to 50 m above OD on the south side, but is around 61 m above OD on the north side; the maximum elevation of the deposit is around 62 m above OD.

5.2.3 Egginton Common Sand and Gravel

This deposit was part of Fox-Strangways (1905) 'High Level Valley Gravel', denoted as 'Old Valley Gravel' on the original 1905 edition of the one-inch Sheet 141 (Loughborough). This was modified to 'Fluvio-glacial Gravel' on later editions of the map. Posnansky (1960, pp. 297-301, figures 4 & 5) clearly described these deposits as belonging to the lower Hilton Terrace of Clayton (1953). The long profiles and thalwegs of the Egginton Common Terrace and its deposits in the lower Dove valley are shown in Brandon and Cooper (1997; Figure 3). On altimetry, the Egginton Common Sand and Gravel is correlated with the Borrowash Sand and Gravel of the lower Derwent and the Balderton Sand and Gravel of the Proto-Trent between Newark and Lincoln (Brandon & Sumbler, 1991; Table 1). The latter is late Wolstonian (oxygen isotope stage 6) in age. It is also correlated on altimetry with the Birstall Sand and Gravel of the Soar Valley.

The largest outcrop of the Eggington Common Sand and Gravel lies to the west of the area on Eggington Common, extending from south of Hilton [260 300] to Willington [290 286]. Here the fluvial deposit mainly comprises orange-brown, strongy involuted and highly leached, coarse-grained, sandy gravel. The ill-sorted clasts, ranging to cobble grade, are mostly Bunter pebbles and frost-shattered flints. In addition, and involuted with the fluvial component, there is a stony clay component which is probably head.

Details:

The Egginton Common Sand and Gravel is present in two places within the southern part of the area. A small deposit is present adjacent to the Coles Brook, just to the south-east of Findern [3133 3023 to 3146 3027]. A ditch section alongside the Derby Southern Bypass, which was under construction, showed up to 0.7 m of orange brown very clayey pebbly sand with about a 40% stone content. This deposit has an elevation of about 48 m above OD and lies at a greater height than the Beeston Sand and Gravel immediately to the south.

The main deposit of the Egginton Common Sand and Gravel is located just to the east of Stenson. Here it was formerly worked in two sand and gravel pits, [3300 3008] and [3285 3000], but these have now been largely infilled with brick and tip. In the surrounding fields the soil comprises clayey sand with abundant pebbles of quartzite and quartz plus abundant flints, including some large cobbles. The deposit extends uphill to a maximum height of about 60 m above OD.

5.2.4 Beeston Sand and Gravel

This deposit forms a distinctive flattish terrace along the south-eastern margin of the area. It has a surface elevation that reaches up to about 48 m above OD and is traversed by the Trent and Mersey Canal. The soil of the terrace is gravelly sand.

Details:

The largest exposure of the terrace was in a borrow pit [3154 3013] excavated to provide material for the construction of the Derby Southern Bypass. Here a section 1.4 m high was exposed. It showed a fairly flat-topped terrace composed of orange-brown sandy gravel. The gravel component, about 10-50%, included abundant quartzite pebbles and quartz pebbles derived from the Triassic pebble beds, together with abundant flints. The deposit was stratified on a 0.5-0.7 m scale with numerous cross-bedded lenses and channels at the same scale as the layering.

At the western end of the Derby Southern Bypass [3085 3003] exposures show that the terrace is capped with a deposit of clay about 2 m thick. This was removed and replace with material from the borrow pit described above to facilitate the construction of the road. The local inclusion of clay in the deposit may have indicated the presence of a former channel.

5.3 Lacustrine Deposits

5.3.1 Lacustrine Deposits: clay

Two outcrops of these deposits are present within the area. The largest is entered on Hall

Pastures Farm [3238 3208] and extends to the south-west along two valleys; much of the heavy clay land hereabouts is laid to grass for grazing. The northern valley opens out again north of Findern, expanding into another area of lacustrine deposits around Okdale Nurseries [307 318]. All the deposits underlie fairly flat ground with an elevation between 50 and 55 m above OD. They mainly comprise clay and are largely stone free. In the north-western part of the area the alluvium from several small streams thinly overlies the earlier lacustrine deposits. There are few good exposures of the deposit, but an excavation for a new storm containment pond [3351 3193] showed 0.3 m of dark brown clay soil on 0.8 m of dark brown and dark grey clay. This in turn rested on 0.4 m of brownish grey stone-free clay.

In the south-east corner of the mapsheet area there is another flat-lying area of lacustrine clay deposits. These lie at an elevation of around 40 m above OD, but rise to around 46 m above OD along the slight valley to the south of Sinfin [3368 3046]. These lacustrine deposits differ from the ones to the west in that numerous layers of peat and white bog marl, or calcareous tufa, are present. They were seen in ditch sections [3479 3056 and 3495 3031] to a depth of 0.8-1.2 m. Elsewhere the lacustrine deposits mainly comprised dark brown, stone-free clay.

5.3.2 Lacustrine terrace deposits

In the far south-eastern corner of the area the lacustrine deposits described above are bounded by a slight scarp. The terrace surmounting this feature is composed of clay, but includes some stony clay and gravel.

5.4 Alluvium

The alluvium of all the streams and rivers in the area consists generally of an overbank deposit of clayey silt, 1.5-2 m thick, overlying c. 2 m of coarse-grained, sandy gravels, the latter derived essentially from the reworking of older gravels. The basal alluvial gravel of the main rivers (Doles Brook and Hell Brook) is only rarely visible in the river banks above water level. The banks generally comprise c. 2 m of slightly reddish brown to brown clayey silt.

All the streams of the area are associated with narrow tracts of alluvial deposits, typically between 50 m and 150 m in width. These deposits typically comprise c. 1 m of greyish brown, grey or buff, clayey silt overlying c. 1 m of sand and gravel. Along many minor tributary valleys, canalising or piping of streams has allowed a superficial cover of colluvium (Head) to form. The alluvial area of Hell Brook is divided into two sections. The upstream section has formed in the narrow valley that skirts Mickleover Golf Course [3155 3365]. This alluvial deposits opens out onto the lacustrine flats centred on Hall Pastures Farm. The southern section of the Hell Brook alluvial tract extends from the lacustrine deposits just north of Stenson Fields [3236 3151] down towards the Trent Valley.

5.5 Head

This is a variable deposit formed on slopes by a combination of colluvial, solifluction and gelifluction processes. In modern times, with intensive arable cultivation of the steeper slopes, colluviation has become an important depositional agent. In former times, most head was deposited as a result of periglacial gelifluction and related activity. Head generally underlies distinctive, nearly planar to gently concave 'solifluction terraces' which steepen gradually uphill from the flat alluvium and fluvial terrace deposits in the bottom of the valleys to the foot of convex bedrock outcrops. These surfaces are widespread along the Trent and Dove valleys and their tributary streams.

Head lithology depends on the nature of the bedrock and drift deposits up slope. It typically comprises slightly reddish brown, sandy to clayey, stony silt or silty clay. The stones, like most of the sand content, are derived from reworking of the Anglian glacigenic deposits and river terrace sands and gravels. Soliflucted mudstone of the Mercia Mudstone Group is a firm red and variegated clay which would be difficult to distinguish from weathered *in situ* bedrock were it not for its geomorphological form and possible stone content. The upper part of the deposit is generally colluvium and is sandier and lighter in texture. Numerous minor degraded sections in head occur in ditches across the area. The deposit is up to a few metres thick.

The colluvium or surface hill wash was largely produced during the Flandrian by the vegetation stripping caused by arable farming. The processes of solifluction, and in particular gelifluction, mainly operated during the last severe periglacial environment of the late Devensian. Similar deposits dating to earlier cold phases are considered to have been extensively removed or modified by the slope erosion which then occurred. They are found deeply involuted into the gravels of the Etwall and Egginton Common terrace deposits.

Characteristic periglacial soil features, formed from the growth and thawing of ground ice, which can be developed in more or less *in situ* pre-late Devensian deposits, include cryogenic involutions, ice wedge casts and vertical stone orientation. These features have been recorded from the well exposed sequences observed on the surrounding sheets (see Brandon, 1996, Brandon and Cooper, 1997 for a discussion of them).

6. STRUCTURE

Because of the extensive cover of superficial deposits, records of stratal dip in the Triassic Mercia Mudstone bedrock are sporadic and knowledge of the disposition of the beds is severely restricted. Structural information here comes from one of four sources: rare exposures in cuttings, along steams and in gravel pits, where the dip can be measured; the bedrock disposition deduced from borehole data; extrapolation of structural trends from adjoining areas; unpublished seismic profile interpretations (Oral communication, T.C. Pharaoh, 1996).

The structure of the area is dominated by faults which are mostly post-Triassic reactivations of

Variscan structures; the position of many of the faults is largely conjectural.

6.1 Stratal Dip

There are a few measurements of dip recorded within the strata of the area. One problem with all the dip readings is the effect of ice-heave and cryogenic disruption of the strata. The cluster of dip readings to the south of the Derby Hospital [3293 3482] all show a dip of around 2-3 degrees to the south-west. These localities are situated only 200-300 m away from a postulated fault. It is common in the Loughborough/Derby area for the strata to dip towards the faults on both sides of the faults, and so the dip cannot be used to infer a direction of throw.

Numerous measurements of dip have also been made in the southern half- kilometre of the area, south of Findern. In the centre of this belt [3293 3043] the strata are horizontal; to the west of here [3265 3041 and 31623040] the dip is 1 degree and 3 degrees respectively to the west, while to the east the dips are 2 degrees to the north-east [3323 3033] and 2 degrees to the east [3409 3043]. Farther east from here the dip becomes horizontal again [3421 3033 and 3435 3033]. Just to the north of this belt of exposures the dips along strike mimic those to the south, with an easterly dip of 2 degrees [3341 3112] passing eastwards into horizontal strata [3367 3125]. There are only two other places in the area where a dip has been recorded; in the excavations for the stormwater relief tank near Sinfin [3384 3183] there was a gentle dip to the south-west, and in a ditch section on a new housing estate [3294 3267] the dip was 6 degrees, also to the south-west.

6.2 Faults

The faults within the area are mainly postulated from very scant surface geological information and deep seismic data. The deep seismic data images the base of the Triassic sequence and shows structures in the underlying Carboniferous rocks, but gives very little detail within the Trias. As a consequence of this the faults depicted on the map are surface extrapolations from the deeper seismic sections. It should be noted that the seismic data give little indication of the fault trends; these are only fairly accurate where they are based on data from more than one seismic line. Elsewhere their positions can only be loosely inferred.

The area is crossed by four approximately north-west to south-east trending faults. In the north-east corner of the area a fault with a downthrow to the north-east cuts the Edwalton Formation; it is a continuation of a fault mapped on the Derby sheet and is seen on the seismic sections of ground to the south-east. A further fault passes through the middle of Littleover, towards the south of Normanton. This has a downthrow to the south-west and juxtaposes the Hollygate Sandstone Member and Cropwell Bishop Formation against the Edwalton Formation; it is a continuation of faulting mapped to the south-east. A major fault is inferred to bisect the map area along a line from the south of Mickleover to just south of Sinfin. This fault is imaged on the seismic data and has a downthrow to the north, but it is also inferred to have either a slight scissors movement, or to have slightly different folding on the two sides of it; it is also coincident with a slight synclinal structure recorded in the dips of bedding. The fault in the south-west corner of the area is an extrapolation of one mapped on the adjacent sheet to the west; it is inferred to follow Dole Beck.

6.3 Folds

The opposing dips measured on the Derby Southern Bypass, and recorded above, may suggest a north to north-west trending anticline in the area of Stenson. The dips also suggest the presence of an open synclinal structure whose axis is coincidental with the line of the postulated fault that crosses the middle of the area.

7. OTHER INFORMATION

7.1. Artificial Ground

7.1.1. Worked Ground

Pits or quarries are shown as areas of Worked Ground if no appreciable infill has taken place. These pits are generally much degraded by ploughing, as much of the small scale quarrying was carried out in the last century or even earlier. Where there is evidence for deliberate infill or backfill they are shown as areas of Worked Ground and Made Ground. This applies particularly to the large-scale sand and gravel operations on the northern flank of the Dove valley. Significant railway and road cuttings are also depicted as Worked Ground.

7.1.2 Made Ground

This normally consists of material deposited by man on top of the original land surface, though in some cases the topsoil and subsoil may have been removed first. Areas of Made Ground include ramps for bridges, railway embankments, raised ground on or bordering floodplains connected with industrial and housing developments, and domestic, industrial and council refuse tips. Made Ground is ubiquitous in urban areas, particularly where development has extended onto floodplains, but is only shown if thought to be c. 1 m or more deep and of significant extent.

The former gravel pits in the area (see Economic Geology section) are generally infilled, partly with construction and domestic waste, as is the situation for the gravel pits immediately east of Stenson [3295 3010 and 3285 3000]. Extensive areas of Made Ground have also been constructed over the wet and poorly drained areas of the Lacustrine deposits to the east of Sinfin [3490 3135]. Here the Made Ground is formed by domestic refuse built up to a considerable height (5-10 m) above the original ground level, and covered with topsoil. Other areas of Made Ground have been recorded in the middle of Normanton, where there are currently allotments and housing, but where there were brickpits during the original survey of the area. Another extensive area of Made Ground occupies the site of the former factory [3425 3233] and is now redeveloped for housing. The levelled area here comprises up to 2.5 m of Made Ground above the level of the railway.

7.1.3 Landscaped Ground

Landscaped Ground refers to areas where the original land surface has been extensively re-modelled by earth-moving and tipping, but where it is impractical or impossible to delineate individual deposits of made-up ground or backfill. Made Ground is usually extensive in such areas and substantial thicknesses may be present locally. It normally consists of topsoil, subsoil and rubble but often includes material brought in from elsewhere, including waste and mining spoil. Landscaping is ubiquitous in urban areas and should be expected where urban development is shown on the topographical base map.

7.2. Mineral Resources

7.2.1 Brick Clay and Marl

The silty mudstones of the Gunthorpe, Edwalton and Cropwell Bishop formations of the Mercia Mudstone Group were formerly dug for marl from small pits dotted across the outcrop. These are typically between 30 and 100 m across and are indicated on the map mostly by the Worked Ground symbol.

The mudstones and siltstones of the Edwalton Formation were once dug for brick clay in the area just to the south of Normanton [3415 3400 and 3440 3400]. These pits were recorded on the original field maps, but all traces of them have now vanished beneath Made Ground of unknown origin.

7.2.2. Sand and gravel

The Egginton Sand and Gravel has been worked in the past near Stenson [3295 3010 and 3285 3000] for sand and gravel aggregate; there are no records of the quarry depth.

7.3 Water supply

The principle aquifers within the geological sequence in this area are the permeable sandstones of the Bromsgrove Sandstone formation, Sherwood Sandstone Group and the overlying Sneinton Formation (the old Keuper Waterstones) of the Mercia Mudstone Group. In the central Midlands region as a whole, the Sherwood Sandstone aquifer is a very important source of fresh water and is heavily pumped from boreholes at depths up to 500 m and as far as 20 km from crop (Bath et al., 1987). There are no water boreholes on the mapped area that are reported to be abstracting water, but just west of the area the former Pastures Hospital Borehole was drilled as a water supply.

7.4 Geological Hazards

This section is intended as a summary of the principal geological hazards identified in the area at the last date of survey. It is not exhaustive and should, under no circumstances, be used to replace any part of a geotechnical site investigation.

7.4.1 Head

Head deposits are poorly consolidated and may be susceptible to further downslope movement following periods of heavy rain, snow or frost, especially if undercut or loaded by an overlying structure. Great care must therefore be taken to identify head deposits in site investigation boreholes and pits. Head deposits at the foot of long and steep Mercia Mudstone slopes merit particular caution, as they may be thick and difficult to distinguish from bedrock. The presence of 'exotic' clasts derived from other formations or drift deposits (e.g. Penarth Group mudstone fragments, ‘Bunter pebbles' derived from the drift) are a fairly reliable guide to identification. In site investigation boreholes head is commonly and erroneously described as glacially reworked bedrock.

7.4.2 Peat

Layers and lenses of organic-rich silts and clays as well as peat have been proved in the lacustrine deposits, described in section 5.3.1., to the east and south-east of Sinfin [3479 3056 and 3495 3031] . Such deposits are highly compressible compared to the surrounding deposits and could give rise to excessive and differential settlement of overlying structures. Peat and organic silt layers may also be associated with the alluvial deposits

7.4.3 Man-made deposits

Man-made deposits represent a hazard in three main ways:

1. The commonly uncompacted nature of man-made deposits can give rise to unstable foundation conditions. The composition can be very variable from site to site and within short distances on a single site. In places it may be very weak or cavernous and cause excessive and uneven settlement. Organic material within Made Ground may rot, causing cavitation and settlement below buildings. When spoil is dumped on a slope, the buried soil/organic layer may be weak and therefore might form a potential failure surface.

2. Toxic fluids, either as a primary component of the man-made deposit or generated secondarily by chemical or biological reactions within it, can migrate both within the deposit itself and into adjacent permeable strata.

3. Toxic or explosive gases, particularly methane, can be generated within waste tips and landfill sites. Such gases can migrate - sometimes through permeable strata adjacent to the site - and accumulate within buildings or excavations either on the site itself or some distance from it.

These possibilities should be addressed by appropriate geotechnical investigations in areas where man-made deposits are likely to be present. The man-made deposits shown on sheets SK 33 SW represent those that were identifiable at the time of survey. They were delineated principally by the examination of documentary sources and the recognition - in the field and on aerial photographs - of areas where artificial modification of the natural topography has taken place. Only the more obvious man-made deposits can be mapped by this method and the boundaries shown are likely to be inferred and approximate.

8. BOREHOLES

Abbreviations are as follows: OD Ordnance Datum; SL Surface level; TD Terminal depth
Soil has been omitted from the logs.

SK 23 SE/19 [2968 3317]. Name: "Pastures Hospital", "Asylum" or "Mental Hospital" borehole. Date 1899-1901. SL c. 91.00 m above OD.

Formation	Lithology (most of the descriptions are old drillers terms)	Thickness metres	Depth metres
Existing well			46.18
Mercia Mudstone Group. Cotgrave Member?	'White sand and marl'	1.68	47.86
		Thickness cont.	Depth, cont.
Mercia Mudstone Group. Gunthorpe Formation	'Grey rock', 'red and grey marl', and 'marl' with subordinate amounts of 'red sandstone', 'blue shale' and 'rocky marl'; thin seams of 'white spar' (gypsum) in the upper 15 m	73.91	121.77
Mercia Mudstone Group. Radcliffe Formation?	'Sandstone', 'marl' and 'grey rock' with a little 'red spar'	10.82	132.59
Mercia Mudstone Group. Sneinton Formation	'Grey rock', 'sandstone' and 'marl	9.14	141.73
Sherwood Sandstone Gp. Bromsgrove Formation	'Red sandstone' with some 'grey rock' and 'marl'	15.55	157.28
Carboniferous strata	'Red granite', 'blue shale' and 'grey rock'	17.45	174.73

9. OTHER UNPUBLISHED SOURCES OF INFORMATION

Other sources of information on the area described in this report are as follows:

1. Borehole data lodged with the National Geosciences Data Centre at BGS, Keyworth.

2. BGS six-inch to one-mile county series field slips and standards:

Derbyshire 49 SE, 50SW, 54 NE, 54 SE, 55 NW, 55 NE.

3. BGS 1:50 000 Series Sheet Loughborough (141), reprinted 1976.

4. BGS 1:10 000 field slips and standards for SK 33 SW; 1997.

5. BGS field note sheets AC1-AC124.

6. Loughborough Memoir (Fox-Strangways, 1905)

10. REFERENCES

BATH, A H, MILODOWSKI, A E. and STRONG, G E., 1987. Fluid flow in the East Midlands Triassic sandstone aquifer. Pp. 127-140 in J. C. OFF and B. P. J. WILLIAMS (editors.). *Fluid flow in sedimentary basins and aquifers.* Geological Society of London, Special Publication 34.

BRANDON, A. 1996. Geology of the lower Derwent valley: 1:10 000 sheets SK 33 SE, 43 SW & 43 SE. *British Geological Survey Technical Report* WA/96/07.

BRANDON, A. 1997. Geology of the Stretton and Repton areas, 1:10 000 sheets SK 22 NE and SK 32NW. *British Geological Survey Technical Report* WA/96/02.

BRANDON, A and COOPER, A H, 1997. Geology of the Etwall area; 1:10,000 sheet SK 23 SE. *British Geological Survey Technical Report* WA/97/03

BRANDON, A and SUMBLER, M G., 1988. An Ipswichian fluvial deposit at Fulbeck, Lincolnshire and the chronology of the Trent terraces. *Journal of Quaternary Science*, Vol. 3, 127-133.

BRANDON, A & SUMBLER M G. 1991. The Balderton Sand and Gravel: pre-Ipswichian cold stage fluvial deposits near Lincoln, England. *Journal of Quaternary Science*, Vol. 6, 117-138.

CHARSLEY, T J, RATHBONE, P A & LOWE, D J. 1990. Nottingham: A geological background for planning and development. *British Geological Survey Technical Report* WA/90/1.

CLAYTON, K M, 1953. The glacial chronology of part of the Middle Trent Basin. *Proceedings of the Geologists' Association*, Vol. 64, 198-207.

ELLIOTT, R E. 1961. The stratigraphy of the Keuper Series in southern Nottinghamshire. *Proceedings of the Yorkshire Geological Society*, Vol. 33, 197-231.

FOX-STRANGWAYS, C. 1905. The geology of the country between Derby and Burton-on-Trent, Ashby-de-la-Zouch and Loughborough. *Memoir of the Geological Survey of Great Britain*, Sheet 141 (England and Wales).

GEOLOGICAL SURVEY OF ENGLAND AND WALES. 1905. Sheet 141 (Loughborough).

LAMPLUGH, G W. et al 1908. The geology of the country between Newark and Nottingham. *Memoir of the Geological Survey of Great Britain*, Sheet 126 (England and Wales). 126 pp.

OLD, R A, HAMBLIN, R J O, AMBROSE, K, and WARRINGTON, G. 1991. Geology of the country around Redditch. *Memoir of the British Geological Survey*, Sheet 183 (England and Wales).

POCOCK, T J. 1929. The Trent valley in the glacial period. *Zeitschrift fur Gletscherkunde*, Vol. 17, 302-318.

POSNANSKY, M. 1960. The Pleistocene succession in the middle Trent basin. *Proceedings of the Geologists' Association*, Vol. 71, 285-311.

RICE, R J. 1968. The Quaternary deposits of central Leicestershire. *Philosophical Transactions of the Royal Society of London, Series B*, Vol. 293, 385-418.

ROSE, J. 1994. Major river systems of central and southern Britain during the Early and Middle Pleistocene. *Terra*, Vol. 6, 435-443.

SWINNERTON, H H. 1937. The problem of the Lincoln Gap. *Transactions of the Lincolnshire Naturalists' Union*, Vol. 9, 145-153.

WARRINGTON, G., AUDLEY-CHARLES, M.G., ELLIOTT, R.E., IVIMEY-COOK, H.C., KENT, P.R., ROBINSON, P.L., SHOTTEN, F.W. & TAYLOR, F.M.. 1980. A correlation of Triassic rocks in the British Isles. *Special Report Geological Society of London*, No. 13, 78 pp.