BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WA/97/03

Onshore Geology Series

TECHNICAL REPORT WA/97/03

Geology of the Etwall area:
1:10 000 sheet SK 23 SE

Part of 1:50,000 Sheet 141 (Loughborough)
and a minor part of Sheet 140 (Burton upon Trent)

A BRANDON and A H COOPER

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UK, East Midlands, Etwall, Burnaston,
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1. INTRODUCTION

This account describes the geology of the north flank of the Dove valley from the eastern neighbourhood of Hilton to the A38 and Willington Hill. The area also encompasses the generally sparsely populated ground to the north which rises locally to hills up to c. 90 m above OD and is dissected by the valleys of Etwall Brook and its tributaries. The geology is depicted on 1:10 000 sheet SK 23 SE (Etwall; Figure 1). Most of the area covered by the sheet forms part of 1:50 000 Geological Sheet 141 (Loughborough) although a narrow strip along its western margin falls onto 1:50 000 Sheet 140 (Burton upon Trent).

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

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

The first geological survey of that part of the present area to the east of Etwall was undertaken on the one-inch to one-mile scale by E Hull during the 1850s; it was published as part of the south-western quarter of Old Series One-Inch Geological Sheet 71 (Nottingham) in 1855. That part of the area to the west of Etwall was similarly published between 1852 and 1855 as part of the south-eastern quarter of Old Series One-Inch Geological Sheet 72 (Burton etc.). No geological descriptions were published to accompany these early maps. Most of the present area was resurveyed on the six-inch scale by C Fox-Strangways between 1901 and 1902 and T I Pocock in 1903 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. The extreme western margin of the study area was resurveyed by G H Mitchell in 1947 as part of the New Series One-Inch Geological Sheet 140 (Burton upon Trent), published in 1953. A geological memoir on that district was published shortly after (Stevenson & Mitchell, 1955). As part of the 1:10 000 scale revision of Sheet 141, A Brandon and A H Cooper surveyed the southern and northern halves of the area respectively in 1996.

The ground to the west of the area was surveyed as a component part of 1:50 000 Sheet 140 (Burton on Trent) as County Series sheets D 48 SE, D 53 NE, D 53 SE all surveyed by G H Mitchell in 1947. A description of the Burton on Trent area was written by Stevenson and Mitchell, 1955. The area of 1:50,000 sheet 125 (Derby) lying to the north on 1:10,000 sheet SK 23 NE was surveyed by J G O Smart in 1966. 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 22 NE, A Brandon; SK 33 SW, A H Cooper; SK 32 NW, A Brandon.

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 23 SE. 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.

This report is best read in conjunction with 1:10 000 Geological sheet SK 23 SE. 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 the map; all others are shown broken.

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2. GENERAL ACCOUNT

The Etwall area is mainly rural, with pasture farming along the stream floodplains and with arable farming on the higher ground and river terraces. The few former pastoral settlements are now essentially commuter dormitories. Etwall is the largest settlement and there is an extensive new housing development on the east side of Hilton at Hilton Common. Burnaston and Dalbury are the only villages. Industry is largely confined to new sites at the old Hilton Depot and the new Toyota car factory at Burnaston.

The bedrock over the entire area is mainly red mudstones and siltstones with thin sandstones of the Mercia Mudstone Group, Gunthorpe and Edwalton formations; they are poorly exposed except in temporary excavations. One deep well borehole (see section 8, Boreholes), at the old Pastures Hospital, possibly proved Millstone Grit at the base of the Triassic sequence. This is overlain by red sandstones of the early Triassic Bromsgrove Sandstone Formation of the Sherwood Sandstone Group. This in turn is overlain by the Mercia Mudstone Group. At the latter's base are thinly bedded sandstones, mudstones and siltstones of the Sneinton Formation and laminated mudstones of the Radcliffe Formation, neither of which occur at outcrop. Above this come the Gunthorpe and Edwalton formations.

The drift deposits form two contrasting terrains, although stream floodplain alluvium and head slope deposits are common to both. South of Etwall and Burnaston, the northern flank of the lower Dove valley is covered by extensive patches of sand and gravel forming a flight of terrace deposits. In the south-eastern corner of the area, these deposits are underlain by till and glaciolacustrine deposits infilling a channel carved deeply into bedrock. The deposits underlying large areas of the river terraces have been exploited for sand and gravel aggregate. Nearly all these workings are now infilled and reclaimed with artificial ground, or have been left flooded. The artificial ground is divided into Worked Ground, Made Ground and Landscaped Ground. North of Etwall and Burnaston, the only drift deposits, apart from head and alluvium, are remnant outliers of till that cap the hill tops.

QUATERNARY:	
HEAD	up to c. 3
ALLUVIUM	up to c. 4
HOLME PIERREPONT SAND AND GRAVEL	up to c. 10
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. 7
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	17.45+

Table 1. Geological sequence proved within Sheet SK 23 SE (Etwall), giving approximate thicknesses in metres. Strata below the Gunthorpe Formation of the Mercia Mudstone Group are known only from boreholes. Because the coverage of borehole information is scant it is likely that future boreholes will lead to modification of the geological sequence or thicknesses.

3. UPPER CARBONIFEROUS

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

3.1 Millstone Grit Group

The Pastures Hospital Borehole SK 23 SE/19 [2968 3317] with a surface elevation of about 91 m (see Section 8, Boreholes) proved 17.45 m of strata interpreted as part of the Millstone Grit Group. The drillers log dating from 1899-1901, recorded interbedded 'red granite', 'blue shale' and 'grey rock' underlying '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 they 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 only been proved in the Pastures Hospital Borehole SK 23 SE/19 [2968 3317], between depths of 141.73 m and 157.28 m. The sequence rests on supposed Millstone Grit Group (see previous section).

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). It is considered to be mainly of Anisian age (G W Warrington, oral communication 1997). Elsewhere it is usually characterised by thick-bedded, fine- to medium-grained, *pebble-free*, fluviatile sandstones and subordinate interbedded mudstones and siltstones. In the present area, the only information comes from the Pastures Hospital Borehole. The lower part of the 15.55 m-thick Triassic sequence assigned to this formation is predominantly composed of 'red sandstone' with some 'grey rock' (siltstone?) and about 21% 'marl'.

4.2 Mercia Mudstone Group

The mudstone-dominated, readily degradable strata of this group (Warrington et al., 1980) form rockhead over the entire Etwall area. In the south much of the ground is covered by superficial deposits and there are only a few surface sections. There is little landform feature control on the form of 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. These and stratigraphical information proved elsewhere in the Loughborough district allow the following 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). Within the Loughborough and Nottingham districts the unit is considered to range in age between Anisian and Ladinian (Warrington, oral communication 1997). In the Loughborough district it comprises an heterogeneous sequence at the gradational base of Mercia Mudstone Group. It 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.

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 Pastures Hospital Borehole SK 23 SE/19 [2968 3317] where the interval most probably equivalent to the Sneinton Formation (from 141.73 m to 132.59 m; 9.14 m thick) is recorded as 'grey rock', 'sandstone' and 'marl'.

4.2.2 Radcliffe Formation

In the surrounding region this formation comprises (Elliott, 1961) 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).

In the present area, the formation is tentatively recognised in the Pastures Hospital Borehole SK 23 SE/19 [2968 3317]. 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) 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 sheet. The mapped boundaries, apart from where the Cotgrave Sandstone forms a topographical feature, are entirely conjectural. There are very few noteworthy exposures, the weathered mudstone-dominant strata mostly being seen at surface as superficial red clay. In most boreholes it 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

At the Hilton Lodge borrow pit [257 315] excavated for road embankment fill, the Gunthorpe Formation was exposed beneath the terrace deposits of the Etwall Sand and Gravel. At the east side of the excavation the beds had a dip of about 4° to the south. The section here showed:

	Thickness (m)
ETWALL SAND AND GRAVEL	
Sandy gravel	3.5
GUNTHORPE FORMATION	
Siltstone, red-brown, laminated with traces of cross-lamination and ripple marks	0.84
Siltstone, red-brown, blocky and micaceous	0.10
Sandstone, very fine-grained, cross-laminated with ripple marks of wavelength 0.05	0.07
Siltstone, green-grey	0.04
Siltstone, red-brown	0.08
Siltstone, green-grey	0.01
Mudstone, red-brown	0.26
Red-brown clay, poorly exposed	1.26
Siltstone, red-brown, laminated with a few thin beds; sporadic grey-green spots up to 0.01 across; nodules of hard calcareous? siltstone between 1.2 and 1.5 above the base of the unit	2.10
Water level in excavation	
Total thickness of Gunthorpe Formation exposed	4.76

At the eastern side of the borrow pit [2560 3153] another section in the Gunthorpe Formation was visible, this had a dip of about 11° to the south-west and exposed:

	Thickness (m)
ETWALL SAND AND GRAVEL	
Sandy gravel	2.5-3.0
GUNTHORPE FORMATION	
Mudstone, red-brown, mottled green in places	c.2.0
Mudstone, greenish grey with thin very fine-grained greenish grey sandstone and siltstone beds near the middle of the unit, all of which is loose	c.0.4
Mudstone, red-brown, poorly exposed	c.1.1
Siltstone, pale reddish-brown with laminae of greenish-grey siltstone plus numerous beds of very fine-grained green-grey sandstone and siltstone with cross-lamination. Salt crystal pseudomorphs to 2 mm across	c.1.6
Sandstone, grey-green, very fine-grained, thin bedded	c.0.5
Total thickness of Gunthorpe Formation exposed	c.5.6

Near Dalbury Hollow [2652 3470], in the north of the area, a newly cleaned road cutting section exposed the following with a dip to the south of about 2°:

	Thickness (m)
HEAD DEPOSIT	
Clay, brown and reddish-brown with numerous pebbles and cobbles of quartzite and sandstone	0.7
GUNTHORPE FORMATION	
Clay, weathered red-brown	0.2
Mudstone, red-brown and grey-green, slightly mottled	0.2
Sandstone, pale grey, very fine-grained with one slightly lenticular bed	0.02-0.04
Mudstone, red-brown, homogeneous	0.48
Mudstone, red-brown with lenses and a bed of very fine-grained green-grey sandstone	0-0.02
Mudstone, red	0.6
Thickness of Gunthorpe Formation exposed	2.22

A section at a newly dug pond excavation [2519 3233] at Holy Bush Farm showed c. 1.5 m of red, silty mudstone with numerous, c. 1-3 cm thick, beds of green, silty, fine-grained sandstone and sandy siltstone.

Minor temporary sections occurred in trenches during the construction of the Derby Southern Bypass. Mostly up to c. 1 m of red clay was seen, involuted with Etwall Sand and Gravel or Egginton Common Sand and Gravel. At one point [2634 3090], c. 1.5 m of weathered brick red, silty, shaly mudstone with thin, pale green, very fine-grained sandstone beds were affected by cryoturbation or hill creep. At another point [2660 3080], below c. 0.7 m of gravel, c. 3 m of mainly brick red silty mudstone were exposed containing one 0.3 m bed of pale green, laminated siltstone and fine-grained, silty sandstone. At excavations for a bridge [2691 3072] over Egginton Road, 3 m of dull brick red, clayey siltstone was interlaminated to thinly interbedded with red to pale green sandstone, below c. 2 m of cryoturbated gravel of the Etwall Sand and Gravel.

The formation is inferred to form the hill between Etwall and Burnaston. The following section was exposed at a newly dug section [2784 3201] in an old 'marl pit' on the hill:

	Thickness (m)
Mudstone, brick red, silty, shaly to blocky; 4 cm thick pale green lens 0.25 m down	c. 1.2
Mudstone, pale green mottled brick red, silty, poorly laminated; also in places 50/50 colour banded in same colours; top contact sharp; bedding disturbed and folded as though due to gypsum dissolution (see also given below)	c. 1.0
Mudstone, brick red mottled green, silty; very gradational top	c. 0.8

At the east end of the hill, a further newly dug section [2834 3219] was revealed in an old 'marl pit' prior to infilling:

	Thickness (m)
Topsoil, slightly reddish brown, stony clay	c. 0.5
Mudstone, dark brick red 50/50 mottled medium greenish grey	c. 1.0
Mudstone, brick red, silty, slightly shaly	c. 1.1
Mudstone, dark brick red 50/50 mottled medium greenish grey	c. 1.0
No exposure	c. 1
Mudstone, brick red with a few pale green mottles, silty, slightly shaly, homogeneous	c. 0.5
Siltstone, pale green, interlaminated with brick red siltstone	0.04
Mudstone, brick red with a few pale green mottles, silty, slightly shaly, homogeneous	c. 1.2
Siltstone, variegated brick red and pale to medium greenish grey, soft; weathering crumbly and soft probably due to gypsum dissolution (*see* similar bed in above section)	c. 0.6
Mudstone, brick red with small green mottles, silty, shaly	c. 1.1
Mudstone, dark reddish brown mottled medium greenish grey, silty, shaly	c. 0.3
Siltstone, pale green, shaly; forms floor of pit	c. 0.3

Details: boreholes

The Pastures Hospital Borehole SK 23 SE/19 [2968 3317] was drilled in the bottom of an existing well and penetrated white sand and marl possibly assigned to the Cotgrave Sandstone Member. It then proved 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 numerous boreholes along the Derby Southern Bypass transect although the thickest sequences were proved on Sheet SK 22 NE (Brandon, 1997). The boreholes in the present area proved a typical sequence, at least 36 m thick, of deeply weathered, mainly red, mottled green, thinly to thickly interlaminated, silty mudstone and siltstone below various cryoturbated superficial deposits. Numerous thin beds of greenish grey siltstone are recorded below the deeply weathered zone along with gypsum veins in the lower part of the boreholes.The deeper boreholes occur in four groupings around the intersection with roads and streams:

i. Intersection with A516 (T) [2532 3120 - 2569 3108]: This group of boreholes, e.g. boreholes SK 23 SE/186, 188, 190, 191, 193 and 196, contain strata that are generally deeply weathered to 12 m depth but two boreholes SK 23 SE/299 & 300 provided sections up to 25 m deep. The sequence apparently included fewer siltstone interbeds than boreholes at the other intersections. This might indicate a different level in the Gunthorpe Formation than that encountered in the other borehole groups although, since strata on the west side of the conjectural north - south Needwood Fault are only provisionally ascribed to the Gunthorpe Formation, it might indicate a different stratigraphical level in the Mercia Mudstone Group.

ii. Intersection with Etwall Brook [2637 3089 - 2647 3084]: boreholes SK 23 SE/201, 210, 209 & 211 penetrated a typical but weathered sequence down to 13 m depth.

iii. Intersection with Etwall Road [2682 3071 - 2697 3068]: boreholes SK 23 SE/225, 226 & 295 proved a typical sequence down to 17 m depth. Boreholes SK 23 SE/ 294 & 297 penetrated down to depths of 31 m and 25 m respectively. Although a typical interbedded mudstone/siltstone sequence was recorded in these two boreholes, they both proved sandstones in addition. Borehole SK 23 SE/294 [2682 3071] proved at least 9.27 m of interlaminated sandstone/siltstone at the base of the borehole, with a top boundary at a 35.75 m above OD. This unit is described as reddish brown, fine-grained, laminated, and argillaceous sandstone, thickly to thinly interlaminated with greyish green and white siltstone and reddish brown claystone. Borehole SK 23 SE/297 [2692 3071], sited only 100 m to the east, proved only 0.32 m of greyish green, fine-grained sandstone with laminations of reddish brown mudstone at 34.20 m above OD.

iv. Intersection with A38 (T) [2901 3002 - 2927-3001]: Boreholes SK 23 SE/323, 325 & 331 penetrated through the thick cover of Elvaston Palaeochannel deposits into Gunthorpe Formation. Up to 12.8 m of undisturbed, unweathered, typically interlaminated mudstone and siltstone with gypsum veins were proved.

A very similar sequence of up to 22 m of thinly interbedded to interlaminated reddish brown mudstones and green to 'blue-grey' siltstones with numerous gypsum veins were proved beneath 2.3 to 4.2 m of alluvium by site investigation boreholes SK 23 SE/141-150 [2661 3225 - 2669 3235] at the intersection of the Etwall Bypass with Etwall Brook and the adjacent railway.

4.2.4 Edwalton Formation

The division (Elliot, 1961) comprises mainly reddish brown and greyish green siltstone and mudstone which are typically blocky or very poorly laminated. Although thin beds of fine-grained sandstone occur at many levels within the formation, thicker sandstone beds are concentrated at the base and top and 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 formation forms outcrops in the Etwall - Burnaston - Mickleover area. This is an interpretation based mainly on the identification of a feature-forming sandstone as the Cotgrave Sandstone Member, at the base of the formation. The upper part of the formation and the Hollygate Sandstone Member are not preserved in the area. The mudstones have been dug from numerous small 'marl pits' dotted over the outcrop (see Economic Geology section).

Details: outcrop

The formation is rarely exposed and is typically seen as c. 1 m of red clay in ditches and temporary exposures. Many of the exposures also have fragments of pale grey-green siltstone, commonly with salt pseudomorphs on the bedding surfaces. On Burnaston Hill, the following weathered section [2932 3211] was dug at a new barn at Hill Farm:

	Thickness (m)
Topsoil; brownish grey clay with scattered stones	c. 0.3
Subsoil; reddish brown clay; a few scattered stones	c. 0.5
Mudstone, brick red, shaly	c. 0.5
Mudstone, pale green, silty, laminated	0.1-0.15
Mudstone, brick red with a few green mottles; silty	c. 0.5
Mudstone, 50/50 % mottled red and pale green	c. 0.3

Cotgrave Sandstone Member

The Cotgrave Sandstone is thought to form a bench-like topographical feature [c. 296 317] to the south-east of Burnaston. 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 after halite. The feature appears to terminate westwards at a slack [c. 295 317] infilled with colluvium where the sandstone is inferred to be faulted out.

The Cotgrave Sandstone Member was recognised near to Oakdene [2808 3288] where it formed a slight feature in the field. Associated with the feature the soil included abundant fragments of laminated and very thin-bedded pale grey sandstone and siltstone with abundant salt pseudomorphs. This feature, covered with fragments of similar rocks, can be traced across the A516 and adjoining fields [2832 3314] past Bearwardcote Farm Cottages to the north-east [2862 3316]. From here it can be traced to the north-east to Orchard Plantation where it was slightly off-set by a fault [2915 3412], then across the fields [2907 3436] to near Dunster Plantation [2921 3452]. The feature leaves the area one hundred metres east of the disused railway line.

Details: boreholes

From the mapped position of the Cotgrave Member, and the elevation of the Pastures Hospital Borehole SK 23 SE/19 [2968 3317] (see 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 proved for 1.83 m between the bottom of the well at 46.02 m and a depth of 47.85 m.

5. QUATERNARY

The landscape and drainage of the area is largely a legacy of various erosional and depositional events. These occurred in response to the oscillating climatic conditions of the Quaternary Period, which commenced about 1.5 to 2 million years ago. Alluvial and fluviatile sediments deposited on the floodplains of the River Dove cover large parts of the south of the area; the older sedimentary deposits occur as successively higher terrace remnants. Glacigenic deposits, comprising mainly till, occur as relict patches on ground generally higher than 70 m above OD. Glacigenic and glaciolacustrine deposits also fill a deep palaeochannel cut into the Mercia Mudstone Group; this channel is thought to have been a subglacial tunnel valley. Other important deposits in the area include slope deposits mapped as Head, and artificial deposits including Made Ground.

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 now. 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 known Thrussington Till preserved in the Etwall 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.

Inevitably, regardless of the ice flow direction and provenance of the farther travelled stones, the basal 1 m or so typically incorporates local bedrock from the Mercia Mudstone and the matrix may have a red coloration. In adjacent areas, where the tills of the two provenances are found in association, the Oadby Till always overlies the Thrussington Till and is therefore consistent with a later glacial advance from the east and north-east. In these areas tills of mixed origin occur locally, and it may be inferred that such hybrid tills result from the reworking of Thrussington Till during the later glacial advance.

During glacial advance, the local base level of area was probably considerably higher than at present in the Trent valley and may have been as high as about 70 m above OD. Consequently the Oadby Till, other than that deposited in tunnel valleys beneath the ice (see below), is generally only found capping hills above this height where it is considerably dissected.

Oadby Till also partially infills the Elvaston Palaeochannel, which enters the south-eastern corner of the sheet area and extends onto sheets SK 22 NE, SK 33 SW and SK 32 NW. 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:

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, 1997; 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 22 NE, the stratigraphy of the infill deposits beneath a partial cover of Etwall Sand and Gravel and Eagle Moor Sand and Gravel is fairly clear. The major deposit is a glaciolacustrine unit, termed the Findern Clay (Section 5.1.2). This is generally underlain by a relatively thin deposit of lower Oadby Till which rests directly on bedrock (Figures 2 & 3). In places along the Bypass cutting, 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, Bunter quartzite, coal and sandstones from the Mercia Mudstone Group. No sections in the lower Oadby Till were seen during the survey of the Etwall area, nor was it penetrated by the deeper boreholes connected with the bypass route (see Figures 2 & 3). It was proved on the adjacent part of SK 22 NE and is probably present at the base of the palaeochannel in the present area.

The upper till, exposed in the Derby Southern Bypass cutting [2902 2997] to the west of the A38, comprised c. 1 m of slightly reddish brown-weathering, chalky till cryogenically involuted with the overlying gravel of the Etwall Sand and Gravel. Logs of boreholes along this transect (Figure 2) indicate that up to 5 m of upper till may be present in pod-like bodies although, as stated above, it is extremely difficult from the borehole logs to distinguish between Oadby Till and Findern Clay with dropstones. The bypass sections would seem to indicate that Findern Clay wraps around the upper till, at least in part. A section along the bypass [2852 3011 to 2867 3006] was logged as follows:

	Thickness (m)
Soil: grey, gravelly	c. 0.3
ETWALL SAND AND GRAVEL	
Gravel, buff to deep orange-brown, silty, decalcified; mostly cryogenically involuted throughout; clasts imbricated to 121° in less disturbed parts; clasts mostly Bunter quartzite and quartz with c. 10% flint; sharp undulating base	c. 2 - 3
FINDERN CLAY	
Clay, slightly reddish brown, stoneless, poorly laminated, partly brecciated; in involuted pods (thickness increasing eastwards)	0 - c. 3.5
OADBY TILL (UPPER)	
Clay, slightly reddish brown, silty, stiff; clasts include abundant coal, chalk and angular flint; also chert, grey pyritous sandstone, grey siltstone and Bunter pebbles; chalk clasts are ice-striated; numerous lenses of brown to slightly reddish brown, fine-grained, stoneless sand up to 0.5 m thick; some unweathered, ill-sorted grey gravel lenses, up to 1.3 m thick, with clasts to large cobble grade in very coarse-grained sand to granule grade matrix, clasts comprising chalk, flint, Bunter pebbles, Penarth Group dark grey fissile shale, Mercia Mudstone Group green sandstone and red mudstone, ?Liassic shale, bioclastic limestone and *Gryphaea*, Upper Carboniferous coaly shale; bedding in till inclined to east by c. 5°; some parts of the till contain few stones and could be glaciolacustrine deposit with dropstones	c. 3 - 5

High ground to the north of the Elvaston Palaeochannel

Small patches of Oadby Till occur scattered throughout the northern half of the area above c. 65 m above OD. The most extensive areas occur in the west capping the hills around Ivy House Farm [25253263], Ash Farm [2548 3328] and near Ash Gorse [2604 3363]; a deposit also occurs just west of Dalbury [2585 3434]. The till around here comprises brown and red-brown clay and sandy clay with abundant pebbles and cobbles mainly of Bunter quartzite and quartz and also flints. Elsewhere in the area, the small deposits of till and the larger spread in the north-east of the area [298 346], all have a similar composition.

5.1.2 Findern Clay

The Findern Clay (new name) is the glaciolacustrine deposit infilling the Elvaston Palaeochannel. It has a low height relative to the level of Eagle Moor Sand and Gravel (Figures 2 & 3), the latter representing the Trent valley sandur of the meltout phase of the Oadby Till glacier. This and the general lack of coarse-grained clastic sediments in the palaeovalleys suggest that the Findern Clay must have formed subglacially in a tunnel valley.

Details:

The Findern Clay was exposed in cuttings during construction of the Derby Southern Bypass. It was also penetrated in numerous boreholes along the bypass transect (see Figures 2 & 3) which proved it to be up to 20 m thick within the present area (e.g. Borehole SK 23 SE/244). Its relationship to the Oadby Till and Etwall Sand and Gravel is shown in Figures 2 & 3. 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 in 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.

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 with pale bluish or greenish grey mottles. 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. They have been proved in bypass boreholes to be up to c. 1 m thick (e.g. Borehole SK 23 SE/244; Figure 2). Site investigation boreholes for the Toyota factory (e.g. SK 23 SE/508, 509, 511 & 516) show that orange-brown, silty, fine- to medium-grained sand with lenses of orange-brown sandy clay replaces glaciolacustrine clay at the northern margin of the Elvaston Palaeochannel (Figure 3) although laminated clay overlies the sand. In Borehole SK 23 SE/510 fine- to coarse-grained gravel grading to orange-brown, fine- to coarse-grained, partly gravelly sand replaces this sand. Such sand bodies are thought to be fluvially deposited in channels incised into the lacustrine clay. Similar sand occurs at the top of the Findern Clay at the centre of palaeochannel in the Findern area, on sheets SK 32 NW and SK 33 SW (Figure 2).

5.2 River Terrace Deposits of the Trent and Dove

During mapping of the Loughborough geological sheet considerable changes have been made 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

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	Floodplain deposits	Floodplain deposits Hemington Terrace	Floodplain deposits
	26 K	2	Deposits *	Syston Sand and Gravel *	Deposits * Holme Pierrepont Sand and Gravel *	Holme Pierrepont Sand and Gravel *
Devensian	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?)			
'Swans-combian'	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.
* 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.

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). Following Brandon (1995), those of the River Soar have been modified from what are considered to be the corresponding Soar terraces mapped upriver by Rice (1968). 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) although in that publication the lithological descriptors are not employed and the main coarse-grained, fluvial (sand and gravel) unit beneath each terrace is given member status. Furthermore, flights of terrace deposits in a particular river valley are grouped into a valley formation, e.g. Trent Valley Formation. In common with current British Geological Survey practice, in this report terrace deposits are not given formal hierarchy status. However, a set of deposits underlying a particular terrace is considered by the writer to have informal formational status and a valley assemblage of terrace deposits is thought of as an informal group. Possible differentiation of deposits underlying a terrace would then utilise informal members and even bed ranks. For example, the Beeston Formation, incorporating the Beeston Sand and Gravel Member and any other possible subdivisions, is thought of as part of an informal Trent Valley Group.

Figure 4 shows the river terrace deposits of the lower Dove valley and their thalweg heights relative to OD. Because mapping on the Loughborough Geological Sheet only extended up the Dove valley from the confluence as far as Hilton, and the terraces/terrace deposits of the two valleys are virtually continuous, the terraces/terrace deposits of the lower Dove valley have not been given separate names.

Of the previous researches on the terrace deposits of the Trent, Dove and Derwent, the work of Pocock (1929) stands out as being extraordinarily perceptive for its day, although it appears to have been generally ignored by later workers. He described and gave height ranges for six separate gravelly terrace deposits in the Trent valley, from upriver of the confluence with the Tame at Alrewas [17 13], down river to Weston [40 28], and also along the north side of the lower Dove valley. His terraces were numbered I to VI with increasing height and age above river level. From his geographical and altimetrical descriptions, his numbered terraces can clearly be related to the terraces mapped in the present area (see Table 3) although he did not separate an equivalent of the Hemington Terrace from the floodplain alluvium as Fox-Strangways (1905) had earlier done. He recognised rock steps between all six terrace gravels except for those of terraces III and IV (i.e. the Egginton Common and Etwall deposits). The confusion between his IV and V terraces of the Dove, which are here considered to be both the Etwall Terrace, is probably accounted for by the increased gradient of the long profiles of the Dove valley between Willington Hill and Etwall. His analysis led Pocock (1929, p. 308) to make the following perceptive conclusion: 'Hence there has been an alternating succession of gravel-deposition and erosion six times repeated between the period of the chalky boulder-clay and the alluvium of the floodplain.'

Pocock (1929)	*Height above OD*	*Present survey*
VI (at Etwall and Chellaston)	73.8-75.6 m (E)	Eagle Moor Terrace
IV (Willington Hill) V (at Etwall and Weston)	67.1 m (E) 59.4-61.0 m (W)	Etwall Terrace
III (although Stenson Hill deposit ascribed to IV)	53.3 m (W)	Egginton Common Terrace
II	47.2 m (W)	Beeston Terrace
I	42.4 m (W)	Holme Pierrepont Terrace

Table 3. Correlation of the six terraces of Pocock (1929) with those mapped. The second column gives the height in metres above OD given by Pocock (in feet) at Willington (W) and Etwall (E). River level at Willington given as 39 .6 m above OD.

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). Apart from those of the Flandrian, interglacial deposits are not well represented in the East Midlands rivers.

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. Figure 4 (see also Brandon, 1996, figure 6 for the Derwent terraces; Brandon 1997, figure 5 for the Trent terraces) illustrates 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. The figures also show that base levels fell regularly by approximately 7 m between each successive cold stage.

It is a curious fact that in those parts of 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, except were the valley is orientated north - south, as in the case of that of the Soar. This was first commented on by Fox-Strangways (1905, p. 41) who, with reference to the 'High Level Valley Gravel' deposits of the Trent and Derwent valleys, noted 'They occur almost entirely on the northern sides of these two valleys. The reason for this is not very obvious but shows that the tendency of the rivers has been to cut fresh channels to the south.' This northerly bias to terrace preservation, or southerly uniclinal shift, is not only true of the terraces of the Middle Trent in the Burton to Long Eaton stretch, but also of those of the Dove, the Derwent, and the Proto-Trent valley to the east of the Lincoln Gap (Brandon, 1997).

No systematic lithological clast analyses of the terrace deposits has been undertaken and proportions of the various lithologies are based on field assessments of the larger pebbles only. Nevertheless, it is apparent that all the terrace deposits of the Trent contain a similar assemblage of main clast lithologies (see also Posnansky, 1960). The same applies to lower Dove terrace deposits. 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. In the lower Dove valley the most durable rock types which form the bulk of the gravels are, in order of decreasing abundance, Triassic quartzite and quartz, 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 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 (Figure 4; Brandon, 1977, figure 7) 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 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). Two remnants of the Eagle Moor Sand and Gravel occur in the present area. Its relationships to the other terrace deposits are shown in Figure 4.

Details:

The Eagle Moor Sand and Gravel forms an outlier underlying the flattish ground at the northern end of Etwall with a surface between 75 m and 83 m above OD. The deposit may be up to 7 m thick although a thickness of 2-3 m is probably more typical. The base of the deposit falls westwards in the direction of Etwall Brook from c. 82 m to c. 72 m above OD. A temporary section [2683 3198] of the lower part of the deposit at John Port School revealed:

	Thickness (m)
EAGLE MOOR SAND AND GRAVEL	
Gravel, slightly reddish brown, clayey, ill-sorted; clasts are mostly Bunter quartzite and quartz (c. 70%) and flints (c. 20%) and also common Upper Carboniferous sandstone; numerous intact flint nodules with white cortex up to boulder grade	c. 2.5
Sand, reddish brown, fine-grained, soft; poorly exposed	c. 0.4
GAP	c. 1
MERCIA MUDSTONE GROUP	
Clay, red; dug out	

A further temporary section along the main road [2709 3219] exposed up to 2 m of similar gravel overlying red mudstone. Similar gravel has also been dug out of graves in this area [2685 3206]. Towards the east along Sandypits Lane [2729 3189 to 2758 3195], orange-brown, fine-grained sand with some gravel was dug out of a trench. This deposit may also have been dug from what is now a degraded pit [2744 3208].

The Eagle Moor Sand and Gravel was also proved by a number of site investigation boreholes at the Toyota car factory [c. 29 30] (Figure 3). The deposit comprises mainly orange-brown, fine- to medium-grained, clayey to silty sand and contains only a little quartzite-rich gravel in contrast to the adjacent Etwall Sand and Gravel which overlaps in height range. A constructed cross section (Figure 3) shows that it is the margin of the deposit which is preserved, banked against Mercia Mudstone to the north-west. The deposit is up to 7 m thick. Its base lies at c. 64 m above OD and occurs as high as c. 77 m above OD. The gravel was formerly exposed in cuttings on the northern side of the car factory. Debris on the slopes indicates a clayey deposit comprising Bunter quartzite and quartz (c. 90%) and flint (≤10%). The gravel contains sporadic Lower Carboniferous limestone clasts and large intact flint nodules. The deposit was formerly worked from a small pit [296 308], the site of which has now been removed by the construction of the car factory.

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. 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 Figure 4. Correlations with the terraces of other East Midlands river valleys, based on altimetry, are shown in Table 2.

The terrace and the underlying deposits are well preserved north of the confluence of the Dove and Trent valleys as three dissected outliers extending from Hilton [26 30] to Willington [295 298]. Several minor outliers also occur in this area south of New Close Farm [2820 3134]. At all these occurrences, the Etwall Sand and Gravel and overlying head are severely cryogenically involuted with the Mercia Mudstone bedrock, and in the case of the Willington Hill outlier with Elvaston Palaeochannel deposits. Generally c. 2-3 m of Etwall Sand and Gravel are the most that are preserved.

Details:

The deposit was formerly best known from Hilton, in an outlier that extended as far east as Hilton Lodge [258 313]. Extensive sand and gravel extraction was carried out here [c. 252 315] during the early part of the century, beginning in 1924, by the Hilton Gravel Co. (later BCA; see Economic Geology section). Gravel extraction in that part of Hilton covered by this report was mainly done in the 1940s. Notes on the old 6" field map (metricated here) indicate that between 4.4 and 5.4 m of gravel was worked. A further note referring to a point on the gravel face in 1947 [2516 3151] records 4.71 m of sand and gravel overlying Mercia Mudstone is interpreted as follows:

	Thickness (m)
ETWALL SAND AND GRAVEL	
Gravel, weathered	0.30
Sand, red; polished quartz grains	0.20
Gravel, red; matrix of red sand with polished quartz grains	0.25
Gravel, red, coarse-grained; pebbles up to 5 cm across; small flints	0.81
Gravel, sandy matrix; lenses of sand; persistently black-stained level at 1.67	3.05
MERCIA MUDSTONE	
'Keuper Marl', red and grey	-----

"'Festooning' is common in top 5 to 10 ft (1.52 to 3.05 m) with bleached patches & bands. Also a great patch of marly clay with pebbles - essentially boulder clay 3 ft(?) (0.91 m) across & 10 ft (3.05 m) high rounded base and sides but gravelly for 2 ft (0.61 m) above it in parts. -

evidently a great cake(?) or slab." In a diagram, the involution of 'boulder clay' is shown to penetrate down as far as the black-stained layer.

Armstrong (1939, 1942) described the stratigraphy of the Hilton Gravel Pits in a paper on the artefacts recovered from the working pits (now mostly in Sheffield City Museum; Richer, 1991; Wessex Archaeology, in press). He records the deposit found in pits both west [c. 244 315] and east [c. 250 314] of the Sutton-on-the-Hill road at Hilton, although only part of the Hilton East Pit falls within the present area. He divided the sand and gravel, which varied between 2.74 m and 5.18 m in thickness, into zones A, B and C, in upward order (Figures 5 & 6). These zones had different physical conditions but contained the same constituent stones. 'These are principally Bunter pebbles, derived from the country immediately to the north-east, but a few northern erratics are also present, amongst which Basalts and Limestones from Derbyshire and Yorkshire, Lake District rocks and Granite from the Cheviots have been identified. Eastern erratics occur much more plentifully, including Lincolnshire rocks, and there is a high percentage of flint in large and small fragments and tabular nodules. Amongst the flint constituents the percentage of artifacts is surprisingly high. No chalk fragments have been observed, but the Jurassic material suggests a chalky boulder clay origin.' His Zone A overlay bedrock which was incorporated into the gravel to form the matrix or occurred as lumps and lenticular patches. Artefacts were found most frequently in this zone, which thinned out in the eastern pit, i.e. the one within the present area, where Zone B came to overlie bedrock. Zone B gravel was less compact than Zone A gravel and the artefacts were both less numerous and generally heavily rolled. Armstrong's conclusion was that they were derived from Zone A by reworking. Zone C exhibited excessive contortion and the flint clasts were small and fractured. This is consistent with the upper, more cryogenically disturbed part of the deposit. No Acheulian handaxes were found in this zone, probably due to the degree of fracturing of the flints. The three zones may not have any stratigraphical significance and could merely reflect increasing states of periglacial weathering of the same deposit through zones A to C. This accords with Posnansky's (1963, p. 365) conclusions on the state of wear of the Hilton artefacts. However, it is possible that Zone A gravel represents a basal lenticular interglacial deposit (hence the abundance of artefacts) which was reworked into the overlying gravels that were deposited under stadial conditions. It is curious that Armstrong (1939, 1942) recognised persistent layers of sand between each of his zones. Richer (1991), who reviewed the artefacts found by Armstrong, states that Armstrong visited the Hilton pits between 1938 and 1945. Amongst the artefacts he collected (in the Sheffield City Museum) is one from 'Zone B' at the Hilton West Pit definitely identified by Dr R Jacobi as a Levallois flake (Ms P M Richer, personal written communication 1991). Richer (1991) reproduces several sections exposed at the pits, which are reproduced here as Figures 5, 6 & 7, from Armstrong's manuscript records of 1939-45. The one of the Hilton East Pit (Figure 7) shows truncated pod-like festoons of 'Reddish yellow sand and pebbles' in the upper part of the face. These are thought to be relict Hykeham Soil (Brandon and Sumbler, *in* Bowen et al., in press), a rubified temperate palaeosol in the Trent Basin, thought to be of Ipswichian age, which was subsequently cryoturbated during the Devensian stadial period. Analogous structures are recorded from the top of the Balderton Sand and Gravel of Lincolnshire (Brandon & Sumbler, 1991).

These Hilton pits are flooded and are now a wildlife reserve. The only section currently available [2532 3142] was of c. 0.8 m of deep orange-brown, clayey, cryoturbated gravel displaying vertical stone arrangement. The gravel becomes more clayey above and includes an involuted pocket of red mottled, orange-brown clay from a formerly overlying bed which is probably a relict temperate palaeosol. This is interpreted as the relict Hykeham Soil (see above). Sections in up to 2 m of buff to orange-brown, clast-supported, completely decalcified, cryoturbated gravel to cobble-grade were exposed to the south of the old pits dug during the construction of a roundabout access point for the Derby Southern Bypass in 1994-5 [c. 254 313]. The gravel was sandy in the lower part and clayey in the upper part and had a general chaotic fabric with vertical stones in places. Clasts were mainly Bunter pebbles (c. 90%) and shattered and fractured yellow-brown and white patinated flints (≤10%) with also chert and Mercia Mudstone Group sandstones as minor constituents. The gravel contained several deep orange-brown, medium-grained sand lenses, up to 0.4 m thick, which were disturbed and tilted. In some places mottled orange-brown and grey clay was involuted into the top of the gravel down to a depth of c. 0.6 m. The involuted contact of the gravel on red clay (weathered Mercia Mudstone) was also exposed [2541 3114]. A borrow pit [257 315] dug during bypass construction at Hilton Lodge exposed c. 2 m of similar gravel on Mercia Mudstone Group. The face was degraded at the time of the survey but a twisted ovate flint handaxe was found in gravel debris by the writer.

The Etwall Sand and Gravel forms an outlier [272 309] on the east side of the Egginton Road to the south of Etwall. 'Fine gravel' was formerly worked from a now degraded pit [273309]. The deposit is not exposed and is probably not more than 3 m thick.

Sections were made available in cuttings and excavations during the construction of the Derby Southern Bypass across Willington Hill (see for example the section given above under *Oadby Till*). Figures 2 & 3 show that the base of the deposit rises towards the valley flank. Numerous boreholes in this area indicate that the thickness of the deposit varies considerable over short distances. Great complexity and deformation were manifest in the cuttings, yet in spite of this, the deposits underlie a flat terrace feature on Willington Hill. This terrace surface must be the result of cryoplanation and only approximate to the original depositional surface of the deposit.

In most temporary sections, c. 2 m of gravel and stony clay head are strongly involuted and commonly occur in pods almost totally surrounded by the festoons of Findern Clay which can reach to soil level. Stones are typically vertically arranged and contacts with the Findern Clay festoons are also commonly vertical. The pods of gravel and head generally penetrate down to c. 2 m, and up to 3.5 m, below the surface. The fluvial deposit mainly comprises orange-brown, ill-sorted, highly leached sandy gravel with numerous cobble-grade clasts. The uppermost 1 m is silty and buff-coloured and may be head. The clasts are predominantly Bunter pebbles (c. 80%) and frost-shattered flints (c. 20%); Borrowdale volcanic rocks and Millstone Grit sandstones were also noted. The deposit on Willington Hill was also penetrated by site investigation boreholes (e.g. SK 23 SE/520) for the Toyota car factory (Figure 3). Up to c. 2.5 m of brown, very sandy, fine- to coarse-grained gravel was recorded. The base of the deposit on Willington Hill is generally at c. 60 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 Figures 4. 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 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 in the area, that of Egginton Common, extends from south of Hilton [260 300] to Willington [290 286], only broken by the incised valleys of Etwall and Willington brooks. The fluvial deposit mainly comprises orange-brown, strongly 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 dissected flattish area of Hilton Common in the south-western corner of the sheet [25 30] is largely covered by new housing developments. Site investigation boreholes (SK 23 SE/253-280) [c. 252 307] reveal at least 2.4 m of sand and gravel. Temporary exposures [2520 3098 & 2532 3090] showed at least 2 m of deep orange-brown sandy, clast-supported, mostly small to medium-grained gravel; in both sections the upper part of the gravel was clayey and involuted with vertical pebbles. A ditch section [2525 3051 to 2540 3046] showed up to 1.8 m of buff, sandy, very coarse-grained, cryogenically disturbed gravel which was generally clayey in the uppermost 0.4 m. Clasts, commonly to large cobble grade, were mostly Bunter quartzite and quartz (c. 85%) and frost shattered flints (≤10%). Cryogenic involuted pods of buff stony clay were involuted down into the gravel by up to 1 m and in some places contained red mottles.

These red mottled clays are interpreted as relicts of the Ipswichian temperate Hykeham Soil (see above under Etwall Sand and Gravel). Up to 3.6 m of sand and gravel were formerly worked from the extensive Redland's Hargate House Pit [c. 260 305], situated to the east. This pit is now infilled and fully restored to agriculture. McCullagh (1968, figure 1) undertook a pebble count on the gravel from this pit. The count is interpreted here to be: Bunter quartzite and quartz, 70%; sandstone (probably comprising mostly Upper Carboniferous and Bunter Pebble suite rocks), 19%; Lower Carboniferous limestone, 2%; flint, 3%; Lower Carboniferous chert, 5%; igneous rocks, 1%.

During the course of the survey, sections were seen in cuttings [2660 3083 to 2695 3070] along the Derby Southern Bypass near Tynefield Court, to the south of Etwall. The deposit was also seen in deep excavations for a bridge over Egginton Road [c. 2690 3072]. These sections showed, below c. 0.3 m of sandy gravelly soil, up to 2 m of buff-coloured, passing down to deep orange-brown, coarse-grained, ill-sorted, cobbly, sandy, silty gravel over red mudstone. The basal c. 1 m of the gravel was reddish orange-brown and clayey. The gravel contained some indistinct sand lenses. In the uppermost c. 1 m the gravel was totally decalcified and strongly cryogenically involuted with vertically arranged stones. Locally the gravel was very clayey in the top 0.5 m. The clay was mostly mottled grey and buff and contained vertically arranged stones, but at one point [2684 3073] also contained red blotches, interpreted to be rubification associated with Hykeham Soil development (see above under Etwall Sand and Gravel). The gravel clasts were mostly of Bunter quartzite and quartz and flints, the latter invariably frost-shattered. At one point [2696 3069], east of the Egginton Road, c. 1 m of gravel was apparently undisturbed and exhibited imbrication indicating a palaeocurrent towards 096°.

On Egginton Common [c. 274 300] much of the deposit has been worked out (see Mineral Resources section). Numerous boreholes in the worked out area indicated greatly varying thicknesses of gravel from 0 to 4.3 m. Much of the gravel was clayey and interspersed with red clay. In the Egginton Common area the clasts comprise mainly Bunter pebbles (c. 85%) and frost-shattered flints (c. 5%). The remainder of the clasts were composed of chert, and sandstones from the Mercia Mustone Group and Upper Carboniferous. Two flint handaxes were found by the writer on the reject pile at the Redland Aggregates Etwall Pit [273 297] during 1994 (Wessex Archaeology, in press).

The deposits exposed in this Etwall pit were the subject of field work over several years by Mr P F Jones of Derby University; the bulk of the results are not published. He has found a number of flint hand-axes at the pit (Jones, oral communication 1990). Notes on a geological excursion to this pit [275 300] (Jones et al., 1979) were as follows: 'The gravels were poorly stratified and highly disturbed in a form suggestive of severe periglacial disruption. They made a strong contrast with the low-lying terrace and floodplain sediments. It was mentioned that lumps of 'boulder clay' had been recorded in the Hilton gravels during earlier excavations (Posnansky, 1960). Members of the excursion examined a discontinuous surficial layer of pebbly clay and there was much discussion (particularly amongst the leaders) whether this constituted a till or a solifluction earth. The problem was unresolved. Nevertheless it was noted that the apparently simple planar surface of the terrace is misleading since it obscures a complex internal structure.' A further excursion report on Etwall Gravel Pit [grid reference erroneously given as 275 309]

(Jones, 1981), which was supposedly located on the 'Upper Hilton Terrace', states 'Approximately 3 m of coarse ochreous gravels rest on Triassic bedrock. The gravels are poorly stratified and highly disturbed in a form suggestive of severe periglacial disruption. Lumps of included 'boulder clay' were reported by Posnansky (1960) from a nearby site (2 km SE) but have not been recorded here.' It continues: 'Borehole and geophysical investigations in connection with earlier workings on Eggington Common (1.5 km S) showed that the gravels in that area occupy a series of sinuous channels. These are over 5 m deep and form a dendritic pattern with an apparent drainage direction of E - W (ie opposite the flow the modern river). The borehole logs also record the occasional presence of pebbly red clays at different horizons within the gravel sequence. While the origin of these deposits is not clear, discontinuous surficial layers of pebbly clay exposed in shallow pits on Egginton Common have been interpreted as solifluction earths. Such records do not support the view that the Hilton Terrace had a conventional fluvial origin.' It is suggested here that the dendritic 'channel' pattern possibly results from severe post-depositional periglacial disruption.

5.2.4 Holme Pierrepont Sand and Gravel

The thalwegs and long profiles of this terrace deposit are illustrated in Figure 4. This deposit was graded to a lower base level than Flandrian Trent deposits and as a consequence both underlies the latter and forms a dissected terrace, c. 1-2 m high, bordering the Hemington Terrace. The deposit was previously referred to as (deposits of) the Floodplain Terrace (Swinnerton, 1937) and the Floodplain Sand and Gravel (Brandon & Sumbler, 1988) but was renamed the Holme Pierrepont Sand and Gravel by Charsley et al. (1990). The Holme Pierrepont Sand and Gravel comprises generally pink, ill-sorted, matrix-supported, sandy, trough cross-bedded gravels and is interpreted as a braid plain distal sandur deposit from the late Devensian ice front situated above Burton upon Trent in the Trent valley and near Uttoxeter in the Dove valley.

Details:

Its outcrop just barely enters the south-western corner of the sheet area at Hilton Depot and no sections were encountered.

5.2.5 River Terrace Deposits, undifferentiated

A small area of River Terrace Deposits has been mapped adjacent to Etwall Brook, just to the north-east of Dalbury [2589 3457]. The deposit comprises sandy, gravelly clay and forms a terrace slightly elevated above the clay alluvium of Etwall Brook.

5.3 Alluvium

All the streams of the area are associated with narrow tracts of floodplain alluvial deposits, typically between 100 m and 250 m in width. The named streams of the area are Etwall Brook and its tributaries, the Trusley and Radbourne brooks. These alluvial deposits typically comprise c. 1 m of greyish brown, grey, reddish brown or buff, clayey, stoneless 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.

Details:

A trench [2650 3086] along the route of the Derby Southern Bypass to straighten out the course of Etwall Brook was cut into c. 2 m of reddish brown stoneless clay. Grey clay from a lower level was also dug out.

5.4 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. Locally, these superficial contorted deposits were noted extensively by Deeley (1886; in Bemrose and Deeley, 1896, pp. 508-509) as 'underplight'. They have also been referred to locally as 'Valley Drift' (Fox-Strangways, 1905; Lamplugh et al., 1908). If the superficial deposits are thin enough, the structures penetrate down into the underlying bedrock. Cryogenically involuted terrace gravels are widespread in the southern part of the area and many examples were seen during the survey where the underlying bedrock was also affected. For example, the Etwall Sand and Gravel and

Egginton Common Sand and Gravel are severely affected by involutions except locally where the deposits are greater than 3 m thick (see relevant sections).

The net result of post-Anglian periglacial degradational processes in south Derbyshire is the production of nearly planar surfaces, commonly underlain by complex sequences of glacial drift or other superficial deposits and where the subjacent bedrock is commonly irregular, bearing little or no relationship to the surface morphology (Jones et al., 1979; Jones & Charsley, 1985; Jones & Derbyshire, 1977, 1983). These cryonival processes were no doubt active during all the post-Anglian stadial stages, culminating in the late Devensian Dimlington and Loch Lomond stadials. The former, established explanation for such surfaces (e.g. Clayton, 1953) was that they formed a sequence of erosion surfaces that reflected a denudation chronology in which the pre-glacial south Derbyshire landscape had remained almost unchanged as far back as the Tertiary. That such surfaces were initiated on Anglian drift deposits makes them comparatively recent and the former ancient denudation scenario is clearly not tenable.

Cryogenic structures
In all sections, the uppermost few metres of the higher river terraces, namely the Etwall, Egginton Common and Beeston sand and gravel, are affected by involutions or festoons, the severity generally being proportional to the age of the deposit. The involutions involve underlying deposits and overlying geliflucted head clays. Vertically arranged stones are extremely common in these situations.

Details:

Sections in which red clay, derived from the Mercia Mudstone, and gravel, derived from the Etwall Sand and Gravel, were intimately involuted were well exposed along the Derby Southern Bypass at a number of places in the Hilton [2575 3110 to 2631 3090] and Etwall [2695 3072 2733 3061; 2682 3109 to 2685 3088] areas. These localities all lie on the convex sloping ground between outcrops of *in situ* Etwall Sand and Gravel and Egginton Common Sand and Gravel, i.e. on the bedrock step between the two terrace deposits. This step, at least down to a depth of c. 2 m, is therefore composed of geliflucted material where pod-like masses of red clay, red stony clay, clayey gravel and leached sandy gravel are mixed together in a very irregular association. The red clay even occurs commonly over gravel. All non-spherical stones tend to have their long axes arranged vertically. Unlike the planar terraces, this 'bedrock step' in the ploughed fields is also gravelly but contains abundant traces of red clay.

6. STRUCTURE

Because of the extensive cover of superficial deposits in the lower Dove valley areas, 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 streams 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 (T. C. Pharaoh, oral communication 1996).

The dominant faults of the area are mostly post-Triassic reactivations of Variscan structures. The main fault is the northern continuation of the Needwood Fault (=Hints Fault; Barclay, 1997); its course in the present area 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. In the north of the area near Dalbury [2652 3470] the strata dip gently to the south-south-east, a direction which accords with the strike of the sandstone unit within the Gunthorpe Formation north of Highfields Farm [2700 3407]. This strike is also suggested from the outcrop pattern of the Cotgrave Member both to the north [2867 3354] and south [2965 3176]. In the south of the area a few dips were measured along the Derby Southern Bypass. To the east of Tynefield Court [2690 3072] the strata dip about 5 degrees to the east-north-east; three hundred metres to the west-north-west [2660 3080] the dip is about 5 degrees to the west. A minor anticline is suggested by the dips, it may possibly be related to the northerly-trending fault located about 600 m farther west. West of this fault more variable dips have been recorded in the borrow pit for the new road scheme. At the east of this pit [2573 3155] the dip was recorded as 4 degrees to the south; west of the pit [2560 3153] the dip was 11 degrees to the west-south-west. These variable dips in close proximity may relate to the nearby faulting.

6.2 Faults

The faults within the area are mainly postulated from very scant surface geological information and deep seismic data (interpreted by T C Pharaoh, oral communication 1996). The deep seismic data images the base of the Triassic sequence and the structure in the underlying Carboniferous rocks, but gives very little detail for the Triassic sequence itself. As a consequence many faults are extrapolated from the base of the Trias to the surface. It is noted that the seismic data gives little indication of the trend of the faulting, which can only be inferred where they cut more than one seismic line.

The north-trending Needwood Fault, which throws to the west, lies along the western side of the area and is structurally related to the eastern margin of the Triassic Needwood Basin. The fault is proved in a seismic traverse just south of the area and is further suggested by borehole data there.

In the northern part of the area, an approximately east-west trending fault is suggested from one seismic line near The Cottage [2770 3411]. The westerly continuation of the fault is indicated by the truncation of the sandstone unit that passes about 500 m west of The Cottage. The easterly extension of the fault is suggested by a slight off-set of the Cotgrave Member near Bonehill Farm [2721 3417].

A fault with a north-east to south-west trend passes through the central part of the area just to the north of Etwall. It was proved on a seismic line just to the south-west of Marsh Farm [2780 3310] and truncates a sandstone unit at the farm. The trend of the fault is not well constrained, but it is inferred to approximately follow that of the valley.

A north-west trending fault passes to the south-west of Burnaston and is inferred from the termination of the outcrops of the Cotgrave Member and the form of the local topography. It is the continuation of faulting mapped on the sheets to the east and south-east, but the precise position of the fault is not well constrained.

6.3 Folds

Seismic interpretation for the area (T C Pharaoh, oral communication 1996) suggested that an approximately north-north-west trending anticline enters the south of the area [at 2780 3000], and affects strata at the base of the Triassic. The opposing dips measured on the Derby Southern Bypass [2661 3081 and 2691 3073] may also suggest an anticline, albeit with an axis offset by about 800 m to the west of the structure inferred from the seismic data. Alternatively, the dips on the Derby Southern Bypass may have been influenced by periglacial disruption, or be caused by close proximity to the northerly trending fault which passes just to the west. A similar interpretation may explain the variable dips recorded in the Hilton Borrow Pit [2568 3155].

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. Railway and road cuttings are also depicted as Worked Ground if the ornament does not interfere with presentation of the geological data.

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. Where known, the nature of the Made Ground is shown on the map. Made Ground is ubiquitous in urban areas, particularly where development has extended onto floodplains, but is only shown if known to be c. 1 m or more deep and of significant areal extent.

The extensive former gravel pits in the area (see Mineral Resources section) are generally infilled, partly with power station fly ash and partly with construction and domestic waste.

7.1.3 Landscaped Ground

The Landscaped Ground symbol has been used for 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 commonly 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 and Edwalton 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 out symbol. They are particularly numerous in the Edwalton Formation on the north side of the hill between Etwall and Burnaston.

The interbedded red and green mudstones and siltstones of the Gunthorpe Formation were dug from below the Etwall Sand and Gravel at a borrow pit [257 315] near Hilton Lodge during construction of the Etwall Bypass.

7.2.2 Sand and gravel

The Etwall Sand and Gravel and the Egginton Sand and Gravel have been extensively worked in the past for sand and gravel aggregate. These relatively high level terrace deposits could be worked above the water table.

Eagle Moor Sand and Gravel
This sandy deposit was possibly worked from a small pit [274 321] to the east of Etwall.

Etwall Sand and Gravel
This deposit was worked extensively north of Hilton [252 314], initially by the Hilton Sand and Gravel Co. and later by Blue Circle. These pits, said to have been started c. 1924, were still active in the 1940s. They are now either infilled or restored as a nature reserve. A completely filled pit [253 312], worked by BCA, now underlies the new road interchange. The deposit was relatively recently dug from a pit [257 315] situated north-west of Hilton Lodge during the construction of the Etwall Bypass. A small degraded nineteenth century pit [273 309] occurs to the south-east of Etwall. A minor degraded pit [2817 3104] that was also extended downwards for marl is situated to the south of New Close Farm.

Egginton Common Sand and Gravel
The largest workings were on Egginton Common. Redland Aggregates extracted from their extensive Etwall Pit [27 29], situated north of the railway line, until c. 1994. Redland also extracted aggregate from the Hargate House Pit [c. 260 305] situated between Hilton and Etwall Brook. This pit is now fully restored to agriculture. Two further pits occurred on the south side of the Derby Rd [251 309; 254 307] at Hilton.

7.3 Water Supply

The principal 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 former 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). In the Etwall area, the aquifer formed by the two divisions is confined by the relatively impermeable Carboniferous rocks below, and by less permeable formations of the Mercia Mudstone Group above. At any one place the depth of the top of the upper aquifer below surface depends on which particular stratigraphical level in the Mercia Mudstone forms the bedrock. It is deepest beneath the crop of the Edwalton Formation (at most c. 130 m deep) and least below the Gunthorpe Formation (at least c. 10 m deep).

The Cotgrave Sandstone Member constitutes a minor aquifer in the area. The sandstone is confined by the surrounding impermeable mudstones.

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 down slope 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 Peaty alluvium

Layers and lenses of organic-rich silts and clays as well as peat may occur within the stream valley alluvium. Such deposits are highly compressible compared to the surrounding deposits and could give rise to excessive and differential settlement of overlying structures.

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 23 SE 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

There is only one deep borehole in the area. This is the Pastures Hospital Borehole (SK 23 SE/19 [2968 3317] drilled 1899-1901. As usual in the case of these older records, the stratigraphy is open to interpretation. One interpretation is given below. Abbreviations are as follows: OD Ordnance Datum; SL Surface level; TD Terminal depth. Soil has been omitted from the logs.

Formation	Lithology (most of the descriptions are old drillers terms)	Thickness metres	Depth metres
Existing well			46.18
Mercia Mudstone Gp. Cotgrave Member?	'White sand and marl'	1.68	47.86
Mercia Mudstone Gp. 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 Gp. Radcliffe Formation?	'Sandstone', 'marl' and 'grey rock' with a little 'red spar'	10.82	132.59
Mercia Mudstone Gp. 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 SW, 49, SE, 53 NE, 53 SE, 54 NW, 54 NE, 54 SW, 54 SE.

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

4. BGS 1:50 000 Series Sheet Burton-on-Trent (140), 1953.

5. BGS 1:10 000 field slips and standards for SK 23 SE; 1997.

6. BGS field note sheets KW 604GN-648GN; AC1-AC92

7. Loughborough Memoir (Fox-Strangways, 1905)

8. Burton-on-Trent Memoir (Stevenson and Mitchell, 1955)

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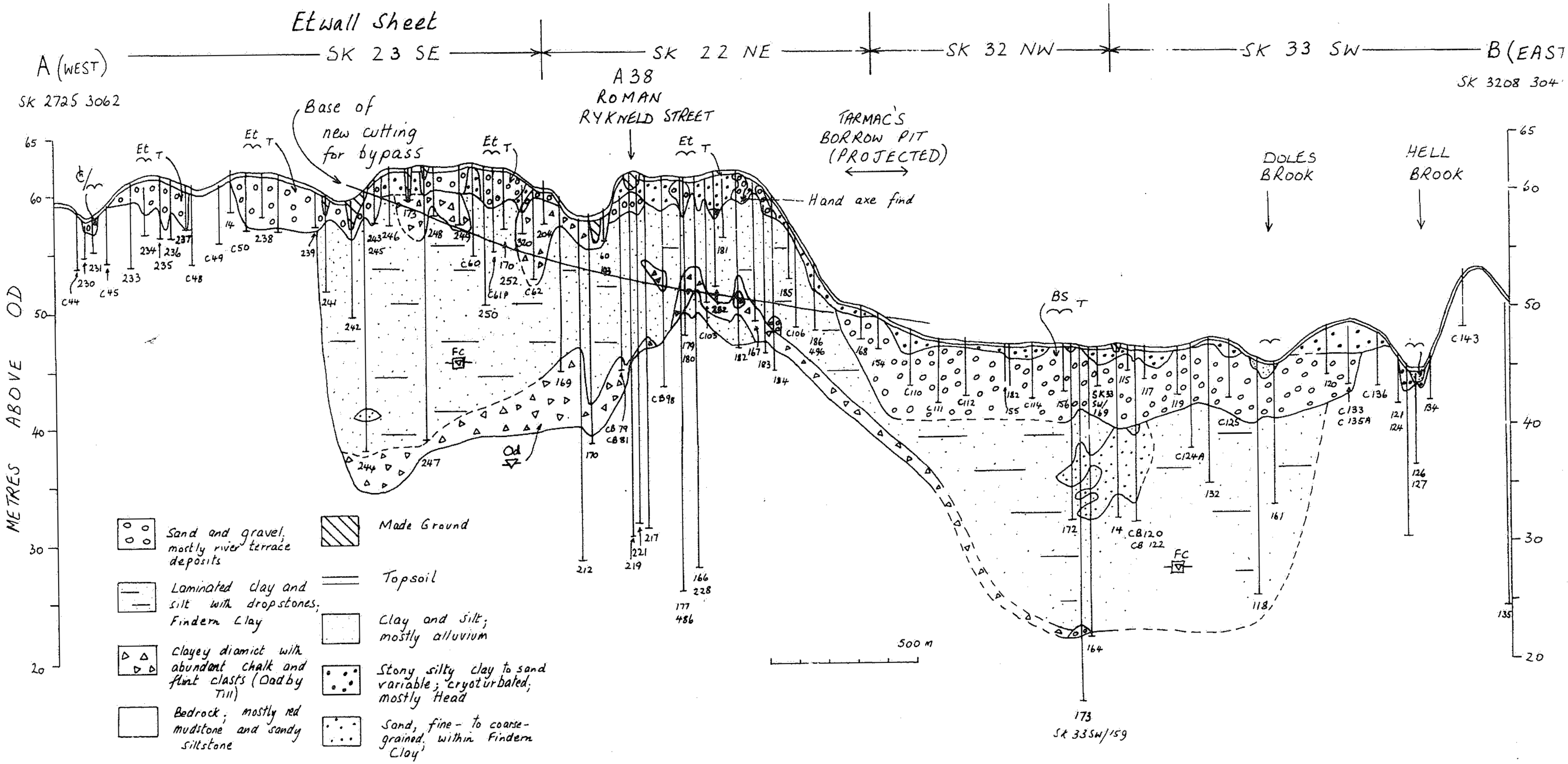

Figure 2. An approximately longitudinal cross section of the Elvaston Palaeochannel deposits constructed from boreholes along the Derby Southern Bypass transect. Note that intense cryoturbation and involution affects the highest parts of the infill deposits, comprising the upper Oadby Till, Findern Clay and also the overlying Etwall Sand and Gravel and Head. The vertical scale is exaggerated by x 40. Numbers below the boreholes are the registered numbers in the BGS archive. In addition, the positions of a selected number of critically positioned, unregistered boreholes are indicated. These belong to the C and CB series of Scott, Wilson and Kirkpatrick and are not currently lodged with BGS. Numbers in brackets refer to those boreholes which have been projected by up to 50 m onto the line of section. Note the position of the hand axe find.

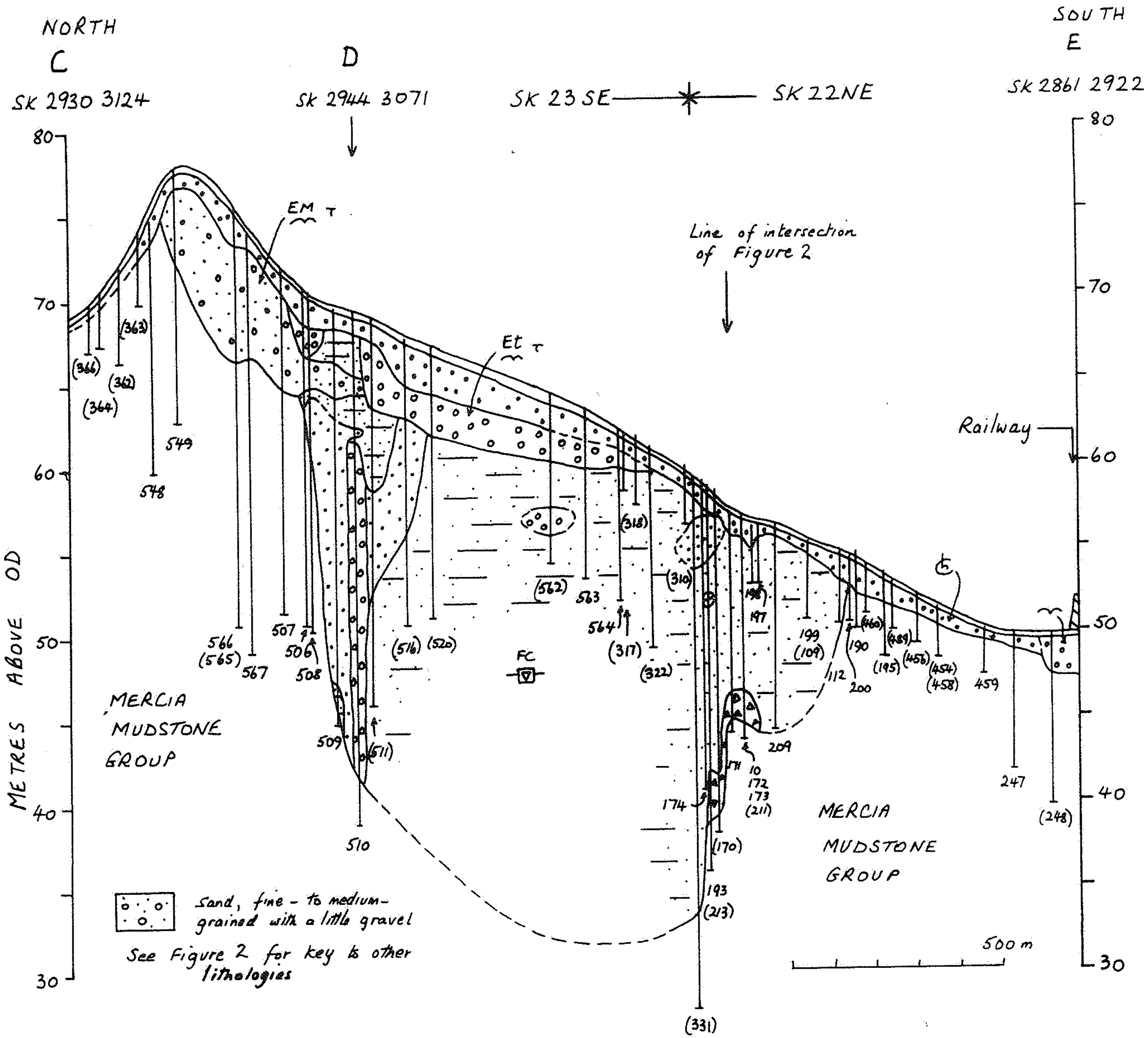

Figure 3. A transverse cross section of the Elvaston Palaeochannel deposits constructed from borehole data. See Figure 2 for key to ornament used. The vertical scale is exaggerated by x 40. Numbers below the boreholes are the registered numbers in the BGS archive. Numbers in brackets refer to those boreholes which have been projected by up to 50 m onto the line of section. Note that most of the cross section lies on Sheet SK 23 SE.

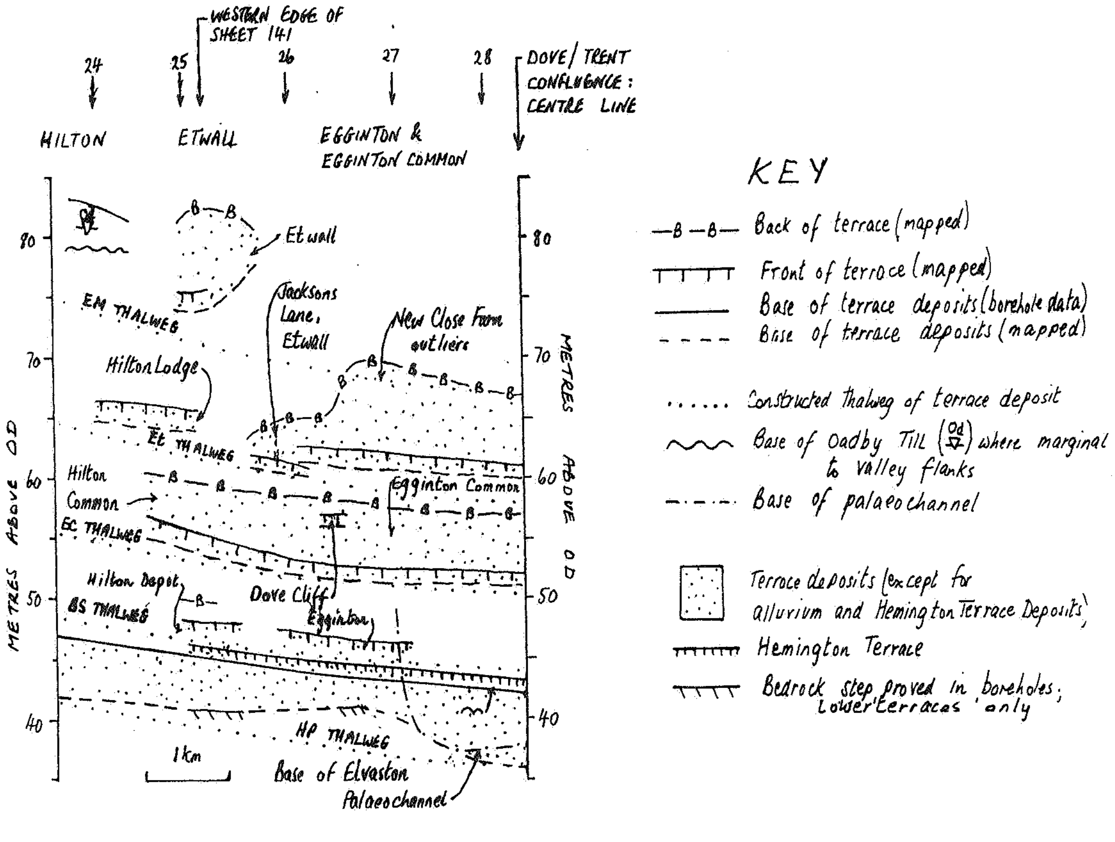

Figure 4. Lower River Dove terrace deposit and alluvium long valley profiles and thalwegs across sheets SK 23 SE and SK 22 NE. The terrace remnants are projected onto a line drawn down the centre of the valley. The height ranges of each remnant are shown rather than the thickness of the deposit at any particular point. Note that deposits underlying the back of the terrace as mapped probably include significant slope deposits. Terrace deposit symbols are as follows: EM Eagle Moor; Et Etwall; EC Egginton Common; BS Beeston; HP Holme Pierrepont.

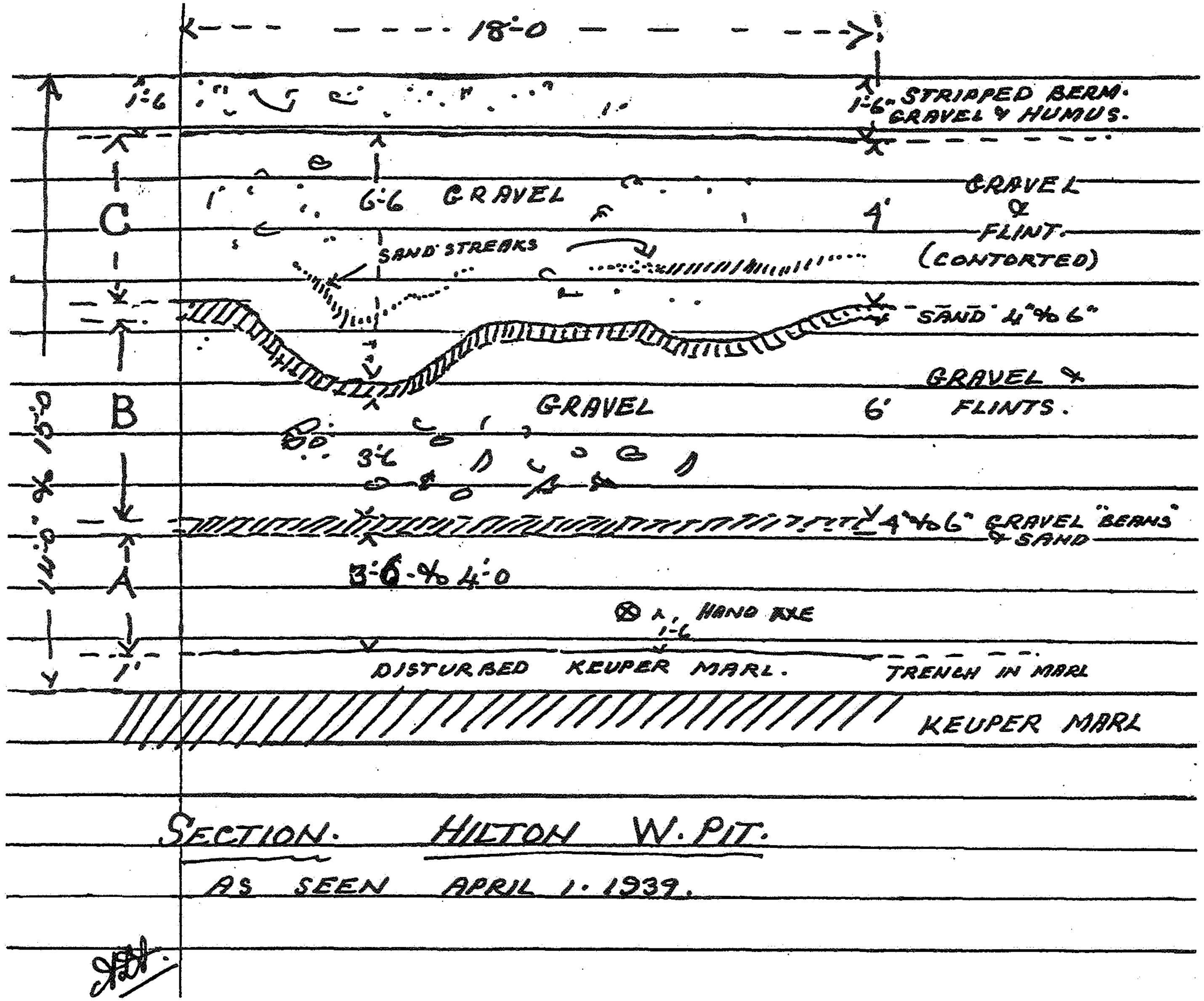

Figure 5. Reproduction of Armstrong's field sketch of the gravel beds at Hilton West Pit

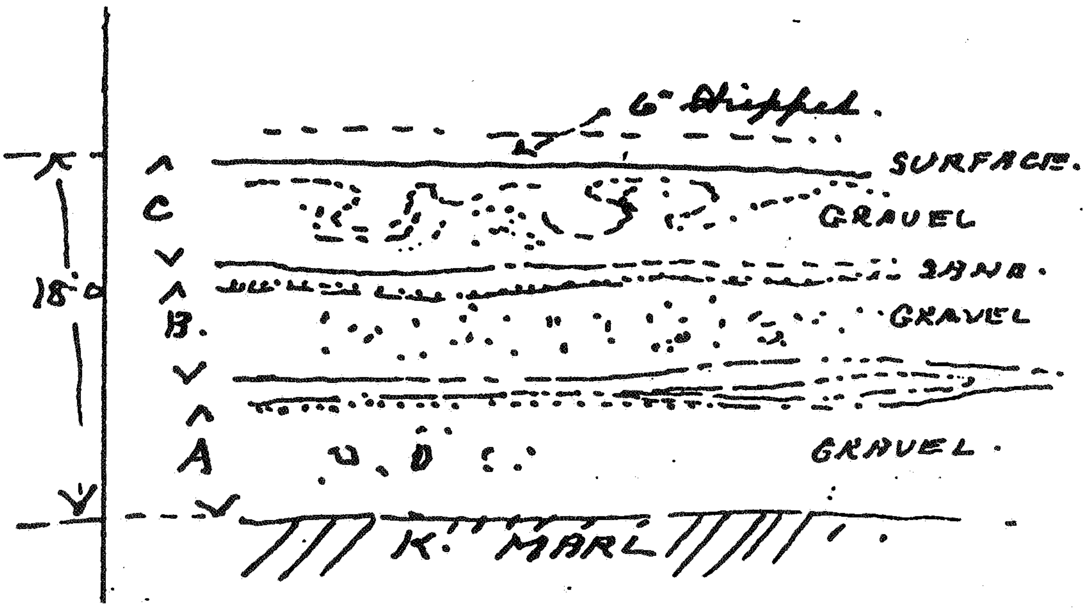

Figure 6. Reproduction of Armstrong's sketch of Hilton West Pit (Armstrong 1942/45 MS)

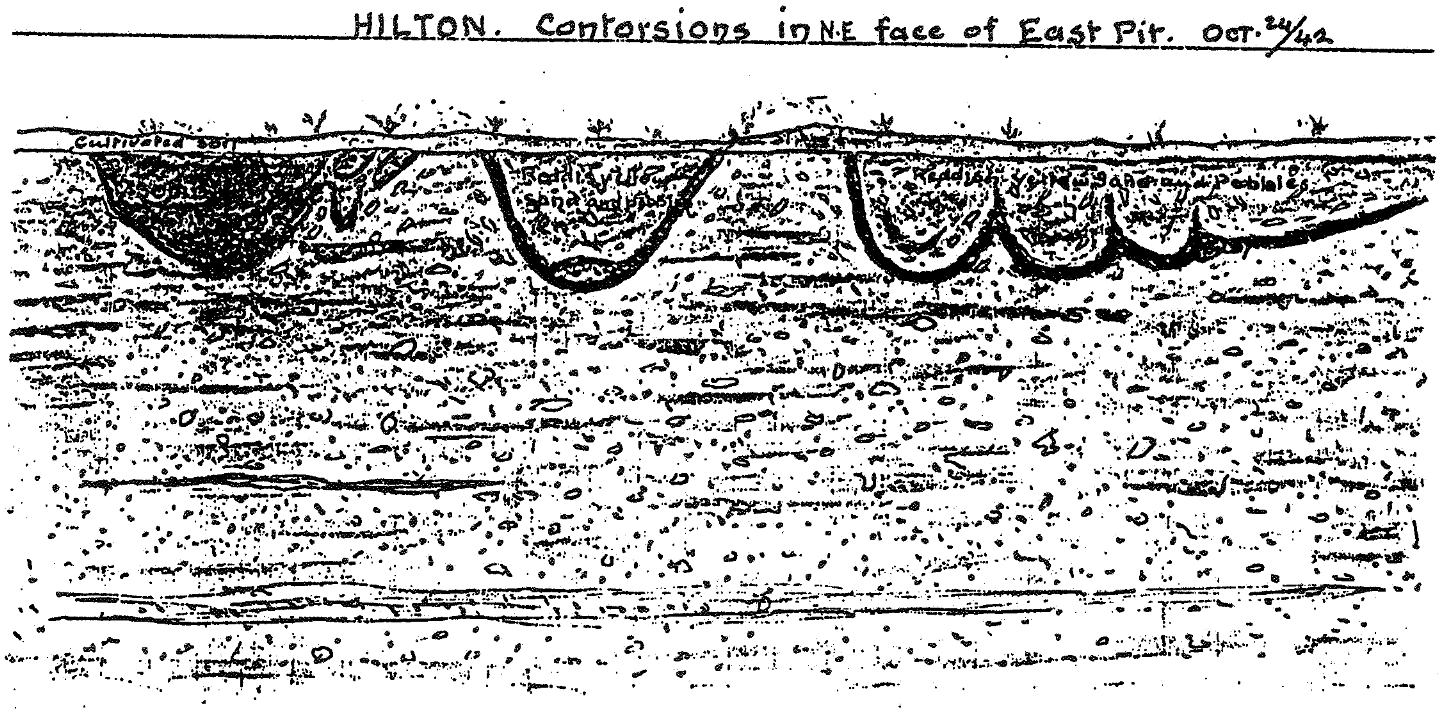

Figure 7. Sketch of the face of Hilton East Pit (Armstrong 1942/45 MS).