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Geology of the Scalford area: 1:10 000 sheet SK72SE

Part of 1:50 000 Sheet 142 (Melton Mowbray)

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1. INTRODUCTION

This report describes the geology of 1:10 000 sheet SK72SE (Scalford). The map sheet (hereafter referred to as the 'area'), falls in the 1:50 000 Geological Sheet 142 (Melton Mowbray). It was first geologically surveyed at one-inch to one-mile scale, by E Hull between 1850 and 1860 and published as part of the Old Series One Inch Geological Sheet 71 (Nottingham). The area was resurveyed on the six-inch scale by C B Wedd in 1906 and published on 1:10 560 County Series Leicestershire Sheets 13 and 20. The New Series One-Inch Geological Sheet 142 (Melton Mowbray) was published in 1909, together with an accompanying memoir (Lamplugh et al., 1909). The Marlstone Rock Formation was resurveyed at the 1:10 560 scale in 1939 by D A Wray and the Northampton Sand Formation by F B A Welch in 1941, both as part of the wartime ironstone survey, with an accompanying memoir (Whitehead et al., 1952). Revisions of the One-Inch sheet were published in 1959 and 1969 and it was reprinted at the 1:50 000 scale in 1976.

Sheet SK72SE was resurveyed at 1:10 000 scale by K Ambrose in 1999. This later mapping constitutes part of the Melton Mowbray Geological Mapping Project, under the direction of T J Charsley (Regional Geologist).

The map sheet lies within the North West Leicestershire administrative area. It covers the north-eastern suburbs of Melton Mowbray and the rural area to the north-east, which encompasses the villages of Scalford, Thorpe Arnold, Wycomb and Chadwell. The area is dominated by agriculture.

The area is almost entirely a dissected till plateau, sloping gently southwards and drained by two north-south flowing streams and numerous, minor, tributary valleys. The streams drain into the River Wreake at Melton Mowbray. Solid rocks crop out only in the north around Scalford and in the north-east corner of the area.

Corresponding reports covering contiguous 1: 10 000 sheets are:

SK61NE, 71NW, 71NE and 81NW (Wreake Valley)	(Brandon, 1999)
SK72SW (Ab Kettleby)	(Ambrose, 1999)
SK72NE (Eastwell)	(Ambrose, 2000)
SK82NW and 82SW (Croxton Kerial and Waltham)	(Carney and Sumbler, 2000)

An index to the adjacent 1:10 000 geological maps is given in Figure 1.

This report should be read in conjunction with the 1:10 000 scale geological sheet SK72SE. This shows the outcrop of solid geological formations and superficial deposits which are mostly unexposed, being hidden beneath soil or man-made deposits. Their outcrop limits, represented by geological boundary lines, are mostly inferred from field observations of landforms and soil type, or are extrapolated from adjoining areas, or from borehole records. The subcrops of the Deep Main Coal, Vanderbeckei Marine Band and principal faults at the Carboniferous – Permo-Triassic unconformity are also indicated. These have been extrapolated from boreholes, plans drawn by British Coal and R J B Mining (UK) Ltd., and seismic information interpreted by Dr T C Pharoah. The map is therefore the interpretation of the surveyor, based on information to hand at the time of the survey. All geological boundaries carry an element of uncertainty. Boundaries of solid formations which (in the opinion of the surveyor) can be located to an accuracy of 10 m or less on the ground, are shown as unbroken lines on the map; all other less-certain boundary lines are shown broken. The subsurface geology described in the report is based on geophysical log interpretation and correlation, and on detailed lithological borehole logs.

Copies of the 1:10 000 map can be purchased from BGS, Keyworth. It should be noted that copyright restrictions apply to the use of this map, or parts thereof, and to the direct copying of the illustrative and text material of this report. This report constitutes an internal publication of the BGS and any information extracted from it should be acknowledged by a bibliographic reference (see title page).

Throughout this report, National Grid references are given in square brackets and all lie within 100 km grid square SK. The borehole numbers given are those of the BGS archives where they are prefixed by the number of the 1:10 000 map sheet.

SK72NW	SK72NE	SK82NW
SK72SW	SK72SE	SK82SW
SK71NW	SK71NE	SK81NW

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

2. GENERAL ACCOUNT

A stratigraphical summary of the area is given in Table 1. The oldest rocks, proved only in the Scalford Borehole, comprise unfossiliferous red-brown, purple and grey siltstones, sandstones and mudstones, provisionally assigned a Devonian age. These rocks are succeeded by a thin Lower Carboniferous (Dinantian) sequence of marine mudstones and limestones, assigned to the **Widmerpool Formation**. The overlying Upper Carboniferous (Silesian) age rocks comprise initially marine mudstones and limestones correlated with the **Edale Shale Group**, succeeded by fine- to coarse-grained sandstones with interbedded siltstones and mudstones of the **Millstone Grit Group**. Continued fluvio-deltaic and fluvio-lacustrine sedimentation in an area of subdued topography formed the **Lower Coal Measures** sequence, whose conformable contact with the Millstone Grit is occupied by mudstones of the *Subcrenatum Marine Band.* The lowermost strata are similar to the Millstone Grit in containing relatively few coal seams. They include sandstones correlated with the *Wingfield Flags*. The main coal-bearing sequence succeeds these beds; it commences with the *Kilburn Coal* and is characterised by cyclic sequences of lacustrine mudstone, distributary channel siltstones and sandstones, seatearths and coal seams, the latter representing peat bogs or mires. The principal seams are the *Blackshale* group of coals, *Parkgate Coal* and the *Deep Main Coal*, which are in excess of 2 m thick. The overlying **Middle Coal Measures**, commencing with the *Vanderbeckei Marine Band*, are similar to the coal-bearing Lower Coal Measures. Basaltic lavas, tuffs and agglomerates of the **Saltby Volcanic Formation** interdigitate with the Coal Measures strata, commencing just below the Kilburn Coal and continuing throughout most of the Lower Coal Measures.

Uplift and erosion preceded deposition of Permian strata, resulting in a significant unconformity that locally cuts out the upper part of the Lower Coal Measures, all of the Middle and probably Upper Coal Measures strata. Within the area, at least 100 m of Carboniferous strata have been removed locally.

The earliest Permian strata comprise the *Permian Basal Breccia*, representing deposition on the eroded and irregular post-Carboniferous land surface by alluvial fan and debris flow processes. The succeeding strata comprise interbedded mudstones and sandstones. They have not been correlated with known Permian strata of adjacent areas, but may include the Edlington, Cadeby and possibly Lenton Sandstone formations. The earliest known Triassic deposits are fluvial sandstones of the **Nottingham Castle Sandstone Formation**, a division of the **Sherwood Sandstone Group**. The succeeding beds of the **Mercia Mudstone Group** comprise, at the base, micaceous mudstones, siltstones and sandstones of the **Sneinton Formation**. These strata were formerly known as the 'Waterstones'. They represent continued aggradation, with deposition probably occurring on a broad alluvial plain with ephemeral streams and bodies of standing water, sheet floods and accretion of wind blown sediment. The overlying **Radcliffe Formation** is a very finely laminated lacustrine deposit. The succeeding strata of the **Gunthorpe, Edwalton** and **Cropwell Bishop formations**, chiefly consist of gypsiferous red mudstones and siltstones that are the accumulations of wind-blown sediments in an arid playa mudflat or sabkha environment. Short-lived sheet flood episodes associated with periods of standing water (playa lakes) caused the deposition of several intercalated beds of greenish grey siltstone and fine-grained sandstone. The *Cotgrave* and *Hollygate Sandstone members*, respectively at the base and top of the Edwalton Formation, are sequences of greenish grey and red-brown, fine-grained sandstones with interbedded siltstones and mudstones. The Cropwell Bishop Formation includes the *Tutbury* and *Newark gypsum* seams. The **Blue Anchor Formation**, at the top of the Mercia Mudstone Group, comprises pale greenish grey mudstones and siltstones, deposited in mixed continental and marine waters.

A marine transgression followed, depositing rocks of the Triassic **Penarth Group**, here represented only by the **Westbury Formation**, which consists mainly of black, fossiliferous, fissile mudstones with thin sandstones. Fully marine conditions in a warm tropical setting were well established at the start of Jurassic times. The **Scunthorpe Mudstone Formation** at the base of the Lias Group has five component members, the *Barnstone*, *Barnby*, *Granby*, *Beckingham* and *Foston members*. These comprise sequences of interbedded mudstone and limestone (Barnstone, Granby and Foston members) and mudstone with a few thin limestones (Barnby and Beckingham members). The Triassic – Jurassic boundary occurs within the lower part of the Barnstone Member and is taken at the incoming of the ammonite *Psiloceras planorbis*. The **Charmouth Mudstone Formation** consists mostly of grey, fossiliferous mudstones, with a few thin limestones and locally common calcite and siderite mudstone nodules. It includes the *Brandon Sandstone, Loveden Gryphaea Bed* and *85 Marker Member*, all recognised on geophysical logs. Shallowing of the sea saw an input of clastic sediment (silt and sand) depositing the **Dyrham Formation**, followed by the formation of ferruginous ooliths, deposited as the **Marlstone Rock Formation**. This bed has formed an important source of iron ore in the present area. A subsequent return to deeper water conditions saw deposition of the fossiliferous **Whitby Mudstone Formation**. This was followed by a second major shallowing phase which resulted in deposition of ferruginous sand and ooliths of the **Northampton Sand Formation**, succeeded by sands, silts and clays of the **Grantham Formation**, and culminating in a carbonate platform with deposition of the **Lincolnshire Limestone Formation**.

AGE	STRATIGRAPHIC UNIT	THICKNESS (m)
QUATERNARY	DRIFT:	
	Head	Up to 3
	Alluvium	Up to 3
	Oadby Till	Up to 26.5
	Oadby Till (flint and chalk-free)	Up to 21
	Glaciofluvial Deposits	Up to 15
JURASSIC	INFERIOR OOLITE GROUP	
	Lincolnshire Limestone Formation	5
	Grantham Formation	1–3
	Northampton Sand Formation	5
	LIAS GROUP:	300–310
	Whitby Mudstone Formation	30
	Marlstone Rock Formation	4–6
	Dyrham Formation	18.5–29
	Charmouth Mudstone Formation	106–125
	Brandon Sandstone	3–4.5
	Scunthorpe Mudstone Formation	121.9–125
	Foston Member	25.2–30
	Beckingham Member	23.9–25.5
	Granby Member	32.4–39
	Barnby Member	24–34.3
	Barnstone Member*	6–6.1
TRIASSIC	PENARTH GROUP:	
	Westbury Formation	2–4
	MERCIA MUDSTONE GROUP:	198–211.1
	Blue Anchor Formation	3–7
	Cropwell Bishop Formation	28–32
	Edwalton Formation	41–43.5
	Hollygate Sandstone Member	4.5–7
	Cotgrave Sandstone Member	4–5.5
	Gunthorpe Formation	64–70.1
	Radcliffe Formation	6.5–9
	Sneinton Formation	47–57.1
	SHERWOOD SANDSTONE GROUP:	
	Nottingham Castle Sandstone Formation	25–35
PERMIAN	Undivided	0–2.73
	Permian Basal Breccia	8.12–30.43
UPPER	COAL MEASURES	
CARBONIFEROUS	Middle Coal Measures	0–60
	Lower Coal Measures	130–?160
	MILLSTONE GRIT GROUP	65
	EDALE SHALE GROUP	165
	CARBONIFEROUS LIMESTONE	
	Widmerpool Formation	68
	?DEVONIAN	123.7

* The lower part of the Barnstone Member is also of Triassic age

Table 1. Sequence of geological units in the Scalford area.

The earliest Quaternary deposits have been proved in boreholes on adjacent areas. They are pre-Anglian sands and gravels of the former Bytham River which flowed eastwards across the area just to the north of Melton Mowbray. Two tributary valleys to this river trend north - south across the area but there are no proven pre-Anglian deposits in them. The earliest glacial deposits comprise till derived from ice sheets that spread across the area from the north-east. The age of this glacial advance was previously placed within the 'Wolstonian' (Saalian of Europe) Stage of the Upper Pleistocene (e.g. Rice, 1968). The weight of new evidence from the English Midlands now suggests that it is older, belonging to the Middle Pleistocene (Anglian) Stage. The glacial drift of East Anglia and Warwickshire was deposited at this time (Sumbler, 1983). The Anglian deposits in this area are represented by the *Oadby Till*. This comprises a lower, grey, Lias-rich till, with pockets of locally derived ironstone and Jurassic limestone clasts, but with no flints or chalk, overlain by till with a brown to grey matrix and clasts of Jurassic and Cretaceous derivation, including common chalk and flints. Both tills represent an ice advance from the east or north-east. Fluvio-lacustrine silts and sands crop out in the extreme south of the area.

The present topography of the area was moulded by the phases of stream incision that accompanied and followed ice retreat. The youngest units of the area consist of modern riverine *Alluvium* and *Head*, the latter consisting of weathered bedrock or glacial material transported downslope by various mass-wasting processes.

3. ?DEVONIAN

The Scalford Borehole (SK72SE/30) [77454 22987] proved 123.7 m of sandstones, siltstones and mudstones to a depth of 1069.54 m. The beds are variably red- to dark red-brown, brown, green, purple, grey and orange. The sandstones are variably to very fine- to medium-grained and generally calcareous. The siltstones are blocky to fissile, weakly to non-calcareous and micaceous in parts. The mudstones are grey, blocky and non-calcareous. No fossils have been recorded and the rocks have been provisionally assigned a Devonian age on the grounds of stratigraphic position and lithology. These rocks have not been proved elsewhere in the Melton district; eastwards, they die out rapidly, the Sproxton Borehole (SK82SW/1) [8451 2394] proving Westphalian strata overlying probable Ordovician basement (Carney and Sumbler, 2000).

4. CARBONIFEROUS

Carboniferous rocks are known only from deep boreholes and extrapolated from seismic data. Dinantian, Namurian and Westphalian strata have all been proved in this area.

4.1 Dinantian (Widmerpool Formation)

Dinantian age rocks have been proved in the Scalford Borehole. They comprise 68 m of interbedded off-white to pale grey, crystalline limestones and mid to dark grey and pale greenish grey, fissile, blocky, calcareous mudstones. The base of the formation, at 945.79 m, is marked by a medium- to coarse-grained dolerite sill overlain by a green, grey, black and white, coarsely crystalline, 'welded' tuff. This sequence was originally assigned to the Namurian (Pendleian) in the well completion report, but has subsequently been correlated with the Dinantian, based on geophysical log correlation. It equates with the marine mudstones and limestone turbidites of the Widmerpool Formation, deposited within the Widmerpool half-graben. The sequence is much attenuated compared to that seen farther west in the half-graben. Eastwards, the formation dies out rapidly, the Sproxton Borehole (SK82SW/1) [8451 2394] proving Westphalian strata overlying ?Ordovician (Carney and Sumbler, 2000).

4.2 Namurian

Namurian strata are represented by the Edale Shale and Millstone Grit groups. The sequences are attenuated compared to those proved to the west (Ambrose 1998; 1999). Eastwards, they are absent in the Sproxton Borehole, about 4.5 km to the east (Carney and Sumbler, 2000).

4.2.1 Edale Shale Group

Rocks assigned to the Edale Shale Group occur in the Scalford Borehole. They consist of 165 m of grey to dark grey, blocky to fissile, carbonaceous mudstones and siltstones with thin, medium- to coarse-grained sandstones. A bed of white to pale grey and brown tuff, described in the log as 'welded', occurs in the upper part of the group. These strata probably represent the turbidite facies that is typical of the Edale Shale Group elsewhere in the Widmerpool half-graben. Fully marine strata probably correlating with the ammonoid marine bands are marked by prominent gamma highs at several levels.

4.2.2 Millstone Grit Group

The group consists of 67 m of interbedded grey mudstones, siltstones and sandstones with subordinate seatearths and thin coals. The coals are generally thin (less than 40 cm) and inferior or dirty. The gamma log shows a very spiky signature for the group, indicating alternations of mainly sandstone with marine mudstones. The sandstones are pale grey and fine- to very fine-grained. The sequence is much thinner compared to the 220 m proved in the area to the west (Ambrose, 1999) and indicates attenuation towards the eastern limits of the Widmerpool half-graben. In the absence of any marine band control, correlation of the sandstones with the main 'grits' in the sequence has not been possible. The Kinderscout, Ashover and Chatsworth grits are probably all represented. A gamma peak at 668.4 m can be correlated with the Cumbriense Marine Band and a thin (c.1.5 m) sandstone at about 661.9 m depth is probably the Rough Rock.

4.3 Coal Measures

Coal Measures are present at depth across the entire area. They lie unconformably beneath Permo-Triassic rocks, the unconformity locally cutting out up to 100 m of strata, including all of the Middle Coal Measures, down to a level just above the Deep Main Coal. The maximum thickness of the sequence, proved in five deep boreholes and imaged by seismic reflection surveys, is estimated to be around 190 to 220 m, with only the Scalford Borehole proving the base. Thickness variations are due mainly to the thick interbedded sills and volcanic sequences of the Saltby Volcanic Formation, proved in the east of the area. Mudstones and siltstones with common coals and seatearths dominate the sequence, which forms the southern limit of the North-East Leicestershire (Vale of Belvoir) Coalfield. Sandstone forms a minor component but there is one locally sandstone-dominant sequence correlated with the Wingfield Flags. The Subcrenatum Marine Band, marking the base of the Coal measures and Westphalian, has been identified from geophysical logs in the Scalford Borehole; the Vanderbeckei Marine Band, marking the Langsettian – Duckmantian stage boundary, has been proved in some of the boreholes. Eastwards, this marine band onlaps onto volcanic rocks and is absent.

Coal seam nomenclature follows that used in the Nottinghamshire Coalfield (e.g. Charsley et al., 1990). A number of seams merge in the Vale of Belvoir Coalfield and the names reflect the two or more coals that combine, for example the Fourth Waterloo and First Ell Coal. The Roof Soft, Deep Soft and Deep Hard seams have merged into the renamed Deep Main Coal; the 2nd Piper, 1st Piper, Hospital, Tupton Roof, Tupton and Threequarters coals have merged to form the Parkgate Coal. Locally, the Threequarters and Tupton coals have split form the Parkgate Coal and the Blackshale, Ashgate, Mickley 1 and Mickley 2, and Mickley 3 coals have merged into one seam.

MIDDLE COAL MEASURES	
4th Waterloo and 1st Ell Coal	1.0
2nd Ell Coal	0.51
LOWER COAL MEASURES	
Joan and Brown Rake Coal	0.44–0.78
Black Rake Coal	0–0.22
Deep Main Coal	1.44–2.65
Parkgate Coal	0–3.54
Tupton and Threequarters Coals	0.83
Yard Coal	0.36–1.30
Yard Floor Coal	0–0.26
Blackshale and Ashgate, Mickley 1 Mickley 2, and Mickley 3 Coals	2.46–2.75
Mickley 4 Coal	0.29–0.48
?Kilburn Coal	c.1.0

Table 2 Coal Seam thicknesses for the Coal Measures of the Scalford area.

4.3.1 Lower Coal Measures

The Lower Coal Measures are present at depth across most of the area. The exceptions are in the south and the eastern part of the area, immediately north of the southern arm of the Normanton Hills Fault (Figure 6) where the uppermost beds are cut out beneath the Permo-Triassic unconformity. A complete sequence of the Lower Coal Measures has not been proved. All of the boreholes prove interbedded sills and sequences of extrusive volcanic rocks in the Lower Coal Measures, extending up into the Middle Coal Measures in the Wycomb and Scalford Station boreholes. The volcanic strata thicken eastwards across the area. Figures 2A and 2B illustrate the relationships between the igneous rocks, coal seams and other interbedded sediments.

In the following interseam descriptions, seatearths underlie all coals unless otherwise stated. The Freeby View Borehole (SK72SE/10) [79638 23406] proved only the Yard, Yard Floor and the combined Blackshale, Ashgate, Mickley 1 and Mickley 2, and Mickley 3 coals. Most of the remaining proven succession is composed of igneous rocks. The range of coal seam thicknesses is given in Table 2.

Subcrenatum Marine Band to Blackshale and Ashgate, Mickley 1 and Mickley 2, and Mickley 3 coals

Thickness: 64.5 m

The full interval between the Subcrenatum Marine Band and the Blackshale Coal has only been proved in the uncored Scalford Borehole. Only the upper few metres have been cored, in all of the other four deep boreholes.

Main Lithologies: The gamma ray log and cuttings indicate a predominantly mudstone sequence above the Subcrenatum Marine Band. A 6.1 m bed of grey, fine- to very fine-grained sandstone, about 33 m above the base of the Lower Coal Measures, has been correlated with the Wingfield Flags. A c.1.0 m thick coal seam at 612.6 m depth has been provisionally correlated with the Kilburn Coal. In the cored boreholes, most of the upper 30 m of the sequence comprises igneous rocks (Section 4.3.3). Three of the boreholes have proved interbedded sedimentary rocks, comprising mainly mudstones and seatearths and including the Mickley 4 Coal in the Scalford Station (SK72SE/8) [75481 23875] and Melton Spinney (SK72SE/9) [76754 22556] boreholes.

The Blackshale and Ashgate Coal has merged with the underlying Mickley 1 and Mickley 2 Coal and the Mickley 3 Coal. In Melton Spinney, dirt bands separate the three seams. In the Wycomb Borehole (SK72SE/7) [77871 24880], a thin (0.10 m) seam equated with the Blackshale Coal overlies dolerite.

Blackshale and Ashgate Coal to Yard Floor Coal

Seam Interval: 13.18–17.58 m (29.55–38.53 where interbedded with igneous rocks)
Main Lithologies: The Low Estheria Band immediately overlies the Blackshale and Ashgate Coal. It is a dark grey to black, carbonaceous, micaceous mudstone with *Euestheria*, fish debris, ostracods and non-marine bivalves. Above this, the complete cycle, comprising mudstones and siltstones, has only been proved in the Scalford Station and Melton Spinney boreholes. In the Freeby View and Wycomb boreholes, this interval is composed mainly of igneous rocks (Section 4.2.3), with 6.01 and 5.95 m of interbedded sedimentary rocks respectively.

Yard Floor Coal to Yard Coal

Seam Interval: 0.51–1.54 m
Main Lithologies: seatearth mudstone

In the Wycomb Borehole, a 0.1 m coal at 652.90 m, between the Parkgate and Blackshale coals is correlated with the Yard or Yard Floor Coal.

Yard Coal to Parkgate Coal

Seam Interval: 9.86–13.05 m (42.91 m where interbedded with igneous rocks)
Main Lithologies: mudstone, siltstone and sandstone; in the Melton Spinney Borehole, sandstone is dominant with a 5 m bed immediately below the Parkgate Coal. In the Wycomb Borehole, this interval mainly consists of igneous rocks (Section 4.2.3) with 4.15 m of interbedded siltstone and seatearth siltstone also present.

In the Scalford Station Borehole, the Threequarters (and ?Tupton) Coal has split from the Parkgate Coal, separated by 0.69 m of seatearth mudstone.

Parkgate to Deep Main Coal

Seam Interval: 15.59–20.60 m (19.02 where interbedded with igneous rocks)

Main Lithologies: mainly mudstone and siltstone with minor sandstone in Scalford Station and Wycomb boreholes, the latter including 8.37 m of igneous rocks (Section 4.2.3). In Melton Spinney, the cycle is approximately 50% sandstone, with a 5.51 m bed in the middle part. There are locally developed sandstones in the middle and upper parts of the cycle in other boreholes. Non-marine bivalves have been recorded in the upper part of the cycle in Scalford Station Borehole.

Deep Main Coal to Black Rake Coal and Joan and Brown Rake Coal

Seam Interval: Deep Main to Black Rake 17.24 m (Scalford Station Borehole)
Deep Main to Joan and Brown Rake 13.39 m (Wycomb Borehole)
Black Rake to Joan and Brown Rake 2.54 m (Scalford Station Borehole)
Main Lithologies: these cycles comprise mudstone and siltstone, with minor sandstone in Scalford Station; above the Black Rake Coal, it is all seatearth mudstone with non-marine bivalves recorded. In the Wycomb Borehole, a 9.44 m sandstone overlies the Deep Main Coal. This forms part of a 1–2 km wide channel sand body, trending north–south and continuing across the area to the north (Ambrose, 2000). In the Melton Spinney, only part of the cycle is preserved beneath the Permo-Triassic unconformity, with a 0.32 m sandstone at the base.

4.3.2 Middle Coal Measures

The Middle Coal Measures subcrop over the greater part of the area, the youngest strata occurring in the extreme north-west corner. In the east, igneous rocks obscure the Lower-Middle Coal Measures boundary. The strata were cored in two boreholes, with 60 m proved, and possibly up to a further 60 m present in the north of the area. The proven sequence includes a 13.94 m dolerite sill above the Vanderbeckei Marine Band (Section 4.3.4).

The Vanderbeckei Marine Band, up to 7.10 m thick, marks the base of the Middle Coal Measures and has been proved in the Wycomb and Scalford Station boreholes. It consists of dark grey, generally laminated mudstone with common burrows, some pyritised, pyrite nodules and thin beds or nodules of ironstone. A few desiccation cracks were noted in the Wycomb Borehole. The base is locally black and canneloid. *Lingula* was noted in both boreholes; other fossils recorded were *Myalina, Orbiculoidea, Pecten,* fish debris, foraminifera, faecal pellets and the trace fossil *Planolites.* Non-marine bivalves have been recorded from the top of the bed.

Joan and Brown Rake Coal to 2nd Ell Coal

Seam Interval: 10.21 m (30.04 m where interbedded igneous rocks)
Main Lithologies: above the Vanderbeckei Marine Band, the cycle is mainly interlaminated siltstone and sandstone, with minor mudstone. In the Scalford Station Borehole, there is a 13.94 m dolerite sill in the upper part of the cycle (Section 4.3.4).

2nd Ell Coal to 4th Waterloo and 1st Ell Coal

Seam Interval: 13.74 m

The full cycle is only proved in the Scalford Station Borehole.

Main Lithologies: there is a thin mudstone at the base, overlain by mainly sandstone with some interlaminated siltstone. The Wycomb borehole proved the lowermost 5.78 m of the cycle, comprising a thin basal mudstone overlain by interlaminated siltstone and sandstone. The beds are all stained red to purple, with some green and khaki staining at the top.

Strata above the 4th Waterloo and 1st Ell Coal

The Scalford Station Borehole proved 13.52 m of strata above the 4th Waterloo and 1st Ell Coal. The sequence comprises mainly mudstone and siltstone, with seatearths and a thin bed of sandstone near the top. Most of the beds are red to purple stained, with some yellow and green colour mottling.

4.3.3 Saltby Volcanic Formation

The suite of volcanic rocks extruded during the Langsettian in the eastern part of the Melton Mowbray district has been named the Saltby Volcanic Formation. The type section is the Egypt Plantation Borehole (SK82NE/424) [86600 27857], sited north-east of the village of Saltby. East of the Melton Mowbray district, borehole evidence suggests a more or less continuous period of eruption, probably commencing early in the Langsettian. Westwards, the sequence splits into two, separated by the Blackshale group of coals and associated strata. In the present area, only the upper part of the formation has been proved, confined to the north-east, in the Wycomb and Freeby View boreholes; the lower part is absent in the Scalford Borehole. The volcanic rocks occur at four stratigraphical levels (Figures 2A and 2B). The age of the volcanism is probably restricted to the Langsettian (Burgess, 1982) although the base of the Saltby Volcanic Formation has not been proved in some boreholes. East of the present area, strata of Early Duckmantian age overlie the formation, but the volcanic rocks were probably all extruded during the Langsettian. In the Asfordby area however, Early Duckmantian volcanism has been reported (Ambrose, 1999).

A range of extrusive igneous rocks has been proved, including, basalt, ash, tuff and volcanic breccia. Dolerite sills are also present (Section 4.3.4). The distinction between basalt lavas and dolerite sills in the borehole logs is not always clear. However, a detailed log of the Freeby View Borehole, and four boreholes in the area to the north (Ambrose, 2000) made by I C Burgess, formerly of the British Geological Survey, has aided the interpretation for parts of the sequence. Rocks described in the logs as 'agglomerate' may be volcanic debris reworked by sedimentary (debris flow or fluvial) processes. They are here referred to as volcanic breccias. The stratigraphical relationships with the interbedded Coal Measures sedimentary rocks are shown in Figures 2A and 2B; Burgess (1982) described the regional overview of the volcanic rocks in the Vale of Belvoir.

The oldest extrusive rocks, above the Blackshale Coal, comprise a 18.95–20.29 m thick sequence of pyroclastic rocks (Figures 2A and 2B). They comprise mainly basaltic rubble, or volcanic breccia, in the form of angular to subrounded blocks or ?bombs of pale greenish grey, amygdaloidal (chlorite, carbonate) basalt with chilled margins, in a dark grey, fine-grained tuff matrix. They also include beds of dark grey, fine-grained tuff with pale green basalt lapilli up to 50 mm long. This unit is widespread, extending into the area to the north (Ambrose, 2000). It may therefore represent a major pyroclastic eruptive phase. In Freeby View, the pyroclastic rocks are overlain by two lava flows totalling 5.56 m thick. They consist of an upper pale green, deeply weathered 'bole' or soil overlying pale to dark grey, amygdaloidal (chlorite/carbonate) basalt with carbonate veins.

The second sequence of extrusive rocks occurs between the Yard and Parkgate coals. In the Wycomb Borehole, there are two sequences, 17.7 m and 19.85 m thick separated by 4.15 m of sedimentary strata. In Freeby View, there is one continuous sequence and the Parkgate Coal is absent. In the detailed log of Freeby View, Burgess has identified at least 5 separate lava flows, all showing evidence of subaerial exposure. Two have a well developed pale green to reddish grey 'bole' at the top, and the remainder are capped by reddened basalt, commonly showing spheroidal weathering. The uppermost lava is capped by a 3.69 m thick 'bole', suggesting a prolonged period of subaerial exposure, prior to the deposition of the succeeding sediments. The lavas are composed of greenish grey to dark grey, fine-grained, amygdaloidal basalt, with common thin veins. The veins and amygdales are infilled with chlorite or carbonate. Two of the flows have rubbly bases. There are localised pyroclastic rocks preserved in the sequence, that include a thin (0.84 m) bed of mottled green and red, fine-grained, lapilli tuff in Freeby View and 3.02 m of green, sphaerosideritic 'ash' capping the sequence in the Wycomb Borehole.

The stratigraphically highest extrusive igneous rocks occur immediately below the Deep Main Coal in the Wycomb Borehole. This borehole proved 0.22 m of 'volcanic ash' overlying 0.22 m of green, poorly bedded ?weathered lava, in turn resting on 6.05 m of pale green vesicular 'dolerite', well-weathered to a depth of 5 m. The deeply weathered profile suggests an extrusive lithology rather than a sill.

4.3.4 Igneous Intrusions

Intrusive dolerite sills occur at four levels in the Scalford area. Their distribution is shown in Figure 3.

The stratigraphically lowest sill lies below the Blackshale and associated coals. It has been proved in all four cored boreholes and was identified as a sill by Burgess. It is split into 4 leaves in Freeby View, with two leaves present in Scalford Station and Melton Spinney (separated by the Mickley 4 Coal) and a single leaf in the Wycomb Borehole. The aggregate thickness ranges from 26.75+ m in Wycomb to 14.3 m in Freeby View. In Freeby View, the sill comprises greenish grey to dark grey, fine- to medium-grained dolerite, with carbonate and chlorite-filled veins and amygdales, and a few xenoliths. The top is brecciated and the sill as a whole is generally well-jointed.

It is correlated with the Mickley 4 Sill of the Asfordby area (Ambrose, 1999). In the Scalford and neighbouring Eastwell areas (Ambrose, 2000), the Mickley 4 Sill occurs both above and below the Mickley 4 Coal; around Asfordby, it only occurs above the coal. Its relationships to the Mickley coals are illustrated in Figures 2A and 2B.

The Blackshale Sill occurs between the Blackshale and Yard/Yard Floor coals and is only present in the Freeby View and Wycomb boreholes (Figures 2A and 2B). It is a 4.65–5.92 m thick dolerite sill of similar composition to that described above. The same sill occurs in the area to the north (Figure. 3; Ambrose, 2000).

A sill has been identified immediately below the Permo-Triassic unconformity in the Freeby View Borehole. It consists of 2.70 m of red-brown, deeply weathered, strongly jointed dolerite. It is correlated with the Parkgate Sill in the area to the north (Figure 3; Ambrose, 2000).

The stratigraphically highest sill, the Joan Sill, occurs between the Vanderbeckei Marine Band and the 2nd Ell Coal and is only present in the Scalford Station Borehole. It is 13.94 m thick and is split into two leaves, the upper one being 0.48 m thick, separated from the main sill by 0.43 m of thermally altered interlaminated siltstone and sandstone. The lowest 0.13 m of the upper leaf is described as 'altered lava and barytes veining'. The rocks are recorded as 'lava' in the log, but no other extrusive rocks have been proved at this level. It correlates with the Joan Sill in the Asfordby area (Ambrose, 1999), which is of very limited lateral extent (Figure 3).

The sills form part of an alkaline dolerite complex that extends over much of the this part of the East Midlands (Falcon and Kent, 1960). Radiometric dates (K-Ar) from sills in the Harlequin Borehole, near Nottingham, gave ages of 296±15 Ma and 302±20 Ma (Francis et al., 1968). The large error ranges preclude estimation of the precise age of intrusion. In the Asfordby and Scalford area, sills have been reddened where they sub-crop beneath the Permo-Triassic unconformity. The balance of evidence suggests the sills post-date extrusive activity, pre-date the Permian and are of Late Carboniferous age (Burgess, 1982), probably latest Westphalian to Stephanian. Petrological work by Kirton (1984) showed the rocks to be olivine dolerites whose compositions reflect those of tholeiitic to alkaline magma types. The principal minerals are olivine, pyroxene, plagioclase (labradorite - bytownite) and Fe-Ti oxides. The sills tend to differ from the basaltic lavas in being more even-grained, much less vesicular and by having markedly chilled, sharp, planar margins with the adjacent sedimentary strata (Old and Riley, 1983).

5. PERMIAN

Permian rocks probably overlie the Coal Measures throughout the area; they have been proved in all of the deep boreholes, ranging from 13.2 to 30.43 m thick. Generally, only the Permian Basal Breccia is proved, but some boreholes prove beds overlying and/or interdigitating with the basal breccia.

5.1 Permian Basal Breccia

This breccia has a red- to purple-brown, generally poorly cemented, coarse-grained sandstone, muddy sandstone or mudstone matrix. It is very poorly sorted, with subangular to subrounded clasts which include sandstone, siltstone, mudstone, limestone, ironstone, quartzite, basic igneous rocks, and metasedimentary rocks. Granitic clasts have been noted in neighbouring areas (Ambrose, 1999; 2000). The clasts vary in size from granule to 6 cm. Some bedding was noted, defined by clast size variations and preferred orientation of platy clasts. Normal grading is suggested by upward fining of clasts and matrix and by cycles fining up from breccia to pebbly sandstone. Core examined in the Willow Farm Borehole in the area to the north (Ambrose, 2000) shows both clast- and matrix-supported breccias, suggesting deposition by both fluvial and debris flow processes. The thickness of the breccia ranges from 8.12 to a maximum of 30.43 m, proved in the Melton Spinney Borehole .

5.2 Permian, undivided

Undivided Permian strata locally overlie the Basal Permian Breccia. They show variable lithologies and have not yet been correlated directly with known Permian lithostratigraphical units in the Nottingham area. Geophysical log correlations show that the strata equate with the Lenton Sandstone, Roxby, Edlington and Cadeby formations of the Nottingham area. Because of the rapid lateral lithological and facies variations noted throughout the district, they may be better correlated with the Moira Formation of the Loughborough area.

The Wycomb Borehole proved 0.55 m of red-brown and green mottled siltstone with sandy and pebbly layers and mud cracks at the top. The Scalford Station Borehole proved 2.73 m of interlaminated sandstone, siltstone and mudstone with mud cracks, mud-flakes and fining up cycles. The suggested depositional environment is a broad alluvial plain with fluvial (sheet floods) and lacustrine associations both present. The desiccation cracks indicate common periods of subaerial exposure. Aeolian ('millet seed') sand grains have been noted in neighbouring areas (Ambrose, 1999) suggesting aeolian processes and/or reworking of nearby dunes.

6. TRIASSIC

Triassic rocks lie at depth below the entire area. They comprise a basal sandstone unit, the Nottingham Castle Sandstone Formation, overlain by the mudstone-dominated Mercia Mudstone Group, succeeded by the dominantly marine Penarth Group mudstones. Typical geophysical log signatures for the sequence are illustrated in Figure 4.

6.1 Nottingham Castle Sandstone Formation

The Nottingham Castle Sandstone, part of the Sherwood Sandstone Group of Scythian age (Warrington et al., 1980), has been proved in all five of the deep boreholes and partially or completely cored in most. The formation ranges in thickness from 17.5 to 35 m and consists of red-brown and greenish grey, fine- to coarse-grained, tabular and trough cross-bedded, cross-laminated or parallel laminated, micaceous sandstones. Small quartzite pebbles are generally scattered throughout, and are locally common, together with intraformational mudstone and siltstone clasts; igneous clasts have been recorded in some boreholes. Subordinate beds of breccia/conglomerate, siltstone and mudstone are also present and mud cracks have been noted in some mudstone beds

The Nottingham Castle Sandstone represents deposition by a major northward flowing fluvial system, draining from north-west France (Audley-Charles, 1970; Warrington & Ivimey-Cook, 1992). The presence of limestone and volcanic clasts suggests there is some locally derived material.

6.2 Mercia Mudstone Group

The Mercia Mudstone Group is present at depth across the entire area and has been proved in five deep boreholes where it is 198–211.1 m thick. All of the component formations are present, as described in the Nottingham area (Elliott, 1961; Charsley et al., 1990); they have been proved in a complete cored sequences in boreholes to the west (Ambrose, 1999) and north (Ambrose, 2000). The formations are easily recognised from geophysical logs signatures, in particular the gamma ray trace (Figure 4), on which all thicknesses given below are based.

There is no conclusive evidence of age for the formation in the area. A number of samples of Mercia Mudstone from the Asfordby Hydro Borehole in the adjacent area to the west, were submitted for palynological determination (Ambrose, 1999). The samples yielded very few palynomorphs; only a few specimens from the Edwalton Formation afforded very poor evidence of a Mid to early Late Triassic (Ladinian to Carnian) age (Warrington, 1997).

6.2.1 Sneinton Formation

The Sneinton Formation varies from 47 to 57.1 m thick. It comprises interbedded and interlaminated red-brown and grey-green, micaceous mudstones, siltstones and fine- to medium-grained sandstones, locally with mudstone clasts. There are calcite-filled vugs in some sandstones and thin gypsum veins. Sedimentary structures noted include parallel lamination, cross lamination, ripple marks, desiccation cracks, convolute bedding and other dewatering structures, load casts and small-scale upward-fining units. The lowermost beds include conglomerate with 'exotic' clasts (slates, igneous rocks) of probable local origin. Similar conglomerates occur at the base of the formation in the Nottingham area (Howard et al., in press).

6.2.2 Radcliffe Formation

The Radcliffe Formation, 6.8 to 10.0 m thick, consists of very finely interlaminated, red-brown, brick-red, purple-brown, pink and greenish grey, micaceous mudstone, siltstone and very fine- to fine-grained sandstone, with a few thicker beds of sandstone. Gypsum veins and calcite-filled vugs are present in places. Sedimentary structures include salt pseudomorphs, mud cracks, cross-lamination and load casts.

6.2.3 Gunthorpe Formation

The Gunthorpe Formation is 64 to 70.1 m thick and consists predominantly of structureless, red-brown, silty mudstones, with green reduction spots and gypsum/anhydrite veins. There are common interbeds of greenish grey, generally laminated or interlaminated dolomitic mudstones, siltstones and sandstones; they are variably parallel laminated or cross-laminated, and may show convolute bedding, load structures, injection structures and salt pseudomorphs.

6.2.4 Edwalton Formation

The Edwalton Formation is 41 to 46 m thick; it consists mainly of red-brown, structureless, silty mudstones, which are locally sandy. Gypsum veins occur and are common in the upper part, immediately below the Hollygate Sandstone Member. There are several thin beds of greenish grey, dolomitic siltstone and fine-grained sandstone throughout the formation.

6.2.4.1 Cotgrave Sandstone Member

The Cotgrave Sandstone, 4 to 5.5 m thick, defines the base of the Edwalton Formation. It consists of pale greenish grey, fine-grained sandstone. Some boreholes show a distinctive geophysical log signature with an upper and lower bed of sandstone, separated by mudstone.

6.2.4.2 Hollygate Sandstone Member

The Hollygate Sandstone, 4.5 to 7 m thick, consists of greenish grey and red-brown, fine- to medium-grained sandstones with subordinate sandy siltstones and mudstones (Charsley et al., 1990).

6.2.5 Cropwell Bishop Formation

The Cropwell Bishop Formation is 27.8 to 32 m thick and consists of structureless, red-brown, silty, gypsiferous mudstones, with only a few beds of green siltstone and mudstone. The Tutbury and Newark Gypsum seams that form the principal workable seams in Nottinghamshire, are present in the area. They are indicated on the gamma ray logs by pronounced lows and on the sonic log by high velocity (low Δt values; Figure 8). The Tutbury Gypsum is moderately well developed, usually represented by 6 to 9 m of highly gypsiferous mudstone commencing 5 to 9 m above the Hollygate Member. Seams of gypsum up to 1 m thick are locally developed at the base and top of this unit. A higher Tutbury seam occurs in some boreholes about 2 m above the main bed. The Newark Gypsum is represented by one, two or three seams, each up to about 1 m thick. The highest seam is 0 to 4 m below the Blue Anchor Formation; locally the Newark Gypsum is absent.

6.2.6 Blue Anchor Formation

The Blue Anchor Formation forms the topmost subdivision of the Mercia Mudstone Group and is 3 to 9.2 m thick in the Scalford area. It consists of pale greenish grey mudstones and siltstones, with thin, indurated beds of dolomitic, well-cemented siltstone.

6.3 Penarth Group

The Penarth Group ranges between 2 and 4 m in thickness. Evidence two cored boreholes on the adjacent area to the west (Ambrose, 1999) and from geophysical logs, suggests that all of the strata can all be assigned to the Westbury Formation. In the area to the north, the cored Willow Farm Borehole proved a thicker Penarth Group sequence including the overlying Cotham Member (Ambrose, 2000). Outcrops of the group in the north-west of the district proved 5 to 7 m of Westbury Formation and 3 to 5 m of Cotham Member (Charsley et al., 1990).

6.3.1 Westbury Formation

The formation consists of dark grey to black, fissile, fossiliferous mudstones with sandy, sometimes pyritic laminae and a few thin beds of sandstone.

7. JURASSIC

Jurassic strata occur at rockhead throughout the area. A complete sequence, from the lower part of the Inferior Oolite Group (Lincolnshire Limestone Formation) down to the base of the system, has been proved in this area, from the combined evidence of outcrop and deep boreholes. The lithostratigraphy of the Lias Group follows Brandon et al., (1990) with modifications by Cox et al. (1998). Following Cope et al. (1980), the base of the Jurassic is taken at the incoming of the ammonite *Psiloceras planorbis.* In the Melton district, this is usually 2 to 3 m above the base of the Lias Group; these lowest beds are therefore of Triassic, Rhaetian age, but are described here for convenience. The ammonite zones follow Dean et al. (1961).

7.1 Lias Group

Five formations are recognised; the Scunthorpe Mudstone and Charmouth Mudstone formations equate with the former 'Lower Lias', the Dyrham Formation equates with the former 'Middle Lias', the Marlstone Rock Formation is the former Marlstone Rock Bed and the Whitby Mudstone

Formation is the former 'Upper Lias'. The subdivisions of the Lias Group are easily recognisable on geophysical logs (gamma ray and sonic) and a typical sequence is illustrated in Figure 5.

7.1.1 Scunthorpe Mudstone Formation

This formation occurs at depth across the entire area. It is 121.9 to 125 m thick and the five component members of Brandon et al. (1990) have all been recognised from geophysical logs in the deep boreholes (Figure 5). The formation consists predominantly of dark grey, fossiliferous, fissile, silty mudstones, with subordinate medium grey, calcareous, structureless, silty mudstones and limestones. The presence or absence of common interbeds of limestone defines the five members. In the following account, descriptions and ages of the members are taken from Brandon et al. (1990), who also publish detailed faunal lists.

7.1.1.1 Barnstone Member

This member, 6.0 to 6.2 m thick, contains up to 30% grey lime-mudstones ('cementstones') in beds 0.1 to 0.2 m thick. The lowermost 'pre-Planorbis' beds, of Triassic age, are usually rich in shell debris; other beds are well laminated. The intervening mudstones also include bituminous 'paper shales'. The member falls mainly within the *planorbis* Zone, extending up into the lowermost *liasicus* Zone.

7.1.1.2 Barnby Member

The Barnby Member, 19.7 to 34 m thick consists mainly of mudstone, with rare thin, lime-mudstones. It is of *liasicus* Zone age.

7.1.1.3 Granby Member

This member is 32.4 to 39 m thick comprises mainly mudstone with 10 to 15% limestone in thin, laterally persistent beds. Individual named limestones have been traced at outcrop into the Vale of Belvoir (Brandon et al., 1990), north of the present area. The limestones are mainly grey, shelly and bioclastic packstones and packstone/grainstones. The member is of *angulata* to *bucklandi* Zone age.

7.1.1.4 Beckingham Member

The Beckingham Member, 23.9 to 31 m thick, is composed mainly of grey, fissile mudstone with rare thin limestones. It is of *bucklandi* to low *semicostatum* Zone age.

7.1.1.5 Foston Member

This member is 25.2 to 32 m thick and comprises mainly mudstone with several thin (c.0.1 m) beds of limestone. The limestones are generally shelly, bioclastic, locally oolitic wackestones and packstones, which become increasingly sandy up the sequence. As with the Granby Member, individual beds have been traced into the Vale of Belvoir (Brandon et al., 1990) and geophysical log correlation indicates they extend beneath the present area. The member is of *semicostatum* to *turneri* and possibly *obtusum* Zone age, although the last has not been proved.

Beds of the Scunthorpe Mudstone Formation, probably the Foston Member, crop out in the extreme south of the area, all beneath glacial deposits. They were identified in the area immediately to the south (Brandon, 1999) and occur within a fault block.

7.1.2 Charmouth Mudstone Formation

The Charmouth Mudstone crops out mainly in the southern part of the area and is everywhere covered by glacial deposits. A thickness of 82 to 128 m has been proved in boreholes. The thinnest sequence, in the Melton Spinney Borehole, is probably faulted, with an estimated 30 to 40 m of strata missing, all from the upper part of the formation, and possibly including the basal part of the overlying Dyrham Formation. The name follows Cox et al. (1998), replacing the former Brant Mudstone Formation of Brandon et al. (1990). The formation consists of grey, fossiliferous mudstones with beds containing abundant calcite, siderite or phosphate mudstone nodules. The lower part contains finely sandy beds, including the Brandon Sandstone. The formation is of *turneri/obtusum* to *davoei* Zone age.

The **Brandon Sandstone**, recognised from geophysical logs as a gamma low, lies 17 to 18 m above the base of the formation. At outcrop in adjacent areas, it is a fine- to very fine-grained, micaceous sandstone and is 2.4 to 4.5 m thick. A second gamma low, 20.8 to 28.9 m above the Brandon Sandstone, delimits the Loveden Gryphaea Bed of Brandon et al. (1990). This bed correlates with the 70 Marker Member of the Oxfordshire area (Horton and Poole, 1977) which is traceable into Warwickshire (Ambrose and Ivimey-Cook, 1982; Old et al., 1987). The succeeding 85 Marker Member of Horton and Poole (1977) has been proved only in the Freeby View Boreholes, where it is 4.8 m thick.

7.1.3 Dyrham Formation

This formation crops out in the northern part of the area and is mostly covered by glacial deposits, apart from a small area between Scalford and Wycomb. The formation is 18.5 to 29 m thick in the boreholes. The thinnest sequence is proved in the Melton Spinney Borehole, where it may be attenuated by faulting. The age of the formation probably spans the upper part of the *daveoi* and *margaritarus* zones.

The lower part of the formation consists of grey, ochreous-weathering, generally poorly cemented micaceous siltstones, clayey siltstones and very fine- to fine-grained sandstones, with siderite mudstone nodules. Two impersistent beds of well-cemented, fossiliferous sandstone have been mapped, about 5 m and 10 m below the top. A third sandstone occurs at the top of the formation, the 'sandrock' of earlier workers. In the Scalford area, this latter bed is generally not developed, apart from a small area north of the village, where it is up to 5 m thick. The only exposure of the formation seen was in the stream bank south of Chadwell, where there is a narrow outcrop in the valley bottom beneath Oadby Till. The section [7801 2395] showed over 1 m of brown silty clay, becoming grey and ochreous- mottled, micaceous and less silty with depth.

Jukes-Browne (1885) noted a section in the Dyrham Formation at Scalford, 'on the east side of the brook at Scalford, at the bottom of a steep bank near the spring.' The section showed micaceous shales with thin layers of micaceous sandstone, the latter containing the fossils *'Cardium truncatum'*, *'Avicula inaequivalvis'* and *'Ammonites sp. (?spinatus)'* Given the probable stratigraphical position of these beds, 5 to 10 m below the Marlstone Rock Formation, the ammonite is more likely to be *Amaltheus margritatus*. The precise location of this section is not known and it is noted that the 1906 survey by C B Wedd shows four springs in the same area.

7.1.4 Marlstone Rock Formation

The Marlstone Rock Formation crops out in the northern part of the area with much of the outcrop covered by glacial deposits. There are five separate outcrops, resulting from a combination of topography, faulting and the presence of drift-filled valleys. It is estimated to be about 4 m thick.

The formation consists mostly of a greenish brown, fossiliferous iron-grainstone. It weathers to a deep rusty brown colour and produces soils of a characteristic deep orange-brown colour. Field brash shows three main facies of the ironstone, which are, in order of decreasing abundance:

Near pure oolite with very little matrix
Oolite with common shells and shell debris
Iron-packstones/wackestones comprising ooliths in an iron-mudstone matrix, with some shells and shell debris.

Petrographically, the Marlstone Rock Formation is a sideritic, chamositic limestone, the ooliths being composed of chamosite (Whitehead et al., 1952).

There are no exposures in the Scalford area.

7.1.5 Whitby Mudstone Formation

The Whitby Mudstone is about 30 m thick and crops out in four main areas, all largely obscured by glacial deposits. In the extreme north-east corner of the area, there are additional small, fault-bounded outcrops. It consists of grey, fossiliferous mudstone, which weathers to a grey and ochreous mottled clay. There are no exposures in the Scalford area; a few ammonite fragments were noted in ploughed fields on the various outcrops.

7.2 Inferior Oolite Group

Strata from the Inferior Oolite Group crop occur in the extreme north-east corner of the area on the outskirts of Waltham on the Wolds. Glacial deposits cover parts of the outcrop. It is cut by several small faults, thought to be related to a pre-Anglian camber structure (Section 9.2). Most of the outcrop boundaries shown have been taken from the 1941 ironstone survey of the Northampton Sand. The only boundary revised is the base of the Northampton Sand to the south of the southernmost fault.

7.2.1 Northampton Sand Formation

This formation is about 5 m thick. The main part of the outcrop dips gently to the west, with faulting probably resulting in local variation in dip. It consists of interbedded oolitic iron-grainstone and fine-grained, ferruginous sandstone but is nowhere exposed. Petrologically, the ironstone component consists of mainly siderite with some chamosite. These minerals weather to limonite, with kaolinite as a bi-product. Details of the petrology are given in Taylor (1949) and Hollingworth and Taylor (1951) have described the stratigraphy, structure and reserves of the formation.

7.2.2 Grantham Formation

The Grantham Formation outcrop boundaries are taken from fieldslips of the 1941 ironstone survey, but the presence of the unit has not been proved in the present survey. Evidence from the area to the north (Ambrose, 2000) shows it to consist of greenish and bluish grey, thinly interbedded or interlaminated grey mudstones and sandstones, estimated to be 1 to 3 m thick.

7.2.3 Lincolnshire Limestone Formation

An estimated 5 m of the formation is present, occurring as two small outcrops which have been taken from the 1941 ironstone survey fieldslips. Stratigraphically, they are the lowermost beds of the formation, informally termed the Lower Lincolnshire Limestone. Evidence from the area to the north (Ambrose, 2000) shows the formation to comprise off-white oolite grainstones, shell detrital, oolitic grainstones and fine-grained packstones/wackestones with scattered shell debris. These beds may equate with the Sproxton Member of Ashton (1980) and may also include the succeeding Greetwell Member.

8. QUATERNARY DEPOSITS

8.1 Bytham Sand and Gravel

Boreholes in the adjacent area to the west (Ambrose, 1999) have proved the presence of a buried valley infilled with sand and gravel beneath the Anglian glacial deposits. The base levels of around 52 m AOD are over 20 m lower than the base of the glacial deposits in the area. This deposit represents an infill of the former course of the Bytham River, a pre-glacial river that flowed eastwards into the North Sea (Rice, 1991; Brandon, 1999). Its course continues across the southern part of the Scalford area, but the deposit has not been proved there. The existence of the valley in this area is indicated by borehole SK72SE/29 [7857 2039], which bottomed glacial deposits (Oadby Till Lias-rich facies) at 58.14 m AOD. This contrast with the general base of the glacial deposits in the Melton Mowbray area, which is about 80 m AOD.

8.2 Glaciofluvial and Glaciolacustrine Deposits

A deposit of probable mixed glaciofluvial-glaciolacustrine association crops out in the extreme south of the area around the village of Thorpe Arnold. It is at least 15 m thick and consists mainly of brown, fine-grained sand, overlain by chalky Oadby Till. In the road cutting west of the village [7696 2009 – 7680 2012], brown silt, silty sand and fine-grained sand are exposed. The base level of the sand is not known but is below 80 m AOD. The deposit is lenticular and dies out rapidly both to the west and east. It was not found on the opposite (eastern) side of the river valley in Melton Mowbray, although it was shown to crop out there on the 1906 fieldslips. It is absent in borehole SK72SE/29, sited only 800 m east of the outcrop. The same borehole proved another glaciofluvial deposit, 5.6 m of pale brown, fine- to coarse-grained, poorly sorted sand down to a level of 62.44 m AOD. This occurs at a stratigraphically lower level, within the Lias-rich facies of the Oadby Till.

8.3 Oadby Till

The Oadby Till can be subdivided into two distinct mappable units. These were recognised by Lamplugh et al. (1909) and formed the Lower and Upper Oadby tills of Rice (1968). Both units are estimated to be up to about 20 m thick, but locally thicker sequences have been proved, for example in borehole SK72SE/29, which proved respectively 26.50 m and 25.50 m of the two subdivisions. These greater thicknesses are due to the infilling of the pre-glacial Bytham River valley. Oadby Till covers most of the area, forming an extensive, dissected plateau sloping gently southwards. The base falls from 165 m AOD at its highest, near Waltham, down to around 80 m AOD in the extreme south. The southern flank of the Bytham River valley proves till down to lower levels, Borehole SK72SE/29 proving the base at 58.14 m AOD. In the area to the south, the till base falls slightly to around 70 m AOD, before rising again, indicating the existence of a pre-glacial valley along the line of the present day River Wreake (Brandon, 1999).

The lower part of the Oadby Till, the Lias-rich facies, consists of dark brownish grey, silty clay that is virtually free of Cretaceous erratics (chalk and flint). This crops out only in the north-west corner of the area, immediately west of Scalford. To the north and east of Scalford, it has been overstepped by the chalk-rich facies. The till contains common limestone clasts (mainly Lincolnshire Limestone and/or Lias Group limestones), ironstone fragments and quartzite pebbles. There are no exposures of note.

The upper part of the Oadby Till is the typical chalk-rich grey clay, also containing common flints, Jurassic limestones, ironstones and fossils, and Triassic quartzite pebbles. Chalk is locally abundant but can also be absent in the upper part due to decalcification. There are no noteworthy exposures apart from a few ditch sections. The 1906 survey fieldslips recorded 8 feet (2.4 m) of 'chalky boulder clay' in the now disused railway cutting [7605 2046] on the outskirts of Melton Mowbray. Grey, chalky clay is also exposed in the banks of the reservoir [761 210] near Crosher's Farm, immediately north-east of Melton Mowbray.

8.4 Alluvium

There are no major rivers in the area and drainage is by two minor streams and their tributaries, flowing southwards into the Wreake. The alluvium in these valleys is generally 1 to 2 m thick and consists of brown, silty to sandy clay, generally becoming grey with depth. Scattered pebbles occur locally and there are sandy or gravelly lags in places. A section recorded in the stream [7876 2472] just east of Chadwell showed 1.2 m of brown, sandy clay passing down into clayey sand. A the base, there is a 0 to 0.2 m, poorly sorted gravel containing clasts up to 0.1 m of flint, limestone, ironstone and quartzite pebbles. In the Scalford Brook, a section [7603 2134] exposes 1.0 m of brown silty clay on 0.6 m of brown silt, in turn resting on 0.3 m of grey-brown, pebbly clay with flints.

8.5 Head

Head deposits mostly occur in the gulleys and tributary valleys incised into the till plateau, with a few valley-bottom head deposits on the solid outcrop immediately north of Scalford. There are no exposures, apart from a few ditch sections. Consequently, head has generally been mapped on the basis of the concave features formed along valley bottoms. Where cultivated, these deposits produce a sandy, pebbly clay soil. Head deposits sourced by till are generally a brown to grey, silty to sandy, commonly pebbly clay with flint, limestone, quartzite and ironstone pebbles. Those sourced by the Marlstone Rock and Dyrham formations are mainly micaceous silts and sands with common ironstone and sandstone pebbles. Thicknesses are unlikely to exceed 3 m.

9. STRUCTURE

9.1 Tectonic Structures

The structural information is derived from the extrapolation of seismic interpretations undertaken for the Asfordby Coal Mine in the area to the west. The data was taken from plans showing the structure at the Permo-Triassic unconformity and at the top of the Deep Main Coal, supplied by the former National Coal Board, British Coal and RJB Mining (UK) Ltd. Additional information has been procured from other seismic data, by Dr T C Pharoah of BGS, and from the mapping.

The principal structure in the area is the Normanton Hills Fault. This fault is also known as the Yaxley House Fault (British Coal/RJB Mining UK Ltd) and the Hoton Fault (e.g. Ebdon et al., 1990). In the present area, the Normanton Hills Fault is represented by two en echelon and sub-parallel structures. The two strands of the fault (Figure 6) trend east-north-east – west-south-west across the area and are 1 to 1.5 km apart. The seismic evidence suggests the southern strand subcrops along its entire length, whilst the northern strand only subcrops for part of its length. The northern strand has an estimated throw of around 100 m and the southern strand has a throw of 40 to 50 m. A second major fault, the Sileby Fault, crops out in the extreme south of the area and has an estimated downthrow to the north of around 30 m. Glacial deposits obscure all of the major faults.

9.1.1 Carboniferous Structures

Deep seismic investigations by Ebdon et al. (1990) show that the Normanton Hills (Hoton) Fault is the rejuvenated extension of the displacement that defines the southern margin of the Widmerpool Gulf or half-graben. Intermittent subsidence within that structure occurred throughout the Tournaisian, Visean and Namurian epochs of the Carboniferous, resulting in the accumulation of a thick sequence of Carboniferous Limestone, Edale Shale and Millstone Grit strata over the graben's hangingwall dip slope, to the west of the Scalford area. All of these strata are relatively thin since the present area is located close to the eastern extremity of the half-graben. In the area to the west (Ambrose, 1999), there is some evidence for continued graben subsidence into earliest Westphalian times, up until around the time of deposition of the Kilburn Coal. The Widmerpool half-graben was subsequently inverted during an end-Variscan phase of compression, in which the Normanton Hills Fault was reactivated as a reverse fault. Post-Jurassic displacements constitute a third major phase of movement along the fault.

The Coal Measures dip at around 3 to 4 to the north-north-west over most of the area to the south of the Normanton Hills Fault. Between the two arms of the fault in the east of the area, the Coal Measures have been folded into a gentle anticline, trending approximately east–west. This fold may in part, have resulted from the post-Jurassic phase of movement. To the north of the northern arm of the Normanton Hills Fault, structure contours drawn on the base of the Vanderbeckei Marine Band, show that the Coal Measures have been folded into a gentle north-south trending syncline and complementary anticline, with the limbs dipping at 2 to 3° (Figure 6). The pattern of the folding here and that shown by other structures in adjacent area to the west (Ambrose, 1998; 1999) suggests a strike-slip component to this phase of tectonic activity (Moody & Hill, 1956).

9.1.2 Post-Jurassic Structures

Geophysical log correlation of boreholes shows that there are no changes in thickness across the Normanton Hills Fault in the Scalford and neighbouring areas area for the Triassic and Jurassic strata and thus no syndepositional activity occurred at these times. The post-Jurassic movements along the Normanton Hill Fault die out upwards on the northern arm of the fault the fault is not everywhere present at subcrop. The southern arm of the fault has been subjected to a greater movement in the post-Jurassic tectonic phase. There are a number of other small faults affecting the Jurassic rocks, mostly with small displacements of up to 10 m. The two east of Scalford have been interpreted from the relative displacements of the Marlstone Rock Formation proved in boreholes. Those to the east of the village have been proved by mapping. In the north-east corner of the area, most of the faults are interpreted as superficial structures (Section 8.1.3).

Within the Scalford area, there are insufficient boreholes to calculate the regional dip of the Jurassic rocks. In the area to the west, they dip south-south-eastwards, generally at about 1 to 2°, decreasing to less than 0.5° in the south (Ambrose, 1999).

9.2 Superficial Structures

A complex area of faulting and westerly dips occurs in the extreme north-east corner of the area, extending northwards (Ambrose, 2000; Carney and Sumbler, 2000). The faults have small throws of less than 10 m and show two main trends of approximately east-west and north-south. They occur on the margin of a drift filled valley and are interpreted as an ancient, pre-Anglian camber structure that formed prior to the infill of the valley.

10. ARTIFICIAL DEPOSITS AND WORKED GROUND

Three categories of artificial deposits: Made Ground, Infilled Ground and Landscaped Ground, together with Worked Ground, have been mapped in the area. The limits of some areas shown are imprecise; other, small areas are not shown, particularly former pits to which the reader is referred to the fieldslips for details. These are locally common on the Oadby Till plateau; many are shown on the topographic map but others are not. Most were probably dug as water ponds for livestock and many have been wholly or partially backfilled. Other areas of artificial deposits may be present that were not recognised during the survey.

10.1 Worked Ground

Worked Ground is restricted mainly to road and railway cuttings. In addition, there are two areas of worked ground in the valley of the Scalford Brook at Melton Mowbray [757 303, 758 203] and a reservoir to the north-east [761 210], at Crosher's Farm.

10.2 Made Ground

Railway and road embankments form the bulk of the Made Ground in the Scalford area. There are a few other small areas of general spoil and a reservoir embankment in the vicinity of Melton Mowbray.

10.3 Infilled Ground

There are several areas of Infilled Ground, mainly former workings for ironstone, clay or sand, and a disused railway cuttings east of Scalford.

10.4 Landscaped Ground

Four areas have been designated as Landscaped Ground: two areas of earthworks, at Thorpe Arnold [769 200] and Goldsmith Grange [775 233], and two areas of irregular cut and fill, at Spinney Farm Cottage [711 219] and Framlands Farm [753 218].

11. OTHER INFORMATION

11.1 Brick Clay

There are a number of former pits that may have been worked for brick clay, all occurring in Oadby Till. Elsewhere in the surrounding area, the Whitby Mudstone and Dyrham formations have been worked for brick clay, but no pits were noted in the present area.

11.2 Ironstone

The Marlstone Rock Formation formed an important source of iron ore in the district, but the outcrop around Scalford has not been worked owing to a low iron content (Whitehead et al., 1952). The Northampton Sand Formation has also formed a major source of iron ore in the past. There are no workings in the outcrop around Waltham on the Wolds, but the formation was worked farther to the west (Hollingworth and Taylor, 1951).

11.3 Building Stone

The Marlstone Rock Formation and underlying cemented sandstone ('sandrock') at the top of the Dyrham Formation have both been worked for building stone in the past, with the stone (mainly the sandstone) being used for buildings in Scalford and Wycomb. Two pits in the Marlstone, at Scalford [760 248] and Wycomb [776 248], were probably worked for building stone.

11.4 Sand and Gravel

Glaciofluvial sand crops out in the Thorpe Arnold area and has been worked locally on a small scale. The deposit is up to 15 m thick.

11.5 Hydrocarbons

The thick mudstone-dominated sequence of Dinantian and Namurian rocks deposited in the Widmerpool Gulf has long been identified as a possible source of hydrocarbons and there has been much exploration in the last 30 years. In this area, the Scalford Borehole was drilled to a depth of 1069.5 m, terminating in ?Devonian strata. Oil shows are indicated in the Wingfield Flags and in a sandstone bed in the Edale Shale Group. The well was drilled on the anticlinal structure between the two arms of the Normanton Hills Fault (Figure 6).

11.6 Coal

Exploration for coal in the Vale of Belvoir began in the mid 1970s, culminating in the development of Asfordby Colliery to the west of the area. The main target seams (Deep Main, Parkgate and Blackshale) underlie the Scalford area but have not been worked. The Deep Main and Parkgate are both absent in the east of the area, due to their onlap onto volcanic rocks.

11.7 Hydrogeology

The water supply of the area has been described by Richardson (1931). All the surface drainage is to the south, into the River Wreake at Melton Mowbray. The Marlstone Rock Formation and sandstones in the Dyrham Formation provide natural aquifers in the area although there are very few documented wells tapping this source. Wells and springs at Scalford formerly supplied water to Melton Mowbray as well as the village. Four springs have been indicated on the 1906 fieldslips of C B Wedd, although the precise location of each is not clear. They all lie within a 350 m area to the north of the road bridge [364 241]. The waterworks was located in the valley in the north-east corner of the village [around 765 243] and there are records of four boreholes at the site; one is given by Richardson (1931) and is entirely within the Dyrham Formation (SK72SE/18). Three other wells were all sunk to greater depths of between 58 and 76 m. The deepest well (SK72SE/13) [7652 2432] terminated close to the Loveden Gryphaea Bed in the Charmouth Mudstone Formation. The record indicates water was struck at depths of 36.3 and 51.8 m, both in the Charmouth Mudstone, with a test-pumping yield of 900 gallons per hour (gph). There are no details of water strikes in the other two wells, but they show significantly different yields: SK72SE/11 [7655 2435] yielded 7 000 gph but SK72SE/12 [7652 2428] yielded only 180 gph. Other potential water sources in the area are limited. Richardson (1931) reported that the glaciofluvial sand at Thorpe Arnold (Section 8.2) had yielded 'a good supply of water' from a well 24.4 to 27.4 m deep. There may be other perched water tables in sand and gravel pockets within the till.

The Sherwood Sandstone Group, which forms an important aquifer in the Nottingham area, occurs at depth (around 400 m) across the entire area, but any contained water is likely to be saline.

The recently drilled boreholes proving the Bytham Sand and Gravel in the area to the west (Ambrose, 1999) have established the presence of a local aquifer. The base level of the aquifer is at around 50–70 m AOD and the thickest proving of sand and gravel is 17.8 m. This aquifer is likely to extend across the whole of the present area, with a width of around 0.5 km, but the sand and gravel may be impersistent locally. There is no information available on yields. Of the 6 boreholes proving the deposit in the area to the west, borehole SK72SW/51 describes 'gravel with a strong spring', SK72SW/69 yielded no water and both the recent BGS boreholes proved water. Other deposits of fluvioglacial sand have been proved at the surface and in boreholes; these may contain perched water tables.

11.8 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.

11.8.1 Head

Head deposits are poorly consolidated and may be susceptible to further downslope movement following periods of heavy rain, snow or frost, especially if undercut or loaded by an overlying structure. Recent trial pits in the Langar and Harby Head deposits showed the presence of common shear planes within the uppermost 1 m. 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 Lias Group and till 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 is a fairly reliable guide to identification.

11.8.2 Peaty alluvium

No peat or peaty alluvium was found during the present survey. However, it may be present in some of the river valleys. Such deposits are highly compressible compared to the surrounding gravels and to a lesser extent the non-organic-rich clays, and could give rise to excessive and differential settlement of overlying structures.

11.8.3 Man-made deposits

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

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.

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.

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 in the area 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.

12. BOREHOLES

A number of boreholes are mentioned in the text. The numbering system for these records commences with the map sheet number, followed by the number given to the borehole when it was archived (e.g. SK72SE/30). The records may be examined at the National Geological Records Centre of the BGS.

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