Natural Environmental Research Council

BRITISH GEOLOGICAL SURVEY

Geological Survey of England and Wales

Geological notes and local details for 1:10 000 sheets.

Sheet SE 32 NE - Oulton

Part of 1:50 000 sheet 78 (Wakefield)

J.R.A. Giles and I.T. Williamson

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Geological notes and local details
for 1:10 000 sheets: sheet SE 32 NE (Oulton)
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BRITISH GEOLOGICAL SURVEY, KEYWORTH 1985

SUMMARY

1. This report embodies the results of a study funded by the Department of the Environment in 1984/5 to provide an up to date geological map and account of the solid and superficial geology and to identify and report on any implications for land use planning. The study derives its information from two main sources:-
   a) archival material comprising mine plans, opencast mining completion plans, quarry plans, borehole records, tip plans and data held by the National Geoscience Database,
   b) a field survey by the authors at a scale of 1:10 000.

2. The resurvey has considerably improved the resolution of the solid and superficial deposits on the geological map. In addition it records the distribution of made ground, opencast mining, quarrying and landscaping. Land use planning implications have been considered in a series of thematic geological maps which depict areas of near-surface mine working, distribution of made ground, distribution of sand and gravel resources and the distribution and thickness of superficial deposits.

3. The study has improved the detailed knowledge of the Westphalian stratigraphy of the district and the report describes it in modern nomenclature. The improved resolution of the geological mapping has identified a number of additional minor coal seams and has also identified denuded terraces of the River Calder, at a level above the previously recorded highest terrace.

   Detailed sampling of temporary exposures of superficial deposits and samples from specially commissioned boreholes have provided a quantitive basis for the assessment of the sand and gravel resources of the district.

   The compilation of boreholes during the study has provided a detailed picture of rockhead relief and has demonstrated an assymetrical buried channel of the Calder which has developmental and resource implications.

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Figures 9 and 10 accompany this report.

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INTRODUCTION

This report is a summary of the geology of 1:10 000 sheet SE 32 NE. It has been produced, along with the accompanying maps, for the Department of the Environment, as Phase 2 of a four-year programme to provide up to date geological base-maps and guidance on the main aspects and implications of the geology as they affect the future land-use planning and development of an area around the rivers Aire and Calder, southeast of Leeds. The geological map is available as an uncoloured dye-line print.

The area falls within the British Geological Survey 1:50 000 Sheet 78 (Wakefield). It was first surveyed at the six inches to the mile scale by A.H. Green, T.V. Holmes, R. Russell and J.C. Ward, the maps being published in 1874 and 1875 as six-inch Yorkshire county sheets 218, 219, 233 and 234. The area was resurveyed by W. Edwards, D.A. Wray and G.H. Mitchell between the years 1924-1935. A vast amount of new information, especially from detailed site investigations for industrial and other developments, roads and mining, has become available since then. The present 1:10 000 map incorporates this in addition to a complete geological resurvey in 1984 by J.R.A Giles and I.T. Williamson. Details of all known shaft and borehole sections are held in the files of the British Geological Survey (formerly Institute of Geological Sciences). Mining records are held by the NCB and the Mines Records Office. Descriptions of the area with details of old cuttings and sections that are now obscured are provided by two publications: 'The Geology of the Yorkshire Coalfield' (Green and others, 1878) and 'The Geology of the country around Wakefield' (Edwards and others, 1940), the latter describing the 1:50 000 Sheet 78.

To accompany the geological map and generalised vertical and horizontal sections, this report includes six Thematic Geological Maps illustrating individually, facets of the geology pertinent to the needs of planners and developers: these are 1. Distribution of Drift Deposits. 2. Thickness of Drift Deposits. 3. Distribution of Made Ground. 4. Borehole Locations. 5. Underground mining. 6. Sand and Gravel Resources.

1. PHYSIOGRAPHY, POPULATION DISTRIBUTION, COMMUNICATIONS AND LAND USE

The district lies south east of the main Leeds conurbation and within the Wakefield Metropolitan District Council administrative area. The principle centres of population are Oulton and Woodlesford. Other smaller townships and villages owe their origin to collieries which have now closed. Most of the ground is of moderate, rolling relief, with some bolder ridges and escarpments formed by the major sandstones, such as the Thornhill and Horbury Rocks. From the highest point (80 m), north west of Royds Green Farm [3540 2680], the ground falls northwards to the Aire valley and southwards to the Calder valley. These two rivers dominate the drainage of the district, with almost all the minor watercourses forming consequent streams flowing directly into them. About two-thirds of the area is rural in character being devoted largely to arable farming with little livestock rearing. Only a few wooded areas remain today, notably Moss Carr Wood [3700 2660], Almshouse Wood [3800 2710] and Peasecroft Wood [3980 2970]; wooded parkland is retained north of the Aire at Swillington Park.

The district is crossed by the M62, the Pontefract to Leeds road (A639) and the Wakefield to Garforth road (A642). Railway lines from Wakefield, Castleford and Pontefract converge at Methley Junction into a single line into Leeds. The canals of the Aire and Calder Navigation parallel both major rivers.

Widespread coalmining since the late eighteenth century has left its mark upon the district in the form of extensive waste tips, reclaimed opencast sites and numerous shafts. One mine, Methley Savile Colliery, is still working, and an opencast site, St Aidens Extension, is currently in operation.

Sandstone, limestone, brickclay, sand and gravel, ironstone and fireclay have been worked locally leaving further scars on the landscape. Recently some of the coal tips associated with former collieries have been worked for low quality aggregates.

2. WESTPHALIAN (COAL MEASURES)

2.1 GENERAL

The area is composed of Upper Carboniferous (Westphalian A+B) rocks forming part of the West Yorkshire Coalfield. A considerable thickness of Westphalian A strata, including numerous worked coals, lies at depth. In addition some 330 metres of Westphalian B strata are exposed in the district. The beds are mainly gently dipping and undulating, but are commonly more steeply inclined near faults. To a large extent the solid rocks are obscured by either a mantle of soil, weathered and soliflucted clay (Head), patches of thicker drift deposits, urban development or waste tips. Consequently few exposures remain, these being largely confined to old quarries and other artificial sections. Details of the solid geology are taken mainly from archival material, itself of varied detail and quality.

Those borehole and shaft sections that have been located are in the B.G.S. archives, and are indexed on 1:10 000 or 1:10 560 National Grid Maps of the Ordnance Survey. These archives may be examined by application to The Manager, National Geosciences Data Centre, British Geological Survey, Keyworth, Nottingham NG12 5GG.

The mine-plans examined during the resurvey are listed in Appendix A, as are details of their availability. Appendix B lists the NCB Opencast information used in the project.

A generalised vertical section illustrating the sequence of solid rocks proved in the area is given on the margin of the 1:10 000 scale geological map; details of shaft and borehole sections are given in Figure 9; and the horizontal cross-section (Figure 10) shows the broad structure and the relationships between the significant coals and sandstones. Little is known of the strata between the coals and the major named sandstones; details of coal sections are given in Green and others 1878, and Edwards and others 1940. These details have not been repeated in this report. Throughout this report the term seam means the combined thickness of coal and dirt partings whereas leaf refers to coal between dirt partings.

2.2 CLASSIFICATION

The Westphalian strata in Britain are subdivided into A (Lower), B (Middle) and C (Upper) with the boundaries at specific marine bands (Stubblefield and Trotter, 1957). There are other subdivisions (zones) based on the non-marine bivalves (Trueman and Weir, 1946-56; Weir, 1960-68) and there are faunal belts within these (Calver, 1956; Eagar, 1947, 1952, 1954) which allow more detailed correlation, particularly in Westphalian A and B. Plants have long been employed as broad zonal indicators, and Smith and Butterworth (1967) have established seven miospore zones of value for seam identification and coarse correlation between coalfields. The main features of the palaeontology of the Westphalian have been described by Calver (in Smith et al, 1967, pp 87-97, pp 42-46).

2.3 WESTPHALIAN ROCK-TYPES

Claystone, Mudstone and Siltstone

The most common lithologies are interbedded claystones, mudstones, silty mudstones and siltstones. They are generally barren of fossils except for discrete fossiliferous bands. Sedimentary structures comprise wave-ripple and lenticular bedding: bioturbation and soft-sediment deformation are also common. Ironstone nodules are commonly associated with these lithologies. The terms claystone and mudstone have been taken to be synonymous with the old mining terms bind, drub, blaes, metal and shale. Likewise siltstone has been taken to be synonymous with the mining terms stone bind, fakey blaes and slaty stone.

Sandstone

The sandstones are normally fine-grained and, when fresh, are grey. However, oxidation of the contained iron causes weathered sandstones to be brown. Coarser grained lenses of interformational breccias composed of angular mudstone and ironstone clasts, represent channel-lag deposits and occur in the thicker sandstones. The sandstones range in thickness from single, isolated, lenticular-bedded units less than 1 centimetre thick to units many metres thick. The latter include named sandstones such as the Thornhill and Horbury Rocks. The bedding varies from massive to flaggy. Sedimentary structures include flat lamination, wave ripple bedding, trough cross-bedding, flaser and lenticular bedding. Bioturbation and soft-sediment deformation structures are also common. Fossil assemblages are dominated by plant material, particularly comminuted plant debris on the bedding surfaces of the more micaceous sandstones. The mining terms cank, freestone, galliard, post, rag, and stone appear to be synonymous with sandstone.

Seatearth

The seatearths include all grades of sediment from claystone through to sandstone, but generally they are distinguished by an absence of bedding and the presence of rootlets. They normally lie directly beneath coals, but some are laterally more extensive than the associated seam. The old mining terms clunch, earth, fireclay, ganister, spavin, stone clunch and stone spavin are synonymous.

Coal

As formally defined coal is a readily combustible rock containing more than 50 per cent by weight, and more than 70 per cent by volume, of carbonaceous material. Coals are laterally extensive, but can change their thickness or number of dirt partings, and can die out laterally. The coals of the district are bituminous, and generally increase in rank southwards (Wandless 1960).

Other

Tonsteins are dense mudstones containing kaolinite aggregates and crystals. They usually occur as thin beds less than 6 centimetres thick. Although rare, they are laterally extensive, forming isochronous, correlative horizons. They are considered to be kaolinised tuff or ash-falls or reworked volcanic detritus (Williamson, 1970).

Rare limestones are present, but they are thin and discontinuous. Eager and Rayner (1952) recorded a 0.15 m "shelly limestone" (probably an impure bio-sparite) from the former Westgate Brick Works [3140 2040]. Trueman (1954, pp27) comments that, 'slabs of mussel bands contain so much carbonate of lime, with varying amounts of carbonate of iron (chalybite), that they form limestone-like masses.'

Ironstone, mainly in the form of impure siderite, is ubiquitous, but most occurs as nodules, bands and lenses of clay ironstone within mudstones. At certain horizons, such as the Black Bed ironstone, sufficient concentrations of iron exist to have made the sideritic ironstone workable in the past.

Oolitic ironstones have also been recorded from the sequence. Dean (1935) records a variable oolitic ironstone, up to 0.25 m thick (Godwin, written communication), in the Robin Hood quarry [SE 3240 2720] at the horizon of the Swallow Wood coal.

2.4 PALAEO-GEOGRAPHY AND SEDIMENTOLOGY

During the Upper Carboniferous the district formed a small part of the Pennine depositional province, which was in turn part of the north-west European paralic belt. Generalised Westphalian palaeo-geographic maps based on previous publications (Calver 1969 and Eames 1975) are published by Anderton et al. (1979, Figs 11.18 and 11.23). Palaeomagnetic data for the Carboniferous, reviewed in the concluding part of Turner and Tarling (1975, pp 483-485) and Scotese et al. (1979 pp 222, 229 and Figs 32 and 33) suggest an equatorial palaeolatitude for much of the Carboniferous including the Westphalian. Over a dozen plate-tectanic models have been proposed to account for the palaeomagnetic data, palaeogeography and the various phases of deformation in the Hercynides. These are reviewed and discussed by Anderton et al. (1979, Ch. 12).

The major depositional system was a complex association of deltaic, fluvial and lacustrine environments with sporadic marine incursions. Within the sediments of the Pennine depositional province a number of facies have been identified (Fielding 1984 a and b; Haszeldine 1983, 1984; Haszeldine and Anderton, 1980; Scott, 1978). These facies can be grouped into a number of facies associations which can be interpreted in the terms of the main environments described from the subaerial delta plain of the Mississippi by Coleman and Prior (1980). These environments are distributary channel fill, interdistributary bays, swamps and crevasse splays. In addition marine incursions have resulted in the formation of marine bands.

Distributary Channel Fill

Thick, sharply based bodies of cross bedded sandstone in elongate belts, 2 to many km wide, are interpreted as representing major distributary channels. These sandstone bodies can be subdivided into a number of facies interpreted as representing sand bars at times of high or low water discharge. Thinly interbedded sandstones, siltstones and claystones in elongate belts parallel to distributary channel deposits are taken to represent overbank flood deposits such as levees.

Interdistributary Bays

This facies association is interpreted as representing lakes isolated from sediment sources by swamp environments and distributary channel levees. Interdistributary bays are dominated by fine-grained sediments. The main facies comprises sheet like deposits, normally less than one metre thick, of black, thinly laminated, carbonaceous claystones. The fossils are non-marine bivalves, crustaceans, plant debris and fish debris and the facies is interpreted as representing an anoxic lake floor. The thin sporadic limestones of Eager and Rayner (1952) are also closely associated with this facies.

The anoxic lake floor deposits may pass laterally into massive or laminated claystones, commonly rooted, containing non-marine bivalves and plant debris. This facies forms elongate, narrow belts parallel to coal seam splits. It is interpreted as a passive lake margin where the lake shallows into a swamp environment.

The preceeding two facies are frequently overlain by massive or laminated claystones containing non-marine bivalves, crustaceans and plant debris; numerous trace fossils may also be present. This facies is sheet-like in form. The interpretation is that it represents an input of fine sediment into the lake either as the most distal deposits of a crevasse splay or as overbank claystones from a distributary channel. Haszeldine (1984) suggests that these deposits, where laminated, may be rhythmites.

Swamps

There are two main facies to this association. The first is seatearth, the lithology of which may vary from claystone to sandstone, generally tending to fine upwards. Rootlets are diagnostic and plant debris and trace fossils are common. This facies has a sheet like geometry. Seatearths are commonly found beneath coal, but the seatearth may be more laterally extensive than the coal or the coal may be absent altogether. Buringh (1970) suggested that seatearths represent subaqueous azonal soils.

The second major facies of this association is coal. This forms a sheet like body which may pass laterally into rooted claystones of the lake margin. It consists almost entirely of plant debris and is interpreted as representing a swamp environment.

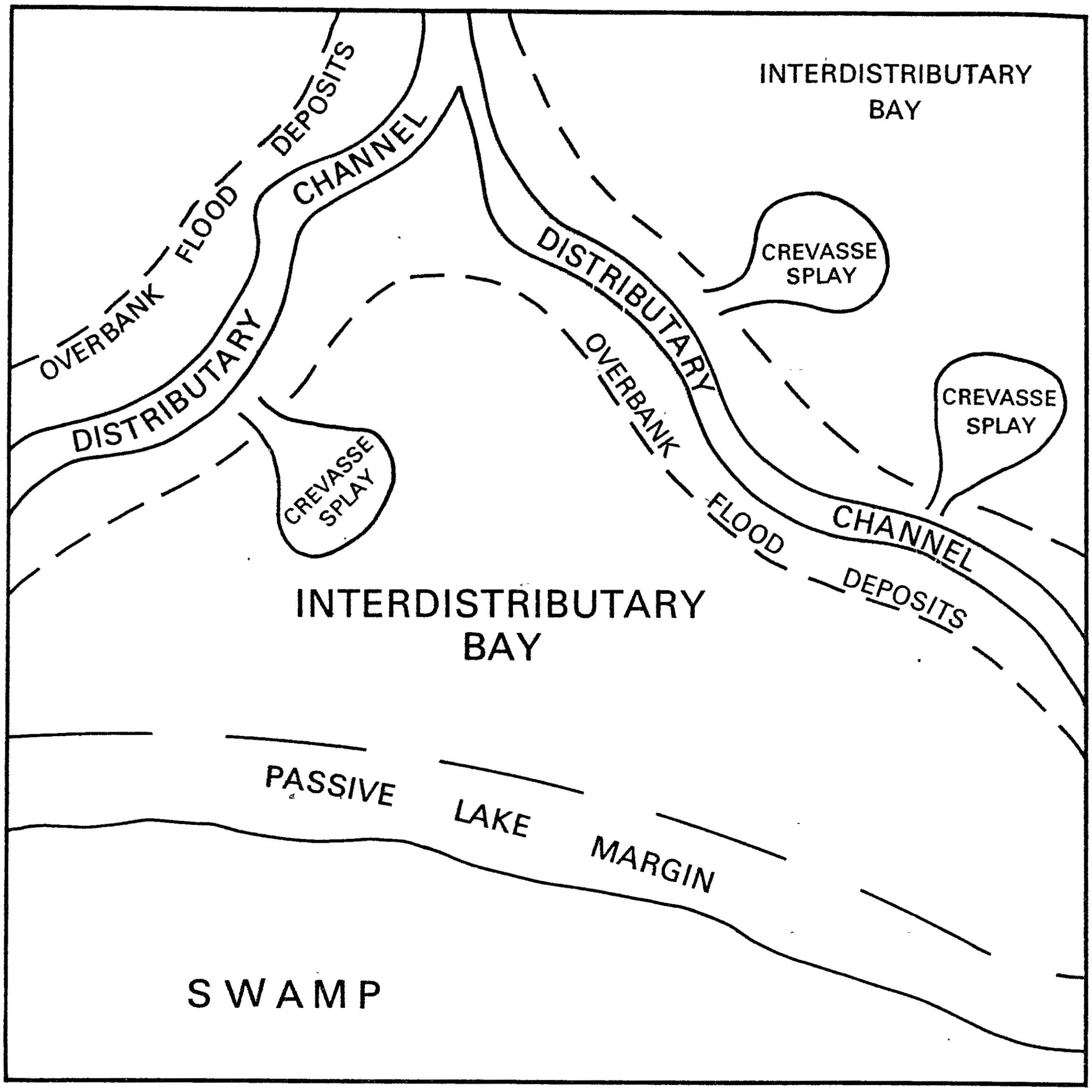


Figure 1. Generalised diagram illustrating the relationships of the major Westphalian depositional environments.

Crevasse Splays

This facies association comprises coarsening upward sequences from claystones and siltstones through to thin channelized, erosively based sandstones. As the coarseness increases upwards, the diversity of the fossils decreases from the varied assemblage of the anoxic lake flow to nonmarine bivalves plus plant debris and finally just plant debris, in the channelized sandstones. This facies association is interpreted as representing the progressive filling of an interdistributary lake by a crevasse splay or series of crevasse splays. During a flood phase the levee of a major distributary channel is breached allowing the formation of a minor channel and a distributary delta. The progressive encroachment of these small deltas and the succeeding delta top channelized sandstones, causes the coarsening up sequences and changes in fossil assemblages commonly called cyclotherms. Fielding (1984a) identifies three main facies in this association which he interprets as representing proximal major crevasse splay channels, medial crevasse splay/minor delta and distal crevasse splay/minor delta environments.

Marine Bands

This facies association is dominated by dark grey to black, fissile, laminated claystones with a sheet like geometry. Complex associations of marine fauna include bivalves, brachipods, crinoids, bryozoa, fish, goniatites and plant debris. Calver (1967 and 1968 a and b) has described the faunal 'phases' of the marine bands and the possible spatial relationships of the marine communities and has discussed these in terms of facies belts.

Rates of Sedimentation

Rates of sedimentation have been discussed by Broadhurst et al. (1970, 1980), Stach (1982) and Haszeldine (1984). Their general conclusion is that the rates vary considerably from facies to facies. The slowest rates probably occur in the black mudstone facies representing anoxic lake bottoms. Haszeldine (1984 pp 812) comments "black mudstone layers represent rock accumulation rates of about 0.5 $m/10^6$ years over time spans of at least 5000 years".

Stach (1982 pp 17-18) discusses the accumulation rates for coals. He concludes that "1 metre of bituminous coal probably represents accumulation over approximately 6000 - 9000 years".

Sedimentation rates for the other main facies are probably much more rapid. The depositional rates of distributary channel fills can be envisaged, from Haszeldine's (1983) description of the palaeo-river which deposited the Seaton Sluice sandstone; "Medial bars migrated westwards parallel to the river-channel axis and then accreted onto the northern bank as part of a large lateral bar. The whole 10-m-thick sandstone at Seaton Sluice was deposited as part of one bar within a 1.9-km-wide low-sinuousity river". Kirk (1983) likewise describes former channel bars producing sandstone units up to 7-m-thick. In terms of geological time such sandstones are deposited almost instantaneously.

Broadhurst et al. (1970) describe the effects of overbank deposits noting the occurence of upright tree trunks preserved in sediment. This indicates many metres of sediment being deposited in a single rapid event. An example of such a fossil tree was noted by the authors in the St Aidans Extension Opencast site above the Warren House Coal.

Likewise rates of sedimentation by crevasse splays into interdistributary lakes are high. Modern Mississippian sedimentation rates of 10-50 years for 1 metre of sediment have been recorded. Even allowing for compaction this is geologically rapid.

Broadhurst et al. (1980) have put forward a convincing case for seasonal sedimentation in some parts of the Westphalian sequence of the Pennine depositional province.

Cyclotherms

The terms rhythms, cycles and cyclotherms are frequently used in connection with Coal Measures deposits. The case for and against cycles has been discussed by Duff and Walton (1962), Duff et al. (1967) and Westoll (1968). The general conclusion is that repeated small scale coarsening upwards cycles are present in parts of the Westphalian. These are thought to represent crevasse splays prograding into interdistributary lakes during phases of net subsidence.

2.5 STRATIGRAPHY

Westphalian A (Lower Coal Measures)

Measures between the Subcrenatum Marine Band and the Better Bed Coal.

Little is known about this part of the sequence in the district. At crop to the north these measures consist of two main units viz. the Ganister Coals and the Elland Flags. Together these total some 180 to 200 m in thickness. To the south in South Kirby No 1 Borehole [SE 4546 1092] the equivalent beds are some 300 m thick.

Better Bed Coal (see footnote)

The lowest recorded beds in the district are the Better Bed Coal and its associated mudstone-seatearth. These were proved in West Riding Collieries, Fox Pit, where, at 472.85 m, there is 0.27 m of coal above 0.90 m of mudstone-seatearth. An extensive industry grew up to the south-east of Leeds extracting the Better Bed seatearth as a refactory clay. However, the proving at Fox Pit seems to have been uneconomic, for no records exist of it having been worked.

Footnote
The order of description is normally stratigraphic (i.e. bottom to top), however, the coals have been described from top to bottom throughout this report.

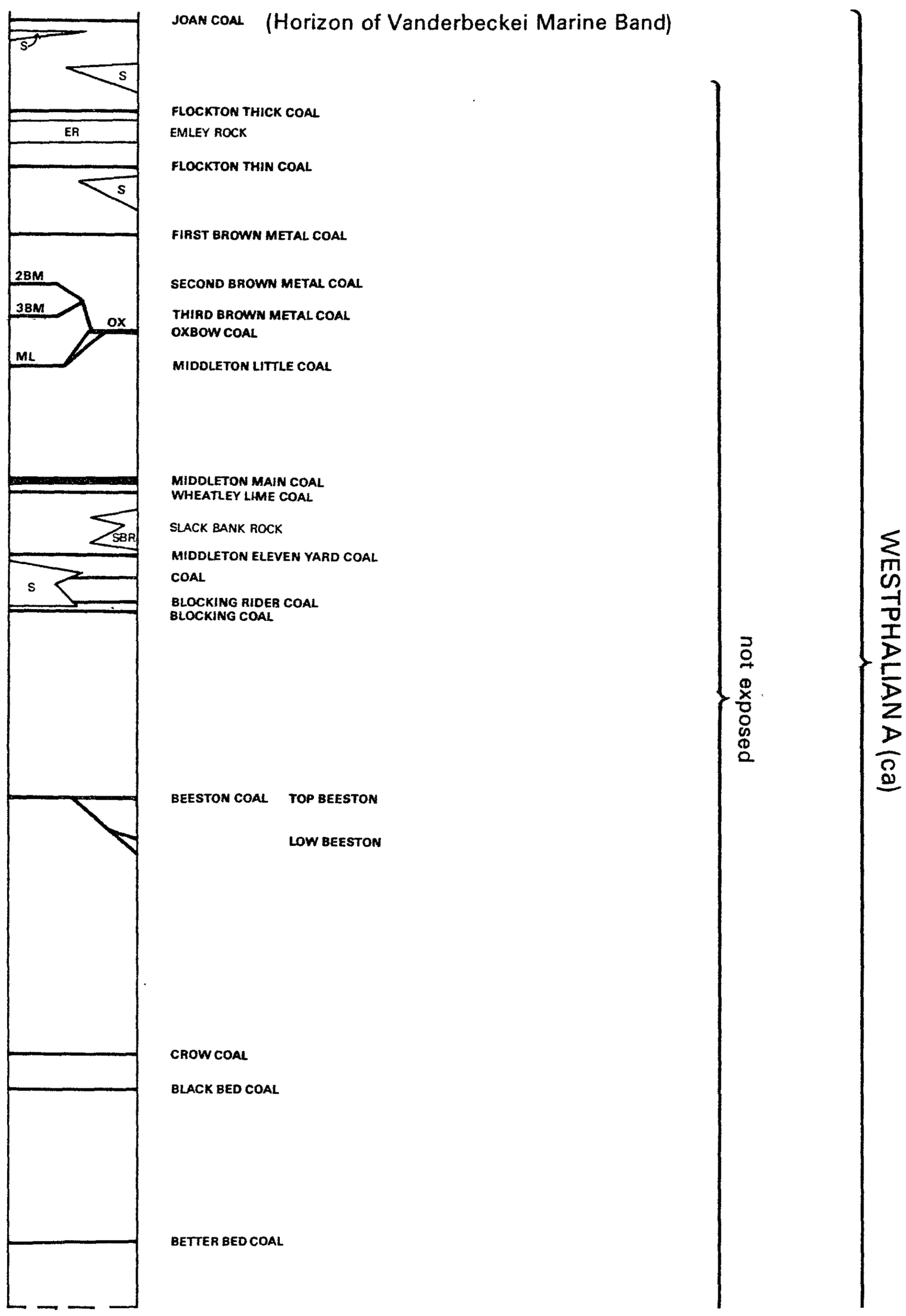


Figure 2. Generalised sequence of the Westphalian A rocks of the Oulton District.

Measures between the Better Bed and Black Bed Coals

The shaft at West Riding Collieries, Fox Pit, is one of only two records of these strata from the district. Here the Better and Black Bed Coals are 35 m apart. The lowest lithology is mudstone, with sporadic bands of siltstone. This passes upwards into sandstone beds, up to 4 m thick, interbedded with mudstone. This sequence of interbedded sandstone and mudstone is probably the lateral equivalent of the Thick Stone of the Leeds area. In a borehole from the base of Allerton Main Colliery, Fleakingly Bridge Pit shaft, the strata for 5.5 m below the Black Bed consist of siltstones with subordinate mudstones and sandstone.

Black Bed Coal

The Black Bed Coal is in one leaf, up to 0.55 m thick, at West Riding Collieries, Fox Pit and in the Fishpond Lock Borehole. In the other available records the seam is split by a variable parting of mudstone up to 0.42 m thick. The upper leaf of the coal is between 0.43 m and 0.54 m thick, whilst the lower leaf is up to 0.10 m of inferior coal. Small areas of this seam have been worked from Rothwell Haigh Collieries, Fanny Pit, from West Riding, Fox Pit, and from Allerton Main, Primrose Hill Pit. Much of the seam is still unworked.

Measures between the Black Bed and Crow Coals

The distance between the two coals is 6.17 m in the Woodend Farm Borehole and 12.92 m at West Riding Collieries, Fox Pit. Their average separation in the area is 8.41 m. The lithology of this interval is very variable. The most persistent feature is the presence of ironstone-rich mudstone immediately above the Black Bed Coal. The strata are locally known as the Black Bed Ironstone, and comprise mudstone with lenses or bands of clay-ironstone containing up to 30% metallic iron. The composite thickness of the Black Bed Ironstone is up to 6.45 m, but in Newsam Green No 2 Borehole significant ironstones are absent.

The Black Bed Ironstone was often worked in conjunction with the underlying coal and formed the basis of a smelting industry in the Leeds area dating back to mediaeval times. However, the ironstone appears unworkable in this district.

The ironstone is succeeded by a mixed sequence of mudstone with sandstones up to 5.58 m thick. West Riding, Fox Pit, records two thin coals, respectively 4.27 m and 8.35 m above the Black Bed Coal.

Crow Coal

The Crow Coal is normally 0.74 m to 1.04 m thick, with an average thickness of 0.87 m. It comprises two or more leaves separated by mudstone or inferior coal partings. In the Woodend Farm Borehole the coal is split into two multi-leaf seams separated by 2.83 m of mudstone, sandstone and mudstone-seatearth. No records exist of it having been worked in this district.

Measures between the Crow Coal and the Beeston Group of Coals

The Beeston Coals are separated from the Crow Coal by 42.62 m to 72.97 m of strata with an average thickness of 58.65 m. The main lithology is Mudstone with siltstone and with some thin sandstones. Several thin coals, all less than 0.16 m thick, have been recorded from various levels in boreholes and shafts.

The Beeston Group of Coals

This group is a complex association of coals with variable partings. The Top Beeston Seam has now been more or less worked out beneath virtually the entire area, except for pillars beneath rivers, canals, villages and shafts. It comprises either a single leaf of between 0.91 m and 1.27 m, or two leaves with a top leaf of between 0.64 and 1.02 m and a lower leaf of between 0.18 m and 0.46 m. The parting separating the two leaves is normally thin but mine-plans for Newmarket Colliery record it up to 0.38 metres.

In the southeast of the district the Low Beeston Coal develops. It is 0.33 m below the Top Beeston at Methley Savile Colliery but the separation has increased to 12.80 m at Methley Junction Colliery only 1.7 km to the south. Other collieries in the southeast of the district record a significant split with the seam. This is 6.68 m at West Riding Collieries, Fox Pit and 8.03 m at West Riding Collieries, Altofts Pit. The parting is composed of mudstone except at Methley Junction where there is 9.45 m of sandstone in addition.

The Low Beeston comprises two leaves where it is within 2 m of the Top Beeston. The upper leaf varies between 0.20 m and 0.40 m thick whilst the lower leaf varies from 0.22 m to 0.61 m in thickness. As the parting between the two Beeston seams increases a third leaf develops in the low Beeston seam. This leaf varies from 0.14 m to 0.28 m in thickness.

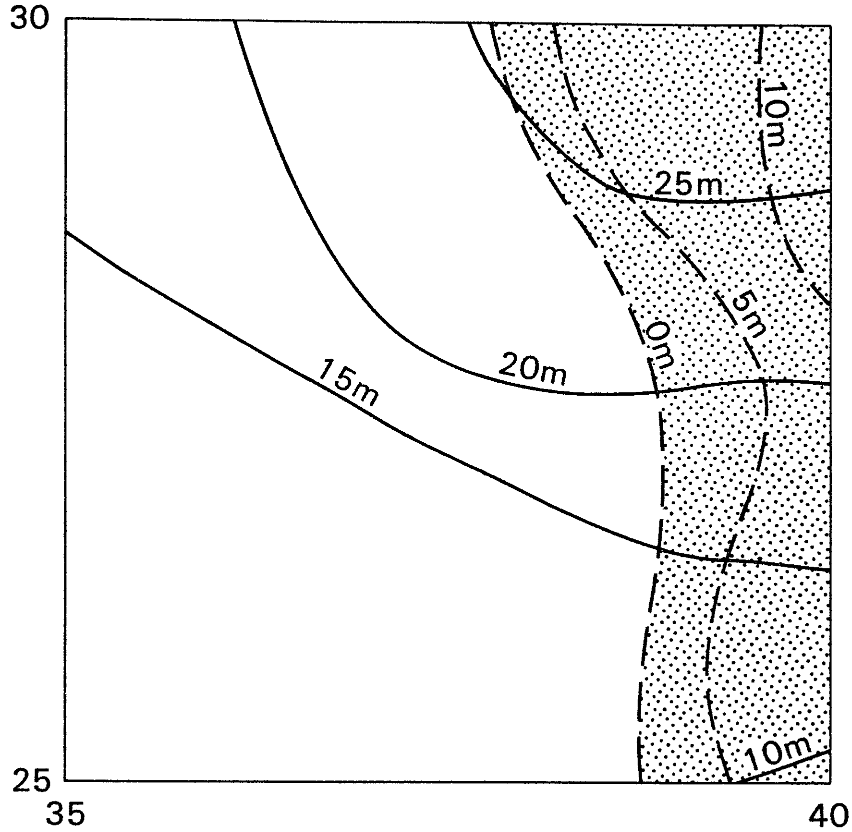
Measures between the Beeston Group and the Blocking Coal

The mean thickness for these measures is 44.11 m, with a range of 33.30 m (Newsam Green No 2 Borehole) to 52.90 m (Water Haigh Colliery shaft). There is a very generalised thickening of the measures southwards by about 20 percent. The major lithologies are mudstone and siltstone, with sporadic sandstone units having thicknesses of up to 5.38 m. Three thin coals are commonly logged in this interval but they appear to be laterally discontinuous as some sections record only two or, more rarely, one.

A coalfield-wide marker, the Low *Estheria* Band, should be present below the Blocking Coal. It has not been recorded from the district, but is probably represented by black shale 10.74 m below the Blocking Coal at Water Haigh Colliery.

Blocking Coal

This is a very variable seam that takes several distinct forms.



Slack Bank Rock (SBR)

5m — Thickness of SBR

15m — Thickness of strata between Middleton Eleven Yard and Middleton Main.

Figure 3. Sketch map showing the thicknesses of the Slack Bank Rock (SBR) and the parting between the Middleton Eleven Yard and the Middleton Main.

It can occur as a single leaf between 0.51 m and 0.73 m in thickness. Elsewhere it can be represented by a two-leaf seam which is split by a mudstone-seatearth that can be over 1 m thick. It can also be a multi-leaf seam split by numerous thin dirt partings, and with a mean seam thickness of 1.34 m. There is no obvious pattern to the distribution of the various seam sections except that the multi-leafed sections tend to occur in the north of the district. There is no record of the seam having been worked in the district.

Measures between the Blocking and the Middleton Eleven Yard coals

These measures are dominantly mudstone and siltstone with some sporadic thin sandstones. The one exception is at Rothwell Haigh Colliery, Fanny Shaft, where 14.22 m of the intervening 17.52 m of strata are composed of sandstone. The average separation of the two seams is 15.34 m, with a recorded range of 11.56 m to 19.06 m, the greater thicknesses generally being in the north.

A thin coal, the Blocking Rider Coal, has an average thickness of 0.21 m. It lies between 1.27 m and 3.32 m above the Blocking Coal throughout the district, the greater separation being recorded in the north-west. A second thin coal is also locally present; It is 12.62 m above the Blocking at Allerton Main Colliery, Victoria No 2 Shaft, and 9.50 m above the Blocking at Whitwood Colliery.

Middleton Eleven Yard Coal

This seam has been widely exploited, particularly in the south-west. It has a mean thickness of 0.93 m, with a range from 0.45 m to 1.28 m. The seam normally comprises one leaf but this is locally split by one or two thin partings.

Measures between the Middleton Eleven Yard and the Middleton Main Coals

In the east of the district, the Slack Bank Rock (see Fig. 3) rests on or just above the Middleton Eleven Yard, and has a maximum proved thickness of 10.0 m. Elsewhere the major lithology is siltstone with some interbedded mudstone.

A short way below the Middleton Main the Wheatley Lime Coal is sporadically present. To the west of the district this coal is a distinct seam that splits off the base of the Middleton Main; in the present district this unification is largely complete and the Wheatley Lime coal can be identified as a separate seam only at West Riding Collieries Fox Pit, Whitwood Colliery, and in the Woodend Farm Borehole; in these provings it is separated from the Middleton Main by, on average, 1.8 m of mudstone.

The measures between the Middleton Eleven Yard and the Middleton Main thicken markedly north-eastwards (see Fig. 1) from below 10 m in the southeast to 28.93 m at Allerton Main Colliery, Primrose Hill Shaft.

Middleton Main Coal

This seam is a composite of the Wheatley Lime and of the Middleton Main of the district to the west. It is not known which leaves originally belonged to which of these seams. The local practice, which has been followed here, is to also call the united seam the Middleton Main.

This seam normally comprises only 1 or 2 leaves, but 3 or even 4 leaves are present locally. These leaves are separated by thin dirt partings. The average thickness of the seam is 1.40 m with a range of 0.89 m to 2.30 m. The seam has been extracted over virtually the whole district except for pillars that remain under rivers, canals, villages and shafts.

Measures between the Middleton Main and Middleton Little Coals

These strata are dominantly mudstones with siltstone bands. Sandstone beds, which are normally thin, occur sporadically: rarely they may be almost 5 m thick. Many sections also record at least one thin coal. A number of mussel bands are present; for example, 'shells' are recorded in the roof of the Middleton Main at Methley Savile Colliery and two mussel bands are recorded from Newmarket Colliery, Nelson Pit, respectively at 12.43 and 15.53 m above the Middleton Main.

The average thickness for these strata in this district is 27.26 m with a range of 21.90 m (Woodend Farm Borehole) to 36.90 m (Swillington Bridge Borehole). There is no simple pattern apparent in the variation in thickness.

Middleton Little and Oxbow Coals

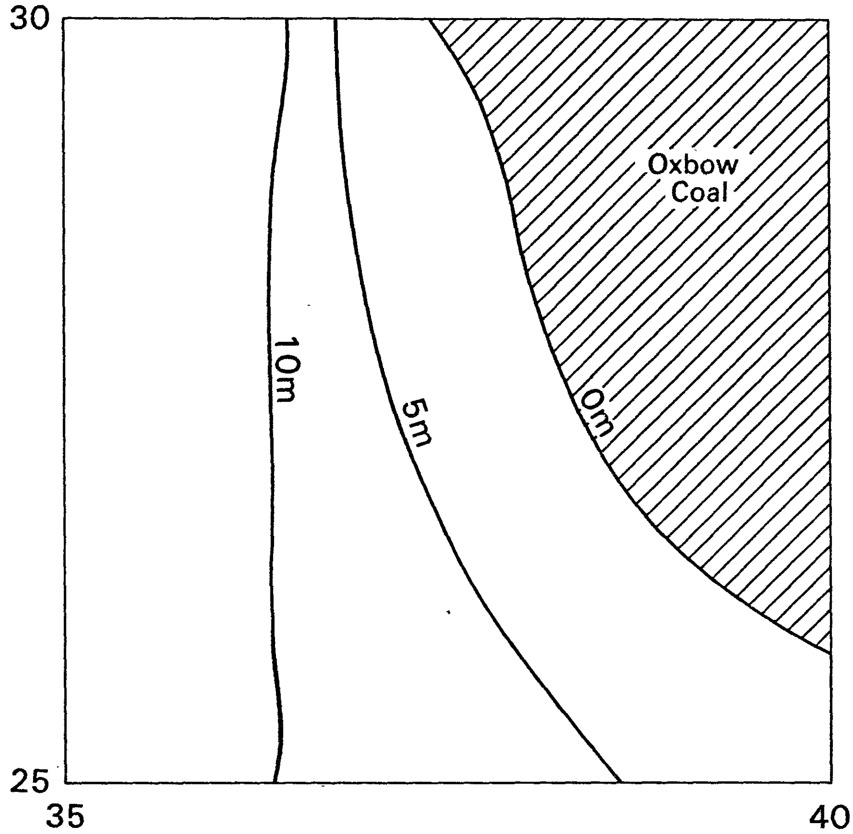
In the west of the district the Middleton Little seam is represented by a single leaf of coal. This varies in thickness from 0.48 m (Bottom Boat Borehole) to 0.67 m (Rothwell Haigh Colliery, Fanny Shaft). A parting develops within the seam and thickens eastwards from 0.04 m in Parkways Borehole to 0.76 m at West Riding Collieries, Altofts Shaft. The upper leaf of the split has an average thickness of 0.62 m; the thinner lower leaf has an average thickness of 0.25 m.

In the northeast of the district (Fig. 4) the Second and Third Brown Metal coals unite with the Middleton Little coal to form a composite seam, known as the Oxbow Coal (Godwin and Calver, 1974). In this district it ranges in thickness from 2.26 m at Allerton Main Collieries, Victoria No 2 shaft, to 3.46 m at Methley Savile shaft, where it comprises 6 separate leaves.

The Middleton Little and the Oxbow coals have been extensively mined throughout the district, although extraction has not been as complete as in the Beeston or Middleton Main.

Measures between the Middleton Little and the Third Brown Metal Coal.

The lithology is dominantly mudstones with subordinate siltstones



Area where Middleton Little, second Brown Metal and third Brown Metal Coals are united to form Oxbow Coal.

Isopachyte of strata between Middleton Little Coal and third Brown Metal Coal

Figure 4. Isopachyte on the strata between the Middleton Little Coal and third Brown Metal Coal.

and sporadic sandstones up to 2.14 m thick. The strata thin progressively in an eastwards and north-eastwards direction (Fig 4), from a maximum recorded thickness for the district of 12.1 m (Fishpond Lock Borehole) to zero. The zero isopach marks the union of the Second and Third Brown Metal Coals with the Middleton Little Coal to form the Oxbow Coal.

Third Brown Metal Coal.

This seam is a single leaf of coal with an average thickness of 0.41 m. It ranges from 0.26 m (Parkways Borehole) to 0.61 m (Rothwell Haigh Colliery, Fanny Shaft). In Fishpond Lock Borehole and at Water Haigh Colliery the Second and Third Brown Metal Coals unite. This compound seam in turn unites with the Middleton Little as noted previously.

Measures between the Third and Second Brown Metal Coals.

These strata are mainly mudstones with lesser amounts of siltstone and sandstone. The maximum recorded separation for this district is 7.74 m (Methley Junction Colliery); however, the strata thin north-eastwards until the Second and Third Brown Metal Coals unite.

Second Brown Metal Coal

This seam normally comprises one leaf of coal with an average thickness of 0.45 m. However, in the Parkway Borehole and at Whitwood Colliery the seam is split into two leaves by a waste parting. The seam unites with the Third Brown Metal and the Middleton Little Coals to form the Oxbow Coal in the east of the district.

A tonstein has been recorded by Salter (1964) in the Oxbow opencast site [SE 3610 3000] at the position of the united Second and Third Brown Metal coals. Mr Goossens (personal communication) also records a tonstein at the level of the Second Brown Metal Coal in No 1 drift at Allerton Bywater Colliery [SE 450 292].

Measures between the Second and First Brown Metal Coals.

The inter-seam strata between the Second and First Brown Metal Coals thin to the southwest from a maximum of 19.67 m in the Dunford House Borehole to a minimum for the district of 5.0 m at Newmarket Collieries, Nelson Shaft. The average separation for the district is 11.58 m.

Most of the beds are mudstones; however, in the east of the district, up to 8.53 m of sandstone are recorded. Thin coals and ironstone bands have also been noted in some sections.

First Brown Metal Coal.

This seam normally has a two-leaf section with a mean thickness of 0.99 m; the mean thicknesses of the upper leaf, the lower leaf and the waste parting are 0.29 m, 0.36 m and 0.34 m respectively. At West Riding Collieries, Fox Pit, the upper leaf is split by an additional 0.07 m parting. At Water Haigh Colliery only a single leaf, 0.36 m thick, is recorded. This probably represents only one of the two leaves.

A small area of this seam has been worked near Methley Savile Colliery; there are no other records of the seam being mined.

Measures between the First Brown Metal and Flockton Thin Coals.

The strata are mainly mudstones. Siltstone and sporadic thin sandstones are also present. At least one thin coal is normally recorded but a second has also been noted. The mean thickness of the strata is 15.38 m, with a range from 8.53 m (Rothwell Haigh Colliery, Fanny Shaft) to 26.41 m (Allerton Main Collieries, Primrose Hill Shaft). There does not appear to be a regular pattern of variation in parting thicknesses across the district.

Flockton Thin Coal

Only one leaf of coal, between 0.39 m (West Riding Collieries, Altofts Shaft) and 0.82 m (Bottom Boats Borehole) thick, is normally present. However, the seam is locally in 2 or even 3 leaves, with mean seam thicknesses of 1.23 m and 1.38 m respectively. There is no apparent pattern to the number of seam partings. Small areas of this seam have been worked in the west of the district from Rothwell Haigh, Fanny Shaft, and Newmarket Collieries, Nelson Shaft.

Measures between the Flockton Thin and Flockton Thick Coals

The separation of these two seams is remarkably uniform in the district. The mean interseam thickness is 11.66 m with a range from 9.00 m (West Riding Collieries, Altofts Shaft) to 12.88 m (Water Haigh Colliery Shaft). Most of the sections record a sequence dominated by mudstone or siltstone, with a sandstone up to 5.20 m thick which probably represents the Emley Rock. Most sections also record one, or sporadically two, additional thin seams of coal.

Flockton Thick Coal

In this district the Flockton Thick Coal has three different sections. In the north of the district, it has three distinct leaves separated by partings up to 0.37 m thick. The mean combined seam thickness for this area is 1.23 m. In the southern half of the district, it has two leaves which are separated by a parting up to 0.48 m thick. The mean seam thickness in this part of the district is 1.06 m. At Whitwood Colliery, the Flockton Thick is a single leaf of 0.40 m of coal.

The seam has been worked extensively from most of the major collieries. However, much of the extraction took place after the development of mechanical long-wall working. Consequently there are areas of coal left unworked which would have been extracted by earlier methods.

Measures between the Flockton Thick and Joan Coals

Immediately above the Flockton Thick Coal there is a pronounced and widespread non-marine bivalve band. This is succeeded by mudstones and siltstones with ironstone bands and one, or more rarely two, thin coals, one of which may be the Smith Coal. In the east of the district a sandstone, up to 6.40 m thick, is consistently recorded.

The mean thickness of these strata is 21.44 m. There is a general thinning to the south, from a maximum recorded thickness of 24.54 m (Dunford House Borehole) to a minimum of 17.73 m (Whitwood Colliery).

Joan Coal and Vanderbeckei (Clay Cross) Marine Band.

The Vanderbeckei Marine Band has not been identified in this district. However, it is known from the roof of the Joan Coal over a wide region. A thin, dirty coal immediately overlain by a black mudstone, up to 1.98 m thick has been consistently recorded in this district and has been taken to be the Joan Coal.

Westphalian B (Middle Coal Measures)

Measures between the Vanderbeckei (Clay Cross) Marine Band and the Lidgett Coal.

Borehole and shaft-sections record a general southwards thickening of these strata from 29.72 m (Water Haigh Colliery) to 43.21 m (West Riding Silkstone Collieries, Fox Pit). The rocks are mudstones and siltstones with sporadic thin coals and sandstones. The latter become thicker and more persistent upwards in the sequence, where the measures become sandstone-dominated, representing the local equivalent of the Thornhill Rock. With the exception of the area around the Methley Junction Colliery Shaft, the maximum thickness of individual sandstone units decreases eastwards.

These strata crop out to the north and west of Woodlesford [3673 2857]. The most conspicuous feature is the escarpment and dip-slope formed by the Thornhill Rock. The base of the sandstone-dominated strata is irregular and ill-defined, appearing to be both diachronous and erosional. It may cut down into the lower measures and "wash out" the Vanderbeckei Marine Band and the Joan Coal. The lowest beds are thin, irregular, lensoid sandstones which show rapid lateral thickness variations. The top of the Thornhill Rock is also ill-defined.

A borehole through the Thornhill Rock in Springhead Park [3544 2872], records 24.27 m of fine-grained, massive, cross-bedded or flazer-bedded, pale yellowish orange sandstone which contains numerous carbonaceous plant fragments, thin lenses of interformational conglomerate and interbedded siltstones and thin mudstones. Thick massive sandstone was recorded in the former Robin Hood Quarries, Oulton [3672 2840] in 1931 by W N Edwards. Northwest of Woodlesford at Home Farm [3825 2983] the sandstone has thinned markedly to less than 5 m. An exposure [3786 2967] records about 2 m of cross-bedded, fine-grained sandstone very similar to those in the above borehole.

The Thornhill Rock appears to undergo a facies change across the district. In the west as on the adjoining 1:10 000 sheet (SE 32NW), the thick, massive, cross-bedded, sandstones probably represent a major distributary channel facies. Eastwards the sandstones thin and are replaced by a thick bed of siltstone; this probably representing siltstone-dominatd overbank deposits associated with proximal crevasse splay facies. The transition between the two major facies seems to be related to the position of the SW-NE Oulton and Water Haigh Faults suggesting syndepositional movement.

The Thornhill Rock has been extensively quarried, particularly to the northwest of the Water Haigh Fault. In a road cutting at Woodlesford [3681 2901] there is some evidence to suggest that shallow mining of the sandstone took place. Such mining would probably have been for the extraction of sandstone beds of specific qualities.

Lidgett Coal

The Lidgett Coal is normally a single seam with a mean thickness of 0.77 m. It splits northwards into two, separated by a variable parting. The coal is present only in the east of the district, a distribution probably related to the distribution of the two facies of the Thornhill Rock: where the latter is in the siltstone-dominated overbank and proximal crevasse-splay facies, the Lidgett Coal is present above it; where the Thornhill Rock is in the thicker distributary channel facies, the top of which is at a higher stratigraphical level, the Lidgett Coal is absent.

Measures between the Lidgett and Haigh Moor Coals

The measures crop out to the west of Oulton Parish Church [3597 2809]. Here, on a steep hillside - capped by the Haigh Moor Rock - some 15 to 20 m of strata are present. A single feature-forming sandstone, some 5 m thick, thins westwards towards a point north of Gravel Pit Wood [3531 2827], beyond where it can be traced no further.

In boreholes and shaft sections, all to the south and east of the Oulton Fault, the strata thin southwards from 29.84 m (Allerton Main Collieries, Victoria No 2 Shaft) to 14.31 m (Methley Junction Colliery Shaft): the mean recorded thickness is 21.93 m. The dominant lithologies are mudstone and siltstone. Sporadic thin coals, up to a maximum of four, are recorded from most sections. A sandstone up to 11.28 m thick is recorded in some shafts; this is probably the same sandstone that crops out west of Oulton Parish Church.

Haigh Moor Group of Coals

This association of coal seams, spanning up to 14.57 m of strata, is known collectively as the Haigh Moor Coals. The uppermost

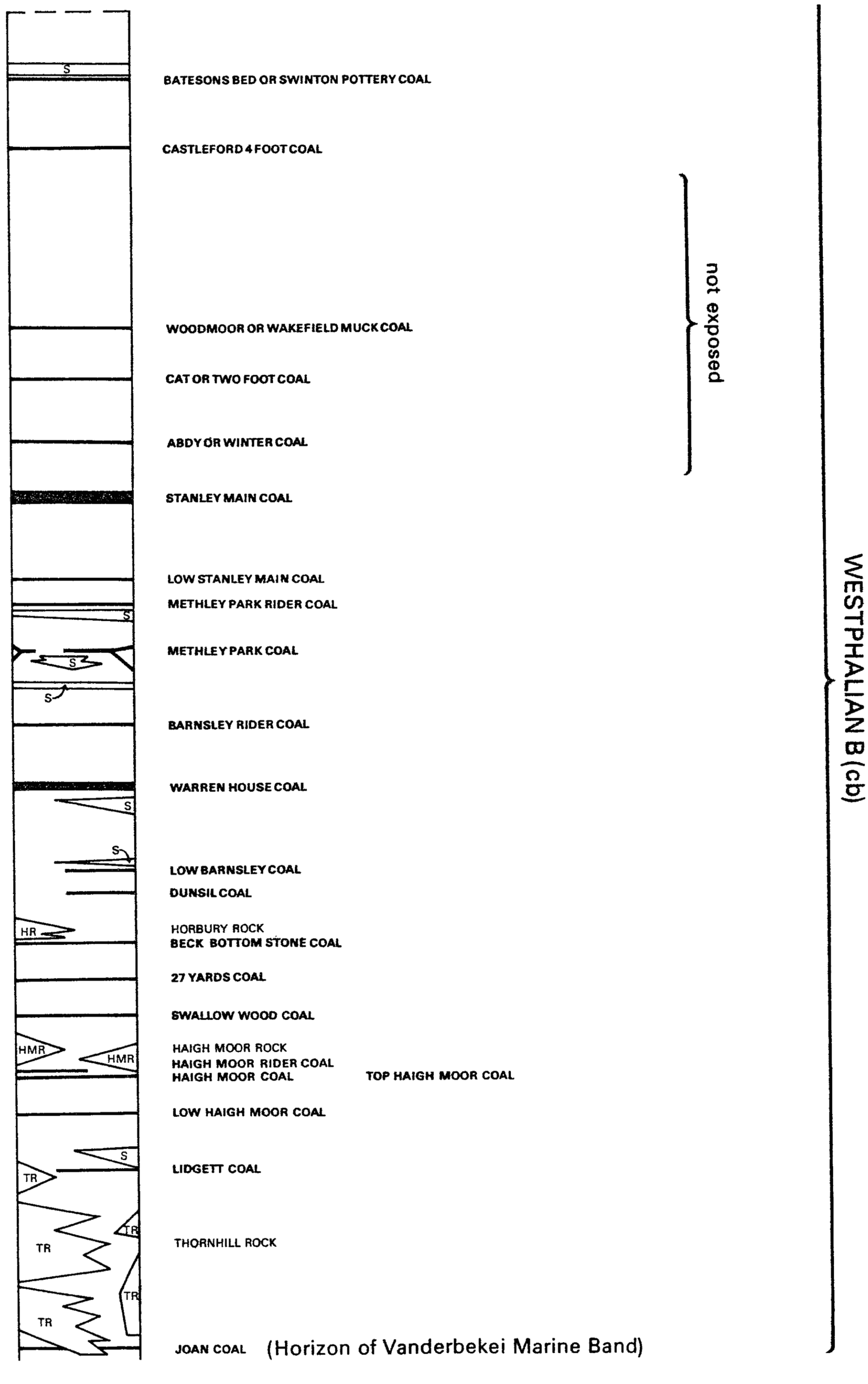


Figure 5. Generalised sequence of the Westphalian B rocks in the Oulton District.

seam, which is known as the Top Haigh Moor Coal, normally comprises two leaves. In some sections the lower of these is referred to as the Little Haigh Moor Coal. The upper and lower leaves are on average 0.88 m and 0.35 m thick respectively, separated by 0.33 m of mudstone. However, at Water Haigh Colliery the Top Haigh Moor Seam is represented by four leaves of coal up to 1.01 m thick.

Beneath the Top Haigh Moor Seam is a mudstone sequence which contains sporadic sandstones up to 2.44 m thick. This sequence has an average thickness of 8.69 m with a maximum of 11.89 m recorded at Water Haigh Colliery.

Below these strata a further coal seam known as the Bottom Haigh Moor is normally present. The Bottom Haigh Moor Coal has a mean thickness of 0.58 m. It normally comprises a single leaf, though two are present locally.

The Haigh Moor Coals have been extensively worked in the district, the upper leaf of the Top Haigh Moor seam being the most valuable. A few pillars of coal are thought to remain beneath rivers, canals, shafts and villages. The Top Haigh Moor has been worked opencast at the Oulton Park site [3540 2785] and at the St Aidans Extension site [3810 2885]. Both sites proved old shallow working which predate records, suggesting that where ever the Haigh Moor is at shallow depth old workings should be suspected.

Measures between the Haigh Moor and Warren House Coals

These complex strata contain several named coals and two important sandstones. Their mean thickness is 68.46 m. There appears to be a progressive southwards thickening from 50.99 m (Allerton Main, Victoria No. 2 Shaft) to 85.67 m (Dunford House Borehole), this thickening being more abrupt in the east of the district than in the west.

A thin coal, known as the Haigh Moor Rider, lies above the Top Haigh Moor Coal in the southwest of the district. Its average thickness is 0.22 m and it is normally between 0.58 m and 2.74 m above the Top Haigh Moor Coal. Elsewhere a sandstone is commonly present in this approximate position. It is up to 9.75 m thick, and is known as the Haigh Moor Rock. At Methley Savile Colliery Shaft it is absent, its stratigraphical level being occupied by siltstones with sandstone bands.

The Haigh Moor Rock crops out to the west of Royds Lane [3530 2775]. Here much of the crop was removed during the extraction of the underlying Haigh Moor Coal in the Oulton Park Opencast Site. However, the remnants of the strong feature it formerly produced can still be seen along Royds Lane. Prospecting boreholes for the Oulton Park Opencast Site show that locally the Haigh Moor Rock had a mean thickness of just over 16 m.

The Haigh Moor Rock was formerly recorded between the Oulton and Water Haigh faults [3812 2889]. The St Aidan's Extension Opencast site proved it to have a mean thickness of some 8 m.

Overlying both the Haigh Moor Rock and Rider is a sequence of mudstones extending upwards to the Swallow Wood Coal. This seam is on average 15.11 m above the Top Haigh Moor Coal and is normally represented by a single leaf though it may be split by one or (rarely) two mudstone partings. Its average thickness of the seam is 0.50 m. Prospecting boreholes for the Oulton Park Opencast Site prove that the Swallow Wood here lies about 3.60 m above the Haigh Moor Rock and has a mean thickness of 0.30 m.

The Swallow Wood Coal is separated from the 27 Yard Coal by about 8 m of strata, although up to 15.09 m are locally recorded. The inter-seam rocks are almost entirely mudstones and siltstones. The 27 yard Coal comprises a single leaf, with a mean thickness of 0.46 m; rarely, there is a thin mudstone parting within it.

The 27 Yard seam is separated from the Beck Bottom Stone Coal by between 2.79 m (Methley Savile Colliery) and 15.57 m (Allerton Main Collieries, Victoria No. 2 Shaft) of strata: the mean separation is 8.76 m. The sediments comprise mudstone and siltstone with thin sandstones, except at Allerton Main Collieries, Victoria No. 2 Shaft where there are 7.12 m of sandstone. The Beck Bottom Stone Coal is an average 0.33 m thick.

Both the 27 Yard and Beck Bottom Stone Coals crop out east of Royds Lane around Swithens Plantation [3507 2748]. Additionally it is calculated that the Swallow Wood, the 27 Yard and the Beck Bottom Stone coals crop out under the river terraces and alluvium of the Aire valley to the northeast of Water Haigh Colliery [3725 2833].

In the west of the district, northwest of the Oulton Fault, the Horbury Rock crops out. It forms a bold feature on which much sandstone "brash" is ploughed. Boreholes prove up to 5.5 m of sandstone. To the southeast of the Oulton Fault none of the shafts in the district records a significant sandstone at this level. For example Altofts Shaft, West Riding Colliery, records 19.5 m of siltstone at the level of the Horbury Rock. This suggests that, at least locally, the Oulton Fault exerted a control on sedimentation (cf Williamson & Giles, 1984).

In the northeast of the district, at Allerton Main Collieries, Victoria No. 2 Shaft and at Methley Savile Colliery, a mudstone and siltstone sequence with thin sandstones and two coals is recorded at the level of the Horbury Rock. In these two shafts their lower coal is respectively 6.67 m and 18.19 m above the Beck Bottom Stone Coal. This seam has been recorded at the St. Aidans [3960 2920] and the St. Aidans Extension opencast coal sites, and is correlated with the Dunsil seam of areas to the south and east. The Dunsil Coal is highly variable, changing from a multi-leaved seam, 2.11 m thick at Methley Savile Colliery, to a two-leaved seam, 0.60 m thick at the St. Aidans Extension opencast site. It does not appear to have been worked except by modern opencast methods.

The upper of the two coals has been recorded from the northeast of the district, and is correlated with the Low Barnsley Seam.

It is an average 6.13 m above the Dunsil Coal. The Low Barnsley normally comprises a three leaf seam with an average thickness of 1.94 m. During the extraction of the Low Barnsley at the St. Aidans and the St. Aidans Extension sites, the seam proved to have been mined extensively.

Above the Low Barnsley there is normally a mudstone and mudstone-seatearth parting, with a mean thickness of 1.14 m, separating it from the Warren House Seam. However, at Methley Savile Colliery the equivalent parting comprises 20.73 m of siltstone and mudstone.

Warren House Coal

Regionally this seam is very variable, but it has a fairly uniform thickness of about 1.50 m within the district. However, the number of leaves of coal in the seam decreases progressively in a north eastwards direction from seven at West Riding Collieries, Fox Shaft to two at the St. Aidans opencast site.

The coal crops out at Eshald Lane [3687 2850] just east of Woodlesford, and has been recorded (W.N. Edwards, BGS Archives 1931) from the former Robin Hood Quarry Oulton [3670 2844]. It has been opencasted at the Coney Warren [3470 2620], St Aidan and St Aidan's Extension sites, and has been worked from a drift mine at Newmarket Collieries [3619 2575]. The opencast sites and drilling associated with them indicate that the seam has been worked extensively where it is at a shallow depth; most of these workings are unrecorded.

Measures between the Warren House and Methley Park Coals

This sequence is largely composed of mudstone with sporadic sandstones of variable thicknesses up to 3.83 m. A thin coal, called the Barnsley Rider is frequently recorded. It is 0.10 m thick at the St Aidans Extension opencast site. The Barnsley Rider is normally some 14 m above the Warren House Coal, but may be as much as 27.69 m above it.

The mean parting between the Warren House and Methley Park Coals is 34.33 m but separations of up to 47.77 m have been noted. These strata crop out between the Oulton and Water Haigh faults around the Oulton Sports Centre [3626 2770]. Much of the crop is drift-covered, but where it is drift-free there is little evidence to suggest the presence of substantial sandstone though around Peasecroft Wood between the Water Haigh Fault and the St Aidans Opencast Site two thin sandstones crop out, the upper being exposed east of Fleakingley Bridge [3940 2958].

At Whitwood Colliery Shaft southeast of Methley Junction, 13.03 m of sandstone washes out the Methley Park Coal and some of the underlying beds.

Methley Park Coal

Williamson and Giles (1984) showed that the Methley Park Coal of this region probably represents the combined Kents Thick and

Kents Thin seams. At Lofthouse Colliery to the west of the Oulton Fault, the two Kents seams are 11.33 m apart. Immediately to the east of the fault the two coals unite to form the Methley Park a seam up to 1.71 m thick. The seam remains united between the Oulton and Water Haigh faults, but once across the latter it splits again, the numerous opencast boreholes in the district giving very tight control on the separation. South-eastwards from the Water Haigh Fault the split grows. It is some 2 m in a borehole north-west of Elm Farm [3741 2595] and 8.41 m in the Hungate II opencast site, adjacent to Park Farm [3782 2613]. The split also increases south-westward from the point where the Water Haigh Fault dies out [3552 2639].

The Methley Park crops out in a broad sweep around the hill that forms the watershed between the Aire and Calder valleys, where it has been worked in many opencast sites. It also crops out beneath the drift of the Aire valley, and is calculated to crop out beneath drift in the Calder Valley. An exposure of it was formerly recorded in a stream north of Newmarket Collieries, Nelson Shaft; shallow crop workings were also recorded in the same area. Just to the east of this colliery, opencast exploration boreholes have proved the seam to be 'washed out' and replaced by mudstone.

The seam has been extensively opencasted in modern times. In addition old crop workings are recorded north of Newmarket Collieries, Nelson Shaft, and there are numerous bell-pits in Almshouse Wood which worked the top leaf of the Methley Park. A seam at around the stratigraphical level of the Methley Park appears to have been worked locally in bell-pits at Peasecroft Wood. The identification of this seam is, however, speculative. Many of the opencast sites have shown the presence of old, unrecorded, workings in the seam, many by pillar-and-stall methods. It should be assumed that where the Methley Park is at shallow depth it is likely to have been worked, at least in part.

The Measures between the Methley Park and Stanley Main Coals

The full thickness of these strata is present only in the west of the district, beneath the outcrop of the Stanley Main at Royds Green Farm and Iveridge Hall [3588 2664]. At these localities some 37 m of strata separate the two seams. In the Dunford House Borehole 34.10 m are recorded between the two.

Above the Methley Park, lies a sequence of mudstone with conspicuous bands of ironstone. At the Hungate II opencast site this sequence is 10 m thick. On the hill-slope northwest of Savile Farm [3717 2557] ironstone has been ploughed up along a faint feature; a newly cleaned ditch [3672 2577], which crosses this feature, exposed a mudstone with numerous thin bands and lenses of ironstone at the time of the survey. In fields to the east of West Hall [3596 2534], a sandstone several metres thick forms a distinct feature at this same level.

A sandstone forming a pronounced feature overlies these mudstones. It can be traced around the hill surmounted by Clumpcliffe Farm [3700 2696]. At the Hungate II opencast site

6.32 m of sandstone were recorded, and at the Methley Park opencast site 8.23 m of sandstone were noted. A similar thickness of sandstone which appears to be at about the same stratigraphical level is also recorded at Cringlesworth [3709 2505] and at Great Preston [3980 2980]. Southeast of Moss Carr Farm [3644 2624] the sandstone clearly has an erosive base, as the base of the feature it forms changes its stratigraphical level. North of Elm Farm this sandstone is affected by cambering.

Above the sandstone there are some 2 m of mudstone succeeded by a thin coal. This coal was worked at the Hungate II opencast site where it was recorded as 0.15 m thick. It was there termed the Methley Park Rider. This coal crops out in ditches [3700 2620; 3715 2654]; at both localities it is 0.10 m thick.

A thin sandstone in places rests directly on the Methley Park Rider. It is thin southwest of Moss Carr Farm. In a ditch [3715 2654] it is 1 m thick, and is fine-grained, thinly bedded, and carbonaceous. It can be traced for a further 0.5 km to the northeast where it dies out. Elsewhere mudstone occurs above the coal.

Opencast prospecting boreholes just east of Moss Carr Farm record another coal up to 0.35 m thick lying between 3.7 m and 3.9 m above the Methley Park Rider. It was exposed in October 1984 in a newly cleaned ditch [3700 2626], where it was repeated by faulting and dipped at 30^{o}, considerably steeper than the regional dip. It was also recorded in a temporary section [3644 2610] just south of Moss Carr Farm. In the Dunford House Borehole a seam 0.75 m thick and 6.15 m below the Stanley Main Coal is regarded as the Low Stanley Main and the coal seam described above may correlate with it.

Mudstone dominates the strata between the Low Stanley Main and the Stanley Main coals. Boreholes north of the Moss Carr Farm record a sandstone 1.60 m thick and the feature formed by it can be traced for about 1 km to Walshan Cottage [3557 2639] where it dies out. What is probably the same sandstone crops out [3677 2558], just northwest of Savile Farm, where it forms a bold feature on the southeast side of the Newmarket fault.

Stanley Main Coal

This seam crops out around Royds Green Farm, where it was worked by opencast methods, and at Iveridge Hall. Sections from the opencast workings show that the seam has three leaves with a total thickness of 2.28 m. At the Dungeon Lane II site, 0.61 m of mudstone-seatearth beneath the coal was worked for fireclay. The Stanley Main is also recorded in two shafts and one borehole within this district, giving a mean thickness of 1.94 m.

Above the Stanley Main

Green et al. (1878, Fig. 104) record a section along a now overgrown railway cutting which exposed details of the Methley Junction Fault; a major NE-SW fracture with displacements of about 100 m, the section includes a 0.18 m coal on the southeast side of the fault. Edwards et al. (1940) regarded this coal as the Bateson's Bed, and from this calculated the position of the Castleford 4 ft seam. Between Methley, Normanton and Castleford, the Castleford 4 ft coal is some 75-80 m above the Stanley Main. These measures also contain several thin coals and the equivalent Wooley Edge Rock. This area is partly drift covered and the remainder is now completely obscured by coal tips. Consequently, the present authors have accepted this interpretation.

3. PERMIAN

In the northeast of the district there is a small outlier of the Lower Magnesian Limestone. It forms a pronounced hill on which part of the village of Great Preston [3990 2990] is built. Scattered blocks of cream coloured, fine-grained limestone occur in the adjacent fields and limestone was recently exposed along Whitehouse Lane during landscaping of private gardens (1982-1983).

The Lower Magnesian Limestone has been extensively quarried for agricultural lime and building stone. Many small quarries on the wooded hill top are now backfilled or overgrown and the ground is largely obscured by limestone debris.

4. STRUCTURE

The regional dip of the strata is normally less than three degrees though minor rolls and flexures noticably steepen the dip near faults where folding is also present. There is no overall direction of regional dip across the district; the direction varying from fault-block to fault-block. The direction of dip also changes vertically, especially where the dip is so low that the effects of differential compaction of the sediments become significant.

The major fault-set is NE-trending (see Fig. 6). This set includes the Oulton, Water Haigh, Methley Savile, Methley Junction and Newmarket faults. These all throw down to the south-east, with throws of up to 120 m. However, the throws decrease rapidly and eventually the faults die out laterally. The Water Haigh Fault, for example, throws the Haigh Moor Coal against the Methley Park Coal, a displacement of some 100 m. Yet, 3.5 km to the southwest the Water Haigh Fault dies out. Similarly the Oulton Fault throws the Beck Bottom Stone against the Stanley Main, a displacement of some 70 m, yet just 4 km to the northeast it can no longer be traced. These two faults are parallel, but en echelon, to each other. As the throw on one fault decreases so the throw on the other increases. A similar situation can be seen in the complex of generally NE-trending faults that include the Methley Savile and Newmarket faults, faults which are obviously related to one and other but are en echelon to each other as they die out.

The major faults are probably most correctly represented by a narrow zone of sub-parallel fractures. At several locations along the Oulton and Water Haigh Faults small areas have been exposed by quarrying or intensively drilled. Each of these localities show that the faults consist of at least two sub-parallel fractures. The faults are also probably multiple fractures elsewhere along their lengths.

A second fault-set is recorded, with minor throws, of normally less than 2 m. These faults have a NW-trend and are more limited vertically and laterally than the major faults. An area between the Oulton and Water Haigh faults is illustrated in Fig. 7. Here, in the Middleton Main seam, numerous minor faults occur between the two major faults. Yet the same density of minor faults is not recorded in seams above and below. Because of this inherent variability, these minor faults have not been projected to the surface though some may penetrate.

Folding is usually in the form of broad open structures. An example is the gently northward-plunging syncline beneath Clumpcliffe Covert [3730 2693]. Minor, very sharp, folds are occasionally recorded in exposures. These probably represent rolls related to minor faults at shallow depth. Folding becomes more pronounced near major faults. In the north-eastern corner of the area the rocks appear to be folded into a broad, gentle syncline which in turn is affected by proximity to the Water Haigh Fault. The otherwise gentle dip of the strata is dramatically increased adjacent to the fault. A consequence of

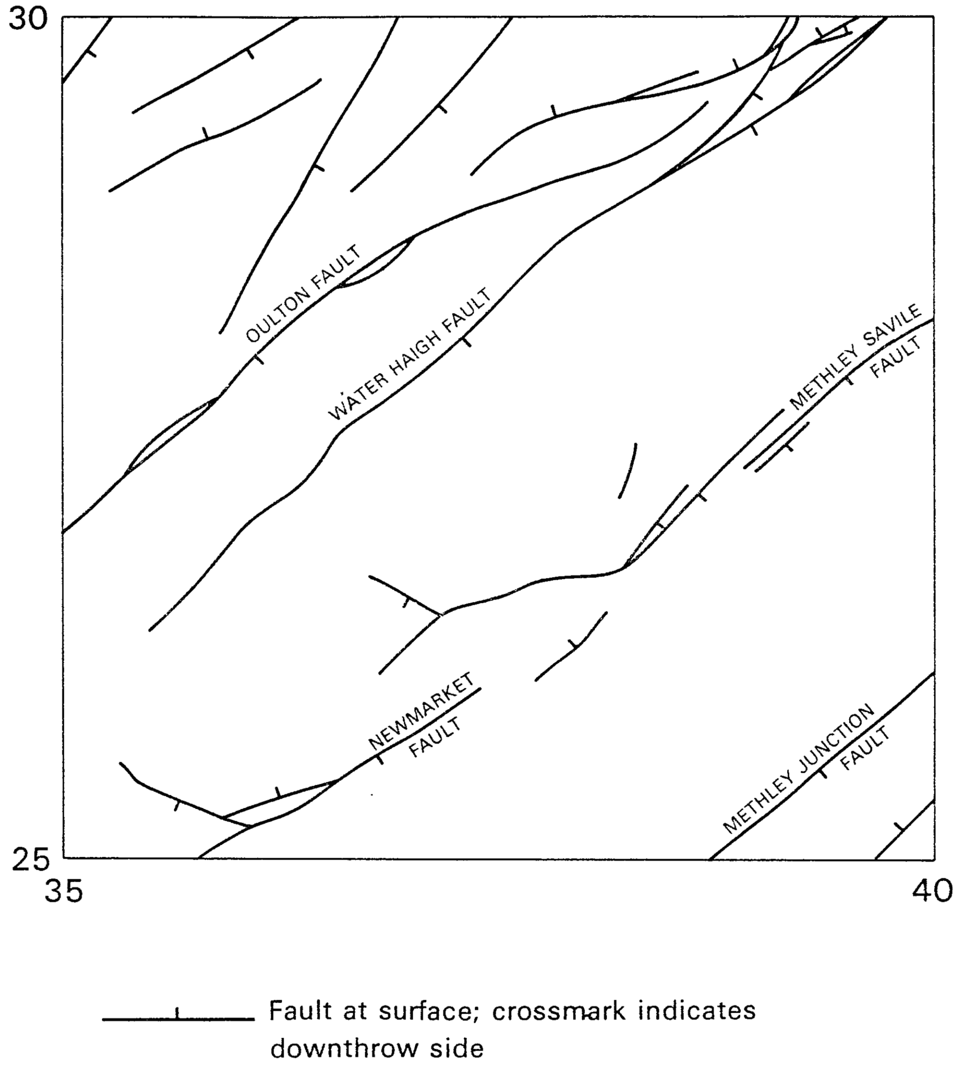


Figure 6. Sketch map of the major faults.

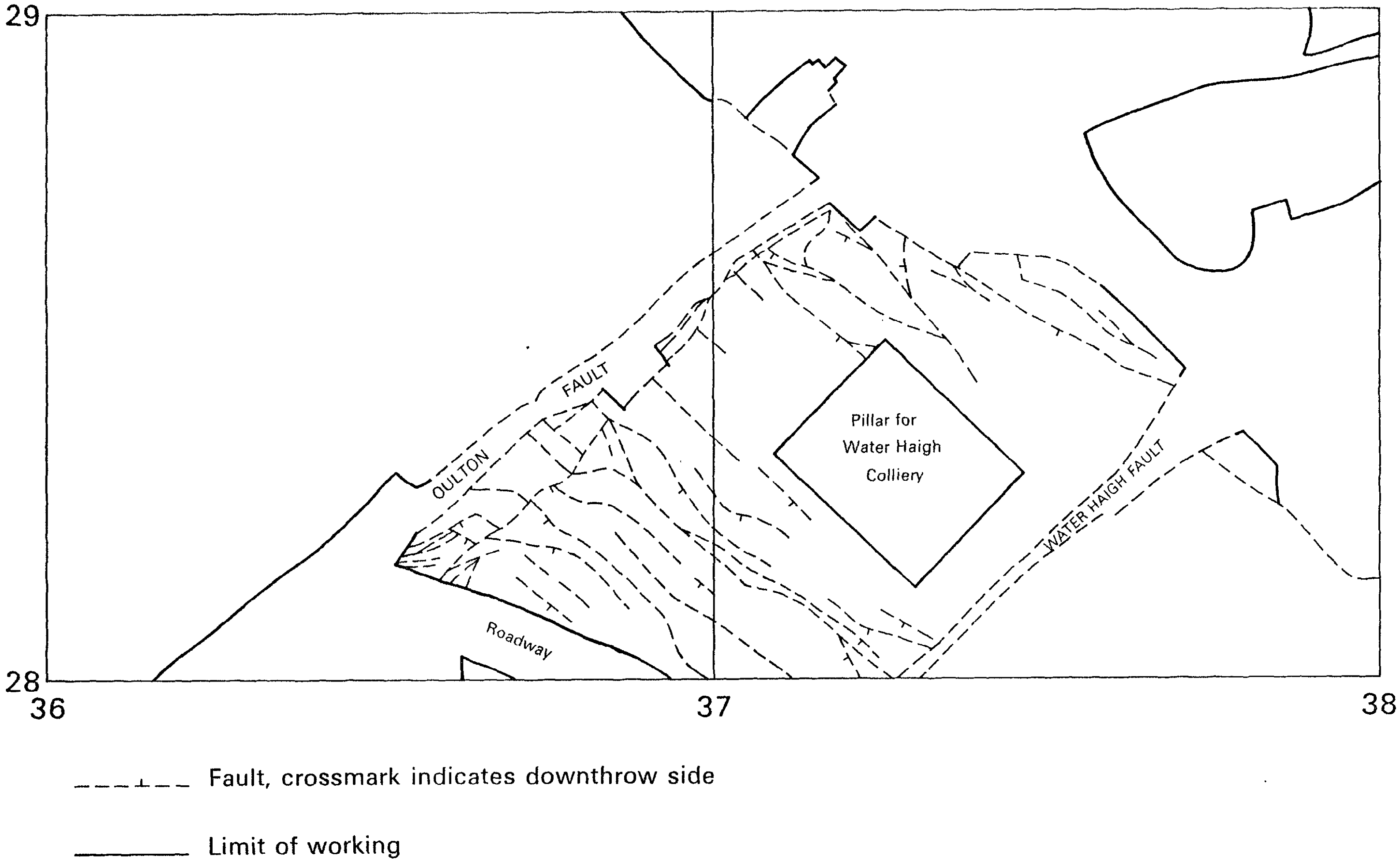


Figure 7. Sketch map based on Abandoned Mine Plan FGB 764. It illustrates numerous minor NW trending faults in the Middleton Main seam between the Oulton and Water Haigh Faults.

this is the apparently considerable angular unconformity between Westphalian B and the Lower Magnesian Limestone below part of Great Preston. In the St Aidans Extension opencast site the normally low dip reaches some 45^{o} adjacent to the Water Haigh Fault. Dips of 30^{o} have also been recorded close to relatively minor faults.

Joint planes are common and are best seen in the thicker sandstones. They are mostly very steep or vertical, and generally comprise two conjugate sets at any one locality. Regionally, however, these vary considerably in trend and no general pattern can be discerned from the sparse data available. The joints near the surface may open where undermined, causing noticable fissures. This has been noted when sites have been cleared prior to development.

Cambering has been recorded at some localities where sandstones cap hills or form pronounced breaks in slopes. At the Oxbow opencast site Gaunt et al. (1970) record an "Anticlinal Ridge" buried by the fluvial deposits of the River Aire. They attribute its origin to solifluction causing down-dip movement of strata on a south-facing slope.

5. DRIFT GEOLOGY

The drift deposits are of Quaternary age, and comprise Till, Glacial Sand and Gravel, River Terrace Deposits, Alluvium, Head and Peat. Some 50% of the area is covered by mappable drift deposits with individual patches widely scattered. The main areas of drift are located in the river valleys of the Aire and Calder and on the interfluve between them. Thematic Geological Map (TGM) 1 shows the distribution of drift deposits and TGM 2 gives isopachytes of drift thickness across the area.

5.1 REGIONAL SETTING

During the Quaternary, West Yorkshire was affected by several cold episodes. Prior to the Ipswichian the region was covered by ice on at least one occasion. Deposits relating to pre-Ipswichian glaccation show no constructional features and are usually extensively decalcified. They are preserved as denuded remnants on the interfluves.

Ipswichian deposits of the last inter-glacial are poorly recorded. Bones of two adults and one juvenile Hippopotamus were found in the terrace deposits of the Aire (Denny 1854) to the north west of the district, unfortunately the original locality is unknown.

In the most recent glaciation, the Dimlington Stadial (Rose 1985), ice advanced down the Vale of York, briefly as far south as Doncaster; but the moraines at York and Eserick represent a more persistent southern limit to the advance. Ice also accumulated on the Pennines producing substantial valley glaciers which flowed down the main Pennine Dales.

It is probable that the Oulton district was free of ice for much of the Devensian as the major glaciers terminated to the north and west of the district. Fluvio-glacial deposits were laid down under peri-glacial conditions in the major dales during the advance and subsequent retreat of the glaciers. At the time of maximum glaciation and for a period during the retreat a substantial pro-glacial lake, Lake Humber, existed in the Vale of York. The initial level of Lake Humber was at about 30 m A.O.D. (Edwards 1936). Related to this are isolated patches of shore line gravels along the edge of the Pennines and along the York-Eserick Moraine. The level of Lake Humber subsequently dropped to between 7 and 8 m A.O.D.

Following the climatic amelioration at the end of the Devensian and the draining of Lake Humber, meandering river systems developed in the major dales resorting and redepositing the fluvio-glacial deposits.

5.2 TILL

Till is confined to the interfluve between the Rivers Aire and Calder. Sections in ditches at Pinders Screed and Moss Carr Wood show that when weathered it is a yellowish-brown in colour with light grey mottling, slightly sandy, silty clay with pebbles and sporadic cobbles. The clasts are dominated by locally-derived sandstone with lesser amounts of chert and ironstone. Borehole NE 77 records 13.4 m of till and borehole NE 78 records 9.9 m of till beneath glacial sand and gravel. Opencast prospecting boreholes in the same area also record till but it is generally thinner and described as containing gravelly beds. Where unweathered the till is medium grey. Thin till-like deposits are preserved locally, but not mapped, across the district again mostly on the higher ground; there are examples north-west of Great Preston.

5.3 GLACIAL SAND AND GRAVEL

Glacial sand and gravel is found in close association with till on the high ground between the Aire and Calder and also at John O'Gaunts. Borehole NE 76 records 5.6 m of glacial sand and gravel near Home Croft. Confidential boreholes elsewhere in the deposit record similar thicknesses. In the past, and apparently for local use only, several small pits exploited the sand and gravel between Oulton Park and Clumpcliffe Covert. The deposit contains an abundance of pebbles and cobbles of locally-derived Carboniferous sandstones and grits with lesser amounts of ironstone, siltstone, chert, quartz and limestone. Gradings indicate between 4% and 24% fines; the mean is 12% fines, 44% sand and 44% gravel, thus classing the overall deposit as a 'clayey' gravel. The poorly exposed sections examined show comparitively minor amounts of well-laminated and cross-bedded sand, in marked contrast to the sections formerly seen in the John O'Gaunts deposit. (see Williamson & Giles 1984). No section or pits are present within the John O'Gaunts outcrop and little is known of it; it is most probably identical to that described in the BGS report covering 1:10 000 Sheet SE32NW.

5.4 RIVER TERRACE DEPOSITS

Much of the drift-covered area comprises the terrace deposits of the rivers Aire and Calder. Two main terraces have been mapped, but other terraces and features of uncertain origin are recorded from several localities, the latter being classified as 'Terrace Deposits undifferentiated' on the accompanying map. The First and Second terraces are equivalent to those originally recognised by Green et al. (1878) and by Edwards et al. (1940). As a consequence of the complexities of the fluvial and fluvial-lacustrine depositional environments the terrace deposits show rapid lithological variations both vertically and horizontally; they range from laminated clays through silts and sands to coarse gravel.

Gaunt et al. (1970) report a radiocarbon date from a mammoth tusk found in a silt at the base of the terrace gravels at the Oxbow opencast site, immediately adjacent to the area. This yields a date of 38,600 + 1720 to -1420 years B.P. The deposition of the main terraces is later than this date.

River Terrace Deposits (Undifferentiated)

In several localities there are deposits where form suggests that they are part of the terrace system but which occur at higher, intermediate or indeterminate levels with respect to the First and Second Terraces already mentioned. They are found in both the Aire and Calder valleys.

At Rothwell Haigh, northwest of Woodend Farm [3582 2969], sand and gravel with subordinate clay are exposed well above the general level of the Alluvium; their relationship to the Second Terrace is uncertain. Although largely obscured by coal tip, the deposit may extend some way to the west. Grading has shown it to contain 20% fines in an otherwise sandy gravel compositionally very similar to the gravels of the Second Terrace. Elsewhere the undifferentiated terrace deposits reflect the variability of the recognised terraces; some are most probably directly related to these rather than forming a separate terrace. A good example is found at Swillington Park.

At Methley Park an area of sand and gravel has been proved in opencast boreholes at a level above the second terrace. It has no constructional features but drapes a south facing slope at around 25 m O.D. Glacial sediments in this position would have been removed by solifluction during the Devensian. It is possibly related to the high level stand line of Lake Humber wich deposited sand and gravel in isolated patches along the sides of Pennine Dales.

Second River Terrace Deposits

Deposits representing this terrace are widespread at the junction of the Aire and Calder valleys at Methley and in the valley of the Aire from Woodlesford and Oulton to Mickletown. In the latter area they are frequently obscured by development and Made Ground. Mining subsidence over many years has significantly affected most of the outcrop. Small, commonly disconnected and relatively insignificant, patches occur at several localities, for example at Leventhorpe [3680 2990; 3706 2968].

The nature of the deposit varies greatly. At Scholey Hill, the terrace is composed of brown, medium sand with 14% fines; elsewhere in Calderdale there is a significant and high percentage of gravel and the deposit is classed as a 'clayey' sandy gravel. The gravel fractions of these deposits is dominated by carboniferous sandstone with some ironstone and quartz. Up to 12% ironstone was recorded in one sample. Within the sands and gravels of the Aire deposits, small spreads of laminated clays may be present. Some of these were examined and commented upon by Gilligan (1918). Borehole NE 79 penetrated 11.3 m of 'clayey' pebbly sand and sand and gravel. Adjacent commercial boreholes suggest that this represents an abandoned channel. Channel-fill deposits of sand and gravel occur in both the Aire and Calder valleys (Edwards et al. 1940).

Despite complications caused by subsidence the terrace can be traced over a considerable area attaining a maximum height of about 6 m above present river-level. The form and lithological variations of the deposits imply an environment more complex than a fluvial one. Edwards et al. suggest that deposition was in part under deltaic conditions; the laminated clay sequences may represent periods of quiescence and lacustrine deposition.

First River Terrace Deposits

Remnants of this terrace are now seen only at Methley, but small patches may be preserved beneath Made Ground within the St Aidans Extension Opencast site and at Fleet Bridge. From the limited information available, the deposits consist of a veneer of sandy clay overlying up to some 7 m of sand and gravel; the percentage of fines is about 26%. The terrace is low-lying and mostly below the present levels of the Aire and Calder, rising near Methley, to about 15 m O.D. Edwards et al. (1940) state that Lake District rocks are common in the Calder Valley but absent in the Aire Valley, and that the coarse gravels are composed mainly of Upper Carboniferous sandstones. It has not been possible to confirm these statements during the present survey.

5.5 ALLUVIUM

Alluvial deposits occur along the margins of the present water courses of both the River Aire and the River Calder forming spreads hundreds of metres wide. They were formed comparatively recently by progressive deposition from these low-sinuousity meandering rivers. At surface the deposits are varied, ranging from gravels to fine silts and clays. No sections were available for examination in the Calder alluvium, but borehole data show several metres of mottled clay with minor gravels. By contrast sections of alluvium are exposed along much of the present course of the River Aire. Most show up to 2 m of sandy silty clay overlying silts or sand and gravel. Lateral variations are common and rapid, and none of the individual beds seen was traceable for more than 50 m. The deposits seen represent sections through parts of the former meander course of the river. Parts of the River Aire have been artificially straightened, and abandoned meanders are seen in several places eg. at Leventhorpe [3660 2975] and Cockpit Round [3755 2920]. Such meanders commonly contain soft peaty clays in addition to silts and gravels. Grading of a typical gravel from the Aire, west of Leventhorpe revealed only 1% fines in an otherwise sandy gravel. Borehole NE 75 near Leventhorpe Cottages records 3.0 m of sandy gravel beneath silty clay. The gravel fraction is composed of 97% sandstone with some siltstone, ironstone and quartz.

Smaller strips of Alluvium occur along Oulton Beck between Rothwell and Oulton, again gravelly in aspect with an overlying clay. Smaller patches of thin, soft, peaty clay occur adjacent to all the minor streams in the area, occurrences of note being at Springs Wood [3695 2571] and in the incised valley cutting the Thornhill Rock, west of Swillington Park [3775 2970]. There are no data on the thickness of these minor occurrences.

5.6 HEAD

Head is the term applied to deposits formed initially by the slow downslope movement of material under periglacial conditions of alternate freezing and thawing but which are probably still forming today under the action of present-day weathering and plant growth. Many of the valley deposits in the area come under this heading and comprise bewildering mixture of soft clay, sands and angular rock fragments, extending over all rock types in the substratum. It may be present over much of the ground and commonly is a yellow sandy clay lacking in cohesion and stability. It tends to be thicker in hollows and against obstructions on slopes. Substantial polymict deposits thought to be mainly head have been mapped on the slopes overlooking Oulton Beck at Springhead Park and south of Iveridge Hall [3575 2620]; these consist of local drift deposits, weathered bedrock and soil. Minor patches of sandy head are located on the valley sides of the suspected glacial drainage channel north of Swillington Park.

The head is generally less than 2 m thick, but may exceed this in some of the main valleys. It is not possible to indicate its complete distribution due to its thinness and its lack of distinguishing characteristics. It should be assumed to be present everywhere unless proved otherwise.

5.7 PEAT

Deposits of peat are common in association with alluvium. Small deposits lie south of Parkin Farm adjacent to the M62 motorway [3780 2535], at the site of a former lake at Methley Park [3815 2650], and adjacent to Oulton Beck southeast of Water Haigh Farm [3803 2786]. Peat was also augered at shallow depth beneath soft clays in and around the abandoned meanders of the River Aire at Leventhorpe and Cockpit Round. No data are available as to the thickness of these deposits.

6. MADE GROUND

Made Ground, constructed from a variety of sources and materials, covers a considerable part of the area. Due to the inherent variability of such deposits, detailed and careful site investigations are necessary where development is to be sited on them, so as to determine their thickness, compressibility and chemical content. Seven main categories are distinguished below; recorded thicknesses are extremely variable.

6.1 LANDSCAPED GROUND

This category covers the ground beneath recent housing developments, schools, industrial estates and recreational areas where the original ground surface is likely to have been modified by earth moving operations. Such areas may or may not be covered by significant Made Ground (generally > 1.5 m), and it is virtually impossible to determine the distribution of any deposit present without a comprehensive investigation.

6.2 MADE GROUND, UNDIFFERENTIATED

This category includes major road and motorway embankments, railway embankments and other general constructional areas. Within any development area such deposits can be widespread. Detailed site investigation will be needed to determine the presence and extent of such deposits, as it was not always practical to delineate them on the map, (TGM 3).

6.3 BACK-FILLED QUARRIES

Excavations of various depth and size for sandstone, clays for brickmaking, limestone and sand and gravel are scattered across the area. Commonly there is no surface indication of their former extent or, in a few cases, of their presence. In most instances archival material has supplied the details. In general no information on the nature or state of compaction of the fill material is available.

6.4 BACK-FILLED OPENCAST COAL SITES

There are numerous former opencast coal sites in the area; their distribution is shown on the accompanying Thematic map. Such sites are effectively landscaped and restored.

6.5 COLLIERY WASTE TIPS

These tips are a conspicuous feature of parts of the district. They generally consist of inert materials but there may also be a considerable proportion of coal. Some of the larger tips have been landscaped and redeveloped. This material has proved unstable in one locality; a small area of landslipping is located about 600 m northwest of Wood End Farm, on the tips for Rothwell Haigh, Fanny Pit, adjacent to the main railway line.

6.6 GENERAL REFUSE TIPS

Domestic and industrial refuse contains a wide admixture of materials which may, upon burial, produce problems of instability and the possible emission of gas. Archival data have proved inadequate in providing the total distribution of waste tips and it is inevitable that not all have been located.

6.7 WORKING OPENCAST COAL SITES

The St Aidans Opencast Site is working at present, and the mounds of discard and spoil surrounding the site consist of all strata types encountered in the sequence down to the Dunsil Seam. Some alluvial deposits are also present. The slopes of these tips at the northern side of the site above Fleakingley Bridge were being covered by topsoil and landscaped at the time of the survey.

7. ECONOMIC GEOLOGY

7.1 COAL

The production of coal still continues in the area. A deep mine, Methley Savile Colliery, and an opencast coal site, St Aidans Extension, are currently working.

Almost the entire district has been undermined, except for pillars protecting settlements, canals, rivers and shafts. Numerous shafts, backfilled opencast coal sites, shallow mines, deep mines, and several large waste tips are a legacy that the coal industry has bequeathed to the district.

Opencast mining has been very extensive in the past. Many sites exploited the Methley Park Seam by removing thin overburden. As excavation methods have improved it has become feasible to work the Warren House, Low Barnsley and Dunsil seams, as at the St Aidans and St Aidan's Extension opencast sites. St Aidan's Extension site is now removing, as overburden, the back-filing of the former Astley Lane site so as to work the underlying seams. Improvements in excavation methods mean that much of the area, including those parts already worked opencast for the Methley Park Coal, should be regarded as containing a valuable coal resource.

7.2 MINESTONE

Extensive areas of colliery spoil lie adjacent to sites of several former large mines. Some of this spoil is now regarded as a resource of 'minestone', which can be processed to meet specifications for a wide variety of uses such as embankments, river and sea defences, land reclamation and brick-making. Minestone was extracted from Rothwell Colliery Tip [3550 2980] in the financial year 1983/84 (the last year for which figures are available).

7.3 FIRECLAY

Mudstone-seatearth can be exploited for fireclay. In particular, the seatearth of the Better Bed Coal was extensively worked to the southeast of Leeds. However, it has been proved at only one shaft in this area, and does not appear to have been worked. The mudstone-seatearth of the Stanley Main Coal was worked for fireclay at the Dungeon Lane II opencast site where 0.61 m of seatearth was removed.

7.4 IRONSTONE

Many shafts and boreholes record bands and lenses of ironstone. Collieries to the south of Leeds which worked the Black Bed Coal commonly also extracted the overlying ironstone-rich strata. In this district little Black Bed Coal was worked, and apparently none of the overlying ironstones. Ironstone concentrations in some abundance are known above the Middleton Little and Flockton Thick Coal, but again there is no evidence of their having been worked. Shallow workings and bell-pitted areas at Peasecroft Wood and Almshouses Wood show much ironstone debris in addition to coal. The ironstones may have been used locally.

7.5 MUDSTONE AND CLAYSTONE

The mudstones and claystones of the Westphalian vary widely in their properties, but several bands are useful for brick-making. The former Robin Hood Quarry at Oulton appears to have extracted a small area to the south of the Oulton Fault for brick-making.

7.6 SANDSTONE

The only sandstone of economic importance is the Thornhill Rock, the lower unweathered parts of which are a source of good quality building stone. It is no longer worked in the district but a number of large quarries formerly operated in Oulton and Woodlesford. The approximate former extent of these is shown on the map. The resource of the Thornhill Rock is now largely sterilised by recent urban development between Rothwell, Oulton and Woodlesford.

Other small quarries, for farm and local use, are common wherever there is a significant sandstone, such as south of Pinders Green [3926 2570] and at Swillington Park [3785 2980].

7.7 LIMESTONE

A small area of the Lower Magnesian Limestone lies beneath the village of Great Preston. It was once extensively quarried for building stone and agricultural lime. The resource is now largely sterilised by the urban development of Great Preston.

7.8 SAND AND GRAVEL

Potentially workable sand and gravel is present in the area. The major resource is the Second Terrace of the rivers Aire and Calder including its extention beneath the First Terrace and Alluvium. The First Terrace and the Glacial Sand and Gravel also contain potential workable resources. These deposits are described above, and an assessment of the sand and gravel resources is given below and in TGM 6.

8. RELATIONSHIPS BETWEEN GEOLOGY AND LAND-USE PLANNING

The two principle geological factors which have implications for land-use planning are subsidence (mainly related to shallow mining) and the extent of mineral resources. To illustrate the controlling factors, TGM 1, 3 and 5 show the distribution of drift deposits, made ground and underground mining respectively. Figure 6 shows the position of major faults and EGM 6 shows the distribution of sand and gravel resources.

8.1 SUBSIDENCE

Methley Savile Colliery (closed October 1985) was the last working colliery in the district but in the past mines were much more numerous. Much of the area has been mined at depth, the principle seams being the Beeston, Middleton Eleven Yard, Middleton Main, Middleton Little, Flockton Thick, Haigh Moor and Warren House.

Shallow mining and crop workings are known from several parts of the district such as Swillington Park, Almshouse Wood and Peascroft Wood. In both woods there are numerous bell pits and shallow crop workings in the Methley Park seam. Many of the opencast sites and prospects recorded evidence of shallow mining in the Warren House and Methley Park coals. On this basis shallow mining has been inferred to have occurred wherever these seams occur within 30 m of rockhead. Where mining has taken place there is a possibility of subsidence for some time after the date of mining. The rate at which old workings collapse depends upon the type of extraction pattern, the geological conditions and the ages of the mining; it cannot be assumed that all settlement has ceased, particularly where pillar-and-stall workings are involved. Because of the extent of inferred shallow mining in the district, detailed site investigations are desirable prior to any development.

Numerous abandoned shafts are recorded in the district, but many more unrecorded ones probably exist. In some cases several shafts are shown closely grouped on the geological map. Such occurences may represent the same shaft differently located on two or more archival documents. The exact location of shafts should be given high priority during site investigations.

The possibility of localized extreme subsidence along faults which cross sites should also be borne in mind. Natural movement along faults, in response to either regional or local factors can cause subsidence but such movements are extremely rare. It is much more common for subsidence to follow faults when coal extraction has been limited by the fault. Such subsidences tend to be most intense when workings approach the fault from the upthrow side. These effects should be considered when planning developments straddle faults.

Differential compaction may occur on sites which are underlain by more than one lithology; whether this is due to the original sedimentation or differing lithologies thrown together by faults. This may become significant if the site is excessively loaded during development.

8.2 MINERAL RESOURCES

In planning the future of this district consideration should be given to siting major developments where they will not sterilize mineral resources, and the possibility of extraction of workable minerals in advance of development.

Much of the district is underlain by coal at shallow depth; the most important shallow seams being the Warren House and the Methley Park coals. Few records exist as to the extent of former mining in these seams. Throughout this region these two seams are regarded as prime opencast targets where they occur close to the surface. Current opencast coal prospecting is taking place in the district and it is likely that many other areas will be prospected in the future.

Much of the district contains significant resources of sand and gravel some of which have been exploited in the past. Current extraction of sand and gravel from fluvial deposits is taking place to the east of Mickletown. Details of the sand and gravel resources are presented below and on TGM 6.

8.3 OTHER CONSTRAINTS ON LAND-USE PLANNING

Slope instabilities can cause further foundation problems. Certain slopes show clear evidence of cambering, especially where a competent sandstone forms a distinct break in slope on a hillside otherwise composed of mudstone. An example is found north of Elm Farm [3735 2625]. Slippage of strata and down-slope mass-movement of superficial deposits can also occur when slopes are over steepened or cuttings constructed.

Landslips have been recorded only in the made ground; for example 0.5 km northwest of Wood End Farm along the margin of a small stream issuing from near the base of Rothwell Haigh Fanny Pit's waste tip [3580 2969]. Similar situations at other waste tips may lead to future slips.

The drift deposits may also constrain development. These deposits can change in lithology and thickness very rapidly, as do, for example, the river-terrace deposits. In consequence the magnitude of compaction under load can vary equally rapidly and is difficult to quantify in advance. The drift deposits may obscure buried channels such as the one between Methley and Wood Row, giving further problems in prediction. Head, which is largely unmappable, covers much of the areas mapped as exposed solid. It is normally thin but may mask rockhead depressions.

It is also very variable in character. As a consequence, all drift deposits should be carefully investigated before development commences.

Made ground and fill may also constrain development. The varied chemical content and compaction of these materials must be carefully investigated before development. Minor backfilled unlocated quarries are probably present in the major sandstones, sand and gravel deposits and, more rarely, in the mudstones. Consideration should be given to investigating for these as part of a full site investigation.

9. THEMATIC GEOLOGY MAPS

Six thematic geology maps have been produced to illustrate various aspects of the geology in a readily assessable form for use in present and future planning and development.

MAP 1 DISTRIBUTION OF DRIFT DEPOSITS

Fluvial and Glacial deposits are depicted on this map. Head (soliflucted material) and downwash are also widespread, mantling much of the solid sequences, but because the occurences are thin and lacking in distinguishing characteristics it is not possible to delimit them accurately and few have been shown. The deposits are discussed in more detail in Section 5 of this report.

MAP 2 THICKNESS OF DRIFT DEPOSITS

The thickness of the Quaternary deposits is shown on this map, the isopachytes interval being 2 m. The contouring has been done by hand and is based on the total archival information available at 31.12.84. Additional information may modify the present interpretation.

The glacial deposits reach a maximum thickness of 12 m at Clumpcliffe but they are generally much thinner and represent a mantle preserved on the interfluves, which mask the original topography.

The fluvial deposits fill channels incised into bedrock. They generally contain up to 8 m of sediment but closed depressions occur in the channel floors which are filled with up to a total of 16 m of sediment. The channel of the Aire is approximately symmetrical whilst the Calder channels are asymmetrical in part. A buried asymmetrical channel is located between Methley and Wood Row.

The overdeepening in the rockhead channels may have a sub-glacial origin.

MAP 3 DISTRIBUTION OF MADE GROUND

Seven categories of Made Ground are distinguished on this map. The categories are (i) Landscaped Ground (ii) Made Ground, undifferentiated (iii) Back-filled Quarries (iv) Back-filled Opencast Coal Workings (v) Colliery Waste Tips (vi) General Refuse Tips (vii) Active Opencast Coal Mining Discard. They are discussed in Section 6.

MAP 4 BOREHOLE LOCATIONS

The locations of all known boreholes and of those areas where shallow drilling has been particularly intensive are shown on this map; the records of the holes form part of the British

Geological Survey's archives. However, it is recognised that not all past boreholes have been archived. Additionally, due to confidentiality, it has not been possible to include the holes drilled by the National Coal Board during exploration for the numerous opencast sites.

MAP 5 UNDERGROUND AND OPENCAST MINING

Coal has been extracted in this area since the late eighteenth century. Records and large-scale plans of abandoned mines held by the National Coal Board have been examined and provide much information on the extent of disused workings. However, many of the older workings have no known plans. Their presence can be inferred only from boreholes, old shafts and tips, and from archival information. Old coal workings are present at depths ranging from immediately subsurface to over 300 m. An arbitary depth of 30 m has been chosen to separate shallow and deep workings.

Three categories of ground are shown on Map 5: (i) areas where coal is known or inferred to have been worked less than 30 metres below rockhead; (ii) areas where coal is known or inferred to have been worked at depths greater than 30 metres below rockhead; and (iii) areas where no workings are known. Particular care is required when developments are planned in areas where the thicker coals (Haigh Moor, Warren House, Methley Park, Stanley Main) are close to the surface, as old pillar and stall workings may stand open for many years, possibly collapsing only after changes in groundwater conditions or after overloading at critical points such as roadway intersections.

The map also shows positions of mineshafts, though it is unlikely that all have been located, and both former and active opencast sites. The information given on the map is generalised. For detailed information on former shafts and mining subsidence problems, reference should be made to the National Coal Board (see page 45).

MAP 6 SAND AND GRAVEL RESOURCES

Both the glacial and alluvial deposits are known to contain sand and gravel. To illustrate the resource potential Map 6 has divided the areas into Resource Blocks where data are available to give estimates of the quality and quantity of the resource. Block A encompasses the glacial sand and gravel and Block B, the fluvial deposits of the Aire and Calder valleys. Accompanying this map, Section 10 of this report gives fuller descriptions and details of the resource and the methodology used in assessing it.

10. SAND AND GRAVEL RESOURCE ASSESSMENT

10.1 INTRODUCTION

The survey is concerned with the estimation of resources, which include deposits that are not currently exploitable but have a foreseeable use, rather than reserves, which can only be assessed in the light of current, locally prevailing, economic considerations. Clearly, neither the economic nor the social factors used to decide whether a deposit may be workable in the future can be predicted; they are likely to change with time. Deposits not currently economically workable may be exploited as demand increases, as higher-grade or alternative materials become scarce, or as improved processing techniques are applied to them. The improved knowledge of the main physical properties of the resource and their variability, which this survey seeks to provide, will add significantly to the factual background against which planning policies can be decided (Archer, 1969; Thurrell, 1971, 1981; Harris and others, 1974).

The survey provides information at the 'indicated' level. 'Indicated' assessments "are computed partly from specific measurements samples or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to permit the mineral bodies to be outlined completely or the grade established throughout". (Bureau of Mines and Geological Survey, 1948, p15).

It follows that the whereabouts of reserves must still be established and their size and quality proved by the customary detailed exploration and evaluation undertaken by the industry. However, the information provided by this survey should assist in the selection of the best targets for such further work. The following arbitary physical criteria have been adopted:

a The deposit should average at least 1 m in thickness.
b The ratio of overburden to sand and gravel should be no more than 3:1.
c The proportion of fines (particles passing a 0.625 mm B.S. sieve) should not exceed 40 per cent.
d The deposit should lie within 25 m of the surface, this being taken as the likely maximum working depth under most circumstances. It follows from the second criterion that boreholes are drilled no deeper than 18 m if no sand and gravel has been proved.

A deposit of sand and gravel that broadly meets these criteria is regarded as 'potentially workable' and is described and assessed as 'mineral' in this report.

Pre-Pleistocene rocks, which are usually consolidated and devoid of potentially workable sand and gravel, are referred to as 'bedrock'; 'waste' is any material other than bedrock or mineral; 'overburden' is waste that occurs between the surface and an underlying body of mineral.

For the particular needs of assessing sand and gravel resources, a grain-size classification based on the geometric scale 1/16 mm, 1/4 mm, 1 mm, 4 mm, 16 mm, 64 mm has been adopted. The boundaries between fines (that is, the clay and silt fractions) and sand, and between sand and gravel grade material, are placed at 1/16 mm and 4 mm respectively (Giles, 1982, Appendix C).

The volume and other characteristics are assessed within resource blocks, each of which, ideally, contains approximately 10 km^2 of sand and gravel. No account is taken of any factors, for example roads, villages or land of high agricultural or landscape value, which might stand in the way of sand and gravel being exploited, although towns are excluded. The estimated total volume therefore bears no simple relationship to the amount that could be extracted in practice.

It must be emphasised that the assessment applies to the resource block as a whole; valid conclusions cannot be drawn about mineral in parts of a block, except in the immediate vicinity of the actual sample points.

The geology of the solid and drift deposits is described in sections 2, 3 and 5 of this report.

10.2 COMPOSITION OF THE SAND AND GRAVEL DEPOSITS

The unconsolidated aggregate resources of the district consist of glacial and fluvial sand and gravel. Details of grading and composition of these deposits, as recorded in boreholes and collected sections, are given at the end of this section; they are summarised below in Figure 8 and Table 1.

Glacial Sand and Gravel

Potentially workable glacial sand and gravel has an overall mean grading of 12% fines, 44% sand and 44% gravel. However, the deposit exhibits considerable variation: borehole and section mean gradings range from 'very clayey' sandy gravel to gravel.

The gravel fractions are mainly coarse and the clasts are predominantly rounded to angular. Carboniferous sandstone commonly accounts for over 90% of the gravel, but cherts and ironstone may be significant components; subordinate constituents include siltstone, mudstone and quartz. Aggregate impact values BS 812 (British Standards Institution, 1975) for composite samples from borehole NE 76 yield an average value of 41. The sand fraction is mainly medium with subordinate amounts of fine and coarse. The sand is generally subangular to rounded quartz with lithic grains, the latter dominating the coarse grades. Fines consist of yellowish brown silt and clay.

Fluvial Sand and Gravel

River Terrace Deposits (Undifferentiated), Second River Terrace Deposits, First River Terrace Deposits and Alluvium are considered under this heading. The potentially workable fluvial deposits range from 'clayey' pebbly sand to gravel. The mean grading for the deposits is 12% fines, 55% sand and 33% gravel. However, the fines normally represent less than 10% of the deposit except in two localities where 14% and 20% were recorded, which significantly bias the mean fines percentage. The fines are composed of silts and clays. The sand is composed of angular to rounded quartz with lithic grains, the latter of which comprise a greater percentage of the coarse fraction. Medium is the modal sand grade with significant amounts of coarse. The gravel is normally fine and composed of rounded to subangular carboniferous sandstone which commonly forms more than 90% of the clasts. Minor amounts of siltstone, mudstone, chert, quartz, ironstone and coal together form the remaining 10%. Exceptionally, in individual samples, up to 12% ironstone and 6% coal were recorded. Aggregate Impact Values for composite samples from boreholes NE 75 and NE 79 ranged between 40 and 42.

10.3 THE MAP

The sand and gravel resource map forms Thematic Geology Map (TGM) 6 accompanying this report. Borehole and section data, which include the stratigraphical relations, thicknesses and mean particle size distributions of sand and gravel samples collected during the assessment survey are also shown on TGM 6. The boreholes are presented in Appendix C of this report. The form of presentation of boreholes and sections follows that of Giles (1982, Appendix D).

Mineral Resource Information

The mineral-bearing ground is divided into resource blocks (Giles, 1982, Appendix A). Within a resource block the mineral is subdivided into areas where it is exposed, that is, where the overburden averages less than 1 m in thickness, and areas where it is present in continuous (or almost continuous) spreads beneath overburden.

Areas where bedrock crops out, where boreholes indicate absence of sand and gravel beneath cover and where sand and gravel beneath cover is interpreted to be not potentially workable are unornamented on the map; where appropriate, the relevant criterion is noted. In such cases it has been assumed that mineral is absent except in infrequent and relatively minor patches that can neither be outlined nor assessed quantitatively in the context of this survey. Areas of unassessed sand and gravel, for example in built-up areas, are indicated by a stipple.

The area of the mineral-bearing ground is measured, where possible, from the mapped geological boundary lines. The whole of this area is considered as mineral-bearing, even though it may include small areas where sand and gravel is not present or is not potentially workable.

10.4 RESULTS

The statistical results are summarised in Table 1. Fuller grading particulars are shown in Figure 8 and Table 2 and 3. The statistical methods used are outlined in Giles (1982, Appendix B).

Accuracy of Results

For resource blocks A and B, assessed at the indicated level, the accuracy of the results at the 95 per cent probability level (that is, on average nineteen out of every twenty sets of limits constructed in this way contain the true value for the volume of mineral) is 31 per cent and 53 per cent respectively. However, the true volumes are more likely to be nearer the figure estimated than either of the limits. Moreover, it is probable that roughly the same percentage limits would apply for the statistical estimate of mineral volume within a very much smaller parcel of ground (say 100 hectares) containing similar sand and gravel deposits, if the results from the same number of sample points (as provided by, say, ten boreholes) were used in the calculation. Thus, if closer limits are needed for a quotation of reserves, data from more sample points would be required, even if the area were quite small. This point can be illustrated by considering the whole of the potentially workable sand and gravel in blocks A and B. The total volume (43 million m^3) can be estimated to limits of $\pm$ 28 per cent at the 95 per cent probability level by a calculation based on the data from sample points spread across the two resource blocks. However, it must be emphasised that the quoted volume of mineral has no simple relationship with the amount that could be extracted in practice, as no allowance has been made in the calculations for any restraints (such as existing buildings and roads) on the use of the land for mineral working.

10.5 NOTES ON RESOURCE BLOCKS

Geological criteria have been used to designate the boundaries of the resource blocks. Block A includes all the fluvial sand and gravel of the various river terrace deposits and alluvium whilst Block B is composed of glacial sand and gravel.

Block A

The assessment of the block uses information from two specially drilled boreholes, NE 75 and NE 79, three records of natural sections and information from 19 borehole records in BGS Archives; 12 of which are held commercial in confidence. These record a range of mineral thicknesses between 13.4 m and 0.8 m with a mean value of 4.3 m. Five records indicate that the total mineral thickness was not proved. Consequently any estimate of sand and gravel resources based on this data set will be conservative. The mean grading for the block is 12% fines, 44% sand and 44% gravel.

Sporadic small, largely overgrown, quarries are recorded. These exploited the fluvial deposits for local use and have made no significant inroads to the resource. No commercial sand and gravel extraction of the resource is recorded; however, substantial areas have been extracted, largely as overburden, during opencast coal mining. St Aidan's Extension Opencast Site is currently removing large areas of fluvial sand and gravel south of the former hamlet of Astley [3900 2880].

Several large colliery spoil tips rest directly on fluvial sand and gravel. This additional thickness of material could render the sand and gravel beneath as not 'potentially workable'. However, the tips themselves are considered as a resource (see Section 7.2, Minestone). In addition land reclamation schemes frequently modify the shape and height of colliery spoil tips to such an extent that they are of insufficient thickness to exclude the sand and gravel beneath from the potentially workable category.

The volume of potentially workable sand and gravel resources of this block is 40.8 million $m^3 \pm 31\%$.

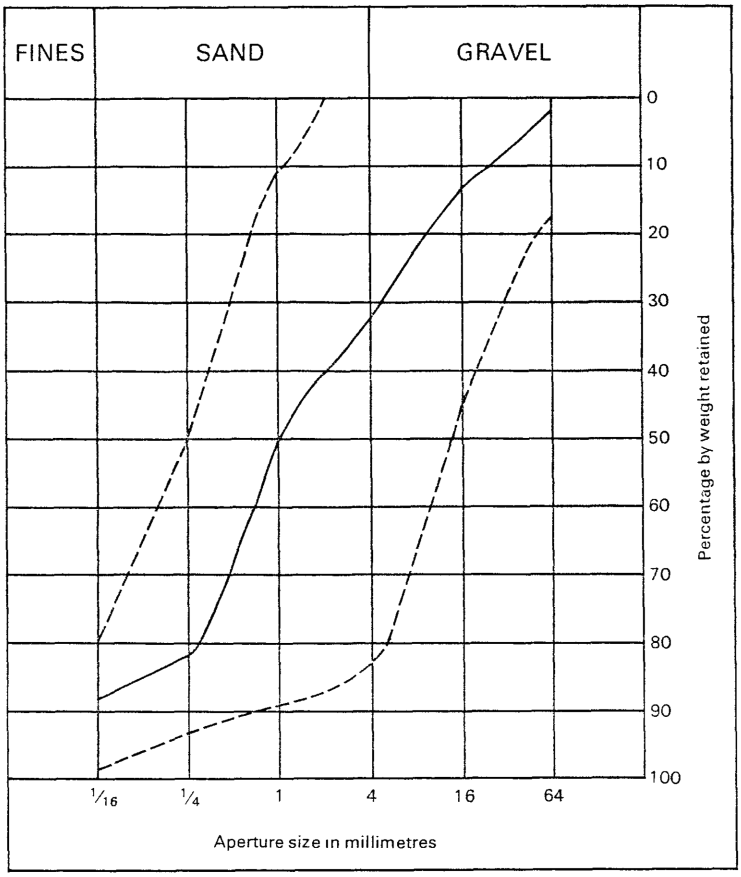
Block B

The resources in this block comprise only a small fraction of the mineral on the resource sheet. However, they are geologically distinct and are treated separately. The glacial sand and gravel is closely associated with the till. Together they form spreads on the interfluve between the rivers Aire and Calder, masking the former topography. Opencast prospecting boreholes suggested that the glacial sand and gravel extended beneath the till. Two boreholes NE 77 and NE 78 were drilled to see if this was so. Both proved thick till which was in part very pebbly. This could have been interpreted as sand and gravel, in the returns from a shell and auger rig, by an inexperienced operator.

The resource has been exploited in a number of localities by small scale quarries for local use. In addition several opencast sites have removed, as overburden, glacial sand and gravel.

The resources are estimated using results from 2 boreholes, 7 collected sections and a number of confidential boreholes including opencast prospecting boreholes. These record a mean thickness of 2.4 m. However, as none of the sections recorded the full thickness of the deposit, this is a conservative estimate. The volume of sand and gravel is 2.2 million $m^3 \pm 53\%$. The large confidence limits reflect the degree of uncertainty in assessing this block. The mean grading is 12% fines, 55% sand and 33% gravel.

Block A: Fluvial Sand and Gravel



Block B: Glacial Sand and Gravel

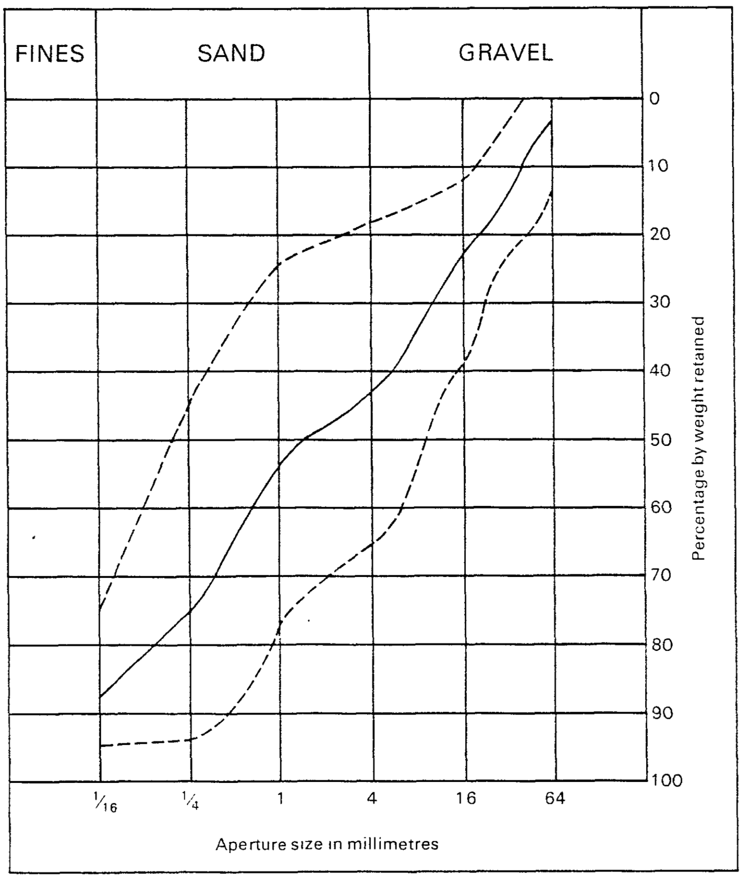


Figure 8. Grading characteristics of the mineral in blocks A and B. The continuous line is the cumulative frequency curve of the mean grading of the block as a whole; the broken lines denote the envelope within which the mean grading curves for individual boreholes and sections fall.

Table 1 The sand and gravel resource of the district: statistical summary.

Block	Area		Mean thickness			Volume of sand and gravel			Mean grading percentage		
	Block	Mineral	Over-burden	Mineral	Waste		Limits at the 95% probability level		Fines	Sand	Gravel
	km^2	km^2	m	m	m	$m^3 \times 10^6$	$\pm$ 96	$\pm$ $m^3 \times 10^6$	-1/16 mm	+1/16-4 mm	+4 mm
A	9.8	9.5	2.3	4.3	0.2	40.8	31	12.6	12	55	33
B	2.2	0.9	0.4	2.4	-	2.2	53	1.2	12	44	44

Table 2 Block A: data from boreholes and sections.

Borehole or section	Recorded thickness			Mean grading percentage						
	Over-burden	Mineral	Waste part-ings	Fines	Sand			Gravel		
					Fine	Medium	Coarse	Fine	Coarse	Cobble
	m	m	m	-1/16 mm	+1/16-1/4 mm	+1/4-1 mm	+1-4 mm	+4-16 mm	+16-64 mm	+64 mm
2	5.1	7.7	-	-	-	-	-	-	-	-
4	2.4	6.7	-	-	-	-	-	-	-	-
17	0.9	6.7+	-	-	-	-	-	-	-	-
34	2.0	5.8+	-	6	10	37	12	24	10	1
37	2.7	1.6+	-	4	3	4	5	39	27	18
40	3.2	0.8	-	9	8	55	26	2	-	-
47	0.2	5.7	2.7	-	-	-	-	-	-	-
75	3.5	3.0	-	6	8	23	17	26	18	2
79	0.3	11.3	0.7	2	5	35	18	27	13	0
E1	1.0	1.5	-	20	20	6	7	23	20	4
E2	1.2	1.0+	-	1	3	31	12	28	25	0
E10	0.3	2.0+	-	14	20	54	12	0	0	0

Table 3 Block B: data from boreholes and sections.

Borehole or section	Recorded thickness			Mean grading percentage						
	Over-burden	Mineral	Waste part-ings	Fines	Sand			Gravel		
					Fine	Medium	Coarse	Fine	Coarse	Cobble
	m	m	m	-1/16 mm	+1/16-1/4 mm	+1/4-1 mm	+1-4 mm	+4-16 mm	+16-64 mm	+64 mm
76	0.5	5.6	-	12	10	22	12	21	21	2
77	-	-	13.4	-	-	-	-	-	-	-
78	1.0	0.5	-	-	-	-	-	-	-	-
E3	0.2	2.0+	-	4	3	19	8	20	31	5
E4	0.3	2.0+	-	12	11	28	11	19	19	0
E5	0.2	0.5+	-	5	2	16	11	28	36	2
E6	0.3	0.8+	-	14	17	24	8	7	17	13
E7	1.0	2.0+	-	24	30	22	5	8	11	0
E8	-	-	-	-	-	-	-	-	-	-
E9	0.1	1.0+	-	9	9	20	8	22	27	5

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APPENDIX A

MINE ABANDONMENT PLANS EXAMINED IN THE PREPARATION OF THESE MAPS AND REPORT.

A OFFICIAL CATALOGUE

1158	NE 1	NE 742
3136	NE 16	NE 743
3368	NE 109	NE 809
3410	NE 283	NE 818
3727	NE 313	NE 834
4150	NE 315	NE 915
4169	NE 316	NE 924
5777	NE 317	NE 925
7223	NE 403	
7742	NE 436	
7993	NE 437	
8067	NE 438	
8122	NE 468	
8484	NE 471	
9352	NE 509	
9354	NE 620	
9872	NE 623	
10356	NE 645	
10432	NE 646	
10450	NE 647	
11380	NE 677	
11650	NE 701	
11719	NE 718	
11998	NE 719	
12301	NE 720	
12815	NE 737	
13090	NE 738	
13813	NE 739	
14083	NE 740	
14277	NE 741	

B PRIVATE CATALOGUE

FGB 73	GCR 86
FGB 107	GCR 90
FGB 108	GCR 93
FGB 164	GCR 115
FGB 298	GCR 119
FGB 299	GCR 120
FGB 300	LM 43
FGB 301	CT 17
FGB 306	CT 59
FGB 440	CT 68
FGB 760	CT 69
FGB 761	MWK 1
FGB 762	
FGB 763	
FGB 764	
FGB 780	
FGB 782	
FGB 797	
FGB 798	
FGB 801	
FGB 802	
FGB 803	
FGB 804	
FGB 805	
FGB 806	
FGB 807	
FGB 808	
FGB 811	
FGB 838	
FGB 967	
FGB 980	

All the above plans may be examines by appointment with:-

Mines Records and Mines Drainage Office
Rawmarsh
Rotherham
South Yorkshire.

Additional information concerning mining and shaft locations is available from:-

National Coal Board
North Yorkshire Area HQ
Allerton Bywater
Castleford
West Yorkshire

APPENDIX B

NCB OPENCAST RECORDS EXAMINED IN THE PREPARATION OF THESE MAPS AND REPORT.

No	Site
012	Oulton
033	Royds Green *
058	Lee Moor
075	Newmarket
087	Oulton Park 3
092	Roman Station Farm *
108	Coney Warren *
181	St Aidans *
216	Fleet Lane
440	Leventhorpe *
514	Methley Park Sites *
575	Oulton Hall *
577	Mickletown
612	Dungeon Lane and Dick Haste Wood *
635	Keep
636	Pinders
639	Hungate Sites *
671	Astley Sites *
678	Fleet Mills
706	Bowers Row
788	Navigation Beck
825	Oxbow*
829	Lowther Sites
872	Penbank
968	Rowley
unnumbered	Oulton Park *
"	Royds Hall (Licence) *
"	Newmarket Farm (Licence) *

Copies of these records may be examined at the discretion of :-

NCB Opencast Executive
Yorkshire Area HQ
Rothwell Colliery
Rothwell
Leeds
LS26 0JZ

In additions the completion plan of those sites marked by an asterisk can be examined by appointment with:-

Mines Records and Mines Drainage Office
Rawmarsh
Rotherham
South Yorkshire.

APPENDIX C

SE 32 NE 75 3669 2980 **Leventhorpe Cottages** **Block A**

Surface level c +16.0 m
Water struck at c +12.5 m
August 1985

Overburden 3.5 m
Mineral 3.0 m
Bedrock 1.0 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Silty clay, medium light grey	3.2	3.5
	Sandy gravel Gravel: fine and coarse, rounded to subrounded, equant sandstone with some siltstone, ironstone and quartz. Sand: medium, subangular to rounded, equant, quartz and lithic grains.	3.0	6.5
Westphalian A	Sandstone, fine grained, micaceous, carbonaceous.	1.0+	7.5

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
6	48	46	3.5-4.5	8	5	12	15	27	33	0
			4.5-5.5	3	7	30	19	29	12	0
			5.5-6.5	7	13	26	18	23	8	5
			Mean	**6**	**8**	**23**	**17**	**26**	**18**	**2**

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
3.5-4.5	98	0	Tr	0	Tr	Tr	1	1
4.5-5.5	94	0	1	0	2	1	1	1
5.5-6.5	99	0	Tr	0	1	Tr	Tr	0
Mean	97	0	1	0	1	Tr	1	Tr

SE 32 NE 76 3537 2808 **Home Crofts** **Block B**

Surface level c +61 m
Water not encountered
August 1985

Overburden 0.5 m
Mineral 5.6 m
Waste 0.4 m
Bedrock 0.9 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.4	0.4
	Stony clay, light brown, sandy	0.1	0.5
Glacial Sand and Gravel	'Clayey' gravel Gravel: fine and coarse, rounded to subangular, equant sandstone with some ironstone and chert. Sand: medium, rounded to subangular, equant, quartz and lithic grains.	5.6	6.1
Till	Clay, moderate brown, pebbly, sandy	0.4	6.5
Westphalian B	Mudstone, light brown	0.9+	7.4

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
12	44	44	0.5-1.5	20	9	14	9	22	23	3
			1.5-2.5	8	8	21	11	25	27	0
			2.5-3.5	9	9	17	14	23	27	1
			3.5-4.5	10	12	25	11	19	17	6
			4.5-5.5	11	14	29	13	18	13	2
			Mean	**12**	**10**	**22**	**12**	**21**	**21**	**2**

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
0.5-1.5	99	0	Tr	0	Tr	0	1	Tr
1.5-2.5	98	0	Tr	0	1	Tr	1	0
2.5-3.5	99	0	Tr	0	1	Tr	Tr	0
3.5-4.5	99	0	Tr	0	Tr	Tr	1	0
4.5-5.5	97	0	Tr	Tr	1	1	1	0
Mean	98	0	Tr	Tr	1	Tr	1	0

SE 32 NE 77 3628 2662 **Pindars Screed** **Block B**

Surface level c +57.0 m
Water struck at c +53.0 m
August 1985

Waste 13.4 m
Bedrock 0.6 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Till	Clay, dark yellowish orange, silty	2.2	2.5
	Silty sand, dark yellowish brown, pebbly	3.3	5.8
	Stony clay, medium grey, silty with pebbles	7.6	13.4
Westphalian B	Mudstone, medium dark grey	0.6+	14.0

SE 32 NE 78 3690 2692 **Clumpcliffe** **Block B**

Surface level c +57.0 m
Water not encountered
August 1985

Overburden 1.0 m
Mineral 0.5 m
Waste 9.9 m
Bedrock 0.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
	Clay. Dark yellowish orange, sandy, pebbly	0.8	1.0
Glacial Sand and Gravel	'Very clay' pebbly sand Gravel: fine, rounded to subangular, equant sandstone Sand: medium, rounded to subangular, equant, quartz and lithic grains.	0.5	1.5
Till	Clay, greyish orange, sandy, pebbly	3.2	4.7
	Clay, pale yellowish brown, silty, pebbly	6.7	11.4
Westphalian B	Mudstone, medium light grey	0.3+	11.7

SE 32 NE 79 3929 2684 **Church Lane Bridge** **Block A**

Surface level c +16.0 m
Water struck at c +13.0 m
August 1985

Overburden 0.3 m
Mineral 3.1 m
Waste 0.7 m
Mineral 8.2 m
Waste 1.2 m
Bedrock 0.5 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Second River Terrace Deposits	'Clayey' pebbly sand Gravel: fine, rounded to subangular, equant, sandstone with ironstone and some coal and quartz Sand: medium, rounded, equant, quartz and lithic grains	3.1	3.4
	Clay, olive grey, silty	0.7	4.1
	Sandy gravel Gravel: fine, rounded to subrounded, equant, sandstone with ironstone Sand: medium, rounded to subangular, equant, quartz and lithic grains.	8.2	12.3
	Clay, light olive grey silty	1.2	13.5
Westphalian B	Mudstone, light grey	0.5+	14.0

GRADING

	Mean for deposit percentages			Depth below surface (m)	Percentages						
	Fines	Sand	Gravel		Fines	Sand			Gravel		
					-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
a.	13	74	13	0.3-1.3	13	13	37	20	16	1	0
				1.3-2.0	15	16	52	9	8	0	0
				2.0-3.4	13	30	41	5	8	3	0
				Mean	**13**	**21**	**42**	**11**	**11**	**2**	**0**
b.	2	58	40	4.1-5.1	3	4	19	17	41	15	1
				5.1-7.1	2	8	47	18	19	6	0
				7.1-9.1	1	6	41	17	23	12	0
				9.1-11.1	2	4	30	16	28	20	0
				11.1-12.3	0	5	25	22	34	14	0
				Mean	**2**	**5**	**35**	**18**	**27**	**13**	**0**

COMPOSITION

	Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
		Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
a.	0.3-1.3	87	0	1	1	7	1	3	0
	1.3-2.0	87	6	0	0	5	1	1	0
	2.0-3.4	85	1	0	Tr	12	1	1	0
	Mean	86	2	Tr	Tr	9	1	2	0
b.	4.1-5.1	93	0	Tr	Tr	5	1	1	0
	5.1-7.1	92	0	0	1	6	0	1	0
	7.1-9.1	92	0	0	1	6	0	1	0
	9.1-11.1	95	0	0	Tr	4	0	1	0
	11.1-12.3	91	0	0	0	8	0	1	0
	Mean	93	0	Tr	Tr	6	Tr	1	0

SE 32 NE E1 3580 2970 **Pickpocket Lane** **Block A**

Surface level c +30.0 m

September 1984

Overburden 1.0 m
Mineral 1.5 m
Bedrock 0.3 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Made ground	0.5	0.5
Head	Stony clay	0.5	1.0
River Terrace Deposits Undifferentiated	'Very clayey' gravel Gravel: fine and coarse, rounded to subangular, equant, sandstone with some ironstone, siltstone and mudstone Sand: fine, rounded to angular, equant, quartz and lithic grains	1.5	2.5
Westphalian A	Mudstone	0.3+	2.8

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
20	33	47	1.0-1.8	22	25	6	6	21	20	0
			1.8-2.5	17	14	5	8	25	21	10
			Mean	**20**	**20**	**6**	**7**	**23**	**20**	**4**

SE 32 NE E2 3641 2983 **Leventhorpe Cottages** **Block A**

Surface level c +15.0 m

Overburden 1.2 m
Mineral 1.0 m+

November 1984

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Alluvium	Silty clay, grey	0.9	1.2
	Gravel Gravel: fine and coarse, rounded equant, sandstone with some chert, siltstone, ironstone and quartz Sand: medium, rounded, equant, quartz and lithic grains	1.0+	2.2

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
1	46	53	1.2-2.2	1	3	31	12	28	25	0

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
1.2-2.2	91	0	3	0	1	4	1	Tr

SE 32 NE E3 3526 2816 **Gravel Pit Wood** **Block B**

Surface level c +56.0 m

Overburden 0.2 m
Mineral 2.0m+

October 1984

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Sand and Gravel	Gravel Gravel: coarse, angular to rounded, equant, sandstone with some chert and siltstone Sand: medium, subrounded, equant, quartz and lithic grains	2.0+	2.2

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
4	30	76		4	3	19	8	20	31	15

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
	95	0	1	0	0	4	0	0

SE 32 NE E4 3609 2710 **Cheesecake Farm** **Block B**

Surface level c +55.0 m

Overburden 0.3 m
Mineral 2.0 m+

May 1984

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	'Clayey' sandy gravel Gravel: fine and coarse, rounded to subrounded, equant, sandstone with cherts and some ironstone, quartz and siltstone Sand: medium, rounded to subrounded, equant, quartz with lithic grains.	2.0+	2.3

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
12	50	38	0.3-1.3	12	11	25	11	23	18	0
			1.3-2.3	12	12	30	11	15	20	0
			Mean	**12**	**11**	**28**	**11**	**19**	**19**	**0**

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
1.3-2.3	83	0	1	0	2	13	1	Tr

SE 32 NE E5 3640 2707 **Sugar Hill Plantation** **Block B**

Surface level c +52.0 m

Overburden 0.2 m
Mineral 0.5 m+

October 1985

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Glacial Sand and Gravel	Gravel Gravel: coarse, rounded to well rounded, equant, sandstone with some ironstone, quartz, cherts and siltstone Sand: medium, subangular to rounded, equant, quartz with lithic grains	0.5+	0.7

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
5	29	76	0.2-0.7	5	2	16	11	28	36	2

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
0.2-0.7	86	0	2	0	5	2	3	2

SE 32 NE E6 3703 2704 **Clumpcliffe** **Block B**

Surface level c +49.0 m

October 1985

Overburden 0.3 m
Mineral 0.8 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Glacial Sand and Gravel	'Clayey' sandy gravel Gravel: coarse, subangular to well rounded, equant and tabular, sandstone, with some quartz, siltstone, ironstone and cherts Sand: medium, rounded, equant, quartz with lithic grains	0.8+	1.1

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
14	49	37	0.3-1.1	14	17	24	8	7	17	13

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
0.3-1.1	94	0	1	0	1	1	2	1

SE 32 NE E7 3700 2686 Clumpcliffe Block B

Surface level c +56.0 m

Overburden 1.0 m
Mineral 2.0 m+

October 1984

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
	Stony clay, light brown	0.7	1.0
Glacial Sand and Gravel	'Very clayey' sandy gravel Gravel: coarse, subangular to rounded, equant and tabular, sandstone with ironstone and some Magnesian Limestone, siltstone, cherts and quartz Sand: fine, rounded, equant, quartz with some lithic grains	2.0+	3.0

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
24	57	19	1.0-3.0	24	30	22	5	8	11	0

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
1.0-3.0	88	0	1	0	7	1	1	2

SE 32 NE E8 3677 2662 **Moss Carr Wood** **Block B**

Surface level c +55.0 m Waste 5.0 m+

September 1984

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.2	0.2
Till	Stony clay, yellowish orange, sandy with pebbles and cobbles	0.8	1.0
	Sandy clay, yellowish orange, with pebbles and cobbles of sandstone, ironstone, chert, quartz, siltstone and mudstone	2.0	3.0
	Stony clay, medium grey	2.0	5.0

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
60	13	27	1.0-3.0	60	3	5	5	6	14	7

COMPOSITION

Depth below surface (m)	Percentages by weight in +4-32 mm fraction							
	Sandstone	Coal	Siltstone	Mudstone	Ironstone	Chert	Quartz	Others
1.0-3.0	94	0	1	1	2	1	1	0

SE 32 NE E9 3741 2691 **Clumpcliffe Covert** **Block B**

Surface level c +55.0 m

Overburden 0.1 m
Mineral 1.0 m+

November 1984

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.1	0.1
Glacial Sand and Gravel	Gravel Gravel: coarse, rounded to angular, equant sandstone Sand: medium, rounded to subangular, equant, quartz and lithic grains	1.0+	1.1

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
9	37	54	0.1-1.1	9	9	20	8	22	27	5

SE 32 NE E10 3814 2582 **Scholey Hill** **Block A**

Surface level c +14.0 m

Overburden 0.3 m
Mineral 2.0 m+

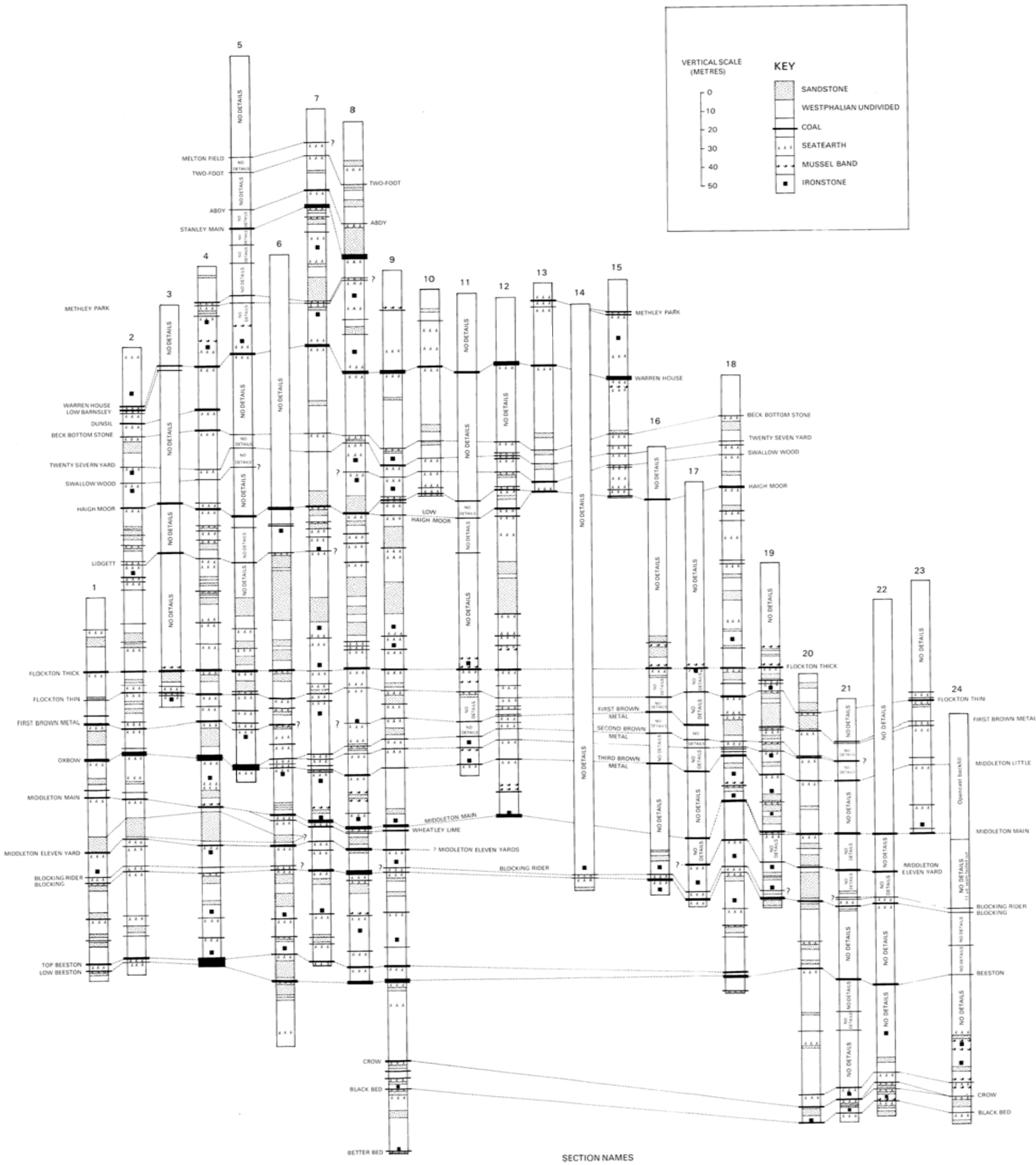
November 1984

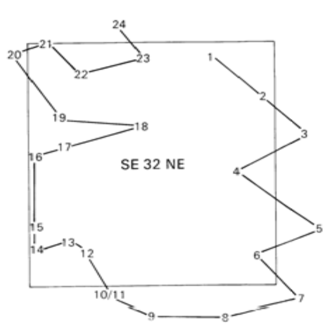
LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil	0.3	0.3
Second River Terrace Deposits	'Clayey' sand: medium, angular to rounded, equant, lithic grains and quartz	2.0+	2.3

GRADING

Mean for deposit percentages			Depth below surface (m)	Percentages						
Fines	Sand	Gravel		Fines	Sand			Gravel		
				-1/16	+1/16-1/4	+1/4-1	+1-4	+4-16	+16-64	+64 mm
14	86	0	0.3-2.3	14	20	54	12	0	0	0



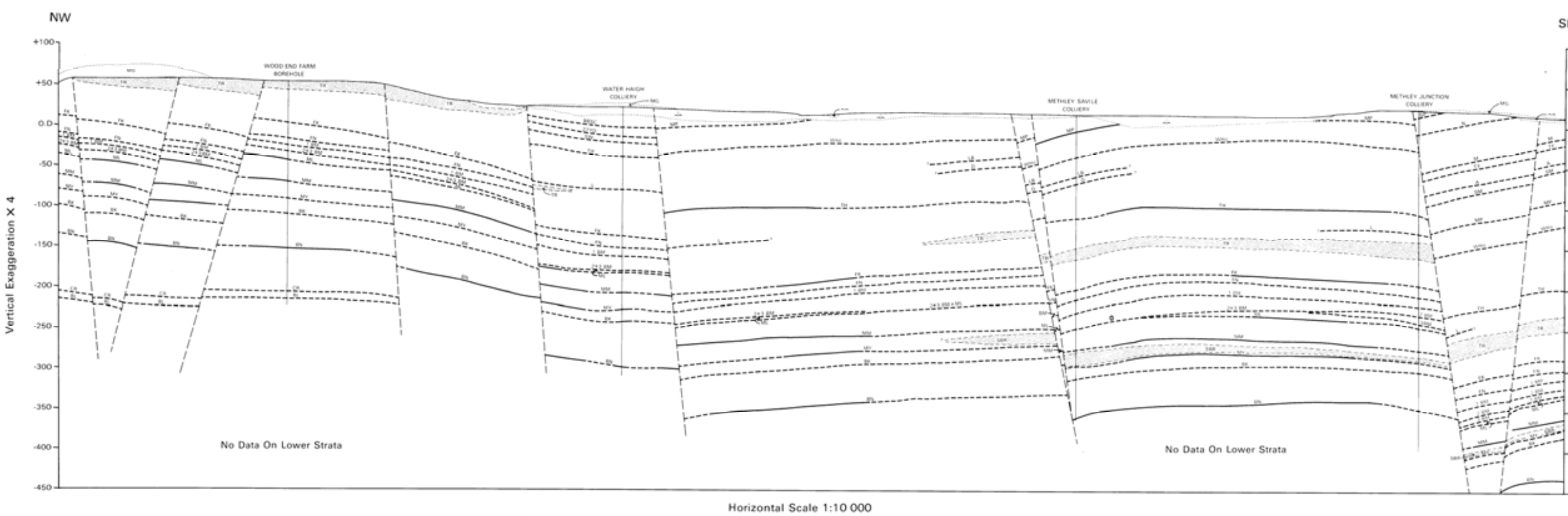


SECTION NAMES

1 Allerton Main collieries, Primrose Hill shaft
2 Allerton Main collieries, Victoria No.2 shaft
3 NCB Angel Inn borehole
4 Methley Savile colliery
5 NCB Dunford House borehole
6 Methley Junction colliery
7 Whitwood colliery
8 West Riding collieries, Altofts shaft
9 West Riding collieries, Fox shaft
10 Bottom Boat colliery
11 NCB Bottom Boat borehole
12 Newmarket collieries, Nelson shaft
13 Newmarket collieries, Spring Wood shaft
14 NCB Patrick Green No. 2 borehole
15 Newmarket collieries, Spencer shaft
16 NCB Royds Lane borehole
17 NCB Oulton Hall borehole
18 Water Haigh colliery
19 NCB Parkways borehole
20 Rothwell Haigh collieries, Fanny shaft
21 NCB Fishpond Lock borehole
22 NCB Woodend Farm borehole
23 Swillington Bridge borehole
24 NCB Newsam Green No. 2a borehole

KD 900'50/1

FIGURE 9 REPRESENTATIVE VERTICAL SECTIONS OF STRATA (Vertical Scale 1:1000)



British Geological Survey

(Figure 10)

Generalized Horizontal Section

SHEET SE 32 NE

(Oulton)

Based on a 1:10 000 geological survey by I.T. Wilkinson and J.R.A. Giles 1984.
I.C. Burgess, Programme Manager.
G.M. Brown, D.Sc., F.R.S., Director, British Geological Survey.

Production of this map was funded by the Department of the Environment

MG	Made Ground
	Alluvium
	Second River Terrace Deposits
	Major Sandstones (TR-Thornhill Rock; SBR-Slack Bank Rock)
	Geological Boundary, Drift and limits of Made Ground
	Geological Boundary, Solid
	Coal Seams. For details of abbreviations see Generalized Vertical Section on 1:10 000 Geological Map
	Faults

Broken lines denote uncertainty

For position of sections see 1:10 000 Geological Map