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1. EXECUTIVE SUMMARY

1. This report embodies some of the results of a study commissioned by the Department of the Environment in 1983 to provide a geological information base, to enable informed consideration to be given to development proposals for the Aldridge - Brownhills area. It is mainly concerned with hydrogeology, subsidence and bulk minerals resources. There is a substantial introductory section on general geology, to give the geological context of these planning-related aspects.

2. Studies of the hydrogeology show that the Wenlock Limestone is subject to considerable fissure-flow but the Wenlock Shales and Ludlow Shales are less permeable. The Westphalian rocks consist predominantly of impermeable mudstones but also contain sandstones. The latter are commonly impersistent laterally but there may be local fissure-flow of water within them. Within the Keele Formation, sandstones are relatively thick and persistent and there is more capacity for water movement. The Kidderminster and Wildmoor Sandstone formations are good aquifers and have been tapped by several boreholes. Considerable quantities of water are extracted at Sandhills Pumping Station. Sand and gravel deposits locally contain water but it is small in quantity and is not exploited.

3. Evidence of subsidence due to coal mining is most common in the east of the district where ten seams have been worked. Differential subsidence effects are concentrated along the Clayhanger and Vigo bounding faults. In the west, workings were shallower, and fewer seams were exploited, subsidence effects are present but less marked; in places they have been obscured by tipping and landscaping. Subsidence of the canal at Catshill may have been caused by fissure-flow of water along fault-parallel joints at or near the base of the Kidderminster Formation.

4. Four landslips in the Etruria Formation were delineated in the course of mapping Atlas Quarry. Should further slipping occur, the canal and the quarry could be at risk.

5. In relation to abandoned limestone workings, further details are added to the work described in'Ove Arup and Partners, 1983'. Areas of disused open workings are defined and likely extensions of pillar-and-stall workings beyond those previously charted are outlined.

6. Abandoned and active quarries for brick-clay, almost exclusively in the Etruria Formation, are listed and briefly described. Potential future resources have been identified near Dumblederry Farm and in the Swag-Shelfield area.

7. Sand and gravel working. The Kidderminster Formation, an important but variable gravel resource, is currently exploited. Further areas of potential are identified on the resource map. The potential of gravel-bearing drift deposits is limited.

8. The lateral and vertical variation of drift deposits and the possible geotechnical implications of this variation are described. Particular reference is made to anticipated problems of foundation design in areas of thick, locally waterlogged, drift, which might include peat or peaty horizons, and in areas of landfill or made ground.

British Geological Survey
Keyworth

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2. INTRODUCTION

This report is intended to be used with 1:10 000 geological sheets SK 00 SW, SE and a set of maps and overlays on the same scale showing rockhead contours, drift thickness, sand and gravel resources, brick clay reserves and coal and limestone mining data.

The area was first surveyed on the one-inch scale by J. Beete-Jukes, A.C. Ramsay and H.H. Howell, and published in 1852 as Old Series One-Inch Sheets 62NW and NE. The primary geological survey on the 1:10 560 scale was undertaken by T.C. Cantrill, C.H. Cunnington and W. Gibson in 1911. This was published as Staffordshire County Sheets 57SW, SE, 63NW, NE, with the explanatory Lichfield Memoir (Barrow and others, 1919).

The present resurvey made on the 1:10 000 scale in 1983 has made use of excellent new quarry sections in the Kidderminster Formation. In the western half of the area, since the survey in 1911, extensive areas have been built over and there are now fewer exposures. However, the present survey has involved the extensive archive of NCB mining plans and, as an addition to the BGS borehole database, a large number of new borehole records, mostly of site investigations, has been obtained. The recent report on limestone mines in the West Midlands (Ove Arup and Partners, 1983), commissioned by the Department of the Environment, has been particularly useful.

The rather featureless topography of the area, particularly in the west, shows little relation to the varied underlying geology. Nevertheless, the geology of the area has had a profound effect on its economic history and on current land-use patterns. Coal has been mined locally for at least two hundred years and several communities initially grew up round the pits, and were served by the canal and railway system. At Daw End, mediaeval diggings in Wenlock Limestone were extended underground in the nineteenth century by shaft and adit. Both these mining activities have left a legacy of subsidence problems, particularly in the case of the limestone workings where some supporting pillars are small and weak.

Large areas of the Etruria Formation outcrop have been worked for marl and brick-making, and the reserves which remain are an important consideration in land-use planning. The occurrence of deep-mined ground beneath impervious Etruria Formation has led to the extensive disposal of toxic waste in the disused workings of Walsall Wood and Aldridge collieries. This is now concentrated at the Empire site, with polymer tipping at surface in the disused marl pit and fluid disposal underground via a borehole.

In the east, the gravels of the Kidderminster Formation are a useful source of aggregate on the fringe of the West Midland conurbation and the resources which remain are an important consideration in land-use planning.

Discussion in the latter half of this report is concentrated on hydrogeology, subsidence and landslip potential, limestone workings at Daw End, and resources of marl, sand and gravel; all these matters particularly relate to planning considerations. Fuller information can be found in the geological notes and local details for SK 00 SW (Lowe and others, 1984) and SK 00 SE (Price and others, 1984) which contain more extensive stratigraphical and structural details.

The following 1:10 000 scale maps and overlays provide further information, and are also available from Keyworth.

MINING BASE MAP: showing limits of areas known to have been mined for coal, ironstone and limestone.

OVERLAYS SHOWING WORKINGS IN INDIVIDUAL SEAMS:

- Bottom Robins Coal
- Wyrley Yard Coal
- Charles Coal
- Brooch Coal
- Eight Foot Coal
- Yard Coal
- Bass Coal
- Cinder Coal
- Shallow Coal
- Deep Coal
- Bottom (Shallow and Deep) Coal
- Ironstones below Bottom Coal

OVERLAY SHOWING POTENTIAL SAND AND GRAVEL RESOURCES

OVERLAY SHOWING SURFACE WORKINGS FOR BRICK CLAY, CLAY IRONSTONE AND LIMESTONE

MAP OF ROCKHEAD CONTOURS

MAP OF DRIFT THICKNESS

The results are based on the survey carried out under contract to the Department of the Environment. The views expressed are those of the authors and not necessarily those of the Department of the Environment. Mr. P. Gordon was the Nominated Officer for the Department of the Environment, and Dr. A.A. Wilson for the Contractors.

3. GEOLOGY

Rocks of Silurian, Upper Carboniferous and Triassic age occur at rockhead within the district and are commonly masked, particularly in the west, by drift deposits of glacial or more recent origin.

The complete succession is:

TABLE 1

DRIFT:	Quaternary -	Alluvium	
		Peat	
		Older River Gravel	
		Glacial Sand and Gravel	
		Sandy Till	
		Till	
		Head	
SOLID:	Triassic -	Wildmoor Sandstone Formation	)Sherwood Sandstone
		Kidderminster Formation	)Group
	Carboniferous -	Bowhills Formation)	
		Keele Formation) 'red measures'	
		Etruria Formation)	
		Productive Coal Measures	
	Silurian -	Lower Ludlow Shale	
		Upper Wenlock Limestone	
		Nodular Beds	
		Lower Wenlock Limestone	
		Wenlock Shale	
	Igneous intrusive rocks (of probable Carboniferous age)		

In the west of the area, where exposure of the solid rocks is poor, the sequence and structure shown on the geological map have been deduced from the evidence of numerous shaft and borehole records and from plans of underground coal or ironstone workings; most lines on the map are therefore considered conjectural.

4. SOLID GEOLOGY

Silurian

Silurian strata form an area of low relief in the south of the area, on the northern fringe of an inlier which extends to Walsall (Fig.1). The structure is relatively simple with a steady dip of about 5° towards the west. The Upper and Lower Wenlock limestones within this sequence have been worked in the past at surface and underground.

Wenlock Shales

In Aldridge, these beds form almost featureless terrain, largely free of glacial drift. Though likely to be some 140 m in thickness, exposure is virtually restricted to the top 53 m, found in the railway cutting at Daw End, a Site of Special Scientific Interest (SSSI).

These are grey and greenish grey mudstones with bands of limestone nodules. At several levels the mudstones are calcareous and weather out as harder beds. At the top of the Wenlock Shales two patch-reefs are well exposed on the north wall of the cutting.

South of the railway, limestone bands and nodules in the Wenlock Shales have been worked in an old opencut (see surface workings overlay). These beds correlate with similar lithologies at about 27 m in the cutting (Fig.2).

The uppermost 13 m of the Wenlock Shales, with numerous limestone nodules and bands, were logged in Manor Farm No. 1 Borehole [0305 0054] by Mr. E.G. Poole.

Lower Wenlock Limestone

This limestone, the chief target for mining and quarrying operations in past years, varies from about 9.5 to 11 m in thickness. Typically it consists of a central portion of purer carbonate, overlain and underlain by nodular limestone with a little mudstone between the nodules. In the workings, 8.5 to 8.8 m of limestone were extracted out of a total thickness of 11 m: the remainder, likely to be mostly nodular limestone, was left as a roof support. Sub-divisions of the formation were termed Chatterer, Thick Burr, Fourteen Inch and Twenty Inch (in ascending order) by quarry men.

The basal nodular beds, about 2 to 3 m thick, are present in Borehole 101 (Fig.2) and Manor Farm boreholes 2 and 3, but not in Borehole 1. These beds are not seen at the surface. Like the overlying bedded limestones, they were presumably once exposed in the opencut working at Linley Wood and Park Pits, but are now obscured by slipped debris and dumped 'deads'. The central beds of the limestone are generally grey with a few wavy mudstone partings. They show a consistent lithology in Manor Farm boreholes 1 - 3 and in Borehole 101. The upper nodular beds are seen in subsidence hollows and at an old adit mouth in Linley Woods [037 005], where the topmost 6 m of limestone, chiefly of nodular aspect, overlie more massive limestone. These upper beds include mudstone bands, possibly tuffaceous, best developed in Borehole 101 (Fig.2).

The most complete present-day exposure in the Limestone is on the north side of the Daw End railway cutting (Fig.2). Here, bedded and nodular limestones are overstepped by 5.3 m of very thickly bedded limestone, rich in compound corals, apparently forming a patch-reef.

Nodular Beds

Between the Upper and Lower Wenlock Limestone are 31 to 36 m of greenish grey mudstones with numerous limestone nodules, commonly forming up to half of the rock and locally containing patch-reefs. Local lenses of nodular limestone (with about 25 percent mudstone) from 0.8 to 6.45 m in thickness occur in three boreholes: near the base of the sequence in Borehole 101 (Fig.2); near the top in Manor Farm No. 3 Borehole (6.45 m of limestone) and in a shallow borehole beside the Royal Oak Inn.

Exposure, currently limited to three locations, was better in 1911, both in the subsidence hollows and in an old clay pit at Winterly (showing 0.6 m mudstone with limestone nodules beneath Coal Measures); these are now largely filled. According to Cantrill (1910), hollows south of Brawns Works Bridge were openworks and sinks in patch-reefs in the Nodular Beds (see surface workings overlay).

Upper Wenlock Limestone

The Upper Wenlock Limestone varies from 3 to 6.8 m in thickness (3.7 m in the worked area near Winterly Bridge). It commonly consists of limestone with gradational contacts, making the accurate estimation of its thickness difficult. Nodules of limestone and mudstone bands and lenses are common, but in the workings around Winterly Bridge the Limestone was described as flaggy by the mine owners. The Limestone was penetrated in Manor Farm boreholes 1 to 3 and in Borehole 101 (Fig.2), but it is not seen in surface exposure, though there are ancient crop workings north of Radley Road (see surface workings overlay) [0347 0115].

Lower Ludlow Shales

These beds form a narrow outcrop at Linley, but are not exposed. They are, however, well known from several boreholes sunk through Carboniferous cover, suggesting that much of the Coal Measures west of the Clayhanger Fault rests on Lower Ludlow Shales brought in by the steady dip to the west in the Silurian beds. The fullest sequence is in Ryecroft Limestone Pit, in which

54.86 m of 'binds and limestone clunch' (interpreted as silty mudstone and calcareous mudstone) have been recorded overlying Upper Wenlock Limestone. The exact position of this pit is in some doubt; one possible site [0198 9984] lies just south of the area boundary, but alternatively it may have been at a nearby site just within the present area.

Three cored boreholes were sunk for a site investigation at Manor Farm. The core of No. 3 Borehole [0276 0062] with the greatest thickness of Lower Ludlow Shale is stored in the BGS archives; the sequence of Lower Ludlow Shales, totalling 54.66 m, has been re-examined during the present project. The strata consist of greenish grey mudstone with scattered limestone nodules, with more numerous bands rich in nodules concentrated in the basal 3 m, just above the Upper Wenlock Limestone (Fig.2). At the base of the sequence, a band with 80 percent limestone nodules, 0.44 m in thickness, is underlain by 0.33 m of pale grey mudstone directly above the Lower Wenlock Limestone. This mudstone, showing bedding contortion in No. 1 and 3 boreholes, is thought to be the 'Fuller's Earth' formerly worked in Lavender's Shaft 400 m to the south. When placed in water, it tends to fall apart rapidly, a feature of fuller's earth. The band thins westwards in the Manor Farm boreholes, from 0.69 to 0.76 m in No. 1 to 0.53 m in No. 2 and 0.33 m in No. 3. It does not appear to have been recorded to the north-east in the Winterly Bridge area where the Upper Wenlock Limestone was formerly worked, and probably dies out in this direction.

Several boreholes [021 005] sunk through Carboniferous cover penetrated up to 9.5 m of gently dipping, greenish grey mudstone located high in the Lower Ludlow Shales sequence and close to the Ryecroft Limestone Pit.

Carboniferous

Upper Carboniferous rocks attributed to the Coal Measures (Westphalian Series), of grey (Productive) and red (Barren) types are present at rockhead or beneath Triassic rocks across the entire area (Fig.1), excepting only the Silurian outcrop previously described. No older Carboniferous rocks have been recorded within the district and it is assumed that the Coal Measures lie upon Silurian, or older Lower Palaeozoic, rocks throughout the area, though only in the south is this major unconformity demonstrated by exposure and borehole records. The discordance of dip between the Silurian rocks and the overlying Coal Measures is small where the junction is exposed, but elsewhere the angular unconformity may be more marked. The best exposure of the unconformity is seen in subsidence hollows east of Daw End (Fig.3).

It shows about 2 m of undulation in the plane of unconformity on a small scarp along the line of a pre-Carboniferous fault. The plane of the unconformity declines westwards at about 2° from the exposed Silurian rocks in the Daw End area west of the Clayhanger Fault. No details of the unconformity east of the Clayhanger Fault are known.

Productive Coal Measures

The maximum thickness of grey Productive Coal Measures recorded locally in continuous sequence is 276 m in the shaft of Aldridge Colliery No. 1 Plant [0472 0240] (Fig.6), whilst the estimated total thickness in the area, based upon numerous shaft and borehole records, is 318 m (c.f. Generalized Vertical Section of SK 00 SW). The apparent thickness of Coal Measures at any given point may be affected by the dip of the beds, by faulting within the sequence or by local variation of depositional history. The sequence consists predominently of mudstone, sometimes shaly, with seatearth, silty mudstone, siltstone, sandstone and, rarely, conglomerate. Coal seams and to a lesser extent beds of ironstone, the rocks of major economic importance in the area, form only a small fraction of the total thickness. Selected grey measure sequences proved by shafts and boreholes are illustrated by figures 4, 5 and 6. West of the Clayhanger Fault workings are known, in descending order, in the Yard, Bass, Cinder, Shallow and Deep coal seams (see Mining Base Map and individual seam overlays). South of Pelsall the Shallow and Deep seams become effectively continuous and were commonly worked together as the Bottom Coal. Above the Yard Coal it is possible that minor working has taken place in several thin seams, including the Heathen and Stinking coals (Fig.5), but no records of such exploitation exist. Below the level of the Deep (or Bottom) Coal several beds of ironstone are known to have been dug from outcrop and by deep mines, though few working plans remain (see surface workings and ironstones overlays). The Gubbin (or Gubbin and Balls), Blue Flats, Silver Threads and Diamonds ironstones (Fig.4) have all been exploited locally. Also at this general level one thin coal, the Mealy Grey (Fig.4) might sporadically have been dug from crop or shafts, but no documentary evidence is extant.

Geological mapping has shown that the general westerly dip and a number of predominently east-west normal faults (Fig.10) in this block have brought all the workable seams close to rockhead in different parts of the area. Workings at shallow depth might therefore be expected in all those coal and ironstone seams mentioned above. Additionally many of the economic deposits were exploited prior to modern mine surveying and frequently mine plans show the more recent workings to end against 'old workings' or 'old gob' (backfill), whilst numerous shafts and tips are shown on old topographical maps in areas with no surviving working plans. By implication most of the area west of the faulted outcrop of the Deep or Bottom Coal may be at least partly underworked at some level, whilst east of the Deep Coal outcrop, particularly in the southwest of the area, workings might be present in the Mealy Grey Coal and various ironstone beds. An attempt has been made on the Mining Base Map to indicate areas with no extant mine plans, where working might have occurred.

At one site [0028 0040] north of Birchills Junction, grey Coal Measures mudstone was dug from a small surface pit for brickmaking (see surface workings overlay), but the site is now backfilled, landscaped and redeveloped.

In the next tract to the east, between the Clayhanger and Vigo faults (Fig.1), a thicker grey measures sequence is preserved, this being downfaulted relative to the western area and overlain, except in the south, by red beds (see below). Many coal seams, worked (see Mining Base Map and individual seam overlays) and unworked, are present in this succession (Fig. 6), which is otherwise lithologically similar to that in the west. In descending order the Bottom Robins, Wyrley Yard, Charles, Brooch, Eight Foot (of Walsall Wood), Yard, Bass, Shallow and Deep seams (the latter two being virtually amalgamated in the south) have been worked and the workings surveyed in recent times. All mining activity has been from deep shafts penetrating the red measure cover at Walsall Wood, Aldridge, Coppy Hall, Leighs Wood and Victoria collieries. Unrecorded workings are unlikely to be extensive, though a possibility exists that minor workings in otherwise uneconomic seams such as the Top Robins or Cinder (Fig.6) might occur, particularly in the older part of the worked area around Victoria Colliery.

Numerous beds of ironstone are present within the sequence, but these tend to be thin and discontinuous and no plans of workings have been located. Small quantities of ironstone from favourable horizons were raised and stockpiled (Barrow and others, 1919, pp.95-97), but only where encountered adjacent to an economic coal seam.

Eastwards of the Vigo Fault (Fig.1) the grey measures are faulted down to still greater depths. Little is known of the detailed structure or stratigraphy of these beds, except in the immediate vicinity of the Aldridge Colliery trial headings (Fig.11). Two parallel headings, commenced in

1913, were driven eastwards across the bounding fault for 1198 m on a downward incline of 1 in 4. A number of potentially economic seams were intersected, but the structure was too complex and the ground too deep for exploitation to be considered at that time. The proof headings were terminated soon after crossing a further major fracture which faulted the productive measures down still deeper to the east. No details of the structure and nature of the grey measures sequence east of this fault are known, though it is assumed that similar beds are present at depth beneath red beds (see below) and Triassic rocks.

Red Coal Measures

The base of the red (barren) Coal Measures is diachronous, such that in the south of the area red beds occur at horizons represented by grey measures to the north (Fig.7). Coal seams are absent within the red sequence, but each of the formations described below has been exploited in the past for brickclay or marl, and is an important resource locally. No red Coal Measures are present to the west of the Clayhanger Fault (Fig.1).

Etruria Formation

Originally known as the Etruria Marl, this formation is a major source of brick clays in the Midlands. The maximum thickness proved in the present area is in shafts at Walsall Wood Colliery. It consists chiefly of unbedded (structureless) mudstones, dominantly reddish brown, interbedded with khaki, purplish brown and pale green. Sandstones vary from fine- to coarse-grained and are chiefly reddish brown. They commonly show cross-bedding and tend to be impersistent. It is likely that the bulk of the sequence lies within Westphalian C.

The base of the Etruria Formation is taken at the lowest major red or variegated marl and can be proved across Linley Lodge Industrial Estate in site investigation and opencast boreholes. Comparing the shaft sections from the Leighs Wood, Aldridge and Walsall Wood collieries (Fig.7), the base of the Etrurias appears to lie at progressively lower horizons southwards. The highest seatearths, lying roughly 60 m above the Top Robins Coal, are in grey beds in the north but pass southwards into red strata, following a similar trend observed in North Staffordshire (Hains and Horton 1969, p.54). The lowest beds of the Etruria Formation near Dumblederry Farm are known in four boreholes (Dumblederry Boreholes 1, 3, 4, 5) which proved dominantly red mudstones with only one impersistent sandstone. Equivalent strata in the colliery shafts are mottled marls with impersistent sandstones (Fig.7).

The middle portion of the Etruria Formation was formerly well exposed in the Victoria and Northywood quarries where T.C. Cantrill recorded a 27 m deep excavation in dark red marls with a few beds of impersistent, coarse-grained 'tuffy' sandstone, some with small quartzite pebbles. Equivalent and slightly higher strata are less well exposed in the Atlas Quarry and include three thin espley-type sandstones. One such band is 1.2 m thick and contains pebbles up to 10 cm long. A borehole in the floor of Atlas Quarry is reported to have penetrated sandstone which inhibited deepening of the working, but no stratal record has been traced. This sandstone is probably that currently exposed as a bedding surface in the floor of the Quarry [0448 0188].

Beds towards the top of the Formation are exposed in Vigo Quarry, and the Highfields South Quarry may be in slightly higher beds since no overlap can be discerned in the lithological sequence (Fig.7). Together, they give a section of about 38 m of strata, dominantly unbedded khaki mudstones with mingled marls common in the upper beds. In the middle of the Vigo quarry section, sandstones make up about half the sequence, ranging from fine- to coarse-grained with lateral variations in thickness and grain size. The sandstones and underlying mudstones probably correlate with similar strata in the Empire Quarry. This section was measured by NCB geologists before tipping began to obscure the quarry face. A cross-bedded 3 m sandstone can be seen to pass laterally eastwards into mudstones.

The sandstone group in Vigo quarry is likely to be equivalent to similar beds high in Joberns' Quarry (now infilled) where T.C. Cantrill (1910) recorded:

Glacial gravel	1.2 to 3.4
Clay (weathered marls)	2.5 to 3.1
Rock (rejected)	1.8 to 2.4
Red marl	3.1 to 3.7
Rock (rejected)	1.2 to 3.5
Red marl with thin layers of rock 0.3 - 0.9 m thick about	15

Keele Formation

These beds, which overlie the Etruria Formation, comprise reddish brown sandstones and mudstones, some laminated, some unbedded. It is likely that the lower half of the sequence is the lateral equivalent, in red facies, of grey strata referred to the Halesowen Formation in other areas. Though formerly worked in three small marl quarries at Walsall Wood the rocks are at present poorly exposed and fail to form features. The lowest 122 m of strata were proved in the Walsall Wood Colliery shafts (Fig.8) where they include several thick sandstones. The lowest sandstone appears to be highly variable in thickness since it is attenuated in Highfields North BH2, an exploratory borehole for brick clay. The Keele Formation is likely to be at least 208 m thick and yet higher beds are concealed under Triassic cover.

A relatively recent NCB Brickworks Executive borehole at Grange Farm (Fig.8) proved typical Keele Formation mudstone and sandstone beneath thick drift, the sequence also including a 0.3 m bed of medium grey limestone with abundant Spirorbis shells. A similar limestone was formerly exposed (in 1911) to the east of the Vigo Fault [0530 0274], lying about 100 m above the base of the Keele Formation and possibly correlating with that in the Grange Farm borehole.

Bowhills Formation

Rocks which are believed to form part of the Bowhills Formation, a series of reddish brown sandstones and unbedded mudstones with conglomerates, are present beneath drift in a narrow fault-bounded tract towards the east of the district (Fig.1). Numerous old marl pits mark the outcrop, but none of these now provides a clear section. Hand augering to a depth of 2 m has obtained stiff red-brown calcareous clay, and the entire outcrop is marked by heavy clay soils, in strong contrast to more sandy soils on the adjacent downfaulted Triassic rocks. Elsewhere in the east of the district, the Bowhills Formation should occur beneath the Triassic cover, which unconformably overlies it.

Igneous rocks within the Coal Measures

Rocks believed to be of igneous intrusive type are known at various levels within the Carboniferous sequence in the west of the district. 'Green rock', which is here presumed to be basalt or dolerite, is recorded in numerous old shaft records, on mine plans and in a small number of more recent provings. Dolerite up to 13.7 m in thickness found by a group of boreholes south-east of Pear Tree Farm [0086 0453] may be part of a thicker (30.5 m) intrusion proved in Fishley Colliery No. 2 Plant Downcast Shaft [0052 0388] (Fig.5) and is the only igneous rock considered to reach outcrop in the area (Fig.1). Elsewhere 'green rock' in sill-like bodies was proved in shafts at Fishley Colliery No. 1 Plant and No. 3 Plant, Hope, Goscote, Goscote Hall and Forest collieries, and more doubtfully in other old shafts in the area. Plans of the workings of these mines, particularly in the deeper seams (see Mining Base Map and seam overlays) show numerous 'rock faults', which are assumed to be intrusive dykes, and also show an arcuate western limit to downdip coal extraction. Whilst some plans indicate that workings ended against 'green rock' others give no such information. It is assumed that the limit of coal workings to the west was governed either by the actual intersection of a large 'green rock' mass, or by the economic coals being rendered worthless by thermal alteration in the vicinity of this supposed major intrusion.

East of the Clayhanger Fault the only certain record of igneous rock is 'green rock' proved at a depth of 531 m in Walsall Wood Colliery No. 2 Shaft [0476 0410]. The lateral extent and thickness of this body are unknown, but it is assumed to be intrusive and may be confined to a highly faulted east-west trough (Fig.10) which runs through the shaft area. 'Green rock' is recorded at much higher levels, within the Etruria Formation, in the shafts of Walsall Wood, Aldridge and Leighs Wood collieries, but there is no evidence to indicate that these beds might be intrusive or extrusive igneous rocks; they are therefore assumed to be sandstone.

The age and mode of emplacement of the various igneous rocks are uncertain. The dyke-like 'rock faults' and some of the larger 'green rock' masses are almost certainly intrusive, since they transgress and locally thermally alter country rock. Other apparently non-transgressive bodies may be intrusive or could conceivably be of extrusive origin (lavas or tuffs). The most likely date of emplacement for the intrusive 'green rock' in the Productive Coal Measures is late Carboniferous, and if this is so, those beds of 'green rock' in the Etruria Formation, or similar beds higher in the succession, might be wholly or partly of contemporaneous extrusive igneous origin.

Triassic

Rocks belonging to the Sherwood Sandstone Group are represented by two formations in the Aldridge - Brownhills area.

Kidderminster Formation

This formation is 75 to 80 m thick and generally consists of soft, reddish-brown, fine- and medium-grained sandstone with several beds of pebbles, up to 18 m thick, rich in quartzite pebbles and cobbles and with rare, thin beds of mudstone.

Whereas much of the Carboniferous terrain is less well exposed than at the time of the 1911 survey due largely to landfill operations, the Triassic rocks are better exposed. Four large quarries (see Sand and Gravel Resources map) are being worked for aggregate and sand at Shire Oak (Tarmac Roadstone), Chester Road (Amalgamated Roadstone Corporation), Aldridge (Ready Mixed Concrete) and Bliss Sand and Gravel, Aldridge. Collectively these quarry sections cover strata from 4 m above the base of the Kidderminster Formation up to about 13 m from the top.

In Shire Oak Quarry there are two sandstones within a predominantly pebbly sequence (Fig.9). Above the basal unconformity, estimated on borehole evidence to be about 4 m below the settling pond, is 13 m of coarse pebbly sand with thin, hard sandstone ribs. The lower sandstone, about 9 m thick, has few pebbles and is generally unbedded. It forms the floor of a large area in the centre of the pit and is overlain by about 14 m of rapidly alternating, laterally variable coarse pebbles, and sandstone with pebbles and rare cross-bedding. At least 10 m of the upper sandstone is exposed in the quarry; it is massive, with few pebbles. Mapping of the surrounding area indicates a total thickness for the upper sandstone of about 24 m.

In Chester Road Quarry the eastern part of the working exposes thick sandstones intermixed with pebbles. The rocks in the western part are higher in the sequence, predominantly pebbly, and equivalent to the pebbly beds between the two sandstones in Shire Oak Quarry.

The three Sandhills Pumping Station Boreholes, though less than 1 km from Shire Oak Quarry, show a thicker sequence with very thick pebbly beds (Fig.9).

The upper sandstone of Shire Oak Quarry is exposed in Aldridge Quarry [067 026] (Fig.9). Here, the sandstone is about 24 m thick and lies between pebble beds.

The country north-east of Aldridge is generally poorly exposed with sporadic exposures along the railway line of fine-grained sandstone with rare pebbles. On the rim of the dry valley near Nuttalls Farm [067 011] a probable pebbly band forms a feature. The fields are covered in pebbles and cobbles of quartzite up to 20 cm long, and the lower slopes are characterised by sand derived from non-pebbly sandstone. The slope of the feature indicates a gentle dip to the east-south-east.

The Bliss Sand and Gravel quarry at Aldridge shows a fairly complete sequence in the lowest 46 m of the Kidderminster Formation (Fig.9). Extraction at the quarry was halted at the water table so as not to interfere with the pumping of water at the Bourne Vale Pumping Station [0740 9979] just to the south. Westphalian rocks are not exposed in the quarry but they cannot be far below the quarry floor since they were proved at a depth of 40.8 m at the pumping station.

The quarry sequence is difficult to estimate accurately because exposures are scattered, but it consists of about 30 m of very soft sandstone with sporadic pebbles and pebbly layers which are so soft that they can be dug by mechanical excavator. These beds are overlain and underlain by beds rich in pebbles and cobbles.

Wildmoor Sandstone Formation

The Wildmoor Sandstone Formation, a reddish brown fine-grained sandstone, is thought to occupy an extensive area in the east of the district, south of the Footherley Fault, but it is nowhere exposed. The sequence is best known from a borehole [0780 0457] 200 m NNE of Shepherds Farm (Fig.9).

5. STRUCTURAL GEOLOGY

Many of the faults shown on the geological map have been taken from or deduced from, mine plans. For simplicity faults known to have less than 1.5 m throw have been omitted. Not all "faults" shown on mine plans, particularly the older plans covering the western part of the area, are tectonic features. For instance, 'rock faults' are believed to be igneous intrusions and 'sand faults' are believed to indicate the outcrop of coal seams against the base of drift deposits. A certain amount of selection has therefore been involved in the translation from mining plans to geological map and it is implicit that tectonic structures additional to those shown on the maps and figures may be present.

Pre-Carboniferous tectonics

Before the deposition of the Westphalian rocks the pre-existing Silurian beds were affected by earth movements resulting in faulting and gentle folding. Where the effects of these movements are visible the present situation is that the Silurian beds dip westwards at about 5°, so that higher strata gradually come in towards the west beneath the plane of unconformity, which itself dips at about 2° to the west. Near Daw End a pre-Carboniferous fault trending E 10° N with a northerly downthrow of about 2 m is exposed beneath the unconformity (Fig.3). 50 m south of this exposure two N-S trending faults of small throw are visible in a subsidence hollow. These, together with a further fault of similar trend and 4.6 m downthrow to the west recorded on plans of the Daw End limestone workings, are probably also of pre-Carboniferous origin.

Post-Carboniferous tectonics

A number of major faults of predominantly NW-SE to N-S trend cross the area (Fig.10) and the scanty available evidence suggests that these are the most recent structures, having been active (or possibly re-activated) in post-Triassic times. In the blocks between these faults the predominent trend of faulting is E-W, being variable between SW-NE and NW-SE (Fig. 10).

The Clayhanger Fault (Figs.10 and 11) appears to be a complex fault belt, its limits being marked by a westerly major fracture and a somewhat smaller, sub-parallel, fracture proved from coal workings to the east. Southwards the two limiting fractures converge and eventually amalgamate as the major fault swings eastwards near Aldridge. The overall throw of the Clayhanger Fault belt is calculated as about 300 m in the south, increasing to some 630 m in the north as a consequence of the northward dip of the beds on the downthrow side. At the southern part of the fault in this area the dip of the measures on the downthrow side steepens to 15-30° in a strip some 300 m wide beneath Linley Lodge Industrial Estate, the steepening probably being due to frictional drag during fault movement.

West of the Clayhanger Fault is an area composed predominently of Productive Coal Measures with a general dip of 2 - 4° to the WNW, though the dip may vary in amount and direction adjacent to faults. Numerous normal faults of relatively small throw cross the area with a dominantly WSW-ENE trend (Fig.10). Eastwards most of these faults are shown as dying out, but this reflects a lack of information in beds beneath the Bottom Coal and the fractures may well continue towards the Clayhanger Fault. One of the larger faults of this group is the Northern Bentley Fault (Hamblin, 1982), which trends E-W with a southerly downthrow of about 30 m.

In the extreme north-west of this area a narrow graben trends SW-NE. Its northerly bounding fault has a recorded downthrow of 55 m and the Wyrley Bottom and Old Park coal seams have been faulted down into the trough. Eastwards a larger graben occurs between two complex E-W fault systems. This is a continuation of the Walsall Wood Graben (Fig.10), which lies to the east of the Clayhanger Fault.

No faults affecting the Coal Measures in this western area were exposed during the geological survey. Interpretation of the available mine plans however suggests that most, if not all, of the faults are normal and that both their hade and throw may vary along their length.

Between one and two kilometres east of the Clayhanger Fault belt is a major sub-parallel structure, the Vigo Fault, which is a normal fault with an easterly downthrow in the order of 200 m (Figs. 10 and 11). The area between these two major fractures has relatively few large faults and the strata dip steadily towards the NNW at 3°-4°, except, as previously noted, adjacent to the Clayhanger Fault in the south and to the north of the Walsall Wood Graben where the dips are somewhat steeper (Fig.10). The Walsall Wood Graben in this block is defined by two almost parallel faults trending WNW-ESE. The northern fracture was encountered in Walsall Wood Colliery No. 1 Shaft and has a southerly downthrow of about 27 m whilst the southern fault, met in No. 2 shaft, has a northerly downthrow of 45 m. West of the Clayhanger Fault this fracture splits to form two lesser faults with northward downthrows of about 24 and 15 m.

North of Leighs Wood Colliery several N-S faults were proved by mine workings (e.g. Yard Seam mining overlay). Some slant into the plane of the Vigo Fault and do not reach the surface, but one fault with a hade of 40° to the east is well exposed (1984) in Vigo Quarry [0492 0273]. Two fractures visible in Atlas Quarry trending NE-SW have not been located in underlying workings; they are thought to be of small throw and to die out above the Productive Coal Measures. Numerous faults are recorded on the mine plans of this block however, particularly in the more recent plots. Most of these tend to parallel the Clayhanger and Vigo structures and are of small throw. Close to the southern limit of the Walsall Wood Graben a host of faults with throws of 1 m or less (not shown on simplified mine plans) parallels the trend of the graben.

The Vigo Fault marks the easterly limit of coal working and is shown on the geological map as a single fracture. Evidence from colliery trial headings (Fig.11) has shown that a major fracture of 200 m throw is flanked to the east by a belt of complex structure with many faults and variable dips, which is in turn faulted against gently dipping coal-bearing strata. Eastwards another fault brings in steeply dipping and faulted Productive Coal Measures which are truncated to the east by a fracture which faults down red Coal Measures. This fracture has been mapped at the surface and locally marks the limit of the Triassic rocks, yet does not extend through the Kidderminster Formation in the large Shire Oak Quarry. An area of gently dipping Kidderminster Formation and Wildmoor Sandstone Formation strata to the east is broken by an upfaulted block of Carboniferous Bowhills Formation (Fig.10). The beds are assigned to the Bowhills Formation on the grounds of lithological similarity and if the correlation is correct the western fault of the horst has a throw of at least 120 m and that to the east 80 m.

Dips within the Triassic rocks generally vary from 4° to 7° towards the north-east in the north or towards the east-south-east in the south. The faulted belt with steep and variable dips proved at depth by the colliery explorations cannot be mapped in detail at the surface since exposure is poor.

6. DRIFT GEOLOGY

Drift or unconsolidated deposits cover most of the area of sheet SK 00 SW (Lowe and others, 1984) and parts of sheet SK 00 SE (Price and others, 1984) (Fig.12) and it is likely that those areas now considered drift-free have reached this state relatively recently due to the erosional removal of superficial material. Most of the Silurian and, to a lesser extent, Triassic terrain is now drift-free, whilst the Carboniferous rocks are mostly drift covered.

Provings of drift thickness are unevenly distributed across the area, but the sub-drift topography is more undulatory then the present day surface. The rockhead topography and the drift thickness of the area west of grid line 06 are represented by maps contoured at 2 m intervals and based upon the available borehole data. In areas of poor data the lines are spaced approximately equidistantly between the nearest reliable data points. The rockhead contour map reveals that a major buried valley crosses the area from north to south, partly following the present line of Ford Brook and probably continuous with the "proto-Ford Brook channel" previously identified in the area to the south (Hamblin and Henson, 1982). This main channel is joined by a number of tributaries, some of which exhibit an uneven thalweg, suggesting that they were totally or in part eroded by sub-glacial streams. The main channel cuts down to at least 112 m OD east of Pelsall, some 30 m or more below the present land surface. Between Shelfield and Aldridge a surface depression is floored by fluvioglacial deposits more than 30.5 m in thickness in places.

The principal glacial deposits, which probably originally covered the entire area, are unbedded or crudely bedded till and bedded outwash sand and gravel. Distinction between the two is not everywhere clear since the till ranges in composition between stiff stony clay (the typical 'boulder clay'), sandy gravel and gravelly sand. In places an attempt has been made to delimit the more sandy areas and these are shown as 'Glacial Sand and Gravel' on the maps.

More recent (post-glacial) deposits which complete the drift sequence are Older River Gravel, Alluvium, Peat and Head.

Drift deposits are more likely to be problematical when encountered in excavation or constructional work than most solid rocks. What is known of the geotechnical properties of the drift in this area is summarised in Section 8.

Till and Sandy Till

The term till is partly, but not totally, synonymous with 'boulder clay'; whereas the latter term is particularly used to describe heterogenous deposits composed of clay, gravel and sand laid down directly by a glacier during its advance or decay, the term till includes those deposits and similar materials formed by mass movement of unstable sediment through air or water and by melt-out from floating ice, all during glacial climatic regimes. The appearance, composition and properties of till reflect not only the depositional process involved in its formation, but also the geology of terrain crossed by the ice-sheet or glacier producing the till and the intensity of consolidation caused by loading and dewatering subsequent to deposition.

Till often contains pebbles or boulders of rock types which are alien to the area occupied by the deposit. If these clasts, known as erratics, can be identified and their source traced the direction of ice movement pertaining at the time of deposition can be postulated. Till deposits in the Aldridge - Brownhills area contain erratics of igneous intrusive and volcanic material typically found in the Lake District and Southern Scotland, indicating that the ice entered the area from the northwest. Study of the relationships of the till deposits to other deposits in the area and to topography suggest that all glacial material currently preserved at surface was deposited by a single ice sheet during its advance and subsequent retreat. The glacial episode concerned is assumed to be the last major advance, the late Devensian, which extended from 26 000 to 10 000 years before present day.

It is probable that till was deposited across most of the Aldridge - Brownhills area, being locally removed or overlain by other glacial or post-glacial deposits in more recent times. Across much of the area (Fig.12) are spreads of red-brown stony clay, a typical 'boulder clay' which is believed to represent a true lodgement till laid down beneath an advancing ice sheet. Natural exposures of this material are poor, but thicknesses of up to 19 m have been recorded by boreholes. Elsewhere the glacial deposits are more variable in composition and the till contains relatively more sand and gravel at some horizons in a more scanty clay matrix. In extreme cases the clay element may be so small that the deposit can be described as clayey sand or clayey gravel. The few available natural sections show that near-surface leaching has often removed much of the clay fraction to leave a thin sand-and-pebble-rich deposit resembling glacial outwash rather than the original parent material. In some cases the leached clay fraction has been redeposited as a 'pan' at a depth of 1 to 2 m, with typical till beneath and ill-sorted remanië sand and gravel above. It has not proved possible to distinguish between areas of arenaceous till and argillaceous till in these mixed deposits, which are believed to be melt-out and flow tills produced during glacial stagnation, and the geological map shows them as sandy till, separated from areas of predominently lodgement till by a conjectural boundary.

Glacial Sand and Gravel

These deposits are believed to have been laid down by streams of glacial meltwater. The source of material is the same as for till, the eroded rock debris carried by the ice sheet, but the mode of transport prior to deposition, and the depositional processes involved are such as to produce more well-sorted sediments than those previously mentioned. In the Aldridge - Brownhills area Glacial Sand and Gravel was probably being laid down contemporaneously with the formation of flow and melt-out tills in late-glacial times, and it has not always been possible to recognise and delimit the two different lithologies. Where possible Glacial Sand and Gravel has been separately shown on the geological map (Fig.12); elsewhere sequences regarded as being of till and sandy till might contain beds of glacial outwash material. Deposits of Glacial Sand and Gravel superimposed on the outcrop of the Kidderminster Formation are probably the product of glacial meltwater downwash from the sand and pebbles of remanië deposits higher upslope.

Older River Gravel

As the Devensian ice-sheet decayed and retreated rivers of meltwater carried abundant clay, sand and gravel along drainage channels (see rockhead contour map) which might have been partly sub-glacial in origin and included sections of overdeepening. The uneven profile, where present, was effectively smoothed and graded by the infilling of the deeper basins by fluvioglacial deposits derived from the material carried in the meltwater. It is believed that several deep sections of such channels occur in the Aldridge - Brownhills area (see rockhead map) and contain mixed deposits of this type, good examples being found along the course of the proto-Ford Brook Channel previously mentioned and in a deep elongate depression flanking Stubbers Green Road, Aldridge (Loc.A, Fig.12). In the latter area the full thickness of the deposits has not been proved, but is in places, at least 30.5 m. In the case of the proto-Ford Brook Channel the sequence is in part mixed with clay-rich material of flow and melt-out till type and it is apparent that several depositional processes were operative as the climate changed radically at this time.

As the irregular profiles of the drainage channels were infilled and smoothed a more typical fluvial sedimentation regime was established and the deposits described above often grade upwards into thicker beds of gravel of river terrace or alluvial type. All the deposits laid down during this episode, including terrace gravels possibly attributable to the 'First Terrace' of modern drainage systems, are included here as Older River Gravel (Fig.12).

Alluvium

Alluvium is essentially the flood plain deposit of a modern stream or river, differing from River Terrace deposits only in age. In the Aldridge - Brownhills area most surface streams are of small size and very gentle gradient, being capable, even in flood, of only limited sediment transport. What alluvium is present (Fig.12) is generally composed of silt and clay in its upper levels, with sand and gravel locally preserved below and reflecting earlier depositional conditions. Along much of the Ford Brook and its tributary valleys alluvium overlies sequences of Older River Gravel in places interbedded with melt-out and flow tills, and it is evident that sedimentation has been continuous (if periodic) along these drainage routes since late glacial times. At some localities silty alluvium can be seen to overlie till deposits or pebbly fluvioglacial material attributed to the

Older River Gravel, and these older deposits are often weathered or re-worked so as to appear to grade into the newer material.

Peat

Recent deposits of partly carbonised, decayed and semi-decayed vegetable matter, usually mixed with minor proportions of clay, are termed peat. Towards the eastern side of the Aldridge - Brownhills area a number of patches of peat have been mapped (Fig.12) as resting on Older River Gravel in the valleys. These spreads are commonly thin, averaging 0.6 m, though locally they may exceed 1 m in thickness. Elsewhere boreholes have proved peat deposits within complex stream deposit sequences.

Head

A deposit of sandy head has been mapped in a dry valley in the Kidderminster Formation at Aldridge [063 012].

7. MADE GROUND

Where feasible all man-made deposits have been delineated on the geological map (also reproduced as a sketch map in Fig.13). These include land reclamation, domestic and industrial waste tips, colliery and quarry spoil heaps, railway, road and canal embankments. Some of these deposits have well-defined morphological limits; elsewhere pre-existing Made Ground has been redistributed and landscaped for building purposes or to improve its amenity value. An attempt has been made to differentiate between Made Ground that fills old pits or opencast workings, that forming recognisable spreads of fill material and areas of extensive landscaping. The latter may include areas of landscaped drift material, but since this is no longer representative of its parent deposit in either morphology or engineering properties, it is considered to form part of the Made Ground. In addition on Fig.13 a general indication is given of the type of fill material predominant in the major spreads, and embankments are differentiated from more general areas of Made Ground where possible. In general, but particularly where areas of old colliery tip have been reworked, the bounderies of Made Ground feather-edge away, and in places, for example where such material is built over in the southwest of the district, the indicated limit is arbitrary.

As might be expected the western part of the area, where mining and quarrying have been carried out for centuries and where industrial development and urbanisation have been greater than in the east, contains the major part of the Made Ground. Many of the older colliery spoil heaps have been landscaped in relatively recent times and some material has been transferred to other areas for landfill purposes, such as northeast of Clayhanger, where the old Walsall Wood spoil heaps have been landscaped and partly moved to infill a depression to the north (W, Fig.13).

Old open workings in the Etruria Formation have been used for disposal of chemical waste at the Aldridge Quarry (X, Fig.13) and Joberns Quarry (Y) and of polymer at the Empire quarry (Z).

8. GEOTECHNICAL PROPERTIES OF DRIFT DEPOSITS

No geotechnical investigations were carried out as part of the current study, though a number of generalisations concerning the drift deposits of the area may be made. It is apparent from the limited surface exposure and more numerous borehole records that the drift deposits, particularly those of glacial origin, are highly variable in both lithology and thickness. Only rarely do significant continuous sequences of homogeneous lithology occur. Elsewhere in the glacial deposits irregular alternations of clay-rich or sand/gravel-rich material are commonplace. Also, where the drift deposits are thickest, (see drift thickness overlay) filling hollows or buried valleys, they are more complex, the thinner drift on the more positive areas of rockhead tending to be less mixed. Another important factor in the thick drift areas, particularly where arenaceous deposits are dominant, is the amount of water in the sequence. Below the 'water table' deposits of sand and gravel encountered by boreholes often display 'quick' or 'running' characteristics, as highlighted by Standard Penetration Test results (Table 2).

The variable nature of the individual lithologies encountered within the drift units delimited on the geological map does not allow a precise quantitative listing of engineering properties across the area. Available geotechnical data have been re-examined in the light of the results of the geological mapping, and a table of generalised drift properties has been compiled (Table 2). Where lithological descriptions were vague in original borehole logs, the interpretation shown in the table is subjective, whilst data concerning tests on certain deposits are lacking.

Soils, in the engineering sense of the word, of cohesive, granular and organic types are present in the area. Though the lithology of the drift deposits shown at surface on the geological maps gives a broad indication of the ground conditions to be expected (Table 2), it is apparent that the complex drift stratigraphy could lead to problems of foundation design in some areas. Problems might be expected in the areas of present day valleys and of buried valleys, where thick and varied drift sequences, possibly including organic material (peat or organic clays), are more likely to be present. Elsewhere, in areas of lodgement till and glacial sand and gravel or in drift-free areas, simple pad or strip footings would probably provide a sufficiently stable foundation for most constructions, since problems of differential settlement would not be expected.

In those complex areas mentioned above, where not only lithology is likely to be highly varied, but also variable water contents might be expected, more sophisticated foundations would possibly be necessary for large or heavy structures. If peat was found to be present at or near surface it could feasibly be excavated prior to the construction of simple foundations, but if present at depth, in all probability rafted or piled foundations would be required. In the case of piled foundations the piles would have to penetrate any organic layers to reach a more solid footing, though side friction in any granular material would also have a significant influence on their bearing capacity. Silty or clayey horizons, particularly if of high moisture content, might also provide problems, but less so than the organic materials. What type of foundations are necessary at a given site will however depend upon the type of building or structure envisaged and the bearing capacities of the local soils as revealed by exploratory drilling and soil testing. It follows that a more detailed site investigation would be advised in the areas of potentially thick and complex drift.

The results of standard penetration tests reproduced in Table 2 give a crude indication of the resistance of each particular soil type to the penetration of a driven steel tipped cylinder, the figure representing the number of blows required for 300 mm penetration. In the case of granular soils this figure is related to the relative density (and hence very low in loose, wet soils and zero in 'quick' conditions) whilst with clay soils the figure relates to the unconfined compressive strength of the material. As previously pointed out, the amount of moisture present in the soil can affect this resistance to penetration and this highly variable factor is partly responsible for the wide spread of SPT values in Table 2. If the maximum SPT figure for each lithology is taken however, comparison between the different soils may be made, to give a crude indication of the relative bearing capacities of the deposits in ideal conditions. Secondary factors, such as the local moisture content, will inevitably result in lower values.

Not included in Table 2 are details of the geotechnical properties of the various types of fill material present across the area (Fig.13). Data are limited, complex and often contradictory. Whilst some fairly recent building development in the area has taken place on redistributed spoil material and over landfill sites, it is considered that the problems of progressive compaction and hence progressive foundation settlement would normally weigh against the erection of large or high-rise structures in such areas, particularly areas of landfill. The properties of many types of landfill are not only complex, but also prone to marked alteration due to settlement, chemical action or decomposition over short or long periods of time, such that any foundation design would have to predict future as well as presently appertaining conditions.

Study of the geological map and Table 2 gives a broad indication of ground conditions to be expected across the area. In the drift-free areas and areas covered by till, problems for foundation design should be few. Elsewhere, in the sandy till and more recent drift areas more detailed site investigation would be recommended, particularly in the areas of thick, valley - filling drift, where peat deposits or 'quick' conditions might exist at depth. Peat deposits and landfill of various types, together with excessive ground water, are the main hazards to successful foundation design to be expected in the area. (See also subsidence sections).

9. HYDROGEOLOGY

The features of the hydrogeology are dealt with in stratigraphical order.

Silurian. The old limestone workings at Daw End lie mainly below the water table and are now largely flooded. The standing water level in the recent exploratory boreholes here (Ove Arup and Partners, 1983) varies from 5 to 8 m below the collar. Indeed, the deepest subsidence hollow [0370 0050] shows a small pond in its base, as does the northern end of the former open working [0382 0057]; in each case the water table lies about 6 to 7 m below ground level. A nearby subsidence hollow [0356 0089] is flooded to within 5 m of ground level.

The Lower Ludlow Shales and Wenlock Shales are likely to be less permeable. They are dominantly argillaceous but contain limestone lenses and are in part silty. Fissure flow in these sequences is probably less than in the Wenlock Limestone.

Productive Coal Measures. These dominantly mudstone measures contain sandstones particularly in Westphalian A, but they are too variable locally to contain large quantities of water. The abandoned workings of Aldridge Colliery are being progressively filled up to Ordnance Datum with fluid toxic waste via the Empire discharge borehole. This borehole and associated monitoring boreholes are confidential and are not shown on the geological map.

Etruria Formation. This sequence consists dominantly of impervious mudstones, and large excavations in it have been used for large-scale surface waste-disposal at the Empire, Aldridge and Joberns sites. It also forms the cap rock to the underground disposal area for fluid toxic waste in the old workings of the Walsall Wood and Aldridge collieries. The proof headings from Aldridge Colliery which may be filled with this toxic waste also probably terminate in the Etruria Formation. The sandstone bands are chiefly impersistent laterally, but there could be local lateral water movement within individual sandstones. Thus it is just possible that a future great deepening of the Highfields South quarry could break through the several sandstone bands recorded in the Empire Quarry, with fluid transfer down-dip towards Highfield South.

Keele Formation. Sandstone members within the mudstone sequence are much thicker and more persistent than in the Etruria Formation and there is more capacity for water movement within individual sandstones which probably form separate aquifers. Mine-water formerly pumped from Walsall Wood Colliery probably come from these beds. Farther south at Aldridge Colliery, with no cover of Keele Formation, the shaft and workings were reputedly dry.

Bowhills Formation. The disposition of the formation east of the Vigo Fault is not known in detail, but it probably directly underlies the Triassic beds across most of this tract. Mudstones are likely to be dominant in the sequence, though individual sandstones may be charged with water.

Triassic - Kidderminster Formation and Wildmoor Sandstone Formation. These formations are both good aquifers which have been tapped in several farm boreholes. However, only one group of boreholes at Sandhills Pumping Station [0677 0494] extracts water in considerable quantity; over the last five years abstraction averaged 1800 million litres/year. Two pumping stations just to the east and south of the present district, at Shenstone and Bourne Vale, averaged 2000 million litres/year and 2300 million litres/year respectively from these rocks.

Drift Deposits. these are not utilised as a source of water, though sands and gravels locally carry limited supplies of doubtful purity.

10. LIMESTONE WORKINGS, POTENTIAL RESOURCES AND SUBSIDENCE

Around Daw End, and to the south, the Wenlock Limestone has been extensively mined by pillar and stall, in an area recently extensively investigated (Ove Arup and Partners, 1983). Besides the charted workings shallow underground works (Mining Base Map) lie close to the outcrops of the Upper and Lower Wenlock limestones at Daw End as evidenced by crater collapse structures and borehole evidence. Deeper uncharted workings are likely to occur at Ryecroft Limestone pits (020002, mining base map) and possible old workings at [0319 0012]. It is likely that much of the area of Carboniferous rocks west of the Clayhanger Fault is underlain at depth by Silurian beds with the Upper and Lower Wenlock limestones. These are a long term resource for limestone mining, but cheaper sources in the Peak District are likely to be used in preference for many years to come.

The following details are given in order to amplify aspects of the Ove Arup and Partners, 1983, report.

Lower Wenlock Limestone. The charted workings in the Lower Wenlock Limestone of the Phoenix Works, Linley Mine, Winterly Mine, East Anglian Cement Company and Lavender's Shaft are exhaustively dealt with in the Ove Arup and Partners, 1983 report. A number of crater subsidences, resulting from roof collapse in these mines were marked on Fig. 1023 of that report. Examination of Cantrill's 1911 field slip shows that there may well be additional subsidences, which have been added to the copy of Fig.1023 reproduced here (Fig.14). The largest of these is a depression [0338 0067] adjacent to the plotted area of failure in 1931 along Winterly Lane. The depression was defined by hachures on the pre-1911 topographical base.

Initially, Cantrill labelled this 40-m wide hollow on his field slip as 'old clay pit' but the last two words are crossed out and the word 'sink' substituted. It appears therefore that he was satisfied that this depression was not a quarry excavation into Westphalian mudstones ('clay c.m.'). Two satellite depressions farther south are labelled "sinks" by Cantrill. Four further depressions, now filled, are marked by hachure on the pre-1911 topographical base in the area of the Containerbase off Anglian Road. The largest [0371 0078] was listed as a "sink" in Barrow and others (1919, p.15). This is Locality 2 (E4) 450 yards north-east of Royal Oak, Daw End and marked with the fossil locality code on the field slip. The three aligned depressions around [0379 0081] are also on the pre-1911 topographical base. There is no note about these on the field slip but they are likely to be craters due to collapse of uncharted workings unrelated to the East anglian Cement Company's adit (see mining base map for estimated area of old workings).

Old workings of the early Linley Mine, probably pre-dating 1860, are apparent in three places in Linley Woods. They take the form of voids in the upper part of the Lower Wenlock Limestone, accessible from subsidence hollows. One of these was recently explored (Ove Arup and Partners, 1983) but progress was hampered by flooding of the workings, the site of an ammunition dump during the Second World War.

South of Bosty Lane the Ove Arup and Partners, 1983, report lists two more recent subsidences [0346 0043 and 0338 0037] slightly beyond the limits of the old workings shown on the existing plans (see Mining Base Map). These were possibly entered via the Blue Hole, a former open working in Lower Wenlock Limestone, now largely obliterated by the railway cutting, but a portion of the old hollow remains [0321 0027] (see Surface Workings Overlay).

Also north of the railway is the old sinking for fuller's earth and limestone, called Lavender's Shaft [0280 0020]. This is the subject of an entry in Cantrill's 1911 notebook in which he lists the depth as 71.3 m (very slightly different from that in the Ove Arup and Partners, 1983, report) with the Captain Limestone at 63.4 m. This is a named band within the Lower Wenlock Limestone, and the top of the latter should be about 59.8 m deep on the basis of the above data. The dumps near Lavender's Shaft seem large for the size of the charted workings.

South of the railway are the extensive Park Pits, ancient open workings in Lower Wenlock Limestone, lying largely outside the present area (see Surface

Workings Overlay). Between the Park Pits and the railway, there are irregularly shaped tips [0320 0012]. The larger, western end of the tips is mostly in clayey debris, but pieces of Wenlock Limestone are common at the eastern end [0324 0011]. A 3-m deep depression [0319 0012] in the surface of the westerly dump is possibly the collar of an old shaft into uncharted workings in Lower Wenlock Limestone (see Mining Base Map). Park Pits themselves, which are considerably affected by solifluction, could conceal old entries into uncharted underground workings.
Four of the twenty-three shafts recorded at Ryecroft Colliery are referred to as 'Limestone Pits' on old maps held in the archives of British Rail. These shafts, numbers 12, 13, 14 and 15, form a SSW-NNE line [0195 0009 to 0200 0019] and are now lost beneath the embankment of the main N-S railway line (see Mining Base Map). One shaft record from Ryecroft is extant (SK00SW/157) and this could be one of the four mentioned above, perhaps the earliest, No. 12 [0200 0019]. It reached a depth of about 150 m and ended within, or at the base of, the Lower Wenlock Limestone. No details are preserved of the workings from these shafts, which could have extended in any direction. It seems reasonable however that workings would extend predominently updip to the east, in such a way as to allow transport of the limestone down inclines to the shaft bottoms for haulage to the surface. If this is the case, workings might be expected updip towards the limit of downdip extraction from the various Daw End mines. Abundant limestone debris is included in railway embankments hereabouts and whilst some of this undoubtedly derives from the Daw End railway cutting, it is probable that a significant amount was procured from local mine dumps, suggesting the possibility of extensive workings. Risk of subsidence due to collapse of these workings is less than in the case of the shallower workings at Daw End, but the possibility of subsidence exists near Ryecroft.

Nodular Beds. Two areas of open workings in Nodular Beds were mapped at [0350 0009 and 0359 0099] (see Surface Workings Overlay). The latter workings near Brawn's Works Bridge were noted by Cantrill as being in 'self lumps' (coralline patch reefs). The craters have now been filled with refuse. One of them is noted as a subsidence hollow on Fig.1023 of the Ove Arup and Partners, 1983, report [0362 0093] within the area worked for 'self lumps', suggesting there may be a combination of open works in Nodular Beds and a subsidence, presumably into Lower Wenlock Limestone workings.

Upper Wenlock Limestone. Besides the ancient open workings at The Radleys [0348 0115] (see Surface Workings Overlay) the Upper Wenlock Limestone has been worked via shafts at Radley Mine [0325 0097]. Borings for the Ove Arup and Partners, 1983, report showed that there were uncharted collapsed workings at this level south of the canal.
Subsidence in a pavement outside the Royal Oak Inn [0338 0051] overlying an area with small pillars in the Upper Wenlock Limestone workings, was noted during the present survey and tested by a shallow borehole sunk by West Midlands County Council. This proved to be due to the infilled beer cellar of the older Royal Oak Inn.

Cores of Manor Farm Boreholes 2 - 3. In 1972, 115 mm diameter borehole cores were taken for the County Borough of Walsall through the mined Silurian sequence and associated strata. Two full cores, BH 2 at [0293 0057] and BH 3 at [0276 and 0062] are stored at BGS Gorst Road Rock Stores, London and present an excellent large-diameter record of the succession. Owing to pressure of time, only the Lower Ludlow Shales of BH 3 were examined for the present work (Lowe and others, 1984, Fig.1).

11. COAL WORKINGS, POTENTIAL RESOURCES AND SUBSIDENCE

Many of the coal seam outcrops shown on the geological map and also the limits of workings shown on the Mining Base Map and a series of individual coal seam overlays, are derived from plans of abandoned coal mines. Production of maps at 1:10 000 scale has involved, in most cases, an initial reduction of the original plans to a scale of 1:2 500, followed by a further reduction to the working scale. Most of the original plans are very old and show limited topography; the problems of marrying this to the somewhat stylised topography of current 1:10 000 maps, coupled with the inherent distortion of photographic reduction, have necessitated a finished product which must be considered a guide to, rather than a definitive statement of, the limits of coal workings in the area. Additionally mine plans exist which could not be accurately tied to modern base maps, which showed workings in un-named seams, or had confused or contradictory nomenclature. It is recommended that the Mining Base Map and overlays are used as a guide only, and that fuller details of any possible workings should be obtained from full-scale original plans held by the National Coal Board Mines Records Department, Staffordshire House, Stoke-on-Trent.

The thickest seams, the Deep, Shallow (or Bottom where they combine), Charles and Bottom Robins coals have been extensively worked throughout their areas of occurrence and many of the thinner seams have been worked close to crop. Unworked coal undoubtedly remains in thin seams and small areas of the thicker seams, but it is impossible to quantify the resources because the extent of the workings not recorded on mine-plans is unknown. Certainly, there are insufficient resources for a major colliery, but scope might exist for small private mines in the area west of the Clayhanger Fault. Several of the thicker seams occur at relatively shallow depths here, but the rocks are faulted and any unrecorded coal workings, if not yet collapsed, might be liable to subsidence.

There appear to be potential resources of coal for opencast exploitation, although much of the area is built over. Twelve opencast prospects have been drilled and the Deep and Shallow seams have been worked on a small scale near Heath End. The drilling has proved substantial areas of old workings previously unrecorded, which significantly reduce the potential resources of coal. Near Coal Pool, Goscote and Pelsall, coal resources have been proved but the overburden/coal ratios were too high and the areas have now been built over. Farther north, around Ryders Hayes, substantial resources remain between the Deep and the Yard seams, where faulting brings the coals closer to the surface locally. Further details may be obtained from: The Regional Opencast Director, National Coal Board Opencast Executive, Ash Hall, Ash Bank, Stoke-on-Trent.

The coal resources of the area east of the Vigo Fault are largely unproven. There are no workings here but the coals lie at considerable depths and could only be exploited by a major colliery development, following a substantial programme of coalfield exploration and drilling.

Subsidence

The subsidence caused by coal mining is considered in relation to the two main mining areas. A suite of map overlays showing the limits of workings known in each coal seam and a mining base map showing the total known under-worked area are available.

Eastern area, between the Clayhanger and Vigo faults. This area shows the most marked subsidence effects in consequence of the working of ten seams (Lowe and others, 1984), up to, but not beyond, the bounding faults where the differential subsidence effects are concentrated.

An extensive lake [040 018] at Stubber's Green formed in about 1897, a few years after about 3.7 m of coal from the Shallow and Deep seams had been extracted. The eastern fracture of the Clayhanger Fault complex terminated these workings to the west. The size of the lake has been reduced by tipping and Stubber's Green Road crosses it on an embankment.

Farther north, the eastern fracture of the Clayhanger Fault complex defines the western limit of workings from Walsall Wood and crosses Bridge Street, Clayhanger, where tie bars and cracked masonry can be seen in the houses. Unusually steep slopes on alluvium [0395 0385] south-east of Clayhanger Sewage Works are probably also due to subsidence in workings just east of the Clayhanger Fault.

At the southern end of the Clayhanger Fault, the brick work of the canal bank [0450 0064] near Victoria Colliery has cracked and been repaired, and so has the concrete floor of a nearby factory [047 006].

Along the Vigo Fault, older buildings are affected by subsidence along Common Side [0508 0464 to 0517 0417]. The most marked effects in recent years have been at Holly Bank where Walsall District Council have plotted a line of demolished buildings (Fig.15) lying along the outcrop of the Vigo Fault. These structural failures appear to be linked to coal extraction in about 1953 from the Bottom Robins seam (see Seam Plan). This is the highest worked seam in the area and lies about 236 m below ground. Another shallow seam, the Wyrley Yard, was worked in 1963. A severely cracked, new industrial building [0520 0224] at Leighswood is adjacent to the Vigo Fault, but the workings beneath are old. An old sand pit, now infilled, underlies this site and the cracking could relate to differential compaction of the fill within the pit compared with the surrounding ground.

Besides those buildings lying close to the major faults, a number of other houses in Walsall Wood and Brownhills appear to have been affected by mining subsidence, as for instance along Lindon Road, Brownhills [0487 0424 to 0550 0459].

Western Area. Workings here are shallower than in the east. Subsidence effects due to such workings are seen, for instance, in the road surface and canal banks around [0110 0060]. These are believed to be due to the collapse of drift deposits into old workings where the Bottom Coal was worked up to its sub-drift crop ('sand fault') from the Forest and Harden collieries.

East of Birchills Junction, a cracked bridge and broken canal banks [0018 0013 to 0032 0013] lie on or close to the outcrop of the E-trending Northern Bentley Fault. Uncharted workings from Newfield Colliery on the north side of the fault probably caused this subsidence.
Boggy depressions west of Clayhanger probably mark collapsed shallow workings from Ryders Hayes, Highbridge and Moat collieries.
A patch of alluvium [009 039] east of Fishley appears to have been tilted to the west since the 1910 survey. It lies close to the limit of working in the Shallow and Deep seams from Fishley Colliery. The gently undulating nature of Pelsall Common [0225 0295] may have resulted in part from the subsidence of workings in the Deep seam at shallow depth; at least one enclosed hollow has been noted - in addition to the pool at [0217 0266]. The irregular nature of the sub-drift floor in the valley south-west of Pelsall may be due in part to subsidence. Much of the ground in the valley bottom has been tipped over; it was formerly marshy in places and two pools remain.

Subsidence potential.
Assessment of subsidence potential in the areas outlined above is complex, involving such variables as age and type of workings, groundwater conditions and anticipated land use. Quantitative data on the extent and effect of past subsidence are lacking and any predictions made must necessarily be viewed with this in mind. The problems fall into two main areas:

Eastern area between the Clayhanger and Vigo faults. Working for coal in this area was at considerable depths and took place relatively recently using modern mining methods and subsidence control. The major part of the subsidence occurred during and shortly after mining, and subsidence due to further re-adjustments since mining ceased has been noted above. This has been concentrated mainly along the boundary faults. Further major subsidence is unlikely, but minor movements close to the boundary faults cannot be discounted. The Vigo Fault, in particular, may continue to re-adjust, especially if fluid pressures along the fault zone are increased by the underground waste disposal programme (see also page 28).

Western area. Workings for coal and ironstones in this area are generally older than those in the east, and are less well-documented. The mines were shallow and locally extended to the ground surface or to the base of the drift. Mining was largely by pillar-and-stall methods. Most of the subsidence no doubt occurred long ago and there appears to be little subsidence at present but the shallower workings, where ground pressures are less, may not have collapsed. It is commonly the case that pillars are thin or in poor condition in such workings and back-filling was incomplete. Such shallow workings can fail catastrophically when loaded by modern development and are a hazard to all types of foundations. The problem is most acute where the workings lie within about 15 m of the surface. Within this area it would be adviseable for the risk of subsidence to be assessed by survey and if necessary, site investigation, before a site is developed.

12. OTHER SUBSIDENCE

Local subsidences have occurred apparently unrelated to the mining of coal or limestone. For example, a short section of the canal at Catshill [0540 0497] subsided in 1982, and the brick-built canal bed has since been replaced with reinforced concrete at this locality. The subsidence is unlikely to have been caused by coal mining as the area is east of a major fault marking the eastern edge of the worked area. As the subsidence was linear, with voids created along a line running south from the canal for about 150 m, it may have been caused by a fissure flow of water along major fault-parallel joints at or near the base of the Kidderminster Formation. Engineering difficulties associated with the infilled branch canal to Sandhills Farm may also have contributed to the problem, and the position is not clear.

Many of the disused pits, quarries and areas of low-lying ground throughout the area have been backfilled with various types of waste (Fig.13). Some have already been built over, (for example, the small pits at Walsall Wood and Birchills). As the fill compacts, minor subsidence can occur but it is progressive rather than catastrophic.

13. CLAY WORKINGS AND POTENTIAL RESOURCES

A Surface Workings overlay showing sites and areas mentioned in the text is available.

The marl industry, now largely carried on by Ibstock Aldridge working the Vigo Quarry, has been active in this area for at least 170 years. The Jobern's quarry was already a century old in 1911 at the time of Cantrill's survey. The past and present workings are almost exclusively in the Etruria Formation, a source of both red and blue brick, depending on the technique used in the firing. The large abandoned workings are now a valuable area for waste disposal in view of their impermeability. Abandoned quarries, more or less infilled with waste, are as follows:

1. Northywood and Victoria pits [041 019] were about 27 m deep in 1910 (T.C. Cantrill 1910 notebook, p.57) and contained dark red marls with a few impersistent beds of coarse-grained sandstone. They have since been totally filled and no trace exists of these deep quarries.

2. Aldridge Pit [049 022] has been extended since 1911 and has been totally filled in recent years. However, substantial deposits of marl remain under the present working kilns and stockyards.

3. Jobern's Pit [951 923] has been filled to the top of its marl and is surrounded by a rim of gravelly drift about 3 to 4 m thick. Both Aldridge and Jobern's pits include chemical waste within the fill.

4. The Empire Pit [042 023] was 21 m deep in 1911 and has been extended laterally since then. It is partially filled with solidified polymer and polymer slurry is being treated at present. Each polymer pond is divided from the next by a clay bund.

5. Springfield Pit [046 019]. This is an old excavation, already flooded in 1911. The northern half has been filled in and the southern half remains a pool to this day.

Working quarries are as follows:

1. Vigo Pit [047 026] is currently being worked to a depth of about 24 m. Its geology is described in the stratigraphical section. Some extension might be possible under old buildings at the south-west corner but in general the site is surrounded by housing and factories.

2. Highfields South. About 12 to 15 m in depth, this pit [042 025] has been worked until recently and would seem capable of considerable deepening and extension towards the south-west. A thin sandstone band occurs within the sequence.

3. Atlas Pit [044 020] is about 20 m deep. Working has been sporadic in recent years and there has been extensive slippage on the face of the quarry. The resources of the pit extend towards Stubbers Green Road beneath the existing kilns and the remainder of the dumps of Coppy Hall Colliery.

The following areas appear to contain the main potential resources of clay.

1. Dumblederry Farm. Drilling has revealed a drift-free patch, some 12 hectares in area [042 012] on the western edge of the farm, where substantial resources occur. Drift does thicken greatly to the east, however, and near Stubber's Green Road it is 30 m thick (see drift thickness map). A combined working of brick clay from the Etruria Formation and gravel from the drift might be possible.

2. The Swag - Shelfield [038 019]. There is likely to be marl here but drainage is poor except on the rising ground at Shelfield House Farm. Drift hereabouts is likely to be thick, but boreholes are rather scattered and there just might be a prospect with relatively thin drift near Shelfield House Farm, east of the Clayhanger Fault.

Three small marl pits were worked at Walsall Wood [0457 0463, 0470 0442 and 0460 0432] in the Keele Formation. It may well be that these beds proved too calcareous for good bricks since the workings were not widely developed. Highfields North, however, has been tested by two boreholes (Highfields North 1 and 2). Fortunately, the lower beds of the Keele Formation here contain less sandstone than in the Walsall Wood Shaft, but there is still a strong chance of sandstones occurring in the northern part of the Highfields North area, not yet tested by drilling. Farther north, there is a limited opportunity of marl extraction but the only modern proving, the Grange Farm borehole, showed thick drift cover and a substantial sandstone in the local succession (see Appendix 2). The overlay shows the area with over 6 m of overburden.

14. SAND AND GRAVEL WORKING AND POTENTIAL RESOURCES

The Triassic terrain is the site of four large quarries (Sand and Gravel Resources map SK 00 SE). Undoubtedly the best sand and gravel is within the Kidderminster Formation, which forms an important source of gravel, rich in tough quartzite pebbles, with the best gravel in the lower two thirds of the Formation. It is also a source of sand. The stratigraphy of individual quarries is detailed in the geological description of SK 00 SE (Price and others, 1984). The individual beds of gravel are very variable in thickness, but an attempt has been made on the sand and gravel overlay to define areas where there are substantial gravel beds. However, this is a resource map prepared on the basis of available data only, without the benefit of systematic drilling. Many boreholes would be needed to prove the resources of these areas. Much gravel remains in depth at Bliss Sand and Gravel, Aldridge [067 003], but cannot be taken out due to the proximity of the Bourne Vale Pumping Station which taps the Kidderminster Formation as an aquifer.

Substantial areas of sandy, gravelly till, possibly workable for sand and gravel, are seen in the western part of the area. Much of this terrain is built-over, however. As long as the quarries in the Kidderminster Formation are more easily worked, there will be little incentive to exploit the more limited Quaternary deposits, accessible only in corridors of open land between housing developments. The best of these areas, not at present built-over, is probably that near Goscote, in a tract [024 013] underlying thin alluvium (see Resource map).

The farmland [046 013] adjoining Stubbers Green Road, Aldridge, contains substantial fluvioglacial deposits, including gravels. Their economic potential is limited in places by clay bands and till within the drift sequences (see boreholes 231A, 234 and Appendix 2 and boreholes 18/R2, 18/R4 in Appendix 4). These deposits, however, overlie large marl reserves in the Etruria Formation and it might be worth extracting them to get at the marl.

Extensive valley tracts of fluvioglacial gravel (Older River Gravel) in the east probably contain only thin deposits (see Resource map.)

15. LANDSLIPS

In the course of mapping the Atlas Quarry, four landslips in the Etruria Formation were delineated. They are chiefly in unbedded mudstones and have arcuate back scarps overlooking slurried downfaulted masses. One slip [0453 0213] has a marked arcuate back scarp about 3 m high and has recently moved. The canal bank has recently been strengthened with an apron of rip-rap, creating an extra load on this unstable slope. Should a fresh landslip occur, the canal might be endangered.

16. CONCLUSIONS

1. The hydrogeological characteristics of the rocks relate to planning considerations in two different ways. The Kidderminster Formation is an excellent aquifer and there is a public supply pumping station in the area and two on its perimeter. Possible pollution via the new quarries in the Kidderminster Formation, particularly where waste is tipped, is an important consideration. In contrast, the Etruria Formation is, with the exception of its impersistent sandstones, much less permeable. Old quarries within it have been extensively used for waste disposal. Toxic wastes have been processed locally to make polymer, an inert solid used to back-fill pits in the Etruria Marl. The Formation also forms a cap rock for the underground disposal of toxic fluids into old mine workings in Walsall Wood and Aldridge collieries.

   At the eastern edge of these old workings stands the Vigo Fault, a line of faulted ground where some of the fissures may have been opened by mining subsidence. Provided that the fluids in the old colliery workings are not under fluid pressure, there is unlikely to be much leakage along the Vigo Fault and its associated fractures.

2. Subsidence due to coal working has been worst in Walsall Wood where mining has been most recent. Locally this can be related to movement in workings flanking the Vigo Fault.

3. Old pillar and stall limestone workings at Daw End pose a problem of land stability and there is a history of crater subsidence. Likely extensions beyond the limit of charted workings have been outlined and a possible shaft and uncharted working located south of the railway. Areas of old open workings have also been defined.

4. Active landslips in Atlas quarry pose a threat to the canal which is uphill from the quarry area in which waste disposal is likely to be carried out in the future.

5. The area contains valuable potential brick clay resources in the Etruria Formation, particularly in a new area at Dumblederry Farm. A second area at Shelfield Farm might also have resources beneath a sufficiently thin drift cover, and drilling is adviseable to test this.

6. Gravel within the Kidderminster Formation constitutes a large but laterally variable resource. Areas which should repay further examination are shown on the resource map.

17. REFERENCES

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18. GLOSSARY

The meanings of terms are defined in the context of this report and may have wider connotations elsewhere.

ARENACEOUS: consisting wholly or partly of sand-sized fragments.

ARGILLACEOUS: consisting wholly or partly of clay-sized particles.

BURIED VALLEY/CHANNEL: a depression in an ancient land surface or in bedrock, now filled by younger deposits.

DIACHRONOUS: of differing age in different areas; cutting across time planes.

(DOWN)THROW: the amount of (downward) vertical movement of a fault.

DRIFT: unconsolidated sediment, usually of glacial or more recent origin.

DYKE: tabular igneous intrusion, usually vertical or sub-vertical, which cuts across the bedding of country rock.

ERRATIC: rock fragment of any size carried by glacial ice and deposited at a distance from its outcrop.

EXTRUSIVE: igenous rock that has been erupted onto the surface of the earth.

FACIES: the aspect, appearance and characteristics of a rock unit, usually reflecting the conditions of its origin.

FLOW TILL: a superglacial till which is modified or transported by plastic mass flow.

FLUVIOGLACIAL: pertaining to glacial meltwater streams and the deposits or landforms produced by them (also glaciofluvial).

GRABEN: block of rock strata relatively lowered between two faults.

HADE: the angle that a fault (or other structural surface) makes with the vertical.

HEAD: locally-derived angular rubble, formed generally by solifluction processes in periglacial conditions.

HORST: block of rock strata relatively raised between two faults.

IGNEOUS: pertaining to rock formed by solidification of molten material (magma)

INTRUSIVE: rock formed by emplacement of magma (see IGNEOUS) in pre-existing rock.

LEACHING: selective removal of rock or soil constituents by downward water movement.

LODGEMENT TILL: a till formed beneath a glacier or ice-sheet.

MARL:originally a lime-rich clay; often used to refer to massive, structureless mudstones.

MELT-OUT TILL: till derived from slow melting of debris-rich ice, often deposited through water.

NORMAL FAULT: fault in which the hanging wall appears to have moved downwards relative to the footwall; usually of tensional origin.

PAN: hard layer in soil or rock caused by clay or mineral enrichment.

PATCHREEF: small lens of fossiliferous limestone surrounded by rock of unlike facies.

PERIGLACIAL: environmental conditions in which frost action is important; marginal to ice-sheet influence.

QUARTZITE: very hard sandstone composed predominantly of quartz grains cemented by secondary silica.

REMANIE: derived from a pre-existing formation, usually by removal of one or more components of the original.

ROCKHEAD: the upper surface of consolidated (solid) deposits; surface form after removal of drift cover.

SEATEARTH: rock generally (but not necessarily) underlying a coal seam, derived from the soil in which coal forests grew.

SILL: tabular intrusive body which tends to parallel the planar structures (especially bedding) of the country rock.

SINK: collapse of material back to surface into old workings.

SOLIFLUCTION: slow downslope movement of rock caused by alternate freezing and thawing of wet ground.

TECTONIC: pertaining to the deformation of the earth's crust.

THALWEG: line of maximum gradient along a valley long profile.

TILL: unsorted or poorly sorted glacier-derived deposit composed of clay, silt, sand, pebbles and boulders.

UNCONFORMITY: a break or gap in the geological succession during which strata were not deposited or eroded; said to be angular if there is a change of bedding dip across the time gap due to intervening tectonic activity.

19. APPENDICES

APPENDIX 1

Notes on Surface Exposures, SK 00 SW

(Locations are indicated on 1:10 000 geological sheet).
Depths and thicknesses are in metres.

A. TEMPORARY SECTION IN SEWER TRENCH [0078 0449]

Sand and gravel passing north westwards along trench into boulder clay.	3.2
Dark grey shaly mudstone with mussels	2.1
Coal	0.08
Seatearth mudstone passing down into mudstone	1.2

B. DISUSED QUARRY NOW FILLED IN [0460 0432]
(BGS photograph A1539).

Section in 1911 showed (see also Fig. 8 Section 2)

Sandy red marl	c 5.5
Soft dark red sandstone with thin conglomeratic cornstone near top	c 3.0
Red marls	c 4.6

C. VIGO QUARRY NORTH FACE [0495 0273]

See also Fig. 7, Section 2

Sand and gravel	2
Structureless mudstone mostly in variegated colours	2.7
Laminated reddish brown mudstone	1.5
Structureless mudstone mostly in variegated colours	6.5
Structureless reddish brown mudstone with three sandstones up to 2.3 m thick	11.3

D. HIGHFIELD SOUTH QUARRY [0425 0265]

(See also Fig. 7, Section 2)

KEELE FORMATION

Poorly laminated reddish-brown sandstone	0.5
Siltstone passing laterally into fine-grained purplish grey sandstone	1.5
Purplish brown siltstone	0.8
Laminated reddish-brown mudstone	0.7
Gap	1.0

ETRURIA FORMATION

Structureless mudstone mostly in variegated colours	5.5
Structureless reddish-brown mudstone	1.8

E. **VIGO PIT SOUTH FACE [0478 0253]**

(See also Fig. 7, Section 2)

Reddish-brown sandstone	0.8
Structureless mudstone dominantly reddish brown	8.6

F. **ALDRIDGE QUARRY [0485 0230]**

Now filled in

Section in 1911 showed:

Red marls with some magenta and green bands, coarse sandstone 2.4 m thick near middle

Limestone, largely nodular (Lower Wenlock Limestone) some mudstone bands (with pre-Carboniferous fault)	5.0

G. **ATLAS QUARRY [0446 0212]**

Structureless reddish-brown mudstone with bands of coarse-grained sandstone	1.25
Coarse-grained pebbly sandstone	1.20
Structureless reddish-brown mudstone	0.30

H. **ATLAS QUARRY [0439 0192]**

Structureless reddish-brown mudstone	3.0
Laminated reddish brown siltstones	1.0
Structureless reddish-brown mudstone	1.0

I. **NORTHYWOOD AND VICTORIA QUARRY [049 019]**

Completely filled in, section in 1911 showed:

Structureless reddish-brown mudstones with a few impersistent beds of coarse-grained sandstone. Pit c 27 m deep.

J. **BRAWNS WORKS LIMESTONE DIGGINGS [0358 0099]**

Now almost completely filled in

Massive limestone patch reefs formerly seen within mudstones with limestone nodules.

K. **OLD QUARRY [0285 0090]**

Former exposure in sandy gravel	4.6

L. **WINTERLY CLAY QUARRY [0349 0082]**

Now totally filled in. Section in 1911 showed:

WESTPHALIAN A	
Ferruginous yellow and buff shaly mudstones	3.0
NODULAR BEDS (TOPMOST PART)	
Nodular fossiliferous limestone and mudstone	0.6

M. **CRATER SUBSIDENCE [0373 0079]**

Now filled in

Alternating thinly bedded nodular limestone and shaly mudstone	9.1

N. **DUMP FROM BACK-SLOPE OF EXCAVATION FOR BIRLEC FACTORY [0406 0076]**

Grey clay with blocks of greenish grey sandstone and sideritic siltstone (Westphalian C)

O. **CRATER SUBSIDENCE [0374 0065]**

Clay	1.0
Grey mudstone with limestone nodules	2.5

P. **CRATER SUBSIDENCE [0379 0056]**

Stony clay	1.4

Lower Wenlock Limestone

Nodular limestone with mudstone laminae round nodules	1.8
Thickly bedded limestone, nodular towards top	1.8
Worked void	1.2

Q. **CRATER SUBSIDENCE [0370 0050]**

WESTPHALIAN A

Fine-grained cross-bedded sandstone	3.0
Siltstone	0.7

SILURIAN

Mudstone (Nodular Beds)	1.0

R. **SECTION BESIDE RAILWAY LINE [0484 0051]**

Exposed in 1911

Mudstones with a few thin limestone bands rich in fossils (Wenlock Shales) faulted against red Westphalian beds on E side.

S. **SECTION IN OLD OPEN WORKINGS [0382 0049]**

WESTPHALIAN A

Fine-grained cross-bedded sandstone	2.5

T. **SECTION BESIDE FACTORY [0428 0047]**

Stony clay	0.8
Deeply weathered khaki mudstone	1.0

U. **EXPOSURE [0377 0045]**

Well bedded fine-grained sandstone	1.5

V. **SECTION ABOVE FORMER MOUTH OF ADIT [0369 0043]**

See also Figure 3, inset view of section

WESTPHALIAN A

Fine-grained sandstone passes laterally into thinly bedded ferruginous conglomerate	0.70

SILURIAN

Gap	0.40
Calcareous mudstone	1.00
Limestone, nodular in part	0.85
Mudstone	0.08
Nodular limestone	1.90

W. **SECTION IN RAILWAY CUTTING [0334 0025 to 0383 0033]**

See Also Fig. 2, Columns, 4, 5

LOWER WENLOCK LIMESTONE

Thickly and indistinctly bedded limestone rich in compound corals	3.5-5.3
Well bedded limestone with mudstone bands	0.6-2.4

WENLOCK SHALES

Olive-brown mudstone with bands of limestone nodules	53.0

X. **EXPOSURE [0317 0023]**

Thinly bedded limestone interbedded with mudstone	0.8

Y. **EXPOSURE [0314 0019]**

Tough light grey ferruginous siltstone (Westphalian A)	0.3

Z. **OLD DIGGING FOR LIMESTONE NODULES [0349 0011]**

Clayey banks with limestone nodules rich in brachiopods	3.0
Nodular grey limestone	1.3

APENDIX 2

Selected Summary Shaft and Borehole Sections, SK 00 SW: the numbers are those of the BGS 1:10 000 Record System.

Depths and thicknesses are given in metres.

1. FISHLEY COLLIERY NO. 3 PLANT:

Downcast Shaft [0007 0491]

Drift	to	6.50
Heathen	at	13.26
Stinking	at	30.53
Yard	at	? 41.25
Bass	at	55.93
Cinder	at	66.93
Shallow	at	80.49
Deep	at	96.39

2. FISHLEY COLLIERY NO. 2 PLANT

Downcast Shaft [0059 0391]

Drift and made ground	to	8.08
Yard	at	41.20
Bass	at	51.93
Shallow	at	80.49
Deep	at	94.62

3. FISHLEY COLLIERY NO. 1 PLANT:

No. 1 Shaft [0068 0450]

Drift	to	? 6.71
Yard	at	16.26
Bass	at	? 27.43
Cinder	at	49.07
Shallow	at	59.01
Deep	at	71.58

4. **PELSALL COLLIERY:**

Upcast Shaft	[0128 0450]	
Drift	to	6.55
Heathen	at	12.39
Stinking	at	28.60
Yard	at	40.60
Bass	at	? 53.10
Cinder	at	76.58
Shallow	at	84.23
Deep	at	97.38

5. **HOPE COLLIERY:**

No. 4 Shaft	[0118 0279]	
Drift	to	6.15
Bass	at	18.42
Bottom	at	56.24

6. **GOSCOTE COLLIERY**

	[0095 0247]	
Drift	to	8.67
Yard	at	20.12
Bottom	at	64.01

12. **PELSALL HALL COLLIERY:**

No. 2 Pit	[0155 0317]	
Drift	to	5.03
Yard	at	23.16
Bass	at	31.39
Cinder	at	50.13

Shallow	at	58.52
Deep	at	62.03

13. **PELSALL HALL COLLIERY:**

No. 3 Shaft [0178 0292]

Drift	to	2.54
Yard	at	12.19
Bass	at	22.25
Cinder	at	41.76
Bottom	at	51.28

23. **MOAT COLLIERY:**

No. 1 Shaft [0285 0469]

Yard Coal	at	46.3

24. **SHAFT OF RYDER'S HAYES COLLIERY:**

[0322 0460]

Bass Coal	at	31.4

29. **WALSALL WOOD COLLIERY:**

No. 1 Shaft [0475 0423]

Made ground and drift	to	2.4
Keele Formation	to	120.7
Etruria Formation	to	270.47
Top Robins	at	343.2
Bottom Robins	at	374.9
Wyrley Yard	at	378.6
Charles	at	386.5

?Eight Foot (Wyrley Bottom)	at	434.3
Shallow	at	497.9
Deep	at	513.8

34. **ALDRIDGE COLLIERY:**

No. 1 Plant [0473 0238]

(see also Fig. 6, Section 4, Fig. 7, Section 4)

Made ground	to	6.7
Sandy clay (suspect record)	to	12.0
Etruria Formation	to	152.4
Top Robins	at	200.3
Bottom Robins	at	236.5
Charles	at	254.5
Brooch	at	265.8
Shallow and Deep	at	408.4

35. **WOODHALL COLLIERY SHAFT:**

[0015 0125]

Sand and gravel	to	4.0
Yard	at	13.7

41. **FOREST COLLIERY:**

No. 11 Shaft [0054 0110]

Yard	at	20.1
Bass	at	32.9
Cinder	at	42.4
Top of Green rock	at	51.2
Base of Green rock	at	76.8
Bottom	at	80.5

56. **COPPY HALL COLLIERY**

No.1 (Downcast Shaft) [0453 0177]

(See also Fig. 6, Section 5)

Red marl	to	64.2
Bottom Robins (Seven Foot)	at	196.6
Wyrley Yard (Four Foot)	at	207.5
Charles (Five Foot)	at	218.5
Brooch (Three Foot)	at	232.2
Stinking (Sulphur)	at	328.3
Yard	at	340.1
Cinder (Fireclay)	at	360.3
Shallow and Deep	at	381.7

57. **VICTORIA COLLIERY, SPEEDWELL PIT:**

[0499 0066]

(See also Fig. 6, Section 7)

Sand and loam	to	13
Top Robins	at	39.3
Bottom Robins	at	79.55
Four Foot	at	92.4
Charles?	at	113.9
Yard	at	121

71. **BIRLEC NO. 2** **[0406 0080]**

Drilled prior to excavation of the Birlec Site.

Stony clay	to	0.70
Shaly mudstone	to	3.35
Coal (Top Robins)	to	4.57
Chiefly shaly mudstone	to	7.00
Coal (Top Robins)	to	8.38
Chiefly shaly mudstone	to	24.40

89. **[0075 0315]**

Fill	1.8
Grey, green, and brown sandy stony clay	6.1
Black shale	-

102. **MANOR FARM**

No. 1 Borehole [0305 0054]

Reputed Drift (Suspect)	to	3.05
Westphalian A	to	8.7
Lower Ludlow Shales	to	20.0
Upper Wenlock Limestone	to	22.9
Nodular Beds	to	57.4
Lower Wenlock Limestone	to	67.1
Wenlock Shales	to	80.0

103. **MANOR FARM**

No. 2 Borehole [0293 0057]

(see also Fig. 4, Section 6)

No Core	to	6.1
Westphalian A	to	20.2
Lower Ludlow Shales	to	32.2
Upper Wenlock Limestone	to	39.0
Nodular Beds	to	70.9
Lower Wenlock Limestone	to	81.4
Wenlock Shales	to	94.0

104. **MANOR FARM**

No. 3 Borehole [0276 0062]

(see also Fig. 2, column 1, Fig. 4, Section 6)

Entire core at BGS Gorst Road Rock Store, London

Drift (thought to be weathered solid on basis of later Geotechnical Survey)	to	c 5.0
Westphalian A		
Mudstone with some ironstone bands	to	15.0
Seatearth Sandstone	to	16.2
Seatearth Mudstone	to	16.6
Fine to coarse-grained sandstone	to	19.9
Mudstone with *Planolites*?, seatearth in part	to	20.9
Chiefly mudstone, seatearth at base	to	22.3
Lower Ludlow Shales		
Grey and greenish grey mudstones with scattered limestone nodules becoming abundant near base, brachiopods, trilobites	to	48.5
Fullers Earth Bed, pale greenish grey mudstone	to	48.8
Upper Wenlock Limestone		
Pale brown limestone	to	50.3
Greenish grey mudstone	to	50.5
Grey and light grey nodular limestone with 30-45% mudstone	to	55.5
Nodular Beds		
Mudstone with 40% limestone nodules	to	60.5
Grey nodular limestone with 25% mudstone	to	67.0

Mudstone with c 40% limestone nodules	to	72.2
Light grey limestone	to	73.2
Dark grey mudstone with many limestone nodules, corals and brachiopods	to	86.9

Lower Wenlock Limestone

Light brownish grey irregularly bedded limestone, nodular near top	to	97.0
Nodular limestone with mudstone	to	98.7

Wenlock Shales

Grey mudstone with limestone nodules	to	107.3

161. **GOSCOTE HALL COLLIERY**

No. 2 Shaft [0142 0172]

Drift	to	19.8
?Bass	at	27.1
?Cinder (4 leaves)	at	36.3
Bottom	at	57.0

185. **BOREHOLE 19** **[0388 0457]**

Soil sand and gravel	to	1.8
Clay with gravel and cobbles	to	5.2
Red marl with sandstone bands	to	8.6
Red mudstone, part conglomeratic	to	17.1
Red marl with thin sandstone bands	to	28.6

189. **BOREHOLE 23** **[0382 0495]**

Soil, sand and gravel	to	6.4
Sandy clay with gravel	to	19.6
Red marly clay	to	25.9
Red marly clay with sandstone bands	to	30.5

204. **PELSALL RELIEF SEWER**

No. 1 Borehole [0236 0327]

Fill	to	0.9
Fine sand	to	1.2
Sandy clay	to	3.3
Sand and gravel	to	3.6

205. **PELSALL RELIEF SEWER**

No. 2 Borehole [0240 0306]

Fill on sand	to	3.55
Sandy stony clay	to	1.55
Sand and gravel	to	2.90

206. **PELSALL RELIEF SEWER**

No. 3 Borehole [0247 0287]

Fill	to	1.25
Silty sand	to	0.07
Sand and silt	to	3.20

211. **[0145 0205]**

Soil	to	0.6
Sand and gravel	to	11.4

sandy stony clay	to	1.5
Grey shale	to	13.6
Sandstone	to	4.4
Coal (disturbed)	to	c 1.5
Grey shale	to	1.2

217. **NEWFIELD COLLIERY**

No. 1 Shaft [0022 0069]

Soil, clay and gravel	to	4.6
?Stinking	at	4.9
Yard	at	25.6
Bass	at	46.6

218. **NORTH WALSALL COLLIERY SHAFT [0097 0028]**

Gravel and sand	to	20.1
Clod (?clay or shale)	to	21.9
Bottom	to	25.9

220. **EMPIRE BRICK QUARRY**

No. 1 Borehole [0388 0224]

Brown clay and gravel	to	3.5
Chocolate brown and variegated mudstone with 14 sandstone bands varying from fine-grained to coarse-grained conglomerate sandstones up to 1.8 m in thickness	to	61.6

222. **EMPIRE BRICK QUARRY**

No. 3 Borehole [0420 0229]

(see also Fig. 7, Section 3)

Made ground	to	0.6
Mottled mudstone with two thin sandstones to 0.2 m	to	2.2
Brown siltstone	to	0.8
Medium to coarse-grained sandstone, conglomerate at base with thin mudstone partings	to	3.1
Chocolate brown mudstone, mottled near top	to	1.6
Sandstone passing down into conglomerate with some mudstone (probably same as 1.2 mudstone in quarry base)	to	1.6
Mottled mudstone alternating with chocolate brown	to	11.2
Purplish brown mudstone	to	7.2
Fine to medium-grained sandstone	to	1.0
Chiefly siltstone	to	0.8

223. **EMPIRE BRICK QUARRY [0425 0225]**

Composite section measured by NCB.

(See also Fig. 7, Section 3)

Sand and gravel with clay lenses	to	2.1
Coarse-grained, purplish sandstone with mudstone bands	to	2.3
Purplish brown silty structureless mudstone	to	3.4
Coarse-grained sandstone with some pebbles	to	1.2
Brown structureless mudstone with two 0.4 m sandstones	to	6.0
Gap	to	1.2

Very coarse-grained sandstone, fine at top	to	1.8
Very silty reddish-brown mudstone	to	4.6
Medium to coarse-grained sandstone	to	1.2
Reddish-brown mudstone	to	0.9

224. **GRANGE FARM BOREHOLE** **[0384 0343]**

(See also Fig. 8, Section 3)

Superficial Deposits

Rock bit	to	2.7
Pebbly silty clay and loamy sand	to	4.7
Sand	to	5.3
Stony clay	to	6.9
Gravel	to	7.3
Contorted mudstone	to	7.8
Silty pebbly clay	to	8.5

Keele Formation

Purplish brown structureless mudstone, brecciated near top	to	11.15
Limestone with <u>Spirorbis</u>	to	11.46
Purplish brown mudstone	to	12.8
Purplish brown medium-grained sst.	to	17.4
No Core	to	18.9
Purplish grey mudstone	to	21.95

225. **BOREHOLE A1** **[0035 0053]**

Fill		1.5
Drift (Sandy Till)	to	6.0
Stinking	at	12.6
Yard	at	27.7

227/15A [0342 0378]

Soil	to	0.2
Clayey sand and gravel	to	1.1
Silty clay with gravel	to	5.7

228. **HIGHFIELDS NORTH**

Borehole No. 1 [0406 0279]

(see Fig. 8, Section 4 for details)

Open hole	to	0.9
Stony clay	to	8.2

Keele Formation

Mudstone (see Fig. 8 for details)	to	24.9
Coarse-grained sandstone	to	25.5
Mudstone (see Fig. 8 for details)	to	30.5

229. **HIGHFIELDS NORTH**

Borehole No. 2 [0383 0253]

(See Fig. 7, Section 4 for details)

Silty organic clay	to	0.9
Pebbly clay	to	5.5
Plastic clay, rare pebbles near base	to	9.1
Stiff pebbly clay	to	9.9

Keele Formation

Mudstone (see Fig. 8 for details)	to	25.2
Coarse-grained sandstone	to	28.4
Chiefly mudstone	to	32.3

Fine-grained sandstone	to	33.8
Mudstone	to	35.7

230. **BOREHOLE 1** **[0234 0120]**

Asphalt and fill	to	1.0
Clayey peat with gravel	to	1.2
Gravel with sand	to	2.3
Silty sand with gravel	to	2.6
Coarse sand with gravel	to	3.4

231A **McKECHNIE METALS**

No. 1 Borehole [0477 0088]

Made Ground	to	2.90

Fluvioglacial

Silty clayey sand with a little gravel	to	6.65
Sand and silty clay with some gravel	to	7.50

Devensian Till

Stiff red brown sandy clay with some stones	to	10.45

233. **DUMBLEDERRY**

Borehole 1 [0454 0112]

Open Hole Drilling, (See also Fig. 7, Section 7)

Boulder Clay	to	2.7

Etruria Formation

Marl, (see Fig. 7 for details)	to	30.5

234. **DUMBLEDERRY**

Borehole 2 [0482 0134]

Chiefly sand and gravel	to	5.5
Sand with clay bands	to	7.3
Soft red marly clay	to	12.8
Clay with sand and gravel	to	30.5

235. **DUMBLEDERRY**

Borehole 3 [0455 0147]

Open Hole drilling. (See also Fig. 7, Section 8)

Clay sand and gravel	to	6.1
Red marly clay and gravel	to	8.2

Etruria Formation

Red and grey marls with sandstones (see Fig. 7 for details)	to	30.5

236. **DUMBLEDERRY**

Borehole 4 [0420 0152]

(See also Fig. 7, Section 6)

Chiefly sand and gravel	to	5.5
Sandy clay	to	7.6

Etruria Formation

Marls (see Fig. 7 for details)	to	30.5

237. **DUMBLEDERRY**

Borehole 5 [0419 0114]

(See also Fig. 7, Section 9)

Top soil	to	0.5
Etruria Formation		
Marls (see Fig. 7 for details)	to	30.5

244. **CANNOCK RELIEF SEWER**

No. 117 Borehole [0096 0437]

Soil and stony clay	to	3.7
Weathered ?dolerite	to	6.1
Dolerite	to	7.0
Coal and black mudstone	to	0.3
Grey mudstone	to	2.4
COAL	to	0.6
Grey sandstone	to	4.6
Grey mudstone	to	14.9

247. **CANNOCK RELIEF SEWER**

No. 123 Borehole [0097 0376]

Boulder clay	to	18.9
Grey-green sandstone	to	2.1
Grey sandy mudstone	to	4.0
Grey sandstone	to	1.5
COAL	to	0.9
Grey sandy mudstone	to	6.1

263. **CANNOCK RELIEF SEWER**

Borehole No. 8a [0081 0447]

Soil on stony sandy clay	to	2.0
Gravel	to	1.0
Grey clay and mudstone	to	5.0

296. **CANNOCK RELIEF SEWER**

Borehole No. 35 [0135 0291]

Fill	to	1.25
Sandy gravel	to	4.55
Mudstone and clay	to	2.20

299. **DAW END (SUMMARY LOG)**

Borehole No. 101 [0335 0093]

(See Fig. 2, Columns 2, 3 for details)

No recovery	to	4.71
WESTPHALIAN A		
Fine-grained sandstone	to	5.37
Mudstone and siltstone	to	5.67
Fine-grained seatearth sandstone	to	7.34
LOWER LUDLOW SHALES	to	16.43
UPPER WENLOCK LIMESTONE	to	c 21.80
NODULAR BEDS	to	54.83
LOWER WENLOCK LIMESTONE	to	65.08
WENLOCK SHALES	to	70.18

300. **DAW END**

Borehole No. 101A [0336 0091]

No core	to	11.72
Collapsed beds	to	16.93
Nodular beds	to	22.31
No core	to	41.52
Nodular beds	to	54.48
Lower Wenlock Limestone	to	55.96
Worked out void (Lower Wenlock Limestone)	to	62.55
Collapsed strata	to	63.55
Wenlock Shales-Lower Wenlock Limestone Passage Beds	to	65.05

301. **DAW END**

Borehole 102 [0042 0081]

No core	to	8.30
Lower Ludlow Shales?	to	9.75
Upper Wenlock Limestone on collapsed beds	to	11.73
Nodular beds	to	47.02
Worked out void (Lower Wenlock Limestone)	to	53.38
Collapsed strata	to	56.67
Wenlock Shales	to	59.61

302. **DAW END**

Borehole 104 [0343 0068]

No core	to	2.94
WESTPHALIAN A	to	5.53
LOWER LUDLOW SHALES?	to	8.43

NODULAR BEDS	to	14.47
No core	to	35.78
Collapsed strata with some less disturbed nodular beds (collapse into Lower Wenlock Limestone workings)	to	53.06
Wenlock Shales	to	56.41

303. **LAVENDER'S SHAFT** [0280 0020] to 71.3 m

Captain limestone	at	63.4
Estimated top of Lower Wenlock Limestone	at	59.8

304. **SITE INVESTIGATION BOREHOLE [0338 0052]**

Fill	to	3.40

PROBABLE WESTPHALIAN A

Olive grey clay (Drillers log)	to	5.50
Siltstone with sphaerosiderite	to	7.40
Silty mudstone, clay flake - breccia at base	to	9.55

SILURIAN - NODULAR BEDS

Limestone nodules in a matrix of 30-70% mudstone	to	14.85

APPENDIX 3

Notes on Surface Exposures, SK 00 SE (in order from north to south).

Depths and thicknesses in metres.

A CATSHILL [0538 0497]

Made Ground		0 - 0.7
Abundant pebbles in orange sand		0.5
Abundant pebbles in grey sand		0.3
Abundant pebbles in pale orange sand		0.5
Dark orange-brown sand with pebbles	at least	0.2

B SHIRE OAK QUARRY [0627 0433] AT 147m AOD

Sand and sand with pebbles	1.0
Green silty clay	0.3
Sandstone with few pebbles	2.0
Cross-bedded sandstone	0.61
Sandstone with small pebbles in thin bands	0.6
Silty sandstone	0.09
Sandstone with small pebbles in thin bands	0.32
Abundant pebbles	0.48
Green laminated siltstone	0.10
Irregular sandstone	0 - 0.18
Abundant large pebbles with rare thin sandstone lenses	7.0
Finely laminated sandstone	0.32
Abundant large pebbles	0.85
Cross-bedded sandstone	0.62
Abundant large pebbles	0.75
Sandstone	0.13
Abundant small pebbles	0.31
Pebbly sandstone	0.6
Abundant large pebbles	0.25
Very pebbly sandstone	0.3
Abundant large pebbles	2.3
Sandstone	

C SHIRE OAK QUARRY [0620 0429] AT 137m AOD

Abundant large pebbles	1.5
Hard sandstone	3.5
Sandstone with small pebbles	0.5
Hard sandstone	4.5
Abundant large pebbles, with channel	3.5
Sandstone	0.5
Abundant small and large pebbles with thin sandstone	0.5
Sandstone	0.5
Abundant large pebbles with sandstone	5.0

D SHIRE OAK QUARRY [0640 0428] AT 142m AOD

Abundant pebbles in sandstone	1.0
Massive sandstone with rare cross-bedding	5.0
Siltstone, broken up and rafted in part	0 - 0.3
Massive cross-bedded sandstone	5.0
Abundant pebbles, with thin, impersistent sandstones	11.0

E SHIRE OAK QUARRY [0610 0404] AT 161m AOD

Alternating mudstone and siltstone	3.0
Cross-bedded sandstone	1.2
Thin siltstone	c. 0.1
Sandstone	0.48
Abundant large pebbles	2.0
Sandstone with few pebbles	1.92
Abundant large pebbles	2.4

F SHIRE OAK QUARRY [0629 0403]

Fault slickensiding and mineralisation. Fault trends 098/60^{o}N, downthrow to the south.

G CHESTER ROAD QUARRY [0578 0392] AT 183m AOD

Numerous small faults downthrowing west, with 6m of abundant pebbles to the west and rapidly alternating sandstone and abundant pebbles east.

H CHESTER ROAD QUARRY [0582 0380] AT 185m AOD

Sand with impersistent pebbly bands	1.0
Abundant pebbles	0.2-0.3
Sand, split by an impersistent pebbly band	2.0
Abundant pebbles with irregular sand bands, grading into the sand above	2.3

I CHESTER ROAD QUARRY [0609 0376] AT 175m AOD

Pebbles and soil	1.0
Cross-bedded sand with few pebbles	2.5
Hard sandstone with mudstone fragments	0.35
Hard cross-bedded sandstone with rare pebble bands	0.38
Graded pebbly sand with large mudstone fragments	0.6
Coarse, poorly sorted abundant pebbles	2.0

J DISUSED QUARRY [0640 0341]

2-4m of sandstone, with abundant cross-bedding and many scattered pebbles, several small faults, downthrow north.

K ALDRIDGE QUARRY [0654 0265] AT 167m AOD

Abundant pebbles	c.1.0
Soft sand with few pebbles	c.7.0
Hard mudstone	0.32
Hard sandstone	0.92

L ALDRIDGE QUARRY [0668 0263] AT 163m AOD

Abundant pebbles (made ground)	0 - 2.0
Poorly bedded sandstone with channels, impersistent mudstone and mudstone clasts	5.0
Sandstone beneath thin mudstone	0.9
Sandstone with impersistent thin mudstone, beneath thin mudstone	1.7
Sandstone with few pebbles, cross-bedding and contorted bedding below thin mudstone	2.5
Sandstone with cross-bedding, mudstone clasts and pebbles, below thin mudstone	4.6
Mudstone, in part green	0.87-1.2

M ALDRIDGE QUARRY [0679 0258] AT 160m AOD

Soil and pebbles over abundant pebbles with sand lenses (Made ground)	2.0
Pale sand with trough- and cross-bedding	1.2
Dark sandstone with abundant cross-bedding and hard sandstone ribs	3.0
Hard muddy sandstone rib	0.4
Sand	2.2

N ALDRIDGE QUARRY [0654 0254] AT 172m AOD

Abundant pebbles	7.0
Soft sand	6.0

O FORMER SECTION IN JOBERNS' QUARRY [0515 0232]

Weathered marls	2.4-3.0
Sandstone	1.8-2.4
Red marl	3.1-3.7
Sandstone	1.2-1.5
Red marl with thin sandstones about	15.0

P EXPOSURE [0522 0208]

Sand and gravel partially seen	4.0
Fox earth in much reddish brown sand.	

Q TEMPORARY PIT [1504 0181]

Made Ground	1.0
Reddish brown marl	2.0

R OLD MARL QUARRY [0558 0149]

Stony clay	1.0
Reddish brown structureless mudstone	0.5

S FORMER EXPOSURE [0585 0095]

Sandy gravel	0.9
Medium-grained dark red soft sandstone with pebbles of red mudstone and a few of quartz	2.44

T EXPOSURE [0631 0031]

Fine-grained soft reddish brown sandstone with a few pebbles	0.5

U BLISS SAND AND GRAVEL [0648 0030]

Fine-grained reddish brown sandstone	4.7
Reddish brown mudstone	0 - 0.2
Pebbles with many quartzite pebbles	5.8
Gap to quarry floor in reputed pebbles	5.0

V BLISS SAND AND GRAVEL [0690 0011]

Sandstone with pebble bands passing westwards into sandstone	5.5
Fine-grained reddish brown sandstone	9.0
Coarse-grained pebbly sandstone	3.6
Gap	1.3
Fine-grained reddish brown sandstone	2.0

W BLISS SAND AND GRAVEL [0704 0006]

Pebbles with sandstone lenses	3.0
Fine-grained reddish brown sandstone	8.1
Pebbly sandstone	1.0

APPENDIX 4

Selected Summary Borehole Logs, SK 00 SE: the numbers are those of the BGS 1:10 000 Records system.

Depths and thicknesses are in metres.

3 WALSALL WOOD COLLIERY UNDERGROUND BOREHOLE NO 9

[0515 0356] Downwards from Bottom Robins Horizon, commenced at -108.2m AOD.

Wyrley Yard (Four Foot)	at	7.54
Aegiranum (Charles) Marine Band	at	16.07
Charles (Five Foot)	at	20.57
Brooch	at	31.47
Maltby (Sub-Brooch) Marine Band	at	34.24
Coal	at	59.58
Coal	at	62.36
Coal	at	66.75
Coal	at	72.82
Coal	at	79.34

4 LYNN HOUSE FARM BOREHOLE [0781 0454] at 125m AOD

Soil	to	0.30
Clayey sandstone	to	16.76
Light red sandstone	to	24.69
Marl	to	27.43
Fine-grained red-brown sandstone	to	41.76
Marl	to	42.06
Dark red sandstone	to	49.99
Marl	to	50.14
Coarse-grained, light red sandstone	to	68.28
Marl	to	68.35
Coarse-grained, buff sandstone with pebbles	to	76.20

5 CHESTER ROAD, STONNAL BOREHOLE [0594 0396] at 175m AOD

Existing dug well	to	17.7
Pebbly sandstone	to	21.0
Pebbly conglomerate	to	23.2
Marl with thin layers of sandstone	to	28.7

Pebbly marl	to 35.7
Marl	to 43.6
Pebbly marl	to 46.9
Pebbly sandstone	to 47.9
Sandstone	to 49.4
Marl	to 64.3

6 SWAN FARM BOREHOLE [0835 0379] at 115m AOD

Soil	to 0.30
Brown stony clay	to 1.52
Sandy clay	to 3.66
'Matted' gravel, and sand and gravel	to 10.06
Hard marly sandstone	to 21.34

7 SHIREOAK BREWERY BOREHOLE [0570 0425] at 173m AOD

Pebbly conglomerate	to 25.60
Red sandstone	to 30.78
Red marl, sandy near the base	to 43.13
Yellow rock	to 45.22
Soft sandstone	to 46.34
Conglomerate	to 46.95
Marl with thin sandstone bands	to 53.33
Soft sandstone	to 55.49
Marl	to 57.34
Alternating marl and sandstone, undifferentiated	to 91.44

13 LICHFIELD ROAD, SHIRE OAK, BOREHOLE [0600 0420] at 164m AOD

Pebbly congolomerate	to 21.0
Red clay	to 24.4
Marl and sandstone in bands of 0.7m	to 50.3
Soft marl	to 56.7
Soft sandstone	to 62.8
Marl	to 67.4
Sandstone	to 75.6
Marl	to 76.2

15 LEIGH'S WOOD COLLIERY NO 3 PIT NO.2 PLANT [0501 0163]

Clay and sand	to 2.7
Etruria Formation	to 109.7
Top Robins	at 160.5
Bottom Robins	at 198.7
Wyrley Yard(Four Foot)	at 207.3
Charles (Five Foot)	at 218.8
Brooch	at 232.0
Shallow & Deep	at 375.4

18/R4 BOREHOLE [0530 0054]

Chiefly sand and gravel	to 3.50
Stony clay	to 7.31
Chiefly red and purple marl	to 17.98
Purple sandstone	to 18.59
Red and purple marl	to 24.38

18/R2 BOREHOLE [0510 0050]

Sand and gravel	to 1.22
Stony clay with some sand	to 7.92
Sand and gravel	to 17.95
Stony clay	to 17.68
Grey mudstones with sandstone bands	to 30.48

24-25 SANDHILLS PUMPING STATION BOREHOLES [0676 0496 and 0676 0494] at 123m AOD

Soil	to 0.5-0.8
Gravel	to 1.2-1.4
Sandy marl	to 1.8-2.0
Red sandstone and marl	3.4-3.7
Red sandstone with thin marl bands	to 11.3-11.6
Fine red sandstone	to 15.2-16.3
Red sandstone	to 23.8
Red sandstone with micaceous partings	30 -30.8
Red sandstones with a few pebbles, mottled in the lower half	to 37.8
Red sandstone with pebbles and marl partings	to 41.8-41.9
Red sandy marl	to 42.4-42.5
Hard red sandstone with pebbles	to 46.6-48.2
Coarse red sandstone with pebbles	to 47.7-48.9
Pebbly conglomerate	to 50.3-51.8
Red sandstones with pebbles, nodules of marl and marl bands	to 69.6
Red sandstone with pebbles and impersistent pebbly conglomerate	to 72.7-72.8
Pebbly conglomerate	to 82.6-82.9
Red sandstone with few pebbles and pebbly conglomerate bands	to 93.0-93.3
Red sandstone with bands of red and grey marl	to 94.0-94.3
Pebbly conglomerate	to 113.4-113.7
Red sandstone with small pebbles and nodules of marl	to 121.6
Red marl with bands of sandstone and grey marl	to 151.3-151.5
Light red sandstone with thin bands of red sandy marl	to 160.0

29-34 CATSHILL BOREHOLES (BRITISH WATERWAYS BOARD) c.[0543 0497] at 144m AOD

Topsoil	0.2-1.1
Clayey sand and gravel	to 3.4-5.9
Red medium-grained sand with pebbles and occasional mudstone bands	to 31.0-32.6
Thin bedded sandstone and mudstone	to 35.0-40.0

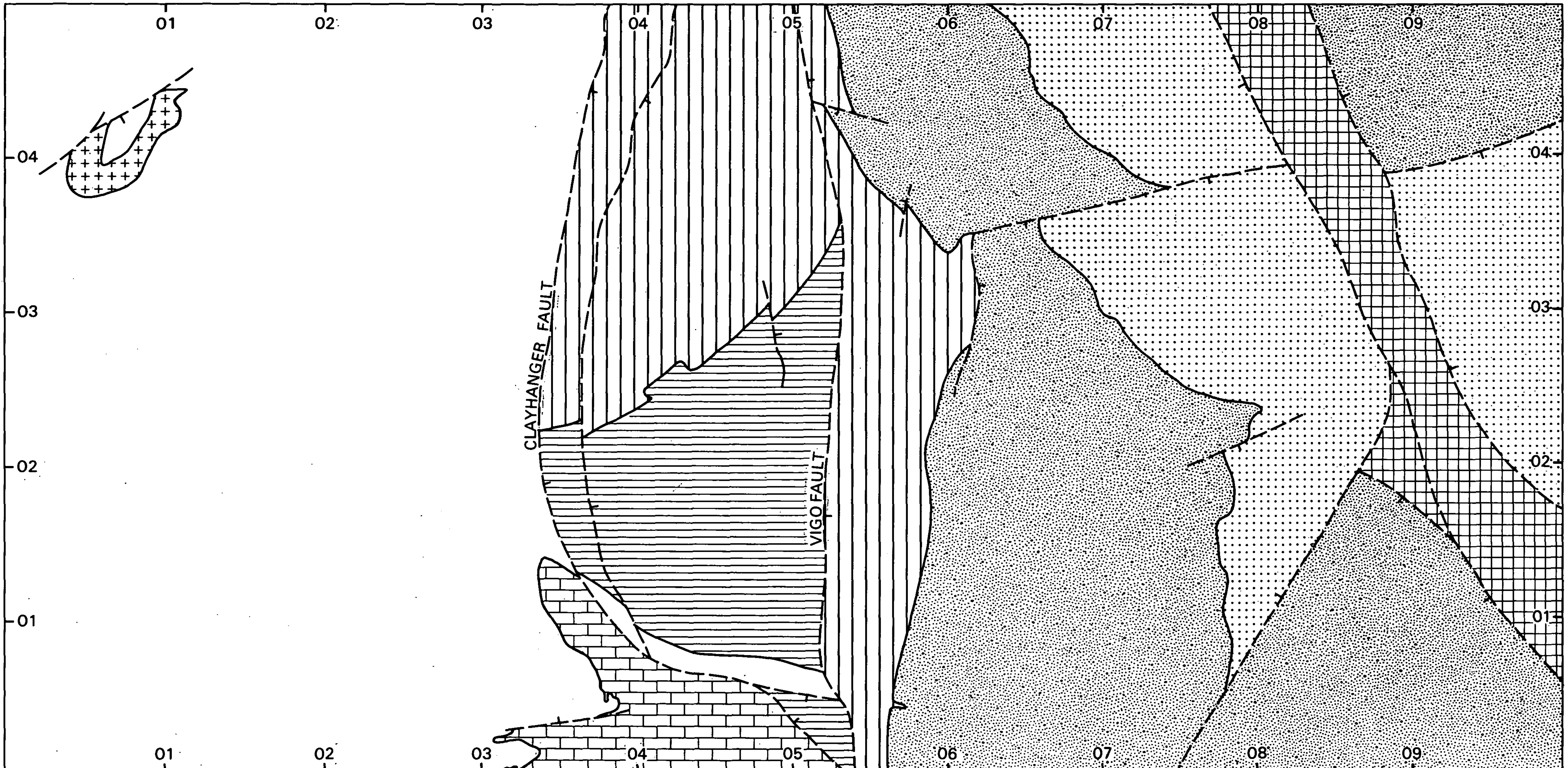


FIGURE 1

SKETCH MAP TO SHOW THE GENERALIZED SOLID GEOLOGY OF THE ALDRIDGE – BROWNHILLS AREA

Scale

0 ½ 1 2 kilometres

Triassic:
- Wildmoor Sandstone Formation
- Kidderminster Formation

Carboniferous:
- Bowhills Formation
- Keele Formation
- Etruria Formation
- Productive Coal Measures

Silurian, undifferentiated

Dolerite

Geological boundary, Solid

Fault at surface, crossmark indicates downthrow side

Note: to avoid confusion only those faults forming geological boundaries are shown on this map, for fuller details of structure see Figure 10

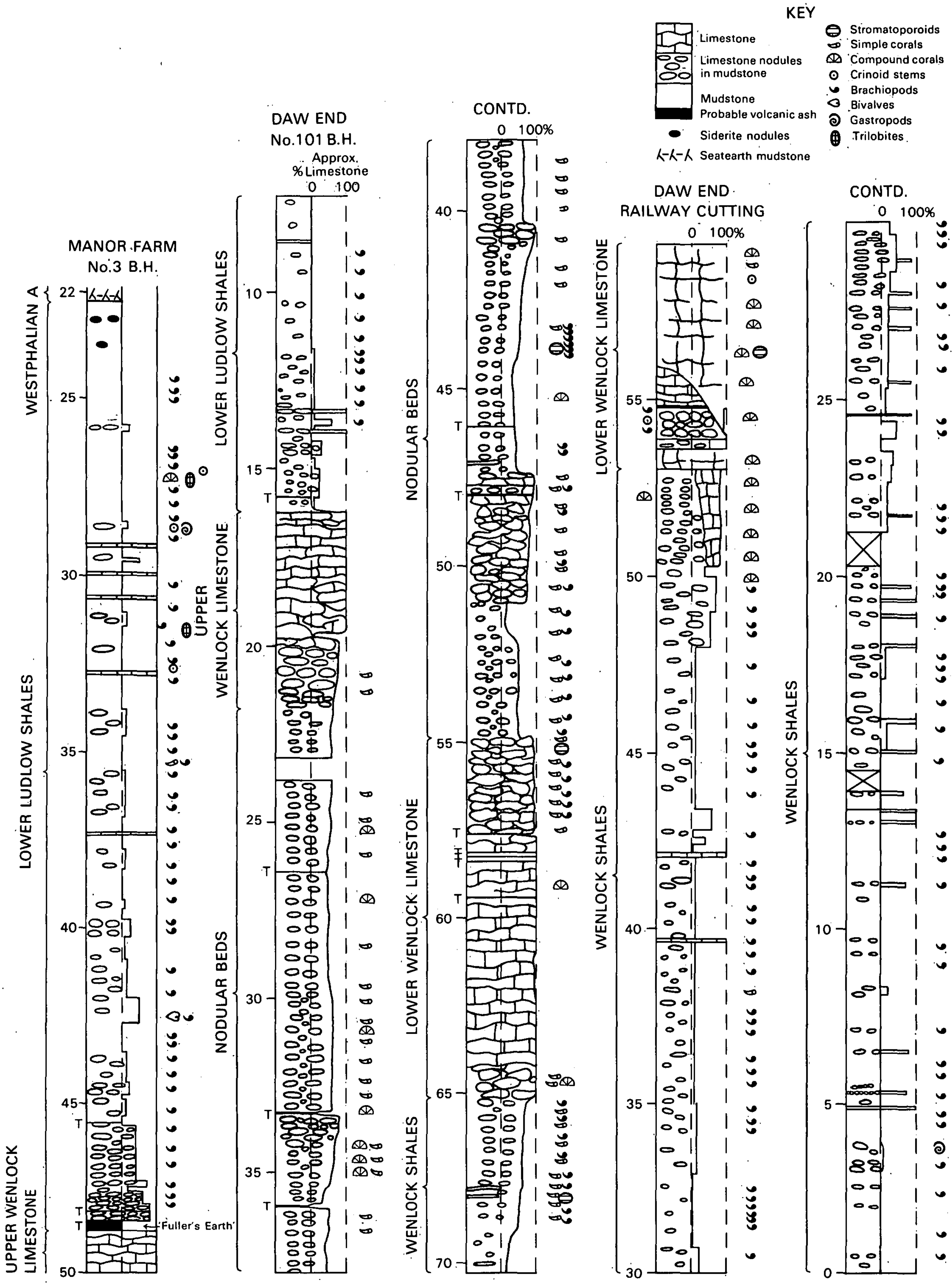


Fig.2 Silurian strata in boreholes and surface exposures at Daw End.

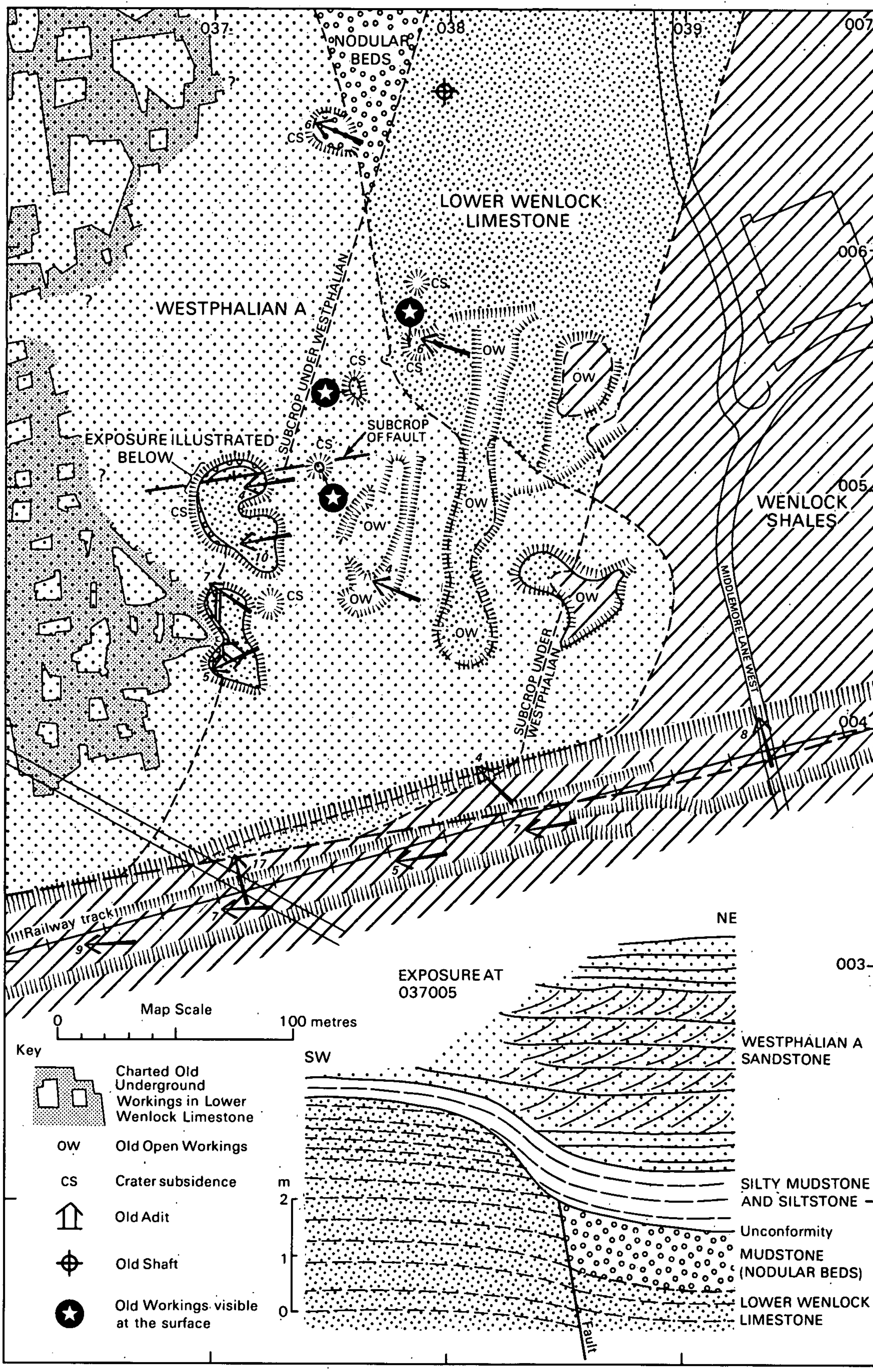


Fig. 3 Relationships of Westphalian A with the underlying Silurian rocks near Daw End

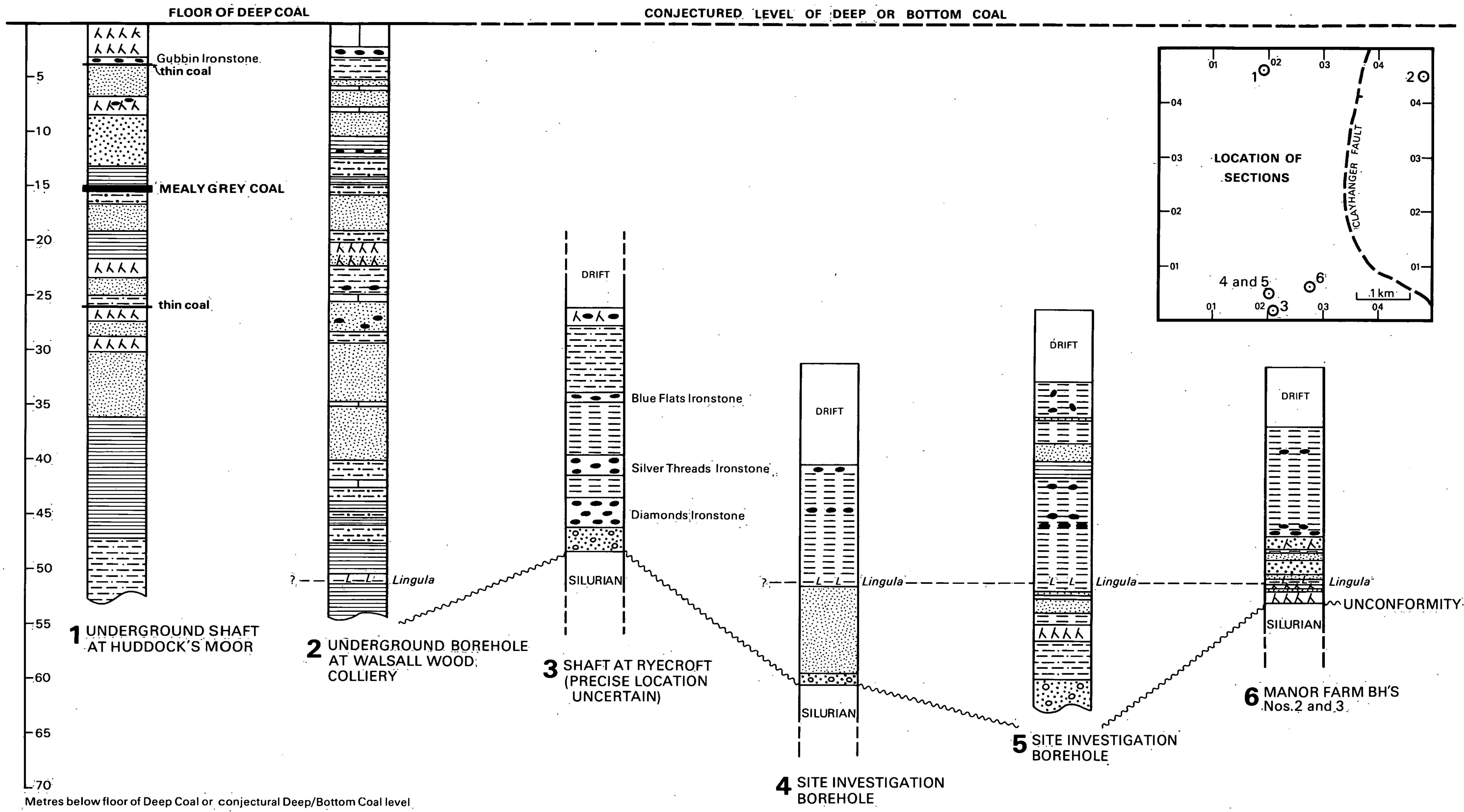


Fig. 4 Variation of Measures Below the Deep or Bottom Coal, SK00SW
(Symbols as on Fig. 8)

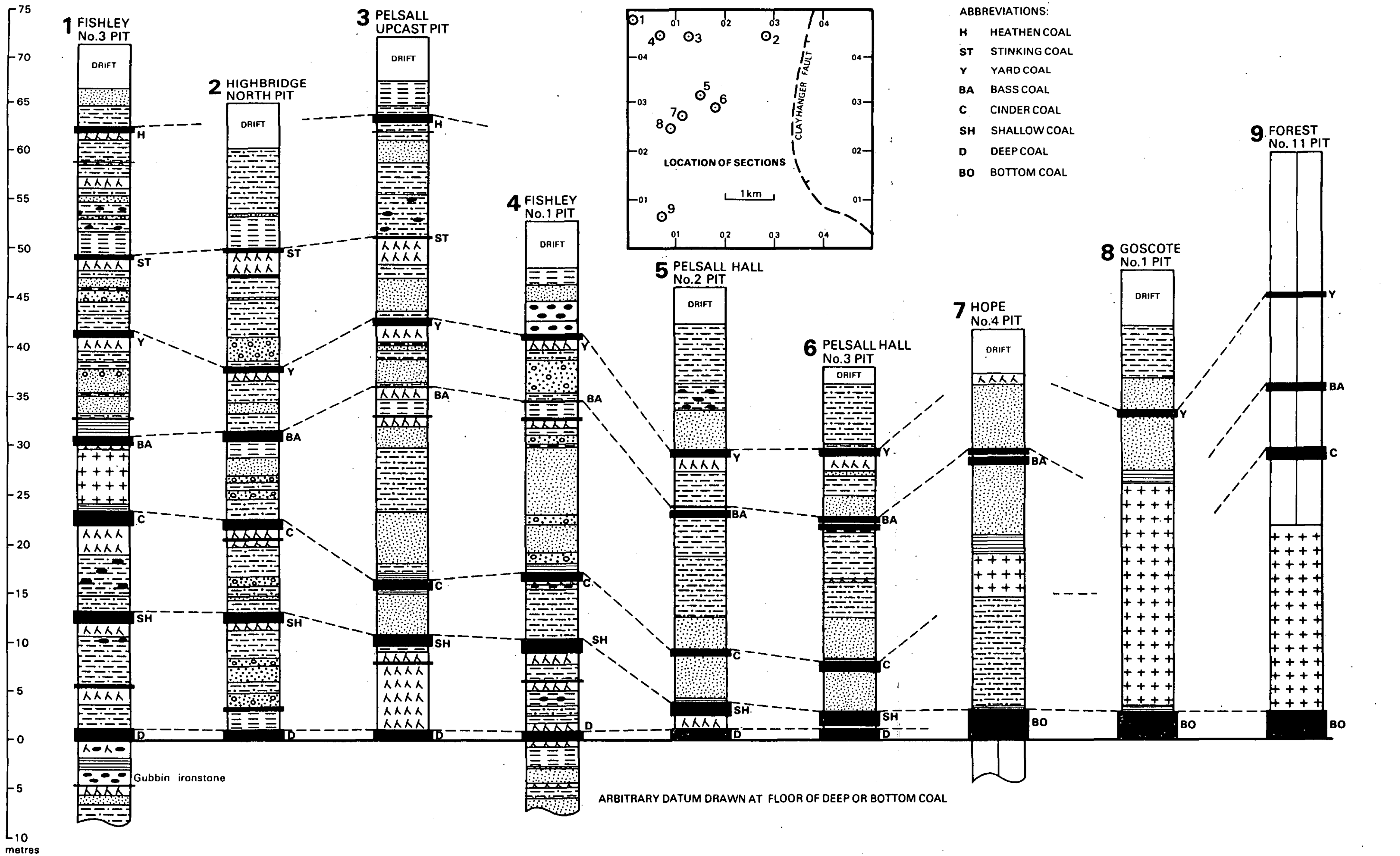


Fig. 5 Correlation of Westphalian Strata West of the Clayhanger Fault, SK 00 SW

(Symbols as on Fig. 8)

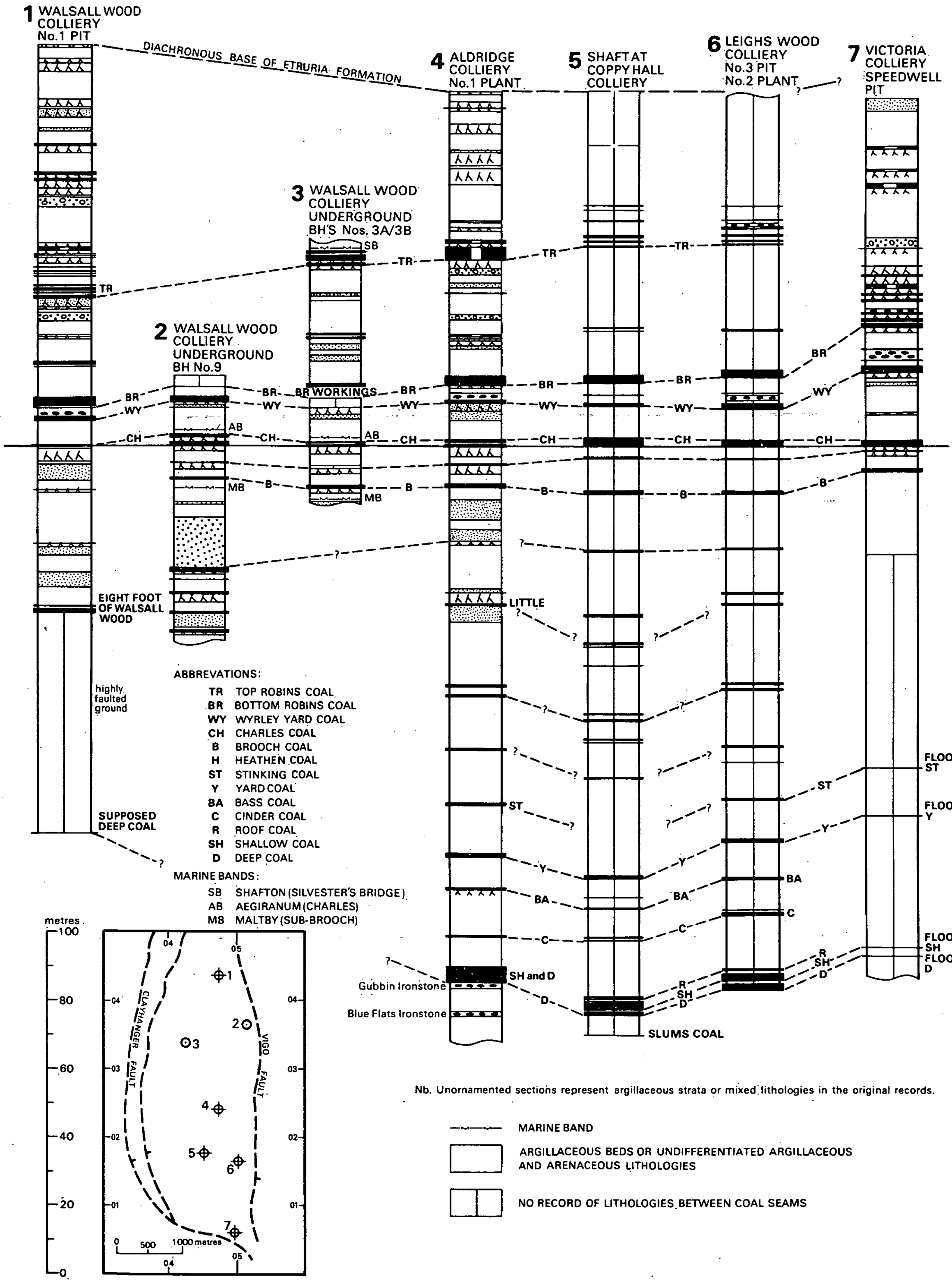


Fig. 6 Correlation of coal seams between the Clayhanger and Vigo Faults, SK00SW and 00SE (Symbols as on Fig. 8)

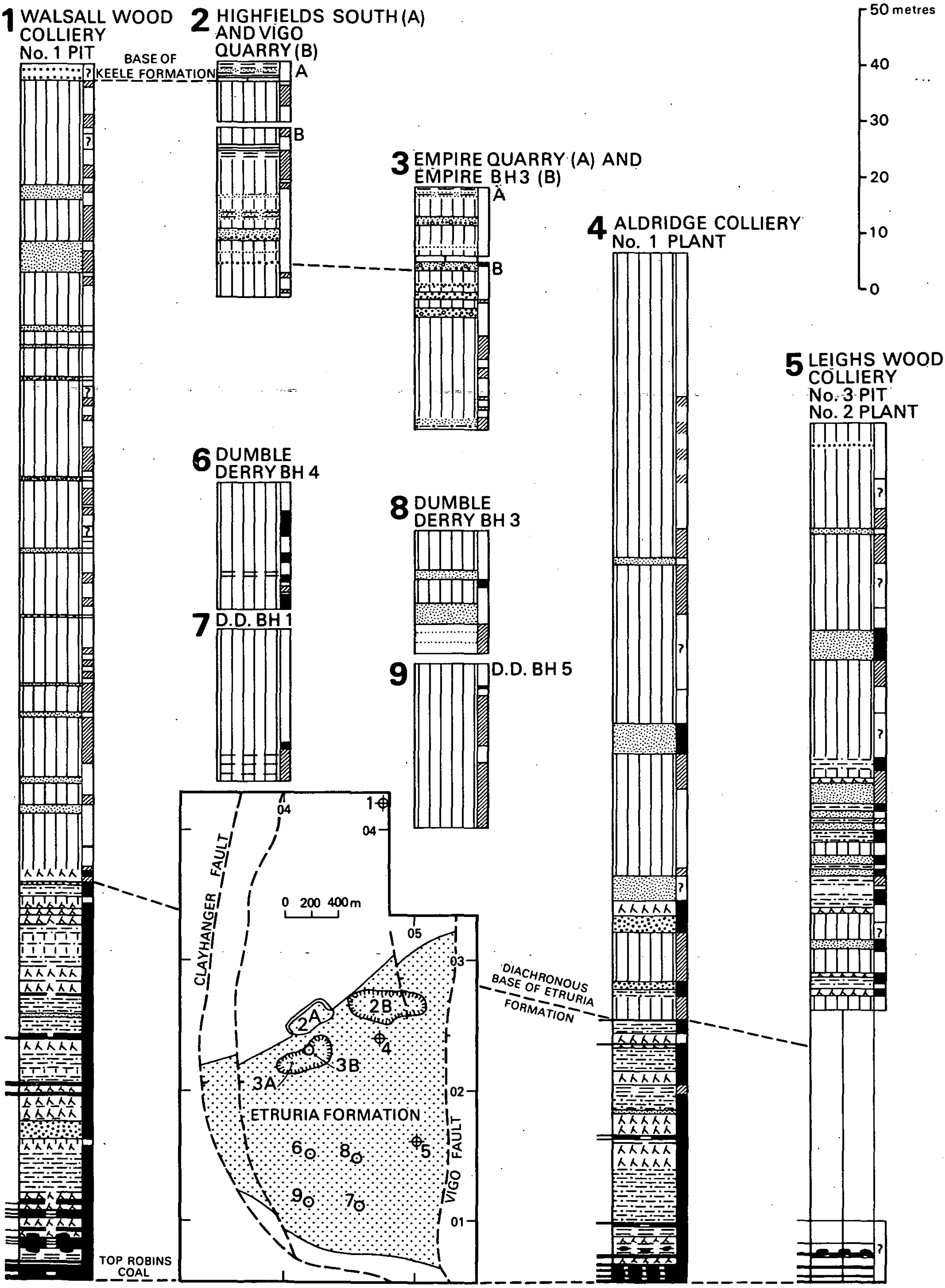


Fig. 7 Correlation of the Etruria Formation (Westphalian C)

(Symbols as on Fig. 8)

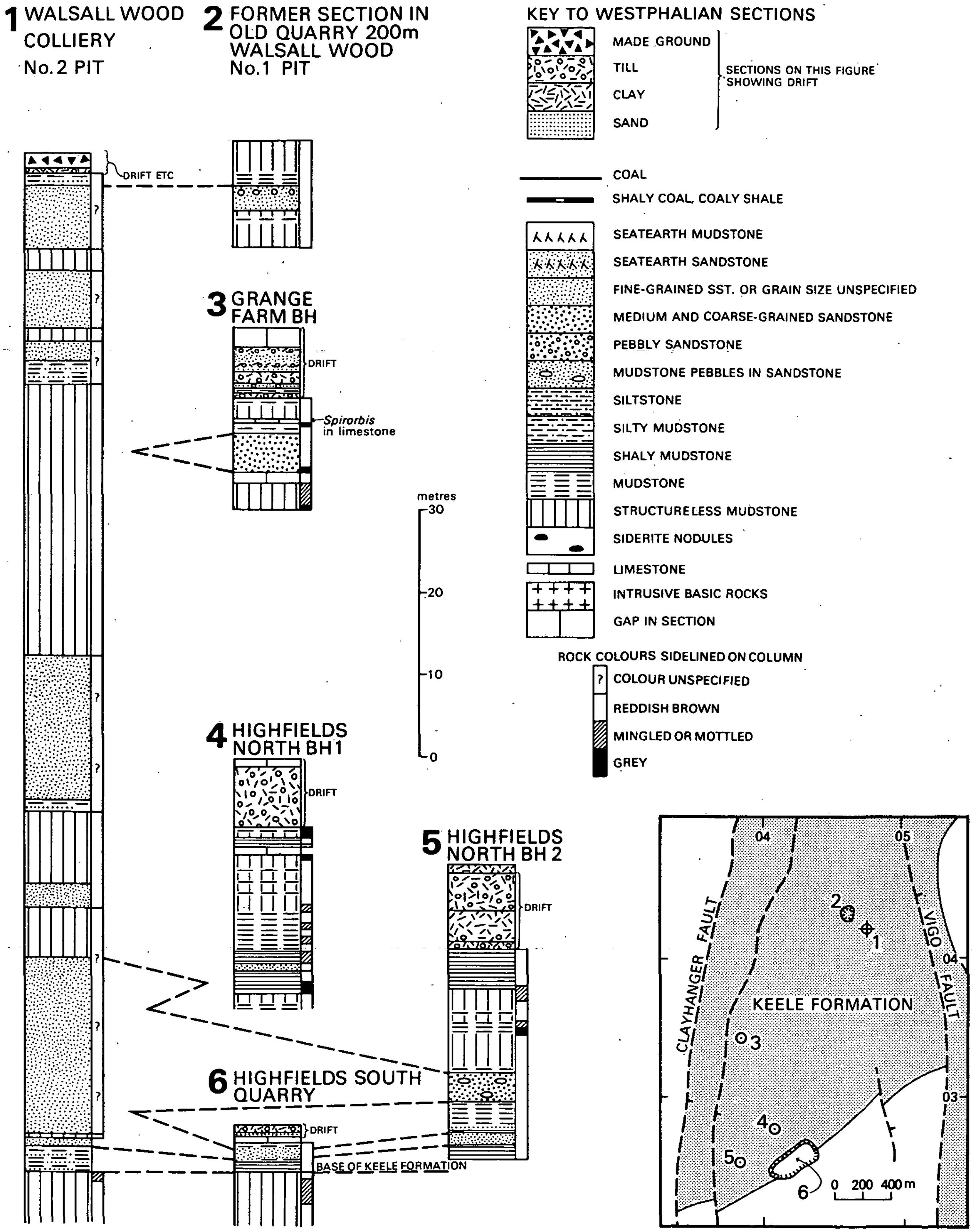


Fig. 8 Correlation of the Keele Formation (Westphalian D)

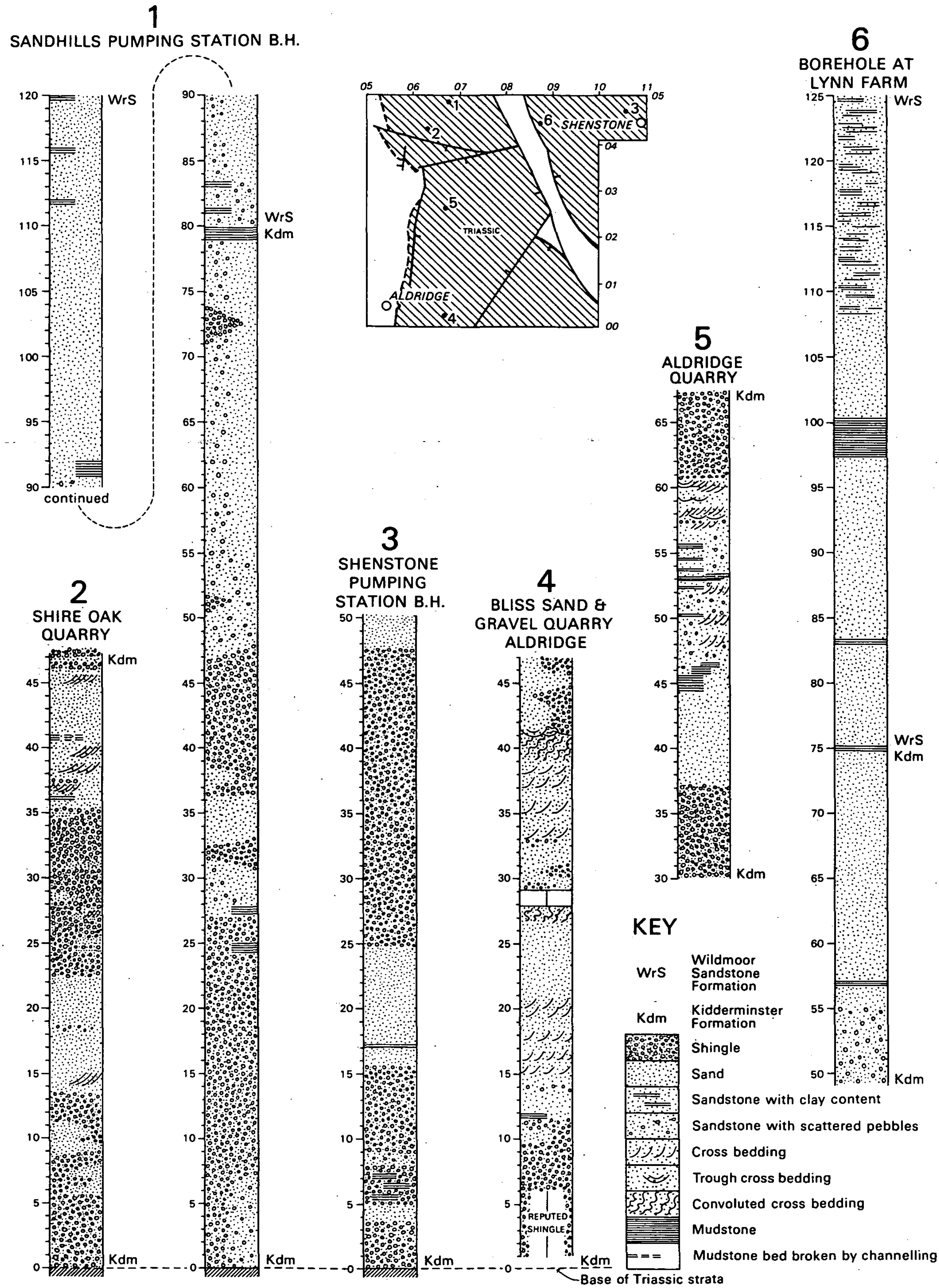


Fig. 9 DETAILS OF SHERWOOD SANDSTONE SEQUENCE
(HEIGHTS ON COLUMNS ARE IN METRES ABOVE BASE OF TRIASSIC ROCKS)

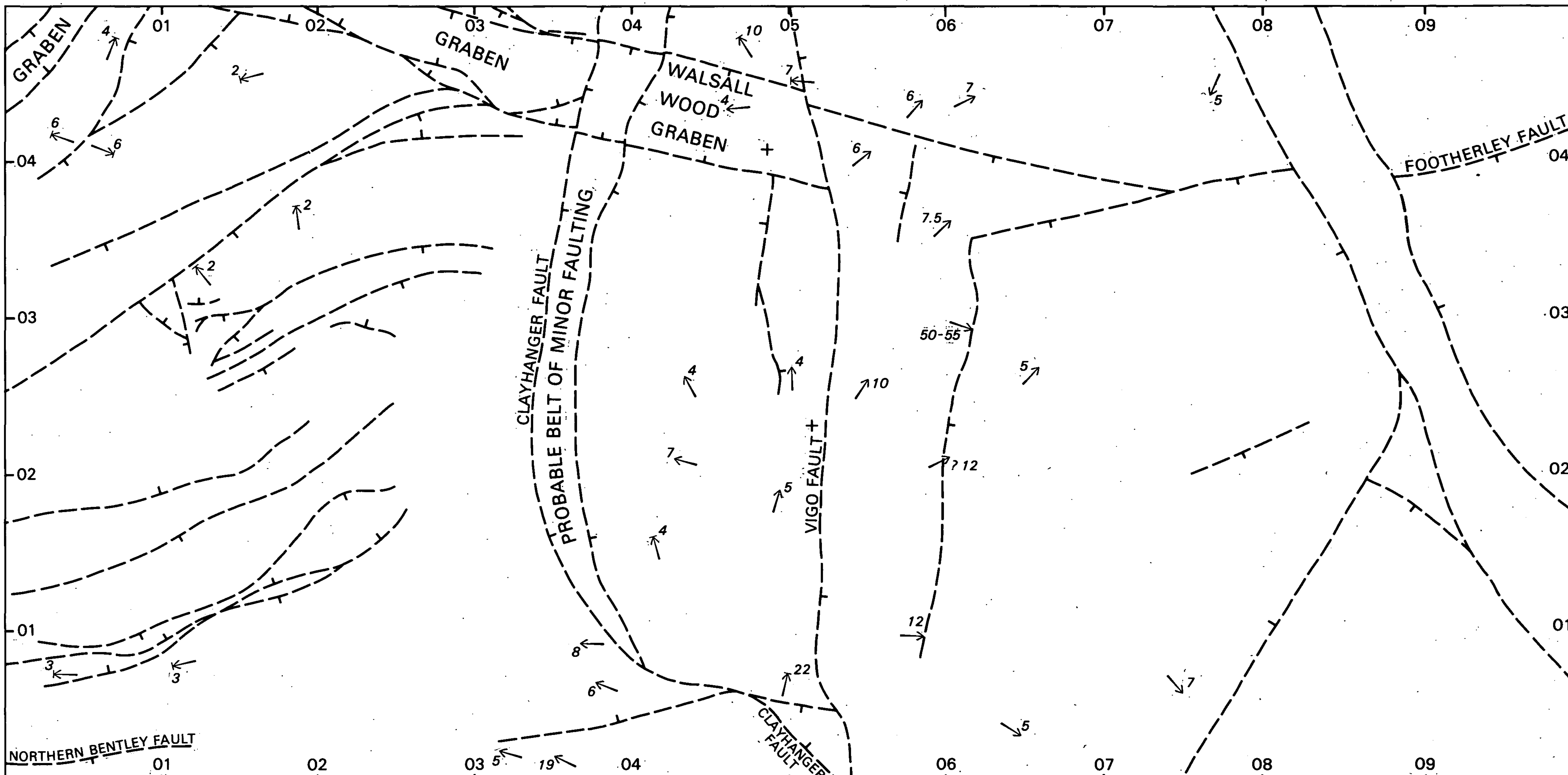


FIGURE 10

SKETCH MAP TO SHOW THE STRUCTURE OF THE ALDRIDGE–BROWNHILLS AREA

Scale

0 ½ 1 2 kilometres

Fault at surface, crossmark indicates downthrow side

Horizontal strata

Inclined strata, dip in degrees

Inclined strata underground, dip in degrees

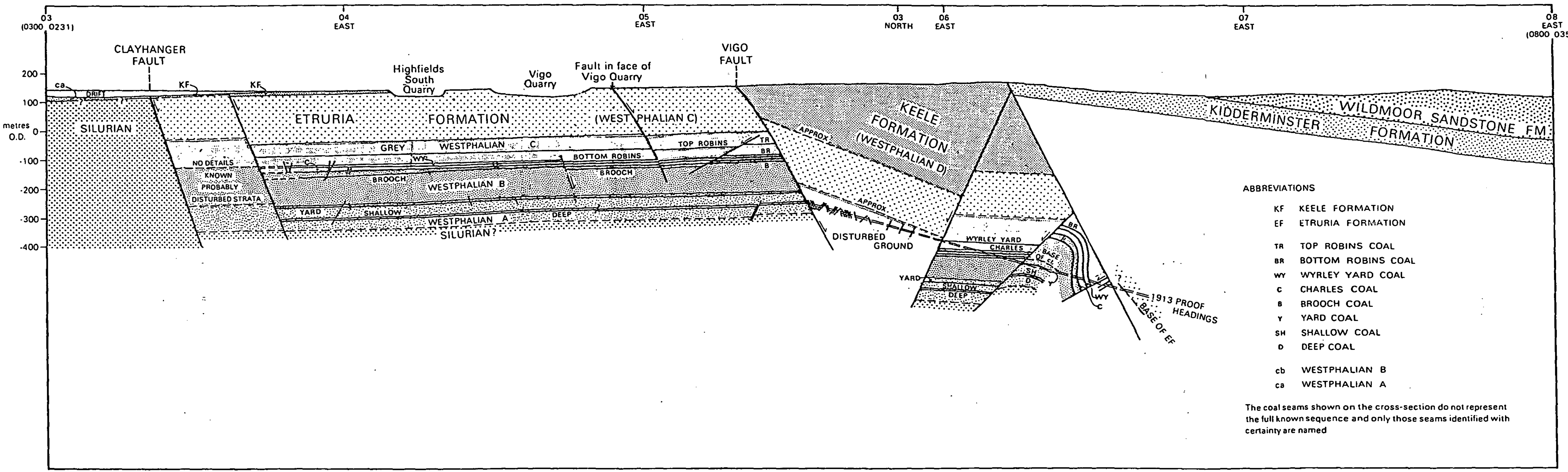


Fig. 11 Horizontal section through the Aldridge Colliery Workings and proof headings.
The line of section is shown on the mining base map.

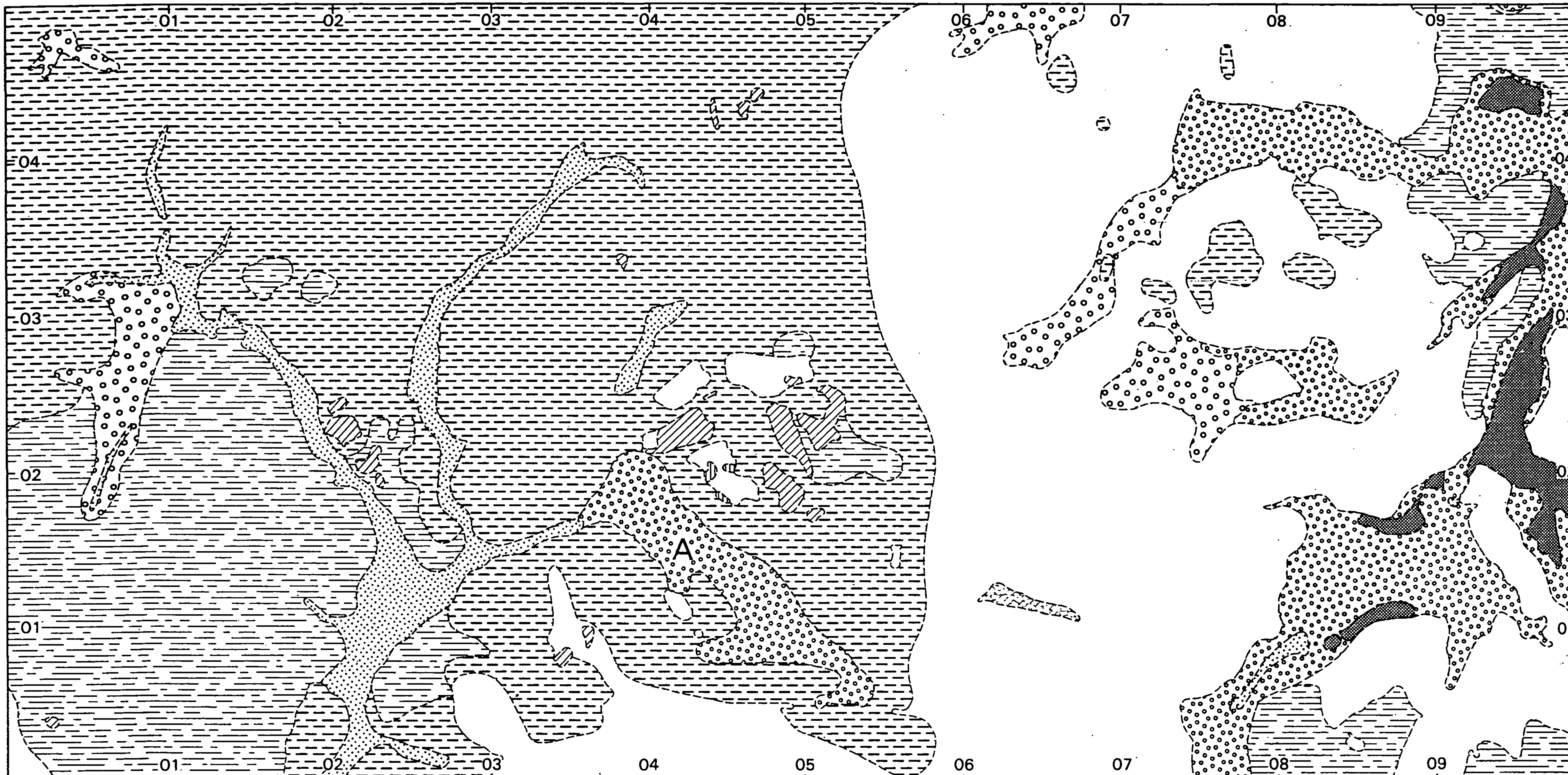


FIGURE 12

SKETCH MAP TO SHOW THE GENERALIZED DRIFT GEOLOGY OF THE ALDRIDGE–BROWNHILLS AREA

Scale

0 ½ 1 2 kilometres

- Drift-free areas
- Peat
- Alluvium
- Older River Gravels
- Glacial Sand and Gravel
- Sandy Till
- Till
- Head
- Landslip
- Geological boundary, Drift
- Backfilled quarry or opencast coal workings

Note: to avoid confusion, areas of Made ground or Landscaped ground, other than infilled workings, have been omitted. See Figure 13

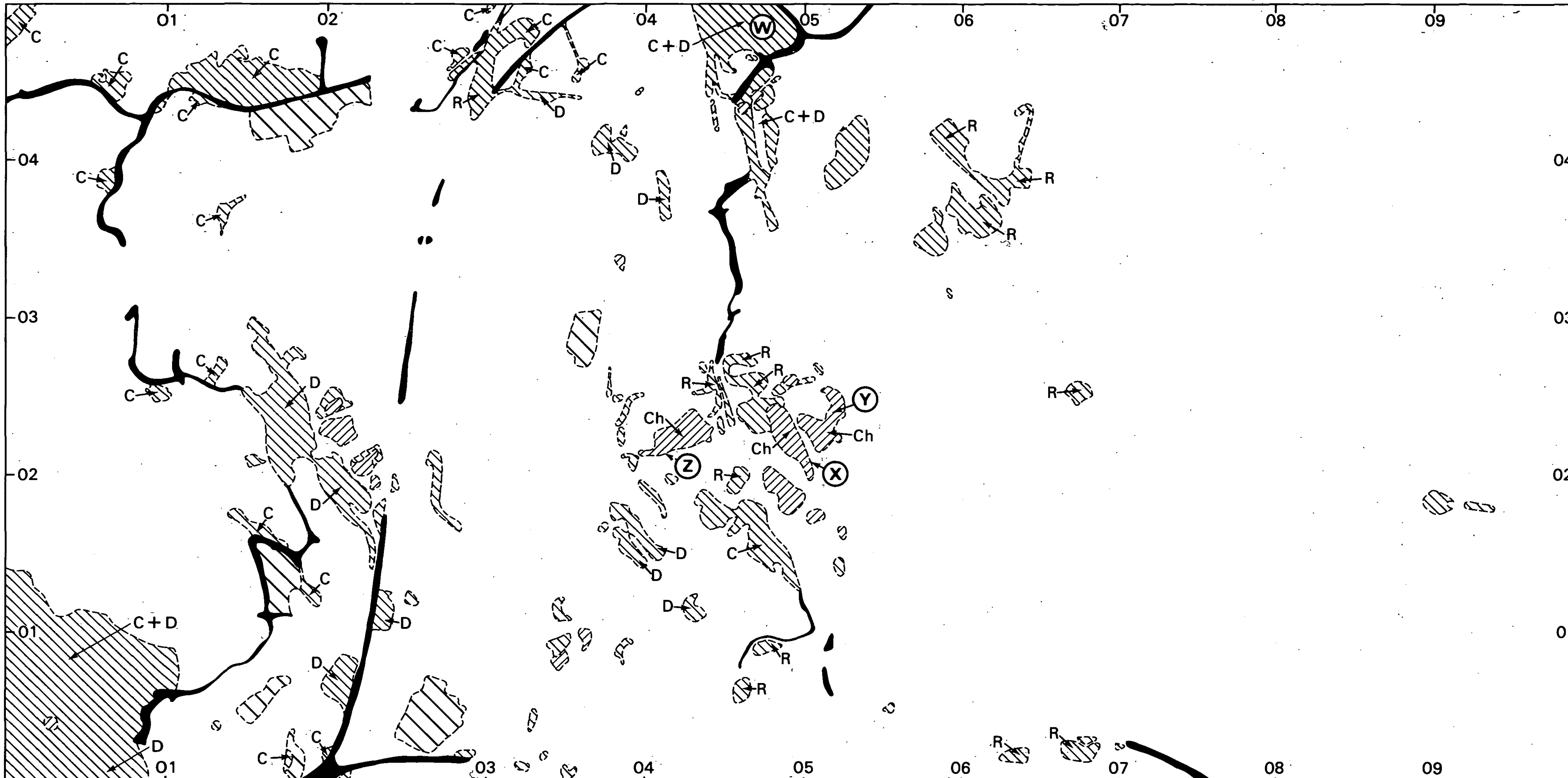


FIGURE 13

SKETCH MAP TO SHOW THE DISTRIBUTION OF MADE GROUND AND LANDSCAPED GROUND IN THE ALDRIDGE–BROWNHILLS AREA

Scale

0 ½ 1 2 kilometres

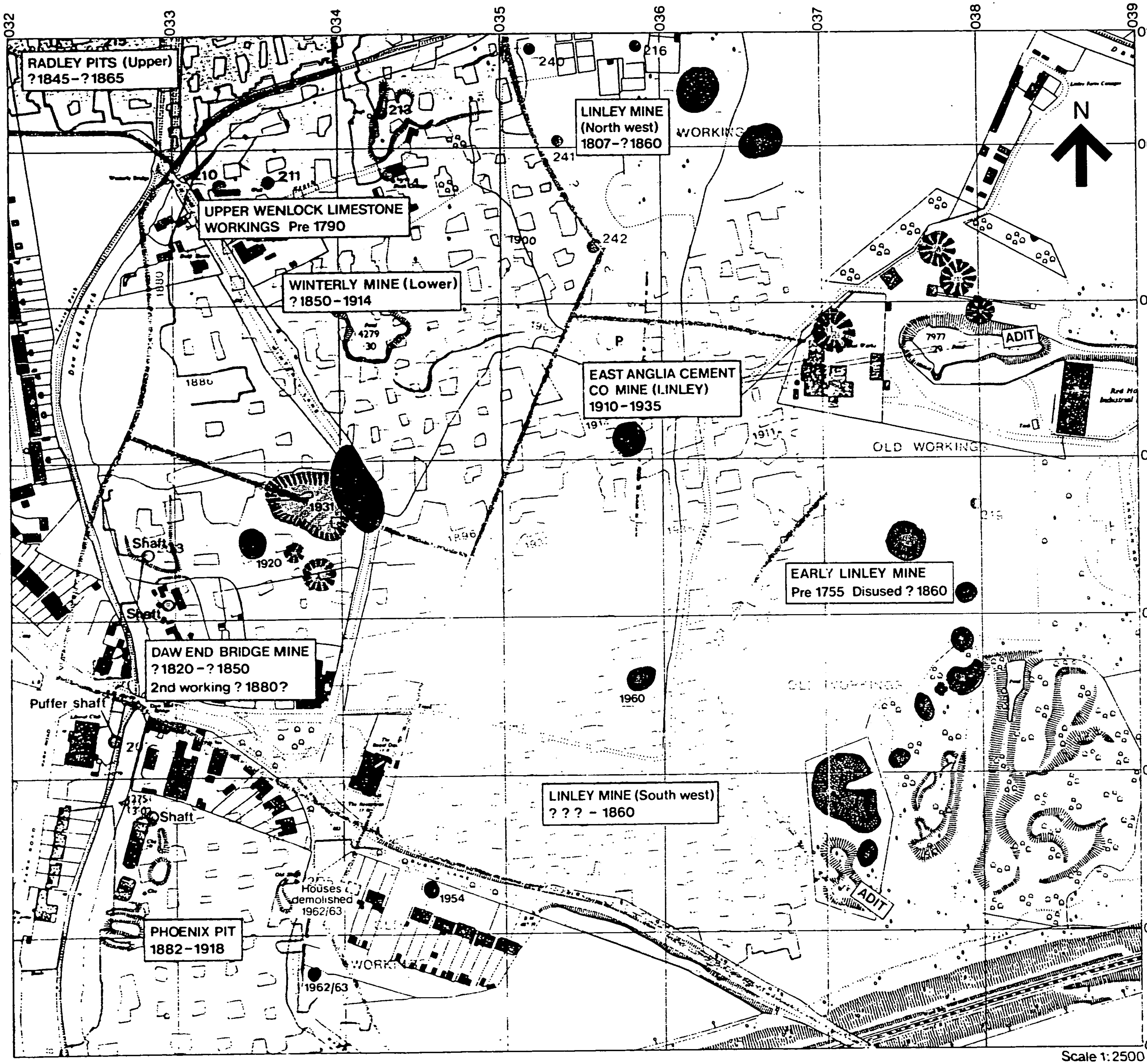
Backfilled quarry, opencast working or borrow pit

Landscaped areas including reworked Made Ground and Drift

Railway, canal and road embankments

Made Ground:
C – Colliery spoil and ironworks slag locally
Ch – Chemical waste
D – Domestic refuse and building rubble
R – Rubble or railway ballast only

(X) Location cited in text



Surface expression of underground collapse

Approximate extent of individual mine

N

Note :-

Manor Farm Boreholes, numbered 201, 202 & 203 in Appendix C are respectively about 500, 340 & 220m West of Puffer shaft, as shown in Drawing SKOOSW.

Probable crater subsidence additional to that mentioned in the D.O.E. report on Limestone Mines (this information added by B.G.S. in 1984).

DAW END
HISTORY OF MINING

FIGURE 14

ALDRIDGE-BROWNHILLS BORO CONST
SK 0502 NW

Demolished building

Subsidence effects along the Vigo Fault
FIGURE 15

TABLE 2: Generalised description and properties of Drift Deposits.							
Deposit shown on Map	Occurrence (see Figure 12)	Lithology	Bulk Density Kg/m^3	Moisture %	Liquid Limit	Plastic Limit	Standard Penetration Test (SPT)
PEAT	Thin beds generally less than 1m, overlying Older River Gravel or within alluvial sequences.	Dark partially carbonized vegetable matter with minor admixed silty clay.	No local data ?600-1200	Highly variable	-	-	less than 5
ALLUVIUM	Thin spreads along some valley bottoms, particularly in the west of the area. Often passes downwards into older fluvial or fluvioglacial material.	Clay, silty clay or silt.	1300-1700	15-20	32-34	11-21	24-40[1]
		Sand and sandy gravel locally.	2100-2300	up to 33	-	-	0-20[2]
OLDER RIVER GRAVEL	Infilling deep channels in west (often beneath other deposits) and as terraces in valleys further east. Thickness highly variable.	Gravel and sand, locally clayey.	2135-2300	up to 30	-	-	0-43[2]
		Clay and silt, often sandy.	1800-2000	16-22	34-60	10-20	8-17
GLACIAL SAND AND GRAVEL	Interbedded with till or sandy till deposits; also present as discrete spreads downslope of Kidderminster Formation outcrops in east. Thickness highly variable.	Generally sand with pebbles, some deposits more pebble-rich. Variable clay, admixed or as discrete beds.	2135-2320	5.4-19[3]	-	-	7-60
SANDY TILL	Fairly large spreads in the east, large and small spreads in the west, passing into till or Glacial Sand and Gravel laterally. Very variable thickness; may be thin skin on hill tops or valley sides or may form part of thick complex sequences in valleys	Red-brown sandy pebbly clay	1990-2410	6.5-23	No data[4]	No data[4]	10-68
		Sand and gravel locally as pods, lenses and discontinuous beds.	2135-2320	5.4-19	-	-	7-60
		Clay and silt locally; may be massive or laminated.	1800-2000	20-30	50-60	20-29	10-20
TILL	Large spreads, generally fairly thin in west, small spreads in east. Locally very thick and passing laterally into more arenaceous glacial deposits. May be present beneath sandy till or more recent material	Predominantly grey or grey-brown stony clay with varying amounts of sand. May be reddish locally. Extremely strong where undisturbed and unweathered	2010-2400	10-19	21-30	15-17	12-95

1. The upper limit is considered rather high and probably reflects very dry, near-surface samples. Values near the low figure are more typical.
2. The zero values indicate 'quick' conditions where the SPT tool sank under its own weight.
3. These are the only recorded values in the area. Higher moisture contents, up to 35%, might be expected locally.
4. No suitable data available. Values similar to those for till might be expected.

Quantitative values reproduced above are derived from reports originating from many different laboratories over a number of years. Data are more complete for some deposits than for others; values reproduced therefore indicate recorded extremes rather than averages for each lithology. Also data sets for different properties may be derived from material from varied localities and processed by more than one laboratory, such that the values quoted represent those of an idealised lithology across the area.