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Geology of the Burnley area

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Geology of the Burnley area (SD82NW and SD83SW)

E Hough

Key words

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1 Introduction

This report describes the geology of 1:10 000 sheet SD82NW (Dunnockshaw) and SD83SW (Burnley) (figures 1 and 2). The area (hereafter referred to as 'the district') was first geologically surveyed on the 'old' county series by E Hull and published in 1875. W Lloyd and L H Tonks subsequently remapped the district on the 'new' county series sheets Lancashire 56, 64 and 72 in 1922-3. The one-inch Geological Sheet 76 (Rochdale) was published in 1927. The area was resurveyed on the 1:10 000-scale by E Hough in 1999.

Topographic variation within the district varies from 80 m in the Calder Valley [8000 3390] to 399 m at Hameldon Hill [8100 2880]. The district comprises upland moors in the south, which fall to the north to the Calder Valley; Burnley is situated on the northern-facing slopes to the south of the Calder Valley. The district is drained in the south by the south-flowing Limy Water and Whitewell Brook, both tributaries of the River Irwell. The River Brun and Lancashire Calder drain the northern part of the district. Coal and sandstone have been heavily worked in the district from numerous collieries and quarries; both resources are no longer exploited.

The district is underlain by rocks of Millstone Grit Group to Pennine Lower Coal Measures Group. The youngest strata from the Burnley sub-basin of the South Lancashire Coalfield, including the Doghole Rock, come to crop within the district at Burnley and Ightenhill.

All National Grid references in this report lie within 100 km quadrant SD. They are given as eight figure numbers within square brackets. All borehole depths are given in metres below ground level.

The area to the east is described in Hough (2004), 'Geology of the Cliviger district'.

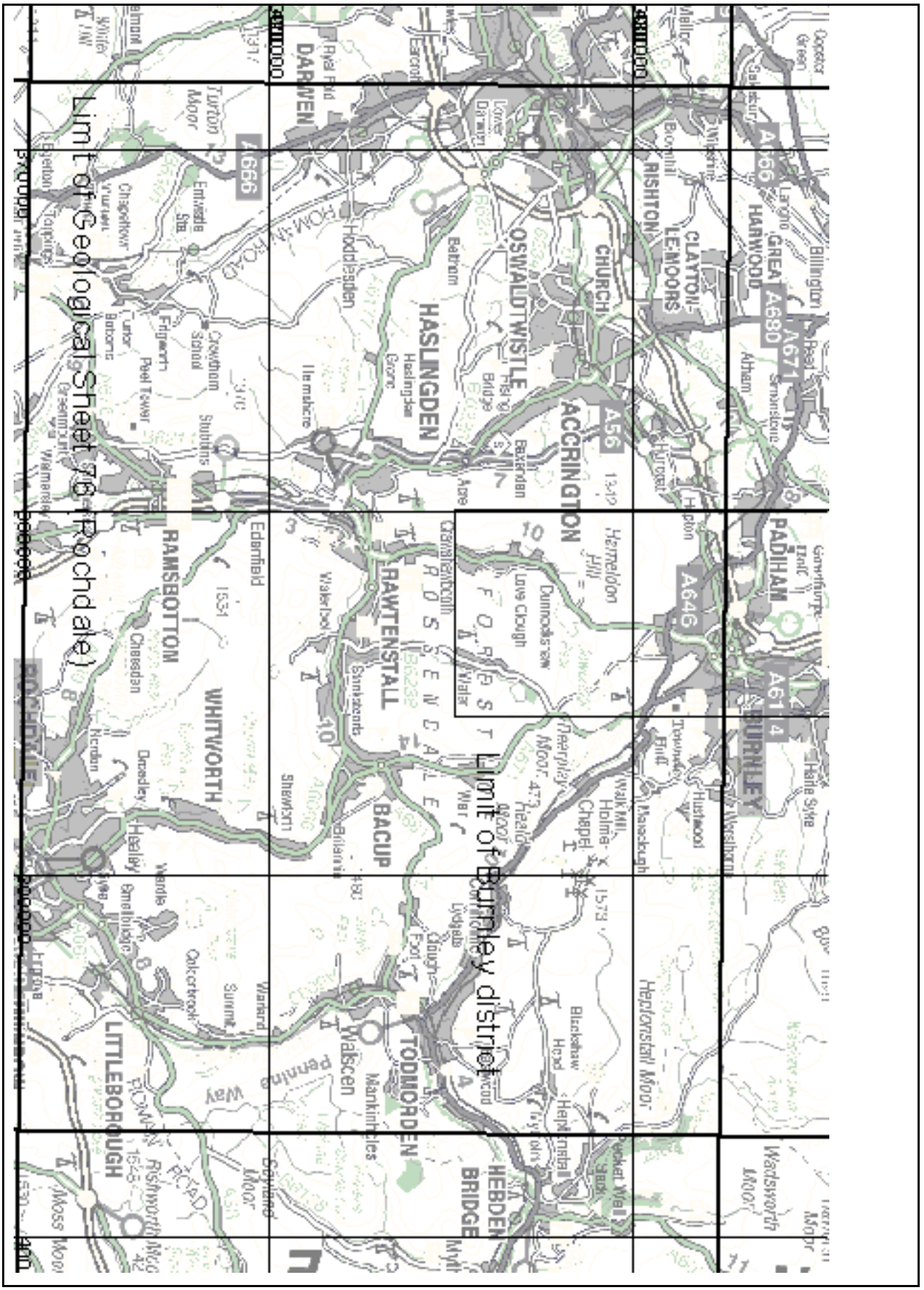


Figure 1: limit of the Rochdale Geological Sheet showing the Burnley district explained in this report

Figure 2: Map of the Burnley district. Graticule at 1km intervals.

2 Geological Sequence

DRIFT

Flandrian	Alluvium, Head, Debris Cone, Peat
Pre-Flandrian	Till, Glaciofluvial Deposits

SOLID

Silesian (Upper Carboniferous)

Westphalian	Pennine Lower Coal Measures Group
Namurian	Millstone Grit Group

3 Carboniferous

3.1 MILLSTONE GRIT GROUP

Strata from the Millstone Grit Group are present at outcrop in the southern parts of the district, in the Goodshaw Chapel [812 255] and Forest Holme [839 251] areas. A section at Clough Bottom (SD82NW/1) gives gross lithological and thickness details for the units. Namurian Millstone Grit strata proved within the district are shown in Figure 5.

The **Holcombe Brook Grit** is 13 m thick, and is present in the Limy Water valley at Crawshawbooth [8110 2500].

The **Holcombe Brook Coal** is 0.3 m thick. A mudstone unit overlying the Holcombe Brook Coal is thought to represent the **Cancelloceras cancellatum Marine Band G_{1a1}**.

The **Lower Haslingden Flags** overlie approximately 20 m of mudstone on the Hocombe Brook Coal. The unit comprises a lower sandstone that is 6.7 m thick, and an upper 5.5 m thick sandstone, with an intervening 11.1 m mudstone. The Lower Haslingden Flags have been worked from a quarry 500 m to the west of Crawshawbooth [8090 2540]. Sections at the quarry (Figure 3) expose 7 m of grey, low-angle cross-bedded and planar-bedded, ripple-laminated sandstone with subordinate siltstone interbeds. Fossilised wood fragments are preserved in some of the sandstone beds.

Figure 3: Lower Haslingden Flags exposed at a disused quarry 500 m to the west of Crawshawbooth [8090 2540]. Section shows well-developed downcutting basal surfaces within a generally parallel-bedded sandstone. Image taken to the north-west; quarry face is approximately 7 m high.

The **Cancelloceras cumbriense Marine Band G_{1b1}** has tentatively been identified in the Clough Bottom section, where it is approximately 5.5 m above the top of the Lower Haslingden Flags.

The **Upper Haslingden Flags** overlie 13 m of mudstone. The unit is 28 m thick, and is exposed in a disused quarry approximately 500 m to the east of Crawshawbooth at Bottomley Bank Farm

[817 254]. Here, 8 m of grey-green sandstone is exposed in upward-fining planar-bedded overlain by planar-laminated units.

The **Rough Rock** overlies the Upper Haslingden Flags; a thin intervening mudstone may be preserved between the two units. The Rough Rock, which is 20 m thick, is exposed along Folly Clough, to the east of Goodshaw Chapel [8181 2601] (Figure 4) and [8209 2616] (Locations 4 and 5). The lithology is pale yellow-brown, coarse-grained and poorly sorted pebbly sandstone. Pebbles of quartz are up to 12 mm in diameter, and are sub-rounded and sub-angular. The sandstone is well trough cross-bedded, with foreset azimuths indicating palaeoflow to both 013 (northwards) and 194 (southwards). Major bounding surfaces occur at 0.5-1 m intervals vertically, and sets are broadly upwards-fining.

Figure 4: Rough Rock exposed at Folly Clough [8206 2616], to the east of Goodshaw Chapel. Section shows well-developed trough cross-bedding that is cross-cut by younger depositional events. Image taken to 280; mapcase for scale is 30 cm high.

The **Sand Rock Coal** has been proved 12.6 m above the base of the Rough Rock

The **Six-Inch Coal** has not been proved within the district, although it is thought to overlie the Rough Rock in at least the southern part of the district. Elsewhere in the Rochdale region, the Six-Inch Coal is 0.1-0.5 m thick.

The **Subcrenatum Marine Band** has not been proved in the district, but is thought to be present overlying the Six-Inch Coal.

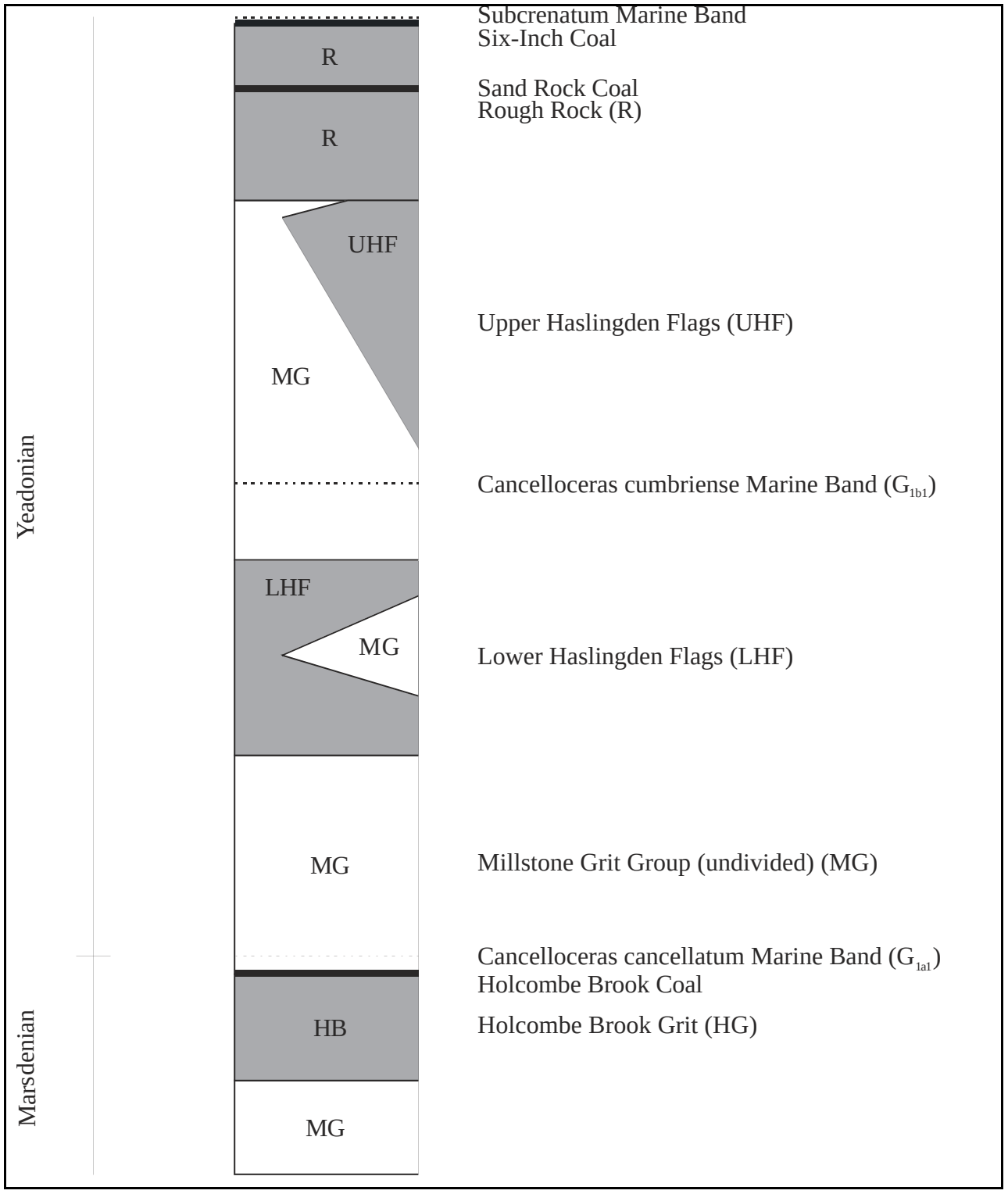


Figure 5: Generalised vertical section of the Namurian Millstone grit proved within the district. Scale approx. 1: 650 (1cm to 6.5 m).

3.2 PENNINE LOWER COAL MEASURES GROUP

The Pennine Lower Coal Measures Group are known from exposures, boreholes and from workings for coal (both deep-mined and opencast) and sandstone quarries within the area. Strata up to the Milnrow Sandstone are exposed in the southern part of the district; to the north of this, younger units within the succession, up to the Doghole Rock, are brought to crop by numerous faults. Generalized vertical sections of Pennine Lower Coal Measures Group strata within the Dunnockshire and Burnley district is shown in figures 6, 8 and 9.

The **Woodhead Hill Rock** rests on 12-20 m of mudstone on the Rough Rock. The Woodhead Hill Rock is 13-16 m thick in adjacent districts, and a similar thickness is thought to be present in the Dunnockshaw area. The Woodhead Hill Rock comprises a yellow, medium-grained sandstone that may be pebbly. A pond-side exposure 150 m to the south-east of Crown Farm [8221 2530] shows 0.6 m of flay-lying sandstone from the lower part of the unit.

The **Bassy Coal** rests on the Woodhead Hill Rock. The coal is thought to be 0.3-0.6 m thick in the Dunnockshaw area, based on provings from adjacent districts.

The **Lower Foot Coal** is present about 13 m above the Bassy Coal, the intervening strata being composed of mudstone. The thickness of the Lower Foot Coal is 0.31 m at Old Burnt Hall Pit (SD82NW/4).

The **Gannister Rock** is an impersistent silaceous sandstone that is up to 3 m thick in adjacent areas. Although it has not been proven within the district, it is thought to be present in at least part of the southern part of the district.

The **Lower Mountain Coal** rests on the Gannister Rock or where the Gannister Rock is absent, on mudstone. In the extreme mid-eastern part of the district, the Lower Mountain Coal amalgamates with the Upper Foot Coal, forming the Union Coal. The Lower Mountain Coal is between 0.7 (Heights Farm Opencast prospect: SD82NW/16) to 0.9 m thick (Liver Hill Opencast prospect SD82NW/25). The Lower Mountain Coal has been crop-worked and bell-pitted to the north of Stony Hill [8350 2775].

The **Great Arc Sandstone (Bullion Rock)** overlies 6.78 m of mudstone above the Lower Mountain Coal. The total thickness of the sandstone has been proved in Old Burnt Hill Pit (SD82NW/4) as 8.23 m. The sandstone is exposed in a disused quarry 400 m to the north-east of Windy Bank [8456 2734] (Location 6). The sandstone is grey and orange, fine- to coarse-grained, and moderately-sorted. The sandstone is both medium-bedded and massive. A disused quarry 200 m to the north-west of Meadows Farm [8490 2655] exposed 0.5 m of white and grey medium-grained, trough cross-bedded sandstone.

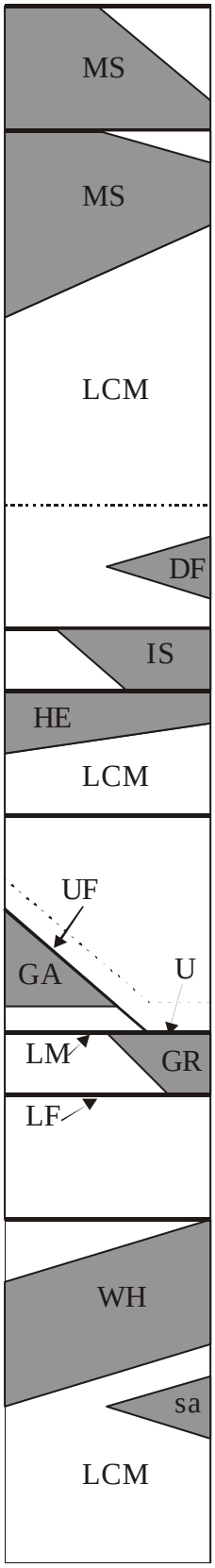
The **Upper Foot Coal (Bullion Coal)** rests on the Great Arc Sandstone. The coal is between 0.16 m (SD82NW/10) and 0.23 m thick (SD82NW/3).

The amalgamation of the Upper Foot and Lower Mountain coals forms the **Union Coal**, which outcrops approximately 700 m to the north of Clough Bottom Reservoir [8490 2765], and at depth to the north of the Deerplay Fault. The Union Coal is 0.9 m thick in the Wholaw Nook Colliery Shaft (SD82NW/9). The Union Coal has been worked in parts of the Helm Opencast Site, e.g. at [8215 2965].

The Listeri Marine Band is thought to occur above the Union and Upper Foot coals, although the marine band has not been identified in the district.

The **Inch Coal** overlies approximately 15 m of mudstone on the Upper Foot Coal. The coal is between 2.5 cm thick (SD82NW/10) and 15 cm thick (SD82NW/5).

The **Helpet Edge Rock (Warmden Sandstone)** overlies approximately 5 m of mudstone on the Inch Coal. The Helpet Edge Rock forms good features to the north-west of Love Clough, and also the high ground of Meadow Head [8275 2710] in the central part of the district. The Helpet



Pasture Coal

Cemetery Coal

Milnrow Sandstone (MS)

Amalie (Tonge's) Marine Band

Darwen Flags (DF)

Cannel Coal
Icconhurst Sandstone (IS)
Upper Mountain Coal
Helpet Edge Rock

Inch Coal

Listeri Marine Band
Upper Foot Coal (UF)
Union Coal (U)
Great Arc Sandstone (GA)
Lower Mountain Coal (LM)
Gannister Rock (GR)
Lower Foot Coal (LF)

Bassy Coal

Woodhead Hill Rock (WH)

Figure 6: Generalised vertical section of the Westphalian A strata proved in the district, from the base of the Westphalian to the Pasture Coal. Sandstones named or 'sa' when unnamed; uncoloured parts of the section are mudstone-dominated Pennine Lower Coal Measures Group. Scale approx. 1: 700 (1cm to 7m).

Edge Rock fails to the north, where mudstone is proved in the Inch – Upper Mountain Coal interval.

The **Upper Mountain Coal (Top Bed Coal)** overlies the Helpet Edge Rock; where this is absent the Upper Mountain Coal rests on 13.3 – 15.1 m mudstone overlying the Inch Coal. The Upper Mountain Coal is up to 0.9 m thick and is one of the main worked coals within the district. The coal has been worked at the Helm Opencast Sites, to the north-west of Hameldon Hill.

The Icconhurst Sandstone is a laterally impersistent sandstone that attains a maximum thickness of 6 m (SD82NW/4). The sandstone is apparently only present at surface within the western part of the district, around Townend Close [8025 2785].

The **Cannel Coal** overlies the Icconhurst Sandstone, and is approximately 0.2 m thick. The coal has been worked in parts of the Helm Opencast Site.

The **Darwen Flags** comprise a fine-grained, micaceous, cross-bedded sandstone that is up to 4 m thick.

The **Amaliae (Tonge's) Marine Band** has been tentatively identified in borehole SD82NW/11, where black fissile mudstone with ghosts of ?Dunbarella occur approximately 13 m above the Cannel Coal.

The **Milnrow (Crutchman) Sandstone** is a major channelised sandstone that apparently thickens northwards in the district to at least 37 m. The sandstone lies approximately 52 m above the Cannel Coal. The Milnrow Sandstone is exposed at a waterfall section in Thorny Bank Clough [8014 2943] (Location 8). The 3.1 m section comprises trough and ripple cross-laminated sandstone. Troughs are up to least 3 m wide and 0.7 m deep. The axes of some of the trough sets indicate a south-easterly palaeoflow. Some of the trough sets are overlain by up to 0.1 m of planar-laminated mudstone.

The **Cemetery Coal** occurs within the Milnrow Sandstone, or on an intervening mudstone that is up to 6 m thick. The coal is up to 0.4 m thick (SD83SW/4).

The **Pasture Coal** rests on the Milnrow Sandstone, or on an intervening mudstone that is up to 8 m thick.

The **Dyneley Knoll Flags** overlie up to 30 m of mudstone on the Pasture Coal. The crop of the unit is much disrupted by faulting in the district; the unit comes to crop between Thorn Bank Clough [8000 2935] and Crown Point [8500 2900].

The mudstone-dominated interval between the Dyneley Knoll Flags and the Old Lawrence Rock are locally known as the **'Accrington Mudstones'**. This interval is 18-27 m thick, and in the Accrington district is one of the prime brick-clay resources.

The **Old Lawrence Rock** forms the high ground between Hameldon Hill [8080 2980] and Nutshaw Hill [8220 2880], Crown Point [8490 2870], and the area around Crown Point House [8380 2950]. The sandstone has been widely worked, and is relatively well-exposed in the district. The base of the Old Lawrence Rock is exposed to the west of Hameldon Hill [8003 2899] (Location 1). The sandstone is grey-green and fine-grained. A thick-bedded planar sandstone unit forms the basal part of the Old Lawrence Rock; this downcuts approximately 1 m into the underlying mudstone and ripple-laminated siltstone sequence. The base of the sandstone is also exposed in a quarry south of Nutshaw Hill [8232 2852] (Location 9). The lithology of the sandstone at Nutshaw Hill is similar to that at Hameldon Hill. The sandstone is well-bedded, with parallel bedding predominating over low-angle cross-bedding.

At Park Scout [8087 2906] (Location 2; figure 7), the Old Lawrence Rock is exposed in an extensive quarry on the northern flank of Hameldon Hill. The lithology comprises sets of fine- to medium-grained sandstone that is trough cross-bedded. Main trough sets are overlain by up to 0.3 m of pale yellow, fine-grained, micaceous sandstone that is low-angle cross-bedded, and in

part ripple-laminated. Primary current lineation (PCL) within the sandstone, and the azimuths of trough axes indicate a palaeoflow to 178 (south).

Figure 7: Old Lawrence Rock exposed at Park Scout [8087 2906]. Section shows trough cross-bedded green-grey sandstone. Image taken to the west; mapcase for scale is 30 cm high.

The Old Lawrence Rock is exposed in a disused quarry 200 m west of Crown Point [8472 2878] (Location 10). A section at the back of the quarry shows 2.1 m of green-grey, fine-grained sandstone. Co-sets consisting of a lower trough cross-bedded unit overlain by planar-laminated sandstone and massive sandstone are repeated through the section. The axes of trough sets indicate a depositional flow to the south west (bearing 216).

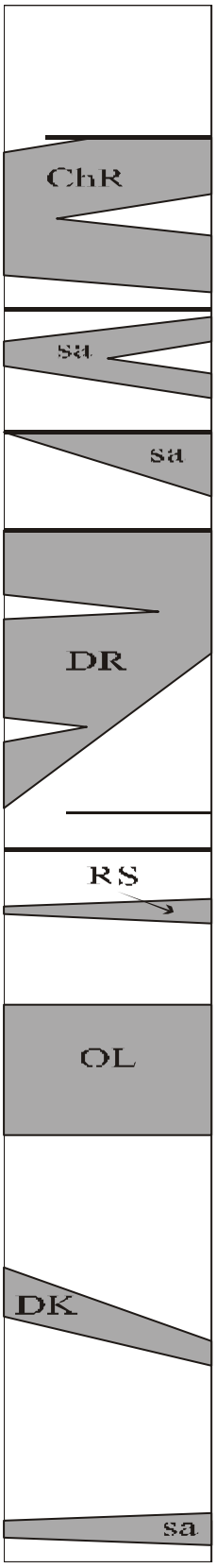
The **Riddle Scout Rock** overlies up to 23 m of mudstone on the Old Lawrence Rock. The Riddle Scout Rock is between 1-5 m thick (thinning to the north) and comprises a greenish-grey, micaceous, cross-bedded sandstone.

The **Arley Coal (Cliviger Four Foot Coal)** is up to 1.7 m thick and lies on 2 m of mudstone on the Riddle Scout Rock. The coal was previously taken as the base of the Middle Coal Measures (Wright *et al.* 1927); as such, it is one of the main marker horizons that was commonly picked out in borehole logs and shaft sections in the district.

The **Dandy Rock** overlies up to 10 m of mudstone with impersistant coal on the Arley Coal (see Figure 8). Beds form the mid-part of the unit are exposed in a small, disused quarry 480 m north of Townend Close [8016 2850] (Location 3). The exposure may be split into two units. The lower unit comprises 0.58 m pale grey, medium-grained sands tone which is slightly micaceous. The sandstone is thinly bedded, with planar-based ripple-laminated structures dominant; low-angle cross bedding is rarely preserved. The upper unit comprises 0.75 m of fine- to medium-grained sandstone, which is medium-grained. The sandstone is trough cross-bedded; flutes at the base of the unit, and the trough axis azimuth trend broadly to 020 (north-north eastwards).

The **Dandy Coal (Top Coal; Cally Coal)**, rests on the Dandy Rock, and is 0.6-1.7 m thick.

The **Crackers Coal (Cannel Coal)** lies approximately 10-16 m above the Dandy Coal; the intervening measures are mudstone-dominated, but sandstone beds up to 8 m thick are present locally.



Lady Coal

China Rock (ChR)

China Coal

Crackers Coal

Dandy Coal

Dandy Rock (DR)

Coal

Arley Coal

Riddle Scout Rock (RS)

Old Lawrence Rock (OL)

'Accrington Mudstones'

Dyneley Knoll Flags (DK)

Figure 8: Generalised vertical section of the Westphalian A strata proved in the district, from the Pasture Coal to the Lady Coal. Sandstones named or 'sa' when unnamed; uncoloured parts of the section are mudstone-dominated Pennine Lower Coal Measures Group. Scale approx. 1: 800 (1cm to 8m).

A mudstone and sandstone interval of 13-19 m lies between the Crackers Coal and the **China Coal**. The China Coal is 0.2-0.7 m thick.

The base of the **China Rock** lies up to 10 m above the China Coal, the intervening measures being mudstone-dominated. The China Rock comprises 15-20 m of massive sandstone with subordinate mudstone beds.

The **Lady Coal** rests on the China Rock The coal is 1.5 m thick in the Fulledge Colliery Shaft Section (SD83SW/17).

Correlation between strata above the Lady Coal is hampered due to the high incidence of faulting, and the thick cover of Superficial Deposits in the Burnley area. Correlations are further complicated by the large variations in the thicknesses of some of the sandstone units (e.g., the Tim Bobbin Rock, c. 3-49 m), and the presence of numerous laterally impersistent, unnamed sandstone units in the upper part of the succession.

The **Tim Bobbin Rock** overlies approximately 17 m of mudstone on the Lady Coal. A variation in thickness from c. 3 m to c. 49 m is attributed to facies variations within the unit. The sandstone is grey-brown, fine-grained, cross-bedded and contains ironstone concretions.

The **King Coal (Great Coal; Bing Coal; Six Feet Coal)** lies approximately 50 m above the China Coal. The coal has been opencast at the Royle site [821 3475] where it was 2.55 m thick, including a 0.6 m parting 0.45 m above the base.

The **Fulledge Thin Coal (Habergham Blindstone)** is 0.8 m thick and lies 17 m above the Lady Coal in the Fulledge Colliery shaft section (SD83SW/17). The coal has been opencast at the Tipping Hill site [8040 3370].

The amalgamation of the King and Fulledge Thin coals forms the **Padiham Thick Coal**, the thickest coal in the South Lancashire Coalfield, which is present at surface in the north-western part of the district, around Brookfoot Farm [8040 3470]. The Padiham Thick Coal has been worked in the Gawthorpe Hall Opencast Site [8040 3470], where it was recorded as 5.3 m thick (with partings).

The **Inferior Cannel Coal** is 0-0.8 m thick.

The **Low Bottom Coal (Steam Coal; Clifton Blindstone Coal; Toe Rag Coal; Cornfield Four Foot Coal)** lies approximately 7 m above the Inferior Cannel Coal. The coal has been opencast at the Tipping Hill [8065 3375] and Royle [8260 3430] sites.

The **Low Bottom Rider Coal (Blindstone Rider Coal)** is up to 0.2 m thick, and lies approximately 5 m above the Low Bottom Coal. The coal has been opencast at the Tipping Hill site [8065 3375].

The **Lower Yard Coal** overlies 15-27 m of mudstone on the Low Bottom Coal. The coal is 2 m thick with partings in Fulledge Colliery Middle Pit shaft section (SD83SW/20). The coal has been opencast at the Tipping Hill site [8090 2370].

The **Lower Yard Rider Coal** lies approximately 4 m above the Lower Yard Coal in the north-western part of the district. The coal is up to 0.5 m thick. The coal has been opencast at the Tipping Hill Opencast Coal site [8090 2370].

The measures between the Lower Yard Rider and Maiden coals comprises a mudstone-dominated succession with unnamed sandstone units approximately 5 and 25 m above the Lower Yard Rider Coal. An unnamed coal that is up to 0.2 m thick has been proved approximately 23 m above the Lower Yard Rider Coal.

The **Maiden Coal (Old Yard Coal)** lies on 28-52 m of mudstone overlying the Lower Yard Coal. The coal has a maximum proved thickness of 1.4 m in the Fulledge Colliery Middle Pit shaft section (SD83SW/20).

The **Burnley Four-Foot Coal (Low Coal; Old Thick Coal; Palace House Low Bed Coal)** lies on 7-10 m of mudstone and sandstone overlying the Maiden Coal. The coal attains a thickness of 1.5 m in the central Burnley area.

The **Shell Coal (Top Palace House Thin Bed Coal)** lies on 3-8 m of mudstone and sandstone overlying the Burnley Four-Foot Coal. The coal is up to 1.3 m thick, and comes to crop to the north and west of Burnley.

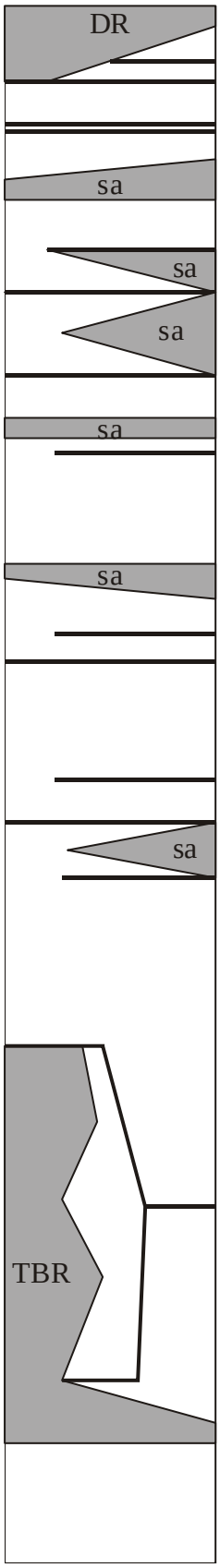
The **Charlie Coal (Palace House Top Bed)** lies on approximately 20 m of mudstone and sandstone overlying the Burnley Four Foot Coal. The coal is 0.9 m thick in the Old Pit shaft section located at the Burnley Cattle Market (SD83SW/10).

The **Kershaw Coal** lies approximately a metre above the Charlie Coal. The coal is 2.3 m thick (with mudstone partings).

The **Doghole Coal** lies on approximately 5-10 m of mudstone overlying the Kershaw Coal. The coal is 2.0 m thick in the Fulledge Colliery Middle Pit (Pine Street) shaft section (SD83SW/20).

The **Doghole Rider Coal** is 0.5 m thick; the coal is locally washed out by the Doghole Rock; in some areas the Doghole Rider Coal has been proven to lie on the Doghole Rock (Earp et al. 1961).

The **Doghole Rock** is a highly siliceous sandstone that lies up to 6 m above the Doghole Coal; the sandstone may incise the intervening strata to rest directly on the Doghole Coal. The Doghole Rock is the youngest lithological unit proved within the Burnley sub-basin of the South Lancashire Coalfield. Up to 9 m of interbedded siltstone and sandstone equating to the Doghole Rock was proved in site investigation boreholes associated with the Leeds and Liverpool Canal at Burnley (e.g., SD83SW/164).



Doghole Rock
Doghole Rider Coal
Doghole Coal
Kershaw Coal
Charlie Coal

Shell Coal
Burnley Four-Foot Coal

Maiden Coal

Coal

Lower Yard Rider Coal
Lower Yard Coal

Low Bottom Rider Coal
Low Bottom Coal
Inferior Cannel

Fulledge Thin Coal (FT)

Padiham Thick Coal

Tim Bobbin Rock

King Coal

Figure 9: Generalised vertical section of the Westphalian A strata proved in the district, from the Tim Bobbin Rock to the Doghole Rock. Sandstones named or 'sa' when unnamed; uncoloured parts of the section are mudstone-dominated Pennine Lower Coal Measures Group. Scale approx. 1: 900 (1cm to 9m).

4 Quaternary

4.1 DEBRIS CONE

Debris cone development has been identified on the northern slopes of Park Scout [8085 2910]. The deposits are composed of matrix-supported sandstone blocks, predominantly of Old Lawrence Rock. The deposit is actively moving downslope at the present time.

4.2 HEAD

Head is typically composed of unconsolidated, poorly sorted and stratified sand, silt and clay, although it may contain bedrock clasts. Head in the district is formed by solifluction and soil creep processes. Consequentially, Head deposits are generally restricted to topographic hollow and lows.

Head is commonly associated with deeply incised **glacial meltwater channels**. These channels, cut by meltwater during the last glaciation, are up to 5 m deep, and 50 m wide. The channels are commonly dry, with Head deposits at their base. Head deposits in the district are not likely to exceed 2-3 m in thickness.

4.3 HILL PEAT

The main spreads of Hill Peat are present around Hameldon Hill [8085 2885], Swinshaw Moor [8265 2540], south-west of Crown Point [8460 2835], and Red Moss [8440 2765]. Hill Peat is typically composed of wet, dark brown, partially decomposed vegetation with interbeds of silt and sand. Hill Peat in the district is estimated to be no more than 4 m thick.

4.4 ALLUVIUM

Thin tracts of Alluvium have developed in the southern part of the district, along parts of the Limey Water, Brun, Green Brook, Hapton Clough, Micklehurst Clough, Calder and Whitewell Brook valleys. Alluvium is not proved by boreholes in the district. It typically comprises sand, gravel and clay which may be well-bedded. The thickness of Alluvium in the southern parts of the district is not likely to exceed 3 m. In the northern part of the district, Alluvium is well-developed associated with the River Calder, where it is 8-11 m thick, comprising 1 m of 'loamy sand resting on [0.3 m] banded pebbly sand underlain by coarse gravel' (Earp *et al.* 1961).

4.5 ALLUVIAL FAN DEPOSITS

An Alluvial Fan has been mapped at [8100 3500], at the mouth of a tributary of the River Calder.

4.6 RIVER TERRACE DEPOSITS

River Terraces associated with the River Calder have been mapped in the northern part of the district. Further details are given in Earp *et al.* (1961), p. 253-4.

4.7 GLACIOFLUVIAL SAND AND GRAVEL

Small patches of Glaciofluvial Sand and Gravel have been mapped in the southern part of the district. Some of these have a steep-sided morphology (e.g., [8170 2745], to the south-east of Dunnockshaw), which may indicate deposition in contact with a retreating ice-margin. The

northern slopes of Hameldon Hill, around New Barn [8110 3040] are mantled by a smooth cover of sand and gravel. The deposit is likely to be thin and patchy, and has been dug through in order to work the underlying sandstone approximately 300 m to the north-west of New Barn [8090 3060]. Glaciofluvial Sand and Gravel is typically composed of poorly-sorted, unconsolidated sand and gravel, with silty lenses.

4.8 TILL

Although Till mantles much of the lower ground in the district, it is poorly-exposed. Till is exposed in the east bank of Thorny Bank Clough [8016 2965] (Location 7). The till fabric comprises clast supported sandstone boulders up to 0.6 m in diameter, with rounded, tabular mudstone pebbles, in a sandy clay matrix. Boulders are sub-rounded and non-spherical. Clasts are in part imbricated, indicating a northerly palaeoflow.

5 Structure

The district is situated on the northern fringe of the Rossendale anticline (Williamson, 1956). The Burnley district lies within the central part of the Burnley Coalfield, which is part of the South Lancashire Coalfield.

The dip of strata in the district is variable, being shallow to the south and west but steepening considerably in the vicinity of fault zones. The dip azimuths vary widely, with the beds rolling and flexing, again partly due to the influence of localised faulting. Strata in the district generally young northwards, with the oldest strata preserved in Limy Water at Goodshaw Chapel and Whitewell Brook at Forest Holme. The youngest strata within the Burnley Coalfield are present within the district, incropping beneath Quaternary deposits in the Stoneyholme [8400 3350] and Burnley [8480 3230] areas.

Strata within the district are affected by numerous faults. In the southern part of the district, where drift cover is sparse, the faults have been proven by field mapping. On the southern margin of the Calder Valley the thickness of drift deposits increases, and the presence of faults has been inferred mainly from numerous deep mine workings. Only the major faults within the area are described in this report, from south to north.

An unnamed fault trending north-westwards has been mapped from Red Moss [8445 2735] to Nutshaw Hill [8215 2870]. The fault has a throw in the region of 120 m to the north-east, throwing the Milnrow Sandstone against the Woodhead Hill Rock.

An unnamed fault trending westwards has been mapped from Clowbridge Reservoir [8285 2830] to Hameldon Hill [8010 2860]. The fault has a throw in the region of 200 m to the north, throwing the Old Lawrence Rock against the Bassy Coal. Lead mineralization has developed in association with this fault.

The **Deerplay Fault** crosses the middle part of the district, trending north-westwards from White Hill [8500 2770] to approximately 1200 m south of Lowerhouse [8110 3170]. The fault has a throw estimated to be up to 100 m to the north-east. The fault was synsedimentary, and affected the deposition of the Union/Lower Mountain/Upper Foot coals (see Hough, 2004 for a fuller description).

The **Thievely Lead Mine Fault** is present in the area to the north of White Hill [8470 2795 - 2795 8500]. The fault, which trends westwards, throws approximately 140 m to the north. Mineralisation, including Galena and Barites has developed along part of the fault further to the east in the Cliviger district (Hough, 2004).

An unnamed fault trending north-westwards has been mapped from north-east of Clowbridge Reservoir [8350 2885] to Habergham [8030 3375]. The fault has a throw up to 150 m to the north, throwing the China Rock against the Old Lawrence Rock.

The Cliviger Valley Fault trends north –westwards, passing beneath Burnley and terminating at Hunter's Oak [8200 3478]. The fault, which throws up to 396 m in the Cliviger Valley, has a throw down to the north-east of approximately 280 m in the south-eastern part of the district; the throw diminishes to the north-west.

An unnamed fault trending north north-westwards has been mapped beneath Burnley, from [8500 3205] to [8360 3500]. The fault has a throw in the region of 100 m to the north north-east, throwing the Doghole Rock against the Low Bottom Coal.

Numerous faults trending north north-westwards have been mapped in the north of the district. The faults generally throw less than 100 m to the north north-east.

6 Economic Geology

6.1 COAL

Coal is one of the main resources of the area, and although not presently worked, it has been extensively worked in the past. Extraction was by crop working and shaft and adit mining prior to the 1950s, after which opencast methods became dominant (Table 1). Practically all the seams in the district have been mined at one time or another, with workings concentrated in the thicker seams.

BGS Ref. No.	Site name and approximate Grid Reference of site centre	Coal worked	Year ceased	Restoration
SD82NW/20	Helm and Helm Extension	Union; Upper Mountain, Cannel	1957	Full
SD83SW/116	Royle Zone	King; Fulledge Thin; Low Bottom;	1954	Full
SD83SW/125	Gawthorpe Hall	Padiham Thick	1961	Full
SD83SW/116a	Tipping Hill	Fulledge Thin; Low Bottom; Low Bottom Rider; Lower Yard; Lower Yard Rider		Full

Table 1: Opencast coal sites within the Burnley district.

6.2 LEAD

Lead is associated with three faults in the district, the Thievely Lead Mine Fault, an unnamed fault trending east-west from south-west of Hameldon Hill to Clowbridge Reservoir, and an unnamed fault trending south-east from Nutshaw Hill to south of Red Moss. There are no records of Lead mining in the district; lead associated with the Thievely Lead Mine Fault was worked in the Cliviger district, to the east of the Dunnockshaw area (Thornber, 1988).

6.3 LIMESTONE

Limestone boulders within the Till have been mined by opencast methods since the 17th Century. Mining took place between Lower Park and Hapton Tower [8085 2960] (Figure 10).

Water from streams was collected in header ponds, and directed along ‘goits’ (channels) to ‘hush’ (scour) the Till, to wash away small debris and soil, leaving the larger sandstone and limestone boulders. Unwanted boulders (mostly sandstone) were discarded in ‘sheddings’ (heaps), which form most of the prominent mounds in the opencast areas. Limestone was burnt in local kilns. Limestone was used to lime acidic soils, and in mortar.

Figure 10: Former limestone hushings at Lower Park and Hapton Tower [8085 2962]. Limestone boulders were scoured from the Till and the remaining boulders left as piles or sheddings. Image taken to the west.

6.4 SANDSTONE

Workings for sandstone. Many sandstone quarries within the district have been wholly or partially backfilled. The main areas of sandstone quarrying within the district are shown in Table 2.

Site location and approximate grid reference of quarry	Sandstone worked
500 m to the west of Crawshawbooth [8090 2540]	Lower Haslingden Flags
500 m to the east of Crawshawbooth at Bottomley Bank Farm [8170 2540]	Upper Haslingden Flags
600 m to the north-west of Love Clough [8065 2745]	Woodhead Hill Rock
400 m to the north-east of Windy Bank [8456 2734]	Great Arc Sandstone
200 m to the north-west of Meadows Farm [8490 2655]	Great Arc Sandstone
Higher Nutshaw [8265 2870]	Milnrow Sandstone
Nutshaw Hill [8232 2852]	Old Lawrence Rock
Park Scout [8087 2906]	Old Lawrence Rock
200 m west of Crown Point [8472 2878]	Old Lawrence Rock
Broadhead Moor Farm [8320 3040] and [8330 3020]	Old Lrwrence Rock

480 m north of Townend Close [8016 2850]	Dandy Rock
375 m north-west of Bullions Close Farm [8200 3390]	Tim Bobbin Rock

Table 2: Main sandstone quarries within the Burnley district.

7 Man-Made Deposits and Worked Ground

7.1 MADE GROUND

The main areas of Made Ground in the district occur at:

SD82NW

Clowbridge [8235 2800], Clough Bottom [8460 2673] and Short Clough [8128 2515] reservoir embankments

Quarry spoil, west of Crawshawbooth [8080 2535]

Quarry spoil, east of Crawshawbooth [8162 2544]

Crawshawbooth Industrial Estate [8110 2560]

Kippax Mill [8080 2635]

Love Clough industrial area [8100 2725] (this area includes reservoir embankments, surface landfill and a levelled factory site)

SD83SW

Burnley town centre [8440 3240]

Industrial land at Rose Grove [8140 3270]

M65 road embankments [8075 3212]-[8258 3278]

Leeds-Liverpool canal embankment [8445 3230]

Infilled reservoirs, Lowerhouse [8070 3260]

Minor areas of Made Ground include small patches of quarry spoil, mining waste from adits, made-up ground associated with residential developments, reservoir and railway embankments and covered reservoirs.

7.2 WORKED GROUND

The main areas of Worked Ground occur at:

SD82NW

Sandstone quarry, west of Crawshawbooth [8080 2546]

Sandstone quarry, east of Crawshawbooth [8170 2542]

SD83SW

M65 road cuttings [8000 3200]-[8340 3335]

Townley Colliery spoil [8480 3070]

Minor areas of Worked Ground are associated with railway cuttings, sandstone quarries and clay pits.

7.3 INFILLED GROUND

Infilled Ground includes excavations fully or partially backfilled. BGS does not hold records of the nature or type of backfill for the majority of sites. The main areas of Infilled Ground occur at:

SD82NW

Backfilled opencast coal sites: see section 6.1 for site details

Backfilled sandstone quarries: see section 6.5 for location details

Lower Park Limestone Hushings [8085 2960]. This extensive but ill-defined area of surface workings and spoil have been defined as Infilled Ground: see section 6.3 for details

Backfilled quarry, 200 m north of Higher Nutshaw [8280 2900]

SD83SW

Backfilled clay pit [8308 3100]

Land south of the M65 [8165 3226]

Minor areas of Infilled Ground are associated with sandstone quarries and crop workings for coal.

7.4 LANDSCAPED GROUND

SD82NW

Burnley Golf Course [8400 3000]

SD83SW

Burnley Municipal Golf Course [8500 3140]

Billington Road Industrial Estate [8180 3145]

Network 65 Industrial Estate [8070 3175]

Industrial site north of Knotts Bridge [8020 3230]

7.5 DISTURBED GROUND

The main areas of disturbed Ground occur at:

SD82NW

150 m north of Crown Point House (origin unknown) [8367 2989]

East Bank (origin unknown) [8425 2600]

8 Geological Hazards

8.1 UNCONSOLIDATED DEPOSITS

Unconsolidated deposits in the Burnley and Dunnockshaw area include **Debris Cone, Head, Alluvium, Glaciofluvial Sand and Gravel, Made and Infilled Ground.** Unconsolidated deposits are internally heterogeneous, and can be highly compressible compared with other drift deposits or bedrock, and may give rise to excessive or differential settlement of superposed structures. For this reason particular care should be taken in the siting of any construction on such deposits. The presence of relatively impermeable till beneath sand may cause the presence of a perched water table. Running conditions may be encountered in such unconsolidated deposits if encountered below the water table.

8.2 LANDSLIP

Steep slopes consistng of interbedded sandstone and mudstone (such as those formed by parts of the Pennine Lower Coal Measures Group and Millstone Grit Group) may be susceptible to slope instability and failure. Till may also be susceptible to slope instability and failure. A large-scale historic composite slip lies to the north of Hameldon Hill, at Hapton Park [8080 292]. The slip appears to be composed of both Till and mudstone between the Dyneley Knoll Flags and Old Lawrence Rock. Smaller landslips hae been identified at Ley Cottage [8142 2794], to the north of Folly Clough [8182 2603] and Carr Bank Farm [8054 2545]. The slips are characterised by smooth, moundy surfaces. At Ley Cottage and Folly Clough, trees growing on the slips have bent trunks, indicating fairly recent movement.

8.3 MAN MADE DEPOSITS

Man Made Deposits represent a hazard in three main ways:

1. Areas of backfill (see 'Infilled Ground', above) may have been poorly compacted when emplaced or may contain materials likely to rot or corrode. The composition of the fill material can vary from site to site, and within short distances on a single site. This may lead to unpredictable bearing capacity and uneaven settlement. Additionally, the backfill material may be partly water-soluble and the slow dissolution by water over time may result in the formation of voids and unpredictable ground conditions. If the spoil is dumped on a slope, any buried soil/organic layer may form a plane of weakness and therefore might form a potential failure surface. Poorly managed groundwater flow in embankments and spoil heaps may allow pore pressures to build up in these deposits, resulting in slope failure.
2. Toxic residues, either as a primary component of a Man Made Deposit or generated secondarily by chemical or biological reactions, can migrate both within a deposit itself, and into adjacent permeable strata. The presence of partially backfilled quarries in this area may provide a source of such a hazard.
3. Toxic or explosive gases, particularly methane, can be generated within waste tips and landfill sites. Such gases migrate (sometimes through adjacent permeable strata) and accumulate within buildings or excavations either nearby or some distance away (Aitkenhead and Williams, 1991; Hooker and Bannon, 1993). As with toxic residues, the presence of backfilled quarries may provide a potential hazard.

The possible problems presented by Man Made Deposits in various geological contexts should be addressed by appropriate geotechnical investigations. It must always be borne in mind that, in an area of past and active opencast mining and quarrying, Man Made Deposits are common. Those shown on 1:10 000 Geological Sheets SD82NW (Dunnockshaw) and SD83SW (Burnley) were delineated principally by recognition in the field and the examination of documentary sources. As such, only the more obvious Man Made Deposits can be mapped by this method, and the boundaries shown may contain inaccuracies.

8.4 COAL MINING SUBSIDENCE

Much of the area has been undermined, often at many levels under any one site, and from surface to potentially considerable depths. Deep mining ceased in the 1950s and any subsidence affects are likely to have long ceased. A detailed picture of the mining history and possible effects that may be related to mining can be obtained from the Coal Authority, Mining Reports, 200 Lichfield Lane, Mansfield, Nottinghamshire NG18 4RG.

Details of the coal mines of east Lancashire and Burnley are given by Nadin (1997; 1999).

8.5 MINEWATER POLLUTION

Minewater pollution has been a problem since the cessation of deep mining in the region. Polluted minewater (also called ‘race’) has escaped into the local waterways from numerous collieries in the region. After the mine-pumps are turned off, rising groundwater can exit the mine void through shafts and adits.

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Appendix 1

Index data of boreholes referred to in the report.

BGS Reference Number	Borehole Name	Grid Reference	Date Drilled (if known)
SD82NW/1	Lower Clough Bottom	8443 2651	
SD82NW/3	Burnt Hill	8252 2896	
SD82NW/4	Old Burnt Hall Pit	8275 2855	
SD82NW/5	Head of Copy Clough	8460 2949	
SD82NW/9	Wholaw Nook Colliery Shaft	8320 2880	
SD82NW/10	NCB Thorny Bank Clough A4/6A	8005 2930	1949
SD82NW/11	NCB Hameldon Hill A4/6B	8057 2947	1950
SD83SW/10	Burnley Cattle Market	8417 3233	c. 1850
SD83SW/17	Fulledge Colliery	8456 3229	
SD83SW/20	Fulledge Colliery Middle Pit (Pine Street)	8458 3234	c. 1850
SD83SW/164	Leeds-Liverpool Canal BH6	8453 3276	1982

Appendix 2

Location details of numbered locations referred to in the report.

Location Number	**Grid reference**	**Stratigraphy exposed; location**
Location 1	[8003 2899]	Old Lawrence Rock;
Location 2	[8087 2906]	Old Lawrence Rock; Hapton Park-Park Scout
Location 3	[8016 2850]	Dandy Rock; Townend Close
Location 4	[8181 2601]	Rough Rock; Folly Clough
Location 5	[8202 2616]	Rough Rock; Folly Clough
Location 6	[8456 2734]	Great Arc Sandstone; Clough Bottom
Location 8	[8014 2943]	Milnrow Sandstone; Hapton Park
Location 9	[8232 2852]	Old Lawrence Rock; Nutshaw Hill
Location 10	[8472 2878]	Old Lawrence Rock; Crown Point