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Geology of the Cliviger area (SD82NE and part of SD83SE)

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BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT WA/00/29

Geology of the Cliviger area (SD82NE and part of SD83SE)

E Hough

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1 Introduction

This report describes the geology of 1: 10 000 sheet SD82NE (Cliviger) and SD83SE (Worsthorne) south of northing 4̄33 (figures 1 and 2). The area (hereafter referred to as 'the district') was first geologically surveyed on the 'old' county series by E Hull, J R Dakyns, J C Ward and C Fox Strangeways, and published in 1870. W Lloyd subsequently remapped the district on the 'new' county series sheets Lancashire 64NE and SE, and 65 NW and SW in 1922-23. The one-inch Geological Sheet 76 (Rochdale) and the accompanying sheet memoir (Wright *et al.*,) were 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 117 m in Fulledge to 449 m at Thieveley Pike. The district may be conveniently split between upland moors and lowland pasture. The district straddles a watershead between the Lancashire Calder, part of the Ribble river system, and the Yorkshire Calder, which ultimately drains into the Humber. Coal, limestone and lead have been historically exploited within the district; only coal is worked on a small scale today; this has left livestock farming as the mainstay of the local economy.

The district is underlain at depth by rocks of Lower Palaeozoic to Marsdenian age, and at surface by rocks of highest Marsdenian, up to the Kershaw Coal, which is one of the uppermost units proved within the Burnley coal basin. The Cliviger area has had an active Quaternary history, during which extensive tracts of till were deposited, and spectacular over-deepened glacial meltwater channels (most notably the Cliviger Valley) were cut.

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.

Uncoloured dyeline copies of the 1: 10 000 sheets SD82NE and SD83SE (part) can be purchased from the Survey's offices at Keyworth, and records of the boreholes in the area may also be consulted there.

2 GEOLOGICAL SEQUENCE

DRIFT

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

SOLID

Carboniferous	Silesian (Upper Carboniferous)
	Lower Coal Measures
	Millstone Grit
	Bowland Shale Group
	Dinantian (Lower Carboniferous)
?Lower Palaeozoic	

3 ?LOWER PALAEOZOIC

Knowledge of the strata older than the upper part of the Middle Grit Group comes from the Holme Chapel Borehole (SD82NE 69). This borehole was drilled to a depth of 1982.9 m by Quintana Petroleum in 1974, 1500 m to the west of Holme Chapel. The biostratigraphy and correlation of strata proved by the borehole was interpreted by Riley and McNestry (1988), from which the Dinantian and Millstone Grit parts of this report draw heavily. The depths quoted for the Holme Chapel Borehole (SD82NE 69) are uncorrected for deviation and lag-time. Strata below the Bilinguites Superbilinguis Marine Band proved by the Holme Chapel Borehole (SD82NE 69) are shown in Figure 3.

Strata from 1968.6-982.9 m in the Holme Chapel Borehole (SD82NE 69) consist predominantly of slate, which is micromicaceous, reddened and cleaved. Detailed petrographic analysis was carried out by (BGS, 1982) on two samples from within this unit.

The sample WG440 was of clay and rarely silt-grade, pinkish-brown, thinly laminated and slickensided. A heavy coating of a secondary crystallisation of hematite was noted. The sample gave a very strong basal reflection of illite at -10O with X-ray diffraction (XRD) analysis. This indicates a very well-ordered lattice due to recrystallisation under low-grade metamorphic conditions.

The sample WG440A was of black shale, thinly-laminated and fissile, with a few grains of vein quartz and calcite. The XRD trace showed a typical argillaceous rock composition of poorly crystallised illite followed by kaolinite, chlorite, illite-montmorillonite and trace quartz.

The strata were tentatively interpreted as possibly Lower Palaeozoic by Quintana Petroleum (SD82NE 69).

4 DINANTIAN (LOWER CARBONIFEROUS)

The Holme Chapel Borehole (SD82NE 69) proved 468 m of strata assigned to the Dinantian. Although a local lithostratigraphical nomenclature is not availible for the Dinantian in the borehole, the strata may be split into three distinct lithological units.

Basal unit (1928.3 - 1968.6 m)

This consists of interbedded dolomitic and silicic sandstone, pebbly sandstone and siltstone, and microcrystalline dolomite. The base of the unit may be represented by a breccia composed of reworked clasts from the underlying slate unit.

Middle unit (c. 1859.8 - 1928.3 m)

Dolomite and dolomitic limestone dominate this interval. For the most part, the strata are brown, grey and white, and the dolomite is fine- to medium-grained. Rare vugs and fractures have been noted from within this interval.

Upper unit (1500.6 – c. 1859.8 m)

This unit is composed of micrite and biomicrite with subordinate calcite, sparite and dolomite. The strata are brown, light and dark grey in colour. Crinoid stem fragments and algal pellets are common throughout this interval. Rarer are bivalve and ostracod shells. A poor hydrocarbon trace of oil was noted around 1824.7 m.

It is thought the upper unit developed within a carbonate platform sequence, and is not composed of limestone turbidites (Riley, 1988).

5 SILESIAN (UPPER CARBONIFEROUS)

5.1 BOWLAND SHALE GROUP

The **Upper Bowland Shale Formation** is present between 1463.4 and 1500.6 m in the Holme Chapel Borehole (SD82NE 69). Due to a non-sequence and facies change, the Lower Bowland Shale Formation is absent and the formation rests unconformably on the Dinantian limestone sequence. It is likely that the upper part of the formation has been faulted out in the Holme Chapel Borehole (SD82NE 69), which explains why only 37.2 m is preserved. The unit is composed of shale, dark grey, pyritic, slickensided. Barite veining was noted on the original oil company log.

5.2 MILLSTONE GRIT

The **Pendle Grit Formation** is the lower of two sandstone-dominated units of Pendleian age. The Holme Chapel Borehole (SD82NE 69) proved 224.1 m of the formation, from 1239.3 to 1463.4 m. The base in this area is probably faulted. The strata are composed of light and dark grey, calcareous, with subordinate shale interbeds. The lower c. 30 m is a dark grey and brown micaceous sandstone with non-calcareous shale. Scolecodonts, indicative of a marine environment of deposition, occur between 1393.3 and 1396.3 m.

The **strata between the Pendle Grit and the Warley Wise Grit formations** is between 1131.1 and 1239.3 m (108.2 m thick) in the Holme Chapel Borehole (SD82NE 69). The interval is dominanted by fine-grained and poorly-sorted sandstone with micaceous sandy siltstone interbeds, which are in part pyritic. Siltstone dominates the lower part of the unit (below 1219.5 m) while the unit becomes sandier above this point.

The **Warley Wise Grit Formation** is present between 1054.0 and 1131.1 m, is 78.1 m thick in the Holme Chapel Borehole (SD82NE 69). The formation is conformable on the underlying strata. This interval is composed of sandstone, which is pebbly in the lower part, white and pale grey, fine- to medium-grained and moderately- to well-sorted.

The **Sabden Shale Formation** is present between 908.5 and 1051.8 m (143.3 m thick) in the Holme Chapel Borehole (SD82NE 69). The formation is conformable on the Warley Wise Grit Formation. The Cravenoceras cowlingense Marine Band is present at the base of the formation. Dark grey and black shale, which is fissile and partially calcareous, comprises the majority of the formation. The shale is interbedded with rare, thin limestone and sandstone beds. Thin coal seams were noted at approximately 960.4 m, 91.4 m above the base of the formation. The formation is thought to be Arnsbergian to Kinderscoutian in age.

The **Todmorden (Parsonage) Grit** is 56.4 m thick in the Holme Chapel Borehole (SD82NE 69) (between 852.1 and 908.5 m). This rests conformably on the Sabden Shale Formation. The grit is Kinderscoutian in age. The basal part of the Todmorden Grit is an interbedded sequence of micaceous sandstone which is fine- to medium-grained, and fissile dark grey shale. The upper part is a quartz-rich sandstone which is fine-grained.

The **Kinderscout Grit** is predominantly sandstone, grey and brown, fine- to coarse-grained, with subordinate micaceous shale partings. The upper part of the grit is affected by faulting, represented in the core by considerable calcite veining and slickensiding. The magnitude of the faulting is unknown. The grit is 386.2 m thick in the Holme Chapel Borehole (SD82NE 69) (between 465.9 and 852.1 m).

The interval between the Kinderscout Grit and the top of the Millstone Grit Group is an alternating series of sandstone and mudstone-dominated units, with rare coal beds. The interval is Marsdenian in age.

In the Holme Chapel Borehole (SD82NE 69), the **interval between the top of the Kinderscout Grit Group**, at 465.9 m, **and the base of the Alum Crag Grit** of the Middle Grit Group, at 451.2 m, is dominated by dark grey fissile shale. The Bilinguites gracilis Marine Band is present 0.61 m above the base of this unit. This unit is conformable on the Kinderscout Grit Group.

The **Alum Crag Grit** is 68.6 m thick (present between 382.6 and 451.2 m) in the Holme Chapel Borehole (SD82NE 69). The unit is composed of upward-fining sandstone units with pebble bases and fine grained sandstone, or siltstone tops. These units are thought to be turbiditic in origin (Riley and McNestry, 1988). Sandstone units are pale grey, micaceous and moderately- to poorly-sorted. This is overlain by 15.2 m of mudstone, which includes the Bilinguites bilinguis Marine Band that lies 7.0 m above the top of the Alum Crag Grit.

The interval from the Marsdenian Gorpley Grit to the Kershaw Coal, within the Lower Coal Measures is present at surface. Strata above the Holcombe Brook Grit are proved in numerous British Coal exploration boreholes. A comprehensive account of the geology of Cliviger Valley by Williamson was published in 1956.

The **Fletcher Bank (Gorpley) Grit** is present between 321.6 - 367.4 m (45.8 m thick) in the Holme Chapel Borehole (SD82NE 69). The grit is a grey and brown sandstone and pebbly sandstone which is poorly sorted. The Fletcher Bank Grit is overlain by 26.5 m of dark grey mudstone and shale, which is micaceous, with subordinate thin beds of sandstone and coal.

Within the Holme Chapel Borehole (SD82NE 69), the **Helmshore Grit** consists of 34.5 m of grey sandstone and pebbly sandstone which is poorly-sorted. On the Helmshore Grit rests 12.2 m of mudstone, within which lies the second Bilinguites bilinguis Marine Band.

The **Hazel Greave Grit** is 18.6 m thick, and present between 229.9 and 248.5 m in the Holme Chapel Borehole (SD82NE 69). It is a grey-brown micaceous sandstone with subordinate siltstone beds. Sections recorded in Green's Clough during the previous survey show the Hazel Greave Grit to be massive or thinly-bedded, and coarse-grained. Ripple marks in the Hazel Greave Grit were recorded by Williamson (1956). The Hazel Greave Grit is overlain by 22.0 m of black micro-micaceuos shale; the Bilinguites superbilinguis Marine Band is present within this, and was 7.3 m above the top of the grit in the Holme Chapel Borehole (SD82NE 69).

The Holme Chapel Borehole (SD82NE 69) proved 13.7 m of the **Holcombe Brook Grit**, from 194.2 to 207.9 m. The grit is exposed in Ratten Clough [8912 2691], where it is a yellow-brown coarse-grained sandstone.

A generalised vertical section of strata between the Holcombe Brook Grit and Subcrenatum Marine Band is shown in Figure 4.

The **Holcombe Brook Coal** and overlying **Cancelloceras cancellatum Marine Band** are exposed at Ratten Clough [8911 2689]. In the Cliviger district, the coal is typically between 0.2 and 0.3 m thick. The marine band occurs within a dark fissile carbonaceous mudstone, approximately 10 m above the top of the Holcombe Brook Grit. Fossils present, listed by Williamson (1956), include *Lingula, Gastrioceras cancellatum, Reticuloceras superbilingue, Posidonia insingis* and *Dunbarella elegans.*

The **Lower Haslingden Flags** overlie approximately 18 m of mudstone on the Holcombe Brook Coal. The unit varies in thickness from approximately 10m at Ratten Clough

[8904 2679] to at least 22 m in Green's Clough [8936 2614]. Exposure is limited to the southern face of Cliviger Valley, and as far north as the Cliviger Lead Mine Fault. The Lower Haslingden Flags are composed of interbedded fine-grained sandstone and siltstone. Current ripple-

lamination and minor channeling at the base of some of the major sandstone units are common features of the flags in the district.

The **Upper Haslingden Flags** overlie about 18 m of dark grey mudstone with ironstone nodules and subordinate sandier beds. The flags are 24 m thick at Green's Clough [8926 2606] (McLean and Chisholm, 1996). The Upper Haslingden Flags are exposed in a quarry to the south-east of Green's Clough [8941 2605]. The lithology is fine-grained grey-green silty sandstone with clay-draped ripples, and abundant lithified wood fragments.

The **Rough Rock** is typically a yellow-brown pebbly sandstone with rare mudstone and coal beds. It overlies approximately 12 m of grey mudstone that overlies the Upper Haslingden Flags. The Rough Rock is 27.4 m thick in Green's Clough [8922 2600], and is generally massive or trough cross-bedded. The Rough Rock crops out along the southern slopes of the Cliviger Valley, and the eastern margin of Cant Clough Reservoir [9000 3110] and [9000 3088]. The Rough Rock contains many lithified stems of *Calamites, Cordaites, Sigillaria, Lepidodendron and Stigmaria* (Learoyd, 1988), which probably occurred as log-jams in the depositional fluvial system (Wignall and Kabrna, 1994).

The **Sand Rock Coal**, which occurs within the Rough Rock, was not examined during the present resurvey. The coal seam varies between 12 and 26 cm thick, and overlies approximately 1 m of fireclay at Fish Pond Clough [8774 2742] (Williamson, 1956).

The **Six-Inch Coal** overlies the Rough Rock. It was not examined during the present resurvey. The coal seam is 53 cm thick, and overlies 76 cm of fireclay in the Fish Pond Clough section (Williamson, 1956). The **Subcrenatum Marine Band**, which overlies the Six-Inch Coal, is exposed in Ratten Clough [8897 2664], where it consists of a blue-grey mudstone with goniatites, *Posidonia insignis* and *Dunbarella papyracea.*

McLean and Chisholm (1996) discuss the relationship between palynomorph assemblage and the Lower Haslingden Flags- Rough Rock interval. The assemblage suggests a source area from the west or south. This broadly concurs with palaeocurrent data, which suggests a westerly derivation for the interval.

5.3 LOWER COAL MEASURES

The Westphalian Lower Coal Measures are known from exposures, boreholes, and from workings for many former collieries and opencast sites and quarries in the area. A significant number of these workings have taken place since the previous survey, and therefore post-date the publication of both the Survey's Rochdale memoir (Wright *et al.*,1927), and the original coalfield memoir (Hull *et al.* 1875). A generalised vertical section of Lower Coal Measures strata in the Cliviger district, up to the Lady Coal is shown in Figure 5.

The **Woodhead Hill Rock** rests on 12-15 m of hard blue-grey mudstone that overlies the Subcrenatum Marine Band. The sandstone is between 12.8 and 14.6 m thick. The Woodhead Hill Rock is exposed in a natural crag, locally known as 'Beacon Rock', at Thievely [8748 2758] (Location SD82NE 2). The sandstone is greyish-yellow, coarse-grained and micaceous. The exposure had previously been incorrectly identified as the Rough Rock (Pettijohn and Potter, 1964; Shackleton, 1962). A quarry at the east of Clough Bottom Reservoir [8520 2715] (Location SD82NE 4) exposes approximately 4 m from the middle part of the Woodhead Hill Rock. The exposure shows sandstone, yellow-green, with sub-angular to angular grains, with mica on bedding surfaces and dark silty laminae in places. The sandstone is trough cross-bedded, and migrating barforms are well preserved.

The **Bassey Coal** overlies a thin seatearth on the Woodhead Hill Rock. The seam is in the region of 61 cm thick in the south-eastern part of the district. The Bassey Coal was formerly exposed near Dean Scout c.[8730 2753], where it was 35 cm thick (Williamson, 1956).

The **Lower Foot Coal** is present about 15 m above the Bassey Coal, the intervening strata being composed of grey-blue mudstone. The Lower Foot Coal is 23 cm thick in Green's Clough, recorded in an unpublished log drawn up during the previous survey.

The **Gannister Rock** is an impersistent sandstone up to approximately 3 m thick. It is exposed at the headwaters of Ratten Clough, on Heald Moor [8842 2655]. It is medium-grained, orange-brown, micaceous and ripple-laminated.

The **Lower Mountain Coal** rests on the Gannister Rock; where this is absent, it overlies approximately 15 m of mudstone-dominated strata above the Lower Foot Coal. The Lower Mountain Coal has been mapped to the south of the Deerplay Fault; to the north of this fault, the coal amalgamates with the Upper Foot Coal, forming the Union Coal. The Lower Mountain Coal was worked at the Higher Deerplay- Dean Head opencast site, where the coal was 1.43 m thick.

The **Great Arc Sandstone (Bullion Rock)** comes to crop to the south of the Deerplay Fault. It forms a prominent dip slope between Bent Hill [8565 2700] and Sod Hey Farm [8665 2610]. The sandstone is likely to be in the region of 5-10 metres thick. The sandstone is not exposed in the district; in the Bacup area, to the south of the Cliviger district, it is typically a fine- to medium-grained well-bedded sandstone.

The **Upper Foot Coal (Bullion)** rests on the Great Arc Sandstone; consequentially, it only crops out to the south of the Deerplay Fault. Boreholes within the district have not proved the coal seam. In the Bacup district (Hough, 2004), the coal seam is between 0.2 and 0.3 m thick.

The amalgamation of the Upper Foot and Lower Mountain coals forms the **Union Coal**. The Union Coal has been opencast in two sites on the southern margin of The Cliviger Valley. The coal was 1.17 m thick in the Cowside Opencast site, and 0.91 – 1.06 m thick in the Cragg Moor Opencast site.

The Union and Upper Foot coals are overlain by the **Listeri Marine Band**. This was exposed during the previous survey in Green's Clough. The marine band is also present in Hurstwood No. 1 Borehole (SD83SE 50) where it is a black and grey fissile mudstone with lingula and goniatite impressions.

The **Inch Rock** overlies approximately 20 m of mudstone on the Listeri Marine Band. The Inch Rock is only present south of the Deerplay Fault, where it forms a poor feature on the slopes of Scar End Hey [8760 2513] and Dean Heights [8576 2525] and [8670 2537].

The **Inch Coal** overlies the Inch Rock; where the Inch Rock is absent, the coal rests on the mudstone succession above the Listeri Marine Band. The Inch Coal is present throughout the district, and is typically 0.05-0.1 m thick.

The **Helpet Edge Rock** rests on 6-11 m of mudstone. The unit typically comprises up to 3 m of greyish-brown coarse-grained, massive sandstone.

The **Upper Mountain Coal** overlies the Helpet Edge Rock. The coal is between 0.5 and 0.9 m thick in southern and central parts of the district, thinning to 0-0.2 m in the Worsthorne area. The coal has been opencast in four sites in the district. The coal was 0.53 m thick in the Higher Deerplay- Dean Head site. The coal was 0.51-0.58 m thick in the Higher Deerplay and Flowers Farm sites, both on the southern margin of the district, and 0.41 m thick in the Cowside opencast site.

The **Cannel Coal** is an impersistent coal which is up to 0.7 m thick in the district. The seam overlies 3.04 m of dark and pale grey mudstone at the Cowside Opencast Site, where the 0.38 m thick seam was worked.

The **Darwen Flags** range in thickness between 0 and 9.1 m in the district, broadly thickening towards the north. The flags are exposed in a section on the north-western bank of Easden Clough [8606 2842] (Location SD82NE 1). The sandstone is fine- to medium-grained, with some coarse-grained muscovite flakes on bedding surfaces, and rare coalified plant remains.

Both current and interference ripple-lamination is common, with silty drapes on some of the ripple tops. Ripple-laminated units are typically planar-based, with planar current lineation on these planar surfaces trending 045-225. Small-scale trough-sets are also preserved at this locality. Plant remains are common within the flags in the Hurstwood No. 1 Borehole (SD83SE 50).

The **Amaliae (Tonge's) Marine Band** has been tentatively identified in the Hurstwood No 1 (SD83SE 50), 2 (SD83SE 51) and Deerplay 3a (SD82NE 22) boreholes. The horizon is represented by black fissile mudstone; *Planolites* were identified in the Deerplay 3a Borehole (SD82NE 22). The marine band occurs 23 m above the Darwen Flags in the Hurstwood No. 2 Borehole (SD83SE 51). The marine band is exposed in the back scar of a landslip at Scout [8687 2838], where it is a 3 cm bed of well-bedded mudstone with *Dunbarella* and ironstone nodules (Williamson, 1995).

The **Milnrow Sandstone** is a major sandstone unit within the district, attaining a maximum proved thickness of 21 m in Hurstwood No. 1 Borehole (SD83SE 50). The sandstone crops out along the Calf and Craggs Moor-Thievely Pike ridge [8500 3000] to [8935 2500], and to the east of Hurstwood [8940 3300] to [9000 2815]. The Milnrow Sandstone has been quarried on a small scale throughout the district. The Milnrow Sandstone is exposed in a small sandstone quarry 10 m west of the summit of Thievely Pike [8714 2711] (Location SD82NE 5). Spoil debris shows the lithology consists of coarse-grained and rarer medium- and fine-grained sandstone. Grains are composed of quartz, volcanic rock fragments and mica. Grains are subspherical and angular to very angular. The sandstone is low-angle cross-bedded throughout, with sub-parallel bounding surfaces.

The **Cemetery Coal** occurs 2.44 m below the top of the Milnrow Sandstone, and is 0.30 m thick, overlying 3.04 m of mudstone within the Milnrow Sandstone in the Hurstwood No. 2 Borehole (SD83SE 51). The Cemetery Coal is 0.25 m thick in the Deerplay Colliery Borehole (SD82NE 25), where it occurs 1.89 m below the top of the Milnrow Sandstone.

The **Pasture Coal** occurs up to 3 m above the Milnrow Sandstone, from which it is separated by mudstone. It is up to 0.3 m thick in the south of the district, thickening northwards to 1.09 m in Rowley No. 2 Borehole (SD83SE 5), near Worsthorne.

The **Dyneley Knoll Flags** overlie approximately 12-31 m of mudstone on the Pasture Coal. They are typically composed of greenish-grey micaceous sandstone that is well bedded, and rarely cross-bedded. The district encompasses the type area for the flags, which is at Dyneley Knoll [8580 2870]. The Dyneley Knoll Flags have been quarried on a small scale within the southern and central parts of the district. The flags are exposed in a small quarry 300 m north-east of Maiden Cross on the Long Causeway [8966 2896] (Location SD82NE 3). Approximately 3 m of pale buff-brown sandstone is exposed. The grainsize is fine- to medium, and grains are moderately-sorted. The sandstone is ordered in co-sets, each up to 1 m in height. The basal and mid part of the cycles is planar-bedded; current ripple-lamination is common towards the upper part of the cycles, with silt drapes common on ripple tops. The flags are also exposed in a quarry 450 m to the south of Warcock Hill [8990 2801]. As at Maiden Cross, the sandstone is ordered into ripple-laminated co-sets bounded by very low angle surfaces.

Approximately 50 m comprising mudstone with subordinate sandstone beds overlies the Dyneley Knoll Flags. This interval is locally known as the '**Accrington Mudstones**', and is the main brick clay resource in the area. The mudstones are typically unfossiliferous and blue-grey in colour (Williamson, 1956).

The **Old Larwence Rock** overlies the Accrington Mudstones. The sandstone is between 25 and 32 m thick in the district, and is feature-forming, being responsible for Slipper Hill [8830 3260], Wasnop Edge [8950 3260] and Brown Edge [8840 3205] in the northern part of the district. The Old Lawrence Rock is exposed in quarries on the north-western side of Hurstwood Reservoir

[8866 3170]. The sandstone is fine- to medium-grained, grey-green and slightly micaceous. The sandstone is commonly ripple-laninated.

The **Riddle Scout Rock** overlies up to 25 m of mudstone on the Old Larwence Rock. The Riddle Scout Rock is between 3 and 13 m thick, and is best exposed at the type section, Riddle Scout [8917 2756]. The sandstone is greenish-grey, fine- to medium grained, micaceous and cross-bedded.

The **Arley Coal (Cliviger Four Foot)** was historically the most economically important coal within the Burnley Coalfield. The coal ranges in thickness between 0.9 and 1.5 m. The coal has been crop worked, notably along the valley north-east of Broughton Wood [8770 2965]. Deep workings are common throughout the district, with the coal worked from many collieries, including Copy Colliery, Cliviger (SD82NE-21). Extensive workings in the seam were carried out to the east and north of Holme Chapel, in the Causeway Group- Helley Platt, Short Edge Zone and Maiden Cross opencast sites.

The Arley Coal is overlain by 7-25 m of mudstone, with a thin coal proved in the west of the district in the Crown Point Road area [3015 2800]. On this mudstone-dominated succession rests the **Dandy Rock**. This is a well-jointed and cross bedded sandstone. The log from Copy Colliery, Cliviger proves the Dandy Rock to be silty, including up to two mudstone-dominated units up to 3.6 m thick. The Dandy Rock is exposed in a quarry to the east of Rock Water [8827 3093]. The sandstone is medium-grained, and slightly micaceous. Trough cross-bedding and silt-draped current ripples are common, and loading structures are present on the bases of some bedding planes. The sandstone is rarely massive.

The **Dandy Coal** rests on up to 10 m of mudstone on the Dandy Rock. The seam is up to 2 m thick, as proved by in Copy Colliery, Cliviger . Further to the north, the seam may be split into a lower leaf, 0.2-1.1 m, a middle leaf, 0-0.2 m, and an upper leaf, 0.2-0.9 m, separated by thin mudstone partings, as proved by Hurstwood A4/11d Borehole (SD83SE 15). The seam has been widely worked in the district by both deep and opencast methods. At Bradget Hey [8875 2764], the Dandy Coal is be overlain by approximately 3 m of sandstone.

The **Crackers Coal** occurs 14-32 m above the Dandy Coal, the intervening succession being composed of mudstone with laterally impersistent sandstone and coal beds. The coal was named after the crackling noise made as it burnt (Williamson, 1956). The coal is 1.07 m thick in the Round Hill A4/4f Borehole (SD83SE 9) at Overtown. The coal is 0.8 m thick in Copy Colliery, Cliviger. The coal may be split into two leaves, a lower 0.3 m, and an upper 0.5 m. The Crackers Coal has been worked north of the Cliviger Valley Fault by deep mining methods.

The **China Coal (Cliviger Two Foot)** is typically 0.5-0.8 m thick in the district, the maximum thickness of 0.84 m being proved in an air shaft section from Cliviger Colliery. The coal has been extensively worked by both deep and opencast methods.

A thin, unnamed coal up to 13 cm thick has been proved 10.1-14.6 m above the China Coal. The thin seam crops out in the Short Edge Pasture area [8869 2838].

The **China Rock** is a composed of sandstone with up to two subordinate mudstone-dominated units in the lower part. The China Rock is 17.3 m thick in the Cowpe's Oakbank Mills Borehole (SD83SE 47). The China Rock is typically a pale buff, well cemented, massive sandstone. The sandstone forms an excellent dipslope to the east of Spring Gardens [8615 2945], and forms several features between The Lowe and Green Clough Wood, on the northern side of Cliviger Valley.

The **Lady Coal** crops out in the northern part of the district, between the Bacup Road [8542 3000] and Pike Hill [8658 3216], under considerable drift cover. The Lady Coal is typically 0.3 m thick, and rests on up to 7.9 m of mudstone on the China Rock in the Burnley Equitable Industrial Society Borehole (SD83SE 32).

A generalised vertical section of Lower Coal Measures strata in the Cliviger district above the Lady Coal is shown in Figure 6.

The **Tim Bobbin Rock** overlies between 0 and 7.3 m mudstone on the Lady Coal. The sandstone, which is not exposed in the district, is typically composed of grey-brown, fine-grained sandstone with ironstone concretions. The sandstone is interbedded with numerous mudstone beds, and is cross-bedded. The sandstone attains a maximum proved thickness of 47 m (top not proved) in the Cowpe's Oakbank Mills Borehole (SD83SE 47) in Burnley.

The **King Coal** is between 0 and 1.5 m thick, and is typically split into two leaves, a lower 0.5-0.6 m, and an upper 0.4-0.8 m. The seam has been opencast at the Burnley Ridge site, north of Brunshaw [8598 3264], where it was 1.46 m thick. The seam may rest on, or be overlain by, leaves of the Tim Bobbin Rock.

The **Fulledge Thin Coal (Haberham Blindstone)** crops out in the north-western part of the district. The seam was opencast at the Burnley Ridge site, where it was 1.2 m thick. The seam may be split into upper and lower leaves, 1.2 m and 0.6 m respectively.

The **Inferior Cannel Coal** rests on approximately 20 m of interbedded mudstone and sandstone. The Inferior Cannel Coal is up to 1.0 m thick in the Burnley area to the west, but is thought to be absent under some parts of the district. The coal was exposed in the Burnley Ridge Opencast Site, but not worked there.

The **Low Bottom Coal (Steam; Clifton Blindstone)** overlies between 0 and approximately 4 m of unnamed sandstone. The coal was opencast in the Burnley Ridge Opencast Site, where it was 1.21 m thick.

Strata above the Low Bottom Coal have not been proved by boreholes within the district. The strata are not exposed in the district as they incrop under drift. These strata are therefore described from provings to the west of the district, in the Burnley area (SD83SW), towards the depocentre of the Burnley Coal Basin.

The **Low Bottom Rider Coal** is approximately 0.1 m thick. The coal, which is laterally impersistent, occurs on 5 m of mudstone on the Low Bottom Coal. The Low Bottom Rider has not been shown on the accompanying 1:10 k map (SD83SE).

The **Lower Yard Coal** is one of the thickest coal seams in the Burnley Coal Basin, typically attaining a thickness of 2.0 m. The Lower Yard Coal subcrops under drift at Townley Park [8520 3108].

The **Lower Yard Rider Coal** overlies approximately 5 m of mudstone on the Low Bottom Coal. The seam is typically between 0 and 0.5 m thick.

The Lower Yard Rider Coal is overlain by 33 m of strata comprising mudstone, two unnamed sandstone units up to approximately 4 m thick, and an unnamed coal seam that is 0.2 m thick.

The **Maiden Coal (Old Yard)** is between 0.9 and 1.5 m thick. The Maiden Coal subcrops under drift at Townley Park [8510 3158].

The **Burnley Four-Foot Coal (Low; Old Thick)** rests on an unnamed sandstone up to 10 m thick. The seam is between 0.6 and 1.5 m thick in the Burnley area.

The **Shell Coal** is between 0 and 1.3 m thick. In the Burnley district, the coal overlies

1.2 m of an unnamed sandstone that overlies the Burnley Four-Foot Coal.

The **Kershaw Coal** is the highest named stratigraphical unit in the district. It is typically between 0.8 and 1.0 m thick, and subcrops under drift at Fulledge [8500 3200].

6 QUATERNARY

6.1 ALLUVIUM

The main area of Alluvium present within the district is between Fulledge [8500 3240] and Cliviger Mill Bridge [8636 3010], under Townley Park. The Alluvium is associated with the Calder, and is in excess of 600 m wide in places. The Burnley Co-Operative Laundry A Borehole (SD83SE 2), in the northern part of the deposit, proves 3.05 m of 'coarse sand and large stones' resting on glacial deposits. Thin tracts of Alluvium are developed at the base of The Cliviger Valley, at Walk Mill [8670 2965], Holme Chapel [8705 2880] and [8741 2850], and Portsmouth [9000 2620]. Alluvium is also present along the River Brun- Rock Water valley, from [8815 3107] to [8635 3264], at Brunside.

6.2 HEAD

Head is typically composed of unconsolidated, poorly sorted and poorly 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 restricted to topographic hollows and lows.

An interesting feature of the northern Cliviger area are deeply incised **glacial meltwater overflow channels**. A thin ribbon of Head commonly floors these channels, which may be in excess of 1000 m long and up to 15-20 m deep. Prominent lobes of Head are present east of Dean Scout, [8725 2757] and [8745 2770]. These would have formed through the dewatering of a debris flow, and may be up to 15 m thick (Williamson, 1995). Elsewhere in the district, Head is estimated to be less than 2 m thick.

6.3 RIVER TERRACE DEPOSITS, 1

River Terrace Deposits, 1 (formerly 'First Terrace') occur south-west of Rowley, in the northern part of the district. The terrace is associated with the River Brun. The deposits were mapped during the previous survey, but are totally obscured at the present time by colliery spoil, landfill the recently constructed Rowley Reservoir (not shown on the current OS basemap). River Terrace Deposits are typically composed of silt, sand and gravel, and may be cross-bedded.

6.4 DEBRIS CONE

Debris Cone Deposits have been identified on the southern side of The Cliviger Valley, between Dean Scout [8744 27614] and Ratten Clough [8911 2676]. The deposits are composed of matrix-supported sandstone blocks, predominantly of Rough Rock, with subordinate amounts of other sandstone units. Rock fragments have toppled from the cliffs of Thieveley Scout[8783 2736], Earl Bower [8804 2725], White Kirk [8818 2716], Scarth Rake [8874 2700] and Ratten Clough 8902 2673].

6.5 HILL PEAT

Three main areas of Hill Peat are present in the district: Deerplay Moor to Carr and Craggs Moor [8570 2765]-[9000 2500], Scar End Hey [8800 2510], and Dean Height [8625 2510]. Some of the deeper streams, and the Cragg Moor, Cowside, Flowers and Mean Hey opencast sites have cut through the Peat to expose bedrock. Hill Peat is typically composed of wet, dark brown,

partially decomposed vegitation with interbeds of silt and sand. Hill Peat in the district is estimated to be no more than 4 m thick.

6.6 GLACIOFLUVIAL SAND AND GRAVEL

Two areas of Glaciofluvial Sand and Gravel have been mapped, at Higher Cliviger [8665 3100] and to the north of the Calder [8600 3101]. The topography of the deposits is rounded, but they form slight positive features, perhaps indicating deposition at or near to a retreating ice margin. Glaciofluvial Sand and Gravel is typically composed of poorly sorted sand and gravel, with silty lenses. The deposit is unlikely to exceed 10-15 m in thickness.

6.7 TILL

Generally, glacial Till becomes more widespread towards the north of the district. Till is typically composed of reddish-brown and grey, pebbly and silty clay, with irregular lenses and pods of sand and gravel. To the south of Deerplay Moor, Till floors the valleys of the Irwell c.[8740 2545], Shepherd Clough c.[8540 2560], and of Whitwell Brook, to the north-east of Clough Bottom Reservoir c.[8510 2730]. Till is present along Cliviger Valley, which has been subjected to landslipping; to the north of this, Till underlies much of the area between Holme Chapel [8770 2840] and Burnley Ridge [8500 3345], on the northern margin of the district. Till also occurs in the broad valley north of Maiden Cross [89502870] to Hurstwood Brook [8970 3250], and along the Brun Valley c.[8760 3155]. A small area of Till is present north and east of Short Edge Plantation [8900 2850]. The thickness of Till is extremely variable, generally thickening north-westwards. The maximum thickness of Till proved is 26.52 m, by the Burnley Co-Operative Laundry A Borehole (SD83SE 2).

7 STRUCTURE

The district is situated between the Pennine and Rossendale anticlines (Williamson, 1956). The Cliviger district lies within the eastern and central parts of the Burnley Coalfield, part of the South Lancashire Coalfield. The Cliviger area lies on the 'Central Lancashire High', a Dinantian block area present at considerable depth between the Craven Basin to the north and the Rossendale Basin to the south. The architecture of the Dinantian in this area is discussed further by Evans and Kirby (1999).

The dip of strata in the district is variable, being shallow to the south and west, and steepening to the east, as the axis of the Pennine Anticline is approached. The dip azimuths vary widely, with the beds rolling and flexing, partly due to dragging by faults. Generally, strata to the south of Cliviger Valley dip to the south-east. North of Cliviger Valley, dip is typically to the east, with beds in general younging towards Fulledge [8500 3215].

The strata in the Cliviger district are affected by a number of faults of varying magnitude. The major faults in the area trend north-west south-east, and throw both to the north-east and north-west, towards the central part of the coal basin. A set of east-west trending faults typically have throws less than the north-west trending faults.

The **Deerplay Fault** traverses the south-western part of the district, from Scar End Hey [8801 2500] to north of Clough Bottom Reservoir [8500 2700]. The fault has a throw of 160 m to the north-east, and was proved in workings in the Union Coal at Deerplay Colliery. The Deerplay Fault is a synsedimentary structure that was active during the deposition of the Union Coal-Upper Foot Coal sequence (Broadhurst and Simpson, 1983). The split of the Union Seam southwards into the Lower Mountain and Upper Foot coals suggests the fault originally had a throw down to the south-west. The distribution of 'Rigs' (sediment bodies formed in ponds of water on the peat surface prior to coal formation) in the upper part of the Union and Lower Mountain seams supports the assumption that the Deerplay Fault originally threw down to the south-west. Subsequent reactivation of the fault with movement down to the north east explains the current north-easterly throw.

Four faults trending broadly south-west occur to the south-west of the Deerplay Fault. The faults, which all throw towards the south-east are relatively minor, with throws not exceeding 30 m.

The **Theiveley Lead Mine Fault** trends east-west, from Crown Point Road [8500 2792] to its termination against the Cliviger Valley Fault at Calder Head [8805 2769]. The fault has a throws approximately 310 m to the north. Mineralisation, including Galena and Barites, has developed along part of the fault.

An unnamed fault trending north-westwards has been mapped from Calder Head [8810 2765], terminating on Heald Moor [8881 2640]. The fault has a throw in the region of 15 m to the north-east, repeats the upper part of the Woodhead Hill Rock and Bassy Seam.

The **Cliviger Valley Fault** is one of the major basin extensional faults within the Burnley Coalfield. The fault, which trends north-westwards, has a throw up to 396 m to the north-east, bringing the Dandy Rock against the Millstone Grit Group at Copy Bottom [8821 2757]. The throw of the fault decreases both north-westwards and south-eastwards as the fault bifurcates.

A number of faults have been identified between the Theiveley Lead Mine and Cliviger faults. The faults have throws between 3 and 54 m, and were identified from underground workings.

The **Worsthorne Fault**, which trends north north-westwards can be traced from 200 m east of Willingate Wham [8972 2790] to the northern margin of the district, at Brownside [8710 3300]. The throw of the fault increases northwards to approximately 150 m to the south-west. The fault has been proved by both surface mapping, and in underground workings in the Arley Coal.

An unnamed fault trends broadly east-west from the Cliviger Valley Fault at [8666 2866] to the Worsthorne Fault at [8964 2815]. The western part of the fault has a throw of 100 m to the south; this decreases eastwards to 76 m.

There are many other unnamed faults between the Cliviger Valley and Worsthorne faults. The faults have been identified mostly in underground workings, and have throws ranging up to approximately 25 m. Trends and throw directions are variable; generally the more important faults trend broadly east-west.

8 ECONOMIC GEOLOGY

Figure 7 shows areas that have been worked for opencast coal, sandstone, brickclay, sand and limestone within the Cliviger district.

8.1 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 (see Table 1). Practically all the seams in the area 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
SD82NE 31	Helly Platt [8780 2910]	Arley	1956	Full
SD82NE 33/ SD82SE 16	Higher Deerplay [8625 2525]	Upper Mountain	1954	Full
SD82NE 44	Short Edge [8860 2870]	Arley	1951	Full
SD82NE 46	Maiden Cross [8910 2810]	Arley- China	1950	Full
SD82NE 48	Dyneley Lodge [8630 2925]	Dandy	1957	Full
SD82NE 50	Higher Deerplay-Dean Head [8670 2615]	Lower Mountain-Upper Mountain	1951	Full
SD82NE 56	Causeway Group [8830 2925]	Arley	1948	Full
SD82NE 57	Sod Hay [8655 2595]	Lower Mountain	1943	Full
SD82NE 60	Cowside [8700 2740]	Union- Arley	1960	Full
SD82NE 64	Cragg Moor [8850 2640]	Union	1949	Full
SD83SE 65	Mosley Height [8775 2992]	Dandy- China	1955	Full
SD83SE 66	Burnley Ridge [8580 3300]	Low Bottom-King	1950	Full

Table 1: Opencast sites within the Cliviger district

8.2 FIRECLAY

Fireclay has been worked from the mudstone unit above the Holcombe Brook Grit in the Deanwood Fireclay Mine, southwest of the A646 [8922 2689] to [8940 2673].

8.3 LEAD

Lead deposits have been developed in lodes associated with the Thieveley Lead Mine Fault. Lead has been mined from the former Thieveley Lead Mine [8736 2780] since about 1627 Century (Thornber, 1988). Lead was smelted at Thieveley and the site of Pot Oven Farm [8790 2805]. Mining is unknown after 1635 (Gill, 1988).

8.4 LIMESTONE

Limestone boulders within the Till have been mined by opencast methods since the 17th Century. Mining took place in the north-east of the district at the following locations:

Sheddon Clough [8935 2980] (Location SD82NE 6)

West of Middle Pasture [8890 3040]

East of Hurstwood Reservoir [8930 3160]

Swindon Water [8960 3300]

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 kilns, the remains of which are present in the Sheddon Clough area [8940 2980]. Limestone was used to lime acidic soils and in mortar. Thornber (1989) gives further detail and background to the Sheddon Limestone Hushings.

8.5 SANDSTONE

Workings for sandstone have in the past been concentrated in the lower and mid-parts of the Lower Coal Measures. Most of the larger quarries have been part or wholly backfilled, mainly with sandstone spoil. The main areas of sandstone quarrying within the district are shown in Table 2.

Site location and approximate Grid Reference of quarry	**Sandstone worked**
200 m north-east of Clough Bottom Reservoir [8715 2715]	Woodhead Hill Rock
North of Burnley Road [8717 2754]	Woodhead Hill Rock
300 m north-west Cant Clough Farm [8945 3130]	Milnrow Sandstone
350 m north-east of Old Wambs Farm [8830 2555]	Dyneley Knoll Flags
100 m north-east of Yew Tree Farm [8790 2795]	Dyneley Knoll Flags
Stone House Edge [8650 2817]	Dyneley Knoll

	Falgs
Sheddon Clough- Warcock Hill [8965 2897]; [8974 2828]; [8990 2800]	Dyneley Knoll Flags
Deerplay Hill [8594 2715]; [8608 2696]; [8630 2684]	Old Larwence Rock
North-west of Hurstwood Reservoir [8874 3173]	Old Larwence Rock
400 m east of Worsthorne [8792 3234]	Old Larwence Rock
Robin Cross Hill [8815 2965]; [8831 2963]; [8808 2945]	Dandy Rock
Rock Water [8822 3100]	Dandy Rock
200 m north of Calder Head [8809 2792]	China Rock

Table 2: Main areas of sandstone quarrying within the Cliviger district.

8.6 BRICK CLAY

Brick Clay has been worked from two sites in the district. The Deerplay Landfill site [8568 2845], worked mudstone from the 'Accrington Mudstones' until the 1970s. A small clay pit to the east of Carr and Craggs Moor [9000 2551] worked mudstone from the Millstone Grit Group, between the Upper and Lower Haslingden Flags.

8.7 SAND AND GRAVEL

Sand and gravel has been worked from Glaciofluvial Sand and Gravel deposits in the northern part of the district, at Higher Cliviger [8665 3100] and to the north of the Calder [8600 3101]. The sand was probably used for building purposes, and was worked before 1922.

9 MAN MADE DEPOSITS and WORKED GROUND

9.1 MADE GROUND

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

The former Deerplay Colliery site (colliery spoil)[8715 2655]

Deerplay Landfill site (quarry spoil and refuse) [8590 2842]

Easden Clough (quarry spoil) [8600 2840]

Thieveley (mine spoil) [8703 2783]

Warcock Hill (possible quarry spoil) [8973 2840]

Hurstwood [8830 3155] and Cant Clough [8943 3089] reservoir embankments

Burnley Ridge (colliery spoil and landfill) [8600 3330]

Brownside (covered reservoirs) [8725 3290]

Minor areas of Made Ground include road and railway embankments, embankments adjacent to the Calder, and small patches of quarry spoil.

9.2 WORKED GROUND

The main areas of Worked Ground occur at:

Deerplay Landfill site (currently being infilled) [8568 2845]

Hurstwood [8850 3140] and Cant Clough [8935 3085] reservoirs: pits dug for embankment material

Higher Cliviger sand pit [8668 3090]

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

9.3 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:

Backfilled opencast sites: see Chapter 8 for site details.

Backfilled sandstone quarries: see Chapter 8 for location details.

Brownside (infilled reservoirs) [8680 3300]

Backfilled sand pit, Looe Crescent [8605 3110]

Limestone Hushings. These extensive but ill-defined areas of surface workings and spoil have been defined as Infilled Ground; see Chapter 8 for location details.

9.4 LANDSCAPED GROUND

The main areas of Landscaped Ground occur at:

Burnley Municipal Golf Course [8510 3140]

Golf course, Pike Hill [8620 3180]

Tullis Mill [8535 3195]

Towneley Hall [8544 3086]

School site [8500 3300]

The sites consist of ill-defined patches of shallow made and worked ground.

9.5 DISTURBED GROUND

The main areas of Disturbed Ground occur at:

Heald Top Farm (ill defined sandstone quarries) [8873 2518]

Bradget Hey- Riddle Scout (bell-pitted areas) [8770 2775] and [8920 2770]

10 GEOLOGICAL HAZARDS

10.1 UNCONSOLIDATED DEPOSITS

Unconsolidated deposits in the Cliviger area include **Debris Cone, Head, Alluvium, River Terrace Deposits, 1, Glaciofluvial Sand and Gravel, Till, 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.

10.2 LANDSLIP

Steep slopes consistng of interbedded sandstone and mudstone (such as those formed by parts of the Lower Coal Measures and Millstone Grit Group), or steep sloped mantled by Till may be susceptible to slope instability and failure. Large-scale historic rotational and composite landslips flank much of Cliviger Valley, Easden Clough, Green's Clough and the valley north of Broughton's Wood [8770 2965]. Smaller areas of slip are present 100 m north-east of Scar End Farm [8755 2520], Portsmouth [8982 2628], north of Whillingate Wham [8960 2787], and north-east of Overtown House [8740 3012]. A slip lobe at Scout [8700 2850] is estimated to contain over 1.5 million tons of debris (Williamson, 1995). The Holme Railway Tunnel was driven through a prominent slip lobe at Royd Wood [8780 2783]. The surfaces of the landslips are commonly smooth, with gently scalloped terraces visible in many places (for example, in the area around Dean Cottage [8975 2965]). Trees on the slips commonly exhibit bent trunks, indicating fairly recent movement of surface debris. Identification of margins of the slips in the Walk Mill- Holme Cliviger area is hampered as the character of the slip and glacial Till are similar. Many of the slips are currently being stabilised by plantations, part of the 'Burnley Millennium Forest' scheme. It is likely that much of the slipped material consists of glacial Till, and not solid bedrock. Oversaturated Till would have been prone to slipping soon after deposition on steeper slopes in the district.

Slopes consisting of poorly-consolidated and managed Made Infilled Ground can also become unstable. Steep slopes in the Cliviger District where Made and Infilled Ground occur are found between Monk's House Rake and the A646 Burnley Road [8934 2675], and north of Easden Clough [8612 2884]. At both these localities, Made Ground is actively slipping, as evidenced by cracks and hollows in adjacent roads and pavements. Overburden debris from the Cragg Moor Opencast Site slumped down Ratten Clough during 1947 after a period of heavy rain. The spoil blocked the Burnley Road, and much debris is still evident in Ratten Clough (Williamson, 1994).

10.3 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 SD82NE (Cliviger) and SD83SE (part) (Worsthorne) 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.

10.4 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. Hill Top Colliery [8899 2564], at the head of Green's Clough, is the only remaining deep mine in the area; large-scale deep mining ceased during the 1950s, and any subsidence affects due to closed workings 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 the Burnley area are given by Nadin (1997; 1999).

10.5 MINEWATER POLLUTION

Minewater pollution has been a problem since the cessation of deep mining in the region. Polluted minewater (also called 'race') has escaped and been channelled 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. Remediation is currently underway at several sites within the district.

Appendix 1

Index data of boreholes referred to in the report.

BGS Reference No.	**Borehole name**	GRID REFERENCE	**Date drilled (if known)**
SD82NE 11	Cliviger Colliery Air Shaft	8850 2775	
SD82NE 21	Copy Colliery, Cliviger	8842 2750	
SD82NE 22	Deerplay 3a	c. 8690 2650	Logged 1962
SD82NE 25	Deerplay Colliery	c. 8690 2650	1964
SD82NE 69	Holme Chapel	8608 2878	1974
SD83SE 2	Burnley Co-Operative Laundry A	8541 3202	1907
SD83SE 5	Rowley No. 2	8781 3269	Pre 1927
SD83SE 9	Round Hill A4/4f	8764 3087	1948
SD83SE 15	Hurstwood A4/11d	8766 3145	1952
SD83SE 32	Burnley Equitable Society	8566 3217	1936
SD83SE 47	Cowpe's Oakbank Mills	8533 3487	1961
SD83SE 50	Hurstwood No. 1	8897 3087	1964
SD83SE 51	Hurstwood No. 2	8920 3220	1964

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

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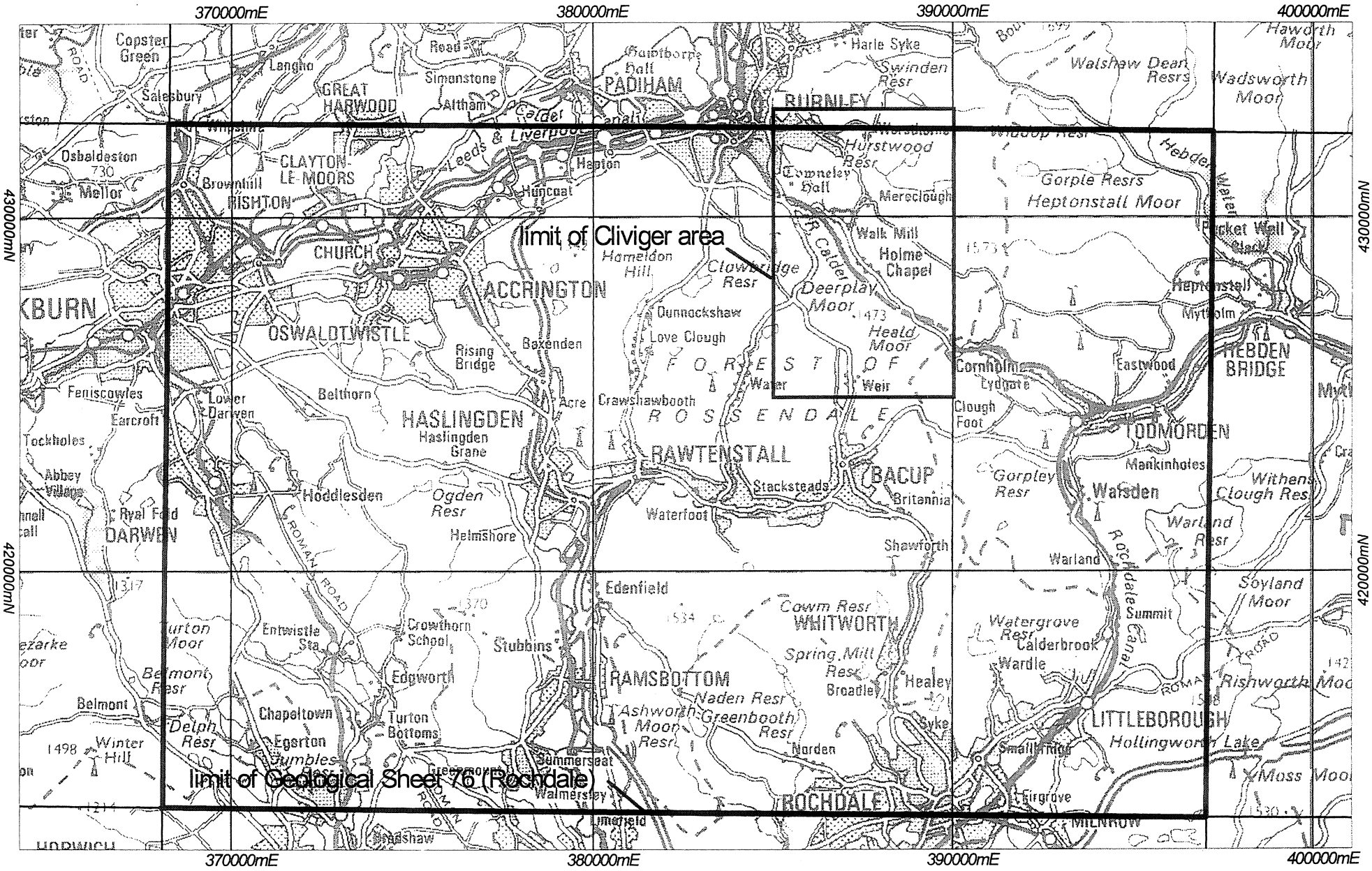


Figure 1: limit of Rochdale Geological Sheet showing Cliviger area explained in this report

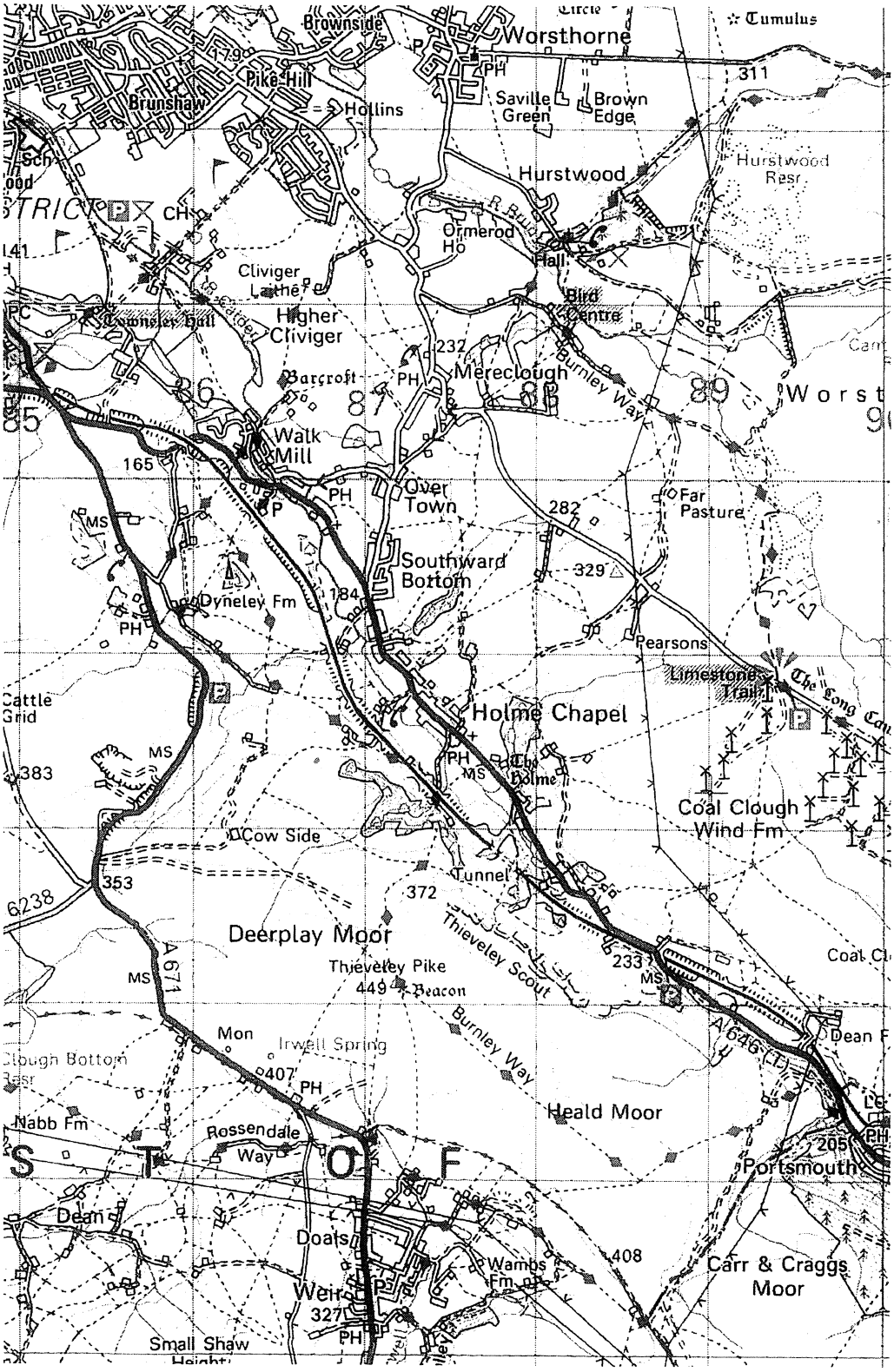


Figure 2: Map of the Cliviger district Grabade: 1 km squares

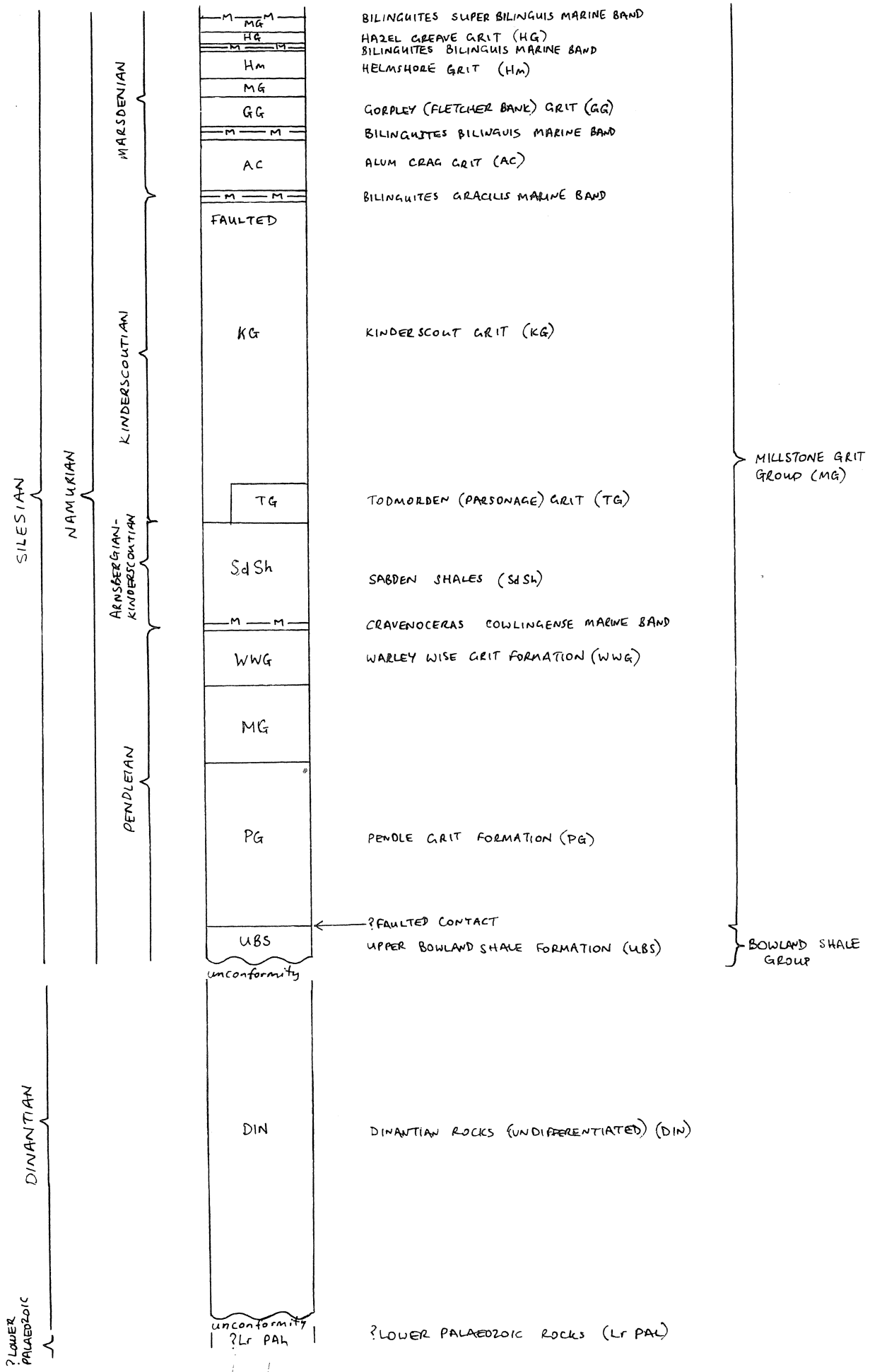


Figure 3: Log of the Holme Chapel Borehole (SD82NE-69) [8608 2878], below the Bilinguites Superbilinguis Marine Band Scale approx 1: 7,800

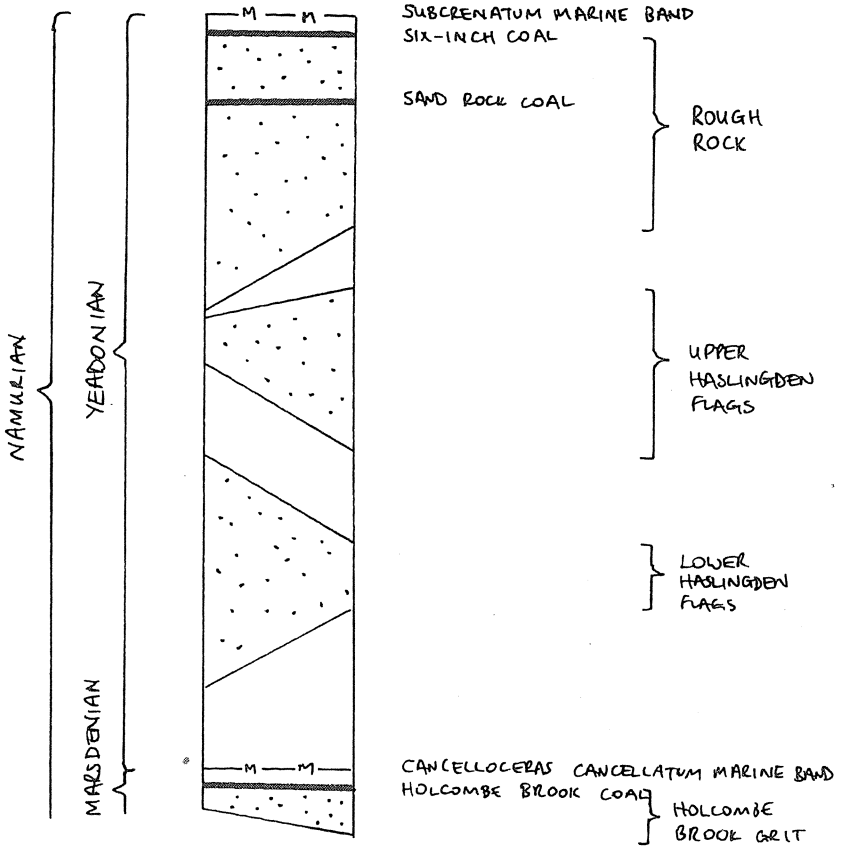


Figure 4: Generalised vertical section of the Millstone Grit Group present above the Holcombe Brook Grit within the Cliviger district; chronostratigraphy on the left, lithostratigraphy on the right.
Scale approx. 1:1000

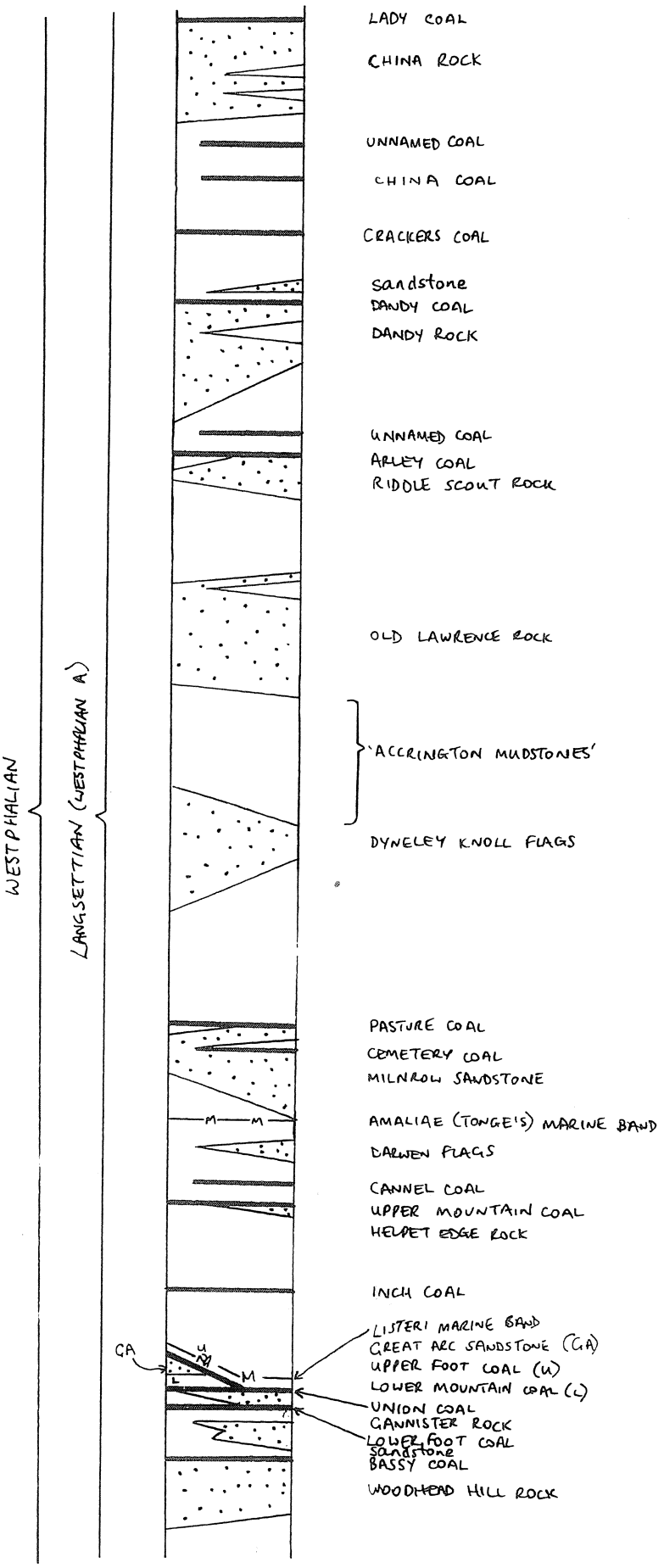


Figure 5: Generalized vertical section of the Lower Coal Measures proved within the Cliviger district, up to the Lady Coal; chronostratigraphy on the left, lithostratigraphy to the right. Scale approx. 1: 1500

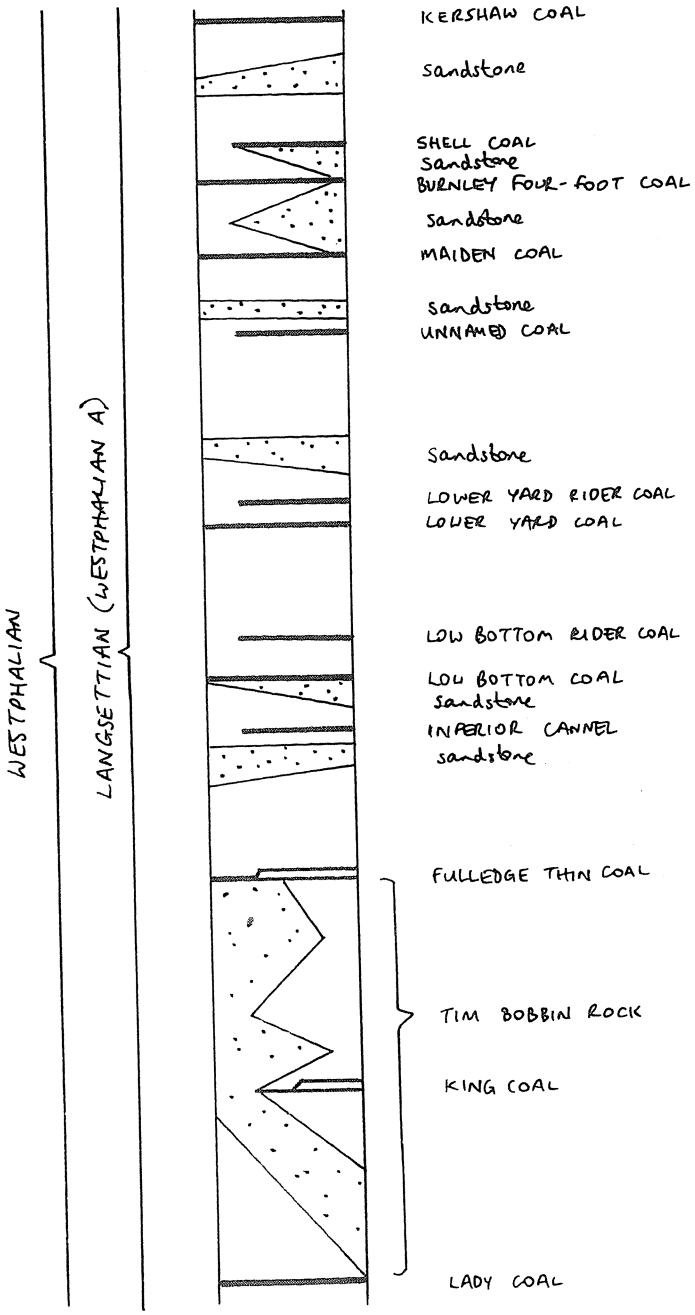


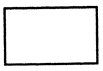
Figure 6: Generalized vertical section of the Lower Coal Measures proved within the Cliviger district, above the Lady Coal; chronostratigraphy on the left, lithostratigraphy to the right. Scale approx. 1: 1000

Key for Figure 7: Areas that have been worked for opencast coal, sandstone, brickclay, sand and opencast limestone in the Cliviger district.

Opencast coal site, named, working: LM: Lower Mountain Coal
UM: Upper Mountain Coal
U: Union Coal
Ca: Cannel Coal
A: Arley Coal
D: Dandy Coal
Ch: China Coal
K: King
LB: Low Bottom Coal

Sandstone quarry: WH: Woodhead Hill Rock
DK: Dyneley Knoll Flags
OL: Old Lawrence Rock
ChR: China Rock

Limestone hushings



Brickpit (mudstone)

Sandpit (Glaciofluvial Sand and Gravel)

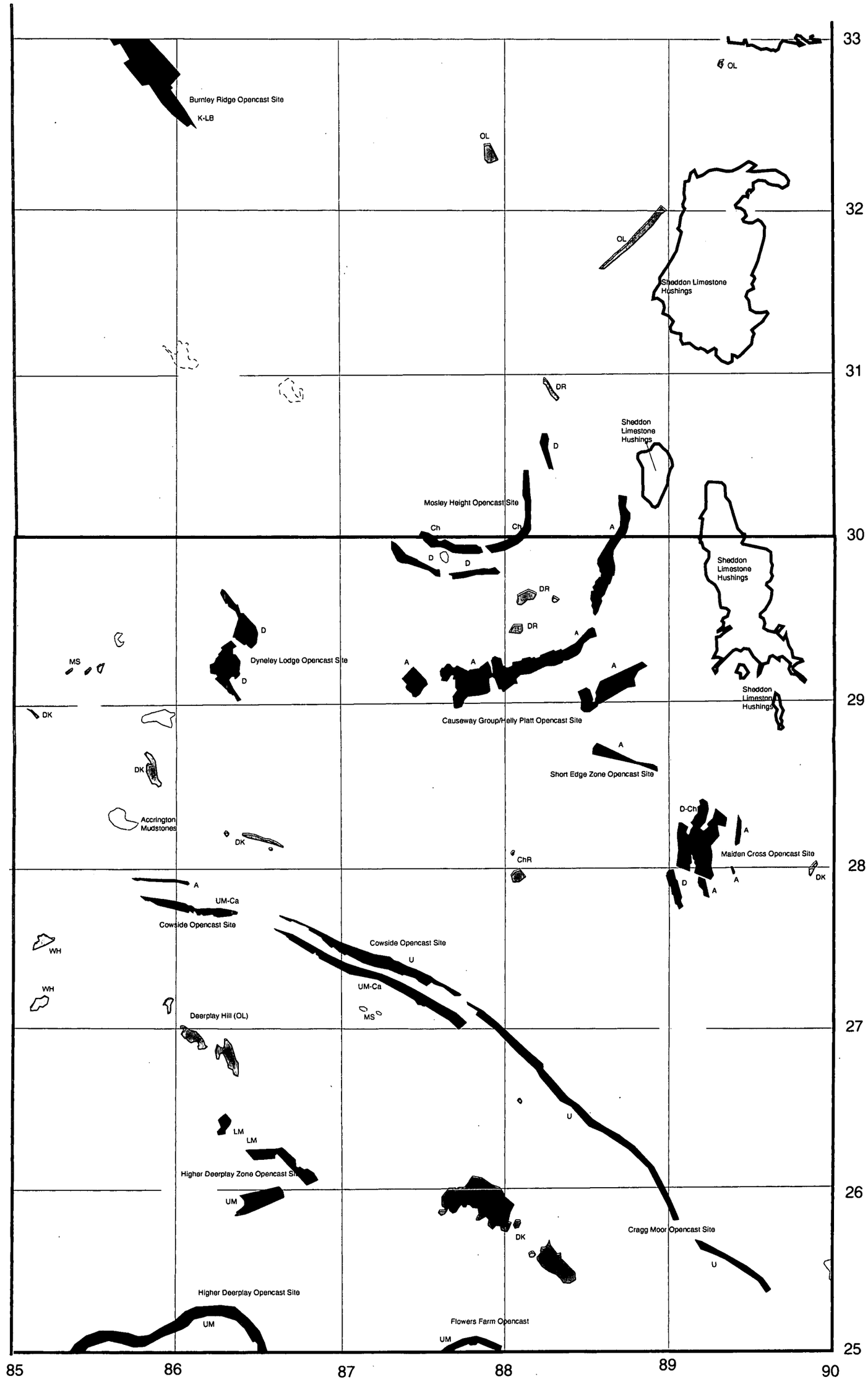


Figure 7: Areas that have been worked for opencast coal, sandstone, brickclay, sand and opencast limestone in the Cliviger district.