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Landslide and Mass Movement Processes and Their Distribution in the Longdendale Valley and Glossop District (Sheet 86).

Physical Hazards Programme

Internal Report IR/05/26

BRITISH GEOLOGICAL SURVEY

PHYSICAL HAZARDS PROGRAMME
INTERNAL REPORT IR/05/26

Landslide and Mass Movement Processes and Their Distribution in the Longdendale Valley and Glossop District (Sheet 86).

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Keywords

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Front cover

Cover picture View of southern side of Longdendale valley.

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Foreword

This report is the published product of the British Geological Survey's Physical Hazards Programme's Landslide Project. The report describes the study of the landslides and mass movement processes that have affected the geological formations in the Glossop district. Described in particular detail are the landslides of Longdendale, which form some of the most significant and interesting landslides of the district. The work was done in association with the geological mapping team Bob Addison, Colin Waters, Don Aldiss, Ed Hough and Gisela Ager, who are thanked for their assistance in understanding the geological context of the area and for the many helpful discussions that took place during the project.

Acknowledgements

In addition to the BGS staff acknowledged in the Foreword, many individuals in and outside BGS have freely given their advice, and provided the local knowledge to the project and we would like to thank them for their assistance.

The authors of this report would also like to thank A Gibson and K Northmore for their advice and constructive comments, during the drafting of this report. Paul Turner is also thanked for his help and advice with aerial photography used during the detailed Longdendale investigations. From the drawing office, Paul Lappage and Jane Smalley are thanked for their assistance with the cross sections.

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Summary

This report describes the geographical extent of the landslides and the mass movement mechanisms responsible for landslide deposits in the Longdendale valley. In addition an overview of the slope processes in the Glossop district is also presented.

1 Introduction

The aim of this research was to determine the geographical extent of the landslides and mass movement mechanisms responsible for landslide deposits in Longdendale valley and the surrounding Glossop district. This was achieved by the analysis of data collected and observations made during a field walkover survey, and office based remote sensing investigations. This study has followed the definitions of a landslide as discussed by Gibson et al., 2004. For this study the rear scarp and landslide deposit are recorded separately. All other landslide characteristics (style, type, material type, age etc.) follow the landslide mapping guidance in (Forster, 2002).

This research was undertaken in collaboration with the resurveying of the district by the survey team of Bob Addison, Colin Waters, Don Aldiss and Ed Hough. They identified the presence of a number of excellent landslides in the district that required further investigation, to aid in the understanding of how and why they have formed.

Within the report the geology of the district is explained along with a brief overview of the Hydrogeology of the area. Detailed case studies for the Longdendale valley landslides are presented along with examples from the nearby Crowden Valley and the surrounding district. The idea of Slope Behaviour Units (SBU's) is introduced concluding with the suggested slope units for this district.

2 Geology

This section gives a brief outline of the solid and superficial geology as well as relevant information on the geomorphology, hydrogeology and land use of the district.

2.1 SOLID

The geology of the Glossop District comprises of a succession of sedimentary rocks from the Namurian (Millstone Grit Group) and Westphalian (Coal Measures Group). The extent of the strata is shown in Figure 2.1.

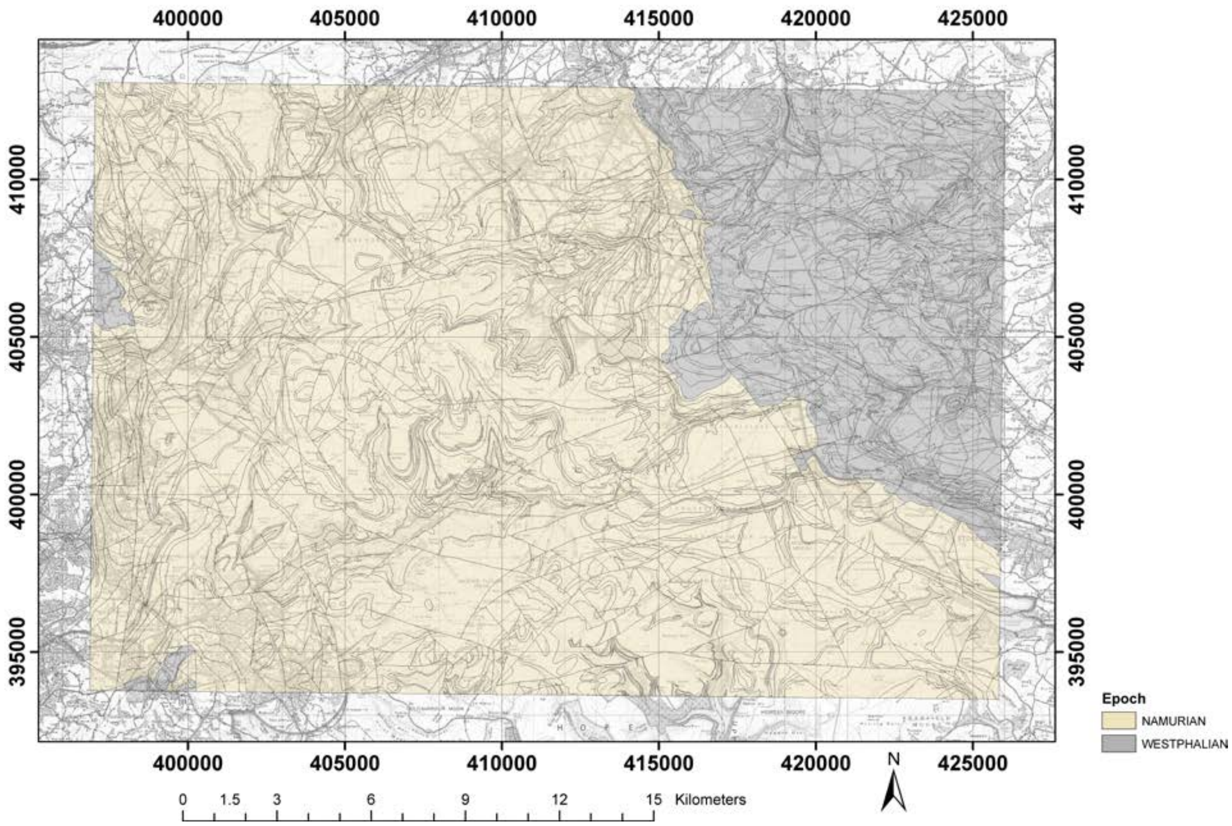


Figure 2.1 - General regional geology of the Glossop District.

2.1.1 The Millstone Grit Group

The Namurian, Millstone Grit Group is encountered mainly in the centre and to the west of the district (Figure 2.1). The Millstone Grit Group is primarily composed of grey to greyish brown, moderately strong to strong (based on intact strength of fresh and slightly weathered rock) arkosic, medium to coarse-grained, fluviatile deltaic sandstones; alternating with medium to dark grey, weak to moderately strong, well-bedded to laminated siltstones and mudstone horizons (Figure 2.2).

Within the Millstone Grit Group (MGG/MG) the fluviatile deltaic sandstones form a dominant and characteristic component of the Millstone Grit Group (Aitkenhead et al., 2002). Within the Glossop District: the Rough Rock (RF/RR), Huddersfield White Rock (CHG), Beacon Hill Flags

(GSYG), Heyden Rock, Readycon Dean Formation (RDG), Upper Kinderscout Grit (UK), Kinderscout Grit (LK/KG) fluviatile deltaic sandstones are encountered (Figure 2.3).

The Shale Grit (SG) is another dominant formation found in the Glossop District (Figure 2.3) and was deposited in turbidite flows at the edge of an advancing delta. This formation comprises of strong, thickly bedded, medium to locally coarse grained sandstones with frequent mudstone interbeds of variable thicknesses (Smart et al., 1978).

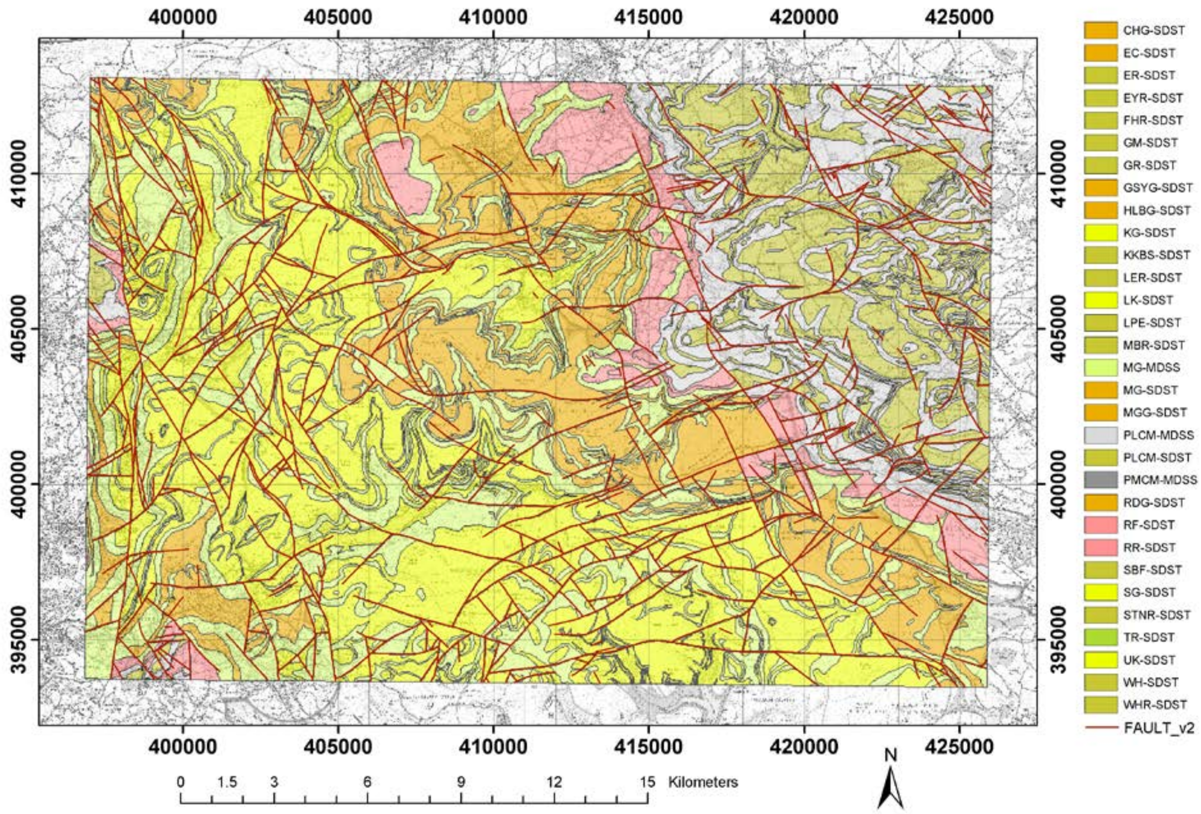


Figure 2.2 - 1:50 000 Solid Geology of the Glossop District (Legend used is BGS_Lex_Rock)

Between each of the fluviatile deltaic sandstones, mudstones are found (Figure 2.3). Within this District, between the Shale Grit and the Kinderscout Grit, the mudstones encountered are locally known as the Grindslow Shales (Smart et al., 1978). These are weak to moderately strong (Cripps and Taylor, 1981), well-bedded to laminated micaceous mudstones and siltstones. Between the other fluviatile deltaic sandstones highly micaceous Millstone Grit Group mudstones and siltstones with occasional marine, coal and seatearth bands are found. The mudstones are particularly susceptible to breakdown due to the effects of weathering. Locally zones of highly weathered material comprising softened mudstone clasts in a silty clay matrix may occur to depths of about 10 to 15 m, and possibly deeper in fault zones (Waters et al., 1996)

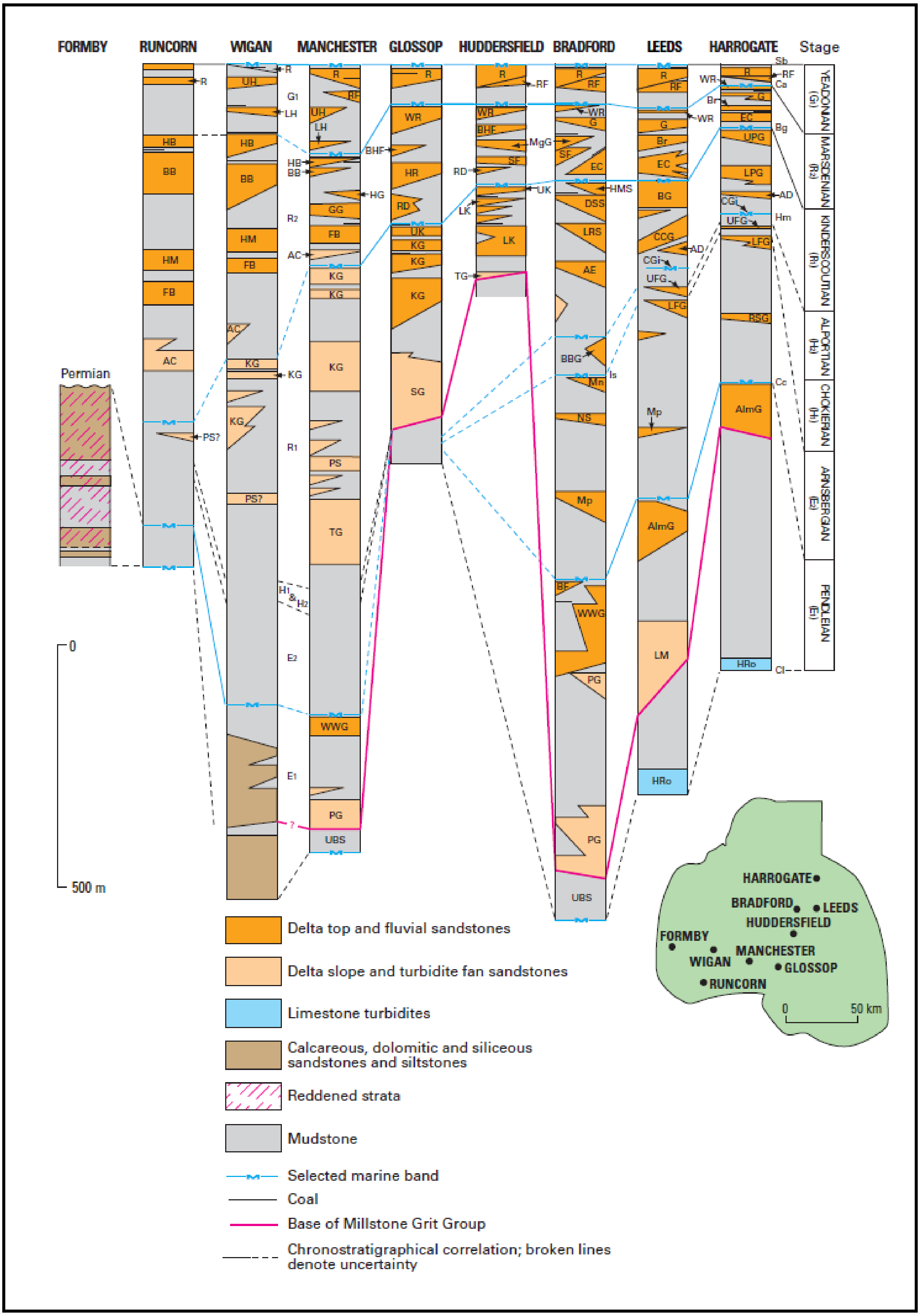


Figure 2.3 - Generalised vertical sections of Namurian strata across the Pennines (Aitkenhead et al., 2002).

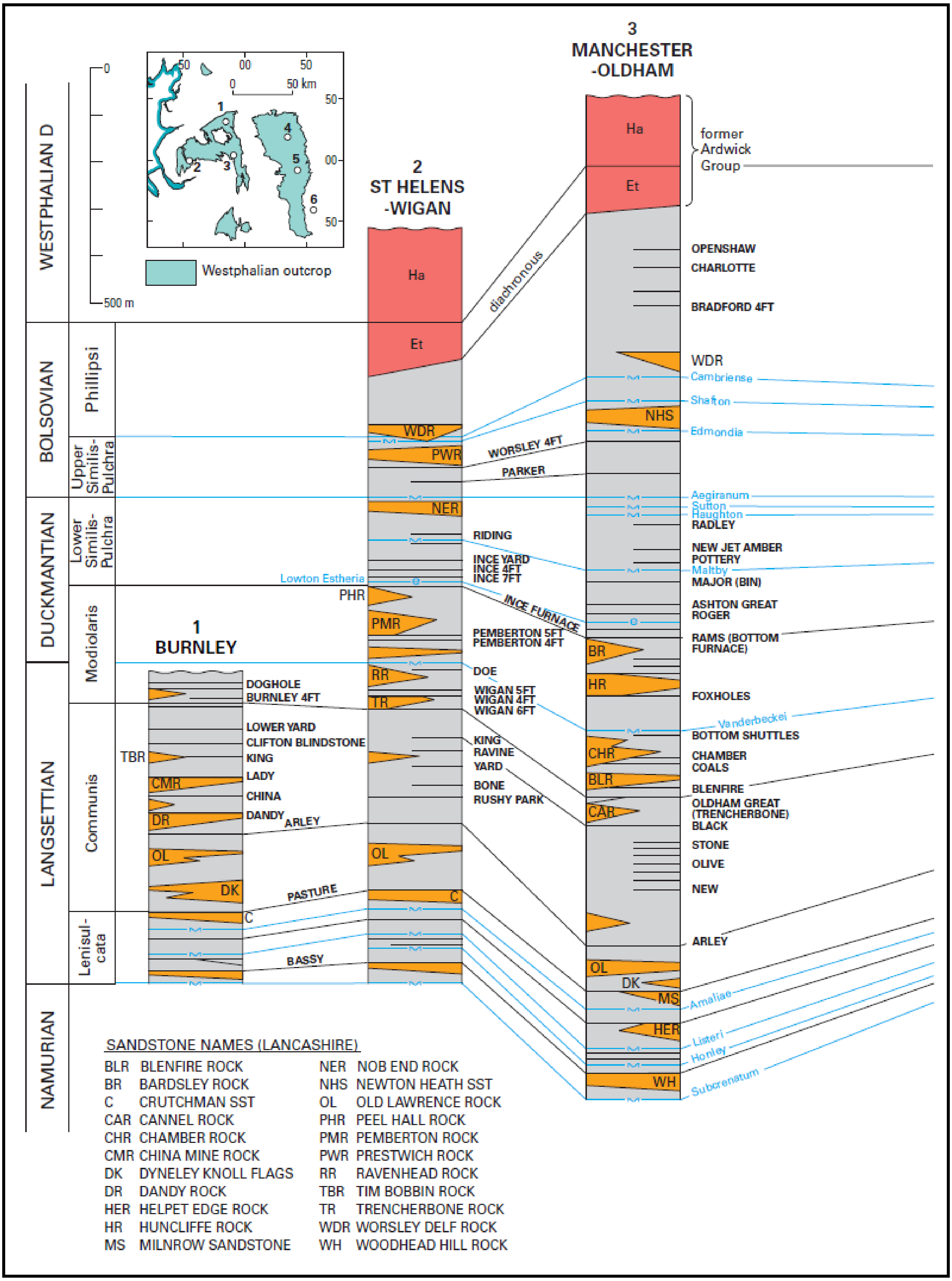
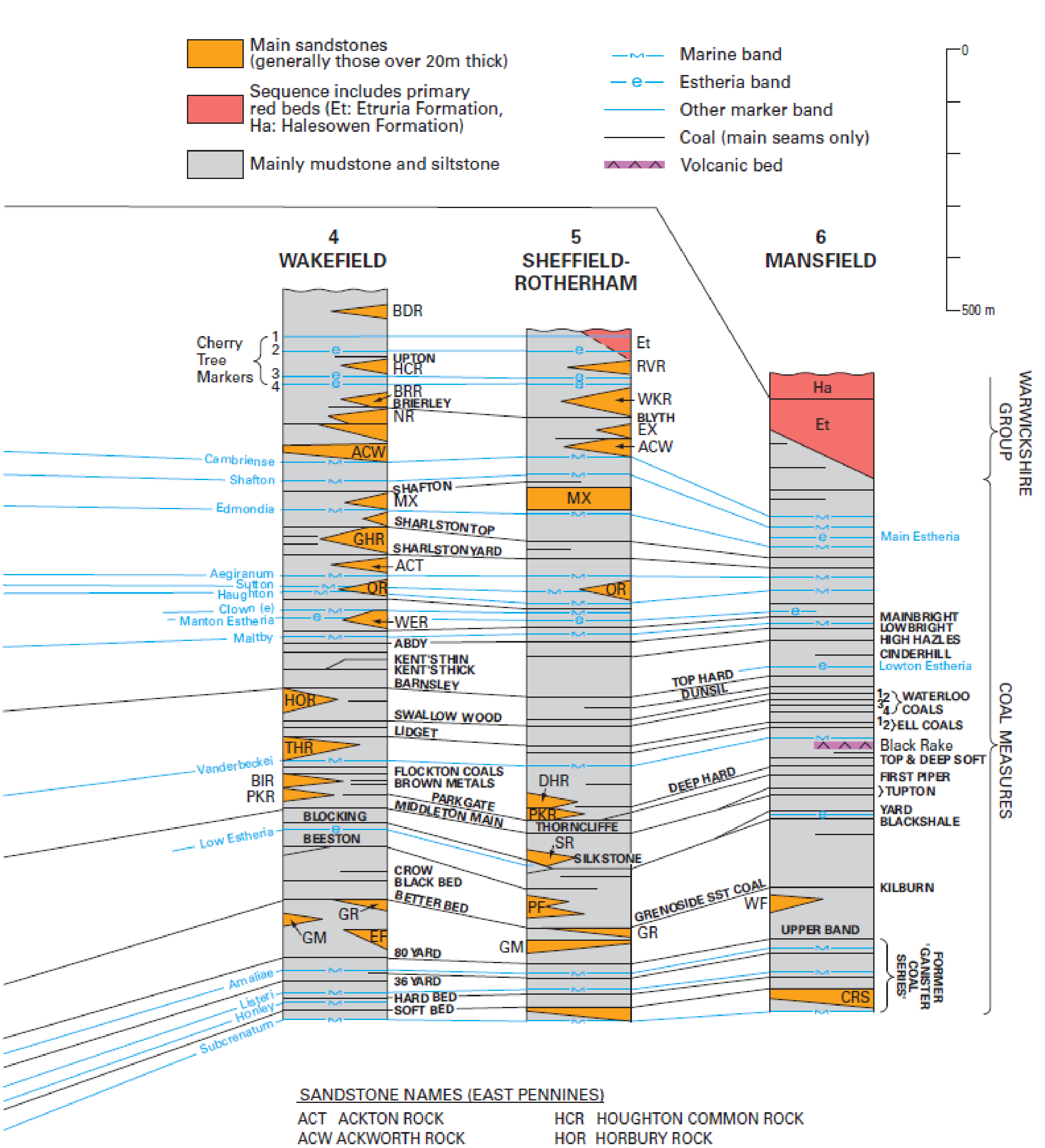


Figure 2.4 - Generalised vertical sections of Westphalian strata across the Pennines (Aitkenhead et al., 2002).



SANDSTONE NAMES (EAST PENNINES)

ACT ACKTON ROCK	HCR HOUGHTON COMMON ROCK
ACW ACKWORTH ROCK	HOR HORBURY ROCK
BDR BADSWORTH ROCK	MX MEXBOROUGH ROCK
BIR BIRSTALL ROCK	NR NEWSTEAD (PONTEFRACT) ROCK
BRR BRIERLEY ROCK	OR OAKS ROCK
CRS CRAWSHAW SANDSTONE	PF PENISTONE FLAGS
DHR DEEP HARD ROCK	PKR PARKGATE ROCK
EF ELLAND FLAGS	RVR RAVENFIELD ROCK
EX 'EXTRA' ROCK	SR SILKSTONE ROCK
GHR GLASS HOUGHTON ROCK	THR THORNHILL ROCK
GM GREENMOOR ROCK	WER WOOLLEY EDGE ROCK
GR GRENOSIDE SANDSTONE	WF WINGFIELD FLAGS
	WKR WICKERSLEY ROCK

Figure 2.5 - Generalised vertical sections of Westphalian strata across the Pennines (Aitkenhead et al., 2002).

2.1.2 Westphalian Coal Measures Group

The Westphalian Coal Measures Group in this District are mainly found to the east (Figure 2.1). They are predominantly grey and contain significant amounts of coal. The coal measures are made up of interbedded grey mudstones, siltstones and sandstones (Figure 2.4 and 2.5) with subordinate amounts of coal and ironstone (Aitkenhead et al., 2002).

The order in which the main lithologies follow one another tends to show a cyclical pattern, a typical cyclic unit (cyclothem) being:

- Coal
- Seatearth
- Sandstone
- Siltstone
- Mudstone
- Coal (of next cycle down)

Due to the complex cyclic nature of the Westphalian Coal Measures Group's stratigraphy (Figure 2.4), only a generalised description of the lithologies found within this District will be discussed.

The mudstones (Pennine Lower Coal Measure (PLCM-MDST), Pennine Middle Coal Measures (PMCM)) of the Westphalian Coal Measures Group (Figure 2.4 and 2.5) in this District are generally weak to moderately strong (Cripps and Taylor, 1981), medium to dark grey, moderately fissured, laminated micaceous mudstones and siltstones with subordinate coal, seatearths (unbedded mudstone and siltstone rootlet beds) and ironstone (Waters et al., 1996). The darkest of the mudstones are the most carbonaceous and fissile (Aitkenhead et al., 2002). The mudstones are particularly susceptible to breakdown due to the effects of weathering and completely weathered firm to stiff, orange-brown and pale grey clays grey mottled clays commonly occur within 2-5 m of the rockhead. Locally zones of highly weathered material comprising softened mudstone clasts in a silty clay matrix may occur to depths of about 10 to 15 m, and possibly deeper in fault zones (Waters et al., 1996).

On the Glossop sheet the sandstones (Elley Rock (ER), 80 Yard Rock (EYR), Fall House Rock (FHR), Greenmoor Rock (GM), Grenoside Sandstone (GR), Kirkburton Sandstone (KKBS), Loxley Edge Rock (LER), Lepton Rock Edge (LPE), Middle Bank Rock (MBR), Pennine Lower Coal Measures (PLCM-SDST), Soft Bed Flags (SBF), Stanningley Rock (STNR), Thornhill Rock (TR), Woodhead Hill Rock (WH), Wharncliff Rock (WHR)) in the Westphalian Coal Measures Group (Figure 2.3) are generally moderately strong to strong, pale grey (weathering to pale brown at the surface), very fine to medium-grained and locally coarse-grained quartzose sandstones with occasional siltstone and mudstone interbeds and coal partings (Waters et al., 1996). Bedding separation ranges from very thinly to massive, and ripple laminations, cross-bedding and low-angle planar laminations are common.

Coal is composed of mainly carbon and generally occurs in thin seams resting on seatearth. Bright coal is finely laminated, dull coal is less well layered, cannel is not laminated and breaks with a subconchoidal fractures.

2.2 STRUCTURE

Within the District the main structural control of the area comes from the Variscan orogeny that took place in the late Carboniferous and early Permian. This caused the deformation of the Namurian and Westphalian strata causing gentle folds and extensive faulting (Figure 2.3) (Aitkenhead et al., 2002). As a consequence the District is structurally controlled by the Pennine and Alport Anticlines. Between these two major structures the beds dip generally at low angles to the north-east (Figure 2.6), although in the north of the district the dip swings around to the east (Bromehead et al., 1933).

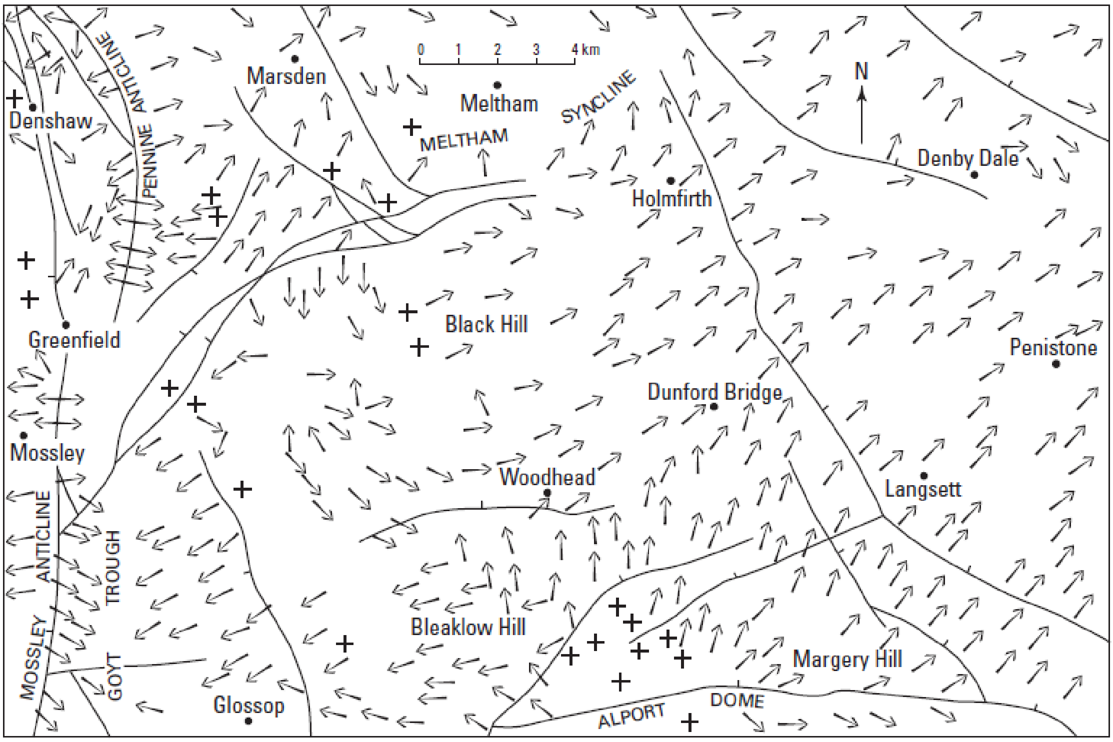


Figure 2.6 - Map of the principal folds and dips (Bromehead et al., 1933).

2.3 SUPERFICIAL DEPOSITS

The Superficial geology of the Glossop District comprises of a Till (TILLD), River Terrace Deposits (RTDU), Peat (PEAT), head (HEAD), Glaciofluvial Deposits (GFDUD) and alluvium (ALV). The extent of the superficial deposits encountered within the District is shown in Figure 2.6.

During Late Devensian times (c. 24 000 to 10000 years BP), ice streams radiating from centres in the Lake District and adjoining Irish Sea Basin advanced across the district (Figure 2.7). The general pattern of movement, based on glacial striae and till fabrics (Worsley, 1968), supports ice streams entering the area from a north-westerly or westerly direction, with subsidiary streams constrained to the east by the Pennine escarpment. The till laid down during this period forms a firm to very stiff, red-brown slightly gravelly sandy clay with some channels and lenses of sand, gravel and laminated clays. It is encountered mainly in the south-west of the District.

During the waning of the ice sheets, a complex subglacial marginal drainage system was formed, which caused the Glaciofluvial Deposits to be deposited mainly in the south-west of the District. These materials consist predominantly of medium dense, fine- to coarse-grained sands and medium dense to dense, fine- to medium-gravels with occasional cobbles and boulders. Impersistent layers and lenses of clay and silt were also developed locally.

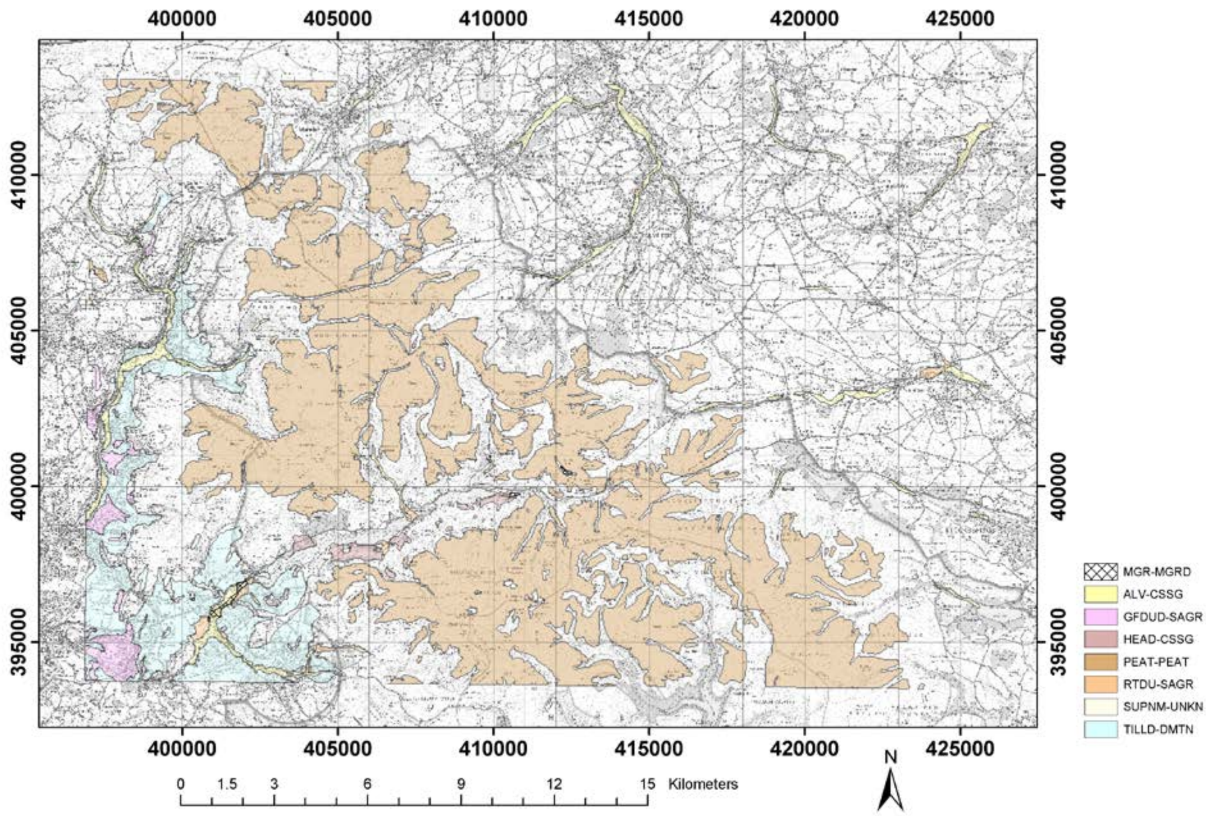


Figure 2.7 - 1:50 000 Superficial Geology of the Glossop District (Legend used is BGS_Lex_Rock)

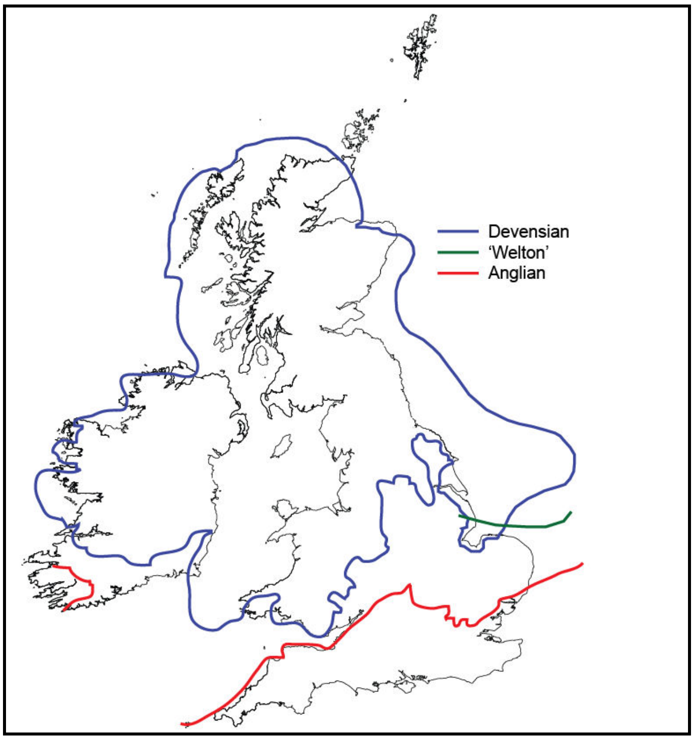


Figure 2.8 - The limit of the Devensian ice-sheet.

During the waning of the ice sheets, a complex subglacial marginal drainage system was formed, which caused the Glaciofluvial Deposits to be deposited mainly in the south-west of the District. These materials consist predominantly of medium dense, fine- to coarse-grained sands and medium dense to dense, fine- to medium-gravels with occasional cobbles and boulders. Impersistent layers and lenses of clay and silt were also developed locally.

In the Late Devensian, periglacial climates caused the development of widespread permafrost in much of the Glossop District, as it lies outside the limits of the Late Devensian ice sheet (Figure 2.7). This caused the accumulation of head by solifluctional downslope movement of water saturated near-surface material, which involved the freezing and thawing of the ground. This material is usually soft to firm mid brown grey sandy clay.

Post-glacial (Holocene) deposits are largely confined to the modern river valleys and include River Terrace Deposits and tracts of Alluvium. The River Terrace Deposits consists predominantly of medium dense, fine- to coarse-grained sands and medium dense to dense, fine- to medium-gravels with occasional cobbles and boulders. Impersistent layers and lenses of clay and silt are locally developed. The Alluvium is generally firm to very stiff sandy, gravely clay with some channels and lenses of medium dense to dense sand and gravel. Holocene Peat deposits are also found extensively over the centre of the District. They mainly cap the high ground of the Pennines and can be up to 3m thick, although the deposits are being actively eroded by wind and water. The Peat is described as a very soft to soft, brown, fiberous or amorphous organic soil.

2.4 GEOMORPHOLOGY

Within this District, apart from the dissection by streams it has a remarkably even topography (Figure 2.8) and the geological structure (section 2.2) appears to controls the morphology of the District. This explains the general asymmetry of the valleys, the distribution of the escarpments and the susceptibility of the valley slopes to failure. Below the ancient peat covered landscape the streams (cloughs) and rivers have incised their valleys through the massive fluviatile deltaic sandstones and thick series of incompetent mudstones and siltstones (Figure 2.9). This has caused a stepped profile in most slopes (Figure 2.10). Prominent benches form wherever the main sandstone beds outcrop (Figure 2.8) and more concaved slopes on the mudstones (Johnson and Walthall, 1979).

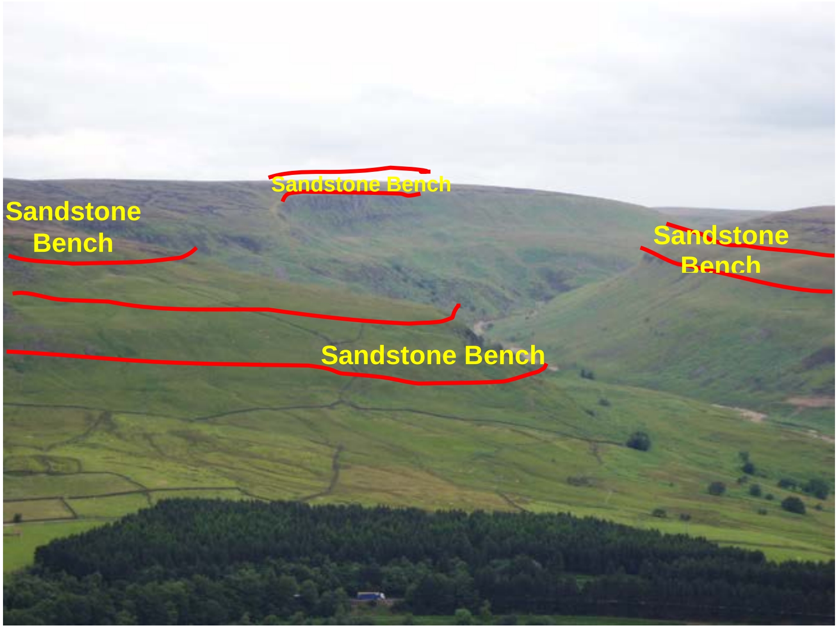


Figure 2.9 - Looking North up the Crowden Valley at the even topography and the sandstone benches (BNG 407259 397452).

Figure 2.10 - Looking North-east down the insisted cut of Wildboar Clough. Seen cutting through the sandstones and mudstones (BNG 407750 3982)

Apart from a comparatively small area in the west, the majority of the Glossop District has not been shaped by glacial events, being outside the limits of the Late Devensian ice sheet (Figure 2.7). As a result the majority of the District has been affected instead by periglacial climates in the Late Devensian. This environment would have therefore enabled the development of strong pore water pressures in the rocks and soil, which are likely to have assisted in the mass movement of debris by landsliding, solifluction and creep processes. In additional on the upper sandstone escarpments frost was the dominant agent of attack causing rockfalls and scree runs to form. In some areas of the District this has caused the formations of tors (Johnson and Walthall, 1979).

Figure 2.11 - Example of stepped slope profile caused by the Kinderscout Grit at the top of the escarpment and Grindslow Shales at the bottom (BNG 407131 397818 facing 260º).

2.5 HYDROGEOLOGY

The Millstone Grit forms a multi-layered aquifer in which the thick, well cemented sandstones effectively act as separate aquifers; the intervening mudstones act as aquicludes and aquitards (Aitkenhead et al., 2002). The most important aquifers in the District form in the Shale Grits, Kinderscout Grit, Huddersfield White Rock and the Rough Rock; although in the northern part of the District these formations are unusually dense and free from discontinuities, which make it practically useless as a source of water (Bromehead et al., 1933). Groundwater storage and movement is predominantly through discontinuities (fractures, joint and faults), with only minor intergranular flow (Aitkenhead et al., 2002). The difference between the hydrogeological properties of the well cemented fractured sandstones and the impervious mudstones cause seepages and springs to form at the boundary between these two formations (Figure 2.11).

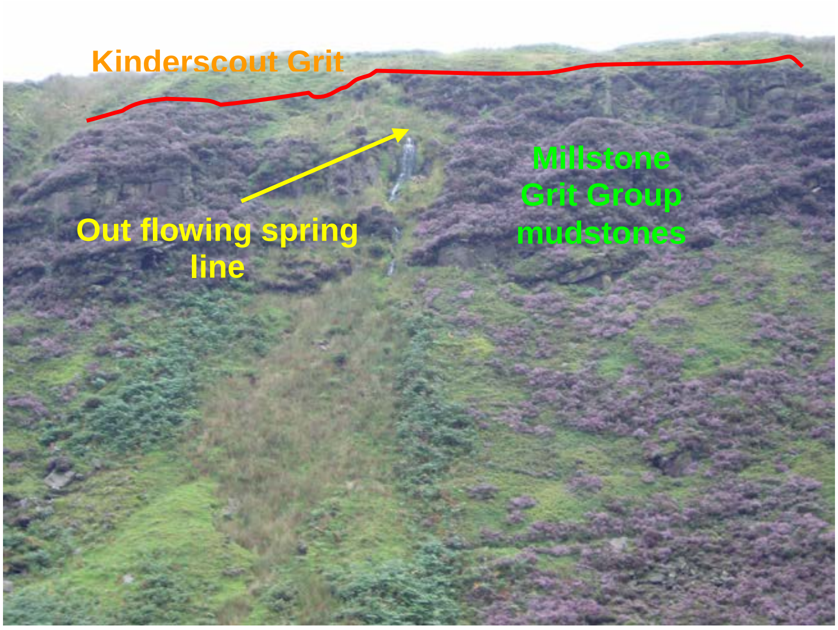


Figure 2.12 - A spring line out flowing just below the Kinderscout Grit and mudstone boundary on the rear scar of Rake's Rocks landslide (BNG 406198 400480 facing 230º).

The Coal measures form complex, multilayered minor aquifers. The argillaceous strata act as aquicludes and aquitards, isolating the few thicker sandstones, which effectively act as separate aquifers. The sandstones are generally fine-grained, well cemented and laterally impersistent. (Aitkenhead et al., 2002). The more important aquifers in the District form in the Greenmoor Rock and Grenoside Sandstone (Bromehead et al., 1933). Groundwater storage and movement is predominantly through discontinuities. Within the Coal measures folding and faulting have caused aquifers to be isolated, although mining activities have sometimes breached these by the construction of shafts, galleries and adits causing interconnection and flow (Aitkenhead et al., 2002).

2.5.1 Flash Floods

Along deep gorge like form of the Longdendale Valley there are several examples of hanging tributaries falling over the southern escarpment, formed in the strong basal bed of the Kinderscout Grit. The Wildboar Clough is one of such features, a deeply incised gully located opposite the Hamlet of Crowden (NGR 408035, 398060). Along its route the Clough falls 91m in the 1646m between its source on Bleaklow Moor and the Longdendale valley edge, but a sharp change occurs as it reaches the steep slopes of the Valley and it falls steeply over 274m in the 1463m between the valley edge and the river Ethrow.

The rivers draining the high flat moorland Pennines Rivers draining the Pennines are susceptible to flash flooding with rain fall reaching 125cm annually at Woodhead (Bromehead *et al.* 1933). Water on the high peat moorland is channeled into the shallow streams on the plateau and Cloughs, which cascade over the escarpment, scouring deep channels and causing erosion of peat and vegetation. This also provides a further mechanism for slope instability as result of channel incision and the removal of potentially stabilising debris. This phenomenon was viewed during the walkover survey on the 10th August 2004 after an overnight period of heavy rain. Streams could clearly be seen cascading over the escarpment of the southern side of the valley of which Shinning Clough (NGR 409556, 398665) was one such feature (Figure 2.12).

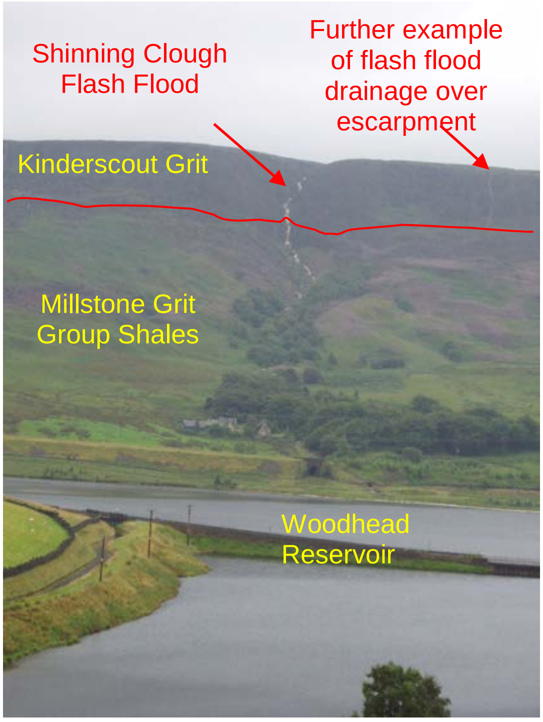


Figure 2.13 - Shinning Clough in Flood 10.08.04 (BNG 409466, 400463 facing 180º)

2.6 LANDUSE

Most of the District lies in upland moorland which is sparsely populated. As a result most of the land has been left untouched and fallow, apart from being used for the grazing of animals. Although the District is remotely situated, it is surrounded by urban areas of dense population, to the west by Manchester, to the southeast by Sheffield and to the north by Huddersfield. As a consequence a number of anthropogenic activities have affected some of the District to provide materials (water, aggregate, coal, timber) and services (roads and railways) and their features are etched onto the landscape (Figure 2.13).

Throughout the District a number of water reservoirs are encountered. In the Longdendale Valley for example a succession of dams were constructed to create a number of water reservoirs. Within the Longdendale Valley five reservoirs are encountered: Woodhead (completed 1877), Torside (1864), Rhodeswood (1855), Valehouse (1869) and Bottoms Reservoirs (1877).

Historically, the Millstone Grit has been quarried within the district for building stones and flagstones. Most of the older towns and villages are built almost entirely from Kinderscout Grit. Although the smaller quarries of the district are no longer active they still form distinctive features on the landscape (Figure 2.13), some similar in appearance to the rotational failures within the district. Coal is not produced in any great quantity within the area. Working mines were developed on a very small scale and purely for local use rather than economic value

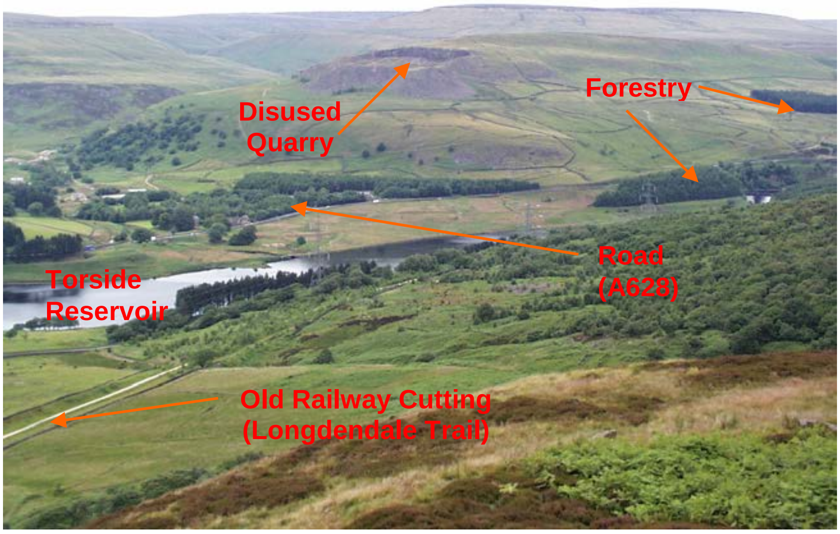


Figure 2.14 - View looking over the Longdendale Valley to Brockholes Quarry, with the main anthropogenic activities highlighted (BNG 407370 397890 facing 025º).

As a result of farming habits, few of the native oak and birch that once would have so dominated the district remain. The high, exposed moorland are covered in a deep peat blanket and are mainly colonised by cotton grass, whilst the slightly shallower peat layer of the mid slopes are heather dominated. Such plants as cotton grass, bilberry and hare's tail are also common. The majority of the lower slopes are now colonised by newer managed conifer plantations for timber.

The Glossop District forms part of a major trading route across the Pennines, from Lancashire to Yorkshire. To the south of the Longdendale reservoirs, the 6.5 mile (10.4Km) Longdendale Trail (walking and cycling path) follows the route of the old Great Central Manchester to Sheffield railway which included the 3 mile long Woodhead tunnel. The railway originally brought prosperity and employment to the area with heavy coal traffic between the pits of Yorkshire and Nottinghamshire and the industries of Lancashire until its closure to freight in 1981. Running alongside the Longdendale Valley, on the opposite side to the old railway, is the busy A628 which is one of the main trans-Pennine road routes between Manchester and Sheffield.

3 Remote Sensing

Two remote sensing techniques were used in this study to help identify landslides and their features prior to the main fieldwork investigation. For the detailed study of the Longdendale valley, air photos were analysed and for the rest of the Glossop District Next Map Shaded Relief maps were created and analysed.

3.1 AIR PHOTOS

Air photographs of the Longdendale Valley were analysed using the ImageStation system. ImageStation is a photogrammetric visualisation and interpretation system. It allows the production of stereomodels, DEMs and ortho-images from aerial photographs and provides an environment for accurate 3D stereomodel interpretation.

3.1.1 Resources and Processing

The ImageStation workflow required contact prints (or negatives), which were scanned on a photogrammetric scanner. Ground control points were then established, for this study, x, y, z points were collected from 1:10k OS maps. Camera parameters required for data processing were defined by the camera calibration certificate, provided by the air photo supplier. All the photos were spatially connected using a combination of automatically derived tie points, these, combined with the ground control points allowed the construction of an image model that accurately fitted the ground surface. Once an accurate solution was obtained the photos were interpreted within ImageStation Stereo Display (ISSD), with one stereomodel (overlap between two photographs) being interpreted at a time. Features digitised in ISSD had correct x, y and z co-ordinates and were easily exported to Shape file format for use within ARC GIS software.

40 black and white 1:25000 scale air photos were processed in approximately 14 days of staff time. This included one-day’s training, and together with occasional support, was found to be sufficient for a new user to be able to work with the basic functions of ISSD.

3.1.2 Methodology

Landslide back scars and deposits were identified from the stereomodels using breaks in slope, changes in vegetation, tonal variations and shadows. ImageStation provided a useful method for identifying and interpreting landslides in this area as their large lateral extent created line of sight problems when in the field. The ability to recognise slope features was greatly helped by the knowledge gained from a preliminary 1-day field visit. The combination of the preliminary field visit and analysis of air photography enabled a greater area to be covered in the Longlendale Valley.

3.1.3 Output

The Image Station system was used to identify landslide deposits and backscar features. Using ARC GIS software these features were easily exported to Shape file format and enabled the production of field maps. The field maps were taken out during the main field investigation in the Longdendale Valley. This enabled both the linework to be checked in situ as well as aiding a quicker progression of the survey. The field slips were also used to identify the type of slide, as well as measurements of the parameters entered into the Landslide Proforma. These include the dimensions and location of the slide.

3.2 NEXT MAP SHADED RELIEF

To accompany the standard Ordnance Survey Topographic maps used for the walkover survey and aerial photograph interpretation a Digital Surface Model (DSM) derived from the NEXTMap Britain dataset of England, Wales and Scotland was used. This is based on data collected between 2002 and 2003 using advanced airborne radar. The radar sensor was mounted on a Lear Jet aircraft flying at night at an altitude of up to 8.5 km, producing a ground elevation point every 5m. The NEXTmap model is illuminated from the northwest to illustrate topographic features and is greyscale to illustrate topographic height variations. Dark colours represent low relief areas, moving through as elevation increases to represent the higher areas. NEXTMap Britain elevation data from Intermap Technologies.

4 Field Investigations

Field surveys of both the Longdendale Valley and the Glossop District were carried in July 2004 and August 2004 to determine the nature and form of landslides. A number of sites, identified from the remote sensing analysis were chosen for detailed investigation as they were considered to be representative of different types of landslides within the district.

Each site was examined using conventional walkover survey techniques. Their geographical location was established using a handheld GPS and 1: 10 000 scale map. Where appropriate, slope angles were established using conventional Abney levels or sighting clinometers (Silver type). Where access and vegetation allowed landslides were circumnavigated and traversed.

Each landslide was described using a notebook style National Landslide Database Proforma (Appendix 1), which contains fields for location, dimensions, landslide type and causal factors. The information on these proformas was transferred to the National Landslide Database, creating a unique record for each landslide. Accordingly each landslide recorded during this investigation has been attributed a National Landslide Database Number (NLDN) (See Appendix 2) In some instances data collected from the field investigations has been used to create schematic cross sections of the slope and landslide morphology (Appendix 3).

4.1 LONGDENDALE VALLEY LANDSLIDE ASSESSMENT

Along the southern side of the Longdendale Valley, to the East of Torside Clough, the northerly dipping strata of the Kinderscout Grit and the underlying Shales contain great landslides. The exposed scars of the grit have formed a large cliff escarpment along the valley side. A number of landslides have been identified here and a selection are discussed below.

4.1.1 Long Gutter Edge Landslide

The Long Gutter Edge landslide (NLDN 10903, NGR 407235, 397945) is the first of the Longdendale landslides that you encounter from the south west. Located in the Longdendale Valley at the northern edge of Sykes Moor, this large mass movement failure has detached and rotated down slope towards the Torside Reservoir in a north-westerly direction (315^{o}), leaving a clearly defined back scar (Figure 4.1). The back scar has formed in the coarse grained massive Kinderscout Grit, which overlie the thick mudstones and siltstones of the Grindslow Shales. The strata are generally dipping out of the slope towards the South West. A schematic cross section of Long Gutter Edge landslide can be seen in Figure 4.2.

The slide is classified as a rotational slide that includes a large degraded rotated block up to 3m diameter, with a hummocky debris flow. The lip of the main rotated block is easily identified and forms Long Gutter Edge (Figure 4.1). The walkover survey enabled the maximum width of slide to be recorded as 500m and its length as1km. These figures were corroborated with the use of the aerial photography. More recent slumping has occurred on the slope below the degraded block.

Vegetation across the landslide varies. Heather is encountered on the steeper well drained slopes, with bracken on the gentler better drained lower slopes. Grasses occur on the flatter, hummocky areas.

The walkover survey identified some small scale shallow peat slides adjoining the main landslide. A potential Peat sink hole was identified within the debris flow at the base of landslide that had a spring line that was noted.

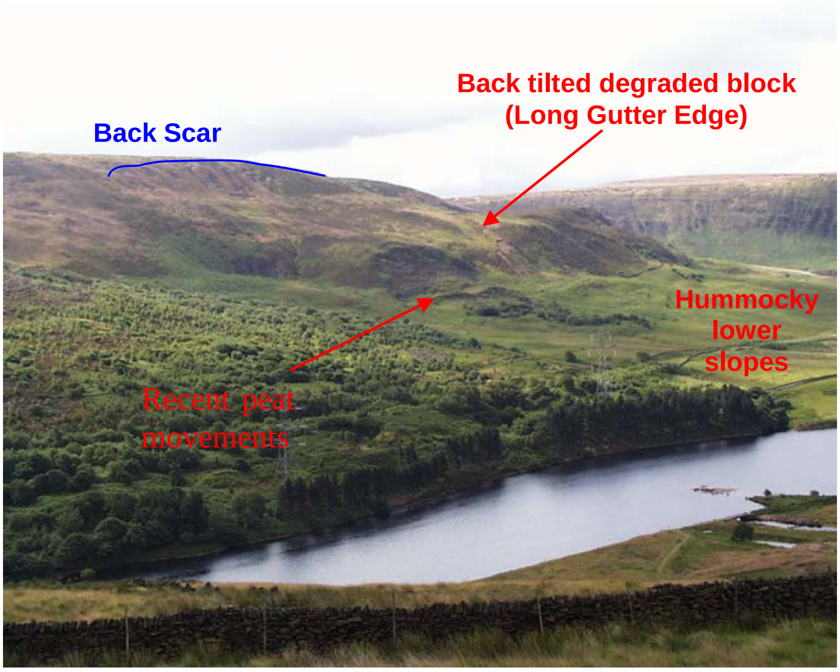


Figure 4.1 - View looking over to Long Gutter Edge Landslide (BNG 407441 399639 facing 225º).

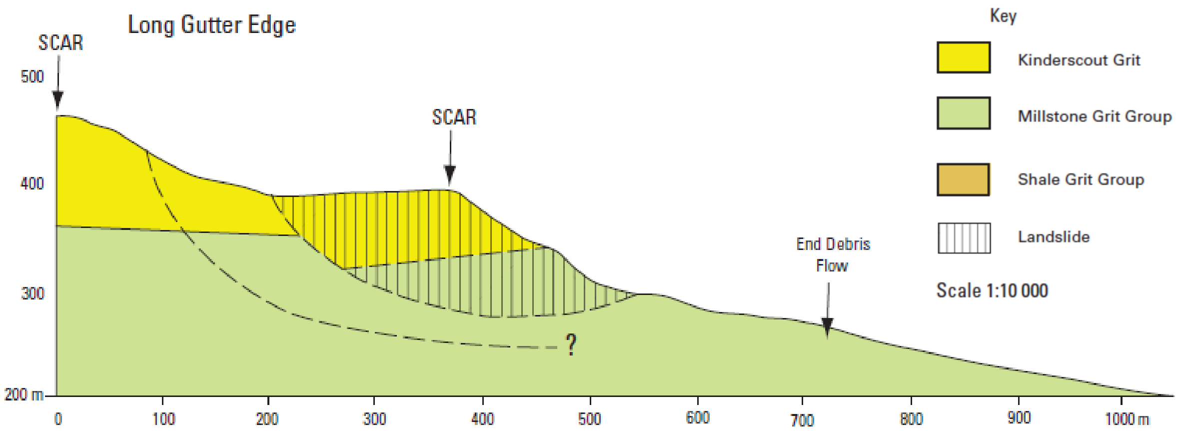


Figure 4.2 – Schematic cross section of Long Gutter Edge Landslide (compiled using data collected on field survey)

4.1.2 Rollick Stones Landslide

The large Rollick Stones landslide (NLDN 10920, NGR 408050, 397940) is located on the southerly side the Longdendale Valley, this large mass movement failure has detached and rotated down slope towards the Torside Reservoir in a north westerly direction (315º), leaving a clearly defined back scar (Figure 4.2). The back scar has formed in the coarse grained massive Kinderscout Grit, which overlie the thick mudstones and siltstones of the Grindslow Shales. The strata are generally dippingout of the slope towards the North West

The landslide is classified as a rotational landslide and appears to display evidence of a three fold movement including rotated blocks, a debris flow and rock falls. The walkover survey and aerial photography interpretation enabled the maximum width of slide to be recorded as 800m and its length as 1.2Km.

The upper section of the landslide displays a number of features indicative of a deep seated rotational movement including a large exposed back scar, large rotated back tilted blocks and several smaller arcuate scar features. However, the rotational movement forms only a small part of the landslide morphology as the lower section of the landslide comprises a vast expanse of a degraded mudstone debris flow. (Figure 4.2). A schematic cross section of Rollick Stones landslide can be seen in Figure 4.4.

A borehole record at SK 07360, 98468 (borehole number SK09NE/08) on the western edge of Rollick Stones landslide, notes slip debris described as “Angular rock fragments in a sandy silty grey clay matrix, rock fragments mostly mudstone but occasional sandstone boulders up to 18” and small concentrations of sandstones fragments in places with internal structure streaky (shearing)” to a depth of 18.4m below the surface. The geology map of the area shows the mudstones at this location are very thick in comparison to the overlying Grit and therefore have a large influence over the resulting expanse of debris flow and morphology of the landslide.

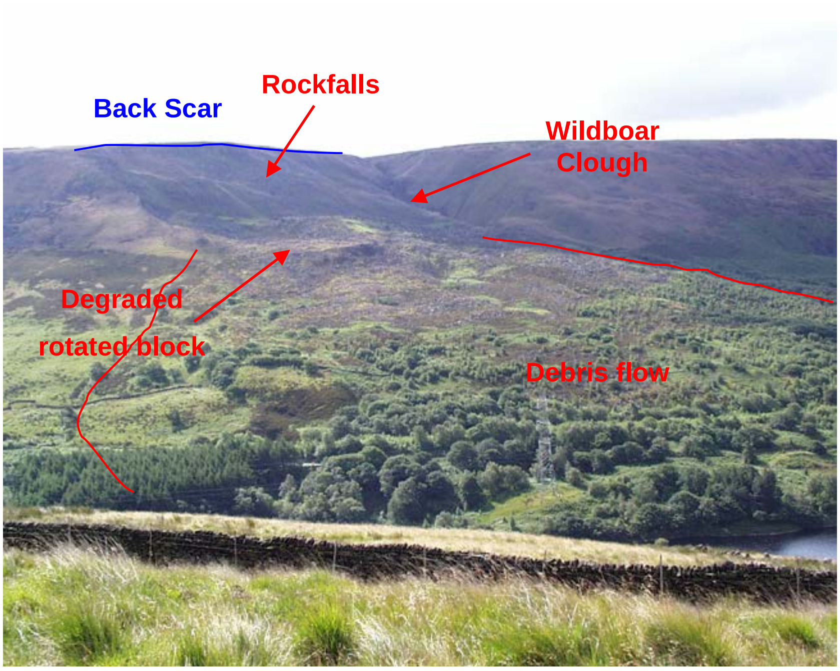


Figure 4.3 - View looking over to Rollick Stones Landslide (BNG 407441 399639 facing 180º).

Freeze thaw action on the exposed sandstones on the back scar of the landslide has resulted in rock falls, with large block fields displayed over the lower valley sides and exposed fractured sandstone faces. In some areas the rocks and boulders have been transported further down slope by subsequent solifluction.

Vegetation across the landslide varies with heather and bracken both present. The debris flow is vegetated with grasses and bracken, with established woodland and shrubs on the lower slopes.

The south west boundary of Rollick Stones landslide is limited by the Wildboar Clough (Figure 4.2), a deeply incised gulley of notable size, corresponding with a fault line, its presence increasing the susceptibility of the debris flow to form over such a large area. Although the landslide is recorded as having a total length of 1.2 km, the toe is thought to have extended further but has since been worked and removed in part as a result of the construction of the reservoirs

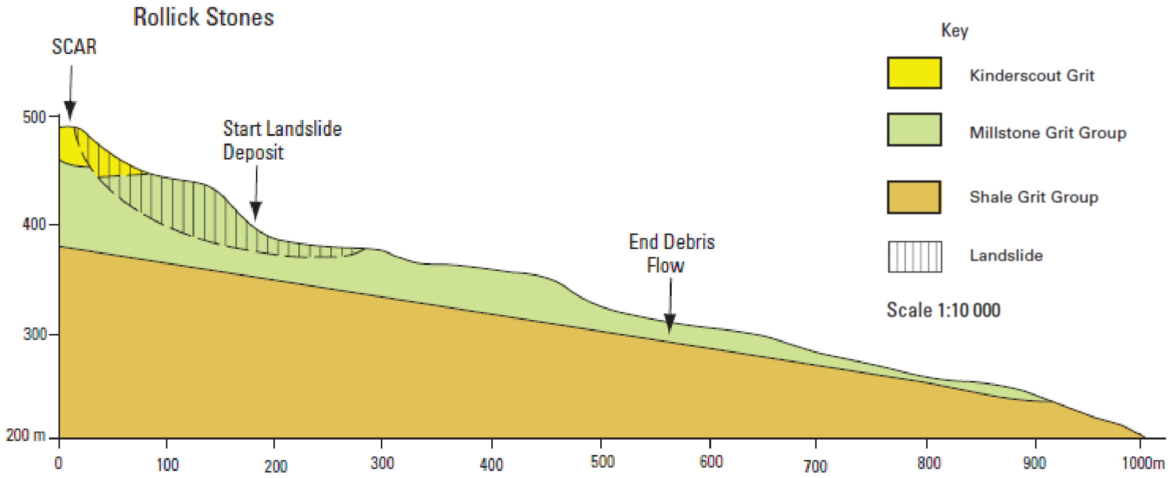


Figure 4.4 – Schematic cross section of Rollick Stones Landslide (compiled using data collected on field survey)

4.1.3 Birchen Bank Landslide

The Birchen Bank landslide (NLDN 10918, NGR 410375, 399080) is again located on the Southerly side of the Longdendale Valley. This large mass movement failure has detached and rotated down slope towards Woodhead Reservoir in a northerly (0^{o}) direction. At this point in the valley the geology of the slopes changes slightly where the mudstones and siltstones of the Grindslow Shale are interbedded with an extra, thick, band of Kinderscout Grit, with further mudstones then overlain by the Kinderscout Grit. The strata are generally dipping out of the slope towards the North. A schematic cross section of Birchen Bank landslide can be seen in Figure 4.6.

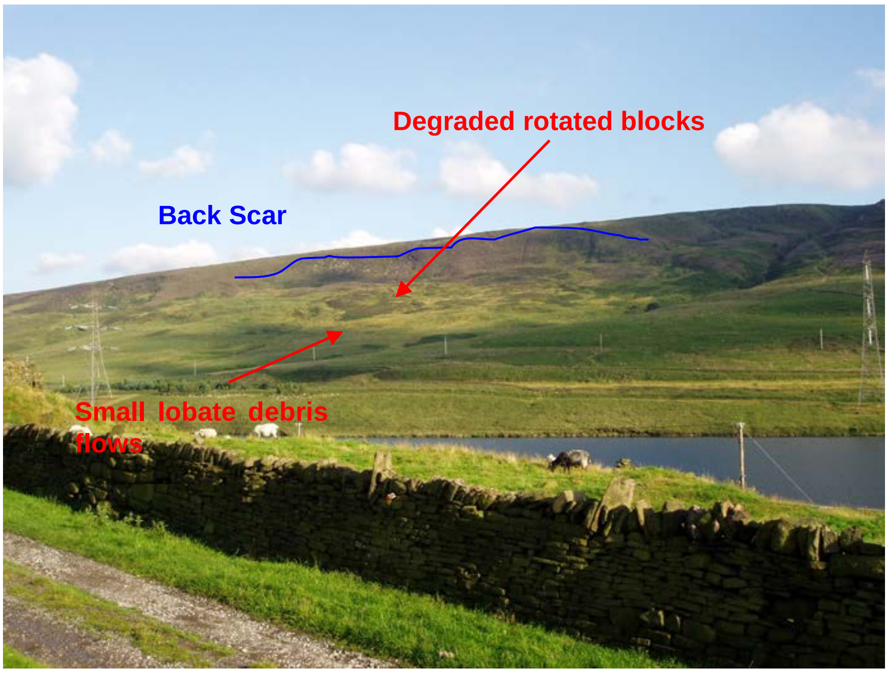


Figure 4.5 - View looking over towards Birchen Bank Landslide (BNG 409618, 399900 towards 180^{o})

The landslide is classified as a rotational failure, with rockfalls near the main scarp line. The walkover survey enabled the maximum width of the landslide to be recorded as 590m and the maximum length as 370m. The morphology of the slide appeared hummocky towards the toe of the slide with a far smaller secondary debris flow than those recorded on previous landslides along the southern side of the valley. Failures appear to have been further modified by secondary slip movements and very shallow mud flows (Figure 4.5) but only over the upper slope areas.

Vegetation on the slide was recorded as heather and blueberry.

During the walkover survey, sections of the Kinderscout Grit sandstone was recorded to be angled into slope, with further more blocky and mixed dips recorded near the top of the slide at an exposure located above the rotated mass. Where it was exposed above the rotational mass, the insitu sandstone appeared to be dipping out of the slope. Spring lines were apparent at the junctions between the mudstone and sandstones causing potential slip planes. The Birchen Bank Landslide is much shorter in length than those previously described in the Longdendale Valley, due to lesser impact of the debris flow at this location as a result of the thinner band of Mudstone and siltstone.

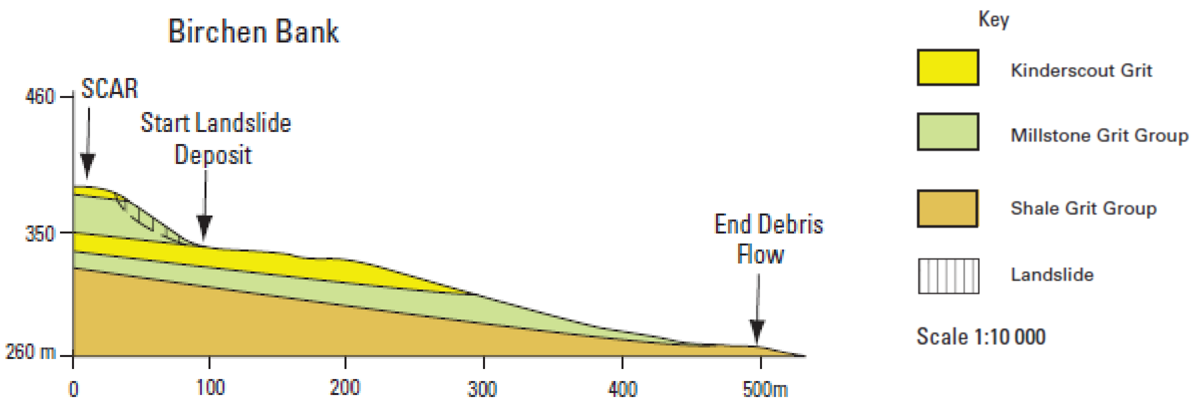


Figure 4.6 – Schematic cross section of Birchen Bank Landslide (compiled using data collected on field survey)

4.2 CROWDEN VALLEY

Crowden is a small hamlet located on the River Ethrow tributary valley of the Great Crowden Brook, alongside Torside Reservoir. The Crowden Moors of Kinderscout Grit end in a line of rocky scarps on the northern side of Longdendale. The landslides are not as extensive as those on the Southern Longdendale Valley.

4.2.1 Black Tor Landslide

The Black Tor landslide (NLDN 11251, NGR 406120, 400220) is located alongside the Pennine way in the Crowden tributary valley. The mass movement failure has detached and rotated down slope into the valley, incised by the Great Crowden Brook, towards the north east (45^{o}) leaving a clearly defined back scar (Figure 4.4). The back scar has formed in the coarse grained massive Kinderscout Grit, which overlies the thick mudstones and siltstones of the Grindslow Shales. The strata are generally dipping towards the South East.

The landslide is classified as a rotational landslide that includes a large degraded rotated block with secondary debris flows.

The presence of spring lines was identified between sandstone and mudstone. A zone of depletion was noted behind the degraded block.

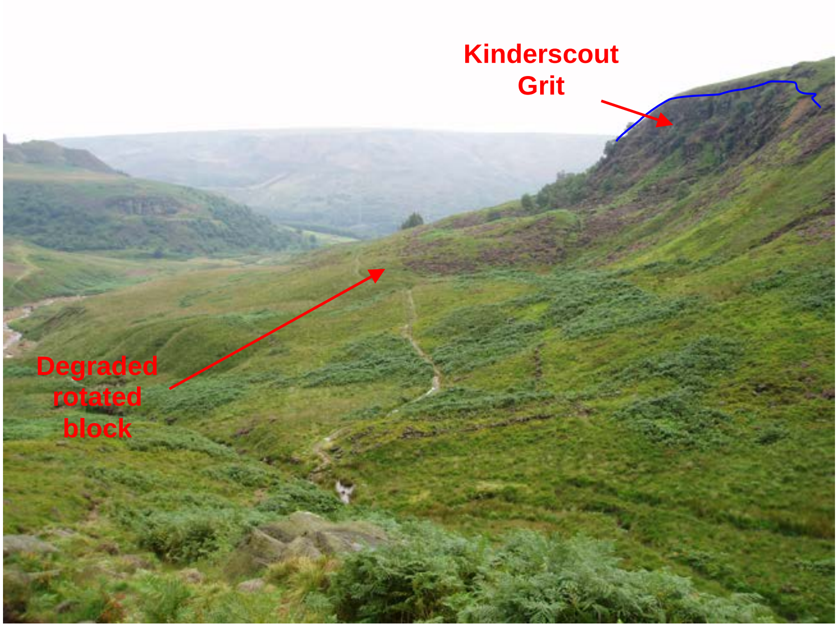


Figure 4.7 - View looking over to Black Tor Landslide (BNG 406180 400494 facing 150°)

4.3 REGIONAL LANDSLIDES

The thickness of the underlying mudstones appears to be a controlling factor in the morphology of the mass movement failures of the area. Several further landslides surveyed in the surrounding District are discussed below.

4.3.1 The Binns Landslide (Heyden Moor)

The Binns (Heyden Moor) landslide (NLDN 10923, NGR 409350, 402400) is located in a small incised valley by the Heyden Brook within Heyden Moor. The landslide is situated alongside the A6024 Holmfirth Road. This large mass movement failure has caused a number of deep seated multiple rotational slides to develop that have a strong backwards rotation of the blocks (Figure 4.5), in an easterly direction (90°). The landslide is situated alongside the A6024 Holmfirth Road. The slope failure has formed in a series of thin interbedded mudstones and sandstones of the Millstone Grit Formation.

The landslide is classified as a multiple rotational landslide and a number of clear arcuate features and degraded rotational blocks are observed over the landslide mass (Figure 4.5). Along the back scar of the landslide, the slopes have been eroded in places by numerous large gullies, leaving sharp crested ridges aligned perpendicular to each other and perpendicular to the face. Small debris flows extend from the foot of each channel. Numerous flow features are observed on the lower sections of the slopes, some of which still appear to be active.

The channel of the Heyden Brook is down cutting through the toe (Figure 4.5), basal slide debris and previously undisturbed strata and is removing some of the deposits potentially acting to stabilise the slide in the long term. Valley bulge structures can be seen on the floor of the valley where erosion has exposed sections of the underlying strata.

The main difference between this landslide and those previously discussed is the lack of massive cap rock on this landslide.

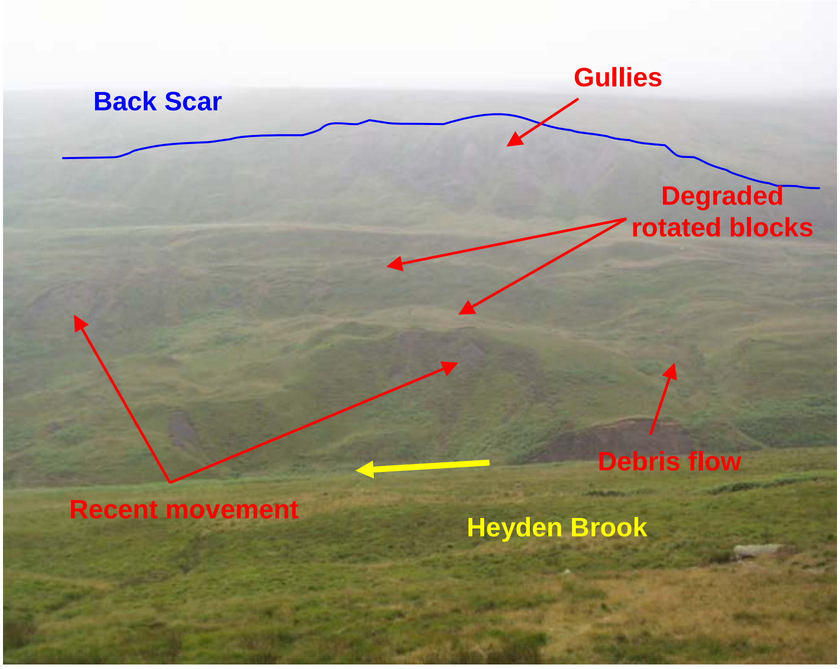


Figure 4.8 - View looking over to Heyden Moor Landslide (BNG 409920,402890 towards 270^0)

4.3.2 Ashton Clough Landslide

The Ashton Clough Landslide (NLDN 10904, NGR 407920, 394360) is located within the valley known as Doctors Gate, towards the southern area of Bleaklow (Shelf) Moor. This large mass movement failure has detached and rotated down slope into the valley in a southeasterly direction (225^o), leaving a clearly defined back scar (Figure 4.6). The back scar has formed in the coarse grained massive Kinderscout Grit, which overlies the thick mudstones and siltstones of the Grindslow Shales. The strata are generally dipping towards the West.

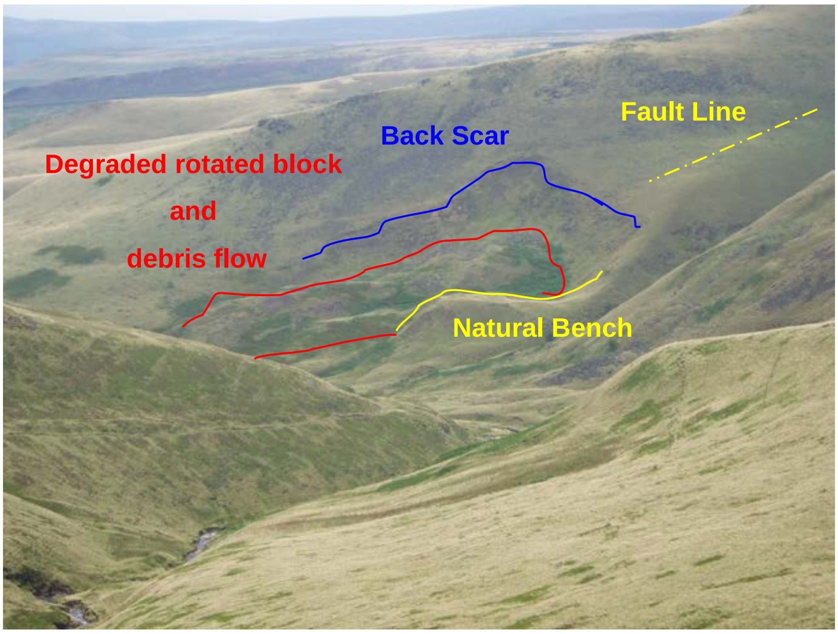


Figure 4.9 - View looking over to Ashton Clough Landslide (BNG 408794 393460 facing 315^o).

Ashton Clough is classified as a rotational landslide. Within the slide complex, strong arcuate features, scarps and large degraded rotational blocks can be observed. Recent peat failures are visible on the upper slopes of the landslide. Insitu bedded sandstone can be clearly seen within exposures on the face of the back scar. A natural sandstone bench is observed in the foreground of the landslide (Figure 4.6) and the landslide is as bounded by Ashton Clough near its eastern side, a steep gorge that climbs 240m over 750m.

Vegetation on the landslide was recorded grasses.

4.3.3 Canyards Hill

The Canyards Hills Landslides (NLDN 10906, NGR 425060, 394700) is situated approximately 8 km north-west of the edge of the City of Sheffield, to the south of Broomhead Reservoir. This large complex of mass movement deposits has detached in a series of movements and rotated down slope in a north easterly direction (45^{o}). The steep 10m high northern back scar is formed in the massive well bedded Huddersfield White Rock sandstones which overlie the mudstones and siltstones of the Millstone Grit Group shales, great masses of the slipped material cover the slopes below (Figure 4.8). The north-easterly dip is causing the rock to slip over the underlying shales.

The site is registered as a Site of Special Scientific Interest (SSSI) and a Geological Conservation Review site, covering and area of 0.64 Km^{2}. The landslide is classified as a complex landslide and is a mass of sub-parallel ridges, separated by narrow areas of marshy ground. The site shows the most extreme form of 'tumbled ground' (Figure 4.8), with numerous small Millstone Grit blocks, controlled by jointing, forming the large landslip with debris flows occurring near the toe of the complex.

Vegetation across the landslide varies. The vegetation across the ridges is dominated by heather with abundant bilberry and cowberry. The troughs between the ridges contain many boggy areas with ponds.

Figure 4.10 - View looking over Canyards Hill Landslide (BNG 426239, 395143 towards 250^{o})

5 Landslide processes in the Glossop District

The landslides of the Glossop district can be classified into a number of *Slope Behaviour Units*, this can help describe why the landslides have formed and evolved in a certain manner. This process is described below in more detail and is used as a technique to collectively discuss the processes surrounding the formation of the landslides.

5.1 SLOPE BEHAVIOUR UNITS: THE THEORY

Slope Behaviour Units (SBUs) are a convenient way to consider the processes that form and maintain a slope (Lee 1997, Lee and Clark 2002, Gibson *et al.* 2004). This approach is based upon the idea that slopes with similar geomorphological components: geology, topography, and hydrogeology have been subject to similar climatic conditions and can be expected to produce slopes of similar characteristics. Characterizing ground in this way is an efficient and effective method of classifying different slope types. It also provides a useful method by which variations in landforms can be interpreted back to variations in the principal components, useful for instance in identifying geological structure.

5.2 SBU ASSESSMENT OF THE LANDSLIDES OF THE GLOSSOP DISTRICT

The slopes of Longdendale and the Glossop District are all products of erosion during periods of very cold climate which occurred during the last glaciation. During this time the area was part of a periglacial climate extending eastwards from the margins the West Britain ice sheets (Johnson and Walthall, 1979). Melt water, supplied from the snowfields of the Pennine plateaus, together with localised permafrost would have resulted in a fluctuating high water table. As a result of these high water tables, the development of strong water pressures in the rocks would have periodically reached critical points inducing massive failures in the integrity of the material, already weakened from severe weathering.

The thickness of the underlying mudstones is a factor in the morphology of the mass movement failure of the District and is considered in the SBU assessment of the area. During the walkover study was noted that the thickness of the mudstones appeared to control the secondary mudflows. It is clear that within the district, the dip of the strata is one factor in the formation of the mass movement deposits. Sandstone formations dipping out of the slope slip over the underlying shales. In these cases movements are constrained to a particular side of a valley, often resulting in an asymmetrical valley profile.

Within the Glossop district, the geology of the slope is deemed to be the overriding control in mass movement process. As a result of the studies carried out, all the slopes within the Namurian in the district have been classified into SBUs. The landslides in the Westphalian strata, in the North east of the district, have not been included as no data was collected from the area during this study. The landslides have taken the form of two distinct Slope Behaviour Units in the Namurian strata (demonstrated in Figure 5.1);

- SBU A Kinderscout Grit over Millstone Grit Group Shales
- SBU B Huddersfield White Rock /Rough Rock Sandstone over Millstone Grit Group

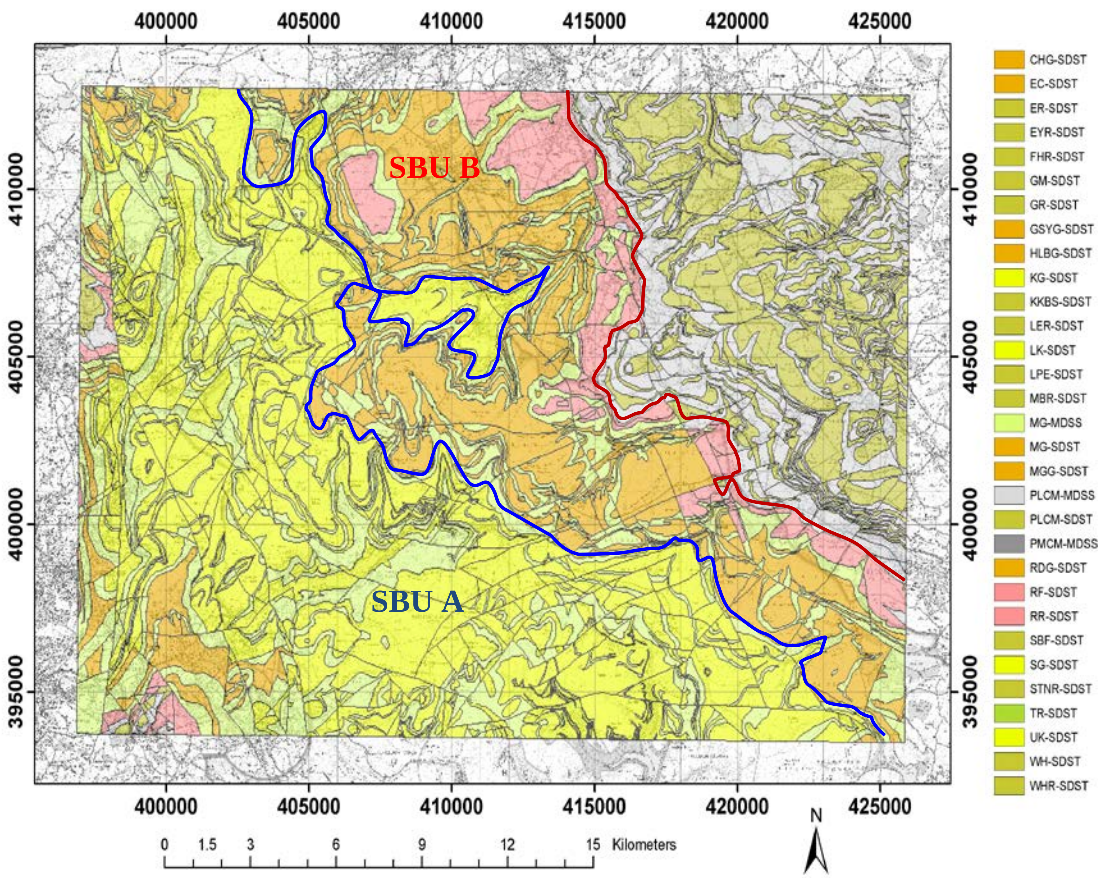


Figure 5.1 - Slope Behaviour Units in the Glossop District

5.2.1 SBU A - Kinderscout Grit over Millstone Grit Group Shales

Slope Behaviour Unit A contains the strata from the Kinderscout Grit overlying the Millstone Grit Group Shale (Figure 5.1). In this unit there are variations of the landslide morphology, resulting from the range of thickness of the strata. The Longdendale Valley has a number of good examples of SBU A landslides, where the large scale mass movements are constrained to the southern side due to the north westerly dipping strata.

This causes landslides that are deep seated rotational landslides with small debris flows to form. As the mudstones become thicker towards the eastern side of the valley, the rotational element becomes a lot smaller and less important whilst the debris flows become greater and more dominant. The dip and the thickness of the mudstones therefore appear to control the morphology of final landslide. High cliff-like escarpments of sandstone are present along the large, deeply incised gorge like valley where freeze thaw and weathering of the sandstone has resulted in secondary topples and rock falls also happening.

Over the rest of the district, including the Crowden Valley and Dovestone reservoir area to the west of Saddleworth Moor, SBU A comprises of much thinner bedded mudstones within subsidiary valleys and more subdued and gentle topography. Again, the mechanisms are the same comprising deep seated rotations and the presence of degraded rotated blocks but the debris flows are much less pronounced.

To the east of the Longdendale Valley where there have been a number of single rotational failures with no substantial debris flow such as the previously described Birchen Bank landslide, are also classified within SBU A.

5.2.2 SBU B – Huddersfield White Rock/ Rough Rock Sandstone over Millstone Grit Group

Slope Behaviour Unit B contains the more competent stronger Huddersfield White Rock and Rough Rock sandstones which overlie the weaker strata of weathered mudstones (Figure 5.1). Landslides in SBU B were deemed to be mostly either complex or multiple slides that formed from a series of movements occurring at a similar time.

The landslides of SBU B appear to be more variable in their morphology than those of SBU A with geologically similar sites in close proximities displaying landslides of a complex, multiple and singular failure. The mudstones underlying the sandstones within SBU B are not as prominent or extensive as those underlying the Kinderscout Grit, thus the landslides of SBU B are not as dominated by debris flows. One exception to this observation is Canyards Hill (NGR 425060, 394700) where the comparatively thick mudstone has resulted in an extensive multiple rotational landslide with several flow components.

6 Landslide Distribution

The distributions of the surveyed landslides within the Glossop District are shown in Figure 6.1. 61 newly surveyed landslides have been added to the National Landslide Database. 57 of these were as a result of notebook proformas being filled in during the detailed walk over survey and air photo interpretation.

As can be seen in Figure 6.1 there does appear to be some correlation between geology, or the previously described Slope Behaviour Units (SBU), and the distribution of the different styles of landslides in the Glossop District.

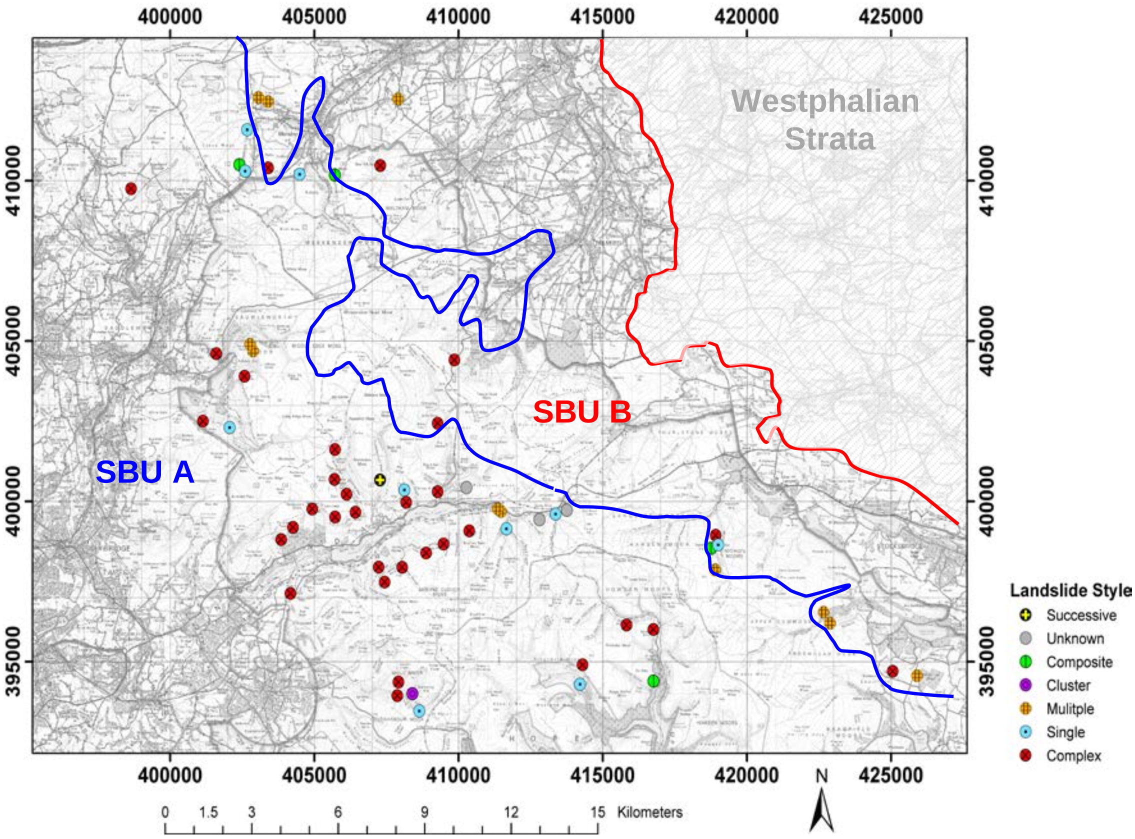
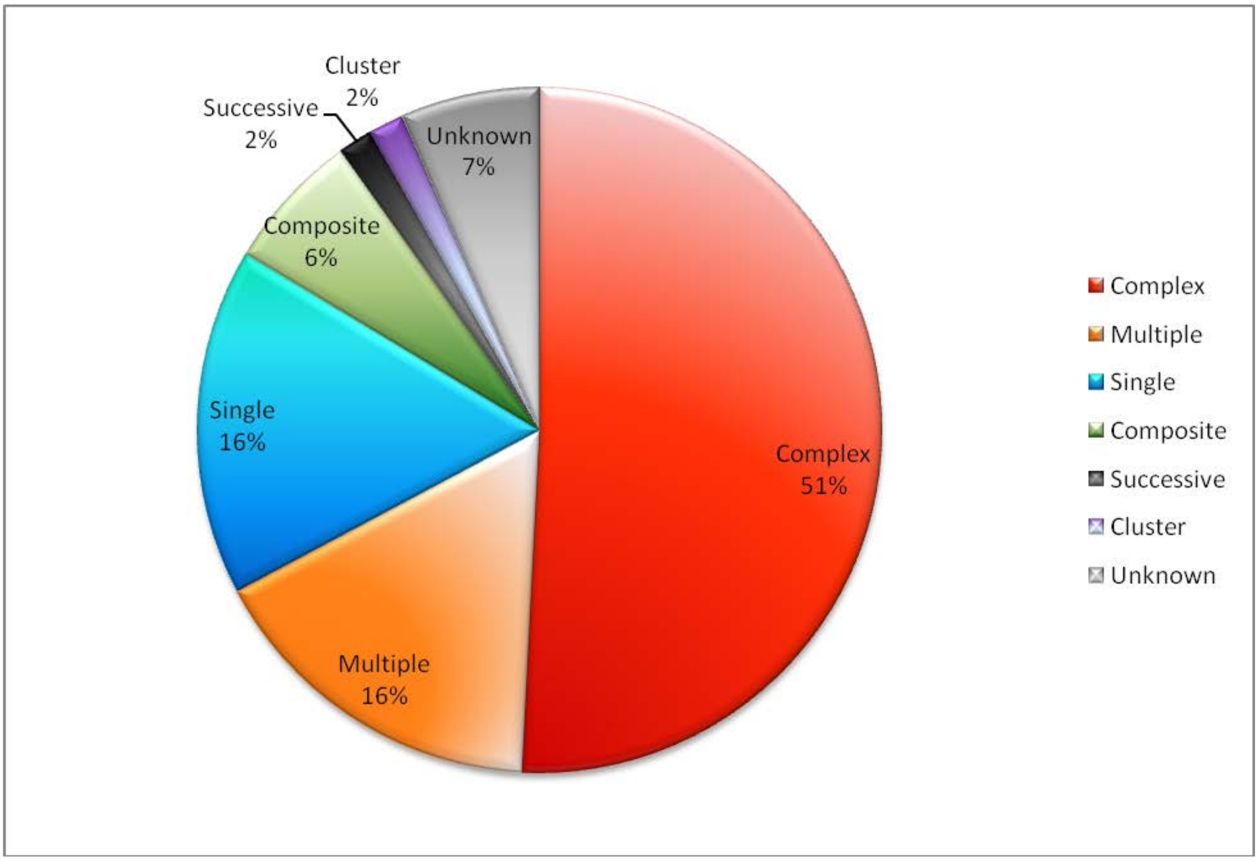


Figure 6.1 - The Distribution of newly surveyed landslides within the Namurian of the Glossop District.

As displayed in Figure 6.2, 50% of the surveyed landslides within the Glossop district are classified as being of a complex nature. This is determined by the sequence of a deep seated rotational movement occurring followed by debris flow and, in some cases, topple or rockfall. The majority of these complex landslides are located in the SBU defined as 'A' where massive Kinderscout Grit overlies the weak strata of weathered shale (Figure 6.1). The single and multiple style landslides occur in either the shale of SBU A or SBU B where the dense Rough Rock or Huddersfield White Rock sandstones overlie incompetent shales.



Description	Code	Definition
Single	S	A single event failure with no additional movements of the same type.
Multiple	**M**	A series of movements of the same type e.g. a series of slices failing in multiple rotational style.
Cluster	**G**	Cluster or group of small landslides on a section of slope with similar characteristics.
Composite	**C**	A composite landslide exhibits at least two movements simultaneously in different parts of the displacing mass.
Complex	**X**	A complex slide involves one of the five main types of movement followed by two or more of the other main types of movement.
Successive	+	Repeated shallow rotational slips each of limited extent down slope but considerable extent across it, forming cross slope steps or terraces.

Figure 6.2 - Styles of Landslides in the Namurian of the Glossop District (Descriptions taken from the BGS Landslide proforma Appendix 1)

7 Conclusions

There are a large number of landslides within the Glossop district. The aim of this research was to determine the geographical extent of the landslides and mass movement mechanisms responsible for landslide deposits in the Longdendale valley and the surrounding district. The geology of the District comprises a succession of sedimentary rocks from the Namurian (Millstone Grit Group) and Westphalian (Coal Measures Group).

Within the Namurian of the Glossop district, the geology of the slope is deemed to be the overriding control in mass movement process. The landslides form in discrete areas as a result of the interaction between geology, structure (dip) and topography. This forms two distinctive slope behaviour units (SBU's) which are:

- SBU A Kinderscout Grit over Millstone Grit Group Shales
- SBU B Huddersfield White Rock/ Rough Rock Sandstone over Millstone Grit Group

Within SBU A the landslides are deep seated rotational landslides with small debris flows. As the mudstones become thicker the rotational element becomes a lot smaller and less important whilst the debris flows become greater and more dominant. The dip and the thickness of the mudstones therefore appear to control the morphology of final landslide within SBU A. The landslides of SBU B appear to be more variable in their morphology, with geologically similar sites in close proximities displaying landslides of a complex, multiple and singular failure.

This work enabled 61 newly surveyed landslides to be entered into the National Landslide Database (Appendix 2). This was achieved by the analysis of data collected, and the observations that were made during a field walkover survey and office based remote sensing investigations.

8 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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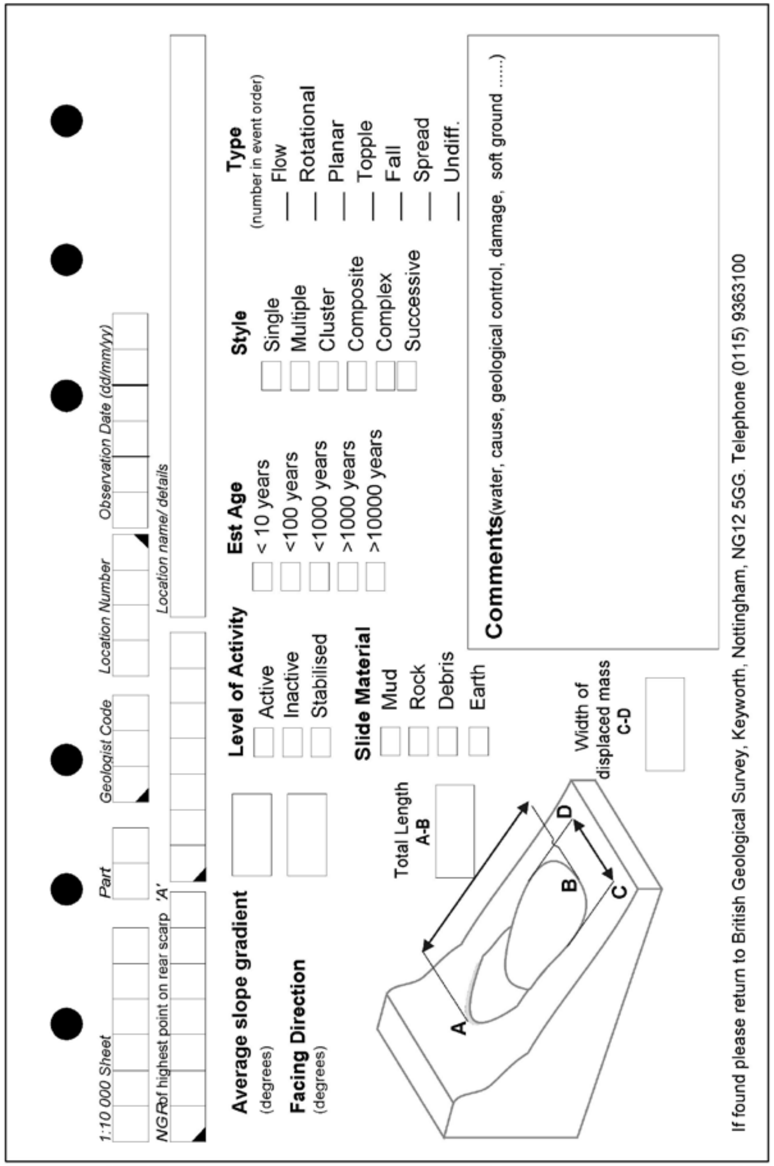
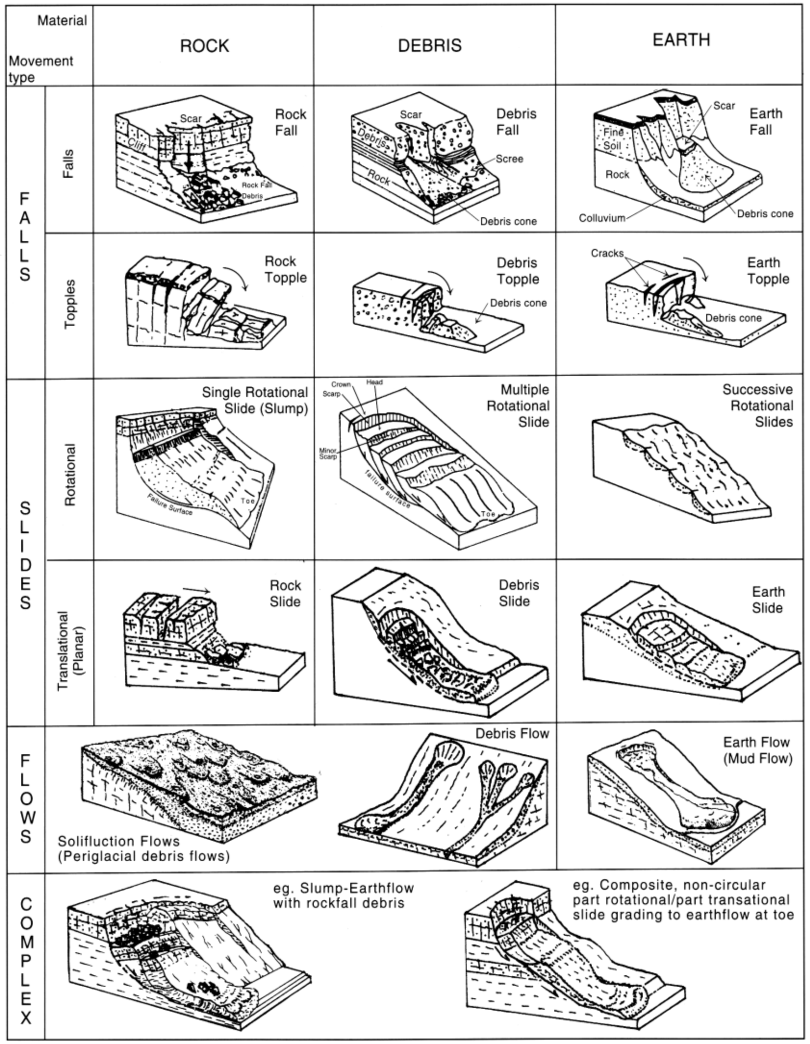
Appendix 1 Proforma sheets used during field and remote survey





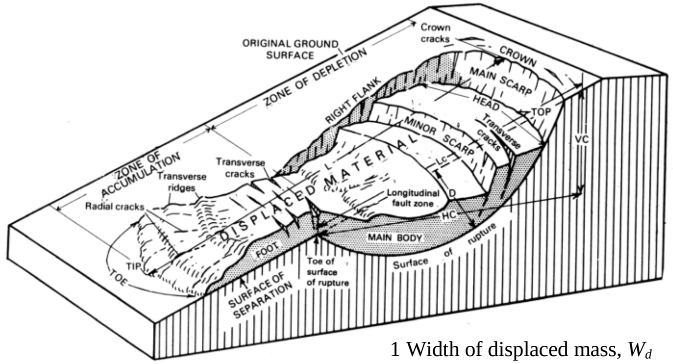
Falls - Mass detached from steep slope/cliff along surface with little or no shear displacement, descends mostly through the air by free fall, bouncing or rolling; Topples - forward rotation about a pivot point; Rotational slides - sliding outwards on one or more concave-upward failure surfaces; Translational (planar) slides - sliding on a planar failure surface running more or less parallel to the slope; Flows - slow to rapid mass movements in saturated materials which advance by viscous flow, usually following initial sliding movement. Some flows may be bounded by basal and marginal shear surfaces but the dominant movement of the displaced mass is by flowage; Complex slides - slides involving two or more of the main movement types in combination.

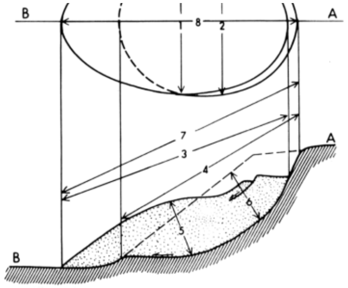
Style

Description	Code	Definition
Single	S	A single event failure with no additional movements of the same type.
Multiple	**M**	A series of movements of the same type e.g. a series of slices failing in multiple rotational style.
Cluster	**G**	Cluster or group of small landslides on a section of slope with similar characteristics.
Composite	**C**	A composite landslide exhibits at least two movements simultaneously in different parts of the displacing mass.
Complex	**X**	A complex slide involves one of the five main types of movement followed by two or more of the other main types of movement.
Successive	+	Repeated shallow rotational slips each of limited extent down slope but considerable extent across it, forming cross slope steps or terraces.

Type

Flow	**FL**	Slow to very rapid movement of saturated inter-grain movement predominating over shear surface movements. Initial displacement usually by sliding, rapidly transforming to flow.
Rotational slide	**SR**	Down slope movement of soil or rock, dominantly on a curved surface of rupture or relatively thin zones of intense shear strain. The mass may slide beyond the surface of rupture over the ground surface called a surface of separation.
Planar slide	**SP**	Down slope movement of soil or rock, dominantly on a planar surface of rupture or relatively thin zones of intense shear strain. The mass may slide beyond the surface of rupture over the ground surface, which becomes a surface of separation.
Fall	**FA**	Detachment of soil or rock from a steep slope with little or no shearing. Descent mainly through air by falling, bouncing or rolling. Rapid to extremely rapid. Initial detachment may be by sliding or toppling.
Spread	**SD**	An extension of a coherent soil or rock mass combined with the subsidence of the fractured mass of cohesive material into softer underlying material. The surface of rupture is not a surface of intense shear.
Topple	**TO**	Forward rotation out of slope of soil or rock about a point or axis below the centre of gravity of the displaced mass. Extremely slow to extremely rapid sometimes accelerating throughout the movement.
Undiff.	**UN**	Slide Undifferentiated





1 Width of displaced mass, W_d

2 Width of surface of rupture, W_r

3 Length of displaced mass, L_d

4 Length of surface of rupture, L_r

5 Depth of displaced mass, D_d

6 Depth of surface of rupture, D_r

7 Total length, L

8 Length of centre line, L_{cl}

9 Slope gradient (degrees)

Age

Very Recent	< 10 Years Remembered, features very fresh occurred under current climatic conditions.
Recent	<100 Years. Recorded, degraded, occurred under current climatic conditions.
Old	< 1000 Years? not recorded, relict, may have occurred under different climatic conditions.
Relict	>1000 Years? Prehistoric, relict, occurred under different climatic conditions to the present.

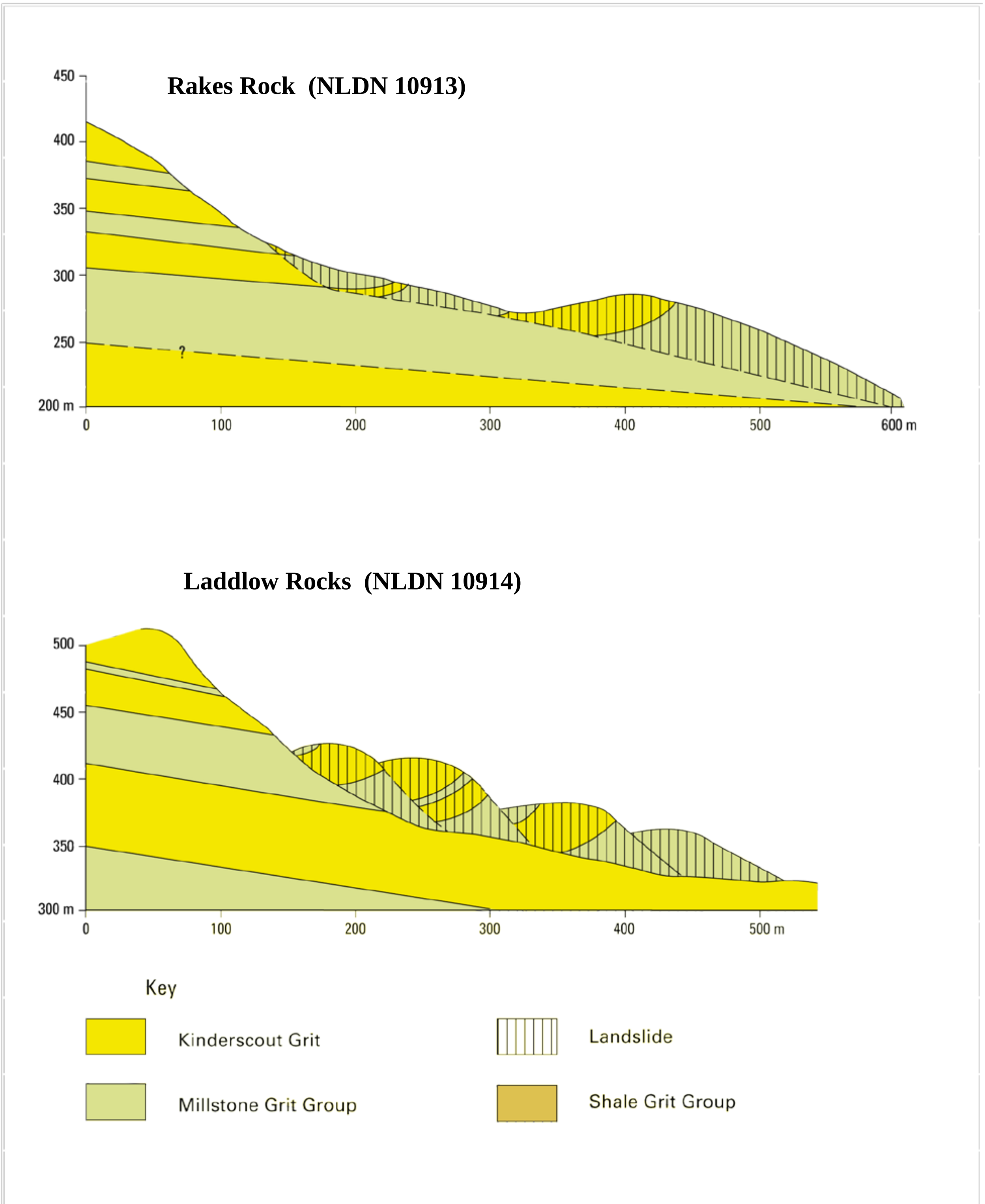
Material

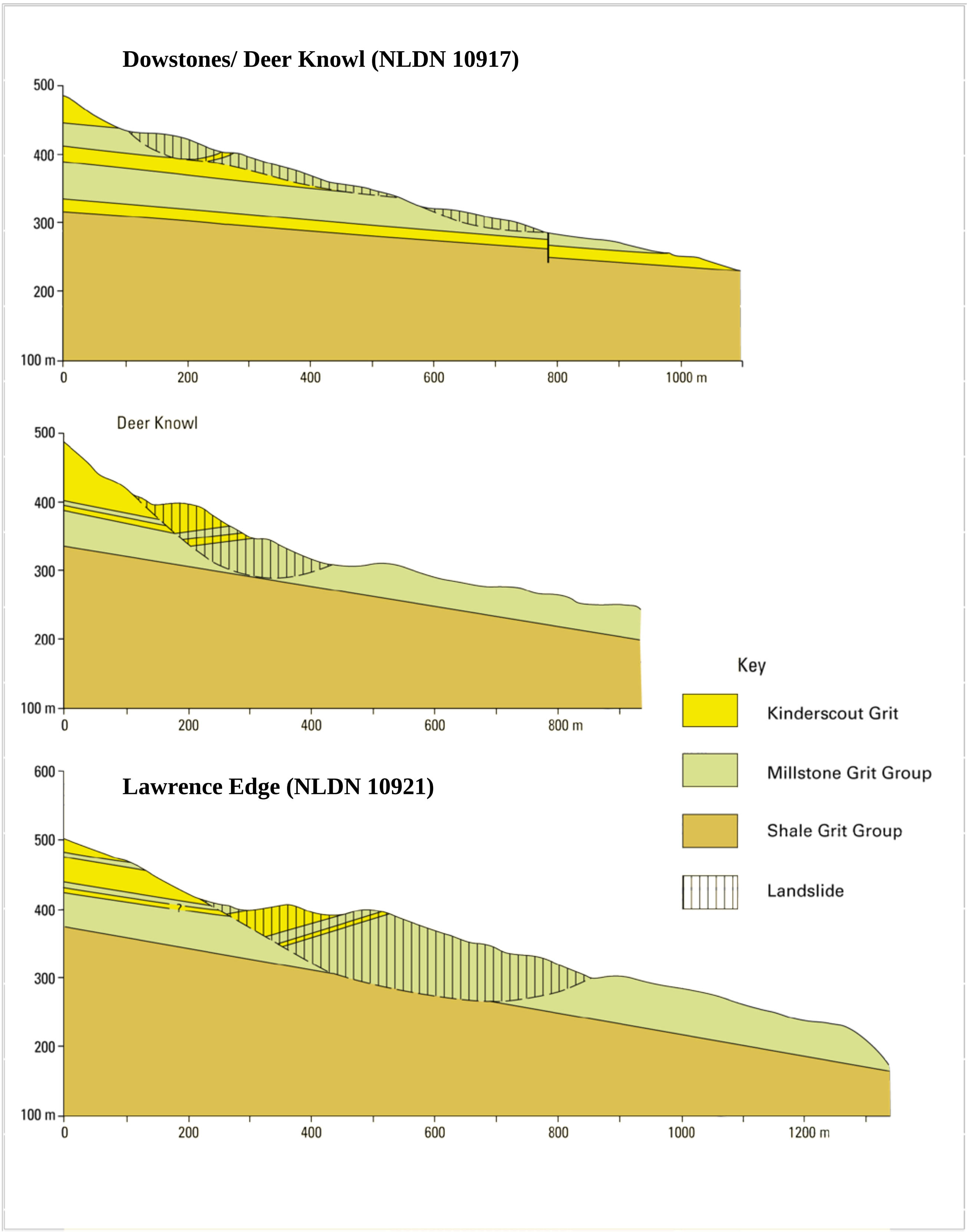
Rock	Engineering rock lithified or indurated to a degree that it cannot be excavated by digging.
Debris	Coarse grained engineering soils dominated by material of gravel size or greater (including boulders)
Earth	Fine-grained engineering soils dominated by clay to sand-size fractions
Mud	Fine-grained engineering soils dominated by clay to sand-size fractions in a wet condition.

Appendix 2 New landslide records in the NLDB

Landslide database Number	Locality Name	Location	NGR Easting	NGR Northing	Movement Style
10924	White Holes	Meltham Moor, West Yorkshire, England	407290	410475	Complex
10925	Varley Road	Slaithwaite, West Yorkshire, England	407900	412550	Multiple
10926	Scar Head	Binn Moor, West Yorkshire, England	405710	410180	Composite
10927	Scout Farm	Marsden, West Yorkshire, Endland	405500	411250	Unkown
10928	Piper Holes	West Yorkshire, England	403065	412595	Multiple
10929	Redbrook Clough	West Yorkshire, England	402670	411590	Single
10930	Butterfly Clough	West Yorkshire, England	404490	410200	Single
10931	Pule Hill	West Yorkshire, England	403400	410400	Complex
10932	Waters Road	West Yorkshire, England	403400	412470	Multiple
10933	Brack Rolls	West Yorkshire, England	402400	410500	Composite
10934	Far Owlers	West Yorkshire, England	402600	410300	Single
10923	The Binns	Derbyshire, England	409280	402430	Complex
11264	Ashway Rocks	Greater Manchester, England	402875	404689	Multiple
11265	Yeoman Hey Reservoir	Greater Manchester, England	402770	404900	Multiple
10890	White Clough	Derbyshire, England	408400	394000	Cluster
10891	Well Springs	South Yorkshire, England	422660	396540	Multiple
10893	Mickleden 1	South Yorkshire, England	418920	398940	Complex
10894	Mickleden 2	South Yorkshire, England	418750	398535	Composite
10895	Mickleden 3	South Yorkshire, England	418900	397865	Multiple
10896	Mickleden 4	South Yorkshire, England	419005	398640	Single
10898	Mosley Bank	Derbyshire, England	416760	396000	Complex
10901	Near Black Clough	Derbyshire, England	411660	399145	Single
10904	Ashton Clough	Derbyshire, England	407920	394360	Complex
10905	Doctor's Gate	Derbyshire, England	407880	393940	Complex
10906	Canyard's Hill	South Yorkshire, England	425060	394700	Complex
10907	Moor Side	South Yorkshire, England	422880	396200	Multiple
10910	Deer Holes	Derbyshire, England	415830	396140	Complex
10911	Ox Hey	Derbyshire, England	416760	394395	Composite
10912	Far Small Clough	Derbyshire, England	413365	399605	Single
10913	Rake's Rocks	Derbyshire, England	405700	400680	Complex
10914	Laddlow Rocks	Derbyshire, England	405720	401616	Complex
10915	Millstone Rocks	Derbyshire, England	404930	399760	Complex
10916	Tintwistle Knarr	Derbyshire, England	404265	399190	Complex
10917	Dowstones/Deer Knowl	Derbyshire, England	409482	398670	Complex
10918	Birchen Bank	Derbyshire, England	410375	399080	Complex
10921	Lawrence Edge	Derbyshire, England	408880	398390	Complex
11251	Black Tor	Derbyshire, England	406120	400220	Complex
11252	Hey Edge	Greater Manchester, England	408125	400355	Single
11253	Woodhead Bridge	Derbyshire, Engand	409280	400300	Complex
11254	Pikenaze	Derbyshire, England	410275	400430	Unknown
11255	Devil's Elbow	Derbyshire, England	404175	397125	Complex
11256	Didsbury Intake	Greater Manchester, England	403855	398805	Complex
11257	Bareholme Moss	Greater Manchester, England	407280	400670	Successive
11258	Hey	Greater Manchester, England	408190	399970	Complex
11259	Rose Clough	Derbyshire, England	412810	399430	Unknown
11260	Salter's Brook	South Yorkshire, England	413756	399725	Unknown
10886	Little Hey	Northern side of Holme Moss, West Yorkshire	409898	404406	Single
10888	Dry Clough	Derbyshire, England	414303	394900	Complex
10892	Birchen Bank Wood	Derbyshire, England	411470	399685	Multiple
10899	Woodhead Station	Derbyshire, England	411360	399765	Multiple
10900	Ridge Upper Moor	Derbyshire, England	414212	394294	Single
10902	Long Gutter Edge 1	Derbyshire, England	407440	397480	Complex
10903	Long Gutter Edge 2	Derbyshire, England	407235	397945	Complex
10908	Ox Hey Top	Greater Manchester, England	398650	409750	Complex
10909	Alderman Hill	Greater Manchester, England	401603	404606	Complex
10919	Highstone	Derbyshire, England	405725	399510	Complex
10920	Rollick Stones	Derbyshire, England	408050	397940	Complex
10922	Highstone Rocks	Derbyshire, England	406430	399660	Complex
11261	Great Dove Stone Rocks	Greater Manchester, England	402580	403900	Complex
11262	Stable Stones Brow	Greater Manchester, England	402060	402300	Single
11263	Winberry Stones Brow	Greater Manchester, England	401140	402500	Complex

Appendix 3 Schematic cross sections produced for a selection of surveyed landslides.




Dowstones/ Deer Knowl (NLDN 10917)
500
400
300
200
100 m
0
200
400
600
800
1000 m
Deer Knowl
500
400
300
200
100 m
0
200
400
600
800 m
Lawrence Edge (NLDN 10921)
600
500
400
300
200
100 m
0
200
400
600
800
1000
1200 m
?
Key
Kinderscout Grit
Millstone Grit Group
Shale Grit Group
Landslide