British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Landslides of the area around Chesterfield, Geological Sheet 112

Land Use and Development

Open Report OR/09/022

BRITISH GEOLOGICAL SURVEY

LAND USE AND DEVELOPMENT

OPEN REPORT OR/09/022

Landslides of the area around Chesterfield, Geological Sheet 112

CVL Pennington, HM Evans and C Foster

Keywords

Landslide, Chesterfield.

National Grid Reference

SW corner 425000,355000
Centre point 440000,365000
NE corner 455000,375000

Map

Sheet 112, 1:50 000 scale, Chesterfield

Front cover

Fallinge Edge, Derbyshire. Photograph taken from Beeley Hilltop [SK273689] facing SSW.

Bibliographical reference

PENNINGTON, C.V.L., EVANS, H. M. AND FOSTER, C.. 2009. Landslides of the area around Chesterfield, Geological Sheet 112. *British Geological Survey Open Report,* OR/09/022. 23pp.

Keyworth, Nottingham British Geological Survey 2009

BRITISH GEOLOGICAL SURVEY

The full range of our publications is available from BGS shops at Nottingham, Edinburgh, London and Cardiff (Welsh publications only) see contact details below or shop online at www.geologyshop.com

The London Information Office also maintains a reference collection of BGS publications, including maps, for consultation.

We publish an annual catalogue of our maps and other publications; this catalogue is available online or from any of the BGS shops.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as basic research projects. It also undertakes programmes of technical aid in geology in developing countries.

The British Geological Survey is a component body of the Natural Environment Research Council.

British Geological Survey offices

BGS Central Enquiries Desk
Tel 0115 936 3143 Fax 0115 936 3276
email enquiries@bgs.ac.uk

Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG
Tel 0115 936 3241 Fax 0115 936 3488
email sales@bgs.ac.uk

Murchison House, West Mains Road, Edinburgh EH9 3LA
Tel 0131 667 1000 Fax 0131 668 2683
email scotsales@bgs.ac.uk

Natural History Museum, Cromwell Road, London SW7 5BD
Tel 020 7589 4090 Fax 020 7584 8270
Tel 020 7942 5344/45 email bgslondon@bgs.ac.uk

Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff CF15 7NE
Tel 029 2052 1962 Fax 029 2052 1963

Forde House, Park Five Business Centre, Harrier Way, Sowton EX2 7HU
Tel 01392 445271 Fax 01392 445371

Maclean Building, Crowmarsh Gifford, Wallingford OX10 8BB
Tel 01491 838800 Fax 01491 692345

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF
Tel 028 9038 8462 Fax 028 9038 8461
www.bgs.ac.uk/gsni/

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon SN2 1EU
Tel 01793 411500 Fax 01793 411501
www.nerc.ac.uk

Website www.bgs.ac.uk
Shop online at www.geologyshop.com

Contents

FIGURES

TABLES

Summary

This report provides a compilation of landslide information as part of the 1:10 000 scale re-survey of the Chesterfield, Matlock and Mansfield geological sheet (112). The resulting published products will comprise the landslides information of the revised 1:50 000 scale map.

1 Introduction

The Chesterfield 1:50 000 geological map (Sheet 112) district lies at the eastern tip of the Pennines and includes areas of unspoilt landscape beauty in the west and more residential and industrial areas in the east. The district was first surveyed from 1904 to 1908 and then resurveyed from 1951 to 1956. As part of the resurveying of the sheet by the East Midlands Team, the Landslides Survey Team was approached to assist in the mapping of landslides in the region.

This report provides a compilation of landslide information as part of the 1:10 000 scale re-survey of the Chesterfield, Matlock and Mansfield geological sheet (112). The resulting published products will comprise a revised 1:50 000 scale map.

2 Study area

The district covered by the Chesterfield 1:50 000 scale Geological Sheet 112 (Figure 1) lies chiefly in Derbyshire, but extends east into Nottinghamshire; the greater part falls within the East Midlands Coalfield (Figure 2). The sheet includes Chesterfield in the north, and extends to Matlock in the south-west and the towns of Mansfield, Sutton in Ashfield and Kirkby in Ashfield in the south-east. The district is rural in nature (moorland and hill pasture), particularly in the western part, which is underlain by the Peak Limestone Group (formerly part of the Carboniferous Limestone) and Millstone Grit Group strata. Moorland, hill farms and scattered small settlements predominate with the only large town being the spa town of Matlock. The northern part of this region has several small colliery towns, but it retains a rural aspect with arable farms, woods and parkland. The central section, underlain by the Pennine Coal Measures Group strata, although largely rural with widespread farming, is more densely populated with numerous larger villages, many of which were formerly associated with coal mining. Much of the eastern section of the district is underlain by Lower and Middle Coal Measures formations where alternations of mudstone and sandstone give rise to a varied and undulating topography, generally between 91 and 183 m above O.D. Here coal mining and other industries share the landscape with mixed farming. In addition to the large town of Chesterfield, there are numerous minor centres of population, among which Clay Cross and Alfreton are noteworthy. The east of the district is bounded by the escarpment of the Cadeby Formation (formerly the Lower Magnesian Limestone), 152 to 183 m above OD. This is part of the Permo-Triassic sequence that forms most of a plateau-like area formed by the gently easterly dipping limestone dip-slope. The extreme south-eastern corner of the district, underlain by Triassic sandstones, is rural being mainly farmed or wooded.

The topography in the district is very varied with the highest ground in the west. Here moorland has developed on the Millstone Grit sequence that rises to a maximum elevation of about 367 m above OD at Beeley Moor [SK 3009 6816]. Ground elevations generally reduce to the east.

The only major river in the district is the south-flowing Derwent located in the west. It drains the Millstone Grit Group area and has a wide flood plane north of Matlock. At Matlock it enters a series of narrow gorges cutting through the flank of the Peak Limestone sequence and much of the Millstone Grit in the south. The Coal Measures are drained to the north by the Rother and its tributaries, notably the Hipper, Calow Brook and the Doe Lea, and to the south by the Amber, itself a tributary of the Derwent, and its tributaries, the Alfreton and Normanton brooks. On the Permo-Triassic outcrop the only rivers of note are the Poulter and Meden which flow north-eastwards, in steep-sided valleys cut into the Cadeby Formation, to join the Idle beyond the district boundary. For further information about the hydrogeology of this district, see Cheney (2007) and Jones *et al*. (2000).

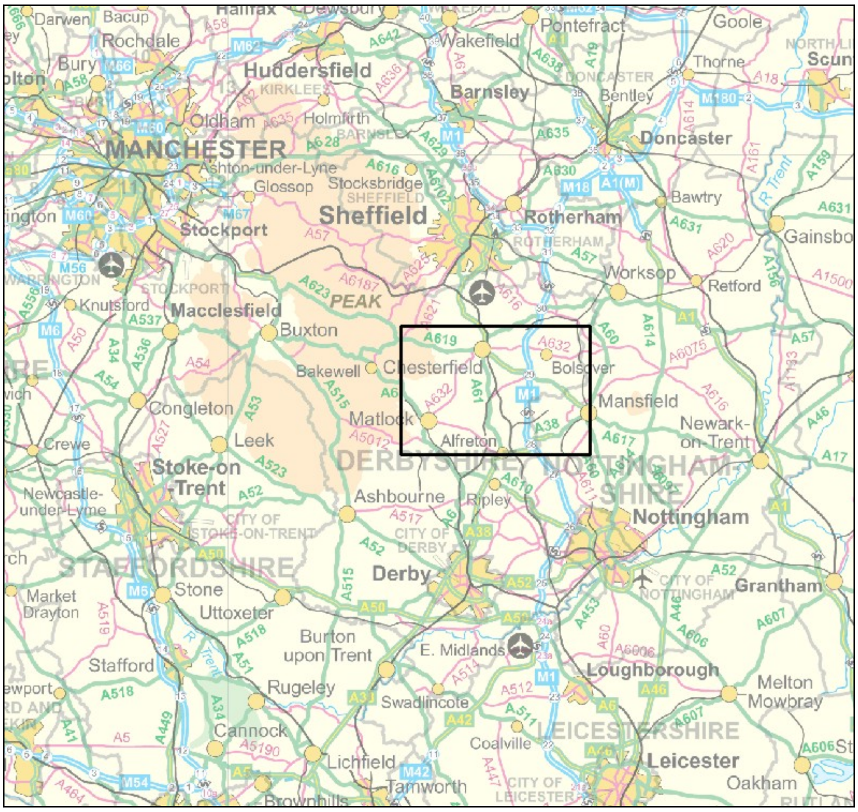


Figure 1 Chesterfield Sheet 112 location

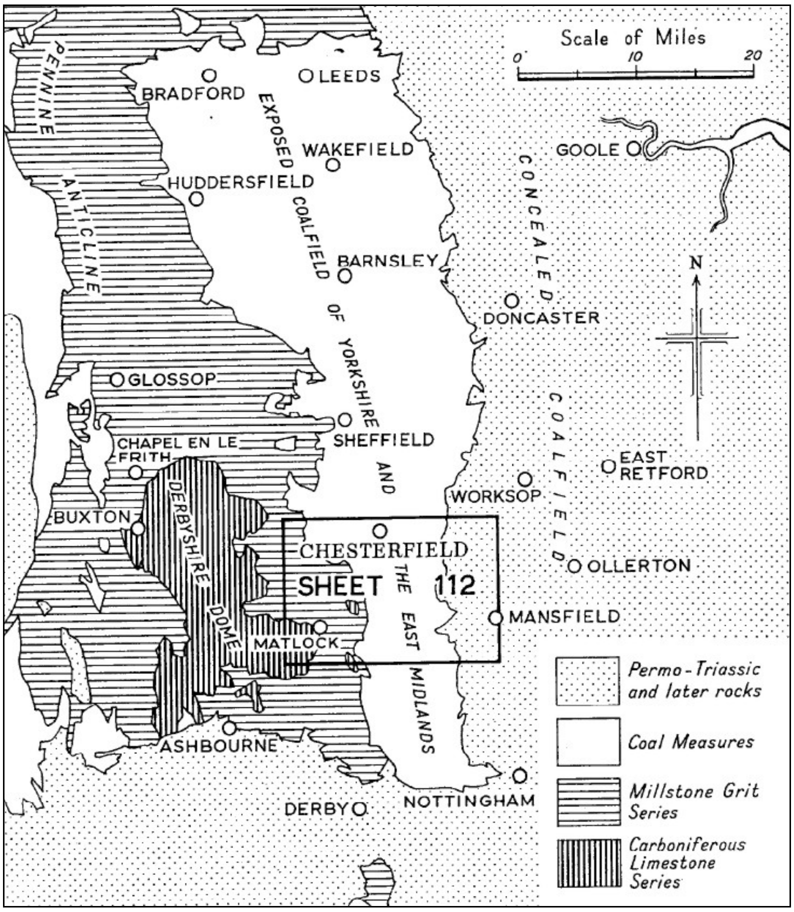


Figure 2 Sketch-map showing the general geological relations of the district (taken from Smith *et al.*, 1967)

3 Mining and quarrying

Much of the Peak Limestone Group has also been subject to intense mineralisation, giving rise to the presence of ore bodies and mineral veins, such as fluorspar, calcite, barites, galena and sphalerite of economic importance. The Chesterfield district has a long mining history based on exploitation of its lead, zinc and silver probably dating back to Roman times but reached a peak in the eighteenth century (Smith *et al.*, 1967; Cheney, 2007). Ironstones, coals and fireclays of the Coal Measures were largely responsible for the industrial development of the district in the nineteenth century. The sandstones, limestones and clay rocks of both the Carboniferous and Permo-Triassic formations have been widely used by the constructional, chemical and metallurgical industries.

Intensive quarrying activity in the area over centuries has left landscape features that could be misinterpreted as landslide deposits. Many landslides have sandstone at their backscarps, which has been quarried. The spoil was tipped down the slope below, producing a hummocky topographic relief in some areas, which could be misinterpreted as a landslide deposit. This shows the importance of consulting aerial photographs and historic Ordnance Survey maps as well as mapping in the field.

4 Geology

4.1 BEDROCK GEOLOGY

The bedrock geology of the Chesterfield district is illustrated in the simplified geological map provided in Figure 3 and Table 1 and described as follows (Smith *et al.*, 1967; Cheney, 2007):

4.1.1 Carboniferous

4.1.1.1 DINANTIAN

The main limestone outcrop is located in the south-western corner of the district, with smaller outcrops located on the southern border to the north of Crich and in the core of an anticlinal structure around Ashover.

The Peak Limestone Group (formerly 'Carboniferous Limestone' in the Peak District) consists predominantly of thinly bedded, cherty limestones with reef knolls in the uppermost part of the sequence but more massive, cherty and often porcellaneous limestone below the uppermost 60 m. The limestones in the district are capped by up to 15 m of mudstones and are interbedded with considerable thicknesses of basic volcanic strata, particularly in the Matlock area. Here two discrete basalt lava horizons (Upper and Lower Matlock Lava Formations) are present, the upper being up to 37 m thick and the lower ranging up to 45 m (exceptionally up to 115 m). In the Ashover area, brecciated lavas (often referred to locally as 'toadstone'), tuffs and basalt lavas predominate, the greatest thickness of limestone (up to 55 m thick) occurring in the upper part of the sequence.

Large parts of the limestones have been intensively dolomitised, the contact between limestone and dolomite commonly being sharp, cutting across bedding at many locations. Silicification of the limestones is also widespread.

4.1.1.2 Namurian

The Bowland Shale Formation underlies the central western area of the Chesterfield Sheet. It is composed of mainly dark grey fissile and blocky mudstone, weakly calcareous, with subordinate sequences of interbedded limestone and sandstone. It is fossiliferous in discrete bands.

The Millstone Grit Group forms a broad outcrop extending from the southern central border to the north-eastern corner of the district. It typically consists of coarsening-upward cycles of dark grey carbonaceous mudstones, grey silty mudstones and siltstones, and fine- to very coarse-grained feldspathic sandstones (formerly referred to as 'grits'). Subordinate coals and residual soil horizons typically cap the cycles in the upper part of the group (Jones *et al.*, 2000). The sandstones can range from coarse-grained and cross-bedded or massive, to fine-grained, micaceous and thinly laminated types.

In the Chesterfield district, four major named sandstone successions are present: the Ashover Grit is the oldest, followed by the Chatsworth Grit with the Redmires Flags and Rough Rock near the top of the sequence. The Kinderscout Grit, commonly positioned towards the base of the sequence in areas farther north, is not present at outcrop in the district, the lower section of the Millstone Grit below the Ashover Grit consisting predominantly of mudstones between 60 and 90 m thick.

The Millstone Grit Group produce relatively steep-sided valleys and slopes and it is this terrain that contains the highest frequency of landslides.

The Ashover Grit is the equivalent to the Roaches Grit to the west of the Pennines. In the south of the district, it consists of up to 60 m of massive medium- to coarse-grained sandstone with bands of pebbles but thins to the north, passing into finer-grained sandstone with interbedded siltstone and mudstone. In the Chesterfield district the Ashover Grit may consist of up to four laterally discontinuous sandstone 'leaves' separated by argillaceous horizons.

In the north west, in the type area around Chatsworth House, the Chatsworth Grit sequence thickness totals about 150m, consisting of two main sandstones separated by up to 60 m of mudstone with additional local sandstone beds. The lower main sandstone horizon dies out to the south of Chatsworth House although thin sandstones may constitute its equivalent further to the south. The upper sandstone persists southward, varying in thickness from 20 to 38 m (Smith *et al.*, 1967). The beds between the Ashover and Chatsworth Grits consist of between 15 and 60 m (average about 40 m) of grey to dark grey mudstones and siltstones, with sporadic ironstone bands and two coal horizons.

The Redmires Flags are thickest in the north, where they are about 14 m thick but are not laterally continuous across the district, thinning and occurring only locally to the south of Ashover where their maximum thickness is only about 3.7 m. They consist predominantly of medium- to fine-grained sandstones, although some grits are present in the north. The Redmires Flags and the Chatsworth Grit are separated by up to 26 m of predominantly mudstone strata.

The Rough Rock has a composition that varies from siltstone with sandstone bands to a hard flaggy sandstone. It is not laterally persistent within the district and does not attain a thickness greater than about 12 m. The Rough Rock is separated from the underlying Redmires Flags by strata that predominantly consist of mudstones and are between 25 and 40 m thick.

4.1.1.3 Westphalian

The central portion of the sheet is underlain by the Pennine Lower and Middle Coal Measures Formations of Carboniferous (Westphalian) age, which form the southern limb of the East Pennine Coalfield.

The Pennine Coal Measures Group comprises grey mudstones and siltstones, with alternations of pale grey sandstone, the latter are typically well cemented, fine-grained and often ochreous when weathered; they occur together with frequent coal seams, palaeosol horizons and ironstones (Jones *et al.*, 2000). These strata were deposited in a cyclic manner, which when fully developed comprise a basal dark grey marine mudstone passing up to grey mudstone that becomes increasingly silty, succeeded by siltstone or sandstone, seatearth and coal. One or more phases may be absent, but seatearth and grey mudstone are usually present (Smith *et al.*, 1967). Sandstones are rarely present in many cycles, but occasionally are more persistent. The development of sandstone horizons are very variable, most having a flattened lensoid shape, commonly passing laterally as well as vertically into siltstones and mudstones, or wedging out. There are, however, some individual sandstone beds that are laterally extensive (>100 km^2) and can exceed 20 m in thickness, such as the Wingfield Flags and Crawshaw Sandstone.

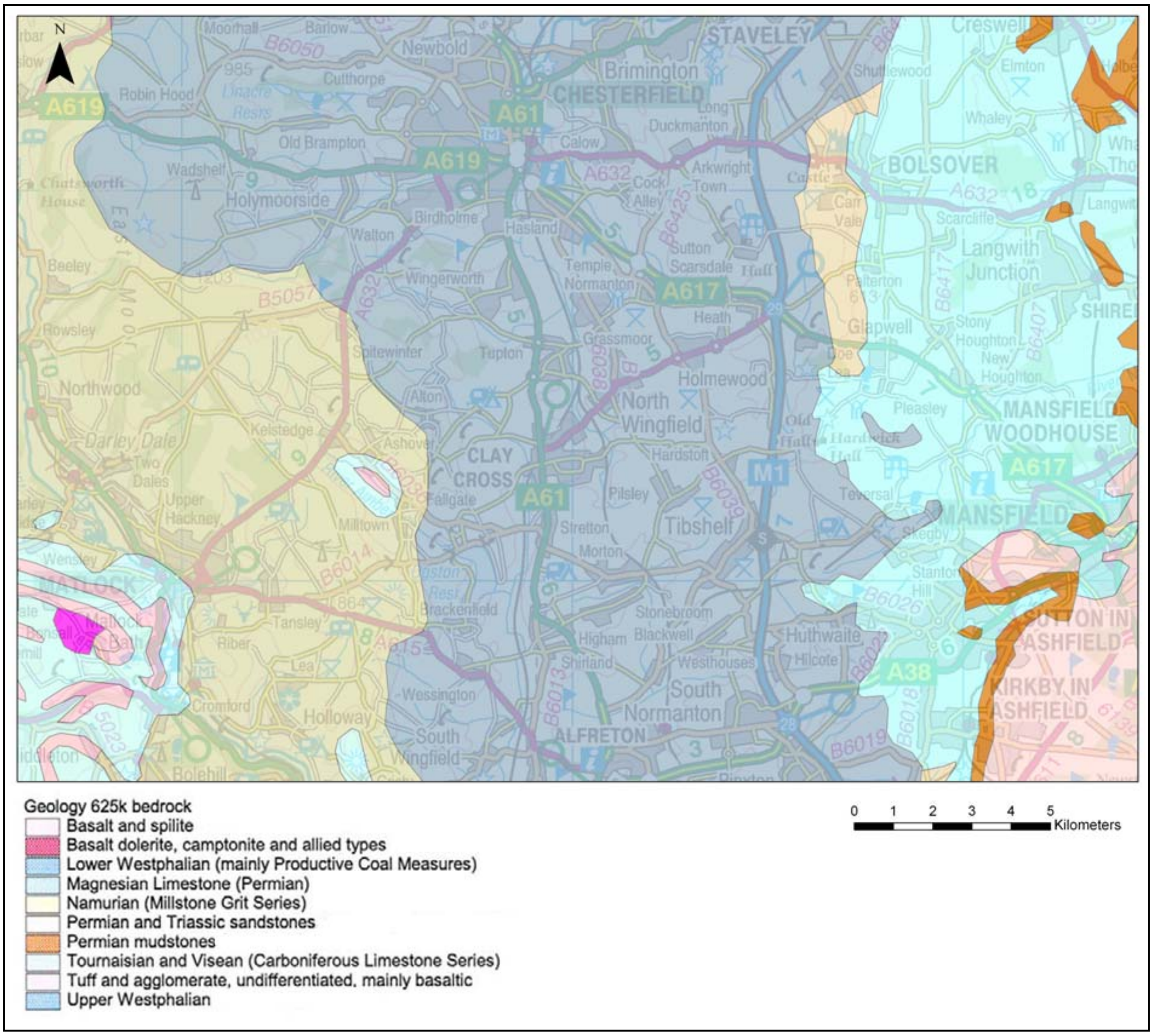


Figure 3 Simplified geology (bedrock) map of the Chesterfield District, Matlock and Mansfield district (extract from 3rd Ed. Solid 1:625 000 scale Geological Map of the United Kingdom [south] 1979)

In contrast to the numerous named coal seams, only those sandstones that are particularly thick and/or laterally persistent tend to be individually named. Several significant sandstone horizons occur in the lower section of the Pennine Lower Coal Measures in the Chesterfield District, namely the Crawshaw Sandstone (up to 55 m thick) close to the base; a sandstone immediately below the Forty-Yards Coal (the local equivalent to the Loxley Edge Rock of the Sheffield district); and the Wingfield Flags (up to 75 m thick). Sandstones are relatively common throughout the Pennine Lower Coal Measures above the Wingfield Flags but are normally thin

Table 1 . Simplified stratigraphy of the Chesterfield, Matlock and Mansfield district (taken from Cheney, 2007)

Group	Formation	Former Name	Lithology	Thickness (m)
	Hill peat; alluvium; river terrace deposits; solifluction and glaciofluvial deposits, till. (Holocene & Pleistocene age)		Peat, clay, silt, sand, gravel	largely absent; up to c. 5 m
Permo-Trias				
Sherwood Sandstone	Nottingham Castle Sandstone	Bunter Pebble Beds	Sandstone with pebbles	up to 30 m
	Lenton Sandstone	Lower Mottled Sandstone	Fine-grained sandstone	up to 30 m
Zechstein	Edlington	Middle Permian Marl	Mudstone and siltstone	0 to 36.5 m (Note 1)
	Cadeby	Lower Magnesian Limestone	Dolomitic limestone	9 to 45 m (Note 2)
		Lower Permian Marl	Mudstone with carbonate beds	17 to 33 m (Note 3)
Carboniferous				
Pennine Coal Measures	Pennine Middle Coal Measures	Middle Coal Measures	Cyclic packages of mudstone, siltstone, sandstone, seatearth and coals.	c.533 m
	Pennine Lower Coal Measures	Lower Coal Measures		c.550 m
Millstone Grit		Millstone Grit	Mudstones with thick, massive to cross-bedded sandstones and grits.	c. 1075 m
Craven	Bowland Shale	Edale Shale	Dark grey mudstones, weakly calcareous, with sequences of interbedded limestone and sandstone.	120-620 m
Peak Limestone		Carboniferous Limestone	Massive limestones, bedded limestones with mudstone and basic volcanic rocks	>250 m

Note 1: Edlington Formation – attains a maximum thickness of 36.6 m near the north east corner of the area but thins southward and although absent in the vicinity of Mansfield Woodhouse, is up to 12 m thick to the south of Mansfield.
Note 2: Cadeby Formation - attains a maximum thickness of about 46 m in the north, thinning fairly regularly southward to between 6 and 12 m in the south.
Note 3: 'Lower Permian Marl' – generally 24 to 27 m thick, with thinnest known section of 17.2 m at Sutton Colliery and thickest (33.6m) at Cross Hills borehole; up to 36.6 m may be present in Langwith Colliery shaft and Top Farm borehole

and of only local development; thicker sandstones of wider lateral extent are found above the Tupton and Deep Hard Coals (Smith *et al.*, 1967).

In common with the underlying Millstone Grit Group rocks, the Pennine Coal Measures Group strata are strongly dislocated by faults, which dominantly trend to the north-northwest with a subsidiary north-easterly trending system. The strata have also been gently folded about north-west/south-east trending axes (Smith *et al.*, 1967). These produce a relatively undulating landscape, with locally over-steepened valley sides where mudstones crop out between stronger sandstone beds.

4.1.2 Permian and Triassic

The eastern part of the Chesterfield sheet is underlain by a mixed Permian sequence of sandstone, calcareous mudstone and dolomite. The Permian strata unconformably overlie the Pennine Coal Measures Group, occupying an area that is over 6 km wide in the north-east of the district, narrowing southward to as little as 1 km wide in the south. At the base there is the Yellow Sands Formation overlain by the mudstones and dolomites of the Cadeby Formation. These in turn are overlain by the sandstones of the Lenton Sandstone Formation and the Triassic Nottingham Castle Formation both of the Sherwood Sandstone Group (Table 1). These form the relatively low relief of the residential and industrial areas in the east of the sheet where landslide frequency is low.

The Yellow Sands Formation (formerly called the Basal Permian Sands) consists of sandstone only to the north of a line approximately between Bolsover and Shirebrook; it is replaced by breccia to the south (Smith *et al.*, 1967). The sands vary from a quartzose to a marly sand; they are grey when fresh (in boreholes), but weather to an orange-brown or yellow colour. They are very variable in thickness, with up to about 3.6 m recorded at Shirebrook but as little as 2.5 cm in the Bolsover Moor borehole, and absent at other locations. This thickness variation is due to their depositional mode as low sand dunes. The sands only occur at outcrop in the vicinity of Oxcroft in the extreme north of the district. The thickness of the breccias is also highly variable; between 3.5 m and 4 cm have been recorded and they are absent in places (Smith *et al.*, 1967).

The Yellow Sands Formation are overlain by strata formerly known as the Lower Permian Marl, which are now incorporated into the lower part of the Cadeby Formation. They consist of calcareous mudstone with carbonate beds, and are generally pale grey when unweathered. These beds are between 24 and 27 m thick but range from a recorded minimum of about 17 m at Sutton Colliery [SK 483 602] to over 33 m at Cross Hills borehole [SK 5086 6947]. This horizon acts as an aquitard below the overlying water-bearing Cadeby Formation.

The Cadeby Formation (formerly known as the Lower Magnesian Limestone), consists largely of bedded dolomitic limestones. Thickness of the formation varies from about 46 m in the north of the district to between 6 and 12 m in the south, although even here an exceptional 43 m was recorded at Sherwood Colliery (Smith *et al.*, 1967). The upper part of the Cadeby Formation consists predominantly of yellow, buff or occasionally pink dolomitic limestone and forms virtually the entire outcrop. The basal part of this upper division commonly consists of a more sandy type of limestone (the Mansfield Sandstone), which can be up to 15 m thick. The lower section consists of close-grained limestones with beds of ooidal limestones, particularly in the north of the district.

The Permian strata are relatively little disturbed by faulting or folding, in comparison with the underlying Pennine Coal Measures Group strata. They have a gentle regional dip to the east-south-east. Fault trends are predominantly from northwest to southeast, commonly with small downthrows to the northeast.

The Sherwood Sandstone, consisting of the Nottingham Castle Sandstone and the Lenton Sandstone formations, only occurs in the south-eastern corner of the district. The Nottingham Castle Sandstone Formation (formerly known as the Bunter Pebble Beds) consists predominantly of a brown and pink, coarse pebbly sandstone whilst the Lenton Sandstone Formation (formerly the Lower Mottled Sandstone) consists of a red to red-brown, fine-grained sandstone. A maximum of up to 60 m of Sherwood Sandstone Group strata is likely to be present in the district, with each of the two formations being up to 30 m thick.

4.2 SUPERFICIAL GEOLOGY

The distribution of superficial deposits in the Chesterfield District is shown in Figure 4. The following is summarised from Smith *et al*. (1967):

Glacial deposits are not widespread. Patches of till are found on the high Millstone Grit and Carboniferous Limestone ground in the west, and also on the outcrop of the Permo-Triassic rocks in the south-east where they are associated with glacial sand and gravel. In addition there is, almost everywhere over the Permo-Triassic outcrop, a scattering of erratic pebbles in the soil.

Head is widespread but most conspicuous in the west where it mantles the slopes beneath the scarps of the thick sandstones, on the margins of which landslips are common. Terrace deposits are insignificant and, apart from a remnant two to three feet above the present alluvial plain of the River Poulter at Nether Langwith and a similar one at Shirebrook, are associated only with the River Derwent. Recent alluvium occupies the flood-plains of the rivers and brooks, notably of the Derwent, Rother, Doe Lea and Amber. Peat is found on the high moors of the west but, outside Leash Fen, is not extensive.

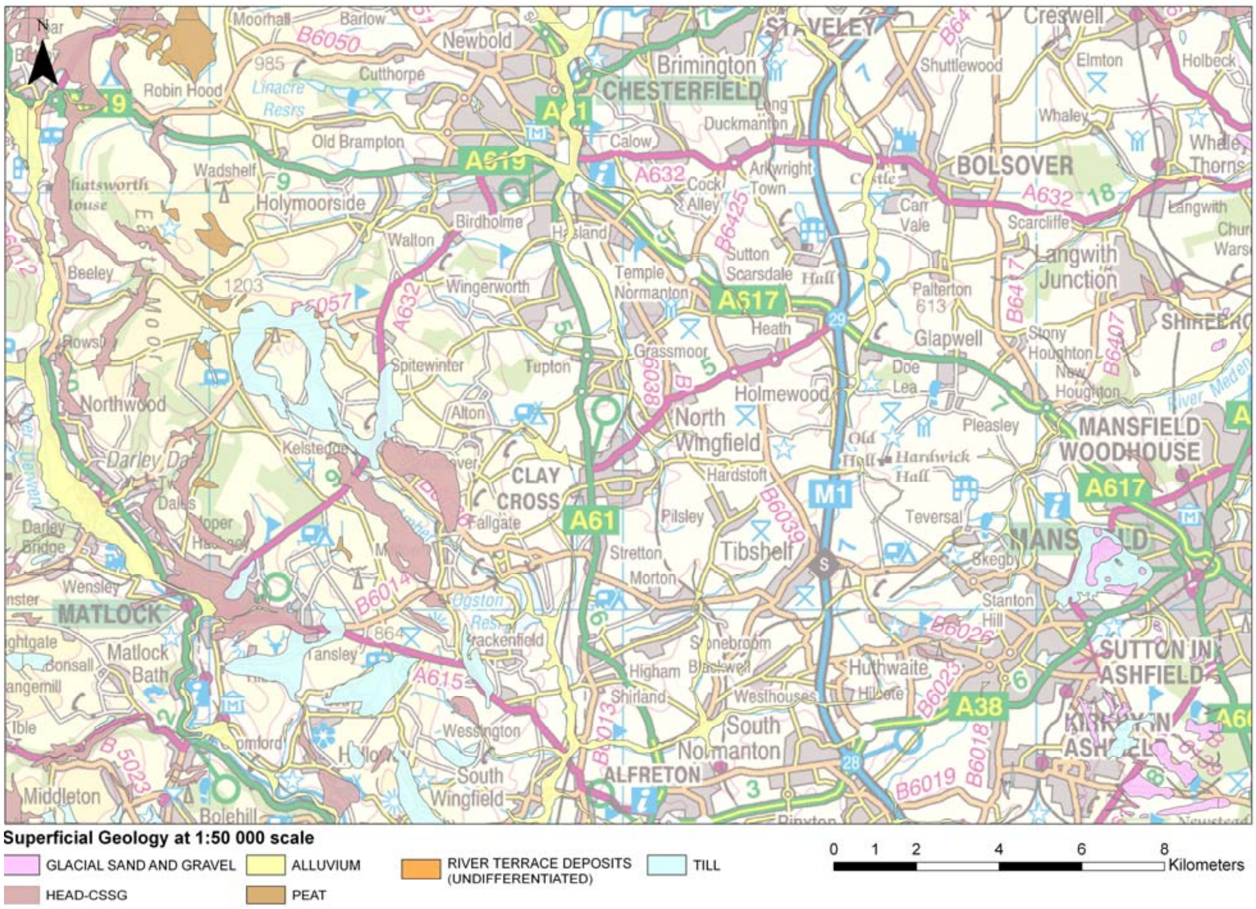


Figure 4 Simplified superficial geological map

5 Landslide Distribution

The Varnes (1978) landslide classification was used to classify landslides during the remapping of the Chesterfield sheet (Appendix 1). There were 94 landslides recorded in the National Landslide Database, of which 41 had an associated mapped mass movement polygon from both DigMap50 and the more recent phase of mapping. 136 landslide polygons were mapped by the most recent phase of mapping, however, 25 of these were subsequently deleted and 13 have been modified as a result of new evidence obtained from aerial photograph interpretation and field observations. In addition two further landslides were mapped in the Chesterfield sheet area. The final landslide map (Figure 5) has 111 landslides, all of which have been entered into, or had their existing records updated in, the National Landslide Database.

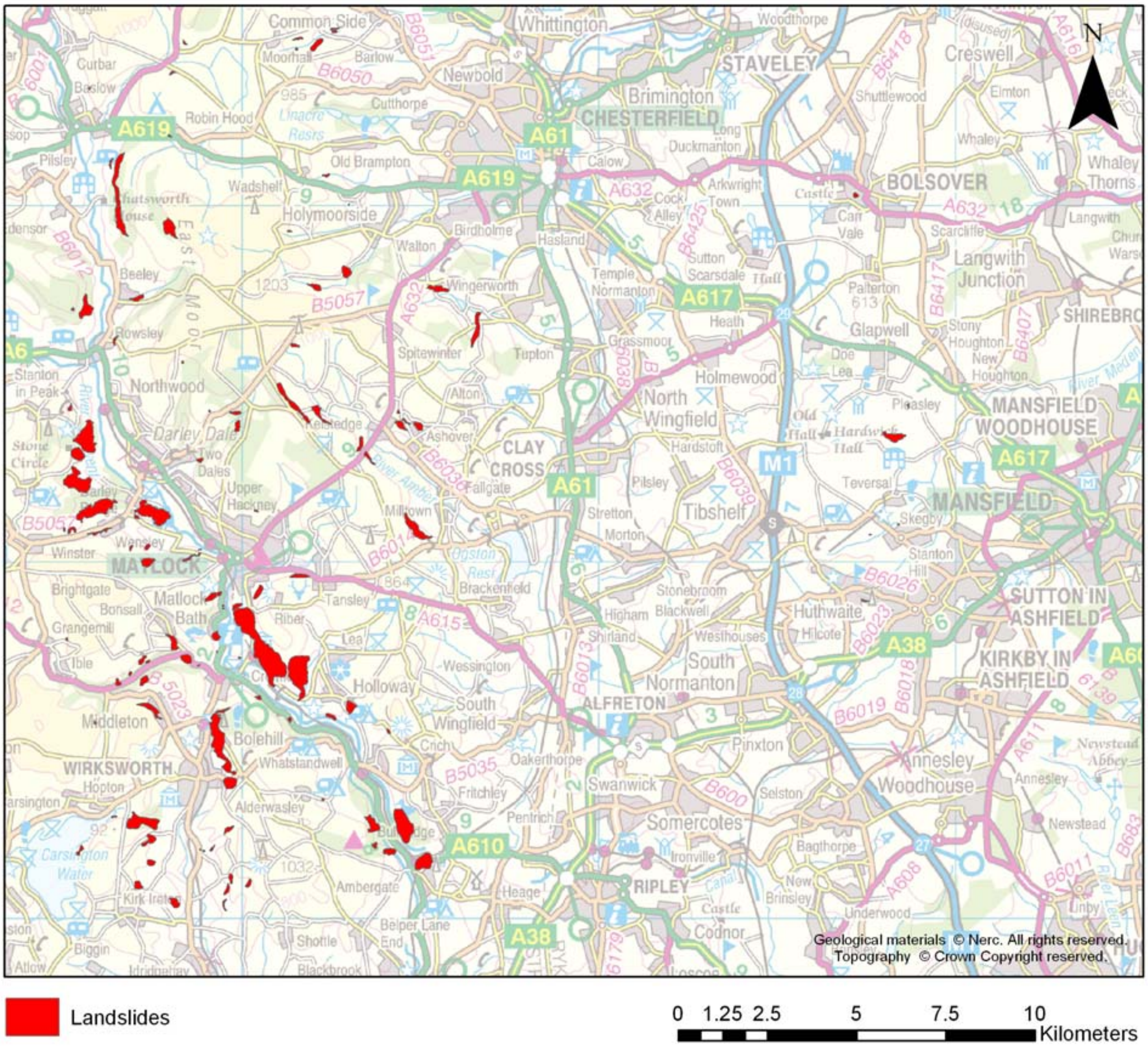


Figure 5 Distribution of landslides on the Chesterfield sheet

The majority of landslides occur where Chatsworth or Ashover Grit overlie the Millstone Grit Group mudstones or Bowland Shale (Figure 11). Surprisingly, the Pennine Coal Measures Formations only account for eleven landslides. Coal Measures are associated with widespread landsliding in South Wales (Forster and Jenkins, 2005), however the corresponding topography formed in Derbyshire is considerably more subdued than the glaciated valleys associated with the Coal Measures in South Wales. The 1967 geological memoir (Smith *et al.*) described some landslides in detail:

"The landslip in the Cat Hole valley, south-west of Holymoorside, consists of a series of humps below a marked scar in the Crawshaw Sandstone. The largest of these humps, nearest the scar, has recently been quarried. There are reports that the road crossing this slip has moved within living memory and the area is significantly called 'Falling Bank'.

The landslip which comprises the greater part of Oaker Hill, north-west of Matlock, resulted from the slipping of an outlier of Ashover Grit which has nearly disappeared, the only part left in situ being a small area of sandstone along the crest of the hill.

Between the River Derwent and the road from Lea Bridge to Lea there are two landslips, each about a third of a square mile in area, one on either side of a narrow north-south ridge of Ashover Grit. The ridge is all that remains of a more extensive outcrop of the Grit, parts of which have slipped down into the valleys. Small quarries exist in the slipped rock".

6 Landslide Analysis

6.1 GEOLOGY AND LANDSLIDE FREQUENCY

Landslides are most common on slopes in the Derwent Valley where the geology is either horizontal or dips towards the river. When comparing the underlying bedrock geology to landslide distribution, there is a strong correlation between landsliding and the presence of Namurian sedimentary rocks (Figure 6). These are mainly of the Bowland Shale Formation and Millstone Grit Group especially where sandstones of the Ashover and Chatsworth Grits are present.

The areas with Namurian mudstones, siltstones and sandstones account for 69% of the landslides in the Chesterfield area; 18% are associated with Dinantian limestones; 11% occur in Westphalian Pennine Lower and Middle Coal Measures formations. The remaining 2% of landslides are underlain by the Permian Cadeby Formation.

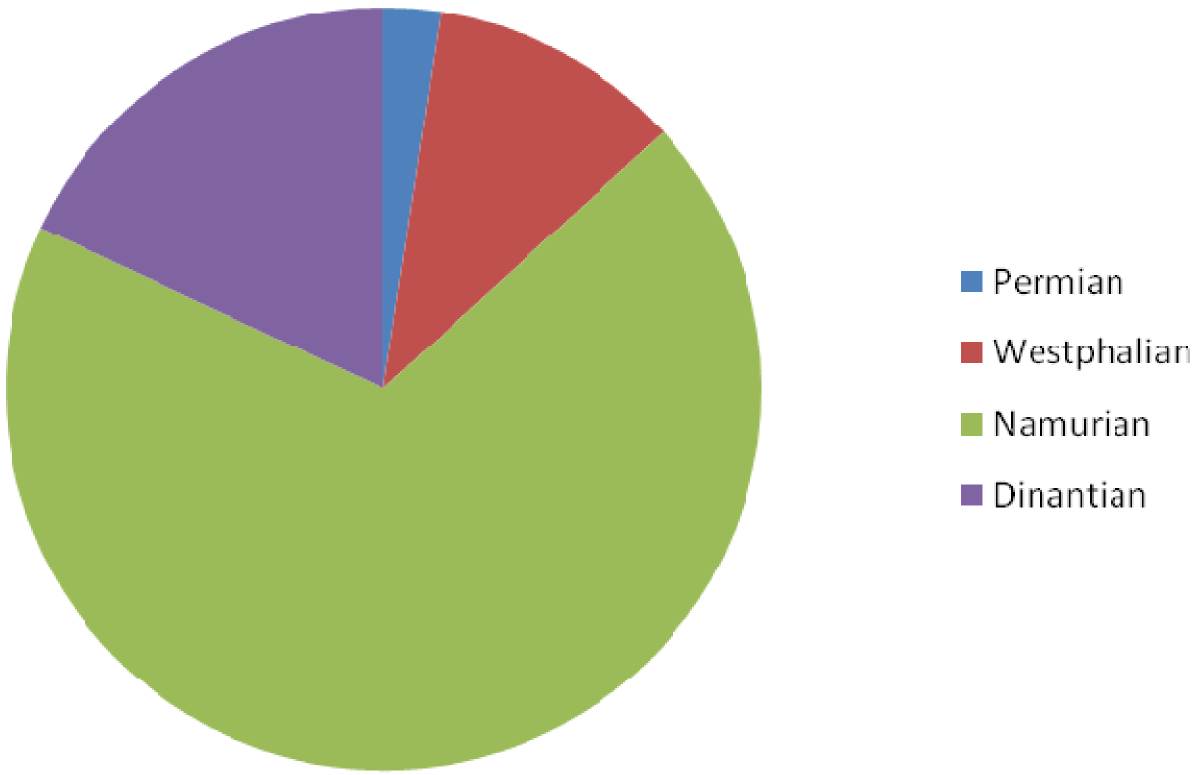


Figure 6 Frequency of 111 landslides related to bedrock stratigraphy

Dimensionally, landslides within Namurian strata range from 1 250 000 m^2 to 2 000 m^2 and typically form the largest landslides in the region. Landslides observed within the Dinantian strata range from 300 000 m^2 to 1 400 m^2. Landslides occurring within Westphalian strata range from 150 000 m2 to 600 m^2. Landslides affecting Permian rocks range from 1 400 m^2 to 1 000 m^2. The landslides in the Namurian strata account for the majority of slope instability in the Chesterfield area, the same is true for the neighbouring Derby Sheet (Jenkins and Booth, 2008).

6.2 STYLE AND MECHANISM OF LANDSLIDING

With only a few exceptions, the dominant style of landsliding observed was rotational failure. Most commonly, these were multiple in nature, degrading into flows towards the base. Landslide features seen in the field varied from small-scale lobe features (similar to solifluction or head deposits) to large areas of rotated blocks.

A common causal element of multiple rotational landslides in the Chesterfield area is lithological variation of the Namurian stratigraphy. These slopes are composed of competent and porous sandstone beds overlying less competent siltstones and mudstones with relatively low bedding dip; Figure 7 is an example of this. This stratigraphic relationship (where a more competent porous lithology overlies a less competent lithology) also applies to multiple rotational landslides that occur in the Cadeby Formation where dolostone overlies mudstone (Permian), and the Pennine Lower and Middle Coal Measures Formations (Westphalian). Flows were observed towards the base of the larger multiple rotations where they formed secondary failures distal from the sources of overlying, more competent sandstone/limestone beds.

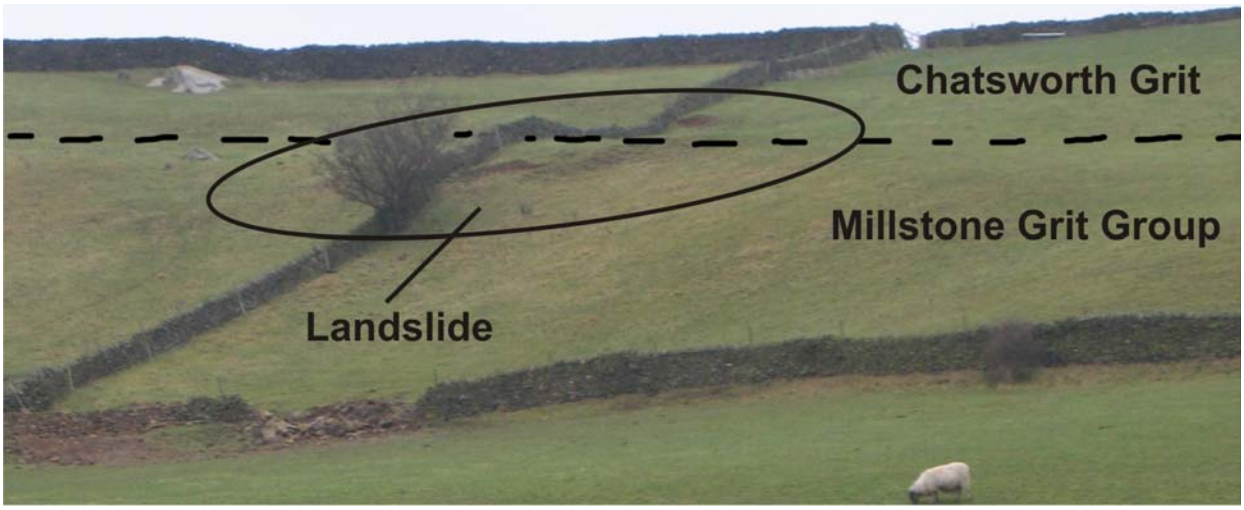


Figure 7 Small degraded rotational landslide at SK257733 observed in the Namurian geology. Stone wall highlights the morphology.

The landslides that occur in the Peak Limestone Group (Dinantian) are, in most cases, due to oversteepening of valley slopes on the down-dip side of the soft (usually clay) beds in the limestone sequence. The Matlock Upper and Lower lavas provide such horizons, since the top and bottom 0.6 metre or so are invariably altered to soft clay. The overlying limestone has slipped over these beds in several places, particularly in the Derwent Valley south of Matlock and in the Via Gellia Valley (Smith *et al.*, 1967).

Large-scale multiple rotational landslide complexes are present in the area around Matlock. The combination of thick sandstone and mudstone lithologies and the effect of river incision have created conditions that are favourable for large-scale failures. The landslides around Starkholmes (Figure 8) form a large, deep-seated complex of failures. The landslide is predominantly a multiple rotational landslide with more minor translational and mudflow elements. The landslide is positioned above the Matlock railway station and has many houses located on its main body along with a road. The landslide complex is within the Bowland Shale Formation, a particularly slide-prone formation in the Chesterfield sheet and surrounding area. In Figure 8, it is possible to see the 50 m high landslide scar in the Ashover Grit above the village; rotated blocks are also visible picked out by the lines of trees and houses.

Figure 8 Rotational landslide blocks at Starkholmes (SK299582).

Further south of Matlock, two large landslides have occurred at Coumbs Wood and Wood End. Both landslides are large scale deep-seated rotational failures, probably triggered during the Pleistocene.They have formed within the Bowland Shale Formation with the backscarps visible in the Ashover Grit. The larger of the two slides, Wood End House, is over 800 m in width and approximately 650 m in length. Large blocks are visible in the Wood End House landslide, although no evidence of recent movement is apparent as the slopes and landslide features are smoothed and vegetated (Figure 9).

Figure 9 Degraded landslide features at Wood End, Cromford (SK308570).

Not all of the landslides recorded within the Chesterfield area are large and deep-seated. A number of more minor shallow slides were observed. These failures are likely to involve the superficial material present on a slope as well as any weathered material. The failure plane is likely to be the contact between bedrock and superficial material; slope angle is likely to be a limiting factor in these types of slides. The slide observed near Station Quarry involved a translational movement of material that grades into a flow (Figure 10). The landslide has formed over the Eyam Limestone Formation, although it is likely that there are some slope deposits involved along with the weathered bedrock.

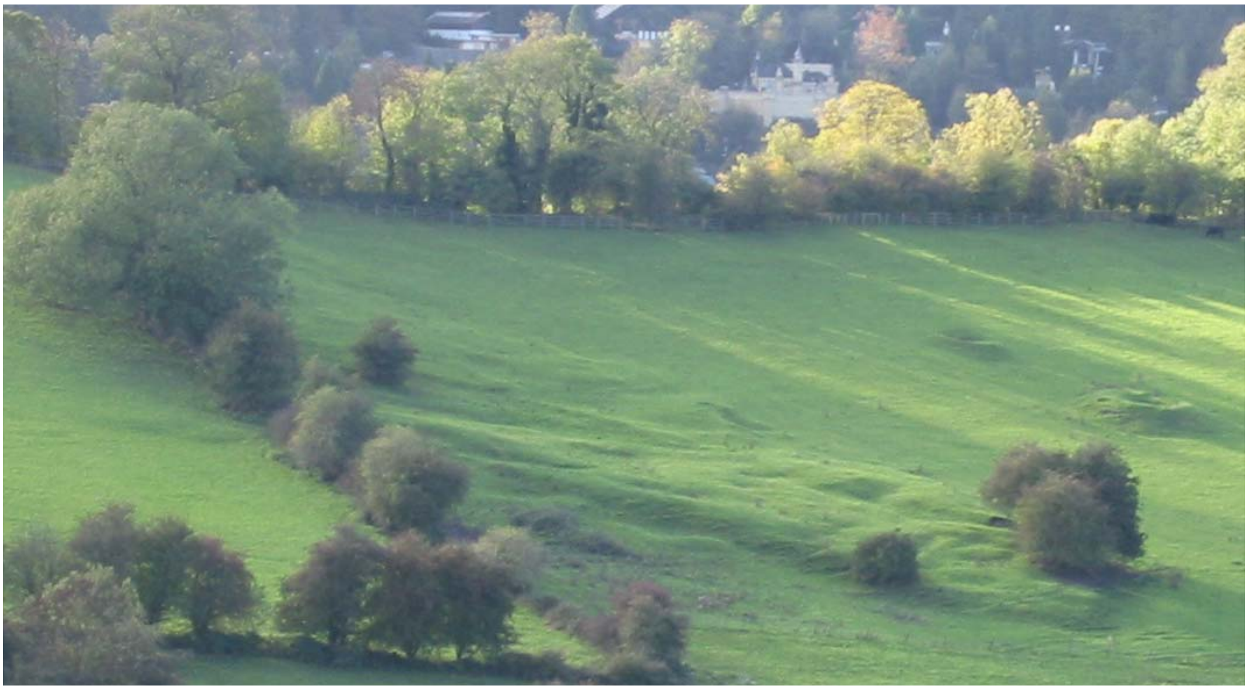


Figure 10 Shallow landslide near Station Quarry, Matlock (SK 297580).

6.3 LANDSLIDE AGE AND ACTIVITY

Landslides in the Chesterfield area are predominantly greater than 1 000 years in age (probably Pleistocene - Smith *et al.*, 1967) and stationary as far as can be ascertained from the fieldwork and aerial photograph interpretation. The landslides are thought to have been formed concurrently with, or subsequent to, the formation of Head, though in some cases movement has continued into Recent times (Smith *et al.*, 1967).

Geomorphologically the majority are degraded with features often quite subtle in the field, and very subtle when viewed in aerial photographs. Very few landslides featured clearly definable backscarps and many are associated with the sandstone quarrying. Some disturbance due to quarrying which has caused further slipping is reported by Smith *et al.* (1967). They report one example above Hoptonwoodstone Quarry, Middleton, where cracks several feet wide (about 0.6 m) appeared in previously foundered limestones of the Matlock Group; the latter were observerd creeping down-dip over the Matlock Lower Lava which crops out round the top edge of the quarry.

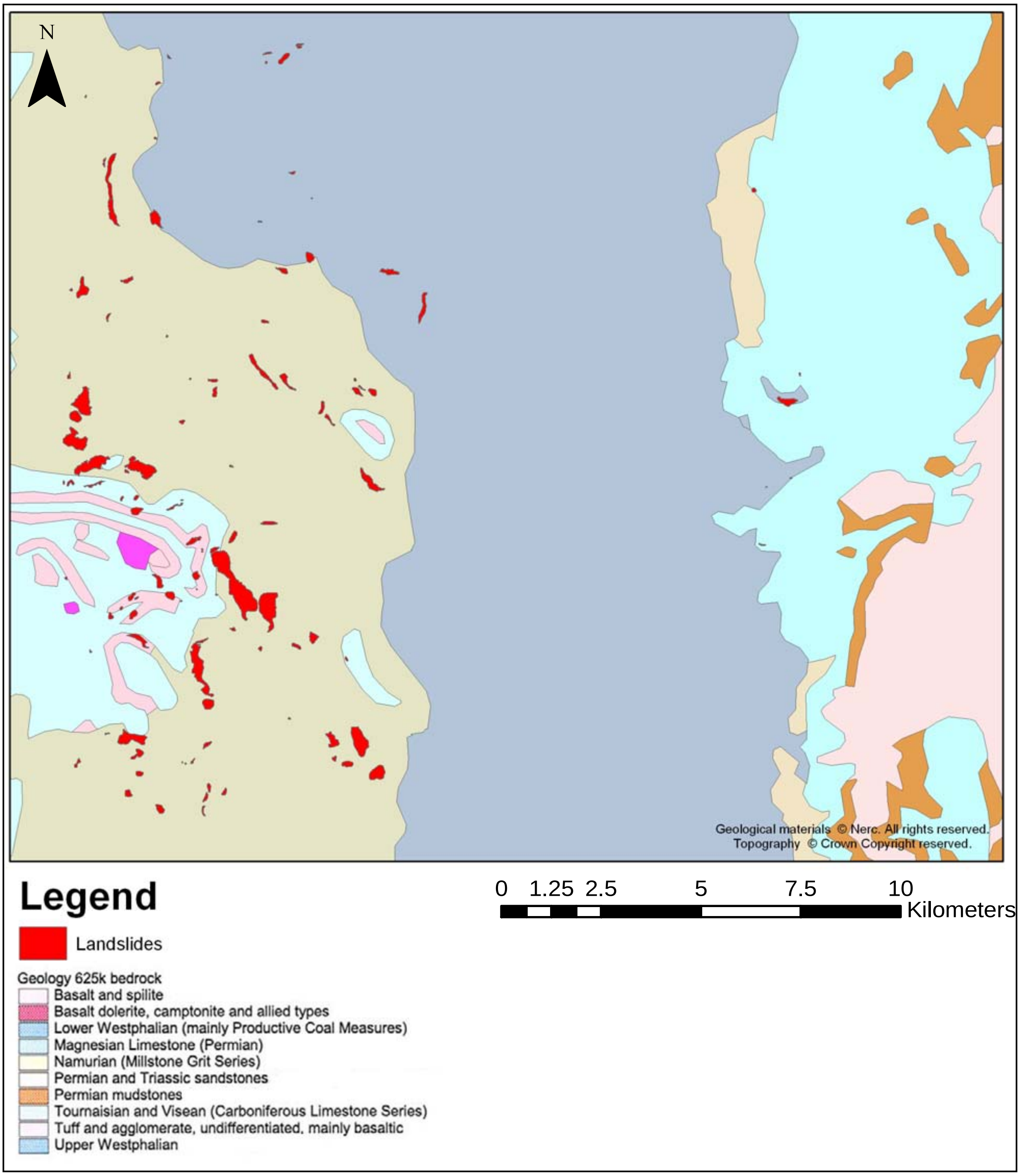


Figure 11 Distribution of landslides with respect to bedrock geology

6.4 LANDSLIDING AND SLOPE ASPECT

Landsliding within the Chesterfield district is most common on west, south-west, or north-east facing slopes (Figure 12). Of the landslides surveyed, 21 had formed on west-facing slopes, 20 on south-west-facing slopes 18 on north-east-facing slopes. 14 landslides were observed on north-facing slopes, 14 on north-west and 13 on east-facing slopes. Slopes with aspects between south and south-east accounted for the remaining 11 landslides, with only four landslides occurring on south-east-facing slopes.

Many of the north-east and south-west facing landslides occur on either side of a south-east/north-west trending river or stream where the river has eroded the geology causing failure on banks on both sides. It is possible that south, south-east and south-west (discounting river cuttings) facing slopes may be subject to warmer and therefore drier conditions, resulting in fewer landslides. West facing slopes may receive more rainfall. North facing slopes may have been affected by a longer duration of freeze-thaw during the last glaciation.

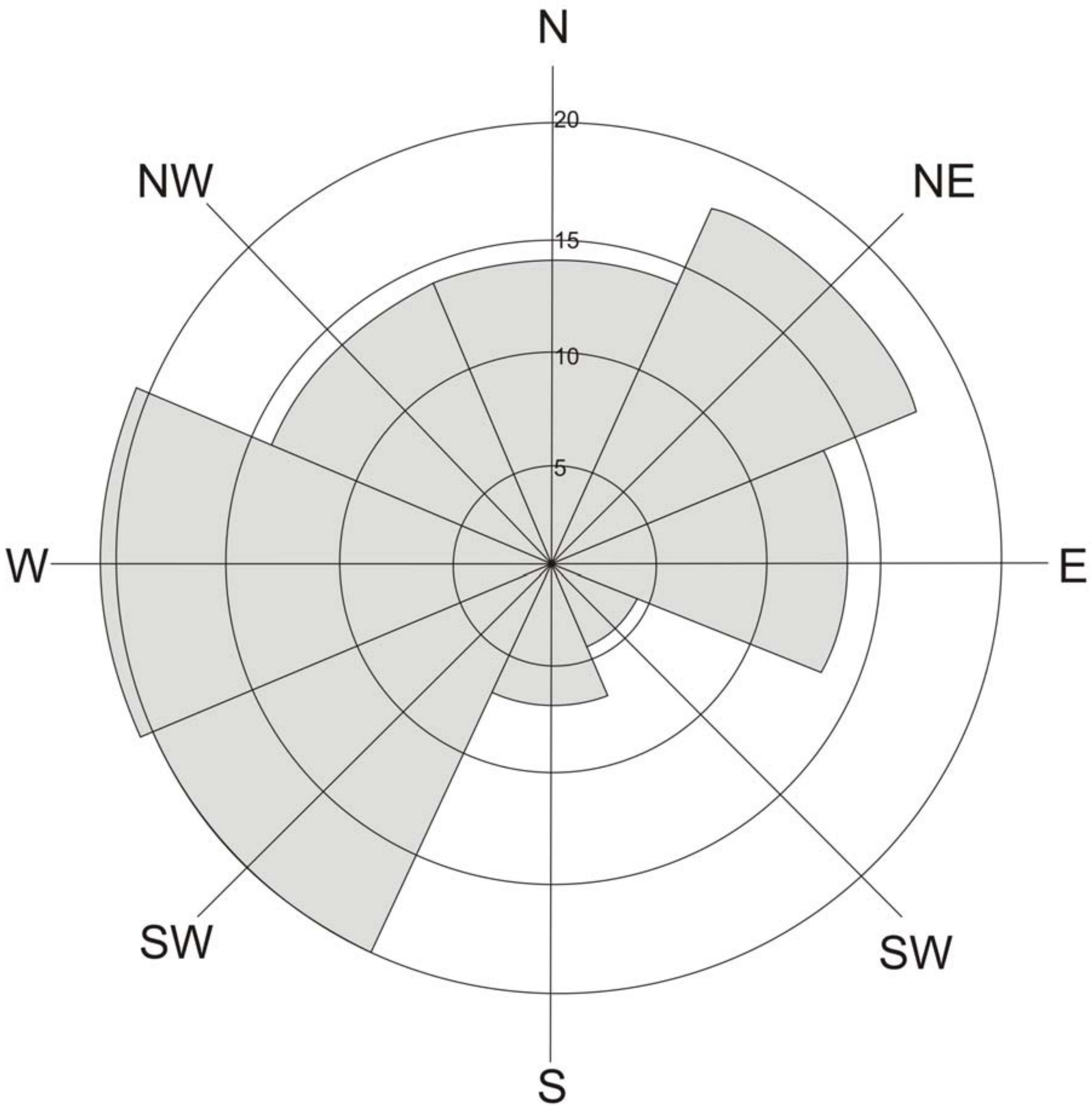


Figure 12 Rose diagram to show distribution of the 111 landslides according to slope aspect

7 Conclusions

Within the Chesterfield 1:50 000 map sheet area multiple rotations, with flows towards the base, have been observed to be the dominant landslide style. There are numerous landslides in the west of the district on slopes in the Derwent Valley in areas of high relief where the geology is either horizontal or dips towards the river. The Namurian Bowland Shale Formation and Millstone Grit Group account for the majority (69%) of landslides. Surprisingly only 11% of the recorded landslides were underlain by Coal Measures, a sequence that is closely related to high landslide frequencies in other areas such as South Wales. In terms of aspect, landslides are most frequent on west and south-west-facing slopes. The landslides that occur in the Peak Limestone Group (Dinantian) are, in most cases, due to oversteepening of valley slopes on the down-dip side of the softer beds usually clay beds in the limestone sequence.

Landslides in the region are very degraded which is a good indication of their antiquity. The main period of landslide activity was probably during the Pleistocene when periglacial climatic conditions prevailed. The landslides are thought to have been formed concurrently with, or subsequent to, the formation of Head, though in some cases movement has continued into Recent times.

As a result of this study and recent mapping survey, 58 new landslides have been added to DigMap50, 46 new records have been added to the National Landslide Database, and 15 existing DigMap50 landslide polygons have been updated.

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

Cheney, C.S., 2007, The hydrogeology of the Chesterfield, Matlock and Mansfield district (Geological Map Sheet 112), British Geological Survey,

Forster, A., and Jenkins, G.O., 2005, The assessment of landslide hazard potential as a guide to land use and planning in the South Wales Coalfield, *in* Bassett, M.G., Deisler, V.K., and Nichol, D., eds., Urban Geology in Wales: 2, Volume 24: Cardiff, National Museum of Wales Geological Series p. 81-87.

Jenkins, G.O., and Booth, K.A., 2008, Landslide nature and distribution on the Derby 1:50k geological sheet, British Geological Survey Internal Report, OR/08/032.

Jones, H., Morris, B., Cheney, C., Brewerton, L., Merrin, P., Lewis, M., MacDonald, A., Coleby, L., Talbot, J., McKenzie, A., Bird, M., Cunningham, J., and Robinson, V., 2000, The physical properties of minor aquifers in England and Wales, British Geological Survey, Keyworth, Nottingham, UK,

Smith, E.G., Ryhs, G.H., and Eden, R.A., 1967, Geology of the Country around Chesterfield, Matlock and Mansfield (explanation of one-inch geological sheet 112, new series) Natural Environment Research Council, Institute of Geological Sciences incorporating the Geological Survey of Great Britain, the Museum of Practical Geology and Overseas Geological Surveys, London.

Varnes, D., 1978, Slope movement types and processes, Special report 176: Landslides: Analysis and Control: Washington DC, Transportation Research Board.

Appendix 1

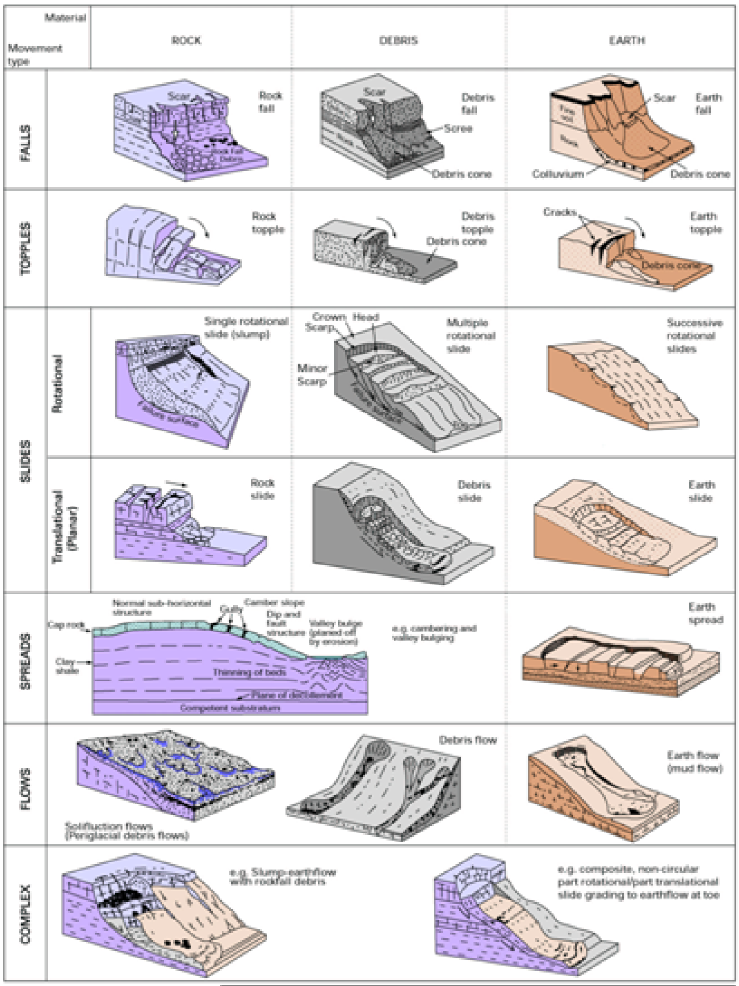
CLASSIFICATION OF LANDSLIDES

The classification of landslides by the BGS follows the scheme based on Varnes (1978) and Cruden & Varnes(1996). The scheme terminology is also that suggested by the Unesco Working Party on the 'World Landslide Inventory' (WP/WLI 1990, 1993)

The main classification criteria are:

- type of movement (falls, topples, slides spreads, flows), and
- type of material involved in the movement (rock, debris, earth)

Combining *movement* and *material type* terms enables an appropriately descriptive landslide name to be formulated. Naming can become more detailed with the addition of other descriptive details related to activity state, water content, rate of movement, etc., if known (e.g. *active, complex, extremely rapid, dry rock fall-debris flow*).



Falls: masses are detached from steep slope/cliff along surfaces with little or no shear displacement (e.g. joints/fissures) and descend mostly through air by free fall, bouncing or rolling.

Topples: movements of rock, debris or earth masses by forward rotation about a pivot point.

Rotational slides (slumps): masses slide outwards and downwards on one or more concave-upward failure surfaces that impart a backward tilt to the slipping mass, which sinks at the rear and heaves at the toe.

Translational (planar) slides: movements occur along planar failure surfaces that may run more-or less parallel to the slope.

Spreads: involve the fracturing and lateral extension of coherent rock or soil masses due to plastic flow or liquefaction of subjacent material.

Flows: slow to rapid movements of saturated or dry materials which advance by flowing like a viscous fluid, usually following an initial sliding movement. Some flows may be bounded by basal and marginal shear surfaces but dominant movement of the displaced material is by flowage.

Complex slides: involve a type of movement style that combines two or more of the main movement types (fall, topple, slide, spread, flow) occurring in sequence. Complexity may be indicated by combining the main movement terms, e.g. *complex rotational earth slide-earth flow (or complex slump-earth flow).*

Only a small selection of the wide spectrum of landslide types that may develop in nature are shown here

Varnes, DJ. 1978. Slope movement types and processes. In *Special report 176: Landslides: Analysis and Control*, Transportation Research Board, Washington, D.C.

Cruden, DM & Varnes, DJ. 1996. Landslide types and processes. In *Special Report 247: Landslides: Investigation and Mitigation*, Transportation Research Board, Washington D.C..

WP/WLI. 1990. A suggested method for reporting a landslide. *Bulletin of the International Association of Engineering Geology*, No. 41.

WP/WLI. 1993. A suggested method for describing the activity of a landslide. *Bulletin of the International Association of Engineering Geology*, No. 47.