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Landslide nature and distribution on the Derby 1:50k geological sheet

Land Use and Development Programme

Internal Report OR/08/032

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Landslide nature and distribution on the Derby 1:50k geological sheet

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Keywords

Landslides, Derby, Namurian, Wesphalian, Triassic, Bowland Shale Formation.

National Grid Reference

SW corner 425260,335600
Centre point 439710,345500
NE corner 454400,354627

Map

Sheet 125, 1:50 000 scale, Derby

Front cover

Shallow multiple rotations in the upper part of the Mill House landslide, Derbyshire.

Bibliographical reference

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Foreword

This report is the published product of the British Geological Survey's Land Use and Development Programme's Landslide Hazards and Research Project, part of the Shallow Geohazards team. The report describes the landslides that have affected the geological formations in the Derby 1:50 000 map sheet area.

Acknowledgements

The authors of this report would also like to thank A Cooper for his advice and constructive comments during the drafting of this report.

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FIGURES

Summary

This report describes the extent and character of the landslides and the mass movement processes in the area covered by the 1:50 000 scale BGS map of Derby (Sheet 125). The work includes the revision of fourteen landslides along with fifteen new landslide records to be added to the National Landslide Database. The work has assisted the continuing study of landslides and mass movements in Great Britain.

1 Introduction

The Derby 1:50 000 geological map (Sheet 125) district lies at the south-eastern tip of the Pennines and includes areas of unspoilt beauty in the west, contrasting markedly with the industrial landscape of the East Midlands coalfield to the east (Frost and Smart, 1979). The district was most recently resurveyed along the northern margin between 1952 and 1960, with the remainder resurveyed between 1960 and 1966. The existing map was published in 1972. As part of the resurveying of the sheet by the East Midlands mapping team, the landslide survey team was approached to assist in the mapping of landslides in the region.

Due to time and budget constraints, the landslide survey consisted of traditional aerial photo interpretation using a stereoscope and hard copy aerial photographs. This was combined with landslide polygons digitised from the 1972 map and existing entries in the BGS National Landslide Database. These datasets provided the basis for a six day field checking campaign in June 2008 of both existing and potential new landslide polygons along with National Landslide Database entries.

2 Study area

The Derby 1:50 000 geological map area is located to the north of the city of Derby, incorporating the northern half of Derby itself, along with the western districts of the city of Nottingham (Figure 1). The southern margin of the Derby sheet is underlain by Triassic bedrock consisting of the Mercia Mudstone and Sherwood Sandstone Groups, which form relatively low relief and rolling agricultural land. To the west and north west of the map sheet, the underlying Namurian rocks of the Millstone Grit Group produce relatively steep-sided valleys and slopes and it is this terrain that contains the highest frequency of landslides. The central portion of the map area 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. These produce a relatively undulating landscape, with locally oversteepened valley sides where mudstones outcrop between stronger sandstone beds. The eastern sector of the map is occupied by Permian dolostones, mudstones and sandstones of the Zechstein Group, which unconformably overlie the Pennine Middle Coal Measures Formation. These produce a relatively subdued topography, with gently sloping hillsides and valleys.

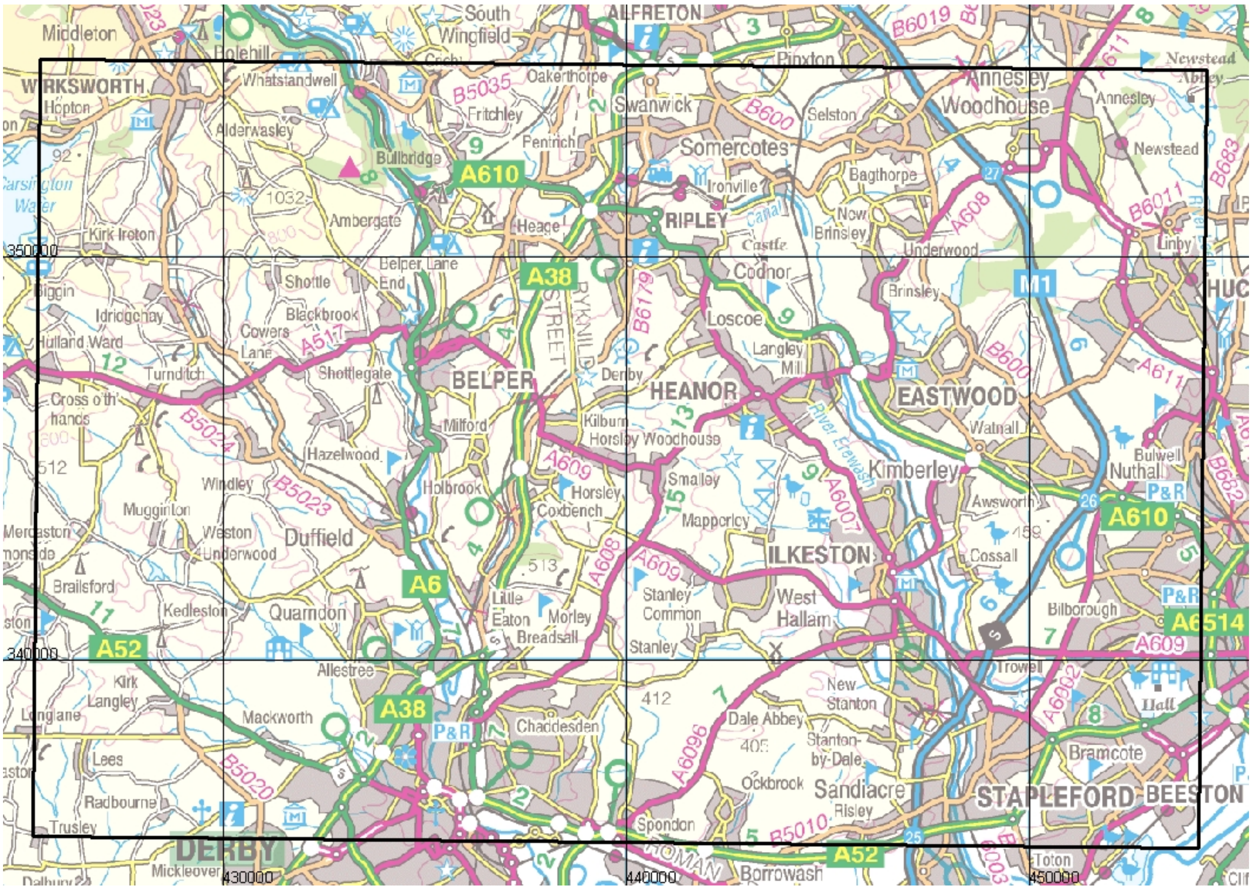


Figure 1. Location of the Derby 1:50 000 geological map sheet 125.

3 Geology

The geology of the Derby Sheet consists of a complex sequence of Palaeozoic (Carboniferous and Permian) and Mesozoic (Triassic) sedimentary rocks deposited in fluvial, deltaic, swamp, marine and enclosed basin conditions (Figure 2). It is necessary to understand the lithologies present, in order to understand the patterns and distribution of landsliding within the Derby region. Each of the stratigraphic units and lithologies present will behave differently due to their mechanical and structural characteristics and will be susceptible to different types of mass movement due to these factors. The stratigraphic relationships of these lithologies are also important to slope stability. Vertical differences in both mechanical strength and hydrogeological factors can influence slope stability and the type of landsliding (Jones and Lee, 1994). A common situation relating to landslides is where an underlying clay formation is overlain by a more competent and porous formation such as sandstone, chalk or limestone. The presence of clay layers within a slope/landslide also allows water to be retained and therefore facilitates a quicker response (and possible failure) to changes in precipitation (Baum *et al.*, 2003). These clay layers also provide an impermeable surface along which water flows and it is this layer along which landslide slip planes commonly occur.

The geology of the Derby Sheet area can be roughly divided into five main regions. The southern margin of the Sheet is underlain by Triassic sandstones, siltstones and mudstones, with a small pocket of Dinantian limestones and mudstones in the south west corner. The central western and north western portion of the sheet is dominated by Namurian mudstones and sandstones, with the central eastern area underlain by Westphalian Coal Measures. Along the eastern margin of the sheet are Permian dolostones, sandstones and mudstones (Frost and Smart, 1979).

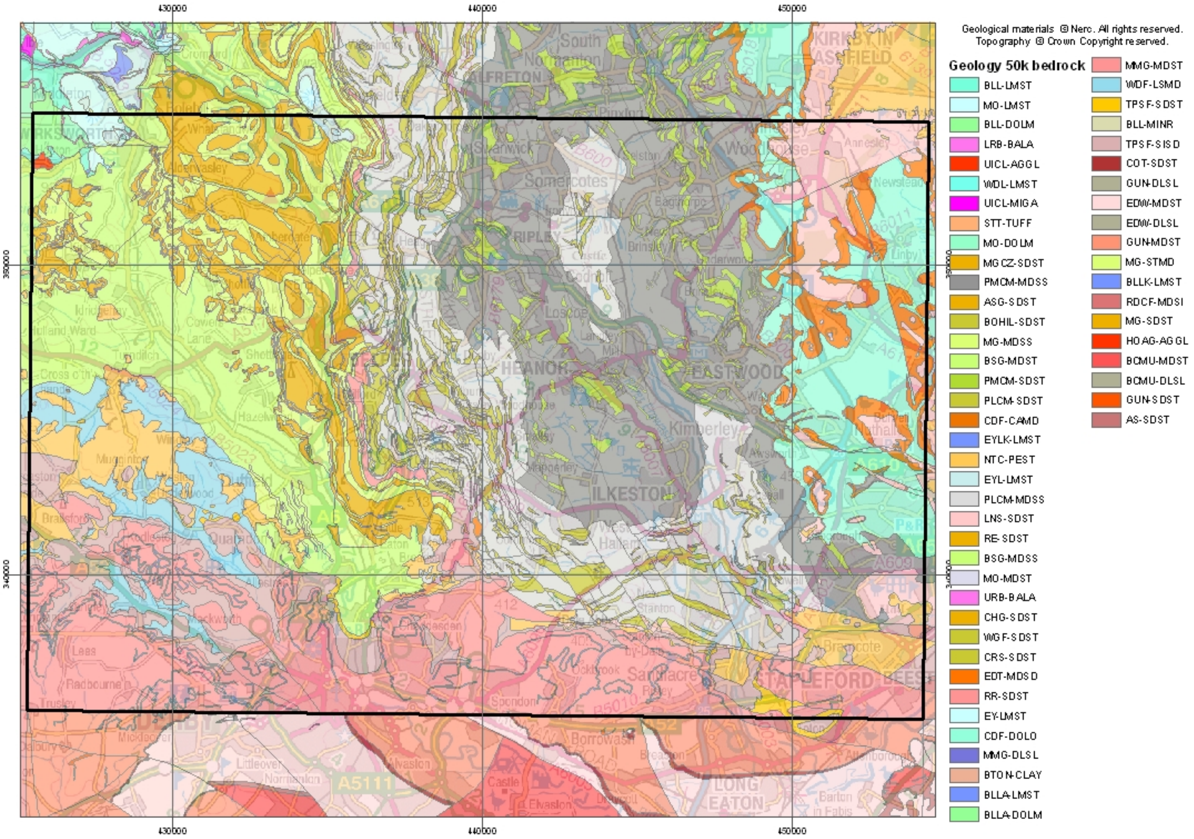


Figure 2. DiGMap V2, 1:50 000 bedrock geology of the Derby Sheet (125).

3.1 CARBONIFEROUS

Carboniferous strata underlie the majority of the sheet, extending from the north west corner of the Derby sheet, eastwards to the M1 motorway, with the southerly outcrop running in a line between north-west Nottingham and the northern limits of Derby.

3.1.1 Dinantian

The Widmerpool Formation forms an outcrop in the western portion of the Derby sheet. It is composed of dark to pale brown or grey, calcareous and locally carbonaceous, pyritic, fissile mudstone, thinly interbedded with turbidite, argillaceous cherty limestone and thin beds of quartzose siltstone, calcareous or quartzose sandstone and tuff.

3.1.2 Namurian

The Bowland Shale Formation underlies the central western and north western areas of the Derby 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. This is overlain by sandstones of the Ashover Grit Formation and the Chatsworth Grit Formation. The Ashover Grit Formation is a massive or cross-bedded, medium to coarse-grained, often pebbly and feldspathic sandstone. The Chatsworth Grit Formation is a fine to coarse grained, massive and cross bedded, locally pebbly sandstone, with minor interbedded mudstone and siltstone.

3.1.3 Westphalian

Coal Measures underlie the central eastern and northern sectors of the Derby Sheet. The Pennine Lower Coal Measures Formation consists of interbedded grey mudstone, siltstone and pale grey sandstone, commonly with mudstones containing marine fossils in the lower part, and more numerous and thicker coal seams in the upper part. The Pennine Middle Coal Measures Formation is composed of interbedded grey mudstone, siltstone, pale grey sandstone and common coal seams, with a bed of mudstone containing marine fossils at the base, and several marine fossil-bearing mudstones in the upper half of the unit.

3.2 PERMIAN

Permian rocks of the Zechstein Group outcrop along the eastern margin of the Derby Sheet. They consist of the Cadeby Formation which is overlain by the Edlington Formation. The Cadeby Formation consists of dolostone, which is grey to buff grey, commonly oolitic or granular, with subordinate mudstone, dolomitic siltstone and sandstone. The Edlington Formation is composed of a red-brown mudstone, with subordinate siltstone and sandstone. A greenish-grey sandstone is more common in Nottinghamshire. Dolostone and gypsum/anhydrite are locally common.

3.3 TRIASSIC

The southern margin of the Derby Sheet is underlain by Triassic rocks of the Sherwood Sandstone Group, the Mercia Mudstone Group and the Tarporley Siltstone Formation. In the Derby Sheet area the Sherwood Sandstone Group is represented by the Nottingham Castle Formation and the Lenton Sandstone Formation. The Lenton Sandstone Formation is a very fine- to medium-grained, argillaceous sandstone. It is red-brown with light brownish yellow mottles, cross-stratified and has subordinate beds of red-brown mudstone and conglomerate. The Nottingham Castle Formation is composed of a pinkish red or light brownish yellow – grey, medium- to coarse-grained, pebbly, cross-bedded, friable sandstone and has subordinate lenticular beds of reddish brown mudstone. The Mercia Mudstone Group consists of dominantly red, less commonly green-grey, mudstones and subordinate siltstones. Thin beds of gypsum/anhydrite are widespread and sandstones are also present. The Tarporley Siltstone Formation is comprised of interlaminated and interbedded mudstones, siltstones and sandstones in approximately equal proportions.

4 Landslide distribution

The Varnes (1978) landslide classification was used to classify landslides during the remapping of Derby sheet (Appendix 1). There were 76 landslides recorded in the National Landslide Database, of which 64 had an associated DigMap50 mass movement landslide polygon. Fourteen of these polygons have been modified as a result of new evidence obtained from aerial photograph interpretation and field observations. Fifteen new landslides have been mapped in the Derby Sheet area (Figure 3). The majority of landslides occur where the mudstones, siltstones and sandstones of the Bowland Shale Formation outcrop through the central western and north western parts of the district (Figure 2). Surprisingly the Pennine Lower and Middle Coal Measures Formations only account for six 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 deeply eroded glacial valleys associated with the Coal Measures in South Wales.

5 New landslide records

In addition to the 64 existing DigMap50 mass movement polygons (of which fourteen were modified in the 2008 resurvey), fifteen new landslides were recorded during the June 2008 resurvey. Thirteen landslides were recorded on the Bowland Shale Formation and two were recorded on the Pennine Middle Coal Measures Formation. These are identified as follows:-

Bowland Shale Formation:

Biggin Head Farm, [427344 348913]; Bridge View, [435379 345465]; Ecclesbourne Farmhouse, [428730 348278]; Gorseybank, [429428 353277]; Hob Wood, [428651 352579]; Long Wood, [431292 354107]; Quarndon Common, [433682 341271]; Rakestones Farm 1, [427363 348753]; Rakestones Farm 2, [427788 348781]; Rookery Farm, [429693 349258]; Soldier's Knoll, [426884 352813]; Whatstandwell, [433919 354160]; Woodpecker Hill, [444217 338724].

Pennine Middle Coal Measures:

Bagthorpe, [446419 351896]; Bagthorpe Brook, [446045 351407].

(the NGR indicates the approx centre points of the polygons)

All of these landslides had the same characteristics of the existing mapped landslides. They were all multiple rotations, degrading into flows at the base. All were highly degraded and interpreted as greater than 1000 years old. It is interesting to note that the two landslides on the Pennine Middle Coal Measures occurred on very low angle slopes (less than 10°). This is probably due to the landslides being activated by erosion at the toe of the slope by Bagthorpe Brook.

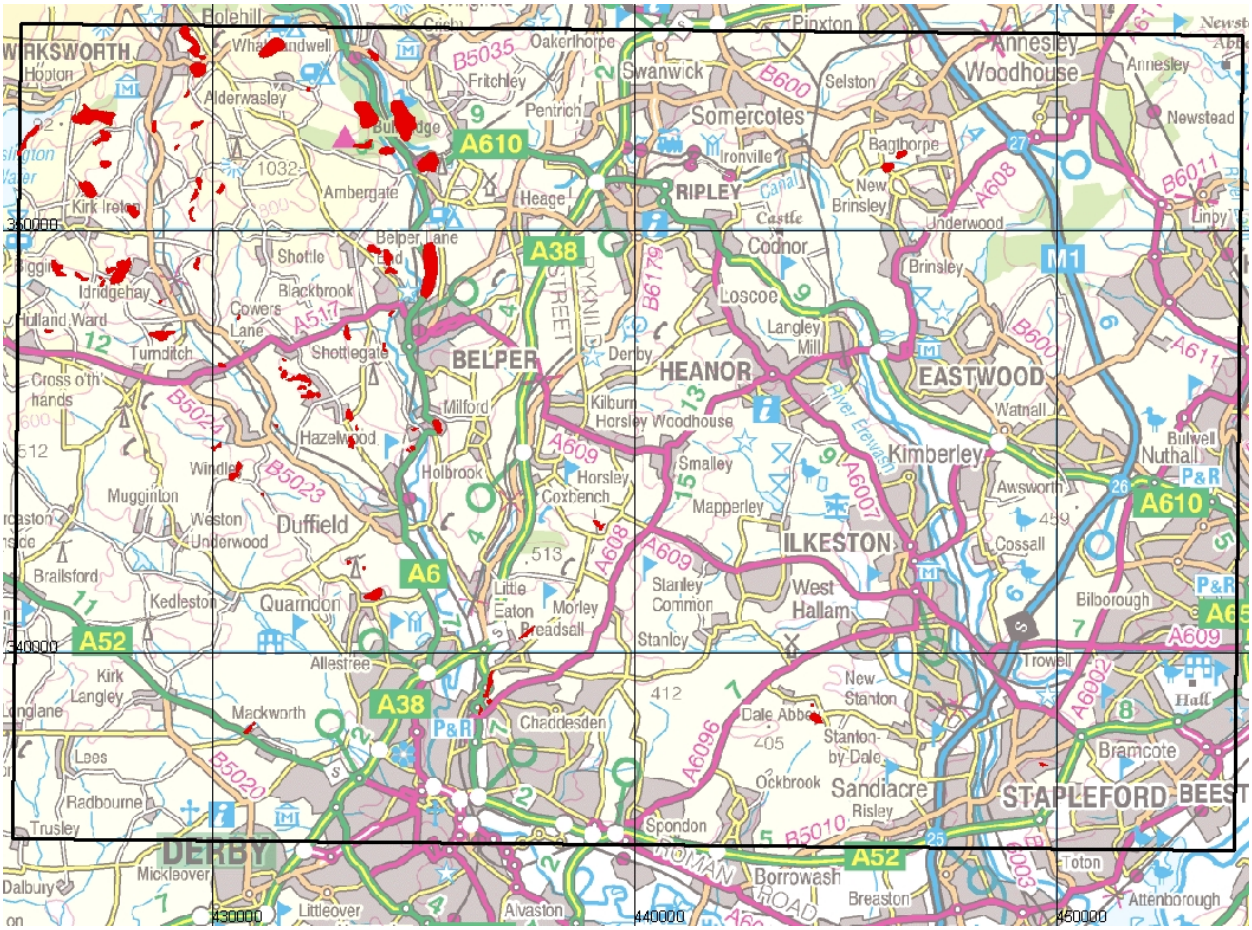


Figure 3. Distribution of landslides (landslide polygons in red) within the Derby 1:50 000 geology sheet area.

6 Landslide analysis

6.1 GEOLOGY AND LANDSLIDE FREQUENCY

When comparing the underlying bedrock geology to landslide distribution, a strong correlation between the Namurian sedimentary rocks of the Bowland Shale Formation and landsliding is observed (Figure 4). The underlying Namurian mudstones, siltstones and sandstones account for 86% of the landslides in the Derby area. Only 7% of landslides occur where the Pennine Lower and Middle Coal Measures Formations (Westphalian) outcrop. The remaining 4% of landslides are underlain by interbedded limestones and mudstones of the Widmerpool Formation (Dinantian), and 3% are underlain by Triassic sedimentary rocks of the Mercia Mudstone and Sherwood Sandstone Groups.

Dimensionally, landslides within Namurian strata range from 1 300 m x 450 m to 86 m x 43 m, and landslides within this group typically form the largest landslides in the region. Landslides occurring within Westphalian strata range from 276 m x 183 m down to 58 m x 63 m. Landslides observed within the Dinantian strata display a long, narrow trend with dimensions ranging from 235 m x 117 m to 60 m x 60 m (the smaller landslides showing an exception to the general trend).

The landslides in the Namurian strata account for the majority of slope instability in the Derby area (Figure 5).

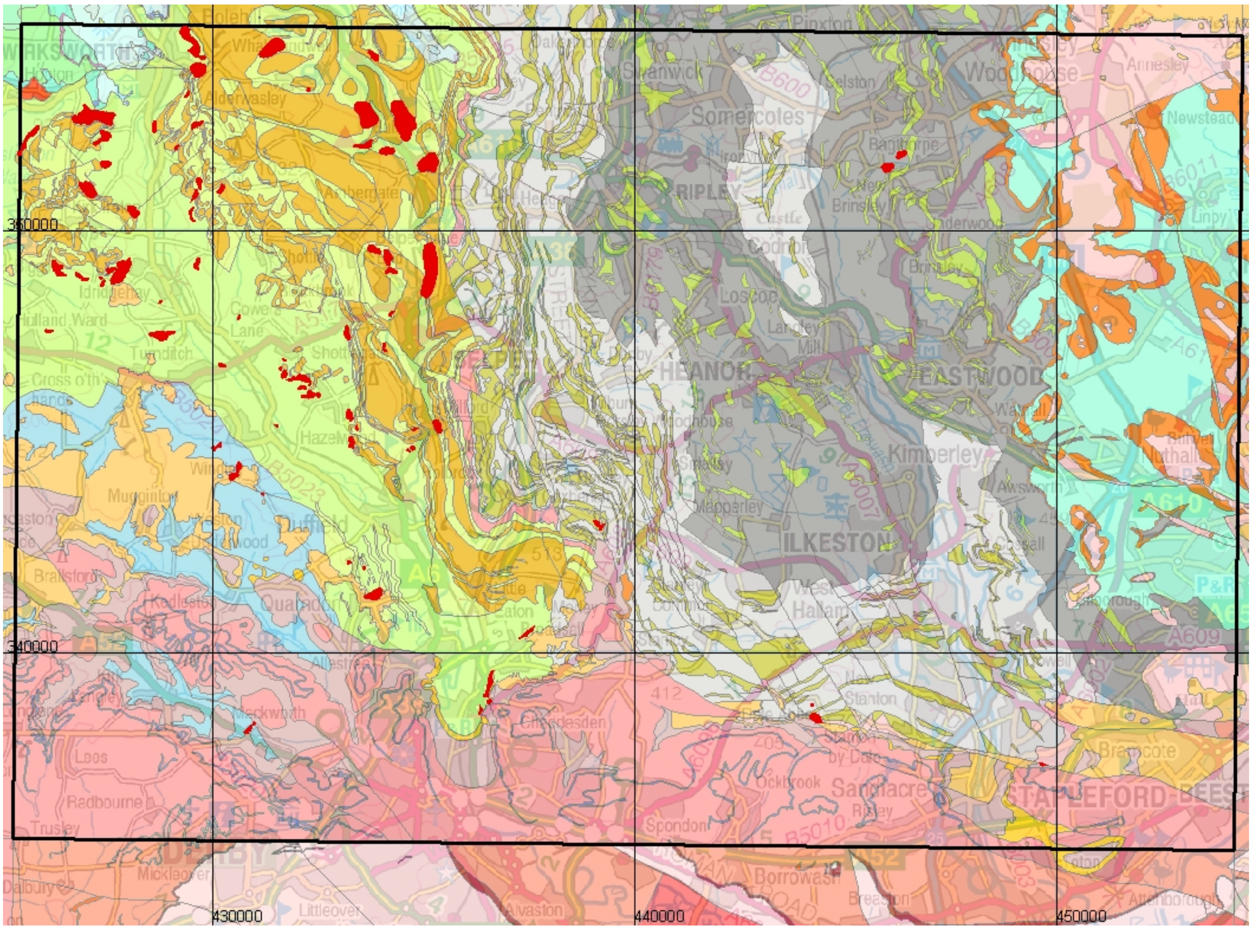


Figure 4. Distribution of landslides in relation to bedrock geology (landslide polygons in red).

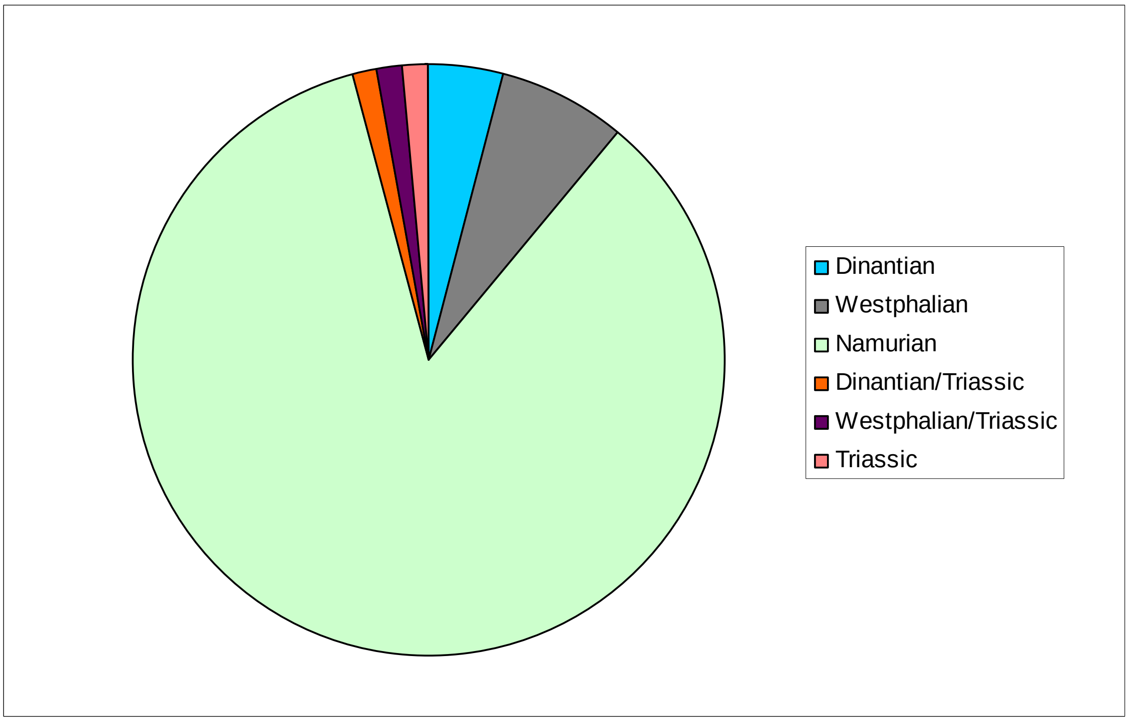


Figure 5. Frequency of the 79 landslides related to chronostratigraphy/bedrock composition.

6.2 STYLE AND MECHANISM OF LANDSLIDING

With only a few exceptions, the dominant style of landsliding observed in the Derby sheet area was rotational failures. Most commonly these were multiple rotations, degrading into flows towards the base. The Namurian stratigraphy, composed of more competent sandstone beds overlying less competent siltstones and mudstones (with relatively low dips), is a common causal element of multiple rotational landslides in the Derby area. Water from the sandstone lubricates the underlying mudstones, leading to the development of shear planes along which the slip moves (Frost and Smart, 1979). This stratigraphic relationship (where a more competent lithology overlies a less competent lithology) also applies to multiple rotational landslides that occur in the Widmerpool Formation (Dinantian), and the Pennine Lower and Middle Coal Measures Formations (Westphalian). Single rotations were only observed in three landslides, all underlain by the Namurian Bowland Shale Formation.

Flows were only 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.

6.3 LANDSLIDE AGE AND ACTIVITY

Landslides in the Derby area are predominantly interpreted as greater than 1000 years in age. The majority are degraded with features commonly quite subtle in the field, and very subtle when viewed in aerial photographs. This high degree of degradation dictated that the landslides were not very photogenic, with already subtle features flattened when photographed with a digital camera (hence the lack of photographs in this report). Very few landslides (five) featured clearly definable backscars. Only two of the 72 landslides observed showed any signs of activity (Wirksworth, [429800 353710]; and Rough Rams Carr, [426970 350900]). The landslide at Wirksworth displayed widespread tension cracks in the lower part of the slide, suggesting reactivation of the slope (Figure 6). The backscar of the Rough Rams Carr landslide cuts Topshill Lane at [426970 350884] (north west edge) and [426989 350840] (south east edge).

Two tension cracks were observed in the road following the line of the backscar, and the road had sunk by approximately 0.2 metres (Figure 7). This suggests that this landslide may also be showing signs of reactivation.

Figure 6. Tension cracks in the lower portion of the Wirksworth landslide. Photograph taken at NGR [429582 353881].

Figure 7. Tension crack in Topshill Lane towards the backscar of the Rough Rams Carr landslide. Photograph taken at [426970 350884], Orientation 315°.

6.4 LANDSLIDING AND SLOPE ASPECT

Landsliding within the Derby district is most common on west, north-west or north-facing slopes (Figure 8). Of the landslides surveyed, 19 had formed on west-facing slopes and 16 on north-facing slopes (Figure 9). Nine landslides were observed on north-west-facing slopes. Slopes with aspects between north-east and south accounted for 28 landslides respectively, with only two landslides occurring on south-west-facing slopes.

The topography of the north-western part of the Derby sheet displays relatively steep valley and hill sides trending north-south (Figure 8). These formed as a result of east-west compressional forces during the Variscan Orogeny in Late Westphalian and early Permian times (Frost and Smart, 1979). Consequently, a large proportion of the hill and valley sides in the region have a west-facing aspect. Couple with this, the majority of faults in the north-western part of the Derby sheet have an east-west trend. Subsequent erosion has occurred along these faults, producing numerous north-facing slopes.

The region was last glaciated during the Wolstonian (Frost and Smart, 1979). During the Devensian the region was subjected to a harsh periglacial climate, as glacier ice terminated further to the north. During this period westerly facing slopes would be subject to freeze-thaw conditions coupled with a cold, wet climate which would weaken the bedrock and facilitate landsliding. North-facing slopes would also have been more exposed to harsher conditions than those impacting on the more sheltered easterly and southerly-facing slopes, thus providing more favourable conditions for landsliding.

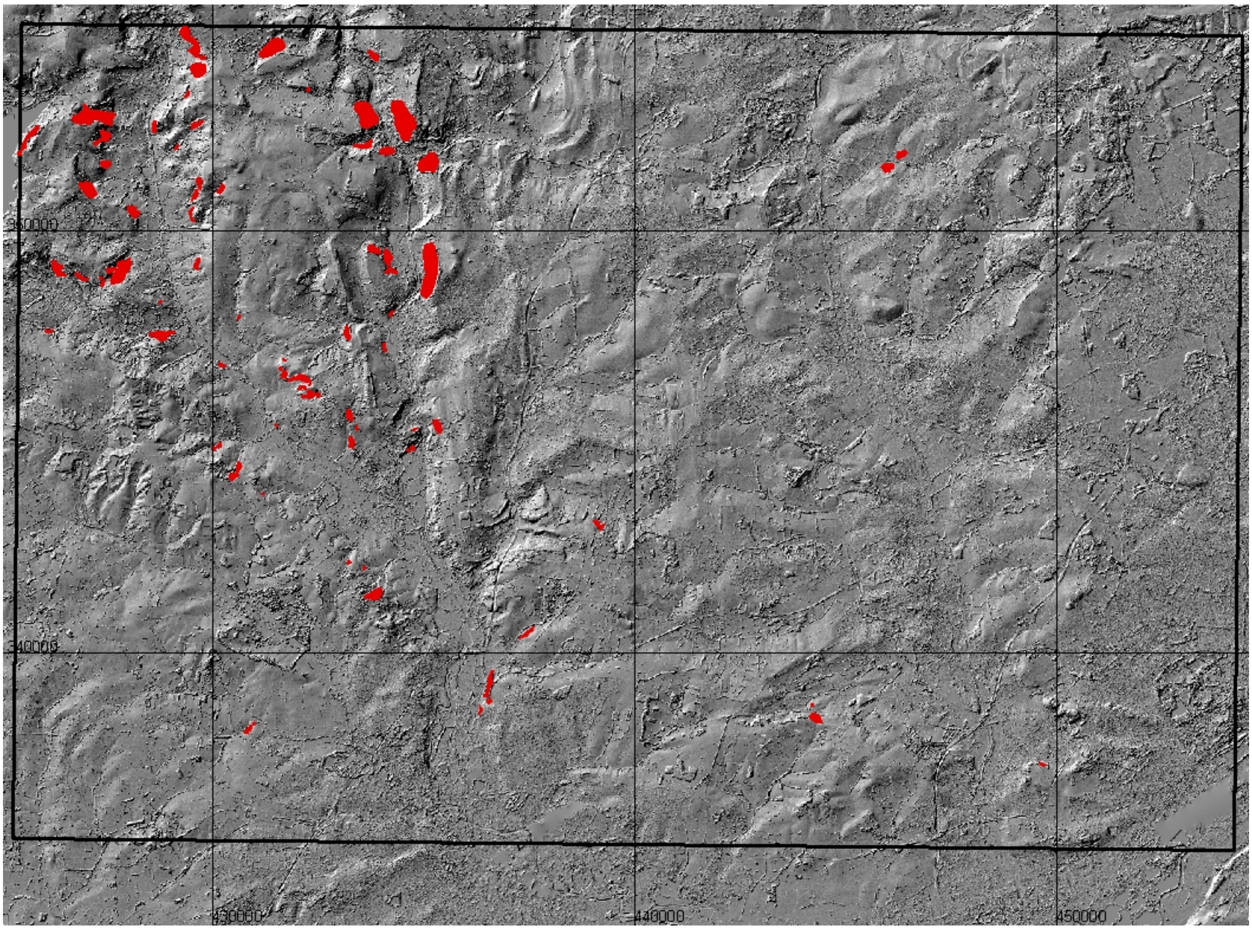


Figure 8. Landslide distribution overlaid on NEXTMap digital surface model.

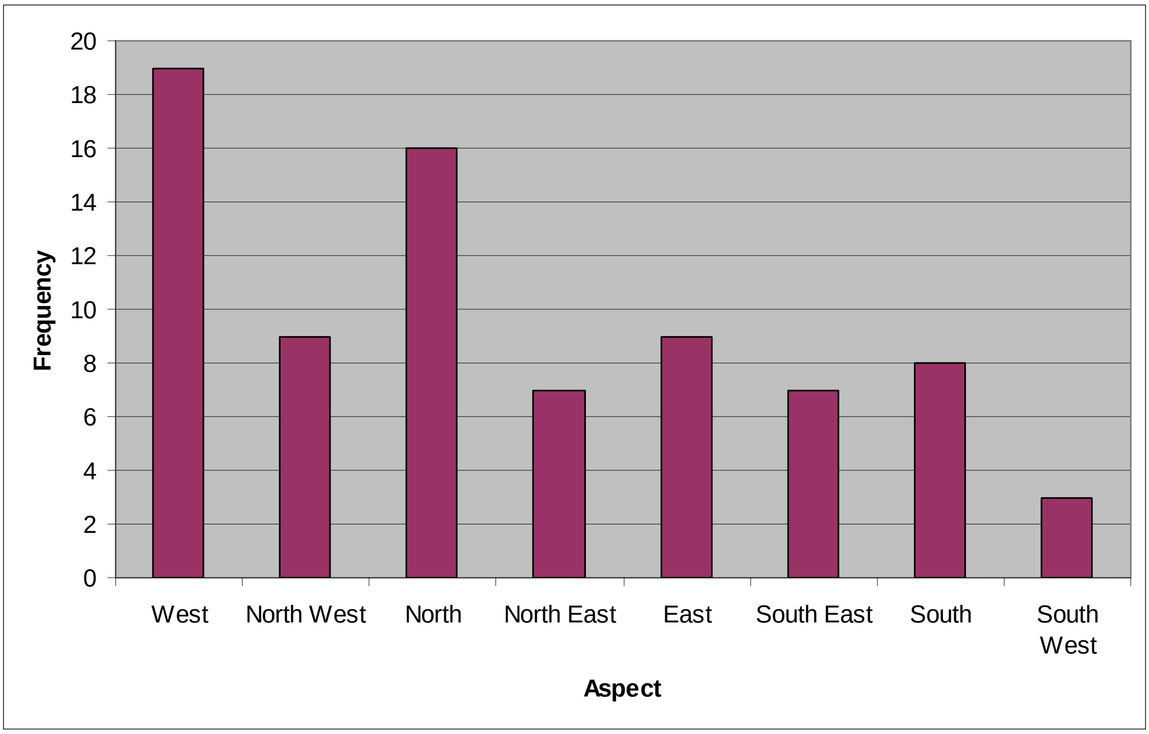


Figure 9. Frequency of landslides relating to aspect on the Derby sheet.

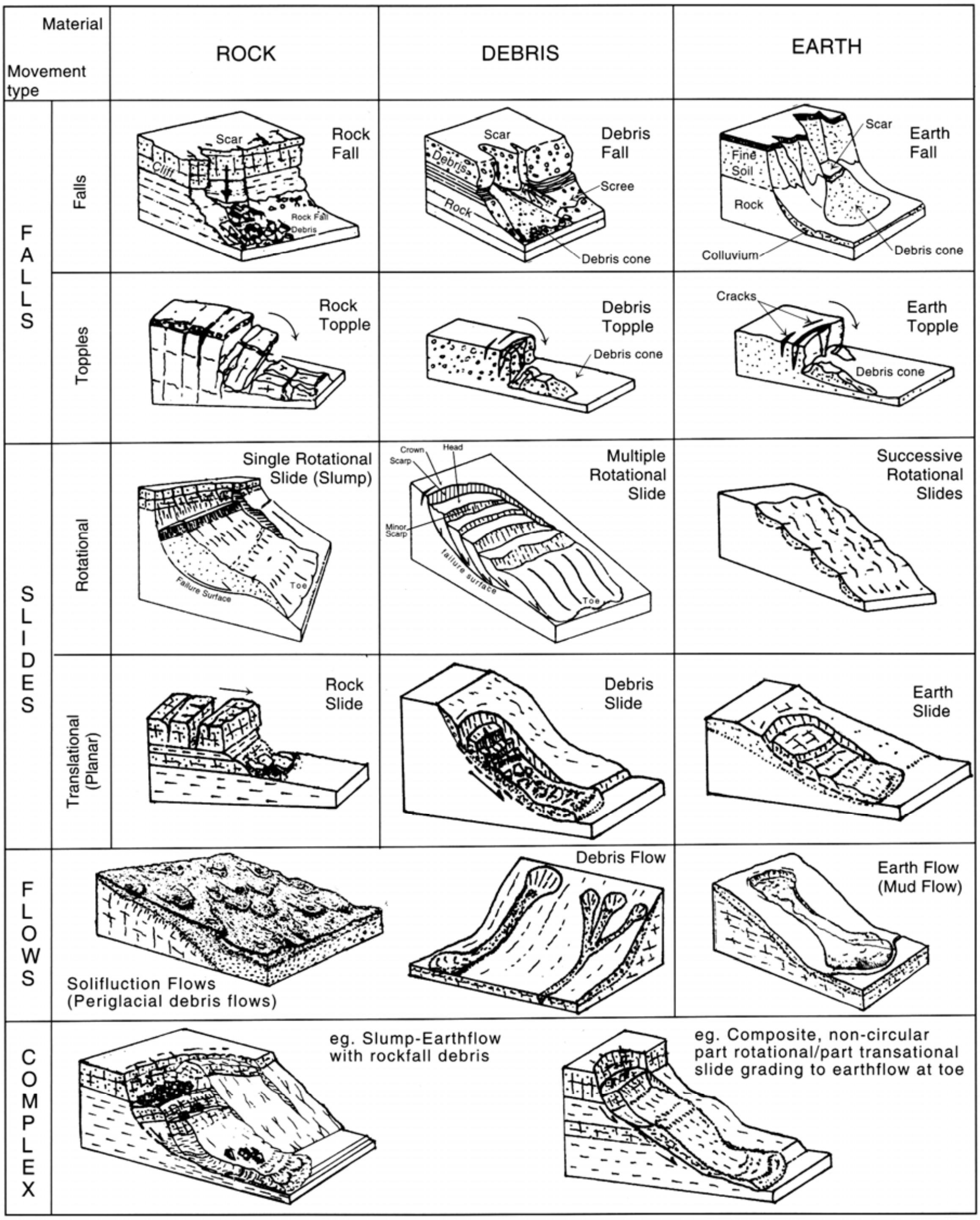
7 Conclusions

Within the Derby 1:50 000 map sheet area multiple rotations, with flows towards the base, have been observed to be the dominant landslide style. The Namurian Bowland Shale Formation accounts for the majority (86%) of landslides. Surprisingly only 7% of the landslides recorded were underlain by Coal Measures, whose stratigraphy is closely related to high landslide frequencies in other areas such as South Wales. In terms of aspect, landslides are most frequent on north and west-facing slopes. This is probably due to the tectonic evolution of the area which in combination with local climatic conditions (influenced by aspect) has led to increased landsliding on north and west facing slopes.

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 Devensian when periglacial climatic conditions prevailed. Only two landslides observed showed any signs of recent activity (Wirksworth and Rough Rams Carr landslides). The Bolehill Landslide also has a documented recent history of movement (Frost and Smart, 1979). As a result of this study fifteen new landslide records have been added to the National Landslide Database, and fourteen existing DigMap50 landslide polygons have been updated.

Appendix 1

CLASSIFICATION OF LANDSLIDE TYPES (VARNES, 1978)



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.

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