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

Land Use and Development Programme

Internal Report OR/10/013

BRITISH GEOLOGICAL SURVEY

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INTERNAL REPORT OR/10/013

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

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National Grid Reference

SW corner 483482,373686
Centre point 498498,383245
NE corner 512624,392719

Map

Sheet 102, 1:50 000 scale, Market Rasen

Front cover

South Carlton Landslide.

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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 Lincolnshire Escarpment in the Market Rasen 1:50 000 map sheet area.

Acknowledgements

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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 Market Rasen (Sheet 102). The work includes the identification of seven 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 Market Rasen 1:50 000 geological map (Sheet 102) area lies to the north of the city of Lincoln, with the town of Market Rasen located in the north eastern corner of the sheet. It encompasses part of the Lincolnshire Escarpment which extends from Oakham in the south, passing northwards where it forms a more subdued slope, before it terminates at the Humber Estuary. Within the Market Rasen 1:50 000 sheet area, the escarpment slope lowers and broadens in a northwards direction. This work is a continuation of the studies by Forster (1992) and Booth & Jenkins (2009) of landslide nature and distribution along the Lincolnshire Escarpment, which focussed on the Grantham and Lincoln 1:50 000 geological sheets respectively.

2 Study area

The Market Rasen 1:50 000 geological map area (Figure 1) is underlain by Mesozoic rocks of Triassic and Jurassic age. The area is dominated by agriculture, the majority of which is arable and this forms a striking patchwork mosaic when viewed from the air. The Lincolnshire Limestone Formation forms a distinct flat plateau, a feature which has provided the ideal site for the location of RAF Scampton. The junction between the Whitby Mudstone Formation, Grantham and Northampton Sand formations and the overlying Lincolnshire Limestone Formation provides the focus for this study. This succession of rocks has led to the formation of the Lincoln Escarpment which provides the only notable topography within the Market Rasen sheet area. To the west of the escarpment the land flattens and is drained by the River Till before extending to the catchment of the River Trent. To the east the topography slopes gently eastwards along the shallowly dipping Middle and Upper Jurassic bedrock.

3 Geology

3.1 BEDROCK

The bedrock geology of the Market Rasen sheet progresses from Mid Triassic rocks of the Mercia Mudstone Group in the west, to the Upper Jurassic rocks of the Kimmeridge Clay Formation in the east (Figure 2). The rocks dip gently to the east, with a north-south strike that is clearly evident in outcrop. The main area of interest is along the Lincolnshire Escarpment, a feature that has formed due to the presence of the following units described from base to top:

3.1.1 Lower Jurassic: Lias Group

3.1.1.1 WHITBY MUDSTONE FORMATION

The Whitby Mudstone Formation (formerly referred to as ‘Upper Lias’) consists of over-consolidated, stiff, dark grey, laminated, fissured, silty clay (Forster, 1992), with subordinate nodular limestone, and platy calcareous siltstone beds, especially near the base (Berridge *et al.*, 1999). All of the landslides in the Market Rasen sheet area have occurred in the Whitby Mudstone Formation.

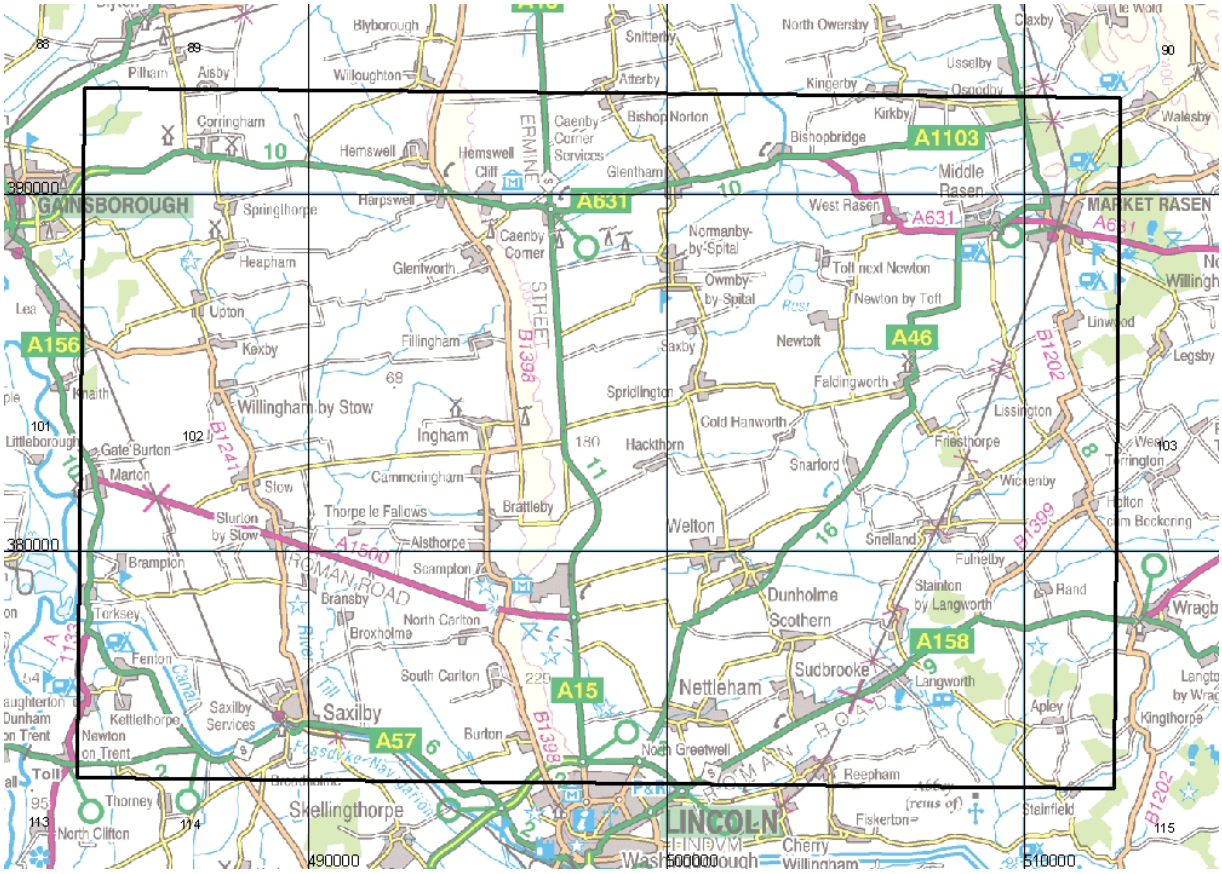


Figure 1. Location of the Market Rasen 1:50 000 geological map sheet 102.

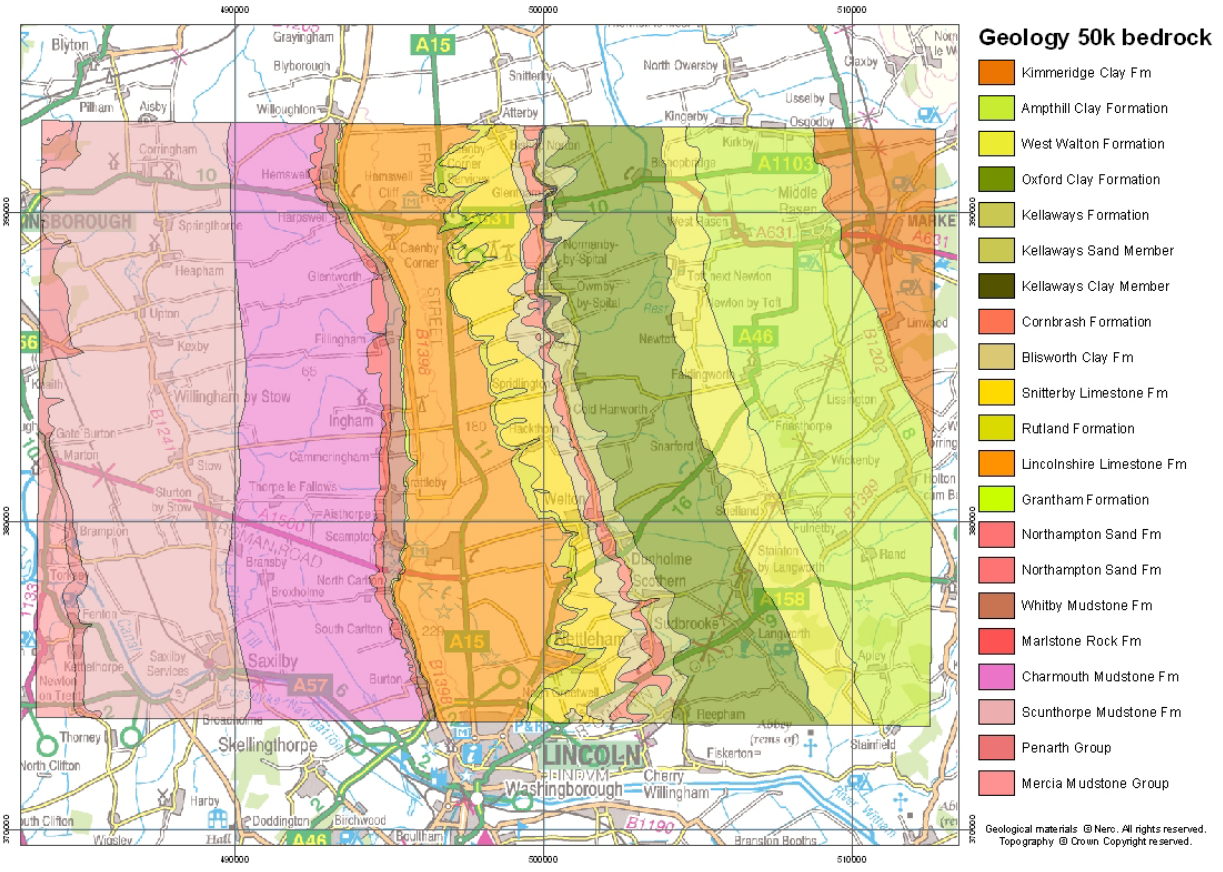


Figure 2. DiGMapGB V5, 1:50 000 bedrock geology of the Market Rasen Sheet (102).

3.1.2 Middle Jurassic: Inferior Oolite Group

3.1.2.1 NORTHAMPTON SAND FORMATION

The Northampton Sand unconformably overlies the Whitby Mudstone. It is composed of fine-grained ferruginous sand or sandstone with segregations of iron ore that locally dominate the sequence (Berridge *et al.*, 1999). The unit includes lenses of limestone and mudstone in places.

3.1.2.2 GRANTHAM FORMATION

The Grantham Formation (formerly the Lower Estuarine Series) succeeds the Northampton Sand Formation and is unconformably overlain by the Lincolnshire Limestone Formation. It is dominated by thinly bedded sandstones, siltstones and mudstones, rich in plant material with traces of coal and sideritic ironstone (Berridge *et al.*, 1999).

3.1.2.3 LINCOLNSHIRE LIMESTONE FORMATION

The Lincolnshire Limestone Formation is a very thinly to medium bedded, moderately strong to strong, buff/grey limestone which is typically composed of calcilutites and peloidal wackestones and packstones in the lower part, and high energy ooidal and shell fragmental grainstones in the upper part. It commonly includes a sandy limestone in the basal part and may contain substantial units of mudstone particularly from the Lincoln area northwards.

All of these units dip at a low angle to the east. The Middle Jurassic strata which cap the scarp are permeable, but the underlying Whitby Mudstone Formation is impermeable and impedes the downward percolation of water (Berridge *et al.*, 1999). Although the majority of the water flows downdip to the east, some reappears as springs and seepages on the scarp face. This wetting, accompanied by natural weathering processes, significantly weakens the Whitby Mudstone Formation, making it highly susceptible to failure through landsliding.

Although other landslide prone lithologies exist to the east of the Lincoln Edge (such as the Oxford Clay Formation), the subdued topography negates any possibility of slope instability.

3.2 QUATERNARY

Widespread evidence exists for glacial and periglacial activity in the area (e.g. Till, Glaciofluvial Deposits, solifluction deposits, River Terrace Deposits and Aeolian sand). The area was last covered by ice during the Anglian glaciation (c. 450 000 years BP) and this is thought to have enhanced the morphology of the Lincolnshire Escarpment as the ice carved across the landscape. Ice cover did not extend over this area during the Devensian glaciation (c. 20 000 years BP), but terminated some distance to the north and east. This resulted in significant modification of surface water movement (Penn *et al.*, 1983). Water which would have normally drained northwards into the Humber was blocked by the North Sea Ice and Vale of York glacier. This resulted in the formation of an ice-dammed lake which then drained through the Witham Gap as the North Sea Ice retreated northwards. Solifluction deposits also formed during the periglacial conditions of the Devensian, and these weakened deposits subsequently failed as landslides along the Lincoln Escarpment.

4 Landslide distribution

The Varnes (1978) landslide classification was used to classify landslides during the remapping of Market Rasen sheet (Appendix 1). No previous records exist in the National Landslide

Database, and no landslide polygons have been identified on the associated DigMap50-GB maps. Seven new landslides have been identified during the survey, the main concentration of which is in the southern portion of the sheet. Several areas were highlighted along the length of the escarpment for field investigation from aerial photograph and NextMap™ slope model interpretations, but the vast majority of these revealed uniform, commonly ploughed, slopes.

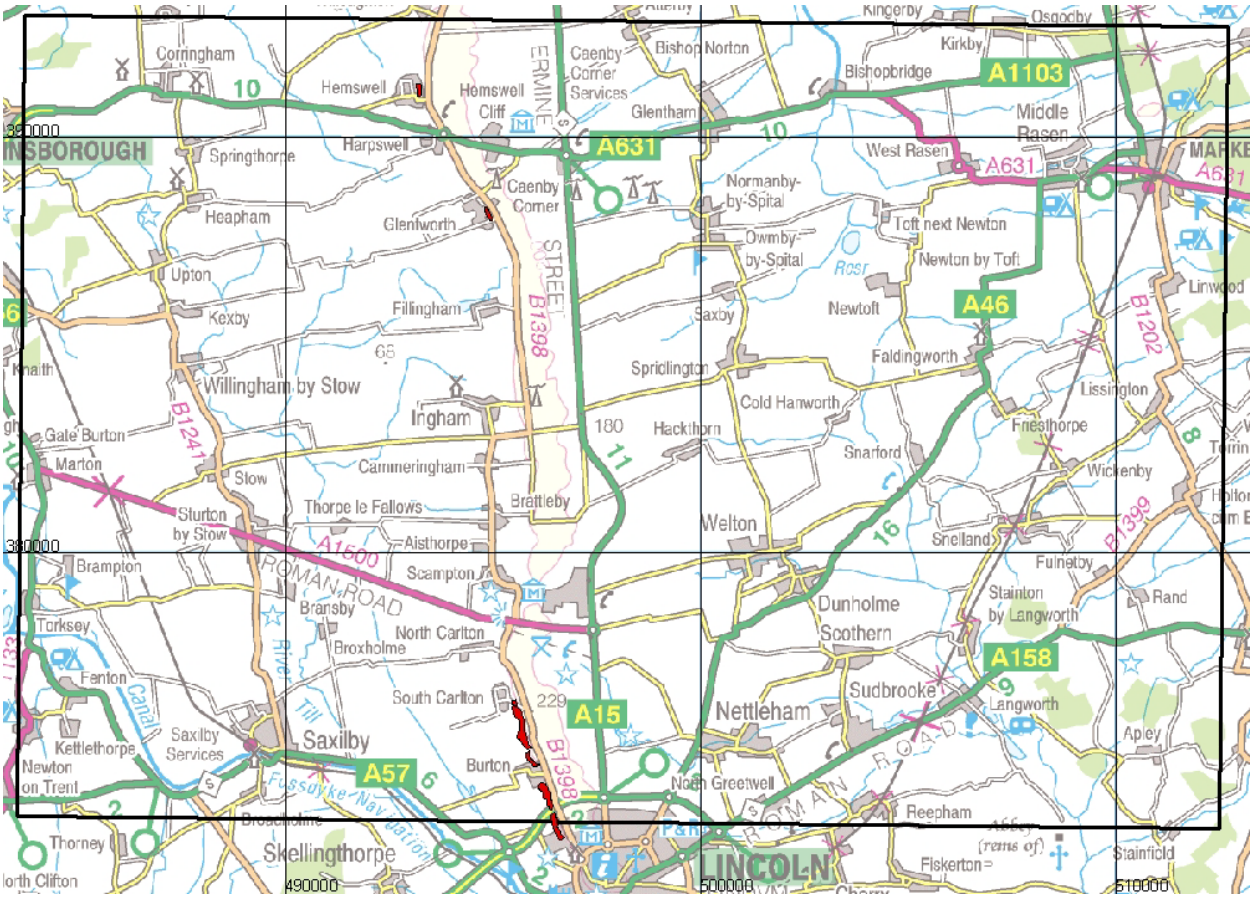


Figure 3. Distribution of landslides (landslide polygons in red) within the Market Rasen 1:50 000 geology sheet area.

4.1 NEW LANDSLIDE RECORDS

Seven new landslides were recorded for the Market Rasen sheet (the Ermine landslide also overlaps the Lincoln sheet to the south), all of which had occurred in the Whitby Mudstone Formation:

Burton Park, [496364 374250]; Ermine, [496578 373479]; Glentworth, [494911 388213]; Hemswell, [493272 391092]; Mill House, [495923 375018]; South Carlton, [495573 376389]; South Carlton 2, [495743 376020].

All of these landslides exhibited the same characteristics: shallow single rotations degrading into flows at the base, with the exception of the larger landslides (Burton Park, Ermine and South Carlton 2) which were interpreted to be multiple rotations degrading into flows.

4.2 LAND USE AND LANDSLIDE PRESERVATION

It has already been noted that the Lincolnshire Escarpment lowers and broadens towards the north away from the city of Lincoln. This decrease in slope height appears to facilitate more widespread arable land use, with a gentler, lower slope allowing regular ploughing. Several areas were identified along the escarpment from NextMap™ digital surface model slope data as having slope angles at or close to the angle of stability (between 3.8º and 12.5º with a median

value of 6.3º, Forster, 1992) for the Whitby Mudstone Formation. However, observation of the slope during the field survey revealed at best only very subtle lobate features which could not be confidently classified or mapped as landslides. Examples of this include the slope to the east of the village of Ingham [495450 383130] where a landslide was initially mapped from aerial photograph interpretation, but during the survey revealed only very subtle features within a ploughed field, and the slope to the south of Willoughton where NextMap™ digital surface model slope data suggested areas susceptible to landsliding (Figure 4). There is good reason to suspect that landsliding may well have occurred in areas such as this, and it is likely that shear surfaces would be evident in trial pits. However, due to repeated ploughing, coupled with natural processes of degradation such as hill wash and soil creep, any landslide features have subsequently been erased and overprinted. Therefore it is possible that landslides are more widespread than those mapped during this survey.

Conversely land use at the Glentworth and Hemswell landslides consists of rough pasture. Due to the absence of ploughing, hummocky, lobate landslide features have been preserved and were more easily identifiable than those in areas of arable land use.

Figure 4. Typical ploughed slope profile in an area of suspected landsliding south of Willoughton. Photograph taken from NGR 493180 392143, orientation 135º.

5 Landslide analysis

5.1 STYLE AND MECHANISM OF LANDSLIDING

All of the landslides are very shallow in nature, with failure planes estimated to be no greater than 10 metres below the surface. Dimensionally the landslides range from 160 m x 120 m up to

1 095 m x 215 m, and are generally wider horizontally along the escarpment. The larger landslides (Burton Park, Ermine and South Carlton 2) were interpreted to be multiple rotations, and the smaller landslides single rotations, degrading into flows towards the base with failure occurring entirely within the Whitby Mudstone Formation. The Jurassic stratigraphy, composed of gently dipping more competent sandstone or limestone beds overlying less competent siltstones and mudstones, is a common causal element of rotational landslides in the Market Rasen area. Water draining from the overlying sandstone and limestone saturates the underlying mudstone and raises the pore water pressure causing a lowering of the effective shear strength. This can result in failure, the formation of shear planes and the initiation of rotational landslides (Jones and Lee, 1994). The surface morphology of the landslides, akin to the landslides observed on the Lincoln sheet (Booth and Jenkins, 2009), is very subtle in the field, very subtle when viewed using aerial photographs, and commonly consists of hummocky ground.

Cambering may also be present along the escarpment edge. Penn *et al.* (1983) undertook a detailed geophysical survey of the escarpment prior to the construction of the A46 – A15 Lincoln relief road. They report the development of small cambered blocks and major gulls parallel to the principle (approximately 140º) joint direction in the Lincolnshire Limestone Formation along the escarpment edge. The occurrence of the more competent Lincolnshire Limestone Formation overlying the relatively plastic Whitby Mudstone Formation forms very favourable conditions for cambering and gull formation. However it is difficult to detect cambering from surface geomorphology alone.

5.2 LANDSLIDE AGE AND ACTIVITY

Landslides in the Market Rasen sheet area are interpreted to be between 100 and 1 000 years in age. The Ermine, Mill House (Figure 5), South Carlton (Figure 6) and South Carlton 2 (Figures 7 & 8) landslides all showed signs of recent activity. Cracks were also observed in the road between the South Carlton and South Carlton 2 landslides [495539 376298]. But the large scale movement responsible for the overall morphology of the slides is estimated to have occurred between 100 and 1000 years ago. The Burton Park, Glentworth and Hemswell landslides were all highly degraded, showing no signs of recent activity, and these too are interpreted to have formed between 100 and 1000 years ago.

Although only seven landslides have been documented for the Market Rasen sheet, it is likely that the majority of the Lincoln Escarpment to the north of Lincoln is potentially unstable. A change to wetter climatic conditions, loading at a critical site, or removal of support by excavation could all potentially result in the reactivation of landsliding or the activation of a new landslide.

Figure 5. Fresh scarp features within the Mill House landslide. Photograph taken from NGR 495797 375113, orientation 090º.

Figure 6. South Carlton landslide. Photograph taken from 495366 376396, orientation 090º.

Figure 7. Fresh backscar feature at southern end of South Carlton 2 landslide. Photograph taken from 495604 375502, orientation 090º.

Figure 8. Close up of backscar at southern end of South Carlton 2 landslide. Photograph taken from 495759 375212, orientation 040º.

6 Conclusions

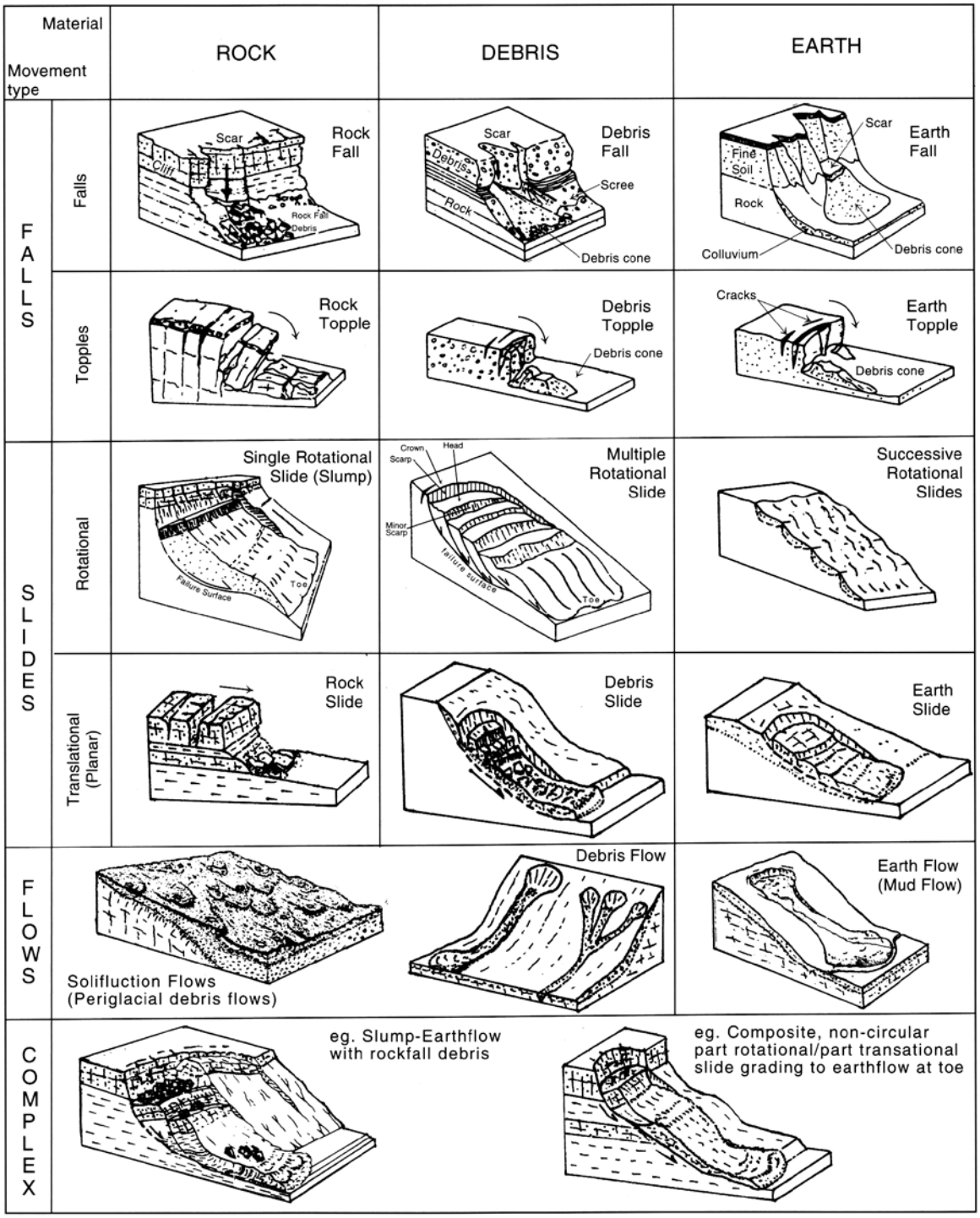
The Lincolnshire Escarpment, where the Lincolnshire Limestone Formation and Grantham and Northampton Sand formations overlie the Whitby Mudstone Formation, is the focus for landsliding on the Market Rasen 1:50 000 geological sheet (102). Seven new landslides have been recorded and entered into the National Landslide Database. The landslides are all shallow (<10 metres), single or multiple rotations, degrading to flows towards the base and all occur within the Whitby Mudstone Formation.

The landslides are highly degraded and interpreted to be between 100 and 1 000 years old. Four of the landslides (Ermine, Mill House, South Carlton and South Carlton 2) all showed signs of more recent activity.

Land use has a strong influence on the preservation and identification of landslide features. The Market Rasen area is dominated by arable agriculture and the associated ploughing erases and overprints any existing landslide features. Therefore it is highly likely that cambering and landsliding is more widespread within the Market Rasen sheet area than is indicated by the landslide polygons mapped during this survey.

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.

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.

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