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

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

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National Grid Reference

SW corner 483300,354400
Centre point 498000,364000
NE corner 513100,373800

Map

Sheet 114, 1:50 000 scale, Lincoln

Front cover

Landslide on the escarpment at Harmston, Lincolnshire [496996 362452].

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 Lincoln 1:50 000 map sheet area.

Acknowledgements

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Contents

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 Lincoln (Sheet 114). The work includes the identification of 29 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 Lincoln 1:50 000 geological map (Sheet 114) district lies to the east of the Trent Valley and encompasses the River Witham. The city of Lincoln lies in the north of the district.

The district was originally surveyed in 1878 and further surveys, focussing on the central area around Nocton, occurred in 1937 and 1941. This work concentrated on the Lincolnshire escarpment and the Lincolnshire Limestones of the Inferior Oolite Group. A new compilation map was published in 1971. The existing map was published in 1973.

As part of the resurveying of the Lincoln sheet by the East Midlands mapping team, the landslide survey team was approached to assist in the mapping of landslides in the district.

The landslide survey consisted of preliminary data gathering, including digital stereo aerial photograph interpretation using the software, SOCET SET^{TM}, as well as a review of the NEXTMap^{TM} digital terrain model and GeoSure datasets. No landslide polygons had previously been identified on the 1973 published geological map and only one location is entered in the BGS National Landslides database. This information provided the basis for a three day field checking campaign in March 2009, which involved checking, identifying and delimiting potential new landslide polygons.

2 Study area

The Lincoln 1:50 000 geological map area encompasses part of the low-lying valley of the River Trent in the west, and extends from the north eastern outskirts of Newark in the southwest, eastwards into the low-lying country and wide alluvial plane of the River Witham, continuing to the Jurassic scarp and dip slope beyond. The greater part of the area is drained by the River Witham and its tributaries, the principal of which are the Till and the Brant (Figure 1).

The River Witham flows northwards towards Lincoln before curving back towards the southeast to Boston and The Wash. The city of Lincoln itself lies in the north of the district. It is sited on the northern bank of the River Witham, at a point where the main north-south trending scarp is breached. This scarp, clearly visible in Figure 2, is created by the outcrop of the Lincolnshire Oolite Groups, of Jurassic age.

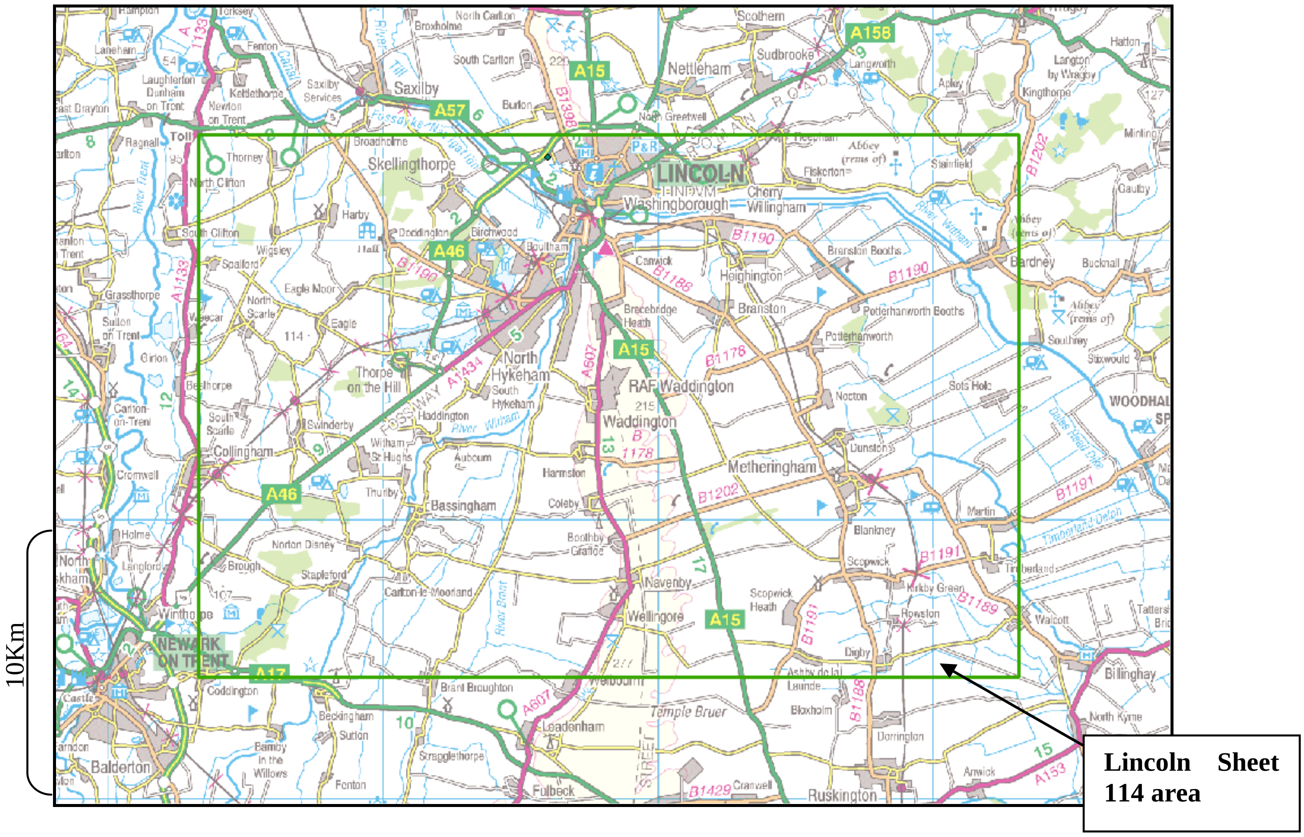


Figure 1. Location of the Lincoln 1:50 000 geological map sheet 114

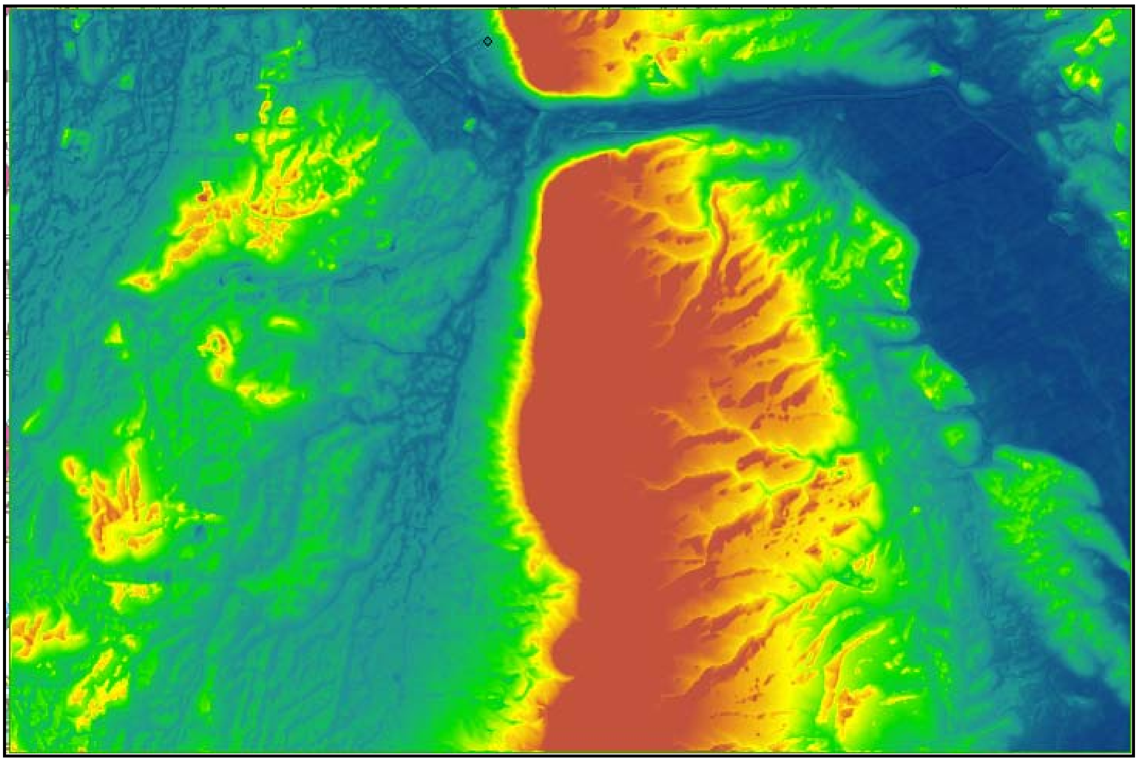


Figure 2. NextMap shaded relief digital terrain model (DTM) of the Lincoln sheet area. [red = high; blue = low]. The Jurassic escarpment forms a marked feature dominating the Lincoln sheet area.

3 Geology

The geology of the Lincoln sheet consists of a complex sequence of Mesozoic (Triassic and Jurassic) sedimentary rocks deposited in fluvial, deltaic, marine and enclosed basin conditions (Figure 3). It is necessary to understand the lithologies present, in order to understand the patterns and distribution of landsliding within the Lincoln 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.

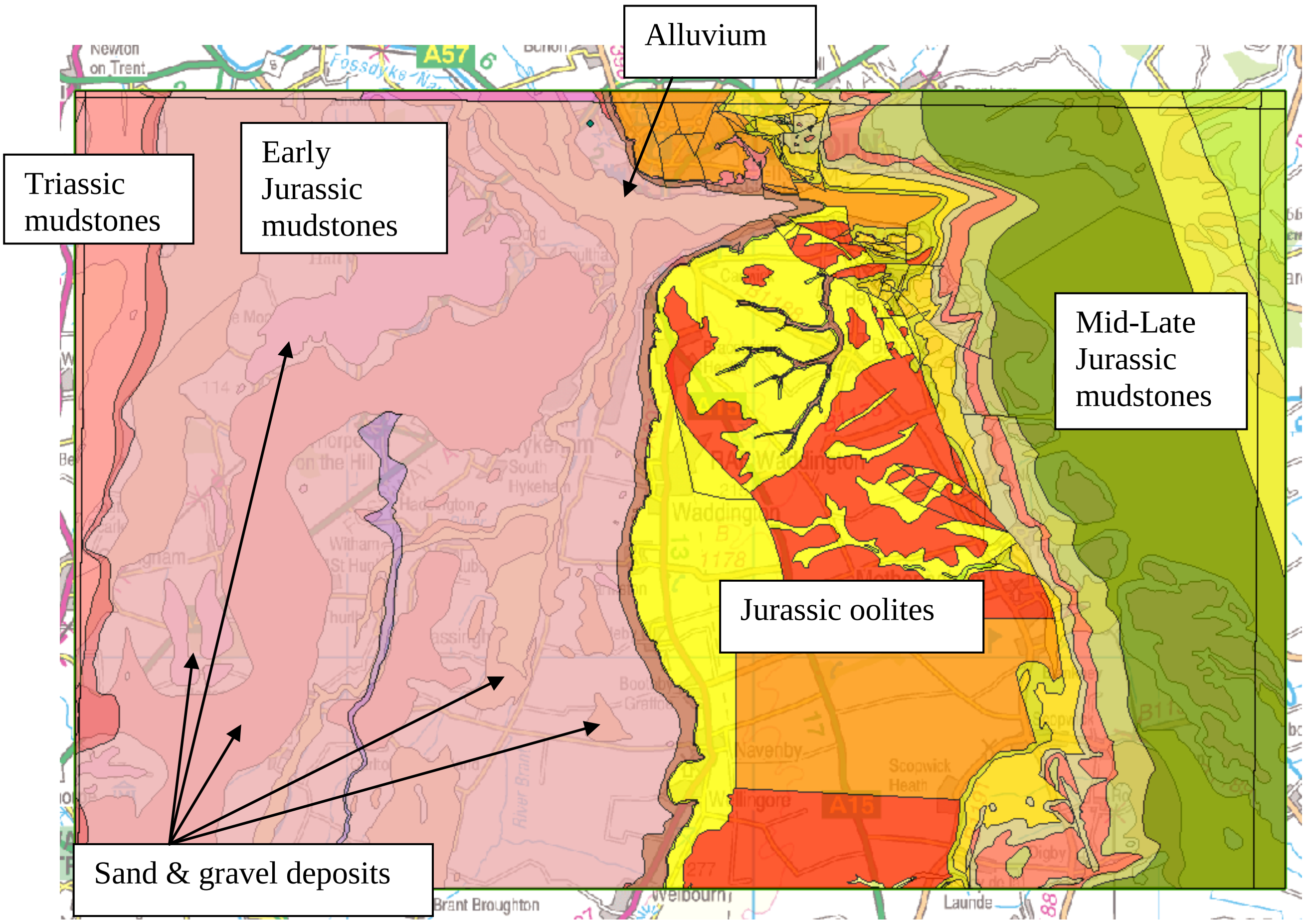


Figure 3. DiGMapGB-V5, 1:50 000 bedrock and superficial geology of the Lincoln Sheet (114).

The geology of the Lincoln sheet area can be roughly divided into four main regions from west to east comprising; the Triassic mudstones and sandstones, the early Jurassic mudstones the Jurassic oolites and the mid to late Jurassic sandstones, siltstones and mudstones.

3.1 TRIASSIC MUDSTONES

The late Triassic deposits in the western part of the district are drained by the Trent and its tributaries. They consist of the Mercia Mudstone Group and Penarth Group mudstones which form low hills along the western margin of the sheet area.

3.2 EARLY JURASSIC MUDSTONES

Moving eastwards, the broad low-lying plain of the Witham valley is underlain by the mudstones of the Lias Group (early Jurassic in age) that consist of the Scunthorpe Mudstone Formation (silty mudstone with thin beds of argillaceous limestone) overlain by the Whitby Mudstone Formation (fossiliferous silty mudstone). Typically, the Whitby Mudstone Formation (Upper Lias of Forster, 1992) consists of over-consolidated, stiff, dark grey, laminated, fissured, silty clay; the weathered zone may extend to a depth of 3.5 – 4.5 metres at outcrop (Forster, 1992).

3.3 JURASSIC OOLITES

The Jurassic rocks in this district contain a variety of lithologies deposited under dominantly marine conditions. The sequence shows an alternation of shales and clays with limestones and ironstones, siltstones and sandstones.

The main part of the Lincolnshire escarpment is formed by the Inferior Oolite Group, which overlies the Whitby Mudstone Formation (Lias Group). This change upwards from the mudstone-dominated Lias Group into a predominantly limestone succession of the Lower Jurassic is the most likely geological combination for potential landslide activity in this area. The underlying mudstones act as an impermeable layer beneath the limestones and sandstones, inhibiting vertical water flow through the strata but concentrating bedding-parallel flow. The mudstones are less competent strata, and the outcrop location on the relatively steep escarpment causes additional instability.

The Inferior Oolite Group in this district is up to 50 metres thick and consists of the basal impersistent Northampton Sand Formation (ironstone and sandstone) overlain by the Grantham Formation, followed by the Lincolnshire Limestone Formation (typically limestones and peloidal wackestones and packstones in the lower part (Lower Lincolnshire Limestone) and high energy ooidal and shell fragmental grainstones in the upper part (Upper Lincolnshire Limestone)). In the Lincoln district the formations have not been distinguished individually but mapped as the 'Grantham Formation and Northampton Sand Formation (Undifferentiated)'. They typically consist of highly weathered yellow-brown clayey silty fine sands with thinly bedded nodular ironstone and clayey laminae. The Lincolnshire Limestone is a moderately strong to strong fine grained oolitic limestone.

The overlying Great Oolite Group, up to 23 metres thick, is a series of inter-bedded limestones mudstones, clay, ironstone, sandstone and siltstone forming the back of the Jurassic escarpment dipping gently the east. The lower boundary is marked by a sharp upward change (unconformity) from an ooidal limestone (Lincolnshire Limestone Formation) into a mudstone, siltstone, limestone and sandstone succession of the Great Oolite Group (Rutland Formation, Blisworth Limestone Formation, Blisworth Clay Formation, and Cornbrash Formation). In this district, the geological map shows numerous faults, predominantly within the Great Oolite Group.

3.4 MID – LATE JURASSIC MUDSTONES

The Great Oolite Group is overlain by the sandstone, siltstones and mudstones of the Ancholme Group. This Group includes the Kellaways Formation which is overlain by the Oxford Clay and

West Walton formations. These deposits form the low land in the east of the district and underlie the broad expanse of the River Witham valley.

4 Landslide distribution

The Varnes (1978) landslide classification was used to classify landslides during the remapping of Lincoln sheet (Appendix 1). Only one landslide had been recorded in the National Landslide Database, and no landslide polygons had been identified on the associated DigMap50-GB mass movement maps.

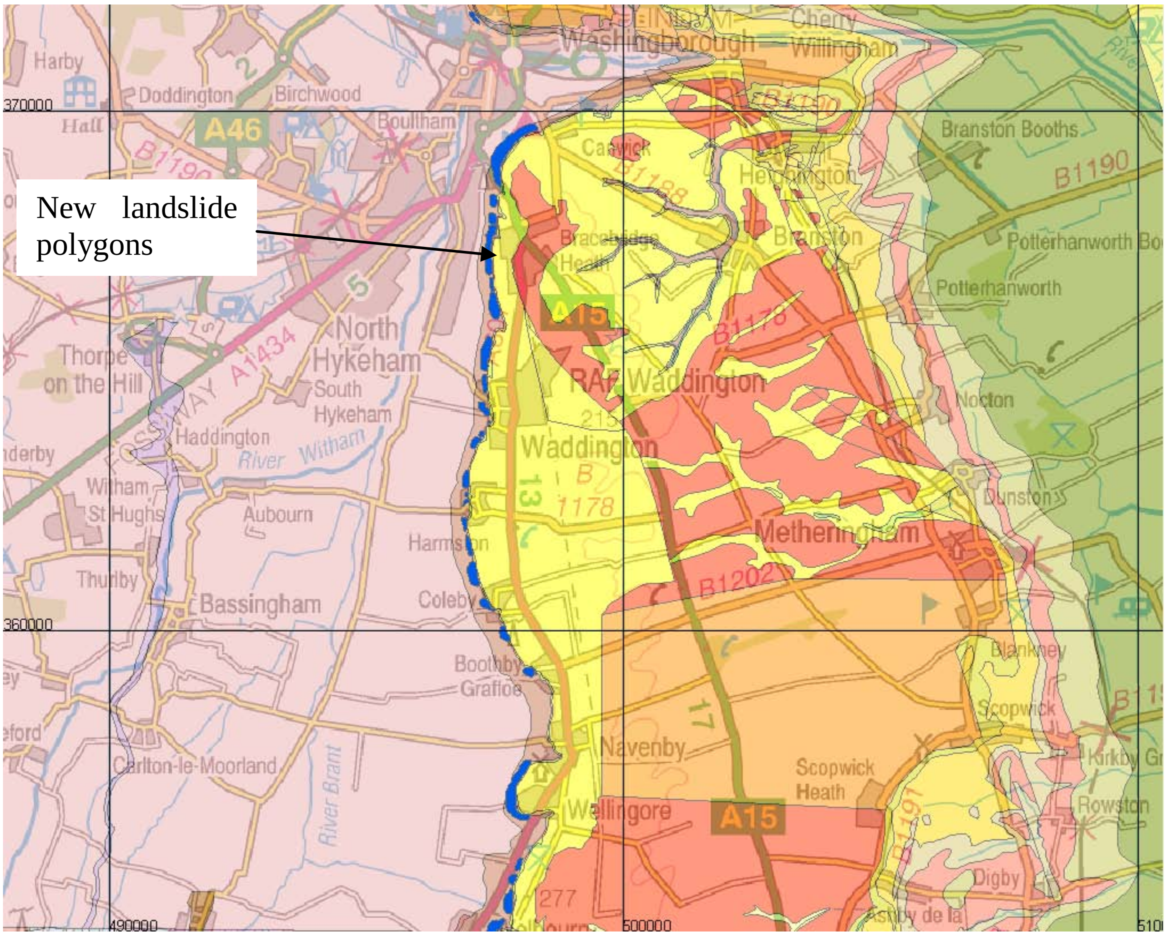


Figure 4. Distribution of landslides in relation to the bedrock geology (landslide polygons in blue) within the Lincoln 1:50 000 geology sheet area.

4.1 NEW LANDSLIDE RECORDS

During the resurvey twenty-nine new landslides were mapped in the Lincoln sheet area (Figure 4). The majority of landslides occur along the main Lincolnshire escarpment in the central part of the district where the Inferior Oolite Group rests on the Whitby Mudstone Formation of the Lias Group (Figure 4). One landslide has been mapped within the Charmouth Mudstone Formation of the Lias Group and one in the Rutland Formation of the Great Oolite Group.

Charmouth Mudstone Formation

Liquorice Park, [497086 371893]

Whitby Mudstone Formation:

Brickyard Plantation, [49702 355218]; South Barn Farm, [497845 354760]; Reservoir Plantation, [498000 355465]; Wellingore, [497895 356845]; Boothby Graffoe Hall, [498226 359296]; Colby 1, [497759 359929]; Colby 2, [497392 360508]; Coleby Hall, [497152 361089]; Belt Plantation, [497039 361639]; Harmston Park, [496952 362105]; Harmston 1, [497001 362519]; Harmston 2, [496975 362623]; Harmston 3, [496996 362895]; Waddington 1, [497161 363595]; Waddington 2, [497288 363774]; Waddington 3, [497424 364014]; Waddington 4, [497389 364223]; Waddington 5, [497355 364739]; Waddington 6, [497391 365300]; Bracebridge 2, [497527 366439]; Bracebridge, [497463 366716]; Churchill Avenue, [497529 367735]; Cross O'Cliff Court, [497529 367927]; Coningsby Crescent, [497548 368274]; South Common, [497728 369156]; Carline Road, [497195 371834]; Carline Road 2, [497330 371759].

Rutland Formation, Great Oolite Group:

Heighington, [502676 369176]

All of these landslides had similar characteristics, they were all multiple or single rotations, with occasional flow characteristics.

A rotational slide is typically the 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.

A flow is typically a movement that resembles a viscous liquid, caused by saturated inter-grain movement predominating over shear surface movements. Initial displacement is usually by sliding, rapidly transforming to flow.

The majority (25) of landslides were highly degraded and estimated to be between 100 and 1000 years old. These landslide events are most likely to have been relatively minor and are unlikely to be of a significant magnitude to have been recorded previously.

One landslide was classified as Ancient/relict, greater than 1000 years old (South Common landslide) and considered to be in a relict condition having occurred under different (probably wetter and colder) climatic conditions to the present time.

Three landslides, situated within the built-up area of Lincoln city, were classified as 'recent' (Liquorice Park, Carline Road and Carline Road 2). These are estimated as less than 100 years old, somewhat degraded but having occurred under current climatic conditions. These landslides were all situated in residential areas and damage to walls and buildings was evident (Figure 5).

Figure 5. Vertical cracks in brickwork of a house walls indicating ground movement. Carline Road, Lincoln [497147 371869].

Figure 6. Typical single rotational slide on the Lincolnshire escarpment, exhibiting backscarp and subdued degraded features [497149 363607]

Figure 7. Subdued, degraded landslide features along the Lincolnshire escarpment, Lincoln cathedral visible in the distance [497569 366310].

5 Landslide analysis

5.1 GEOLOGY AND LANDSLIDE FREQUENCY

When comparing the underlying bedrock geology to landslide distribution, there is a strong correlation between landsliding and the outcrop of the Whitby Mudstone Formation and overlying Grantham and Northampton Sand formations. This geological situation accounts for 93% of the landslides in the Lincoln Sheet area.

Dimensionally, landslides range from larger 1200 m x 240 m to smaller 70 m x 50 m scale, and are generally wider horizontally along the scarp. Most are situated on the north-south trending escarpment, exhibiting degraded hummocky terrain, which occasionally may still have associated small degraded back scarps.

5.2 STYLE AND MECHANISM OF LANDSLIDING

The dominant style of landsliding observed in the Lincoln sheet area was rotational failures. Most commonly these were single rotations, sometimes degrading into flows towards the base. 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 Lincoln area. Water draining from the 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). Flows were only observed towards the base of the larger rotational slides where they formed secondary failures distal from the sources of overlying, more competent sandstone/limestone beds.

5.3 LANDSLIDE AGE AND ACTIVITY

Landslides in the Lincoln area are interpreted to be predominantly between 100 and 1000 years in age. The majority are degraded with features usually quite subtle in the field, and very subtle when viewed using aerial photographs. Very few landslides (six) featured clearly definable backscars. Only three of the 29 landslides observed showed any signs of recent activity (Liquorice Park, [497086 371893], Carline Road, [497195 371834]; Carline Road 2, [497330 371759].). It is believed that these landslides are currently active as a result of loading from overlying buildings, coupled with drainage complications possibly caused by soakaways, broken service pipes and surface sealing (i.e. tarmac roads, driveways etc.) These landslides displayed uneven ground, cracked pavements and cracks in building and garden walls. Much remedial work was evident in the form of rebuilding retention walls.

5.4 LANDSLIDING AND SLOPE ASPECT

Landsliding within the Lincoln district is most common on west-facing slopes (Figure 8). Of the landslides surveyed, 20 had formed on west-facing slopes and 4 on southwest-facing slopes. Two were observed on north-facing and a further two on south-facing slopes. Only one landslide occurred on a northwest-facing slope.

The topography of the central part of the Lincoln sheet displays a relatively steep north-south trending escarpment with an average elevation of 30 metres. Subsequent erosion has occurred relative to the underlying geology. Consequently, a large proportion of the scarp in the region has a west-facing aspect and this has a strong influence on landslide aspect.

The region was extensively glaciated during the Anglian Glaciation (480-430Ka) and possibly afterwards during later Middle Pleistocene glaciations. During the Devensian Glaciation (115-15Ka) the region was subjected to a harsh periglacial climate. During this period slopes would be subject to freeze-thaw conditions coupled with a cold, wet climate which would weaken the bedrock and facilitate landsliding. The glacial erosion and periglacial processes (i.e. freeze-thaw, frost heave, solifluction and gelifluction) active during these glacial periods would have left a 'fresh' scarp face along the escarpment, which has subsequently become susceptible to rotational failure. As other examples have shown, for instance in the Vale of York and the South Downs, failure planes can be initiated during cold periods, and then reactivated on several successive occasions by changes in ground conditions.

In more recent times, periods of prolonged precipitation have caused the reactivation of some ancient failures. The steeper areas are close to their limiting angle of stability. The limestone and sandstone act as aquifers and discharge water into the escarpment at the junction with the impermeable Upper Lias Whitby Mudstone below. The water input to the slope saturates the underlying material, raises the pore water pressure causing a lowering of the effective shear strength and as a result reactivates relict failure planes and initiates landsliding in the weakened and remoulded deposits (Jones and Lee, 1994); further landsliding may take place in the future if the necessary conditions (i.e. long-term climate change, short-term prolonged wet weather or man-made influences) prevail.

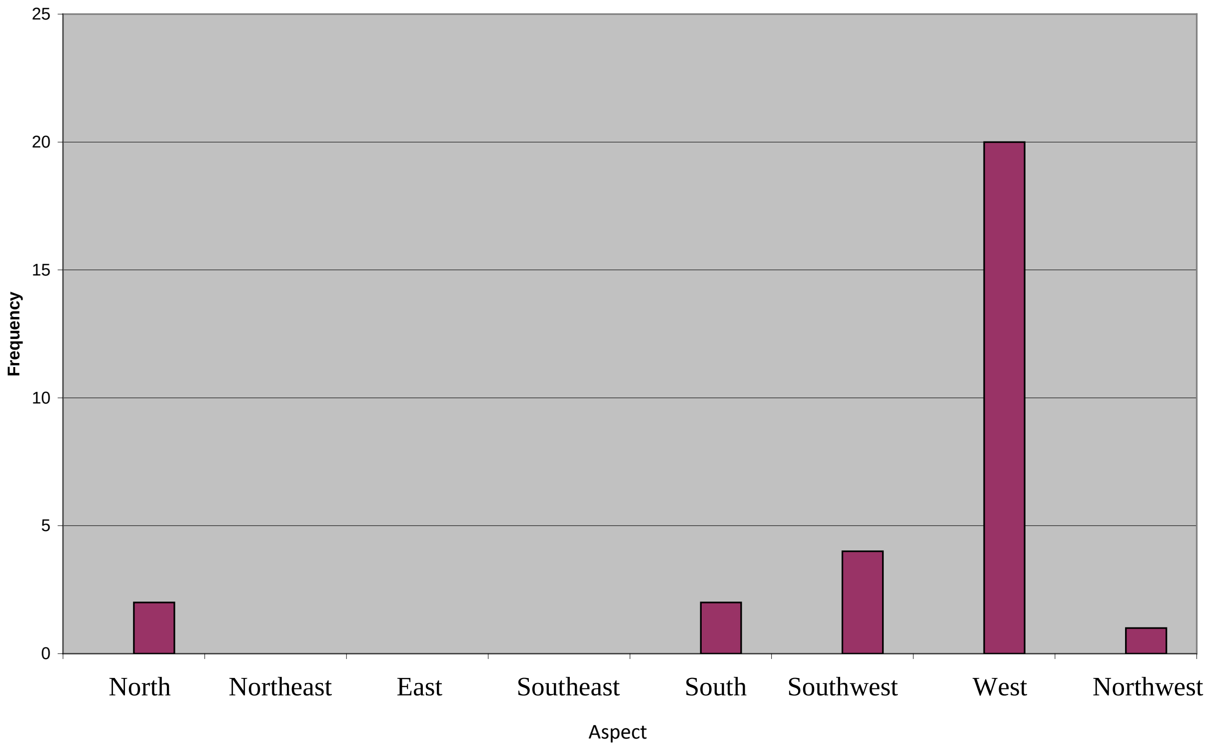


Figure 8. Frequency of landslides relating to aspect on the Lincoln sheet.

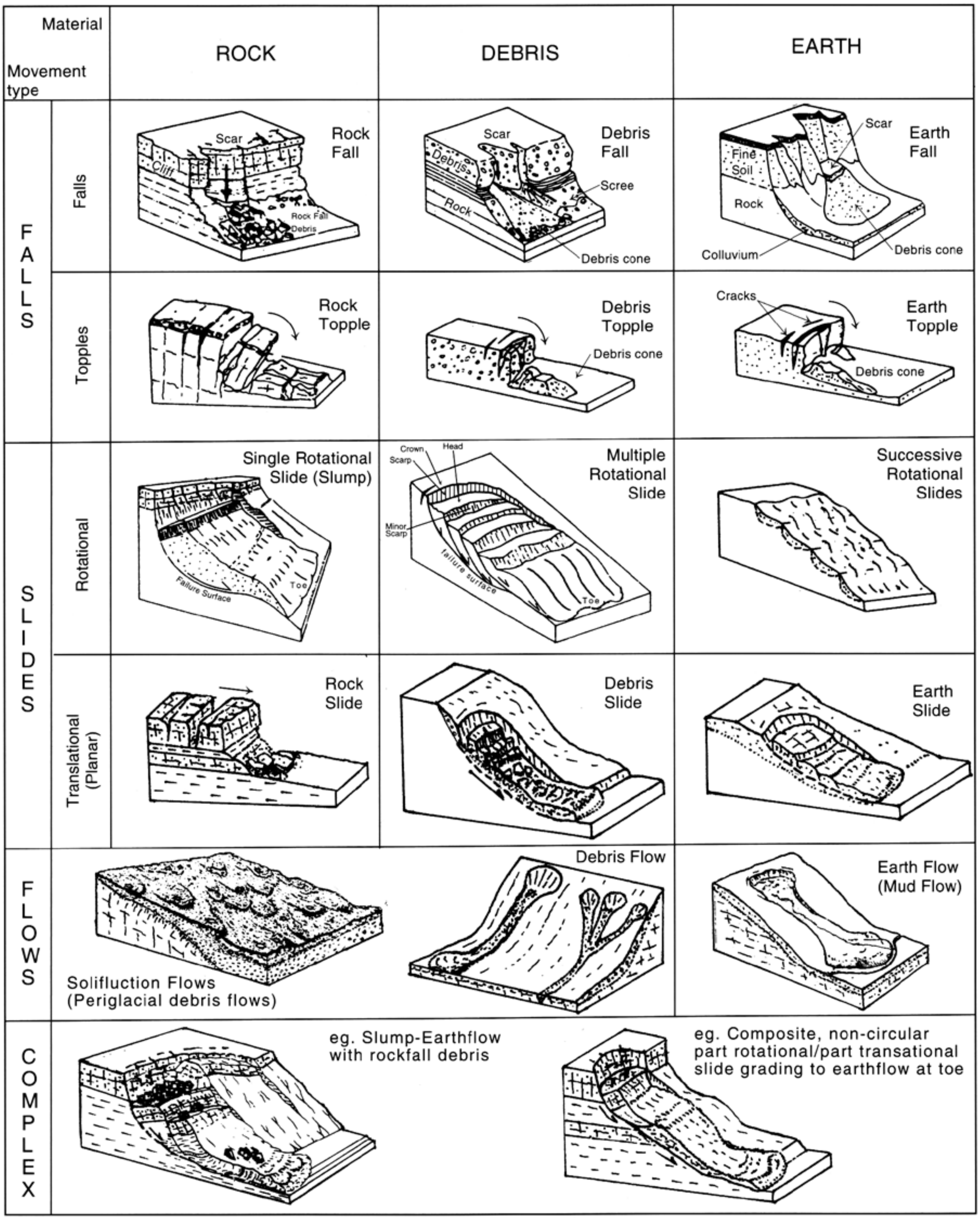
6 Conclusions

Within the Lincoln 1:50 000 map sheet area single rotational slides have been observed to be the dominant landslide style. The Whitby Mudstone Formation and overlying Grantham and Northampton Sand Formations account for the majority of landslides. In terms of aspect, landslides are most frequent on the west-facing escarpment slope. This is probably due to the lithostratigraphy of the area which in combination with local climate and topography has led to increased landsliding on the relatively steeper west-facing slopes.

Landslides in the region are very degraded which is a good indication of their antiquity. The initial period of landslide activity was during the Devensian and Anglian Glaciations when periglacial climatic conditions prevailed. Reactivation of these surfaces may have been caused by climatic conditions such as prolonged periods of precipitation, an increase in water saturation and associated raising of the water table. Only three landslides observed showed signs of recent (<100 years) activity. All of these were located in the urban environment of Lincoln. As a result of this survey 29 new landslide records have been added to the National Landslide Database, and DigMapGB-50 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.

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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