Mass Movements in Great Britain

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Many specialists were involved in the assessment and selection of sites, and this vital work is gratefully acknowledged.

JNCC invited Roger to build on his site-selection work, and to undertake the preparation of a text for publication for JNCC in the late 1990s, and later invited Denys Brunsden to assist Roger during the writing stages of the book in an editorial capacity.

Following Roger's death, Denys kindly took on the job of bringing the book to a publication-ready state, a task which is not to be understated, considering the amount of material that had to be sifted, which Roger had accumulated to inform his writing work. At a late stage in the preparation of the volume for publication, Vincent May, with help from Rebecca Cook (who catalogued Roger's GCR papers) also became involved, helping to ensure that the illustrative material for the book was completed, and providing some editorial input.

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Access to the countryside

This volume is not intended for use as a field guide. The description or mention of any site should not be taken as an indication that access to a site is open. Most sites described are in private ownership, and their inclusion herein is solely for the purpose of justifying their conservation. Their description or appearance on a map in this work should not be construed as an invitation to visit. Prior consent for visits should always be obtained from the landowner and/or occupier.

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Countryside Council for Wales,
Maes-y-Ffynnon,
Penrhosgarnedd,
Bangor,
Gwynedd LL57 2DW.

Natural England,
Northminster House,
Peterborough PE1 1UA.

Scottish Natural Heritage,
Great Glen House,
Leachkin Road
Inverness IV3 8NW.

Foreword

Dr Roger Cooper
1949–2001

Born in Camberley, Surrey, Roger read Geography at the University of Hull. After completing his PhD entitled '*Geomorphological Studies: the Hambleton Hills, North Yorkshire*' in 1979, he joined the Geography Group at the then Dorset Institute of Higher Education in Bournemouth. In 1981, he began the not inconsiderable task of preparing the Landslides (Mass Movements) 'Block' for the Geological Conservation Review (GCR). By the mid-1980s, strategic changes to the departmental and curriculum structure led to Roger enjoying a rare year's sabbatical at Birkbeck College studying Geographical Information Systems under David Rhind (later Director General of the Ordnance Survey). He then provided all GIS teaching in Bournemouth's new and highly regarded MSc in Coastal Zone Management. However, soon after he returned to Bournemouth, Roger's health deteriorated and he had a brain tumour removed in September 1988. He regarded this as merely an inconvenience as he embarked on his contribution to the GCR; over the next twelve years he explored, mapped, investigated and described mass-movement features throughout Great Britain. Roger visited many of the sites identified in his initial consultation with colleagues throughout the world, surveying and mapping some for the first time. Resulting from this work, he produced the original site list that became the Mass Movements GCR Block. He brought to the description and justification for selection of the sites his usual meticulous attention to detail. Neither institutional circumstances nor his health made his task easy. Very few of his colleagues even knew that he was working on it, and yet he persevered, sometimes with little encouragement (since, by the mid-1990s, it was not regarded as relevant to his teaching), apart from those close to him.

Roger had a sharp analytical mind and he used it, not least, to approach institutional decision-making in the same spirit of peer review expected in any scholarly work. This did not always make for easy relationships, but Roger's involvement at a grass-roots level in the developments that led to the rapid transformation from Dorset Institute to Bournemouth University should not be underestimated.

Roger was an enthusiast. He was insatiably curious and enthused colleagues and students alike with a sense of excitement at discovery and gaining understanding. For many years, he edited one of the main journals in cave studies,

'*Studies in Speleology*'. He was deeply involved in the Pengelly Cave Trust and was a caver himself. He explored and described caves on the Isle of Portland that result from the gradual toppling seawards of the limestone. He researched and wrote. When he discovered that his grandfather had been caught up in the Boxer Rebellion in China, he set out to find out about the exact circumstances and published an account of it. When he found out that John Wesley had described a Yorkshire landslide, he went back to the records and worked out how well they helped to date the landslide event.

Roger was principled, caring, precise in all his work and full of sharp wit. But these were nothing without his friendship, his intellectual and physical energy, and his belief in the future: *and* his ability to share those qualities. This volume is an appropriate memorial for a man who was above all a scholar with integrity and a sense of conviction about the place of scholarship in the world.

V.J.May
February 2007

Preface

There is such a diversity of rocks, minerals, fossils and landforms packed into the piece of the Earth's crust we call 'Britain' that it is difficult to be unimpressed by the long, complex history of geological change to which they are testimony. But if we are to improve our understanding of the nature of the geological forces that have shaped our islands, further unravel their history in 'deep time' and learn more of the history of life on Earth, we must ensure that the most scientifically important Earth science sites, which offer us evidence, are conserved for future generations to study, research and enjoy. Moreover, as an educational field resource and as training grounds for new generations of geologists on which to hone their skills, it is essential that such sites continue to remain available for study. The first step in achieving this goal is to identify the key sites, which was a primary aim of the Geological Conservation Review.

The GCR, launched in 1977, is a world-first in the systematic selection and documentation of a country's best Earth science sites. No other country has attempted such a comprehensive and systematic review of its Earth science sites on anything near the same scale. After over two decades of site evaluation, consultation with the scientific community, and site documentation, we now have an inventory of over 3000 GCR sites, selected for 100 categories covering the entire range of the geological and geomorphological features of Britain.

The minimum criterion for GCR site selection was that sites should offer the finest and/or the most representative feature for illustrating a particular aspect of geology or geomorphology. The resulting GCR sites are thus, at the very least, of national scientific importance and many of these include features regarded as either 'classic' (i.e. a 'textbook example'), internationally important or simply 'unique'. Some are, in addition, visually spectacular. Others, though less spectacular, are of considerable importance in demonstrating a particular aspect of geology or geomorphology.

The present volume is the 33rd to be published in the GCR series of books, which will be completed in over 40 volumes. It represents the results of the GCR assessment and selection programme of British Mass Movement sites conducted in the early 1980s, in describing the ultimately selected sites. These localities will be conserved for their contribution to our understanding of mass-movement processes and their manifestations. This volume summarizes the considerable research that has been undertaken on the localities. The book will be invaluable as an essential reference book to those engaged in the study of these sites and will provide a stimulus for further investigation. It will also be helpful to teachers and lecturers and for those people who, in one way or another, have a vested interest in the GCR sites: owners, occupiers, planners and, those concerned with the practicalities of site conservation. The conservation value of the sites is mostly based on a specialist understanding of the Earth science features present and is, therefore, of a technical nature. The account of each site ends, however, with a brief summary of the geomorphological interest, framed in less technical language, in order to help the non-specialist. The first chapter of the volume, used in conjunction with the glossary (contained within Chapter 1), is also aimed at a less specialist audience.

This volume deals with the state of knowledge of the sites available at the time of writing, which for the material written by the late Roger Cooper was between 1996–2000, and it must be seen in this context, although some editorial work was kindly undertaken by the editors to introduce references to more-recent publications about the sites.

However, mass-movements studies, like any other science, are ever-developing, with new discoveries being made, and existing models being subject to continual testing and modification as new data comes to light. Increased or hitherto unrecognized significance may be seen in new sites. Indeed, more recent research into Highland mass movements, separate from the original GCR writing work undertaken by Roger, has provided important new information about Scottish sites, which has been translated into up-to-date text for Chapter 2, and reports in Chapters 4 and 6, by David Jarman and Colin Ballantyne. Therefore, it is possible that further sites worthy of conservation will be identified in future years for the study of mass movements in Britain, as research continues. However, it must be stressed that the GCR is intended to be a *minimalist* scheme, with the selection for the GCR of only the best, most representative, example of a geological feature, rather than the selection of a series of sites showing closely analogous features.

Nevertheless, there is still much to learn about the GCR sites documented here, many of which are as important today – in increasing our knowledge and understanding of mass-movement processes – as they were when they were first selected.

This account will clearly demonstrate the value of British sites to mass-movement studies and the importance of the sites within the wider context of Britain's outstanding scientific and natural heritage.

N.V. Ellis,
GCR Publications Manager
January 2007

Chapter 1

Introduction

R.G. Cooper

MASS MOVEMENTS IN CONTEXT

Mass movements in the British context

Jones and Lee (1994) describe 'mass movement' as 'a broad spectrum of gravity[-driven] slope movements', of which the larger discrete movements are generally described as 'landslides'.

These mass-movement phenomena are a major influence on much of the landscape of Great Britain, but vary considerably in scale. Some mass-movement processes are shallow (operating near the land surface), slow, and affect large areas. For example, 'soil creep' has been taking place on nearly all terrestrial slopes since the retreat of glaciers during the Devensian Stage (the last glacial period of the Pleistocene Epoch in Britain, which ended about 11 500 calendar years ago). Similarly, many landscapes (e.g. Dartmoor) are mantled by 'solifluction' sheets of sediment (slow downslope-moving saturated soil or rock debris), the process that created them usually being ascribed to former periglacial (tundra-like) climatic conditions.

At the other end of the scale are deep-seated 'landslides', whose occurrence under *present* climatic conditions in Britain is relatively rare both areally and temporally (except on particular stretches of the east and south coasts). Many of these have clearly taken place in the past under conditions more conducive to mass movements and are very widespread. These mass-movement features are the principal subject of the present volume.

A study undertaken in 1984–1987 for the former Department of the Environment (DoE) by Geomorphological Services Ltd (GSL; published in 1988) in association with Rendel Palmer & Tritton, that produced an inventory of 8835 landslides in Great Britain has been analysed by Jones and Lee (1994). A major conclusion drawn from the analysis is that most inland landslides in Great Britain are relict but dormant (i.e. capable of being re-activated by engineering works, building or other disruptive activities). In contrast, coastal landsliding is a present-day process, possibly associated with rising sea level and drainage.

A particular value of the inventory has been the provision of information for local and regional planners (Clark *et al.*, 1996), who have to deal with the consequences of landslides – present-day, recent and relict – in relation to land-development applications.

No other Geological Conservation Review (GCR) volume has had the benefit of such a major survey of the features with which it is concerned carried out by another organization at a critically important time. The survey took place around the time of the period of GCR fieldwork in the 1980s. The GSL survey, however, was concerned with landslides that have been mentioned or shown in documents. Therefore it does not purport to be a complete inventory of known landslides in Great Britain. The distribution of landslides identified by the survey, described as 'ancient' and 'youthful', is shown in Figure 1.1.

The present writer (RGC) was involved as a collector of data for north-east England in the GSL exercise, which led to the production of the distribution map (Figure 1.1). It was clear that when plotted on a 1:125 000 scale map, the distribution of reported landslides in north-east England alone was likely to be a very poor representation of the true distribution of landslides actually identifiable in the field. A major reason for this was that landslides were not recorded equally well in the different surveyed areas, creating apparent, but not actual, demarcations of high- and low-density areas of landslides (see below). The demarcations, as recorded in the literature, often correlated to the boundaries between the various map areas of individual British Geological Survey maps, memoirs, and Mineral Assessment Reports. Examples included a cluster of landslides in North Yorkshire immediately west of Ripon, another around Barnard Castle in County Durham, and a group around Bellingham in Northumberland. Since it is unlikely that landslide density correlates to British Geological Survey map-sheet areas, this must indicate unevenness in the documentation between the sheets, memoirs or reports for adjacent areas. There are several reasons for such unevenness:

(a) It is clear that for areas surveyed up to some time in the 1930s, landslides were simply not marked on the resulting published British Geological Survey sheets. Examination of the one-inch sheets of the North York Moors area produced from surveys made by C. Fox-Strangways between 1880 and 1910 reveals no landslides at all. Yet the six-inch maps from which they were

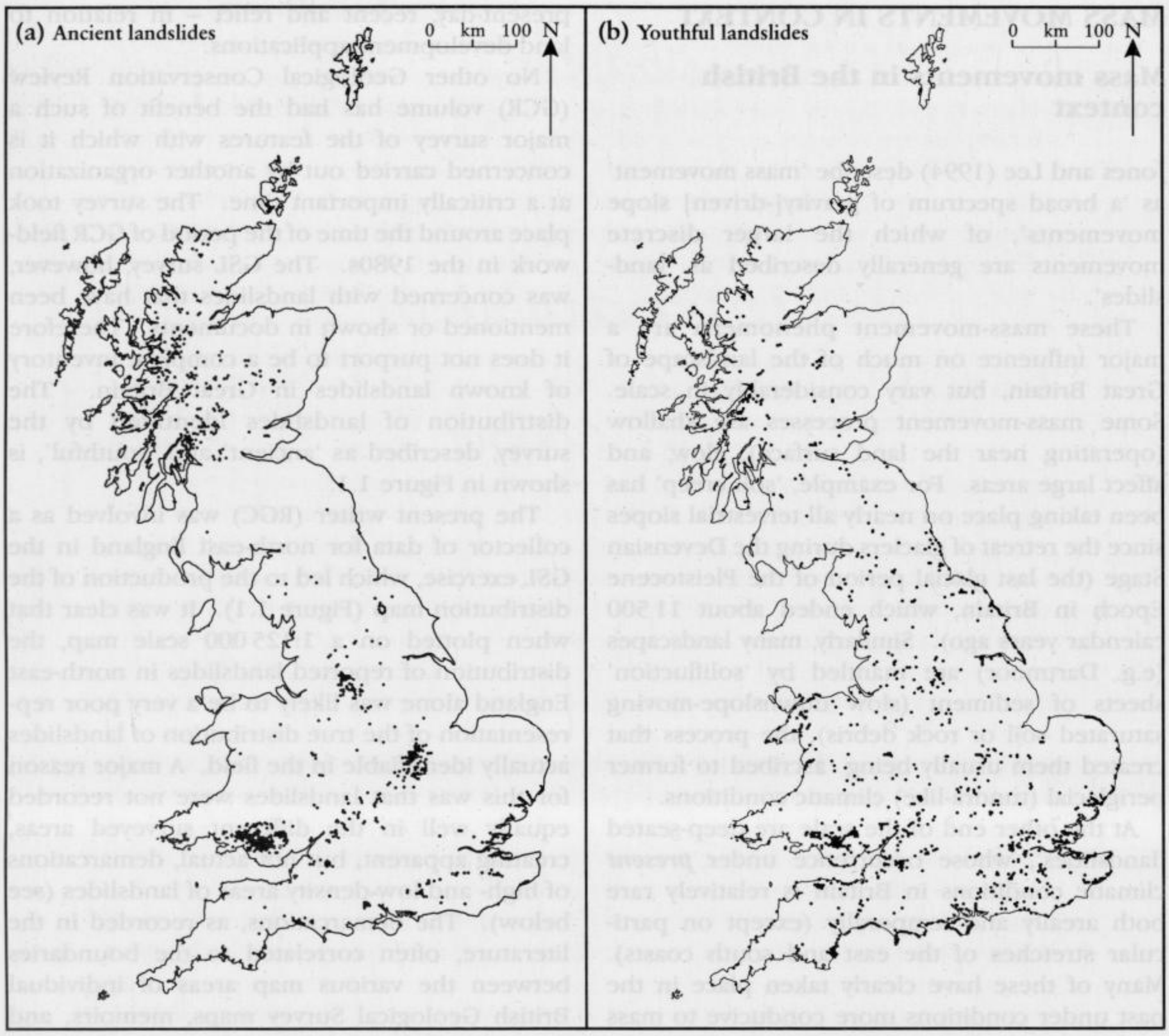

Figure 1.1 The distribution of (a) ancient and (b) youthful landslides in Great Britain recorded as a result of the survey of landslides in Great Britain commissioned by the former Department of the Environment (DoE), and completed by Geomorphological Services Ltd (GSL) between 1984 and 1987. After Jones and Lee (1994).

compiled show a very large number of slides. These do not have marked boundaries: the word 'slip' is written across the relevant slope; nevertheless, they were identified, marked and recorded by the surveyor.

(b) Even though it has been British Geological Survey practice to mark landslides on the one-inch and 1:50 000 sheets, some sheets specifically exclude them. These include one-inch sheet 50 (Hawes), published in 1971, which has a note appended to the legend: 'N.B. Landslips are not indicated on this map'.

(c) The interests and aptitudes of each surveyor have had an influence. About half of the currently available British Geological Survey memoirs have 'landslip' in their indexes. Where they do not, either there are none in the area concerned, or the surveyors were not interested in such phenomena. The latter is the present writer's (RGC's) explanation of the low number of recorded landslides in Nottinghamshire (seven in table 2.2 of Jones and Lee, 1994). The county was surveyed by geologists selected for their expertise in coal and economic geology; landslides were, therefore, not a major concern to them. The memoirs that they produced concentrate heavily on phenomena at depth; surficial geology is assigned a very minor role.

Taking a national view, even where 'landslip' can be found in the index of a British Geological Survey memoir, recorded coverage of such mass movements is very variable. The area under consideration may contain a single large and obvious slide, recorded as such and which a surveyor could hardly fail to mention, but smaller movements in the region may be overlooked or neglected. Alternatively, an area may have no *major* mass movements, but the surveyor may have a particular interest in landslides, perhaps because of Quaternary research interests, and so may record comparatively many more occurrences. Differences in the interests and aptitudes of surveyors is the only tenable explanation of why some of the recently surveyed one-inch and 1:50 000 sheets of Northumberland are replete with landslides (sheet 13 (Bellingham) has 71) while some of the adjacent sheets, with similar geology and comparable terrain – but different surveyors – show none at all.

Similar observations were made about other parts of the country by other collectors of data for the exercise, leading Jones and Lee (1994) to observe that 'the patchiness of the distribution raises questions as to the extent to which the concentrations displayed in the map [here Figure 1.1] reflect the true pattern of landslides on the ground as against spatially variable reporting'. They continue:

'It now seems certain that the pattern merely highlights those landslides which happen to have been investigated, mapped and reported, and the extent to which the total available corporate knowledge of landsliding was tapped by the survey. It is undoubtedly true that many reports of landslides published in obscure journals and old newspapers were not accessed by the survey, and the same is true of the data held in the files of numerous individual professionals, companies and even some national organizations. It must also be stressed that there must be numerous other landslides that have not yet been recorded because they exist in remote areas, are concealed by woodland, are relatively insignificant or have yet to be actually recognized as landslides. This is clearly illustrated by the results of the ... Applied Earth Science Mapping of the Torbay area (1988) which raised the total of known and reported landslides from 4 to 304. Even in the South Wales Coalfield, which has been the subject of a major landslide inventory exercise by the British Geological Survey, a detailed mapping programme in the Rhondda valleys resulted in an increase in the number of recorded landslides from 102 to 346. Clearly, in some areas, the harder you look the more examples you find. Indeed, extrapolation leads to the inevitable conclusion that the actual number of landslides in Great Britain is many times in excess of the 8835 recorded so far by this survey.'

The Torbay study referred to is described in Geomorphological Services Ltd (1988) and Doornkamp (1988). As stated by Jones and Lee (1994), the pattern of landslides displayed on the map (Figure 1.1) must be treated with caution in that it reflects under-representation of the true pattern, as an artefact of investigative interests and recording bias.

Mass movements in the European context

A large amount of research has been carried out on mass movements in Europe, particularly in relation to three broad factors: climate, topography and geology. It is worth noting, however, that this tripartite division does not create exclusive, distinct categories. Geology and topography, in particular, are intimately linked, with the geology (lithology and structure) controlling the topography in some detail. Also, few mass movements can be ascribed to a single causal factor, or even to a single type of causal factor.

(a) Climatic factors

Two initiatives by the European Commission (EC) have been concerned with Europe-wide collection and analysis of data on mass movements: the EPOCH project (Temporal Occurrence and Forecasting of Landslides in the European Community) and the TESLEC project (The Temporal Stability and Activity of Landslides in Europe with Respect to Climatic Change). The EPOCH project collected data on the past occurrence and frequency of landsliding in Europe. The UK EPOCH team then went on to extract from these data changes of geomorphological activity that may be related to climatic change in the last 20 000 years. These results are summarized in Figure 1.2 for Holocene times

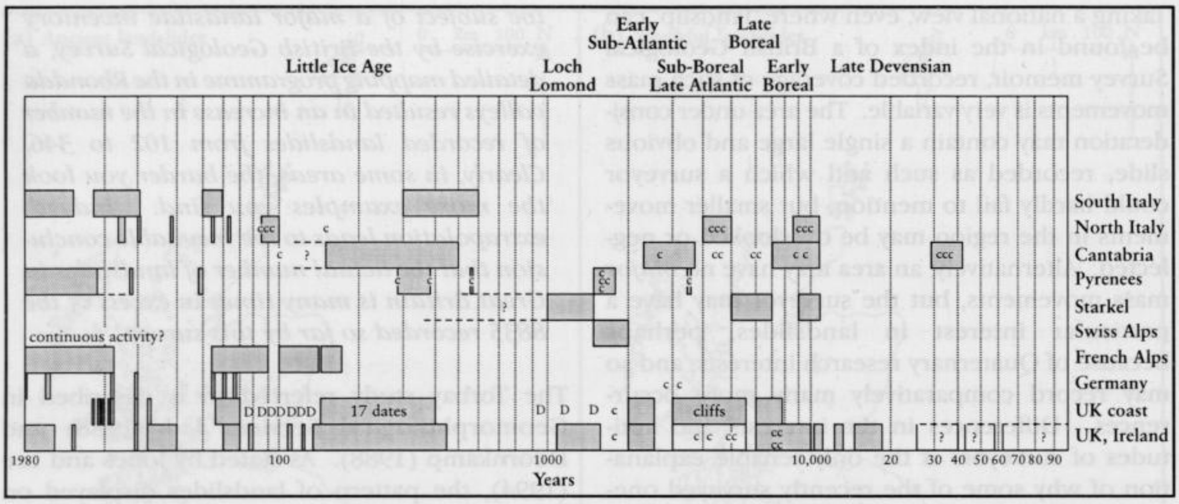

Figure 1.2 Indicative periods of major landslide activity in Europe derived from EPOCH data (c = radiocarbon (C^{14}) dates; D = important individual dates from the historical record). After Brunsden and Ibsen (1997).

based on dates of named landslides in the UK and for selected European countries, respectively (Brunsden and Ibsen, 1997; Ibsen and Brunsden, 1997). They suggest that landslide activity may be related to specific climatic periods and that the existing knowledge of this could be substantially improved.

The TESLEC project has been concerned with the effects and modelling of climate change on mass movements in Europe. This has involved continued collation of data on the past distribution of landslides. This work has shown that there are few decades when landslide events have not occurred in certain regions such as the Spanish Pyrenees and Barcelonette in the French Alps (Brunsden *et al.*, 1996a).

The 'Landslide Recognition' survey (Dikau *et al.*, 1996; the production of the survey was an initial objective of the TESLEC project), and the DoE review revealed that in Great Britain the major problem with respect to climate change scenarios is the potential for the re-activation of dormant landslide complexes, rather than the potential for first-time slides. By far the biggest potential problem is the possibility that climate change might generate widespread movement in the very large landslide complexes that lie at the foot of many of the escarpments in Mesozoic strata. These complexes are, however, rather rare on Chalk, for example the Chiltern Hills, Salisbury Plain and the Marlborough Downs, and along the North and South Downs. However, where clay is exposed at the base of a slope in Chalk strata, occasional landslide complexes are to be found, for example the Castle Hill landslide at the entrance of the Channel Tunnel, the coastal termination of the North Downs at **Folkestone Warren** (see Chapter 7), the Dorset coast, and inland at Birdsall Brow in North Yorkshire.

(b) Topographical factors

The investigations of climatic factors also required other influences on mass movements to be identified, such as unloading, sea-level rise, seasonal ground freezing, and caprock loading (Brunsden and Ibsen, 1997). However, the European chapters of a worldwide survey of the extent and economic significance of landslides (Brabb and Harrod, 1989) point to the over-riding importance of individual high-intensity weather events, rather than climatic trends, as a precipitating factor for many mass movements. As stated, this has happened in Great Britain, but only rarely. However, a landslip in Yorkshire in 1755 took place 149 days after a very high-intensity, short-duration, small area rainfall event. The reason for this time-lag is not known, but it is within the range of flow-through times from precipitation of water on the ground surface to its emergence at groundwater-fed springs in the area. An earthquake can probably be ruled out as the immediate trigger of this landslide (Cooper, 1997).

France (Flageollet, 1989) has important topographical differences from Great Britain, including relatively new mountain ranges with steep, high slopes, such as the Alps and the Pyrenees. This topography leads to a similar range of types of mass movements to Great Britain, but the proportions are different. Particularly instructive are the variations of style of failure along the Bessin Cliffs on the north coast of Normandy, at Pointe du Hoc, Raz de la Percée, le Bouffay, le Chaos and Cap Manvieux (Maquaire and Gigot, 1988).

(c) Geological factors

Generally, where areas of Europe have geological situations not found in Great Britain, they also have types of mass movement not found there. The most obvious case is the quickclay deposits of Norway and Sweden, where marine clays deposited during Holocene times have been uplifted isostatically to become part of the land surface (Gregersen and Sandersen, 1989). Since emerging from the sea, these deposits have been subject to subaerial erosion, and the salt water has leached out from the soil matrix. This leaching increases the sensitivity (s_t) of the clay from, typically, an s_t value of 3–6, to a value greater than $s_t = 20$. When the salt content falls below $1\ g\,l^{-1}$, the clay becomes a quickclay. An unleached marine clay remains plastic on re-moulding, but a quickclay can transform into a liquid (Bjerrum, 1954; Bjerrum *et al.*, 1969).

Norway also has a large area of hard-rock mountains, liable to rockfalls and rockslides, rather like the Scottish Highlands.

Mass movements in the global context

From the global perspective, mass movements in Great Britain are unremarkable for their size, frequency, the hazards they pose, and their overall variety. They are, perhaps, remarkable for the small proportion that are currently active, and conversely for the large proportion that are generally attributed to past climatic conditions rather than those of the present day, in particular periglacial conditions and immediate post-glacial conditions.

The reasons for this limited manifestation of mass movements here are not hard to find. The British Isles are not located close to a tectonic plate boundary, and have not been subject to volcanic activity or significant seismic activity for many millions of years, so these potential triggering mechanisms do not play a major role. Isostatic re-adjustment to the melting of the most recent Quaternary glaciers, and retreat of the last ice-sheet, may still produce minor earthquakes, but these are infrequent, and hardly of significance even in the triggering of the few active mass movements that are located in the Scottish Highlands.

The principal limiting factor for British mass movements seems to be available relief. The highest point in Great Britain, the summit of Ben Nevis, reaches only 1343 m above OD; long, steep slopes are, therefore, something of a rarity. However, Great Britain's steep slopes in upland areas have been the sites of debris flows, but comparatively only a few rockfall avalanches.

Great Britain's temperate maritime climate has seldom produced extremes of rainfall capable of giving rise to a large-scale spate of mass-movement events in an area over a timescale of a few hours. This has been known to happen, for example on Exmoor in August 1952 (Gifford, 1953; Delderfield, 1976), but such events are very uncommon, although climate change may increase their frequency in the future. Likewise, although solifluction has been an important mass-movement process across much of Great Britain, it is only in the extremes of upland Britain that conditions are sufficiently cold for periglacial processes such as solifluction to be currently taking place (Ballantyne and Harris, 1994).

On the other hand, Great Britain has an immense variety of landforms, which occur on bedrock of varied geological age and reflect differences in lithology (rock-type) and geological structure (such as faults and folds). This variety has given rise to slopes that, in valley-sides, expose rocks of greatly varying resistance to erosion, and so produce a variety of degrees of slope steepness. Many slopes of the upland areas have been steepened relatively recently by glacial erosion. Likewise many kilometres of the British coast consist of vertical or sub-vertical cliffs, of variable height. As would be expected, these features have led to the development of a great number of mass-movement sites. While the majority are unremarkable, collectively they demonstrate a variety of features associated with Quaternary erosion, scarp retreat, and landscape shaping.

There is, however, one aspect of the mass movements in Great Britain that has had a substantial, and possibly disproportionate, influence globally. This is their role in the development of knowledge of mass movements, their mechanisms and their countermeasures (Hutchinson, 1984). Thus, one of the mass-movement sites chosen for the GCR includes, arguably, the first ever large-scale landslide to be described by geologists, the Bindon landslide, part of the **Axmouth–Lyme Regis** mass-movement GCR site. In addition, a long series of studies of the behaviour of London Clay (Eocene-age deposits) has illuminated the mass-movement behaviour of all clay strata. More recently, the recognition of toppling as a separate and distinct type of slope failure has depended upon the study of British examples.

CLASSIFICATION OF MASS-MOVEMENT TYPES

The classification of mass movements into types has attracted much attention since the suggestions made in 1938 by Sharpe. Classification is dealt with in some detail in the present chapter. However, characterizing landslide type, while important scientifically, has not been the sole consideration in the selection of mass-movement GCR sites, some of which were selected on the basis of the presence at a site of an atypical or otherwise particularly interesting feature or group of features.

The classification system of mass-movement features adopted for the purposes of selecting mass-movement GCR sites in the 1980s, was originally that of Hutchinson (1968a), the overall breadth of which, including creep, frozen-ground phenomena and landsliding, indicated a convenient scope to adopt for the term 'mass movement' (Table 1.1a). Hutchinson (1968a) makes a most significant point about mass movement: 'mass movements exhibit great variety, being affected by geology, climate and topography, and their rigorous classification is hardly possible'.

Despite this general proviso, several classifications were published in the 1970s, 1980s and 1990s, including those of Zaruba and Mencl (1969), Varnes (1978), Brunsden (1979), Selby (1982), Geomorphological Services Ltd (in Jones and Lee, 1994), Hutchinson (1988; see Table 1.1b) and most notably *The Multilingual Landslide Glossary* developed by the International Geotechnical Societies' UNESCO Working Party for World Landslide Inventory (WP/WLI, 1993; see below, where the glossary is reproduced in full). Where possible the recommendations and terminology of this last-mentioned group are now used throughout this volume in order to follow international practice.

All such classifications are to some extent imperfect, in that any classification of mass movements is essentially trying to divide a continuum into classes, raising the obvious difficulty of locating the distinguishing boundaries between types. Furthermore, many sites incorporate a number of different features of a variety of mass-movement types belonging to different classes. Thus placing sites into a particular category is subject to opinion.

The introduction to Chapter 2 of the present volume addresses this difficulty in respect of the old hard rocks of the British mountains, adapting the Hutchinson (1988) schema to more specific circumstances.

Arguably, the classification used by civil engineers gives perhaps the most clearly defined and separate 'types', as it is a classification not of mass-movement types, but of *failure* types (e.g. in Hoek and Bray, 1977).

The Multilingual Landslide Glossary

The Multilingual Landslide Glossary is an international standard for the description of landslides (WP/WLI, 1993; Cruden *et al.*, 1994). Its English version is given here in full (see also Dikau *et al.*, 1996). The glossary is available in Arabic, Chinese, English, French, German, Hindi, Italian, Japanese, Persian, Russian, Spanish, Sinhala, and Tamil. While giving a comprehensive glossary of terms for the various features of a landslide (Figures 1.3 and 1.4), it also divides landslides into five types: fall, topple, slide, spread and flow (Figure 1.5). Each of these types is modified by other qualities, of which two are of particular relevance to the classification: distribution of activity (seven qualifiers of type; Table 1.1b, Figure 1.6), and style of activity (five qualifiers of type; Figure 1.7). This leaves two that are of less relevance to classification of 'type': dimensions (Figure 1.8), and state of activity (see Figure 1.5).

Therefore there are 175 ($5 \times 7 \times 5$) theoretically possible types. Of these, the editors and contributors to *Landslide Recognition* (Dikau *et al.*, 1996) choose to describe 15, which leaves one to speculate on the actual existence of field examples of the remaining 160.

Table 1.1 (a) Hutchinson's classification of mass movements on slopes (1968a); (b) Hutchinson's (1988) classification (first two levels only).

(a)

CREEP	(1) Shallow, predominantly seasonal creep	
		(a) Soil creep
		(b) Talus creep
	(2) Deep-seated continuous creep; mass creep	
	(3) Progressive creep	
FROZEN GROUND PHENOMENA	(4) Freeze–thaw movements	
		(a) Solifluction
		(b) Cambering and valley-bulging
		(c) Stone streams
		(d) Rock glaciers
LANDSLIDES	(5) Translational slides	
		(a) Rock slides; block glides
		(b) Slab, or flake slides
		(c) Detritus, or debris slides
		(d) Mudflows
		(i) Climatic mudflows
		(ii) Volcanic mudflows
		(e) Bog flows; bog bursts
		(f) Flow failures
		(i) Loess flows
		(ii) Flow slides
	(6) Rotational slips	
		(a) Single rotational slips
		(b) Multiple rotational slips
		(i) in stiff, fissured clay
		(ii) in soft, extra-sensitive clays; clay flows
		(c) Successive, or stepped rotational slips
	(7) Falls	
		(a) Stone and boulder falls
		(b) Rock and soil falls
	(8) Sub-aqueous slides	
		(a) Flow slides
		(b) Under-consolidated clay slides

(b)

A	Rebound		
		1	Movements associated with man-made excavations
		2	Movements associated with naturally eroded valleys
B	Creep		
		1	Superficial, predominantly seasonal creep; mantle creep
		2	Deep-seated, continuous creep; mass creep
		3	Pre-failure creep; progressive creep
		4	Post-failure creep
C	Sagging of mountain slopes		
		1	Single-sided sagging associated with the initial stages of landsliding
		2	Double-sided sagging, associated with the initial stages of double landsliding, leading to ridge spreading
		3	Sagging associated with multiple toppling
D	Landslides		
		1	Confined failures
		2	Rotational slips
		3	Compound failures (markedly non-circular, with listric or bi-planar slip)
		4	Translational slides
E	Debris movements of flow-like form		
		1	Mudslides (non-periglacial)
		2	Periglacial mudslides (gelifluction of clays)
		3	Flow slides
		4	Debris flows, very to extremely rapid flows of wet debris
		5	Sturzstroms, extremely rapid flows of dry debris
F	Topples		
		1	Topples bounded by pre-existing discontinuities
		2	Topples released by tension failure at rear of mass
G	Falls		
		1	Primary, involving fresh detachment of material; rock and soil falls
		2	Secondary, involving loose material, detached earlier; stone falls
H	Complex slope movements		
		1	Cambering and valley-bulging
		2	Block-type slope movements
		3	Abandoned clay cliffs
		4	Landslides breaking down into mudslides or flows at the toe
		5	Slides caused by seepage erosion
		6	Multi-tiered slides
		7	Multi-storeyed slides

Landslide features (Figure 1.3)

(1) ***Crown***: the practically undisplaced material still in place and adjacent to the highest parts of the *main scarp* (2).
(2) ***Main scarp***: a steep surface on the undisturbed ground at the upper edge of the landslide, caused by movement of the *displaced material* (13) away from the undisturbed ground. It is the visible part of the *surface of rupture* (10).
(3) ***Top***: the highest point of contact between the *displaced material* (13) and the *main scarp* (2).
(4) ***Head***: the upper parts of the landslide along the contact between the *displaced material* (13) and the *main scarp* (2).
(5) ***Minor scarp***: a steep surface on the *displaced material* (13) of the landslide produced by differential movements within the *displaced material* (13).
(6) ***Main body***: the part of the *displaced material* (13) of the landslide that overlies the *surface of rupture* (10) between the *main scarp* (2) and the *toe of the surface of rupture* (11).
(7) ***Foot***: the portion of the landslide that has moved beyond the *toe of the surface of rupture* (11) and overlies the *original ground surface* (20).
(8) ***Tip***: the point on the *toe* (9) farthest from the *top* (3) of the landslide.
(9) ***Toe***: the lower, usually curved margin of the *displaced material* (13) of a landslide; it is the most distant margin of the landslide from the *main scarp* (2).
(10) ***Surface of rupture***: the surface that forms (or which has formed) the lower boundary of the *displaced material* (13) below the *original ground surface* (20).
(11) ***Toe of the surface of rupture***: the intersection (usually buried) between the lower part of the *surface of rupture* (10) and the *original ground surface* (20).
(12) ***Surface of separation***: the part of the *original ground surface* (20) overlain by the *foot* (7) of the landslide.
(13) ***Displaced material***: material displaced from its original position on the slope by movement in the landslide. It forms the *depleted mass* (17) and the *accumulation* (18).

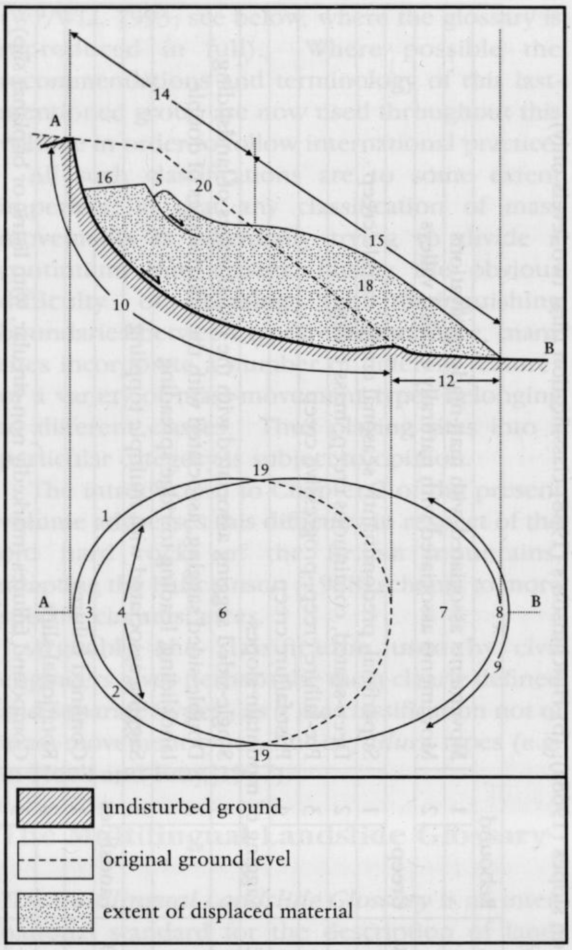

Figure 1.3 Terminology of landslides used in *The Multilingual Landslide Glossary*; profile and plan views. See text for explanation of numbers. After WP/WLI (1993).

(14) ***Zone of depletion***: the area of the landslide within which the *displaced material* (13) lies below the *original ground surface* (20).
(15) ***Zone of accumulation***: the area of the landslide within which the *displaced material* (13) lies above the *original ground surface* (20).
(16) ***Depletion***: the volume bounded by the *main scarp* (2), the *depleted mass* (17), and the *original ground surface* (20).
(17) ***Depleted mass***: the volume of the *displaced material* (13) which overlies the *surface of rupture* (10) but underlies the *original ground surface* (20).

(18) ***Accumulation***: the volume of the *displaced material* (13) which lies above the *original ground surface* (20).

(19) ***Flank***: the undisplaced material adjacent to the sides of the *surface of rupture* (10). Compass directions are preferable in describing the flanks, but if left and right are used, they refer to the flanks as viewed from the *crown* (1).

(20) ***Original ground surface***: the surface of the slope that existed before the landslide took place.

Landslide dimensions (Figure 1.4)

(1) The ***width of the displaced mass***, *Wd*, is the maximum breadth of the displaced mass perpendicular to the *length of the displaced mass*, *Ld* (4).

(2) The ***width of the rupture surface***, *Wr*, is the maximum width between the flanks of the landslide, perpendicular to the *length of the rupture surface*, *Lr* (5).

(3) The ***total length***, *L*, is the minimum from the tip of the landslide to the crown.

(4) The ***length of the displaced mass***, *Ld*, is the minimum distance from the tip to the top.

(5) The ***length of the rupture surface***, *Lr*, is the minimum distance from the toe of the surface of rupture to the crown.

(6) The ***depth of the displaced mass***, *Dd*, is the maximum depth of the displaced mass, measured perpendicular to the plane containing *Wd* (1) and *Ld* (4).

(7) The ***depth of the rupture surface***, *Dr*, is the maximum depth of the rupture surface below the original ground surface measured perpendicular to the plane containing *Wr* (2) and *Lr* (5).

Types of landslides (Figure 1.5)

(1) A ***fall*** starts with detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place. The material then descends largely through the air by falling, saltation or rolling.

(2) A ***topple*** is the forward rotation, out of the slope, of a mass of soil or rock about a point or axis below the centre of gravity of the displaced mass.

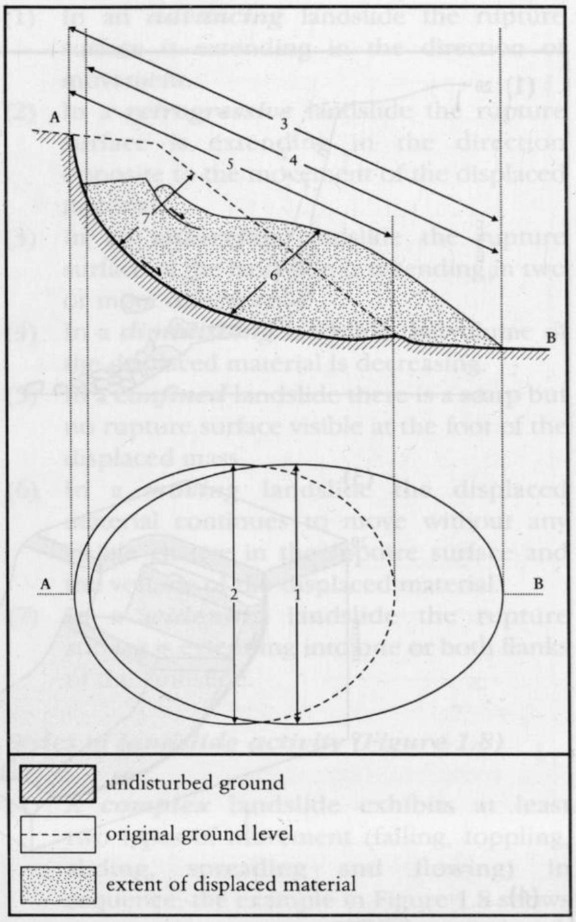

Figure 1.4 Landslide dimensions recommended in *The Multilingual Landslide Glossary*. See text for explanation of numbers. Based on WP/WLI (1993) and Cruden *et al.* (1994).

(3) A ***slide*** is the downslope movement of a soil or rock mass occurring dominantly on surfaces of rupture or relatively thin zones of intense shear strain.

(4) A ***spread*** is an extension of a cohesive soil or rock mass combined with a general subsidence of the fractured mass of cohesive material into softer underlying material. The rupture surface is not a surface of intense shear. Spreads may result from the liquefaction or flow (and extrusion) of the softer material.

(5) A ***flow*** is a spatially continuous movement in which surfaces of shear are short-lived, closely spaced and usually preserved. The distribution of velocities in the displacing mass resembles that in a viscous fluid.

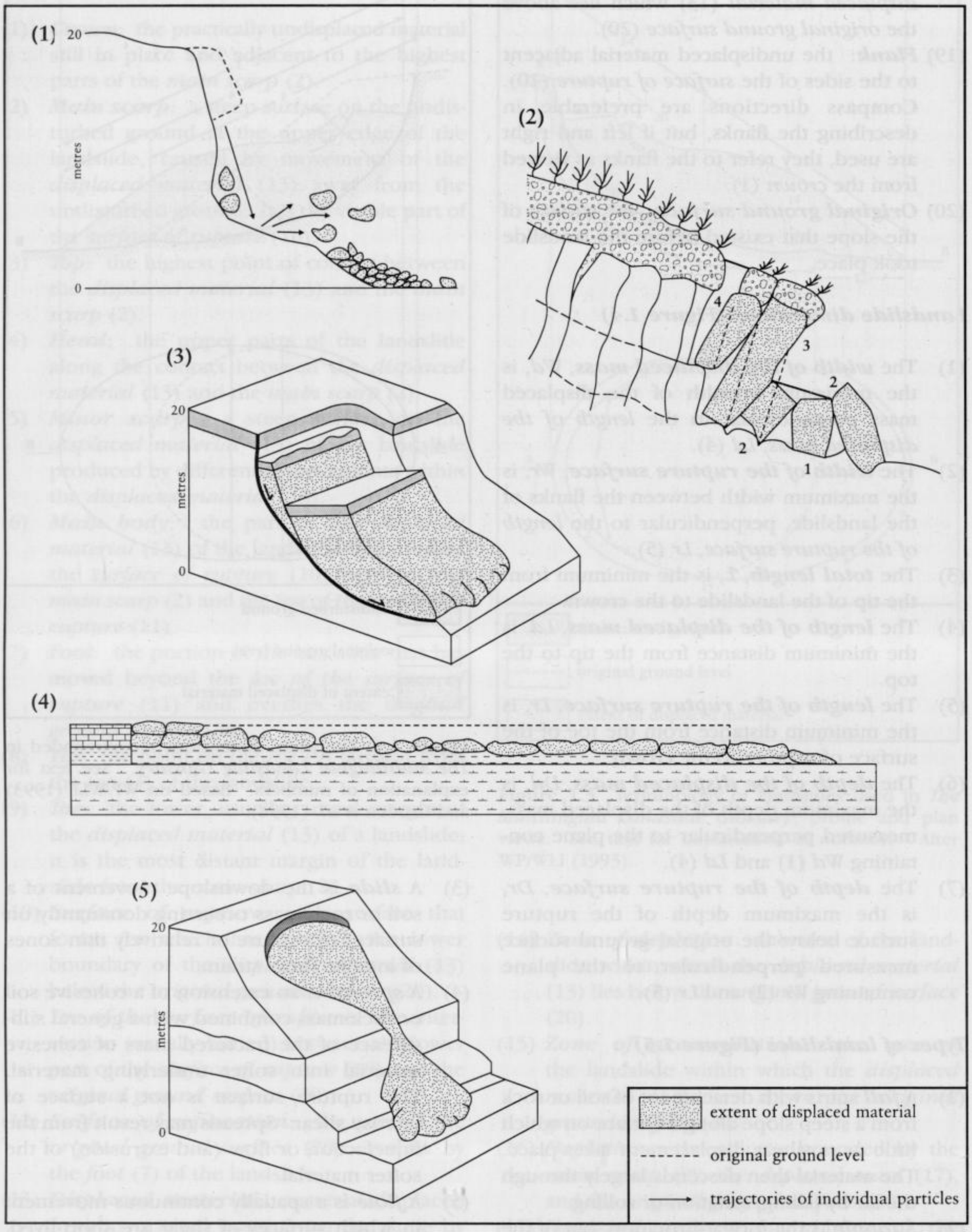

Figure 1.5 Types of landslides: (1) a fall; (2) a topple; (3) a slide; (4) a spread; (5) a flow. See text for explanation of types. After WP/WLI (1993).

States of activity of landslides (Figure 1.6)

(1) An ***active*** landslide is currently moving; the example in Figure 1.6 shows that erosion at the toe of the slope causes a block to topple.
(2) A ***suspended*** landslide has moved within the last 12 months, but is not *active* (1) at present; the example in Figure 1.6 shows local cracking in the crown of the topple.
(3) A ***re-activated*** landslide is an *active* (1) landslide which has been *inactive* (4); the example in Figure 1.6 shows that another block topples, disturbing the previously displaced material.
(4) An ***inactive*** landslide has not moved within the last 12 months and can be divided into four states: (5) *dormant*, (6) *abandoned*, (7) *stabilized*, and (8) *relict*.
(5) A ***dormant*** landslide is an *inactive* (4) landslide which can be *re-activated* (3) by its original causes or by other causes; the example in Figure 1.6 shows that the displaced mass begins to regain its tree cover, and scarps are modified by weathering.
(6) An ***abandoned*** landslide is an *inactive* (4) landslide which is no longer affected by its original causes; the example in Figure 1.6 shows that fluvial deposition has protected the toe of the slope; the scarp begins to regain its tree cover.
(7) A ***stabilized*** landslide is an *inactive* (4) landslide which has been protected from its original causes by remedial measures; the example in Figure 1.6 shows that a wall protects the toe of the slope.
(8) A ***relict*** landslide is an *inactive* (4) landslide which developed under climatic or geomorphological conditions considerably different from those at present; the example in Figure 1.6 shows that uniform tree cover has been established.

Distribution of activity in landslides (Figure 1.7)

Section 2 in each part of Figure 1.7 shows the slope after movement on the rupture surface indicated by the shear arrow in the section.

(1) In an ***advancing*** landslide the rupture surface is extending in the direction of movement.
(2) In a ***retrogressive*** landslide the rupture surface is extending in the direction opposite to the movement of the displaced material.
(3) In an ***enlarging*** landslide the rupture surface of the landslide is extending in two or more directions.
(4) In a ***diminishing*** landslide the volume of the displaced material is decreasing.
(5) In a ***confined*** landslide there is a scarp but no rupture surface visible at the foot of the displaced mass.
(6) In a ***moving*** landslide the displaced material continues to move without any visible change in the rupture surface and the volume of the displaced material.
(7) In a ***widening*** landslide the rupture surface is extending into one or both flanks of the landslide.

Styles of landslide activity (Figure 1.8)

(1) A ***complex*** landslide exhibits at least two types of movement (falling, toppling, sliding, spreading and flowing) in sequence; the example in Figure 1.8 shows gneiss and a pegmatite vein toppled with valley incision. Alluvial deposits fill the valley bottom. After weathering had weakened the toppled material, some of the displaced mass slid farther downslope.
(2) A ***composite*** landslide exhibits at least two types of movement simultaneously in different parts of the displacing mass; the example in Figure 1.8 shows that limestones have slid on the underlying shales causing toppling below the toe of the slide rupture surface.
(3) A ***successive*** landslide is the same type as a nearby, earlier landslide, but does not share displaced material or rupture surface with it; the example in Figure 1.8 shows that the latter slide, AB, is the same type as CD, but does not share displaced material or a rupture surface with it.
(4) A ***single*** landslide is a single movement of displaced material.
(5) A ***multiple*** landslide shows repeated development of the same type of movement.

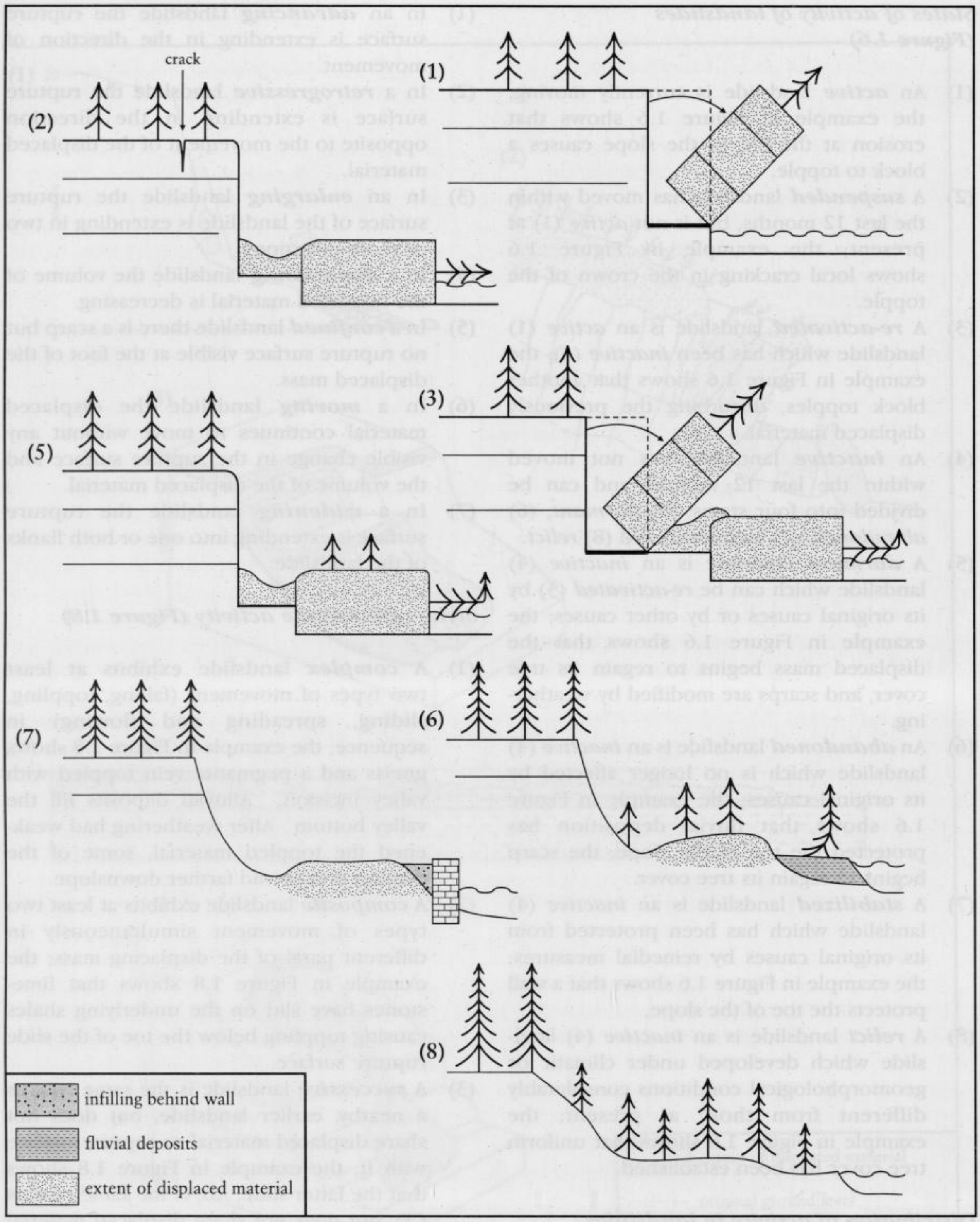

Figure 1.6 Classification of the states of activity of landslides used in the *Multilingual Landslide Glossary*: (1) active; (2) suspended; (3) re-activated; (5) dormant; (6) abandoned; (7) stabilized; (8) relict. State (4) inactive is divided into states (5)–(8). See text for explanation of states. After WP/WLI (1993).

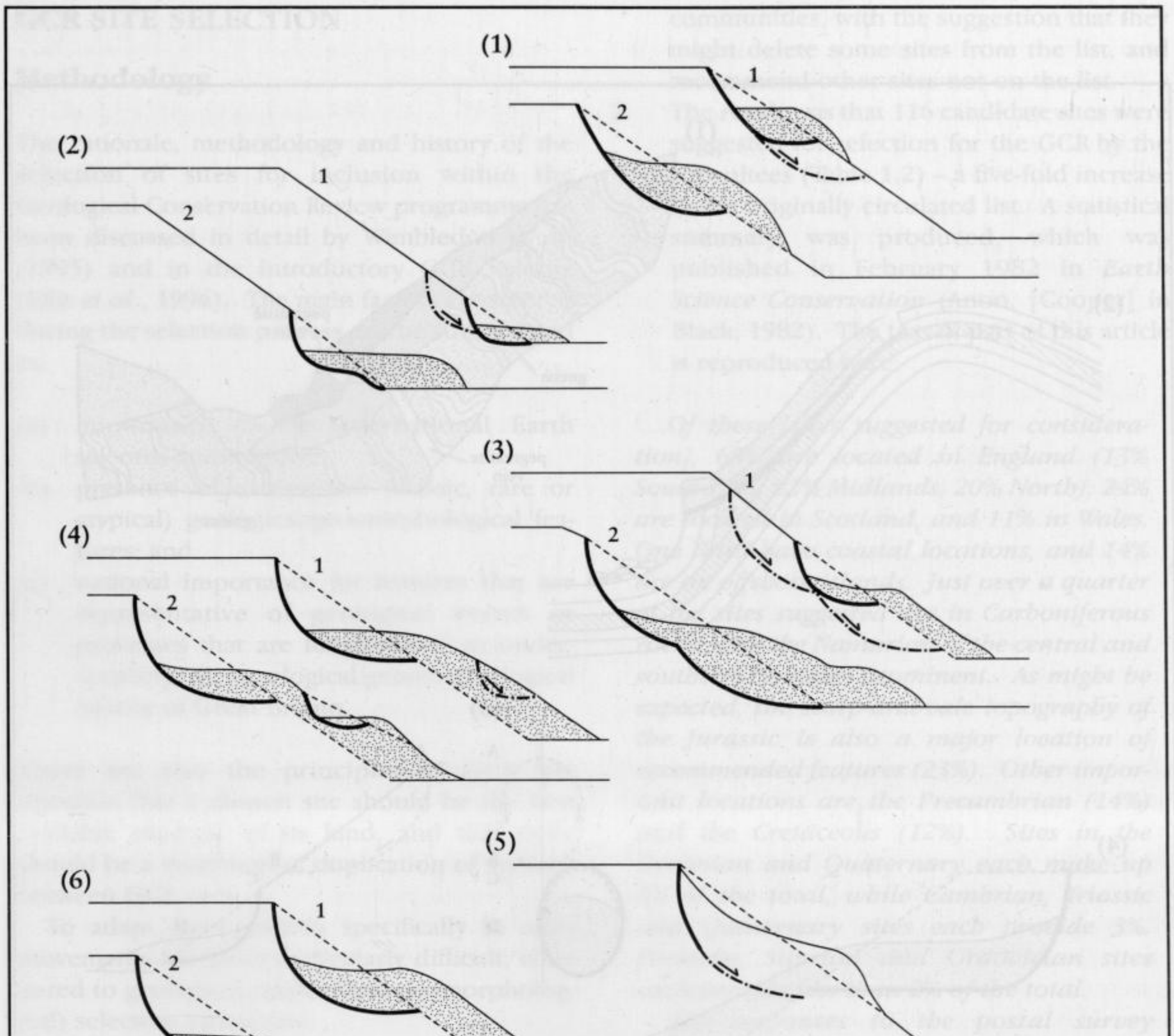

Figure 1.7 Distribution of the activity of landslides: (1) advancing; (2) retrogressive; (3) enlarging; (4) diminishing; (5) confined; (6) moving; (7) widening. See text for explanation of terms. After WP/WLI (1993).

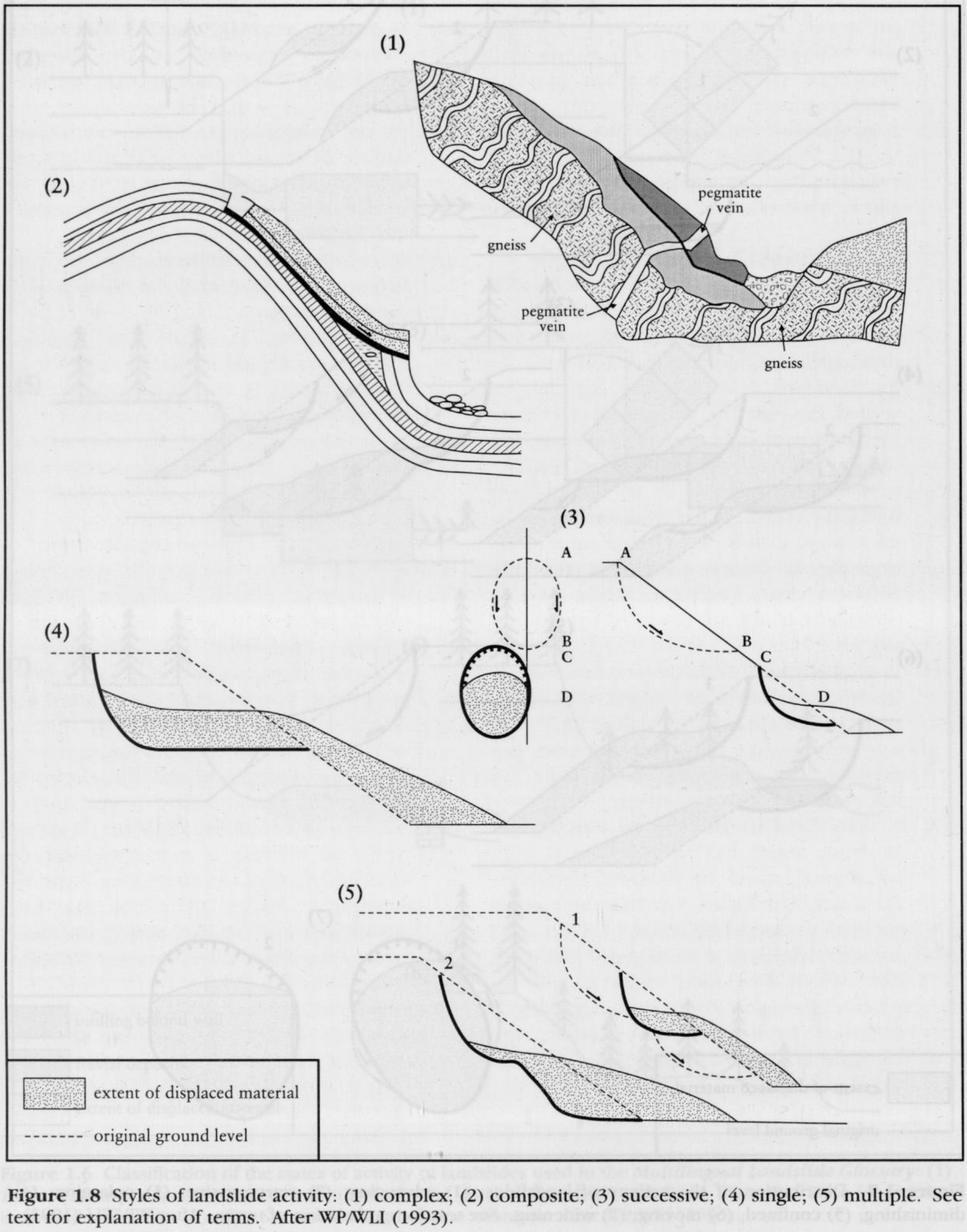

Figure 1.8 Styles of landslide activity: (1) complex; (2) composite; (3) successive; (4) single; (5) multiple. See text for explanation of terms. After WP/WLI (1993).

GCR SITE SELECTION

Methodology

The rationale, methodology and history of the selection of sites for inclusion within the Geological Conservation Review programme has been discussed in detail by Wimbledon *et al.* (1995) and in the introductory GCR volume (Ellis *et al.*, 1996). The main factors considered during the selection process can be summarized as:

(a) importance to the international Earth scientist community;
(b) presence of exceptional (classic, rare or atypical) geological/geomorphological features; and
(c) national importance for features that are representative of geological events or processes that are fundamental to understanding the geological/geomorphological history of Great Britain.

There are also the principles in GCR site selection that a chosen site should be the best available example of its kind, and that there should be a minimum of duplication of features between GCR sites.

To adapt these criteria specifically to mass movements has been particularly difficult, compared to geological (rather than geomorphological) selection categories.

Given Hutchinson's (1968a) classification, *one* particular 'type' of mass movement might be represented by *several* sites to show the different circumstances in which that 'type' typically occurs. However, during original GCR site selection it was not envisaged that, for example, the 'type' called 'rotational slips' would be represented in the ultimate GCR register by an example in strata from each of the geological periods, or in each region of the country, in which that type is found. Using the GCR ethos (Wimbledon *et al.*, 1995; Ellis *et al.*, 1996), the method of GCR site selection followed for mass movements was that set out below.

1. A first-tranche list of 23 candidate GCR sites was assembled, following literature survey and initial research. This list was circulated to relevant members of the geological, geomorphological and civil engineering communities, with the suggestion that they might delete some sites from the list, and recommend other sites not on the list.
2. The result was that 116 candidate sites were suggested for selection for the GCR by the consultees (Table 1.2) – a five-fold increase in the originally circulated list. A statistical summary was produced, which was published in February 1982 in *Earth Science Conservation* (Anon. [Cooper] in Black, 1982). The text of part of this article is reproduced here:

'...*Of these [sites suggested for consideration], 65% are located in England (13% South-East, 22% Midlands, 20% North), 24% are located in Scotland, and 11% in Wales. One third have coastal locations, and 14% are on offshore islands. Just over a quarter of the sites suggested are in Carboniferous rocks, with the Namurian of the central and southern Pennines prominent. As might be expected, the scarp-and-vale topography of the Jurassic is also a major location of recommended features (23%). Other important locations are the Precambrian (14%) and the Cretaceous (12%). Sites in the Devonian and Quaternary each make up 6% of the total, while Cambrian, Triassic and Quaternary sites each provide 3%. Permian, Silurian and Ordovician sites each provide less than 2% of the total.*

The responses to the postal survey exposed several general problems associated with site selection. Firstly, there is the problem of the transience of most medium- and small-scale mass movement phenomena. Features which yield valuable information and are educationally instructive immediately after the mass movement has taken place, may after a few years become totally obscured by the smaller-scale processes that tend to even-out irregularities on slopes. In other words, the value of such sites often resides in their freshness. There would be little point in selecting for conservation sites which are unlikely to persist, since, unlike quarry sections, mass movement sites can seldom be 'cleaned up' without destroying those features in which their academic interest resides. Secondly, the well-known mass movement classifications of Hutchinson and of Varnes include types

Table 1.2 The candidate mass-movement GCR sites suggested by the panel of experts consulted in the 1980s.

Southern England	English Midlands	Northern England	Wales	Scotland
Axminster	Alport Castles	Askrigg	Aberfan–Cilfynydd	An Teallach
Axmouth–Lyme Regis	Bredon Hill	Bilsdale	Black Mountains	Arran north coast
Bath University	Bretton Clough	Birdsall	Blorenge	Arrochar
Beachy Head	Charlesworth	Buckland's Windypit	Bodafon Mountain	Beinn a'Ghlò
Black Ven	Crowden	Canyards Hills	Cefn-y-Gader	Beinn Alligin
Blacknor Cliffs	Deer Holes	Castle Eden Dene	Craig Cerig Gleisiad	Ben Attow (Beinn Fhada)
Brighton–Saltdean	Golden Valley, Chalford	Cautley Spout	Cwmystwyth	Ben Lawers
Chale Bay cliffs	Grindesgrain Tor	Dee, Wirral	Llangollen screes	Ben Tianavaig
Charmouth foreshore	Heyden Brook	Farndale	Llyn-y-Fan Fâch	Ben Wyvis
Clovelly	Hob's House	Fremington Edge	Nant Gareg-Iwyd	Braeriach
Folkestone Warren	Jackfield	Gordale screes	Ponterwyd	Castle Ewen
Golden Cap	Lockerbrook Heights	Hilbeck Fell	Tal-y-Llyn valley	Cnoc Roll
Hadleigh	Longdendale	Holderness coast	Taren-y-Gigfran	Coire Gabhail
Herne Bay	Lud's Church	Kettleness, Staithes	Ysgyryd Fawr	Cuillin screes
High Halstow	Mam Tor	Lake District screes		Drumochter Pass
Hog's Back cliffs	Norfolk Coast	Malham		Eigg
Hooken Cliff, Beer	Northants ironstone field	Marske		Gleann an Dubh-Lochain
Hythe–Lympne–Aldington	Peter's Rock	Peak Scar		Glen Pean
Kent and Sussex Chalk cliffs	Postlip Warren	Rosedale		Glen Tilt
Keynsham railway cutting	Rockingham	Rowlee Pasture		Gribun, Mull
Maidstone cambering	Stow-on-the-Wold	Runswick Bay		Jura
Oaken Wood, Medway	The Wonder	Scarborough		Lairig Ghru
Osmington	Westend Valley	Speeton Bay		Loch Teachuis
Sevenoaks bypass	Wytham Hill	Teesdale		Lochnagar
Spot Lane, Maidstone		Wakerley		Quiraing
Stonebarrow		Whitestone Cliff		Hallaig, Raasay
Ventnor Undercliff				Rudha Gorbhaig
Warden Point				St Kilda
Winterford Heath				Storr
				Streap
				Tinto Hills

which are either of little importance or absent altogether in Great Britain. Some correspondents expressed the view that coverage should include as wide a range of examples of mass movement types as possible, while others suggested that only sites with a pronounced morphological expression, either on the surface or in section, should be considered. A third problem is that many continuously operating, small-scale processes, which are of great importance in Great Britain, do not give rise to recognizable features either on the surface or in section. For this reason they are not readily conservable. However, such processes, for example soil creep, are so widespread and commonplace that they are deemed not to require conservation at a few, specified, 'representative' sites. A pragmatic solution has been adopted, whereby, as far as possible, Great Britain's 'best' example of each mass movement type is only to be selected if that example is also a 'good' one when viewed from a global perspective.

Of the individual sites recommended in the responses to the postal survey, the complex of rotational slips on the south coast between Axmouth and Lyme Regis was the most often mentioned, closely followed by the slumps in Quaternary deposits on the north Norfolk coast around Cromer and Trimingham. Next most frequently suggested was Warden Point on the coast of the Isle of Sheppey, followed jointly by Folkestone Warren in Kent, the solifluction lobes on the Lower Greensand escarpment near Sevenoaks, the Undercliff on the south coast of the Isle of Wight, the slips at Chale Bay on the Isle of Wight, and the massive features at Quiraing and The Storr, in the Trotternish peninsula of the Isle of Skye. Other much-mentioned sites included High Halstow in Kent, the area around Bath, screes in the Lake District and near Llangollen, Mam Tor in the Peak District, and the abandoned cliff at Hadleigh Castle in Essex. Even between these most mentioned sites, there are obvious overlaps of mechanism, of surface form, and of cross-sectional features, so that the inclusion of all of them in the Review would involve unwarranted duplication. Conversely, several sites have already been assessed as suitable for inclusion, even though each was only suggested by a single correspondent.

At the close of the 1981 field season, 62% of the recommended sites had been either examined in the field, or excluded from the exercise without a visit. The latter course has been taken either through prior personal knowledge of the site in question, or because a reading of the literature shows the site to be an inferior duplicate. Many sites have been examined in aerial view at the Cambridge University Collection of Air Photographs. This has proved a most valuable aid to site selection or elimination. It is anticipated that between twenty and thirty sites will eventually be selected for inclusion in the Review; the final choice awaits completion of the programme of field visits.'

3. After sifting the original and emended lists, the remaining sites were all visited in the field during 1981 and 1982 by the present author (RGC). Photographs were taken along with some measurements, facilitating direct comparison of what might be termed 'competitive' candidate sites (the GCR being a minimalist scheme, see Ellis *et al.*, 1996). The aim at this stage was to ensure that a complete network of sites was established to *represent the variety* of mass-movement types and forms found in Great Britain. After consultation and revision, a list of 28 sites was finally produced; this list, with short descriptions, has been published in Jones and Lee (1994, pp. 242–7). This is the list (Table 1.3) that was finally adopted, and is described in the present book, with the exception of the site at Spot Lane Quarry near Maidstone in Kent, described by Worssam (1963), which was included as an example of strata exhibiting two superficial structures: cambering and gulling. However, between 1980 when the site was visited, and a return visit in 1996, a housing estate had been extended onto the area concerned. A small exposure has been preserved there on account of the fossil fauna of a gull filling (selected for the Quaternary of South-East England GCR Block), but otherwise this remnant exposure now shows camber and gull features no better than many other sites across the country.

Table 1.3 The final list of selected mass-movement sites as drawn up in the early 1980s.

Alport Castles, Derbyshire
Axmouth–Lyme Regis, Devon–Dorset
Beinn Fhada, Highland
Black Ven, Dorset
Blacknor Cliffs, Dorset
Buckland's Windypit, North Yorkshire
Canyards Hills, Sheffield
Coire Gabhail, Highland
Eglwyseg Scarp (Creigiau Eglwyseg), Clwyd
Entrance Cutting at Bath University, Avon
Cwm-du, Ceredigion
Folkestone Warren, Kent
Glen Pean, Highland*
Hallaig, Isle of Raasay, Highland
High Halstow, Kent
Hob's House, Derbyshire
Llyn-y-Fan Fâch, Carmarthenshire
Lud's Church, North Staffordshire
Mam Tor, Derbyshire
Peak Scar, North Yorkshire
Postlip Warren, Gloucestershire
Rowlee Bridge, Derbyshire
Spot Lane Quarry, Kent*
Stutfall Castle, Kent
Trimingham Cliffs, Norfolk
Trotternish Escarpment, Isle of Skye, Highland (The Storr and Quiraing)
Warden Point, Kent

* Glen Pean and Spot Lane Quarry have now been deleted from the Mass-Movements GCR 'Block' (selection category) – see text.

GCR Editor's note:

A review of the Scottish Highland mass movements carried out after Roger Cooper's death showed that there were eight sites, which, as a result of recent investigations by Colin Ballantyne and David Jarman, met GCR standards. The new sites (described in Chapter 2) are listed in Table 1.4. Had this information been available at the time of the original scoping exercise, when none of these sites were suggested, there is little doubt that they would have been included. The review also showed that applying the 'minimalist' principle, one site, Glen Pean, would not now have been included in the GCR. Revised site information also became available for several of the already selected Scottish sites (**Coire Gabhail** – Chapter 4; and the **Trotternish Escarpment** (Quiraing and The Storr) – Chapter 6). Tables 1.5 and 1.6 have been revised to recognize these changes.

Table 1.4 The supplementary sites added to the GCR following recent research in Scotland.

Beinn Alligin, Highland
Ben Hee, Highland
Benvane (Beinn Bhàn), Stirling
Carn Dubh, Ben Gulabin, Perthshire
The Cobbler (Beinn Artair), Argyll and Bute
Druim Shionnach, Highland
Glen Ample, Stirling
Sgurr na Ciste Duibhe, Highland

Site classification

The style and type categories from *The Multilingual Landslide Glossary*, with the codes from Hutchinson's classifications of 1968a and 1988, are shown along-side brief descriptions for each of the mass-movement sites selected for the GCR, in Table 1.5. However, the GCR deals with *sites* (areas of land with a defined boundary), and the classifications deal with the *types* of movement involved in a displaced mass, or mass undergoing displacement. Thus, **Warden Point**, for example, is recorded as *composite* in style, involving both sliding and toppling. This could give the misleading impression that at Warden Point mass-movement events characteristically involve both toppling and sliding together. In fact, Warden Point shows the results of several mass-movement events, side by side along the coast. Of these, most are slides, but one shows toppling.

Table 1.6 shows the mass-movement GCR sites described in the present volume, classified in two ways. First, by the stratigraphical order of the major geological systems in which the mass-movement phenomena occur in Great Britain. The second classification shows the broad movement mechanisms by which material moves downslope. According to this classification less than half of the sites exhibit more than one type of mass movement, but a few exhibit more than two types. There is some correlation with the areal extent of a site and the number of types present, but this is not always the case. For example, the **Axmouth–Lyme Regis** GCR site runs along about 10 km of coastline, and exhibits six of Hutchinson's (1968a) types, while Quiraing, part of the **Trotternish Escarpment** GCR site, also a very large site, exhibits just one type. Most sites of small areal extent, however, exhibit a single type of mass movement. Rotational slips (groups 6a and 6bi) are the most common; the character of this type is discussed in further detail below.

Table 1.5 The mass-movement GCR sites cdescribed in the present volume; style and type are according to the World Landslide Inventory (WP/WLI 1993), classifications are according to Hutchinson (1968a) and (1988) – described in Table 1.1a,b.

Site	Authors' classifications	Style	Type	Hutchinson categories 1968a	Hutchinson categories 1988
Alport Castles	Mass rock creep, retrogressive rotational, translational	Composite	Slide, flow	2, 5a, 6bi	B2, D2, D4
Axmouth–Lyme Regis	Translational, rotational, subsidence	Complex	Slide, spread	5a, 6bi, 6a, 6c, 7a, 7b	D2, D3, D4
Beinn Fhada (Ben Attow)	Large-scale slope deformation, local slides, possible sags or forward topples	Complex	Spread	2, 5a	A2, B2, C1, D4, F1
Beinn Alligin	Large rockfall with excess run-out	Single	Fall, flow	5fii, 7b	E3, G1
Ben Hee	Arrested translational slide	Multiple	Slide	5a	D4
Benvane	Slope deformation and translational slide	Multiple	Spread, slide	2, 5a	B2, D4
Black Ven	Mudslides	Complex	Slide	5di	E1
Blacknor Cliffs	Block slide, slab failure	Complex	Slide, topple	5a	D4
Buckland's Windypit	Block slides	Multiple	Slide	5a, 4b	D4
Canyards Hills	Translational with breakup into ridges, lateral extension	Multiple	Slide	5a	D4
Carn Dubh, Ben Gulabin	Translational slide to flow	Single	Slide, flow	5a, 5fii	D4, E4
Coire Gabhail	Rockfalls, landslide dam, run-up opposite	Multiple	Fall	7b	G1
Cwm-du	Sub-snow solifluction sheets OR 'landslides'	Multiple	Slide	4a, 5c	E2
Druim Shionnach	In-situ slope deformation progressing to toppling	Composite	Spread	2	B2, C3
Eglwyseg Scarp (Creigiau Eglwyseg)	Active screes and relict clitter slopes	Multiple	Fall	7a, 7b	G
Entrance Cutting at Bath University	Gulls, cambers, dip-and-fault structure	Composite	Spread	4b	H
Folkestone Warren	Rockfalls, clay extrusion, rotational	Complex	Fall, slide	6bi	D2, G, H
Hallaig	Rotational slide, possibly seismically triggered	Single	Slide	6a	D2
Glen Ample					
Beinn Each	Compressional slope deformation, local rockfall	Multiple	Spread	2, 7b	A2, G1
Ben Our	Extensional slope deformation, slides, topples	Complex	Spread	2, 5a	B2, C1, D4,F1
High Halstow	Shallow successive rotational slips, hillwash, soil creep	Successive	Slide	1a, 6bi, 6c	B, D2
Hob's House	Rotational slip	Single	Slide	6a	D2
Llyn-y-Fan Fâch	Debris flow	Multiple	Flow	5c	E3
Lud's Church	Bed-on-bed translational sliding within a rotational mass	Single	Slide	5a, 6a	D2, D4
Mam Tor	Slump-earthflow	Multiple	Slide, flow	6c, 5c	D3, E3, H4
Peak Scar	Block slide, topples	Complex	Slide, topple	5a	D4, F
Postlip Warren	Large-scale gravitational slips, 'founders'	Successive	Spread	5a, 4b	H
Rowlee Bridge	Valley-bulge	Complex	Spread	4b	H
Sgurr na Ciste Duibhe	Extensional slope deformations and slides	Complex	Spread, slide	2, 5a	B2, D4
Stutfall Castle	Soil creep, earthflow, translational	Complex	Flow, slide	1a, 5c, 6b	B, D4, E1
The Cobbler	Short-travel arrested translational slide; also sub-cataclasmic	Single	Slide, fall	5a, 7b	D4, E3
Trimingham Cliffs	Blockfall, seepage failure, mudslides, rotational slip	Composite	Fall, slide	5di, 6a	D2, E1, G, H
Trotternish Escarpment					
Quiraing	Retrogressive translational slide, rockfall	Multiple	Slide, fall	5a, 7b	D4, G1
The Storr	Retrogressive translational slide, topples	Multiple	Slide, topple	5a, 7b	D4, F2
Warden Point	Rotational, topples	Composite	Slide, topple	6b	D2, F

Table 1.6 The sites described in the present volume classified by geological age and by WLI mass-movement type: (PC = Precambrian–Cambrian; Si = Silurian; De = Devonian; Ca = Carboniferous; Ju = Jurassic; Cr = Cretaceous; Eo = London Clay; Pl = Pleistocene; fa = fall; to = Topple; sl = slide; sp = spread; fl = flow; * = sites which display cambering and valley-bulging).

Site name	Geological age								Mass-movement type				
	PC	Si	De	Ca	Ju	Cr	Eo	Pl	fa	to	sl	sp	fl
Alport Castles				X							X		X
Axmouth–Lyme Regis					X	X			X		X	X	
Beinn Alligin	X								X				X
Beinn Fhada *	X									X	X	X	
Ben Hee	X										X		
Benvane	X										X	X	
Black Ven					X	X					X		X
Blacknor Cliffs					X					X	X		
Buckland's Windypit					X						X	X	
Canyards Hills				X							X		
Carn Dubh, Ben Gulabin	X										X		X
Coire Gabhail			X						X				
Cwm-du		X									X		
Druim Shionnach *	X											X	
Eglwyseg Scarp (Creigiau Eglwyseg)				X					X				
Entrance Cutting at Bath University *					X							X	
Folkestone Warren						X			X		X		
Glen Ample													
Beinn Each *	X								X				X
Ben Our	X									X	X	X	
Hallaig					X						X		
High Halstow							X				X		
Hob's House				X							X	X	
Llyn-y-Fan Fâch			X								X		X
Lud's Church				X							X		
Mam Tor				X							X		X
Peak Scar					X					X	X		
Postlip Warren					X						X	X	X
Rowlee Bridge *				X								X	
Sgurr na Ciste Duibhe	X										X	X	
Stutfall Castle						X					X		X
The Cobbler	X								X		X		
Trimingham Cliffs								X	X		X		
Trotternish Escarpment													
Quiraing					X		X		X		X		
The Storr					X		X			X	X		
Warden Point							X			X	X		

Representativeness

Since 1980 a focusing of GCR objectives has taken place, whereby 'representativeness' is a term now used to encapsulate many of the 18 selection criteria recommended in 1992 (Gordon, 1992). At the time of the original selection process (1980s), GCR sites were not selected on the basis of their ability to represent mass movements in different geological formations or areas of the country, but rather to create an inventory of the most important mass-movement sites in Great Britain by mass-movement type. In reconsidering the Mass-Movements GCR Block in the light of the more focused objectives in the late 1990s (when the present volume was commissioned), sites were reconsidered against a scheme of stratigraphical and, thereby, areal representativeness (compare with the US system of geological site selection for conservation; Cooper, 1985). This re-focusing has brought about a change to the approach to the present mass-movement GCR volume, such that the text is divided into chapters on the basis of stratigraphy (age of the geological strata in which the mass movements occur; Figure 1.9).

'Representativeness' involves the notion of what is typical, or 'archetypal', but it is important to note that 'atypical' or 'exceptional' sites may provide insights into the nature of 'type' examples, and this is also a criterion for the GCR.

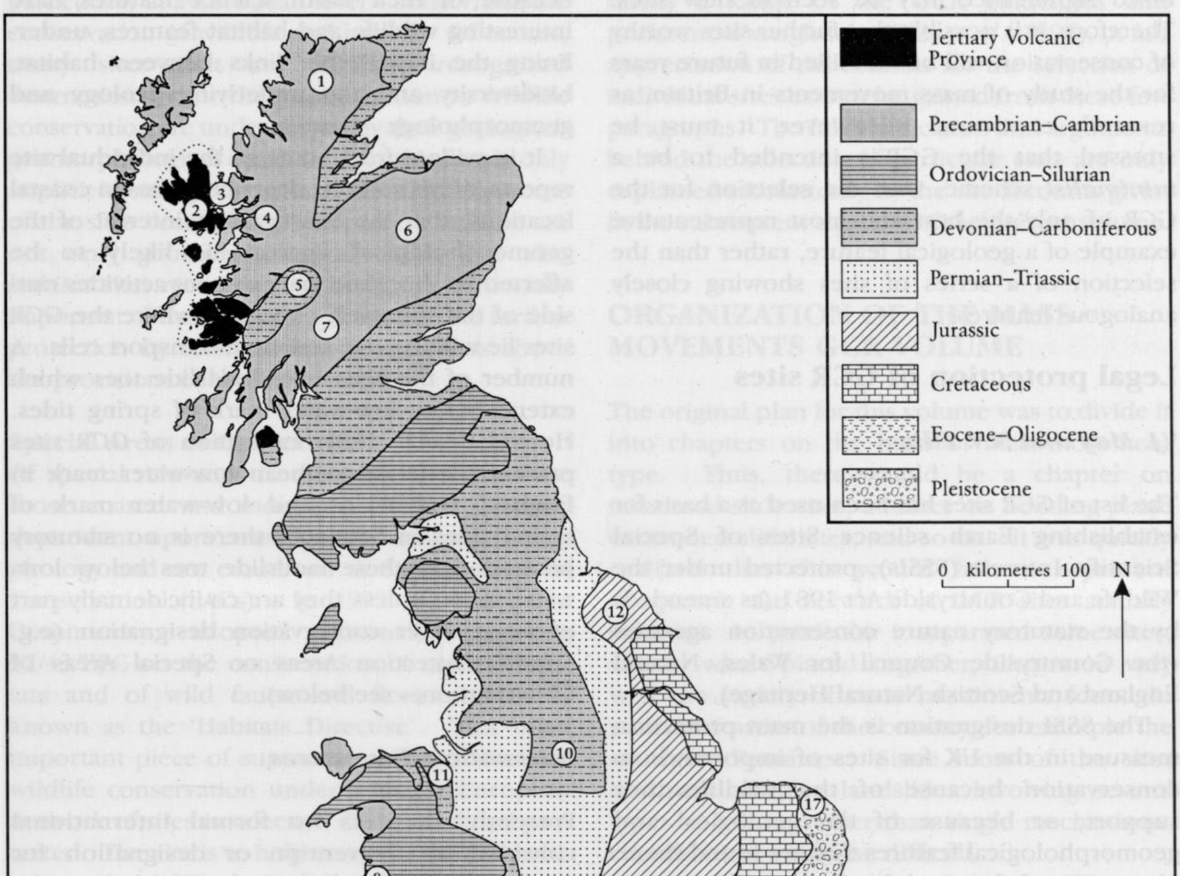

Figure 1.9 Simplified geological map of Great Britain, with the general locations of the mass-movement GCR sites numbered: (1 – Ben Hee: 2 – Trotternish Escarpment: 3 – Hallaig; Beinn Alligin: 4 – Beinn Fhada; Sgurr na Ciste Duibhe; Druim Shionnach: 5 – Coire Gabhail: 6 – Carn Dubh: 7 – The Cobbler; Benvane; Glen Ample: 8 – Cwm-du: 9 – Llyn-y-Fan Fâch: 10 – Hob's House; Alport Castles; Canyards Hills; Lud's Church; Mam Tor; Rowlee Bridge: 11 – Eglwyseg Scarp: 12 – Peak Scar; Buckland's Windypit: 13 – Postlip Warren; Entrance Cutting at Bath University: 14 – Axmouth–Lyme Regis; Black Ven; Blacknor Cliffs: 15 – Folkestone Warren; Stutfall Castle: 16 – High Halstow: Warden Point: 17 – Trimingham Cliffs).

Revision of the GCR in the future

Mass-movements studies, like any other science, are ever-developing, with new discoveries being made, and existing models being subject to continual testing and modification as new data come to light. Increased or hitherto unrecognized significance may be seen in new sites. Therefore, it is possible that further sites worthy of conservation will be identified in future years for the study of mass movements in Britain, as research continues. However, it must be stressed that the GCR is intended to be a *minimalist* scheme, with the selection for the GCR of only the best and most representative example of a geological feature, rather than the selection of a series of sites showing closely analogous features.

Legal protection of GCR sites

V.J. May and N.V. Ellis

The list of GCR sites has been used as a basis for establishing Earth science Sites of Special Scientific Interest (SSSIs), protected under the Wildlife and Countryside Act 1981 (as amended) by the statutory nature conservation agencies (the Countryside Council for Wales, Natural England and Scottish Natural Heritage).

The SSSI designation is the main protection measure in the UK for sites of importance to conservation because of the wildlife they support, or because of the geological and geomorphological features that are found there. About 8% of the total land area of Britain is designated as SSSIs. Well over half of the SSSIs, by area, are internationally important for a particular conservation interest and are additionally protected through international designations and agreements.

About one third of the SSSIs have a geological/geomorphological component that constitutes at least part of the 'special interest'. Although some SSSIs are designated solely because of the importance to wildlife conservation, there are many others that have both such features and geological/geomorphological features of 'special interest'. Furthermore, there are localities that, regardless of their importance to wildlife conservation, are conserved as SSSIs solely on account of their importance to geological or geomorphological studies.

Therefore, many SSSIs are composite, with site boundaries drawn from a 'mosaic' of one or more GCR sites and wildlife 'special interest' areas; such sites may be heterogeneous in character, in that different constituent parts may be important for different features.

Many of the SSSIs that are designated solely because of their Earth science features have interesting wildlife and habitat features, underlining the inextricable links between habitat, biodiversity and the underlying geology and geomorphology.

It is evident from some of the individual site reports in this volume, describing sites in coastal locations, that the conservation interest of the geomorphological features is likely to be affected by shoreline management activities outside of the site itself, especially where the GCR sites lie within large sediment-transport cells. A number of the sites have landslide toes which extend below low-water mark of spring tides. However, since SSSI notification of GCR sites presently extends to mean low-water mark in England and Wales and low-water mark of spring tides in Scotland, there is no statutory protection of these landslide toes below low-water mark, unless they are co-incidentally part of some other conservation designation (e.g. Special Protection Areas or Special Areas of Conservation – see below).

International measures

Presently, there is no formal international conservation convention or designation for geological/geomorphological sites below the level of the 'World Heritage Convention' (the 'Convention concerning the Protection of the World Cultural and Natural Heritage'). World Heritage Sites are declared by the United Nations Educational, Scientific and Cultural Organisation (UNESCO). The objective of the World Heritage Convention is the protection of natural and cultural sites of global significance. Many of the British World Heritage Sites are 'cultural' in aspect, but the Giant's Causeway in Northern Ireland and the Dorset and East Devon Coast ('the Jurassic Coast') are inscribed because of their importance to the Earth sciences as part of the 'natural heritage' – the Dorset and East Devon Coast World Heritage Site is of particular relevance here insofar as it was the outstanding geology and coastal geomorphology (including sites described in this volume and other sites described in the *Coastal Geomorphology of Great Britain* GCR volume (May and Hansom, 2003) that include mass-movement phenomena).

In contrast to the Earth sciences, there are many other formal international conventions – particularly at a European level – concerning the conservation of wildlife and habitat. Of course, many sites that are formally recognized internationally for their contribution to wildlife conservation are underpinned by their geological/geomorphological character, but this fact is only implicit in such designations. Nevertheless, some of the sites described in the present volume are not only geomorphological SSSIs, but also *habitat* sites recognized as being internationally important. These areas are thus afforded further protection by international designations above the provisions of the SSSI system.

Special Areas of Conservation (SACs)
Of special relevance to the present volume are those coastal and mountain habitats that are dependent upon coastal or mountain geomorphology and are conserved as Special Areas of Conservation (SACs). In 1992 the European Community adopted Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora, commonly known as the 'Habitats Directive'. This is an important piece of supranational legislation for wildlife conservation under which a European network of sites is selected, designated and protected. The aim is to help conserve the 169 habitat types and 623 species identified in Annexes I and II of the Directive.

Special Protection Areas (SPAs)
Special Protection Areas are strictly protected sites classified in accordance with Article 4 of the EC Directive on the conservation of wild birds (79/409/EEC), also known as the 'Birds Directive', which came into force in April 1979. They are classified for rare and vulnerable birds, listed in Annex I to the Birds Directive, and for regularly occurring migratory species.

Although SACs and SPAs are identified for the conservation importance of their biological features, individually or collectively, many also include scientifically important geomorphological features.

GCR site selection in conclusion

It is clear from the foregoing that many factors have been involved in selecting and protecting the sites described in this volume. Sites rarely fall neatly into one category or another; normally they have attributes and characteristics that satisfy a range of the GCR guidelines and preferential weightings (Ellis *et al*., 1996). A full appreciation of the reasons for the selection of individual sites cannot be gained from these few paragraphs. The full justification and arguments behind the selection of particular sites are only explained satisfactorily by the site accounts given in the subsequent chapters of the present volume.

ORGANIZATION OF THE MASS-MOVEMENTS GCR VOLUME

The original plan for this volume was to divide it into chapters on the basis of mass-movement type. Thus, there would be a chapter on rotational slide sites, another on bedding-plane controlled slide sites, and so on. It was quickly realized that this would fail to represent adequately the network of GCR sites actually selected. In particular it separated some sites, which, when placed together, illustrated very well the variety of mass movements found in particular areas of the country, for example the southern Pennines. Since most of the sites illustrate complex landslides involving several types of failure, rather than single mechanisms, classification would be difficult.

However, a succession of chapters, some of which were based on mass-movement type, while others were based on regional considerations, gave a disorganized impression. Accordingly the present stratigraphical arrangement was adopted. This is still less than ideal. While it works well in highlighting the main mass-movement producing systems in Great Britain: Carboniferous, Jurassic and Cretaceous strata (which together account for 75% of the landslides identified in the DoE survey; Jones and Lee, 1994), it is less successful for sites in other geological systems. Since all of the mass movements in Great Britain represented by the sites described in the present volume have taken place in Quaternary times, the relevance of the age of the rocks in which they have taken place is indirect. More significant factors include the attitude of bedding, the frequency of jointing, and above all the succession of lithological types cropping out down a slope or a coastal cliff. In particular, and this is the key to the prolific numbers of landslides in the Carboniferous, Jurassic and Cretaceous age rocks, is the presence of soft, 'incompetent' strata cropping out downslope or 'down cliff' from hard, jointed, 'competent' strata. An attempt to develop an ad-hoc order of presentation for the present volume was based on characteristics of physiography and geological succession at the selected sites. However, the arrangement of chapters by geological system for the purposes of publishing the accounts has been retained (Figure 1.9).

COMMENTS ON SOME GENERAL ASPECTS OF THE SITES SELECTED

In addition to this introductory chapter in which general matters of relevance to the whole book are discussed, each of the following chapters has an introductory section in which geomorphological principles pertinent to the sites described in that chapter are discussed. However, some issues are described in the following text, which are of relevance to more than one of the chapters of site descriptions.

Movement

Mass-movement sites have in common that they represent the *results* of mass movements, i.e. movements that have already taken place; in other words, in only some of the selected GCR sites has the actual occurrence of movement been detected and recorded as it occurred. Movement may be detected in two main ways: measurement and eyewitness accounts. Measurement is generally carried out by identifying a fixed point (or points) on the ground surface and marking it/them with wooden or metal pegs. Its precise position is then surveyed, generally by triangulation from two locations whose positions are already known, by marking on a recent aerial photograph of the site, or using GPS techniques. After a period of time, perhaps one year later, the process is repeated using the same survey points (and taking new aerial photographs, GPS or laser-measurement data). A difference in the position of the marked point will indicate that mass movement has indeed taken place, and data can be recorded about the distance and direction of the movement. The problem with measurement of this type is that it is only worthwhile at a location where movement may be expected to take place over the surveying period, for example a location where movement is believed to have taken place in the previous year. However, the technique has been successfully used at East Pentwyn, Bourneville, Ironbridge, **Mam Tor**, St Mary's Bay, **Black Ven**, Stonebarrow, **Folkestone Warren**, St Catherine's Point, and the north coast of the Isle of Sheppey.

Eyewitness accounts exist for the 1839 movement of part of the **Axmouth–Lyme Regis** coast, now a National Nature Reserve. Eyewitness accounts were also collected by John Wesley, the Methodist preacher, of the collapse of Whitestone Cliff, North Yorkshire, in 1755 (reproduced in Jones and Lee, 1994; see also Cooper, 1997). Such accounts also exist for movements at, for example, Black Ven in Dorset, Robin Hood's Bay in North Yorkshire, and on the north coast of the Isle of Sheppey in Kent. Black Ven in Dorset is an important site where one can rely on seeing mudslides in motion, if visiting at the right time of year and after a suitable spell of wet weather. Black Ven has been intensively studied, with a complete record of movements for over 50 years. Stonebarrow, the next cliff to the east of Black Ven, has displacement and pore-pressure records for three years in the late 1960s, and the slides at Lyme Regis are currently heavily monitored. Many other records for short periods are associated with sites which require engineering stabilization works (e.g. Mam Tor). The fact remains, however, that many of the mass-movement GCR sites are only known in terms of simple morphological or geological descriptions.

Mudflows, mudslides and earthflows

Mudflows are generally taken to be rheological flows of material that consist predominantly of clay-sized particles, under the influence of gravity, and sufficiently wetted for the moisture content to be above the 'Plastic Limit'.

Mudslides are taken to be similar to mudflows, except that they experience shearing at the contact with adjacent solid material. This zone of shearing is usually as sharp as a knife cut, with a 'scraped off' soft layer immediately above. The shear surface will be polished and striated. Deep-seated slides and extrusion layers may have a thicker zone of displacement. Mudslides can form within mudslides as they dry out, but still they are bounded by separate, clear shears (Brunsden, 1984).

This distinction largely became acknowledged with the publication of an important paper by Hutchinson and Bhandari (1971), in which it was explicitly recognized that many of the mass movements previously described as mudflows actually advance by sliding on discrete boundary shear surfaces, and that such mass movements are better termed 'mudslides', a term used by Fleming (1978) and by Cailleux and Tricart (1950). It was demonstrated that very often the surging forward of a 'mudflow' was caused not by flowage, but by undrained loading of its rearward parts, the whole mass moving downslope by sliding. However, the term 'mudflow' is still valid for very fine-grained flows, but it is also an old term for mudslides. Hutchinson's 1968a 'climatic mudflows' (see Table 1.1a above) are now mudslides (Brunsden, 1984).

In the World Landslide Inventory (WP/WLI 1993) classification, the American usage 'Earthflow' is preferred. Buma and van Asch state in *Landslide Recognition* (Dikau *et al.*, 1996) that 'the American usage 'earthflow' is replaced in European literature by 'mudslide''. However, 'earthflow' is used by Skempton *et al.* (1989) in describing part of the landslide at **Mam Tor** (see Chapter 5). Varnes (1978), the principal American source on such matters, does not endorse this one-to-one correspondence in terminology. Stating that earthflows range in water content from above saturation to essentially dry, he places mudflows at the wet end of the scale, as 'soupy end members of the family of predominantly fine-grained earthflows'. This neglects the important observation that the 'stiffer' forms slide on discrete surfaces.

Undrained loading

Hutchinson and Bhandari (1971) provided an expanded account of a suggestion made by Hutchinson (1970) which applies to many mudslides and also to a variety of other types of mass movement. They observed that many 'mudflows' were advancing downslope by shearing on slopes that were of considerably lower angle than the slope of limiting equilibrium for residual strength on the sliding surface and groundwater co-incident with and flowing parallel to the slope surface. For example, with slopes at Bouldnor, Isle of Wight that have residual strength of $c_r' = 0$, $\phi_r' = 13.5°$ (where c_r' is residual cohesion and ϕ_r' is angle of internal friction), it was shown using infinite slope analysis (Skempton and Delory, 1957) that the lowest slope angle at which sliding could occur is 6.1°. Measurement of these slopes showed that they stand at angles as low as 3.9° (Hutchinson and Bhandari, 1971). They suggested that the sliding is brought about by the virtually undrained loading of the headward parts of the mudslides by debris discharged from steeper slopes to the rear. This undrained loading develops a forward thrust in the rear part of the mudslide, where the basal slip-surface is inclined fairly steeply downwards, giving rise to shearing movements on very low angle slopes (Figure 1.10), even at slopes of zero or negative inclination for short distances (Hutchinson and Bhandari, 1971).

Collapse of caprocks

There is a group of mass movements, generally characterized by a hard but possibly jointed caprock, which does not have to be thin and can be several tens of metres in thickness, overlying a stratum or series of strata characterized by 'incompetence', the inability to support the overlying 'competent' caprock at locations where erosion has cut down to expose the incompetent strata. This can lead, according to local circumstances, to one or more of a variety of recognized mass-movement types, in the terms of Hutchinson (1988) rebound associated with naturally eroded valleys, post-failure creep, and complex failures of types (1) cambering and valley bulging, and (2) block-type slope movements.

This phenomenon has been more widely accepted in continental Europe and other parts of the world than in Great Britain (Brunsden, 1996a). Possibly, British workers, who naturally are those who have been most closely concerned with British mass movements, have been too circumspect. Why invoke a thick mobile stratum when a thin one will do? This shows confusion between theory and verification. In a highly empirical subject like geology such theorizing must give way to evidence that shows nature to be more complex than expected.

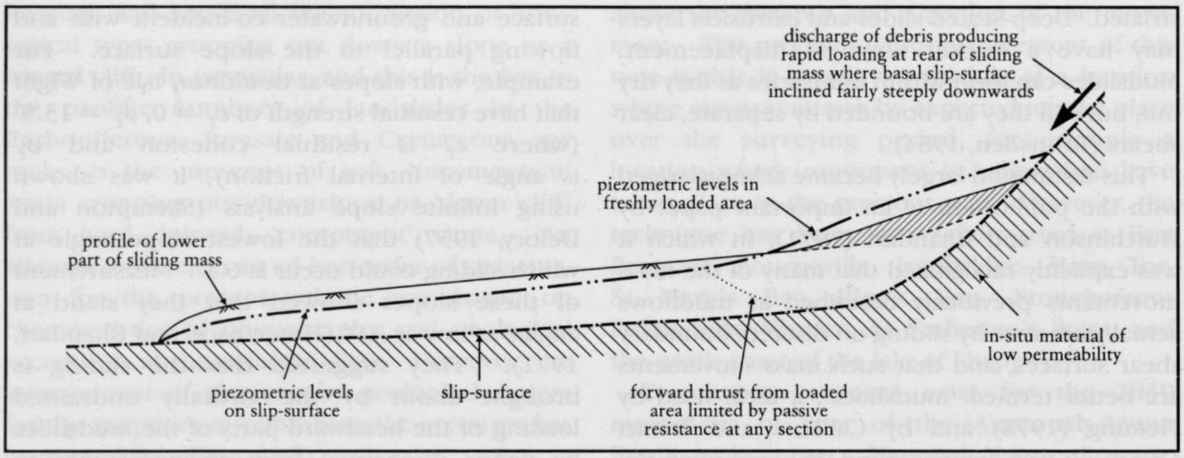

Figure 1.10 The example model of undrained loading suggested by Hutchinson and Bhandari (1971).

Non-circular failure surfaces

Some failures take place over a surface which, when seen in section, has the form of an arc of a circle. A rotational slip over such a surface results in the slipped mass tilting backwards, and the form of the surface enables slipping to happen without the slipped mass breaking up. This observation has been used by geotechnical engineers to provide a simple method of analysing such 'circular failure', using 'circular failure charts' (see, for example, Hoek and Bray, 1977). This, in turn, has led to the expectation that many failure surfaces will have the form of a circular arc. Thus, many slipped masses which have rotated backwards are assumed to have rotated on a circular arc.

That this perception has been recognized as over-simple is illustrated by one of the differences between Hutchinson's 1968a and 1988 mass-movement classifications (Tables 1.1a and 1.1b). The term *listric* ('spoon-shaped'), used in Table 1.1b, refers to a surface that is at all points concave upwards, but of which the radius of curvature decreases downslope. This naturally causes the slipped mass to crack and break up. A further point tending to make circular failures rather unusual is that in sedimentary rocks, at least, the sedimentary sequence is rarely massive enough to be effectively anisotropic with respect to physical properties. As a result, whenever a failure surface meets a pre-existing plane of weakness, it tends to follow it, whether it be a fault, a joint or a bedding plane. An important result of this is that, in many cases, the failure plane may be a non-circular concave-upwards curve beneath the upper parts of a landslip, but follows a sub-horizontal planar bedding beneath the downslope parts (this argument is from Varnes (1978), although Barton (1984) traces it to Taylor (1948); see Figure 1.11).

Rib and Liang (1978) point out that downslope decrease in the curvature of the failure plane produces tension and ultimate failure in the slump block owing to lack of support on its uphill side. This can lead to the formation of a graben in the rear of the slope (Figure 1.11). However, Barton (1984) has observed, from the opportunities that exist for the examination of 'rotational' slips in cross-section, that often the only concave-upwards segment of a slip-surface is of small radius of curvature, at the foot of a straight, steeply dipping segment, and grading into the angle of the bedding on its downslope side (Figures 1.12 and 1.13). He goes so far as

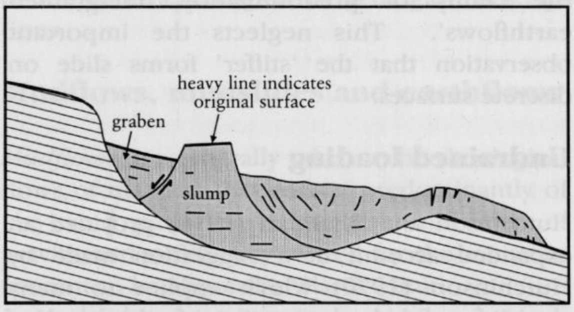

Figure 1.11 Illustration of a 'circular' failure in which the slump block rotates uphill and the graben rotates downhill (after Taylor, 1948). In more recent literature the 'graben' morphology is generally interpreted as being diagnostic of planar failure surfaces (non-circular) often related to the dip of the bedding.

Figure 1.12 The shape of a landslide shear surface in stratified soil with horizontal bedding compared with a hypothetical circular arc surface. After Taylor (1948).

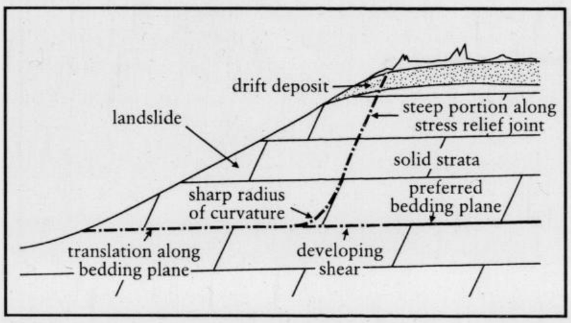

Figure 1.13 The main characteristics of compound landslides with flat-lying bedding. After Barton (1984).

to suggest that this is such a common observation worldwide that it should be 'regarded as the norm and such a surface should be assumed until, and unless, definite evidence to the contrary is obtained'. This conclusion is amply borne out by the mass-movement sites selected for the GCR. Further, although this is not mentioned in its accompanying text, the diagram illustrating a 'single' landslide in *The Multilingual Landslide Glossary* (Figure 1.8) shows a failure surface of this type.

GENERAL CHARACTERISTICS OF GCR SITE DESCRIPTIONS

The length and detail of each site description herein has been determined by the volume of research that has been published on the site. Generally, the most significant sites in terms of the development of understanding of mass movements in Great Britain are those that have received the most detailed study, often over a long period of time, and over which contending views may have developed. On the other hand, some sites have been selected about which very little has been written, but which nonetheless exhibit features of special interest. In these cases the text concentrates on general description rather than detailed scientific explanation. It is hoped that this will provide an incentive, justification and/or rationale for further research.

Overall, the site descriptions vary considerably in length, detail, and degree of illustration. To have imposed a rigid uniformity on the descriptions would have failed to give an accurate impression of the variety of mass-movement sites to be found in Great Britain, and would have failed to do justice to the most intensively studied sites, those with innovative and/or enterprising methods of study, and those with the longest history of study.

Consideration was given to providing each site description with a stereopair of aerial photographs, so that the physiographical expression of mass movement at each site may be illustrated. However, there is a risk that at some sites this could lead to an inappropriate concentration on the physiographical aspects of the site and not their scientific causes/importance *per se*. Also, woodland or forest vegetation tends to obscure or smooth over such features as viewed from above.

Many of the site descriptions are provided with cross-sections. Where they are not, this is because no reasonably accurate cross-section has been published. However, some of the sites are illustrated by slope profiles measured by the present author (RGC). In all cases these were measured in successive 1.5 m ground lengths using a slope pantometer (Pitty, 1966). They run directly downslope, and are orthogonal to the contours. In order to avoid this orthogonal line appearing as a curve in plan, locations for measurement were selected where the contours were roughly parallel to each other. All profiles were originally plotted at a scale of 1:400, and are drawn without vertical exaggeration.