Quaternary of Northern England

D. Huddart
Liverpool John Moores University,
Liverpool, UK

and

N.F. Glasser
University of Wales,
Aberystwyth, UK

With contributions from

Jim Innes
David Evans
John Boardman
Silvia Gonzalez
Richard Chiverrell
Wishart Mitchell
Andy Plater
Sarah Morriss
Cynthia Burek
Stephan Harrison
Richard Jones
Graham Wilson

GCR Editor: **G.S.P. Thomas**

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Contents

Contents

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Access to the countryside

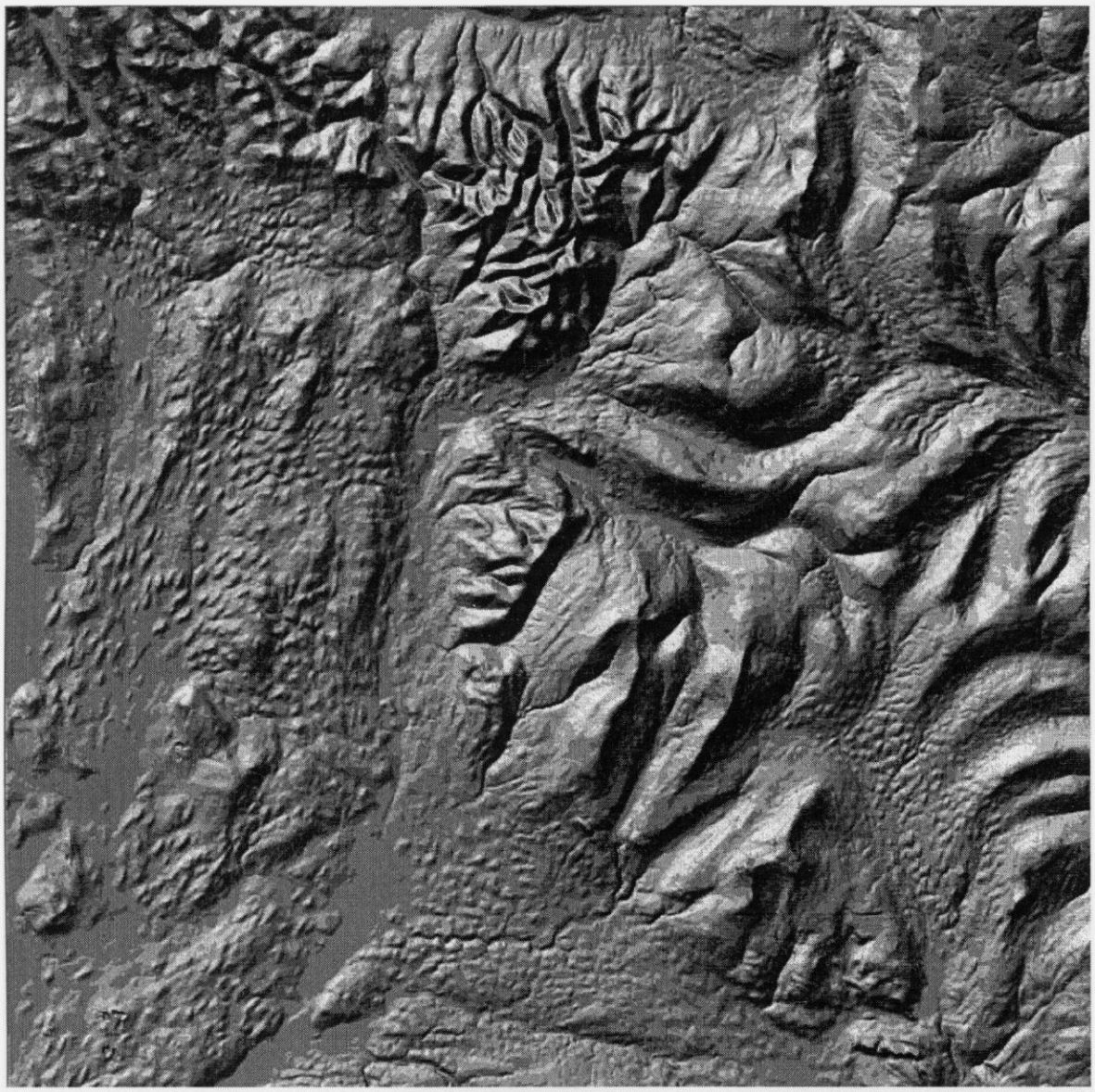
This volume is not intended for use as a field guide. The description or mention of any site should not be taken as an indication that access to a site is open. Most sites described are in private ownership, and their inclusion herein is solely for the purpose of justifying their conservation. Their 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.

Information on conservation matters, including site ownership, relating to Sites of Special Scientific Interest (SSSIs) or National Nature Reserves (NNRs) in particular counties or districts may be obtained from the relevant country conservation agency headquarters listed below:

Countryside Council for Wales,
Plas Penrhos,
Ffordd Penrhos,
Bangor,
Gwynedd LL57 2LQ.

English Nature,
Northminster House,
Peterborough PE1 1UA.

Scottish Natural Heritage,
12 Hope Terrace,
Edinburgh EH9 2AS.



This rendition of a digital elevation model (DEM) illustrates an extensive suite of drumlins recording former ice flow patterns around the Kendal and Sedbergh area. Classical drumlins are clearest in the mid-west portion of the image (around Kendal) and record ice flowing towards the south-west. In the south-east corner, smaller drumlins, and of more varied morphology, record southwards flow from Cam Fell. In the north-east, drumlins and subglacially-moulded tranverse ridges indicate converging flow eastwards leading into the trunk valley of Wensleydale. It is unlikely that these flows were contemporaneous, but rather that they demonstrate snapshots of flow configuration as the ice cover over the region gradually thinned, leading to greater topographic control on flow pattern. Image provided by C.D. Clark (University of Sheffield), and is a simulated solar shading of an Ordnance Survey, 50 m DEM. Illumination is from the north-west, and the east–west dimension of the image is *c.* 30 km. For further details of methods see Clark (1997) and for drumlin patterns see Mitchell, (1991b).

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 not to be impressed 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 and learn more of the history of life on Earth, we must ensure that the most scientifically important of Britain's geological and geomorphological localities 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 and geomorphologists, 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, both at national and local levels.

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 and 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.

This volume, detailing the Quaternary of Northern England GCR sites, is the 25th to be published in the intended 42-volume GCR series. It contains not only descriptions of key localities that will be conserved for their contribution to our understanding of the events during this time, but also excellent summaries of their key morphological, sedimentological and palaeoecological features and the palaeoclimatic significance that can be attached to them. This volume also serves to highlight the scientific research that has been undertaken on these sites. It will be invaluable as an essential reference book to those engaged in the study of Quaternary science 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, those concerned with the practicalities of site conservation and indeed the local people for whom such sites are an environmental asset. The conservation value of the sites is mostly based on a specialist understanding of the stratigraphical, palaeontological and sedimentological features present and is therefore, of a technical nature. The account of each site in this book ends, however, with a brief summary of the geological 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, is also aimed at a less specialized audience. This volume is not intended to be a field guide to the sites, nor does it cover the practical problems of their ongoing conservation. Its remit is to put on record the scientific justification for conserving the sites.

This volume deals with the state of knowledge of the sites available at the time of writing, in 1998–2002, and must be seen in this context. Quaternary Science, like any other science, is an ever-developing discipline. As new discoveries are made, existing models and paradigms are subject to continual testing and modification as new data come to light. Increased or hitherto unrecognized significance may emerge in new sites, and it is possible that further sites worthy of conservation will be identified in future years. Indeed, during the writing of this volume, a small number of sites were identified by the authors as potential GCR sites that should be considered for conservation in order to more fully represent the Quaternary history of northern England. These sites are described in this volume and are being investigated for formal addition to the GCR.

There is still much to learn about Quaternary environmental change and the sites described in this volume are as important today as they have ever been in increasing our knowledge and understanding of this, the most recent of the geological time periods. This account clearly demonstrates the value of these sites for research, and their important place in Britain's scientific and natural heritage. This, after all, is the *raison d'être* of the GCR Series of publications.

N.V. Ellis
GCR Publications Manager
May 2002

Chapter 1

Introduction to the Quaternary of northern England

N. F. Glasser

RATIONALE FOR SELECTION AND CONSERVATION OF QUATERNARY SITES IN NORTHERN ENGLAND

Northern England is a large geographical area, stretching from the Cheshire–Shropshire lowlands in the south to the Scottish Borders in the north. As such it contains a wide variety of distinctive landscapes and much scenic diversity. This varied topography reflects the interplay of geological controls, geomorphological processes and the effects of climatic change, most recently during the Quaternary Period. The present landscape, therefore, is the result of a long history of evolution that reflects the interaction of geology, topography, climate, geomorphological processes, and their changes through time. The effects of climatic changes are recorded both in landforms and sediments, and in the records of flora and fauna and their change over time. Evidence for environmental change during the Quaternary Period, therefore, is widespread and diverse in its nature. It is clear that we need to understand the nature of these environmental changes if we are to have any success in predicting future changes in climate. It follows that the sites containing the most important evidence for Quaternary climatic change must be preserved for future research and study.

Selecting the sites for conservation that best reflect these changes is, however, a challenge to the conservationist. Decisions have to be made about the scientific value of individual sites, about the nature of the evidence present at each and about the suitability of individual sites for long-term conservation. Decisions also must reflect the holistic nature of the subject and are sometimes based on the contribution that a site makes to a suite of related sites, which imbues it with more importance than it has in isolation.

SITE SELECTION GUIDELINES

The former Nature Conservancy initiated the identification of the most important geological and geomorphological sites in Britain in 1949, before the Nature Conservancy Council (now the Countryside Council for Wales, English Nature, Scottish Natural Heritage and Joint Nature Conservation Committee) began a systematic review of the key Earth science localities in 1977. The site selection phase of this review, known as the 'Geological Conservation Review' (GCR), was completed in 1990. The aim of the GCR was to identify, and to help conserve, the geological and geomorphological sites of national and international importance in Britain. No other country has attempted such a systematic and comprehensive review of its Earth heritage resource. The majority of sites documented in this volume were selected for the GCR between 1977 and 1990, although, as a result of preparing a text for publication a small number of additional sites have been proposed for features not yet represented in the 1990 list, reflecting changes in interpretation and new scientific discoveries.

Site selection was determined on the basis of a number of guidelines. These guidelines aim to encapsulate the full range of scientific interests within the disciplines of geology and geomorphology in Britain. Decisions concerning the sites that should be conserved were made on the basis of a number of criteria (Ellis *et al.*, 1996). Two operational criteria were used by the GCR workers in site selection:

1. There should be a minimum of duplication of features of interest between sites;
2. It should be possible to conserve any proposed site in a practical sense.

All scientific factors being equal, sites that cannot be conserved, or which entirely or largely duplicate the interest of another, were excluded. Overall, a preference was given to the sites that are least vulnerable to potential threats, to those that are most accessible and to those sites where the interest is not duplicated by other sites.

Sites were selected within individual subject areas known as 'GCR Blocks'. Each block covers a specific geological time period or event, or, in the case of Quaternary sites, a geographical area. Within individual blocks, preference was given to sites that:

1. Demonstrate an assemblage of geological features or scientific interests;
2. Show an extended, or relatively complete, record of the feature of interest. In the case of geomorphological sites this often equates to sites that contain features that have been least altered after formation. For Quaternary GCR Blocks, this relates to sites containing an extended fossil record, including pollen, insects and molluscs, which can be used to infer vegetation history or environmental change;

3. Have been studied in detail and which have a long history of research and re-interpretation;
4. Have potential for future study;
5. Have played a significant part in the development of the Earth sciences, including former reference sites, sites where particular British geological phenomena were first recognized, and sites that were the focus of studies that led to the development of new theories or concepts.

In order to ensure that GCR site status is confined to sites of national or international importance, the number of sites selected was restricted to a reasonable minimum. Only those that are necessary to characterize the block in question, that is, to demonstrate the current understanding of the range of Earth science features in Britain for that block, were selected. These factors are important in the justification of the scientific value of a GCR site if subsequently it is to be designated a Site of Special Scientific Interest. For example, the scientific case for conserving a given site is stronger if it is the only one of its kind, or if it is demonstrably the best of a set of similar examples.

Some of the sites described in this volume are unique, in that they are either the only known representatives of particular parts of the geological record or they may be without counterparts in the rest of England or even internationally. Hightown, Formby Point, Chelford, Thornsgill Beck, Warren House Gill, Mosedale Beck and Wolf Crags, and Sewerby are good examples of such sites.

A second group of sites are those that are included because they are nationally or internationally recognized as being classic examples of particular landforms or features that are referred to in standard textbooks. Examples of such sites include Roman Wall, Giggleswick Scar, Norber Erratics, Newtondale and Wasdale Screes.

Other sites are representative of important aspects of geomorphology, landscape evolution or environmental change in northern England during the Quaternary Period. Certain sites, therefore, were selected because they are the best-studied, the best-preserved and/or contain the most complete local representation of phenomena that otherwise are widespread. They are therefore important reference sites for the particular phenomena or area concerned. Examples are sites containing glacial deposits or landforms such as end or hummocky moraines, meltwater channels, kames, kettleholes and eskers. Included in this category are sites such as Bradford Kames, Humbleton Hills and the Trows, Ludworth Intake, Newtondale and the Hole of Horcum, and Aqualate Mere. Other sites may represent either formally or informally recognized reference sites for Quaternary stratigraphy, such as Four Ashes, Chelford, Dimlington, Blelham Bog and Low Wray Bay.

Where there is a strong geographical component in the scientific interest, a series or 'network' of GCR sites was chosen to include different aspects of one general type of phenomenon that shows significant regional variation in character, for example in relation to climate, geology or relief. Such networks may comprise unique, classic or representative sites. A prime example is the network of sites selected for the GCR to demonstrate the evolution of tors during the Quaternary Period in northern England (Table 1.1). This small network, comprising a total of eight sites, illustrates not only the lithological and morphological variety of these tors, but also their different pre-Quaternary and Quaternary history (for example, relationship to glacial events). Collectively, this network represents the minimum number of sites required to show this diversity in tor morphology and development history. There is also a minimum of duplication of interest between individual sites, with each site representing a different aspect of tor evolution in northern England.

Another good example of the GCR network approach is those sites that illustrate the types and rates of vegetational change in the Quaternary Period following the climatic amelioration at the end of the Late Devensian. The pattern and timing of the spread of trees and vegetation at this time varied throughout the country. Clearly no single site can encapsulate such a complex and diverse aspect of Quaternary history. Examples of sites for which this site selection principle was particularly applicable include those sites that illustrate the nature of mountain periglacial landforms and sediments (Helvellyn, Skiddaw and Cross Fell), Late-glacial and Holocene vegetation change (Kildale Hall, Skipsea Bail Mere, Skipsea Withow, Fen Bogs, Gormire, Tadcaster, Willow Garth (Boyton), Featherbed Moss, Red Moss and Blea Tarn) and Holocene changes in sea level (Lytham, Hartlepool and Downholland Moss).

Some sites are included in the GCR because they demonstrate the nature of current debates

Table 1.1 Quaternary of northern England: tor evolution network

Site name	GCR selection criteria
Great Almscliff Crag, North Yorkshire	Representative of Pennine tors developed on Millstone Grit; within the Dimlington Stadial ice limit
Burbage Brook, High Peak	Representative of Pennine tors developed on Millstone Grit; demonstrates relationship between tors, geological structure and slope evolution
Brimham Rocks, North Yorkshire	Representative of Pennine scarp-edge tors developed on Millstone Grit
Wyns Tor, High Peak	Representative of Pennine tors developed on dolomitized limestone; evidence for a former weathering cover surrounding tor
Bridestones, North Yorkshire	Representative of North York Moors tors developed on limestone
Blackstone Edge, Greater Manchester	Representative of the Pennine weathering cover (Millstone Grit grus); demonstrates that the majority of weathering is mechanical in origin
Stiperstones, Shropshire	Representative of quartzite tors developed adjacent to Dimlington Stadial ice limit; demonstrates association with periglacial landforms and sediments
Cheviot Tors, Northumberland	Representative of tors developed in andesite and granite; demonstrates relationship with deeply weathered bedrock and glacial landforms and sediments

within Quaternary science. A good example of this is the network of sites that were selected to illustrate the nature of events during the Late Devensian deglaciation of the Irish Sea Basin. Sites such as Thurstaston, St Bees, Holme St Cuthbert and Annaside and Gutterby Banks on the western side of northern England were all selected for this reason. A related network of sites is that which provides information regarding events on the eastern side of northern England during the same time period (Warren House Gill, Speeton, Shippersea Bay (Easington), Dimlington and Sandy Bay).

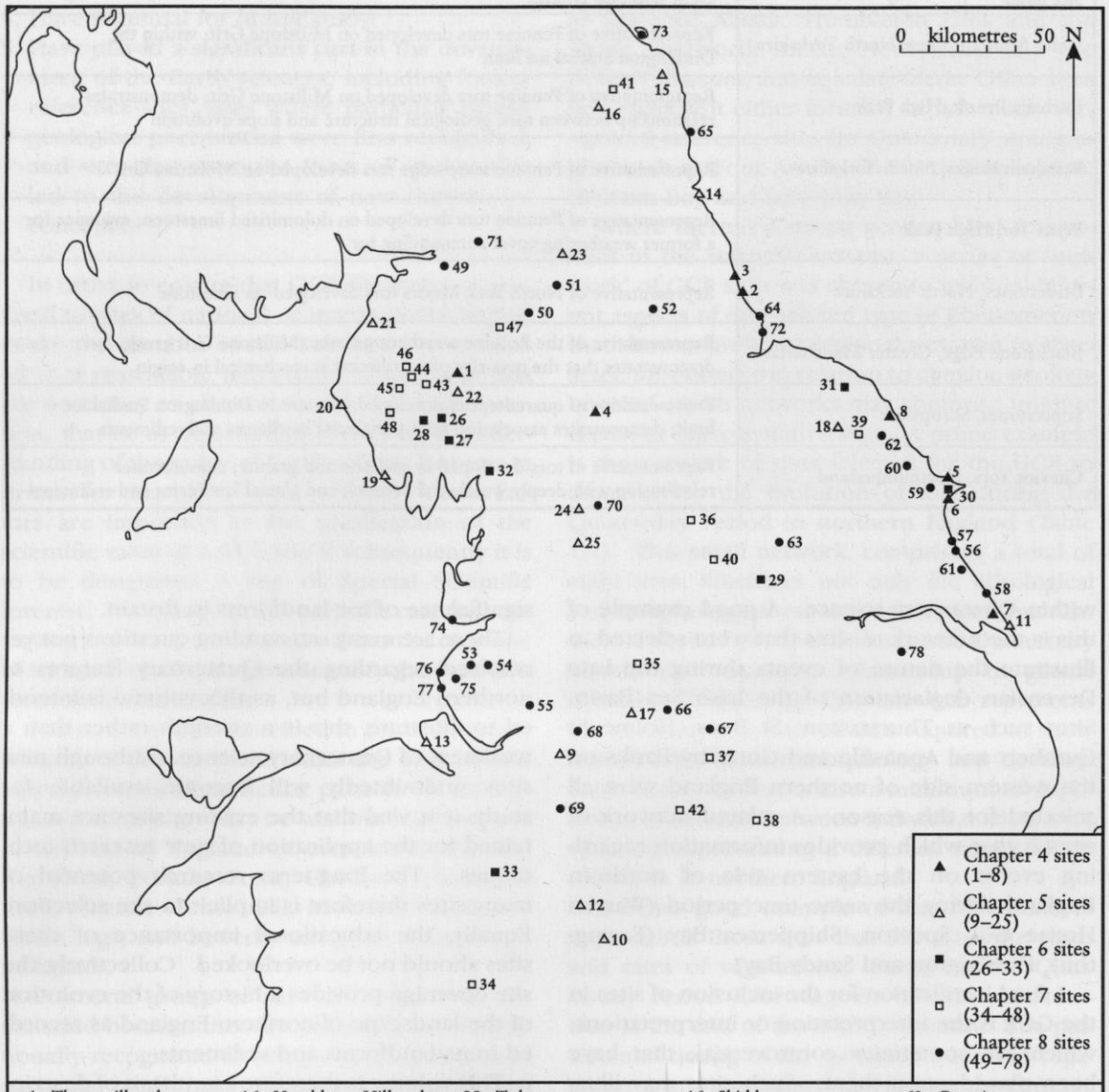
A final justification for the inclusion of sites in the GCR is the interpretation or interpretations, which are sometimes controversial, that have been placed upon them. Such sites may illustrate the development of scientific thinking on the subject of landscape evolution and the debates concerning process and chronology that are characteristic of Quaternary science. It clearly is important that such sites are conserved for further study and to stimulate active scientific debate. A good example of this is the network of sites selected for the GCR that have been the subject of debate on the development of tors and associated weathering features. The descriptions and interpretations of sites such as the Bridestones, Blackstone Edge, Brimham Rocks, Burbage Brook, Great Almcliff Crag, the Stiperstones, Wyns Tor, and Cheviot Tors have all been important in the interpretation of the age and significance of tor landforms in Britain.

There are many outstanding questions not yet resolved regarding the Quaternary features of northern England but, as this volume is intended to illustrate, this is a strength rather than a weakness of Quaternary science. Although new sites undoubtedly will become available for study, it is vital that the existing sites are maintained for the application of new research techniques. The long-term research potential of many sites therefore is implicit in site selection. Equally, the educational importance of these sites should not be overlooked. Collectively, the site coverage provides a history of the evolution of the landscape of northern England as recorded in its landforms and sediments.

This volume is therefore a synthesis of descriptions of all of the sites in northern England that merit statutory conservation for their importance to Quaternary science (Figure 1.1). Modern process studies of coastal and fluvial geomorphology, karst and caves, and large-scale mass movements are each reviewed in separate thematic volumes of the GCR series (Gregory, 1997; Waltham *et al.*, 1997; May and Hansom, in press).

STRUCTURE OF THE VOLUME

In the chapters that follow, the sites are arranged according to broad themes related to important



1	Thornsgill and Mosedale	16	Humbleton Hill and the Trows	29	Tadcaster	46	Skiddaw	63	Gormire
2	Warren House Gill	17	Ludworth Intake	30	Gransmoor	47	Cross Fell	64	Thorpe Bulmer
3	Shippersea Bay	18	Newtondale and Hole of Horcum	31	Kildale Hall	48	Wasdale Screes	65	Low Hauxley
4	Scandal Beck	19	Annaside and Gutterby Banks	32	Hawes Water	49	Scaleby Moss	66	Featherbed Moss
5	Speeton	20	St Bees	33	Crose Mere	50	Valley Bog	67	Leash Fen
6	Sewerby	21	Holme St Cuthbert	34	Stiperstones	51	Upper Teesdale	68	Lindow Moss
7	Kelsey Hill	22	Helvellyn	35	Blackstone Edge	52	Neasham Fen	69	Wybunbury Moss
8	Harwood Dale	23	Roman Wall	36	Brimham Rocks	53	Mere Sands Wood	70	Malham Tarn Moss
	Moor	24	Norber Erratics	37	Burbage Brook	54	Martin Mere	71	Bolton Fell Moss and
9	Chelford	25	Giggleswick Scar	38	Wyns Tor	55	Red Moss		Walton Moss
10	Four Ashes	26	Low Wray Bay (Windermere)	39	Bridestones	56	Skipsea Bail Mere	72	Hartlepool
11	Dimlington	27	Blelham Bog	40	Great Almscliff Crag	57	Skipsea Withow	73	Holy Island
12	Aqualate Mere	28	Blea Tarn, Langdale	41	Cheviot Tors	58	The Bog, Roos	74	Lytham
13	Thurstaston			42	Ecton	59	Willow Garth	75	Downholland Moss
14	Sandy Bay			43	Throstle Shaw	60	Star Carr	76	Formby Point
15	The Bradford Kames			44	Sandbeds Fan	61	Old Mere, Hornsea	77	Hightown
				45	Grasmoor	62	Fen Bogs	78	Castlethorpe

Figure 1.1 Location of the 78 sites described in this volume.

time periods and events during the Quaternary history of northern England. Each of these chapters begins with an overview of events in northern England during that time period, highlighting the particular aspects of the Quaternary that are scientifically important. The individual site reports within these chapters are syntheses of the scientific documentation currently available, together with an interpretation of this information. Chapter 2 provides an introduction to the Quaternary Period, covering topics such as climatic change and the techniques used to establish this change. Chapters 3 and 4 provide details of the pre-Quaternary inheritance of northern England, including Tertiary landforms and deposits, and the Early and Middle Quaternary development of the area, respectively. Chapter 5 deals with the Devensian glacial stage, the period providing most evidence of glacial conditions in northern England. Chapter 6 gives details of the very varied environments that arose from rapid climatic change at the end of the Devensian cold stage and Chapter 7 provides details of the periglacial inheritance from this period. The volume ends with details of the numerous sites that show adaption to the milder environmental conditions that have prevailed since the end of the Devensian glacial stage and their relationship to the anthropogenic influences.