Quaternary of Scotland

Edited by J.E. Gordon, Scottish Natural Heritage, Edinburgh, Scotland and D. G. Sutherland Edinburgh, Scotland.

GCR Editor: W.A. Wimbledon

Chapman & Hall

London, Glasgow, New York, Tokyo, Melbourne, Madras

Published by Chapman & Hall, 2–6 Boundary Row, London SE1 SRN

Chapman & Hall, 2–6 Boundary Row, London SE1 8HN, UK

Blackie Academic & Professional, Wester Cleddens Road, Bishopsbriggs, Glasgow G64 2NZ, UK

Chapman & Hall Inc., 29 West 35th Street, New York NY10001, USA

Chapman & Hall Japan, Thomson Publishing Japan, Hirakawacho Nemoto Building, 6F, 1–7–11 Hiralcawa-cho, Chiyoda-ku, Tokyo 102, Japan

Chapman & Hall Australia, Thomas Nelson Australia, 102 Dodds Street, South Melbourne, Victoria 3205, Australia

Chapman & Hall India, R. Seshadri, 32 Second Main Road, CIT East, Madras 600 035, India

First edition 1993

Typeset in ITC Garamond 10/12 by Columns Design & Production Services Ltd, Reading Printed in Great Britain at the University Press, Cambridge

ISBN 0 412 48840 X

A catalogue record for this book is available from the British Library Library of Congress Cataloging-in-Publication data

The Quaternary of Scotland / edited by J E. Gordon, D. G. Sutherland. — 1st ed. p. cm. — (The Geological conservation review series ; 6) Includes index. ISBN 0–412–48840–X 1. Geology, Stratigraphic–Quaternary. 2. Geology–Scotland. I. Gordon, J E. (John E.) II. Sutherland, D. G. (Donald G.) III. Series.

QE696.Q3365 1993 551.7'9'09411—dc20 93–12124 CIP

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Acknowledgements

Work on this volume was initiated by the Nature Conservancy Council and has been seen to completion by the Joint Nature Conservation Committee on behalf of the three country agencies, English Nature, Scottish Natural Heritage and the Countryside Council for Wales. Each site description bears the name of its author(s), but we would like to acknowledge the many colleagues who gave help and advice. In addition to the named contributors, many members of the Quaternary community assisted with information or advice during site selection and documentation: Dr K. D. Bennett, Professor G. S. Boulton, Dr S. Campbell, Dr M. Clapperton, Dr R. Cornish, Dr E. A. FitzPatrick, Dr A. M. D. Gemmell, Dr B. A. Haggart, Dr W. G. Jardine, Dr R. P. Kirby, Dr J. K Maizels, Dr J. H. Martin, Dr R. J. Price, Professor J. Rose, Dr J.

B. Sissons, Professor D. E. Sugden, Dr J. A. T. Young and Professor W. B. Whalley. Dr G. P. Black and Dr W. A. Wimbledon also provided early stimulus for the project.

We are particularly grateful to Professor D. Q. Bowen and Professor J. D. Peacock for reviewing the entire text, and we also thank the following people for reviewing or revising parts of the text: Dr C. A. Auton, Dr C. K Ballantyne, Dr S. Campbell, Dr C. R. Firth, Dr A. M. Hall, Dr J. W. Merritt, Professor J. Rose, Professor D. E. Sugden, Dr M. J. C. Walker and Professor W. B. Whalley.

It is a pleasure to acknowledge the Word Processing Department of the former Nature Conservancy Council for typing the original drafts, in particular Susan Bull, Shirley Drake, Kathy Harrison, Ann Murkett and Maureen Symons; also Peter Cann, Caroline Mee, Kevin Hayward and Tanya Jardine and the Library Services of the Nature Conservancy Council, Scottish Natural Heritage and the British Geological Survey (Edinburgh) for assistance with the bibliography and tracing references.

Special thanks go to the GCR publication production team: Dr D. O'Halloran (Project Manager), Neil Ellis (Publications Manager), Valerie A. Wyld (Sub-editor) and Nicholas D. W. Davey (Scientific Officer); and to Lovell Johns Ltd of Colwyn Bay for cartographic production.

The contributions by C. A. Auton and J. W. Merritt are published with permission of the Director of the British Geological Survey (NERC).

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 or that a right of way exists. 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 in no way 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:

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

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

English Nature, Northminster House, Peterborough PE1 1UA.

Foreword

One of the great insights of nineteenth century geology was the recognition that the environmental backdrop against which the drama of human evolution and history had been played was not static, as had been hitherto assumed, but had changed dramatically on relatively short timescales. The young Swiss geologist, Louis Agassiz, who played a major role in bringing about this change in thinking, visited Scotland in 1840 to advocate his new glacial theory, which suggested that the northern continents had suffered widespread glaciation in the recent past. Scottish geologists such as Lyell, Jamieson, MacLaren, Croll and Geikie were quick to pick up his ideas and, seeing ubiquitous evidence of change in their own country's dramatic landscape, led the world in exploring the implications of this revolutionary new concept. These pioneers established the flow patterns of the ice masses which had moulded the rock slabs of the Cuillin of Skye and had dispersed the rocks of Ailsa Craig into England; demonstrated rebound of crust after ice disappearance, which uplifted old shorelines around Oban and Mull high above modern sea level; and showed that great floods of meltwater from the decaying ice masses had produced the hummocky ridges on which many of Scotland's best golf courses are now built. They also showed that there had been rapidly alternating warm and cold periods in the past and that the ultimate drive for

climatic change was the Earth's fluctuating orbit around the Sun.

Only recently, however, has the advent of techniques such as pollen analysis, uranium-series dating and radiocarbon dating been able to place a precise timescale on these events. They have revealed the dramatic overlap between an almost unimaginable geological past and a human present as reflected in prehistory and history, showing for example, that 11,000–10,000 years ago, when Jericho was a thriving city, the sites of many modern cities in Scandanavia, and many towns and villages in the Scottish Highlands, were overlain by more than a kilometre of ice.

It is only in the last two decades, with increasing public awareness of the fragility of the ecosystem, of the fact that well-protected botanical reserves appear to 'deteriorate', and of the vulnerability of the Earth's climate itself, that the significance of the geological record of Quaternary environmental change has been generally realised. The record tells us about the frequency and magnitude of natural change in the past, how mean annual temperatures have changed by as much as 5°C in the period of a human lifetime; how floral assemblages have changed rapidly, both in response to climatic change and without any apparent climatic drive; and how the composition of the atmosphere, including its 'greenhouse gases', has varied cyclically and in phase with the climate. The record also tells us about the frequency and magnitude of natural change that long-term dwellers on this Earth should expect, what the consequences of an increased atmospheric greenhouse gas concentration might be, and what processes should be taken into account in theories about future climate and environmental change.

This understanding is drawn from natural geological archives such as those represented by the sites described in this volume. Many of these archives have been well-read and understood: many others, no doubt, await new techniques or new insights before they yield up their secrets. Just as no civilised person would lightly destroy the books in an ancient library, no more should we lightly contemplate the destruction of this record of the past. However, roads need to be built, minerals need to be mined, food must be grown and people need to be housed, and Quaternary sediments are soft and easily destroyed or removed. Moreover, farmers, in their desire to improve their pastures, may wish to drain bogs containing superb records of past climate and ecological change, whilst elsewhere some of our finest surviving eskers are the most readily available source of sand and gravel for building. Clearly there are difficult decisions to be made about the balance between the need to preserve the geological archive and the need for us to use the land. Such decisions as these, which must be made as a result of debate involving the new natural heritage organisations, need information about the extent and nature of our heritage. This splendid volume is of fundamental importance in helping to define that heritage.

The Quaternary of Scotland documents the most important known Quaternary sites in Scotland and provides a basic factual archive, although there are, no doubt, other sites which are known which will prove to be equally important as a result of new insights and new methods, and others as yet undiscovered which will also join these ranks in the future. The site-by-site observational information described in this volume is associated with interpretations, which indicate the significance of each site in adding to our understanding. The site descriptions are incorporated into regional and Scottish syntheses, so that the role of the individual observations in determining the large-scale theoretical framework can be seen. So great is the amount of the data now available that few syntheses are able to go back to the primary observations, but are based on second and third hand sources. John Gordon and Donald Sutherland have not only done a great service to conservation but also to Quaternary geology in relating the facts to the interpretive framework. Much of the speculation may not survive changes in scientific fashion and theory, but the basic observations will.

The text has great clarity for such a complex subject and the quality of the illustrations is a reminder of that great lure to field science in Scotland: the beauty of the land.

Geoffrey Stewart Boulton FRS, FRSE Regius Professor of Geology, The University of Edinburgh

Preface

Structure of the volume and terminology used

This book contains scientific descriptions of 138 localities of national importance for Quaternary geology, geomorphology and environmental change in Scotland. It consists of two chapters that provide a general overview, followed by 16 regional chapters. The objective of the former chapters is to permit the reader to understand how the details of individual sites fit into the national scheme.

The locations of the regions are shown in (Figure 1.1). Each of the regional chapters has a brief introduction which outlines the Quaternary geology and geomorphology and places the individual sites in their regional context. The individual site descriptions form the core of the book. In each chapter they are arranged, broadly, from oldest to youngest, although many of the sites cover significant periods of time. Each site report consists of a description of the evidence; interpretation of that evidence, with correlation, where relevant, with other localities; and assessment of the significance of the site in a regional, national or international context. Where sites form part of a wider network, then cross-reference is made to related sites to provide fuller understanding of the feature or period being discussed. In addition, where sites are of particular historical significance, then the history of study of the site is dealt with in detail.

There is at present no universally accepted system of terminology for the subdivision of Quaternary deposits in Britain. Mitchell *et al.* (1973) proposed a correlation scheme based on standard stages. Since that date, however, not only has there been a great increase in knowledge of the Quaternary succession so that the 1973 system is now incomplete, but also certain of the stage names proposed at that time have been questioned as to their suitability or even existence. To avoid confusion, therefore, (Table 1) and (Figure 2.7) have been compiled to show the terminology and approximate accompanying chronology that is used in this book; a simplified summary chart showing the position of each site in the chronology is given in Table 2. The basis of the chronology is the oxygen isotope signal recognized in deep-sea sediments. This signal has been shown to be a function of the Earth's orbital parameters (Hays *et al.,* 1976), and astronomical data have been used to 'tune' the geological time-scale (cf. Imbrie *et al,* 1984; Pre11 *et al.,* 1986; Ruddiman *et al,* 1986, 1989; Martinson *et al,* 1987). For the period back to about 620 ka, the time-scale is that developed by Imbrie *et al* (1984), which has been substantiated by later work (Prell *et al.,* 1986; Shackleton *et al,* 1990). For the earlier part of the Quaternary, the revised time-scale of Shackleton *et al* (1990) is adopted.

Where radiocarbon 'dates' (age estimates) are cited, they are quoted in radiocarbon years before present (AD 1950). It should be noted that the radiocarbon time-scale diverges from the calendrical one, and although calibration is available hack to 9000 years in detail (cf. Pitcher, 1991) and to 30,000 years in outline (Bard *et al ,* 1990), the interpretation of radiocarbon measurements, particularly during parts of the Late Devensian is additionally complicated (cf. Ammann and Lotter, 1989; Zhinden *et al.,* 1989).

Table 2 Summary of stratigraphical positions of sites described in this volume. Sites appear more than once where they have multiple interests or interests of different ages. Sites with features pre-dating the Late Devensian are grouped together because of uncertainties over dating

Shetland	**Orkney**	**Inverness Area**	**South-west Highlands**	**Western Highland Boundary**	**Western Central Lowlands**
Western Isles	**Caithness**	**North-east Scotland**	**Inner Hebrides**	**Eastern Highland Boundary**	**Lothians and Borders**
	North-west Highlands	**Eastern Grampians**		**Fife and Lower Tay**	**South-west Scotland**

Holocene

Garths Voe
Ronas Hill
Borve
Gleann Mòr

Ward Hill
Loch of Winless
An Teallach
Sgùrr Mòr
Loch Sionascaig
Lochan an Drum
Loch Maree

Dores
Barnyards
Munlochy Valley
Ben Wyvis
Findhorn Terraces
Muir of Dinnet
Philorth Valley
The Cairngorms
Abernethy Forest
Loch Etteridge
Allt na Feithe Sheilich
Coire Fee
Glen Feshie
Morrone

Glenacardoch Point
Kingshouse
Pulpit Hill
Loch Cill an Aonghais
Eas na Broige
Western Hills of Rum
West Coast of Jura
Gribun
Loch an t-Suidhe
Loch Ashik
Loch Cleat
Loch Meodal

South Loch Lomond
Rim Point
Western Forth Valley Mollands
Tynaspirit
Dryleys
Maryton
Milton Ness
Stormont Loch
Carey
Silver Moss
Pitlowie
Kincraig Point
Black Loch

Dundonald Burn
Tinto Hill
Din Moss
Newbie
Loch Dungeon
Round Loch of Glenhead

Late Devensian	'Loch Lomond Stadial	Burn of Aith	Ward Hill	Coire Dho	Isle of Lismore		
			Loch of Winless	Fort Augustus	Moss of Achnacree		
			Achnasheen	Dores	South Shian	Aucheneck	
			An Teallach	Barnyards	Glen Roy	Croftamie	
			Baosbheinn	Munlochy Valley	Pulpit Hill	Gartness	Loch Skene
			Beirut Alligin	Ben Wyvis	The Cuillin	South Loch Lomond	Beanrig Moss
			Cnoc a'Mhoraire	Muir of Dinnet	Beirut Shiantaidh	Rhu Point	Dunbar
			Coire a'Cheud-chnoic	The Cairngorms	Western Hills of Rum	Western Forth Valley	Tauchers
			Creag nan Uamh	Lochnagar	Northern Islay?	Tynaspirit	Bigholm Burn
			Cam Loch	Loch Etteridge	West Coast of Jura?	Stormont Loch	Redkirk Point
			Lochan an Druim	Morrone	Loch an t-Suidhe	Black Loch	
				Glen Feshie	Loch Ashik		
				Coire Fee		Croftamie	
						Gartness	
				Ardersier		South Loch Lomond	
				Findhorn Terraces	Glenacardoch Point	Geilston	
				The Cairngorms	South Shian	Rhu Point Tynaspirit	
	Lateglacial Interstadial	Burn of Aith	Loch of Winless	Lochnagar	Pulpit Hill	Dryleys	Beanrig Moss
			Cam Loch	Loch Etteridge	West Coast of Jura	Milton Ness	Bigholm Burn
			Lochan an Druim	Abernethy Forest	Loch an t-Suidhe	North Esk & West Water	Redkirk Point
				Morrone	Loch Ashik	Stormont Loch	
				Glen Feshie		Inchcoonans & Gallowflat	
						Kincraig Point	
						Black Loch	

North-west Coast of Lewis

Port of Ness

Tolsta Head

Glen Valtos

Den Wick?

Mill Bay?

Baile an t-Sratha?

Drumhollistan?

Leavad?

Gairloch Moraine

An Teallach

Corrieshalloch Gorge

Clava

Ardersier

Struie Channels

Kildrummie Kames

Littlemill

Torvean

Findhom Terraces

Boyne Quarry

eindland

Castle Hill

Kippet Hills

Muir of Dinnet

Kirkhill Bellscamphie

The Cairngorms

Loch Ettendge

Glen Feshie

The Cuillin

Scarisdale

Beinn Shiantaidh?

Northern Islay

West Coast of Jura

Croftamie

Gartness

Geilston

Nigg Bay

Burn of Benholm

Almondbank

Shochie Burn

North Esk & West Water

Afton Lodge

Nith Bridge

Greenock Mains

Carstairs Kames

Clochodrick Stone

Falls of Clyde

Agassiz Rock

Hewan Bank

Keith Water

Carlops

Rammer Cleugh

Port Logan

Bigholm Burn

			Clunas			
			Dalcharn			
		Den Wick?	Allt Odhar			
		Mill Bay?	Clava			
		Muckle Head & Selwick	Windy Hills	Tangy Glen		
	Fugia Ness	Baile an t-Sratha?	Moss of Cruden	Glenacardoch Point	Nigg Bay	
Pre-Late Devensian	Sel Ayre	Drumhollistan?	Hill of Longhaven	Isle of Lismore?	Burn of Benholm	Afton Lodge
	North-west Coast of Lewis	Leavad?	Kirkhill	Northern Islay	Milton Ness	Dunbar
	Tolsta Head	Corrieshalloch Gorge	Bellscamphie	West Coast of Jura	Kincraig Point	
		Creag nan Uanth	Boyne Quarry?			
			Teindland			
			Castle Hill?			
			The Cairngorms			

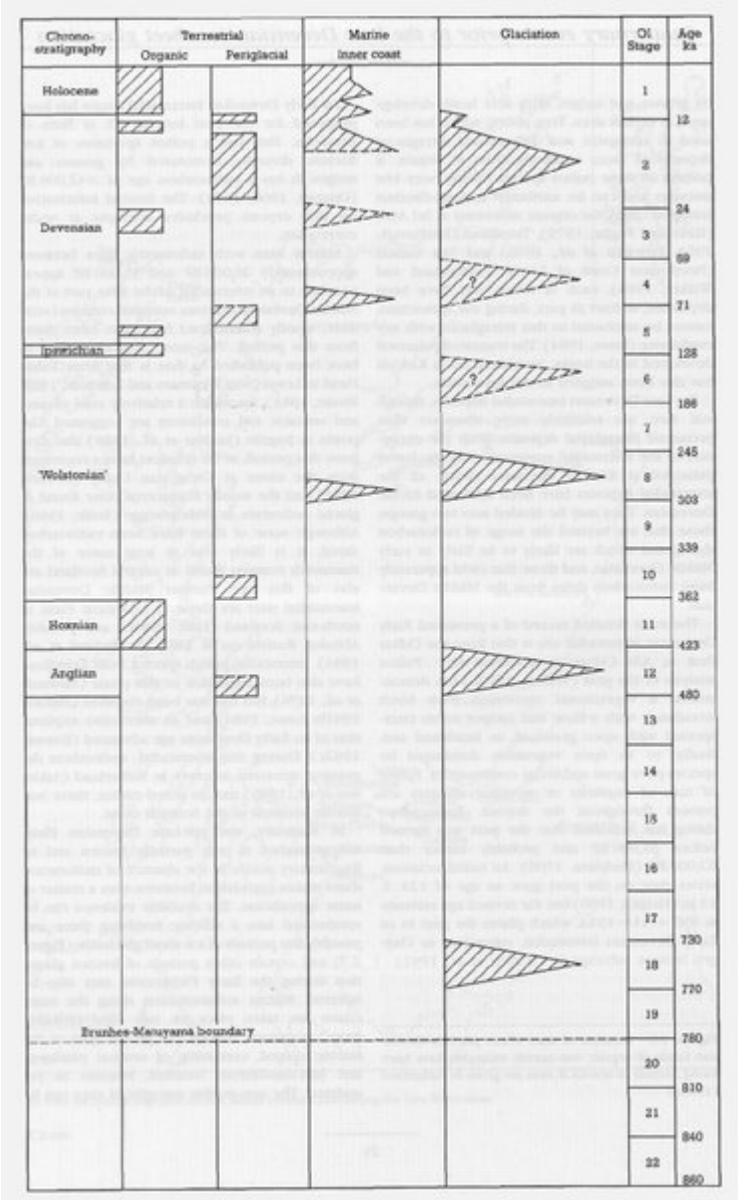
The informal term 'lateglacial' (equivalent to· Devensian late-glacial) is well established in the Scottish Quaternary literature and is used throughout this volume following the definitions of Gray and Lowe (1977a). The terms Lateglacial Interstadial and Loch Lomond Stadial are also used. These are climate-stratigraphic, or climatostratigraphic, terms, and as such differ from chronostratigraphic, or time-stratigraphic terms. The latter are intervals of time based on a definition tied to a particular rock-sequence. Climate-stratigraphic terms, however, are based on climatic inferences drawn from rocks, either at a site, or from several sites. The terms Lateglacial Interstadial and Loch Lomond Stadial describe the inferred nature of the climate towards the end of the Devensian Stage. In general terms, the former relates to the time between approximately 13,000 and 11,000 years ago, a time of overall climatic improvement, whereas the latter refers to the time between approximately 11,000 and 10,000 years ago, which corresponds to a time of climatic deterioration.

Comparison with the nomenclature used in Europe shows that the Lateglacial Interstadial corresponds with the Oldest Dryas, Bølling, Older Dryas and Allerød events. The Loch Lomond Stadial corresponds with the Younger Dryas. Attention is drawn to the latter in particular, in view of its importance as an international term in studies seeking to understand the Earth's climate system.

Finally, where the usage of certain local terms for particular landforms or deposits is widely accepted in the literature, these have been retained in the present volume; for example, corrie (cirque) and carse (estuarine silts and clays). Where possible, modern names of marine mollusca are used, following Smith and Heppell (1991).

References

(Figure 1.1) Location of sites and areas described.



(Figure 2.7) Summary of the principal glacial, periglacial, marine and terrestrial depositional events recognized in the Quaternary record in Scotland. Note that the time-scale is not linear. Only those events that can be related to specific deposits on land or on the adjacent continental shelves are plotted.