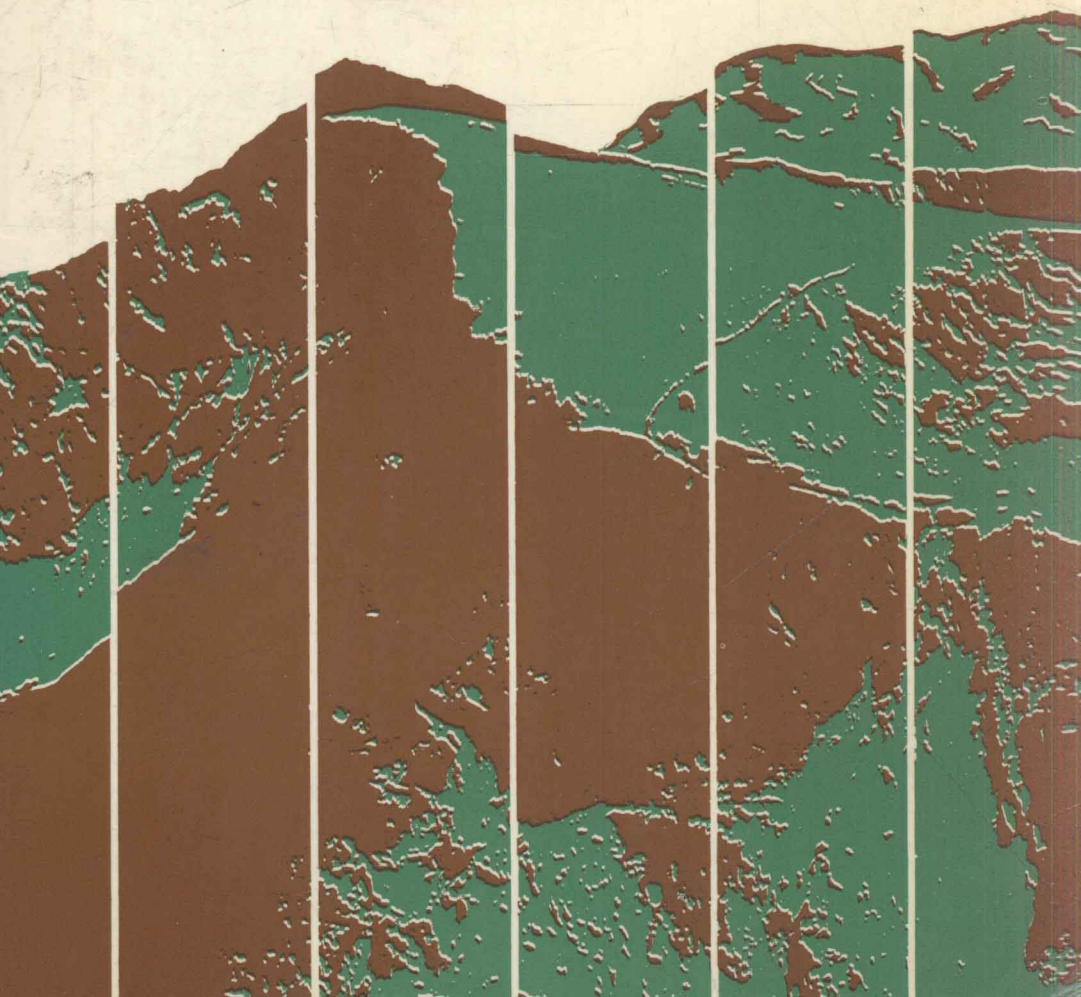


Geomorphology

PURE AND APPLIED

M.G. HART



Geomorphology

PURE AND APPLIED

M.G. HART

Head of Geography, The King's School, Macclesfield

London
GEORGE ALLEN & UNWIN

Boston

Sydney

© M. G. Hart, 1986

This book is copyright under the Berne Convention. No reproduction without permission. All rights reserved.

Allen & Unwin (Publishers) Ltd,
40 Museum Street, London WC1A 1LU, UK

Allen & Unwin (Publishers) Ltd,
Park Lane, Hemel Hempstead, Herts HP2 4TE, UK

Allen & Unwin Inc.,
8 Winchester Place, Winchester, Mass. 01890, USA

Allen & Unwin (Australia) Ltd,
8 Napier Street, North Sydney, NSW 2060, Australia

First published in 1986

British Library Cataloguing in Publication Data

Hart, M.G.

Geomorphology: pure and applied.

I. Geomorphology

I. Title

551.4 GB401.5

ISBN 0-04-551087-3

ISBN 0-04-551088-1 Pbk

Library of Congress Cataloging in Publication Data

Hart, M.G. (Michael G.)

Geomorphology, pure and applied.

Bibliography: p.

Includes index.

I. Geomorphology. I. Title.

GB401.5.H37 1985 551.4 85-18539

ISBN 0-04-551087-3 (U.S.)

ISBN 0-04-551088-1 (U.S.: pbk.)

Set in 10 on 12pt Palatino by Columns of Reading
and printed in Great Britain by Mackays of Chatham

Geomorphology

PURE AND APPLIED

TITLES OF RELATED INTEREST

Physical processes of sedimentation
J. R. L. Allen

The formation of soil material
T. R. Paton

Petrology of the sedimentary rocks
J. T. Greensmith

Elements of geographical hydrology
B. J. Knapp

Thresholds in geomorphology
D. R. Coates & J. D. Vitek (eds)

Fluvial geomorphology
M. Morisawa (ed.)

Glacial geomorphology
D. R. Coates (ed.)

Theories of landform development
W. N. Melhorn & R. C. Flemal
(eds)

Geomorphology and engineering
D. R. Coates (ed.)

Geomorphology in arid regions
D. O. Doehring (ed.)

Geomorphological techniques
A. S. Goudie (ed.)

Terrain analysis and remote sensing
J. R. G. Townshend (ed.)

British rivers
J. Lewin (ed.)

Soils and landforms
A. J. Gerrard

Adjustments of the fluvial system
D. D. Rhodes & G. P. Williams
(eds)

The poetry of geology
R. M. Hazen (ed.)

Applied geomorphology
R. G. Craig & J. L. Craft (eds)

Space and time in geomorphology
C. E. Thorn (ed.)

Sedimentology: process and product
M. R. Leeder

Sedimentary structures
J. D. Collinson & D. B. Thompson

Geomorphological field manual
R. V. Dackombe & V. Gardiner

Geological howlers (boners/bloomers)
I. Rolfe (ed.)

Geomorphological hazards in Los Angeles
R. U. Cooke

The dark side of the Earth
R. Muir Wood

Models in geomorphology
M. Woldenberg (ed.)

Tectonic geomorphology
J. T. Hack & M. Morisawa (eds)

Geomorphology and soils
K. S. Richards et al. (eds)

Environmental change and tropical geomorphology
I. Douglas & T. Spencer (eds)

Principles of physical sedimentology
J. R. L. Allen

Planetary landscapes
R. Greeley

Preface

This book can make some claim to originality. It is not an orthodox textbook on geomorphology. It does not provide the reader with the usual pot-pourri of facts about fluvial, glacial, periglacial, coastal, slope and desert landforms and processes. Instead it deals, in a systematic way, with those lines of enquiry and those concepts which cut right through the subject across the traditional divisions. It reveals the structure of geomorphology. Along the way I have also tried to indicate something of the history and nature of intellectual debate in the subject. Such a background knowledge is taken for granted in history and English literature, and it is perhaps a failing of geomorphology that our students remain rather ignorant of these matters. Some of the implications of modern knowledge and modern thinking are examined. Sometimes the implications are self-evident once you think of them. If the reader, in following through some lines of argument, finds himself thinking: 'Yes, this is interesting because all this is obvious except that it's never occurred to me before', then I am pleased because that is one of my objectives.

This is not a textbook specifically for any existing course in geomorphology, although it should prove useful for almost any course from the introductory level onwards. Some basic knowledge is assumed; all discussions begin there. No time is spent reviewing familiar ground, and no attempt is made to define terms that are well known or easily consulted. Hopefully, the reader will see that there is more to geomorphology than he or she thought, or be guided as to future reading, or see the subject through new eyes. My treatment of each topic is inevitably highly compressed. Whole textbooks have been written on matters that I deal with in one chapter or even less. For example, earthquakes and volcanoes are discussed in a few lines in Chapter 12; then in the Bibliography at the end of the book the reader can find half a dozen textbooks on just volcanoes and earthquakes.

This is, in part, a personal view of geomorphology, and it is intended to be. Virtually all academics could write such a book, and it would come out differently in each case. This book begins with the history of thought on geomorphology in the pre-Daviesian era, and then considers the historical approach that dominated the subject during the first half of this century. Today's work is divided into two parts: modern pure geomorphology, and modern applied geomorphology. This is a classification that will be new to many readers, but it has long been in use in mathematics and indeed in other sciences, where theoretical knowledge is put to the test on some practical problem and

PREFACE

then the results fed back into pure research. I think it is useful to look at geomorphology like that, and it is likely to become a standard classification of the subject.

M. G. Hart

Introduction

Most readers will be familiar with the type of Introduction written for the majority of textbooks. The bulk of the textbook deals with the chosen topic at the intended level of detail, but the Introduction spells out in very simple language what the author is trying to do, places the work in the context of geomorphology as a whole, and makes some appropriate comments about the general nature of the subject. In a way, this book is all Introduction, all context. It is a textbook about geomorphology, not a geomorphological textbook – a geomorphologist's bedside book. The body of knowledge that has accumulated in geomorphology is to be found in the many excellent books and articles on general geomorphology or some specific aspect of the subject. The reader is referred to those if it is part of that knowledge that he wants.

References, in fact, are an eternal problem. Obviously, one cannot quote them all. My intended readership consists of candidates preparing for university entrance exams, undergraduates, student teachers, A-level students and practising schoolteachers. All should find the book of some interest. Most, and especially A-level students and teachers, find it much easier to work with textbooks than magazine articles, so I have concentrated my references on the accessible books. I have mentioned magazine articles if they are classic works or if they make for smooth presentation of a line of thought. Too many references make for staccato reading, and I have made no attempt to be comprehensive. If someone's favourite work is missing, then it is an inevitable casualty of the style adopted.

The book opens with a review of intellectual debate in geomorphology in the pre-Daviesian era. During this period the term 'geomorphology' did not exist, but nonetheless in retrospect we can see advances in science that form the origins of the subject. Chapter 1 traces the development of thought from catastrophism and its ultimate replacement by uniformitarianism and the Glacial Theory through to the pioneer work on process geomorphology done by American geologists towards the end of the 19th century.

Part II (Chs. 2–6) describes the historical approach to geomorphology that dominated the subject in Britain and elsewhere during the first half of the 20th century. This historical approach focuses on tracing the evolution or sequence of events that have led to the formation of a landscape. It appears first in the celebrated work of the American geomorphologist W. M. Davis, who synthesised geomorphology into a recognisable 'subject' for the first time using the unifying theme of the cycle of erosion. Over a period of approximately 40 years from about

1890 to 1930, Davis refined and in some respects modified his basic thesis, and at the same time other geomorphologists enthusiastically applied the cycle concept to specific environments such as arid, glacial and karst areas. In Britain, the line of thought suggested by the cycle was extended to form the basis of denudation chronology, an approach to geomorphology that dominated there from about 1930 to 1960. In recent years both the erosion cycle and denudation chronology have come in for considerable criticism, and the historical approach in general has fallen into disfavour. However, criticism of the cycle concept from French and German geomorphologists has led to the emergence of two important branches of the subject: climatic and structural geomorphology. Part II concludes with a consideration of Pleistocene geomorphology. One of the main aims of this aspect of the subject is to establish the sequence of events during the Ice Age, so this is the last, but important, survivor of the historical approach.

The remainder of the book is then devoted to modern geomorphology. I have chosen to classify the subject into two categories: pure geomorphology (Part III) and applied geomorphology (Part IV).

In identifying pure geomorphology as one of the two major branches of the subject today, we are focusing on the intellectual side of geomorphology and on pure research. It is, in a sense, work done for its own intrinsic academic value, although, as we shall see in Part IV, much of it can be, and is, being made use of in applied geomorphology. Similarly there is a return flow from the practicalities of solving actual problems back to pure research.

With just a few exceptions, applied geomorphology is a fairly new development, so traditionally geomorphology has been all pure. The term 'pure' has become appropriate only in the last 10 years or so with the appearance of applied studies.

It follows that the literature on pure geomorphology is truly voluminous, comprising the vast majority of work in the subject, although it is true that much of the work does have a practical application and that most of the textbooks also make some reference to applied studies. The main modern textbooks on geomorphology in general are those by Bloom (1969, 1978), Easterbrook (1969), Pitty (1971), Sparks (1972), Garner (1974), Ruhe (1975), Strahler (1973, 1975, 1976), Dury (1959), King (1976, 1980), Twidale (1976), Douglas (1977), Rice (1977), Thornes and Brunsden (1977), Gardner (1977), Embleton *et al.* (1978), McCullagh (1978), Small (1978), Cullingford *et al.* (1980), Knapp (1981), Melhorn and Flemal (1981), and Chorley *et al.* (1985). The level of treatment varies from A-level to final-year undergraduate. In addition there are the many textbooks concentrating on one of the traditional subdivisions of geomorphology. Thus on fluvial geomorpho-

logy one can cite Leopold *et al.* (1964), Morisawa (1968), Dury (1970), Chorley (1969c), Schumm (1972, 1977a, b), Weyman (1975), Gregory and Walling (1973), Gregory (1977), Smith and Stopp (1978), and Pitty (1979); on slopes, Brunsdon (1971), Carson and Kirkby (1972), Young (1972), Schumm and Mosley (1973) and Finlayson and Statham (1980); the main works on glacial and periglacial geomorphology are those by Embleton and King (1975a, b), Flint (1971), Embleton (1972), Price and Sugden (1972), Andrews (1975), French (1976), Price (1972), Sugden and John (1976), and Washburn (1979); on coasts we have Steers (1964, 1980), Bird (1968), King (1972), Davies (1980), and Coates (1981a); on deserts the main texts are those by Cooke and Warren (1973), Doehring (1977), Goudie and Wilkinson (1977), Mabbutt (1977), McKee (1980), and Goudie and Watson (1981); and finally on karst, Jennings (1971), Sweeting (1972), Ford and Cullingford (1976) and Bögli (1980).

Most general textbooks on geomorphology discuss theoretical developments in the subject by taking these topics one by one – rivers, then slopes, then glacial features, then coasts, then deserts, and so on. Here, however, in keeping with the approach used in the rest of this book, the following chapters look at the basic structure of pure geomorphology – at those developments that cut right across these traditional subdivisions. We start with the study of land form, pass on to the processes responsible for them, then look at the properties of the materials of which they are comprised. Part III closes with a consideration of the methods used to analyse these three elements of pure geomorphology.

Applied geomorphology is made up of several distinct but related threads. First, there is man's effect on landforms and processes – man acting as a geomorphological agent. Secondly, there is the effect of geomorphology on man. Wherever man uses the land, he has to accommodate its relief, materials and water resources to his purposes. Sometimes geomorphological events occur with such intensity that they constitute a hazard to man. Thirdly, there is the extent to which geomorphology can contribute towards the solution of practical problems, towards the general needs of society. Presumably this must be regarded as the literal meaning of 'applied' geomorphology. It includes environmental management and the evaluation of resources, and it also includes the relevant techniques such as geomorphological mapping and landscape evaluation. These three threads are not separate. For example, man may recognise and evaluate a river flood as a natural hazard, manage the environment so as to minimise the hazard or its effects, and in so doing act as a geomorphological agent. Applied geomorphology is a coherent discipline.

Part V concludes the book with an assessment of geomorphology as a science and a summary of the various approaches and concepts that have dominated the subject over the years.

Contents

Preface	<i>page</i> vii
Introduction	xv
Part I The history of geomorphology	
1 The history of geomorphological debate in the pre-Daviesian era	3
Introduction	3
Catastrophism	3
Uniformitarianism	6
The Glacial Theory	8
The beginnings of process geomorphology	10
Conclusion	12
Part II The historical approach in geomorphology	
2 William Morris Davis: the geographical cycle of erosion	15
Introduction	15
The cycle of erosion	17
Criticisms of Davis's work	18
Conclusion	23
3 Other applications of the cycle concept	25
Introduction	25
Cycles of erosion	25
Conclusion	34
4 The response in Britain to the cycle: denudation chronology	35
Introduction	35
The British scene	38
The world scene	40
Criticisms of denudation chronology	41
Denudation chronology today	44
Conclusion	46
5 The Continental response to Davis's cycle	47
Introduction	47
Adherents to the Daviesian approach in Europe	47

Criticisms of Davis	48
Conclusion	57
6 Pleistocene geomorphology: the impact of environmental change	59
Introduction	59
Pleistocene chronology	59
Fossil landforms	64
Some implications of the discrepancy between form and process	67
Landforms as numerical evidence of climatic change	70
Changes of sea level	71
Conclusion	77
 Part III Modern pure geomorphology	
7 Form	81
Introduction	81
Morphometry	81
Mathematical shapes	84
Small-scale forms	86
Conclusion	87
8 Process	88
Introduction	88
Development of process geomorphology	88
Weathering, biological processes and soils	89
Erosion	91
Transport	92
Slopes and mass movements	95
Deposition, depositional landforms and sediments	96
Rates of present-day processes	99
Tectonic processes and plate tectonics	100
Conclusion	103
9 Materials	104
Introduction	104
Properties of materials	104
Conclusion	107
10 Methods of analysis	108
Introduction	108
Field techniques	108

Remote sensing	110
Laboratory work	111
Quantitative geomorphology	112
Models	114
Systems analysis	119
Thresholds	123
Conclusion	125
 Part IV Modern applied geomorphology	
11 Background to applied studies	129
Introduction	129
The need for applied studies	130
Relevant contemporary developments	133
Conclusion	137
12 Environmental hazards	138
Introduction	138
Soil erosion by water	139
Soil erosion by wind	145
River floods	148
Slope instability	149
Ground-surface subsidence	151
Coasts	151
Periglacial environments	153
Avalanches	155
Volcanoes	156
Earthquakes	157
Geomorphological hazards case study: the Karakoram	159
Conclusion	162
13 Environmental management	164
Introduction	164
Control of soil erosion by water	166
Control and prevention of soil erosion by wind	167
Rivers and river channels	167
Responses to river floods	168
Managing landslides	169
Coasts	170
Periglacial environments	172
The destruction of natural materials by weathering	173
Urban management	175
Road-building	175
Conclusion	176

14	Resource evaluation	177
	Introduction	177
	Material resources	177
	Techniques of scenic evaluation	178
	Land-systems mapping	179
	Geomorphological mapping	182
	Conclusion	183
	Part V The current conceptual status of geomorphology	
15	Pure and applied geomorphology in context	191
	Introduction	191
	The position of applied geomorphology	191
	Approaches to geomorphology	197
	Conclusion	203
	Bibliography	204
	Subject index	214
	Index of place names	227

List of tables

7.1	Sixteen morphometric properties of drainage basins	<i>page</i> 82
7.2	Some morphometric properties of slopes	82
7.3	Some morphometric properties of beaches	82
11.1	The professional roles of the applied geomorphologist	134
12.1	The geomorphological hazards	140
12.2	The mega-disasters	142
14.1	Applications of geomorphological mapping in planning and economic development	182
15.1	The major landmarks in geomorphology	200

PART I

The history of geomorphology