A MANUAL OF GEOLOGY FOR CIVIL ENGINEERS

This page is intentionally left blank

A Manual of Geology for Civil Engineers

JOHN PITTS

Nanyang Technological Institute, Singapore

World Scientific

Published by

World Scientific Publishing Co. Pte. Ltd.

P. O. Box 128, Farrer Road, Singapore 9128

A MANUAL OF GEOLOGY FOR CIVIL ENGINEERS

Copyright © 1984 by World Scientific Publishing Co Pte Ltd.

All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the Publisher.

ISBN 9971-978-05-9

9971-978-12-1 pbk

Printed in Singapore by Singapore National Printers (Pte) Ltd.

PREFACE

This manual of geology has been developed over a decade of teaching geology and engineering geology to undergraduate civil engineering students in the United Kingdom and Singapore. During that time, the course has changed dramatically, and I hope has improved so that it now meets the requirements of students aspiring to become professional civil engineers. One major lesson which has been learned over that decade is that students are more interested in subjects which they find relevant to their chosen vocation. It has therefore been essential to couch geology in terms suitable for civil engineers and deal with topics in geology immediately applicable to their needs. Many aspects of geology of a more esoteric nature are indeed fascinating, but within the time constraints of most civil engineering courses would probably be an unaffordable luxury.

As well as attempting to serve the needs of undergraduate civil engineering students, the aim has also been to put sufficient information in the book for it to serve as a useful handbook of geology for qualified civil engineers. To this end, geological methods employed in current civil engineering practice have been covered in some detail. This information should provide a sound base for geology to be used as a kind of materials science for geotechnics. Without some understanding of the geological make-up of soils and rocks both in the mass and in sample form, soil mechanics and rock mechanics can never fully be appreciated.

The geological information required by civil engineers is however not the same all over the world. The raw materials of soils engineering in particular are very different in the northern latitudes from those in the tropics. Relatively little coverage has been given to tropical conditions in the past, a deficiency which this book tries to remedy.

I should like to thank Mr H Dutton and Dr T Cairney of the Department of Building and Civil Engineering, Liverpool Polytechnic, UK, and Professor C N Chen of the School of Civil and Structural Engineering at the Nanyang Technological Institute, Singapore for their encouragement, and for recognizing the importance of geological training for civil engineers.

Thanks are also due to Yeo Chin Soon for preparing the many illustrations in the book and Jamillah Sa'adon for typing the manuscript.

June 1984

John Pitts
Singapore

ACKNOWLEDGEMENTS

The publisher and author would like to thank the following for permission to quote or modify copyright material (figure numbers refer to this publication, full citations can be found by consulting captions and references).

American Association of Geographers for Fig. 4.1; American Geophysical Union for Fig. 4.17; Edward Arnold (Publishers) Ltd. for Figs. 7.6, 7.7, 7.8, 7.9, 7.13, 7.14; Butterworths for Table 5.2; W.H. Freeman and Company for Fig. 4.18; Geological Society of London for Figs. 1.3, 4.11, 4.12, 4.13, 4.14, 4.15, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 7.1, 7.2, 7.3; The Geologists' Association for Fig. 1.1; The Institution of Civil Engineers for Fig. 1.4; The Institution of Mining and Metallurgy for Figs. 2.22, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.18, 7.10, 7.11, 7.15, 7.16, 7.17, 7.18, 7.19; International Association of Engineering Geology for Fig. 6.19; Longman for Figs. 4.2, 4.4; National Research Council of America for Figs. 4.16(a) to (j) inclusive; Norwegian Geotechnical Institute for Figs. 3.5, 3.17; The Open University for Figs. 6.1, 6.2, 6.3; Singapore Journal of Tropical Geography for Fig. 4.19.

CONTENTS

Preface	v
Chapter 1: BASIC CONCEPTS IN GEOLOGY AND THEIR RELEVANCE IN CIVIL ENGINEERING	
1.1 Plate Tectonics	1
1.2 Uniformitarianism	2
1.3 Superposition	2
1.4 The Geochemical Cycle	3
1.5 Geological Time and the Stratigraphic Column	4
1.6 Geomorphic Systems	5
1.7 Thresholds and Uniformity of Natural Systems	6
1.8 Magnitude and Frequency of Forces in Geomorphic Processes	7
1.9 Equilibrium of Geological Processes and their Disturbance by Engineering Activity	10
Chapter 2: ROCKS, THEIR COMPOSITION, IDENTIFICATION AND PROPERTIES	
2.1 Igneous Rocks	17
1 Classification of igneous rocks	21
2 Control over the form of igneous rocks	23
Volcanics	23
Intrusives	24
2.2 Sedimentary Rocks	24
1 Sedimentation	26
2 Sedimentary facies	27
3 Diagenesis	27
4 Diagenetic effects	28
2.3 Sandstones	29
1 Distinguishing features of sandstones	29
2 Classification of sandstones	30
3 Clean sandstones	30
4 Dirty sandstones	31
5 Feldspathic sandstones	31
2.4 Mudrocks	31

2.5	Carbonate Rocks	32
1	Terminology and classification of carbonate rocks	32
2.6	Metamorphic Rocks	33
2.7	Classification of Rocks	36
1	The use of feldspars in rock classification	36
	Igneous rocks	36
	Metamorphic rocks	36
	Sedimentary rocks	37
2.8	Identification of Rocks	37
1	Identification of igneous rocks	39
2	Identification of sedimentary rocks	43
3	Identification of metamorphic rocks	48
2.9	Some Engineering Properties of Rocks	51
2.10	Elastic Properties of Rocks	51
1	Moduli of elasticity	53
2	Geological influences on the elastic behaviour of rocks	55
3	Poisson's ratio	57
2.11	Strength Properties of Rocks	58
1	Factors controlling the strength of rocks	58
2.12	The Development of Index Properties of Rocks	60

Chapter 3: THE GEOMETRY, DESCRIPTION AND PROPERTIES OF ROCK MASSES

3.1	Folds	64
1	Geometry of folding	64
3.2	Structural Discontinuities	67
1	Faults	68
2	Rock cleavage	71
3	Joints	72
4	Unconformities	73
3.3	Shear Strength of Discontinuities	73
1	Influence of surface roughness on shear strength	74
2	Shear strength along actual joints	76
3	Determination of i	77
4	Apparent cohesion due to surface roughness	78
5	Peak and residual strength	79
6	Shear strength of filled discontinuities	80
3.4	Residual Stress	83
1	Gravitational stresses	83
2	Latent stresses	84
3.5	Sheet Joints	85

Chapter 4:	WEATHERING, EROSION, TRANSPORTATION AND DEPOSITION	
4.1	Weathering and its Significance in Geotechnical Engineering	86
1	Weathering processes	86
2	Weathering and weatherability	86
3	Weathering in humid tropical climate	92
4	Tests to assess weatherability	103
4.2	Engineering Classification of Weathered Rock	103
4.3	Erosion	112
Chapter 5:	SOIL PARTICLES, SOIL FABRICS AND SOIL STRUCTURES	
5.1	Non-cohesive Particles	124
5.2	Cohesive Particles	125
1	Silts	126
2	Clays	126
5.3	Clay Fabrics	129
5.4	Soil Structures	132
5.5	The Description of Engineering Soils	135
Chapter 6:	GEOLOGICAL AND GEOTECHNICAL MAPS	
6.1	Geological Maps and Strike Lines	137
6.2	Three Point Problems	158
6.3	Interpretation of Geological Maps	163
6.4	Geotechnical Mapping	170
1	Stratigraphical mapping	171
2	Structural mapping	171
3	Geomorphological mapping	171
4	Hydrogeological mapping	171
5	Geomechanical mapping	172
6	Mapping the effects of man	172
Chapter 7:	LOGGING ROCK FOR ENGINEERING PURPOSES	
7.1	Logging of Rock Cores	181
1	General requirements of a borehole log	181
2	Information to be recorded	181
3	Information to be recorded on the borehole log	182
4	State of recovery of core	183
7.2	Descriptive Geology	184
7.3	The Description of Rock Masses for Engineering Purposes	185
1	Rock material description	185
2	Rock material indices	187
3	Rock mass indices	188

7.4	Discontinuities	190
1	Weathering and altered state	191
2	Discontinuity spacing in three dimensions	191
7.5	Techniques for Carrying Out Classification Tests ..	194
7.6	Techniques for Obtaining Data	194
1	Observations	194
2	Discontinuity surveys	194
3	Recording and presentation of data	195
7.7	Processing Discontinuity Data	196
References		207
Index		211