

GEOLOGY AND ENGINEERING



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GEOLOGY AND ENGINEERING

THIRD EDITION

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McGRAW-HILL BOOK COMPANY

New York St. Louis San Francisco Auckland Bogotá Caracas Colorado Springs
Hamburg Lisbon London Madrid Mexico Milan Montreal New Delhi Oklahoma City
Panama Paris San Juan São Paulo Singapore Sydney Tokyo Toronto

This book was set in Times Roman by the College Composition Unit in cooperation with Waldman Graphics, Inc. The editor was B. J. Clark; the cover was designed by Joan O'Connor; the production supervisor was Denise L. Puryear. Project supervision was done by The Total Book. Arcata Graphics/Halliday was printer and binder.

Cover Credit

Geology and Engineering: their intimate association is shown here at the left abutment and emergency spillway of Williams Fork Dam, Grande County Colorado.

The insert shows the engineering geologic map of the migmatite coast rock, requiring engineering evaluation of its ability to anchor the dam and to pass the PMF overflow. Courtesy Denver Water Department.

GEOLOGY AND ENGINEERING

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2 3 4 5 6 7 8 9 0 HAL HAL 8 9 3 2 1 0 9 8

ISBN 0-07-037063-X

Library of Congress Cataloging-in-Publication Data

Legget, Robert Ferguson.
Geology and engineering.

Includes index.

1. Engineering geology. I. Hatheway, Allen W.

II. Title.

TA705.L4 1988 624.1'5 87-15181

ISBN 0-07-037063-X (Text)

ISBN 0-07-037064-8 (Solutions Manual)

ABOUT THE AUTHORS

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PREFACE

This volume is intended to provide engineering students with an introduction to the practice of civil engineering and, concurrently, to the geologic input that is essential for all civil engineering work. *Every* site utilized for civil engineering structures or works is unique; there will be differences between even adjoining sites, due to the underlying geologic structure and stratigraphy. Accordingly, planning and design of every civil engineering project must start with a study of site and local geology.

Throughout the book, a main and continuing theme is the vital importance of *observation*, during site investigations, throughout the entire construction process, and in maintenance and regular inspection of completed facilities. *Observation* is far more than just seeing. “You see” said Sherlock Holmes to his friend Dr. Watson, “but you do not observe.” Many of the Holmes adventures, by Conan Doyle, could well serve as supplementary reading to this book.

In consequence, treatment of the subject is entirely descriptive. Mathematics is an essential tool in the design process, a procedure in civil engineering that is entirely dependent upon assumptions made as to ground conditions at the design site. This book deals with the accuracy, or otherwise, of those assumptions upon which the success and safety of all structures depend. Computers now occupy a unique place in data management and structural design, but all that they make possible so effectively is ultimately dependent upon the *actual* geological conditions at the site. It is with these site conditions that this book is concerned.

The volume is at once a third edition of the first author’s book of the same name (first edition 1939, second in 1962) and a major abridgement of the *Handbook of Geology in Civil Engineering* (by Robert F. Legget and Paul F. Karrow, McGraw-Hill, 1983) made with the agreement of the Publishers and Dr. Karrow. Treatment of the subject is therefore by means of carefully selected and usefully illustrative case histories. Essential references to more detailed accounts of the more important histories discussed are given at the end of each chapter. For convenience in use, these reference lists have been kept very short and, in general, include only periodicals (such as *Engineering News-Record*), which are available in all University engineering libraries. Since all the case histories (and many more) are to be found in the *Handbook* noted,

readers are directed to the much more detailed reference lists which it contains for those not given herein.

Metric units are used throughout the book (but always with Imperial units in parenthesis), in keeping with international practice. The authors, with great respect, must dissociate themselves from the spelling of *metre* as *meter* since the International Organisation for Standardisation (I.S.O.) has agreed that *metre* is the accepted spelling, and this is now in universal use except in the United States of America. Answers and questions for all chapters are contained in an accompanying booklet.

The authors are indebted to I. Noffke and M. Jacques for the expert typing of the final version of the text, and to all who so kindly assisted with the provision of illustrations for the *Handbook*, a selection from which now provides the illustrations in this text.

The authors venture to hope that as a by-product of the use of this book, some readers may come to appreciate that geology is indeed "the People's Science" (as was said over a century ago), a reminder that it can be studied by all and that even an elementary knowledge of the science can aid greatly in the appreciation of all scenery and especially of the beauties of the earth.

The proper use of geology as the starting point of all civil engineering achievement will become ever more important with the passing years and the gradual utilization of more favorable sites. Despite all the pressures that will come to bear on them through advancing technology and mounting demands, civil engineers should always remember the words of Francis Bacon, written as the modern world began to emerge:

NATURE, TO BE COMMANDED, MUST BE OBEYED.

Allen W. Hatheway

Robert F. Legget

ACKNOWLEDGMENTS

McGraw-Hill would like to thank the following reviewers for their useful comments: Jerry D. Higgins, Colorado School of Mines; Carol Simpson, The Johns Hopkins University; and James R. Sims, Rice University.

CONTENTS

Preface	xvii
1 The Civil Engineer and Geology	1
TRAINING IN GEOLOGY	3
PRACTICAL EXPERIENCE	5
GEOLOGISTS AND CIVIL ENGINEERING WORK	6
THE PATTERN OF CIVIL ENGINEERING	8
CONSTRUCTION OPERATIONS	12
MAINTENANCE	13
CONCLUSION	13
FURTHER READING	16
2 Rocks and Soils	17
ROCK AS AN ENGINEERING MATERIAL	19
Minerals / Igneous Rocks / Sedimentary Rocks / Metamorphic Rocks / Distinguishing Rock types	
GEOLOGIC STRUCTURE	27
Discontinuities / Bedding Planes / Joints in a Typical Rock Mass / Folding / Faults / Denudation / Unconformity	
ROCK CHARACTERISTICS	34
Rock Properties	
GROUNDWATER	37
IN SITU STRESSES	38
FIELD TESTS AND FIELD OBSERVATIONS	39
Field Observations	
SOIL AS AN ENGINEERING MATERIAL	41
	vii

ROCK WEATHERING	41
Agencies of Weathering / Products of Weathering	
RESIDUAL SOILS	43
TRANSPORTED SOILS	43
Erosion / Aeolian Deposits / Fluvial (Alluvial)	
Soils / Gravitational Deposits / Glacial	
Soils / Glacial Erosion / Types of Glacial	
Deposits / Erratics / Marine Deposits	
SOIL CHARACTERISTICS	53
Gravels / Silts / Clay / Clay Minerals	
ORGANIC SOILS	58
PERMAFROST	59
SOIL MECHANICS AND GEOLOGY	59
Soil Mechanics Today / Soil Testing /	
Links with Geology	
CONCLUSION: DEALING WITH ROCK AND SOIL	64
REFERENCES	65
FURTHER READING	65
3 Groundwater and Climate	66
CLIMATIC EFFECT	67
THE HYDROLOGIC CYCLE	68
HISTORICAL NOTE	69
CHARACTERISTICS OF GROUNDWATER	71
GROUNDWATER IN EARTH MATERIALS	73
GROUNDWATER QUALITY	76
INFLUENCE OF GEOLOGIC STRUCTURE	78
GROUNDWATER MOVEMENT	80
GROUNDWATER SURVEYS	81
SPRINGS AND ARTESIAN WATER	82
GROUNDWATER NEAR THE SEA	86
RAINFALL	88
TEMPERATURE AND WIND	89
CLIMATIC RECORDS	91
CONCLUSION	93
REFERENCES	94
4 Site Investigations	95
PRELIMINARY INVESTIGATIONS	98
Economics of Preliminary Investigations /	
Scope of Preliminary Investigations	

GEOLOGIC METHODS	102
Regional Geology / Photo Interpretation / Correlation with Geology / Geologic Mapping	
EXPLORATION TECHNIQUES	112
Exploratory Boring and Sampling / Exploratory Drilling in Rock / Large-Diameter Exploratory Holes / Exploratory Shafts and Tunnels / In Situ Tests / Supervising Exploration	
GEOPHYSICAL METHODS	122
Seismic Methods / Electrical Methods / Magnetic Methods / Gravitational Methods / Applications in Civil Engineering	
URBAN SITE EXPLORATION	131
Archival Records / Utility Records / Geophysical Exploration	
UTILIZING EXPLORATION RESULTS	140
CONSTRUCTION-RELATED ACTIVITIES	142
When Construction Starts / As-Constructed Drawings	
CONCLUSION	144
REFERENCES	145
FURTHER READING	146
5 Open Excavation	147
A MAJOR EXAMPLE OF EXCAVATION	149
ECONOMICS OF OPEN EXCAVATION	152
OPEN EXCAVATION IN SOIL	154
Preliminary Considerations / Methods Used / Examples of Open Excavation	
SUPPORT FOR EXCAVATION	158
Slurry Trench Method / Tieback Method / An Example of Combined Methods	
SINKING OF SHAFTS	162
CONTROL OF GROUNDWATER	163
DRAINAGE OF OPEN EXCAVATIONS	165
WELL POINTS	167
EFFECTS OF DRAINAGE	170
FILL FOR EMBANKMENTS	173
PROBLEMS WITH FAULTS	174
EXCAVATION OF ROCK	174
Methods of Rock Excavation	
QUARRYING IN CIVIL ENGINEERING	180
CONCLUSION	181
REFERENCES	181

6	Tunnels and Underground Space	183
	HISTORICAL NOTE	185
	GEOLOGY AS THE UNDERPINNING OF DESIGN	187
	PRELIMINARY WORK	188
	TUNNELS FOR NEW YORK CITY	190
	UNDERWATER TUNNELS	193
	PRESSURE TUNNELS	197
	TUNNEL SHAPES AND LININGS	200
	OVERBREAK	201
	CONSTRUCTION METHODS	203
	GROUTING	208
	UNUSUAL GEOLOGICAL PROBLEMS	209
	Groundwater / Presence of Gases / Weathered Rock	
	CONSTRUCTION RECORDS	213
	TUNNELS UNDER BOSTON	217
	USE OF OLD MINES AND QUARRIES	219
	UNDERGROUND POWERHOUSES	222
	UNDERGROUND FUEL STORAGE	224
	UNDERGROUND SPACES FOR HUMAN USE	228
	POTENTIAL PROBLEMS	231
	CONCLUSION	231
	REFERENCES	232
7	Building Foundations	233
	INFLUENCE OF GEOLOGICAL CONDITIONS ON DESIGN	235
	FOUNDATIONS ON BEDROCK	236
	FOUNDATIONS CARRIED TO BEDROCK	237
	FOUNDATIONS ON SOIL	240
	GROUNDWATER	244
	PILED FOUNDATION	246
	"FLOATING" FOUNDATIONS	249
	CAISSON FOUNDATIONS	250
	PRELOADING OF FOUNDATION BEDS	252
	BUILDING ON FILL	253
	SETTLEMENT OF BUILDINGS	254
	PREVENTION OF EXCESSIVE SETTLEMENT	258
	BUILDINGS OVER COAL WORKINGS	260
	UNDERPINNING	261
	PRECAUTIONS ON SLOPING GROUND	262
	SMALL BUILDINGS	263
	<i>POWER HOUSE FOUNDATIONS</i>	264
	GENERAL CONSIDERATIONS	264
	GEO THERMAL POWER	265

TIDAL POWER PLANTS	266
WATER POWER PLANTS	268
The Arapuni Development / The Bonneville Development / The Cheakamus Development / The Kelsey Development / The Foyers Development / The Kootenay Development	
THERMAL PLANTS	273
Problems with Uplift Pressure / Problems with Weak Foundation Strata / Problems with Subsidence	
NUCLEAR PLANTS	276
CONCLUSION	279
REFERENCES	283
8 Bridge Foundations	284
IMPORTANCE OF BRIDGE FOUNDATIONS	285
SPECIAL PRELIMINARY WORK	286
DESIGN OF BRIDGE PIERS	290
DESIGN OF BRIDGE ABUTMENTS	295
PRECAUTIONS AGAINST SETTLEMENT	298
EARTHQUAKES AND BRIDGE DESIGN	299
SCOURING AROUND BRIDGE PIERS	301
SOME CONSTRUCTION REQUIREMENTS	302
COFFERDAM CONSTRUCTION	305
SOME UNUSUAL CASES	308
INSPECTION AND MAINTENANCE	311
GROUTING	314
FOUNDATION STRENGTHENING WITH GROUT	315
CONCLUSION	318
REFERENCES	319
9 Water Supply	320
HISTORICAL NOTE	321
SOURCES OF WATER SUPPLY	322
RELATION OF GEOLOGY TO RUNOFF	322
WATER QUALITY	324
WATER SUPPLY FROM RIVERFLOW	326
WATER SUPPLY FROM IMPOUNDING RESERVOIRS	328
WATER SUPPLY FROM GROUNDWATER	333
REPLENISHMENT OF GROUNDWATER	337
SOME UNUSUAL SOURCES OF SUPPLY	340

SOME GEOLOGICALLY SIGNIFICANT SYSTEMS	342
London, England / Long Island, New York / South Coastal Basin of California / Vancouver, British Columbia / Sydney Australia / Hong Kong / Ogden Valley, Utah / Sheikdom of Kuwait / Honolulu, Hawaii	
REFERENCES	350
10 Dam Foundations	351
HISTORICAL NOTE	352
FAILURES OF DAMS	353
INSPECTION AND MAINTENANCE	358
REVIEW OF DAM CONSTRUCTION	359
PRELIMINARY WORK	361
EXPLORATORY WORK DURING CONSTRUCTION	364
SOUNDNESS OF BEDROCK	367
POSSIBILITY OF GROUND MOVEMENT	370
PERMEABILITY OF BEDROCK	371
DAMS ON PERMEABLE FOUNDATION BEDS	374
CONSTRUCTION CONSIDERATIONS	375
GROUTING AS A SOLUTION TO GEOLOGICAL PROBLEMS	382
PROBLEMS WITH DAMS IN SERVICE	386
GEOLOGIC INFLUENCES ON RESERVOIRS	388
RESERVOIR LEAKAGE	390
SECONDARY EFFECTS OF RESERVOIR FLOODING	394
RESERVOIR SILTATION	395
RIVER DIVERSIONS	398
CONCLUSION	399
REFERENCES	400
11 Transportation Facilities	401
CANALS	402
HISTORICAL NOTE	402
THE CANAL AGE	403
THE PANAMA CANAL	404
THE ST. LAWRENCE SEAWAY	406
CANAL LOCKS	407
SOME EUROPEAN CANALS	409
ROADS	411
HISTORICAL NOTE	411
ROUTE LOCATION	412
CLIMATE	414
DRAINAGE	414

MATERIALS	417
CONSTRUCTION	419
SOME GEOLOGICALLY SIGNIFICANT ROADS	422
<i>RAILWAYS</i>	424
RAILWAY LOCATION	425
RAILWAY CONSTRUCTION	426
"MAINTENANCE OF WAY"	429
ROCKFALLS	433
SPECIAL HAZARDS	434
RELOCATION OF RAILWAYS	436
SUBWAYS	437
<i>London Subway Construction / Some Other Subways</i>	
<i>AIRFIELDS</i>	442
DRAINAGE	444
CUT AND FILL	446
REFERENCES	446
12 Marine Works	448
THE TIDES, WAVES, AND CURRENTS	449
THE EARTH BENEATH THE SEA	451
TYPICAL COASTAL PROBLEMS	452
DOCKS AND HARBORS	454
BREAKWATERS	458
COASTAL EROSION	459
LITTORAL DRIFT	464
MAINTENANCE OF TIDAL ESTUARIES	466
DREDGING	468
SOME SUBMARINE PROJECTS	470
OFFSHORE STRUCTURES	472
RIVER TRAINING WORKS	476
THE MISSISSIPPI RIVER	478
DELTAS AND ESTUARIES	480
RIVER DYNAMICS	482
SMALL-SCALE WORKS	484
BANK PROTECTION	485
CANALIZATION OF RIVERS	486
LAND RECLAMATION	489
<i>Zuider Zee Reclamation / Some Smaller Examples</i>	
CONCLUSION	494
REFERENCES	496

13	Natural Hazards and Environmental Concerns	497
	VOLCANOES AND EARTHQUAKES	499
	Volcanoes / Earthquakes / Seismic Design Requirements / Man-Made Earthquakes / Tsunami	
	LANDSLIDES	508
	Slope Stability / Natural Landslides / Landslides in Sensitive Clays / Causes of Landslides / Preventive and Remedial Works	
	ROCKFALLS	518
	Some Smaller Rockfalls / Minor Rockfalls / Rockslides	
	LAND SUBSIDENCE	523
	Mining-Induced Subsidence / Methods of Avoiding Mining Subsidence	
	SINKHOLES	530
	Sinkholes due to Pumping / Karst Country / Detection and Remedial Works	
	EROSION AND SEDIMENTATION	534
	Erosion by Streamflow / Transportation by Streamflow / Erosion on Construction Projects	
	FLOODS	538
	Catchment Areas / Causes of Floods / Flood Protection / Floodplains	
	CONCLUSION	544
	REFERENCES	545
14	Geology and the Civil Engineer	546
	<i>PLANNING</i>	547
	ELEMENTS OF PLANNING	548
	"DESIGN WITH NATURE"	548
	PLANNING AND GEOLOGY	549
	NATURAL HAZARDS AND PLANNING	551
	SOME EXAMPLES	552
	Washington, D.C / The San Francisco Bay Area / Denver, Colorado / Allegheny County, Pennsylvania / St. Lawrence County, New York	
	GEOLOGICAL INFORMATION	556
	THE FUTURE OF PLANNING	556
	<i>MAN-MADE GEOLOGICAL PROBLEMS</i>	557
	LARGE DAMS	557
	DIVERSION OF WATER	558
	MORE PROBLEMS WITH WATER	559

POLLUTION	560
PROBLEMS WITH METHANE	563
MINE WASTES	564
<i>CONSERVING THE ENVIRONMENT</i>	565
RESTORATION OF LAND	566
SLOPE PROTECTION	568
STABILIZATION OF SAND DUNES	569
SAND AND GRAVEL PITS	569
MINING AND THE ENVIRONMENT	570
ENVIRONMENTAL IMPACT STATEMENTS	572
<i>SOIL EROSION AND CONSERVATION</i>	572
SOIL CONSERVATION	575
A CONSERVATION ETHIC FOR ENGINEERS	575
<i>HOW CIVIL ENGINEERS CAN AID GEOLOGY</i>	576
EXPLORATORY BORINGS	577
GEOTECHNICAL STUDIES	577
OPEN EXCAVATION	578
TUNNEL SHAFTS	579
TUNNELS	580
HIGHWAYS	580
A GEOLOGIC CHALLENGE FOR CIVIL ENGINEERS	582
REFERENCES	582
Appendix A Glossary of Geological Terms	585
Appendix B Some Useful Journals	591
Index	595

THE CIVIL ENGINEER AND GEOLOGY

TRAINING IN GEOLOGY, p. 3
PRACTICAL EXPERIENCE, p. 5
GEOLOGISTS AND CIVIL ENGINEERING WORK, p. 6
THE PATTERN OF CIVIL ENGINEERING, p. 8
CONSTRUCTION OPERATIONS, p. 12
MAINTENANCE, p. 13
CONCLUSION, p. 13
FURTHER READING, p. 16

Every branch of civil engineering deals in some way with the surface of the earth, since the works designed by the civil engineer are supported by or located in some part of the earth's crust. The practice of civil engineering includes the design of these works and the control and direction of their construction. *Geology* is the name given to that wide sphere of scientific inquiry which studies the composition and arrangement of the earth's crust. This book is concerned with the application of the results of this scientific study to the art and practice of the civil engineer.

At the start of the nineteenth century, before engineering had become the highly specialized practice it is today, many civil engineers were also active geologists. William Smith is the outstanding example of these pioneers. Robert Stephenson combined geological study with his early work in railway construction, and other well-known figures in the annals of engineering history were also distinguished in geology.

Today there is widespread recognition of the vital importance of the science of geology to those who practice the art of civil engineering. Geology is commonly included as a basic subject in courses of training for civil engineering (it should be included in *every* civil engineering course); civil engineering papers contain frequent references to the geological features of the sites of works described; and soil mechanics, the generally accepted scientific approach to soil studies, provides a common meeting ground for civil engineer and geologist and a means of fostering their cooperation.

In the past, geological considerations frequently have been featured prominently in the study and discussion of failures of civil engineering works. In fact, to some engineers, geology may still be thought of as merely a scientific aid to the correct determination of the reasons for some of the major troubles that develop during or subsequent to construction operations. Although the assistance rendered by geologists and by the study of geological features in such "postmortem" considerations is valuable, the very fact that geological features may have had something to do with these failures suggests with abundant clarity that the best time to consult a geologist or study geological features is *before* design and construction begin. In this way, the science can serve the art in a constructive rather than merely a pathological manner. It will later be seen, as applications of geology are considered in some detail, that this constructive service of the science can not only prevent possible future troubles, but it can also suggest new solutions to engineering problems and can often reveal information of utility and economic value, even in preliminary work.

The more obvious effects of geological features on major civil engineering works may be seen in the underground railway services in London and New York. In London, because the city is built on a great basin of unconsolidated material (including the well-known London clay), tube railways, located far below ground level and built in clay that was easily and economically excavated, have provided an admirable solution to one part of the city's transportation problems. In New York, on the other hand, the surface of Manhattan Island on which the city is located is underlain to a considerable extent by Manhattan schist. Underground railways had to be constructed in carefully excavated rock cuts just below surface level, as innocent visitors to that great city learn if they happen to stand on a ventilation grating when a train passes in the subway below. Many similar instances of the profound effect of local geological characteristics upon major civil engineering works could be cited, but all would serve to emphasize the same point: how closely the science and the art are related and how dependent civil engineering work generally must be upon geology.

The science of geology stands in relation to the art of the civil engineer in just the same way as do physics, chemistry, and mathematics. The importance of the latter sciences to the civil engineer is never questioned; they are always considered the necessary and inevitable background to civil engineering training. It would be inconceivable for any engineer worthy of the name to be