Benchmark Papers in Geology / 25

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ENVIRONMENTAL GEOLOGY

Edited by

FREDERICK BETZ, JR.

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Dowden, Hutchinson & Ross, Inc.
Stroudsburg, Pennsylvania

Distributed by
HALSTED PRESS *A Division of John W*

Meant for Betty
1921–1974

Benchmark Papers in Geology, Volume 25
Library of Congress Catalog Number: 75-29646
ISBN: 0-470-07170-2

77 76 75 1 2 3 4 5
Manufactured in the United States of America.

LIBRARY OF CONGRESS CATALOGING IN PUBLICATION DATA

Main entry under title:

Enviromental geology.

(Benchmark papers in geology ; 25)
Includes bibliographies and indexes.
1. Engineering geology--Addresses, essays, lectures.
2. Environmental protection--Addresses, essays, lectures.
3. Man--Influence of environment--Addresses, essays, lectures. 4. Man--Influence on nature--Addresses, essays, lectures. I. Betz, Frederick, 1915-
TA705.E64 301.31 75-29646
ISBN 0 470-07170-2

Exclusive Distributor: **Halsted Press**
A Division of John Wiley & Sons, Inc.

ACKNOWLEDGMENTS AND PERMISSIONS

ACKNOWLEDGMENTS

APPALACHIAN REGIONAL COMMISSION, WASHINGTON, D.C.—*Appalachia*
Environmental Analysis in Local Development Planning

ASSOCIATION OF ENGINEERING GEOLOGISTS—*Geological and Geographical Problems of Areas of High Population Density*
Geological and Geographical Factors in the Siting of New Towns in Great Britain

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The Influence of Geology on Military Operations in North-west Europe

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U.S. GEOLOGICAL SURVEY
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Excerpts
Hydrologic Implications of Solid-Waste Disposal
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Excerpts

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Hydrological and Ecological Problems of Karst Regions

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SERIES EDITOR'S PREFACE

The philosophy behind the "Benchmark Papers in Geology" is one of collection, sifting, and rediffusion. Scientific literature today is so vast, so dispersed, and, in the case of old papers, so inaccessible for readers not in the immediate neighborhood of major libraries that much valuable information has been ignored by default. It has become just so difficult, or so time consuming, to search out the key papers in any basic area of research that one can hardly blame a busy man for skimping on some of his "homework."

This series of volumes has been devised, therefore, to make a practical contribution to this critical problem. The geologist, perhaps even more than any other scientist, often suffers from twin difficulties—isolation from central library resources and immensely diffused sources of material. New colleges and industrial libraries simply cannot afford to purchase complete runs of all the world's earth science literature. Specialists simply cannot locate reprints or copies of all their principal reference materials. So it is that we are now making a concerted effort to gather into single volumes the critical material needed to reconstruct the background of any and every major topic of our discipline.

We are interpreting "geology" in its broadest sense: the fundamental science of the planet Earth, its materials, its history, and its dynamics. Because of training and experience in "earthy" materials, we also take in astrogeology, the corresponding aspect of the planetary sciences. Besides the classical core disciplines such as mineralogy, petrology, structure, geomorphology, paleontology, and stratigraphy, we embrace the newer fields of geophysics and geochemistry, applied also to oceanography, geochronology, and paleoecology. We recognize the work of the mining geologists, the petroleum geologists, the hydrologists, the engineering and environmental geologists. Each specialist needs his working library. We are endeavoring to make his task a little easier.

Each volume in the series contains an Introduction prepared by a specialist (the volume editor)—a "state of the art" opening or a summary of the object and content of the volume. The articles, usually some

thirty to fifty reproduced either in their entirety or in significant extracts, are selected in an attempt to cover the field, from the key papers of the last century to fairly recent work. Where the original works are in foreign languages, we have endeavored to locate or commission translations. Geologists, because of their global subject, are often acutely aware of the oneness of our world. The selections cannot, therefore, be restricted to any one country, and whenever possible an attempt is made to scan the world literature.

To each article, or group of kindred articles, some sort of "highlight commentary" is usually supplied by the volume editor. This commentary should serve to bring that article into historical perspective and to emphasize its particular role in the growth of the field. References, or citations, wherever possible, will be reproduced in their entirety—for by this means the observant reader can assess the background material available to that particular author, or, if he wishes, he, too, can double check the earlier sources.

A "benchmark," in surveyor's terminology, is an established point on the ground, recorded on our maps. It is usually anything that is a vantage point, from a modest hill to a mountain peak. From the historical viewpoint, these benchmarks are the bricks of our scientific edifice.

RHODES W. FAIRBRIDGE

PREFACE

The term *environmental geology* has been known only since the early 1960s, when problems created by use and abuse of the environment became a common concern and stimulated numerous disciplines to identify their particular roles in the study of these problems. However, as a subject, environmental geology can be traced in the literature from early in the nineteenth century.

The number of older writings cannot be determined, because the subject did not appear in bibliographies, and book and article titles usually gave no clue to it. The literature on environmental geology has grown rapidly in recent years, but there are still problems in identifying the subject from titles. The term is still used for a variety of purposes.

The readings in this volume provide a sample of environmental geology, necessarily limited in number and length by the available space, limited also to a number of topics that have to do with the purpose, scope, and methods of the subject. There are 30 readings—complete texts or representative portions—grouped in seven sections, which are not wholly independent. The emphasis in a reading determined the section to which it was assigned. Comments by the editor include cross-references to assist in linking sections. The sections conclude with lists of supplemental readings, totaling more than 300 titles.

Among the 30 readings, 21 originated in the United States. About 70 percent of the supplemental readings were published in the United States, although almost 85 percent of those readings that date from before the early 1960s came from other countries.

I am indebted to numerous geologists, as well as specialists in other fields that deal with the physical environment, for discussing with me their views on the concept of environmental science in general, and environmental geology in particular, and for calling to my attention literature that I might wish to include in the volume.

I express my gratitude to Marie Siegrist, bibliographer known to geoscientists around the world, for her invaluable assistance in making it possible for me to examine many publications that otherwise would have been inaccessible.

FREDERICK BETZ, JR.

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INTRODUCTION

The use of the term "environmental geology" is so widespread among geologists today that it seems hardly believable that the term is less than ten years old.

The first use is credited to James E. Hackett. In a personal communication received from him (1973), Hackett states: "The term Environmental Geology was initiated by me to identify a new orientation for the study and use of geology in a coordinated and integrated manner." It was applied to programs conducted by the Illinois Geological Survey, beginning in 1962. As a documented term, Hackett introduced it in a paper presented to a conference on Water Geology and the Future, held at Indiana University in April 1964; the published proceedings appeared in 1967. Hubert E. Risser (1969) and John B. Ivey (1969) confirm that Hackett originated the term. Peter Flawn et al. (1970) attribute the term to Hackett and John Frye.

In 1969, William C. Hayes and Jerry D. Vineyard remarked:

> Indeed, environmental geology is so new that the dictionary doesn't include it. It defines environment as "the complex of climatic, edaphic, and biotic factors that act upon an organism or an ecological community . . . ," and geology is termed "a science that deals with the history of the earth and its life especially as recorded in rocks . . . ," but no comprehensive definition is given. The geologist of today is writing his own definition. He is applying geologic principles to improve man's environment through the wise use of natural resources. He is making the new discipline—"environmental geology"—functional in metropolitan areas, the suburbs, rural areas, and the wilderness.

Looking somewhat further into expressed concepts of "environment," we may take note of remarks by Rhodes W. Fairbridge (1971):

"The concept of environment as commonly employed today is essentially one aspect of the integrated biologic/geologic global system, the physical ecologic habitat of *Man.* In this sense we exclude the social and cultural environment."

Robert F. Legget (1971) observes that "*Environment* has very recently become one of the words of the age. It is a splendid term for use in connection with the interdisciplinary approach to the protection and conservation of renewable natural resources that is at long last being recognized in the public domain after the long years of pleading by the few."

From the viewpoint of a soil scientist, Robert F. Reiske (1968) says that "Environment is the soil landscape, which results from the interaction of climate, relief, organic materials (vegetation), parent materials (geology), over a period of time. . . . Since there are many kinds of climate, relief, vegetation, and geologic materials many variations in the environment occur on the land." Reiske defines a soil landscape as "a three-dimensional segment of the land having similar parent material, soil profile, slope grade and position, drainage pattern, and aspect. [Here] vegetation is also included as part of the soil landscape."

These few samples suffice to indicate the diversity of opinion that exists on the definition of environment. On inspection, similarities can be seen, but the definition reflects the personal interest of the definer.

We could move on to statements from chemists, oceanographers, social scientists, and representatives of many other fields. In passing, I note that, as in the case of Reiske's definition, attention is generally focused on the land. I have mentioned oceanographers, who indeed have a concern with environment. We cannot overlook the marine environment by simply drawing a line between land and sea.

Since it is virtually impossible for any individual or group to deal with the whole of environment and arrive at a synthesis of all pertinent knowledge, we must fall back on consideration of single factors or groups of factors that can yield meaningful syntheses. It is to be hoped that different types of syntheses can be worked into broader understanding of the total environment.

We can readily concentrate on the physicial factors of environment in a geologic investigation and set aside the ecologic, social, and cultural factors. However, in studying the physical factors, it is unreal to think only of those that are regarded as natural factors, or of certain aspects of the biologic world. Thus, man-made features at and below the earth's surface frequently simulate natural features. In the preparation of an environmental map the complex of an urban center should not be indicated by the use of a distinctive color or pattern that would signify an area which is not being evaluated. There is a useful term,

"surface geometry," in common use in military evaluations, it stands not only for natural landforms, but also for positive and negative relief created by man. In the present volume, surface geometry is not considered as a major topic, but human influence as a geologic agent is examined. Just as man-made structures can be integrated into a study of the physical environment, so, too, the physical aspects of biologic features can be included. Regardless of the interests of vegetation specialists in the life and habits of their objects of research, the profile and ground outline of a forest can be treated in the same manner as landforms composed of rock or soil. In a consideration of microrelief, for instance, the fairly uncommon work of animals, the beaver dam, is seen as a part of the areal physiography, and no special concern need be given to the nature of beavers, aside from recognizing them as the builders of the structure.

To return to the immediate subject of this volume, Paul H. Moser commented in 1969:

> Environmental geology uses the principles of geology, hydrology, engineering geology, geophysics and associated sciences and disciplines to determine how the resources of an area may be developed for the maximum benefit of man. It is a science that studies the environment in relation to man and its reports are helpful not just to the scientist but to all concerned with the growth of an area.

Peter T. Flawn et al. (1970) summarize more extensively and explicitly:

> Environmental geology deals with the entire spectrum of man's use of the earth, both in cities and in rural and primitive regions—it includes the location and exploitation of natural resources, the disposal of wastes, the effects of both mass movements and tectonic movements on structures, and the effects of subtle variations in the composition of earth materials on health. It involves the oceans and atmospheres as well as the solid earth—the effects on the earth of the great columns of heat and smoke produced by massive concentrations of people and industry fall within its domain. The key word in environmental geology is *application.*

It is obvious that man's use of the earth has become concentrated in urban centers and, now, conurbations in the developed countries. Therefore, it is not surprising to find that statement by William J. Wayne (1968): ". . . the geology of man's environment becomes most important in and near urban centers; the term *urban geology* is virtually synonymous with *environmental geology.*" Flawn et al. (1970) agreed: "Urban areas are currently the prime focus of environmental geology . . . ."

Nevertheless, it is quite clear that environmental geology is not synonymous with urban geology. In spite of their great importance,

urban problems are only one aspect of land-use planning, which stretches from unoccupied areas to small settlements, to cities, to regions, to entire countries, and, possibly in a very general sense, to still larger units combining occupied and unoccupied tracts (e.g., major river basins, distinctive climatogeomorphic belts). It is also important to recognize that environmental geology has many facets, as cited in the remarks quoted from Flawn et al. but still others that they did not mention. In the present volume, not all these facets can be displayed, and indeed some have not yet emerged in the literature of environmental geology.

The term "environmental geology" has also been adopted by engineering geologists, who sometimes tend to create the impression that we are dealing again with synonyms to designate one field. The opinion of these engineering geologists is supported by the importance of their work both in connection with urban problems and in construction problems away from urban centers. However, as we have already learned from the authors cited, environmental geology stands for much more than engineering geology. The latter converts the implications of the geologic environment into forms usable by engineers. Legget has expressed the same view, somewhat differently, and finds it to be well recognized everywhere.

Furthermore, some geologists see a close linkage between economic geology and environmental geology. But, widely practiced, economic geology seems to be only distantly related to environmental geology. Such a relationship does exist when economic geologists are concerned with the pollution caused by the exploitation of mineral resources both in the immediate proximity of deposits or farther away from them, the destruction of the landscape as a result of strip mining, the results of underground mining, or the effects of the extractive industries on presently active environmental processes. A great range of problems may be involved, to be dealt with variously by mining geologists or mining engineers, sedimentologists, geomorphologists, health and sanitation specialists, and landscape architects.

There are objectors to the term "environmental geology." For instance, Gordon B. Oakeshott (1970) states: " 'Environmental geology' is a ridiculous term!" Continuing, he says, "*All* geology is environmental, and the most basic element in every man's environment is the geologic factor." Having spoken, Oakeshott concedes that the term is too widely accepted to be eradicated.

Legget (1971) dwells more emphatically on his dislike of the term:

> Geology *is* the study of man's physical environment so that to connect the two words is to be guilty of a terminological inexactitude that does real disservice to one of the greatest of the natural sciences. More than this, however, the very use of the term infers . . . that prior to the use