GEOLOGY UNDER CITIES

REVIEWS IN ENGINEERING GEOLOGY
VOLUME V

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GEOLOGY UNDER CITIES

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The Geological Society of America
Boulder, Colorado 80301
1982

Published by the Geological Society of America, Inc.
3300 Penrose Place, P. O. Box 9140, Boulder, Colorado 80301
Printed in U.S.A.

Library of Congress Cataloging in Publication Data
Main entry under title:

Geology under cities.

(Reviews in engineering geology ; v. 5)
Includes bibliographies.
1. Urban geology—Addresses, essays, lectures.
I. Legget, Robert Ferguson. II. Geological Society of
America. III. Series.
TA705.R4 vol. 5 [QE39.5.U7] 624.1'51s [557.3] 82-20991
ISBN 0-8137-4105-X

Contents

Foreword

Digby J. McLaren; President, The Geological Society of America

The Geological Society of America held its annual meeting for 1978 in Toronto, Canada, jointly with the Geological Association of Canada. One of the several symposia featured at that meeting was organized by the Engineering Geology Division of the Society, dealing with *Geology under Cities*. The opening paper dealt, appropriately, with the geology beneath the streets of Toronto. Since I was then the Director-General of the Geological Survey of Canada, the host country, it seemed appropriate to those responsible for the symposium that, in this capacity, I should say a few words by way of introduction. This I was pleased to do. The symposium was well received.

This volume contains revised and enlarged versions of seven of the papers presented at that Toronto meeting, together with two additional papers to give even better coverage of the major cities of North America. I now find myself in the position of President of the Society. The Editor has asked if, again, I would contribute a Foreword. I am glad to do so, since this is, in some ways, a unique volume, containing the first general treatment of its subject yet published by the Society.

Neglect of the geology that lies beneath the roads and streets of our cities is, as the Editor points out in his introduction, a strange gap in the steady development of the science during the last one hundred years. The ground is there, and details of its geology are obtainable (through excavations and other operations of man)—in many cases more easily than in open country. And yet it has been left, in general, for geotechnical engineers to realize the full significance of urban geology, as it may so rightly be called. Today, as this volume shows so well, there is an awakening appreciation of what collaboration between geologists and engineers can achieve in this field.

There were, naturally, individual exceptions to this broad statement about neglect. Let me mention just one—a message from a former member of the staff of the Geological Survey of Canada, Dr. H. M. Ami, a man of broad and varied interests, basically a paleontologist. He presented a paper to the Royal Society of Canada at its meeting in May 1900 on "The Geology of the Principal Cities in Eastern Canada" and had this to say by way of introduction:

> What the drill has to penetrate in any one of our larger centres of activity in Canada, before reaching the old Archaean or original crust of the Earth in this portion of the North American continent covered by the areas under discussion, is a question not only of interest but also of economic value.[1]

Urban geology in Canada might have advanced far if these words had been heeded at the time.

The other side of the coin is well shown by the story of how Hans Cloos solved the riddle of the Rhine Graben by observations that he made in April 1929 during the construction of a short tunnel through the Lorettoberg in the city of Freiburg. This is related in his notable volume *Conversation with the Earth.*[2] The dual contributions possible from study of urban geology, the scientific and the practical, are well illustrated in this volume.

There is much to be done, therefore, in tapping the geological potential that the study of urban geology presents. If all the cities of North America, and the major towns as well, had as good a record of their underground as have the cities considered in the papers that follow, the science of geology would be enhanced and the practice of engineering geology greatly assisted. I hope, therefore, that this volume will act as a catalyst in awakening renewed interest in this neglected branch of applied geology, to the advantage of geotechnique but more particularly for the benefit of the science of geology.

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[1]Ami, H. M., "On the Geology of the Princial Cities in Eastern Canada," *Proceedings and Transactions of the Royal Society of Canada,* Second Series, Volume VI, p. 125–173, Ottawa, 1900.

[2]Cloos, H., *Conversations with the Earth* (trans. E. B. Garside), London: Routledge & Kegan Paul Ltd., 1954.

Introduction

"Nature to be commanded" is not only the first part of a justly famous aphorism of Francis Bacon (1526–1626), the pointed ending being "must be obeyed," but it has been adopted as the title of one of the most remarkable of all the publications of the U.S. Geological Survey. If anyone should pick up this volume and wonder why the Geological Society of America is concerned with the geology that underlies cities, one glance at USGS Professional Paper No. 950 (G. D. Robinson and A. M. Spieker, editors) will set all such doubts at rest. Large in page size (so that it cannot be "tucked away" in a filing cabinet), the paper is vividly illustrated in brilliant colors. Through examples chosen from six very different areas, it shows clearly how geology controls all the development work of man. The title is well chosen since, if nature is to be controlled, as it must be in the orderly development of towns and cities, it must be obeyed in a manner that an accurate knowledge of the local geology alone makes possible.

This message from Francis Bacon is known and appreciated by the members of the Engineering Geology Division of the Society. Officers of the Division, in keeping with this imperative, decided to highlight the importance of geology under cities at the Society's annual meeting in Toronto in 1978. As Dr. McLaren has kindly indicated in his Foreword, the symposium on this subject was well received; this volume is one result. It is a pleasure to record appreciation to all the authors of the papers which follow, two of them specially prepared to supplement revised and enlarged versions of seven of the papers presented orally at Toronto. Their ready cooperation and all the work that their papers represent are appreciated. The assistance of the necessarily anonymous reviewers, whose suggestions were so generally adopted to the benefit of all the papers in this volume, was also valued.

A paper on the unusual geology under Mexico City was to be included, if only to balance the Canadian contributions from the north, but this did not prove possible. It is a matter of real regret that, despite the wide coverage given by the nine papers, no city on the west coast is included. This is not due to any anti-western bias on the part of the Engineering Geology Division, but to the fact that two western papers that were to be included were not available due to circumstances far beyond any editorial influence. Fortunately, some other excellent publications admirably fill this gap. As examples, let me mention the 119-page USGS Bulletin by D. E. Trimble on the geology of Portland, Oregon, and the surrounding district[1]; the well-known USGS maps showing the engineering geology of the Oakland and San Francisco areas[2]; and the comprehensive 1966 report on *Engineering Geology in Southern California,* edited by Lung and Proctor, and still a valuable reference[3].

Selection of the eight cities featured in the oral presentations at the Toronto meeting was not an easy task. This volume may therefore be regarded as an introduction only to a vast subject. Fortunately, the Association of Engineering Geologists has adopted a definite policy of encouraging the preparation of papers similar to those in this volume for publication as a regular feature in its Bulletin. Gradually, therefore, a corpus of information will be developed regarding the geology underlying a number of North American cities, each one unique in some respect so that comparative study will ultimately be of special value.

What has just been said might give the impression that this attention to *urban geology* (as the subject may so rightly be called) is something entirely new. A mere glance at some of the references accompanying the papers that follow will show that this is not the case at all. Dr. McLaren quotes from a paper published in Canada on this subject in 1900. Almost thirty years before that (in 1872), a well-known English Anglican priest, the Reverend Charles Kingsley, gave a series of lectures to young men on the subject of *Town Geology* under the auspices of the Chester Natural History Society, publishing them, with the same

title, in 1873[4]. It was Kingsley who, in these lectures, described geology as "the people's science"—which it really is!

One brief quotation from this book of a century ago, even though in the rolling Victorian prose of the time, warrants inclusion, since it is so relevant to the subject matter of this book:

> It does seem to me strange, to use the mildest word, that people whose destiny it is to live, even for a few short years, on this planet which we call the earth, and who do not at all intend to live on it as hermits. . . should in general be so careless about the constitution of the same planet, and of the laws and facts in which depend, not merely their comfort and their wealth, but their health and their very lives, and the health and the lives of their children and descendants.

Even before Kingsley's time, a few individuals had developed similar interests. In 1862, for example, Professor Eduard Suess published in Vienna a 300-page treatment of the geology, as it was then known, under his famous city. Just after Kingsley, Angelo Heilprin of the Academy of Natural Sciences of Philadelphia published in 1885 a well-illustrated volume on the *Rocks of Philadelphia.* There were probably other pioneers in this field in the nineteenth century. It is to be noted, however, that these were all individual activities, the work of men of vision who had seen the need for attention to the geology beneath their own cities—and this before the start of the major underground facilities that today are an essential part of all modern cities. It was not until the turn into the twentieth century that any corporate activity in relation to urban geology appears to have been undertaken.

An early (1905) Bulletin of the U.S. Geological Survey delineated *The Configuration of the Rock Floor of Greater New York,* an activity later followed up by municipal engineers of New York. The first paper in the first volume of the *Journal of the Boston Society of Civil Engineers* (1914) dealt with *Boston Foundations* and marked the start of the remarkable cooperative work in that city between engineers and geologists which is so well synthesized in the paper on Boston in this volume. In 1937, an interesting record of foundations in New Orleans was published, a WPA project. In Canada, a committee of the Engineering Institute in Winnipeg published, also in 1937, a useful review of foundation conditions in that prairie city—a pioneer venture that is now being actively developed by Professor Baracos of the University of Manitoba.

It was not until after the Second World War that activity in this field could be resumed with what results the papers which follow well demonstrate. Before introducing these, however, it must be observed that there are still all too many cities and towns that have no geologic records available. What is even more remarkable is that almost no municipal governments have yet undertaken the assembly of records of their geology as a civic responsibility. Almost all cases known to me represent the work of interested individuals or voluntary groups of geologists and engineers, in addition to some notable examples carried out by either federal or state geological surveys.

This is difficult to understand, since records of urban geology would be of direct benefit and of invaluable assistance in the carrying out of civic public works. Correspondingly, the works carried out by municipalities include, as but one example, most of the tunnels beneath cities (for water and sewer purposes), works that yield unique geologic information that is thus directly available to the city at no cost. But before indicating what can be done in this direction, attention may be directed to the records that this volume contains.

The order in which to present the papers seemed, at first, an invidious editorial problem since, quite naturally, the papers differ from one another so markedly. Authors were given wide latitude as to treatment of their subjects and the length of their papers. It is now interesting to see how the lengths of the papers reflect, in general and with no editorial input whatever, the relative complexity of the geology underlying each city. Some papers start with engineering problems and then show how geology affects them. Others start with descriptions of the local geology and then proceed to show how this affects engineering works. In every case, however, the papers make vividly clear the benefit to the science of geology of the information revealed by the carrying out of engineering works within cities, when this is acutely observed and correlated with existing information. A prime objective of this volume is to direct attention to and illustrate the potential of this largely untapped wealth of information on urban geology, to the permanent benefit of the science.

Against this background, how then should the papers be arranged? The problem solved itself when once it was realized that the geology underlying the nation's capital city should have pride of place. When the other eight cities were arranged in alphabetical order, taking no account of the U.S.–Canadian border, it was found that an orderly and logical sequence was automatically provided, with the right paper at the end.

Washington D.C., therefore, comes first, the geology beneath which has recently been a matter of wide public interest in view of the construction of the new subway. The geology is complex, but it has had the benefit of many years of study by members of the staff of the US Geological Survey, notably by N. H. Darton, for over fifty years; the authors are members of the Survey staff.

Boston, Massachusetts, occupies a special place in any review of urban geology, since it now has available published records of test borings within the city going back well over 65 years. The paper presents a summary of the author's work in the Boston area for many years, being another contribution from the US Geological Survey; attention

may be directed to another summary by the author—Bulletin No. 1476 of the Survey entitled *The Geology and Early History of the Boston Area of Massachusetts, a Bicentennial Approach,* published (appropriately) in 1976.

Chicago, Illinois, is now using its deep underground in a manner unequalled in any other city known to me; fortunately, construction of the deep drainage tunnels is assisted by the favorable local geology which has been studied for many years by members of the staff of the Illinois Geological Survey.

Edmonton, Alberta, is another city distinguished by cooperation between geologists and geotechnical engineers, now for many years past. Its geology is not as complex as that under some of the other cities featured, but underground construction work in the central city area has often been complicated by the presence of old coal workings of the early settlers. An admirable *Atlas* of these workings is a unique feature of local geological records.

Kansas City, Missouri, has won worldwide recognition in recent years for the use now being made of mined-out space in its underground for a variety of purposes (notably for cold-storage plants). It is not surprising, therefore, to find this featured at the outset of the fifth paper, the favorable and relatively straightforward local geology explaining how this has been possible. There are problems in the use of any underground space, and one problem in Kansas City is due to the properties of a local shale having involved research work of wide significance.

New Orleans, Louisiana, presents a unique geological picture insofar as its location at the mouth of the Mississippi River has given the city not only recent soils as the main foundation beds, but also a water table close to the surface. The combination of these features is at once geologically interesting but also challenging to foundation designers and constructors. The authors make this clear in their wide-ranging review of an underground condition shared by very few cities of the world.

New York, New York, has probably had more engineering works carried out in its underground than most other cities. Fortunately, the geology thus revealed has usually been recorded, and this has enabled the author (a resident of New York until, recently, he joined the US Geological Survey) to prepare a detailed and wide-ranging picture of the complex geology beneath the city—so very different from the popular idea of uniform Manhattan schist everywhere close to the surface.

Toronto, Ontario, in contrast, has a relatively simple geological structure beneath its streets,—glacial deposits overlying almost horizontal Ordovician shale. In recent years, this has been extensively studied because underground construction, especially in the downtown area, has proliferated. This has enabled the author (with the Ontario Geological Survey) to prepare his concise description, just such a summary account as I hoped to find (but did not) when the first section of Toronto's subway system was started well over thirty years ago.

Twin Cities, Minnesota. The brevity of this final paper is deceptive since it describes, accurately but succinctly, what is believed to be the most extensive and significant study of urban geology yet carried out in North America, and this for the large area covered by the twin cities of Saint Paul and Minneapolis. It is unfortunate that publishing restrictions make it impossible to illustrate, even by a small specimen, the fine colored maps prepared with computer aid by utilizing some of the subsurface information for the area previously "locked up" in carefully filed records of test borings. As the best alternative, procurement of a set of the maps described is strongly commended, not only for their intrinsic interest, but also so that they may be used, as occasion permits, to demonstrate what every city and large town can and should do.

The prime objective of the papers now assembled in this volume is to start to fill the very serious gap that exists in the literature of North American geology by describing the geology under some of the major cities of the continent. It is strange indeed that, despite such early individual efforts as have already been briefly mentioned, there has been so little attention given in North America to the geology beneath city streets—almost as if it did not exist! The volume is a modest start at correcting this situation.

The task of preparing such accounts of urban geology is becoming, on the one hand, increasingly difficult with each succeeding year and yet, on the other hand, there is a steadily increasing volume of relevant information waiting to be tapped, if the interest to do this can only be aroused. Information on the geology under cities can be obtained by an initial study of the regional geology, supplemented by examination of such outcrops within municipal boundaries as still remain in view. The number of these is decreasing as development proceeds.

On the other hand, as development does proceed, new structures are being built, and these usually involve excavation. Every new hole that is dug or tunnel that is bored yields—for a very short time only—new exposures of the geological structures that have to be penetrated. The engineering records of such exposures will always be available somewhere when construction is complete; they can be made the more valuable, and the science can be enriched, if they are prepared with geological assistance. Records will also exist, in ever increasing number, for every town and city, of the test borings now almost mandatory at every urban building site prior to the completion of designs.

All nine papers in this volume illustrate, incidental to their main purpose, the use of such records available from engineering works. They demonstrate in this way the complete interdependence of geology and geotechnical engineering if knowledge of the geology beneath city streets is

to be expanded, on the one hand, and if subsurface engineering work is to be safely and economically conducted, on the other.

The situation is so obvious, once thought is given to it, that such a statement as the foregoing would be almost a banality if it were not that the situation is, in general, so little recognized. It is the hope of all concerned with this volume that it may assist in correcting this widespread neglect, to the benefit of the science of geology and the practice of civil engineering.

To this end, may it be suggested, with all due respect, that: (1) In every city or town some arrangement should exist for the examination by geologists of every new exposure, in excavations or in tunnels, a task ideally suited to the geological departments of local universities; (2) all geotechnical engineers should be aware of the geological significance of their work, especially within towns and cities, both in preliminary site studies and in recording exposures in tunnels and excavations, and should do what they can to see that local geologists are aware of it; and (3) both geologists and engineers who appreciate the importance of urban geology should do all they can to ensure that their own municipality accepts responsibility for developing and maintaining the necessary information bank, as a vital local service that could easily be self-supporting.

It remains for me only to ask how an editor is expected to deal with the final paragraph in the introduction to the last paper in the volume, a far-too-generous statement that the author firmly but graciously insists be left in. Attention must be called to it, if only to indicate that the editor knows that it is there, and so that he may record his indebtedness to Dr. Walton for the encouragement given by such a statement in a field in which we both share so close and lively an interest. More than this, however, is the hope that will be shared by authors and editor alike—that this volume will itself prove to be of far more effect in encouraging active interest in the *Geology under Cities* than the writings of any one individual can ever be.

Ottawa Canada — Robert F. Legget
May 1982

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