**Centennial History of the Carnegie Institution of Washington**
**Volume III The Geophysical Laboratory**

For over a century, the Geophysical Laboratory of the Carnegie Institution of Washington has witnessed exciting discoveries and ingenious research, made possible by the scientific freedom granted to members of the department. For the most part, this research has involved laboratory experimentation on the physics and chemistry of rock-forming minerals at high temperature and pressure. This third volume in a series of five histories of the Carnegie Institution documents the contribution made by the members of the Geophysical Laboratory to our understanding of the Earth, from mineral formation deep below the surface, to the search for the origins of life, and out into space to study the chemical evolution of the interstellar medium. Field work has taken researchers from active volcanoes to ships collecting ocean sediments, and geological mapping expeditions around the world. Contemporary photographs throughout illustrate the evolution of the department and its research.

HATTEN S. YODER, JR., internationally known experimental petrologist and geochemist, and Emeritus Director of the Geophysical Laboratory, died in August 2003. After completion of his Ph.D. at the Massachusetts Institute of Technology in 1948, he spent his scientific career at the Geophysical Laboratory. He was also visiting professor at CalTech, University of Texas, University of Colorado, and University of Cape Town, and held honorary doctorate degrees from the University of Paris VI and the Colorado School of Mines. In addition to his services in numerous professional societies, he was a member of the National Research Council's Executive Committee, as well as the US National Committees for Geochemistry, and History of Geology. He advised US Congress on issues ranging from natural resources to the hazards of asbestos.

CENTENNIAL HISTORY OF THE CARNEGIE INSTITUTION OF WASHINGTON

**Volume III**

# THE GEOPHYSICAL LABORATORY

HATTEN S. YODER, Jr.

*Formaly Director Emeritus,*
*Geophysical Laboratory*

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This history of the Geophysical Laboratory was completed by Hatten S. Yoder, Jr. just a few weeks before his death at age 82. Hat was an exceptional scientist, a valued colleague and a fine gentleman. He served his country and his science community well, and was awarded many honors by his peers. A member of the National Academy of Science, he was an aficionado of art, science, and history who kept an open mind on controversial subjects. The Carnegie Institution and the Geophysical Laboratory are proud and grateful that he was one of us. We dedicate this volume to him.

Wesley T. Huntress, Jr., Director of the Geophysical Laboratory

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# FOREWORD

In 1902 Andrew Carnegie, a steel magnate turned philanthropist, had a brilliant idea. Carnegie was prescient in recognizing the important role that science could play in the advancement of humankind. He also believed that the best science came by providing "exceptional" individuals with the resources they need in an environment that is free of needless constraints. He created the Carnegie Institution as a means to realize these understandings, directing the Institution to undertake "projects of broad scope that may lead to the discovery and utilization of new forces for the benefit of man." Carnegie was confident that this unusual formula would succeed. And he was right.

For over a century, the Carnegie Institution has sponsored creative and often high-risk science. Some of the luminaries who were supported by the Institution over the years are well known. For example, Edwin Hubble, who made the astonishing discoveries that the universe is larger than just our galaxy and that it is expanding, was a Carnegie astronomer. Barbara McClintock, who discovered the existence of transposable genes, and Alfred Hershey, who proved that DNA holds the genetic code, both won Nobel Prizes for their work as Carnegie scientists. But many other innovative Carnegie researchers who are perhaps not so well known outside their fields of work have made significant advances.

Thus, as part of its centennial celebration, the Institution enlisted the help of many individuals who have contributed to the Institution's history to chronicle the achievements of the Institution's five major departments. (Our newest department, the Department of Global Ecology, was started in 2002 and its contributions will largely lie ahead.) The result is five illustrated volumes, which describe the people and events, and the challenges and controversies behind some of the Institution's significant accomplishments. The result is a rich and fascinating history not only of the Institution, but also of the progress of science through a remarkable period of scientific discovery.

Andrew Carnegie could not have imagined what his Institution would accomplish in the century after its founding. But I believe that he would be very proud. His idea has been validated by the scientific excellence of the

exceptional men and women who have carried out his mission. Their work has placed the Institution in a unique position in the world of science, which is just what Andrew Carnegie set out to do.

RICHARD A. MESERVE
*President, Carnegie Institution of Washington*

# PREFACE

In celebration of the Centennial of the Carnegie Institution of Washington, the then President Maxine F. Singer requested that each department prepare a history of its scientific accomplishments. I was invited to expand my brief history, "Scientific highlights of the Geophysical Laboratory, 1905–1989," which I had prepared on the occasion of the move to a new building on the campus of the Department of Terrestrial Magnetism in 1990. As with most histories, it records the biased views of a single observer moderated by the available written records and evaluations of others. The early records of the Geophysical Laboratory are minuscule, and even though I have personally witnessed over half the centennial (55 years), memories are not always reliable. It is difficult to subdue the enthusiasm, admiration and pride I have for the Geophysical Laboratory and its past and present members. Having known almost all of the early staff members, perhaps I might be forgiven for any excessive claims of discovery attributed to the staff. All science is built on the discoveries of others, and it is not always evident who arrived at the pinnacle of an idea first, demonstrated its proof, and applied the idea to the solution of a geological problem or capitalized on its promotion. The personal satisfaction of contributing to the growth of science is adequate reward in itself.

The most important factor in the generation of new ideas at the Geophysical Laboratory has been the freedom of choice to follow whatever a staff member believes to be important in the solution of a geological problem. The scientist's overriding goal was to achieve an understanding of the problem so that the critical variables could be recognized, evaluated, and formulated into general concepts useful in solving other problems. The intent, therefore, was to seek knowledge that has broad application to the major problems of the Earth. Because no researcher can predict how a fundamental discovery might be applied to future societal needs or problems, there is no test for relevance or applicability applied to the work at the Geophysical Laboratory as is made in industrial organizations. That freedom to follow whatever is critical to the solution of problems is why the Geophysical Laboratory has remained unique among research organizations. The price of such a generous measure of scientific freedom is greater personal responsibility to produce and greater accountability. Although peer review provides for continual testing,

the responsibility to produce was self-generated and was expressed by the high motivation and involvement of the staff.

In this regard, the Director has had the responsibility to select staff who exhibited the breadth of understanding, dedication, and enthusiasm for the projects they selected. On a few rare occasions an assistant was hired to carry out certain measurements, but in general, each staff member did his or her own work. No one was treated as a "pair of hands" and everyone was expected to contribute to the generation of the science itself. Collaboration was encouraged and took place by mutual agreement where special talents could contribute. Over time as the science became more interdisciplinary, the amount of cooperation has indeed increased.

The range of projects covered in the following chapters is great, but unfortunately, not complete. The extensive documentation was intended to achieve accuracy and to encourage the reader to seek out the details of the problem investigated. I do not pretend to be an expert in all the areas covered, and, hopefully, will be forgiven for errors, and omissions. Perhaps the excitement of discovery and ingenuity of research will retain the reader's attention.

# ACKNOWLEDGMENTS

The cooperation of the staff of both the Geophysical Laboratory and the Department of Terrestrial Magnetism has been particularly helpful in reviewing the chapters close to their interests. Of great assistance in the preparation of the chapters was the availability of the "Indices of the Annual Reports of the Director of the Geophysical Laboratory, 1905–1980," prepared by Robert M. Hazen and Mrs. Margaret H. Hazen and issued as separate paper No. 1860 of the Geophysical Laboratory in 1981. Although I hold an extensive collection of the books and reprints of papers published by the early staff members, it was the timely service of librarians Shaun Hardy and Merri Wolf, who borrowed a substantial number of books and papers from libraries throughout the country, that provided much of the background reading material. Most appreciated was the kind patience of Mrs. Susan A. Schmidt who typed the manuscript and made the many insertions, corrections, and format changes required. All are thanked for their help in providing an accurate history of the scientific work of the Geophysical Laboratory, which will in turn be celebrating its own centennial in 2005.

# IMPERIAL TO METRIC CONVERSION FACTORS

1 inch = 2.54 cm
1 foot = 30.48 cm
1 yard = 91.44 cm
1 cubic inch = 16.387 cubic cm
1 cubic foot = 0.0283 cubic m
1 acre = 0.4047 ha
1 square mile = 2.5899 square km
1 mile = 1.609 km
1 nautical mile = 1.852 km
1 pound = 0.4536 kg