The Earth

Its Birth and Growth

Second Edition

Recent environmental problems and natural disasters have given cause for increasing concern over the future habitability of our planet. It is becoming increasingly apparent that a clear understanding of the Earth's past evolution can provide the key to its possible future development. *The Earth: Its Birth and Growth* explores the evolution of the Earth over 4.6 billion years using basic reasoning and simple illustrations to help explain the underlying physical and chemical principles and major processes involved.

Now fully updated and revised, this rigorous but accessible second edition includes three completely new chapters and additional illustrations. It incorporates recent exciting developments in isotope geology, placing results from these advances within a wider framework of Earth evolution and plate tectonics. Some background in physics and chemistry is assumed, but basic theories and Earth evolution processes are explained concisely in self-contained sections. The book also illustrates specific topics with short accounts of the work of eminent scientists at different stages of discovery in the field. Key research papers and review articles are fully referenced in each chapter to enable readers to explore further.

This book is ideal as a supplementary text for undergraduate and graduate students in isotope geochemistry, geodynamics, plate tectonics, and planetary science. It also provides an enjoyable overview of the Earth's evolution for professional scientists and general readers.

MINORU OZIMA is an Emeritus Professor in the Earth and Planetary Science Department at the University of Tokyo. He was awarded the prestigious V.M. Goldschmidt Medal in 2010, recognizing his major achievements in geochemistry and cosmochemistry. Professor Ozima was among the first to focus attention on the information contained in

noble gas isotopes in application to the formation and evolution of the planets. He is a leading figure in this field, having contributed significantly to the establishment and development of the geochemistry and cosmochemistry of noble gases. He has published several books and is a Fellow of the American Geophysical Union, the Meteoritical Society, the European Association of Geochemistry and the Geochemical Society.

JUN KORENAGA is a Professor of geophysics at Yale University where he studies the evolution and dynamics of the Earth with a variety of theoretical and observational techniques. Professor Korenaga is particularly known for his new theory of the Earth's thermal history and, in recognition of his contributions, was awarded the James B. Macelwane Medal in 2006 from the American Geophysical Union. His current research spans mantle and core dynamics, theoretical geochemistry, and marine geophysics, and he is also extending his work to cover other Earth-like planets within and outside the Solar System.

QING-ZHU YIN is a Professor in the Department of Geology at the University of California, Davis. Having received his Ph.D. with highest distinction from the Johannes Gutenberg University and Max-Planck-Institute for Chemistry in Mainz, Germany, he expanded his research experience at the Department of Earth and Planetary Sciences at Harvard University. His research interests now range from the use of isotopes to study the formation of the Solar System, to isotope and trace element geochemistry with applications to crust mantle evolution. Professor Yin is the author or co-author of over 60 research articles, and is a member of the Geochemical Society, the American Geophysical Union, and the Meteoritical Society.

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Preface to the second edition

A few years ago, Professor David Hilton of the University of California, San Diego mentioned to me that he was still using my book, *The Earth: Its Birth and Growth*, as suggested reading in his class. The book was published in 1979 by Cambridge University Press. Amazed by its longevity, I became curious about how this seemingly plain small book could have survived in the recent swarm of the media world, in which there are a flood of books on astounding findings in Earth and planetary sciences with colorful pictures and illustrations. I read the book once again, and I was convinced that it was worth revising it by incorporating recent developments.

The new edition has therefore attempted to keep the original style of the first edition: that is, to maintain readability without sacrificing scientific rigor. The concise style of the book is important so that readers can see the big picture without being drowned by a formidable amount of information. Obviously many of the materials in the first edition needed to be updated. Also, given recent developments, I wanted to emphasize in the new edition the importance of integrating a vast range of geophysical and geochemical data to develop a coherent view of Earth's evolution.

To update the book as planned above, I first asked Qing-zhu Yin for help, but because of his hectic schedule, he suggested asking Jun Korenaga to join the project. When Jun received the Macelwane medal from the American Geophysical Union, he mentioned that his interest in studying the history of the Earth originated in attending my unorthodox geophysics course taught at the University of Tokyo many years ago, so asking Jun for help seemed quite suitable. Preparation of the new edition benefited greatly from his enthusiasm for the project,

both in speed and quality. Qing-zhu Yin examined a draft at various stages to improve its accuracy and clarity.

Although the book is primarily aimed at general readers, we did not hesitate to include some of our own ideas such as are seen in Chapter 10, since a seriously curious audience, whether science-minded or not, is keen to learn a logical way of thinking rather than to read a mere description of facts. Some of the bold ideas should be inspiring to experts as well. We believe that this small book should answer many basic questions by general readers on Earth's evolution, such as how and when the Earth formed, with as much rigor and brevity as is allowed within the scope of the book, while also being useful to those who specialize in this discipline.

Minoru Ozima

Preface to the first edition

It is thought that the Earth was born as a planet about 4500 million years ago. Throughout the long years since then it has continually evolved, and has undergone a transformation into its present form.

Tracing the evolution of the Earth is a central topic in Earth science, and has been dealt with by many writers. However, most previous histories of the Earth have been concerned with the past 600 million years, since fossils have been found in abundance from this period, and only touch very briefly on the Precambrian period, which is equivalent to roughly seven-eighths of the Earth's history. But those basic qualities of the Earth with which we are so well acquainted – the magnetic field, the layered structure of the core and mantle, the atmosphere and oceans, were all formed in the very early stages of the Earth's history.

Until 1950 virtually nothing was known about the early form of the Earth, but with the appearance of isotope geochemistry using radiogenic elements, it is gradually being brought to light. This book describes the birth of the Earth and its growth, outlining the problems which are now being solved rapidly through isotope geochemistry. It is an attempt to sketch the evolution of the Earth over 4500 million years.

In writing this book, I received much helpful advice from Drs Sadao Matsuo, Kiyoshi Nakazawa, Kenji Notsu, and Naoki Onuma. I would also like to express my deep gratitude to Mr Toshio Ogawa and Ms Yuko Natori of Iwanami Shoten Publishers, who spared no efforts in producing this book.

Minoru Ozima
December 1979

Preface to the English edition

To cover the 4500 million years of the history of the Earth in one book is certainly a formidable task. As my particular field lies in isotope geochronology and rock magnetism, which are the most effective means of clarifying the Earth's evolutionary history, I have been able in this book to present my own view of the Earth's evolution mainly on the basis of results obtained by these two approaches.

In preparing the English edition, I have made a few changes following comments by my colleagues on the original Japanese edition. I have now realised that to prepare the English edition involved far more than mere translation. I have had to admit that the Japanese language is more suited to literature than it is to being a scientific medium. So for Mrs Judy Wakabayashi the task was to convert a language suited to the heart into a language suited to the mind. And as far as the English edition is concerned, I feel that she is almost entitled to be a co-author, and I would like to express my very deep appreciation of her work and for all the "blood, sweat and tears" which she has endured during the past six months.

Minoru Ozima
Tokyo, September 1980