

Cambridge University Press

978-0-521-55213-4 - *Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson*

Stephen G. Brush

Frontmatter

[More information](#)

A history of modern planetary physics

Where did we come from? Before there was life there had to be something to live on – a planet, a solar system. During the past 200 years, astronomers and geologists have developed and tested several different theories about the origin of the Solar System and the nature of the Earth. Did the Earth and other planets form as a by-product of a natural process that formed the Sun? Did the Solar System come into being as the result of a catastrophic encounter of two stars? Is the inside of the Earth solid, liquid, or gaseous? The three volumes that make up *A History of Modern Planetary Physics* present a survey of these theories.

The age of the Earth has been one of the most disputed numbers in science since the 17th century. Although most earth scientists and astronomers accept the Earth's age to be 4.55 billion years, much significance lies in the manner in which that figure was determined. *Transmuted Past* follows the development of theories of stellar evolution and nucleosynthesis in the 20th century and describes radiometric methods for estimating the age of the Earth.

Throughout the 19th and 20th centuries, the reputation of the planetary sciences changed significantly; whereas the planetary sciences once played an integral role in science, they eventually came to be accorded a status inferior to atomic physics and cosmology. Professor Brush explores this shift and shows how a planetary science such as geology can provide a useful example of the scientific approach for comparison with a humanistic discipline such as history.

Cambridge University Press

978-0-521-55213-4 - Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson

Stephen G. Brush

Frontmatter

[More information](#)

OTHER BOOKS BY STEPHEN G. BRUSH

Boltzmann's Lectures on Gas Theory (translator)

Kinetic Theory, Volume 1, *The Nature of Gases and of Heat*; Volume 2, *Irreversible Processes*; Volume 3, *The Chapman–Enskog Solution of the Transport Equation for Moderately Dense Gases* (editor)

History in the Teaching of Physics: Proceedings of the International Working Seminar on the Role of the History of Physics in Physics Education (coeditor)

Resources for the History of Physics (editor)

Introduction to Concepts and Theories in Physical Science (coauthor, second edition)

The Kind of Motion We Call Heat: A History of the Kinetic Theory of Gases in the 19th Century. Book 1, *Physics and the Atomists*; Book 2, *Statistical Physics and Irreversible Processes*

The Temperature of History: Phases of Science and Culture in the Nineteenth Century
Maxwell on Saturn's Rings (coeditor)

Statistical Physics and the Atomic Theory of Matter, from Boyle and Newton to Landau and Onsager

Maxwell on Molecules and Gases (coeditor)

The History of Modern Physics: An International Bibliography (coauthor)

The History of Geophysics and Meteorology: An Annotated Bibliography (coauthor)

The History of Modern Science: A Guide to the Second Scientific Revolution 1800–1950
History of Physics: Selected Reprints (editor)

The Origin of the Solar System: Soviet Research 1925–1991 (coeditor)

Maxwell on Heat and Statistical Mechanics (coeditor)

Nebulous Earth: The Origin of the Solar System and the Core of the Earth from Laplace to Jeffreys

Fruitful Encounters: The Origin of the Solar System and of the Moon from Chamberlin to Apollo

Cambridge University Press

978-0-521-55213-4 - Transmuted Past: The Age of the Earth and the Evolution of the
Elements from Lyell to Patterson

Stephen G. Brush

Frontmatter

[More information](#)

A HISTORY OF MODERN PLANETARY PHYSICS

Transmuted past

*The age of the Earth and the evolution of the
elements from Lyell to Patterson*

STEPHEN G. BRUSH
University of Maryland, College Park



CAMBRIDGE
UNIVERSITY PRESS

Cambridge University Press

978-0-521-55213-4 - Transmuted Past: The Age of the Earth and the Evolution of the
Elements from Lyell to Patterson

Stephen G. Brush

Frontmatter

[More information](#)

PUBLISHED BY THE PRESS SYNDICATE OF THE UNIVERSITY OF CAMBRIDGE
The Pitt Building, Trumpington Street, Cambridge CB2 1RP, United Kingdom

CAMBRIDGE UNIVERSITY PRESS
The Edinburgh Building, Cambridge CB2 2RU, United Kingdom
40 West 20th Street, New York, NY 10011-4211, USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© Cambridge University Press 1996

This book is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without
the written permission of Cambridge University Press.

First published 1996
Reprinted 1997

Printed in the United States of America

Typeset in Bembo

A catalogue record for this book is available from the British Library

Library of Congress Cataloguing-in-Publication Data is available

ISBN 0-521-55213-3 hardback

Cambridge University Press

978-0-521-55213-4 - Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson

Stephen G. Brush

Frontmatter

[More information](#)

Contents

<i>Illustrations</i>	<i>page vii</i>
<i>Preface</i>	<i>ix</i>

PART I EARTH/HISTORY

1.1 Introduction	3
1.1.1 Genesis and geology	3
1.1.2 Darwin and Kelvin	5
1.1.3 Radiometric dating	7
1.1.4 Geology as a science	10
1.2 History and geology as ways of studying the past	12
1.2.1 The sciences and the humanities	12
1.2.2 Ranke and Lyell	13
1.2.3 Trevelyan and Geikie	19
1.2.4 The English revolution	21
1.2.5 Vulcanism and central heat	25
1.2.6 Conclusions	31
1.3 Kelvin and geological time	33
1.3.1 Kelvin's early work on heat conduction theory	34
1.3.2 Principle of Dissipation of Energy	35
1.3.3 Attack on the Uniformitarians	36
1.3.4 Huxley's defense	38
1.3.5 Geikie's compromise	39
1.4 Planetary science: From underground to underdog	41
1.4.1 The stigma of impurity	42
1.4.2 Underdog	43
1.4.3 Moving through space	46
1.4.4 Underground	52

PART 2 TIME AND THE ELEMENTS

2.1 Cosmic evolution of matter	59
2.2 Geochronology in the 20th century	66
2.2.1 The assault on Kelvin's time limit	67

Cambridge University Press

978-0-521-55213-4 - Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson

Stephen G. Brush

Frontmatter

[More information](#)

vi

CONTENTS

2.2.2 Geological resistance	70
2.2.3 Chamberlin's and Russell's estimates	72
2.2.4 Astronomical time scales	74
2.2.5 Is the Earth older than the universe?	76
2.2.6 Lead isotopes	78
2.2.7 Patterson's estimate	82
2.2.8 From geochronology to unleaded gasoline	85
2.3 Stellar evolution and the origin of the elements	87
2.3.1 Classification of stellar spectra and the H–R diagram	87
2.3.2 Relativity and quantum theory	90
2.3.3 Formation of the elements from hydrogen	94
2.3.4 Revision of the Sun's evolutionary track	98
2.3.5 Nucleosynthesis in stars	105
2.3.6 Connections	107
<i>Abbreviations</i>	109
<i>Reference list and citation index</i>	111
<i>Index</i>	131

Cambridge University Press

978-0-521-55213-4 - Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson

Stephen G. Brush

Frontmatter

[More information](#)

Illustrations

1. Arthur Holmes	<i>page</i> 70
2. Alfred Nier	79
3. Friedrich G. Houtermans	81
4. Clair C. Patterson	83
5. Hertzsprung–Russell (H–R) diagram	88
6. Theoretical evolutionary track of a solar-mass star after it uses up most of its hydrogen	100
7. Evolutionary track of a solar-mass star according to astrophysical theories in the late 1950s	101

Cambridge University Press

978-0-521-55213-4 - *Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson*

Stephen G. Brush

Frontmatter

[More information](#)

Preface

This is the second of three volumes presenting the results of my research on theories of the origin of the Solar System, the internal structure of the Earth, and the age of the Earth in the 19th and 20th centuries.

Nebulous Earth discusses theories of the origin of the Solar System – primarily the Nebular Hypothesis – in the 19th century, and follows ideas about the Earth's core (including the geomagnetic dynamo) up to about 1970.

Transmuted Past outlines the attempts to estimate the age of the Earth in the 19th and 20th centuries, reviews related developments in nuclear physics and stellar evolution, and also offers perspectives on the changing reputation of planetary science, and on the comparison of styles in scientific and humanistic research.

Fruitful Encounters surveys the development of theories of the origin of the Solar System in the 20th century, including especially the impact of the *Apollo* lunar missions on ideas about the origin of the Moon.

Readers who are not already familiar with these subjects are advised to begin by reading the first chapter in each part, to get an overall view of the subjects discussed in that part.

This book has benefited greatly from the assistance and criticism of many historians and scientists, especially Louis Brown, Joe Burchfield, G. Brent Dalrymple, H. C. Dudley, J. H. Fremlin, Robert V. Gentry, David James, Rachel Laudan, J. J. Naughton, Alfred Nier, John O'Keefe, Clair Patterson, James Shea, and Dan Wonderly.

Libraries and librarians are essential to any historical research project. I have been fortunate to have had access to the collections of Harvard University, the Institute for Advanced Study at Princeton, the Library of Congress, the National Oceanic and Atmospheric Administration, Princeton University, the Smithsonian Institution, the U.S. Geological Survey, the University of California at Los Angeles, the University of Maryland at College Park, and the University of Minnesota–Twin Cities; I thank the staff at all those libraries for their generous and efficient help.

My research was supported by grants from the History and Philosophy of Science Program of the National Science Foundation. This book was completed while I was a Member of the School of Social Science at the Institute for Advanced Study, Princeton, with financial support from the General Research Board of the University of Maryland and the Andrew W. Mellon Foundation.

Cambridge University Press

978-0-521-55213-4 - Transmuted Past: The Age of the Earth and the Evolution of the Elements from Lyell to Patterson

Stephen G. Brush

Frontmatter

[More information](#)

x

PREFACE

For permission to use previously published material, I thank the following owners of the copyrights: National Science Teachers Association, publisher of *The Science Teacher* (Chapter 1.1); University of Delaware Press, publisher of *Creativity and the Imagination*, edited by Mark Amsler (Chapter 1.2); *Scientia* (Chapter 1.4); History of Earth Sciences Society, publisher of *Earth Sciences History* (Chapter 2.2).

Finally, for all kinds of support throughout this project I am grateful to my wife, Phyllis.