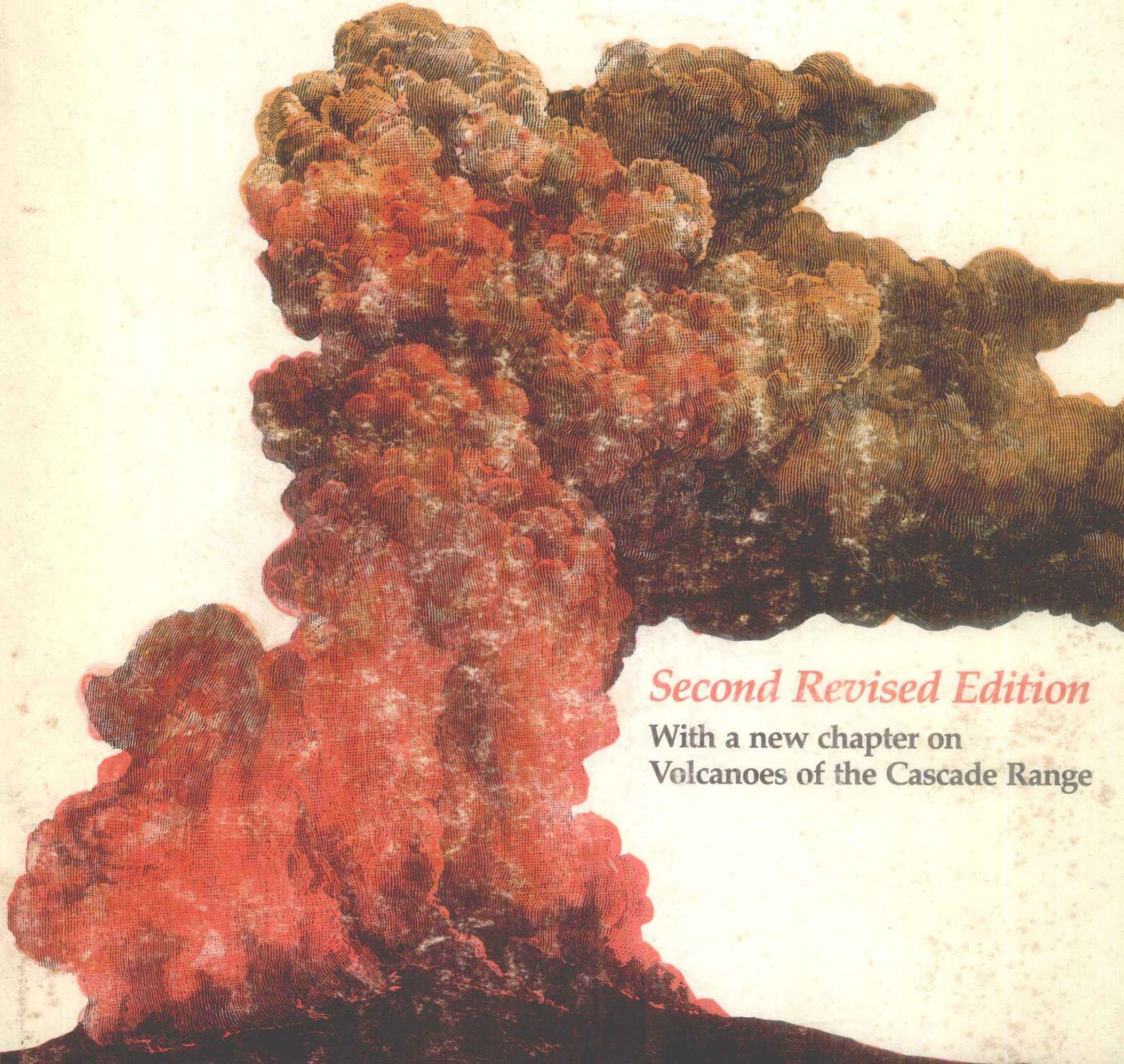
VOLCANOES of the Earth

Fred M. Bullard



Second Revised Edition

With a new chapter on
Volcanoes of the Cascade Range

Volcanoes of the Earth

Second Revised Edition

By Fred M. Bullard

University of Texas Press, Austin

The Dan Danciger Publication Series

Printed in the United States of America

Revised edition of *Volcanoes: In History, in Theory, in Eruption*
Second revised edition, 1984

LIBRARY OF CONGRESS CATALOGING IN PUBLICATION DATA
Bullard, Fred M. (Fred Mason), 1901–
Volcanoes of the Earth.
(The Dan Danciger publication series)
Bibliography: p.
Includes index.
1. Volcanoes. I. Title. II. Series.
QE522.B87 1984 551.2'1 83-21738
ISBN 0-292-78706-5
ISBN 0-292-78707-3 (pbk.)

Volcanoes of the Earth

To Evelyn

Acknowledgments

The material on which this book is based was assembled from studies carried on in volcanic regions in many parts of the world over several decades. For the opportunity to visit the various volcanic regions, for time from my regular duties to make the investigations and to do the research necessary to assemble this material, I am indebted to many organizations, foundations, and individuals. Space does not permit a complete listing, but I would like to acknowledge to the following my appreciation for material aid in various phases of the work: the Geological Society of America and the Instituto de Geología of the Universidad Nacional Autónoma de México for aid in the study of Parícutin Volcano; the University of Texas Research Institute and the Geology Foundation of the University of Texas for research time, travel funds, and aid in the preparation of the manuscript; the U.S. State Department for two Fulbright grants which enabled me to study the volcanoes of Italy and Peru; the United Fruit Company for assistance in the work in Central America; the Compañía Minera de Guatemala (through Mr. Alan Probert, manager) for aid in the work in Guatemala; the Instituto Tropical de Investigaciones Científicas of the Universidad de El Salvador, and the Servicio Geológico Nacional de El Salvador for assistance in the work in El Salvador; Mr. Donald Spencer and associates of the Compañía Minera La India for help in the work in Nicaragua; and the Instituto Geográfico de Costa Rica for aid in Costa Rica. The Pan American Institute of Geography and History and the Inter-American Geodetic Survey also assisted in the work in all of the Central American countries.

I am also indebted to the National Park Service and the Craters of the Moon Natural History Association for the opportunity to carry on research studies at Craters of the Moon National Monument. Some of the results of this study are included in this second edition of the book.

I particularly indebted to the late Professor Arthur Holmes, University of Edinburgh, Scotland, who read the galley proofs of the first edition and offered many constructive suggestions and helpful criticisms. In addition, I greatly appreciate the many constructive reviews of the first edition which have been most helpful in the preparation of this revision.

To my many friends in each of the countries where I have worked, who contributed generously of their time and provided transportation, guides, and other services, I wish to express my deep appreciation; unfortunately the list is too long to print.

All of the photographs not otherwise credited are my own. Those obtained from other sources are acknowledged in each case, and I want to express my thanks to the individuals who have made such contributions.

I have drawn freely on published material both in the preparation of the text and for illustrations. In each case, however, the source is acknowledged, and I wish to express my thanks for the use of this material. I am particularly grateful to the authors and publishers who have granted me permission to reproduce illustrations and to quote directly from their publications.

I wish, also, to express my thanks to the staff of the University of Texas Press for their exceptional cooperation in all aspects of the production of this book.

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Prologue

Volcanoes are unquestionably one of the most spectacular and awe-inspiring features of the physical world, and they have provided humanity with the most exquisite pleasure as well as the most devastating misfortune. The loftiest mountains on the face of the earth, affording majestic scenery enjoyed by millions, are volcanic cones. On the other hand, great volcanic eruptions in historic times have wrought death and destruction to many areas. In ancient times volcanoes were surrounded by mystery and superstition, and even today, notwithstanding the tremendous advances in all sciences, people still ask many unanswered questions about volcanoes. But it is highly probable that when we have learned more about them their terrific power may be harnessed for the benefit of humanity.

This book is an effort to summarize in nontechnical language our present knowledge of volcanoes. Some of the important volcanoes and volcanic regions of the earth are described as examples of the various types of volcanoes. Volcanoes are found in those regions of the earth where mountains are growing. But, since they are but one manifestation of active mountain-building processes, it is understandable that the geologic setting must be presented in the description of a volcanic region.

My own interest in volcanoes began while I was a member of a U.S. Geological Survey expedition to Alaska in 1929. On this trip I first saw an active volcano, and I was tremendously impressed. Only the year before, I had received a Ph.D. degree in geology from the University of Michigan and had taken courses with Professor W. H. Hobbs, a distinguished scholar in the field of volcanoes, earthquakes, and mountain building. Nevertheless, when I actually saw the active volcano I realized that I knew very little about it, notwithstanding my college degrees and the fact that I had been teaching geology in a major university for several years. When I voiced my thoughts to Dr. S. R. Capps, director of our party, he remarked that if I was really interested in volcanoes I should go to Hawaii and work with Dr. Thomas A. Jaggar, director of the Hawaiian Volcano Observatory and a world-famous authority on volcanoes. He further stated that he thought such a program could be arranged. It was arranged. But a severe economic depression (during the mid-thirties) intervened before I was able to go to Hawaii as an assistant to Dr. Jaggar.

There I learned the technique of modern volcanic research and acquired some of Dr. Jaggar's enthusiasm for research on volcanoes. Back in Texas in the early forties I saw little opportunity to apply my newly acquired knowledge, except in so far as it was useful in teaching. However, on February 20, 1943, the situation suddenly changed. On that date a new volcano, Parícutin, was born in Mexico. By a fortunate combination of circumstances I was scheduled to teach a course on the volcanoes of Mexico in the 1943 summer school of the

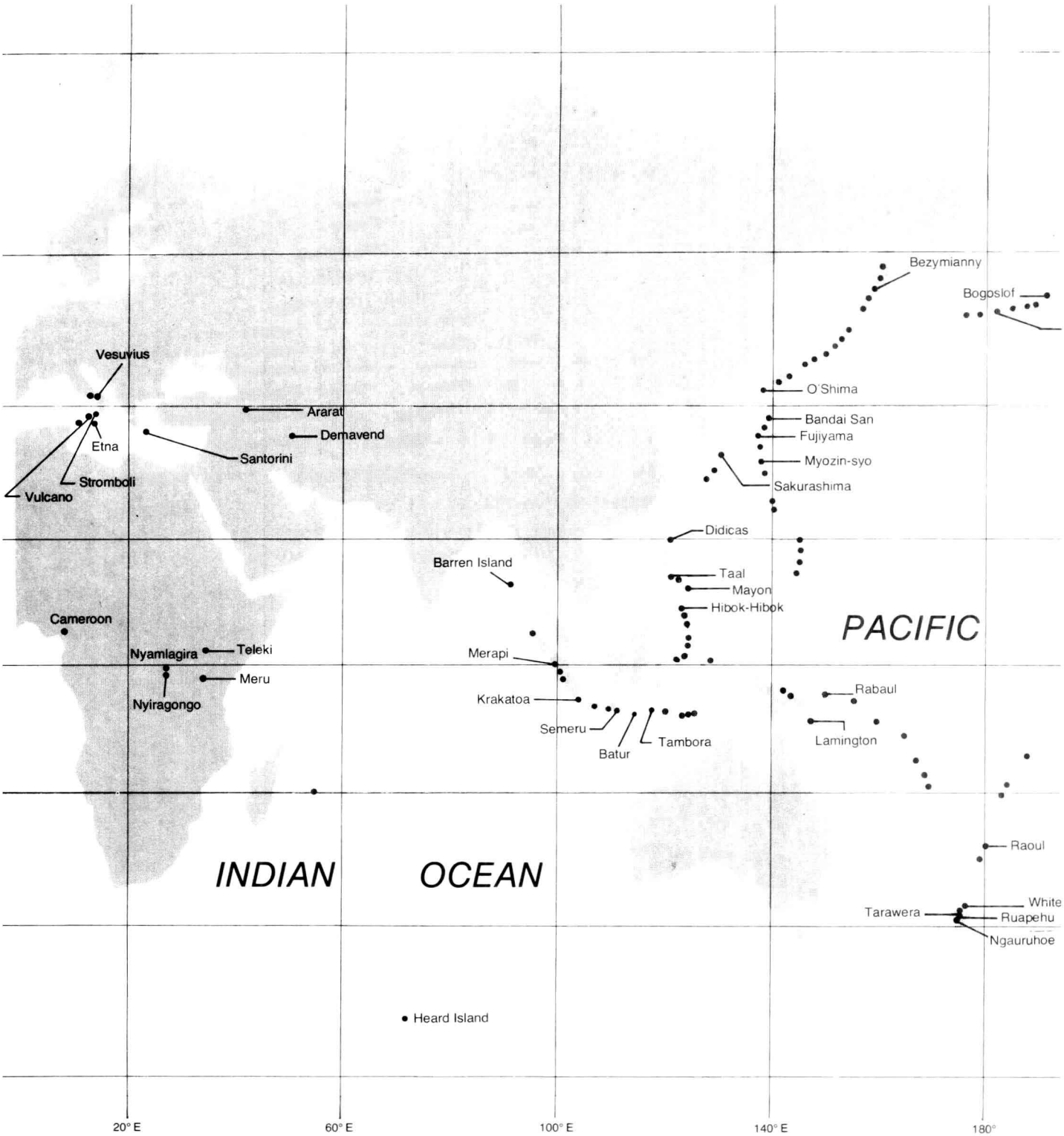
National University of Mexico. Naturally, I lost no time in visiting Parícutin and adopting it as a laboratory for my classes. Circumstances also worked out so that I spent a part of each year for the next seven years at Parícutin and was thus able to follow from personal observations almost its entire life history. Another milestone in my quest for knowledge of volcanoes was the opportunity to spend a year as a Fulbright scholar studying the classic volcanoes of the Mediterranean area. With headquarters at the University of Naples and the Vesuvian Observatory, I studied Vesuvius, Etna, Stromboli, and other volcanoes in Italy, where the science of volcanology had actually developed. Later I had the opportunity to investigate the volcanoes of Central America, followed by a Fulbright lectureship to teach volcanology at the Universidad Nacional de San Agustín de Arequipa in southern Peru. This opportunity to study the active and recently active volcanoes of the high Andes was a rewarding experience. Continuing my quest for active volcanoes, I visited Iceland, the eastern Mediterranean area, Japan, the Rift Valley of Africa, the Canary Islands and Azores of the mid-Atlantic, the Philippines, South Pacific islands, and New Zealand.

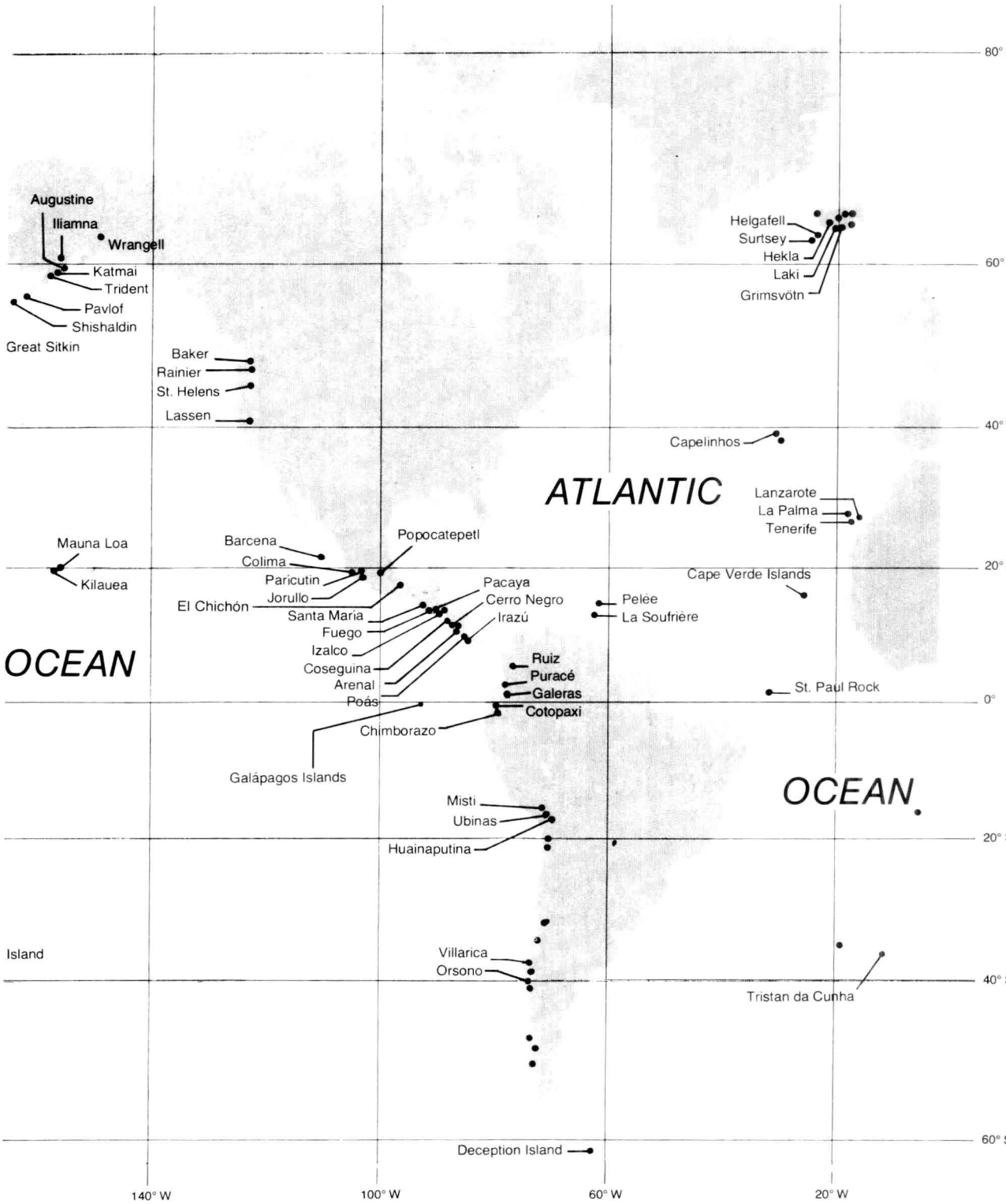
Since the publication of the first edition of this book in 1962, there have been tremendous advances in our knowledge of volcanism, largely as a result of the United States program to land a man on the moon. It had long been known that there were many craters on the moon, but a controversy developed as to whether they were volcanic or due to the impact of meteorites. In an effort to find evidence which might help resolve the controversy, an intensive study was made of many of the earth volcanoes. We now know that both types of craters are present on the moon, but the controversy continues over the assignment of particular craters to the correct type.

The study of volcanoes was long neglected because in Europe, where the science of geology developed, the rocks are mainly sedimentary, and intrusives and volcanism were regarded as superficial phenomena. We now know that almost the entire floor of the ocean is made up of volcanic rocks, and even on land the proportion of volcanic products—basalt plateaus, ash flows, etc.—is far greater than was previously recognized. Further, we now know that gases of volcanic origin play a decisive role in providing the water of the oceans and the gases of the atmosphere, without which our planet would not be habitable. Volcanic activity has taken place to some degree over virtually the entire surface of the earth during the course of its long geologic history. In each geologic age the active volcanoes were associated with the major mountain-making movements, in much the same manner as they are now aligned with the present zones of tectonic unrest.

The advances in recent years in heat flow studies and the development of the concepts of sea-floor spreading and plate tectonics have had a profound effect, not only on volcanology, but on the entire science of geology. An effort is made in this edition to incorporate the new material and the new concepts and to present a view of volcanology consistent with our present state of knowledge.

Active volcanoes of the world. It was not possible, because of the scale of the map, to locate all of the active volcanoes. Most of those mentioned in the text and some of the other more prominent volcanoes are named.

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Great Sitkin
Baker
Rainier
St. Helens
Lassen
Helgafell
Surtsey
Hekla
Laki
Grimsvötn
Capelinhos
ATLANTIC
Lanzarote
La Palma
Tenerife
Mauna Loa
Kilauea
Barcena
Colima
Paricutin
Jorullo
El Chichón
Santa María
Fuego
Izalco
Coseguina
Arenal
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Popocatepetl
Pacaya
Cerro Negro
Irazú
Ruiz
Puracé
Galeras
Cotopaxi
Pelée
La Soufrière
Cape Verde Islands
St. Paul Rock
OCEAN
OCEAN
Misti
Ubinas
Huainaputina
Villarica
Orsono
Island
Tristan da Cunha
Deception Island

Chapter 1 What Is a Volcano?

By turns hot embers from her entrails fly,
And flakes of mountain flame that arch the sky. —VIRGIL'S Aeneid

"What is a volcano?" is a familiar question. An often-given answer is that "a volcano is a burning mountain from the top of which issue smoke and fire." Such a statement, although it does express the popular idea of a volcano, held even today, contains few elements of truth. In the first place, no "burning" in the sense of combustion, such as the burning of wood, occurs in a volcano; moreover, volcanoes are not necessarily mountains; furthermore, the activity takes place not always at the summit but more commonly on the sides or flanks; and, finally, the "smoke" is not smoke but condensed steam, mixed, frequently, with dust particles until it is dark in color, and the "fire" is the reflection of the red-hot material on the vapor clouds above the volcano.

The great cloud of gases, vapor, and ash particles is the most conspicuous feature of the explosive eruption of a volcano. The eruption cloud may be luminous or dark, depending on whether the material is incandescent and whether it contains a small or large amount of ash particles. The "fiery" and "smoky" appearances, together with the red glow reflected from the lava in the crater beneath, are responsible for the popular idea that volcanoes are "burning mountains." Apparently supporting this fallacy, the materials that fall from the eruption cloud (known to the geologist as *pyroclastics* from the Greek *pyro*, meaning "fire," plus *clastic*, meaning "broken") often resemble ash and cinders, by which names they are still known. Although there is intense heat in a volcano, actual burning plays only a minor role in volcanic activity and is confined to almost imperceptible flames from certain combustible gases, such as hydrogen.

To describe what a volcano is *not* is much easier than to give a concise definition of what it *is*. A volcano is a vent or chimney which connects a reservoir of molten matter known as *magma*, in the depths of the crust of the earth, with the surface of the earth. The material ejected through the vent frequently accumulates around the opening, building up a cone, called the *volcanic edifice*. The loftiest mountains on earth are volcanic edifices. The material ejected consists of