

Photomicrograph under crossed nichols of boninite-series high-MgO bronzite andesite from Hole 458, Section 28-1, drilled in the Mariana fore-arc region. The sample shows a complex glomerocryst of intergrown augite (mainly browns and yellows) and bronzite (gray). The groundmass consists of clinopyroxene microlites aligned by stretching of a pillow rim, set in glass. Like most boninite-series lavas, this glassy sample lacks plagioclase.

Initial Reports of the Deep Sea Drilling Project

A Project Planned By and Carried Out With the Advice of the JOINT OCEANOGRAPHIC INSTITUTIONS FOR DEEP EARTH SAMPLING (JOIDES)

VOLUME LX

covering Leg 60 of the cruises of the Drilling Vessel Glomar Challenger Apra, Guam to Apra, Guam March-May 1978

PARTICIPATING SCIENTISTS

Donald M. Hussong, Seiya Uyeda, René Blanchet, Ulrich Bleil, C. Howard Ellis, Timothy J. G. Francis, Patricia Fryer, Ki-Iti Horai, Stanley Kling, Arend Meijer, Kazuaki Nakamura, James H. Natland, Gordon H. Packham, and Anatoly Sharaskin

STAFF SCIENCE REPRESENTATIVE

James H. Natland

EDITORS

Marianna Lee Robert Powell

Prepared for the NATIONAL SCIENCE FOUNDATION National Ocean Sediment Coring Program Under Contract C-482 By the UNIVERSITY OF CALIFORNIA Scripps Institution of Oceanography Prime Contractor for the Project This material is based upon research supported by the National Science Foundation under Contract No. C-482.

Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

It is recommended that reference to the whole or to part of this volume be made in one of the following forms, as appropriate:

Hussong, D. M., Uyeda, S., et al., 1981. Init. Repts. DSDP, 60: Washington (U.S. Govt. Printing Office).

Hussong, D. M., 1981. Underway geophysics—Leg 60 and related surveys. In Hussong, D. M., Uyeda, S., et al., Init. Repts. DSDP, 60: Washington (U.S. Govt. Printing Office), 71-74.

Effective Publication Dates of DSDP Initial Reports

According to the International Code of Zoological Nomenclature, the date of publication of a work and of a contained name or statement affecting nomenclature is the date on which the publication was mailed to subscribers, placed on sale, or, when the whole edition is distributed free of charge, mailed to institutions and individuals to whom free copies are distributed. The mailing date, *not the printed date*, is the correct one.

Mailing dates of the more recent Initial Reports of the Deep Sea Drilling Project are as follows:

> Volume 54—December, 1980 Volume 55—September, 1980 Volume 56, 57—Part 1, November, 1980 Part 2, November, 1980 Volume 58—August, 1980 Volume 59—January, 1981 Volume 61—August 1981

> > Printed March 1982

Library of Congress Catalog Number 74-603338

For sale by the Superintendent of Documents, U.S. Government Printing Office Washington, D.C. 20402

Foreword

Between 1872 and 1876, the H.M.S. CHAL-LENGER undertook the world's first major oceanographic expedition. That expedition greatly expanded man's knowledge of the world's oceans and revolutionized his ideas about this planet earth. A century later, over the course of the past decade, another vessel, also named CHALLENGER, has continued to expand man's knowledge of the world ocean, and has revolutionized his concepts of how the seafloor and continents were formed and continue to change. The D/V GLOMAR CHALLENGER is plying the same waters as its historic counterpart, seeking answers to new questions concerning the history of our planet and the life it supports. The continued advancement of knowledge about the fundamental processes and dynamics of the earth will lead to a greater understanding of our planet and more intelligent use of its resources.

Since 1968, the Deep Sea Drilling Project has been supported by the National Science Foundation, primarily through a contract with the University of California which, in turn, subcontracts to Global Marine Incorporated for the services of the drillship D/V GLOMAR CHAL-LENGER. Scripps Institution of Oceanography is responsible for management of the University contract.

Through contracts with Joint Oceanographic Institutions, Inc. (JOI, Inc.), the National Science Foundation supports the scientific advisory structure for the project and funds some pre-drilling site surveys. Scientific planning is conducted under the auspices of the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). The JOIDES advisory group consists of over 250 members who make up 24 committees, panels or working groups. The members are distinguished scientists from academic institutions, government agencies and private industry in many countries.

In 1975, the International Phase of Ocean Drilling (IPOD) began. IPOD member nations, USSR, Federal Republic of Germany, Japan, United Kingdom and France, provide partial support of the project. Each member nation takes an active role in the scientific planning of the project through organization membership in JOIDES. Scientists from these countries also participate in the field work aboard the D/V

V

GLOMAR CHALLENGER and post-cruise scientific studies.

The first ocean coring operations for the Deep Sea Drilling Project began on August 11, 1968. During the ensuing years of drilling operations in the Atlantic, Pacific and Indian Oceans, the Gulf of Mexico, Caribbean Sea, Mediterranean Sea, and Antarctic waters, the scientific objectives that had been proposed were successfully accomplished. Primarily, the age of the ocean basins and their processes of development were determined. The validity of the hypothesis of sea floor spreading was firmly demonstrated and its dynamics studied. Emphasis was placed on broad reconnaissance and testing the involvement of midoceanic ridge systems in the development of the ocean basin. Later legs of the CHALLENGER's voyages concentrated on the nature of the oceanic crust, the sedimentary history of the passive ocean margins, sediment dynamics along active ocean margins and other areas of interest. The accumulated results of this project have led to major new interpretations of the pattern of sedimentation and the physical and chemical characteristics of the ancient oceans.

As a result of the continued success of the Deep Sea Drilling Project, the National Science Foundation has presently extended the project through fiscal year 1982. The latest contract extends the period of exploration of the deep ocean floors of the world by GLOMAR CHALLENGER to a total of over 14 years.

A new dimension of scientific discovery has been added to the project, the detailed study of paleoenvironment. With the introduction of the hydraulic piston corer in 1979, virtually undisturbed cores of the soft sediment layers can now be obtained. This technological advance, together with the new pressure core barrel, has greatly enhanced the ability of the project to study ancient ocean climates as recorded by the micro flora and fauna preserved in the sedimentary layers.

These reports contain the results of initial studies of the recovered core material and the associated geophysical information. The contribution to knowledge has been exceedingly large. Future studies of the core material over many years will contribute much more.

People of our planet, in their daily living and work activities, will benefit directly and/or indirectly from this research. Benefits are derived from the technological advances in drilling, coring, position-keeping and other areas as well as through the information being obtained about natural resources and their origins. As with the original H.M.S. CHALLENGER oceanographic expedition, this second CHALLENGER expedition will have profound effects on scientific understanding for many years to come.

Washington, D.C. June 1981

Preface

Recognizing the need in the oceanographic community for scientific planning of a program to obtain deep sedimentary cores from the ocean bottoms, four of the major oceanographic institutions that had strong interests and programs in the fields of marine geology and geophysics formed, in May 1964, the Joint Oceanographic Institututions for Deep Earth Sampling (JOIDES). This group-Lamont-Doherty Geological Observatory; Rosenstiel School of Marine and Atmospheric Science, University of Miami; the Scripps Institution of Oceanography, University of California at San Diego; and the Woods Hole Oceanographic Institutionexpressed an interest in undertaking scientific planning and guidance of the sedimentary drilling program. It was the purpose of this group to foster programs to investigate the sediments and rocks beneath the deep oceans by drilling and coring. The membership of the original group was later enlarged, in 1968, when the University of Washington became a member and again in 1975 when University of Hawaii Institute of Geophysics, the Oregon State University School of Oceanography, the University of Rhode Island Graduate School of Oceanography, and Texas A&M University Department of Oceanography became members. In accordance with international agreements, institutions of participating nations became members of JOIDES. Thus, during 1974 to 1976, the Bundesanstalt für Geowissenschaften und Rohstoffe of the Federal Republic of Germany, the Centre National pour l'Exploitation des Océans of France, the National Environmental Research Council of the United Kingdom, the University of Tokyo of Japan, and the Academy of Sciences of the USSR became JOIDES members.

Through discussions sponsored by the JOIDES organization, with support from the National Science Foundation, Columbia University's Lamont-Doherty Geological Observatory operated a drilling program in the summer of 1965 on the Blake Plateau region off Jacksonville, Florida.

With this success in hand, planning began for a more extensive deep sea effort. This resulted in the award of a contract by the National Science Foundation to the Scripps Institution of Oceanography, University of California at San Diego for an eighteen-month drilling program in the Atlantic and Pacific oceans, termed the Deep Sea Drilling Project (DSDP). Operations at sea began in August 1968, using the now-famous drilling vessel, the *Glomar Challenger*.

The goal of the Deep Sea Drilling Project is to gather scientific information that will help determine the age and processes of development of the ocean basins. The primary strategy is to drill deep holes into the ocean floor, relying largely on technology developed by the petroleum industry.

Through the efforts of the principal organizations and of the panel members, who were drawn from a large cross section of leading earth scientists and associates, a scientific program was developed.

Cores recovered from deep beneath the ocean floor provide reference material for a multitude of studies in fields such as biostratigraphy, physical stratigraphy, and paleomagnetism that afford a new scope for investigating the physical and chemical aspects of sediment provenance, transportation, deposition, and diagenesis. In-hole measurements, as feasible, provide petrophysical data to permit inference of lithology of intervals from which no cores were recovered.

A report, describing the core materials and information obtained both at sea and in laboratories onshore, is published after the completion of each cruise. These reports are a cooperative effort of shipboard and shorebased scientists and are intended primarily to be a compilation of results which, it is hoped, will be the starting point for many future new and exciting research programs. Preliminary interpretations of the data and observations taken at sea are also included.

Core materials and data collected on each cruise will be made available to qualified scientists through the Curator of the Deep Sea Drilling Project, following a Sample Distribution Policy (p. xix) approved by the National Science Foundation.

The advent of Glomar Challenger, with its deep-water drilling capability, is exceedingly timely. It has come when geophysical investigation of the oceans has matured through 20 to 30 years of vigorous growth to the point where we have some knowledge about much of the formerly unknown oceanic areas of our planet. About one million miles of traverses have been made which tell us much about the global pattern of gravity, magnetic and thermal anomalies, and about the composition, thickness, and stratigraphy of the sedimentary cover of the deep sea and continental margin. The coverage with such data has enabled the site selection panels to pick choice locations for drilling. The knowledge gained from each hole can be extended into the surrounding area. Detailed geophysical surveys were made for most of the selected locations prior to drilling.

The earth sciences have recently matured from an empirical status to one in which substantial theories and hypotheses about major tectonic processes are flourishing. Theories about the origin of magnetic fields and magnetic reversals, about ocean floor spreading and continental drift, and about the thermal history of our planet have led to specific predictions that could be tested best by an enlightened program of sampling of deep sea and continental margin sediments and underlying rocks.

In October 1975, the International Phase of Ocean Drilling (IPOD) began. This international interest, and the true participation of both the scientists and governments of a number of nations, are eloquent testimony to the importance of the work being done by the Deep Sea Drilling Project.

The members of JOIDES and DSDP and the scientists from all interested organizations and nations who have served on the various advisory panels are proud to have been of service and believe that the information and core materials that have been obtained will be of value to students of earth sciences and to all humanity for many years to come.

Deep Sea Drilling Project

MEMBER ORGANIZATIONS OF THE JOINT OCEANOGRAPHIC INSTITUTIONS FOR DEEP EARTH SAMPLING (JOIDES):*

- Bundesanstalt für Geowissenschaften und Rohstoffe, Federal Republic of Germany
- University of California at San Diego, Scripps Institution of Oceanography
- Centre National pour l'Exploitation des Océans, Paris
- Columbia University, Lamont-Doherty Geological Observatory
- University of Hawaii, Hawaii Institute of Geophysics
- University of Miami, Rosenstiel School of Marine and Atmospheric Science
- Natural Environment Research Council, London
- Oregon State University, School of Oceanography
- University of Rhode Island, Graduate School of Oceanography
- Texas A&M University, Department of Oceanography
- University of Tokyo, Ocean Research Institute
- University of Washington, Department of Oceanography
- U.S.S.R. Academy of Sciences
- Woods Hole Oceanographic Institution

*Includes member organizations during time of the cruise.

OPERATING INSTITUTION:

Scripps Institution of Oceanography University of California at San Diego La Jolla, California W. A. Nierenberg, Director

DEEP SEA DRILLING PROJECT

Dr. W. A. Nierenberg Principal Investigator

Dr. M. N. A. Peterson Project Manager

Mr. Frank C. MacTernan Principal Engineer and Deputy Project Manager

Dr. Yves Lancelot Chief Scientist

Dr. Matthew H. Salisbury Associate Chief Scientist for Science Operations

Dr. William R. Riedel Curator

Mr. Stanley T. Serocki Project Development Engineer

Mr. Barry Robson Operations Manager

Mr. William T. Soderstrom Finance Administrator

Mr. Robert Olivas Logistics Officer

Mr. Robert S. Bower Contracts Officer

Ms. Sue Strain Personnel Officer

Participants aboard GLOMAR CHALLENGER for Leg Sixty

Dr. Donald M. Hussong Co-Chief Scientist Hawaii Institute of Geophysics University of Hawaii at Manoa 2525 Correa Road Honolulu, Hawaii 96822

Dr. Seiya Uyeda Co-Chief Scientist Earthquake Research Institute University of Tokyo Hongo, Tokyo 113 Japan

Dr. René Blanchet Sedimentologist Laboratoire d'Océanologie et Géodynamie Département des Sciences de la Terre Université de Bretagne Occidentale 29279 Brest, Cedex France

Dr. Ulrich Bleil Paleomagnetist Institut für Geophysik Ruhr Universität 4600 Bochum Federal Republic of Germany

Mr. C. Howard Ellis Paleontologist (nannofossils/foraminifers) Denver Research Center Marathon Oil Company Littleton, Colorado 80106

Dr. Timothy J. G. Francis Geophysicist and Physical Properties Specialist Institute of Oceanographic Sciences Brook Road, Wormley Godalming, Surrey GU8 5UB United Kingdom

Ms. Patricia B. Fryer Igneous Petrologist Hawaii Institute of Geophysics University of Hawaii at Manoa 2525 Correa Road Honolulu, Hawaii 96822

Dr. Ki-Iti Horai Heatflow Specialist Lamont-Doherty Geological Observatory Columbia University Palisades, New York 10964 Dr. Stanley Kling Paleontologist (radiolarians) Marine Life Research Group, A-022 Scripps Institution of Oceanography La Jolla, California 92093 Dr. Arend Meijer Igneous Petrologist Department of Geosciences University of Arizona Tuscon, Arizona 85712 Dr. Kazuaki Nakamura Volcanoclastic Sedimentologist Earthquake Research Institute University of Tokyo Hongo, Tokyo 113 Japan Dr. James H. Natland Igneous Petrologist and Shipboard Science Representative Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093 Dr. Gordon H. Packham Sedimentologist Department of Geology University of Sydney New South Wales 2600 Australia Dr. Anatoly Sharaskin Igneous Petrologist Vernadsky Institute of Sciences U.S.S.R. Academy of Sciences 117334 Moscow U.S.S.R. Mr. Robert Knapp Cruise Operations Manager Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093 Mr. Robert Connolly Weatherman NOAA—National Weather Service Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093 Captain Loyd Dill Captain of the Drilling Vessel Global Marine, Inc. Los Angeles, California 90017

Mr. Otis Winton Drilling Superintendent Global Marine, Inc. Los Angeles, California 90017

Mr. Ted Gustafson Laboratory Officer Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Mr. Robert A. Benoit Logging Technician Gearhart-Owen Industries, Inc. P.O. Box 1936 Forth Worth, Texas 76101

Mr. James Harrington Curatorial Representative Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Mr. James Pine Chemist Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Mr. Dale Dixon Electronics Technician Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Mr. Paul Laughlin Electronics Technician Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093 Mr. Donald Cameron Marine Technician Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Mr. Craig Hallman Marine Technician Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Mr. Richard Myers Marine Technician Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Mr. Victor Sotelo Marine Technician Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Mr. Kevin Reid Photographer Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Ms. Gayle Burns Yeoperson Deep Sea Drilling Project, A-031 Scripps Institution of Oceanography La Jolla, California 92093

Deep Sea Drilling Project Publication Staff

Publications Manager Marianna Lee

Editors

Rosemary Amidei Susan Orlofsky Larry N. Stout Production Manager Raymond F. Silk

Production Assistants Elaine M. Bruer Madeleine A. Mahnken Teresa Whisenhunt

Production Coordinators Mary A. Young Nancy Durham Art-Photo Supervisor Virginia L. Roman

Illustrators Myrtali Anagnostopoulos Vicki Cypherd Tommy F. Hilliard (this volume) Elizabeth Peters Kathleen Sanderson Alice N. Thompson

JOIDES Advisory Groups*

Executive Committee Dr. Maurice Rattray, Jr. University of Washington Professor Dr. F. Bender Bundesanstalt für Geowissenschaften und Rohstoffe Dr. John V. Byrne Oregon State University Dr. William W. Hay Rosenstiel School of Marine and Atmospheric Science Dr. Charles E. Helsley Hawaii Institute of Geophysics Sir Peter Kent, F.R.S. Natural Environment Research Council Dr. John A. Knauss University of Rhode Island Monsieur Yves La Prairie Centre National pour l'Exploitation des Océans Dr. Ryuzo Marumo University of Tokyo Dr. William A. Nierenberg Scripps Institution of Oceanography Dr. Worth D. Nowlin, Jr. Texas A&M University Dr. M. N. A. Peterson (ex-officio) Scripps Institution of Oceanography Academician A. V. Sidorenko Academy of Sciences of the U.S.S.R. Dr. John Steele Woods Hole Oceanographic Institution Dr. Manik Talwani Lamont-Doherty Geological Observatory **Planning Committee** Dr. Joe S. Creager University of Washington Dr. Helmut Beiersdorf Bundesanstalt für Geowissenschaften und Rohstoffe Dr. William R. Bryant Texas A&M University Dr. J. Dymond Oregon State University Dr. C. G. A. Harrison Rosenstiel School of Marine and Atmospheric Science Dr. Dennis E. Hayes Lamont-Doherty Geological Observatory Dr. James R. Heirtzler Woods Hole Oceanographic Institution

* Membership at time of cruise.

Dr. Anthony S. Laughton Institute of Oceanographic Sciences Dr. Xavier LePichon Centre National pour l'Exploitation des Océans Dr. Ralph Moberly Hawaii Institute of Geophysics Dr. David G. Moore (ex-officio) Scripps Institution of Oceanography Dr. T. C. Moore, Jr. University of Rhode Island Dr. Noriyuki Nasu University of Tokyo Dr. L. Nikitin Academy of Sciences of the U.S.S.R. Dr. William Riedel (ex-officio) Scripps Institution of Oceanography Dr. E. L. Winterer Scripps Institution of Oceanography

Advisory Panel on Sedimentary Petrology and Physical Properties

Dr. A. Richards Lehigh University Dr. R. Bennett National Oceanic and Atmospheric Administration Mr. R. E. Boyce (ex-officio) Scripps Institution of Oceanography Dr. William R. Bryant (ex-officio) Texas A&M University Dr. S. E. Calvert Institute of Oceanographic Sciences Dr. C. J. Clausen Norges Geotekniske Institutt Dr. J. Conolly Era North America Inc. Dr. John W. Handin Texas A&M University Dr. G. deVries Klein University of Illinois Dr. Frédéric Mélières Université Pierre et Marie Curie Dr. G. Müller Laboratorium für Sedimentforschung, Heidelberg Dr. O. H. Pilkey Duke University Dr. P. O. Timofeev Academy of Sciences of the U.S.S.R.

Advisory Panel on Organic Geochemistry Dr. Keith Kvenvolden U.S. Geological Survey Dr. Earl W. Baker Florida Atlantic University Dr. Ellis E. Brav Mobil Oil Company, Inc. Dr. Geoffrey Eglinton (ex-officio) University of Bristol Dr. J. Gordon Erdman Phillips Petroleum Company Dr. Eric M. Galimov Academy of Sciences of the U.S.S.R. Dr. John M. Hunt Woods Hole Oceanographic Institution Dr. John W. Kendrick Shell Development Company Dr. Erwin Suess Oregon State University Dr. B. Tissot Institut Français du Pétrole Dr. Dietrich Welte Lehrstuhl für Geologie, Geochemie, und Lagerstatten des Erdöls und der Kohle Mr. Oscar Weser (ex-officio) Scripps Institution of Oceanography Dr. E. L. Winterer (ex-officio) Scripps Institution of Oceanography **Advisory Panel on Information Handling** Dr. M. A. Rosenfeld Woods Hole Oceanographic Institution Dr. D. W. Appleman Smithsonian Institution Mr. J. G. Barr Standard Oil Company of California Dr. Joe S. Creager (ex-officio) University of Washington Dr. H. Glashoff Bundesanstalt für Geowissenschaften und Rohstoffe Dr. A. Loeblich, Jr. University of California, Los Angeles Dr. M. S. Loughridge National Oceanic and Atmospheric Administration Dr. J. Usher (ex-officio) (deceased) Scripps Institution of Oceanography Dr. V. V. Zdorovenin Academy of Sciences of the U.S.S.R. **Industrial Liaison Panel** Mr. W. A. Roberts Phillips Petroleum Company Mr. R. L. Adams Continental Oil Company

Professor Vsevolod V. Fedvnskiv Ministry of Geology of the U.S.S.R. Mr. Melvin J. Hill Gulf Oil Corporation Dr. Ing. Guenter Peterson Deutsche Schachtbau und Tiefborhrgesellschaft mbH Monsieur Gilbert Rutman Société Nationale des Pétroles d'Aquitaine Mr. G. Williams United Kingdom Offshore Operators Association, Ltd. **Advisory Panel on Ocean Crust** Dr. J. R. Cann University of Newcastle-upon-Tyne Dr. J. L. Bischoff U.S. Geological Survey Dr. N. A. Bogdanov Academy of Sciences of the U.S.S.R. Dr. Paul J. Fox State University of New York at Albany Dr. Jean Francheteau Centre National pour l'Exploitation des Océans Dr. J. M. Hall Dalhousie University Dr. C. G. A. Harrison (ex-officio) Rosenstiel School of Marine and Atmospheric Science Dr. James R. Heirtzler (ex-officio) Woods Hole Oceanographic Institution Dr. Roger L. Larson Lamont-Doherty Geological Observatory Dr. James H. Natland (ex-officio) Scripps Institution of Oceanography Dr. John Orcutt Scripps Institution of Oceanography Dr. M. Ozima University of Tokyo Dr. H.-U. Schmincke Ruhr-Universität, Bochum Dr. M. Treuil Institut Physique du Globe Advisory Panel on Ocean Margin (Active) Dr. Roland von Huene U.S. Geological Survey Dr. Michael Audley-Charles University of London Dr. René Blanchet Université de Bretagne Occidentale Dr. Creighton Burk University of Texas, Austin Dr. Joe S. Creager (ex-officio) University of Washington Dr. W. R. Dickinson Stanford University

Dr. D. M. Hussong Hawaii Institute of Geophysics Dr. Daniel Karig Cornell University Dr. Kazuo Kobayashi University of Tokyo Dr. I. P. Kosminskaya Academy of Sciences of the U.S.S.R. Dr. Keith Kvenvolden (ex-officio) U.S. Geological Survey Dr. David G. Moore (ex-officio) Scripps Institution of Oceanography Dr. James H. Natland (ex-officio) Scripps Institution of Oceanography Dr. H. W. Walther Bundesanstalt für Geowissenschaften und Rohstoffe Dr. A. Watts Lamont-Doherty Geological Observatory Advisory Panel on Ocean Margin (Passive) Dr. Joseph R. Curray Scripps Institution of Oceanography Dr. Helmut Beiersdorf (ex-officio) Bundesanstalt für Geowissenschaften und Rohstoffe Professor Dr. D. Bernoulli Geologisch-Paläontologisches Institut, Basel Dr. William R. Bryant (ex-officio) Texas A&M University Mr. John I. Ewing Woods Hole Oceanographic Institution Mr. John A. Grow U.S. Geological Survey Dr. K. Hinz Bundesanstalt für Geowissenschaften und Rohstoffe Dr. John M. Hunt (ex-officio) Woods Hole Oceanographic Institution Dr. H. Kagami University of Tokyo Dr. L. Montadert Institut Français du Pétrole Dr. David G. Moore (ex-officio) Scripps Institution of Oceanography Dr. D. G. Roberts Institute of Oceanographic Sciences Professor Dr. E. Seibold Universität Kiel Dr. Robert E. Sheridan University of Delaware Dr. S. Snelson Shell Development Company Dr. J. Thiede Universitetet Oslo Dr. P. R. Vail Exxon Production Research Company

Dr. S. Zverev Academy of Sciences of the U.S.S.R. Advisory Panel on Pollution Prevention and Safety Dr. Louis E. Garrison U.S. Geological Survey Dr. George Claypool U.S. Geological Survey Dr. Joe S. Creager (ex-officio) University of Washington Dr. Joseph R. Curray Scripps Institution of Oceanography Dr. H. Grant Goodell University of Virginia Dr. Arthur E. Green Exxon Production Research Company Dr. Brian T. R. Lewis (ex-officio) University of Washington Dr. A. Mayer-Gurr Eichhaldestrasse 79/3, Urach Dr. G. A. Pommier Compagnie Français des Pétroles Dr. Maurice Rattray, Jr. (ex-officio) University of Washington Dr. E. Vekilov Ministry of Geology, U.S.S.R. Dr. Roland von Huene U.S. Geological Survey Mr. Oscar E. Weser Scripps Institution of Oceanography **Advisory Panel on Inorganic Geochemistry** Dr. Joris M. Gieskes Scripps Institution of Oceanography Dr. W. B. Clarke McMaster University Dr. D. S. Cronan Royal School of Mines, London Dr. V. Holodov Academy of Sciences of the U.S.S.R. Dr. Frank T. Manheim U.S. Geological Survey Dr. Ralph Moberly (ex-officio) Hawaii Institute of Geophysics Dr. Samuel M. Savin Case Western Reserve University Dr. Erwin Suess Oregon State University Dr. Y. Tardy Laboratoire de Pédologie et Géochimie, Toulouse Dr. K. K. Turekian Yale University Dr. K. H. Wedepohl Geochemisches Institut der Universität, Göttingen

Advisory Panel on Ocean Paleoenvironment Dr. Yves Lancelot Centre National pour l'Exploitation des Oceans Dr. Wolfgang Berger Scripps Institution of Oceanography Dr. G. Eglinton (ex-officio) University of Bristol Dr. Kenneth Hsü Eidg. Technische Hochschule, Zürich Dr. James C. Ingle Stanford University Dr. Hugh C. Jenkyns University of Oxford Dr. A. P. Lisitzin Academy of Sciences of the U.S.S.R. Dr. T. C. Moore, Jr. University of Rhode Island Dr. I. O. Murdmaa Academy of Sciences of the U.S.S.R. Dr. Michael Sarnthein Universitat Kiel Dr. N. Shackleton University of Cambridge Dr. W. V. Sliter U.S. Geological Survey Dr. Y. Takayanagi Tohoku University Dr. H. Thierstein Scripps Institution of Oceanography Dr. J. Usher (ex-officio) (deceased) Scripps Institution of Oceanography Dr. E. L. Winterer (ex-officio) Scripps Institution of Oceanography Advisory Panel on Site Surveying Dr. Brian T. R. Lewis University of Washington Dr. A. Beresnev Institute of Physics of the Earth Dr. Elizabeth T. Bunce Woods Hole Oceanographic Institution Dr. Leroy M. Dorman Scripps Institution of Oceanography Dr. Edgar S. Driver Gulf Research and Development Company Dr. Davis A. Fahlquist Texas A&M University Dr. Dennis E. Hayes (ex-officio) Lamont-Doherty Geological Observatory Dr. Donald M. Hussong Hawaii Institute of Geophysics

Dr. Ralph Moberly (ex-officio) Hawaii Institute of Geophysics Dr. Shozaburo Nagumo University of Tokyo Dr. Philip D. Rabinowitz Lamont-Doherty Geological Observatory Dr. Vincent Renard Centre Océanologique de Bretagne Dr. Roland Schlich Observatoire Géophysique du Parc St.-Maur Dr. Gunter Stober Deutsche Erdolversorgungsgellschaft mbH, Essen Dr. Roland von Huene U.S. Geological Survey Dr. Joel Watkins Gulf Science and Development Company Dr. S. White (ex-officio) Scripps Institution of Oceanography

Stratigraphic Correlations Panel Dr. R. H. Benson Smithsonian Institution Dr. W. A. Berggren Woods Hole Oceanographic Institution Professor Dr. H. M. Bolli Eidg. Technische Hochschule, Zürich Dr. D. Bukry U.S. Geological Survey Dr. P. Čepek Bundesanstalt für Geowissenschaften und Rohstoffe Dr. R. G. Douglas University of Southern California Dr. Stefan Gartner Texas A&M University Dr. S. R. Hammond Hawaii Institute of Geophysics Dr. C. G. A. Harrison (ex-officio) Rosenstiel School of Marine and Atmospheric Sciences Dr. N. Hughes Sedgwick Museum, Cambridge Dr. V. Krasheninnikov Academy of Sciences of the U.S.S.R. Dr. W. R. Riedel Scripps Institution of Oceanography Dr. J. B. Saunders Naturhistorisches Museum, Basel Dr. J. L. Usher (deceased) Scripps Institution of Oceanography

Downhole Measurements Panel

Dr. R. Hyndman Pacific Geoscience Centre Dr. Heinz Beckmann

Technische Universität Clausthal Dr. N. Christensen

University of Washington

Dr. James R. Heirtzler (ex-officio) Woods Hole Oceanographic Institution Dr. A. H. Jageler Amoco Production Research Company
Dr. Yuri Neprochnov Academy of Sciences of the U.S.S.R.
Dr. A. Richards Lehigh University
Dr. O. Serra ELF-ERAP
Mr. J. R. Severns

McCulloh Oil Corporation

Deep Sea Drilling Project SAMPLE DISTRIBUTION POLICY^{*}

Distribution of Deep Sea Drilling samples for investigation will be undertaken in order to (1) provide supplementary data to support GLOMAR CHAL-LENGER scientists in achieving the scientific objectives of their particular cruise, and in addition to serve as a mechanism for contributions to the *Initial Reports;* (2) provide individual investigators with materials that are stored with samples for reference and comparison purposes.

The National Science Foundation has established a Sample Distribution Panel to advise on the distribution of core materials. This panel is chosen in accordance with usual Foundation practices, in a manner that will assure advice in the various disciplines leading to a complete and adequate study of the cores and their contents. Funding for the proposed research must be secured separately by the investigator. It cannot be provided through the Deep Sea Drilling Project.

The Deep Sea Drilling Project's Curator is responsible for distributing the samples and controlling their quality, as well as preserving and conserving core material. He also is responsible for maintaining a record of all samples that have been distributed, shipboard and subsequent, indicating the recipient and the nature of the proposed investigation. This information is made available to all investigators of DSDP materials as well as to other interested researchers on request.

The distribution of samples is made directly from one of the two existing repositories, Lamont-Doherty Geological Observatory and Scripps Institution of Oceanography, by the Curator or his designated representative.

1. Distribution of Samples for Research Leading to Contributions to Initial Reports

Any investigator who wishes to contribute a paper to a given volume of the *Initial Reports* may write to the Chief Scientist, Deep Sea Drilling Project (A-031), Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California 92093, U.S.A., requesting samples from a forthcoming cruise. Requests for a specific cruise should be received by the Chief Scientist two months in advance of the departure of the cruise in order to allow time for the review and consideration of all requests and to establish a suitable shipboard sampling program. The request should include a statement of the nature of the study proposed, size and approximate number of samples required to complete the study, and any particular sampling technique or equipment that might be required. The requests will be reviewed by the Chief Scientist of the Project and the cruise co-chief scientists; approval will be given in accordance with the scientific requirements of the cruise as determined by the appropriate JOIDES advisory panel(s). If approved, the requested samples will be taken, either by the shipboard party if the workload permits or by the curatorial staff shortly following the return of the cores to the repository. Proposals must be of a scope to ensure that samples can be processed and a contribution completed in time for publication in the Initial Reports. Except for rare, specific instances involving ephemeral properties, sampling will not exceed one-quarter of the volume of core recovered, with no interval being depleted and one-half of all core being retained as an archive. Shipboard sampling shall not exceed approximately 100 igneous samples per investigator; in all cases co-chief scientists are requested to keep sampling to a minimum.

The co-chief scientists may elect to have special studies of selected core samples made by other investigators. In this event the names of these investigators and complete listings of all materials loaned or distributed must be forwarded, if possible prior to the cruise or as soon as possible following the cruise, to the Chief Scientist through the DSDP Staff Science Representative for that particular cruise. In such cases, all requirements of the Sample Distribution Policy shall also apply.

If a dispute arises or if a decision cannot be reached in the manner prescribed, the NSF Sample Distribution Panel will conduct the final arbitration.

Any publication of results other than in the *Initial Reports* within twelve (12) months of the completion of the cruise must be approved and authored by the whole shipboard party and, where appropriate, shore-based investigators. After twelve months, individual investigators may submit related papers for open publication provided they have submitted their contributions to the *Initial Reports*. A paper too late for inclusion in the *Initial Reports* for a specific cruise may not be published elsewhere until publication of that *Initial Reports* for which it was intended. Notice of submission to other journals and a copy of the article should be sent to the DSDP Staff Science Representative for that leg.

^{*}Revised October 1976

- 2. Distribution of Samples for Research Leading to Publication Other than in Initial Reports
 - A. Researchers intending to request samples for studies beyond the scope of the *Initial Reports* should first obtain sample request forms from the Curator, Deep Sea Drilling Project (A-031), Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California 92093, U.S.A. On the forms the researcher is requested to specify the quantities and intervals of the core required, make a clear statement of the proposed research, state time required to complete and submit results for publication, and specify the status of funding and the availability of equipment and space foreseen for the research.

In order to ensure that all requests for highly desirable but limited samples can be considered, approval of requests and distribution of samples will not be made prior to 2 months after publication of the Initial Core Descriptions (I.C.D.). ICD's are required to be published within 10 months following each cruise. The only exceptions to this policy will be for specific instances involving ephemeral properties. Requests for samples can be based on the Initial Core Descriptions, copies of which are on file at various institutions throughout the world. Copies of original core logs and data are kept on open file at DSDP and at the Repository at Lamont-Doherty Geological Observatory, Palisades, New York. Requests for samples from researchers in industrial laboratories will be handled in the same manner as those from academic organizations, with the same obligation to publish results promptly.

B. (1) The DSDP Curator is authorized to distribute samples to 50 ml per meter of core. Requests for volumes of material in excess of this amount will be referred to the NSF Sample Distribution Panel for review and approval. Experience has shown that most investigations can be accomplished with samples 10 ml or smaller. All investigators are encouraged to be as judicious as possible with regard to sample size and, especially, frequency within any given core interval. The Curator will not automatically distribute any parts of the cores which appear to be in particularly high demand; requests for such parts will be referred to the Sample Distribution Panel for review. Requests for samples from thin layers or important stratigraphic boundaries will also require Panel review.

(2) If investigators wish to study certain properties which may deteriorate prior to the normal availability of the samples, they may request that the normal waiting period not apply. All such requests must be reviewed by the Curator and approved by the NSF Sample Distribution Panel.

- C. Samples will not be provided prior to assurance that funding for sample studies either exists or is not needed. However, neither formal approval of sample requests nor distribution of samples will be made until the appropriate time (Item A). If a sample request is dependent, either wholly or in part, on proposed funding, the Curator is prepared to provide to the organization to whom the funding proposal has been submitted any information on the availability (or potential availability) of samples that it may request.
- D. Investigators receiving samples are responsible for:

(1) publishing significant results; contributions shall not be submitted for publication prior to 12 months following the termination of the appropriate leg;

(2) acknowledging, in publications, that samples were supplied through the assistance of the U.S. National Science Foundation and others as appropriate;

(3) submitting five (5) copies (for distribution to the Curator's file, the DSDP repositories, the GLOMAR CHALLENGER's library, and the National Science Foundation) of all reprints of published results to the Curator, Deep Sea Drilling Project (A-031), Scripps Institution of Oceanography, University of California at San Diego, La Jolla, California 92093, U.S.A.;

(4) returning, in good condition, the remainders of samples after termination of research, if requested by the Curator.

- E. Cores are made available at repositories for investigators to examine and to specify exact samples in such instances as may be necessary for the scientific purposes of the sampling, subject to the limitations of B (1 and 2) and D, above, with specific permission of the Curator or his delegate.
- F. Shipboard-produced smear slides of sediments and thin sections of indurated sediments, igneous, and metamorphic rocks will be returned to the appropriate repository at the end of each cruise or at the publication of

the *Initial Reports* for that cruise. These smear slides and thin sections will form a reference collection of the cores stored at each repository and may be viewed at the respective repositories as an aid in the selection of core samples.

3. Reference Centers

As a separate and special category, samples will be distributed for the purpose of establishing up to five reference centers where paleontologic materials will be available for reference and comparison purposes. The first of these reference centers has been approved at Basel, Switzerland.

Data Distribution Policy

Data gathered on board D/V *Glomar Challenger* and in DSDP shore laboratories are available to all researchers 12 months after the completion of each cruise. The files are part of a coordinated computer database, fully searchable and coordinated to other files. Data sets representing a variety of geologic environments can be arranged for researchers who may wish to manipulate the database directly.

Most data requests are filled free of charge, except if they are unusually large or complex and direct costs exceed \$50.

When data are used for publication, the National Science Foundation must be acknowledged and DSDP provided with five reprints for inclusion in the DSDP index of publications and investigations. Requests for data should be submitted to:

> Data Manager, Deep Sea Drilling Project Scripps Institution of Oceanography (A-031) University of California, San Diego La Jolla, California 92093

Telephone: (714) 452-3526 Cable Address: SIOCEAN

- I. The database includes files generally available both in digital form on magnetic tape and as microfilm copies of the original observation forms.
 - A. Geophysical data include underway bathymetry, magnetics, and sub-bottom profiles; bathymetry data exist both as 12-kHz and 3.5-kHz records. Underway data are processed by DSDP and the Geological Data Center at Scripps Institution of Oceanography (SIO). Seismic records are available in microfilm and photographic prints.

B. Physical property data obtained on board Glomar Challenger include:

Analytical water content, porosity, and density

Density and porosity by Gamma Ray Attenuation Porosity Evaluator (GRAPE) Acoustic velocity by Hamilton Frame Method Thermal conductivity

Heat flow (in situ)

Natural gamma radiation (discontinued after Leg 19) Well logs

C. Sediment data obtained on board ship and from core samples in DSDP shore laboratories include:

> Core photographs Visual core descriptions Smear slide descriptions X-ray diffraction X-ray fluorescence Total carbon, organic carbon, and carbonate determinations

Grain-size determinations (sand, silt, clay) Interstitial water chemistry Gas chromatography

- D. Igneous rock data include: Core photographs Visual core descriptions Rock chemistry Paleomagnetics Thin-section descriptions
- E. Paleontologic data include fossil names, abundance, preservation, and age of sample and are available, for selected sites, for Tertiary and Mesozoic taxa. Range charts can be generated from the database, using the line printer. A glossary of fossil names is available on microfiche or magnetic tape.
- F. Ancillary files include: Site positions Sub-bottom depths of cores Master Guide File (a searchable core data summary file)
- II. Additional publications, aids to research, are periodically updated and distributed to libraries. Single copies, at no charge, are distributed on microfiche at 48X magnification, except for the Data Datas (C, opposite), which are at 24X. They include:
 - A. Guides to DSDP Core Materials, a series of printed summaries containing maxima, minima, and typical values for selected observations. Guides are available for each of the

major ocean basins and for Phases I, II, and III of the drilling program. The source data summary file is also available.

- B. Index to Initial Reports and Subsequent Publications and Investigations is a comprehensive key word index to chapters of the Initial Reports and to papers and investigations in progress which cite DSDP samples or data. The Index and its annotated bibliography serve to inform researchers of other investigators working on similar projects. Each paper is assigned key words for field of study, material, geographic area, and geologic age. A complete citation, including the assigned key words, is printed in the bibliography. Key words are permuted to form a comprehensive cross-index to the author reference list.
- C. Data Data, a series of informal memoranda providing a quick reference to accessible data, is available on microfiche. Also available is a site position map to assist researchers in largearea studies. (Site positions are plotted on a bathymetry map compiled by the SIO Geologic Data Center.)
- D. Data Retrieval and Application Computer Programs to perform data management and retrieval functions and a set of programs designed to provide special graphic displays of data are available; they may be of limited use because of differences in computer hardware. All current programs are written in ALGOL for a Burroughs 7800 computer system. Software inquiries may be addressed to the Data Manager.

CONTENTS

Chapter

PART I: INTRODUCTION

PART II: SITE SURVEYS AND UNDERWAY GEOPHYSICS

2.	STRUCTURE AND TECTONICS OF THE MARIANA ARC AND FORE-ARC: DRILLSITE SELECTION SURVEYS Donald M. Hussong and Patricia Fryer	33
3.	SEAFLOOR SPREADING IN THE MARIANA TROUGH: RESULTS OF LEG 60 DRILL SITE SELECTION SURVEYS Patricia Fryer and Donald M. Hussong	45
4.	MULTICHANNEL SEISMIC REFLECTION SURVEYS OF LEG 60 SITES, DEEP SEA DRILLING PROJECT Cary L. Mrozowski, Dennis E. Hayes, and Brian Taylor	57
5.	UNDERWAY GEOPHYSICS—LEG 60 AND RELATED SURVEYS Donald M. Hussong	71
PART III: SITE REPORTS		
6.	SITE 452: MESOZOIC PACIFIC OCEAN BASIN Shipboard Scientific Party	77
7.	MARIANA TROUGH—BACKGROUND AND OBJECTIVES S. Uyeda and D. M. Hussong	95
8.	SITE 453: WEST SIDE OF THE MARIANA TROUGH Shipboard Scientific Party	101
9.	SITE 454: NEAR THE CENTER OF THE MARIANA TROUGH Shipboard Scientific Party	169

Chapter		Page
10.	SITE 455: EAST SIDE OF THE MARIANA TROUGH Shipboard Scientific Party	203
11.	SITE 456: EAST SIDE OF THE MARIANA TROUGH Shipboard Scientific Party	215
12.	MARIANA ARC AND FORE-ARC BACKGROUND AND OBJECTIVES D. M. Hussong and S. Uyeda	251
13.	SITE 457: MARIANA ISLAND ARC Shipboard Scientific Party	255
14.	SITE 458: MARIANA FORE-ARC Shipboard Scientific Party	263
15.	SITE 459: MARIANA FORE-ARC Shipboard Scientific Party	309
16.	SITE 460: INNER WALL OF THE MARIANA TRENCH Shipboard Scientific Party	371
17.	SITE 461: INNER WALL OF THE MARIANA TRENCH Shipboard Scientific Party	399

PART IV: SEDIMENTOLOGICAL STUDIES

18.	MINERALOGY OF SEDIMENTS CORED	
	DURING DEEP SEA DRILLING PROJECT	
	LEGS 58-60 IN THE NORTH AND SOUTH	
	PHILIPPINE SEA: RESULTS OF X-RAY	
	DIFFRACTION ANALYSES	415
	Ulrich Nagel, German Müller, and	
	Dieter Schumann	
19.	X-RAY MINERALOGY STUDIES, DEEP	
	SEA DRILLING PROJECT LEG 60	437
	C. Latouche, N. Maillet, and R. Blanchet	
-		

Chapter

PART V: PALEONTOLOGY AND BIOSTRATIGRAPHY

Chapter

- 29. PLIOCENE AND QUATERNARY DIATOMS, SILICOFLAGELLATES, SPONGE SPICULES, AND ENDO-SKELETAL DINOFLAGELLATES FROM THE PHILIPPINE SEA, DEEP SEA DRILLING PROJECT LEGS 59 AND 60...... 565 Erlend Martini

PART VI: PETROLOGICAL STUDIES

- 31. PETROGRAPHY AND MINERAL COMPOSITIONS OF GABBROS RECOVERED IN DEEP SEA DRILLING **PROJECT HOLE 453 ON THE WESTERN** SIDE OF THE MARIANA TROUGH 579 James H. Natland 32. BASALTIC GLASSES FROM THE MARIANA TROUGH 601 Patricia Fryer, John M. Sinton, and John A. Philpotts 33. GEOCHEMISTRY OF IGNEOUS ROCKS **RECOVERED FROM A TRANSECT** ACROSS THE MARIANA TROUGH, ARC, FORE-ARC, AND TRENCH, SITES 453 THROUGH 461, DEEP SEA DRILLING PROJECT LEG 60 611 D. A. Wood, N. G. Marsh, J. Tarney, J.-L. Joron, P. Fryer, and M. Treuil 34. PETROGRAPHY AND GEOCHEMISTRY

Chapter

- 36. ABSTRACT: CHEMICAL AND SR-ISOTOPIC COMPOSITIONS OF IGNEOUS ROCKS FROM DEEP SEA DRILLING PROJECT LEGS 59 AND 60 679 Richard Lee Armstrong and Graham T. Nixon
- 37. CRYSTAL MORPHOLOGIES AND PYROXENE COMPOSITIONS IN BONINITES AND THOLEIITIC BASALTS FROM DEEP SEA DRILLING PROJECT HOLES 458 AND 459B IN THE MARIANA FORE-ARC REGION..... 681 James H. Natland
- 38. PETROLOGY OF VOLCANIC ROCKS FROM THE FORE-ARC SITES..... 709 Arend Meijer, Elizabeth Anthony, and Mark Reagan
- 39. PETROLOGY OF HIGH-MgO BRONZITE ANDESITE RESEMBLING BONINITE FROM SITE 458 NEAR THE MARIANA TRENCH..... 731 I. Kushiro
- 40. RARE-EARTH ELEMENT GEOCHEMISTRY OF MARIANA FORE-ARC VOLCANICS: DEEP SEA DRILLING PROJECT SITE 458 AND HOLE 459B..... 735 R. L. Hickey and F. A. Frey
- 41. ⁴⁰Ar-³⁹Ar DATING OF ROCKS DRILLED AT SITES 458 AND 459 IN THE MARIANA FORE-ARC REGION DURING LEG 60...... 743 Y. Takigami and M. Ozima

PART VII: PORE FLUIDS, ALTERATION, AND **HEAT FLOW**

- 42. INTERSTITIAL WATER STUDIES, DEEP SEA DRILLING PROJECT LEG 60 ... 749 Joris M. Gieskes and Jeff Johnson
- 43. TEMPERATURES OF HYDROTHERMAL ALTERATION IN DEEP SEA DRILLING **PROJECT HOLE 453, WESTERN** MARIANA TROUGH 755 James R. Lawrence and James H. Natland
- 44. HYDROTHERMAL ALTERATION OF BASALTS AND SEDIMENTS AT DEEP SEA DRILLING PROJECT SITE 456, MARIANA TROUGH 759 James H. Natland and Roger Hekinian

Chapter

45.	ALTERATION OF IGNEOUS ROCKS AT DEEP SEA DRILLING PROJECT SITES 458 AND 459, MARIANA FORE-ARC REGION: RELATIONSHIP TO BASEMENT STRUCTURE James H. Natland and John J. Mahoney	769
46.	HEAT FLOW MEASUREMENTS ON DEEP SEA DRILLING PROJECT LEG 60 S. Uyeda and K. Horai	789
PAF DO	RT VIII: PHYSICAL PROPERTIES AND WNHOLE EXPERIMENTS	
47.	ACOUSTIC PROPERTIES OF TUFFACEOUS AND CALCAREOUS SEDIMENTS, DEEP SEA DRILLING PROJECT LEG 60 R. L. Carlson	803
48.	SEISMIC VELOCITIES AT ELEVATED PRESSURES OF IGNEOUS ROCKS FROM THE MARIANA TROUGH AND FORE- ARC REGION, DEEP SEA DRILLING PROJECT LEG 60	805
49.	THERMAL CONDUCTIVITY OF SEDIMENTS AND IGNEOUS ROCKS RECOVERED DURING DEEP SEA DRILLING PROJECT LEG 60 Ki-Iti Horai	807
50.	EFFECT OF DRILL STRING MOVEMENT ON SHAPE OF THE HOLE AND ON THE CORED ROCKS AT HOLE 459B	835

51. LARGE-SCALE RESISTIVITY EXPERIMENT AT DEEP SEA DRILLING PROJECT HOLE 459B 841 T. J. G. Francis

PART IX: PALEOMAGNETISM

T. J. G. Francis

52. PALEOMAGNETISM OF DEEP SEA DRILLING PROJECT LEG 60 SEDIMENTS AND IGNEOUS ROCKS FROM THE MARIANA REGION 855 Ulrich Bleil

Page

PART X: SYNTHESES

- 54. TECTONIC PROCESSES AND THE HISTORY OF THE MARIANA ARC: A SYNTHESIS OF THE RESULTS OF DEEP SEA DRILLING PROJECT LEG 60 ... 909 Donald M. Hussong and Seiya Uyeda

BACK-POCKET PLATES

CHAPTER 3: PLATE 1. MARIANA ISLAND ARC NEAR 18°N GEOPHYSICAL MAPS. UNDERWAY GEOPHYSICS – LEG 60 AND RELATED SURVEYS. (Hussong, 1981)

CHAPTER 3: PLATE 2. MARIANA ISLAND ARC NEAR 18°N CRUSTAL STRUCTURE. UNDERWAY GEOPHYSICS, LEG 60 AND RELATED SURVEYS. (Hussong, 1981)



VALDEMAR F. LARSON 1930-1981

As the final page proofs for Volume 60 were being corrected, we were saddened by the passing of Valdemar Larson—known by everyone at the Deep Sea Drilling Project as "Swede"—after a long illness. The following remarks were prepared by colleagues of Swede's in the DSDP Engineering and Operations Departments. At their request, we are pleased to dedicate this volume to the memory of Swede Larson, who was directly or indirectly responsible for much of the operational success of nearly every Deep Sea Drilling Project leg, including Leg 60.

Swede Larson was a key figure in the Deep Sea Drilling Project for 12 of its 13 operating years. Joining the Project in 1969, he served as Operations Manager until May 1980, when he became head of the Engineering Department. He retired in January 1981 for reasons of poor health and passed away on July 15, 1981. Sixteen years as an engineer with Standard Oil Company of California had endowed Swede with an extraordinary knowledge of the technology and the people involved in the offshore drilling industry. His innovative mind and tenacity systematically eliminated technical problems and continually upgraded the scientific productivity of DSDP systems. As much as any other person, he was the man who made the Deep Sea Drilling Project work.

Yet to those of us who knew and worked with Swede, he was much more than a fine engineer and manager. He was a larger-than-life human being whose opinions and guidance in many areas were respected and solicited by his associates. His ready smile and deliberate manner of speaking will remain a part of DSDP for a long time.

ACKNOWLEDGMENTS

A scientific venture of the magnitude of Leg 60 requires great care in its planning, which in this case took several years. We are grateful to the National Science Foundation and the various JOIDES member countries for providing support for the planning and execution of the South Philippine Sea drilling and particularly to the JOIDES Active Margins Panel, several of whose members reaped the fruits of their labors by participating on Leg 60. The Leg was devised as part of a two-leg transect across the ridges and troughs of the South Philippine Sea and was based largely on the results of excellent regional and site-specific surveys by numerous scientists and institutions. We thank all who organized and participated in these surveys.

During Leg 60, an unusual number of quite diverse sites were successfully drilled, including two in record water depths in the Mariana Trench. New downhole experimental programs for heat flow, electrical resistivity, and logging were conducted. These efforts were skillfully managed and carried out under the supervision of Operations Manager Bob Knapp and Drilling Superintendent Otis Winton. To them and their crew of drillers, pushers, and roughnecks, we owe a considerable vote of thanks for the success of the drilling. We also thank Mr. Edwin L. Denton and Mr. Robert A. Benoit for successfully introducing Gearheart-Owen logging to the repertoire of *Glomar Challenger* capabilities.

We thank Captain Lloyd Dill and the crew of the *Glomar Challenger* for ably and safely guiding the vessel to and from the sites, keeping it on station, and ensuring the safety and comfort of all on board. We thank Laboratory Officer Ted Gustafson and his fine group of technicians for their support in the shipboard laboratories and Gayle Burns, who patiently transformed pages of usually indecipherable penmanship into the typed reports that form the core of the site chapters of this volume.

For support on the beach in the production of this volume we thank our editors, Robert Powell and Marianna Lee; members of the DSDP Production Department Elaine Bruer and Madeleine Mahnken, who worked on the barrel sheets; Tommy Hilliard and the others who did the illustrations; Janice Bowman and later Nancy Durham, who kept track of all the manuscripts; and Mary Young and Ray Silk, who handled the pasteup and other matters.

Finally, we thank our scientific colleagues who have helped shape the direction of our inquiries and the interpretation of the scientific results of Leg 60 either in conversation or in writing. We especially acknowledge the interest and comments of Loren Kroenke, Bob Scott, and the other participants on Leg 59, which drilled the western half of the South Philippine Sea transect. And we thank all who contributed their time and effort to preparing reports for Volume 60, whether or not they actually participated in the drilling. Their work is the outcome of all the planning, surveys, drilling, experiments, and sample studies and is why all of it was done in the first place.

For the Leg 60 Scientific Party

Donald M. Hussong Seiya Uyeda