



F O U R T H E D I T I O N

Oceanography

An Introduction

Dale E. Ingmanson
William J. Wallace
San Diego State University

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Oceanography

An Introduction

*To all those who make their living respectfully on, in, or
about the ocean.*

Preface

The earth has often been viewed as a possession to be subdued and exploited. The ocean that makes up about 70% of the earth has not been easily subdued or exploited despite heroic attempts. As a result, people still refer to the ocean as a frontier or as a vast resource that will enable us to solve such problems as food shortage or a shortage of valuable minerals. One reason for writing *Oceanography: An Introduction* was to explore the myths and realities according to our present understandings of the ocean.

In our opinion textbooks should present the guiding philosophy of the authors very early on. Our book was the first general oceanography text to take serious issue with environmental topics. When one considers the recent (March, 1986) statement by the Foundation for Oceanographic Research that there has been more marine pollution in the past ten years than in the previous 400 years combined, it is obvious that people must be made aware of the problems before they can become concerned. But real awareness is based on understanding. So the primary aim of this book is to present the fundamental geological, chemical, physical, and biological marine processes necessary to understand the ocean environment. We hope this understanding and awareness will help to generate the desire to help in the preservation of this planet's last frontier.

We have been on, in, and around the ocean all of our lives. From a purely pragmatic viewpoint this quote by Kenneth Grahame is worth a mention: "There is nothing—absolutely nothing—half so much worth doing as simply messing about in boats . . . or with boats . . . In or out of 'em, it doesn't matter." This would include, of course, scientific activity as well.

This fourth edition of *Oceanography* is substantially rewritten and updated. An extensive survey of faculty who have read or adopted the text and of students in our classes at SDSU has been used to help guide us to make substantial changes. The sequence of chapters remains the same as the last edition with discussions of the chemical and physical properties of sea water split into two chapters.

Dr. David Milne, marine biologist from Evergreen State College, has completely rewritten the three

chapters dealing with marine biology. Highly knowledgeable about current concepts in marine biology, Dr. Milne is an experienced teacher of undergraduate students and a capable writer.

The chapters dealing with marine geology have been substantially rewritten and updated with the suggestions made by Dr. Tjeerd van Andel of Stanford University.

This text remains the only introductory oceanography text with a chapter on polar oceanography, an area receiving increasing scientific attention.

The chapters on marine resources, ocean technology, pollution, and management have been extensively updated with more than fifty new or revised tables and figures. There are also new sections on marine transportation, marine recreation, and the exclusive economic zone.

The book emphasizes visual materials: There are over four hundred line drawings and photographs, more than three hundred of which are original. Many illustrations have been added to this edition. Illustrations are essential to an oceanography text because some students have never experienced the ocean in person, while many others have seen it only from the shoreline or from the deck of a boat, usually in only a few locales. If properly executed, illustrations can be good substitutes for direct observation.

This edition continues an extensive glossary based on the *Glossary of Oceanographic Terms* published by the U.S. Naval Oceanographic Office and other specialized sources. Key terms are set in boldface type for easy identification. Also, coastal maps of the USA show coastal configuration, locations, and the 30- and 100-fathom contours.

To give the book another dimension, we display at the beginning of each chapter an original photograph along with quotations from the works of Carroll, Melville, Conrad, Whitman, Arnold, and others. We hope these quotations and photographs will convey the variety of human experience with the ocean in a stimulating way. As Alice said, "What is the use of a book without pictures?" (Lewis Carroll).

Extensive Manuscript Review

We would especially like to thank the many reviewers who contributed their time and ideas to all four editions.

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Contents

Preface / xiii

O N E

The Ocean in Perspective / 2

The Word *Oceanography* / 4
Emergence of the Science of Oceanography / 5
Chemistry and the Sea / 8
Physics and the Sea / 9
Biology and the Sea / 10
Geological Oceanography / 13
Postscript / 16

T W O

The Origin of the Earth, Ocean, and Life / 18

The Origin of the Universe / 20
The Origin of the Sun / 21
The Origin of the Planets / 21
The Origin of the Ocean and Atmosphere / 22
The Origin of Life / 23

T H R E E

Obtaining Information about the Ocean Basins / 26

Research Ships / 28
Methods of Sampling Sediments / 30

Depth Recording / 30

Dredging / 31

Coring / 33

Properties of the Ocean Crust / 33

Heat Conduction / 33

Rock Magnetism / 34

Gravity Anomalies / 34

Seismic Profiling / 35

F O U R

Ocean Basins and Sediments / 36

What Is an Ocean Basin? / 38

Composition / 39

Density / 40

Isostasy / 40

Features of the Seafloor / 40

Oceanic Ridges / 40

Abyssal Plains / 42

Seamounts, Coral Reefs, and Island Chains / 44

Island Arcs and Trenches / 46

Characteristics of Ocean Sediments / 47

Particle Size / 47

Density and Shape / 47

Color / 48

Mineral Composition / 48

Thickness of Sediments and Rate of Deposition / 48

Classification of Ocean Sediments / 48

Pelagic Sediments / 49

Biogenic Sediments / 49

Pelagic Clay / 50

Authigenic Sediments / 50

Volcanic Deposits / 50

Terrigenous Sediments / 51

Muds / 51

Turbidites / 51

Glacial Deposits / 51

Cosmogenic Sediments / 52

Distribution of Marine Sediments / 52

FIVE

***Plate Tectonics* / 54**

Continental Drift: The First Approach / 56

Rock Magnetism / 57

Seafloor Spreading: The Data Converge / 59

Plate Tectonics: A Unifying Concept / 61

The Driving Force / 65

Summary of Evidence / 65

Earthquake Locations / 65

Magnetic Bands / 65

Sediment Age and Thickness / 65

Continental Margin Configuration / 65

Bedrock Age / 65

Heat Flow / 65

Lithologic Correlation / 65

Terrestrial Fossil Correlation / 66

SIX

***Margins of the Continents* / 68**

Classification of Margins / 70

Continental Shelves / 73

Glaciation / 75

Sea-Level Changes / 78

Waves and Currents / 78

Sedimentation / 78

Carbonate Deposits / 79

Faulting and Volcanism / 79

Continental Slopes / 80

Submarine Canyons / 81

Continental Rises / 83

SEVEN

***The Chemical Properties of Water* / 86**

Properties of Water / 88

Properties of Seawater / 89

Origin of Salinity / 90

Determination of Salinity / 91

Seawater Sampling Methods / 96

Minor Constituents / 97

Dissolved Gases / 98

Oxygen / 98

Carbon Dioxide / 99

EIGHT

***The Physical Properties of Seawater* / 102**

Temperature Distribution in Seawater / 104

Measurements of Temperature / 106

Pressure / 108

Density / 111

Light and Color / 114

Light in the Sea / 114

How the Sea Looks from Within / 115

Sound in the Sea / 116

Sound Velocity in the Sea / 116

Sonar / 116

Shadow Zones and SOFAR Channels / 118

How the Sea Sounds from Within / 120

Ice / 120

NINE

***Climate and the Ocean* / 122**

The Nature of Solar Energy / 127

The Heat Budget / 127

The Role of Water in Weather / 129

The Coriolis Effect / 132

General Circulation of the Atmosphere / 134

Weather / 140

Tropical Cyclones / 143

Storm Surges / 144

Waterspouts / 147

Reciprocal Influences of Atmosphere and the Ocean / 148

The Future / 148

Ocean Circulation / 150

- Surface Circulation / 152
 - Some Major Ocean Currents / 154
 - The North Atlantic* / 154
 - The North Pacific* / 155
 - Flow Rate / 156
 - The Boundary Currents / 156
 - Western Boundary Currents* / 156
 - Eastern Boundary Currents* / 157
 - Equatorial Currents* / 157
 - Forces Causing the Surface Currents / 157
- Subsurface Currents or Undercurrents / 161
- Other Surface-Circulation Phenomena / 161
 - Convergence and Divergence / 161
 - Upwelling / 161
 - El Niño / 162
 - The Sargasso Sea / 164
 - Coastal Currents / 164
- Instruments for Measuring Current / 168
 - The Gulf Stream Revisited / 172
 - Energy from Ocean Currents / 173
- Oceanic Circulation: The Deep Currents / 175
 - Temperature-Salinity Diagram / 176
 - Water Age / 178
 - Atlantic Ocean / 179
 - Pacific Ocean / 181
 - Indian Ocean / 181
- Marginal Seas / 182

Waves / 184

- Types of Waves / 188
 - Wind Waves / 189
 - Swell / 191
 - Shallow-Water Waves / 194
 - Breaking Waves / 194
 - Surfing and Rip Currents / 195
- Refraction, Diffraction, and Reflection / 198
- Problem Waves / 198
 - Seismic Sea Waves / 198
 - Rogue Waves / 200
- Internal Waves / 203
- Wakes / 205
- Seiches / 206
- Energy from Waves / 207

Tides / 208

- Periodicities / 210
- Tide-Generating Forces / 212
- Solar and Lunar Tides / 213
- The Tides According to Newton / 215
- Dynamic Tides / 217
- Tidal Range / 219
- Tidal Currents / 221
 - Whirlpools / 222
 - Tidal Bore / 226
- Tidal Prediction / 228
- Energy from Tides / 229

Coastal Processes and Estuaries / 232

- Coasts and Coastal Processes / 234
 - Coastal Rock and Sand / 235
 - Changes in Sea Level / 236
 - Energy Acting on Coasts / 237
 - Large-Scale Earth Movements / 242
 - Human Activities / 242
 - Dams* / 242
 - Land Reclamation* / 243
 - Dredging* / 243
 - Development of Dune Areas* / 244
 - Erosion Control Structures* / 244
- Classification of Coasts / 247
 - Coasts Shaped by Nonmarine Processes / 249
 - Coasts Shaped by Marine Processes or Marine Organisms / 252
- Coasts of the United States / 258
 - Descriptions / 258
 - Active Processes / 259
 - New England* / 259
 - Mid-Atlantic Shelf* / 262
 - Florida* / 262
 - Gulf Coast* / 264
 - Southern California* / 265
 - Oregon and Washington* / 267
- Minor Beach Features / 267
- Estuaries / 267
 - Classification / 267
 - Estuarine Circulation / 269
 - Estuarine Currents / 270
 - Types of Estuaries / 270
 - Origin and Fate / 270

Life in the Sea: Bacteria, Protists, Plants, and Invertebrates / 272

- Classification and Terminology / 275
 - Classification / 275
- Bacteria: The Kingdom Monera / 277
- Single-Celled Organisms: The Kingdom Protista / 279
 - Diatoms / 279
 - Dinoflagellates / 280
 - Microflagellates / 282
 - Forams and Radiolarians / 283
- Multicellular Plants: The Kingdoms Protista and Plantae / 283
 - Seaweeds / 283
 - Other Plants / 286
- Invertebrate Animals: The Kingdom Animalia / 287
 - Sponges / 287
 - Cnidaria / 288
 - Echinoderms / 291
 - Mollusca / 293
 - Snails, Sea Slugs, and Chitons* / 293
 - Clams and Their Relatives* / 295
 - Octopuses and Squids* / 297
 - Annelid Worms / 299
 - Crustaceans / 301
 - Crustacean Anatomy and Life Cycle* / 301
 - Shrimps, Crabs, and Anormurians: The Decapod Crustaceans* / 303
 - Krill, Copepods, Isopods, Amphipods, Barnacles: The Nondecapods* / 304
 - Other Marine Arthropods* / 308
 - The Invertebrate Chordates / 309
 - The Rest of the Invertebrates / 310

Life in the Sea: Vertebrates / 312

- Sharks and Their Relatives / 315
- Fishes / 318
 - Adaptations / 319
 - Fish of Commercial Significance / 322
 - Herrings and Their Relatives* / 322
 - The Cod Fishes* / 323
 - Halibuts* / 324
 - Albacores and Tunas* / 324

- Reptiles / 326
- Birds / 328
 - Seabird Feeding / 328
 - Penguins / 329
 - Albatrosses / 330
 - Pelicans / 331
- Mammals / 332
 - Pinnipeds / 333
 - Sea Cows / 334
 - Cetaceans / 335
 - Marine Mammals and People / 339
- Other Marine Vertebrates / 340

The Distribution and Abundance of Life in the Sea / 342

- Seawater Properties: Their Effects on Marine Life / 345
 - Density and Viscosity / 345
 - Salinity / 346
 - Temperature / 346
 - Dissolved Gases / 347
 - Light / 348
 - Pressure / 349
 - Depth / 350
- Plant Productivity and Food-Chain Dynamics / 350
 - Photosynthesis / 350
 - Primary Productivity / 352
 - Measuring Productivity* / 353
 - The Distribution of Productivity* / 354
 - Nutrient Cycles / 356
 - The Nitrogen Cycle* / 356
 - The Phosphorus Cycle* / 358
 - The Loss of Energy in Food Chains / 359
- Light, Nutrients, Upwelling, Symbiosis: Life in Four Marine Systems / 360
 - The North Atlantic Ocean / 361
 - The Sargasso Sea / 363
 - The Antarctic Ocean / 363
 - Coral Reefs / 364
- Depth, Darkness, Shortage of Food: Life in Deep Water / 366
 - The Pelagic Realm / 367
 - The Deep-Sea Floor / 372
 - Hydrothermal Vents / 373
- Salinity Fluctuations: Life in Estuaries / 375
- Interactions Among Organisms: Life Along the Shore / 376

Deep-Ocean Zones / 380
Broad Geographic Patterns: The Legacy of
Prehistoric Events / 380
Summary / 382
Life in the Sea: A Nonscientific Perspective / 382

S E V E N T E E N

Polar Oceanography / 384

Magnetism / 386
The Arctic Ocean / 387
The Antarctic / 387
The Heat Budget / 389
Life in the Polar Regions / 390
Ice in the Sea / 392
 Sea Ice / 392
 Icebergs / 393
 Ice Islands / 398
 Putting Ice to Use / 400
Survival in the Sea / 400
 Drowning / 400
 Hypothermia / 401
 Thirst, Hunger, and Exposure / 401

E I G H T E E N

***Marine Resources and Ocean
Technology / 402***

Shipping / 404
Submergence / 406
 Scuba Gear and Underwater Habitats / 406
 Deep-Sea Submersible Vehicles / 407
Mineral Exploitation / 413
 Hydrocarbons / 413
 Manganese Nodules / 415
 Phosphate / 416
 Gold / 417
 Diamonds / 417
 Salt / 417
 Importance of Undersea Mining / 418
 Desalination / 418
Energy from the Sea / 420
 Tides / 420
 Waves / 420
 Thermal Differences / 421
Fisheries / 421
Exclusive Economic Zone / 426

Endangered Living Resources / 428
 Overfishing / 428
 Invertebrates / 429
 Reptiles / 429
 Birds / 429
 Mammals / 429
Aquaculture / 431
Marine Natural Products / 432
Sunken Treasure / 433
Marine Recreation / 433
Overview / 434

N I N E T E E N

***Ocean Pollution and
Management / 436***

What Is Pollution? / 441
The Sea as a Dump / 441
 Sewage / 441
 Heavy Metals / 443
 Synthetic Organic Compounds / 445
 Oil / 447
 Radioactivity / 452
 Heat / 454
 Solid Refuse / 454
The Carbon Dioxide Problem / 455
Coastal Land Use / 458
 Landfill / 458
 Coastal Development / 459
Ocean Management / 462
 History / 462
 U.N. Law of the Sea / 463
 Coastal Zone Management / 465

Appendixes

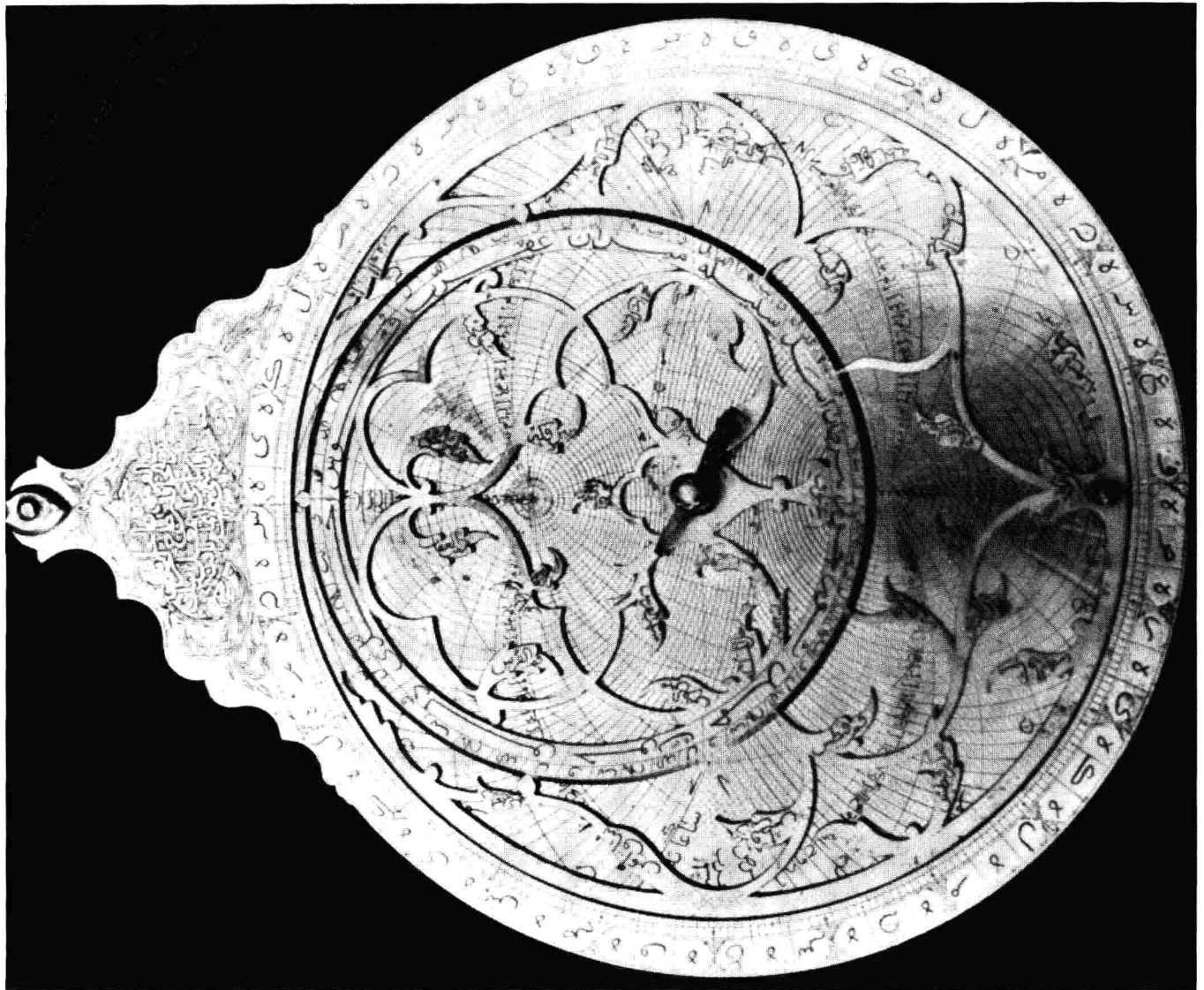
I Latitude and Longitude / 467
II Time and the Date Line / 468
III Scientific Notation / 469
IV Constants and Equations / 470
V Supplementary Topics to Chapter 8 / 471
VI The Coriolis Effect / 472
VII Geologic Time Scale / 473
VIII The U.S. Coastline / 474
IX A Classification of Living Organisms / 483

Glossary / 486

Index / 504

Oceanography

An Introduction



The sea does not reward those who are too anxious, too greedy, or too impatient. To dig for treasures shows not only impatience and greed, but lack of faith. Patience, patience, patience, is what the sea teaches. Patience and faith. One should lie empty, open, choiceless as a beach—waiting for a gift from the sea.

Anne Morrow Lindbergh

*The Ocean
in Perspective*

-
- I. *The word Oceanography*
 - II. *Emergence of the Science of Oceanography*
 - III. *Chemistry and the Sea*
 - IV. *Physics and the Sea*
 - V. *Biology and the Sea*
 - VI. *Geological Oceanography*
 - VII. *Postscript*

You hear it long before you see it—a muffled roar, thunder in the distance. This is no ominous rumbling of some passing storm. It is the compelling, rhythmic sound of the world's ocean, its waters surging against the land.

You round a bend in the road or step through a break in the coastal forest or near the edge of a cliff, and you see it for the first time. Before you is an expanse of water so dynamic, so vast, so primal, that the turmoil of cities is forgotten. At that moment, your world expands. That moment, in Anne Morrow Lindbergh's phrase, is a gift from the sea.

Some people who experience that moment go on to become oceanographers of one sort or another. They may turn to chemical oceanography—the study of the distribution of chemical substances in the ocean water and the reactions that take place between them—or to physical oceanography—the study of the transmission of light, sound, and kinetic energy through the ocean, the distribution of temperatures, and air-sea interactions. They may become specialists in biological oceanography—the study of interactions of marine organisms with one another and with their environment. Or these people may become interested in geological oceanography—the study of the origin and physical characteristics of the ocean basins and the processes that have shaped them.

Whatever their special interest, oceanographers have all glimpsed a magnificent natural force, and they are all in their own ways responding to its challenge. Oceanography is more than a profession; it is a special way of viewing one of the great features of nature.

THE WORD OCEANOGRAPHY

Sir John Murray commented in his book *The Oceans*, published in 1910, on the word *oceanography*:

The term *Thalassography* has been used, largely in the United States, to express the science which treats of the ocean. The term *Oceanography* is, however, likely to prevail. The Greeks appear to have used the word *Thalassa* almost exclusively for the Mediterranean, whereas the almost mythical "oceanus" of the ancients corresponds to the ocean basins of the modern geographer. In recent times I believe the word *Oceanography* was introduced by myself about 1880, but I find from Murray's English Dictionary that the word *océanographie* was used in French in 1584, but did not then survive.

The German word *Ozeanographie*, now largely replaced by *Meereskunde*, was used somewhat earlier than the English version.



1.1 Japanese woodcut prints (by Masanobu Kano) showing early nori cultivation techniques: preparing and planting brush as a foundation for *Porphyra* spores (Kode, 1877).

The suffix graphy suggests drawing, describing, or reporting, as in *biography* and *geography*. The suffix -logy refers to a science or a branch of knowledge. Surely the study of the ocean has progressed beyond a pure description, and *oceanology* would be a more accurate term than *oceanography*. Still, *oceanography* retains its currency, and we shall use it throughout this book.

The term *hydrography* is sometimes used incorrectly as a synonym for *oceanography*. Hydrography deals primarily with the charting of coastlines, bottom topography, currents, and tides for practical use in ocean navigation. *Oceanography* is a more comprehensive discipline that uses chemical, physical, biological, and geological principles in its study of the ocean at large.

EMERGENCE OF THE SCIENCE OF OCEANOGRAPHY

Artists, poets, philosophers, admirals, and merchants have long had a passionate relationship with the ocean, and people of all ranks have harvested fish, shellfish, and seaweed from the sea for thousands of years (Figure 1.1). Seafarers have sailed the world in search of fortune and far horizons. Since the time of Homer,

Plato, and Aristotle, and probably long before, poets and philosophers have reflected on the sea. Indeed, in Plato's model of the world system, which comprised earth, air, fire, and water, the water was the ocean (Figure 1.2). Aristotle devised a system for classifying living creatures and perceived the connection between marine fossils and living organisms.

However, *oceanography* developed late as a science. The study of the ocean began in earnest with the voyage of *HMS Challenger* (Figure 1.3). In December 1872, under the direction of Wyville Thomson of Britain, the *Challenger* embarked on the first major oceanographic expedition in history—an expedition that lasted almost three and a half years. During that time, the *Challenger* covered 68,890 nautical miles (Figure 1.4). (A nautical mile equals one minute of latitude, or 1/21,600, of a great circle of the earth; this is equal to 1,852 m [6,076.1 ft].) It was the first steamship ever to reach the Antarctic ice barrier and the first to cross the Antarctic Circle. (wrong - Cap. T. Cook was -)

The wealth of information gathered during that expedition prompted J. Y. Buchanan, the chemist on the expedition, to comment:

The history of the *Challenger* expedition is well known to all students of oceanography, which, as a special science, dates its birth from