M. GRANT GROSS

OCEANOGRAPHY

a view of the earth

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State University of New York
at Stony Brook

Illustrated by **Roger Hayward**

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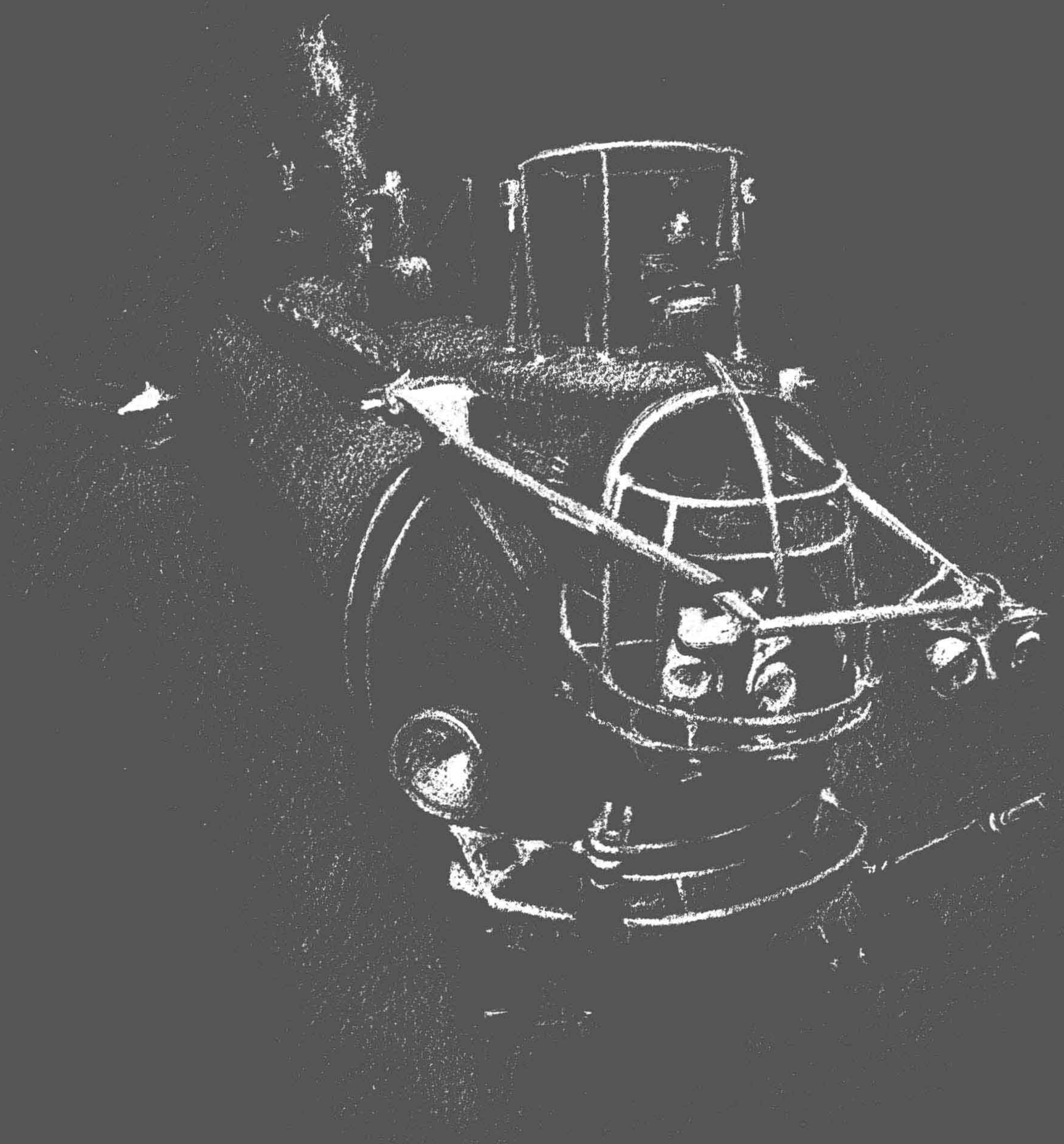

PREFACE

Oceanography—the scientific study of the ocean—presents a view of the earth that is new and useful to us. We have traditionally viewed the earth from the land and from a human frame of reference. But study of the ocean, the earth's most distinctive feature, shows us that continents are only large islands surrounded by a single body of water. Marine processes active in any single area are eventually felt throughout the world ocean. We see an earth with a finite surface area and a limited capacity for production or abuse, an earth whose weather and ocean currents are powered by energy from the sun and where we as humans have had little success in either controlling or modifying them.

This book examines the world ocean and those processes that control its major features and the life in it. It is intended for a general survey course, either for beginning science students or for students who may never take another course in science. The primary objective of the book is to investigate the major features of the ocean and to present some of the problems that have occupied oceanographers during the century since the beginnings of the science.

A second objective of the book is to illuminate the workings of modern science. Oceanography is still evolving at a rapid rate. Because of this rapid development, one must recognize that many of the "facts" given in this book are actually hypotheses—ideas on trial. Some will stand the test of careful examination, further observation, and more sophisticated analyses of available data. These ideas will survive. Many will not, however, and they are then discarded or replaced by other hypotheses that explain the observations more fully or make more accurate predictions. Hence, it should be remembered that our view of the earth represents a momentary glance at a rapidly changing picture.

A book of this nature necessarily omits or condenses many aspects of oceanography. In general the ocean areas and processes selected for discussion are those most likely to be seen by land dwellers or to affect our lives. For instance, those processes that affect the coastal ocean are emphasized—beach formation, coastal currents, and sea ice formation are just a few examples. Other interesting areas have been condensed, such as the discussion of the deep structure of the earth's crust or the early history of the earth and evolution of presently living organisms. References to more detailed treatments of these topics have been included at the end of the chapters, to aid in finding further material on specific subjects.

The view offered here of the coastal ocean and its limitations should be useful beyond the bounds of a college course. As citizens we are increasingly called on to make decisions or to evaluate recommendations about utilization of the coastal ocean and the coastline at its margins. Should a salt marsh be used for a housing development? A sanitary landfill? A marina? Or perhaps left in its natural state? Should waste disposal be permitted in a bay or on the continental shelf? Reasonable decisions in these areas require a knowledge of basic environmental processes. With an increased awareness and improved understanding of the processes affecting ocean and atmosphere, perhaps we can eventually break out of the cycle of buying time for today's problems by creating new problems for tomorrow. This is especially important, for the use of the ocean involves not just our own coastline but the entire planet.

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OCEANOGRAPHY — THE SCIENCE

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Challenger Expedition The first oceanographic expedition to circle the globe, sponsored by the British Navy and the Royal Society, was a scientific party headed by Sir Wyville Thomson aboard the *Challenger*, a full-rigged corvette with an auxiliary 1234-horsepower steam engine. She set out in December, 1872, to investigate "everything about the sea" and returned to England in May, 1876 with data that eventually filled fifty large volumes; working up the reports employed seventy-six authors over a 23-year period.

This immense project was inspired by the discovery in 1860, when the prevailing theory held that life below 600 meters was impossible, that strange and wonderful creatures existed at depths of 2 kilometers or more below sea level. The *Challenger* staff was asked to investigate physical and biological conditions in every ocean and to record everything that might influence the geographical distribution of marine species. This included taking water samples and temperature measurements of both bottom and surface waters, recording currents and barometric pressures, and collecting bottom samples in order to study sediments and attempt to find new species. Swimming animals were caught in nets dragged behind the ship.

Laboratory conditions and scientific equipment aboard the *Challenger* were the finest to be had, and first-class data were collected during the three-and-one-half-year expedition. Every ocean was sounded except the Arctic; 4717 new species of animals were collected and classified by specialists.

The *Challenger* Expedition was probably the most innovative single oceanographic research voyage ever made. It established the tradition of large-scale team efforts that characterize modern oceanographic research.

Oceanography is the scientific study of the world ocean, the surface feature that makes this planet unique among those in the solar system. Oceanographic research requires multidisciplinary team effort: a typical project employs scientists recruited from most of the major scientific disciplines, and involves problems that do not fit easily within the confines of a narrow, compartmentalized view of science.

The importance of oceanography to our understanding of the earth and to our everyday life has been underscored by two dramatic developments of the late 1960's and early 1970's—the beginnings of manned space exploration and increased concern about the state of the environment, including urban areas—especially those in coastal areas. Both have led to a new view of the earth in which the ocean occupies a central position. In this and the following chapters, we shall develop this ocean-oriented view of the earth—in sharp contrast with our traditional, land-oriented, man-dominated view.

Earth-orbiting artificial satellites have provided us with pictures of the earth, as in Fig. 1–1, showing it to be about 70 percent covered with ocean and about half obscured by clouds at any instant. To understand fully the earth and the processes acting on its surface, we must understand its characteristic feature—the ocean. This is more than just a subject for curious inquiry. Regardless of whether we live on the ocean coast or in the middle of the continent, the ocean plays a major role in our lives. Not only is it the key to weather and climate, the ocean is also our backyard, recreational area, highway, and dumping ground for wastes.

A large percentage of the United States' population (75.3 percent in 1970) live in 29 states bordering either the ocean or one of the Great Lakes. In the middle of the nineteenth century, the opening of the continent's interior reduced the proportion of people living in coastal counties from 37 percent in 1800 to 25 percent in 1850, but the percentage has been steadily rising since then. Our children will also most probably live near water in large cities on estuaries, harbors, or lakes. It has been estimated that by 1980, 7 out of every 10 Americans will live in metropolitan areas. Seven of the largest metropolitan areas in the U. S. are on the coast. Most of the projected "megalopoli" are also coastal—for example, the Boston–New York–Philadelphia–Washington complex, or the Vancouver–Seattle–Tacoma and Los Angeles–San Diego complexes.

In this century the shallow ocean bottom bordering the continents has become a source of raw materials and fuels for industry. In 1968, the production of petroleum from offshore oil fields supplied about 16 percent of the world's petroleum production. In 1978, this source is expected to provide about one-third of the world's demand. The production of natural gas from submerged fields is an important fuel source for countries around the North Sea.

For centuries the ocean provided a significant part of the world's protein supply. Fish provide about 3 percent of the direct human intake of protein, but probably account for about 10 percent of the total intake because of the large amounts of fish used for feeding animals such as chickens. Most experts agree that the take of fish from the ocean could be increased to twice their 1968 levels, and likely even more, if new equipment is developed, additional species of fish utilized, and new areas fished. The ocean is by no means an unlimited source of food and protein, but its resources can be better utilized than they have been in the past.

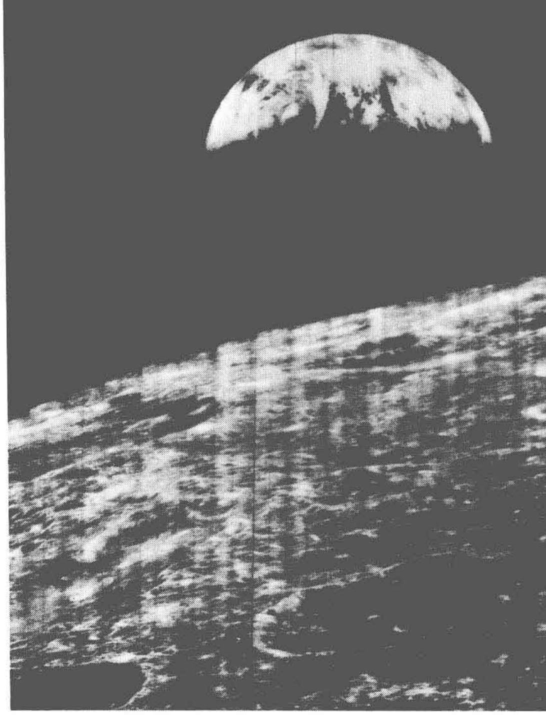

FIG. 1–1
A view of the earth taken from a space craft circling the moon. Much of the earth's surface is obscured by clouds. The cratered moon surface is seen in the bottom portion of the photograph. (Photograph courtesy NASA)

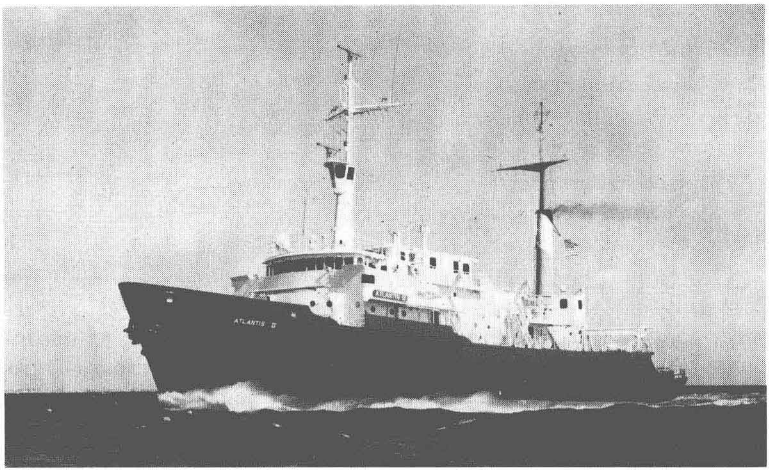

FIG. 1–2
Atlantis II, a modern vessel designed for oceanographic research, is operated by the Woods Hole Oceanographic Institution. (Photograph courtesy Woods Hole Oceanographic Institution)

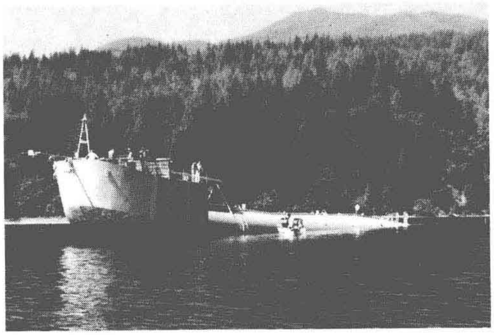

FIG. 1–3a
FLIP (FLoating Instrument Platform) is a research platform 103 meters (355 ft.) long, shaped somewhat like a ship but lacking motive power, so it must be towed to location.

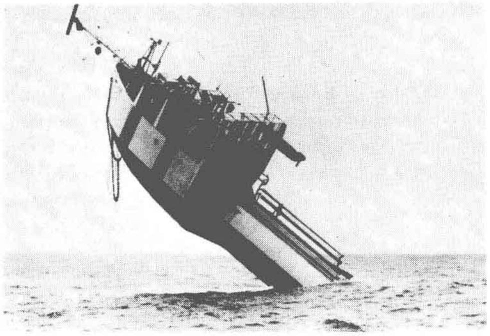

FIG. 1–3b
On location, one part of the hull is flooded causing it to rotate into a vertical position.

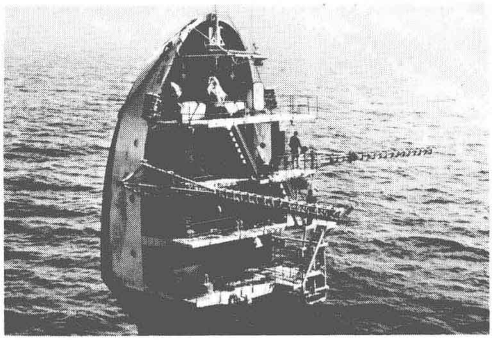

FIG. 1–3c
In the vertical position about 90 meters (300 ft.) is submerged. It forms an extremely stable platform from which to carry out scientific experiments. (Official U.S. Navy photographs).

The ocean also serves purposes that most of us take for granted. For the United States, both the Atlantic and Pacific Oceans are defense barriers; on the more pleasant side, the oceans serve as a major recreational area, from beaching to boating. With increased population and continued spoiling of open land spaces, the ocean will become increasingly valuable as a recreational resource.

Finally, the ocean is a major factor determining our weather, regardless of where we live on earth. The ocean is an important reservoir of the heat and water vapor that power atmospheric storms. Also the ocean stores heat in summer and releases it slowly in the fall and winter to modify climatic extremes; thus coastal areas do not experience the extremes of very cold winters and very hot summers characteristic of continental interiors.

OCEANOGRAPHERS—THOSE WHO STUDY THE OCEAN

The world ocean is too vast a subject for a single person to be an expert on all its aspects, even after a lifetime of study and work, if only because study of the ocean requires the application of a wide variety of scientific disciplines—primarily physics, chemistry, geology, and biology. Consequently, oceanographers usually specialize in one aspect or subdiscipline, although a broad understanding of related fields is required in order to work effectively with other scientists on mutually interesting problems.

As a profession, oceanography is a small field. In the mid-1960's there were probably only a few thousand persons in the United States who called themselves oceanographers, although the field grew rapidly during that decade. In 1960, there were about 1300 oceanographers employed at 24 universities and U.S. federal agencies. Their breakdown by subdiscipline showed:

biological oceanographers	48 percent
chemical oceanographers	7
geological oceanographers (including geophysicists)	11
physical oceanographers (including meteorologists)	34

Oceanographers being a diverse lot, the methods they use for studying the oceans are many and various. Certain technical constraints, however, are common to all aspects of oceanographic research. Most projects involve work aboard ship, whether it be a converted Army tug, an aged oyster boat for work in coastal and inshore waters, or a modern, fully equipped research ship 300 feet long, outfitted for spending months at sea. Even the largest research vessels are rather slow-moving (10–15 knots or about 18–27 km/hour) and provide an unsteady wave-tossed platform. Where stability is essential, other research platforms may be substituted, such as special-purpose ships like the FLIP (Floating Instrument Platform; shown in Fig. 1–3) or submersibles (small, special-purpose submarines). Helicopters, fixed-wing aircraft, or hydrofoils are used where speed is essential, but none is as versatile or as widely used as the research ship.

A characteristic feature of oceanographic research is the lowering of instruments or samplers on a wire line (Fig. 1–4). A winch aboard ship lets out a thin cable, and pulls it back aboard; a metered wheel indicates the amount of line let out, and by measuring the angle of the wire the instrument depth may be calculated. A small brass weight, called a *messenger*, runs down the wire to actuate the instrument. Limited to the use of such remotely controlled devices, an oceanographer can rarely observe his instruments at work or see in their natural state the water, sediment, or organisms he is trying to retrieve. The analogy has been drawn comparing the oceanographer who studies the ocean with a person studying the earth from a balloon that is perpetually above the clouds. Using ropes and grappling hooks, the latter might retrieve rocks, tree branches, and an occasional TV antenna, but he would never see the surface he is studying.

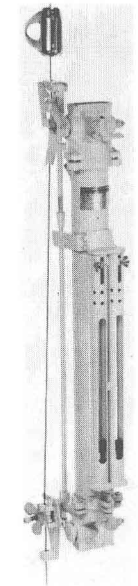

FIG. 1–4
A Nansen bottle attached to a wire line for lowering into the water. The messenger (a brass weight on the line above the bottle) releases the trigger permitting the bottle to invert and take a sample. Precision reversing thermometers in the two cases mounted on the bottle record the temperature at the time the sample is taken. (Photograph courtesy G M Manufacturing and Instrument Co.)

PHYSICAL OCEANOGRAPHY

Physical oceanographers study physical processes in the ocean, such as ocean currents and tides, or the interactions between the ocean and the atmosphere. One of their major contributions has been to map ocean surface currents. Most of the data for this project has been taken from ships' logs, which record the extent to which a ship has been deflected by currents in a particular part of the ocean.

Systematic mapping of currents, not yet complete, was begun in the mid-nineteenth century by the pioneer American oceanographer Matthew Fontaine Maury (1806–1873; see Vignette II at the end of this chapter). Recent long-range studies of such major currents as the Atlantic Gulf Stream and Pacific Kuroshio Current may finally answer questions first asked by eighteenth-century naturalists. Eventually it may be possible to predict changes in ocean-current patterns, including current strength and direction. Such predictions, combined with improved long-range weather and wave forecasts, should permit substantial savings in ship travel time.

Another task for physical oceanographers is mapping subsurface currents, both at intermediate depths and near the ocean bottom. These currents cannot be studied using information from ships' logs; instead elaborate apparatus is required, including current meters and floating devices combined with computer-assisted data reduction systems (Fig. 1–5). Such studies, while they require substantial investments of time and money, reveal much hitherto unavailable information about deep-ocean phenomena.

Where fresh water enters the ocean from river mouths, complex circulation patterns are set up as moving water masses meet

FIG. 1–5
An instrumented, general purpose buoy is used to support various current and atmospheric measuring devices. The buoy has a self contained power system to operate data recording and transmitting systems. Such buoys can be moored in deep ocean areas to measure ocean and atmospheric conditions eliminating the expense of maintaining ships at sea for long periods. (Photograph courtesy U. S. Office of Naval Research)